0099072

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

11-AMCP-0222

SEP 15 2011

Mr. D. A. Faulk, Program Manager
Office of Environmental Cleanup
Hanford Project Office
U.S. Environmental Protection Agency
309 Bradley Boulevard, Suite 115
Richland, Washington 99352

Ms. J. A. Hedges, Program Manager
Nuclear Waste Program
State of Washington
Department of Ecology
3100 Port of Benton
Richland, Washington 99354

RECEIVED
SEP 20 2011
EDMC

Addressees:

HANFORD SITE GROUNDWATER MONITORING REPORT FOR 2010, DOE/RL-2011-01, REVISION 0

This letter transmits two compact discs each of the Hanford Site Groundwater Monitoring Report for 2010, DOE/RL-2011-01, Revision 0, to the U.S. Environmental Protection Agency (EPA) and State of Washington Department of Ecology (Ecology).

This report has been posted on the Hanford Soil and Groundwater Remediation Project external website http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports. One copy each were hand delivered to EPA and Ecology on August 31, 2011.

If you have any questions, please contact me, or your staff may contact, Briant Charboneau, of my staff, on (509) 373-6137.

Sincerely,

Jonathan Dowell

Jonathan A. Dowell, Assistant Manager
for the Central Plateau

AMCP:JGM

Attachment

cc: See Page 2

SEP 15 2011

cc w/attach:
G. Bohnee, NPT
L. Buck, Wanapum
L. E. Gadbois, EPA
S. Harris, CTUIR
R. Jim, YN
S. L. Leckband, HAB
N. M. Menard, Ecology
K. Niles, ODOE
D. Rowland, YN 4 CDs
Administrative Record
Environmental Portal

cc w/o attach:
D. G. Black, CHPRC
D. E. Dooley, CHPRC
R. E. Piippo, MSA
J. G. Vance, MSA

DOE/RL-2011-01
Revision 0

Hanford Site Groundwater Monitoring Report for 2010

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

Approved for Public Release;
Further Dissemination Unlimited

DOE/RL-2011-01
Revision 0

Hanford Site Groundwater Monitoring Report for 2010

Date Published
August 2011

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

Release Approval Date 08/25/2011

RECEIVED
SEP 20 2011
EDMC

DOE/RL-2011-01
Revision 0

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Abstract

The U.S. Department of Energy's Hanford Site in southeastern Washington State was a weapons production facility from 1943 until the 1980s. During operations, process chemicals and radioactively contaminated water were released to the soil and migrated through the vadose zone to the groundwater. Since 1989, the primary mission at the Hanford Site has been remediation of the site, including the groundwater. This report presents the results of groundwater monitoring at the Hanford Site during the 12-month period from January 1, 2010, through December 31, 2010, and is produced for the U.S. Department of Energy. The results of ongoing groundwater remediation activities and vadose zone characterization and monitoring results are summarized, and the status of well drilling, maintenance, and decommissioning is provided.

This report meets the annual reporting requirements for *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring at 24 waste management areas:

- Fourteen waste management areas under interim or final status contaminant indicator evaluation or detection monitoring programs, with the objective of determining whether these units have adversely affected groundwater
- Eight waste management areas under interim status groundwater quality assessment programs to assess the rate and extent of contaminant migration
- Two waste management areas under final status corrective action programs.

Results of monitoring for RCRA indicated that one additional site, the single-shell tank Waste Management Area A-AX Tank Farms, will be monitored under a groundwater quality assessment program due to the impact of dangerous constituents to groundwater from the unit. Groundwater flow evaluations have continued in the 200 East Area, where the hydraulic gradient is extremely low, and the existing groundwater networks are currently believed to be capable of meeting monitoring requirements. The monitoring network at Low-Level Waste Management Area 3 in 200 West Area is not currently compliant because there is no upgradient well; however, a new upgradient well is planned for installation in 2011.

Monitoring for the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* is conducted in twelve groundwater interest areas. The purpose of this monitoring is to define and track plumes and to monitor the effectiveness of remedial actions. One groundwater operable unit in the southern portion of the Hanford Site, the 1100-EM-1 Operable Unit, was previously removed from the National Priorities List (40 CFR 300, Appendix B) because final remediation goals were reached. Interim groundwater remediation in the 100-K, 100-D, and 100-H Areas, using a combination of pump-and-treat and in situ methods, continued to reduce the amount of chromium reaching the Columbia River. An in situ treatment system for sequestering or immobilizing strontium-90 is being used in the 100-N Area. A pump-and-treat system for technetium-99 and uranium in the 200-UP-1 Operable Unit, near the 216-U-1/2 Cribs in the 200 West Area, operated during the reporting period, as did a pump-and-treat system near Waste Management Area T in the 200-ZP-1 Operable Unit. A pump-and-treat system for the capture of carbon tetrachloride in the upper aquifer, also located in the 200-ZP-1 Operable Unit (west of Waste Management Area TX-TY), operated for most of the reporting period.

Groundwater contaminant plumes underlie an area of ~186 square kilometers at concentrations exceeding one or more drinking water standards. The largest groundwater plumes with concentrations above background are tritium, iodine-129, and nitrate. These contaminants originate from multiple sources. The largest plumes

extend from the Hanford Site's Central Plateau to the southeast, toward the Columbia River, with maximum concentrations within the plumes generally declining. Carbon tetrachloride and associated organic constituents form a large plume that exceeds drinking water standards beneath the west-central portion of the site, originating in the 200 West Area. Other constituents forming significant plumes exceeding drinking water standards are hexavalent chromium, strontium-90, technetium-99, and uranium. These constituents exist beneath the reactor areas along the Columbia River and beneath the west-central portion of the site, as well as the Central Plateau and the 300 Area. Small contaminant plumes with concentrations greater than their respective drinking water standards include carbon-14, cesium-137, cis-1,2-dichloroethene, cyanide, fluoride, plutonium, sulfate, and trichloroethene.

Levels of some contaminants exceed drinking water standards in water samples collected from aquifer sampling tubes along the Columbia River shore. The greatest exceedances were strontium-90 in the 100-N Area, chromium in the 100-D Area, and uranium in the 300 Area.

Highlights for the reporting period include the following:

- Release of the draft remedial investigation/feasibility study and proposed plan documents for the 200-UP-1 Operable Unit within the Central Plateau, meeting Milestone M-015-17A of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989)
- Expansion of pump-and-treat systems for chromium remediation in the 100-D and 100-H Areas
- Optimization of pump-and-treat systems for chromium remediation in the 100-K Area
- Submittal of the draft treatability test plan, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74), to the U.S. Environmental Protection Agency, completing Tri-Party Agreement Milestone M-015-082
- Approval and issuance of remedial investigation/feasibility study work plans and initiation of field studies in the 100 and 300 Areas.

During the reporting period, drillers completed 282 new wells for monitoring, remediation, or characterization. One hundred eighty-two soil tube well installations were decommissioned (filled with grout).

This report is available on the Internet through the Hanford Site Soil and Groundwater Remediation Project (http://www.hanford.gov/rl/?page=1334&parent=1333).

Acknowledgements

This report represents the efforts of dozens of individuals who contribute to the Soil and Groundwater Remediation Project: planners, schedulers, samplers, laboratory technicians, data management staff, scientists, editors, GIS professionals, and production staff.

The GIS, graphics, editing, and production team included Jennifer Baker, Angela Corbett, Randy Douglas, George Kelty, Theresa Larsen, Chris Martin, Patricia McNary, JoAnne Rieger, Michelle Riffe, Bill Webber, and Wally Williams. JoAnne Rieger also retrieved and formatted data for maps, trend plots, and tables. These coworkers are remarkable for their ability to work hard under pressing deadlines and yet maintain professionalism and retain their sense of perspective (and sense of humor).

Thanks also to the many reviewers whose comments and suggestions helped to improve this report, as well as the following key personnel for the report:

Chris Martin:	Coordination and technical lead
George Kelty:	Graphics coordination lead
Michelle Riffe:	Editing and text processing
Trisha McNary:	Design and layup
Jennifer Baker:	Publications Group coordination

This page intentionally left blank.

Report Contributors

The production of the *Hanford Site Groundwater Monitoring Report for 2010* required the knowledge, skill, expertise, and cooperation of many people and several organizations. The contributions and cooperation of the following authors are gratefully acknowledged.

The authors' names are listed in their respective sections of the report.

CHPRC/FFS/Freestone/GRAM/INTERA

D.J. Alexander
J.G. Blount
S.J. Champoux
M.E. Caron
G.D. Cummins
J.G. Douglas
J.A. Eluskie
D.B. Erb
S.L. Fitzgerald
E.J. Freeman
D.A. Gamon
E.A. Garcia
L.C. Hall
M.J. Hartman
B.J. Howard
G.L. Kasza
R. Khaleel
J.W. Lindberg
C.M. Martin
J.P. McDonald
C.A. Newbill
S.W. Petersen
R.F. Raidl
J.T. Rieger
V.J. Rohay
J.L. Smoot
G.S. Thomas
K.R. Thompson
M.J. Tonkin
S.J. Trent
D.C. Weekes
B.A. Williams

Pacific Northwest National Laboratory

J.S. Fruchter
R.E. Peterson
J.A. Sanford
D.S. Sklarew
C.J. Thompson
M.J. Truex
V.R. Vermeul
Z.F. Zhang

Washington Closure Hanford, LLC

R.L. Weiss

Washington River Protection Solutions

J.G. Fields
D.A. Myers
D.L. Parker
H.A. Sydnor
C.L. Tabor

This page intentionally left blank.

List of Terms

AEA	*Atomic Energy Act of 1954*
ANN	artificial neural network
bgs	below ground surface
CCU	Cold Creek unit
CCU_g	Cold Creek gravel unit
CCU_z	Cold Creek silt unit
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
COPC	contaminant of potential concern
CY	calendar year
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FS	feasibility study
FY	fiscal year
HEIS	Hanford Environmental Information System
HRL	Horn Rapids Landfill
IDF	Integrated Disposal Facility
IFRC	Integrated Field-Scale Subsurface Research Challenge
ISRM	In Situ Redox Manipulation
LERF	Liquid Effluent Retention Facility
LIGO	Laser Interferometer Gravitational-Wave Observatory

LLWMA	low-level waste management area
LWDF	liquid waste disposal facility
MC	Markov chain
MCL	Maximum Contaminant Level
NAVD88	North American Vertical Datum of 1988
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	operable unit
PFP	Plutonium Finishing Plant
ppm	parts per million
ppmv	parts per million by volume
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium-Uranium Extraction (Plant)
PRB	permeable reactive barrier
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
REDOX	Reduction-Oxidation (Plant)
RI	remedial investigation
ROD	Record of Decision
RPO	remedial process optimization
S&GRP	Soil and Groundwater Remediation Project
SALDS	State-Approved Land Disposal Site
SESP	Surface Environmental Surveillance Project
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases (model)
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWL	Solid Waste Landfill
TEDF	Treated Effluent Disposal Facility

TP	transition probability
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and disposal
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WCH	Washington Closure Hanford
WIDL	Well Information and Document Lookup
WMA	waste management area

This page intentionally left blank.

Executive Summary

Introduction

This document presents the results of Hanford Site groundwater monitoring for calendar year (CY) 2010, providing the primary means to report monitoring results for *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) units; for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater operable units (OUs) where no active remediation is currently taking place; and for the *Atomic Energy Act of 1954* (AEA), as required by U.S Department of Energy (DOE) orders. This report provides a summary of vadose zone monitoring, investigations, and results; and well installation, remediation, and decommissioning activities. Details on the CERCLA remediation activities (e.g., pump-and-treat operations) are presented in separate reports and are summarized in this report.

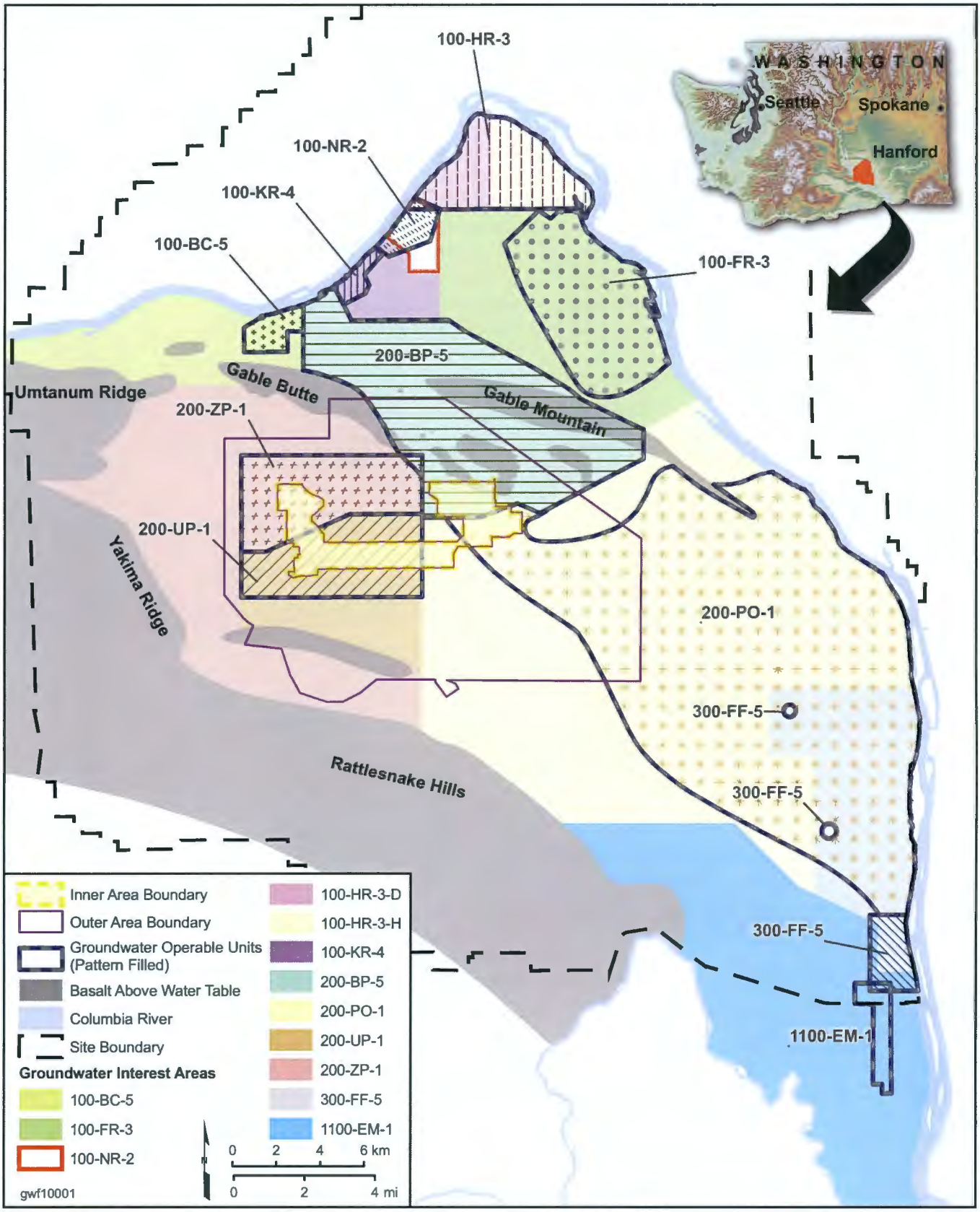
The layout of this report presents the various OUs and groundwater interest areas in numerical order (100 Area, followed by 200 Area, etc.). However, throughout this report, certain areas may also be discussed as aggregate units (e.g., Central Plateau and River Corridor). For the purposes of this report, the Central Plateau includes the 200 East and 200 West Areas, off-river sites (400 Area), and the surrounding nonoperational area (600 Area). The River Corridor refers to those portions of the Hanford Site adjacent to the Columbia River and includes the 100 Area, 300 Area, and the 1100-EM-1 groundwater interest area.

The Hanford Site encompasses ~1,500 square kilometers in southeast Washington State and is part of the DOE's nuclear weapons complex, but the Site no longer has a defense mission. The Hanford Site is located in the Lower Columbia Basin, with the Columbia River forming its northern and eastern boundaries. The federal government acquired the Hanford Site in 1943 and used it to produce plutonium until the 1980s. The site is currently surrounded by various units of the Hanford Reach National Monument, which was formed in 2000.

Management of waste associated with plutonium production has been a major activity throughout the Hanford Site's history, with the most hazardous and radioactive waste associated with underground storage tanks. Waste management continues today but now also includes managing waste generated by the remediation of former waste disposal sites and from decontaminating and demolishing unused production facilities. Beginning in the 1990s, the DOE has focused on cleaning up the Hanford Site. The data presented in this report, as well as information on well locations, construction, and screened intervals can be found through the DOE's Environmental Dashboard Application at http://environet.hanford.gov/EDA/.

The DOE is committed to protecting the Columbia River, human health, and the environment from the Hanford Site's contaminated groundwater. As part of this commitment, the DOE developed a detailed strategy for the protection, monitoring, and remediation of the Hanford Site's contaminated groundwater (DOE/RL-2002-59, *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation*). To further bolster this commitment, DOE created a plan to accelerate groundwater remediation as detailed in *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection* (DOE/RL-2002-68). The DOE's most recent recommitment to groundwater protection is outlined in *Hanford Integrated Groundwater and Vadose Zone Management Plan* (DOE/RL-2007-20), which outlines the steps for addressing groundwater and vadose zone contamination in conjunction with the above strategy.

The Hanford Integrated Groundwater and Vadose Zone Management Plan sets out a strategy for groundwater that focuses on three key areas: groundwater protection, groundwater monitoring, and remediation of contaminated groundwater.



Hanford Site groundwater monitoring is organized by areas of interest, which are informally named after the groundwater operable units. The areas of interest are useful for planning and scheduling groundwater monitoring and interpreting data.

Even with this strong commitment, some contaminants have reached the Columbia River by moving downward from waste sites, through the vadose zone, into the groundwater, and then moving laterally with the groundwater into the river. The DOE works with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) to make cleanup decisions based on sound technical information.

The DOE monitors groundwater at the Hanford Site to fulfill state and federal regulations, including the AEA, RCRA, CERCLA, and various sections of the *Washington Administrative Code* (WAC).

DOE O 450.1A, *Environmental Protection Program*, and DOE O 435.1, *Radioactive Waste Management*, implement requirements of the AEA at DOE sites. DOE O 450.1A requires environmental monitoring to detect, characterize, and respond to releases of radionuclides from DOE activities; assess impact; and characterize potential exposure pathways. The order recommends implementing a site-wide approach for groundwater protection, and it requires compliance with other applicable environmental protection requirements. DOE O 435.1 includes responsibilities and requirements for management of radioactive waste.

To manage Hanford Site cleanup, waste sites are grouped within geographic areas known as operable units (OUs) so the CERCLA cleanup process can be efficiently implemented. Most of the OUs are source OUs (i.e., surface and vadose zone areas where waste was disposed) but eleven are groundwater OUs. The concept of the groundwater OU was adopted to separate characterization of the waste sites from the groundwater. This approach recognizes differences between localized contaminants in the soil column at the sources and the more widespread, co-mingled contamination in groundwater. Groundwater samples are collected from monitoring wells to define the nature and extent of contaminant plumes, and to evaluate the effectiveness of groundwater remediation efforts.

Groundwater monitoring requirements for the Hanford Site's RCRA units fall into one of two broad categories: interim status or final status. A permitted RCRA unit requires final status monitoring, as specified in WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring, as specified in WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (based on 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). Although the single-shell tank farms and inactive TSD units are listed in Part A of the Hanford Facility Dangerous Waste Permit (WA7890008967), they are operated under interim status requirements until an approved operating permit for each unit is issued. The single-shell tank farms are all operated under RCRA groundwater assessment and are designated as waste management areas (WMAs).

The RCRA groundwater monitoring is conducted under one of three possible phases: (1) contaminant indicator evaluation/final status detection monitoring, (2) groundwater quality assessment/compliance monitoring, or (3) corrective action monitoring. In contaminant indicator evaluation monitoring, four indicator parameters (pH, specific conductivity, total organic carbon, and total organic halides) are monitored and evaluated against statistically derived threshold values calculated from upgradient wells. In final status detection monitoring, site-specific indicators are evaluated using statistical methods identified in the respective permit. Groundwater quality assessment/final status compliance monitoring occurs when a facility appears

to have impacted groundwater quality. The objective of the monitoring program shifts from detection to assessing the nature and extent of the problem. Under corrective action monitoring, some form of groundwater remediation has been stipulated by Ecology. The goal of a corrective action groundwater monitoring program is to determine if the corrective action is effective.

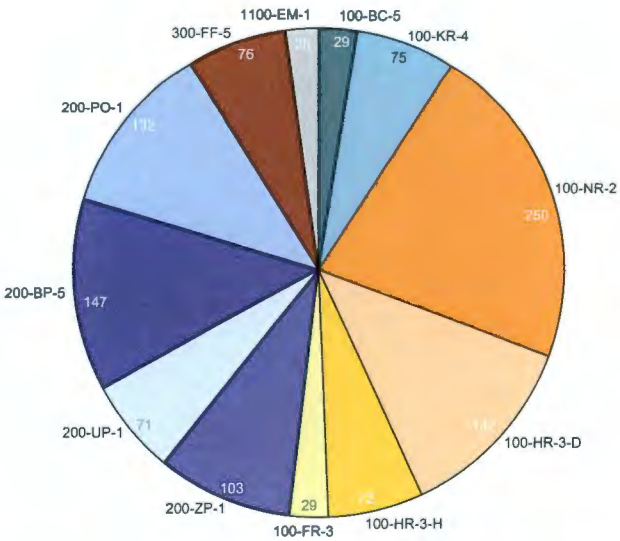
This report covers the period from January 1, 2010, through December 31, 2010. The following date conventions are used throughout this report.

- FY 2010: Refers to the fiscal year (FY); FY 2010 covers the period of October 1, 2009, to September 30, 2010.
- CY 2010: Refers to the calendar year (CY); CY 2010 covers the period from January 1, 2010, to December 31, 2010.

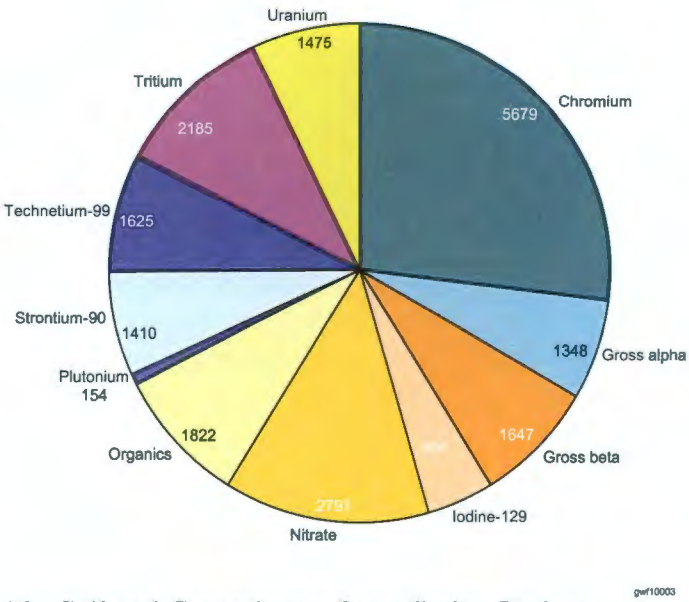
The DOE sampled 1,311 monitoring wells during the reporting period. Chromium, nitrate, and tritium are constituents frequently analyzed.

During the reporting period, workers sampled 1,311 monitoring wells and 145 shoreline aquifer tubes to determine the distribution and movement of contaminants. Many of the wells and aquifer tubes were sampled multiple times during the reporting period, resulting in 4,277 well sample trips. A total of 51,860 analyses were performed for the groundwater program, yielding over 283,000 results during the reporting period.

During the reporting period, a total of 5,679 samples of Hanford Site groundwater were analyzed for total chromium (with a nearly equal amount of hexavalent chromium analyses); 2,791 samples for nitrate; and 2,185 samples for tritium. Other constituents frequently analyzed include technetium-99 (1,625 samples), uranium (1,475 samples), and carbon tetrachloride (1,822 samples). These totals include results for routinely sampled groundwater wells, pump-and-treat operational samples, and aquifer tube samples.



The number of wells and aquifer tubes sampled in each groundwater interest area during the reporting period.



The Soil and Groundwater Remediation Project requests specific laboratory analyses based on well locations, historical contaminant trends, and regulatory requirements. This graphic shows the number of analyses requested for the most common constituents during the reporting period.

Groundwater Program Highlights

The highlights from groundwater projects for the CY 2010 reporting period are summarized below. Details can be found in the appropriate chapter discussions for the OUs.

The DOE is focusing remediation efforts on activities that protect the Columbia River.

- ***River Corridor baseline risk assessment.*** To support the decision-making process for final CERCLA remedial actions within the River Corridor, the DOE is conducting a CERCLA remedial investigation (RI) including a baseline risk assessment for the River Corridor portion of the Hanford Site. The risk assessment consists of three components: (1) the 100 Area and 300 Area Component, (2) the Inter-Area Component, and (3) the Columbia River Component. The 100 Area and 300 Area Component and the Inter-Area Component will be integrated with groundwater and source OU data into a series of final CERCLA RI reports for the operational areas of the River Corridor.

In 2010, the DOE began intensive field studies in the River Corridor. Data collected under these studies will be used to select methods for final remediation of soil and groundwater.

- ***Remedial investigation/feasibility study.*** In CY 2010, the DOE began field studies under RI/feasibility study (FS) work plans and associated sampling and analysis plans for the six River Corridor decision areas. Field studies included drilling boreholes and also installing groundwater monitoring wells and aquifer tubes. Other studies included conducting aquifer tests, evaluating groundwater and soil samples for contaminants of potential concern, and refining geologic and hydrologic models. The data will be used to select methods for remediating soil and groundwater. The selection of the final remedial actions will be documented in Records of Decision (RODs).
- ***100-KR-4 OU pump-and-treat expansion.*** During CY 2010, the three pump-and-treat systems (KW, KR-4, and KX) continued operations to treat hexavalent chromium contamination in the 100-KR-4 Groundwater OU. Three new extraction wells were drilled and connected to the KX pump-and-treat system, and two new monitoring wells were drilled. Three extraction wells in a groundwater region containing high tritium concentrations were realigned from the KX system to the KR-4 system to contain tritium within the 100-KR-4 groundwater plume. The realignment included adding one new injection well to the KX system and one new well to the KR-4 system. Two extraction wells where groundwater containing hexavalent chromium was cleaned up were converted to monitoring wells, along with one injection well. Modifications to the KR-4 pump-and-treat system programmable logic controller and extraction well electrical components were initiated in CY 2010 to upgrade the systems to a design similar to the more recent KX pump-and-treat system. The total treatment capacity for the three pump-and-treat systems is 4,167 liters per minute.
- ***100-KR-4 OU remedial process optimization.*** Design and construction was initiated in CY 2010 to implement Phase 3 realignment of the 100-KR-4 OU pump-and-treat systems identified through remedial process optimization (RPO). This activity will continue through CY 2011 to add one new extraction well to the KW pump-and-treat system and one new extraction well and two monitoring wells to the KR-4 pump-and-treat system to provide capture near the Columbia River.
- ***100-N Area apatite barrier.*** Since injections of apatite-forming chemicals ceased at the permeable reactive barrier (PRB) in July 2008, a steady decline has been observed for strontium-90 and gross beta in the wells being sampled, with very few exceptions. As of August 2010, some wells showed a slight upward trend

in strontium-90/gross beta concentration. However, all of the wells along the existing barrier were still showing a 90% or greater decline in strontium-90/gross beta from measured pre-injection values.

- ***100-HR-3 OU remedial process optimization.*** The DOE began to expand and optimize the 100-HR-3 OU treatment systems in CY 2009. Construction on the new DX pump-and-treat facility (with a total design capacity of 2,300 liters per minute) was completed at the end of CY 2010, which will increase the treatment capacity in the 100-D Area and the southwest portion of the horn area. A pilot test of the facility started in December 2010 and treated 55.3 million liters, removing an additional 18.4 kilograms of hexavalent chromium for the year. Construction of the HX pump-and-treat system (with a design capacity of 3,000 liters per minute) is progressing ahead of schedule, with the treatment building nearly complete. The HX system is scheduled to go online in December 2011 and will expand pump-and-treat capacity and areal coverage in the 100-H Area and the northeast portion of the horn area.
- ***200-ZP-1 OU interim action pump-and-treat system and 200 West Area pump-and treat system.*** During CY 2010, the two interim pump-and-treat systems at the 200-ZP-1 OU and WMA T continued operations to reduce contamination for the primary contaminants carbon tetrachloride and technetium-99, respectively. Extraction well 299-W15-44 was removed from the 200-ZP-1 OU extraction well network and well 299-W15-225 was added. The new well is screened over a longer interval compared to other interim extraction wells that only produce from the upper 15 meters of the unconfined aquifer. The decision to screen the new extraction wells through the entire unconfined aquifer is based on discrete, vertical sampling from which higher carbon tetrachloride concentrations were observed at greater depths than were considered for interim pump-and-treat wells. Extraction well 299-W15-225 accounted for 52% of the cumulative production for this pump-and-treat system and contributed to a 60% increase in the mass of carbon tetrachloride removed during CY 2010 relative to CY 2009. Additional information on this change can be found in Chapter 12.0, Section 12.3. Work continued to install additional injection and extraction wells and construct an expanded effluent processing plant that are identified as the final remedy in the *Declaration of the Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* (EPA et al., 2008). Well installation and plant construction are scheduled for completion at the end of CY 2011.
- ***300-FF-5 OU studies.*** Laboratory treatability tests involving polyphosphate solutions were performed during CY 2010, with plans to continue field treatability tests at a second test site during CY 2011, where the focus is on immobilizing uranium in the vadose zone.
- ***Columbia River monitoring.*** In CY 2010, DOE and Washington Closure Hanford continued evaluating Hanford Site contaminant releases to the Columbia River by collecting porewater samples from within the bottom sediments of the Columbia River itself, as well as samples of sediment and river water. The information obtained from this investigation will ultimately be used to help make final cleanup decisions for Hanford Site contaminants that exist in and along the Columbia River. The field sampling part of this study concluded in CY 2010, and the results were published in early 2011 (WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*). The findings from this report are summarized under the 100-BC-5 OU highlights below and in Chapter 4.0.

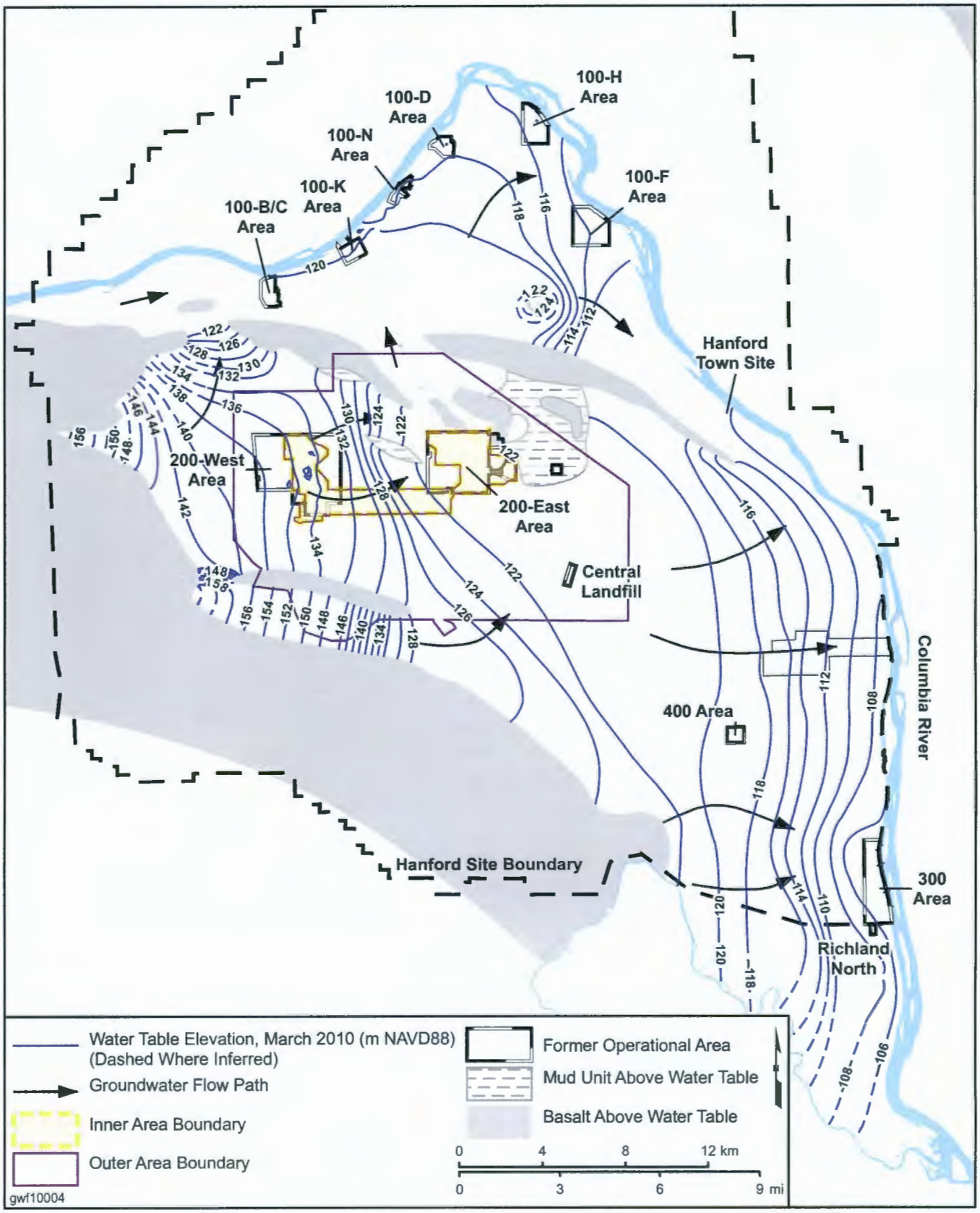
- ***Groundwater sampling work stoppage.*** Groundwater sampling was stopped between September 27, 2010, and November 8, 2010, when a safety-related work stoppage closed down all sampling activity performed by the Soil and Groundwater Remediation Project. A recovery plan was put in place to address the required sampling at RCRA TSD units. The recovery plan identified 70 agreed-upon priority wells out of 130 RCRA wells scheduled for sampling during the last quarter of 2010. The collection of most groundwater samples was delayed until December. Groundwater Sampling Operations collected 68 of the 70 RCRA TSD unit samples agreed upon in the recovery plan (two required maintenance). An additional 50 of the 130 RCRA wells originally scheduled for sampling in the fourth quarter and not in the recovery plan were also sampled in December. This left only twelve RCRA TSD wells (including the two requiring maintenance) scheduled for sampling in the fourth quarter of 2010 not sampled, and six of those were sampled in January 2011. Additional details on this event can be found in the Administrative Record for the February 15, 2011, meeting minutes on Groundwater Sampling Stop Work Information.

Groundwater Flow

Groundwater flow direction is illustrated on the water table map for March 2010. Groundwater flow directions are inferred from water table elevations, barriers to flow (e.g., basalt or mud units at the water table), and contaminant distributions. Groundwater enters the unconfined aquifer from recharge areas to the west and eventually discharges to the Columbia River. During periods of high water, the Columbia River recharges the aquifer adjacent to the river. Additional water infiltrates through the vadose zone. Hydrologists estimate that the total discharge of groundwater from the Hanford Site unconfined aquifer to the Columbia River is in the range of 0.08 to 2.8 cubic meters per second (PNNL-SA-56038, *Hanford Site Groundwater and the Columbia River, South-Central Washington*), but the distribution of discharge rates along the length of the River are not well known. In addition, only a portion of this discharge is contaminated. This total groundwater discharge rate is less than 0.001% of the average flow of the Columbia River (~3,400 cubic meters per second).

The water table beneath much of the central portion of the Hanford Site is relatively flat because the aquifer is primarily within the highly permeable sediments of the Hanford formation, and natural recharge rates are low. Groundwater enters the region of the 200 East Area from the west and southwest. This flow of water divides as it approaches the central portion of the 200 East Area; some flow is to the north through the gap between Gable Butte and Gable Mountain (Gable Gap), and some flow is to the southeast toward the central portion of the Hanford Site. This groundwater divide is located near the north-central portion of the 200 East Area, but the precise location is unknown and may in fact change over time depending on the stresses imposed on the hydrologic system.

A long-term study of the low hydraulic gradient in the northwest portion of the 200 East Area was initiated in 2005 and extended across the entire northern portion of the 200 East Area in CY 2010. The additional results of this study did not produce any unexpected results during CY 2010. The long-term average flow direction for the northwestern portion of the 200 East Area continued to be north-northwest. The groundwater gradient in the northeastern portion of the 200 East Area has proven to be too flat to measure at the available instrument accuracy. Similarly, ambiguous



The water table and inferred groundwater flow directions in March 2010. Groundwater flows from areas where the water table is high to where it is lower, and eventually discharges to the Columbia River.

flow directions due to the flat gradient from the south-central and south-eastern portion of the 200 East Area around the Integrated Disposal Facility (IDF) and the Plutonium-Uranium Extraction (PUREX) Cribs are consistent with data collected in previous years. The water-level measurements indicate eastward flow in this area generally consistent with the regional flow direction toward the southeast.

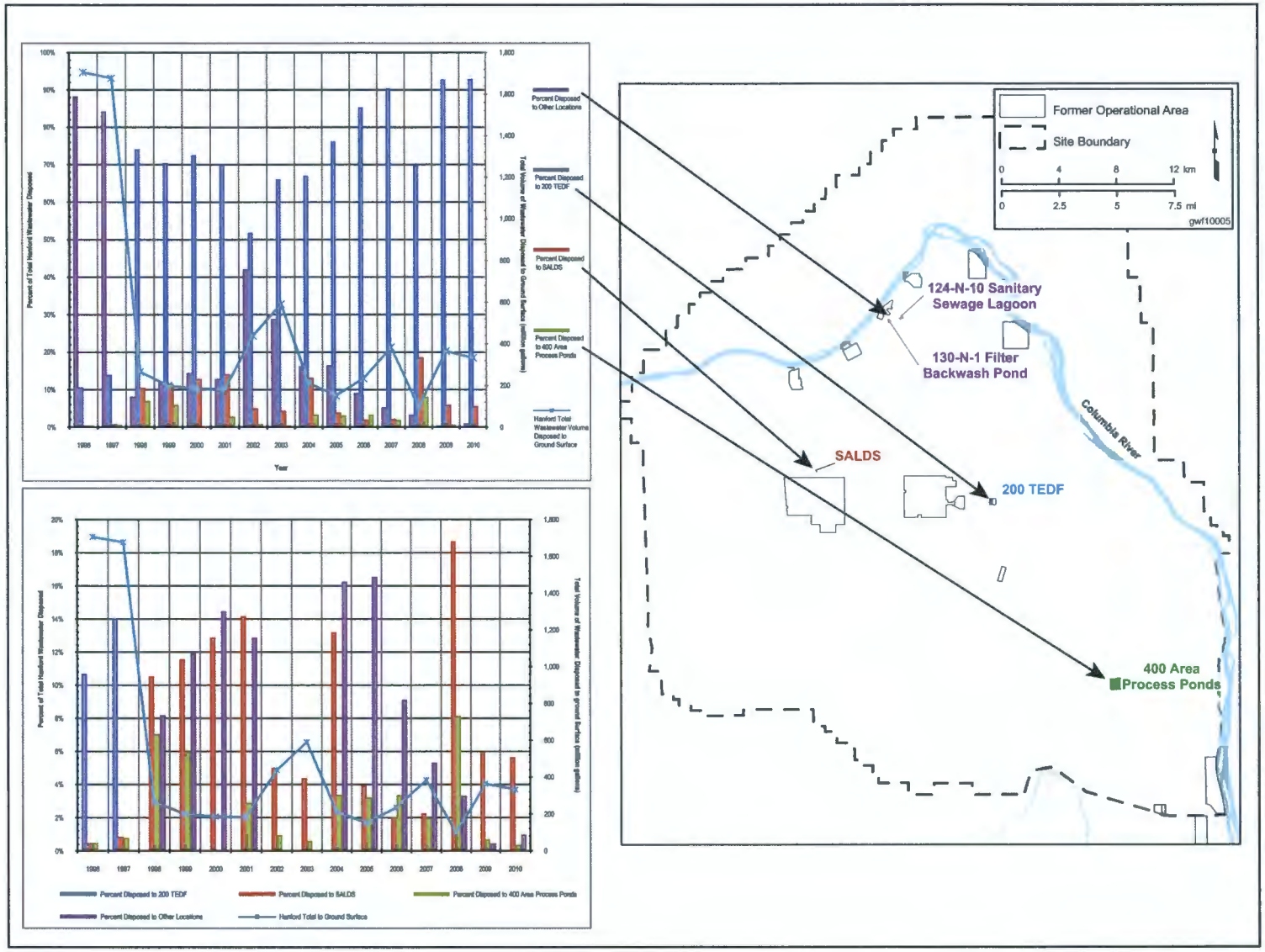
The natural pattern of groundwater flow was altered during the Hanford Site's operating years by water table mounds. The mounds were created by discharge of large volumes of wastewater to the ground and were present in each reactor area and beneath the 200 East and 200 West Areas. Since the sitewide decrease in effluent disposal in the 1990s, these mounds dissipated in the reactor areas and have declined considerably in the 200 Area. Wastewater is currently discharged to the ground at five locations; however, only two discharge sufficient volumes to affect local groundwater movement: the State-Approved Land Disposal Site (SALDS) (north of the 200 West Area) and the 200 Area Treated Effluent Disposal Facility (TEDF) (east of the 200 East Area). A small groundwater mound has developed under SALDS, but the infiltration from TEDF encounters the Ringold lower mud above the water table and moves off to the southeast without forming a mound.

Changes in groundwater flow in the unconfined aquifer are more pronounced where extraction or injection wells are used for pump-and-treat systems. Extraction wells in the 100-K, 100-D, 100-H, and 200 West Areas capture contaminated water for treatment. Water flows away from injection wells, which when upgradient of the contaminant plumes, increases the hydraulic gradient toward the extraction wells. Injection wells downgradient of a contaminant plume are often designed to act as barriers to flow, controlling plume migration.

In most places south of Gable Mountain, the base of the unconfined aquifer is the Ringold Formation lower mud unit (Figure 2-2 in Chapter 2.0). Where this unit is absent, the dense, interior portion of the uppermost basalt flow is usually the base of the unconfined aquifer. In some locations, such as at the Liquid Effluent Retention Facility (LERF), the unconfined aquifer is known to occur in the fractured basalt flow top. It is unknown how common the occurrence of the aquifer in fractured basalt is, but the overlying aquifer may extend to below the top of basalt in other places at the Hanford Site where fractured, vesiculated, rubble flow tops are present.

Several wells north of and within the 200 East Area have shown evidence of intercommunication between the unconfined and both the Ringold and upper basalt-confined aquifers. The intercommunication has been attributed to erosion of the upper Saddle Mountains Basalt, although structural uplift, thinner basalt flows, and increased fracturing of the basalt may also be factors. In these areas, the uppermost sedimentary interbed within the basalts, the Rattlesnake Ridge interbed, exhibits unconfined characteristics. Since an upward hydraulic gradient is now present in the 200 East Area/Gable Gap region (except near the 216-B-3 Pond), the upper basalt-confined aquifer discharges to the overlying unconfined aquifer, especially within Gable Gap where the Elephant Mountain Basalt was removed by erosion.

Along the River Corridor, groundwater flow is toward the river during most of the year, thus flow may be to the north, east, or west depending on location along the river. During the spring high river stage, the Columbia River loses water to the aquifer. This reverses the local groundwater flow direction. Another difference between the River Corridor and the central portion of the Hanford Site is that the base of the unconfined aquifer is generally bounded by the Ringold upper mud unit along the River Corridor. This unit is missing from the Central Plateau region.



Discharge of liquid effluent to the ground has been curtailed since the late 1980s. Currently, permitted liquid discharges to the ground surface at only five locations. The main chart represents the percent of the total Hanford wastewater volume discharged to the ground that was received at each discharge location. The second chart shows only those locations that received less than 20% of the total during a year (e.g., 200 Area TEDF discharge is not shown for the years 1998 through 2010). It is important to note that changes are percentages and not related to redirection of effluent (i.e., the change between 1997 and 1998 from other to TEDF is <u>not</u> the result of shifting effluent from the other locations to TEDF [in fact, total volume decreased], but merely shows that after 1998 TEDF became the main contributor to the total wastewater discharged).

Confined aquifers occur in some areas where beds of sand and gravel are within or below fine-grained units of the Ringold Formation. Along the River Corridor, a confined aquifer occurs within or beneath the Ringold upper mud unit, while in the Central Plateau it occurs between the uppermost basalt and the Ringold lower mud unit. Groundwater elevation in the Ringold Formation confined aquifer in the 200 East Area on the Central Plateau still retains signs of the residual recharge mound in the area of the decommissioned 216-B-3 Ponds.

Deeper confined aquifers are present in the interbeds, interflow zones, and fractures of the basalts beneath the Hanford Site. The uppermost of these basalt-confined aquifers is in the Rattlesnake Ridge interbed, which is found between the Elephant Mountain and Pomona Members of the Saddle Mountains Basalt. Groundwater flow in this aquifer moves generally from west to east.

Groundwater Monitoring and Remediation

Sampling and analysis of groundwater provides data to help characterize the nature and the potential fate and transport of contaminants in the environment.

Most of the monitoring wells on the Hanford Site are screened near the top of the unconfined aquifer (approximately within the upper 10 meters); however, in the past several years, additional wells have been installed deeper (especially in the 200 West Area) to assess the vertical extent of groundwater contamination. In some locations, these wells have shown significant contamination (primarily carbon tetrachloride) deep in the aquifer. Data from some of the 200 East Area wells installed deep in the aquifer or from characterization samples collected while drilling have also indicated contamination deep in the aquifer; this is also true in portions of the 300-FF-5, 100-HR-3, and 100-NR-2 OUs. Some contaminants (most notably carbon tetrachloride) are more dense than water and can be more widespread deeper in the aquifer. It is also known that the liquid waste stored in the tank farms was high in salts and had densities above the 1 g/cc of water. Historical downward hydraulic gradients may also have increased contamination at depth in some areas. Studies of contaminant distribution with depth are being conducted for some plumes, particularly in the 200 West Area. Contamination with depth is discussed in those chapters where studies indicate (or have shown in the past) the presence of contaminants in the deeper portions of the aquifer. For the most part, however, the shallow portion of the aquifer is the most contaminated. The contaminant plume maps and plume area calculations in this report are based on data from the top of the aquifer (upper 10 meters), unless otherwise noted.

Groundwater monitoring plays a key role in delineating groundwater contaminant plumes at the Hanford Site. Contaminant conditions for most of the major plumes in CY 2010 were similar to CY 2009. The increases in area for chromium, iodine-129, nitrate, technetium-99, and tritium are not due to the incorporation of new data points but rather are a result of revisions to how the plume contours are drawn. In previous years, contours were drawn between wells with concentrations below the drinking water standard (DWS) and those with concentrations above the DWS. While technically accurate, this resulted in areas where the plume shape was questionable. This year, contours were drawn to make hydrologic sense, with the result that some wells with concentrations below the DWS appear inside the plume. This also increased the apparent area of the plumes. Of these groundwater contaminant plumes, tritium and iodine-129 cover the largest areas, with concentrations above DWSs of 20,000 pCi/L and 1 pCi/L, respectively. The sources of these plumes originate in the 200 East Area and extend several miles toward the east and southeast. Less extensive tritium and iodine-129 plumes are also found in the 200 West Area.

Technetium-99 exceeds the DWS (900 pCi/L) in localized plumes at the 200 East and 200 West Areas. One technetium-99 plume extends to the northwest, beyond the 200 East Area boundary, confirming groundwater flow to the northwest. Local uranium plumes are found in the 200 East, 200 West, and 300 Areas; these plumes are less extensive, in part, because uranium is less mobile than tritium, iodine-129, or technetium-99. Strontium-90 exceeds the DWS (8 pCi/L) in the 100 Area, 200 East Area, and beneath the former Gable Mountain Pond. Cesium-137, cobalt-60, and plutonium exceed the DWS in only a few individual wells in the 200 East Area.

Nitrate is the most widespread chemical contaminant in Hanford Site groundwater, with plumes originating from the 100 and 200 Areas and from offsite industrial and agricultural sources near the 300-FF-5 OU and 1100-EM-1 groundwater interest area, as well as upgradient from the Hanford Site. In portions of the 200 West, 100-K, and 100-D Areas, chromium is found at levels above the 100 µg/L DWS. Hexavalent chromium also exceeds Washington State's cleanup standard of 48 µg/L and the aquatic water quality criterion of 10 µg/L in these areas and in portions of the 100-B/C, 100-H, 100-F, and 600 Areas. Local chromium plumes are also present in the 200 Area. Carbon tetrachloride is the most widespread organic contaminant on the Hanford Site, forming a large plume beneath the 200 West Area. Other more minor organic contaminants in the 200 West Area include chloroform and trichloroethene. The 100-F, 100-K, and 300 Areas also have trichloroethene plumes.

Major Groundwater Contaminants on the Hanford Site

Plume Contaminant	Primary Locations	Plume Area Above DWS (km^2)	Drinking Water Standard	Remediation in Place?	Mobility and Half-Life
Carbon tetrachloride	200-ZP-1	11.5	5 µg/L	Yes	Mobile[a] (denser than water)
Chromium (hexavalent)	100-KR-4, 100-HR-3	3.1	48 µg/L[b]	Yes	Mobile
Cyanide	200-BP-5	0.3	200 µg/L	No	Mobile
Iodine-129	200-BP-5, 200-PO-1, 200-UP-1, 200-ZP-1	66.6	1 pCi/L	No	Mobile; 15.7 million years
Nitrate (as NO_3)	100-HR-3, 100-FR-3, 200 Area	36.3	45 mg/L	No	Mobile
Strontium-90	100-NR-2, 200-BP-5	1.6	8 pCi/L	Yes at 100-NR-2 No at 200-BP-5	Moderate;[c] 28.8 years
Technetium-99	200-BP-5, 200-UP-1	2.8	900 pCi/L	Yes at 200-UP-1 No at 200-BP-5	Mobile; 211,000 years
Trichloroethene	100-FR-3, 200-ZP-1	0.8	5 µg/L	Yes at 200-ZP-1 No at 100-FR-3	Mobile
Tritium	200 Area, 300-FF-5	129.1	20,000 pCi/L	No	Mobile; 12.3 years
Uranium	200-UP-1, 200-BP-5, 300-FF-5	1.4	30 µg/L	Yes at 200-UP-1 No at 200-BP-5 and 300-FF-5	Moderate; 246,000 years (U-234), 4.5 billion years (U-238)
Area of combined plumes[d]		**186.3 km^2**			

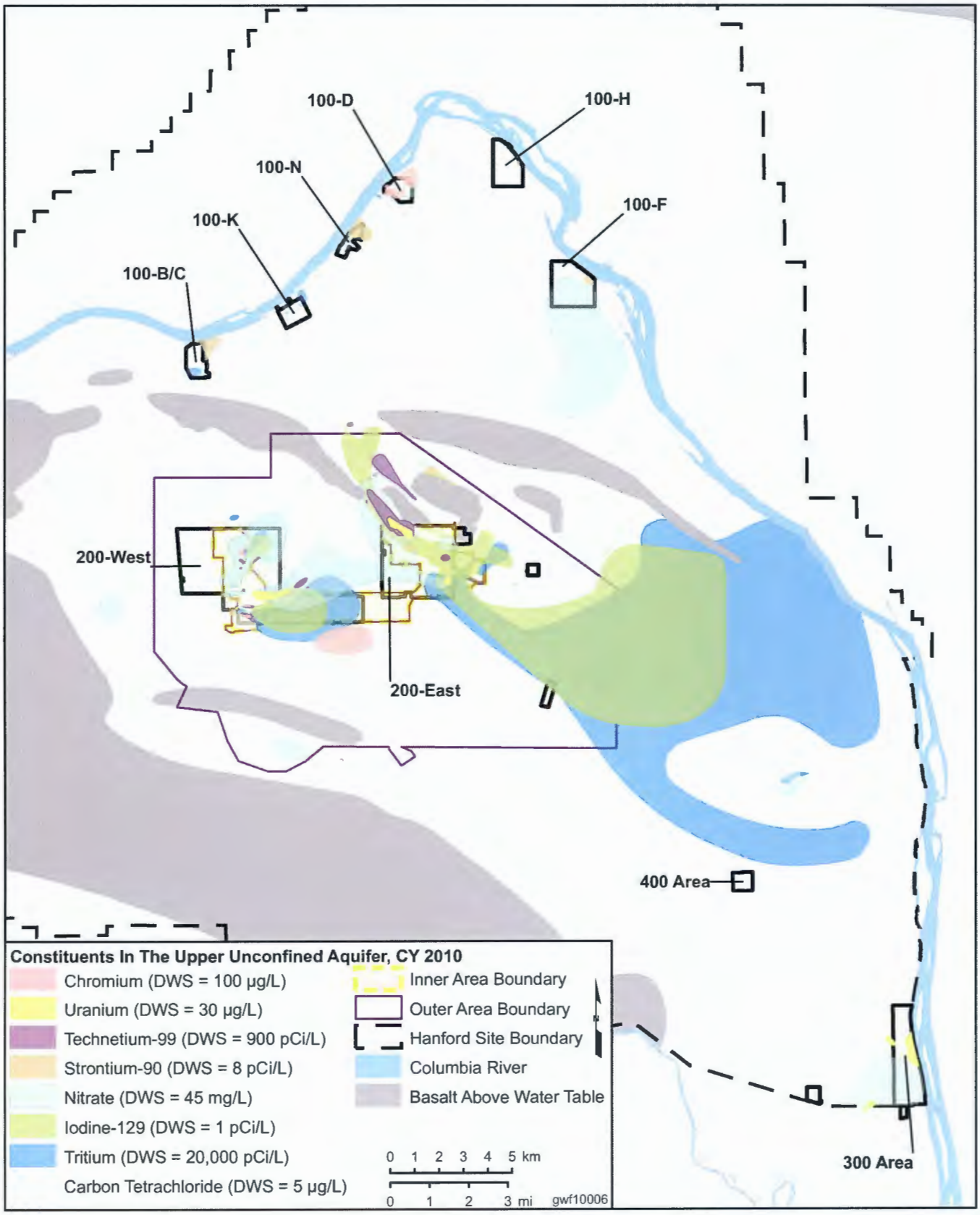
Note: Increase in plume areas for chromium, iodine-129, nitrate, technetium-99, and tritium are due to revisions in how the plume contours were drawn. See text discussion for details.

a. "Mobile" means a contaminant moves readily in groundwater.

b. The value shown is the Washington State Model Toxics Control Act groundwater cleanup standard, not the drinking water standard.

c. "Moderate" means a contaminant undergoes some retardation due to geochemical reactions, and thus moves slower than the groundwater.

d. Many plumes overlap, thus the area of combined plumes is less than the sum of the individual plume areas.



This map illustrates the distribution of the major contaminant plumes on the Hanford Site at concentrations above drinking water standards in approximately the upper 10 meters of the unconfined aquifer.

Groundwater Remediation of Major Contaminants

Remedial Action Site	Dates Active	Purpose and Progress on Major Contaminants Through December 2010
100-K Area: KR4 pump-and-treat system	1997 to present	Decreases chromium to river; 354.7 kg removed. System is being expanded.
100-K Area: KW pump-and-treat system	2007 to present	Decreases chromium to river; 137.4 kg removed. System is being expanded.
100-K Area: KX pump-and-treat system	2009 to present	Decreases chromium to river; 83.7 kg removed. System was completed and brought online.
100-N Area: 100-NR-2 pump-and-treat system	1995 to 2006	1.8 Ci of strontium-90 removed.
100-N Area: apatite barrier	2006 to present	Test injections completed; apatite formation verified; currently in performance monitoring.
100-D and 100-H Areas: HR-3 pump-and-treat system	1997 to present	Decreases chromium to Columbia River; 392.9 kg removed.
100-D and 100-H Areas: DR-5 pump-and-treat system	2004 to present	Decreases chromium to Columbia River; 326.2 kg removed.
100-D Area: In Situ Redox Manipulation (ISRM)	1999 to present	Decreases chromium concentrations downgradient of barrier. Showing breakthrough; amendments being tested.
100-D Area: DX System	January 2011 to present	Testing of the DX system was completed in December 2010; 18.4 kg removed.
100-H Area: HX System	Oct 2011	Testing is planned to be completed in September 2011; in preparation for October 2011 operation.
200 West Area: 200-ZP-1 pump-and-treat system	1994 to present	Prevents high-concentration portion of carbon tetrachloride plume from spreading; 12,647 kg removed. System is being expanded to implement final ROD.
200 West Area: soil vapor extraction	1992 to present	Reduces carbon tetrachloride movement to groundwater; 79,751 kg removed from vadose zone.
200 West Area: WMA T pump-and-treat system	2007 to present	Removes technetium-99 from the aquifer; 63.6 g (1.08 Ci) removed.
200 West Area: 200-UP-1 (U Plant) pump-and-treat system	1994 to 2005, 2007 to present	Removes technetium-99 and uranium from the aquifer; 127.6 g of technetium-99 (2. 17 Ci) and 220.3 kg of uranium removed.
200 West Area: S-SX Tank Farms well 299-W23-19 extended purging	2003 to present	Removes some technetium-99 from the aquifer; 0.57 g (0.01 Ci) removed.
300 Area: Monitoring and institutional controls on groundwater use (interim action, 300-FF-5)	1996 to present	Uranium concentrations remain above the target value, with contamination level relatively constant and or gradually decreasing. Cis-1,2-dichloroethene concentrations remain above target value at one well, with constant trend. Trichloroethene concentrations are below target value in unconfined aquifer, but well above it in finer grained subinterval. Nitrate concentrations exceed target levels in the southern portion of the 300 Area. Uranium and nitrate remain elevated above target levels in samples from shoreline aquifer tubes.
618-11 Burial Ground: monitoring and institutional controls on groundwater use (interim action, 300-FF-5)	2000 to present	Tritium concentrations remained highly elevated above the target value during 2010.
618-10 Burial Ground: monitoring and institutional controls on groundwater use (interim action, 300-FF-5)	2000 to present	Uranium and organic compounds continued to be monitored, but were at concentrations lower than the target values during 2010.
1100-EM-1: natural attenuation (final action)	1996 to present	Trichloroethene concentrations below 5 μg/L since 2001.

The following discussion summarizes groundwater contamination, monitoring, and remediation for each of the eleven groundwater OUs and for the confined aquifers.

100-BC-5 Operable Unit

The 100-BC-5 OU includes groundwater beneath the B and C Reactors and adjacent area along the Columbia River. Contamination is related to disposal of both solid and liquid wastes associated with operation of two water-cooled reactors. Groundwater in the 100-BC-5 OU is contaminated with hexavalent chromium, which forms a large plume at relatively low concentrations (less than 50 µg/L). Tritium and strontium-90 exceed the DWSs in several wells.

Groundwater activities during the reporting period included RI studies (DOE/RL-2009-44, *Sampling and Analysis Plan for the 100-BC Decision Unit Remedial Investigation/Feasibility Study*) and routine groundwater monitoring (DOE/RL-2003-38, *100-BC-5 Operable Unit Sampling and Analysis Plan*).

Ten new monitoring wells and nine vadose boreholes were installed in 100-B/C Area for the RI and waste site remediation purposes.

New groundwater monitoring wells were installed for the RI in CY 2010. When field studies are complete in 2011, ten new groundwater monitoring wells will have been installed. Data from these wells will help to refine geologic and hydrologic knowledge of the site and will enhance definition of groundwater contaminant plumes both horizontally and vertically. Nine aquifer tubes were also installed for the RI. The studies also include vadose zone boreholes and test pits, which provide data on soil contamination and mobility beneath former waste sites.

Porewater from within the sediments of the Columbia River was sampled in fall 2010 under the RI studies. Concentrations of chromium in most of the samples were below the aquatic water quality criterion of 10 µg/L. The maximum chromium concentration was 13.6 µg/L.

100-KR-4 Operable Unit

The 100-KR-4 OU underlies the 100-K Area and extends to the northeast to the N Reactor fence line. The principal groundwater issues for this OU are cleaning up hexavalent chromium in the groundwater, tracking plumes from past-practice sites, and monitoring groundwater near the KE and KW Basins. Interim remedial actions include three pump-and-treat systems to remove hexavalent chromium contamination from the groundwater.

A number of CERCLA activities were accomplished during the reporting period, including the following:

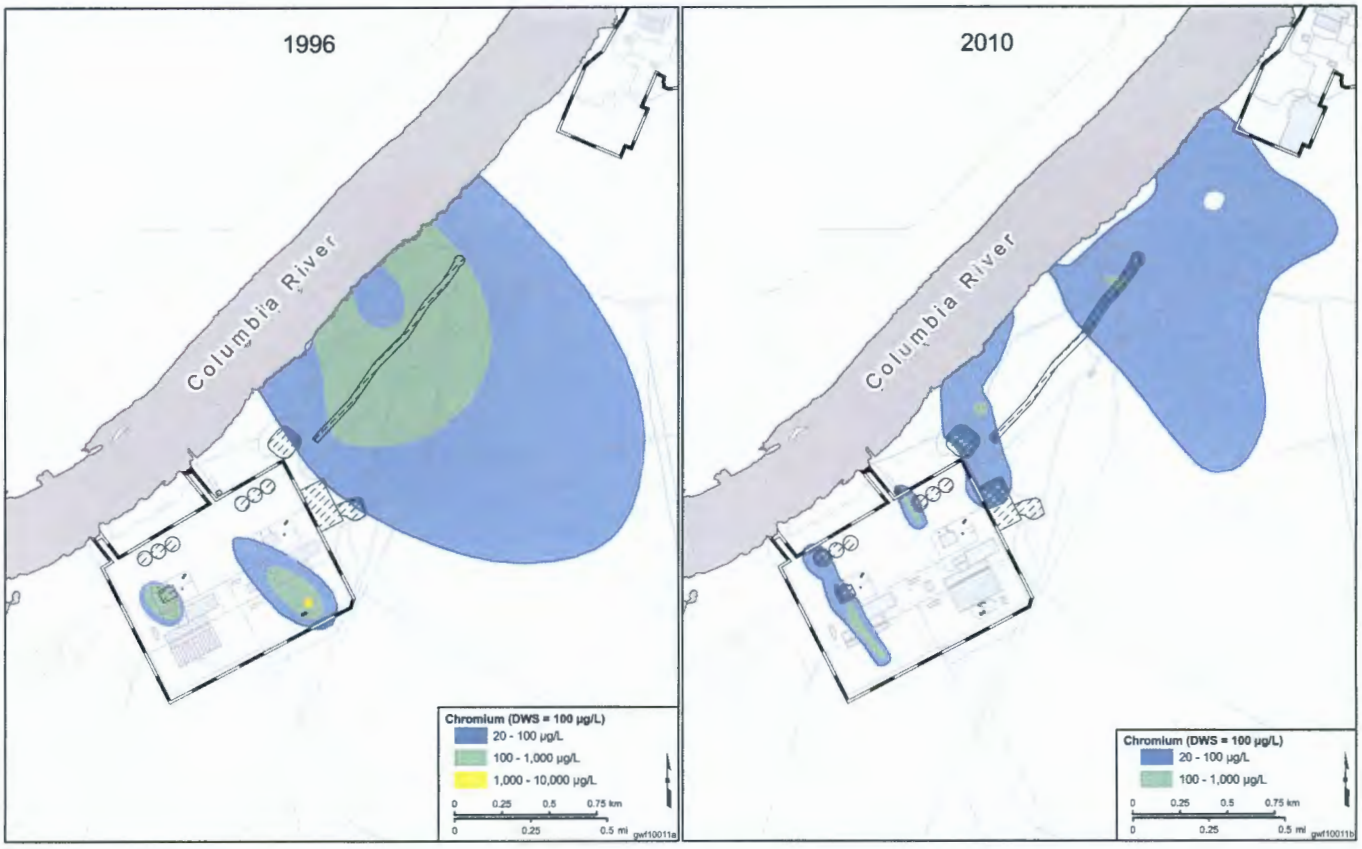
- Continued RPO activities for systematic evaluation and enhancement of site remediation processes to ensure that human health and the environment are being protected over the long term at minimum risk and cost, and implementing the results.
- Completed and obtained approval of the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (DOE/RL-2008-46-ADD2) and the *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study* (DOE/RL-2009-41).
- Continued operation of the three pump-and-treat systems in accordance with the interim Record of Decision (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton*

County, Richland, Washington). A system upgrade was performed on the KR-4 pump-and-treat system in the fourth quarter of CY 2010.

- Initiated RI/FS characterization activities for the final ROD.

Hexavalent chromium is the primary contaminant of concern (COC) in groundwater beneath the 100-K Area and is associated with disposal trenches and materials handling areas for the reactors' water treatment systems. The primary source for the hexavalent chromium contamination was the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate. Unplanned spills and leaks of the 70% to 75% sodium dichromate stock solution to the ground are other potential sources of hexavalent chromium contamination. Hexavalent chromium is distributed in plumes, with concentrations remaining above the 20 µg/L remedial action goal (for near-shore wells) in the 100-KR-4 OU.

Tritium, carbon-14, strontium-90, trichloroethene, and nitrate concentrations remained above the DWS in several 100-K Area wells. Tritium was detected across much of the K Reactor area at concentrations below the DWS but was found above the DWS at only a few wells downgradient of the 116-KE-1 gas condensate crib and 118-K-1 Burial Ground. Strontium-90 was detected downgradient of the 116-KE and 116-KW fuel rod basin cribs and the 116-K-2 Trench during CY 2010. An increasing trend of strontium-90 was observed at a KX extraction well downgradient of the 116-KE fuel rod basins, reaching 12 pCi/L in early January 2011. Carbon-14 was detected above the DWS in several wells downgradient of the gas condensate cribs. Technetium-99 was detected but not above the DWS. Trichloroethene was measured



Three pump-and-treat systems reduce the amount of chromium entering the Columbia River from the 100-K Area. Concentrations and size of the main plume have declined as a result of remediation.

above the DWS in samples from wells in the KW Reactor area. Total petroleum hydrocarbons that were previously detected in several wells near the KW Reactor building were not detected in CY 2010.

Interim remedial action. Two pump-and-treat systems, KR-4 and KX, are in place for removing hexavalent chromium from the aquifer beneath the 116-K-2 Trench. A total of 47 kilograms of chromium was removed by these two systems in CY 2010. Chromium concentrations in most of the compliance wells near the Columbia River have decreased. The concentration goal for the interim remedial action is 20 µg/L.

In 1998, chromium concentrations in groundwater near the KW Reactor began to increase, with concentrations in this plume reaching the highest levels observed in the 100-K Area. In response to the increased chromium concentrations, the DOE installed and has operated the KW pump-and-treat system for plume remediation since 2007. The system removed 54.14 kilograms of chromium in CY 2010, totaling 137.4 kilograms since system startup. Concentrations in the extraction and monitoring wells have been declining since operations were initiated. Increased hexavalent chromium concentrations were observed at well 199-K-173, with the highest concentration in March 2010 at 974 µg/L; however, the concentration at this well was 659 µg/L in the last sample taken in January 2011.

Remedial process optimization was implemented at the 100-KR-4 Groundwater OU in CY 2009 and continued through CY 2010.

Remedial process optimization activities. The RPO activities were implemented at the 100-KR-4 OU in CY 2009 and continued through CY 2010. This process is intended to improve treatment system performance to meet *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) milestones. The goal of the Tri-Party Agreement milestones is to improve remediation of the hexavalent chromium plumes and other plumes that have been determined to impact groundwater and the Columbia River. The approach is to model groundwater flow and determine where the hexavalent chromium plume would reach the Columbia River if additional intervention was not implemented, and then revise the current treatment system well configuration to prevent plume movement into the river. Five Phase 2 wells were drilled in late 2009 and early 2010 to improve control over existing plumes, and four Phase 3 wells at the KW and KR-4 systems will be completed in CY 2011 to further enhance plume control. Additional modeling has been used to determine how to address longer term concerns where more extensive system modifications away from the river (including alternate treatment technologies) can be applied. Under Phases 4 and 5, additional well drilling will be used to supplement expanded pump-and-treat systems along with the use of alternate treatment technologies. Details of the modeling effort can be found in *100-KR-4 Remedial Process Optimization Modeling Data Package* (SGW-41213) and *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model* (SGW-46279).

Remedial investigation/feasibility study activities. Characterization activities began at thirteen well sites, two boring locations, and a three aquifer tube site for the 100-K Area. Characterization locations were identified in the 100-K Area RI/FS sampling and analysis plan (DOE/RL-2009-41), and frequent soil and groundwater sampling was conducted at each of the well locations. The wells were geophysically logged and slug tested to determine aquifer properties following well construction. The two borings were converted to temporary wells after sample collection was unsuccessful. At the end of CY 2010, ten wells, the two borings/wells, and the three aquifer tubes were completed. Data will be reported in the RI/FS report to be released in the fall of 2011.

KE and KW Basins. The concrete KE and KW Basins were integral parts of each reactor building. From the late 1970s through 2004, the K Basins were used to store irradiated fuel from the last run of N Reactor, as well as miscellaneous fuel fragments recovered during remedial actions at other reactor areas. Groundwater issues associated with these units are related to leaks at and around the basins themselves. Shielding water was removed from the KE Basin, the basin was demolished, and soil remediation around the basin initiated and was nearing completion by the end of CY 2010. Demolition of the KW Basin is scheduled to begin after CY 2014. Soil remediation continued during CY 2010.

100-NR-2 Operable Unit

The 100-NR-2 OU covers groundwater beneath the N Reactor area along the Columbia River. The principal groundwater issue for this OU is cleanup of groundwater contamination near the former wastewater disposal sites. A PRB has been installed as an interim remedial action to reduce concentrations of strontium-90 in the groundwater reaching the Columbia River.

The primary groundwater contaminant plume in the 100-N Area is strontium-90, which originated at the 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities (LWDFs). Chromium, iron, manganese, nitrate, sulfate, total petroleum hydrocarbons, and tritium are also present in the groundwater.

In 2010, strontium-90 exceeded the DWS of 8 pCi/L in the 100-N Area surrounding the former LWDFs. None of the wells had tritium concentrations exceeding the 20,000 pCi/L DWS. Nitrate concentrations continue to exceed the 45 mg/L DWS in much of the 100-N Area. Sulfate concentrations were all below the 250 mg/L secondary DWS, except for well 199-N-18 (504 mg/L). It is believed that the level of petroleum (diesel) contamination in this well may be the cause of the elevated sulfate concentration, as it is not in the area downgradient of known sulfate plume migration. Several wells exceeded the secondary DWS of 50 µg/L for manganese and the 300 µg/L secondary DWS for iron. With the exception of wells 199-N-26, 199-N-32, and 199-N-57, other wells with iron concentrations above the DWS are under the influence of the current diesel plume. Natural biodegradation of hydrocarbons creates chemically reducing conditions, which increases the solubility of metals such as iron and manganese. Only one well in the 100-N Area has dissolved chromium concentrations above the 100 µg/L DWS potentially due to known corrosion of the stainless-steel well screen.

The 100 Area RI/FS work plan was approved and being implemented in CY 2010.

Primary CERCLA accomplishments during the reporting period included the following:

- Approval and issuance of the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2008-46-ADD5) and the *Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation Feasibility Study* (DOE/RL-2009-42)). The RI/FS drilling began in March 2011.
- Continued operation/monitoring of the PRB under the interim ROD (EPA/541/R-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*).
- Several ongoing RI activities are working toward development of a final ROD.
- Completion of several alternate strontium-90 treatment technology tests.

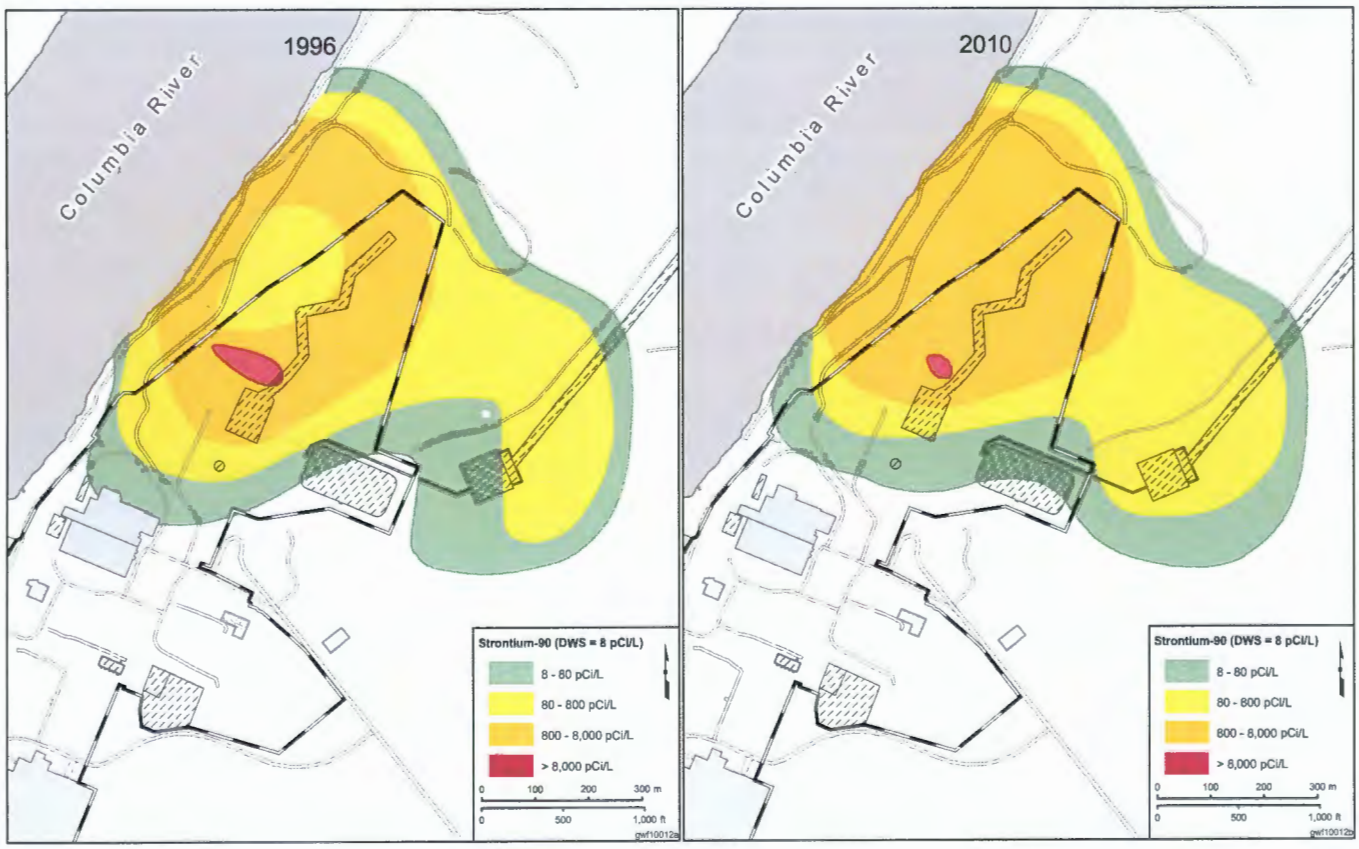
- Installation of 146 additional injection/barrier wells and 25 monitoring wells for the expansion of the apatite PRB along the entire section of contaminated 100-N Area shoreline.
- Addition of two new sets of aquifer tubes near the 100-N Outfall and RI/FS sampling of five sets of aquifer tubes upriver, adjacent to, and downriver of the 100-N Outfall.
- Porewater sampling of the 100-N shoreline to perform follow-up sampling of strontium-90 and chromium detections found during the WCH porewater sampling performed in 2008 and 2009.

Additional highlights for the PRB and alternate treatment technologies are discussed below.

The 100-NR-2 OU contains one active CERCLA interim action for groundwater, multiple alternate treatment test sites, and four RCRA TSD units.

Strontium-90 concentrations have shown ~90% decline in response to the 100-N Area apatite barrier.

Interim remedial actions. The DOE is applying an in situ technology, apatite sequestration, for treatment of strontium-90 contamination in the 100-N Area. The goal is to create a PRB that will capture strontium-90 as groundwater flows through the barrier to the Columbia River. Apatite-forming chemicals were injected into a line of wells along the river shoreline in CY 2006, CY 2007, and CY 2008. As the injected chemicals reacted with the aquifer and sediments, strontium-90 levels initially increased in downgradient wells and aquifer tubes. However, since injections ceased at the PRB in July 2008, a general, steady decline has been



The overall shape of the 100-N Area strontium-90 plume at the 8 pCi/L DWS level has not changed in many years, despite the operation of the pump-and-treat system from 1995 until March 2006. A permeable reactive barrier system is immobilizing strontium-90 near the river.

observed for strontium-90 and gross beta in the wells being sampled, with very few exceptions. All of the wells have shown ~90% decline in gross beta from measured pre-injection values.

Other forms of remediation being investigated at the 100-N Area include jet injection of apatite-forming chemicals, phytoextraction (plants) to treat contamination above the average water table, and passive infiltration of apatite forming chemicals. In December 2009, jet injection tests were performed in three plots located along the 100-N Area shoreline, upriver from the existing apatite PRB. The three plots each received a specific injection solution using a phosphate-only solution, or a phosphate-only solution followed by a suspension of fishbone apatite, or a suspension of fishbone apatite-only solution. Groundwater is being monitored to assess the continued effectiveness of the 2009 injections.

1301-N and 1325-N Cribs. These two RCRA units are located in the 100-N Area. During 2010, the sites remained under interim status contaminant indicator evaluation monitoring programs. The indicator parameter of specific conductance continued to exceed the threshold value at the 1325-N Crib, which is the result of elevated sulfate and sodium (both nonregulated constituents under RCRA/WAC) associated with releases to the 1324-NA Pond. The CERCLA monitoring continued to track the non-RCRA contaminant strontium-90 and tritium plumes from the 1301-N and 1325-N facilities. It is the belief of the DOE that the monitoring network remains capable of the detection of indicator constituents in the uppermost aquifer.

1324-N Surface Impoundment and 1324-NA Percolation Pond. These two units are located adjacent to one another in the 100-N Area. The sites remained under interim status contaminant indicator evaluation monitoring program. Specific conductance associated with the non-RCRA/WAC contaminants sodium and sulfate continued to exceed the threshold value. The exceedance was reported to Ecology previously, and this exceedance remained through December of CY 2010. The CERCLA monitoring continued to track the non-RCRA contaminant sulfate from the 1324-NA percolation pond. The DOE believes that the monitoring network remains capable of detection of indicator constituents in the uppermost aquifer.

100-HR-3 Operable Unit

The 100-HR-3 OU underlies the 100-D and 100-H Areas, as well as the region between these two areas. Hexavalent chromium is the primary COC in groundwater. A principal cause for the hexavalent chromium contamination was the routine disposal of reactor coolant, which contained a corrosion inhibitor of sodium dichromate. Additionally, periodic spills and leaks of sodium dichromate stock solution to the ground are another potential source of hexavalent chromium contamination. Hexavalent chromium concentrations remain above the remedial action goal of 20 µg/L at multiple locations within the 100-HR-3 OU.

Strontium-90 continued to exceed the DWS in a plume in the 100-H Area. Nitrate levels were below the DWS in the 100-H Area but exceeded the DWS beneath the 100-D Area. Technetium-99 and uranium concentrations remained below the DWS in both the 100-D and 100-H Areas. Tritium was below the DWS in the 100-H Area and in nearly all of the 100-D Area, with the exception of well 199-D4-85, which had tritium concentrations at the DWS in the last sampling event.

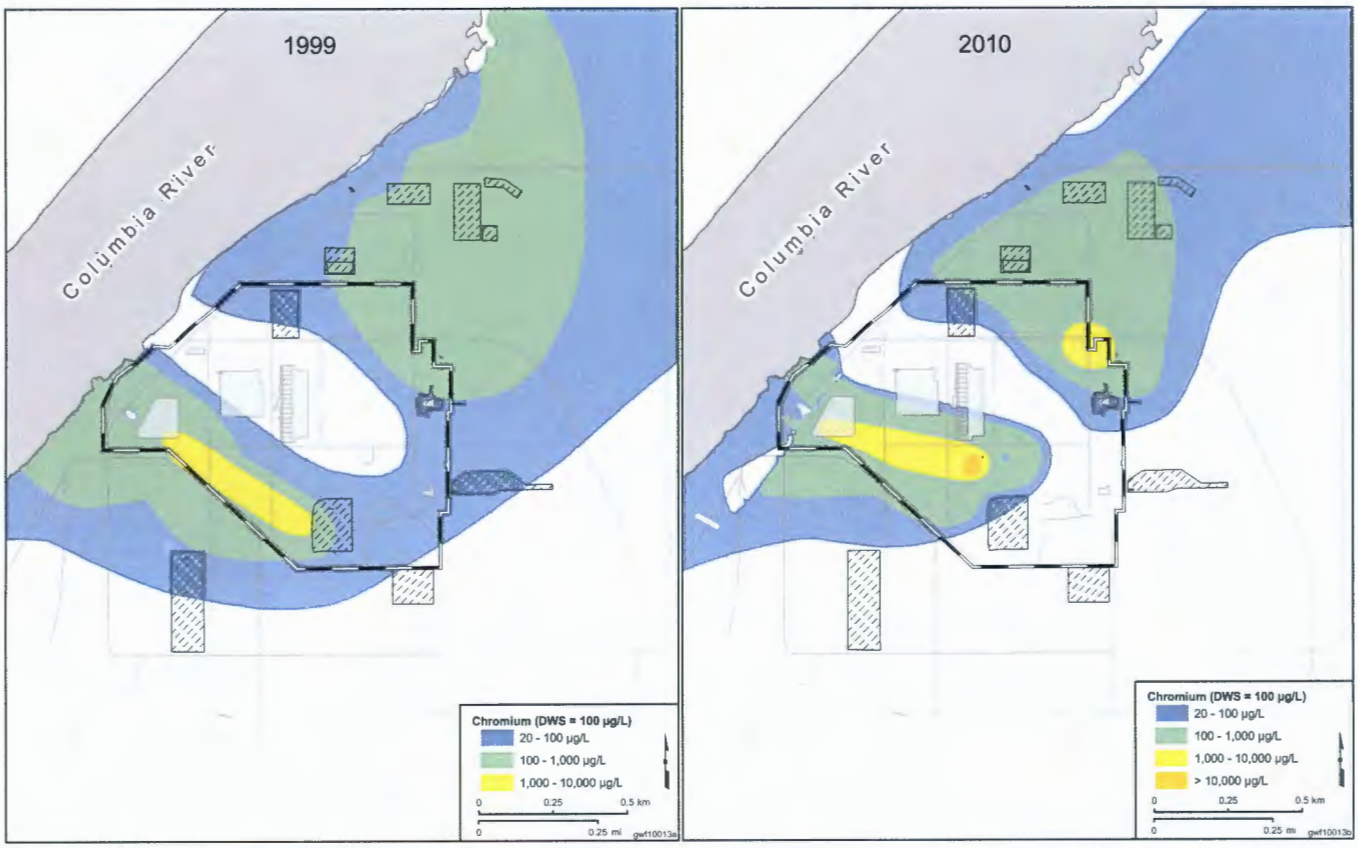
The CERCLA accomplishments in CY 2010 related to the 100-HR-3 OU include the following:

- Continued operation of two pump-and-treat systems and operation/monitoring of the In Situ Redox Manipulation system in accordance with the interim ROD (EPA/ROD/R10-96/134)
- Completed construction on the new DX pump-and-treat facility and began pilot testing
- Began construction of the HX pump-and-treat facility, with completion due in December 2011
- Initiated RI/ FS field work, with more than 50% of the work completed at the end of CY 2010
- Prepared the aquifer test report for the Ringold upper mud unit underlying the 100-H Area.

The 100-HR-3 OU contains two active CERCLA groundwater interim actions, one PRB interim action site, and one facility monitored under RCRA regulations, in coordination with CERCLA requirements.

Two extraction systems, one each in the 100-D and 100-H Areas, removed a combined 105.9 kilograms of hexavalent chromium from the aquifer in CY 2010.

Interim remedial action. Hexavalent chromium is the target of two pump-and-treat systems that are designed to reduce the amount of hexavalent chromium in the groundwater and entering the Columbia River in the 100-D and 100-H Areas. In CY 2010, hexavalent chromium concentrations remained above the 20 µg/L remedial action goal in compliance wells for the pump-and-treat systems. During CY 2010, the HR-3 and the DR-5 extraction systems removed a combined total of 105.9 kilograms of hexavalent chromium from the aquifer. Pilot testing at the new DX pump-and-treat facility removed an additional 18.4 kilograms of hexavalent chromium in December 2010. The southern 100-D Area hexavalent chromium

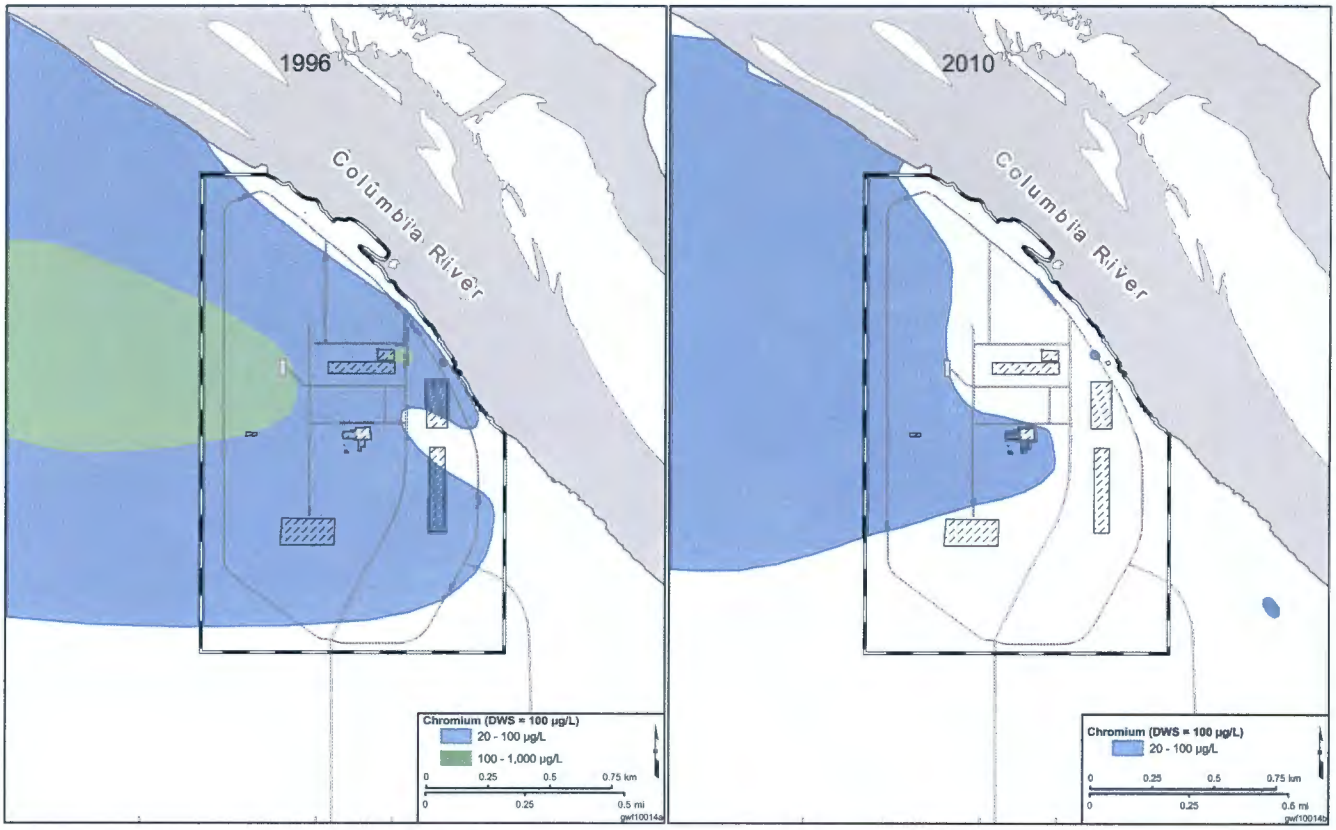


To reduce the amount of chromium entering the Columbia River from the 100-D Area, two pump-and-treat systems are operating in the north and an in situ treatment system is operating in the south.

plume is also being remediated using a PRB that immobilizes hexavalent chromium in the aquifer. However, data from recent years indicate that hexavalent chromium is breaking through in some areas of the barrier. At the end of CY 2010, concentrations in barrier wells ranged from below detection limits to 2,960 µg/L. Most of the elevated concentrations are in the northeastern half of the barrier. Downgradient of the barrier, the 20 µg/L remedial action goal was met at two of the seven compliance wells in CY 2010.

By the end of CY 2010, more than 50% of the scheduled RI/FS work has been completed.

Remedial investigation/feasibility study activities: An RI/FS is being conducted to support the final ROD for the 100-D and 100-H Areas. Characterization activities began in CY 2010, as described in the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan Addendum 1: 100-DR-1, 100-DR-2,100-HR-1,100-HR-2, and 100-HR-3 Operable Units* (DOE/RL-2008-46-ADD1) and implemented through the *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2,100-HR-1,100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-40). The RI/FS addresses contaminant sources, contaminant flow and transport, exposure assessment, risk characterization, remedial action selection, performance monitoring, and site closure. Data gaps have been identified and are currently being addressed through additional data collection and other investigations that will support final remediation decisions. A series of fifteen monitoring wells, six aquifer tubes, ten vadose zone boreholes, and five test pits constitute the subsurface characterization activities. Field work was initiated in CY 2010, with more than 50% of the work completed by the end of CY 2010. The field work is scheduled for completion by the end of 2011, with the RI/FS draft report scheduled for submittal by November 2011.



A pump-and-treat system in the 100-H Area has reduced the amount of chromium entering the Columbia River. Concentrations have decreased beneath the 100-H Area but remain elevated in a plume to the west (upgradient).

Chromium in the Ringold upper mud unit. Aquifer tests were performed in CY 2009 to gather additional data on deeper hexavalent chromium contamination in the first water-bearing unit within the Ringold upper mud unit. The aquifer tests were performed using existing monitoring wells in the 100-H Area, which identified a hydraulic connection between a well screened in the unconfined aquifer and a well screened in the Ringold upper mud near the H Reactor. The data suggest that there is an area where the Ringold upper mud is thinner than in most other locations, and could transmit water into the sandy lens within the Ringold upper mud under conditions of high hydraulic head, such as observed in the vicinity of the retention basins. During the aquifer test, a small but significant hydraulic response was observed. This fits with the general eroded surface of the Ringold upper mud unit resulting in thinning of this unit from the edge of the 100-D Area east across the horn area to the Columbia River.

The results are summarized in the *Aquifer Testing and Rebound Study in Support of the 100-H Deep Chromium Investigation* (SGW-47776) and suggest that the likely explanation for the origin of the hexavalent chromium in the Ringold upper mud unit in the 100-H-Area is from large volumes of contaminated cooling water from the H Reactor that were discharged to the ground. This water formed a mound that provided sufficient hydraulic driving force to push the contaminated water through what appears to be a more eroded relatively thinner area of the Ringold upper mud. Hexavalent chromium concentrations are not observed in the first water-bearing layer within the Ringold upper mud unit upgradient (toward the Columbia River). The contaminated zone appears to correlate with the groundwater mound that developed during operations near the cooling water retention basins. Chromium concentrations are also consistent with a cooling water origin at less than 700 µg/L.

An evaluation of hexavalent chromium concentration versus time did not indicate any clear concentration trends for hexavalent chromium in unconfined aquifer monitoring wells subsequent to temporary shutdown of the HR-3 pump-and-treat system. Therefore, there was no support for significant "rebound" of hexavalent chromium concentrations.

116-H-6 (183-H) solar evaporation basins. The former 183-H solar evaporation basins constitute the only RCRA site located in the 100-HR-3 OU. Leaks from the basins contaminated groundwater with chromium, fluoride, nitrate, technetium-99, and uranium. Technetium-99 and uranium were included in the monitoring plan and were incorporated in the Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*). Concentrations of total chromium were above the Permit concentration limit in only one of the four RCRA monitoring wells (well 199-H4-12C). The concentrations of the other contaminants (i.e., nitrate, fluoride, technetium-99, and uranium) at the 183-H solar evaporation basins remained below the applicable concentration limits. Well 199-H4-12C was converted to an extraction well under CERCLA in August 2010; pumping historically had been from well 199-H4-12A. The site is monitored in accordance with RCRA corrective action regulatory requirements (WAC 173-303-645) during the post-closure period to track contaminant trends during operation of the CERCLA interim action for chromium.

100-FR-3 Operable Unit

The 100-FR-3 OU includes groundwater beneath the former F Reactor area along the Columbia River. The principal groundwater issues for this OU are related to the disposal of both solid and liquid wastes associated with operation of the water-cooled F Reactor. Contaminants present include both nonradioactive (nitrate, chromium, and trichloroethene) and radioactive (strontium-90) constituents.

Three new monitoring wells and three vadose zone boreholes were installed in the 100-F Area in CY 2010.

Groundwater activities during the reporting period included RI studies (DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-F Decision Unit Remedial Investigation/Feasibility Study*) and routine groundwater monitoring (DOE/RL-2003-49, *100-FR-3 Operable Unit Sampling and Analysis Plan*).

Three new groundwater monitoring wells were installed in CY 2010 for the RI. Data from these wells helped to refine geologic and hydrologic knowledge of the site and better define groundwater contaminant plumes. The studies also include vadose zone boreholes, which provide data on soil contamination and mobility beneath former waste sites.

Nitrate concentrations in groundwater exceed the DWS beneath much of the 100-F Area and the downgradient region. One well in the eastern 100-F Area has strontium-90 concentrations above the DWS. Three wells in the southwestern 100-F Area exceed the DWS for trichloroethene, but concentrations are declining overall. Chromium exceeds the 10 µg/L aquatic water quality criterion in wells located near the 116-F-14 retention basins and 116-F-9 Trench.

200-BP-5 Operable Unit

The 200-BP-5 OU includes groundwater beneath the northern 200 East Area and the region to the northwest to the Columbia River where mobile contaminants, including tritium and technetium-99, have historically and continue to move northward between Gable Mountain and Gable Butte. Decreasing water levels over more than two decades and a nearly flat groundwater table contribute to little change in the contaminant plume configuration versus last year in the 200-BP-5 OU. Most of the groundwater contamination in the OU is concentrated beneath the facilities in the north-central/northwest portion of the 200 East Area known as the B Complex (e.g., WMA B-BX-BY and adjacent waste sites).

The COCs defined in the sampling and analysis plan (DOE/RL-2001-49) include nitrate, cyanide, iodine-129, technetium-99, uranium, strontium-90, cobalt-60, cesium-137, plutonium-239/240, and tritium. Cobalt-60 has decayed to levels below the DWS. Most contaminants are generally constrained near the source site in the northeast portion of the 200 East Area. Where the aquifer is thinnest in the northwest corner of the 200 East Area, several contaminants extend 2 kilometers or more to the northwest as a result of past groundwater flow. Iodine-129 and nitrate extend from the southern portion of the OU to the Gable Mountain/Gable Butte gap.

During CY 2010, the DOE continued the 200-BP-5 OU RI/FS. The primary CERCLA accomplishments for the reporting period included:

- Successful sampling and analyses of all but three wells specified in the *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49)
- Completion of a full suite of chemical and physical property analyses for three RI wells

- Completion of the Tri-Party Agreement Milestone M-015-082 through submittal of the *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74, Draft A)
- Preparation of the *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit* (DOE/RL-2009-127)
- Completion of the *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit: November 2004 through November 2009 Groundwater Data* (SGW-44071).

The highest concentrations of uranium, cesium-137, plutonium-239/240, and cyanide on the Hanford Site during 2010 were sampled from wells in the 200-BP-5 OU.

Six TSD units in the 200-BP-5 OU are monitored under RCRA in coordination with CERCLA and AEA requirements. The monitoring results are summarized below.

Low-Level Waste Management Area 1 (LLWMA-1). The LLWMA-1 is monitored under RCRA interim status contaminant indicator monitoring requirements as specified in the revised monitoring plan (DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for LLBG WMA-1*). Like last year, specific conductance exceeded its threshold value. The exceedances originated in 1999 in the northeast corner of the WMA and were attributed to cribs to the east. The exceedance was reported to Ecology in 1999 and documented in the *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington* (PNNL-14859) and do not indicate contamination originated from the WMA. All other indicator parameters were below their respective threshold values. Recent evaluation of water levels (low-gradient evaluation) supports a predominantly northwestern groundwater flow direction at this unit. The DOE believes the monitoring network remains capable of detection of indicator constituents given a predominant northwestern flow direction. Two additional wells were installed to detect groundwater contamination that could emanate from the buried RCRA-regulated wastes associated with Trench 9 in the 218-E-10 Burial Ground.

All indicator parameters at LLWMA-2 were below their threshold values during CY 2010.

Low-Level Waste Management Area 2 (LLWMA-2). The LLWMA-2 is monitored under RCRA interim status contaminant indicator monitoring requirements as specified in the revised monitoring plan (DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for LLBG WMA-2*). All RCRA indicator parameters remain below their respective threshold values. Although the water table gradient in this area is less than the measurement error, the monitoring network is believed by the DOE to be capable of detecting constituents migrating from the facility because wells are located along the west and south boundaries while the elevation of the basalt rises above the aquifer to the north and east.

Waste Management Area B-BX-BY (WMA B-BX-BY). The RCRA groundwater quality assessment monitoring continues at this site. Contaminants of interest in groundwater include cyanide and chromium (dangerous waste constituents under RCRA); however, both constituents have their sources from nearby cribs, not the WMA. The non-RCRA contaminants uranium, nitrate, and technetium-99 are also monitored regularly to support CERCLA investigations. Contaminants have migrated to the northwest for more than two decades, with the most mobile constituents (nitrate and technetium-99) having moved 2 kilometers from their source area beneath the BY Cribs. The current network, with the addition of six 200-BP-5 OU RI/FS wells, is believed by the DOE to be capable of evaluating the rate and extent of contaminant migration originating in WMA B-BX-BY. A revised groundwater assessment monitoring plan, *Groundwater Quality Assessment Monitoring Plan for Waste Management Area B-BX-BY* (DOE/RL-2008-72), was submitted to DOE and Ecology for review in October 2010.

Waste Management Area C (WMA C). The RCRA groundwater quality assessment monitoring continued at this site in CY 2010 as detailed in the RCRA assessment plan for WMA C (DOE/RL-2009-77, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*). Cyanide, a dangerous waste constituent, was determined to be associated with releases from WMA C. Metals and volatile organics continue to be evaluated. Although water-level elevation measurements previously indicated groundwater flow to the southwest, the measurements were based on uncorrected water-level data. Recent efforts to reduce the measurement error have shown the water table is too flat to currently determine the flow direction or rate. Two wells were added to the well network in CY 2010 and provide sufficient information to establish the extent of the dangerous waste constituent cyanide. Four CERCLA constituents of concern were reported above the DWS at WMA C in CY 2010: nitrate, sulfate, iodine-129, and technetium-99.

Liquid Effluent Retention Facility (LERF). The LERF operates under final status permit conditions. A revised monitoring plan was drafted in CY 2010 and includes two new wells, for a total of four wells in the monitoring network. Although the plan is not yet listed in the Permit, all four of the wells in the network were sampled twice during CY 2010. Nitrate exceeds the DWS in wells 299-E26-10 and 299-E26-77, with maximum concentrations of 50.9 and 53.9 mg/L, respectively. Nitrate has been increasing in well 299-E26-10 since 2003 and in wells south and east of the LERF. The regional increase of anions and cations is evident in wells located in the central and eastern portions of the 200 East Area. Statistical evaluations using monitoring data from the new wells have not yet been initiated.

216-B-63 Trench. This site is monitored under a RCRA interim status contaminant indicator monitoring program. All indicator parameters were below their threshold values. A revised interim status groundwater monitoring plan was issued for implementation in June 2010 (DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*). The new monitoring plan reduced the number of wells from twelve to seven and established semiannual sampling at these wells. The DOE believes the revised monitoring network is capable of the detection of indicator constituents from the TSD unit.

200-PO-1 Operable Unit

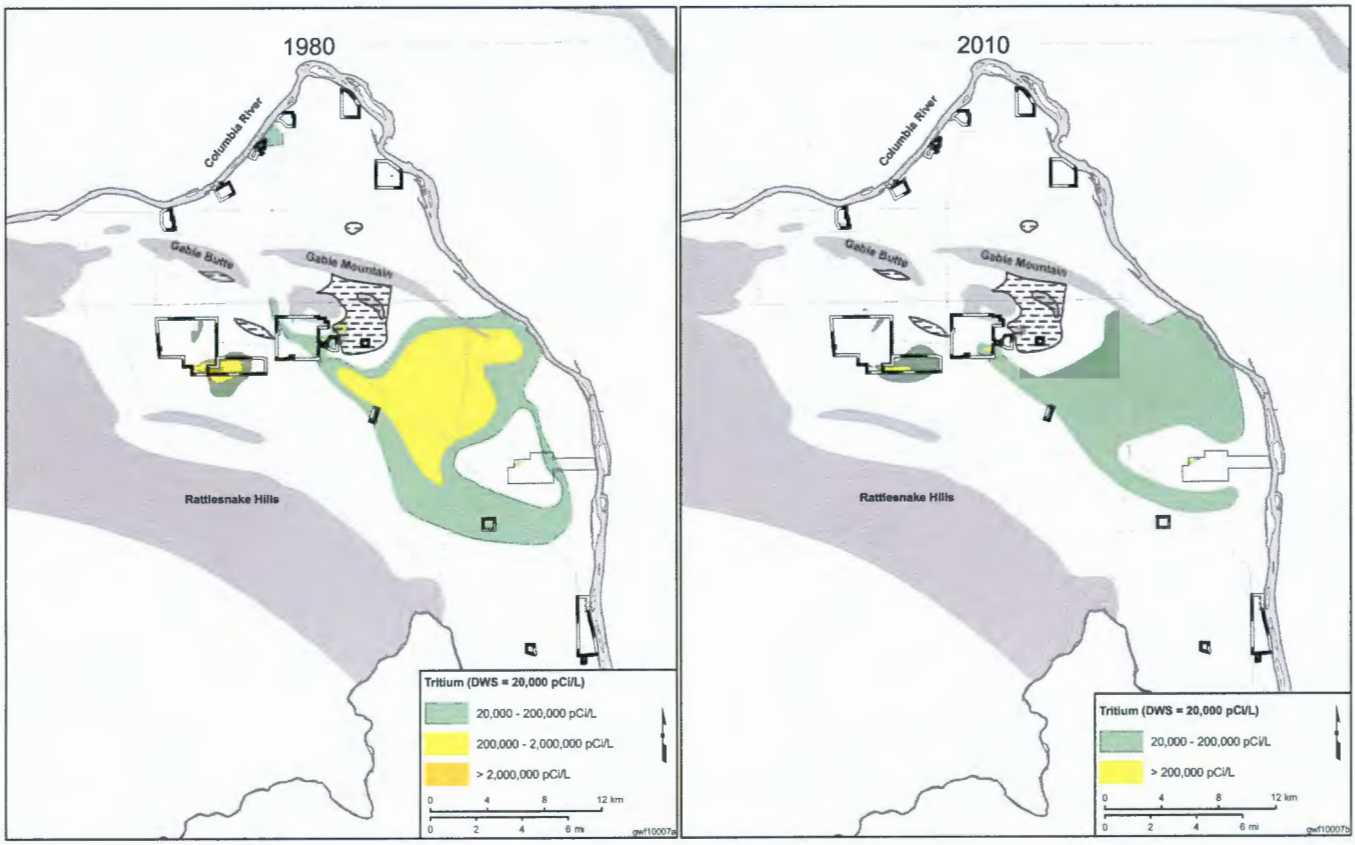
The 200-PO-1 OU encompasses the southern portion of the 200 East Area and a large region to the east and southeast as far as the Columbia River where groundwater is contaminated with tritium, iodine-129, and nitrate. Concentrations of tritium continued to decline as the groundwater plume attenuates naturally due to radioactive decay and dispersion. The iodine-129 plume above the 1 pCi/L isopleths has changed very little, but the maximum concentrations have declined significantly as a result of dispersion; the mass of contamination remains the same, thus the volume of contaminated groundwater has increased. Nitrate covers a large area, with levels elevated above background but mostly below the DWS. Other contaminants include strontium-90, technetium-99, and uranium, but these contaminants are limited to smaller areas near their respective sources.

During CY 2010, routine monitoring continued under the *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04). The COCs listed in the sampling and analysis plan include nitrate, iodine-129, strontium-90, technetium-99, tritium, and uranium. Other contaminants of potential interest are arsenic, chromium, manganese, and vanadium.

Among the eighty far-field wells monitored in the 200-PO-1 OU, two well transects (containing fourteen wells each) are routinely monitored under the approved CERCLA sampling and analysis plan. The southeast transect is located ~2 to 6 kilometers southeast of the 200 East Area, and the Columbia River transect is essentially adjacent to the Columbia River (~1 to 1.5 kilometers west). Most of the anions, metals, and radioactive constituents detected in southeast transect wells during the reporting period are naturally occurring or are typical of Hanford Site background values. The only constituents exceeding the DWSs were tritium and iodine-129. Technetium-99 was detected at levels above Hanford Site background, but it was at levels less than 10% of the DWS downgradient from the 200 East Area. Other detected constituents include chromium, cobalt, copper, nickel, vanadium, nitrate, and sulfate. Results of sampling from wells in the Columbia River transect also had anions, metals, and radioactive constituents typical of Hanford Site background values. Tritium was the only constituent exceeding its DWS along the river transect.

The primary CERCLA accomplishments for the 2010 reporting period included the following:

- Continued groundwater monitoring of near- and far-field wells under the routine sampling and analysis plan
- Completion of Draft A of the *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2009-85), which includes the results of a baseline risk assessment that concluded a CERCLA FS is warranted.



These maps show Hanford Site-wide tritium plumes in the upper portion of the unconfined aquifer in 1980 and 2010. Concentrations in the core of the plume have decreased over the years and the south margin is no longer spreading.

Groundwater is monitored at eight regulated units in the 200-PO-1 OU. Water supply wells in the 400 Area, which fall within the footprint of the 200-PO-1 OU, are also monitored. Monitoring results for the reporting period are summarized below.

Integrated Disposal Facility (IDF). The IDF is a lined, RCRA-compliant landfill and it is not yet operational. Because the unit is not operating, results from monitoring are added to the baseline data set. A Permit modification approved in June 2010 allows sample collection on an annual frequency during the pre-active life of the IDF.

The PUREX Cribs contributed to the regional plumes of iodine-129, nitrate, and tritium. Nitrate and tritium concentrations are generally declining.

Plutonium-Uranium Extraction (PUREX) Cribs. The 216-A-10, 216-A-36B, and 216-A-37-1 Cribs were monitored under a RCRA interim status groundwater quality assessment program. The cribs have contributed to widespread contaminant plumes in the area, including the non-RCRA contaminants nitrate, tritium, and iodine-129; tritium and nitrate have migrated to the Columbia River. The nitrate and tritium plumes are generally attenuating throughout most of the area, while the iodine-129 plume appears mostly stable. During CY 2010, the 216-A-10 Crib was officially removed from Part A of the Hanford Facility Dangerous Waste Permit. The two remaining cribs, 216-A-36B and 216-A-37-1, will remain in RCRA interim status. Separate RCRA groundwater monitoring plans were written for these cribs (DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*; DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*), returning the cribs to indicator evaluation programs. Both of the new plans will be implemented in CY 2011.

Waste Management Area A-AX (WMA A-AX). The RCRA groundwater quality assessment monitoring continued in CY 2010 for this WMA. Results of the "first determination" assessment indicated that the tank farm had impacted groundwater quality with dangerous waste or dangerous waste constituents (nickel). A new groundwater quality assessment monitoring plan, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX* (DOE/RL-2009-70), was written as required by WAC 173-303-400, which will continue the path forward in an interim status groundwater quality assessment program. The plan is currently under review by Ecology and should be approved in CY 2011.

216-A-29 Ditch. The groundwater beneath this site is monitored as required under RCRA interim status indicator evaluation regulations. Indicator parameters have continued on historic trends, with specific conductance exceeding the threshold values; the elevated specific conductance is caused by nondangerous constituents. Groundwater quality beneath the ditch is similar to the regional groundwater composition, and the site remains in indicator evaluation monitoring. Groundwater flow direction is changing from southwest to the south and southeast beneath the 216-A-29 Ditch as a result of the cessation of wastewater discharges at the 216-B-3 Ponds. This change in groundwater flow direction is sufficient to warrant changing the upgradient well from 699-43-45 to 299-E26-12. An additional upgradient well, 299-E26-13, was included and well 299-E25-34 was dropped from the network altogether. These changes were implemented with issuance of a revised groundwater monitoring plan in March 2010 (DOE/RL-2008-58, *Interim Status Groundwater Monitoring for the 216-A-29 Ditch*).

216-B-3 Pond. The groundwater beneath this site also continued to be monitored as required by RCRA interim status indicator evaluation regulations. None of the threshold values were exceeded during the reporting period. The DOE believes the monitoring network is capable of detecting and evaluating indicator constituents from the TSD unit. A revised monitoring plan that included COCs was completed

and issued in September 2010. Monitoring will be implemented in CY 2011 under the revised plan, *Interim Status Groundwater Monitoring for the 216-B-3 Pond* (DOE/RL-2008-59).

Nonradioactive Dangerous Waste Landfill (NRDWL). This RCRA site is located in the 600 Area, within the footprint of the regional tritium and iodine-129 plumes. Monitoring for interim status indicator parameters continued during CY 2010. The threshold value for specific conductance was exceeded during 2010, but the exceedance did not require verification sampling or regulatory notification. Exceedance of this indicator parameter occurred earlier at NRDWL and was determined to be caused by nondangerous waste constituents. Volatile organic compounds were not detected in downgradient NRDWL wells during CY 2010.

During CY 2010, a new combination RCRA groundwater monitoring plan was written for the NRDWL and Solid Waste Landfill (SWL). Because the two landfills are adjacent to one another, combining the remedial action for the two landfills was considered a reasonable option to maximize available resources. In the new plan, NRDWL groundwater monitoring will move into RCRA final status under WAC 173-303-645. This plan is under review by Ecology; until approved, the NRDWL will continue to be monitored under the current plan in interim status.

Solid Waste Landfill (SWL). This facility is adjacent to the NRDWL and is regulated under Washington State solid waste handling regulations. As in previous years, some of the downgradient wells showed higher concentrations of regulated constituents than the statistically calculated background threshold values. Background threshold values exceeded during CY 2010 included coliform bacteria, pH, specific conductance, sulfate, and temperature.

A new RCRA groundwater monitoring plan was written in CY 2010, combining the current groundwater monitoring with the NRDWL (see previous NRDWL description). At the SWL, closure and post-closure groundwater monitoring are subject to the requirements of WAC 173-350-500, "Solid Waste Handling Standards," "Ground Water Monitoring"; however, compliance with groundwater monitoring requirements for the SWL are proposed to be achieved through deferral under WAC 173-303-645. The new monitoring plan is under review by Ecology; until approved, the SWL will continue to be monitored under the existing groundwater monitoring plan.

200 Area Treated Effluent Disposal Facility (TEDF). A state waste discharge permit governs groundwater sampling and analysis in the three monitoring wells at this facility. None of the permit criteria for constituents in groundwater were exceeded in CY 2010.

400 Area water supply wells. Three water supply wells provide drinking water and serve as an emergency water supply for the 400 Area. Because the 400 Area is in the path of the Hanford Site-wide tritium plume, the wells are routinely monitored for tritium. These wells are screened deep in the unconfined aquifer, just above the Ringold lower mud unit. Tritium concentrations in all samples were below the DWS during the reporting period.

200-UP-1 Operable Unit

The 200-UP-1 OU underlies the southern portion of the 200 West Area and adjacent areas to the east and south. The primary contaminants forming extensive plumes within the OU are technetium-99, uranium, tritium, iodine-129, nitrate,

chromium, and carbon tetrachloride. Other contaminants identified in the groundwater at concentrations above a DWS include strontium-90 and trichloroethene. Carbon tetrachloride originated from sources in the 200-ZP-1 OU. During CY 2010, the DOE began groundwater monitoring under the RI/FS work plan for the 200-UP-1 OU.

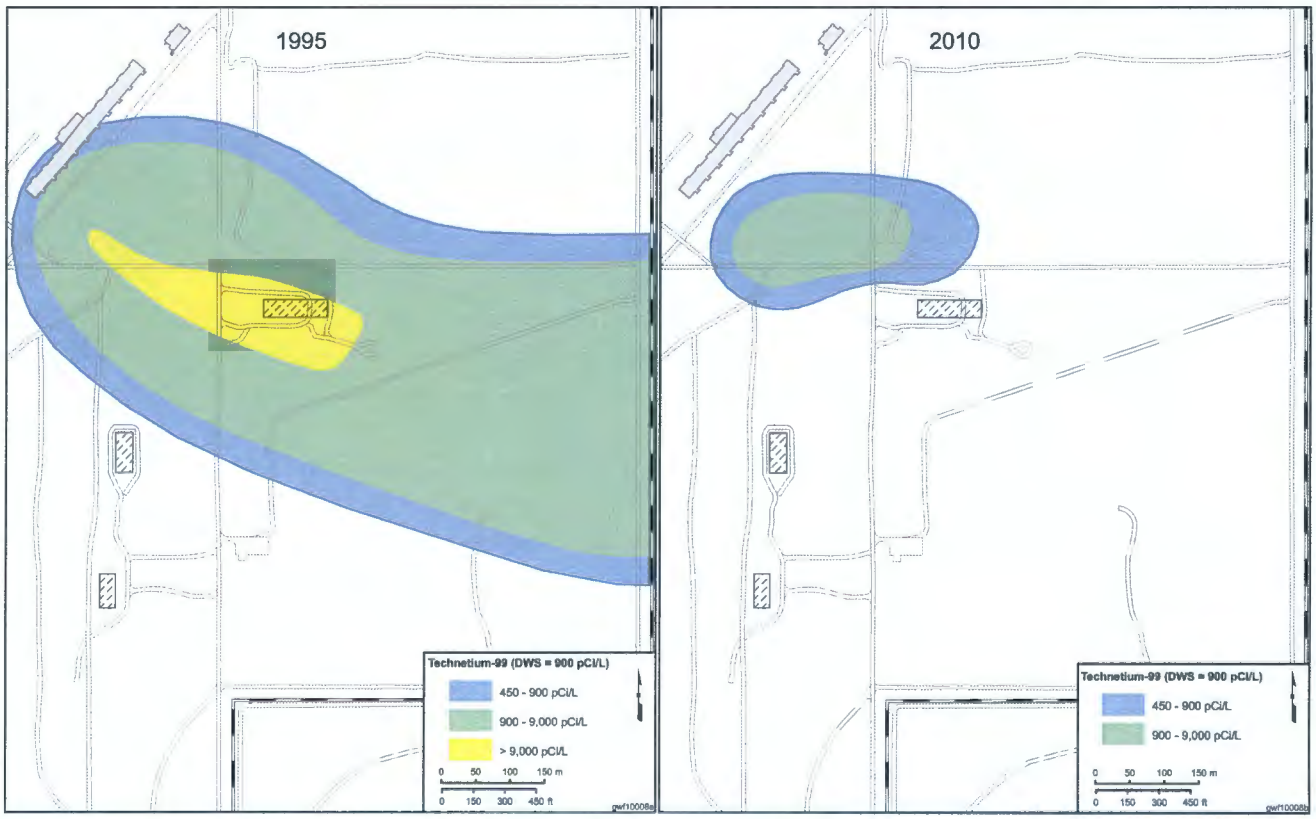
Accomplishments related to CERCLA actions during the reporting period included the following:

- Release and initiation of work from the draft RI/FS report and proposed plan report, meeting Tri-Party Agreement Milestone M-015-17A
- The revised remedial design/remedial action work plan, *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36, Rev. 3), was released to implement changes made to the interim action ROD by the *Explanation of Significant Differences for the Interim Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Washington* (EPA et al., 2009b), which was issued in 2009. The decision lowered the uranium remedial action goal to 300 µg/L.

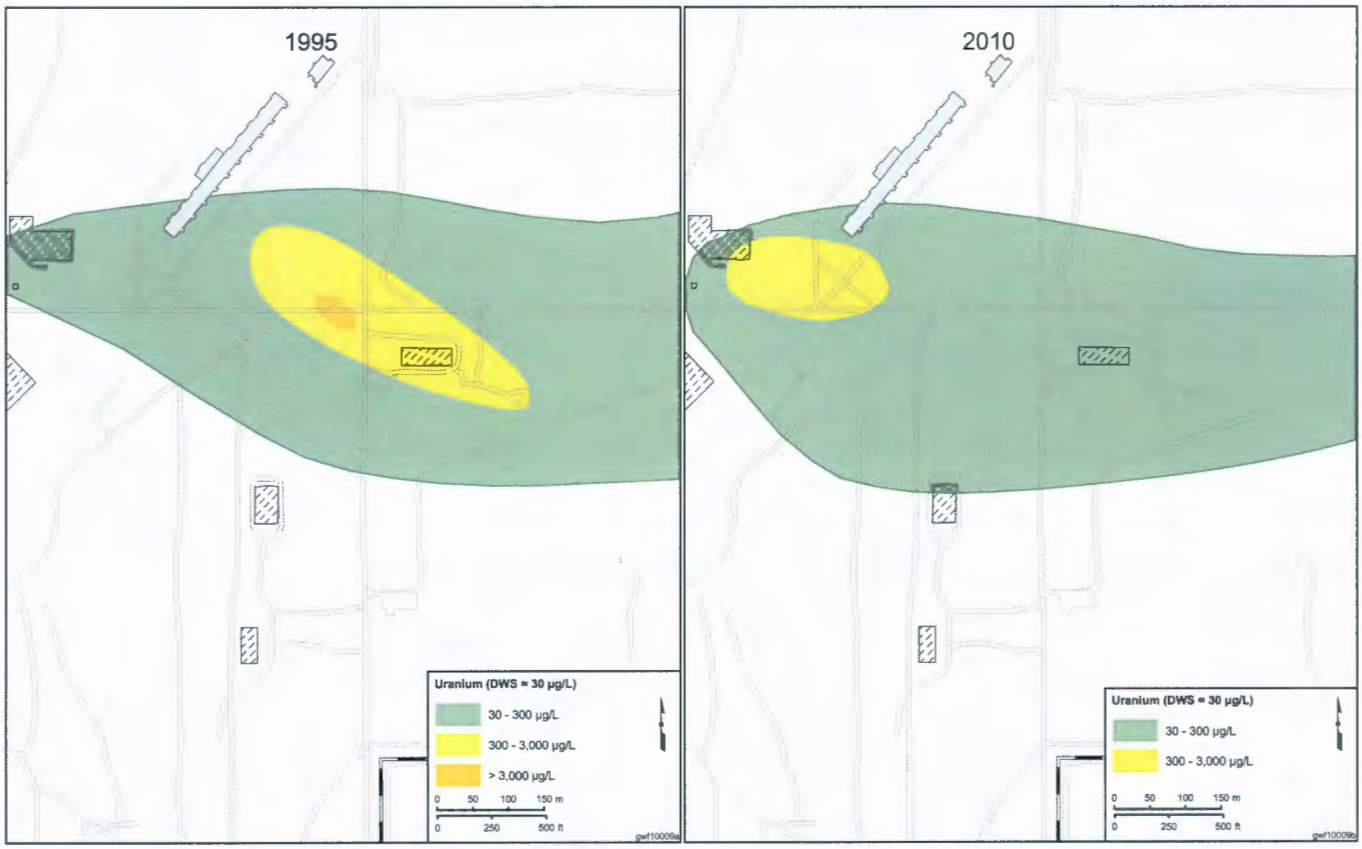
At the U Plant pump-and-treat area, technetium-99 and uranium groundwater concentrations were below their respective remedial action objectives of 9,000 pCi/L and 300 µg/L at all but one well during 2010.

The 200-UP-1 OU includes one CERCLA interim action pump-and-treat system, three TSD units monitored under RCRA, and one CERCLA disposal site (Environmental Restoration Disposal Facility [ERDF]).

Interim remedial action. Since 1994, the DOE has operated an interim remedial action pump-and-treat system to remove technetium-99 and uranium from the groundwater near U Plant. At all wells, the technetium-99 concentrations were below the remedial action objective of 9,000 pCi/L during 2010. Uranium declined below the RAO of 300 µg/L in all wells except 299-W19-18, located upgradient by the 216-U-1/2 Cribs and beyond the influence of the pump-and-treat system.



A pump-and-treat system at the 200-UP-1 OU (200 West Area) has decreased the size of the technetium-99 plume in the upper portion of the aquifer. The system began operation in the fall of 1995.



Uranium contamination in the 200-UP-1 OU (200 West Area) does not respond to the pump-and-treat system as quickly as technetium-99. Unlike technetium-99, uranium interacts with aquifer sediment, slowing its movement and response to remediation.

The pump-and-treat system operated about one-third of the time during 2010; downtime was due to facility upgrades at the Effluent Treatment Facility (ETF) and well rehabilitation. Flow rates from the extraction wells remained low (less than 30.2 liters per minute combined), and the rehabilitation attempts to increase the flow were not successful. During CY 2010, the pump-and-treat system removed a total of 0.9 kilograms of uranium, 0.047 grams (0.025 curies) of technetium-99, 0.9 kilograms of carbon tetrachloride, and 2,092 kilograms of nitrate from the 4.9 million liters of groundwater pumped.

Waste Management Area S-SX (WMA S-SX). The RCRA groundwater quality assessment monitoring continued at this WMA in CY 2010. Groundwater beneath WMA S-SX is contaminated with tank waste constituents, including nitrate, chromium, and technetium-99, which are attributed to two general source areas within the WMA. Chromium is the only dangerous waste constituent subject to RCRA requirements. The contaminants have migrated ~650 meters downgradient (east) from the TSD unit at concentrations above respective DWSs, and all three were above their respective DWSs during the reporting period. A new well was installed during CY 2010 to define the southwest boundary of the contaminant plume. A revised groundwater quality assessment plan, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX* (DOE/RL-2009-73), was issued in January 2011. An interim-action pump-and-treat system targeting the technetium-99 plumes was in the planning stage during CY 2010; the system is expected to be operational by the end of CY 2011.

Waste Management Area U (WMA U). The RCRA groundwater quality assessment monitoring at WMA U continued during CY 2010. This WMA has been identified as the source of groundwater contamination that is limited to the downgradient (east) side of the unit. Constituents of interest include the non-RCRA contaminants nitrate and technetium-99. During the reporting period, both contaminants were above their respective DWSs. A revised groundwater quality assessment plan, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U* (DOE/RL-2009-74), was issued in January 2011.

216-S-10 Pond and Ditch. The 216-S-10 Pond and Ditch continued to be monitored under a RCRA interim status indicator evaluation monitoring program during CY 2010. The *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch* (DOE/RL-1008-61) was issued and implemented in March 2010. New threshold values for indicator parameter evaluation were determined during the year using the new upgradient well installed during 2008. However, due to a large standard deviation, the threshold value for total organic carbon was not used in CY 2010. New threshold values were calculated for pH, specific conductance, and total organic halides based on data collected in 2009. No exceedances occurred during the year of any threshold values. Chromium concentrations continue to increase at one downgradient well, although concentrations remained below the DWS at the end of CY 2010. The DOE believes the monitoring network is capable of the continued detection and evaluation of indicator constituents from the TSD unit in the uppermost aquifer.

Environmental Restoration Disposal Facility (ERDF). This low-level mixed waste facility is used for disposal of waste generated from surface remedial actions and other activities on the Hanford Site. The facility was constructed under CERCLA and is designed to meet all hazardous waste landfill standards. The results of groundwater monitoring continue to indicate that the facility has not adversely impacted groundwater quality.

200-ZP-1 Operable Unit

The 200-ZP-1 OU encompasses the northern and central portions of the 200 West Area and adjacent areas to the north and east. Groundwater monitoring continued under the *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network* (DOE/RL-2002-17). Groundwater at this OU is monitored to assess interim pump-and-treat performance and to track existing contaminant plumes. Other activities are conducted for facility-specific monitoring.

The primary COC for the 200-ZP-1 OU is carbon tetrachloride. Other contaminants of interest include tritium, nitrate, hexavalent chromium, chromium, iodine-129, technetium-99, and trichloroethene. The distribution of carbon tetrachloride is complex because it can migrate as a dense, nonaqueous-phase liquid; as a gas; or dissolved in water. Previous studies have not found free-phase dense, nonaqueous-phase liquid in the groundwater; therefore, density effects in the groundwater are not believed to contribute to vertical migration of the carbon tetrachloride plume. Contamination occurs at increasing depth to the east (downgradient) of the known source areas in the 200-ZP-1 OU. In this area, lithologic controls and recharge may have pushed carbon tetrachloride contamination in the upper portion of the aquifer to deeper parts of the formation.

During the reporting period, CERCLA accomplishments included issuance of the *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit*

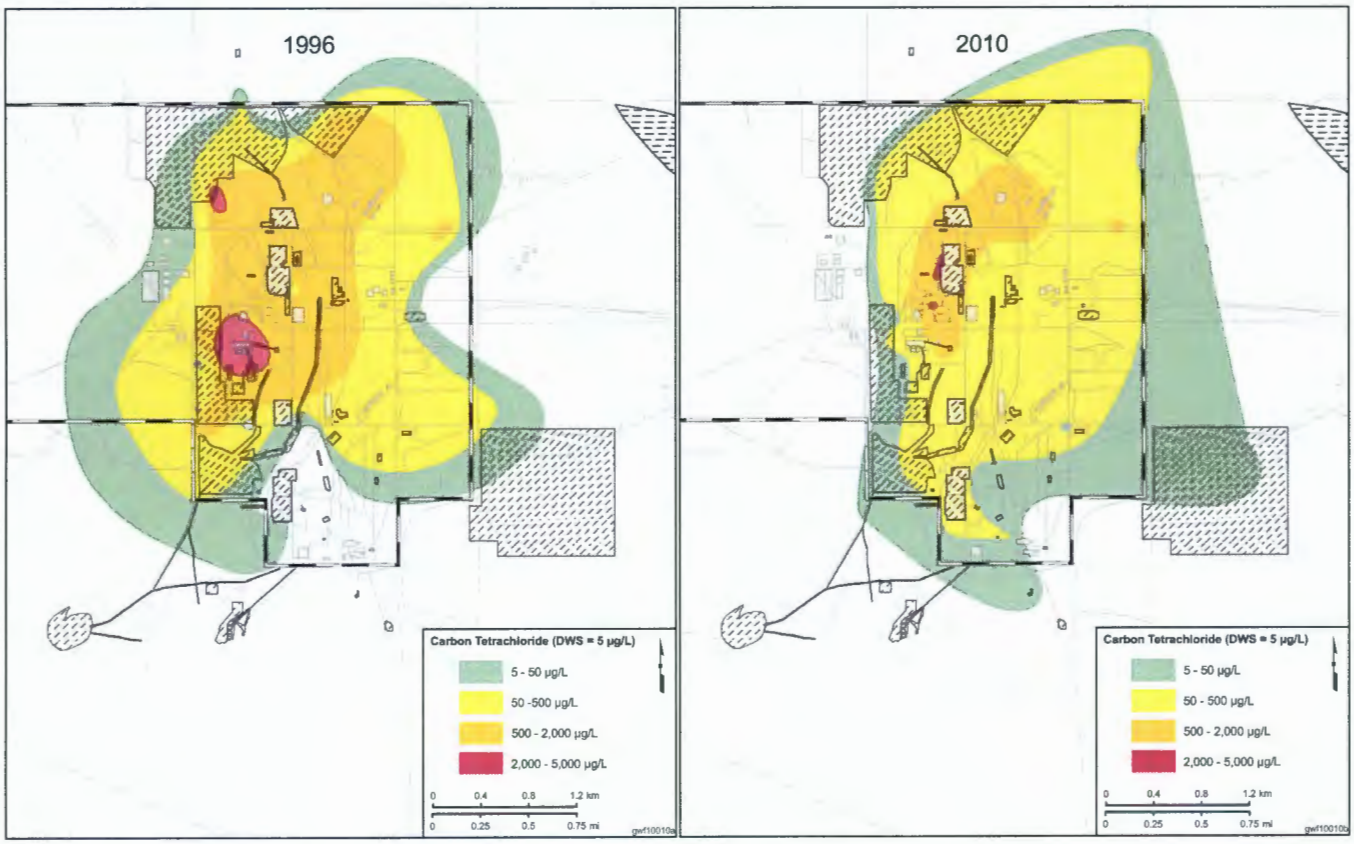
Remedial Action (DOE/RL-2009-115). This document serves to guide groundwater monitoring data collection activities associated with 200-ZP-1 OU remedial action.

The 200-ZP-1 groundwater interest area contains two CERCLA interim action pump-and-treat systems for groundwater, one soil vapor remediation system for the vadose zone, four TSD units monitored under RCRA (in coordination with CERCLA and AEA), and one state-permitted unit (the SALDS).

Interim remedial action. Since 1994, the DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride in the upper portion of the aquifer from spreading. The system is limiting movement of the shallow, high-concentration portion of the plume but does not address contamination deeper in the aquifer and at the periphery of the plume. In CY 2010, the system removed more than 700 kilograms of carbon tetrachloride from 5.7 million liters of groundwater. In 2009, under the ROD for final remediation (EPA et al., *2008*), the DOE began construction of an expanded pump-and-treat system to address groundwater contamination relating to all of the COCs.

Groundwater remediation systems removed over 700 kilograms of carbon tetrachloride from the subsurface during the reporting period.

A second pump-and-treat test system began operation in September 2007 as part of a designed interim remediation activity to treat technetium-99 contamination downgradient of the WMA T. During CY 2010, the total volume treated was 52.2 million liters, allowing for removal of 16.35 grams (0.278 curies) of technetium-99, 27.86 kilograms of carbon tetrachloride, 6.25 kilograms of chromium, 245 grams of trichloroethene, and 22,959 kilograms of nitrate from the aquifer.



These maps illustrate the carbon tetrachloride plume beneath the 200 West Area in the upper portion of the unconfined aquifer. Since 1996, a pump-and-treat system has been helping to prevent further spreading of the plume's core.

Soil vapor extraction is also used to remove carbon tetrachloride from the vadose zone in the 200-ZP-1 OU. A new system came online at the 216-Z-18 and 216-Z-1A well field in CY 2010. During 2010, both the new and existing vapor extraction systems removed a total of 193 kilograms of carbon tetrachloride from the vadose zone.

Low-Level Waste Management Area 3 (LLWMA-3). The RCRA groundwater monitoring continued under interim status indicator evaluation requirements in CY 2010. There are no upgradient monitoring wells for LLWMA-3, but a new well is planned for construction in 2011. A new interim status groundwater monitoring plan was issued during the reporting period, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3* (DOE-RL-2009-68). Until the new upgradient monitoring well is installed and background conditions are established, statistical evaluations have been suspended.

Low-Level Waste Management Area 4 (LLWMA-4). The RCRA groundwater monitoring continued under interim status indicator evaluation requirements in CY 2010. Groundwater monitoring at the LLWMA returned to contaminant indicator evaluation monitoring in 2010 following an assessment program that had been in effect since 2009. A new interim status groundwater monitoring plan was issued during the reporting period, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4* (DOE-RL-2009-69). The last upgradient well, 299-W18-21, went dry in early 2010. Statistical evaluations will continue using threshold values calculated from the most recent several years of data from this well. Construction of an upgradient well is not expected until the hydraulic effects of the expanded 200-ZP-1 OU pump-and-treat system are known. Operation of the additional extraction wells will modify groundwater flow directions in the entire 200 West Area. The DOE believes the monitoring network remains capable of the continued detection and evaluation of indicator constituents from the TSD unit until startup of the new pump-and-treat system.

Waste Management Area T (WMA T). The RCRA groundwater quality assessment monitoring for this WMA continued in CY 2010. A new interim status assessment monitoring plan was drafted and was approved at the end of the reporting period and went into effect in early 2011, *Interim Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area-T* (DOE-RL-2009-66). Sources in WMA T have contaminated groundwater with the dangerous waste constituent chromium. In addition, technetium-99, nitrate, and other non-RCRA tank waste contaminants from the WMA and adjacent waste disposal facilities have impacted the unconfined aquifer in the area. Chromium contamination in groundwater extends at least 2.5 kilometers downgradient. Two extraction wells (part of the 200-ZP-1 pump-and-treat remediation for technetium-99) operate immediately east and downgradient of the WMA. Concentrations of the non-RCRA contaminant technetium-99 have fluctuated as a result of these extraction activities.

Waste Management Area TX-TY (WMA TX-TY). The RCRA groundwater quality assessment monitoring for this WMA continued during CY 2010. A new monitoring plan was drafted during the reporting period and issued in early 2011, *Interim Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area-TX-TY* (DOE-RL-2009-67). Sources in WMA TX-TY have contaminated groundwater with chromium (a dangerous waste constituent) and other non-RCRA tank waste constituents such as technetium-99 and nitrate. The more mobile contaminants have migrated to wells ~250 meters downgradient of the WMA. The groundwater flow rate and direction has been affected beneath WMA TX-TY due

to operation of the 200-ZP-1 pump-and-treat system. Extraction wells are operating south and west of the WMA.

State-Approved Land Disposal Site (SALDS). This active liquid waste disposal facility is regulated under a state waste discharge permit. The disposal site receives treated groundwater containing tritium from the ETF. Groundwater in area monitoring wells is tested for tritium and fifteen other constituents. Concentrations of all constituents of interest in the permit did not exceed enforcement limits during CY 2010.

300-FF-5 Operable Unit

The 300-FF-5 OU includes three geographic regions: the 300 Area, the 618-11 Burial Ground region, and the 618-10 Burial Ground/316-4 Cribs region. The OU is currently regulated under a ROD (EPA/ROD/R10-96/143, *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington*) for interim remedial action, which requires groundwater monitoring and institutional controls for groundwater use.

The COCs in 300 Area groundwater are uranium, trichloroethene, and cis-1,2-dichloroethene. Monitoring and plume characterization activities indicate relatively constant or gradually decreasing levels for these contaminants, with some exceptions. Uranium is the primary COC, having persisted longer than expected, and remains above the DWS of 30 µg/L beneath part of the 300 Area. Also, a new area of localized uranium contamination developed to the southeast of the former 618-7 Burial Ground as a result of remediation activities in 2007 and 2008. The plume has migrated downgradient and is merging with the larger uranium plume. Trichloroethene remained below the 5 µg/L DWS in wells monitoring the top of the unconfined aquifer. Concentrations of trichloroethene above the DWS were revealed in groundwater samples collected from a relatively finer grained sediment interval during RI drilling, but only in a limited area. Due to very low yield from this interval and the likely ineffectiveness of pumping samples, none of the monitoring wells have been screened in this sediment. However, at aquifer tube sites along the Columbia River, at least one tube is screened in this interval and has produced samples that reveal trichloroethene contamination.

Tritium concentrations remained stable or increased slightly downgradient of the 618-11 Burial Ground.

Groundwater downgradient of the 618-11 Burial Ground contains a high-concentration tritium plume, likely originating from irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from the peak values of several million pCi/L observed in 1999 and 2000. The plume extends eastward from the burial ground across the northern portion of the Energy Northwest complex and has maintained its basic shape since discovery in 1999. Concentrations are stable in the central portion of the plume, while increasing slightly at the downgradient edge of the plume, reflecting migration to the east. Characterization activities in preparation for remediation of the 618-11 Burial Grounds were conducted during CY 2010.

Principal activities conducted during 2010 included drilling at numerous locations for the purpose of characterizing contamination remaining in the vadose zone and unconfined aquifer. Each borehole was subsequently completed in 2011 as a monitoring well. The renewed RI work was performed under approval of the *300 Area Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units* (DOE/RL-2009-30). Other CERCLA accomplishments included implementation of treatability testing and research on

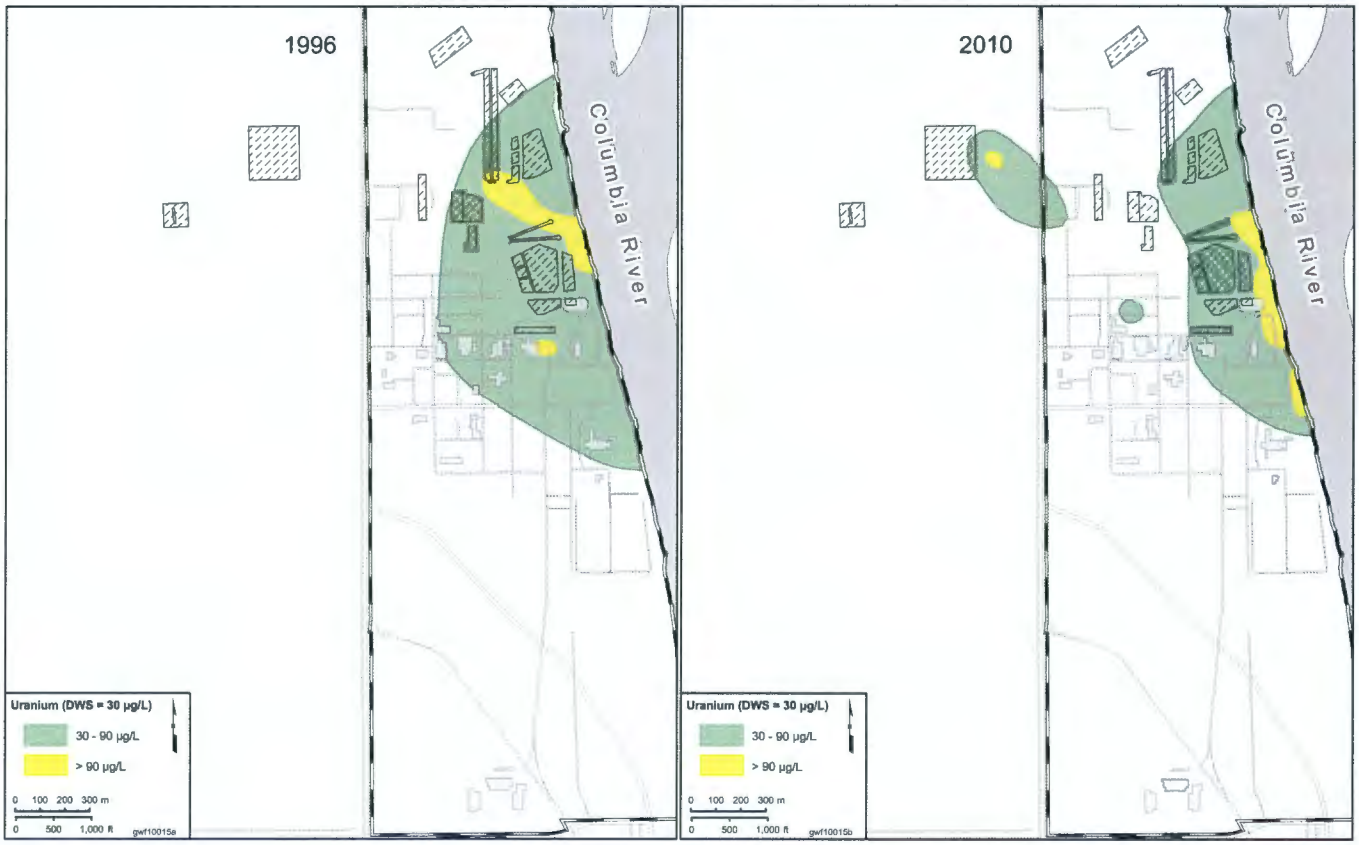
uranium contamination in the vadose zone and groundwater. Five new Tri-Party Agreement milestones have been established pertaining to the 300-FF-5 OU, with the first being completion of an RI/FS report and proposed plan by the target date of December 31, 2011. Additional highlights on the uranium treatability tests and research activities are discussed below.

The DOE is investigating remediation methods for uranium in the 300 Area.

The 300 Area subregion of the 300-FF-5 OU contains a treatability test site, a field research site, and a TSD unit monitored under RCRA regulations.

Uranium treatability test. Laboratory testing has demonstrated that polyphosphate and calcium chloride solutions introduced to groundwater contaminated by uranium can promote the formation of minerals that cause the dissolved uranium to become sequestered in solid form in the new minerals. A field test of this process was conducted in the 300 Area aquifer in June 2007 and revealed additional challenges associated with implementing the process under field conditions. A final report on the aquifer injection test is provided in *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report* (PNNL-18529). Follow-up testing of potential schemes to immobilize uranium in the vadose zone using alternate polyphosphate solutions were conducted in 2009 and continued during 2010.

Integrated Field-Scale Research Challenge Program. The DOE's Office of Biological and Environmental Research (Office of Science) is supporting field research involving the mobility of uranium under a program referred to as Integrated Field-Scale Research Challenge. The Hanford Site 300 Area is one of three DOE sites where field and laboratory research activities are being performed. A highly instrumented, three-dimensional array of sensors is installed in the vadose zone and



The uranium plume in the 300 Area, at the 30 µg/L level, is attenuating slowly. The DOE is investigating alternatives for more rapid remediation.

upper portion of the aquifer beneath a portion of the former South Process Pond liquid waste disposal site. A closely associated project uses a variety of near-surface geophysical methods to characterize preferential pathways for groundwater movement and discharge to the Columbia River channel. The results of this project were published in 2010 ("Use of Electrical Imaging and Distributed Temperature Sensing Methods to Characterize Surface-Water/Groundwater Exchange Regulating Uranium Transport at the Hanford 300 Area, Washington" [Slater et. al., 2010]). Additional information on the Integrated Field-Scale Research Challenge is available through the following Internet link: http://ifchanford.pnnl.gov/.

The DOE has also funded a groundwater flow and uranium transport modeling project for the 300 Area via the Scientific Discovery Through Advanced Computing Program. This project involves massively parallel, high-speed computing and conducts calculations that would otherwise require exceedingly long computing times using conventional computer equipment. Two reports on the initial results of the project were published in 2010 ("Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area Using High Performance Computing" [Hammond and Lichtner, 2010]), "Stochastic Simulation of Uranium Migration at the Hanford 300 Area" [Hammond et. al., 2010]).

300 Area Process Trenches. This former liquid waste disposal site was the last site in the 300 Area to receive uranium-bearing effluent, with uranium discharges ending in 1985 and all discharges ending in December 1994. The site, which has been remediated, is regulated under RCRA, and groundwater is monitored in accordance with post-closure corrective action requirements (WAC 173-303-645[11]); the remedial activities are currently deferred to CERCLA. Uranium currently exceeds the DWS in wells downgradient from the waste site. Cis-1,2-dichloroethene concentrations exceed the DWS at downgradient well 399-1-16B, which is completed near the bottom of the unconfined aquifer. Most results for trichloroethene and tetrachloroethene were below detection limits during the reporting period, with the exception of two detections of trichloroethene in samples from well 399-1-16B and one detection of trichloroethene from 399-1-17A, but the concentrations were near the detection limit.

1100-EM-1 Groundwater Interest Area

The 1100-EM-1 groundwater interest area (which includes the former 1100-EM-1 OU) is located in the southern portion of the Hanford Site. Groundwater is also monitored south of the Hanford Site, including the areas formerly designated as the 1100-EM-2 and 1100-EM-3 areas, the 3000 Area, the city of Richland's sanitary landfill, and the North Richland Well Field. Even though this OU was deleted from the CERCLA National Priorities List in 2006, waste was left in place prompting continued groundwater monitoring during the reporting period under the most recent revision of the *Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit* (PNNL-12220), change notice TPA-CN-163, and AEA requirements.

In the 1100-EM-1 groundwater interest area, trichloroethene concentrations continued to be below the cleanup level.

Trichloroethene was the primary COC in the 1100-EM-1 OU, but concentrations remained below the 1 µg/L detection limit in CY 2010. Contaminants also flow into the area from offsite sources (e.g., nitrate from agricultural and industrial sources). The final remedy selected for 1100-EM-1 OU groundwater is monitored natural attenuation of volatile organic compounds.

Wells in the North Richland Well Field are monitored frequently to detect any changes in potential Hanford Site contaminants near these wells. Tritium associated with the plume originating from sources in the 200 East Area has not been detected in these wells. Low levels of tritium (less than 500 pCi/L) continued to be detected from unknown source or sources.

Elevated levels of gross alpha are detected downgradient of an offsite industrial facility. Uranium concentrations in wells downgradient of DOE's inactive Horn Rapids Landfill have slowly been increasing since 1996 but remained below the DWS in CY 2010. The presence of uranium at these locations is likely associated with the plume moving northeast from the AREVA facility.

Confined Aquifers

Although most Hanford Site groundwater contamination is found in the unconfined aquifer, the DOE monitors wells in deeper aquifers due to potential downward movement of contamination and potential migration of that contamination offsite through the confined aquifers. Evidence has not been detected of offsite migration via the confined aquifers.

One confined aquifer occurs within sand and gravel comprising the lowest sedimentary unit of the Ringold Formation. This aquifer is confined below by basalt and above by the Ringold lower mud unit. Groundwater in this aquifer flows generally west to east near the 200 West Area. In the central portion of the Hanford Site, flow in this confined aquifer appears to converge into the 200 East Area from the west, south, and east. Some groundwater discharges from the confined aquifer to the overlying unconfined aquifer where the confining Ringold lower mud unit has been removed by erosion.

While effluent disposal was occurring at the 216-B-3 Pond system, mounding within the unconfined aquifer in the central Hanford Site led to downward movement of groundwater into the Ringold confined aquifer. During CY 2010, sampling was conducted at seven wells in this region that are completed in the Ringold confined aquifer. None of the dangerous waste or radioactive constituents associated with waste disposal exceeded their respective DWSs. Iron and manganese, exceeded secondary DWSs and because these elements are constituents of common soil minerals and are not COCs from any nearby Hanford waste sites, the elevated concentrations are likely the result of local groundwater/soil interactions rather than contamination from Hanford Site operations.

In the northern Hanford Site, a fine-grained unit informally called the Ringold upper mud confines deeper sediments in the Ringold Formation. Investigations on the properties of this unit were conducted at multiple locations in the 100 Area.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system. Groundwater in the upper basalt-confined aquifer generally flows from west to east across the Hanford Site. Groundwater also flows vertically through fractures or other pathways in the confining layers, into the overlying unconfined aquifer and into the Columbia River. Vertical gradients between the upper basalt-confined aquifer and the unconfined aquifer are upward across most of the Hanford Site. Localized downward gradients occur in the western portion of the Hanford Site, as well as near 216-B-3 Pond and to the north and east of the Columbia River.

In CY 2010, twenty upper basalt-confined aquifer wells were sampled. Tritium continued to be detected at low levels in some wells, primarily in wells located in or near the 200 East Area.

Shoreline Monitoring

The DOE samples groundwater near the Columbia River via aquifer tubes and springs.

The DOE monitors groundwater along the Columbia River by collecting samples from aquifer tubes and riverbank springs (seeps). Aquifer tubes are small-diameter, flexible tubes with a screen at the lower end. The aquifer tubes are implanted into the shallow aquifer along the Columbia River shoreline. Sampling of aquifer tubes and springs is intentionally performed in the fall during low river stage to minimize the effects of groundwater dilution by river water. In addition, samples are considered diluted and not collected if the specific conductance is below 160 µS/cm (with the exception of the 100-N Area and RI/FS tubes that are sampled regardless of conductance readings). This cut off is based on empirical results gathered over the years of aquifer tube sampling.

Twenty-six new aquifer tubes were installed and sampled in CY 2010 in support of RI studies in the River Corridor OUs. Most of the older tubes were scheduled for sampling in the fall; however, the fall 2010 sampling was delayed into CY 2011 and sampling of many tubes was cancelled, mostly due to the site-wide work stoppage during October. As a result, fewer aquifer tubes were sampled in CY 2010 than were planned. Most of the sampling that occurred in CY 2010 was for tubes that are sampled semiannually, quarterly, or monthly.

The following observations are based on aquifer tube monitoring during the reporting period and from previous years:

- Strontium-90 concentrations exceed the 8 pCi/L DWS in aquifer tubes in the 100-B/C, 100-N, and 100-H Areas. Levels exceed the 1,000 pCi/L derived concentration guideline in certain aquifer tubes in the 100-N Area.
- Tritium concentrations have exceeded the 20,000 pCi/L DWS in one tube in the 100-B/C Area and one tube in the southern 100-D Area. Tritium also exceeds the DWS in riverbank springs and aquifer tubes at the Hanford town site in the 200-PO-1 OU.
- Uranium concentrations exceed the 30 µg/L DWS in aquifer tubes and riverbank springs in the 300 Area.
- Chromium concentrations in aquifer tubes or seeps exceed the 10 µg/L aquatic water quality criterion in the 100-B/C, 100-K, 100-D, 100-H, and 100-F Areas.
- Nitrate concentrations exceed the 45 mg/L DWS in aquifer tubes in the 100-K, 100-N, and 100-H Areas.
- Trichloroethene is detected in several aquifer tubes in the 300 Area and exceeds the 5 µg/L DWS in some tubes monitoring a fine-grained unit.

Columbia River

Many actions have already been taken to address principal threats to the Columbia River and groundwater, including the following:

- Ceasing discharge of all unpermitted liquids in the central Hanford Site
- Remediating the former liquid waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination

- Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat.

Pacific Northwest National Laboratory samples Columbia River water, river sediment, and riverbank seeps to determine the extent of Hanford Site or other contaminants. The data provide a historical record of radionuclides and chemicals in the environment. Concentrations of tritium and uranium downstream of the Hanford Site are higher than upstream of the Site but meet water quality standards. A statistically significant difference does not exist for concentrations of other Hanford Site contaminants.

Washington Closure Hanford is performing the River Corridor baseline risk assessment. The 100 Area and 300 Area Component of the baseline risk assessment addresses post-remediation, residual contaminant concentrations in these areas, as well as the Hanford and White Bluffs town sites. The assessment is also investigating the risks related to the potential transport of Hanford Site contaminants into Columbia River riparian and near-shore environments adjacent to the operational areas.

The DOE and Washington Closure Hanford completed an investigation of Hanford Site contaminant releases in the Columbia River in 2010. Samples were collected of porewater (i.e., groundwater upwelling beneath the river bottom into the space between rocks and sediment of the river bed), river sediment, river water, fish, and island soil. Porewater in some locations was contaminated with hexavalent chromium, strontium-90, tritium, or uranium. The results of this investigation are documented in *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398).

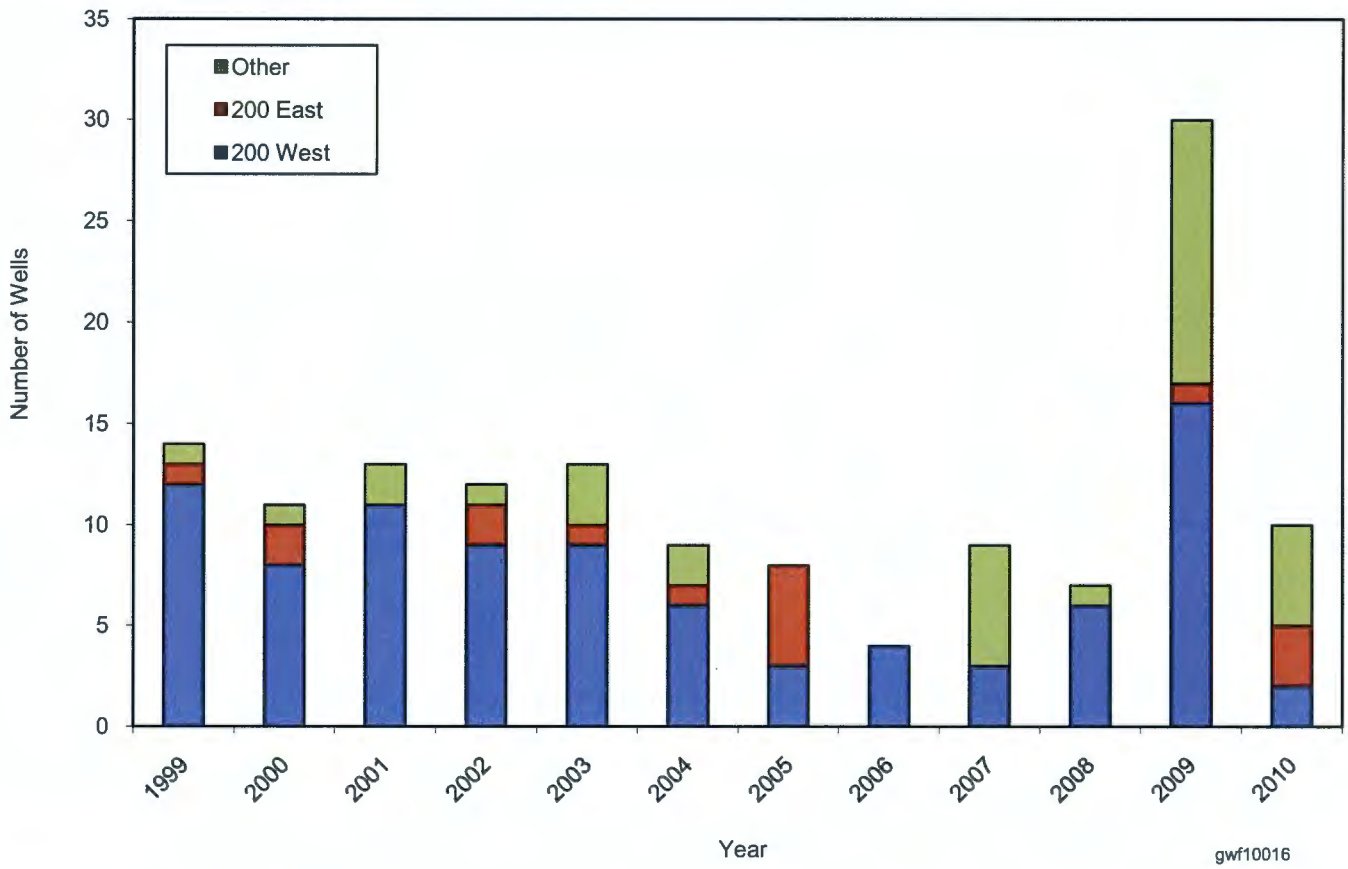
Well Installation, Maintenance, and Decommissioning

During the reporting period, the DOE installed 282 new wells and decommissioned 181 soil tubes.

The DOE installs new wells when needed for monitoring or characterization, maintains wells to ensure good operating/usable condition, and decommissions wells that are no longer needed by a program or that can no longer be used. Ecology, EPA, and DOE worked together to develop a prioritized list of new wells needed to meet the requirements of various groundwater monitoring regulations. During CY 2010, the DOE installed a total of 282 new wells on the Hanford Site, 26 new wells on the Central Plateau and 256 new wells along the River Corridor.

Approximately 10,979 unique well identification numbers have been identified at the Hanford Site, which includes all wells, characterization boreholes, aquifer tubes, soil vapor probes, piezometers, or other subsurface installations. During CY 2010, a total of 3,841 unique well identification numbers were documented as "in use." One hundred eighty-one soil tube wells were physically decommissioned during CY 2010, and no boreholes were administratively decommissioned during the reporting period.

During CY 2010, 82 temporary characterization boreholes were installed in the Central Plateau to support various projects. Eight characterization boreholes were installed in the River Corridor. Temporary boreholes are installed for subsurface characterization of radiological or chemical contaminants, or hydrogeologic property determination (e.g., moisture and grain-size distribution). While typically installed to characterize the vadose zone, temporary borings can be drilled to groundwater to obtain a one-time sample. Most boreholes are then decommissioned, although some are completed as temporary wells in order to obtain a more representative groundwater sample after the effects of drilling and well installation have dissipated.



This chart shows the number of monitoring wells that went dry each year since 1999. Most of the wells were in the 200 West Area, where the water table declined the most.

Staff performed maintenance on 929 wells during CY 2010: 337 wells on the Central Plateau, 485 wells along the River Corridor, and 107 wells in the 600 Area. Surface maintenance includes labeling wells; maintaining well caps; and repairing surface casing, wiring, or pump-discharge fittings. Subsurface tasks include repairing and replacing sampling pumps, performing camera surveys, retrieving pumps and equipment, and replacing discharge tubing.

Wells Installed During Calendar Year 2010

Location (Facility)	Number of New Wells
100-BC-5	6
100-FR-3	3
100-HR-3	67
100-KR-4	5
100-NR-2	171
200-BP-5	8
200-UP-1	2
200-ZP-1	15
300-FF-5	5
Total	**282**

Vadose Zone

Vadose zone activities during the reporting period included leachate monitoring, soil vapor extraction and monitoring, surface geophysics, and borehole geophysical logging.

Leachate monitoring at the ERDF. The ERDF is used for disposal of radioactive and mixed waste generated during waste management and remediation activities at the Hanford Site. Leachate is collected in the bottom of the facility and then sent to the ETF for treatment and disposal. The composite leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. Constituents that decreased in concentration include gross alpha (1,450 pCi/L), gross beta (650 pCi/L), and total uranium (~1,800 µg/L).

Leachate and soil vapor monitoring at the SWL. Leachate (collected from beneath two of the trenches) is sampled and tested quarterly for ammonia, metals, anions, total organic carbon, total organic halides, total dissolved solids, and volatile organic compounds. Concentrations during the reporting period were similar to previously reported concentrations and did not identify areas of concern. Soil vapor is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. In CY 2010, only methane, carbon dioxide, 1,1,2-trichloroethane, and ammonia were detected in soil vapor samples.

As of December 2010, ~79,600 kilograms of carbon tetrachloride had been removed from the vadose zone since vapor extraction operations began in 1991.

Soil vapor extraction. Soil vapor extraction is used to remove carbon tetrachloride from the vadose zone in the 200 West Area. A new system was online in CY 2010 at the 216-Z-18 and 216-Z-1A well field and one system was operated at the 216-Z-9 well field. Both the new system and the existing system operated from March 1 to November 1, 2010. During the reporting period, the 216-Z-9 well field system removed 101 kilograms of carbon tetrachloride and the 216-Z-1A and 216-Z-18 system removed 93 kilograms.

Tank farm vadose zone activities. The Vadose Zone Integration Program is responsible for implementing the tank farm RCRA corrective action program through field characterization, laboratory analyses, technical analyses, risk assessment for past tank leaks, and installation of interim measures to reduce the threat from contaminants until permanent solutions can be found. In CY 2010, the Vadose Zone Integration Program advanced nineteen direct-push boreholes for soil sampling and geophysical logging in the C, S, and BY Tank Farms. Multi-depth electrode strings were also installed in the C, S, and BY Tank Farms in CY 2010 for future use with surface geophysics. Surface geophysical surveys at WMA S-SX and UPR-200-E-86 were also completed. Effectiveness monitoring at the interim surface barrier over a portion of the T Tank Farm continued with installation of a solar-powered and remotely controlled soil/water monitoring system. Conditions are continuously monitored at four locations beneath the barrier and at one site outside the barrier footprint. During CY 2010, an interim surface barrier was constructed over the TY Tank Farm.

Conclusions

Groundwater monitoring remains a crucial part of the Hanford Site baseline throughout the cleanup mission and will remain a component of long-term stewardship after remediation is completed. The DOE will continue monitoring the groundwater to meet its obligations under the AEA, CERCLA, RCRA, and WAC regulations. During ongoing groundwater remediation, the Soil and Groundwater Remediation Project will monitor, assess, and report on activities at the groundwater OUs. More detailed information about the Soil and Groundwater Remediation Project can be found online at http://www.hanford.gov/page.cfm/GroundwaterRemediation.

Contents

1.0 Introduction 1.0-1
1.1 Purpose and Scope 1.0-3
1.2 Groundwater Monitoring 1.0-4
1.3 Compliance Summary for CERCLA Operable Units 1.0-6
1.3.1 100-BC-5 Operable Unit 1.0-6
1.3.2 100-KR-4 Operable Unit 1.0-6
1.3.3 100-NR-2 Operable Unit 1.0-7
1.3.4 100-HR-3 Operable Unit 1.0-7
1.3.5 100-FR-3 Operable Unit 1.0-8
1.3.6 200-BP-5 Operable Unit 1.0-8
1.3.7 200-PO-1 Operable Unit 1.0-9
1.3.8 200-UP-1 Operable Unit 1.0-9
1.3.9 200-ZP-1 Operable Unit 1.0-10
1.3.10 300-FF-5 Operable Unit 1.0-11
1.3.11 1100-EM-1 Operable Unit 1.0-11
1.4 Compliance Summary for Sites Regulated Under the Resource Conservation and Recovery Act 1.0-12
1.4.1 1301-N (116-N-1) Liquid Waste Disposal Facility 1.0-13
1.4.2 1324-NA (120-N-1) Percolation Pond and 1324-N (120-N-2) Surface Impoundment 1.0-13
1.4.3 1325-N (116-N-3) Liquid Waste Disposal Facility 1.0-14
1.4.4 183-H (116-H-6) Solar Evaporation Basins 1.0-14
1.4.5 Low-Level Waste Management Area 1 ..... 1.0-15
1.4.6 Low-Level Waste Management Area 2 ..... 1.0-15
1.4.7 Waste Management Area B-BX-BY 1.0-15
1.4.8 Waste Management Area C 1.0-15
1.4.9 Liquid Effluent Retention Facility 1.0-16
1.4.10 216-B-63 Trench 1.0-16
1.4.11 Integrated Disposal Facility 1.0-16
1.4.12 RCRA PUREX Cribs 1.0-16
1.4.13 Waste Management Area A-AX 1.0-17
1.4.14 216-A-29 Ditch 1.0-17
1.4.15 216-B-3 Pond 1.0-17
1.4.16 Nonradioactive Dangerous Waste Landfill 1.0-18
1.4.17 Waste Management Area S-SX 1.0-18
1.4.18 Waste Management Area U 1.0-18
1.4.19 216-S-10 Pond and Ditch 1.0-18
1.4.20 Low-Level Waste Management Area 3 ..... 1.0-19
1.4.21 Low-Level Waste Management Area 4 ..... 1.0-19
1.4.22 Waste Management Area T 1.0-19
1.4.23 Waste Management Area TX-TY 1.0-20
1.4.24 Former 300 Area Process Trenches (316-5 Waste Site) 1.0-20
1.5 Other Regulated Facilities 1.0-20
1.5.1 Solid Waste Landfill 1.0-21
1.5.2 Treated Effluent Disposal Facility 1.0-21
1.5.3 State-Approved Land Disposal Site 1.0-21
1.6 Shoreline Monitoring 1.0-22
1.7 CERCLA Five-Year Review 1.0-23
1.8 Quality Control Summary 1.0-23
1.9 Other Information Sources 1.0-24
1.10 Conventions Used in This Report 1.0-25
1.11 Sources of Additional Information 1.0-27

2.0 Overview of Hanford Hydrogeology and Geochemistry 2.0-1
2.1 Stratigraphic Setting 2.0-1
2.1.1 Columbia River Basalt Group 2.0-1
2.1.2 Ringold Formation 2.0-2
2.1.3 Cold Creek Unit 2.0-5
2.1.4 Hanford Formation 2.0-5
2.1.5 Clastic Dikes 2.0-7
2.1.6 Holocene Surficial Deposits 2.0-7
2.2 Tectonic Setting 2.0-7
2.3 Hydrologic Setting 2.0-8
2.3.1 Confined Aquifer 2.0-8
2.3.2 Unconfined Aquifer 2.0-9
2.3.3 Vadose Zone 2.0-10
2.3.4 Groundwater/River Interactions 2.0-10
2.4 Physical and Hydraulic Properties 2.0-12
2.4.1 Vadose Zone Properties 2.0-12
2.4.2 Saturated Zone (Unconfined Aquifer) Properties 2.0-13
2.5 Geochemical Overview of Selected Hanford Site Groundwater Contaminants 2.0-14
2.5.1 Uranium 2.0-15
2.5.2 Chromium 2.0-15
2.5.3 Nitrate 2.0-17
2.5.4 Carbon-14 ..... 2.0-18
2.5.5 Technetium-99 ..... 2.0-18
2.5.6 Tritium 2.0-19
2.5.7 Strontium-90 ..... 2.0-19
2.5.8 Iodine-129s 2.0-20
2.5.9 Carbon Tetrachloride 2.0-20
2.6 Selected Bibliography 2.0-20

3.0 Overview of Groundwater Flow 3.0-1
3.1 March 2010 Water Table and Changes from 2009 ..... 3.0-1
3.2 200 East Area Hydraulic Gradient Evaluation 3.0-5
3.2.1 Low-Level Waste Management Area 1 ..... 3.0-7
3.2.2 Integrated Disposal Facility/PUREX Cribs 3.0-8
3.2.3 Low-Level Waste Management Area 2 and 216-B-63 Trench 3.0-9

4.0 100-BC-5 Operable Unit 4.0-1
4.1 Groundwater Contaminants 4.0-2
4.1.1 Strontium-90 ..... 4.0-2
4.1.2 Tritium 4.0-3
4.1.3 Chromium 4.0-4
4.1.4 Nitrate 4.0-5
4.1.5 Additional Contaminants of Potential Concern 4.0-5
4.2 CERCLA Groundwater Activities 4.0-6
4.2.1 Remedial Investigation Activities 4.0-6
4.2.2 CERCLA Groundwater Monitoring 4.0-7
4.3 Conclusions and Recommendations 4.0-7

5.0 100-KR-4 Operable Unit 5.0-1
5.1 Contaminant Monitoring 5.0-5
5.1.1 Hexavalent Chromium Monitoring Results 5.0-6
5.1.2 Tritium Monitoring Results 5.0-10
5.1.3 Strontium-90 Monitoring Results 5.0-12

5.1.4 Carbon-14 Monitoring Results 5.0-14
5.1.5 Nitrate Monitoring Results 5.0-15
5.1.6 Volatile Organic Compounds Monitoring Results 5.0-16
5.1.7 Other Contaminants of Interest 5.0-17
5.2 CERCLA Groundwater Activities 5.0-18
5.2.1 Remedial Investigation/Feasibility Study Activities 5.0-20
5.2.2 Remedial Process Optimization Activities 5.0-21
5.2.3 100-KR-4 OU Pump-and-Treat Systems (KR4, KX, and KW) 5.0-22
5.2.4 Calcium Polysulfide Treatability Test 5.0-30
5.3 100-K Basins 5.0-31
5.3.1 KE Basin 5.0-32
5.3.2 KW Basin 5.0-33
5.4 Conclusions 5.0-33
5.5 Recommendations 5.0-36

6.0 100-NR-2 Operable Unit 6.0-1
6.1 Groundwater Contaminants 6.0-2
6.1.1 Strontium-90 ..... 6.0-3
6.1.2 Tritium 6.0-6
6.1.3 Nitrate 6.0-6
6.1.4 Petroleum Hydrocarbons 6.0-7
6.1.5 Sulfate 6.0-9
6.1.6 Manganese and Iron 6.0-10
6.1.7 Chromium 6.0-11
6.2 CERCLA Activities 6.0-13
6.2.1 CERCLA Decision Documents 6.0-13
6.2.2 Status of the Five-Year Review Action Items 6.0-13
6.2.3 Interim Action Monitoring 6.0-14
6.2.4 Permeable Reactive Barrier 6.0-15
6.2.5 Other Strontium-90 Treatment Technologies 6.0-20
6.2.6 Characterization of Petroleum Contamination 6.0-22
6.2.7 River Sediment Porewater Sampling 6.0-23
6.2.8 Remedial Investigation/Feasibility Study Aquifer Tube Sampling 6.0-25
6.3 RCRA Facility Monitoring 6.0-26
6.3.1 116-N-1 (1301-N) Liquid Waste Disposal Facility 6.0-26
6.3.2 120-N-1 (1324-NA) Percolation Pond and 120-N-2 (1324-N) Surface Impoundment 6.0-27
6.3.3 116-N-3 (1325-N) Liquid Waste Disposal Facility 6.0-27
6.4 Conclusions and Recommendations 6.0-28

7.0 100-HR-3 Operable Unit 7.0-1
7.1 Groundwater Contaminants 7.0-4
7.1.1 Hexavalent Chromium 7.0-4
7.1.2 Strontium-90 ..... 7.0-8
7.1.3 Technetium-99 and Uranium 7.0-8
7.1.4. Tritium 7.0-9
7.1.5 Nitrate and Nitrite 7.0-10
7.1.6 Sulfate 7.0-10
7.1.7 Gross Beta 7.0-11
7.2 CERCLA Groundwater Activities 7.0-11
7.2.1 Remedial Investigation Activities 7.0-13
7.2.2 Pump-and-Treat Systems 7.0-16
7.2.3 In Situ Redox Manipulation System 7.0-20
7.2.4 Zero-Valent Iron Injection 7.0-21

7.2.5 Characterization of Hexavalent Chromium Within the Ringold Upper Mud Unit 7.0-21
7.2.6 Horizontal Direction Drilling—Technology Demonstration 7.0-22
7.3 RCRA Groundwater Monitoring of 183-H Solar Evaporation Basins 7.0-23
7.4 Conclusions and Recommendations 7.0-24
7.4.1 Conclusions 7.0-24
7.4.2 Recommendations 7.0-26

8.0 100-FR-3 Operable Unit 8.0-1
8.1 Groundwater Contaminants 8.0-2
8.1.1 Nitrate 8.0-2
8.1.2 Strontium-90 ..... 8.0-3
8.1.3 Chromium 8.0-3
8.1.4 Trichloroethene 8.0-4
8.1.5 Tritium 8.0-4
8.1.6 Uranium and Gross Alpha 8.0-4
8.1.7 Additional Contaminants of Potential Concern 8.0-5
8.2 CERCLA Groundwater Activities 8.0-5
8.2.1 Remedial Investigation Activities 8.0-5
8.3 Conclusions and Recommendations 8.0-7

9.0 200-BP-5 Operable Unit 9.0-1
9.1 Groundwater Contaminants 9.0-5
9.1.1 Nitrate 9.0-6
9.1.2 Iodine-129 ..... 9.0-15
9.1.3 Technetium-99 ..... 9.0-17
9.1.4 Uranium 9.0-21
9.1.5 Strontium-90 ..... 9.0-23
9.1.6 Cyanide 9.0-24
9.1.7 Cesium-137 ..... 9.0-25
9.1.8 Plutonium-239/240 ..... 9.0-26
9.1.9 Tritium 9.0-26
9.1.10 Sulfate 9.0-27
9.2 CERCLA Groundwater Activities 9.0-28
9.2.1 Routine Groundwater Monitoring 9.0-28
9.2.2 Remedial Investigation Activities 9.0-29
9.2.3 Treatability Test Plan 9.0-31
9.3 RCRA Treatment, Storage, and Disposal Unit Monitoring 9.0-31
9.3.1 Low-Level Waste Management Area 1 ..... 9.0-32
9.3.2 Low-Level Waste Management Area 2 ..... 9.0-36
9.3.3 Waste Management Area B-BX-BY 9.0-40
9.3.4 Waste Management Area C 9.0-45
9.3.5 Liquid Effluent Retention Facility 9.0-49
9.3.6 216-B-63 Trench 9.0-51
9.4 Conclusions and Recommendations 9.0-53
9.4.1 Conclusions 9.0-53
9.4.2 Recommendations 9.0-55

10.0 200-PO-1 Operable Unit 10.0-1
10.1 Groundwater Contaminants 10.0-3
10.1.1 Tritium 10.0-4
10.1.2 Iodine-129 ..... 10.0-5
10.1.3 Nitrate 10.0-6
10.1.4 Strontium-90 ..... 10.0-7

10.1.5 Technetium-99 ..... 10.0-7
10.1.6 Uranium 10.0-7
10.1.7 Other Constituents 10.0-8
10.2 CERCLA Groundwater Activities 10.0-9
10.2.1 Remedial Investigation Report 10.0-10
10.2.2 CERCLA Groundwater Monitoring 10.0-11
10.2.3 Geophysical Investigations 10.0-13
10.3 RCRA Groundwater Monitoring 10.0-13
10.3.1 Integrated Disposal Facility (Immobilized Low-Activity Waste) 10.0-14
10.3.2 216-A-10, 216-A-36B, and 216-A-37-1 (RCRA PUREX) Cribs 10.0-15
10.3.3 Waste Management Area A-AX 10.0-17
10.3.4 216-A-29 Ditch 10.0-20
10.3.5 216-B-3 Pond 10.0-22
10.3.6 Nonradioactive Dangerous Waste Landfill 10.0-25
10.4 Other Regulated Facilities 10.0-26
10.4.1 Solid Waste Landfill 10.0-26
10.4.2 200 Area Treated Effluent Disposal Facility 10.0-30
10.4.3 400 Area Water Supply Wells 10.0-31
10.5 Conclusions and Recommendations 10.0-32
10.5.1 Conclusions 10.0-32
10.5.2 Recommendations 10.0-33

11.0 200-UP-1 Operable Unit 11.0-1
11.1 Groundwater Contaminants 11.0-4
11.1.1 Technetium-99 ..... 11.0-5
11.1.2 Uranium 11.0-6
11.1.3 Tritium 11.0-7
11.1.4 Iodine-129 ..... 11.0-8
11.1.5 Nitrate 11.0-9
11.1.6 Chromium 11.0-10
11.1.7 Chlorinated Hydrocarbons 11.0-11
11.1.8 Strontium-90 ..... 11.0-12
11.1.9 Other Constituents 11.0-12
11.2 CERCLA Groundwater Activities 11.0-13
11.2.1 Remedial Investigation/Feasibility Study 11.0-14
11.2.2 U Plant Pump-and-Treat System 11.0-14
11.2.3 Extended Purging of Well 299-W23-19 ..... 11.0-18
11.3 Facility Monitoring 11.0-18
11.3.1 Waste Management Area S-SX 11.0-18
11.3.2 Waste Management Area U 11.0-22
11.3.3 216-S-10 Pond and Ditch 11.0-25
11.3.4 Environmental Restoration Disposal Facility 11.0-29
11.4 Conclusions and Recommendations 11.0-31
11.4.1 Conclusions 11.0-31
11.4.2 Recommendations 11.0-32

12.0 200-ZP-1 Operable Unit 12.0-1
12.1 Conceptual Model 12.0-1
12.2 Groundwater Contaminants 12.0-3
12.2.1 Carbon Tetrachloride 12.0-3
12.2.2 Trichloroethylene 12.0-5
12.2.3 Nitrate 12.0-5
12.2.4 Chromium 12.0-5

12.2.5 Tritium 12.0-6
12.2.6 Iodine-129 ..... 12.0-6
12.2.7 Technetium-99 ..... 12.0-6
12.2.8 Other Constituents 12.0-7
12.3 CERCLA Groundwater Activities 12.0-8
12.3.1 CERCLA Decision Documents 12.0-9
12.3.2 Pump-and-Treat System for Carbon Tetrachloride 12.0-10
12.3.3 Pump-and-Treat System for Technetium-99 ..... 12.0-15
12.3.4 Vertical Distribution of Technetium-99 Throughout the Unconfined Aquifer Sediments 12.0-17
12.4 Facility Monitoring 12.0-17
12.4.1 Low-Level Waste Management Area 3 ..... 12.0-18
12.4.2 Low-Level Waste Management Area 4 ..... 12.0-20
12.4.3 Waste Management Area T 12.0-23
12.4.4 Waste Management Area TX-TY 12.0-26
12.4.5 State-Approved Land Disposal Site 12.0-30
12.5 Conclusions and Recommendations 12.0-32
12.5.1 Conclusions 12.0-32
12.5.2 Recommendations 12.0-34

13.0 300-FF-5 Operable Unit 13.0-1
13.1 Groundwater Contaminants 13.0-4
13.1.1 Uranium 13.0-5
13.1.2 Volatile Organic Compounds 13.0-10
13.1.3 Tritium 13.0-11
13.1.4 Nitrate 13.0-12
13.1.5 Other Constituents 13.0-13
13.2 CERCLA Groundwater Activities 13.0-14
13.2.1 Remedial Investigation/Feasibility Study 13.0-15
13.2.2 Interim Remedial Action Monitoring 13.0-17
13.2.3 Treatability Tests for Uranium Contamination in the Subsurface 13.0-17
13.2.4 Research Activities 13.0-18
13.3 Facility Monitoring: 300 Area Process Trenches 13.0-18
13.3.1 Network Evaluation and Compliance Status 13.0-19
13.3.2 Groundwater Contaminants 13.0-19
13.4 Conclusions and Recommendations 13.0-20
13.4.1 Conclusions 13.0-20
13.4.2 Recommendations 13.0-21

14.0 1100-EM-1 Groundwater Interest Area 14.0-1
14.1 Groundwater Contaminants 14.0-3
14.1.1 Trichloroethene 14.0-3
14.1.2 Nitrate 14.0-4
14.1.3 Tritium 14.0-4
14.1.4 Gross Alpha and Uranium 14.0-5
14.2 CERCLA Activities 14.0-5
14.3 Conclusions and Recommendations 14.0-5

15.0 Confined Aquifers 15.0-1
15.1 Ringold Formation Confined Aquifer 15.0-2
15.1.1 Groundwater Flow in the Ringold Confined Aquifer 15.0-2
15.1.2 Groundwater Quality in the Ringold Confined Aquifer 15.0-3
15.2 Upper Basalt-Confined Aquifer System 15.0-4
15.2.1 Groundwater Flow in the Upper Basalt-Confined Aquifer System 15.0-5

15.2.2 Groundwater Quality in the Upper Basalt-Confined Aquifer System 15.0-6
15.3 Conclusions and Recommendations 15.0-9

16.0 Well Installation, Maintenance, and Decommissioning 16.0-1
16.1 Well Installation 16.0-1
16.2 Characterization Boreholes and Direct-Push Technology Installation 16.0-2
16.3 Well Maintenance 16.0-3
16.4 Well Decommissioning 16.0-4

17.0 Columbia River 17.0-1
17.1 Seep and River Monitoring 17.0-1
17.2 River Corridor Baseline Risk Assessment 17.0-2
17.3 Hanford Site Releases to the Columbia River 17.0-3
17.4 Columbia River Porewater Sampling in the 100-BC and 100-N Areas 17.0-3

18.0 Vadose Zone Remediation, Monitoring, and Characterization 18.0-1
18.1 Carbon Tetrachloride Soil Vapor Monitoring and Remediation 18.0-1
18.1.1 Soil Vapor Extraction 18.0-2
18.1.2 Monitoring of Offline Wells and Probes 18.0-3
18.1.3 Passive Soil Vapor Extraction 18.0-3
18.2 Tank Farm Vadose Zone Activities 18.0-4
18.2.1 Direct-Push Boreholes and Sampling 18.0-4
18.2.2 Surface Geophysical Exploration 18.0-5
18.2.3 Geophysical Logging 18.0-5
18.2.4 Interim Barriers 18.0-6
18.3 Comparison of Three Methods for Characterizing Heterogeneous Hanford Sediments 18.0-7
18.3.1 Field Injection Experiment 18.0-7
18.3.2 Comparison of Observed and Simulated Moisture Plume 18.0-9

19.0 References 19.0-1
Public Laws 19.0-1
Code of Federal Regulations 19.0-1
Washington Administrative Code 19.0-1
Revised Code of Washington 19.0-2
Other References 19.0-2

Appendices

A Supporting Information for CERCLA Groundwater Operable Units ..... A-i
B Supporting Information for Monitored Facilities ..... B-i
C Supporting Information for Aquifer Sampling Tubes ..... C-i
D Quality Assurance and Quality Control ..... D-i

Tables

Table 1-1. Reporting Requirements for Groundwater Monitoring 1.0-29
Table 1-2. Number of Groundwater Analyses for Selected Constituents, CY 2010 ..... 1.0-29
Table 1-3. Maximum Concentrations of Selected Groundwater Contaminants in Groundwater Interest Areas, January Through December 2010 ..... 1.0-31

Table 1-4. RCRA Monitoring Status for the Reporting Period 1.0-35
Table 1-5. Selected Drinking Water Standards and Groundwater Cleanup Levels 1.0-36
Table 1-6. Derived Concentration Guides, 4-mrem Effective Dose Equivalent Concentrations, Drinking Water Standards, and Risk-Based Concentrations for Hanford Site Radionuclides in Groundwater 1.0-37

Table 2-1. Hydrostratigraphic Units for Which Physical, Hydrologic, and Geochemical Data Can Be Defined 2.0-23
Table 2-2. Best Estimate for Selected Site-Wide Vadose Zone Properties 2.0-25
Table 2-3. Ranges of Horizontal Hydraulic Conductivity Values for Each Hydrostratigraphic Unit 2.0-27
Table 2-4. Best Estimate for Selected Site-Wide Saturated Zone Properties 2.0-29

Table 3-1. Hydraulic Gradient Determinations for Low-Level Waste Management Area 1 ..... 3.0-11
Table 3-2. Hydraulic Gradient Determinations for Integrated Disposal Facility/PUREX Cribs 3.0-12

Table 4-1. Contaminants of Potential Concern for 100-B/C Area 4.0-8
Table 4-2. 100-B/C Area Remedial Investigation Groundwater Activities in 2010 ..... 4.0-10

Table 5-1. Hexavalent Chromium Concentrations at the 116-K-2 Plume Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-38
Table 5-2. Hexavalent Chromium Concentrations at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-41
Table 5-3. Hexavalent Chromium Concentrations at the KE Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-42
Table 5-4. Tritium Activities at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-43
Table 5-5. Tritium Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-45
Table 5-6. Tritium Activities at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-46
Table 5-7. Strontium-90 Activities at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-47
Table 5-8. Strontium-90 Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-49
Table 5-9. Strontium-90 Activities at the KE Reactor Wells and Aquifer Tubes 5.0-50
Table 5-10. Carbon-14 Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-51
Table 5-11. Carbon-14 Activities at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-52
Table 5-12. Nitrate Concentrations at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-53
Table 5-13. Nitrate Concentrations at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-55
Table 5-14. Nitrate Concentrations at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010 ..... 5.0-56
Table 5-15. KR4 Pump-and-Treat System Operation Parameters, CY 2010 ..... 5.0-57
Table 5-16. KX Pump-and-Treat System Operational Parameters, CY 2009 and CY 2010 ..... 5.0-58
Table 5-17. KW Pump-and-Treat System Operation Parameters, CY 2009 and CY 2010 ..... 5.0-59

Table 6-1. Nitrate Concentrations in Wells in the 100-N Area Exceeding the Drinking Water Standard (45 mg/L) ... 6.0-31
Table 6-2. Hydrocarbon Product Removal from Well 199-N-18 (2003 to Present) 6.0-31
Table 6-3. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Timeline 6.0-32
Table 6-4. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Monitoring Locations (Includes Barrier Wells, Monitoring Wells, and Aquifer Tubes) 6.0-33
Table 6-5. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Performance Monitoring Constituents 6.0-34
Table 6-6. Porewater Sampling Results for Strontium-90, Tritium, and Hexavalent Chromium 6.0-35
Table 6-7. Remedial Investigation/Feasibility Study Aquifer Tube Sampling Results for Strontium-90, Tritium, and Hexavalent Chromium 6.0-36

Table 7-1. Concentration Limits for 183-H Solar Evaporation Basins 7.0-28

Table 8-1. Contaminants of Potential Concern for 100-F Area Groundwater 8.0-8
Table 8-2. Maximum Concentrations of Gross Alpha and Uranium in 100-F Area Groundwater, CY 2010 ..... 8.0-10
Table 8-3. 100-F Area Remedial Investigation Groundwater Activities in 2010 ..... 8.0-11

Table 9-1. Monthly Corrected Groundwater Elevations in Northwest Corner of 200 East Area Used to Derive Groundwater Flow Direction and Rate 9.0-57

Table 10-1. Summary of Groundwater Conditions in 200-PO-1 Operable Unit Exceeding Standards and Basis for Feasibility Study 10.0-35
Table 10-2. Well Screen Characteristics of the Three 400 Area Water Supply Wells 10.0-36

Table 11-1. 200-UP-1 Operable Unit Treatment System Summary 11.0-34
Table 11-2. 200-UP-1 Operable Unit Pump-and-Treat System Mass/Activity of Contaminants Removed from Aquifer 11.0-34
Table 11-3. Quantity of Treated Groundwater and Technetium-99 Removed from Aquifer During Extended Purging at Well 299-W23-19 ..... 11.0-34

Table 12-1. 200-ZP-1 Operable Unit Pump-and-Treat Performance Summary, CY 2010 ..... 12.0-36
Table 12-2. 200-ZP-1 Operable Unit Treatment System Availability, CY 2010 ..... 12.0-36
Table 12-3. Waste Management Area T Treatment System Availability, CY 2010 ..... 12.0-36
Table 12-4. Waste Management Area T Pump-and-Treat Performance Summary, CY 2010 ..... 12.0-37

Table 13-1. Maximum Observed Concentrations for 300 Area Process Trenches Waste Indicators in Groundwater, 2008 Through 2010 ..... 13.0-23

Table 15-1. Potential Contaminants of Interest in Ringold Confined Aquifer, 2008 Through 2010 ..... 15.0-10
Table 15-2. Potential Contaminants of Interest in the Upper Basalt-Confined Aquifer, Calendar Year 2008 Through Calendar Year 2010 ..... 15.0-12
Table 15-3. Upper Basalt-Confined Aquifer Field Parameters for Calendar Year 2010 ..... 15.0-15

Table 16-1. Well Installations for the Reporting Period 16.0-5
Table 16-2. Characterization Boreholes and Direct-Push Technology Installation, Calendar Year 2010 ..... 16.0-12
Table 16-3. Well Maintenance Summary for the Reporting Period 16.0-13
Table 16-4. Decommissioned Wells for the Reporting Period 16.0-24

Table 17-1. Hanford Site Contaminants in Columbia River Seeps (Springs), Calendar Year 2010 ..... 17.0-5

Table 18-1. Carbon Tetrachloride Inventory Removed by Vapor Extraction from Primary Disposal Sites 18.0-12

Figures

Figure 1-1. Location of the Hanford Site 1.0-38
Figure 1-2. Groundwater Operable Units and Groundwater Interest Areas on the Hanford Site 1.0-39
Figure 1-3. Average CY 2010 Tritium Concentrations on the Hanford Site, Upper Portion of Unconfined Aquifer 1.0-40
Figure 1-4. Average CY 2010 Iodine-129 Concentrations on the Hanford Site, Upper Portion of Unconfined Aquifer 1.0-41

Figure 2-1. Location of the Pasco Basin and Hanford Site 2.0-31
Figure 2-2. Stratigraphic Column for the Hanford Site Showing Nomenclature 2.0-32
Figure 2-3. General Geologic Structures of the Pasco Basin and Hanford Site 2.0-33
Figure 2-4. Facies of the Ringold Formation Within the Central Pasco Basin 2.0-34
Figure 2-5. Hydrogeologic Cross-Section 3 (C-C') 2.0-35
Figure 2-6. Lower Ringold Formation Beneath the 200 East Area 2.0-37
Figure 2-7. Facies Distribution for the Cold Creek Unit Within the Central Pasco Basin 2.0-38
Figure 2-8. Ice Age Flood Geomorphic Features of the Pasco Basin 2.0-39

Figure 2-9. Cross-Section Location Map 2.0-40
Figure 2-10. Hydrogeologic Cross-Section 1 (A-A') 2.0-41
Figure 2-11. Hydrogeologic Cross-Section 2 (B-B') 2.0-43
Figure 2-12. Distribution of Hydrogeologic Units at Maximum Water Table (after PNNL-14753) 2.0-44
Figure 2-13. Hydraulic Conductivity Distribution at Maximum Water Table (after PNNL-14753) 2.0-45
Figure 2-14. Hydraulic Conductivity Distribution Along Cross-Section (a) A-A' and (b) B-B' at the Maximum Water Table (after PNNL-14753) 2.0-46

Figure 3-1. Groundwater Monitoring Wells on the Hanford Site 3.0-13
Figure 3-2. Hanford Site Water Table Map, March 2010 ..... 3.0-15
Figure 3-3. 200 East Area Water Table Elevations and Monthly Disposal Volumes at the Treated Effluent Disposal Facility, Calendar Years 2009 and 2010 ..... 3.0-17
Figure 3-4. Low-Level Waste Management Area 1 Water-Level Monitoring Well Network 3.0-18
Figure 3-5. Integrated Disposal Facility/PUREX Cribs Water-Level Monitoring Well Network 3.0-19
Figure 3-6. Low-Level Waste Management Area 2/216-B-63 Trench Water-Level Monitoring Well Network 3.0-20

Figure 4-1. Facilities, Groundwater Monitoring Wells, and Shoreline Monitoring Sites (Aquifer Tubes) in the 100-B/C Area 4.0-11
Figure 4-2. Stratigraphic and Hydrogeologic Units of 100-B/C Area 4.0-12
Figure 4-3. 100-B/C Area Water Table Map, March 2010 ..... 4.0-13
Figure 4-4. Strontium-90 Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010 ..... 4.0-14
Figure 4-5. Strontium-90 Concentrations in Central 100-B/C Area Wells 4.0-15
Figure 4-6. Strontium-90 Concentrations in Northern 100-B/C Area Wells 4.0-15
Figure 4-7. Tritium Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010 ..... 4.0-16
Figure 4-8. Tritium Concentrations in Northern 100-B/C Area Wells 4.0-17
Figure 4-9. Tritium Concentrations in Southern 100-B/C Area Wells 4.0-17
Figure 4-10. Tritium Concentration Profile in New Wells 4.0-18
Figure 4-11. Chromium Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010 ..... 4.0-19
Figure 4-12. Chromium Concentrations in Well 199-B3-47, Northeastern 100-B/C Area 4.0-20
Figure 4-13. Nitrate Concentrations in Northern 100-B/C Area Wells 4.0-20

Figure 5-1. 100-K Area Location Map 5.0-60
Figure 5-2. Overview of 100-KR-4 Operable Unit Wells and Facilities 5.0-61
Figure 5-3. Water-Level Contours at the 100-KR-4 Operable Unit 5.0-63
Figure 5-4. Spring and Fall 2010 Hexavalent Chromium Plume Map 5.0-65
Figure 5-5. Spring and Fall 2010 Tritium Plume Map 5.0-67
Figure 5-6. Spring and Fall 2010 Strontium-90 Plume Map 5.0-69
Figure 5-7. Spring and Fall 2010 Carbon-14 Plume Map 5.0-71
Figure 5-8. Spring and Fall 2010 Nitrate Plume Map 5.0-73
Figure 5-9. Spring and Fall 2010 Trichloroethene Plume Map 5.0-75
Figure 5-10. Fall 2010 Hexavalent Chromium Plume Map for KR4 Pump-and-Treat System 5.0-77
Figure 5-11. Fall 2010 Hexavalent Chromium Plume Map for KX Pump-and-Treat System 5.0-79
Figure 5-12. Fall 2010 Hexavalent Chromium Plume Map for KW Pump-and-Treat System 5.0-81
Figure 5-13. Composite Capture Zone Efficiency/Effectiveness Maps for 100-KR-4 Operable Unit Pump-and-Treat Systems 5.0-83
Figure 5-14. Individual Capture Zone Efficiency/Effectiveness Maps for the 100-KR-4 Operable Unit Pump-and-Treat Systems 5.0-84

Figure 6-1. Facilities and Groundwater Monitoring Wells in the 100-N Area 6.0-39
Figure 6-2. Aquifer Tubes, Monitoring Wells, and Apatite Permeable Reactive Barrier Monitoring Locations on the 100-N Area Shoreline 6.0-40
Figure 6-3. 100-N Area Water Table Map, March 2010 ..... 6.0-41
Figure 6-4. Average Strontium-90 Concentrations in the 100-N Area, Upper Portion of Unconfined Aquifer 6.0-42

Figure 6-5. Strontium-90 in Groundwater at the Apatite Permeable Reactive Barrier Study Area, Fall 2010, Upper Portion of Unconfined Aquifer 6.0-43
Figure 6-6. Strontium-90 Concentrations and Water Levels near 116-N-1 Liquid Waste Disposal Facility 6.0-44
Figure 6-7. Strontium-90 Concentrations and Water Levels near 116-N-3 Liquid Waste Disposal Facility 6.0-44
Figure 6-8. Cross Section of Wells and Aquifer Tubes and Strontium-90 Concentrations with Depth Along the 100-N Area Shoreline 6.0-45
Figure 6-9. Cross Section of Wells and Aquifer Tubes and Strontium-90 Concentrations with Depth Along the Apatite Permeable Reactive Barrier, 100-N Area Shoreline 6.0-46
Figure 6-10. Strontium-90 Vertical Profile in the NVP2-Series Aquifer Tubes 6.0-47
Figure 6-11. Strontium-90 Concentration in Aquifer Tubes in 100-N Area 6.0-47
Figure 6-12. Strontium-90 and Gross Beta Concentrations in Aquifer Tube NVP2-116.0m 6.0-48
Figure 6-13. Average Tritium Concentrations in the 100-N Area, Upper Unconfined Aquifer 6.0-49
Figure 6-14. Tritium Concentrations near 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities 6.0-50
Figure 6-15. Average Nitrate Concentrations in the 100-N Area, Upper Unconfined Aquifer 6.0-51
Figure 6-16. Nitrate Concentrations for the 116-N-1 Liquid Waste Disposal Facility 6.0-52
Figure 6-17. Nitrate Concentrations for the 116-N-3 Liquid Waste Disposal Facility 6.0-53
Figure 6-18. Nitrate Concentrations for the 120-N-1 Percolation Pond 6.0-53
Figure 6-19. Total Petroleum Hydrocarbon-Diesel Range Concentrations in 100-N Area, April Through December 2010, Upper Unconfined Aquifer 6.0-54
Figure 6-20. Sulfate Concentrations in 100-N Area, Upper Unconfined Aquifer 6.0-55
Figure 6-21. Manganese and Iron Detections in 100-N Area, Upper Portion of Unconfined Aquifer 6.0-56
Figure 6-22. Filtered Total Chromium and Sulfate Trend Plot for Well 199-N-80 ..... 6.0-57
Figure 6-23. Chromium Detections in 100-N Area, Upper Portion of Unconfined Aquifer 6.0-58
Figure 6-24. Gross Beta Trend Plot for Middle Upper Section of Apatite Permeable Reactive Barrier 6.0-59
Figure 6-25. Gross Beta Trend Plot for Middle Lower Section of Apatite Permeable Reactive Barrier 6.0-59
Figure 6-26. Gross Beta Trend Plot for the Highest Strontium-90 Concentration Portion of Apatite Permeable Reactive Barrier 6.0-60
Figure 6-27. Location of Core Wells at the Pilot Test #2 Site, Apatite Permeable Reactive Barrier 6.0-61
Figure 6-28. Location of Jet Injection Test Plots and Core Wells Along 100-N Area Shoreline 6.0-62
Figure 6-29. 100-N Area Follow-Up River Porewater Sampling Locations, November/December 2010 ..... 6.0-63
Figure 6-30. Potential Contaminant Source Pathways for 100-N Outfall Structure Strontium-90 ..... 6.0-64
Figure 6-31. Remedial Investigation/Feasibility Study Aquifer Tube Sampling Locations 6.0-65
Figure 6-32. Specific Conductance in Well 199-N-73 ..... 6.0-66

Figure 7-1. Facilities, Wells, and Shoreline Monitoring Sites in the 100-D Area 7.0-29
Figure 7-2. Facilities, Wells, and Shoreline Monitoring Sites in the 100-H Area 7.0-30
Figure 7-3. Facilities, Wells, and Shoreline Monitoring Sites within the Horn Area of the 100-HR-3 Operable Unit 7.0-31
Figure 7-4. Conceptual Cross Section of the 100-D and 100-H Areas 7.0-32
Figure 7-5. 100-HR-3 Operable Unit Water Table Elevation Map, March 2010 ..... 7.0-33
Figure 7-6. 100-HR-3 Operable Unit Water Table Elevation Map, September 2010 ..... 7.0-35
Figure 7-7. 100-HR-3 Operable Unit Water Table Elevation Map, June 2010 ..... 7.0-37
Figure 7-8. 100-HR-3 Operable Unit Hexavalent Chromium Map, Spring 2010 ..... 7.0-39
Figure 7-9. 100-HR-3 Operable Unit Hexavalent Chromium Map, Fall 2010 ..... 7.0-41
Figure 7-10. 100-D Area Hexavalent Chromium Trend Plots (South Plume) 7.0-43
Figure 7-11. 100-D Area Aquifer Tubes 7.0-45
Figure 7-12. 100-D Area Hexavalent Chromium Trend Plots (North Plume) 7.0-47
Figure 7-13. 100-H Area Hexavalent Chromium Trend Plots 7.0-49
Figure 7-14. 100-D Area Nitrate Map, Spring 2010 ..... 7.0-51
Figure 7-15. Injection/Extraction Well Locations in the 100-D Area 7.0-52
Figure 7-16. Injection/Extraction Well Locations in the 100-H Area 7.0-53
Figure 7-17. HR-3 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010 ..... 7.0-54
Figure 7-18. DR-5 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010 ..... 7.0-55

Figure 7-19. In Situ Redox Manipulation Detail Map 7.0-56
Figure 7-20. In Situ Redox Manipulation Map 7.0-57
Figure 7-21. Chromium Trend Plots for Compliance Wells 7.0-58

Figure 8-1. Facilities and Groundwater Monitoring Wells in the 100-F Area 8.0-12
Figure 8-2. Stratigraphic and Hydrogeologic Units in 100-F Area 8.0-13
Figure 8-3. 100-F Area Water Table Map, March 2010 ..... 8.0-14
Figure 8-4. Nitrate Concentrations in 100-F Area and Vicinity, Unconfined Aquifer, Fall 2010 ..... 8.0-15
Figure 8-5. Nitrate Concentrations in Central (199-F5-4) and Southwestern (199-F7-3) 100-F Area 8.0-16
Figure 8-6. Strontium-90 Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010 ..... 8.0-17
Figure 8-7. Strontium-90 Concentrations in Wells Monitoring the Eastern 100-F Area 8.0-18
Figure 8-8. Chromium Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010 ..... 8.0-19
Figure 8-9. Chromium Concentrations in Wells Monitoring the Eastern 100-F Area 8.0-20
Figure 8-10. Trichloroethene Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010 ..... 8.0-21
Figure 8-11. Trichloroethene Concentrations in Wells Monitoring Southwestern 100-F Area 8.0-22

Figure 9-1. Boundaries of 200-BP-5 Groundwater Operable Unit and Adjacent Operable Units 9.0-58
Figure 9-2. Facilities and Groundwater Monitoring Wells in 200-BP-5 Operable Unit Portion of 200 East Area 9.0-59
Figure 9-3. Facilities and Groundwater Monitoring Wells in 600 Area Associated with 200-BP-5 Operable Unit 9.0-61
Figure 9-4. 200 East Area Water Table Map, March 2010 ..... 9.0-63
Figure 9-5. Comparison of Treated Effluent Disposal Facility Discharges with 200 East Area Groundwater Elevations 9.0-65
Figure 9-6. Low-Level Waste Management Area 1 Historical Trend Surface Results and Associated Azimuth Directional Vectors 9.0-67
Figure 9-7. Average Groundwater Nitrate Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-69
Figure 9-9. Cross Section B-B' of the B Complex Conceptual Model Density Plume for Nitrate 9.0-71
Figure 9-9. Cross Section L2-L2' of the Nitrate Plume and Top of Basalt Conceptualization from the B Complex to the Gable Gap 9.0-73
Figure 9-10. Comparison of Historical Groundwater Elevation Trends for Wells 299-E33-18 and 699-60-60 ..... 9.0-75
Figure 9-11. Nitrate Trend Plot of Wells 299-E28-18, 299-e28-26, 299-E28-27, 299-E28-28, and 299-E32-4 ..... 9.0-76
Figure 9-12. Cross Section C-C' for the Nitrate Distribution Conceptual Model for Wells 299-E28-18, 299-E28-26, and 299-E28-30 ..... 9.0-77
Figure 9-13. Nitrate Trend Results for Wells 299-E28-9 and 299-E28-16 ..... 9.0-79
Figure 9-14. 450 mg/L Nitrate Contour Near Well 299-E28-30 at Approximately 7 meters Below Groundwater Table 9.0-80
Figure 9-15. Cross Section A-A' of the Nitrate Contaminant Portrayal Through Wells 699-50-53A to 699-53-55A 9.0-81
Figure 9-16. Nitrate Trend Plot at Waste Management Area C Monitoring Well 299-E27-14 ..... 9.0-82
Figure 9-17. Average Groundwater Iodine-129 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-83
Figure 9-18. Average Groundwater Technetium-99 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-85
Figure 9-19. Groundwater Elevation Comparison Between the Confined and Unconfined Aquifers 9.0-87
Figure 9-20. Technetium-99 Trend Plot Between Wells 299-E33-41, 299-E33-339, and 299-E33-343 ..... 9.0-88
Figure 9-21. Trend Plot Comparison of Technetium-99 Between Wells 299-E33-26 and 299-E33-38 ..... 9.0-89
Figure 9-22. Map View of the Interpreted Technetium-99 Plume Associated with Depth-Discrete Sample Results at 3.05 and 9.14 meters Beneath Water Table Southwest of Waste Management Area C 9.0-90
Figure 9-23. Comparison of Ion Chemistry for Five Waste Management Area C Wells 9.0-91
Figure 9-24. Technetium-99 to Nitrate Ratio Contour Map at WMA C and Alternative Technetium-99 Contour Plume Map at WMA C 9.0-93
Figure 9-25. Average Groundwater Uranium Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-94

Figure 9-26. Average Groundwater Strontium-90 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-95
Figure 9-27. Average Groundwater Cyanide Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-97
Figure 9-28. Average Groundwater Tritium Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-99
Figure 9-29. Average Groundwater Sulfate Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010 ..... 9.0-101
Figure 9-30. Trend Plot of Wells 299-E27-10 and 299-E34-7 ..... 9.0-102
Figure 9-31. 216-E-10 Burial Ground Site Map and LLWMA-1 Well Network 9.0-103
Figure 9-32. 216-E-12B Burial Ground Site Map and LLWMA-2 Well Network 9.0-104
Figure 9-33. Ion Chemistry for Groundwater Sample at Well 299-E34-13 ..... 9.0-105
Figure 9-34. Trends of Selected Anions and Metals for Well 299-E33-47 ..... 9.0-106
Figure 9-35. Interpreted Extent of Detectable Cyanide at Waste Management Area C 9.0-107

Figure 10-1. Facilities and Wells in 200 East Area (Near-Field) 10.0-37
Figure 10-2. Map of 200-PO-1 Operable Unit Boundaries, Far-Field Wells, Shoreline Monitoring Sites, and Transects 10.0-39
Figure 10-3. Water Table Map for the 200-PO-1 Operable Unit, March 2010 ..... 10.0-40
Figure 10-4. Tritium Plume Map for 200-PO-1 Operable Unit 10.0-41
Figure 10-5. Tritium Plume Map (Near-Field) 10.0-43
Figure 10-6. Tritium Concentrations in PUREX Cribs 10.0-45
Figure 10-7. Iodine-129 Plume Map for 200-PO-1 Operable Unit 10.0-47
Figure 10-8. Iodine-129 Concentration in Well 299-E17-19 at the 216-A-10 Crib 10.0-49
Figure 10-9. Nitrate Plume Map — 200-PO-1 Operable Unit (Far-Field) 10.0-50
Figure 10-10. Nitrate Plume Map — 200 East Area (Near-Field) 10.0-51
Figure 10-11. Nitrate Concentration in Well 299-E17-19 Near the 216-A-10 Crib 10.0-52
Figure 10-12. Technetium-99 Concentrations in Wells at Waste Management Area A-AX 10.0-52
Figure 10-13. Local Plume Map for Uranium Near the PUREX Cribs 10.0-53
Figure 10-14. Uranium Concentration Near the PUREX Cribs 10.0-54
Figure 10-15. Cross Section of the Airborne Electromagnetic Geophysical Survey North of the 300 Area 10.0-55
Figure 10-16. Nitrate Concentrations in Wells at 216-A-36B Crib 10.0-56
Figure 10-17. Nitrate Concentrations in Wells at 216-A-10 Crib 10.0-57
Figure 10-18. Nitrate Concentrations in Wells at 216-A-37-1 Crib 10.0-57
Figure 10-19. Total Organic Carbon Concentrations in Wells at Waste Management Area A-AX 10.0-58
Figure 10-20. Nitrate Concentrations in Wells at Waste Management Area A-AX 10.0-58
Figure 10-21. Technetium-99 Plume Map of Waste Management Area A-AX and Waste Management Area C 10.0-59
Figure 10-22. Major Anions and Specific Conductance in Well 299-E25-32P 10.0-60
Figure 10-23. Specific Conductance in 216-A-29 Ditch Wells 10.0-60
Figure 10-24. Tritium Concentrations in the Three 400 Area Water Supply Wells 10.0-61

Figure 11-1. Facilities and Groundwater Monitoring Wells in 200-UP-1 Operable Unit 11.0-35
Figure 11-2. Cross Section Locations for the 200-UP-1 Operable Unit 11.0-37
Figure 11-3. Water Table Map for 200-UP-1 Groundwater Interest Area, March 2010 ..... 11.0-39
Figure 11-4. Chromium, Technetium-99, and Uranium Plume Areas Above the Drinking Water Standard in the 200-UP-1 Groundwater Interest Area 11.0-41
Figure 11-5. Iodine-129, Nitrate, and Tritium Plume Areas Above the Drinking Water Standard in the 200-UP-1 Groundwater Interest Area 11.0-42
Figure 11-6. Average Technetium-99 Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-43
Figure 11-7. Cross Section of the Technetium-99 Plume from the 216-U-1/2 Cribs 11.0-45
Figure 11-8. Chromium, Nitrate, and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX 11.0-47

Figure 11-9. Cross Section of the Southern Technetium-99 Plume from Waste Management Area S-SX 11.0-49
Figure 11-10. Nitrate, Chromium, and Technetium-99 Concentrations in Well 299-W22-44 Downgradient from S Tank Farm 11.0-51
Figure 11-11. Nitrate, Chromium, and Technetium-99 Concentrations in Well 299-W22-26 Downgradient from S Tank Farm 11.0-51
Figure 11-12. Average Uranium Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-52
Figure 11-13. Cross Section of the Uranium Plume from the 216-U-1/2 Cribs 11.0-53
Figure 11-14. Average Tritium Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-55
Figure 11-15. Average Iodine-129 Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-57
Figure 11-16. Cross Section of the Iodine-129 Plume from the 216-U-1/2 Cribs 11.0-59
Figure 11-17. Average Nitrate Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-61
Figure 11-18. Cross Section of the Nitrate Plume from the 216-U-1/2 Cribs 11.0-63
Figure 11-19. Average Chromium Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer 11.0-65
Figure 11-20. Cross Section of the Chromium Plume East-Southeast of the 200 West Area 11.0-67
Figure 11-21. Cross Section of the Carbon Tetrachloride Plume Within the 200-UP-1 Operable Unit 11.0-69
Figure 11-22. 200-UP-1 Operable Unit Pump-and-Treat System Capture Frequency, CY 2010 ..... 11.0-71
Figure 11-23. Uranium Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells 11.0-72
Figure 11-24. Technetium-99 Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells 11.0-72
Figure 11-25. Carbon Tetrachloride Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells 11.0-73
Figure 11-26. Nitrate Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells 11.0-73
Figure 11-27. Average Uranium Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Area, Upper Portion of Unconfined Aquifer 11.0-74
Figure 11-28. Average Technetium-99 Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Area, Upper Portion of Unconfined Aquifer 11.0-75
Figure 11-29. Average Nitrate Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer 11.0-76
Figure 11-30. Average Chromium Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer 11.0-77
Figure 11-31. Average Technetium-99 Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer 11.0-78
Figure 11-32. Average Nitrate and Technetium-99 Concentrations in Waste Management Area U, Upper Portion of Unconfined Aquifer 11.0-79
Figure 11-33. Specific Conductance in the 216-S-10 Pond and Ditch Monitoring Wells 11.0-80
Figure 11-34. Nitrate Concentrations in the 216-S-10 Pond and Ditch Monitoring Wells 11.0-80
Figure 11-35. Sulfate Concentrations in the 216-S-10 Pond and Ditch Monitoring Wells 11.0-81

Figure 12-1. Facilities and Groundwater Monitoring Wells in the 200-ZP-1 Operable Unit 12.0-39
Figure 12-2. 200 West Area Water Table Map, CY 2010 ..... 12.0-41
Figure 12-3. Hydrograph for Selected Wells in Northern Portion of 200 West Area 12.0-43
Figure 12-4. Average Carbon Tetrachloride Concentration in the 200 West Area, Upper Portion of Unconfined Aquifer 12.0-45
Figure 12-5. Average Carbon Tetrachloride Concentration in 200 West Area Throughout the Unconfined Aquifer and Locations of the Final Remedy Extraction and Injection Wells 12.0-47
Figure 12-6. Carbon Tetrachloride Concentration in Well 699-48-71, Northeast of 200 West Area 12.0-48
Figure 12-7. 200-ZP-1 Groundwater Operable Unit Carbon Tetrachloride Concentration Plan View at 94 m Elevation Above Mean Sea Level and Cross Section A A' 12.0-49
Figure 12-8. 200-ZP-1 Groundwater Operable Unit Carbon Tetrachloride Plume Cross-Section A-A' 12.0-50
Figure 12-9. Average Trichloroethylene Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer 12.0-51

Figure 12-10. Average Nitrate Concentration in Central and Northern 200 West Area, Upper Portion of the Unconfined Aquifer 12.0-52
Figure 12-11. Average Filtered Chromium Concentration Northern 200 West Area, Upper Portion of Aquifer 12.0-53
Figure 12-12. Average Tritium Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer 12.0-54
Figure 12-13. Average Iodine-129 Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer 12.0-55
Figure 12-14. Average Technetium-99 Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer 12.0-56
Figure 12-15. 200-ZP-1 Operable Unit Approximate Extent of Capture Overlaid with Contoured Extent of Carbon Tetrachloride, CY 2010 ..... 12.0-57
Figure 12-16. Carbon Tetrachloride Trend Plots for Monitoring Wells 12.0-58
Figure 12-17. Chloroform Trend Plots for Monitoring Wells 12.0-59
Figure 12-18. Trichloroethylene Trend Plots for Monitoring Wells 12.0-60
Figure 12-19. Carbon Tetrachloride Trend Plots for Extraction Wells 12.0-61
Figure 12-20. Technetium-99 Trend Plots for Monitoring Wells 12.0-62
Figure 12-21. Technetium-99 Trend Plots for Extraction Wells 12.0-62
Figure 12-22. 200-ZP-1 Groundwater Operable Unit Technetium-99 Concentration Plan View at 127 m Elevation Above Mean Sea Level and Cross-Section A-A' 12.0-63
Figure 12-23. 200-ZP-1 Groundwater Operable Unit Technetium-99 Plume Cross-Section A-A' 12.0-64
Figure 12-24. Concentration of Selected Contaminants in Wells 299-W14-3 and 299-W14-5, Waste Management Area TX-TY 12.0-65
Figure 12-25. Tritium Concentrations in Wells Monitoring the State-Approved Land Disposal Site 12.0-66

Figure 13-1. Index Map Showing 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units 13.0-24
Figure 13-2. 300 Area Monitoring Wells, Waste Sites, Buildings, and Shoreline Monitoring Sites 13.0-25
Figure 13-3. Monitoring Wells Near 618-11 Burial Ground 13.0-26
Figure 13-4. Monitoring Wells Near 618-10 Burial Ground 13.0-27
Figure 13-5. Water Table Elevation Map for Region Containing the 300-FF-5 Operable Unit 13.0-28
Figure 13-6. Index Map to the Hydrogeologic Cross Sections Illustrating Aquifer Beneath the 300 Area 13.0-29
Figure 13-7a and b. Hydrogeologic Cross Sections Illustrating Aquifer Beneath the 300 Area 13.0-30
Figure 13-8. Uranium Concentrations in Groundwater Near Former 300 Area Process Trenches 13.0-31
Figure 13-9. Uranium Plume in Groundwater Beneath 300 Area, June 2010 ..... 13.0-32
Figure 13-10. Uranium Concentration Trends and Water Levels at (A) Near-River Wells and (B) Inland Wells, 300 Area Groundwater 13.0-33
Figure 13-11. Uranium and Chromium Concentration Trends in Groundwater Downgradient from Former 618-7 Burial Ground 13.0-34
Figure 13-12. Uranium Distribution in Groundwater Beneath 300 Area Shoreline 13.0-35
Figure 13-13. Uranium Concentration Trends at Wells Adjacent to 618-10 Burial Ground 13.0-36
Figure 13-14. Trichloroethene Concentrations in Groundwater Beneath 300 Area Shoreline 13.0-37
Figure 13-15. Volatile Organic Compound Concentrations in Lower Portion of Unconfined Aquifer at Well 399-1-16B, 300 Area 13.0-38
Figure 13-16. Cross Section Showing Volatile Organic Compounds Encountered During Drilling, 300 Area 13.0-39
Figure 13-17. Tritium Plume in Groundwater Near 618-11 Burial Ground 13.0-41
Figure 13-18. Tritium Concentration Trends at Wells Near 618-11 Burial Ground 13.0-42
Figure 13-19. 300 Area Index Map Showing Remedial Investigation Drilling Locations, Treatability Test Site, and IFRC Site 13.0-43

Figure 14-1. Facilities and Groundwater Monitoring Wells in the 1100-EM-1 Operable Unit 14.0-7
Figure 14-2. 1100-EM-1 Operable Unit and Adjacent 300 Area Water Table Map, March 2010 ..... 14.0-8
Figure 14-3. Trichloroethene Concentrations in 1100-EM-1 Operable Unit and Adjacent Richland North Area, Upper Portion of Unconfined Aquifer 14.0-9

Figure 14-4. Average Nitrate Concentrations in the 1100-EM-1 Operable Unit and Adjacent 300 Area, Upper Portion of Unconfined Aquifer 14.0-10
Figure 14-5. Average Tritium Concentrations in the 1100-EM-1 Operable Unit and Adjacent 300 Area, Upper Portion of Unconfined Aquifer 14.0-11

Figure 15-1. Extent of Partial or Complete Erosion of the Elephant Mountain Basalt in the 200 East Area/Gable Mountain Region (from DOE/RL-2008-01) 15.0-16
Figure 15-2. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 2010 ..... 15.0-17
Figure 15-3. Groundwater Monitoring Wells Sampled in Ringold Formation Confined and Upper Basalt-Confined Aquifers, Fiscal Year 2007 Through Calendar Year 2010 ..... 15.0-18
Figure 15-4. Potentiometric Surface Map of Upper Basalt-Confined Aquifer System, March 2010 ..... 15.0-19
Figure 15-5. Comparison of Observed Heads for Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer 15.0-20

Figure 16-1. Categorization of Unique Well Identification Numbers 16.0-27
Figure 16-2. Hanford Site and Surrounding Area Depicting Various Geographic Regions 16.0-28
Figure 16-3. Site-Wide Well Installations for the Reporting Period 16.0-29
Figure 16-4. 100-B/C, 100-K, and 100-N Area Well Installations for the Reporting Period 16.0-30
Figure 16-5. 100-D and 100-H Area Well Installations for the Reporting Period 16.0-31
Figure 16-6. 200 East Area and 200 West Area Well Installations for the Reporting Period 16.0-32

Figure 18-1. Locations of Carbon Tetrachloride Soil Vapor Extraction Wells at 216-Z-1A/216-Z-12/216-Z-18 and 216-Z-9 Well Fields 18.0-13
Figure 18-2. Results of Three-Dimensional Resistivity Survey of UPR-200-E-86 ..... 18.0-14
Figure 18-3. Results of Well-to-Well Resistivity Survey of Waste Management Area A-AX 18.0-15
Figure 18-4. Aerial Photograph of Interim Surface Barrier and Evapotranspiration Basin, TY Tank Farm 18.0-16
Figure 18-5. Plan View of the Sisson and Lu Injection Site and the Well Numbering Scheme 18.0-17
Figure 18-6. (a) Observed Moisture Plume at the Sisson and Lu Injection Site on July 31, 2000; (b) Upscaling Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000; (c) Cokriging/Artificial Neural Network (ANN) Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000; and (d) Transition Probability (TP)/Markov Chain (MC) Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000 ..... 18.0-18

1.0 Introduction

C.J. Martin

The Hanford Site, part of the U.S. Department of Energy's (DOE's) nuclear weapons complex, encompasses ~1,500 square kilometers in southeastern Washington State (Figure 1-1). The Hanford Site is located in the Lower Columbia Basin and is divided by the Columbia River. The federal government acquired the Hanford Site in 1943 and, until the 1980s, the site was used to produce plutonium and uranium for the national defense mission. Management of waste associated with weapons material production has been a major activity throughout Hanford's history and continues today at a much reduced scale. Beginning in the 1990s, the DOE has focused work efforts primarily on characterization, removal, treatment, and disposal of contamination from past operations at the site.

The DOE's groundwater strategy focuses on protecting groundwater from contaminants, monitoring groundwater conditions, and cleaning up contaminated groundwater.

The DOE is committed to protecting the Columbia River from the Hanford Site's contaminated groundwater. Groundwater is the primary exposure route for site contaminants to reach human and environmental receptors. The *Hanford Integrated Groundwater and Vadose Zone Management Plan* (DOE/RL-2007-20) outlines the steps for addressing groundwater and vadose zone contamination. The DOE developed the plan in consultation with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology).

Beginning in the 1990s and continuing today, the DOE has remediated hundreds of waste sites along the River Corridor. The remediation effort has included demolishing structures, excavating contaminated soil, and disposing contaminated material in an engineered landfill in the central portion of the Hanford Site. The former waste sites are being filled in with clean material and the land revegetated. The DOE has identified nearly 1,500 waste sites in the River Corridor, and approximately two-thirds of these waste sites have been remediated to date. Removing the contaminated material eliminates sources of contamination that otherwise could be carried to groundwater by infiltrating precipitation. The DOE has initiated the remedial investigation (RI)/feasibility study (FS) process to collect additional data needed in order to make final decisions regarding cleanup of waste sites and groundwater along the River Corridor.

Key elements associated with managing the Hanford Site's groundwater and vadose zone are to (1) protect the Columbia River and groundwater, (2) develop a cleanup decision process, and (3) achieve final cleanup.

This report is designed to meet the following objectives for the reporting period:

- ***Report on the current groundwater conditions on the Hanford Site***
- ***Fulfill the reporting requirements of RCRA, CERCLA, AEA, and Washington Administrative Code***
- ***Describe the results of monitoring the vadose zone***
- ***Summarize the installation, maintenance, and decommissioning of Hanford Site monitoring wells.***

Protect the Columbia River and groundwater. Many actions have already been taken to address principal threats to the Columbia River and groundwater. These actions include the following:

- Cease discharge of all unpermitted liquids in the central Hanford Site
- Remediate the former liquid waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination
- Contain groundwater plumes and reduce the mass of primary contaminants through remedial actions such as pump-and-treat.

Develop a process for cleanup decisions. Final decisions will be based on the processes outlined in the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and/or the *Resource Conservation and Recovery Act of 1976* (RCRA). The following five key elements will support the final decisions:

- Gather sufficient characterization data, focusing on waste sites with deep contamination that pose a future risk to groundwater
- Evaluate the performance of early actions (waste site remediation along the River Corridor and groundwater interim actions) to help guide future cleanup
- Identify cleanup goals for waste sites that support long-term groundwater remediation
- Identify new technologies to reduce the mobility of deep contamination and limit its movement to groundwater
- Improve integration of cleanup decisions for waste sites and groundwater.

The Tri-Parties (i.e., DOE, Ecology, and EPA) recently took a major step toward accomplishing these goals in 2010 when they developed a strategy to make final decisions necessary to complete cleanup in the River Corridor. Part of the strategy includes dividing the final cleanup decisions into smaller, more manageable pieces of work.

In January 2010, the DOE released the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan* (DOE/RL-2008-46) and a series of addenda addressing specific segments of the River Corridor. Final cleanup decisions for the 100 Area will be developed for areas associated with the following operable units (OUs): 100-D and 100-H Areas, 100-K Area, 100-B/C Area, 100-F/IU-2/IU-6 Area, and 100-N Area. The 300 Area OUs (300-FF-1, 300-FF-2, and 300-FF-5) are included in a separate work plan (DOE/RL-2009-30, *300 Area Decision Unit Remedial Investigation/ Feasibility Study Work Plan*), which was issued in April 2010.

The work plans, addenda, and related sampling and analysis plans identify data gaps and the data to be collected. During 2010, much of the field work required under the work plan was completed. The data will be used to develop a proposed plan for remedial action. The final decisions for the OUs will address cleanup of contaminated soil, solid waste burial grounds, groundwater, and releases from reactor buildings. The objective for all of these decisions is to protect human health and the environment. The selection of the final action will be documented in Records of Decision (RODs).

Attain final cleanup. The DOE, EPA, and Ecology are committed to complete cleanup of past-practice waste sites at the Hanford Site by September 2024. Substantial progress has been made toward cleanup of the 100 and 300 Areas. Strategies used for making final decisions in the 100 and 300 Areas will provide a basis for attaining similar final decisions for the 200 East and 200 West Areas.

Groundwater monitoring fulfills a variety of state and federal regulations, including the *Atomic Energy Act of 1954* (AEA), RCRA, CERCLA, and various sections of the *Washington Administrative Code* (WAC).

1.1 Purpose and Scope

This document presents the results of Hanford Site groundwater monitoring for calendar year (CY) 2010, providing the primary means to report monitoring results for RCRA treatment, storage, and disposal (TSD) units; for CERCLA groundwater OUs where no active remediation is currently taking place; and the AEA as required by DOE orders (Table 1-1). This report will also provide a summary of vadose zone monitoring, investigations, and results; and well installation, remediation, and decommissioning activities. The report covers the period from January 1, 2010, through December 31, 2010. The following date conventions are used throughout this report:

- FY 2010: Refers to fiscal year (FY) (i.e., October 1, 2009, to September 30, 2010).
- CY 2010: Refers to calendar year (CY) (i.e., January 1, 2010, to December 31, 2010).
- Reporting period: Refers to the CY covered for this report, unless otherwise noted in the text.

Details on the CERCLA remediation activities (e.g., pump-and-treat operations) are presented in separate reports and have been summarized in this report. This report provides Internet links to assist the reader in locating other relevant documents. The layout of this report presents the various OUs and groundwater interest areas in numerical order (100 Area, followed by 200 Area, etc). However, throughout this report certain areas may also be discussed as aggregate units (e.g., Central Plateau and River Corridor). For the purposes of this report, the Central Plateau includes the 200 East and 200 West Areas, off-river sites (400 Area), and the surrounding nonoperational area (600 Area). The River Corridor refers to those portions of the Hanford Site adjacent to the Columbia River and includes the 100 Area, 300 Area, and the 1100-EM-1 groundwater interest area (Figure 1-2). The portion of the River Corridor north of the 300 Area and south of the 100-F Area is discussed as part of the 200-PO-1 OU.

Appendix A includes supporting information for CERCLA monitoring. Appendix B contains tables and figures that support RCRA and other regulated unit monitoring. Appendix C provides supporting information for aquifer tube sampling. The quality assurance and quality control results and issues for the reporting period are provided in Appendix D.

The size of the Hanford Site and the volume of work associated with groundwater monitoring, contamination evaluation, and remediation prohibit detailed discussions of many topics in this report. This report provides data interpretation and discussion of groundwater monitoring results for 2010 data and notable changes in trends from previous data. Background information including descriptions of regulatory requirements, waste sites, analytical methods, regional geology, and statistics is provided separately in *Hanford Site Groundwater: Settings, Sources, and Methods* (PNNL-13080), with the most recent update provided in Appendix C of *Hanford Site Groundwater Monitoring for Fiscal Year 2001* (PNNL-13788). Some background information is provided in this report for completeness.

This report attempts to avoid unnecessary repetition of information that is more appropriately included in OU-specific documents for groundwater or contaminant sources. Such information is summarized in this report, where appropriate, but more detailed information is available in other documents. References and/or Internet links to these documents are provided. Detailed information includes the following:

- Details on the design and logic behind the approach, monitoring system design, data collection methods, and quality assurance/quality control requirements are provided in RCRA monitoring plans, work plans, etc.
- Specific descriptions of the groundwater geology and hydrology at specific sites are included in RCRA monitoring plans and in work plans and reports for those sites.
- Details on conceptual models, risk evaluation, and groundwater modeling are provided in work plans and reports for the specific OUs.
- Contaminant capture zone and hydraulic analyses are included in pump-and-treat performance reports for the 100-KR-4 and 100-HR-3 OUs and the 200 West Area OUs.
- Vadose zone contaminant sources are discussed in work plans and reports, both for source OUs and groundwater OUs, as applicable. Deep vadose zone activities are also discussed in those reports.
- Columbia River upwelling and hyporheic zone investigations are discussed in other reports (see Chapter 17.0).

1.2 Groundwater Monitoring

During the reporting period, staff sampled 1,311 wells and 145 aquifer tubes for radiological and chemical constituents.

To streamline cleanup, Hanford waste sites are grouped into source OUs (i.e., sites that received waste from the same or similar source[s]). Because groundwater at a given location may be impacted by multiple waste sites, it is divided into groundwater OUs that do not necessarily coincide with the waste site OUs. The concept of OUs is to group waste sites with similar characteristics/sources into manageable components for investigation and to allow for better prioritization of cleanup work. The groundwater OUs are defined by contamination and, therefore, do not cover the entire Hanford Site (Figure 1-2). Groundwater staff has defined informal groundwater interest areas (which include the groundwater OUs and the intervening regions) to provide scheduling, data review, and data interpretation for the entire site. Figure 1-2 illustrates the relationship between the interest areas and the OU boundaries.

Various documents (i.e., monitoring plans or sampling and analysis plans) define the wells to be sampled, sampling frequency, and constituents to be analyzed. These choices are based on the data needs for various monitoring purposes, such as complying with regulations, evaluating the performance of remediation activities, defining plumes and concentration trends, or identifying emerging problems.

During the reporting period, Hanford Site staff sampled 1,311 wells. Staff collected 335 aquifer tube samples from 145 aquifer tubes in 2010. The large decrease in aquifer tube samples from 2009 is the result of the work stoppage that resulted in most of the fall 2010 aquifer tube sampling being delayed into 2011. Many of the wells and tubes were sampled multiple times, for a combined total of 4,277 successful sampling trips. These numbers include routine groundwater sampling associated with remediation activities.

Groundwater sampling was stopped between September 27, 2010, and November 8, 2010, when a safety-related stop work closed down all sampling activity performed by the Soil and Groundwater Remediation Project. A recovery plan was put in place to address the required sampling at RCRA TSD units. The recovery plan was approved by DOE, EPA and Ecology, and it identified 70 priority wells out of 130 wells scheduled and impacted by the stop work. Collection of most groundwater samples was delayed to December, and 68 of the agreed-upon 70 samples were collected. Two wells that were not sampled required maintenance. In addition, 50 more wells not in the recovery plan were sampled, leaving only 10 of the original 130 scheduled RCRA wells not sampled during the quarter. Of the ten wells, six were sampled in January 2011.

Most of the monitoring wells on the Hanford Site are screened near the top of the unconfined aquifer; however, in the past several years, additional wells have been installed deeper (especially in the 200 West Area) to assess the vertical extent of groundwater contamination. In some locations, these wells have shown significant contamination, primarily carbon tetrachloride, deep in the aquifer. Data from some of the 200 East Area wells installed deep in the aquifer or from samples collected while drilling have indicated contamination deep in the aquifer; this is also true in portions of the 300-FF-5, 100-HR-3, and 100-NR-2 OUs. Some contaminants, most notably carbon tetrachloride, are more dense than water and can be more widespread deeper in the aquifer. Historical downward hydraulic gradients may also have increased contamination at depth in some areas. Studies of contaminant distribution with depth are being conducted for some plumes, particularly in the 200 West Area. Contamination with depth is discussed in those sections where studies indicate (or have shown in the past) the presence of contaminants in the deeper portions of the aquifer. For the most part, however, the shallow portion of the aquifer is the most contaminated. Most of the contaminant plume maps and plume area calculations in this report are based on data from the top of the aquifer (upper ~10 meters).

Chromium (total or hexavalent) was the most frequently analyzed constituent. Anions, tritium, iodine-129, metals, technetium-99, strontium-90, and volatile organic compounds were other commonly analyzed constituents (Table 1-2).

Tritium, nitrate, and iodine-129 are the most widespread contaminants on the Hanford Site.

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Figures 1-3 and 1-4 depict the distributions of these contaminants above the drinking water standard (DWS) in the upper unconfined aquifer. The most prominent portions of these plumes originated at waste sites in the 200 East and 200 West Areas and moved with the regional groundwater flow toward the southeast. Nitrate and tritium also had significant sources in the 100 Area.

Table 1-3 lists the maximum concentrations of selected groundwater contaminants in each groundwater interest area. The electronic data files accompanying this report are included for the reporting period and historical data.

Groundwater monitoring objectives of RCRA, CERCLA, and AEA often differ slightly, and the contaminants monitored are not always the same. For RCRA-regulated TSD units, monitoring focuses on nonradioactive dangerous waste constituents. While radionuclides (source, special nuclear, and byproduct materials) may be monitored in some RCRA unit wells to support objectives of monitoring under AEA and/or CERCLA, they are not subject to RCRA regulation. Pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority. Therefore, while this report is used to

satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA Permit.

1.3 Compliance Summary for CERCLA Operable Units

This section provides a brief introduction on the status of compliance for each of the Hanford Site groundwater OUs. The OU discussions are presented in the order in which they appear in this report.

1.3.1 100-BC-5 Operable Unit

The CERCLA monitoring requirements for the 100-BC-5 OU are driven by the *100-BC-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-38) and *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) change notices TPA-CN-240 and TPA-CN-293. All wells were sampled as scheduled during the reporting period. Details on CERCLA groundwater monitoring activities for the 100-BC-5 OU are provided in Chapter 4.0, Section 4.2.

An RI/FS work plan addendum was implemented in 2010 to collect additional data needed to support final CERCLA cleanup decisions. New wells and new aquifer tubes are helping to define the extent of contamination both aerially and vertically.

1.3.2 100-KR-4 Operable Unit

The CERCLA activities for the 100-KR-4 OU are conducted in accordance with the requirements presented in the *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units* (EPA/ROD/R10-96/134). The interim ROD focused on remediating hexavalent chromium in the groundwater associated with reactor operations using ion-exchange pump-and-treat systems, as discussed in the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action* (DOE/RL-96-84). Treatment has been expanded through the installation of two additional ion-exchange systems, KW and KX, described in *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action* (DOE/RL-2006-52) and the *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System* (DOE/RL-2006-75), respectively. Details on the CERCLA groundwater monitoring activities for the 100-KR-4 OU are provided in Chapter 5.0, Section 5.2. The monitoring requirements for the 100-KR-4 OU pump-and-treat systems are specified in the *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90).

Hexavalent chromium is distributed in plumes, with concentrations remaining above the 20 μg/L remedial action goal in several near-shore locations. Remedial process optimization is continuing for systematic evaluation and enhancement of site remediation processes to ensure that human health and the environment are being protected over the long term at minimum risk and cost.

Pump-and-treat remediation activities have removed a combined total of almost 576 kilograms of hexavalent chromium from the 100-N Area. The KR4 pump-and-treat system has removed a total of 354.7 kilograms of hexavalent chromium from the area around the 116-K-2 Trench since 1997, while the KW pump-and-treat system has removed a total of 137.4 kilograms of hexavalent chromium from the area around

the KW Reactor since 2007. An additional 83.7 kilograms of hexavalent chromium were removed from the northern end of the 116-K-2 Trench and beneath the N Reactor fence line since the new KX pump-and-treat system came online in 2009.

An RI/FS study is being conducted to support the final ROD for the 100-K Area. Characterization activities began in CY 2010, as described in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (DOE/RL-2008-46-ADD2) and implemented through the *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study* (DOE/RL-2009-41).

1.3.3 100-NR-2 Operable Unit

The CERCLA monitoring requirements for the 100-NR-2 OU are driven by two documents: the *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27) (and associated Tri-Party Agreement change notices) for the interim action monitoring program, and *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit* (DOE/RL-2005-96) (and associated Tri-Party Agreement change notices) for the apatite permeable reactive barrier. An integrated monitoring plan combining all monitoring programs will be submitted with the 100-N Area CERCLA RI report and proposed plan, scheduled for September 2012. Additional details on 100-NR-2 OU CERCLA groundwater monitoring activities for the reporting period are provided in Chapter 6.0, Section 6.2.

The sampling schedules dictated by DOE/RL-2001-27 and DOE/RL-2005-96 were met, with two exceptions: (1) one well could not be sampled for interim action monitoring due to technical difficulties with the pump, and (2) shallow (Hanford formation) apatite permeable reactive barrier wells can only be sampled when the river level is high. For the reporting period, at least one sample was taken from the Hanford formation wells during the four quarters.

1.3.4 100-HR-3 Operable Unit

Three CERCLA interim action remedies are currently operating in the 100-HR-3 OU. These include the original HR-3 pump-and-treat system in the 100-H Area (which treats groundwater from both the 100-D and 100-H Areas), the DR-5 pump-and-treat system in the 100-D Area, and the In Situ Redox Manipulation (ISRM) barrier also in the 100-D Area. Details on 100-HR-3 OU CERCLA groundwater monitoring activities for the reporting period are provided in Chapter 7.0, Section 7.2.

The monitoring requirements for the HR-3 pump-and-treat system are specified in the *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90). Long-term monitoring requirements in the 100-D Area have been modified (expanded) from *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units* (Waneck, 1998). There are currently no compliance wells for the DR-5 pump-and-treat system; however, new compliance wells are being determined during revisions to the interim action monitoring plan that is currently under development.

Hexavalent chromium concentrations in two compliance wells for the HR-3 pump-and-treat system were above the 10 µg/L aquatic water quality criterion in both the 100-D and 100-H Areas. Remedial process optimization is being conducted for the 100-HR-3 OU to provide additional treatment capacity and to enhance remediation. A new pump-and-treat facility (referred to as the DX system) will expand the treatment capacity in the 100-D Area to 2,300 liters per minute, while a

new pump-and-treat facility in the 100-H Area (referred to as the HX system) will expand treatment capacity there to 3,000 liters per minute.

Pump-and-treat remediation activities have removed a combined total of 737 kilograms of hexavalent chromium from the northern horn area of the Hanford Site. The DR-5 pump-and-treat system has removed a total of 326 kilograms of hexavalent chromium from the 100-D Area since 2004, while the HR-3 pump-and-treat system has removed a total of 393 kilograms of hexavalent chromium from the 100-H Area since 1997. An additional 18.4 kilograms of hexavalent chromium were removed in December 2010 during pilot testing of the new DX pump-and-treat system.

Remedial action monitoring for the ISRM barrier is described in the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation* (DOE/RL-99-51). Overall, the ISRM barrier continues to help reduce hexavalent chromium in the aquifer; however, during periods of low river flow, hexavalent chromium values above the remedial action goal are observed in some wells. With the addition of the new DX pump-and-treat system, the intent is to reduce the contaminant load impinging on the barrier, as well as to capture and treat any remaining downgradient hexavalent chromium.

An RI/FS study is being conducted to support the final ROD for the 100-D and 100-H Areas. Characterization activities began in CY 2010, as described in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (DOE/RL-2008-46-ADD1) and implemented through the *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-40). Data gaps were identified and are currently being addressed through additional data collection and other investigations that will support final remediation decisions. A series of fifteen monitoring wells, six aquifer tubes, ten vadose zone boreholes, and five test pits constitute the subsurface characterization activities. Field work is scheduled for completion by the end of 2011. The RI/FS study report will address the data and information needed to support selection of a final remedy for the 100-D and 100-H Areas. The DOE will finalize the RI/FS study report and issue a proposed plan detailing the proposed final remedy by the Tri-Party Agreement milestone date of July 31, 2011.

1.3.5 100-FR-3 Operable Unit

The CERCLA monitoring requirements for the 100-FR-3 OU are driven by the *100-FR-3 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-49) and change notice TPA-CN-241. All wells were sampled as scheduled during the reporting period. Details on 100-FR-3 OU CERCLA groundwater monitoring activities are provided in Chapter 8.0, Section 8.2.

An RI/FS work plan addendum was implemented in 2010 to collect additional data needed to support final CERCLA cleanup decisions. New wells are helping to define the extent of contamination both aerially and vertically.

1.3.6 200-BP-5 Operable Unit

The CERCLA monitoring requirements for the 200-BP-5 OU are derived from the *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49). During the reporting period, all but 3 of the 108 wells scheduled were successfully sampled. The primary CERCLA reporting accomplishments for the reporting period included (1) completion of the Tri-Party Agreement

Milestone M-015-082 through submittal of the *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74, Draft A), (2) initiation of the *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit* (DOE/RL-2009-127), and (3) completion of the *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit: November 2004 through November 2009 Groundwater Data* (SGW-44071). Details on 200-BP-5 OU CERCLA groundwater monitoring activities for the reporting period are provided in Chapter 9.0, Section 9.2.

1.3.7 200-PO-1 Operable Unit

Groundwater monitoring at the 200-PO-1 OU supports the RI/FS process under the direction of *Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2007-31) and two sampling and analysis plans. One sampling and analysis plan covers routine groundwater sampling (DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* [referred to as the "routine" sampling and analysis plan]), and the other covers short-term characterization to supplement routine groundwater monitoring (Appendix A of DOE/RL-2007-31 [referred to as the "characterization" sampling and analysis plan]). The characterization sampling and analysis plan has been implemented and the results were reported in the *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* (DOE/RL-2010-11), the *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (DOE/RL-2008-66), and the *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2009-85, Draft A [currently being reviewed by Ecology and EPA prior to final publication]). Details on 200-PO-1 OU CERCLA groundwater monitoring activities for the reporting period are provided Chapter 10.0, Section 10.2.

Although 130 wells are listed in the routine sampling and analysis plan, only 111 wells were scheduled for sampling during the reporting period. The remaining wells are sampled only once every 3 years (triennially) and will be sampled again in 2012, or they were triennial wells scheduled in the final quarter of 2010 and affected by the work stoppage. Of the 111 wells scheduled for sampling in 2010, 103 wells were sampled successfully. Six wells were attempted but were unsuccessful due to a variety of reasons, including maintenance issues, wellhead damage, access problems, or dry wells. Two wells were scheduled during the work stoppage in October 2010 and were not sampled prior to February 2011.

1.3.8 200-UP-1 Operable Unit

The CERCLA activities for the 200-UP-1 OU during the reporting period included preparing the draft RI/FS and proposed plan reports, operating an interim remedial action pump-and-treat system, and performing groundwater monitoring. The *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-2009-122, Draft A) and the *Proposed Plan to Amend the 200-ZP-1 Groundwater Operable Unit Record of Decision to Include the Remedial Actions for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-2010-05, Draft A) were released in September 2010, meeting Tri-Party Agreement Milestone M-015-17A.

The revised *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36, Rev. 3) was released in January 2010. This document was prepared to implement changes made by the *Explanation of Significant Differences for the Interim Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Washington* (EPA et al., 2009a). The work plan included a preliminary design for an interim action pump-and-treat system targeting both the north and south technetium-99 plumes at the S and SX Tank Farms. This system is expected

to be operational by the end of 2011 in support of Tri-Party Agreement Milestone M-016-120. Since 2003, operation of the current U Plant pump-and-treat system has removed a total of 220.3 kilograms of uranium, 127.6 grams (2.17 curies) of technetium-99, 41.3 kilograms of carbon tetrachloride, and 49,667 kilograms of nitrate from the 886 million liters of groundwater pumped.

Groundwater monitoring is governed by the *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-92-76, Appendix A), which specifies the wells to be sampled, analytes, and sample frequency. During CY 2010, all wells were sampled as planned with the following exceptions: (1) three of the quarterly samples from extraction wells 299-W19-36 and 299-W19-43 were missed due to pump-and-treat system outages and the sampling stop work, (2) three of the quarterly samples were missed for well 299-W19-101 due to maintenance issues, (3) samples were missed from four wells due to the sampling work stoppage, (4) samples were missed from 299-W18-21 and 699-35-70 because the wells went dry, and (5) samples from several wells were delayed until early 2011 due to the work stoppage. Details on 200-UP-1 OU CERCLA groundwater monitoring activities for CY 2010 are provided in Chapter 11.0, Section 11.2.

1.3.9 200-ZP-1 Operable Unit

The CERCLA groundwater performance monitoring and interim remedial measures at the 200-ZP-1 OU are outlined in the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA/ROD/R10-95/114) and are implemented through the *200-ZP-1 Interim Remedial Measure Remedial Design Report* (DOE/RL-96-07) and the *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network* (DOE/RL-2002-17). Details on 200-ZP-1 OU CERCLA groundwater monitoring activities for the reporting period are provided in Chapter 12.0, Section 12.3.

The primary contaminants of concern identified in the interim ROD are carbon tetrachloride, chloroform, and trichloroethene. Remediation of elevated technetium-99 at wells east of Waste Management Area (WMA) T prompted interim remedial activity in accordance with the ROD (EPA/ROD/R10-95/114) and *Technetium-99 Pump-and-Treat System to Support the 200-ZP-1 CERCLA Remedial Investigation/Feasibility Study Process* (DOE/RL-2007-23). Remediation activities require removing contaminants from the high-concentration areas (greater than 2,000 µg /L) of carbon tetrachloride and reducing concentrations to the DWS of 900 pCi/L for technetium-99. The primary means to achieve the remedial targets is through withdrawing groundwater and removing contaminant mass via ex situ treatment using pump-and-treat operations. Since 2007, carbon tetrachloride has been reduced in the areas of highest concentration through extraction of over 5.02 billion liters of contaminated water, from which 12,647 kilograms of carbon tetrachloride were removed. A second system treating technetium-99 in the WMA T area has removed 72.7 grams of technetium-99 (1.24 curies), lowering concentrations that once exceeded 113,000 pCi/L to 4,000 pCi/L and 4,500 pCi/L at extraction wells since start up. This system has also removed 71.3 kilograms of carbon tetrachloride and 72,262 kilograms of nitrate.

The design, installation, and operation of the remedial action monitoring network and treatment system is discussed in the *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78). Additional tasks performed during CY 2010 to support the final ROD (*Declaration of the Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*

[EPA et al., 2008], issued in September 2008) included installing eleven extraction/injection wells to supply the groundwater treatment facility, and ongoing construction of the radiological process facility and the biological treatment facility to support startup of the treatment facility by the end of 2011. Extraction well 299-W15-44 was removed from the well network and extraction well 299-W15-225 was added, resulting in a 40% increase in production volume for the entire extraction network. Chapter 12.0, Section 12.3.4 discusses the screened depths of wells and the vertical distribution of contamination. Pump-and-treat operations of the existing 200-ZP-1 system since 1994 have reduced contamination in the aquifer through the removal of 12,648 kilograms of carbon tetrachloride from over 5 billion liters of groundwater treated.

1.3.10 300-FF-5 Operable Unit

The 300-FF-5 OU is in the later stages of the RI/FS process. Current activities are directed at assembling information to support decisions for final remedial actions involving groundwater (DOE/RL-2009-30, *300 Area Decision Unit Remedial Investigation/Feasibility Study Work Plan*). The principal contaminant of concern for the 300 Area is uranium, although additional waste indicators also exceed regulatory standards for groundwater in the 300 Area and in two outlying subregions containing the 618-10 and 618-11 Burial Grounds. Details on 300-FF-5 OU CERCLA groundwater monitoring activities for the reporting period are provided in Chapter 13.0, Section 13.2.

While the RI/FS process continues, groundwater is monitored under an operation and maintenance plan, which describes the strategy for monitoring and characterization activities during the period of interim remedial action (DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*). The *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11) implements the groundwater monitoring requirements. The period of interim action is governed by the *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-96/143), which was prepared in 1996 and expanded geographically in 2000 to include the two outlying subregions (EPA/ESD/R10-00/524, *EPA Superfund Explanation of Significant Differences: Hanford 300-Area [USDOE]*). Remedial actions during the interim period involve continued monitoring of groundwater and institutional controls to restrict groundwater use. These activities are deemed appropriate while other actions are underway to remediate waste disposal sites, unplanned release sites, and former 300 Area facilities.

Significant activities contributing to the RI/FS are being conducted in the 300 Area, including drilling at sixteen locations, with the primary objective to characterize the contamination remaining in the vadose zone and unconfined aquifer. Field testing is in progress using potential technologies to remediate uranium contamination in the subsurface. Groundwater monitoring via wells and river shoreline aquifer tubes is providing data used to evaluate the nature and extent of contamination, contaminant concentration trends, and associated risk. The DOE's Office of Science supports detailed research on the mobility characteristics of uranium beneath the 300 Area, as well as on the groundwater pathway leading to discharge into the Columbia River. Completion of the RI/FS process and submittal of a proposed plan for final remedial action have a Tri-Party Agreement milestone due date of December 31, 2012.

1.3.11 1100-EM-1 Operable Unit

The 1100-EM-1 OU, including the inactive Horn Rapids Landfill, was delisted from the National Priorities List in 2006 and, therefore, is no longer considered

an active CERCLA site. The results of the CERCLA investigation for the 1100-EM-1 OU are presented in the *Draft Remedial Investigation/ Feasibility Study for the 1100-EM-1 Operable Unit, Hanford* (DOE/RL-92-67) and the *Declaration of the Record of Decision for the 1100 Area* (EPA/ROD/R10-93/063). Details on 1100-EM-1 OU groundwater monitoring activities for the reporting period are provided in Chapter 14.0, Section 14.2.

The selected remedy for groundwater, which consists of monitored natural attenuation of volatile organic compounds with institutional controls on drilling of new water supply wells, continues to be successful. Monitoring includes analysis of trichloroethene and its breakdown products (e.g., vinyl chloride and 1,1-dichloroethene), as well as nitrate in wells downgradient of the Horn Rapids Landfill, as recommended in the *Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit* (PNNL-12220) and TPA-CN-163. Concentrations of trichloroethene and its breakdown products remained below the 5 µg/L DWS.

1.4 Compliance Summary for Sites Regulated Under the Resource Conservation and Recovery Act

The groundwater monitoring requirements for the Hanford Site's RCRA TSD units fall into one of two broad categories: interim status or final status. A permitted RCRA unit requires final status monitoring, as specified in WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring, as specified in WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (based on 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities").

Under the requirements of WAC 173-303-400 (interim status), groundwater monitoring is conducted under one of three programs:

- ***Contaminant indicator evaluation***: Any interim status facility subject to RCRA regulations initially implements a contamination indicator evaluation monitoring program. This program uses groundwater data from specified indicator parameters (pH, specific conductance, total organic carbon, and total organic halogens) to determine and monitor the impact of the facility, if any, on groundwater. In addition annual sampling for the groundwater quality parameters chloride, sulfate, iron, manganese, sodium, and phenols is also required. A contamination indicator evaluation monitoring program started under interim status continues until a permit is issued or until monitoring results indicate a statistically significant change in one of the specified indicator parameters.
- ***Groundwater quality assessment***: When contamination indicator evaluation monitoring data confirm a statistically significant change in a specified indicator parameter, then a groundwater quality assessment monitoring program is implemented. If the assessment program identifies that dangerous constituents from the site have impacted groundwater, monitoring continues under groundwater quality assessment. A groundwater quality assessment program has confirmed that an impact to groundwater has occurred, and the objectives change from looking for contamination to assessing the levels, rate, and extent of migration of site-specific contaminants.

- ***Corrective action*:** This phase of RCRA groundwater monitoring may occur if the source of the contamination is determined to be the unit and contaminant concentrations exceed applicable limits. If this occurs, Ecology may then require corrective action. Groundwater is monitored to determine if the corrective action is effective.

The requirements of WAC 173-303-645 (permitted or final status) also are conducted under one of three programs:

- ***Detection monitoring*:** A facility operating permit will include requirements for the final status detection monitoring program. Determination of a statistically significant change is made by comparing the concentrations of site-specific indicator parameters in downgradient wells to a value that is statistically derived from the background wells (usually upgradient wells unless intra-well comparisons are made). The derivation of comparison values is detailed in PNNL-13080. If a statistically significant change in one or more of the site-specific indicator parameters is confirmed and dangerous constituents from the site have impacted groundwater, then the facility is required to move to the second phase of monitoring.
- ***Compliance monitoring*:** When detection monitoring data confirm dangerous constituent(s) from the site have impacted groundwater, a compliance monitoring program is implemented. In this program, the objectives are to determine the levels and extent of contamination, and whether the groundwater concentration limit is exceeded. If a concentration limit is exceeded, corrective action may be required.
- ***Corrective action*:** Groundwater corrective action may be required if the concentration limits established under compliance monitoring are exceeded. This phase of monitoring is performed to determine if the corrective action is effective.

Table 1-4 lists the status of RCRA facility monitoring for each unit during the reporting period. The following discussion presents a compliance summary for these regulated facilities.

1.4.1 1301-N (116-N-1) Liquid Waste Disposal Facility

The 1301-N (116-N-1) Liquid Waste Disposal Facility (LWDF) is included in the Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*). The Permit states that RCRA monitoring during closure activities will follow the requirements of the *100-N Pilot Project: Proposed Consolidated Groundwater Monitoring Program* (BHI-00725). That plan and a supplemental plan (PNNL-13914, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*) are similar to an interim status contaminant indicator evaluation program. Indicator parameters remained below their critical mean values in 2010. Upgradient/downgradient comparison values for indicator parameters have been revised based on recent data for use in 2011 comparisons. A summary of the groundwater monitoring activities for the reporting period at the 1301-N LWDF is provided in Chapter 6.0, Section 6.3.1.

1.4.2 1324-NA (120-N-1) Percolation Pond and 1324-N (120-N-2) Surface Impoundment

The 1324-NA percolation pond and the 1324-N surface impoundment are both included in the Hanford Facility RCRA Permit (WA7890008967). The Permit

states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. That plan and a supplemental plan (PNNL-13914, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*) are similar to an interim status contaminant indicator evaluation program. The two units are monitored as a single site (WMA) because of their proximity and similar waste types. Average specific conductance values in downgradient wells continued to exceed the critical mean value in 2010 related to increases in the nondangerous constituents sodium, calcium, and nitrate. The average total organic carbon concentration exceeded the critical mean value of 865 µg/L in well 199-N-73 in September 2010 but was below the limit of quantitation of 990 µg/L. No other critical mean exceedances occurred during the reporting period.

Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the 1324-NA percolation pond and 1324-N surface impoundment groundwater monitoring activities for the reporting period is provided in Chapter 6.0, Section 6.3.2.

1.4.3 1325-N (116-N-3) Liquid Waste Disposal Facility

The 1325-N LWDF is also included in the Hanford Facility RCRA Permit (WA7890008967). The Permit states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. That plan and a supplemental plan (PNNL-13914) are similar to an interim status contaminant indicator evaluation program. The average specific conductance values in downgradient well 199-N-41 continued to exceed the critical mean value in 2010 related to increases in the nondangerous constituents sodium, calcium, and nitrate. This exceedance is a continuation of previous exceedances noted through 2009. No other critical mean exceedances occurred in 2010. Detection monitoring will continue in 2011. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011. A summary of the groundwater monitoring activities for the reporting period at the 1325-N LWDF is provided in Chapter 6.0, Section 6.3.3.

1.4.4 183-H (116-H-6) Solar Evaporation Basins

The 183-H solar evaporation basins are the only RCRA site in the 100-H Area. The 116-H-6 solar evaporation basins are incorporated into the Hanford Facility RCRA Permit (WA7890008967) as the "183-H solar evaporation basins." The site is being monitored during the post-closure period under the corrective action monitoring requirements of WAC 173-303-645(11)(g). The RCRA Permit requires annual monitoring of the facility, which includes sampling four wells for chromium, fluoride, nitrate, technetium-99, and uranium. The four wells in the RCRA network were sampled as scheduled per the RCRA recovery schedule for the constituents of interest listed in the groundwater monitoring plan. It should be noted that wells 199-H4-3 and 199-H4-4 also serve as extraction wells for the 100-H Area pump-and-treat system. Well 199-H4-12C began to be used as an extraction well in August 2010. Overall, the contaminant concentrations at the 183-H solar evaporation basins remained below applicable Permit limits during the reporting period except for chromium in well 199-H4-12C. A summary of the 183-H solar evaporation basins groundwater monitoring activities for the reporting period is provided in Chapter 7.0, Section 7.3.

Chromium concentration in well 199-H4-12C exceeded the 122 µg/L Permit concentration limit in December 2010 at 128 and 133 µg/L in filtered and unfiltered samples, respectively. Well 199-H4-12C was converted to an extraction well in August 2010, providing a likely explanation for the increase in chromium. Nitrate

concentrations ranged from 4.83 to 939.8 mg/L during the reporting period. The non-RCRA contaminant technetium-99 was positively detected in at least one sample from each well during the reporting period, with the highest concentration in well 199-H4-12A at 94 pCi/L.

1.4.5 Low-Level Waste Management Area 1

The LLWMA-1 continued to be monitored under RCRA interim status contaminant indicator evaluation monitoring requirements in accordance with WAC 173-303-400. Specific conductance continued to exceed its critical mean value. This is a continuation of previously reported increases associated with non-RCRA constituents. Two additional wells were installed in anticipation of shrinking the footprint of the WMA. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the LLWMA-1 groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.1.

1.4.6 Low-Level Waste Management Area 2

The LLWMA-2 continued to be monitored under RCRA interim status contaminant indicator evaluation monitoring requirements in accordance with WAC 173-303-400. All RCRA indicator parameters were below the respective critical mean values. The DOE believes the monitoring network is capable of detecting constituents migrating from the site into the uppermost aquifer because wells are located along the west and south boundaries while the elevation of the basalt rises above the aquifer to the north and east. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the LLWMA-2 groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.2.

1.4.7 Waste Management Area B-BX-BY

The WMA B-BX-BY continued under an interim status groundwater assessment program during the reporting period in accordance with WAC 173-303-400. The primary dangerous waste constituent found beneath WMA B-BX-BY is cyanide. It is important to note that the cyanide found beneath WMA B-BX-BY did not originate from the WMA, but rather from an adjacent non-RCRA waste site. Nitrate is monitored as a major supporting constituent. Contaminant levels in network monitoring wells continued general increasing trends during the reporting period, with the non-RCRA constituents nitrate, nitrite, sulfate, technetium-99, and uranium above their respective DWSs in wells monitoring the tank farms. The DOE believes the monitoring network, including five new RI wells installed in FY 2008, will remain capable of monitoring the extent and concentrations of contaminants in 2011. A revised and updated groundwater monitoring plan for this unit was submitted for review to DOE and Ecology in October 2010 (DOE/RL-2009-72, *Interim Status Groundwater Quality Assessment Plan for WMA B-BX-BY*). A summary of the WMA B-BX-BY groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.3.

1.4.8 Waste Management Area C

The RCRA groundwater quality assessment monitoring continued at this WMA in CY 2010 in accordance with WAC 173-303-400. Cyanide, a dangerous waste constituent, was determined to be associated with releases from WMA C. Metals and volatile organics continue to be evaluated. Two wells were added to the well network in CY 2010 and provided sufficient information to establish the extent

of the dangerous waste constituent cyanide. Four non-RCRA constituents were reported above the DWS at WMA C: nitrate, sulfate, iodine-129, and technetium-99. The groundwater quality assessment plan was issued in June 2010 (DOE/RL-2009-77, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*). A summary of the WMA C groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.4.

1.4.9 Liquid Effluent Retention Facility

The Liquid Effluent Retention Facility (LERF) operates under final status Permit conditions agreed to by DOE and Ecology, but statistical analyses are not yet performed on results. Analysis of samples collected during the reporting period indicate that all constituents in the permit were either undetected or were below Permit limits. All four of the wells at the LERF were sampled as required and the DOE believes remain capable of detecting constituents migrating from the site into the uppermost aquifer in CY 2011. A new final status plan was prepared and is pending inclusion in the Permit. A summary of the LERF groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.5.

1.4.10 216-B-63 Trench

The 216-B-63 Trench continued in interim status contaminant indicator evaluation monitoring throughout the reporting period in accordance with WAC 173-303-400. The DOE believes the monitoring well network is capable of determining groundwater quality downgradient of the site and for performing required statistical comparisons. To date, the required statistical evaluations of the RCRA contamination indicator parameters have not exceeded critical mean values and do not indicate that the 216-B-63 Trench has affected groundwater quality in the uppermost aquifer beneath the unit. A revised and updated groundwater monitoring plan for this unit was issued in June 2010 (DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*). The revised plan reduced the number of wells in the network from twelve to seven. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the 216-B-63 Trench groundwater monitoring activities for the reporting period is provided in Chapter 9.0, Section 9.3.6.

1.4.11 Integrated Disposal Facility

The Integrated Disposal Facility (IDF) is an expandable, lined, RCRA-compliant landfill in detection monitoring, in accordance with WAC 173-303-645(9). The facility is not yet receiving waste. A Permit modification approved in June 2010 changes the frequency of sample collection to once per year during the pre-active life of the unit. A summary of the IDF groundwater monitoring activities for the reporting period is provided in Chapter 10.0, Section 10.3.1.

1.4.12 RCRA PUREX Cribs

The RCRA Plutonium-Uranium Extraction (PUREX) Cribs remained in interim status groundwater quality assessment monitoring in accordance with WAC 173-303-400. The non-RCRA constituent nitrate remained above the DWS during the reporting period. The 216-A-10 Crib has been removed from the Permit after meeting closure requirements in March 2010. Revised groundwater monitoring plans were written for the 216-A-36B Crib and 216-A-37-1 Crib (DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*; DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*). These two units will be monitored under interim status indicator

evaluation programs beginning in 2011. A new set of data will be collected for each of the units to determine the indicator parameter background comparison values. Groundwater samples scheduled for October were obtained in either November or December. A summary of the groundwater monitoring activities for the reporting period at the PUREX Cribs is provided in Chapter 10.0, Section 10.3.2.

1.4.13 Waste Management Area A-AX

During 2010, WMA A-AX remained in interim status groundwater assessment monitoring in accordance with WAC 173-303-400. With the installation of well 299-E25-236 in 2008, the DOE believes the groundwater monitoring well network is capable of assessing groundwater contamination from the site. Two wells scheduled for sampling in December 2010 were not sampled: one well is upgradient and the other well is used for information purposes only and not for RCRA decision purposes. Sampling at these two wells was missed due to the work stoppage in October 2010. A new groundwater monitoring plan (DOE/RL-2009-70, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*) is being reviewed by Ecology. Until the new monitoring plan is approved, WMA A-AX will continue to be monitored under the existing groundwater monitoring plan (PNNL-15315, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*). A summary of the WMA A-AX groundwater monitoring activities for the reporting period is provided in Chapter 10.0, Section 10.3.3.

1.4.14 216-A-29 Ditch

The 216-A-29 Ditch continued in interim status contaminant indicator evaluation monitoring throughout the reporting period in accordance with WAC 173-303-400. Required statistical evaluations of the specified indicator parameters continue to show specific conductance above the critical mean in three wells. The elevated specific conductance is from nondangerous constituents. To date, no dangerous waste/dangerous waste constituent subject to WAC 173-303 regulations has affected groundwater quality in the uppermost aquifer beneath the 216-A-29 Ditch. A revised and updated groundwater monitoring plan for this unit was issued in March 2010 (DOE/RL-2008-58, *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch*). Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. The DOE believes the monitoring well network is capable of determining groundwater quality downgradient of the site and for performing the required statistical comparisons. A summary of the groundwater monitoring activities for the reporting period at the 216-A-29 Ditch is provided in Chapter 10.0, Section 10.3.4.

1.4.15 216-B-3 Pond

The 216-B-3 Pond continued in interim status contaminant indicator evaluation monitoring throughout the reporting period in accordance with WAC 173-303-400. To date, the required statistical evaluations of the specified indicator parameters have not exceeded critical mean values and do not indicate that the 216-B-3 Pond has affected the groundwater quality in the uppermost aquifer beneath the unit. A revised and updated groundwater monitoring plan for this unit was issued in September 2010 (DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*). The DOE believes the revised monitoring well network continues to be capable of determining groundwater quality downgradient of the site and for performing required statistical comparisons. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011

comparisons. A summary of the 216-B-3 Pond groundwater monitoring activities for the reporting period is provided in Chapter 10.0, Section 10.3.5.

1.4.16 Nonradioactive Dangerous Waste Landfill

During 2010, the Nonradioactive Dangerous Waste Landfill (NRDWL) was monitored under interim status contamination indicator evaluation monitoring in accordance with WAC 173-303-400. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the NRDWL groundwater monitoring activities for the reporting period is provided in Chapter 10.0, Section 10.3.6. All wells were sampled during the timeframe scheduled, with the exception of well 699-25-34A; the first semiannual sample for the January through July timeframe was not collected due to limited sampling team resources.

Also in 2010, a new RCRA groundwater monitoring plan was written for the combination of the NRDWL and the Solid Waste Landfill (SWL) (DOE/RL-2010-28, Rev. 1, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*). Because the two landfills are adjacent, combining the remedial action for the two landfills was considered a reasonable option to maximize available resources. In the new plan, NRDWL groundwater monitoring will move into RCRA final status under WAC 173-303-645. The plan is currently being reviewed by Ecology; until the plan is approved, the NRDWL will continue to be monitored under the current groundwater monitoring plan (PNNL-12227).

1.4.17 Waste Management Area S-SX

The WMA S-SX remained in interim status groundwater quality assessment monitoring in accordance with WAC 173-303-400. The RCRA-regulated dangerous constituent chromium and supporting constituent nitrate exist in two plumes that extend downgradient of the WMA at concentrations above their respective DWSs. A revised monitoring plan (DOE/RL-2009-73, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX*) was issued and will be implemented in January 2011. The revised monitoring system is believed by DOE to be capable of monitoring the distribution of contamination. A summary of the WMA S-SX groundwater monitoring activities for the reporting period is provided in Chapter 11.0, Section 11.3.1.

1.4.18 Waste Management Area U

The WMA U remains in interim status groundwater quality assessment monitoring in accordance with WAC 173-303-400. Nitrate remained above the DWS during the reporting period, while the RCRA-regulated dangerous constituent chromium remained below the analytical detection limit. A revised monitoring plan (DOE/RL-2009-74, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*) was prepared and will be implemented in January 2011. The DOE believes the revised monitoring system is capable of monitoring the distribution of contamination from the WMA. A summary of the WMA U groundwater monitoring activities for the reporting period is provided in Chapter 11.0, Section 11.3.2.

1.4.19 216-S-10 Pond and Ditch

The 216-S-10 Pond and Ditch remain in interim status contaminant indicator evaluation monitoring in accordance with WAC 173-303-400. The period of CY 2009 marked completion for collection of four quarters of RCRA-compliant data from the new upgradient well; thus, new background values were calculated for CY 2010

for the required upgradient/downgradient comparisons. However, due to extreme variability in the total organic carbon results (standard deviation of 2,371), only the parameters of pH, specific conductance, and total organic halides were used from the new well. Additional quarterly sampling was performed during CY 2010, and the data indicate total organic carbon concentrations beginning to stabilize, likely yielding useable values for CY 2011.

To date, RCRA contamination indicator parameters have not exceeded critical mean values and do not indicate that the 216-S-10 Pond and Ditch have affected the groundwater quality in the uppermost aquifer beneath the unit. A revised monitoring plan for this unit was issued in March 2010 (DOE/RL-2008-61, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*). The DOE believes the revised monitoring system is capable of determining groundwater quality downgradient of the site and for performing the required statistical comparisons. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in 2011 comparisons. A summary of the groundwater monitoring activities for the reporting period at the 216-S-10 Pond and Ditch is provided in Chapter 11.0, Section 11.3.3.

1.4.20 Low-Level Waste Management Area 3

The LLWMA-3 continued in interim status contaminant indicator evaluation monitoring throughout the reporting period in accordance with WAC 173-303-400. Statistical evaluations at LLWMA-3 are suspended until the effects of the enhanced 200-ZP-1 OU pump-and-treat system are known and a new upgradient well is installed. A new interim status monitoring plan went into effect during CY 2010 (DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*). A new upgradient monitoring well is planned for construction during CY 2011. During the reporting period, carbon tetrachloride was the only constituent exceeding its DWS. All wells were successfully sampled during the reporting period. Interim status indicator evaluation groundwater monitoring at LLWMA-3 will continue in CY 2011. A summary of LLWMA-3 groundwater monitoring activities for the reporting period is provided in Chapter 12.0, Section 12.4.1.

1.4.21 Low-Level Waste Management Area 4

The LLWMA-4 continued in interim status contaminant indicator evaluation monitoring throughout the reporting period in accordance with WAC 173-303-400. A new interim status monitoring plan went into effect during CY 2010 (DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*). The last active upgradient well, 299-W18-21, went dry in 2010 but sufficient data exist for statistical evaluations to continue for this and future reporting periods using critical means calculated from the most recent several years of data. Construction of an upgradient well is not expected until the effects of the enhanced 200-ZP-1 OU pump-and-treat system are known.

Results of the first determination assessment did not find dangerous waste/ dangerous waste constituents in the groundwater; thus, indicator evaluation groundwater monitoring at LLWMA-4 will continue in CY 2011. A summary of LLWMA-4 groundwater monitoring activities for the reporting period is provided in Chapter 12.0, Section 12.4.2.

1.4.22 Waste Management Area T

The WMA T remains in interim status groundwater quality assessment monitoring in accordance with WAC 173-303-400. The primary dangerous waste constituent in

groundwater from WMA T is chromium. Chromium and the supporting constituents fluoride and nitrate each had at least one well that exceeded the DWS for that contaminant during the reporting period. A new interim status assessment monitoring plan (DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T*) was approved at the end of the reporting period and went into effect at the beginning of CY 2011. The well network is believed by DOE to be capable of monitoring the distribution of contamination from the WMA, and all wells were sampled as scheduled during the reporting period. A summary of groundwater monitoring activities for the reporting period at WMA T is provided in Chapter 12.0, Section 12.4.3.

1.4.23 Waste Management Area TX-TY

The WMA TX-TY remains in interim status groundwater quality assessment monitoring in accordance with WAC 173-303-400. The primary dangerous waste constituent in groundwater at the WMA is chromium. A new interim status assessment monitoring plan (DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T*) was approved at the end of the reporting period and went into effect at the beginning of CY 2011. Chromium and the co-contaminant nitrate each continued to exceed their respective DWS in wells monitoring the WMA during the reporting period. Other non-RCRA contaminants, technetium-99 and iodine-129, also exceeded their respective DWSs in wells at the WMA. The DOE believes the well network remains capable of monitoring the distribution of contamination from the WMA, and all wells were sampled as scheduled during the reporting period. A summary of the WMA TX-TY groundwater monitoring activities for the reporting period is provided in Chapter 12.0, Section 12.4.4.

1.4.24 Former 300 Area Process Trenches (316-5 Waste Site)

Groundwater is monitored under a corrective action program in accordance with the final status requirements of WAC 173-303-645(11). The modified closure plan (DOE/RL-93-73, *300 Area Process Trenches Modified Closure/Postclosure Plan*), which is incorporated into the Hanford Facility RCRA Permit (WA7890008967), states that groundwater remediation is deferred to the 300-FF-5 OU under CERCLA. Sampling and reporting were performed as scheduled during the reporting period. It is the belief of the DOE that the network of one upgradient well (north of the former facility) and three downgradient wells (east, southeast, and south of the facility) remains capable of detecting constituents migrating from the site into the uppermost aquifer.

Concentrations of cis-1,2-dichloroethene in the RCRA network monitoring wells ranged from nondetect to 4.8 µg/L. Analytical results for trichloroethene were all below the detection limit of 1 µg/L during 2010, with the exception of two detections in samples from well 399-1-16B (1.4 and 1.1 µg/L) and one estimated detection at well 399-1-17A (0.31 µg/L). Analytical results for tetrachloroethene were all below the 1 µg/L detection limit during 2010.

1.5 Other Regulated Facilities

This section provides a brief status of compliance for non-RCRA facilities on the Hanford Site that require groundwater monitoring under other regulations (e.g., solid waste rules). Details on sampling at these facilities are in the appropriate chapters of this report.

1.5.1 Solid Waste Landfill

The SWL, located south of the NRDWL, is regulated by Ecology under WAC 173-350, "Solid Waste Handling Standards." The WAC 173-350 constituents and site-specific constituents (including volatile organic compounds and filtered arsenic) are similar to the WAC 173-304 ("Minimum Functional Standards for Solid Waste Handling") requirements for which the groundwater monitoring plan was written in 2000 (PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*). The WAC 173-304 requirements were replaced by WAC 173-350. The regulated constituents are analyzed quarterly. Compliance is determined by comparing sampling results from downgradient wells with statistically derived background threshold values from upgradient wells. However, some downgradient wells continue to show chemical oxygen demand, coliform bacteria, specific conductance, and sulfate above compliance limits, as well as pH below the compliance limit. During 2010, the January, April, and July sampling events occurred as scheduled, but the October sampling event was delayed until December 2010 due to the work stoppage. In addition, three of the nine network wells were not sampled in December 2010. A summary of the SWL groundwater monitoring activities for the reporting period is provided in Chapter 10.0, Section 10.4.1.

During CY 2010, a new RCRA groundwater monitoring plan was written, combining groundwater monitoring at the SWL with the NRDWL (DOE/RL-2010-28, Rev. 1). Because the two landfills are adjacent, combining the remedial action for the two landfills was considered a reasonable option to maximize available resources. At the SWL, closure and post-closure groundwater monitoring are subject to the requirements of WAC 173-350-500 ("Solid Waste Handling Standards," "Ground Water Monitoring"); however, compliance with groundwater monitoring requirements for the SWL will be achieved through deferral under WAC 173-350-710(8) to equal or greater requirements within WAC 173-303-645. The combined monitoring plan is currently under review by Ecology. Until the plan is approved, the SWL will continue to be monitored under the existing groundwater monitoring plan (PNNL-13014).

1.5.2 Treated Effluent Disposal Facility

The 200 Area Treated Effluent Disposal Facility is monitored under *State Waste Discharge Permit ST 4502* (Ecology, 2000b), WAC 173-216 ("State Waste Discharge Permit Program"), and the *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility* (PNNL-13032). The wells are monitored for three constituents with enforcement limits (lead at 5 μg/L, cadmium at 10 μg/L, and pH of 6.5 to 8.5) as required by the state waste discharge permit. Specific conductance, gross alpha and beta, anions, metals, total dissolved solids, trace metals, and tritium are monitored as indicator parameters. During 2010, all groundwater samples were collected as scheduled, and none of the enforcement limits were exceeded. A summary of the groundwater monitoring activities for the reporting period at the Treated Effluent Disposal Facility is provided in Chapter 10.0, Section 10.4.2.

1.5.3 State-Approved Land Disposal Site

The State-Approved Land Disposal Site is monitored under *State Waste Discharge Permit ST 4500* (Ecology, 2000a), WAC 173-216, and the *Groundwater Monitoring and Tritium Tracking Plan for the 200 Area State-Approved Land Disposal Site* (PNNL-13121). Twelve wells are monitored for tritium, and the three proximal wells are monitored for additional constituents including pH, specific conductance, metals, anions, total dissolved solids, and volatile organic analytes. Concentrations of all

chemical constituents with permit limits were within those limits or below detection limits during the reporting period. During the reporting period, all groundwater samples were collected as scheduled. A summary of the groundwater monitoring activities for the reporting period at the State-Approved Land Disposal Site is provided in Chapter 12.0, Section 12.4.5.

1.6 Shoreline Monitoring

M.J. Hartman

Monitoring groundwater quality along the Columbia River is accomplished by collecting samples from aquifer tubes and riverbank springs.

The DOE monitors groundwater quality along the Columbia River by collecting samples from aquifer tubes and riverbank seeps (springs). In 2010, DOE concluded its study and collection of porewater from within the gravel and sand of the Columbia River bed to define where groundwater is discharging to the river.

Hydrologists estimate that groundwater currently flows from the Hanford Site unconfined aquifer to the Columbia River at a rate between 0.8 and 2.8 cubic meters per second (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*; PNNL-SA-56038, *Hanford Site Groundwater and the Columbia River, South-Central Washington*). This rate is less than 0.001% of the average flow of the Columbia River, ~3,400 cubic meters per second.

Water samples from aquifer tubes and riverbank seeps represent a mixture of river water and groundwater.

The rise and fall of the Columbia River creates a zone of interaction that influences contaminant concentrations and groundwater flow patterns. Water samples from aquifer tubes and riverbank seeps nearly always represent a mixture of river water and approaching groundwater. In general, the degree of dilution by river water decreases with depth in the aquifer near the river shoreline. The degree of dilution also varies by location and with seasonal river cycles (PNNL-13674).

Aquifer tubes are small-diameter, flexible tubes that have a screen on one end. The tubes are installed in the aquifer along the Columbia River shoreline. Water is withdrawn from the tube using a portable peristaltic pump. Appendix C provides additional information for the aquifer tubes. Most aquifer tube sites include two or three individual tubes monitoring different depths, from ~1 to 8 meters.

Data from aquifer tubes and seeps are used for the following purposes:

- Data provide indication of the minimum concentrations of contaminants in groundwater approaching the Columbia River.
- Long-term decreases or increases in contamination in aquifer tubes or seeps may indicate real trends in groundwater. Declines could represent movement of the plume, discharge of the plume to the river, dispersion, or the influence of an upgradient remediation system. Increasing concentrations may indicate plume movement or mobilization of contaminants.
- Data from aquifer tubes have helped determine locations for additional monitoring and remediation (e.g., aquifer tube data provided the first indication of the southern 100-D Area chromium plume).

When interpreting these data, the following limitations should be noted:

- Concentrations in aquifer tubes and seeps may vary seasonally and even more frequently based on Columbia River stage (the same is true for near-river wells).
- Dilution of contaminants by mixing with river water can result in lower concentrations; though the amount (mass) of that contaminant is not decreased.

- Because aquifer tubes have much shorter screens than monitoring wells, the data may not be directly comparable to data from near-river wells.
- Aquifer tube and seep data are currently not used in remedial action decision making (i.e., the data are not compliance points for pump-and-treat systems).

In October 2008, the DOE released the *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the U.S. Department of Energy Hanford Site, 100-D Area* (SGW-39305). The report provides an expert panel's observations and suggestions to improve the current understanding of groundwater/surface water interactions in the 100 Area, primarily focusing on the 100-D Area. The recommendations included integrity testing of aquifer tubes. In early 2010, staff evaluated specific conductance data from aquifer tubes collected before and after sampling. The results indicated that pumping the tubes does not cause Columbia River water to migrate down the boring and cause sample dilution (Appendix C).

Aquifer tube sampling is governed by the *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59). The individual OU sections of this report summarize aquifer tube results and include location maps, and Appendix C provides supporting information for the aquifer tube sampling. Table 1-3 lists the maximum contaminant concentrations in aquifer tubes sampled during the reporting period.

1.7 CERCLA Five-Year Review

Whenever contaminants remain in the environment following a remedial action decision, CERCLA regulations require the regulatory agency to conduct a review of the decision at least every 5 years. The DOE released *The Second* CERCLA *Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20) in November 2006. The purpose of the review was to determine whether the selected remedies remain protective of human health and the environment, as well as to recommend appropriate corrective actions if the remedy is not achieving the established goals.

The review identified twenty issues and recommended corrective actions to ensure that selected remedies remain protective of human health and the environment. The three actions pertaining to the River Corridor cross OU boundaries and have all been completed (DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*).

1.8 Quality Control Summary

C.J. Thompson

Groundwater data quality is assessed and enhanced by a multifaceted quality assurance/quality control program. Major components of the program include performance evaluation studies, field quality control samples, blind standards, laboratory quality control samples, and laboratory audits. Overall, evaluation of these components indicates that the majority of the data from the reporting period are reliable and defensible. Specific data values that are associated with out-of-limit quality control results (field blanks, field duplicates, and laboratory blanks) are flagged in the Hanford Environmental Information System (HEIS) database so users can be circumspect when using such data for interpretation. A detailed description of the quality control program and the quality control results for CY 2010 are provided in Appendix D, and highlights include the following:

Evaluation of the groundwater project quality assurance program indicates that the data for the reporting period are reliable and defensible.

The HEIS database can be accessed through the Environmental Dashboard Application at http://environet.hanford.gov/EDA/.

- Ninety percent of the groundwater monitoring data were considered complete (i.e., not rejected, suspect, associated with a missed holding time, or out-of-limit quality control criteria). The majority of the incomplete results were associated with low-level detections of metals in laboratory blanks.
- The six primary laboratories supporting groundwater monitoring participated in several national performance evaluation studies. Overall, the performance was acceptable.
- Field quality control samples include three types of field blanks (full trip, field transfer, and equipment blanks), field duplicates, and split samples. Approximately 97% of the field blank, 93% of the field duplicates, and 95% of the split sample results were acceptable, indicating good sampling and analytical performance.
- Recommended holding times were met for 99% of nonradiological sample analysis requests.
- Overall, laboratory performance for Soil and Groundwater Remediation Project blind standards was fair; 84% of the results were acceptable. Failures for anions, hexavalent chromium, low-level iodine-129, and total organic carbon suggest that some groundwater results could also be biased. These problem areas will be investigated further during 2011.
- Approximately 98% of the laboratory quality control results were within acceptance limits, indicating that the analyses were in control and reliable data were generated. Specifically, 99.2% of method blanks, 99.6% of the laboratory control samples, and 99% of the matrix spikes and matrix duplicates were within the acceptance limits.
- Audits and assessments of the laboratories were conducted by DOE and its contractors. Several findings and observations were identified, along with a number of proficiencies. Corrective actions have been accepted for all of the audits.

1.9 Other Information Sources

Other reports and databases relating to Hanford Site groundwater are discussed below.

HEIS database. The HEIS database is the main environmental database for the Hanford Site. The database is used to store groundwater chemistry data and other environmental data (e.g., soil chemistry and survey data).

PNNL-20548, Hanford Site Environmental Report for Calendar Year 2010. The annual report summarizes environmental data, including groundwater, riverbank seeps, and river water. It also describes environmental management performance and reports the status of compliance with environmental regulations.

Quarterly RCRA summary. The DOE provides formal quarterly presentations to Ecology after groundwater data have been verified and evaluated. These presentations describe the status of RCRA sampling and analysis, statistical analysis results, and changes or highlights from the quarter.

Pump-and-treat reports. The details on operations and effectiveness of the various pump-and-treat operations on the Hanford Site are presented in independent annual reports. The annual reports discuss the removal and treatment efficiencies for the year, as well as any operational issues for the pump-and-treat systems.

RI/FS work plans. The DOE recently released work plans for the 100 Area (DOE/RL-2008-46) and the 300 Area (DOE/RL-2009-30). These documents present a strategy to assist in the decisions to complete cleanup in the River Corridor.

River Corridor Baseline Risk Assessment (RCBRA). A critical step in developing final remedial action decisions is the completion of a quantitative baseline risk assessment. Some recent documents associated with this effort include the following:

- **DOE/RL-2007-21, *Risk Assessment for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment*:** The risk assessment addresses post-remediation residual contaminant concentrations in the 100 and 300 Areas, as well as the Hanford and White Bluffs town sites.
- **DOE/RL-2005-42, *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*:** The plan presents the rationale and approach for sampling and analysis to support risk characterization.
- **WCH-274, *Inter-Areas Component of the River Corridor Baseline Risk Assessment Sampling Summary*:** This document describes the 2006 to 2007 supplemental data collection effort, including sampling locations, samples collected, and any modifications and additions made to the sampling and analysis plan for the 100 and 300 Areas Component of the baseline risk assessment.

***Freedom of Information Act request*:** As with any public agency, not all data are directly available to the general public. However, most information can be obtained by contacting the operating agency (in the case of the Hanford Site, the DOE Richland Operations Office) and requesting the specific data under the *Freedom of Information Act of 1966*.

1.10 Conventions Used in This Report

The well location maps presented in this report include any well used for sampling or water-level measurements over the past 5 years. Wells that have gone dry or that have been decommissioned during this time period are shown with symbols that are different from regularly sampled wells. For clarity, the well name prefixes (e.g., "199-" in the 100 Area and "299-" in the 200 Area) are omitted from most of the maps.

Unless specified otherwise, contaminant plume maps in this report are based on average results for samples collected during CY 2010 for each well shown, excluding data that appear to be nonrepresentative. Data representativeness is determined by the project scientist in charge of the OU or monitored unit using various methods and best professional judgment (Appendix D). Data are averaged to include wells sampled at different times and at different frequencies. In some locations or for certain operations (i.e., pump-and-treat operations), it is advantageous to construct maps based on data from a single sampling event (e.g., chromium in the 100-D Area in spring 2010). Such maps are captioned with the specific timeframe illustrated.

Contour levels for the maps in this report were chosen to meet the following objectives:

- DWSs[1] and multiples of 10 (e.g., 8, 80, and 800 pCi/L for strontium-90)
- Common divisions, such as 50, 100, 500, etc.

1 Although most maps are contoured to a constituent's drinking water standard, the area impacted by the contaminant (i.e., the area with constituent concentrations elevated above background) can be considerably larger.

- Cleanup levels, where applicable (e.g., 20 μg/L for hexavalent chromium)
- Intermediate levels to help define plume shape (e.g., 30, 90, 300, 600, 900, and greater than 2,000 μg/L for uranium).

Uncertainty in plume boundary location is indicated by the use of dashed versus solid contour lines. Where a dense population of wells exists (e.g., within the 200 East Area), the contour lines are shown as solid, indicating good control on the contaminant concentration distribution. Where the well population is less dense, the contour lines may be dashed to indicate a lesser degree of control on the contaminant concentration distribution. Contours are revised based on the previous year's locations and any new data or interpretation of subsurface conditions. In addition, it is important to note that the interface between contaminated and uncontaminated groundwater is not a sharp boundary because of the heterogeneity in pathways followed by groundwater and the diffusion characteristics of the contaminant. Therefore, lines showing equal contaminant concentrations are generalizations with regard to the exact extent of contamination.

Mapped data are rounded to two significant digits. The plume maps are drawn manually and represent the best professional interpretations by project staff using current and historical data, source knowledge, and groundwater flow directions. Staff used data from CY 2008 and CY 2009 if new data were not available for a well in CY 2010. Wells that did not have samples collected during the reporting period and use older data for averaging are given a different symbol than used for wells with current-year data. Older data and data from aquifer tubes along the Columbia River are given less weight than the current well data when maps are contoured. Most maps show data from wells completed in the upper portion of the unconfined aquifer (i.e., generally the top ~10 meters).

Results that were less than detection limits (i.e., flagged as "U" in the HEIS database) are treated in one of two ways when constructing maps:

- For chemical constituents (including total uranium), "U"-flagged values represent the analytical detection limits. These values are treated as zeroes in the data to be averaged. If all of the results (or the only result) for the year were undetected, a "U" qualifier is plotted on the map. If the data represent a mixture of detected and undetected results, the average value is plotted on the map followed by an asterisk (*). If the data represent only detected results, the average value is plotted on the map.
- For radiological parameters, if the counting error is greater than the result, the result is flagged with "U." Other factors may also result in values being "U"-flagged. For plotting on maps, all of the results for the year are averaged, regardless whether or not "U"-flagged, because the reported values are statistically significant. The average values are plotted on the map, followed by "U" (if all results for the year were undetected) or an asterisk (if the data represent a mixture of detected and undetected values). It should be noted that the laboratories correct the results for background radiation, which in some cases can result in values that are negative.

Conventions for handling undetected values do not adversely affect data interpretation for most constituents because the contour intervals are far above detection limits. A notable exception is iodine-129. Iodine-129 is contoured at 1 pCi/L (the DWS), which, in some cases, has been less than the laboratory's detection limit. Historically, the laboratory required that both primary and secondary energy peaks be present before considering iodine-129 as detected. Requiring the secondary

(less sensitive) energy peak added conservatism to the laboratory's report (i.e., the laboratory reports a detection only when certain of the detection); however, review of data indicated that many "U"-flagged values were actual detections and were included in the contours. In FY 2009, groundwater analytical support staff worked with the laboratories to improve the iodine-129 method and resolve the issues identified in FY 2008. The goal was to ensure that the detection levels reported were at or below the 1 pCi/L DWS. This effort was successful, enabling future data to be at or below the DWS. However, 3 years of data are used to support the plume contours. Until sufficient data using the improved technique are obtained, the contour lines will be dashed to show that the distribution of iodine-129 at levels near the DWS is less certain than other contaminants.

The federal and state DWS for nitrate is 10 mg/L (for nitrate measured as nitrogen [NO_3-N]); this relates to the actual nitrogen in nitrate. To convert NO_3-N values to nitrate requires the NO_3-N value to be multiplied by 4.43. Nitrate plume maps provided in this report reflect the converted values and, as such, the DWS appears as 45 mg/L in figures and tables.

Trend plots may omit results that appear to be erroneous if they distort or obscure the scale and data trends; the figure caption and/or text note the omission. All of the data, with appropriate data quality flags, are included in the data files accompanying this report and are available in the HEIS database. The trend plots presented in this report use open symbols to show values below the laboratory detection limit. These results are typically plotted as values that represent the detection limit for chemical parameters and reported values for radiological parameters. Discussion of increasing or decreasing trends is generally based on qualitative observation and not on statistical evaluation.

This report uses the following conventions for chemical results:

- Text, figures, and tables express nitrate and nitrite as the NO_3^- and NO_2^- ions, respectively.
- Maps showing chromium include total chromium in filtered samples and hexavalent chromium in filtered or unfiltered samples. Dissolved chromium in Hanford Site groundwater is virtually all hexavalent (WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*), so filtered total chromium data effectively represent hexavalent chromium. Appendix C of DOE/RL-2008-01 compares chromium data from filtered, unfiltered, total, and hexavalent analyses.
- Contaminant concentrations are compared with state or federally enforceable DWSs (Table 1-5). Although Hanford Site groundwater is generally not used for the purpose of drinking water, these levels provide perspective on contaminant concentrations. Radionuclide concentrations also are compared with DOE-derived concentration guides and risk-based concentrations based on cancer risk coefficients, as well as DWSs (Table 1-6).

Dissolved chromium in Hanford Site groundwater is virtually all hexavalent.

1.11 Sources of Additional Information

All of the data presented in this report are provided on a CD-ROM accompanying this report. Data may also be reviewed on the internet through the DOE's Environmental Dashboard Application at http://environet.hanford.gov/EDA/.

The documents referenced in this report are generally available at the public reading rooms around the state. Some documents are also available online as part

of the Administrative Record at http://www5.hanford.gov/arpir/. Requests for documents can also be made through inter-library loan directly to the DOE or Pacific Northwest National Laboratory libraries.

For additional information on contaminants that are found at the Hanford Site, see Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas (Peterson et al. 2007), available on the Environmental Assessment Division, Argonne National Laboratory website (http://www.ead.anl.gov/pub).

Table 1-1. Reporting Requirements for Groundwater Monitoring

Operable Unit or Facility	Formal Report	Supplemental Report or Summaries
CERCLA		
OUs without RODs (100-BC-5, 100-FR-3, 200-BP-5, and 200-PO-1)	This report	Unit managers' meeting presentations
OUs with interim action RODs (100-KR-4, 100-NR-2, 100-HR-3, 200-UP-1, 200-ZP-1, and 300-FF-5)	Interim Action annual reports, summarized in this report	Unit managers' meeting presentations; this report
OU with final action ROD (1100-EM-1)	This report	None
ERDF	Separate annual report, summarized in this report	This report
RCRA		
Operating RCRA units (IDF, LERF, and LLBG)	This report	Informal quarterly presentations
Closure RCRA units (116-N-1 and 116-N-3; 120-N-1 and 120-N-2)	This report	Informal quarterly presentations
Post-closure RCRA units (116-H-6 and 316-5)	Semiannual reports to Ecology; this report	Informal quarterly presentations
Interim status groundwater quality assessment RCRA sites (PUREX Cribs; WMAs A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U)	This report	Informal quarterly presentations
Interim status indicator evaluation RCRA sites (216-A-29, 216-B-63, 216-S-10 Pond, and NRDWL)	This report	Informal quarterly presentations
Other Facilities		
AEA sites (K Basins; Richland North, 400 Area water supply wells, and confined aquifers)	This report	Unit managers' meeting presentations
SALDS (WAC 173-216)	Annual report (latest is SGW-42604)	This report
TEDF (WAC 173-216)	This report	None
SWL (WAC 173-350)	This report	None

Note: WAC 173-216, "State Waste Discharge Permit Program"; WAC 173-350, "Solid Waste Handling Standards."

Table 1-2. Number of Groundwater Analyses for Selected Constituents, CY 2010

Constituent	Site Total
Carbon tetrachloride	1,273
Chromium (total)	4,333
Chromium (hexavalent)	4,637
Iodine-129	859
Nitrate	2,883
Plutonium-239/240	55
Strontium-90	861
Technetium-99	1,395
Trichloroethene	1,273
Tritium	1,930
Uranium	1,279

This page intentionally left blank.

Table 1-3. Maximum Concentrations of Selected Groundwater Contaminants in Groundwater Interest Areas, January Through December 2010

Contaminant, Units (alphabetical order)	DWS (DCG)[a]	100-BC-5 OU		100-KR-4 OU		100-NR-2 OU		100-HR-3-D		100-HR-3-H		300-FF-5 OU		1100-EM-1		100-FR-3 OU	200-BP-5 OU	200-PO-1 OU	200-UP-1 OU	200-ZP-1 OU	Confined Aquifers
		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Wells	Wells	Wells	Wells	Wells
1,1,1-Trichloroethane, µg/L	200																	0.21			
1,1-Dichloroethene, µg/L	7																	0.14			
1,2-Dichloroethane, µg/L	5					0.72				0.67						0.82					
1,4-Dichlorobenzene, µg/L	75															0.78	0.39				
Antimony, µg/L	6			**52.8**		**40.2**	**44**			0.862		**54.7**				4.3	**59.7**	**62.2**	**48**	**52**	
Antimony (filtered), µg/L	6			**42.4**		**53.2**		**39.1**		0.932		**51.8**	**50.5**	**56**		**55**	**61.9**	**46.4**	**50**	**49**	
Arsenic, µg/L	10	3.6		7.2	2.6	**101**	**11.1**	7.52	2.53	8.24	1.79	**15.7**		**12.7**		**12.7**	**24.6**	**50**	5.8	**12**	
Arsenic (filtered), µg/L	10	5.37		**68**	2.03	**95**	**10.6**	7.16	2.39	**65**	2.21	**60**		**12.2**		**13.5**	**22.9**	**13.8**	5.6	9.45	
Barium, µg/L	2,000	88	53	100	74.6	616	150	1,070	168	128	56	101	117	161	85.3	153	330	249	125	474	
Barium (filtered), µg/L	2,000	146	34	98	51.2	350	105	1,100	177	121	23	102	91.8	168	82.7	157	233	158	125	431	
Benzene, µg/L	5					1.1					0.095										
Beryllium, µg/L	4	0.127		0.226		1.9	0.129	0.307	0.41					0.188			0.146				
Beryllium (filtered), µg/L	4	0.116		0.192		**20**	0.106	0.164		0.379		0.369						**49**	1.4		
Cadmium, µg/L	5			0.072	0.1	**6.6**		**5.9**	0.43	**7.6**			4.6		**6.4**		**31**	4.4			
Cadmium (filtered), µg/L	5	0.063				**14.4**		0.308		0.392		1.3	4.7			0.059			1.5	4.1	
Carbon tetrachloride, µg/L	5					4.2				0.16		**7.4**	3.3				0.22		**1,200**	**2,900**	
Carbon-14, pCi/L	2,000 (70,000)			**10,100**	92.2		13.8									70.7	436	15.9	12.6		
Cesium-137, pCi/L	200	2.04															**2,180**				
Chlorobenzene, µg/L	100			0.17												0.24					
Chloroform, µg/L	100	3		2.2		7.1		5.1	0.32	1.5	1.8	7.1	2.7			1.9	0.66	1.1	12	17	
Chromium, µg/L	100	68.5	15	**1,010**	65	**217**	24	**61,100**	**228**	**133**	37	23		3.18		98.2	**284**	39	**1,100**	**731**	
Chromium (filtered), µg/L	100	56.1	15	**997**	58	**192**	8.72	**5,730**	**241**	**128**	36	28.2		1.81		93	**333**	**288**	**1,180**	**732**	
cis-1,2-Dichloroethylene, µg/L	70										0.093	**170**	0.22								
Cobalt-60, pCi/L	100			12													79			14	
Cyanide, µg/L	200					4.1						3.7					**1,590**			8.4	
Endrin, µg/L	2					0.16															
Ethylbenzene, µg/L	700					9.4			0.11		0.19										
Fluoride (filtered), µg/L	4,000	222															165	338			
Fluoride, µg/L	4,000	290	126	354	130	784	949	1,430	252	468	89.1	3,520	511	1,320	240	610	**97,200**	**9,220**	587	**4,490**	
Gross alpha, pCi/L	15	6.4	2.7	**18**		**18**		9.1		7.9		**74**	**73**	**24**	8.4	11	**1,800**	**26**	2.3	8.2	
Gross beta, pCi/L	50	**110**	16	**180**	9.4	**30,000**	**2,900**	27	4.8	**69**	11	**140**	**57**	**63**	15	**78**	**21,000**	**2,800**	**1,300**	**4,800**	
Gross beta (filtered), pCi/L	50	15																			
Hexavalent Chromium, µg/L	100	57	34.8	**974**	68.6	**189**	5.2	**59,500**	**270**	**139**	39					91.9	**381**	5.8	70.3	52.9	
Hexavalent Chromium (filtered), µg/L	100	58	34.8	**966**	73.5	**186**	5.3	**63,200**	**294**	**140**	42.2					92.9	**380**	5.9	75.2	52.9	
Iodine-129, pCi/L	1																**6.51**	**9.68**	**8.7**	**39.6**	
Mercury, µg/L	2			0.042													1.35			0.136	
Mercury (filtered), µg/L	2			0.11		1.82											1.39			0.125	
Methylene chloride, µg/L	5					**12**		0.61		0.62		1.6				0.18	0.2	1.2	1.7	**15**	
Nickel, µg/L	100	9	7	**109**	7	**633**	**9**	**143**	**170**	16		56		7.9		36	98.4	31	**197**	**247**	
Nickel (filtered), µg/L	100	7	6	97.9	4	**1,510**	**6**	**138**	**171**	19		53.7	4	9.3		30	99.7	25	**183**	91	
Nitrate, µg/L	45,000	44,200	13,800	**84,600**	22,800	**500,000**	**753,000**	**99,200**	37,000	43,700	3,660	**136,000**	**78,200**	**338,000**	**88,000**	**139,000**	**1,540,000**	**172,000**	**1,080,000**	**2,830,000**	
Nitrate (filtered), µg/L	45,000	8,100															40,300	**94,700**			

This page intentionally left blank.

Table 1-3. (Cont.)

Contaminant, Units (alphabetical order)	DWS (DCG)[a]	100-BC-5 OU		100-KR-4 OU		100-NR-2 OU		100-HR-3-D		100-HR-3-H		300-FF-5 OU		1100-EM-1		100-FR-3 OU	200-BP-5 OU	200-PO-1 OU	200-UP-1 OU	200-ZP-1 OU	Confined Aquifers
		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Wells	Wells	Wells	Wells	Wells
Nitrite, µg/L	3,300			690		**5,260**	1,210	3,080	62.4	2,270						328	**4,340**	2,200	281	677	
Nitrite (filtered), µg/L	3,300																342				
Plutonium-238, pCi/L	30															0.26					
Plutonium-239/240, pCi/L	30															1.12	***42.6***				
Radium-226, pCi/L	5					**32.5**															
Radium-228, pCi/L	5																	2.42			
Selenium, µg/L	50	4.2		5.1	2.1	3.94	2.13	6.53	1.76	3.2	0.501	47		3.12		5.38	16.8	13.4		4.54	
Selenium (filtered), µg/L	50	8.31		4.7		45.2	2.11	6.22		2.56		**59**		2.69		5.36	17.5	10.6		47	
Strontium-90, pCi/L	8	**49**	**18**	**45**		***19,000***	**1,200**	5	3.2	**28**	**9.9**					**19**	**4,200**	**16**	2.1	1.4	
Styrene, µg/L	100			0.21		0.24										0.52	0.21				
Technetium-99, pCi/L	900	26		55		45		16		94	6.9	210		13		110	**38,000**	**5,300**	**65,000**	**9,900**	
Technetium-99 (filtered), pCi/L	900	18																			
Tetrachloroethene, µg/L	5					0.5		0.14	0.34	0.16	0.47	0.38	3.2			1.1	0.27		0.12	1.7	
Thallium, µg/L	2	1		**40**	0.98	**64**		**43.6**	0.326	**37.8**		**74**		**67**			**51**	**64**			
Thallium (filtered), µg/L	2	1.2		**41**	1.3	**43**		**39**		**47**		**70**				**52**	**79**	**48**		**35**	
Toluene, µg/L	1,000			0.35		0.31		0.18	0.6	0.062	1.1			0.14		0.17				0.064	
Trichloroethene, µg/L	5	3.3		**7.4**		0.29		0.33		0.44	0.42	3	**430**			**20**	3.9	2.8	**8.8**	**12**	
Tritium, pCi/L	20,000	**69,000**	8,700	**280,000**	6,000	17,500	14,000	9,900	18,000	9,000		**900,000**	6,300	315		3,800	**35,000**	**590,000**	**71,000**	**1,600,000**	
Tritium (filtered), pCi/L	20,000	9,600																			
Uranium, µg/L	30	7.37		9.5	1.55	8.18		4.82	1.44	11	0.701	**188**	**207**	26.5	20.4	15.4	**3,670**	**75.4**	**417**	26.3	
Uranium (filtered), µg/L	30	1.66								12.2							5.29			1.16	
Xylenes (total), µg/L	10,000			0.24		7.1		0.46	0.73		1.4					0.49	0.21				

Notes:

1. Table lists highest value for the 12-month reporting period (January 1, 2010, to December 31, 2010) in each groundwater interest area, excluding those flagged "R" or "Y" or special (non-routine) samples.
2. Concentrations in **bold** exceed federal or state DWS; those in ***bold italics*** exceed derived concentration guideline (DCG).
3. Blank cells indicate a constituent was not detected or not analyzed.

a. Most metals analyses are run both unfiltered and field-filtered samples. Higher concentrations in unfiltered samples indicate particulate matter in the sample. Note that analyses specifically for hexavalent chromium usually are not filtered in the field.

b. There is no DWS for plutonium-239/240. The 4 mrem/year effective dose equivalent is 1.2 pCi/L.

This page intentionally left blank.

Table 1-4. RCRA Monitoring Status for the Reporting Period

RCRA Unit	Report, Section	Status for Reporting Period
1301-N (116-N-1) LWDF	Chapter 6.0, Section 6.3.1	Continued indicator evaluation.[a]
1324-NA (120-N-) and 1324-N (120-N-2) ponds	Chapter 6.0, Section 6.3.2	Continued indicator evaluation.[a]
1325-N (116-N-3) LWDF	Chapter 6.0, Section 6.3.3	Continued indicator evaluation.[a]
116-H-6 (183-H) evaporation basins	Chapter 7.0, Section 7.3	Corrective action alternative program during interim remedial action; chromium and nitrate.
216-A-29 Ditch	Chapter 10.0, Section 10.3.4	Continued indicator evaluation.[a]
216-B-3 Pond	Chapter 10.0, Section 10.3.5	Continued indicator evaluation.[a]
216-B-63 Trench	Chapter 9.0, Section 9.3.6	Continued indicator evaluation.[a]
216-S-10 Pond and Ditch	Chapter 11.0, Section 11.3.3	Continued indicator evaluation;[a] completion of first year of RCRA analyses for three new wells; establishment of new background critical mean values.
316-5 (300 Area) Process Trenches	Chapter 13.0, Section 13.3	Compliance/corrective action; organics.
IDF	Chapter 10.0, Section 10.3.1	Not yet in use; monitoring results added to background data set.
LERF	Chapter 9.0, Section 9.3.5	Two new wells monitor fractured basalt flow top; DOE and Ecology pursuing agreement for monitoring.
LLWMA-1	Chapter 9.0, Section 9.3.1	Continued indicator evaluation.[a]
LLWMA-2	Chapter 9.0, Section 9.3.2	Continued indicator evaluation.[a]
LLWMA-3	Chapter 12.0, Section 12.4.1	Statistical evaluations suspended until upgradient wells installed and background values established. New monitoring plan (DOE/RL-2009-68) implemented in CY 2010.
LLWMA-4	Chapter 12.0, Section 12.4.2	Total organic carbon exceeded critical mean value in August 2008; returned to indicator evaluation status CY 2009; remaining upgradient wells went dry in CY 2010. New monitoring plan (DOE/RL-2009-69) implemented in CY 2010.
NRDWL	Chapter 10.0, Section 10.3.6	Assessment showed elevated total organic carbon to be related to constituents other than dangerous waste constituents; returned to indicator evaluation status in CY 2010.
PUREX Cribs	Chapter 10.0, Section 10.3.2	Started 2010 in assessment; nitrate. 216-A-10 dropped from Hanford Site RCRA Permit. Separate new plans written for 216-A-36B and 216-A-37-1. New plans implemented January 1, 2011; in indicator evaluations status.
SST WMA A-AX	Chapter 10.0, Section 10.3.3	Assessment (first determination) showed site responsible for nickel contamination; continued in assessment; new assessment plan under review by Ecology.
SST WMA B-BX-BY	Chapter 9.0, Section 9.3.3	Continued assessment; cyanide.[b]
SST WMA C	Chapter 9.0, Section 9.3.4	Continued assessment; cyanide[b].
SST WMA S-SX	Chapter 11.0, Section 11.3.1	Continued assessment; chromium.[b]
SST WMA T	Chapter 12.0, Section 12.4.3	Continued assessment; chromium.[b]
SST WMA TX-TY	Chapter 12.0, Section 12.4.4	Continued assessment; chromium.[b]
SST WMA U	Chapter 11.0, Section 11.3.2	Continued assessment; chromium.[b]

a. Analysis of RCRA contamination indicator parameters provided no evidence of groundwater contamination with dangerous waste/ dangerous waste constituents from the unit.

b. Primary RCRA dangerous constituents at this unit.

Table 1-5. Selected Drinking Water Standards and Groundwater Cleanup Levels

Constituent	Unit	DWS	DWS Responsible Agency	MTCA[a]	Groundwater Quality Criteria[b]
Aluminum	µg/L	50 to 200[c]	EPA	16,000	--
Antimony	µg/L	6	EPA, DOH	6.4	--
Arsenic	µg/L	10	EPA, DOH	0.058	50
Barium	µg/L	2,000	EPA, DOH	3,200	1,000
Cadmium	µg/L	5	EPA, DOH	8.0	10
Carbon tetrachloride	µg/L	5	EPA, DOH	0.337	300
Chloride	mg/L	250[c]	EPA, DOH	--	250
Chloroform (TTHM)[d]	µg/L	80	EPA, DOH	7.17	7.0
Chromium	µg/L	100[e]	EPA, DOH	100/48[f]	50
cis-1,2-Dichloroethene	µg/L	70	EPA, DOH	80	--
Copper	µg/L	1,300[g]	EPA, DOH	640	--
		1,000[c]	EPA	--	--
Cyanide	mg/L	200	EPA, DOH	0.320	--
Fluoride	mg/L	4	EPA, DOH	0.960	4
		2[c]	EPA, DOH	--	--
Iron	µg/L	300[c]	EPA, DOH	11,200	--
Lead	µg/L	15[g]	EPA, DOH	--	50
Manganese	µg/L	50[c]	EPA, DOH	752	--
Mercury(inorganic)	µg/L	2	EPA, DOH	4.8	2
Methylene chloride (dichloromethane)	µg/L	5	EPA	5.83	--
Nitrate, as NO^{3-}	mg/L	45[b]	EPA, DOH	115	45[h]
Nitrite, as NO^{2-}	mg/L	3.31[i]	EPA, DOH	5.3	--
pH	--	6.5 to 8.5[c]	EPA, DOH	--	--
Selenium	µg/L	50	EPA, DOH	80	10
Silver	µg/L	100[c]	EPA, DOH	80	50
Sulfate	mg/L	250[c]	EPA, DOH	--	250
Tetrachloroethene	µg/L	5	EPA, DOH	80	0.8
Thallium	µg/L	2	EPA, DOH	1.12	--
Total dissolved solids	mg/L	500[c]	EPA, DOH	--	--
1,1,1-Trichloroethane	µg/L	200	EPA, DOH	16,000	200
Trichloroethene	µg/L	5	EPA, DOH	0.49	3
Uranium (total)	µg/L	30	EPA, DOH	48	--
Zinc	µg/L	5,000[c]	EPA, DOH	4,800	--

a. Model Toxics Control Act (MTCA), Method B cleanup levels for groundwater (WAC 173-340, "Model Toxics Control Act – Cleanup").

b. Groundwater quality criteria are regulated by Ecology under WAC 173-200 "Water Quality Standards for Ground Waters of the State of Washington."

c. Secondary standards are not associated with health effects, but associated with taste, odor, staining, or other aesthetic qualities.

d. Standard is for total trihalomethanes.

e. Total chromium.

f. Total chromium/hexavalent chromium.

g. Action level.

h. 45 mg/L as NO^{3-} is equivalent to 10 mg/L of nitrate as nitrogen.

i. 3.3 mg/L as NO^{2-} is equivalent to 1 mg/L of nitrite as nitrogen.

DOH = Washington State Department of Health (WAC 246-290, "Group A Public Water Supplies")

DWS = drinking water standard (maximum contaminant level for drinking water supplies)

EPA = U.S. Environmental Protection Agency (40 CFR 141, "National Primary Drinking Water Regulations"; 40 CFR 143, "National Secondary Drinking Water Regulations"; and EPA 822/R-96/001, *Drinking Water Regulations and Health Advisories*)

Table 1-6. Derived Concentration Guides, 4-mrem Effective Dose Equivalent Concentrations, Drinking Water Standards, and Risk-Based Concentrations for Hanford Site Radionuclides in Groundwater

Radionuclide	Derived Concentration Guide[a,b,c] (pCi/L)	4-mrem Effective Dose Equivalent[d] (pCi/L)	DWS[e] (pCi/L)	Risk-Based Concentration[f] (pCi/L)	
				Industrial	**Residential**
Antimony-125	60,000	300	300[g]	---[h]	---[h]
Beta particle and photon activity (mrem/yr)	Not applicable	50	4[i], 50[j]	---[k]	---[k]
Carbon-14	70,000	2,800	2,000[g]	1,030	34
Cesium-137	3,000	120	200[g]	60	1.7
Cobalt-60	5,000	200	100[g]	102	3.4
Iodine-129	500	20	1	11	0.36
Plutonium-239/240	30	1.2	None	12	0.39
Ruthenium-106	6,000	30	30[i]	---[h]	---[h]
Strontium-90	1,000	40	8	29	0.95
Technetium-99	100,000	4,000	900[g]	580	19
Tritium	2,000,000	80,000	20,000	2,600	160
Uranium-234[l]	500	20	None	23	0.75
Uranium-235[l]	600	24	None	23	0.76
Uranium-238[l]	600	24	None	25	0.83

a. Concentration of a specific radionuclide in water that could be continuously consumed at average annual rates and not exceed an effective dose equivalent of 100 mrem/year.

b. Values in this column represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford Site operations, and may be adjusted upward (larger) if accurate solubility information is available.

c. From DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*

d. Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/year if consumed at average annual rates. The EPA DWSs for radionuclides listed in Table 1-5 were derived based on a 4-mrem/year dose standard using maximum permissible concentrations in water specified in the *National Bureau of Standards Handbook 69* (NBS 1959). The 4-mrem/year dose standard listed in this table was calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (as implemented in DOE Order 5400.5 in 1993).

e. Concentrations listed in 40 CFR 141, "National Primary Drinking Water Regulations."

f. Based on slope factors from EPA's risk website: "Radionuclide Carcinogenicity Slope Factors" (http://epa.gov/radiation/heastindex.html). In turn, this was based on *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13 (EPA/402/R-99/001). These slope factors represent the risk of getting cancer if a person ingested water contaminated with each radionuclide over a lifetime (residential) or over a working lifetime (industrial). The tritium calculation also considers inhalation of tritium in air; for the other radionuclides, this path is insignificant.

g. The EPA DWSs for radionuclides were derived based on a 4-mrem/year dose standard using maximum permissible concentrations in water specified in *National Bureau of Standards Handbook 69* (NBS 1959).

h. Due to short life (less than 3 years), no risk-based concentration is calculated.

i. Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/year. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/year. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

j. Groundwater quality criteria from Table 1C of WAC 173-200-040, "Water Quality Standards for Ground Waters of the State of Washington," "Criteria."

k. See specific radionuclides for risk-based concentrations.

l. See Table 1-5 for total uranium.

Figure 1-1. Location of the Hanford Site

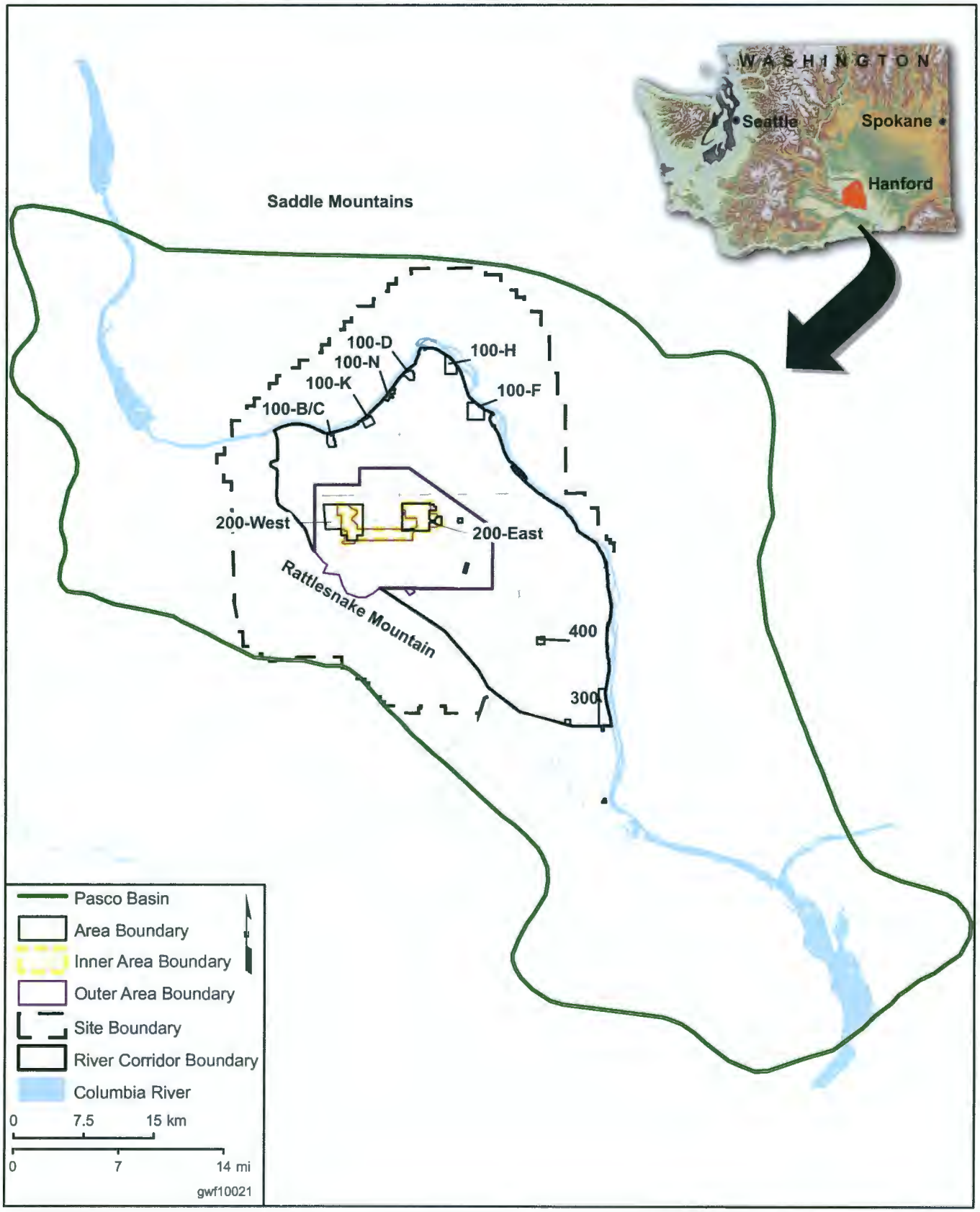


Figure 1-2. Groundwater Operable Units and Groundwater Interest Areas on the Hanford Site

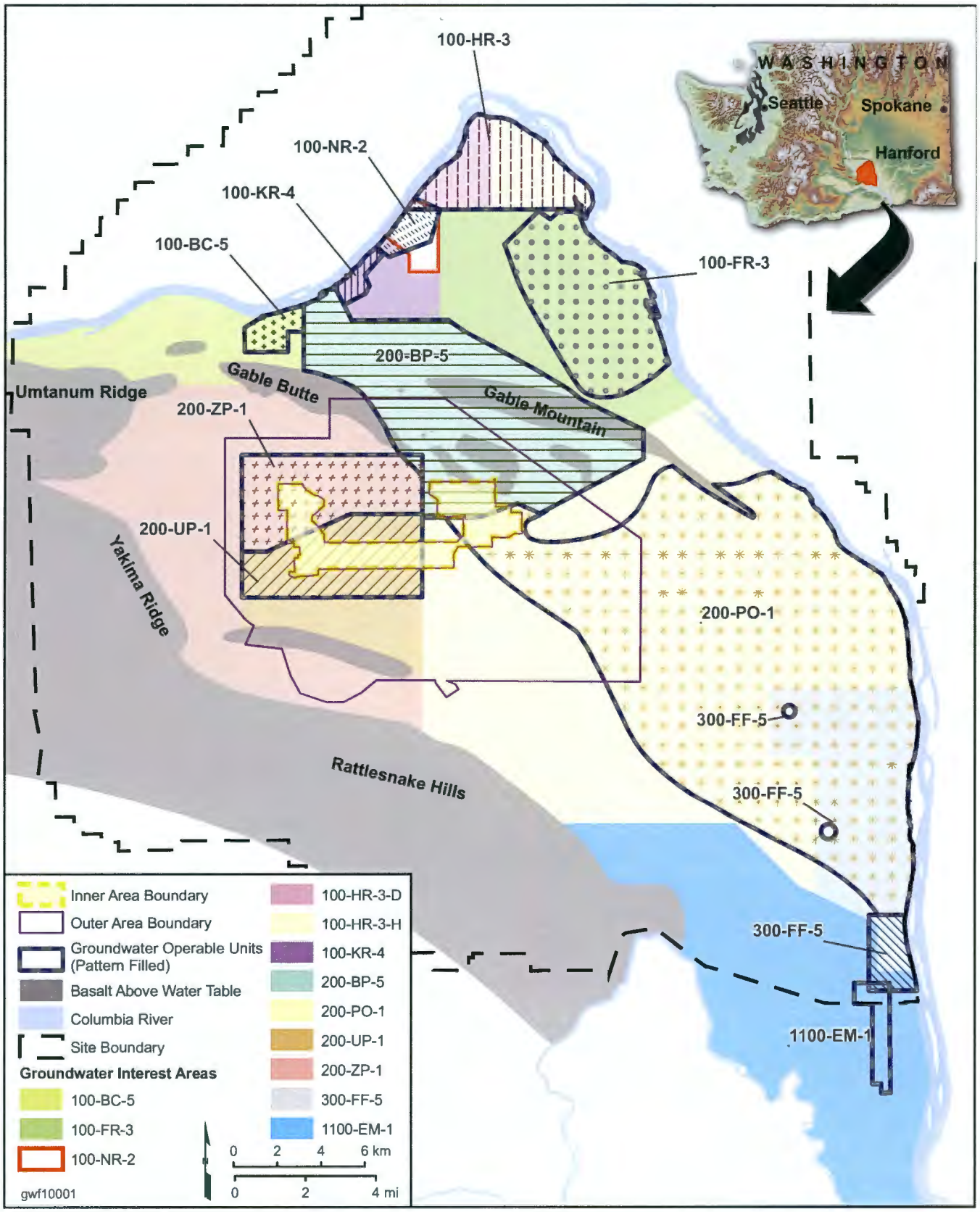


Figure 1-3. Average CY 2010 Tritium Concentrations on the Hanford Site, Upper Portion of Unconfined Aquifer

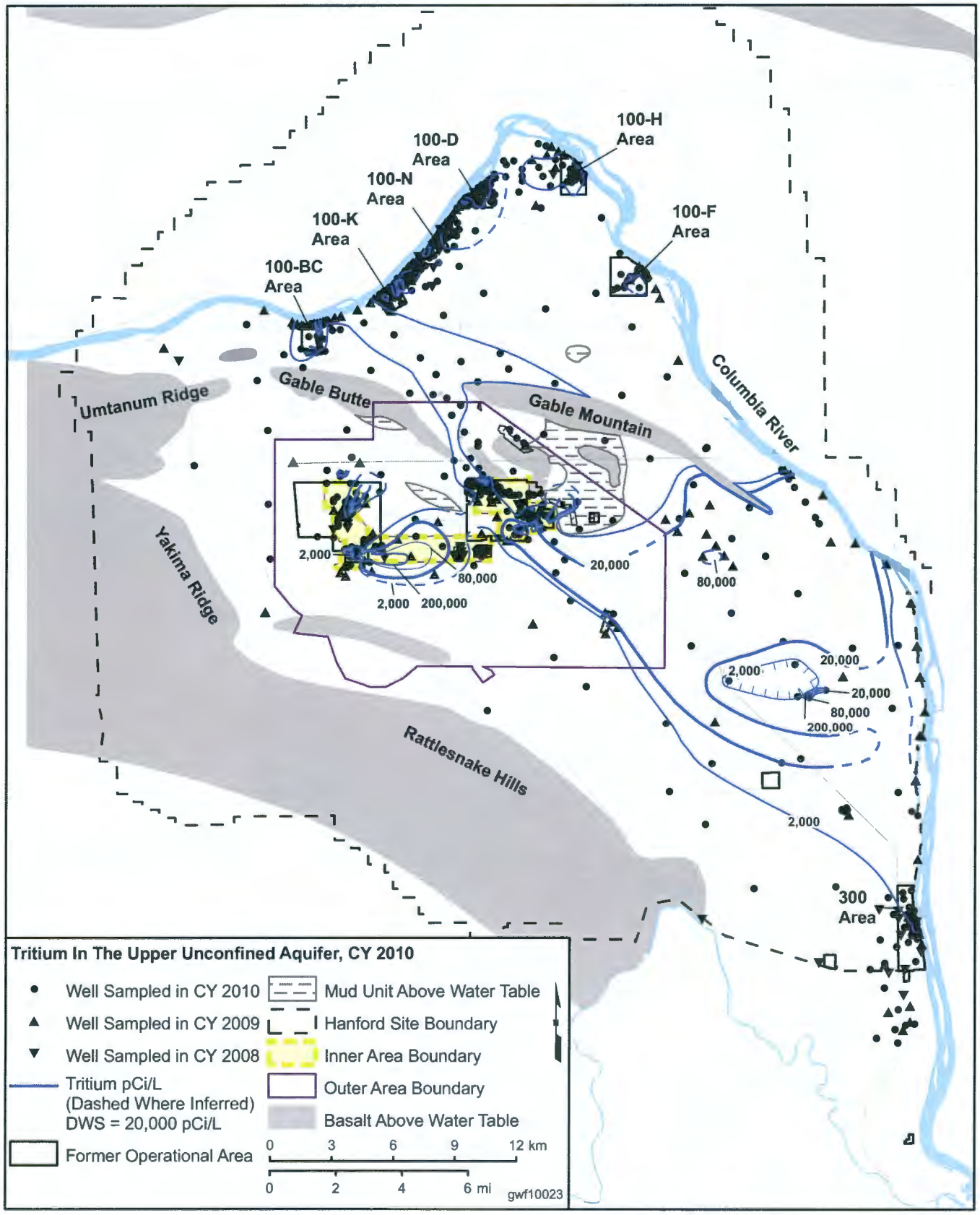
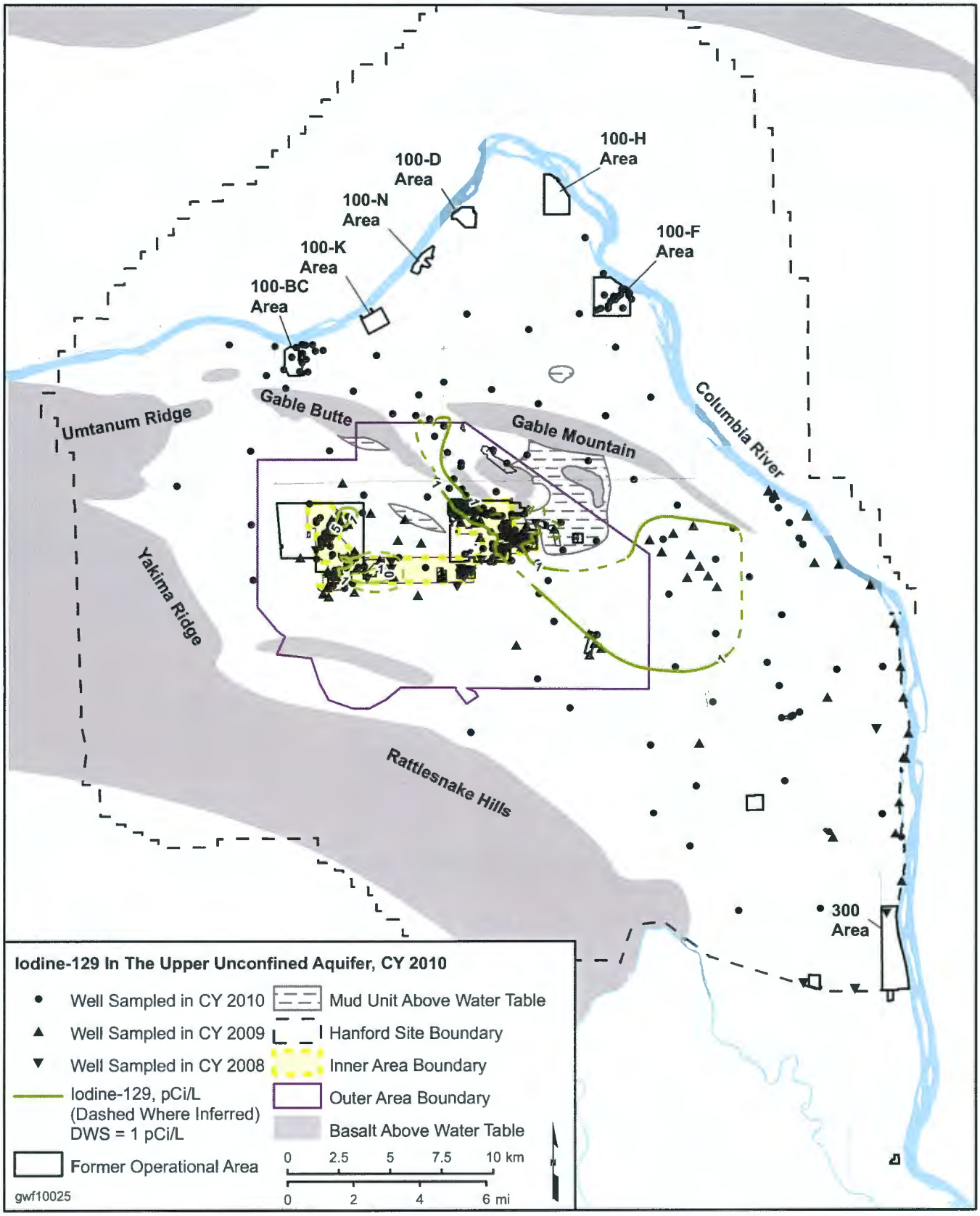


Figure 1-4. Average CY 2010 Iodine-129 Concentrations on the Hanford Site, Upper Portion of Unconfined Aquifer



This page intentionally left blank.

2.0 Overview of Hanford Hydrogeology and Geochemistry

C.J. Martin

This chapter discusses the hydrogeologic setting of the Hanford Site. The deposition and later removal of sedimentary units in certain areas by cataclysmic flooding contribute to the complex hydrogeology. The regional geologic setting of the Pasco Basin and the Hanford Site has been described in the documents listed in Section 2.6. The following sections provide a basic summary of Hanford Site geology, hydrology, and geochemistry.

2.1 Stratigraphic Setting

This section discusses the geology of the Hanford Site. The Hanford Site lies within the Pasco Basin (Figure 2-1). The geology of the Site has been studied extensively over the years. The simplified "layer cake" depositional model of basalt bedrock that is overlain by Ringold Formation sediments, overlain by Cold Creek sediments, overlain by Hanford formation sediments has been complicated by the method of deposition, and later removal, of some of the sedimentary units. During deposition of the Ringold Formation sediments, actions of the ancestral Columbia and Salmon/Clearwater River systems resulted in deposition of a thick sequence of alternating river gravels and sands, as well as overbank flood deposits, and alluvial fans shed from the surrounding hillsides. During the Cold Creek depositional cycle, while the activities in the ancestral river systems continued, large portions of the Pasco Basin remained stable. This stability allowed for the formation of structured soil horizons that can still be identified today in certain areas as the "early Palouse soil." During the last ice age, cataclysmic flooding deposited the coarse gravel to boulder sediments of the Hanford formation, while simultaneously scouring channels of varying depth into the previously deposited Cold Creek and Ringold sediments. As the multiple flooding events waned, and slack water conditions prevailed, fine sands to silts and clays were deposited over much of the Pasco Basin. All of these events contribute to the complex hydrogeology of the Hanford Site.

Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington, (BHI-00184) provides a stratigraphic interpretation for the Ringold Formation based on facies associations and defines the areal extent of these suprabasalt units in the Pasco Basin. *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin* (DOE/RL-2002-39) presents the standardized stratigraphic nomenclature for post-Ringold Formation sediments. A generalized stratigraphic column showing the nomenclature is provided in Figure 2-2. The following subsections discuss the various stratigraphic layers, from oldest (deepest) to youngest (shallowest).

2.1.1 Columbia River Basalt Group

The lowest geologic unit of interest for this report is the Columbia River Basalt Group. Within the Pasco Basin, the Elephant Mountain flows of the Saddle Mountains Basalt formation are generally the uppermost basalt flows. Beneath the Hanford Site's 200 Area, the Elephant Mountain Member consists of two flows and ranges in thickness from 20 to 30 meters (RHO-BWI-ST-14, *Subsurface Geology of the Cold Creek Syncline*). The earlier basalt flows below the Elephant Mountain Member are locally important but will not be discussed here.

The uppermost surface of the Elephant Mountain Member (basalt) is considered the base of the suprabasalt aquifer system (bedrock) because of its low permeability relative to the overlying sediments. This surface can be interpreted as either a groundwater no-flow boundary or a prescribe-flux boundary, depending on whether leakage between the confined and unconfined aquifers is considered significant (PNL-8971, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 93 Status Report*). In areas where the Elephant Mountain Basalt has been partially eroded (e.g., north of the 200 East Area), a similar boundary exists at the contact between the Rattlesnake Ridge interbed to the top of the Pomona basalt. In some areas, the upper surface of the Elephant Mountain Basalt is sufficiently fractured or rubbly to allow it to transmit water. In these areas the unconfined aquifer may extend into the upper portion of the basalt, and the massive flow interior acts as the no-flow boundary.

The basalt surface beneath the 200 Area dips south, forming the southern limb of the Gable Mountain anticline/northern limb of the Cold Creek syncline ("Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State -- A Summary" [Fecht et al., 1987]). Two smaller basalt folds or anticlinal ridges trending northwest-southeast extend above the water table and create barriers to groundwater flow (Figure 2-3).

Sedimentary interbeds, collectively referred to as the Ellensburg Formation, were deposited between many of the flows of the Saddle Mountains Basalt. The Ellensburg Formation includes fluvial and lacustrine sediments consisting of muds, sands, and gravels. The Rattlesnake Ridge interbed is the uppermost and most laterally extensive of these interbeds on the Hanford Site, and several wells are completed in this confined aquifer.

Intercommunication of groundwater between the uppermost basalt-confined aquifer (the Rattlesnake Ridge interbed) and overlying suprabasalt aquifer system has been documented in some areas of the Hanford Site, most notably beneath the B Pond (RHO-BWI-ST-14) (see Chapter 15.0). Another area of intercommunication is near Gable Gap, where the upper basalt units have been eroded, exposing the lower units and interbeds to the uppermost unconfined aquifer (PNL-10817, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System*). The dominant vertical flow is now upward in most of these intercommunication areas.

2.1.2 Ringold Formation

The thick sedimentary sequence of the Ringold Formation overlies the basalt. The Ringold Formation can be divided into three broad facies types, depending on the proximity to the ancient river systems and basaltic ridges of the time (Figure 2-4):

- **Type I facies:** Consists of gravel and associated sand and silt representing a migrating channel deposit of the ancestral Columbia and/or Salmon/Clearwater River systems. This type of sediment is generally confined to the central portion of the Pasco Basin.
- **Type II facies:** Comprises mainly overbank sand, silt, and clay deposited around the margins of the basin, away from the main fluvial channel system.
- **Type III facies:** A fanglomerate facies comprising angular basaltic debris derived from side-stream alluvium shed from the flanks of the basalt ridges. This facies occurs only locally around the extreme margins of the basin.

To date, two separate Hanford Site stratigraphic classifications have been used to describe Ringold Formation sediments. One classification, developed in BHI-00184, is based on lithology; the second classification, developed by Pacific Northwest National Laboratory (PNNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*; PNL-8971), is based primarily on hydrostratigraphy (also see PNNL-10886). This report uses the hydrostratigraphic classification because it is more applicable to the issue of addressing groundwater movement in the suprabasalt sediments (Figure 2-2). A hydrogeologic summary of these units is presented below.

The Ringold Formation is broadly divided into two units: an upper unit, consisting of lacustrine deposits and intercalated fluvial sands; and a lower unit that is subdivided into five subunits. BHI-00184 provides a detailed description of the upper Ringold unit. The upper Ringold unit forms the bluffs along the Columbia River north and east of the Hanford Site but has largely been removed by erosion from the site itself.

The lower Ringold Formation is subdivided into five subunits (units 5 through 9) and is discussed below, from deepest to shallowest.

2.1.2.1 Ringold Formation Unit 9

The deepest Ringold sediments belong to unit 9, which is a mixture of clay, silt, fine- to coarse-grained sand, and granule to cobble gravel. In the eastern portion of the 200 East Area, unit 9 can be further subdivided into three hydrogeologic units based on markedly different lithologies and hydraulic properties. The primary subunit is characterized as a silt to clay-rich confining zone with low permeability, classified as unit 9B. Subunits 9A and 9C have much higher permeabilities and lower clay content. Subunits 9A, 9B, and 9C can be differentiated and mapped as separate units using geophysical logs, lithologic logs, and drillers' reports based on the correlation of unit 9B where it is laterally continuous.

Unit 9 dips consistently to the south-southwest, roughly comparable to the basalt structure. Unit 9 increases in thickness from north to south into the Cold Creek syncline, suggesting deposition of Ringold unit 9 in an environment of continued structural growth of the Pasco Basin (SD-BWI-DP-039; DOE/RW-0164, *Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*).

The north-northeastern extent of unit 9 is approximate and is delineated as the erosional limit of cataclysmic flooding that traversed across the uplifted Gable Butte anticlinal area (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*). In the scoured area (interpreted to be north of the erosional boundary), most of the Ringold Formation has been all or partially removed and/or reworked within the area of erosion. Data from north and east of the B Pond suggest that only portions of units 9A/9C and 9B are preserved on the lee side and between the smaller anticlinal ridges within this erosional area (PNNL-12261).

In the northern Hanford Site, unit 9 is present beneath the 100-B/C, 100-K, and 100-N Areas.

2.1.2.2 Ringold Formation Lower Mud Unit (Unit 8)

The Ringold lower mud unit is composed of a thick sequence of fluvial overbank, paleosol, and lacustrine silts and clay, with minor sand and gravel. A more detailed description of the lower mud unit is presented in BHI-00184.

The Ringold lower mud unit is the most significant confining unit within the suprabasalt aquifer system on the Central Plateau. The lower mud unit separates

the saturated sediments of the suprabasalt aquifer system into (1) an uppermost unconfined aquifer system often referred to as the Hanford unconfined aquifer, and (2) a lower confined aquifer system referred to as the confined Ringold aquifer system. In the 200 East Area, a secondary confined Ringold aquifer system is composed of subunit 9A/9C gravels separated by subunit 9B. The uppermost unconfined aquifer system includes saturated sediments above the lower mud unit or the top of subunit 9B, or the top of basalt in the areas where the lower mud unit is absent.

BHI-00184 indicates that east of B Pond and south of the 200 East Area, the lower mud unit is regionally continuous throughout the Pasco Basin. However, as BHI-00184 and other publications describe, the lower mud unit is not present on the Gable Mountain anticline, including Gable Gap and the region to the south, extending to the northern boundary of the 200 West Area and including most of the 200 East Area. BHI-00184 suggests that the absence of the lower mud unit is due to either depositional thinning onto the basalt structure or truncation by Ringold unit 5 or Hanford formation sediments. Geologic, geophysical, and hydraulic data indicate that where channeling occurs, erosion appears to have scoured into and/or completely removed all the lower mud unit and unit 5, with the possible exception of small, localized remnants (Figure 2-5).

Where the lower mud unit is present, the maximum thickness is between 26 meters (in the 200 West Area) and up to 29 meters (in the 200 East Area), and it dips south to southwest into the Cold Creek syncline, roughly paralleling the basalt structure. The revised structural map of the Ringold lower mud unit illustrates that it is elevated above the groundwater surface east and south of the B Pond and between the 200 East and 200 West Areas (Figure 2-6). In these areas where the Ringold lower mud unit is at or above the water table, it is mapped as a hydraulic barrier similar to the basalt surface (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*).

The hydrogeologic continuity and thickness of the lower mud unit indicate that groundwater within the Hanford unconfined aquifer and confined Ringold aquifer system does not flow vertically through this unit. However, flow along the lateral boundary of the lower mud unit does occur, and where it has been removed by erosion, groundwater from the confined Ringold aquifer system may be in communication with groundwater from the uppermost unconfined aquifer. Along the May Junction Fault where uplift has juxtaposed the lower mud unit adjacent to the unconfined aquifer, intercommunication between the Ringold confined and the upper unconfined aquifers may also occur.

2.1.2.3 Ringold Formation Units 6 and 7, Overbank Deposits and Upper Mud Unit

Unit 7 consists of fluvial gravels overlain by the fine-grained overbank and lacustrine deposits (clay, silt, silty fine-grained sand, and paleosols) of Ringold unit 6. The shallowest overbank deposits are known informally as the Ringold upper mud unit in the 100 Area, where this unit forms the bottom of the unconfined aquifer. These units have been largely removed by later flooding from beneath the 200 Area or were possibly never deposited in this area.

2.1.2.4 Ringold Formation Unit 5

Unit 5 is the uppermost of the Ringold Formation units in the unconfined aquifer (Figure 2-2) and is composed primarily of fluvial gravels that grade upward into the interbedded fluvial sand and silt of the upper Ringold unit (BHI-00184). The unconfined aquifer resides in Ringold unit 5 beneath the 100-B, 100-N, and

100-K Areas; most of the 200 West Area; and the southern and western portions of the 200 East Area.

In the 200 Area, unit 5 overlies the lower mud unit and is present everywhere, except the very northeastern portion of the 200 West Area and in the northern portion of the 200 East Area. Within the 200 East Area, unit 5 is present only in the southern portion because the unit has been removed by erosion (PNNL-13858).

Ringold unit 5 has also been removed from the Gable Gap and most of the 200 East Area to approximately the May Junction Fault. Unit 5 was not removed from the downthrown side of the fault because of structural displacement into the basin and distance away from the highest forces of the Pleistocene floods (PNNL-12261).

Ringold unit 5 is also absent beneath the eastern part of the "horn" area of the Hanford Site (i.e., the 100-H and 100-F Areas) and beneath the 300 Area.

2.1.3 Cold Creek Unit

After deposition of the Ringold Formation sediments, a period of regional incision occurred, followed by soil development and deposition of windblown sediments during the late Pliocene to early Pleistocene ("Late-Cenozoic Stratigraphy and Tectonic Evolution Within a Subsiding Basin, South-Central Washington" [Bjornstad, 1985]). These deposits are referred to as the Cold Creek unit (CCU). In the eastern portion of the Pasco Basin, the CCU is not found and, therefore, was either not deposited or was eroded later by the Columbia River or cataclysmic flooding.

Several different facies associations are represented by the CCU, including (1) mainstream alluvial, (2) calcic-paleosol, (3) side-stream-alluvial, (4) colluvial, and (5) overbank-eolian facies associations (Figure 2-7). The CCU in the 200 West Area is represented by the calcic paleosol (the early Palouse soil) and overbank/eolian facies (Cold Creek silt unit [CCU_z]), which is a silt and/or well-sorted, fine sand.

In much of the 200 East Area and elsewhere in the Pasco Basin, a quartzo-feldspathic sandy gravel above the Ringold Formation and below the more basaltic Hanford formation has been identified. This intermediate gravel is referred to as the Cold Creek gravel unit (CCU_g) (PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and into the Upper Unconfined Aquifer Below the B-Complex*). The CCU_g is mineralogically similar to the Ringold Formation, with the exception that it often caves and heaves during drilling. The loose, unconsolidated nature of these sediments suggests that they are post-Ringold in age and belong to a mainstream gravel facies of the CCU. These most likely represent fluvial deposits from the ancestral Columbia River, perhaps equivalent to the pre-Missoula gravels (PSPL, 1982) identified east of the 200 Area. The upper surface of the CCU_g unit shows ~10 meters of relief.

2.1.4 Hanford Formation

The "Hanford formation" is the informal name given to Pleistocene-age cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39, RHO-BWI-ST-4, *Geological Studies of the Columbia Plateau – A Status Report*; DOE/RW-064; "Quaternary Geology of the Columbia Plateau" [Baker et al., 1991]; "Geohydrologic Setting of the Hanford Site, South-Central Washington" [Lindsey et al., 1994]). Sources for the floodwaters included Glacial Lake Missoula, pluvial Lake Bonneville, and ice-margin lakes that formed around the margins of the Columbia Plateau (Baker et al., 1991). These floods periodically inundated the Pasco Basin during the Pleistocene, often eroding existing sediments ("Pre-Wisconsin Glacial Outburst Floods: Pedogenic and Paleomagnetic Evidence from the Pasco Basin and Adjacent Channeled Scabland"

[Bjornstad and Fecht, 1989]). As the floodwaters encountered restricted flow through Wallula Gap, both coarse- and fine-grained sediments entrained in the floodwaters were deposited within the basin. As the floodwaters gradually drained away, both deposition and erosion occurred. This sequence of events occurred a number of times, leaving behind distinct geomorphic features (Figure 2-8) and creating a complex stratigraphy within the Hanford formation, with lenses of sand and silt surrounded by sand and gravel. However, fine-grained sediments are mainly found near the margins of the basin, and coarse-grained sediments are found in the central portion where the flood currents were stronger.

The Hanford formation forms a nearly continuous blanket over the entire Hanford Site, except near flood-scoured Gable Butte/Gable Mountain and other basalt outcrops. In the northern portion of the 200 West Area, the Hanford formation directly overlies basalt; further to the south, it overlies the CCU and Ringold Formation. The Hanford formation consists predominantly of unconsolidated sediments covering a wide range in grain size: from boulder-size gravel to sand, silty sand, and silt. Gravel clasts are composed of mostly sub-angular to sub-rounded basalt. Mineralogically, the sand fraction of the Hanford formation averages ~50% mafic rock fragments (i.e., basalt) and ~50% quartz feldspar (RHO-ST-23, *Geology of the Separations Areas, Hanford Site, South-Central Washington*).

Cataclysmic flood deposits of the Hanford formation have been classified into three facies types (gravel, sand, and interbedded sand- and silt-dominated), which grade into one another both vertically and laterally. The three facies may interfinger with or grade from gravel to sand, or sand to fine-grained facies, but rarely from gravel to fine-grained facies.

2.1.4.1 Gravel-Dominated Facies

The gravel-dominated facies of the Hanford formation (designated as "H1" in the cross sections) consists of coarse-grained basaltic sand and granule- to boulder-size gravel. These deposits display an open-framework texture, plane to low-angle massive bedding, and large-scale planar cross-bedding in outcrop. Gravel-dominated beds sometimes grade upward into sand- and silt-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of Ringold Formation clasts, granite, quartzite, and gneiss (WHC-SD-EN-TI-012, *Geologic Setting of the 200-East Area: An Update.*). The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channels (i.e., the Pasco Basin channel way [Figures 2-8, 2-9, and 2-10]).

2.1.4.2 Sand-Dominated Facies

The sand-dominated facies of the Hanford formation (designated as "H2" in the cross sections) consists of fine- to coarse-grained sand and granule gravel. The sands typically have high basalt content and are commonly referred to as black, gray, or "salt-and-pepper" sands. The sands may contain small pebbles and rip-up clasts, pebble-gravel interbeds, and often grade upward into thin (less than 1 meter) zones of silt-dominated facies. This facies commonly displays plane lamination and bedding, and also less flood channels during the waning stages of flooding. This facies is transitional between the gravel-dominated facies and the silt-dominated facies, and it is the major component of the Hanford sand plain (Figures 2-8 and 2-11).

2.1.4.3 Interbedded Sand- and Silt-Dominated Facies

The interbedded sand and silt-dominated facies of the Hanford formation (designated as "H3" but not occurring in any of the cross sections) consists

of thin-bedded, plane-laminated, and ripple cross-laminated silt and fine- to coarse-grained sand. Beds are typically a few centimeters to a meter in thickness and commonly display normally graded bedding (WHC-SD-EN-TI-012). Sediments of this facies were deposited under slack water conditions and in back-flooded areas (DOE/RW-0164; Baker et al., 1991). This facies is typified by the stratigraphy found through the various flood bars (Figure 2-8).

2.1.5 Clastic Dikes

Clastic dikes are vertical to sub-vertical sedimentary structures that crosscut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Area, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation.

Clastic dikes occur in swarms and form four types of networks (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity: Geologic Atlas Series*): (1) regular-shaped polygonal patterns, (2) irregular-shaped polygonal patterns, (3) pre-existing fissure fillings, and (4) random occurrences. Regular polygonal networks resemble four- to eight-sided polygons and typically range from 3 centimeters to 1 meter in width, 2 meters to greater than 20 meters in depth, and 1.5 to 100 meters along strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer skin of clay with coarser infilling material. Clay linings are commonly 0.03 to 1.0 millimeters in thickness, but linings up to ~10 millimeters are known. The width of individual infilling layers ranges from as little as 0.01 millimeters to more than 30 centimeters, and their length can vary from ~0.2 meters to more than 20 meters. Infilling sediments are typically poorly sorted to well-sorted sand but may contain clay, silt, and gravel (HNF-4936, *Subsurface Conditions Description Report for the S-SX Waste Management Area*). The importance of clastic dikes in determining the migration potential of contaminants from the near-surface disposal facilities to the water table is still debated.

2.1.6 Holocene Surficial Deposits

Holocene surficial deposits consisting of silt, sand, and gravel form a thin (less than 5-meter) veneer across much of the Hanford Site. In the 200 West Area and the southern portion of the 200 East Area, these deposits consist dominantly of laterally discontinuous sheets of windblown silt (loess) and fine-grained sand (PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*).

2.2 Tectonic Setting

Tectonic activity has occurred in the Pasco Basin throughout its history but has become fairly stable since the deposition of the CCU sediments. The Columbia River Basalt and Ringold Formation sediments both show extensive structural development in the form of anticlines and synclines (folded ridges and valleys). The larger of these structures on the Hanford Site are shown in Figure 2-3. From a hydrogeologic perspective the Umtanum Ridge-Gable Mountain anticline is the more important feature. This anticline is an upward flexure of the Columbia River Basalt that creates Gable Butte and Gable Mountain and has smaller anticlines associated with its limbs that place the basalt at or above the water table in areas to the southwest.

As an additional visual guide to the key stratigraphic elements, three cross sections from *Hydrogeologic Model for the Gable Gap Area, Hanford Site* (PNNL-19702) are

provided in this chapter. Although of limited extent, these cross sections provide a view of the complex geology of the Hanford Site resulting from structural deformation as well as from cataclysmic floods during the last ice age. Cross-section 1 (A-A') (Figure 2-10) is along a roughly north-south line from the upstream edge of the horn flood bar south through Gable Gap to the southern end of Waste Management Area B-BX-BY (Figure 2-9). Cross-section 2 (B-B') (Figure 2-11) is an east-west line across Gable Gap showing the paleochannels incised into the basalts. Cross-section 3 (C-C') (Figure 2-5) is another roughly east-west line located further south than cross-section 2; it clearly shows how the incised paleochannels left remnants of Ringold Formation sediments and places Hanford formation sediments in direct communication with the basalt-confined aquifers.

2.3 Hydrologic Setting

Both unconfined and confined aquifer systems lie beneath most of the Hanford Site. The unconfined aquifer system is located in unconsolidated to semiconsolidated sediments of the Hanford and Ringold formations overlying the basalt bedrock. In some areas, the unconfined aquifer extends into the fractured upper zone of the underlying basalt. Parts of this aquifer are locally semiconfined or confined (confined Ringold). However, because the entire suprabasalt aquifer system is interconnected on a Hanford Site-wide scale, this system has commonly been referred to as the Hanford unconfined aquifer. Aquifers located within the Columbia River Basalt Group are referred to as the basalt-confined aquifer system.

2.3.1 Confined Aquifer

Confined aquifers within the Columbia River Basalt Group are composed of relatively permeable sedimentary interbeds and the brecciated tops of basalt flows. The horizontal hydraulic conductivities of most of these aquifers range from 10^{-4} to 10^{-10} meters per second. Dense interior sections of the basalt flows have horizontal hydraulic conductivities ranging from 10^{-9} to 10^{-15} meters per second, about five orders of magnitude lower than those of the confined aquifers (DOE/RW-0164). Groundwater in the confined aquifers underlying the Hanford Site results mainly from infiltration of precipitation and stream flow, within recharge areas along the periphery of the Pasco Basin (DOE/RW-0164). Hydraulic head information indicates that groundwater in the confined aquifers flows generally toward the Columbia River and, in some places, toward areas of enhanced vertical flow communication with the unconfined system (*Maps Showing Ground-Water Levels in the Columbia River Basalt and Overlying Materials, Spring 1983, Southeastern Washington* [Bauer et al., 1985]; SD-BWI-TI-335, *Fresh-Water Potentiometric Map and Inferred Flow Direction of Ground Water Within the Mabton Interbed, Hanford Site, Washington State -- January 1987*; DOE/RW-0164).

With regard to development of a conceptual model for groundwater flow and contaminant migration in the unconfined aquifer, the confined aquifer system is important because the two systems are known to be in hydraulic communication in the area northwest of the 200 East Area (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Area of the Hanford Site*; DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*). Although the dominant gradient is now upward in the confined aquifer system (flow moving from the confined to the unconfined aquifer), the potential also exists for significant downward groundwater leakage between the two systems in areas where

hydraulic heads in the unconfined aquifer were artificially increased (see Chapter 15.0, Section 15.2).

2.3.2 Unconfined Aquifer

Groundwater in the unconfined aquifer at the Hanford Site generally flows from recharge areas in the elevated region near the western boundary of the Site, toward the Columbia River on the eastern and northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. The Yakima River borders the Hanford Site on the southwest and is generally regarded as a source of recharge. Natural areal recharge across the entire Hanford Site depends on a number of variables, most notably soil type and vegetation cover. Thus, recharge ranges from a general low of 1.5 millimeters per year for areas with a natural shrub-steppe vegetation cover to a high of 52 centimeters per year for unvegetated areas in the 100-H Area and eastern 200 Area (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*). It should also be noted that recharge can be artificially reduced/enhanced to as low as 0.04 millimeters per year for engineered evapotranspiration covers or as high as 92 millimeters per year for unvegetated gravel areas. Since 1944, the artificial recharge from Hanford Site wastewater disposal operations has been greater than the natural recharge, estimated at 17.2 millimeters per year (PNNL-18807, *Soil Water Balance and Recharge Monitoring at the Hanford Site – FY09 Status Report*). An estimated 1.68 x 10^{12} liters of wastewater were discharged to disposal ponds, trenches, and cribs to date. The volumes of wastewater discharged to the ground surface have steadily declined, from ~14 billion liters in 1990, to ~0.6 billion liters by 2000. The greatest decreases occurred in 1996, when all major waste streams were discontinued and combined into very few Washington State Permitted liquid discharges. In calendar year 2010, ~333 million liters of wastewater were discharged to the ground surface. The two largest discharge locations are on the Central Plateau at the 200 Area Treated Effluent Disposal Facility (~93% of the total site-wide discharge) and the State-Approved Land Disposal Site (~6% of the total). The remaining ~1% of artificial recharge comes from releases to the 400 Area process ponds and the 100-N Area filter backwash pond and sanitary sewage lagoon.

The unconfined aquifer at the Hanford Site lies mainly within the Ringold Formation and Hanford formation. Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from ~10^{-4} to 10^{-5} meters per second (DOE/RW-0164). Because the Ringold sediments are more heterogeneous and consolidated, contain more silt, and are not as well sorted, these sediments are approximately three times less permeable than the sediments of the overlying Hanford formation along the River Corridor and up to 1,000 times less permeable than the Hanford formation sediments in the Central Plateau. Wastewater discharges increased the water table elevation and created groundwater mounds under the two main wastewater disposal areas near the 200 East and 200 West Areas. Because of the increased groundwater elevation during site operations, the unconfined aquifer extended upward into the Hanford formation. This change resulted in increased transmissivity. Since large wastewater discharges ceased, water levels have declined and are approaching pre-Hanford conditions, as well as an associated decrease in transmissivity.

From 1944 through 1989, the largest water table increase of ~24 meters occurred under the 216-U-10 Pond in the 200 West Area, while an increase of ~9 meters occurred under the 216-B-3 Ponds near the 200 East Area. The volume of water discharged to the ground at the 200 West Area is actually less than that discharged at the 200 East Area; however, the lower permeability of the aquifer in the vicinity

of the 200 West Area has inhibited groundwater movement in this area and resulted in a higher groundwater mound. The presence of the groundwater mounds also affected the direction of groundwater movement, causing radial flow from the discharge areas. In *Hanford Site Water-Table Changes, 1950 Through 1980 -- Data Observations and Evaluation* (PNL-5506), changes documented in the water table elevation showed that the edge of the mounds migrated outward from the sources over time until about 1980. Water levels have declined in most areas since 1980 due to decreased wastewater discharges (PNL-7498, *Evaluation of Hanford Site Water-Table Changes -- 1980 to 1990*).

Since non-permitted discharges of wastewater to unlined ponds ceased in 1996, groundwater levels have been declining across the Hanford Site. The water table has decreased 3 meters in the 200 East Area and 13 meters in the 200 West Area. Although some permitted discharges continue today (e.g., Treated Effluent Disposal Facility and State-Approved Land Disposal Site), the water table continues to decline. As a result, groundwater flow directions around the Hanford Site are also changing to a more regional direction (see discussion in Chapter 3.0).

In the 1950s through 1960s, groundwater mounds of 6 to 9 meters were present in each of the 100 Areas (WHC-SD-EN-TI-023, *Hydrologic Information Summary for the Northern Hanford Site*). A mound persisted in the 100-N Area until 1991.

2.3.3 Vadose Zone

The Hanford formation and CCU comprise most of the vadose zone. The CCU (both CCU_z and CCU_g) represents relatively thin, but significant, depositional units of post-Ringold and pre-Hanford sedimentation. The vadose zone ranges in thickness from less than 1 meter near the Columbia River to greater than 50 meters beneath the Central Plateau.

2.3.4 Groundwater/River Interactions

It is widely accepted that the typical groundwater flow system is influenced by the river flow system near the Columbia River. This influence takes the form of a dynamic "zone of interaction," where mixing of groundwater and river water occurs. Physical, chemical, and biological processes occur within the zone of interaction that potentially alter the characteristics of the approaching groundwater. Physical processes include layering and mixing of groundwater and river water (tending to dilute contaminants to lower concentrations), which infiltrates the banks and riverbed sediments, as well as varying hydraulic gradients caused by river-stage fluctuations. Chemical processes may change the characteristics of a contaminant in groundwater so it becomes less mobile (e.g., adsorbs to sediment or precipitates) or more mobile (bonds to non-ionic organic material). Biological activity in the zone may capture and immobilize contaminants, or it may introduce the contaminants into the food chain. Current information to date suggests that physical processes are the dominant influence on contaminant concentrations and fluxes at locations of discharge of the unconfined aquifer at the Hanford Site into the free-flowing stream of the Columbia River.

A number of reports have been issued that address various aspects of the zone of interaction. One of the more detailed of reports, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River* (PNNL-13674), discusses modeling the flow and determining the mixing efficiencies within the zone of interaction. PNNL-13674 notes that discharge into the river environment occurs across two primary interfaces: (1) the region between high and low river stage, generally referred to as the "riparian zone"; and (2) an interface that exists within

the river channel substrate that is constantly submerged (i.e., at elevations below the lowest river stage), known as the "hyporheic zone."

Within the riparian zone, river water infiltrates the banks during periods of high river stage and forms either a layered system or a mixture during interaction with the approaching groundwater. As seepage from the bank occurs during the period of low river stage, the composition of the seepage may change dramatically from nearly pure river water to primarily groundwater.

In the hyporheic zone, sediment porewater is influenced by the entrainment of river water and the gradual influx of groundwater that upwells from the underlying aquifer. As this zone is constantly submerged, the composition is thought to be more stable, although it is possible for areas of preferential upwelling to be present.

Groundwater flow near the river is strongly influenced by fluctuations in Columbia River stage, which in turn is controlled by dams. River stage can vary 1.8 to 2.4 meters daily and 2.4 to 3.0 meters seasonally (PNNL-13647). As a result of these fluctuations, the dynamics of groundwater flow near the river change on multiple scales (hourly, daily, and seasonally). Normal peak discharge occurs during June, and normal low flow occurs in October and November. During low river stage in the fall and winter, the groundwater flow is toward the river; as the river stage increases in the spring and summer, the gradient becomes less and may even reverse direction in response (SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*). These observations suggest that the Columbia River is primarily a gaining reach during times of low flow and may become primarily a losing reach during times of high flow.

While the aquifer response is most pronounced near the shoreline within several tens of meters of the Columbia River, effects can extend inland of the shore up to several hundreds of meters or more. River-stage fluctuations can be detected in wells up to 610 meters inland from the river. Because of the very flat gradient between the river and the 200 East Area, the resulting pressure head changes during the highest stages can effect water levels (and the subsequent gradient) as far as 11 kilometers from the river (see Chapter 3.0, Section 3.2).

The importance of groundwater/river interactions in the 100 Area was the subject of a 3-day workshop where an expert panel of scientist from academia, government, and the consulting industry, and not associated with Hanford, reviewed the current understanding of interactions at Hanford (SGW-39305, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*). A total of twelve recommendations were made on topics from the base conceptual model framework, network design, data acquisition, and analysis, as well as the role of modeling in understanding of groundwater/river interactions and the role that the interactions have on the selection of remedial alternatives. One important concern was regarding the conceptual model. The two-dimensional model results presented in PNNL-13674 indicated that "mixing" occurred throughout the thickness of the unconfined aquifer and provided a 1:1 dilution of contaminated groundwater. This model does not account for the potential existence of an armored layer along the riverbed or the role that geologically controlled preferential pathways might play. The concern was that riverbed armoring and/or aquifer heterogeneities leading to preferential pathways may "short circuit" the mixing zone and allow discharge of contaminated groundwater directly into the Columbia River.

2.4 Physical and Hydraulic Properties

The determination of physical and hydraulic properties and parameters for use at the Hanford Site has a long history dating back to the late 1950s with publication of *Hydraulic Characteristics of Hanford Aquifers* (HW-48916). A number of flow and transport parameters are needed for characterizing and modeling contaminant movement in the subsurface. In general, the physical and hydraulic properties of the sediments present in the subsurface at the Hanford Site have not changed over the Site's operational history; therefore, it could be assumed that the assignment of a single, site-wide, best-estimate value to an individual stratigraphic unit would not be difficult to determine. However, as new data are collected and new methods for determining the properties are developed, the values applied to these properties may change, in some cases significantly. This has been further complicated by (1) the many different contractors and principal investigators that have performed studies at the site over its operational lifetime, (2) the changing nomenclature and descriptions of stratigraphic units and how those descriptions are applied, and (3) the differing approaches used to estimate these properties. In addition to the complications stated above is the tremendous spatial variability and geologic heterogeneity inherent among the various units across the Hanford Site. Determining these properties is also traditionally driven by site-specific workscope and project funding. Therefore, the assignment of a single, site-wide value to an individual stratigraphic unit is difficult.

Because of the difficulties in assigning a single value to any one property (as noted in the previous paragraph), this section introduces the range of values for select physical and hydraulic properties and the parameters encountered at the Hanford Site that affect contaminant fate and transport in both the vadose zone and in the unconfined aquifer. Another key issue when reviewing the physical and hydraulic properties and the parameters on the Hanford Site is that these properties can vary significantly within hydrogeologic formations, making the collection and derivation of these properties location-specific. Many of the properties and parameters are not only location-specific but also scale-specific. Values for some of these properties that are made in the laboratory can bear little resemblance to the same parameter when defined at the field scale. Therefore, it is critical to be aware of how the small-scale laboratory measurements were obtained and what, if any, upscaling techniques are needed to adequately characterize and/or model the large-scale flow and transport behavior.

2.4.1 Vadose Zone Properties

A number of physical and hydraulic properties are necessary to characterize and/or model the movement of contaminants in the vadose zone. All of these properties relate to how moisture containing a contaminant, usually as a component of some type of fluid (e.g., wastewater), moves through the vadose zone. Properties such as bulk density, effective porosity, saturated and unsaturated hydraulic conductivity, and soil moisture content as a function of matric potential have traditionally been defined using a best estimate based on the average of the individual samples tested. Historically, the extent of this testing is based on site-specific workscope and project funding. Factors complicating the derivation of a general site-wide value for any one property arise for many reasons, as noted above. Considering these differences, the Soil and Groundwater Remediation Project set out to re-evaluate and establish a set of consistent and defensible values that could be traced back to their raw data sets, which was completed in 2009 (PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*). Tables 2-1 and 2-2

present the hydrostratigraphic units for which the various properties are defined, as well as the range in values for a few select properties from that report.

Other references containing information on vadose zone properties include the following:

- PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*
- PNNL-17154, *Geochemical Characterization Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*
- RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*
- RPP-RPT-35222, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*
- WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*

2.4.2 Saturated Zone (Unconfined Aquifer) Properties

A similar number of physical and hydraulic properties is also necessary for the saturated zone (the zone below the water table) to characterize and/or model contaminant movement. Properties such as transmissivity, hydraulic gradient, effective porosity, adsorption coefficients, and both horizontal and vertical hydraulic conductivity relate directly to the movement of a contaminant, again usually as a component of some type of fluid (e.g., wastewater), through the porous material of the saturated zone. Other parameters such as storativity and specific yield have to do with the physical property of the aquifer itself. As for the vadose zone these properties have traditionally been extrapolated from individual well samples and/or testing. Historically, the extent of this testing was based on site-specific workscope and project funding. The overriding factor complicating the derivation of a general site-wide value for any one saturated zone property comes from an increased understanding of the complexity of the Hanford Site's subsurface, which reduces the distance that values can be reliably extrapolated from for any given test well. Similar to vadose zone properties, the key properties for the unconfined aquifer sediments cover a range of values linked to the sediment type and contaminants present, and also vary with the particular location, both vertically and horizontally, within the aquifer.

To aid in predicting future contaminant spread and the effectiveness of remedial actions to be used when assessing past practice sites at the Hanford Site, the Soil and Groundwater Remediation Project began developing a site-wide groundwater model in 2005. An initial effort for this work involved reviewing and compiling aquifer testing data to date for use in the 2005 site-wide groundwater model. This information was published in *Groundwater Data Package for Hanford Assessments* (PNNL-14753). Figure 2-12 shows the hydrogeologic units present at the water table in 2005. Table 2-3 presents the minimum and maximum values for horizontal hydraulic conductivity for the different hydrogeologic units that make up the unconfined aquifer, while Table 2-4 presents minimum and maximum values for other selected saturated parameters. As an example of the variability of these properties, Figure 2-13 shows the distribution of horizontal hydraulic conductivity within the upper 10 meters of the hydrogeologic units at the water table, while Figure 2-14 (a and b) shows the vertical distribution of hydraulic conductivity along the two cross sections marked in Figure 2-13.

Additional references containing information on aquifer properties include the following:

- PNNL-14058, *Prototype Database and User's Guide of Saturated Hydraulic Properties for the Hanford Site*
- PNNL-14753, *Groundwater Data Package for Hanford Assessments*
- PNNL-15837, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*
- SGW-42736, *Geohydrologic Data Package in Support of 200-ZP-1 Modeling*
- SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*
- SGW-47040, *Geohydrologic Data Package in Support of 100-FR-3 Modeling.*

2.5 Geochemical Overview of Selected Hanford Site Groundwater Contaminants

J. Blount

The groundwater of the unconfined aquifer at the Hanford Site can be generally described as a calcium-magnesium-bicarbonate-type water that is approximately saturated with respect to calcium carbonate. The groundwater is typically slightly basic with a pH range generally between 7.5 and 8.5. Dissolved oxygen (DO) concentrations generally range between 6 to 12 mg/L, but localized low DO conditions are present in some areas. Exceptions to all of these general characteristics are observed locally as a result of previous waste disposal practices, as well as leaks and spills of contaminated solutions during operations, affecting local groundwater chemistry where applicable.

Although the extent of groundwater contamination for any given Hanford Site contaminant will vary in response to the nature of the waste site and the underlying vadose zone, once a contaminant enters the groundwater, the nature and extent of the resulting plume is controlled by the geochemical characteristics of the contaminant under the local aquifer conditions. Consequently, the fate and transport of the primary groundwater contaminants of concern at the Hanford Site will vary across the Site. It is important to understand the nature of these local and regional variations to develop valid conceptual site models. These models help identify chemical sources for the plumes and guide the development of remedial solutions or identify the need for alternative remediation. Thus, understanding the groundwater chemistry is key to moving toward final cleanup of a site.

The mobility of constituents such as uranium, chromium, and nitrate are sensitive to the reduction-oxidation state of the aquifer. These constituents are typically highly mobile under the oxidizing conditions of the unconfined aquifer. These constituents, however, can undergo chemical or biochemical transformations to much less mobile forms in areas of the aquifer where reducing conditions predominate. The fate and transport characteristics of some contaminants are not directly affected by changes in groundwater reduction-oxidation conditions, but these characteristics are affected by other factors (e.g., changes in groundwater pH or aquifer matrix composition). For example, changes in groundwater pH can increase or decrease the extent of sorption of iodide or the precipitation of strontium-90 as a solid carbonate or phosphate phase. The following subsections present a general overview of the geochemical characteristics of groundwater contaminants in the Hanford unconfined aquifer.

2.5.1 Uranium

During the period of active Hanford Site operations, large amounts of uranium metal were used to fuel the reactors and to produce plutonium. Large-scale reprocessing of spent fuel rods and related waste disposal activities generated hundreds of thousands of kilograms of dissolved uranium in large volumes of waste solutions that were primarily released to the vadose zone in the 200 and 300 Areas (PNNL-17031, *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site*). Based in part on the high volume of the waste solutions discharged, the generally high concentrations in those waste solutions, and the mobility of uranium, a substantial component of the discharged uranium was transported through the vadose zone and into the unconfined aquifer. The component of uranium retained in the vadose zone remains a potential future source of groundwater contamination. A simplified summary of the geochemical characteristics of uranium that contributed to the development of large uranium plumes in the unconfined aquifer are summarized below.

Depending on the reduction-oxidation/pH conditions, dissolved uranium in aqueous solutions can exist in the +3, +4, +5, and +6, oxidation states. In most groundwater environments uranium will exist predominantly in the tetravalent (+4) or in the hexavalent (+6) states (uranium[IV] or uranium[VI]). The high pH (greater than 7.5) and calcium bicarbonate concentrations in most Hanford Site groundwater, combined with the prevalent oxidizing conditions, suggest that uranium(VI) should predominately occur as carbonate complexes; this form of uranium is relatively mobile. However, carbonate complexes of uranium(VI) are sensitive to spatial or temporal changes in groundwater pH. For example, the dominant aqueous uranium species will generally change from the neutral uranyl mono-carbonate complex (UO_2CO_3) at a pH of ~5.5 to 6, to the divalent anionic uranyl di-carbonate complex [$(UO_2(CO_3)_2^{-2}$] at a pH of ~7 to 8, and to the anionic tetravalent uranyl tri-carbonate complex [$(UO_2(CO_3)_3^{-4}$] at a pH above 8.5 (EPA 402-R-99-004B, *Understanding Variation in Partition Coefficient, Kd, Values*). All of these neutral to anionic complexes are slightly absorbing on the aquifer matrix materials, resulting in some degree of retardation of uranium but generally allowing uranium to be mobile enough to form groundwater plumes within the Hanford Site aquifer.

Under reducing conditions with pH values near 8.0, aqueous complexes of uranium(VI) convert to uranium(IV), which tends to precipitate insoluble uranium oxides. Thus, the resulting groundwater concentrations of uranium are very low when uranium(IV) complexes dominate. However conditions sufficiently reducing to convert uranium(VI) to uranium(IV) are rare in any aquifer, especially at the Hanford Site, which has almost universally oxygen-rich groundwater. Several small uranium plumes exist in the groundwater within the 200 West Area with a larger plume under the B Complex in the 200 East Area. Both areas were the site of chemical processing plants, where plutonium and eventually uranium were separated from irradiated fuel rods. The plume with the greatest areal extent is located under the 300-FF-5 Operable Unit area, where uranium rich fuels rods were manufactured for use in the Hanford Site reactors.

2.5.2 Chromium

Chromium typically occurs in the natural environment as trivalent chromium (chromium[III]). Hexavalent chromium (chromium[VI]) is the common form in waste streams and is the most mobile form of chromium. The aqueous mobility of chromium introduced into the unconfined aquifer at the Hanford Site is highly

dependent upon (1) the valence state of the chromium in the waste solution, (2) the chemical characteristics and volume of the waste solution that is transporting the chromium into the aquifer, and (3) the chemistry of the groundwater and associated aquifer matrix.

Cationic chromium(III) species (e.g., $[Cr(OH)]^{2+}$) are stable in strongly acidic solutions, while anionic chromium(III) species ($[Cr(OH)_6]^{3-}$) are stable in strongly basic aqueous solutions. Chromium(III) species are not stable in typical Hanford Site groundwater, with a pH range that is intermediate between these two extremes (e.g., pH between 6.5 and 9). Consequently, if chromium(III) in a disposal area's soil or waste material is mobilized by either a strongly acidic (e.g., less than pH 5) or basic (e.g., greater than pH of 12) solution and subsequently transported to the unconfined aquifer, the chromium(III) will begin to precipitate as low-solubility solid phases, such as $Cr(OH)_3$. This is the result of either the strongly acidic or basic pH of the waste solution being neutralized by interaction with the groundwater and the aquifer matrix. However, the presence of organic acids and other organic complexing agents in the waste solution or in the local groundwater can increase the solubility of chromium(III) somewhat in near neutral groundwater ("The Role of Metal-Organic Complexes in the Treatment of Chromium Containing Effluents in Biological Reactors" [Remoudaki et al., 2003]). Barring the presence of elevated concentrations of organic complexing agents (e.g., acetate), the precipitation of very low solubility chromium(III) phases (e.g., $Cr[OH]_3$) should keep the concentrations of dissolved chromium(III) below the drinking water standard ("Environmental Chemistry of Chromium" [Rai et al., 1989]). Thus, carbonate-buffered aquifers, such as the Hanford unconfined aquifer, are unlikely to support dissolved chromium(III) plumes, even if the aquifer was receiving substantial volumes of acidic or strongly basic waste solutions with elevated concentrations of dissolved chromium(III).

The aqueous chemistry of chromium(VI) is very different than chromium(III) and chromium(VI) forms very stable, highly mobile anionic species (typically chromate $[CrO_4^{2-}]$) in oxidizing soil porewater and groundwater over a range of pH conditions.

The vadose zone and the unconfined aquifer at the Hanford Site contain very little natural organic material, and the vadose zone porewater and underlying groundwater are not sufficiently reducing to convert mobile chromium(VI) to the relatively immobile chromium(III). Consequently, oxidizing waste solutions have the potential to transport substantial amounts of chromium(VI) into the vadose zone where subsequent natural or manmade recharge events can transport much of the chromium(VI) to the unconfined aquifer. The stability and mobility of chromium(VI) complexes in the vadose zone and in the unconfined aquifer at the Hanford Site are supported by (1) the results of saturated flow-leaching tests performed on Hanford soils containing chromium(VI) (PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*), and (2) by the existence of the extensive and long-lived hexavalent chromium plumes within the groundwater operable units in the 100 and 200 Areas.

Although chromium(VI) is stable under oxidizing groundwater conditions, it may be readily converted to chromium(III) if sufficiently reducing conditions are either naturally present in the aquifer or if reducing conditions are imposed on the aquifer system by the implementation of an engineered system. Numerous studies and field applications have demonstrated that the addition of simple organic carbon compounds (e.g., lactate or ethanol) to an aquifer contaminated with chromium(VI) will stimulate the natural microbial assemblage in an aquifer to produce reducing conditions. This bioremediation approach has been used at numerous sites to convert toxic and mobile

chromium(VI) to less toxic and much less mobile chromium(III). In situ chemical methods can also be used to create reducing conditions. The injection of zero-valent iron at the 100-HR-3 Operable Unit has been shown to create reducing conditions and convert chromium(VI) to chromium(III) (DOE/RL-2009-35, *Treatability Test Report on Mending the In Situ Redox Manipulation Barrier Using Nano-Size Zero Valent Iron*). Once chromium(VI) is converted to chromium(III), it will typically rapidly precipitate as a highly insoluble phase such as $Cr(OH)_3$ that will not redissolve once treatment is terminated.

2.5.3 Nitrate

Nitrate occurs naturally in soil when free-living or symbiotic bacteria combine gaseous nitrogen with hydrogen to produce ammonia. This process of fixation is an integral part of the nitrogen cycle. Whether by decomposition of organic material or by nitrogen-fixing bacteria in legume root nodules, the ammonium is further converted to nitrite (NO_2^-) and then nitrate (NO_3^-). Nitrogen as nitrate is stable and mobile in oxygenated environments, and the amount not taken up by plants is leached to the local aquifer.

The elevated nitrate concentrations observed in some Hanford groundwater are primarily the result of plutonium and uranium separations waste streams released to the ground in very large volumes in the early days of processing. Nitric acid was used to declad and dissolve the irradiated fuel rods throughout the history of Hanford Site operations. During the time that waste was retrieved from the single-shell tanks for use in the uranium recovery process and to recover strontium-90 from the B Plant waste fractionization campaign, nitric acid was also used to dissolve solids in the feed stock solution.

Additional sources of nitrate result from many of the later plutonium separations processes used at the Hanford Site. Although the reduction-oxidation process (active from 1952 to 1958) used methyl isobutyl ketone as the solvent extractor, aluminum nitrate nonanhydrate was used as the source for the nitrate ion (DOE/RL-2000-60, *Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan Includes: 200-PW-2 and 200-PW-4 Operable Units*). Aluminum nitrate nonanhydrate was added to the processing stream to drive uranium and plutonium into a solution phase for later chemical removal. Another example of nitrate added to the waste stream is during the uranium recovery process. The final product from the tri-butyl phosphate uranium recovery process was uranyl nitrate hexahydrate. By using calcinators, the uranyl nitrate hexahydrate was converted to uranium trioxide for shipment to plants that processed it to the metal form of uranium for use in reactors. Thus, nitrates were part of the waste streams resulting from the nitrification of the uranyl nitrate hexahydrate to uranium trioxide. This process was conducted at U Plant from 1958 until 1972, and the again from 1984 to 1988.

The only other source of nitrate may be upgradient agricultural use of nitrogen-rich fertilizers. However results from wells monitoring upgradient of the 100 Area and the 200 West Area Central Plateau do not show agricultural activities as a major nitrate source, although several have shown steady increases in nitrate levels that remain below regulatory levels. In the southern Hanford Site around the 300 and 1100 Areas elevated nitrate is from offsite agricultural and industrial sources. However, nitrate in the groundwater beneath most of the Hanford Site is primarily the result of Hanford operations.

2.5.4 Carbon-14

Carbon-12 and carbon-13 are stable nonradioactive isotopes of carbon that account for ~99% and 1%, respectively, of all carbon. Carbon-14 is a radioactive isotope of carbon that is produced naturally in the upper atmosphere, primarily by the interaction of cosmic rays and atmospheric nitrogen, that makes up less than one trillionth (1×10^{-10}) of natural carbon. Carbon-14, which decays to nitrogen-14 by beta emission, has a half-life of ~5,700 years.

At the Hanford Site, carbon-14 was produced as a byproduct during plutonium production at the reactors in the 100 Area. Sources of carbon-14 contaminated groundwater include wastes associated with previous reactor operation decommissioning activities (*Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas*). Several other radioactive isotopes of carbon exist, but their half-lives are extremely short and they are not a health concern for DOE environmental management sites.[1]

The environmental chemistry of carbon-14 is virtually identical to that of common carbon, and it can migrate either as a gas (i.e., carbon dioxide) or in solution as carbonate or bicarbonate species (INEEL/EXT-04-01793, *Multiphase Carbon-14 Transport in a Near-Field-Scale Unsaturated Column of Natural Sediments, Idaho National Engineering and Environmental Laboratory*). The fate and transport characteristics of carbon-14 as carbon dioxide in the vadose zone within or beneath a waste site will reflect a range of factors, including unsaturated water content, extent of microbial biomass production, microbial carbon dioxide production, temperature, diffusion rates, and carbonate equilibriums. These and other factors that affect the transport of carbon dioxide into or out of the vadose zone will be subject to the same gas/water/solid exchange processes as carbon dioxide containing only stable carbon.

Once carbon-14 reaches the water table, the effects of retardation processes such as adsorption and gas/water exchange rates are influenced by the pH and carbonate alkalinity of the groundwater. For example, depending on the pH, carbon-14 in a groundwater plume may be present primarily as carbonic acid, bicarbonate, or carbonate; each of these carbonate species would be subject to somewhat different retardation factors in the aquifer.

2.5.5 Technetium-99

Technetium-99 is a radioactive metal with a half-life of 210,000 years. Technetium-99 is found primarily in radioactive wastes from nuclear processing facilities as a byproduct (or fission product) of reactor operations. Technetium can exist in valence states ranging from 1- to 7+ and is strongly sensitive to oxidation-reduction conditions. Under oxidizing conditions typical of the Hanford Site aquifer, technetium-99(VII) forms the chemically stable pertechnetate anion (TcO^{4-}). Pertechnetate is generally not adsorbed by inorganic aquifer materials under near neutral or higher pH conditions, so is highly mobile in groundwater under these conditions.

When pertechnetate is exposed to reducing conditions, technetium-99 changes from 7+ to 4+ valance state and normally precipitates to the solid TcO_2, removing technetium-99 from the groundwater. This reduction could occur in a natural

1 *Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas* (March 2007), J. Peterson, M. MacDonell, L. Haroun, and F. Monette, Argonne National Laboratory, Environmental Science Division, in collaboration with the U.S. Department of Energy, Richland Operations Office.

environment (e.g., groundwater passing through an area enriched in organic material) or an imposed one. A common remediation technique for a contaminant that behaves in this manner is to reduce the aquifer by injecting a chemical reductant, or by introducing a carbon source into the aquifer, which stimulates indigenous microbes that in turn create reducing conditions in the groundwater and aquifer materials. This will reduce the technetium-99(VII) to technetium-99(IV), which is largely immobile in groundwater. Unlike hexavalent chromium, which remains in the reduced state when conditions return to oxidizing, reduced technetium-99(IV) readily returns to the mobile pertechnetate ion under oxidizing conditions.

2.5.6 Tritium

Tritium is a radioactive isotope of hydrogen with a half-life of 12.3 years that is created naturally in the upper atmosphere and by anthropogenic sources such as nuclear reactors and nuclear weapons testing. The nucleus of a tritium atom consists of one proton and two neutrons and undergoes beta decay to form stable helium-3. The chemistry of tritium is essentially identical to common hydrogen, and it can migrate in soils as a gas and readily reacts with oxygen to form what is known as heavy water (H_3O). Once tritium atoms have been incorporated into water molecules, they will be subject to the same dispersive, advective, and other transport processes as common water and will migrate at the same average velocity (EPA 402-R-99-004B).

The fate and transport of tritium in the subsurface at the Hanford Site is primarily controlled by radioactive decay and by the hydrologic characteristics of the affected vadose or groundwater systems. Although no sorption or precipitation processes are known to retard the movement of tritiated water in the environment, some studies have reported a small but notable retardation of tritium relative to bromide during long-term (~500 days) column testing (INEEL/EXT-04-01793). The modest retardation of tritium (estimated distribution coefficient of ~0.08) in these column tests was speculated to be due to the fixation of tritiated water on clays and other hydrated soil minerals. The 12.3-year half-life of tritium is relatively long compared to the groundwater travel times in many areas of the unconfined aquifer. Consequently, for a given waste site, the extent and magnitude of tritium activity that defines the resulting plume primarily reflects the age and longevity of the contamination event and the local hydraulic properties of the aquifer (e.g., groundwater velocity).

2.5.7 Strontium-90

Strontium is an alkaline earth element that occurs naturally in only the divalent state (2+). Because of the similar size and charge to calcium, these two elements can and commonly do substitute for each other in natural systems. Strontium has four naturally occurring stable isotopes (strontium-84, -86, -87, and -88). Of these, strontium-88 comprises ~82.5% of the total mass of strontium. Numerous short-lived strontium isotopes have been identified as byproducts of nuclear fission (fission products), but strontium-90 (with a half-life of 28.78 years by beta decay) is the only strontium isotope identified as a potential health concern in Hanford Site groundwater.

Strontium forms weak complexes with most inorganic anions (e.g., carbonate, sulfate, chloride, and nitrate) (EPA 402-R-99-004B) and the uncomplexed Sr^{2+} ion typically predominates in groundwater over a wide range of pH conditions. In sufficiently high pH, carbonate-rich environments, the precipitation of strontium carbonate may serve as control on the maximum concentrations in groundwater. Ion exchange of divalent strontium (Sr^{2+}) onto clays and other aquifer phases is a significant mechanism of retardation of strontium transport in groundwater. Although strontium has a higher affinity than calcium for the exchange site of many minerals,

the much greater abundance of calcium in most groundwater commonly results in the preferential displacement of Sr^{2+} from exchange sites by Ca^{2+}. This effect would appear to be substantially more pronounced for strontium-90, which would be several orders of magnitude lower in concentration than common strontium and calcium (EPA 402-R-99-004B). Studies on contaminated soils taken from the 100-N Area indicate that because of strong strontium-90 absorption by ion exchange to sediments (distribution coefficient is 25 cm^3/g in groundwater, yielding a retardation factor of approximately 100 (PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*), approximately 1% of the strontium-90 is in groundwater and 99% is adsorbed onto sediments. The strong affinity for Sr^{2+} to exchange with Ca^{2+} is the basis for the success of the apatite barrier in the 100-N Area (see Chapter 6.0, Section 6.2.4).

2.5.8 Iodine-129s

Iodine has one stable isotope (iodine-127) and 36 known radioactive isotopes. Iodine-129 is by far the longest lived, with a half-life of 15.7 million years. The other isotopes have half-lives ranging from about 100 microseconds (iodine-109) to 59 days (iodine-125). Iodine-129 is produced in small quantities in nature (e.g., by spontaneous fission of natural uranium) but in much larger quantities as a fission product in nuclear reactors. Iodine occurs in +7, +5, +3, +1, and -1 valence states and typically occurs as the diatomic molecule (I_2) in the atmosphere. In groundwater, iodine most commonly occurs as iodide (I^-), although in marine environments the prevalent form is as I^{5+} in the iodate (IO_3^{-1}) complex. As with other similar anionic halogen species (e.g., Cl^-), iodine is relatively mobile in most groundwater environments and displays very little sorption on the organic-poor sediments and moderately basic groundwater in the unconfined aquifer at the Hanford Site ("Linearity and Reversibility of Iodide Adsorption on Sediments from Hanford, Washington Under Water Saturated Conditions" [Um et al., 2004]).

2.5.9 Carbon Tetrachloride

Carbon tetrachloride is a semi-volatile organic liquid that was used in the Plutonium Finishing Plant in association with plutonium production at the Hanford Site. The carbon tetrachloride molecule is nonpolar, which makes it only sparingly soluble in water (approximately 800 milligrams per liter of water). That characteristic, along with a density of 1.6 g/cm^3, classifies it as a dense, nonaqueous phase liquid. Partition coefficients published in the literature for carbon tetrachloride in groundwater range from 0 to 0.83 liters per kilogram; values obtained from contaminated Hanford sediments range from 5.21×10^{-5} to 0.367 liters per kilogram (PNNL-16100, *Carbon Tetrachloride Partition Coefficients Measured by Aqueous Sorption to Hanford Sediments from Operable Units 200-UP-1 and 200-ZP-1*),

Carbon tetrachloride in the subsurface can exist as a vapor phase, as a dissolved aqueous phase, as an absorbed phase on solid matrices, and as a separate organic phase as a dense, nonaqueous phase liquid. In the Hanford Site vadose zone, all of these phases have been detected, although only a very small amount of dense, nonaqueous phase liquid is present. In groundwater, only the dissolved phase has been detected.

2.6 Selected Bibliography

Additional information on the regional geologic setting of the Pasco Basin and the Hanford Site can be found in the following documents:

- BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, 1995
- DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*, 2002
- DOE/RW-0164, *Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*, 1988
- "Geohydrologic Setting of the Hanford Site, South-Central Washington" (Lindsey et al., 1994)
- RHO-BWI-ST-4, *Geological Studies of the Columbia Plateau – A Status Report*, 1979
- WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*, 1993
- WHC-SD-EN-EE-004, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington*, 1991.

The geologic setting for the 200 Area has been described in the following documents:

- HW-61780, *Subsurface Geology of the Hanford Separations Area*, 1959
- PNL-6820, *Hydrogeology of the 200 Areas Low-Level Burial Grounds – An Interim Report*, 1989
- PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, 2000
- PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*, 2002
- PNNL-17913, *Hydrogeology of the Hanford Site Central Plateau – A Status Report for the 200 West Area*, 2009
- PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and into the Unconfined Aquifer Below the B-Complex*, 2010
- PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*, 2010
- RHO-BWI-ST-5, *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*, 1979
- RHO-BWI-ST-14, *Subsurface Geology of the Cold Creek Syncline*, 1981
- RHO-ST-23, *Geology of the Separations Areas, Hanford Site, South-Central Washington*, 1979
- RHO-ST-42, *Hydrology of the Separations Area*, 1981
- WHC-SD-EN-TI-012, *Geologic Setting of the 200-East Area: An Update*, 1992.

The geology of the 100 Area has been described in the following documents:

- WHC-SD-EN-EV-027, *Hydrogeology of 100-N Area, Hanford Site, Washington*, 1993
- WHC-SD-EN-TI-132, *Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington*, 1993
- WHC-SD-EN-TI-133, *Geology of the 100-B/C Area, Hanford Site, South-Central Washington*, 1993

- WHC-SD-EN-TI-221, *Geology of the 100-FR-3 Operable Unit, Hanford Site, South-Central Washington*, 1994
- WHC-SD-EN-TI-294, *Hydrogeology of the 100-K Area, Hanford Site, South-Central Washington*, 1994.

The geology of the 300 Area is described in *Geology and Hydrology of the 300 Area and Vicinity, Hanford Site, South-Central Washington* (WHC-EP-0500). Updated geologic information is presented in *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington* (PNNL-17666).

Table 2-1. Hydrostratigraphic Units for Which Physical, Hydrologic, and Geochemical Data Can Be Defined

Formation/Unit	Subunit (Symbol)	Representative Hydraulic Property Sediment Class		Qualitative Sediment Description
		After PNNL-14702, Rev. 1	After RPP-17209, Rev. 1, RPP-13310, Rev. 1	
Holocene deposits	Backfill (Bf)	Bf	Backfill	Poorly sorted sand and gravel mixed with finer fraction.
Hanford formation	Unit H1a (H1a)	Hfs, Hcs	NA	Mostly sand-dominated sediment with some silt but may contain some gravelly sediments.
	Unit H1 (H1)	Hgs, Hg	Gravelly sand H1	Gravel-dominated sediments with coarse sand found in 200 West Area.
	Unit H2 (H2)	Hfs, Hcs	Sand H2	A mixture of sandy and silty sediment in 200 West Area.
	Unit H2a (H2a)	--	--	A transitional sand and gravel unit between H2 and H3.
	Unit H3 (H3)	Hgs, Hg	Gravelly sand H3	Laterally discontinuous gravelly sediment at the base of the Hanford formation.
	Unit H4 (H4), undifferentiated Hanford/Cold Creek unit (Hf/CCU)	Hss, Hcs	NA	Laterally discontinuous silty sediment at the base of the Hanford formation, including undifferentiated silty Hanford/CCU sediments.
Cold Creek unit (CCU)	Cold Creek unit silt (CCUz)	PPlz	Cold Creek (Unit 4)	Stratified very fine sand to clayey silt at least partially correlative with the "early Palouse" soils.
	Cold Creek unit carbonate (CCUc)	PPlc	Cold Creek (Unit 4)	Calcium-carbonate cemented clay, silt, sand, and/or gravel.
	Cold Creek unit gravels (CCUg)	NA	Cold Creek (pre-Missoula gravels)	Gravelly sand to gravel equivalent to the pre-Missoula gravels.
Ringold Formation	Member of Taylor Flat (Rtf)	PPlz	NA	Well-bedded fine to coarse sand to silt.
	Member of Wooded Island, subunit E (Rwi[e])	Rg	Ringold sandy gravel	Fluvial gravel, moderate to strongly cemented, and interstratified with finer grained deposits.
	Ringold Formation lower mud unit (Rlm)	NA	NA	--
	Member of Wooded Island, subunit A (Rwi[a])	NA	NA	--
Saddle Mountains formation	Elephant Mountain Member (Tem)	NA	NA	--

Note: The information provided in this table is from PNNL-18564, *Selection and Traceability of Parameters To Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report.*

This page intentionally left blank.

Table 2-2. Best Estimate for Selected Site-Wide Vadose Zone Properties

Sediment Class – Description[a]	Bulk Density (g/cm³)				Total Porosity (cm³/cm³)				Effective Porosity (cm³/cm³)				Saturated Water Content, θ_s (cm³/cm³)[b]				Saturated Hydraulic Conductivity, K_s, (cm/s)[b]			
	Minimum	Maximum	Minimum Location	Maximum Location	Minimum	Maximum	Minimum Location	Maximum Location	Minimum	Maximum	Minimum Location	Maximum Location	Minimum	Maximum	Minimum Location	Maximum Location	Minimum	Maximum	Minimum Location	Maximum Location
Bf – Backfill	2.13	2.13	S-SX Tank Farms	C Tank Farm	NA[c]	0.21	--	[d]	NA	0.158	--	[d]	0.138	0.2688	South, S-SX Tank Farms	North, B-BX-BY Tank Farms	5.60E-04	5.94E-04	South, S-SX; North B-BX-BY, & C Tank Farms	[d]
Hss – Hanford formation silty sand	1.58	1.8	S 200 W	N 200W	0.329	0.392	N 200 W	S 200 W	0.282	0.326	N 200 W	S 200 W	0.351	0.437	North, 200-ZP-1; 200NW	South, 200-U1 & U2	6.55E-06	2.40E-04	North, 200-ZP-1	North, B-BX-BY Tank Farms
Hfs – Hanford formation fine sand	1.65	1.76	S 200 E	S-SX Tank Farms	0.318	0.422	N 200 W	BC	0.277	0.388	N 200 W	BC	0.347	0.394	South, 200-U1 & U2	South, IDF	1.71E-05	4.15E-03	South, 200-U1 & U2	South, IDF
Hcs – Hanford formation coarse sand	1.56	1.67	N 200 W	S 200 E	0.384	0.41	200 W	N 200 W	0.348	0.395	200 W	N 200 W	0.292	0.357	North, 200-ZP-1	South, BC	1.09E-03	5.32E-03	200W	South, BC
Hgs – Hanford formation gravelly sand	1.81	1.94	200 W	S-SX & C Tank Farms	0.3	0.335	BC	200 W	0.26	0.305	BC	200 W	0.2126	0.273	South, S-SX Tank Farms	200W	2.35E-04	5.15E-04	200W	North, B-BX-BY & CTank Farms
Hg – Hanford formation sandy gravel	1.79	2.09	N 200 W	S 200 W	0.231	0.237	S 200 W	N 200 W	0.202	0.218	S 200 W	N 200 W	0.15	0.2126	South, 200-U1 & U2	South, S-SX; North B-BX-BY, & C Tank Farms	2.62E-04	3.65E-03	South, S-SX; North B-BX-BY, & C Tank Farms	North, 200-ZP-1
Hrg – Hanford formation gravel (>60% gravel)	NA	1.97	--	[d]	NA	0.259	--	[d]	NA	0.239	--	[d]	0.102	0.138	[d]	South, IDF	5.60E-04	1.46E-03	South, IDF	[d]
CCUz – Cold Creek unit silt	1.58	1.71	N 200 W	S 200W	0.355	0.452	S 200 W	N 200 W	0.308	0.42	S 200 W	N 200 W	0.398	0.448	South, 200-U1 & U2	North, 200-ZP-1	7.27E-06	7.11E-04	South, 200-U1 & U2; 200WS	North, 200-ZP-1
CCUc – Cold Creek unit carbonate	1.65	1.71	S-SX Tank Farms	200W	0.34	0.352	200 W	N 200 W	0.288	0.297	200 W	N 200 W	0.281	0.286	200 W	South, S-SX Tank Farms	5.00E-04	1.03E-03	200W	North, 200-ZP-1
CCUg – Cold Creek unit gravels	2.13	2.13	C Tank Farm	C Tank Farm	NA	NA	--	--	NA	NA	--	--	0.138	0.138	North, C Tank Farm	North, C Tank Farm	5.60E-04	5.60E-04	North, C Tank Farm	North, C Tank Farm
Rg – Ringold Formation sandy gravel	1.82	2.13	S 200 W	S-SX & C Tank Farms	0.299	0.313	200 W	S 200 W	0.258	0.266	200 W	S 200 W	0.138	0.315	South, S-SX; North B BX-BY, & C Tank Farms	South, 200-U1 & U2	7.83E-05	5.60E-04	South, 200-U1 & U2	South, S-S; North B-BX-BY, & C X Tank Farms

a. Values shown are from PNNL-18564, *Sediments and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*. See Table 2-1 in this document and Table 6.1 in PNNL-18564 for details on the sediment classes.

b. Saturated water content and saturated hydraulic conductivity values are from the limited data set of samples tested to date.

c. "NA" indicates not available; total porosity has not been determined for the various types of backfill.

d. After *Vadose Zone Hydrogeology Data package for Hanford Assessments* (Last et. al., 2006)

This page intentionally left blank.

Table 2-3. Ranges of Horizontal Hydraulic Conductivity Values for Each Hydrostratigraphic Unit

Unit[a]	Unit Description[b]	Minimum K_h[c]	Maximum K_h
1	Hanford formation sands, silts, and gravels	6.06	20195
2	Cold Creek unit fluvial facies (CCU_c)	NA[d]	NA
3	Cold Creek unit coarse grained facies (CCU_z)	1.84	5717
4	Upper Ringold Formation silts and clays	0.0005	0.0005
5	Upper Ringold Formation sands and gravels	0.239	2562
6	Ringold Formation middle fines	0.01	0.01
7	Ringold Formation middle coarse	0.0227	101
8	Ringold Formation lower mud unit	0.00001	0.00001
9	Ringold Formation basal sands and gravels	0.00051	4.24

a. Units are as defined in PNNL-14753, *Groundwater Data Package for Hanford Assessments*.

b. Unit descriptions are from Figure 2-2.

c. K_h = horizontal hydraulic conductivity. Values are in meters per day.

d. "NA" indicates that unit is not found below the water table.

This page intentionally left blank.

Table 2-4. Best Estimate for Selected Site-Wide Saturated Zone Properties

Single-Shell Tank Farm – Description	Aquifer Thickness (m)		Effective Porosity[b]		Horizontal Hydraulic Conductivity[c] (m/day)		Transmissivity[c] (m^2/day)		Specific Yield[c] (unitless)		Flow Direction Azimuth (degrees)		Flow Direction		Gradient		Flow Rate[b] (m/day)		Calculated Maximum Flow Rate[d] (m/day)
	Minimum	Maximum		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
200 East Area																			
A	26.09	27.33	[e]	0.3	49.3[d]	109[d]	30[f]	160[f]	NA[g]				Southeast			0.00016	0.026	1.06	0.058
B-BX-BY (northern half)	0.70	5.80		0.3					2.80E-6[h]	1.53E-4[h]			West-southwest[i]	Southwest[i]					0.169 (0.045)[i]
(southern half)	1.26	7.61			22[d]	2,520[d]	15.77[j]	2,527.60[j]					South-southeast[i]	Southeast[i]		0.00002	0.0049	0.17	
C	8.65	9.33		0.3	1,900[d]	6,900[d]	0.024[k]	2,070[k]	NA				Southwest			0.0001	2.13E-5	3.68	2.3 (0.76)[i]
200 West Area																			
S-SX	70	75	0.02	0.671	1.33	14.4	91	1,035	0.09	0.12	82	115	East	East-southeast	0.00164	0.00209	0.013	0.179	0.172
T	50	55	0.045	1.1	0.85	2.02	44	103	0.1	0.11	85	98	5 degrees north of east	8 degrees south of east	0.00114	0.00172	0.022	0.029	0.28
TX-TY (northern half)	50	58	0.002	0.068	1.49	19.6	82	1,130	0.1	0.14	116	162	18 degrees east of south	43 degrees east of south	0.00073	0.0014	0.122	1.1	2.46
(southern half)													South	South-southwest					
U	60	70	0.027		1.18	6.12	345		0.17		76		East		0.00184			0.419	0.352

a. Values shown are from PNNL-15837, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas.*

b. Data from tracer pump-back tests.

c. Data from constant-rate pumping test.

d. Data from slug and/or constant-rate pumping tests.

e. Blank cells indicate that only a single value was determined for this parameter.

f. Calculated by multiplying hydraulic conductivity by thickness of the test interval using pre-1997slug test data.

g. "NA" indicates not available; a specific yield has not been calculated for this unit.

h. Calculated from specific storage and storativity.

i. Flow directions are from the above referenced report and are based on determinations up through 2006; prior to the intensive low-gradient study now underway (see Chapter 3.0, Section 3.2). It is now accepted that the general flow direction for the B-BX-BY Tank Farm as a whole is to the northwest.

j. Values are averages. Given due to high varability in values.

k. Calculated by multiplying hydraulic conductivity of the test interval by thickness of the test interval using pre-1997slug test data.

This page intentionally left blank.

Figure 2-1. Location of the Pasco Basin and Hanford Site

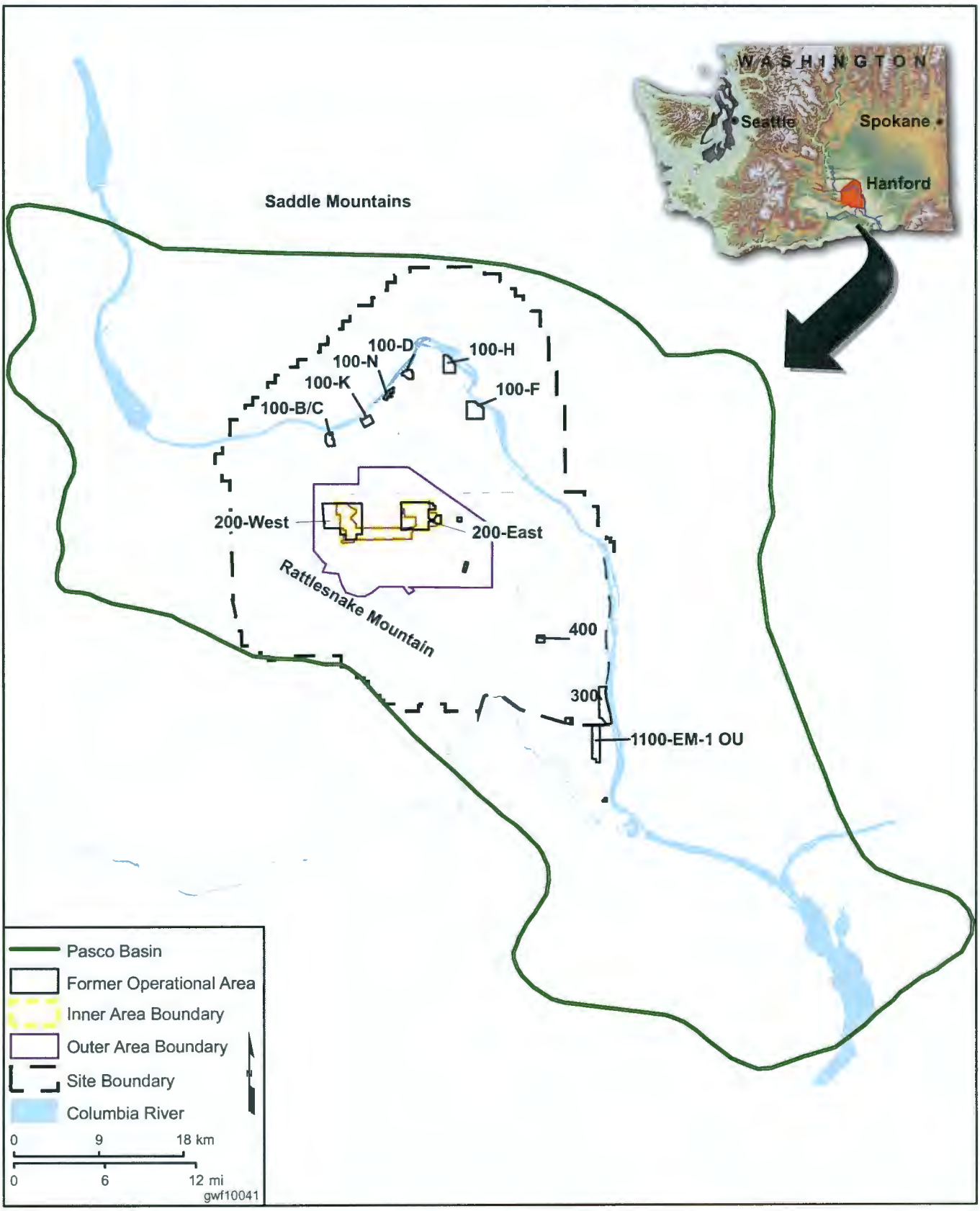


Figure 2-2. Stratigraphic Column for the Hanford Site Showing Nomenclature

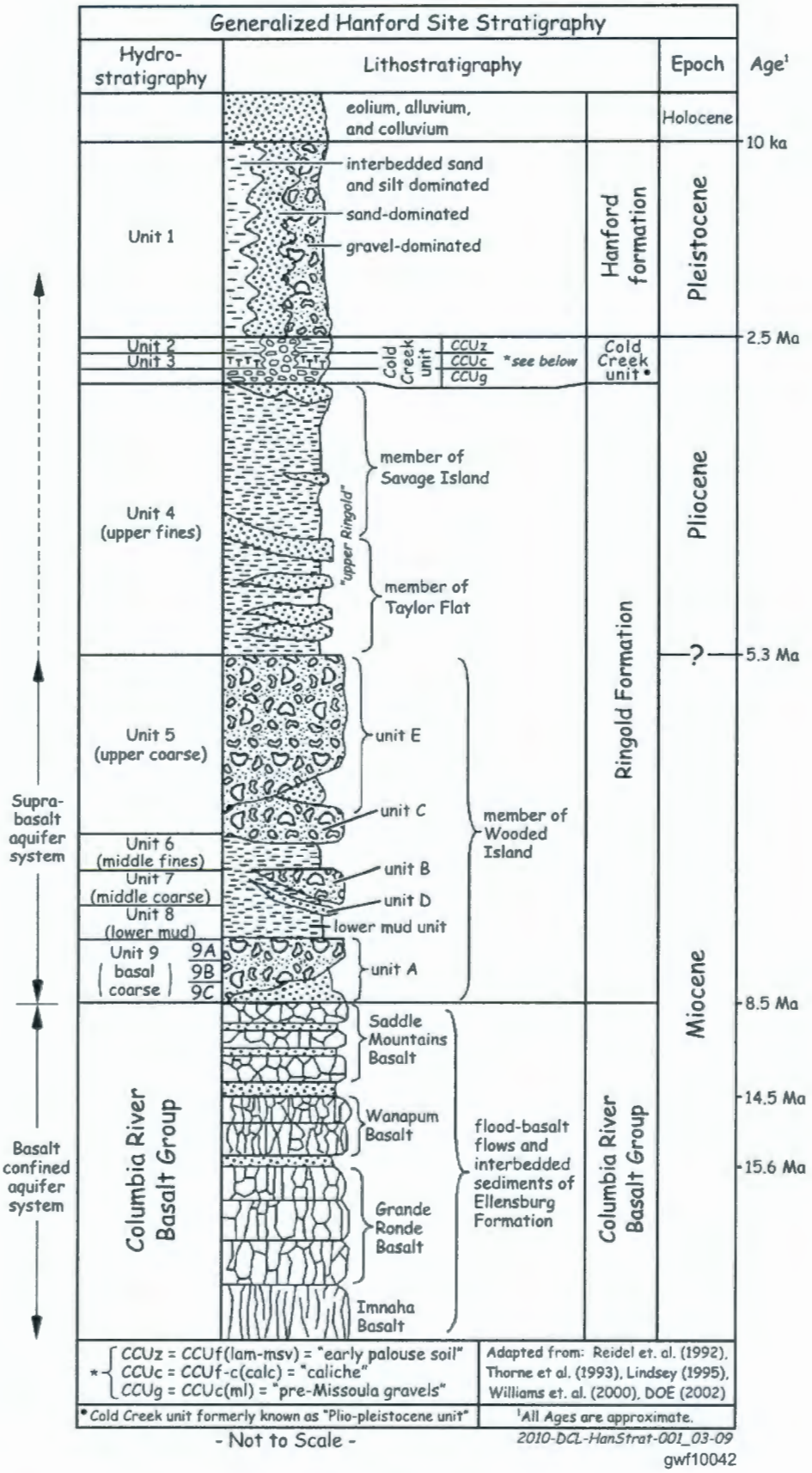


Figure 2-3. General Geologic Structures of the Pasco Basin and Hanford Site

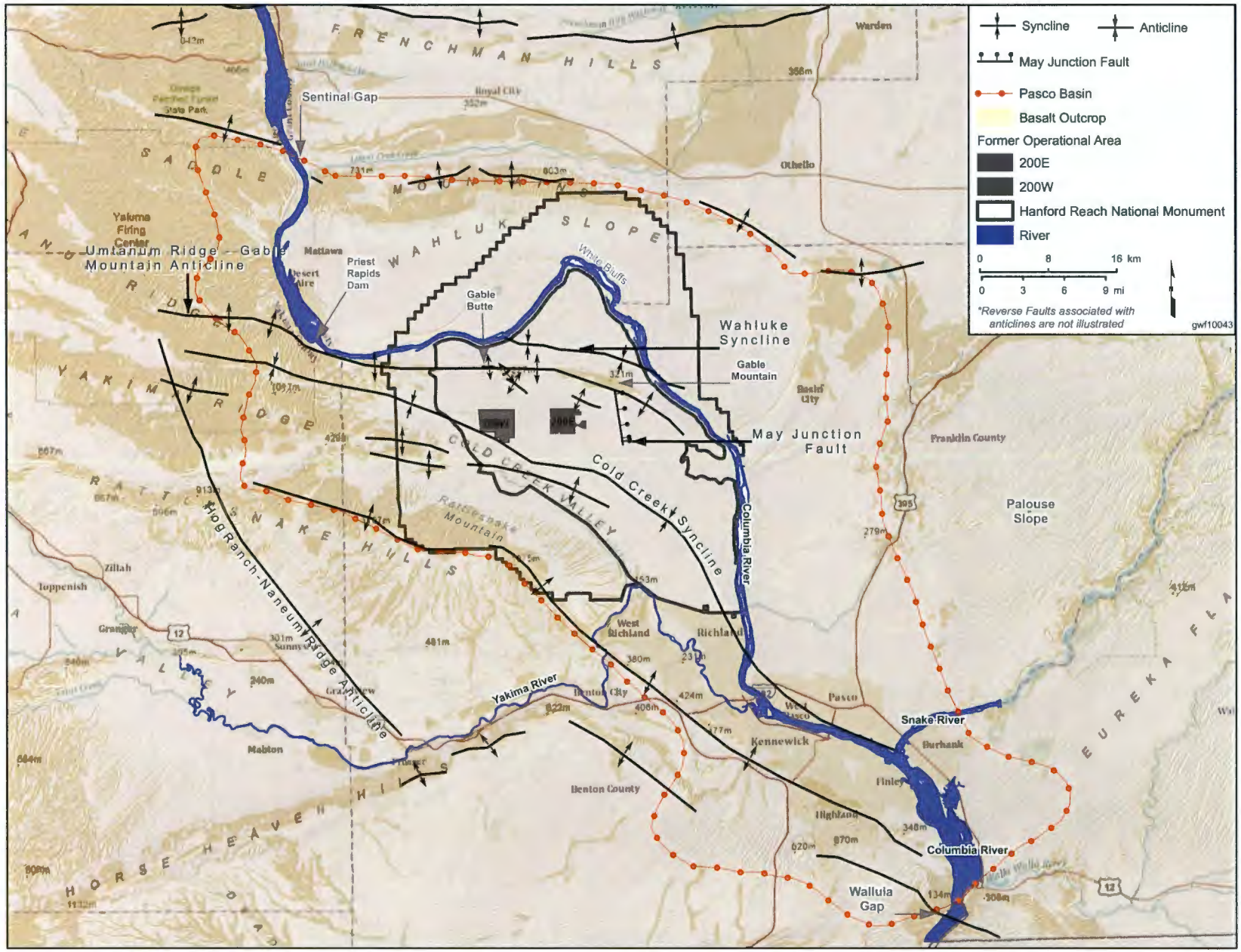


Figure 2-4. Facies of the Ringold Formation Within the Central Pasco Basin

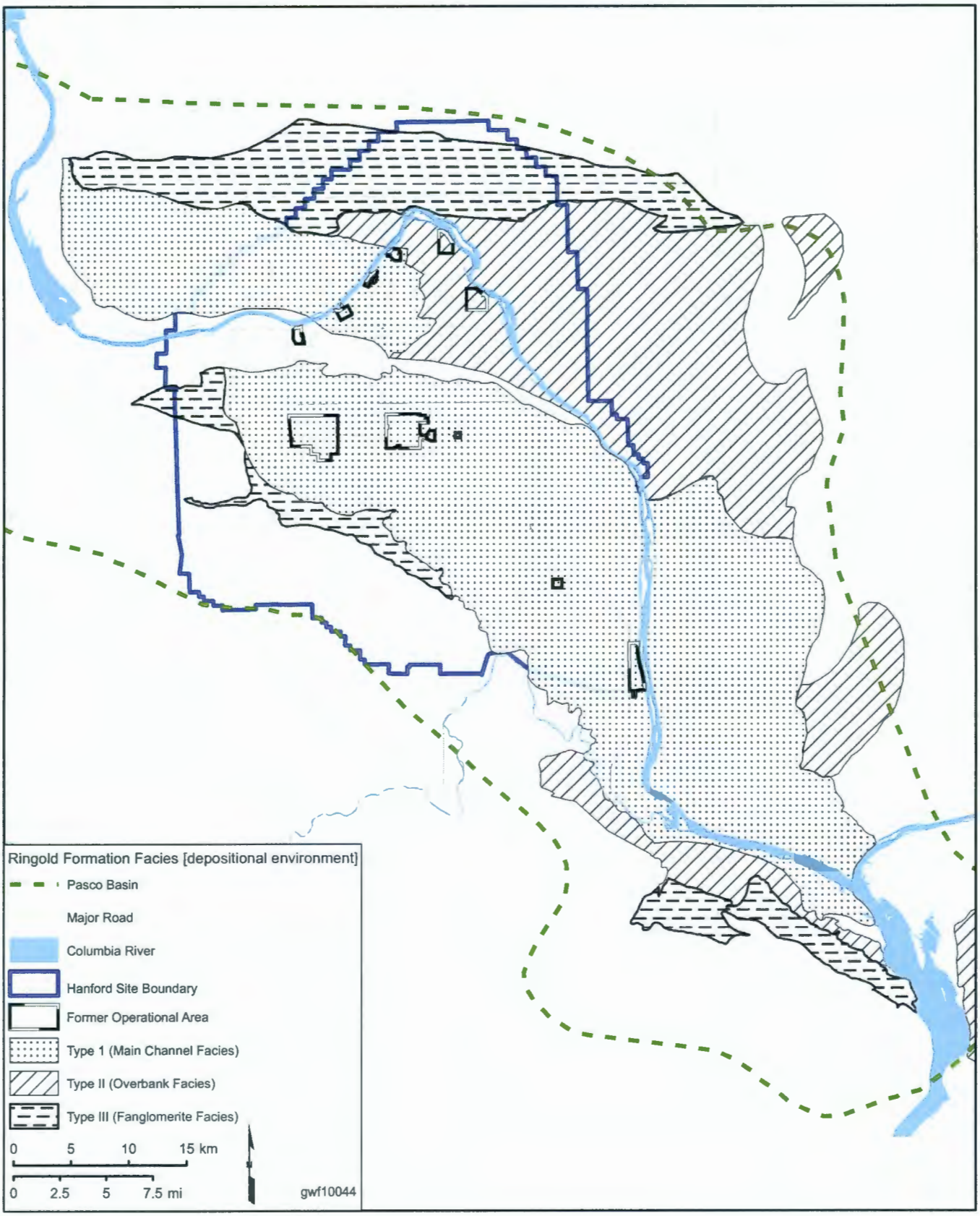
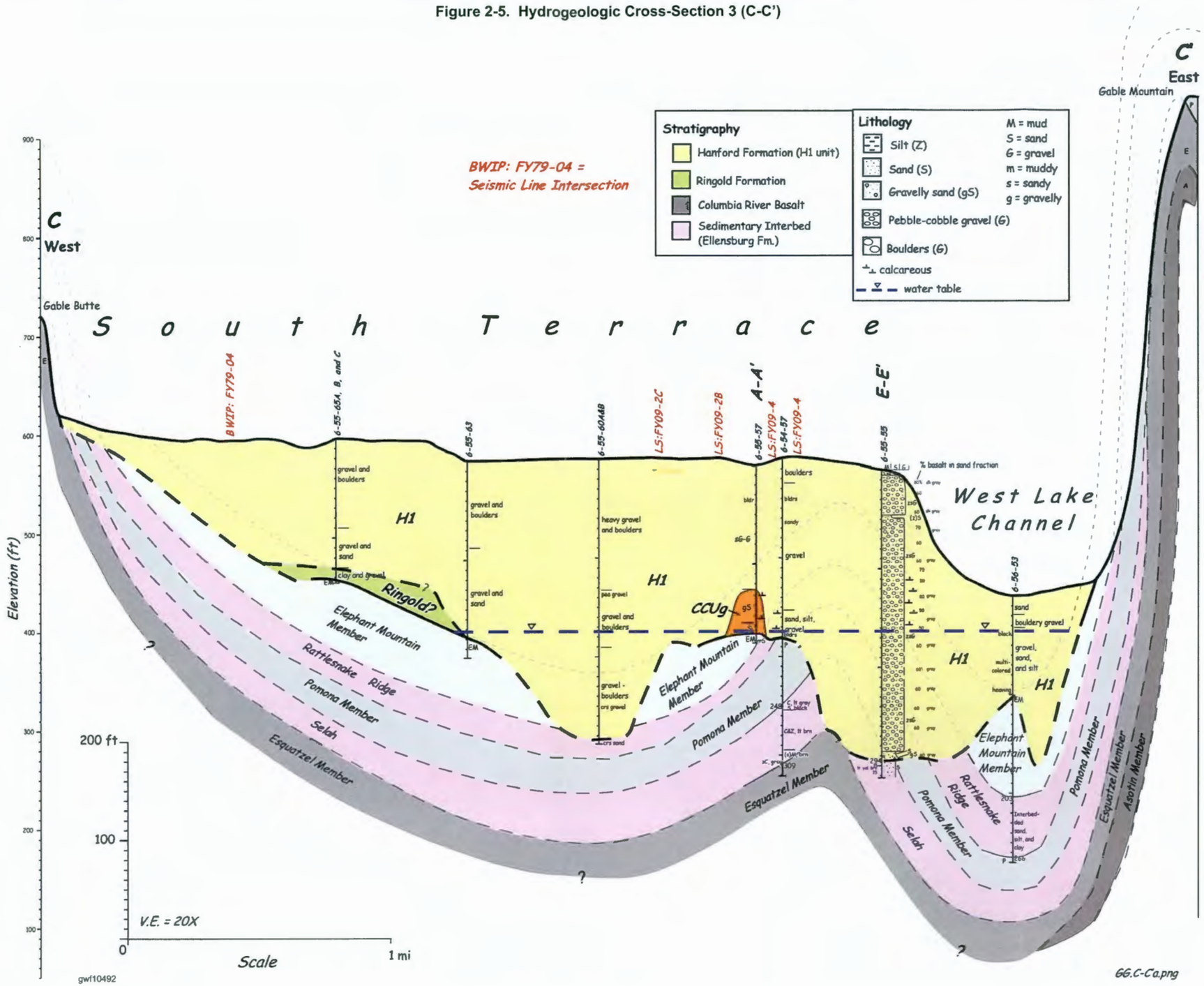


Figure 2-5. Hydrogeologic Cross-Section 3 (C-C')



This page intentionally left blank.

Figure 2-6. Lower Ringold Formation Beneath the 200 East Area

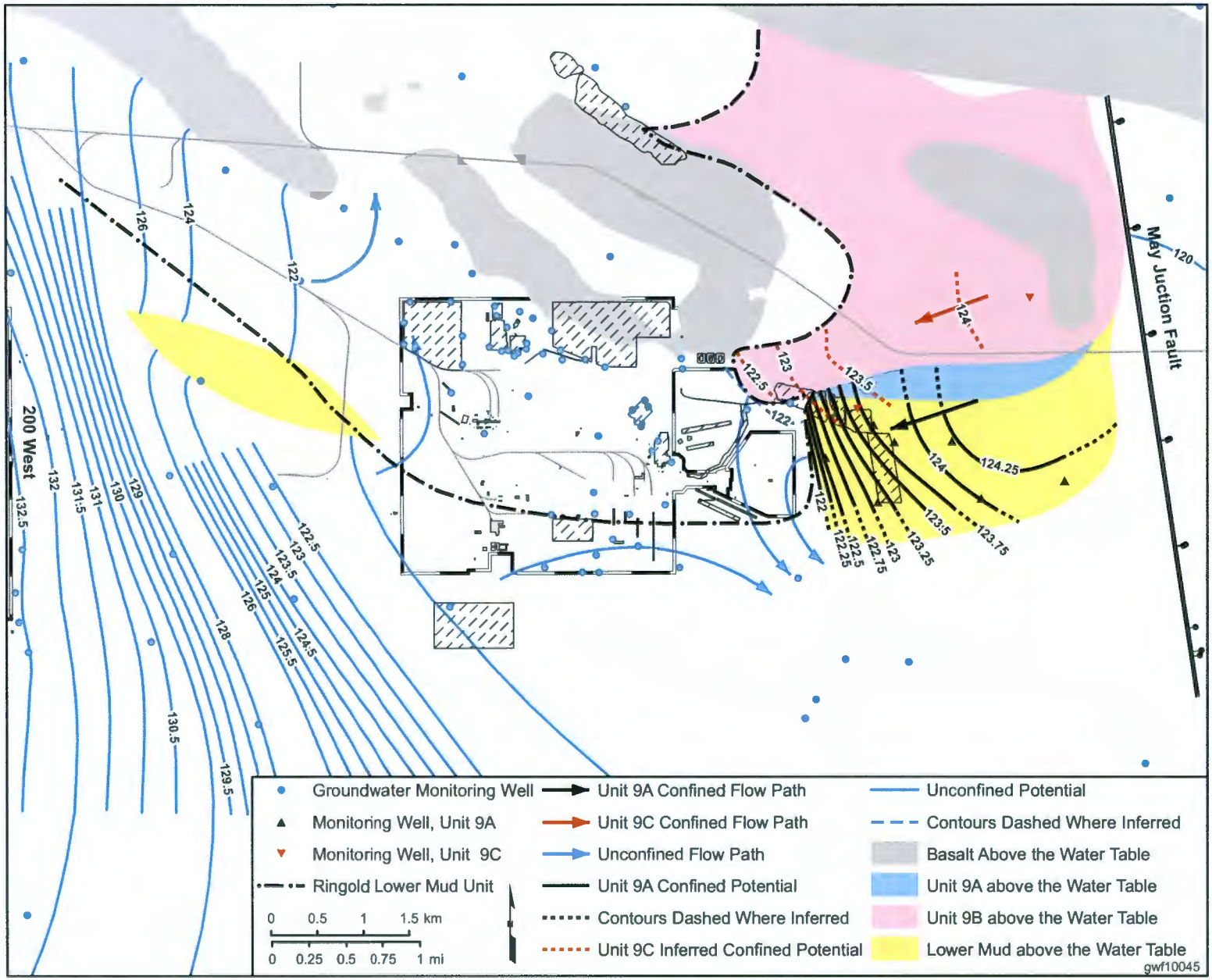


Figure 2-7. Facies Distribution for the Cold Creek Unit Within the Central Pasco Basin

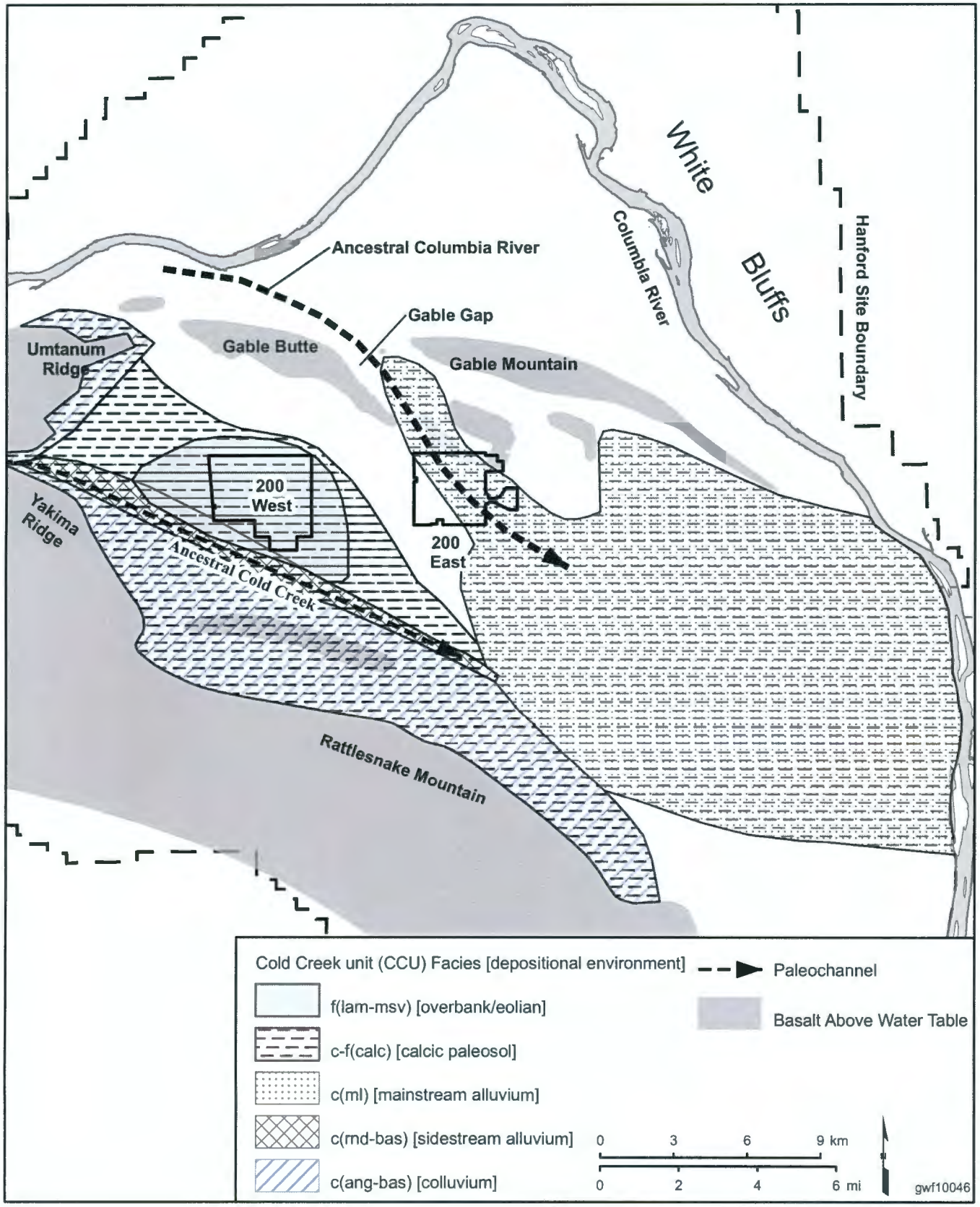


Figure 2-8. Ice Age Flood Geomorphic Features of the Pasco Basin

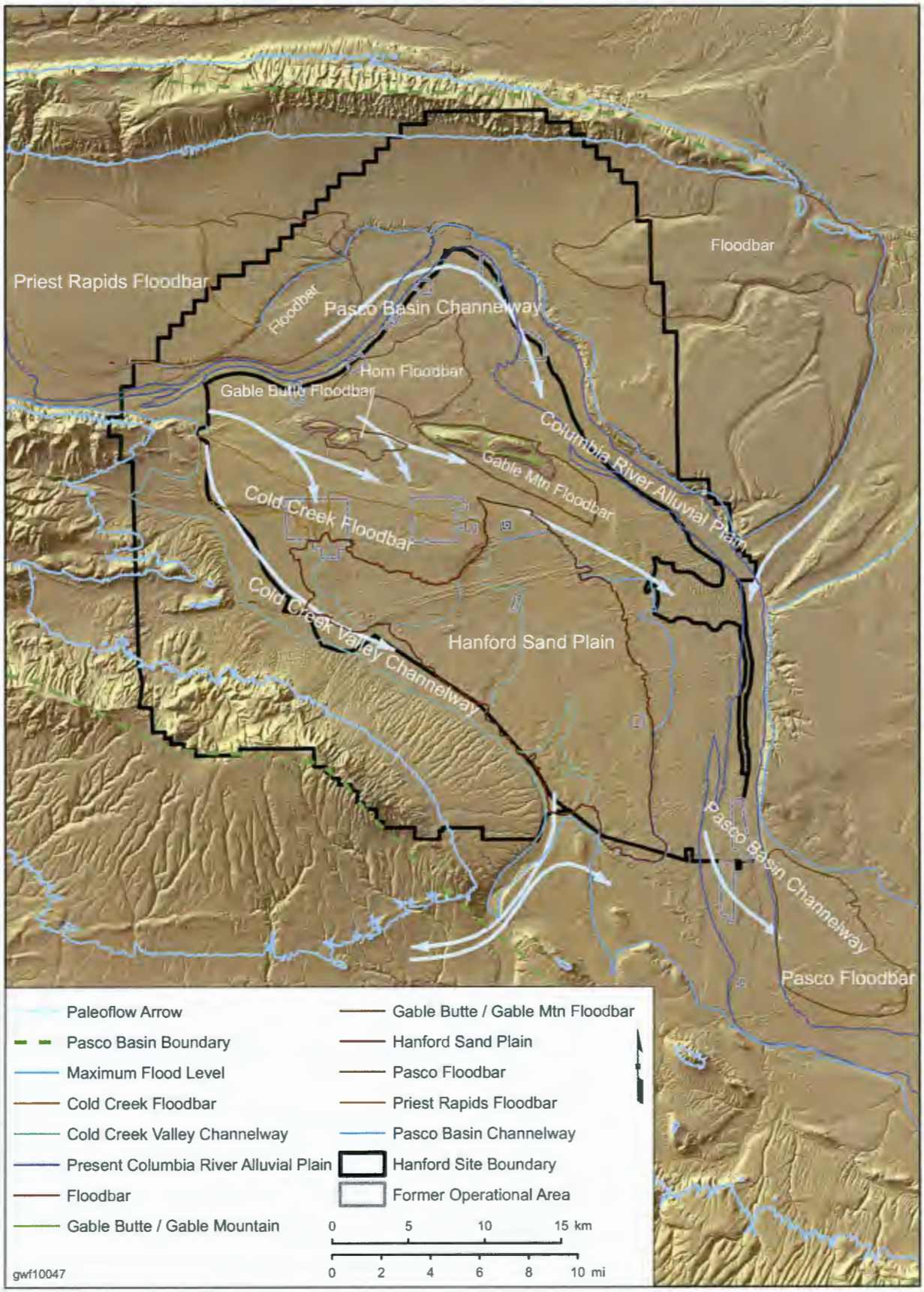


Figure 2-9. Cross-Section Location Map

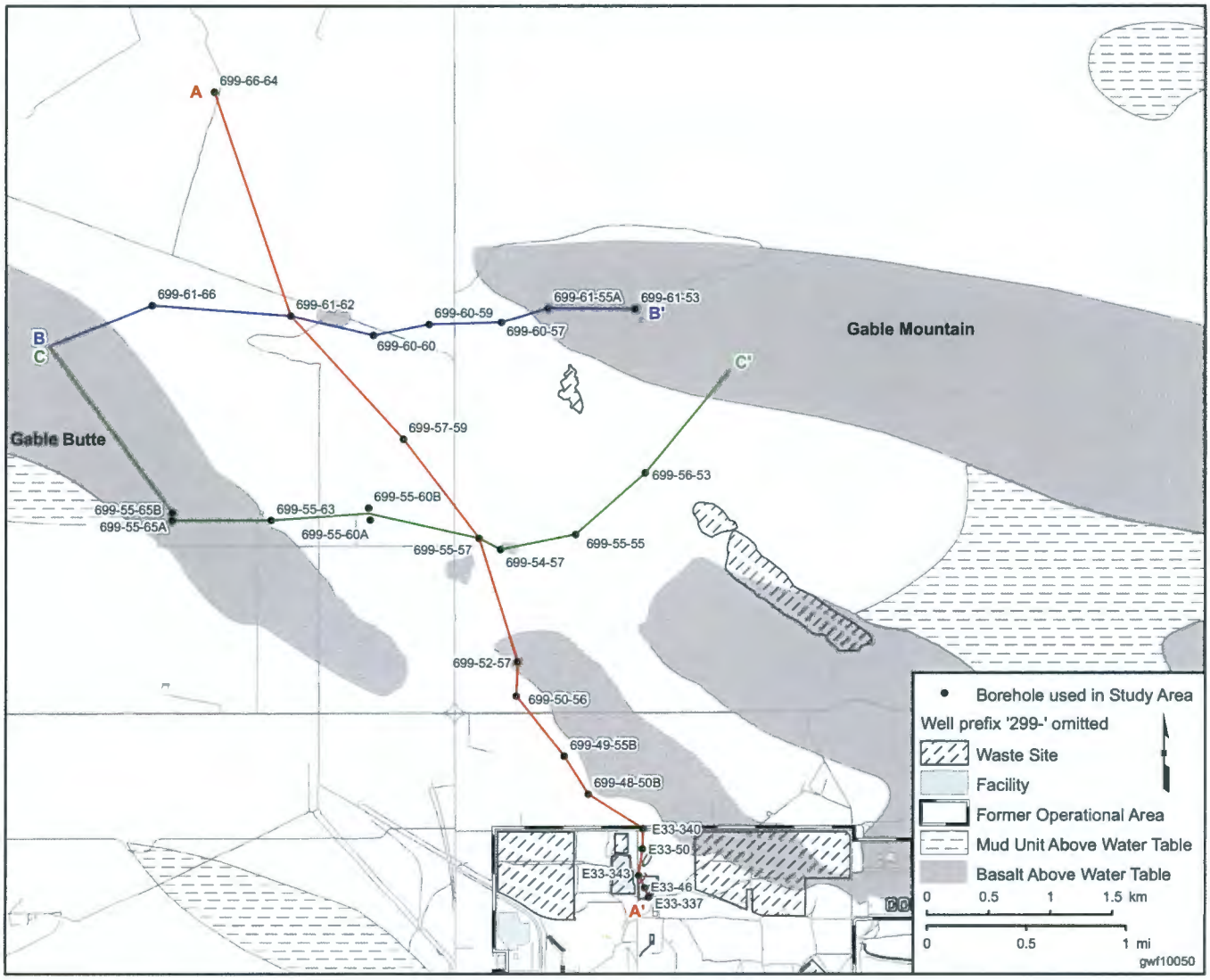
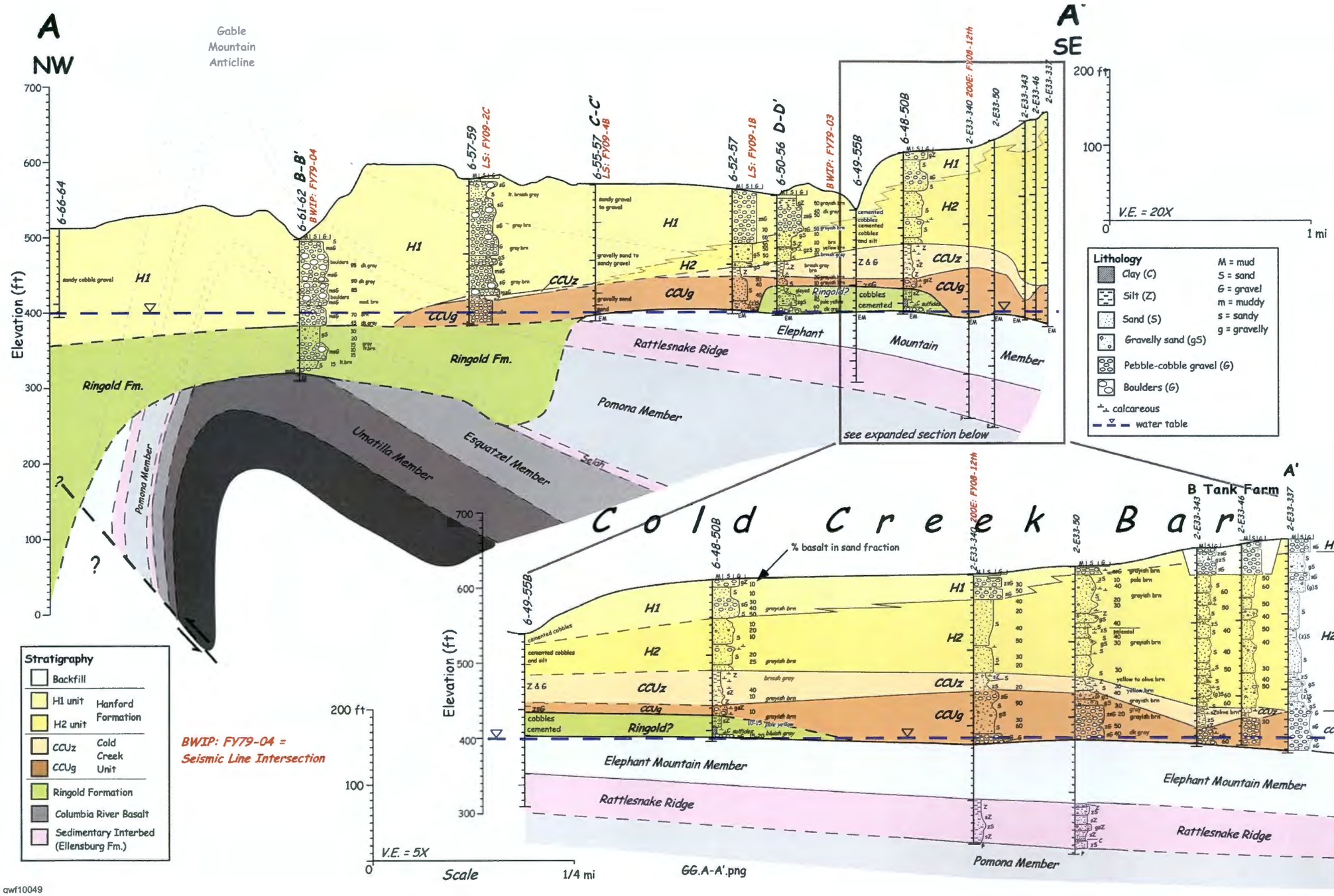


Figure 2-10. Hydrogeologic Cross-Section 1 (A-A')



This page intentionally left blank.

Figure 2-11. Hydrogeologic Cross-Section 2 (B-B')

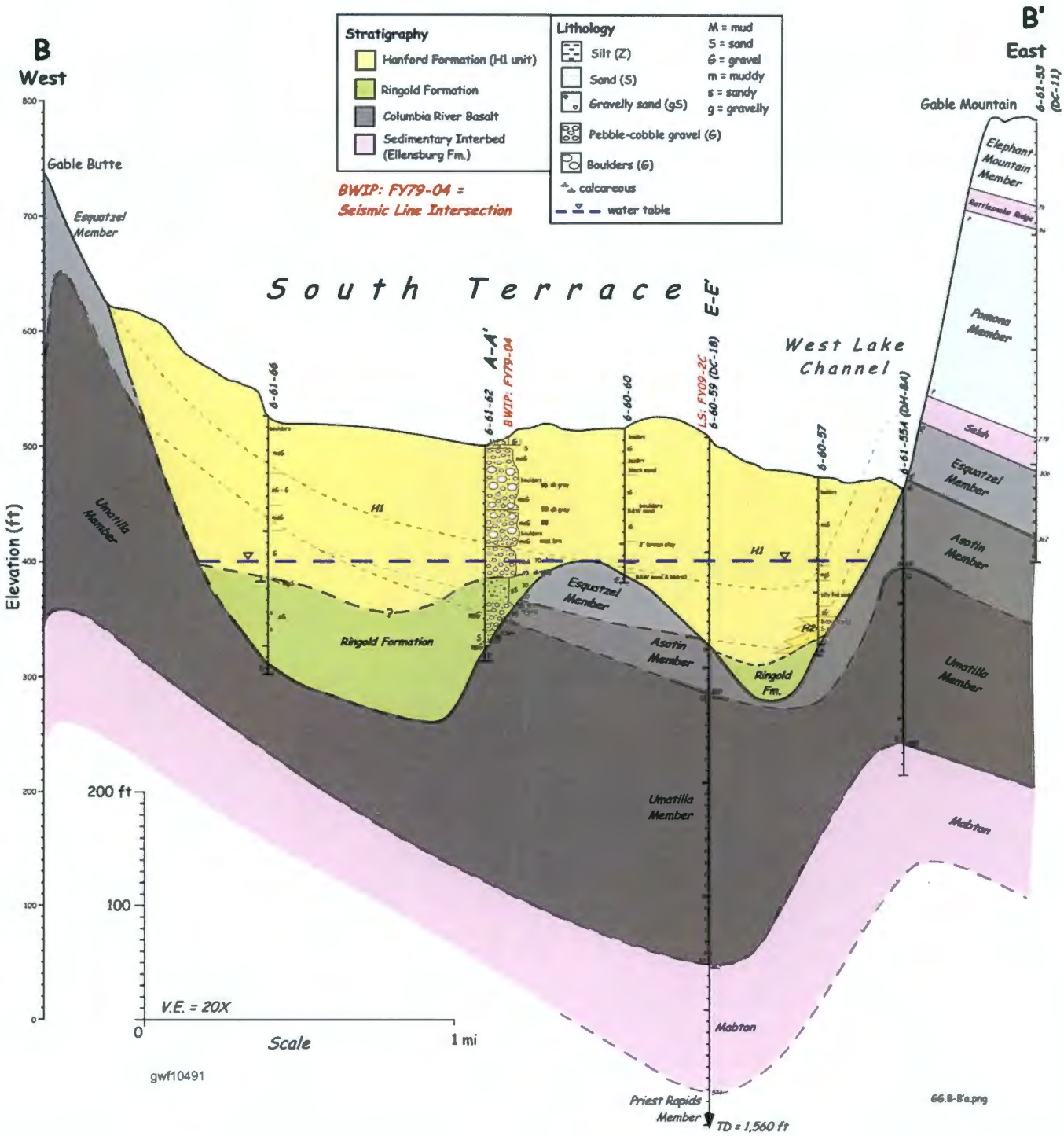
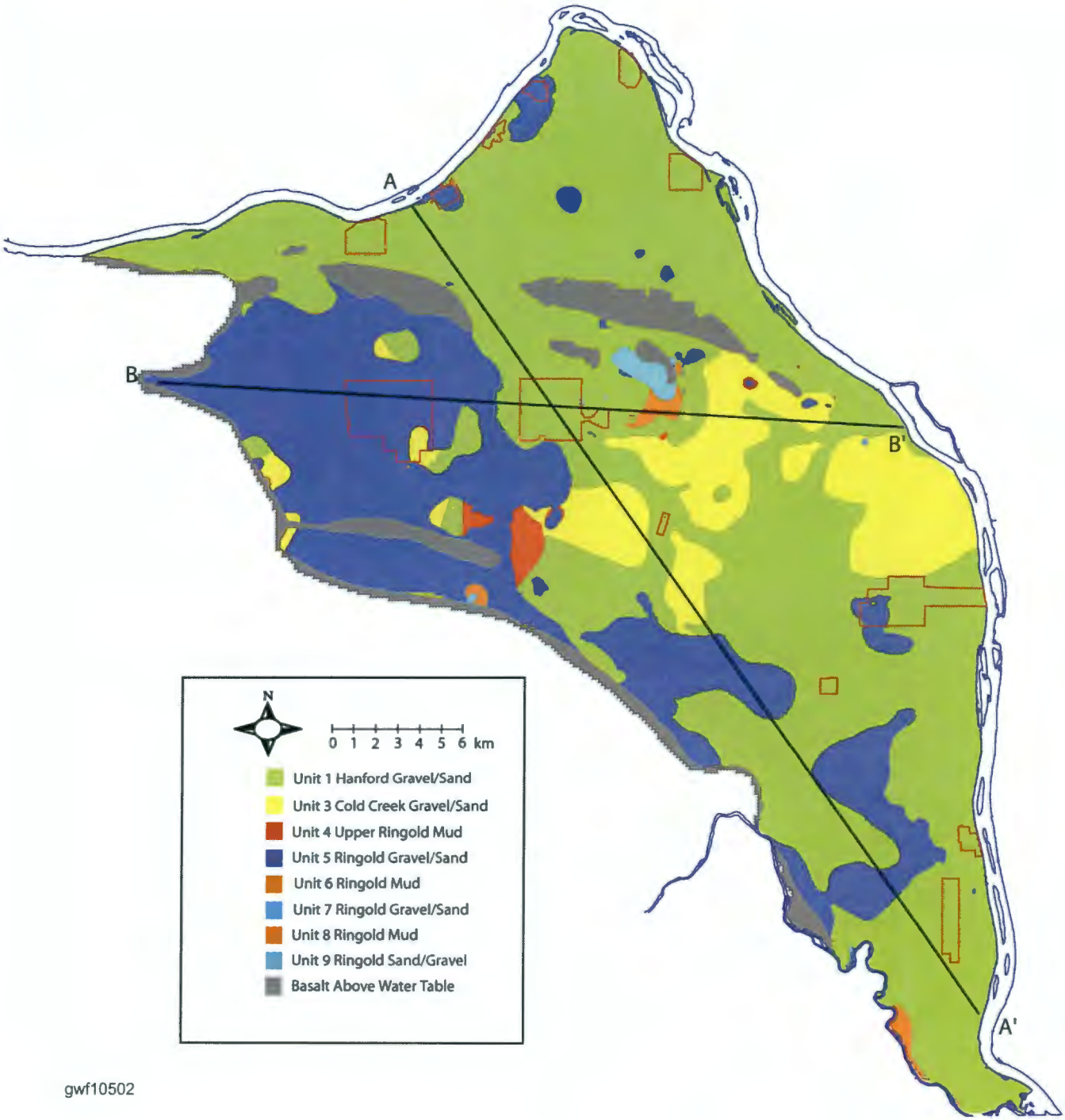


Figure 2-12. Distribution of Hydrogeologic Units at Maximum Water Table (after PNNL-14753)



gwf10502

Figure 2-13. Hydraulic Conductivity Distribution at Maximum Water Table (after PNNL-14753)

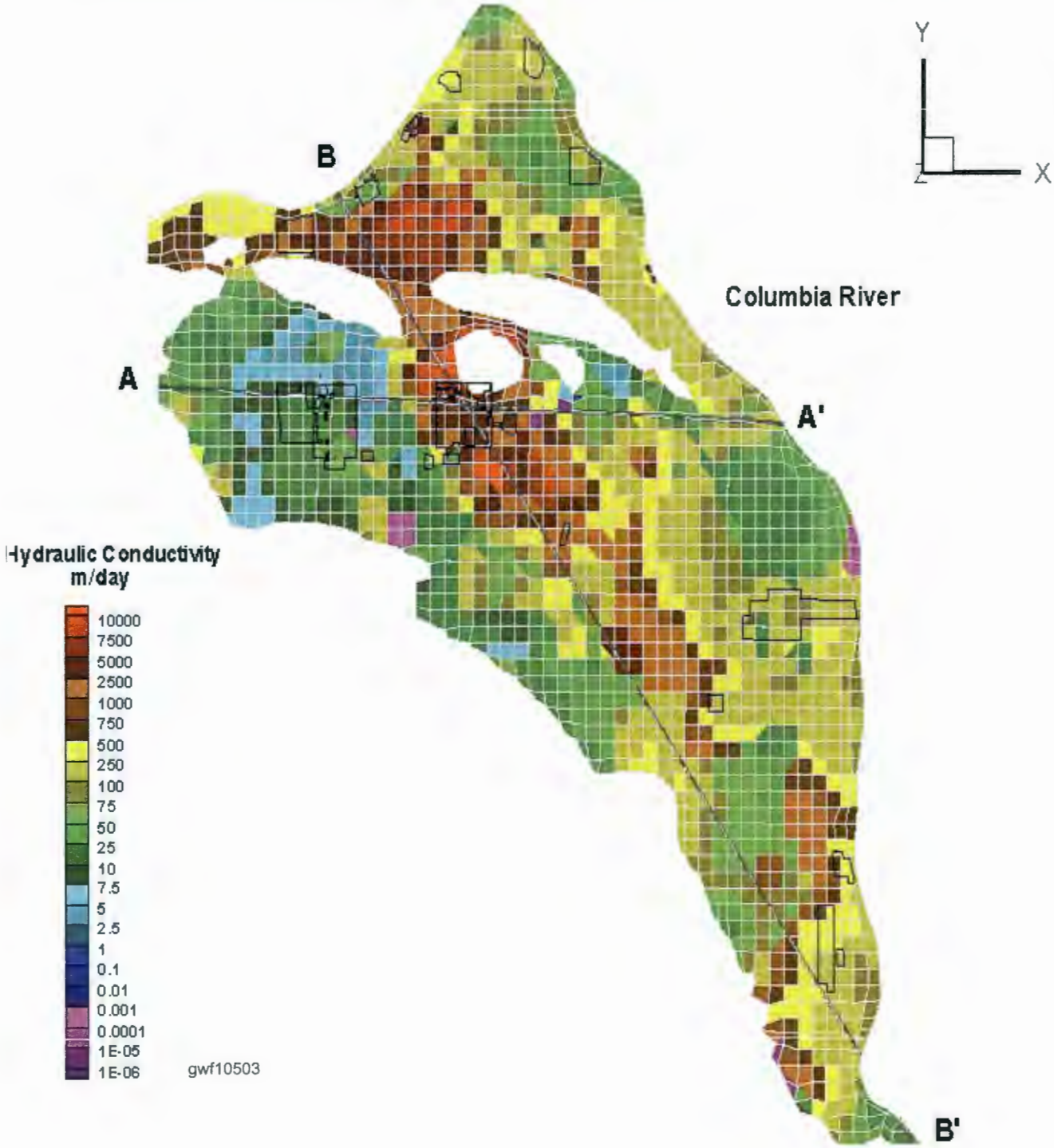
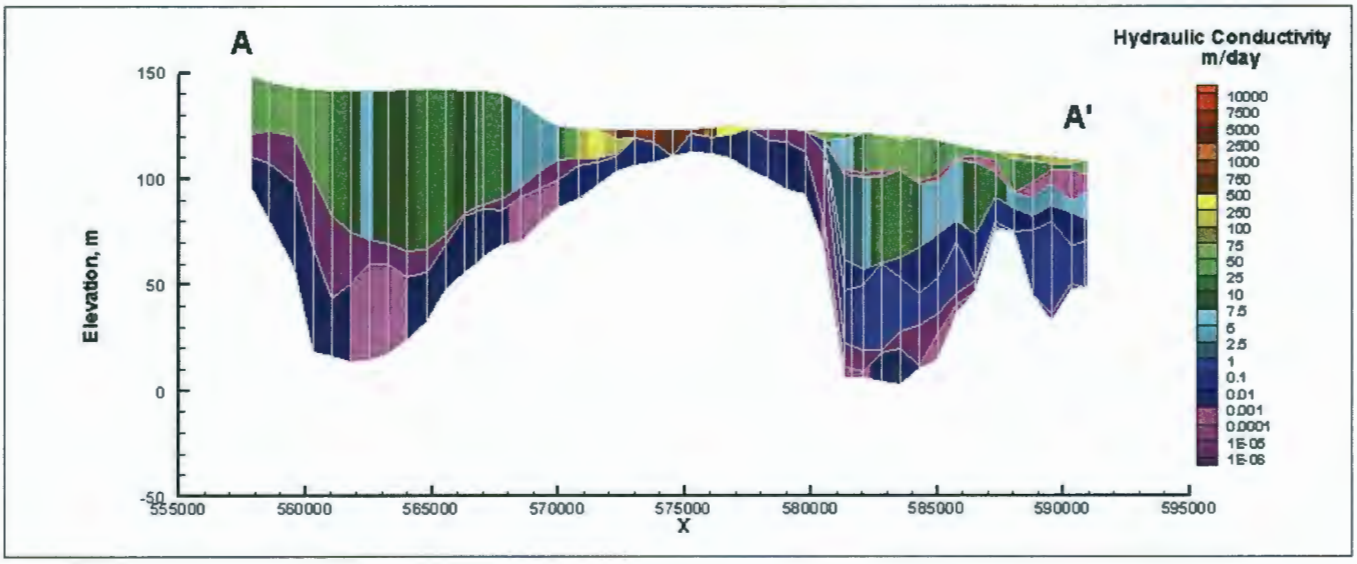
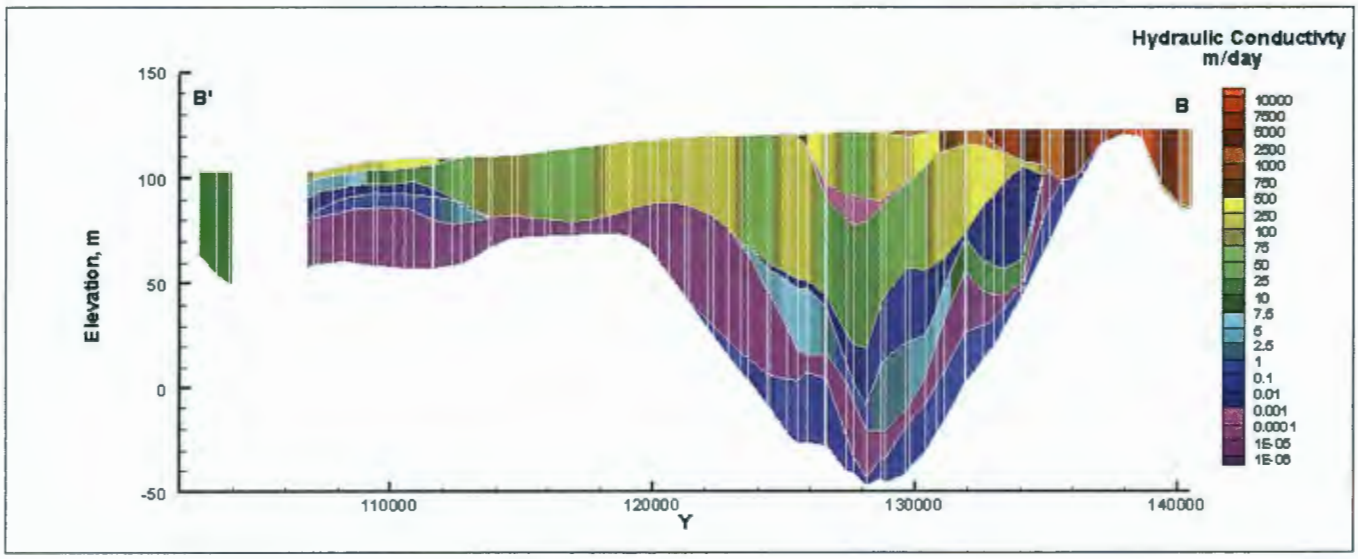


Figure 2-14. Hydraulic Conductivity Distribution Along Cross-Section (a) A-A' and (b) B-B' at the Maximum Water Table (after PNNL-14753)



(a)



gwf10504

(b)

3.0 Overview of Groundwater Flow

J.P. McDonald

This chapter provides a regional overview of groundwater flow beneath the Hanford Site. The uppermost aquifer beneath most of the site is unconfined and is composed of unconsolidated to semiconsolidated sediment of the Hanford formation, Cold Creek unit (CCU), and Ringold Formation, which overlie the basalt bedrock. In some areas, deeper portions of the aquifer are confined locally by layers of silt and clay. Deeper confined aquifers also occur within the underlying basalt and associated sedimentary interbeds (see Chapter 2.0). Wells in the 600 Area, which cover portions of the site other than the former operational areas, are shown in Figure 3-1. More detailed well location maps for specific areas are included in Chapters 4.0 through 15.0.

During March 2010, a total of 808 water-level measurements were collected across the Hanford Site. This information helps scientists understand the direction and rate of groundwater flow.

During March 2010, a total of 808 water-level measurements were collected from wells monitoring the unconfined aquifer system and the underlying confined aquifers beneath the Hanford Site. The data were used for the following purposes:

- Prepare contour maps that indicate the general direction of groundwater movement within an aquifer
- Determine hydraulic gradients, which in conjunction with the hydraulic properties of the aquifer, are used to estimate groundwater flow velocities
- Interpret sampling results.

This chapter describes the results of a regional-scale analysis of these data for the unconfined aquifer, which is the aquifer most affected by Hanford Site operations. Local groundwater flow in each groundwater operable unit (OU) and/or interest area is described in Chapters 4.0 through 14.0. The flow characteristics in the confined aquifers that are present in the lower Ringold Formation and in the upper basalt-confined aquifer system are discussed in Chapter 15.0. The collection and analysis of manual water-level measurements at the Hanford Site are described in *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project* (SGW-38815).

3.1 March 2010 Water Table and Changes from 2009

Figure 3-2 presents the Hanford Site water table map for March 2010. The water table mapping methodology is described in Chapter 4.0 of SGW-38815 (the water-level monitoring plan). In general, water-level measurements are displayed on a map using a geographic information system and contours are hand-drawn by a hydrogeologist. Generation of the March 2010 map differed from the methodology described in SGW-38815 by using a software numerical-grid generation algorithm to guide the hand-generation of contours near the groundwater pump-and-treat systems. This resulted in a better representation of water table drawdown and buildup around extraction and injection wells, respectively. The software (KT3D_H2O) uses the statistical, kriging numerical-grid generation method and includes additional drift terms in the kriging equation to represent extraction and injection wells ("KT3D_H2O: A Program for Kriging Water Level Data Using Hydrologic Drift Terms" [Karanovic et al., 2009]; SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*). Details of the water table configuration near the pump-and-treat systems are not evident in

Groundwater in the unconfined aquifer generally flows from the west toward the east beneath the Hanford Site and discharges to the Columbia River.

Figure 3-2 because of the small scale of the map but are evident on the larger scale water table maps presented in other chapters of this report.

Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge area north and east along the Columbia River. Steep hydraulic gradients occur in the west, east, and north regions of the Hanford Site. Shallow gradients occur southeast of the 100-F Area and in a broad arc extending from west of the 100-B/C Area, toward the southeast between Gable Butte and Gable Mountain (Gable Gap), through the 200 East Area and on into the central portion of the site. The steep gradients in the west and east are associated with low-permeability sediment of the Ringold Formation at the water table, while the low gradients are generally associated with highly permeable sand and gravel of the Hanford formation as well as the gravel-dominated facies of the CCU at the water table (PNNL-19702, *Hydrogeologic Model of the Gable Gap Area, Hanford Site*, Chapter 7.0).

North of Gable Butte and Gable Mountain, groundwater flow directions vary from northwest to east depending on location. Groundwater enters this region through the gaps between Gable Mountain, Gable Butte, and Umtanum Ridge (Figure 3-2), as well as from natural recharge. The Columbia River also recharges the unconfined aquifer west of the 100-B/C Area. Water flowing north through Gable Gap fans out and flows north-northwest toward the Columbia River, as well as toward the northeast and east along the north side of Gable Mountain. Recharge water from the Columbia River and the gap between Umtanum Ridge and Gable Butte is thought to flow east toward the 100-B/C Area and discharge to the river near that area. In the 100 Area, the local groundwater flow is generally toward the Columbia River, although this pattern is altered locally by groundwater pump-and-treat remediation systems in the 100-K, 100-D, and 100-H Areas.

Daily, monthly, and seasonal changes in Columbia River stage affect the flow of groundwater in the near river environment. During periods of high river stage, the Columbia River temporarily recharges the adjacent aquifer all along the river (bank storage effects), whereas during periods of low river stage, groundwater discharges from the aquifer to the river. River stage changes cause a mixing zone to occur in the aquifer along the river. At any given time, water discharging from the aquifer to the river can be composed of nearly all river water in bank storage, nearly all aquifer water, or some mixture depending on the recent history of river stage changes (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*). Modeling results indicate that groundwater flowing into the near river environment generally moves downward at the shoreline in response to river stage effects and then enters the river between ~30 to ~60 meters offshore (PNNL-13674), although areas of groundwater upwelling have been identified in the center of the river channel (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*).

An apparent groundwater mound exists ~2 kilometers north of Gable Mountain and is associated with low-conductivity Ringold Formation mud at the water table. This mound is contoured as if it were part of the unconfined aquifer (Figure 3-2), but it could represent a perched water table above the regional water table. Additional data are needed to distinguish between these alternatives. Water-level elevations indicate that groundwater moving toward the east along the north side of Gable Mountain flows around this apparent mound.

South of Gable Butte and Gable Mountain, natural recharge to the aquifer comes from the Cold Creek Valley, Dry Creek Valley, Rattlesnake Hills, Yakima River, and infiltrating precipitation. Groundwater generally flows from west to east, although some of the flow from the 200 West Area and/or north of the 200 West Area turns north and flows through Gable Gap. Previous effluent discharges at U Pond and other facilities caused a groundwater mound to form beneath the 200 West Area that significantly affected regional flow patterns in the past (e.g., see Figures 4 through 10 in PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site [1950-1970]*). These discharges largely ceased in the mid-1990s but a remnant mound remains, which is apparent from the shape of the water table contours passing through the 200 West Area. Currently, the water table elevation is ~10 meters above the estimated water table elevation prior to the start of Hanford Site operations.[1] Equilibrium conditions will be re-established in the aquifer after dissipation of the mound caused by artificial recharge. When this occurs, the water table may still be ~5 to 7 meters higher than before Hanford Site operations began because of increased irrigation activities west of the site. The water table beneath the 200 West Area is perturbed locally by current discharges from the State-Approved Land Disposal Site, as well as by operation of a groundwater pump-and-treat remediation system at the 200-ZP-1 OU. The water table is expected to be further altered by the expansion of the 200-ZP-1 pump-and-treat system, which is planned to startup in late 2011.

The water table in the 200 East Area is very flat, which makes determination of flow direction difficult.

Groundwater flow in the central portion of the Hanford Site (encompassing the 200 East Area) is substantially affected by the presence of highly permeable buried paleochannels, which lie in a northwest to southeast orientation (PNNL-19702, Section 6.2; PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, Chapter 4.0). The water table in this area is very flat (i.e., the magnitude of the hydraulic gradient is estimated to be ~10^{-5} m/m or less) because of the high permeability of the Hanford formation/CCU sediments. Groundwater flow in this region is affected by the presence of low-permeability sediment (i.e., muds) of the Ringold Formation at the water table east and northeast of the 200 East Area, as well as basalt above the water table. These features generally constitute barriers to groundwater flow, although the unconfined aquifer can occur in the fractured and rubbly basalt flow top where it has not been removed by erosion. The extent of the basalt units above the water table continues to increase slowly because of the declining water table, resulting in an even greater effect on groundwater flow in this area. In Figure 3-2, the depiction of basalt above the water table in the Gable Gap and 200 East Area vicinity was revised for this annual report to be consistent with a recent reinterpretation of the top of basalt (PNNL-19702, Figure 2-5). The water table beneath the 200 East Area is ~1.9 meters higher than estimated pre-Hanford conditions.[2] When equilibrium conditions are re-established, the water table in the 200 East Area is expected to return to very near the pre-Hanford elevation.

1 Based on the March 2010 water-level elevation in well 299-W18-15 (135.6 meters North American Vertical Datum of 1988 [NAVD88]) and the pre-Hanford water table elevation at the location of this well estimated from *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation* (BNWL-B-360) (~125.1 meters NAVD88). The peak historical water-level elevation in the 200 West Area occurred at well 299-W18-15 in 1984 (149.1 meters NAVD88).

2 Based on the average water-level elevation measured in 46 wells within the 200 East Area during March 2010, all of which have been corrected for deviations of the boreholes from true vertical (121.87 meters NAVD88) and the pre-Hanford water table elevation for the 200 East Area estimated from BNWL-B-360 (~120 meters NAVD88).

Water enters the 200 East Area and vicinity from the west and southwest, as well as from beneath the mud units to the east and from the underlying aquifers where the confining units have been removed or thinned by erosion. The flow of water divides beneath the 200 East Area, with some water flowing toward the north through Gable Gap and some flowing southeast toward the central portion of the site. The specific location of the groundwater flow divide is not certain because the flat nature of the water table in the 200 East Area makes determining flow directions difficult (see Section 3.2 for more information). It is known that groundwater flows north through Gable Gap because the hydraulic gradient magnitude within the gap area is large enough to be determined using water-level data. During 2010, the gradient magnitude in Gable Gap averaged 9.3×10^{-5} m/m along a north flow direction, but flow conditions vary during the year due to changes in river stage (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*, Section 2.1.4). Groundwater is inferred to flow southeast within the region between the 200 East Area and the Hanford Central Landfill because the average water-level elevation at the landfill (121.75 meters North American Vertical Datum of 1988 [NAVD88] for March 2010) is 0.12 meters lower than the average elevation in the 200 East Area (121.87 meters NAVD88 for March 2010). This yields a regional hydraulic gradient magnitude of $\sim 1.5 \times 10^{-5}$ m/m.

The hydraulic gradient magnitude in the 300 Area is also very low due to the presence of the highly permeable sediments of the Hanford formation at the water table. Groundwater flow converges on the 300 Area from the northwest, west, and southwest, then generally moves toward the southeast and discharges to the Columbia River (PNNL-15127, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004*, Section 3.1.2). As in the 100 Areas, flow in the 300 Area is also affected by Columbia River stage changes.

The water table continued to decline over much of the Hanford Site. The decline is due to the reduction of effluent discharges to the ground during the 1980s and 1990s.

The water table elevation continued to decline over much of the Hanford Site from March 2009 to March 2010. The decline is a result of the reduction of effluent discharges to the ground during the 1980s and 1990s. Outside of regions affected by groundwater pump-and-treat systems, the largest widespread declines occurred from west of the 200 West Area to the Cold Creek Valley, where the decrease in water levels ranged from 0.20 to 0.46 meters. Within the 200 West Area, water-level declines averaged 0.21 meters in areas away from the pump-and-treat systems. Water-level elevations increased slightly in Dry Creek Valley (i.e., 0.02 to 0.05 meters). The water table elevation also increased in the Richland area between the Yakima and Columbia Rivers. When considering only those wells not associated with pump-and-treat systems, the largest increase was 0.59 meters in well 699-S34-E15 located in North Richland not far from the Columbia River, and the largest decrease was 1.95 meters in well 1199-39-15 at the city of Richland North Well Field. These changes are attributed to operation of the well field and/or changes in river stage.

In the 200 East Area, the elevation of the water table declined by an average of 0.05 meters between March 2009 and March 2010, compared to a decline of 0.09 meters from March 2008 to March 2009 (DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*, Section 2.2). The smaller decline is attributed to increased effluent discharges at the Treated Effluent Disposal Facility (TEDF) (1.3×10^9 liters from March 2009 to February 2010) compared to the previous one-year period (2.6×10^8 liters from March 2008 to February 2009). This facility is located east of the 200 East Area, and it has been previously documented that higher than normal discharges to this

facility cause water-table fluctuations in the 200 East Area (PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, Section 2.1.3). During 2010, the discharge volume to this facility was elevated in April and May and again from August to October. This caused two separate fluctuations in the 200 East Area water table elevation during the year, as shown in Figure 3-3. In fact, the water table elevation in the 200 East Area was essentially the same in January and December 2010 (i.e., no net change occurred in water table elevation during 2010) as a consequence of the TEDF discharges.

3.2 200 East Area Hydraulic Gradient Evaluation

In the previous annual report (DOE/RL-2010-11, Section 2.3), efforts to measure the hydraulic gradient in the 200 East Area at Low-Level Waste Management Area 1 (LLWMA-1) and at the Integrated Disposal Facility (IDF)/Plutonium Uranium Extraction (PUREX) Cribs were described and the results to date were provided. This work continued during 2010. This section provides an update of the study, including the analyses performed during 2010 and a discussion of efforts to measure the hydraulic gradient at an additional location, the area of LLWMA-2/216-B-63 Trench. This discussion emphasizes the collection and analysis of water-level data and the usefulness of the data for determining hydraulic gradients. A more detailed integration of these analyses with the groundwater sampling results is provided in site-specific sections of this report (see Chapter 9.0, Section 9.3.1 for LLWMA-1, Section 9.3.2 for LLWMA-2, and Section 9.3.6 for the 216-B-63 Trench; and see Chapter 10.0, Section 10.3.1 for the IDF and Section 10.3.2 for the PUREX Cribs).

As described in Section 3.1, the water table in the 200 East Area is very flat due primarily to the high permeability of the Hanford formation and CCU, as well as the presence of a groundwater flow divide in this area. The estimated regional hydraulic gradient magnitude of ~1.5×10^{-5} m/m (Section 3.1) equates to a change of 1.5 centimeters in water table elevation per kilometer. The distance from the northwest to the southeast corners of the 200 East Area is ~4 kilometers, so the water table elevation is expected to change no more than ~6 centimeters in the 200 East Area if the hydraulic gradient was uniform. However, because a flow divide is interpreted to exist within this area, the actual water table elevation change is less. Figure 9-4 in Chapter 9.0 indicates that water-level elevations generally vary by ~2 to ~3 centimeters from northwest to southeast across the 200 East Area. Without correcting for the error caused by wellbore deviations from vertical, water-level data collected from the 200 East Area exhibit a range of ~10 centimeters. Thus, uncorrected water-level data are not accurate enough to determine hydraulic gradients within the 200 East Area.

A study is being conducted to determine groundwater flow directions in the 200 East Area to support groundwater monitoring at RCRA waste sites.

Several *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) units are located within the 200 East Area. Groundwater monitoring under RCRA regulations requires that the groundwater flow direction be determined beneath each RCRA TSD unit to distinguish between upgradient and downgradient monitoring wells (e.g., 40 CFR 265.91[a], "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring System," as referenced by WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards," for sites monitored under interim status regulations). Therefore, a study has been ongoing since September 2005 to improve the accuracy of water-level measurements in the 200 East Area so groundwater flow directions beneath the RCRA TSD units can be determined.

This study is being performed at three locations within the 200 East Area: LLWMA-1, the IDF/PUREX Cribs, and LLWMA-2/216-B-63 Trench. A network of wells was established at each site, with the wells chosen so long screen intervals were avoided where possible. The well networks for each site are shown in Figure 3-4 for LLWMA-1, Figure 3-5 for the IDF/PUREX Cribs, and Figure 3-6 for LLWMA-2/216-B-63 Trench. The network for LLWMA-1 initially consisted of ten wells, but four additional wells (299-E28-1, 299-E28-17, 699-49-55A, and 699-50-56) were added in early 2008, forming a network of fourteen wells.

Gyroscope and elevation surveys were performed for each well to improve the accuracy of the water-level measurements. The gyroscope surveys were performed to correct for deviations of the wellbores from vertical. Such deviations result in a measured depth to water that is larger than the true vertical depth to water and, therefore, a calculated water-level elevation that is lower than the true elevation. A gyroscope survey is used to map the position of the wellbore in three-dimensional space, which allows for the difference between the measured and true vertical depths to water to be determined. The largest correction value during this study was 0.367 meters (36.7 centimeters), and the average correction value was 0.040 meters (4.0 centimeters).

The accuracy of water-level measurements in the 200 East Area was improved by conducting wellbore deviation surveys and highly accurate casing elevation surveys.

Casing elevation surveys were performed to a higher degree of accuracy than normally performed for monitoring wells at the Hanford Site. Leveling surveys were performed for each well network using an infrared sighting device and a one-piece invar rod; double runs were performed between wells and the results were averaged. All of the wells resurveyed in the 200 East Area were referenced to a single benchmark. All surveys were performed in loops that closed on the starting point, allowing for misclosure values[3] to be determined. The largest misclosure value was 0.003 meters (0.3 centimeters) and the average misclosure was 0.0011 meters (0.11 centimeters), indicating that high accuracy was achieved.

Water-level measurements were collected using measuring tapes dedicated for this study. The initial measuring tape used was calibrated by a standards laboratory and found to be accurate to within 0.001 meter (1 millimeter) throughout its length.

The water-level measurements were analyzed by trend-surface analysis, in which a plane is fitted to a set of water-level measurements by least-squares regression. The interpreted hydraulic gradient direction corresponds to the dip direction of the fitted plane, and the amount of dip represents the hydraulic gradient magnitude. The degree to which the plane represented the data (i.e., the goodness of fit) was assessed by an analysis of variance statistical test. This test is used to determine whether the data exhibit a true spatially dependent trend to an acceptable probability of error (i.e., the level of significance), which was chosen to be 0.05 for this study (i.e., a 95% confidence level). It should be emphasized that the fitting of a first-degree trend surface (i.e., a plane) is a method that reveals the overall linear trend in the measurements across an entire study area; local deviations from the linear trend can occur within any study area.

3 A misclosure value is the difference in elevation between the starting and ending values of a survey loop that closes on the starting point. Ideally, the misclosure value should be zero, but this is rarely achieved because measurements always have some uncertainty. Thus, the misclosure value provides an indication of the uncertainty in a survey loop. Small misclosure values indicate high accuracy. The misclosure is typically distributed linearly throughout the survey loop to determine final elevations.

3.2.1 Low-Level Waste Management Area 1

Water-level measurements for this study have been periodically collected at LLWMA-1 since September 2005, and the trend-surface analysis results are shown in Table 3-1. The results of the statistical test are given as the *p* value, which is the probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. Where this value is less than 0.05, the trend-surface analysis result is deemed statistically significant at the 95% confidence level (i.e., it is accepted that the fitted trend surface is a good approximation of the overall hydraulic gradient across the study area for the set of measurements being analyzed).

Eleven sets of water-level measurements were collected at LLWMA-1 from September 2005 through June 2008, and all but two of the measurements yielded a statistically significant result, indicating a gradient direction between northwest and north (Table 3-1). The *p* values for the two data sets not deemed statistically significant were 0.060 and 0.070, which are only slightly above 0.05. Using all of the trend-surface analysis results, the average hydraulic gradient magnitude during this time was 8.2×10^{-6} m/m ($\pm 0.7 \times 10^{-6}$ m/m) and the average direction was toward the north-northwest at 338 degrees azimuth (±9 degrees). This interpretation is in general agreement with the orientation of contaminant plumes emanating from nearby Waste Management Area B-BX-BY and the BY Cribs.

At LLWMA-1 in the northwestern portion of the 200 East Area, the long-term groundwater flow direction is toward the north-northwest, although temporary flow reversals can occur due to seasonal changes in Columbia River stage.

The collection of water-level measurements on a monthly basis began at LLWMA-1 during June 2008, and beginning in July 2008, the hydraulic gradient results began to change. The results in July 2008 were not statistically significant with a very high *p* value (Table 3-1). During August, September, and October, the results were statistically significant, with flow directions toward the south for all 3 months. Although the results for November and December were not statistically significant, gradient directions toward the south were indicated with only moderately high *p* values. During January, February, and March 2009, the results were not statistically significant with very high *p* values. Indications of a gradient direction toward the north began again during April and May with moderately high *p* values, and finally a statistically significant northern gradient direction was indicated for July 2009. These results indicate that a temporary reversal in groundwater flow direction occurred, with flow toward the south occurring from August through October 2008, and perhaps into December. The months with high *p* values, (i.e., July 2008 and January, February, and March 2009) indicate periods of transition between northward and southward flow. The mean gradient magnitude and direction was not calculated for the data sets after June 2008 because it would not be representative of groundwater flow during a period of changing flow conditions.

Previous work has suggested that in addition to the long-term decline in water levels due to the reduction of effluent discharges at the Hanford Site, the water table elevation in the 200 East Area is potentially affected by two other stressors: seasonal changes in river stage, and discharges to the TEDF east of the 200 East Area (PNNL-16346, Section 2.1.3). It is feasible for changes in the river stage to affect the water table in the 200 East Area because the aquifer in this area and to the north through Gable Gap is highly transmissive. The two stressors are expected to have opposite effects on the hydraulic gradient at LLWMA-1. Because the TEDF is located southeast of LLWMA-1, discharges to the TEDF should increase the magnitude of the northward hydraulic gradient. In contrast, river stage increases propagating inland from the north should decrease the northward gradient or cause a gradient reversal at LLWMA-1. The flow reversal documented at LLWMA-1 appears to be a result of

high river stage during the summer of 2008 combined with the lack of large-volume discharges to the TEDF that year.

Between September 2009 and May 2010, the hydraulic gradient at LLWMA-1 was not discernable. As shown in Table 3-1, the *p* values during this timeframe were high and the dip direction of the fitted trend surfaces had values in all four quadrants of the compass. This suggests that the hydraulic gradient was extremely low and that flow was stagnant, or nearly stagnant, within the study area during this time. This situation corresponds to a period of low discharge volumes to the TEDF from July 2009 to March 2010 (Figure 3-3).

The measurements collected during June 2010 exhibited a statistically significant gradient direction toward the north. Subsequent measurements in July, September, and in January 2011 indicate northward directions, with *p* values lower than the values in late 2009/early 2010, although none of the results were statistically significant. However, because the *p* values were relatively low during this time, the hydraulic gradient is interpreted to be toward the north throughout the latter half of 2010. This corresponds to a period of high-discharge volumes to the TEDF from April to October 2010 (Figure 3-3).

The remaining error in the water-level elevation determinations was estimated using the six wells in this study that are located around the perimeter of LLWMA-1: 299-E28-27, 299-E32-5, 299-E32-6, 299-E32-8, 299-E33-28, and 299-E33-34. These wells were used because trend-surface analyses on only these six wells indicate that the water table is too flat directly beneath LLWMA-1 to be measured. Thus, it was assumed that all of the variability exhibited by these measurements (on any given measurement date) was due solely to measurement error. Based on the standard deviation of the water-level elevations determined for these wells since June 2008,[4] the 90% confidence interval is ±0.006 meters (i.e., ±6 millimeters), for a total range of 0.012 meters. This represents an upper bound on the total remaining variability in the water-level measurements (because some of the variability could be due to a very low hydraulic gradient magnitude). Sources of this variability include the accuracy limit of the gyroscope and casing elevation surveys, differences in water-level fluctuations between wells due to barometric pressure changes, and the accuracy of the depth-to-water measurements.

3.2.2 Integrated Disposal Facility/PUREX Cribs

At the IDF/PUREX Cribs in the southeastern portion of the 200 East Area, water-level data indicate that the groundwater flow direction is toward the east.

At the IDF/PUREX Cribs, water-level measurements have been collected for this study since June 2008. The measurements at this site exhibit more variability than those from LLWMA-1. Many of the wellbores at the IDF/PUREX Cribs are more substantially deviated from vertical. This results in more friction when a measuring tape is lowered into the well, which makes obtaining an accurate depth-to-water measurement more difficult. In addition, field observations indicate a greater amount of air movement through the wellbores in response to atmospheric pressure changes than has been observed at LLWMA-1, so water-level changes caused by barometric pressure fluctuations could be greater.

The trend-surface analysis results for IDF/PUREX Cribs are provided in Table 3-2. When all of the wells were used in the trend-surface analyses, statistically significant results were not obtained for any set of measurements. To obtain the results shown

4 This analysis considered only the difference of each water-level elevation value from the mean value of all six wells for each measurement date. Thus, changes in the water table elevation over time due to the long-term water-level decline or temporary fluctuations were not included as part of the measurement variability.

in Table 3-2, each data set was analyzed by repeatedly removing the well with the highest residual (i.e., the measurement having the largest difference from the fitted plane) until the dip direction stabilized and the trend-surface result was statistically significant. Three wells were removed from the analyses much more frequently than the others: 299-E17-18 (removed from ten of the sixteen analyses; always biased low), 299-E24-16 (removed from fifteen of the sixteen analyses; always biased high), and 299-E24-18 (removed from thirteen of the sixteen analyses; always biased low). All three wells were drilled by cable tool and constructed with 4-inch-diameter screens inside 8-inch-diameter telescoping screens. However, one other well in the network, 299-E25-36, was drilled and completed in the same manner but its water levels did not exhibit a bias (it was removed from only one of the sixteen data sets). Thus, well construction does not seem to be the cause of the bias. If the bias was due to barometric pressure effects, it is expected that the values would be biased both high and low in the same well depending on whether the barometric pressure was increasing or decreasing at the time of measurement. However, water levels from each of the three wells are always biased either high or low. This suggests that the measurements from these wells are affected by some residual systematic source of bias, either in the well casing elevation surveys, the gyroscope surveys, or that the water level in the well is not representative of the water table for some undetermined reason (to the degree of accuracy needed for this study). From the trend-surface analyses, the resulting hydraulic gradient directions range from northeast (29 degrees azimuth) to south (173 degrees azimuth). The average direction was toward the east at 80 degrees (±17 degrees), and the average gradient magnitude was 2.0×10^{-5} m/m ($\pm 0.2 \times 10^{-5}$ m/m). The average gradient magnitude is in close agreement with the estimated regional gradient magnitude of $\sim 1.5 \times 10^{-5}$ m/m (Section 3.1), and the average direction is in reasonable agreement with previous interpretations of flow toward the east/southeast based on the geometry of contaminant plumes (see Chapter 10.0, Sections 10.3.1 and 10.3.2).

3.2.3 Low-Level Waste Management Area 2 and 216-B-63 Trench

Work has been ongoing to determine the hydraulic gradient at a third location in the 200 East Area, the LLWMA-2 and 216-B-63 Trench vicinity; however, to date, this effort has not been successful. At this location, a network of eight wells was established (Figure 3-6) and gyroscope and casing elevation surveys were performed. The collection of water-level measurements began in March 2009 and continued during 2010. Only two of the trend-surface analysis results were statistically significant out of seventeen data sets. The remaining data sets had p values ranging from 0.2 to 0.9. When using the technique employed for the IDF/PUREX network of removing the measurement with the highest residual and repeating the trend-surface analyses until convergence (Section 3.2.2), nine of the seventeen data sets exhibited statistically significant results. Of these nine data sets, two had dip directions toward the west and the remaining seven had dip directions to the north-northeast toward a basalt subcrop above the water table, which is interpreted as a no-flow boundary. Thus, the trend-surface analyses are considered inconclusive.

Furthermore, the water-level elevations determined for the LLWMA-2/216-B-63 Trench well network exhibited an average range of 0.013 meters on any given measurement date. This range is nearly equal to the estimated error range in the water-level elevations determined for LLWMA-1 of 0.012 meters (Section 3.2.1). It appears that all, or nearly all, of the variability in the LLWMA-2/216-B-63 Trench water-level elevations can be attributed to residual

The hydraulic gradient magnitude is currently too low to measure at the LLWMA-2/216-B-63 Trench site.

error, which explains the unsatisfactory trend-surface analysis results. Therefore, it is concluded that the hydraulic gradient magnitude at LLWMA-2/216-B-63 Trench is currently too low to measure. Data collection and analysis will continue at this site during 2011.

Table 3-1. Hydraulic Gradient Determinations for Low-Level Waste Management Area 1

Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (Azimuth)[a]	*p* Value[b]	Statistically Significant?
Ten-Well Network				
9/1/05	7.7×10^{-6}	312	0.020	Yes
9/12/05	8.2×10^{-6}	329	0.017	Yes
10/11/05	8.0×10^{-6}	356	0.005	Yes
10/25/05	6.4×10^{-6}	320	0.060	No
11/23/05	6.9×10^{-6}	336	0.017	Yes
12/29/05	1.0×10^{-5}	13	0.014	Yes
2/2/06	9.7×10^{-6}	350	0.011	Yes
3/8/06	7.8×10^{-6}	332	0.070	No
6/8/06	1.0×10^{-5}	347	0.009	Yes
1/25/07	7.3×10^{-6}	336	0.015	Yes
Fourteen-Well Network				
6/16/08	8.1×10^{-6}	324	0.005	Yes
Mean (through June 2008)	***8.2×10^{-6} ($\pm 0.7 \times 10^{-6}$)***	***338 (±9)***	--	--
7/21/08	1.3×10^{-6}	97	0.964	No
8/29/08	1.3×10^{-5}	213	0.004	Yes
9/11/08	9.3×10^{-6}	156	0.001	Yes
10/23/08	1.1×10^{-5}	226	0.038	Yes
11/26/08	1.1×10^{-5}	225	0.127	No
12/23/08	5.7×10^{-6}	160	0.289	No
1/12/09	8.9×10^{-7}	130	0.945	No
2/23/09	5.3×10^{-6}	149	0.516	No
3/24/09	6.3×10^{-7}	106	0.974	No
4/13/09	4.7×10^{-6}	316	0.271	No
5/28/09	8.2×10^{-6}	310	0.234	No
7/17/09	2.0×10^{-5}	335	0.013	Yes
9/21/09	3.7×10^{-6}	8	0.573	No
10/27/09	6.0×10^{-6}	100	0.578	No
11/12/09	3.5×10^{-6}	259	0.893	No
1/21/10	1.1×10^{-5}	243	0.675	No
5/23/10	6.3×10^{-6}	358	0.502	No
6/30/10	1.8×10^{-5}	353	0.021	Yes
7/13/10	1.0×10^{-5}	357	0.338	No
9/15/10	7.6×10^{-6}	315	0.065	No
1/4/11	1.1×10^{-5}	2	0.144	No

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p* value is less than 0.05, the fitted trend surface is deemed statistically significant.

Table 3-2. Hydraulic Gradient Determinations for Integrated Disposal Facility/PUREX Cribs

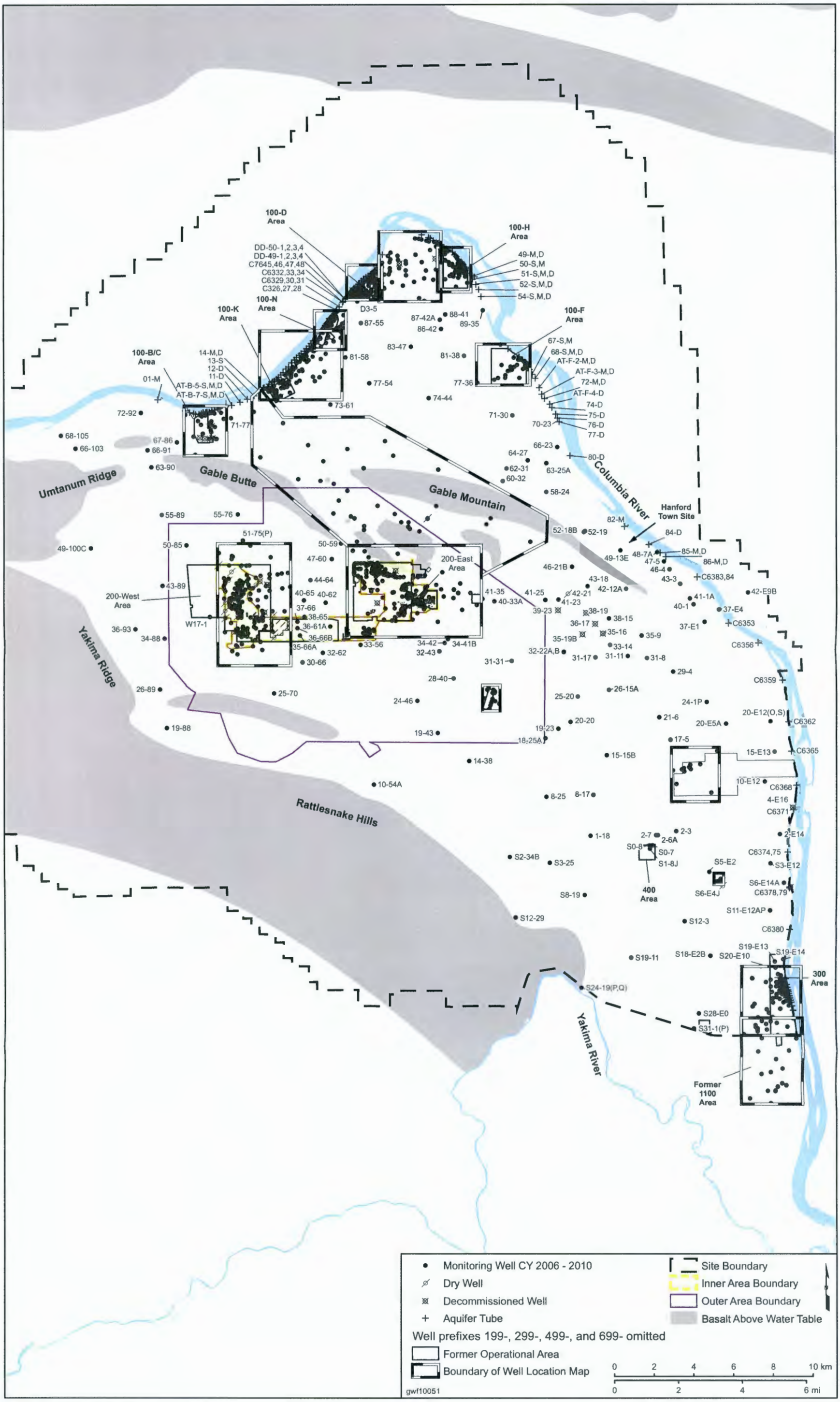
Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (azimuth)[a]	*p* Value[b]	Statistically Significant	Number of Wells[c]
6/16/08	1.7×10^{-5}	61	0.012	Yes	9
8/1/08	2.9×10^{-5}	149	0.004	Yes	8
8/29/08	2.1×10^{-5}	59	0.007	Yes	8
9/11/08	2.7×10^{-5}	173	0.001	Yes	7
10/23/08	2.3×10^{-5}	52	0.026	Yes	7
11/26/08	1.1×10^{-5}	102	0.007	Yes	5
12/22/08	1.3×10^{-5}	91	0.043	Yes	7
1/26/09	1.6×10^{-5}	115	0.006	Yes	7
2/5/09	2.0×10^{-5}	51	0.008	Yes	8
3/24/09	2.0×10^{-5}	46	0.014	Yes	8
6/29/09	2.4×10^{-5}	29	0.010	Yes	5
9/22/09	2.7×10^{-5}	54	0.011	Yes	8
12/30/09	2.8×10^{-5}	84	0.004	Yes	9
3/16/10	2.2×10^{-5}	41	0.007	Yes	8
6/30/10	1.3×10^{-5}	103	0.019	Yes	8
9/14/10	1.2×10^{-5}	68	0.006	Yes	7
Mean	***2.0×10^{-5} ($\pm 0.2 \times 10^{-5}$)***	***80 (±17)***	--	--	--

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p* value is less than 0.05, the fitted trend surface is deemed statistically significant.

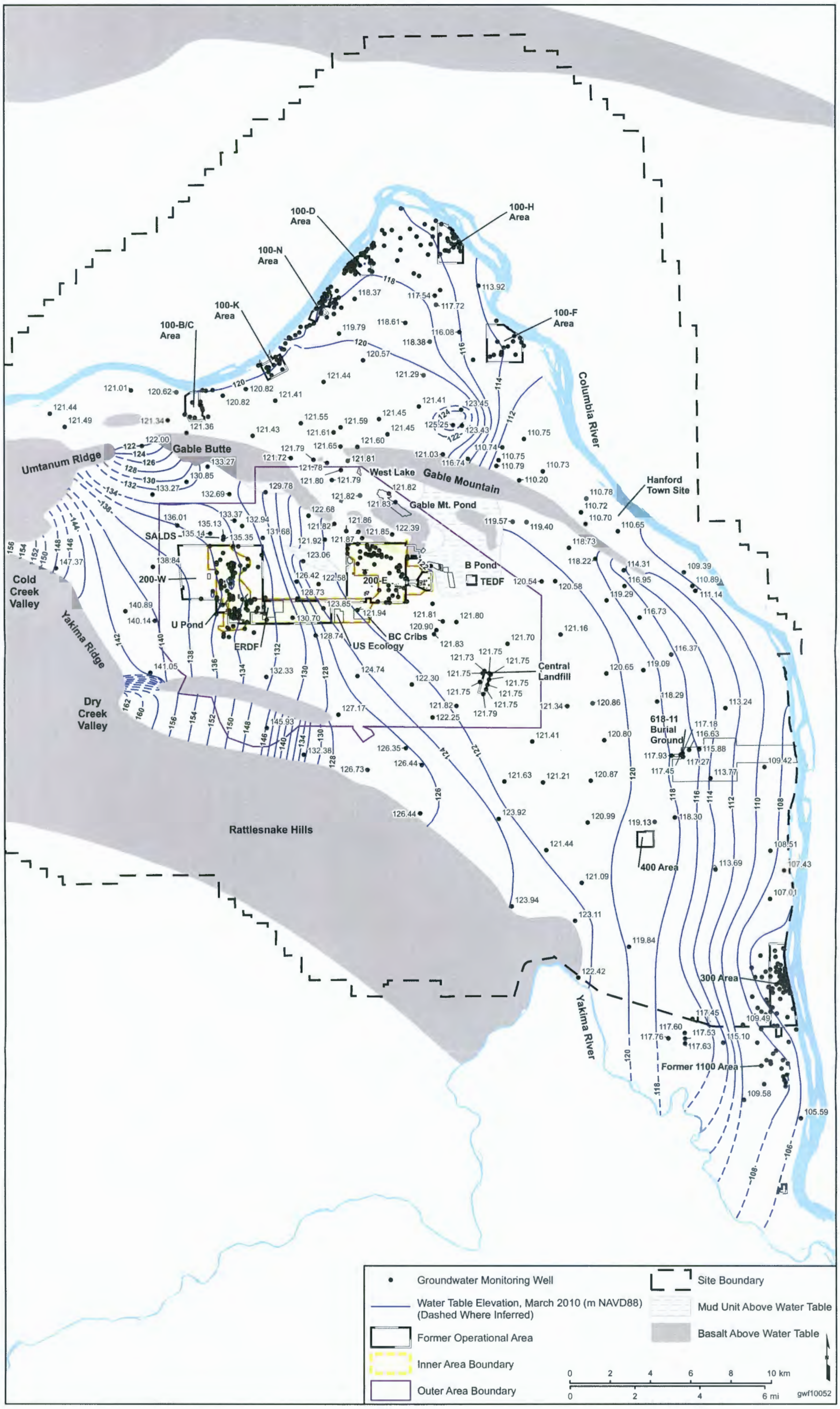
c. A total of eleven wells are in the IDF/PUREX water-level network, but to achieve statistically significant trend surface results, wells with the highest residuals were removed in sequence until a statistically significant result was achieved and the gradient direction stabilized.

Figure 3-1. Groundwater Monitoring Wells on the Hanford Site



This page intentionally left blank.

Figure 3-2. Hanford Site Water Table Map, March 2010



This page intentionally left blank.

Figure 3-3. 200 East Area Water Table Elevations and Monthly Disposal Volumes at the Treated Effluent Disposal Facility, Calendar Years 2009 and 2010

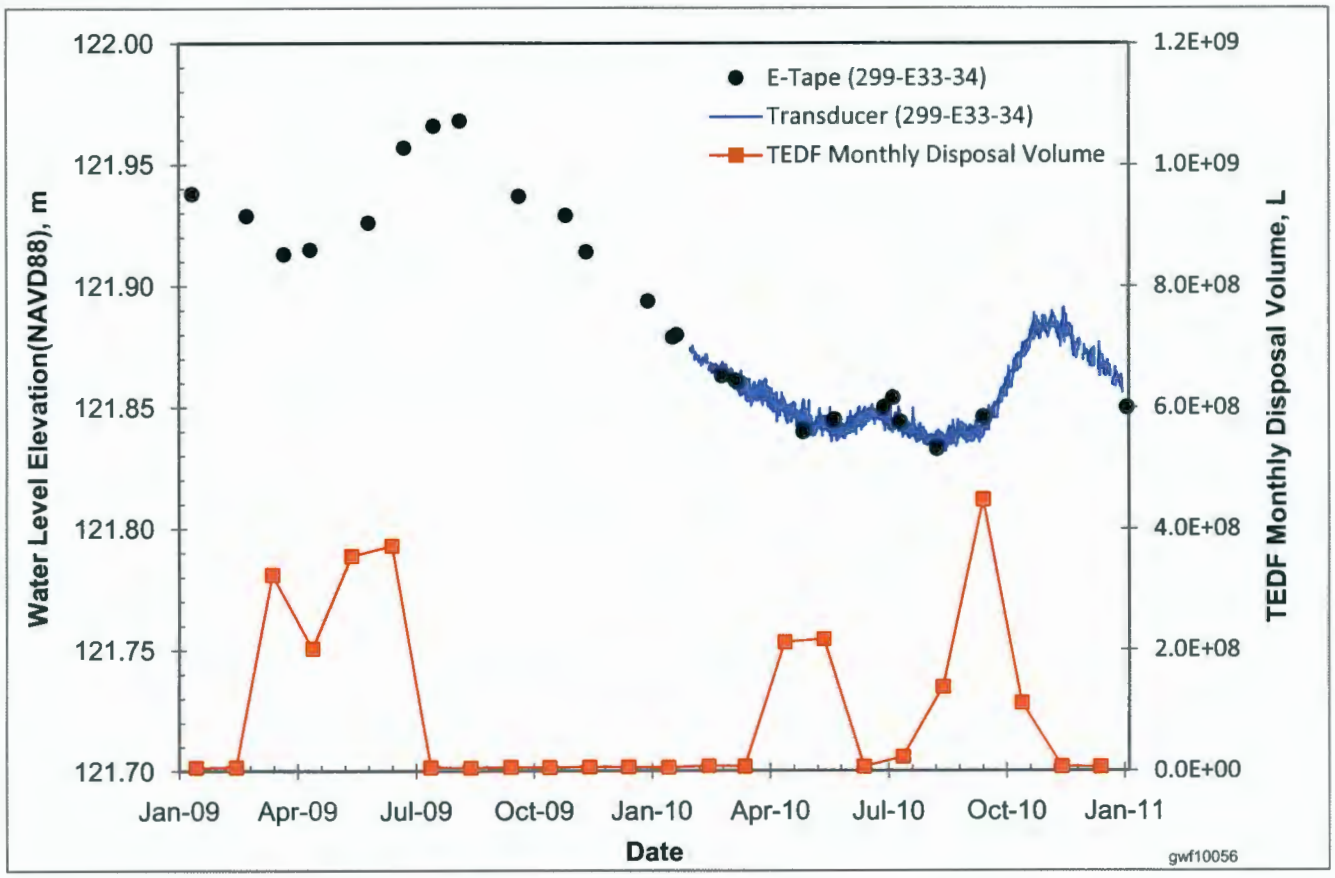


Figure 3-4. Low-Level Waste Management Area 1 Water-Level Monitoring Well Network

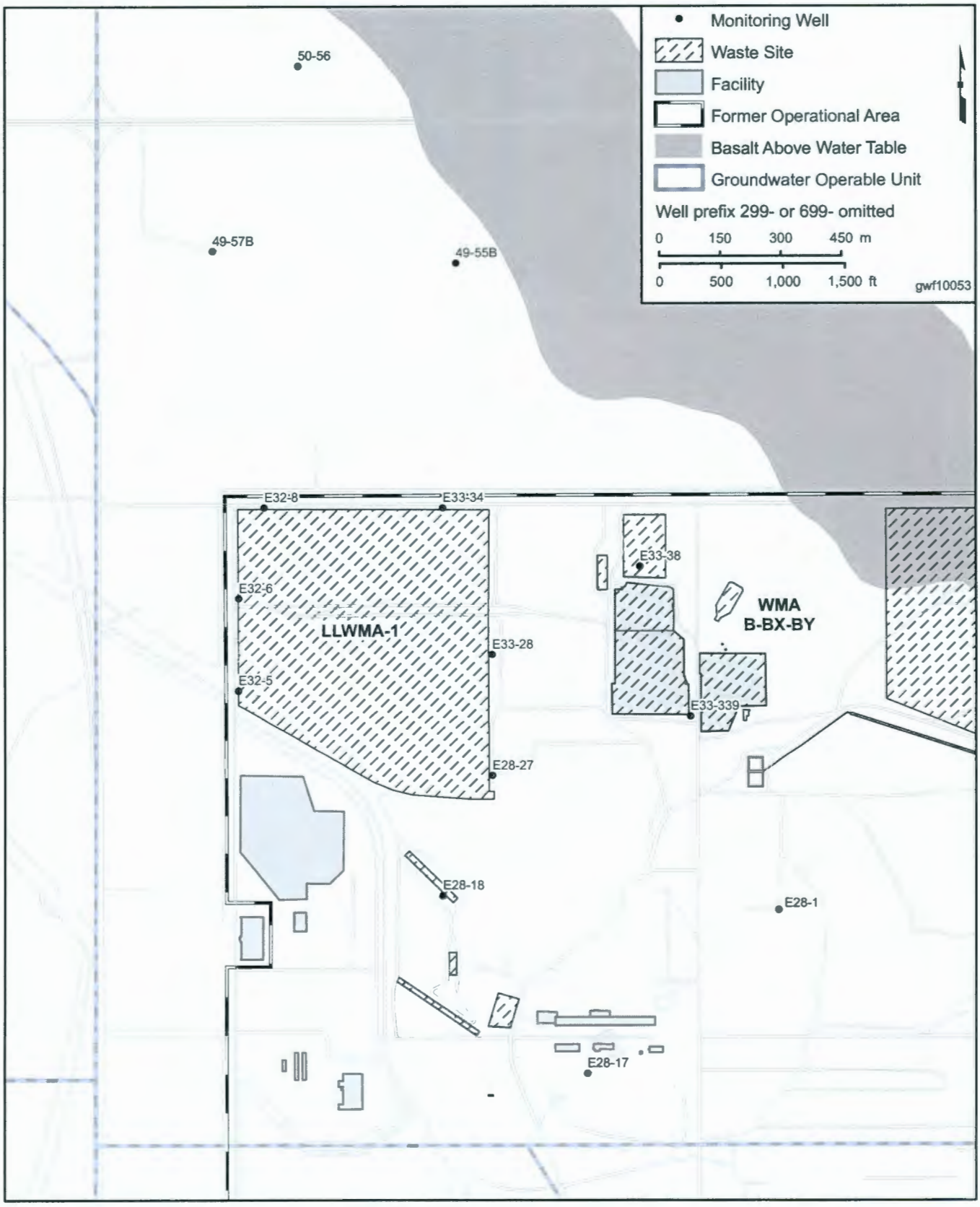


Figure 3-5. Integrated Disposal Facility/PUREX Cribs Water-Level Monitoring Well Network

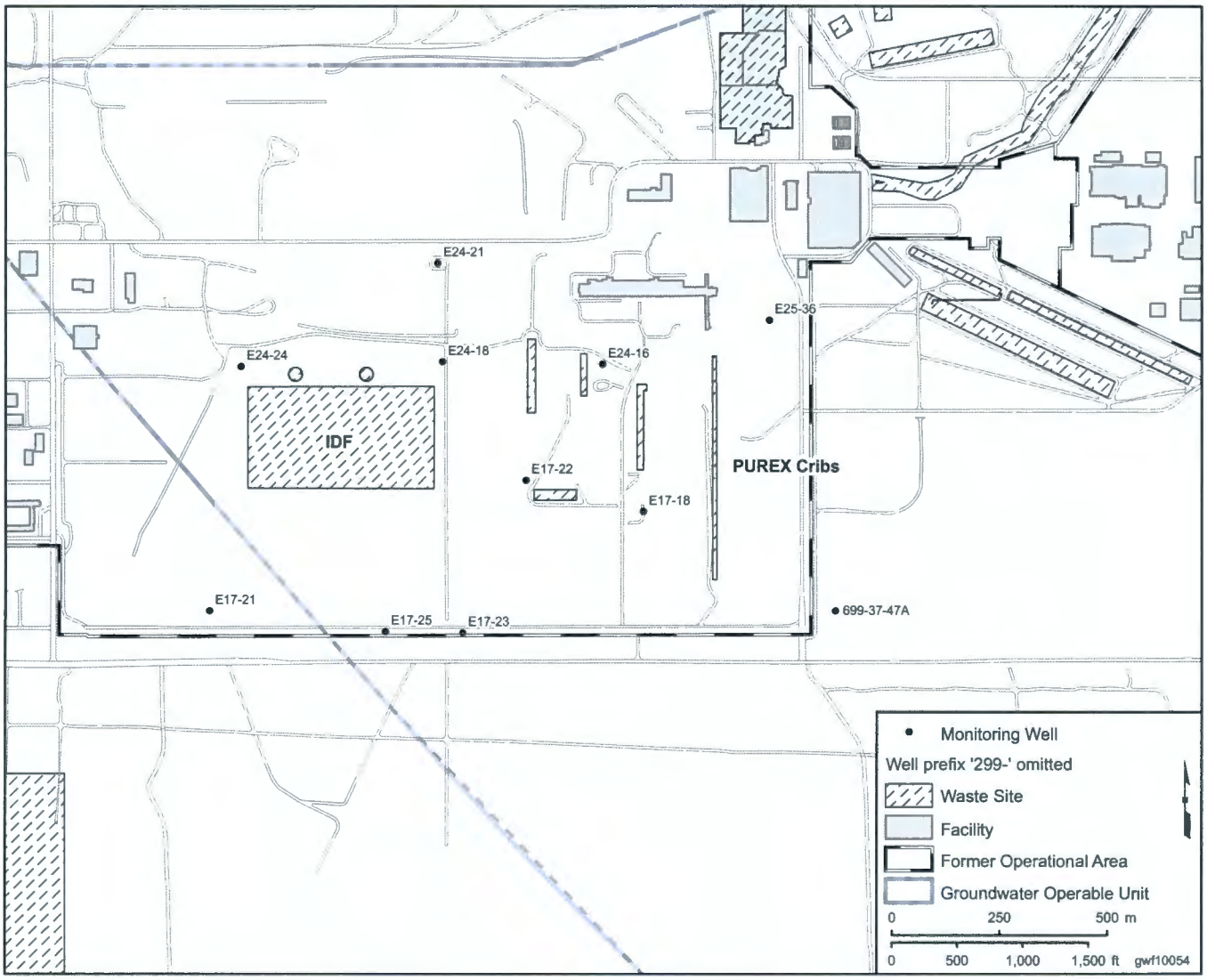
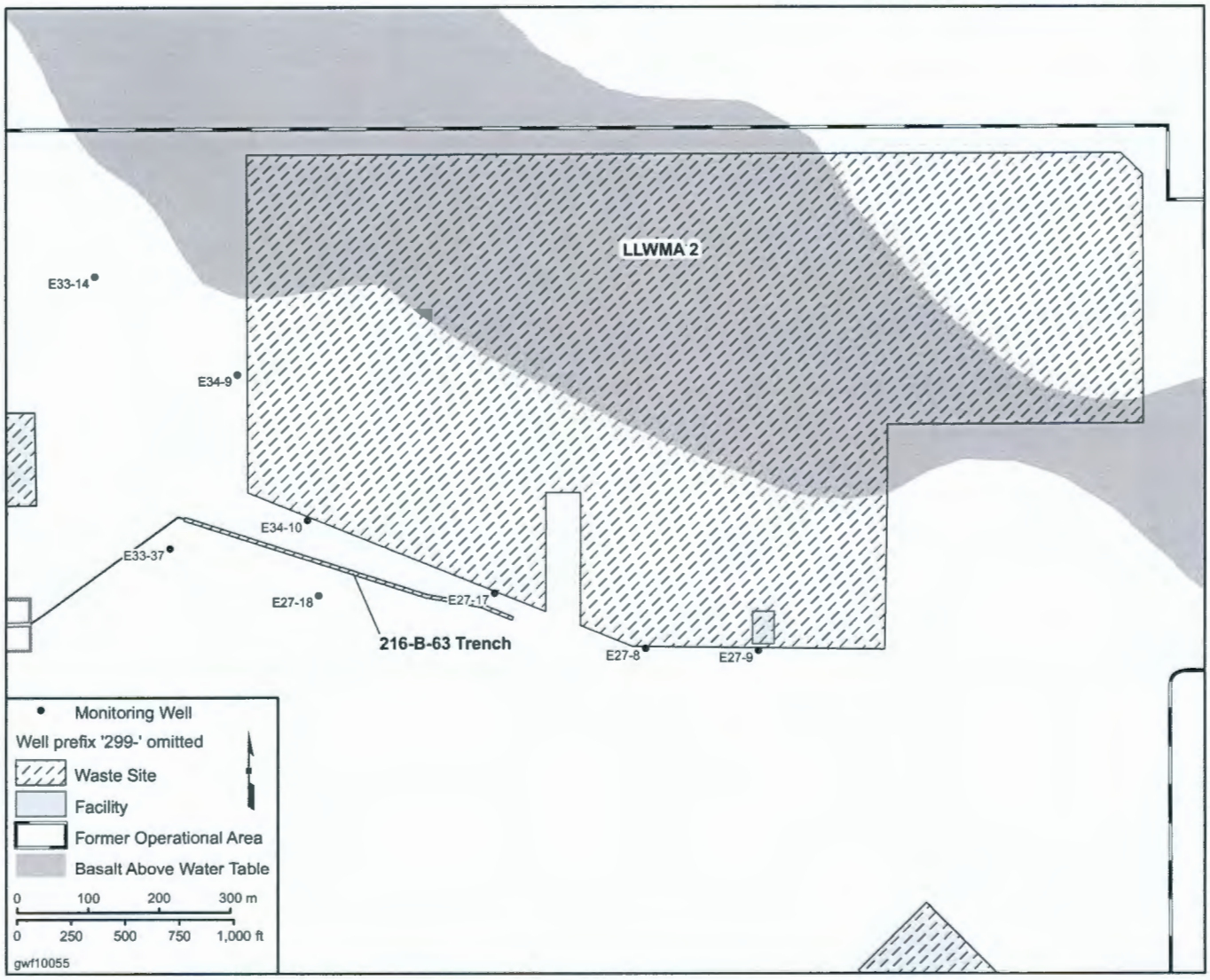


Figure 3-6. Low-Level Waste Management Area 2/216-B-63 Trench Water-Level Monitoring Well Network

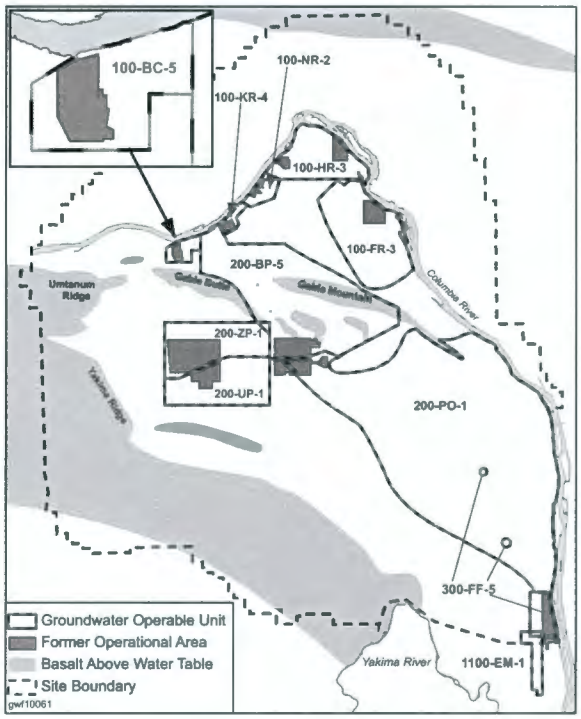


4.0 100-BC-5 Operable Unit

M.J. Hartman

This chapter describes groundwater flow and contaminant distribution in the vicinity of the 100-B/C Area, which is known as the 100-BC-5 Operable Unit (OU). Figure 4-1 shows facilities, wells, and shoreline monitoring sites in the OU.

Groundwater monitoring for the *Atomic Energy Act of 1954* (AEA) is integrated fully with *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring. No active waste disposal facilities or *Resource Conservation and Recovery Act of 1976* sites are located in the 100-B/C Area. Previous assessments have not resulted in any interim remedial measures for groundwater. The area is currently undergoing a CERCLA remedial investigation (RI), which will provide data to support final cleanup decisions.



Some of the main concepts associated with the 100-BC-5 OU include the following.

- The primary sources of contamination were two water-cooled nuclear reactors (B and C Reactors) and associated structures and processes. The B Reactor operated from 1944 to 1968 and C Reactor from 1952 to 1969.
- Reactor operations generated large quantities of liquid and solid waste that were contaminated with radionuclides, hazardous chemicals, or both. Effluents were released directly to the ground and the Columbia River. Solid waste was placed in unlined burial grounds.
- Over the past decade, the U.S. Department of Energy (DOE) has remediated these waste sites, usually by excavating contaminated soil. Remediation is not yet complete at the 100-C-7 waste site, which has chromium contamination deep in the vadose zone.
- The groundwater system comprises the following hydrostratigraphic units (Figure 4-2):
  - Vadose (unsaturated) zone, which is predominantly Hanford formation gravels; 2 to 30 meters thick.
  - Unconfined aquifer, which consists predominantly of Ringold Formation unit 5 (unit E) gravels. The thickness of the unconfined aquifer ranges from ~32 to 48 meters.
  - Uppermost aquitard, informally named the Ringold Formation unit 6 (upper mud unit). The surface of the unit dips to the west.
  - Series of confined and semiconfined aquifers in the Ringold Formation units 6, 7, and 9 (units C, B, and A, respectively), separated by fine-grained, overbank, and paleosol deposits.
  - Basalt aquitard and basalt-confined aquifers (shallowest is the Rattlesnake Ridge interbed).
- Groundwater beneath the 100-BC-5 OU is contaminated with hexavalent chromium, strontium-90, and tritium at levels above aquatic or drinking water standards (DWSs).

The DOE has cleaned up nearly all of the former waste sites in the 100-B/C Area. One waste site with deep vadose zone contamination remains to be remediated.

Groundwater enters the 100-B/C Area from upgradient areas along the Columbia River and the gaps between Umtanum Ridge, Gable Butte, and Gable Mountain. Groundwater flows primarily to the north beneath the 100-B/C Area and discharges to the Columbia River (Figure 4-3). Near the river, the horizontal hydraulic gradient in March 2010 was 0.0027. The hydraulic gradient is very flat in the southern 100-B/C Area. The average gradient from the southern region to the river was 0.0011 in March 2010. When the river stage is high, water levels in wells near the river rise more than wells farther inland, creating a flatter water table.

Additional details about 100-BC-5 OU history, waste sites, and hydrogeology are provided in the *Integrated 100 Area Remedial Investigation Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* (DOE/RL-2008-46-ADD3).

4.1 Groundwater Contaminants

This section summarizes the distribution of groundwater contamination in the 100-BC-5 OU. Routine monitoring requirements are described in the *100-BC-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-38). Under this plan, wells are sampled for the contaminants of concern (COCs) selected using the data quality objectives process (PNNL-14287, *Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units*) (Appendix A, Table A-1). The COCs for routine monitoring are strontium-90, tritium, and hexavalent chromium. Most of the wells are sampled once per year or once every other year.

Plume Areas (square kilometers) in the 100-BC-5 Operable Unit:
Chromium, 20 µg/L — 0.982
Strontium-90, 8 pCi/L — 0.457
Tritium, 20,000 pCi/L — 0.27

Additional monitoring requirements were active in 2010, as described in DOE/RL-2008-46-ADD3 and the *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-44). These documents identified additional contaminants of potential concern (COPCs) to be evaluated in the ongoing RI (Table 4-1). Eighteen wells were sampled three times in 2010 to investigate spatial and temporal variability of the COPCs. Six new monitoring wells were installed in 2010 and 2011 to support the RI. Data from all of these sources are discussed in this section.

A subset of 100-B/C Area aquifer sampling tubes is scheduled for annual sampling in the fall. The fall 2010 sampling was delayed by the work stoppage until early 2011 and many of the tubes were not sampled before the river rose and submerged the tubes. The nine new aquifer tubes (Section 4.2) were the only aquifer tubes sampled during the reporting period (Section 4.2).

4.1.1 Strontium-90

A wedge-shaped strontium-90 plume extends from the central 100-B/C Area north toward the Columbia River (Figure 4-4). The DWS for strontium-90 is 8 pCi/L. Strontium-90 sorbs to aquifer sediment grains, so the plume changes very slowly. The plume was slightly smaller in 2010 than in 2009 because concentrations in wells in the central 100-B/C Area declined below the DWS (Figure 4-5). The width of the plume at the river shore has not changed significantly since at least 2005 (Figure 2.2-3 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*).

Figure 4-6 shows the strontium-90 trends in the northern 100-B/C Area near some of the former contaminant sources: the 116-B-11 retention basin, 116-B-1 Trench, and 116-C-1 Trench. The highest concentration in a monitoring well in 2010 was

49 pCi/L in well 199-B3-46, near the 116-C-1 Trench. Long-term trends are steady or declining.

Seven vadose zone boreholes were drilled for the RI in 2010 (Figure 4-1). Groundwater samples were collected from the top of the aquifer. The maximum strontium-90 concentration was 72.9 pCi/L in borehole C7845, located in the 118-B-6 Burial Ground in the central 100-B/C Area (Figure 4-4). Nearby monitoring wells have lower concentrations of up to 20 pCi/L. Strontium-90 concentrations in groundwater samples from the other vadose zone boreholes were consistent with data from nearby monitoring wells.

Strontium-90 in the 100-B/C Area appears to be limited to the upper portion of the unconfined aquifer. Samples collected during deep characterization drilling of well 199-B2-14 had strontium-90 concentrations below detection limits in all but three samples. The maximum concentration was 5.3 (±4.4) pCi/L at 4.3 meters below the water table. The other two detections were much deeper in the aquifer but were barely above detection limits. Routine samples collected after completion of the well, which is screened at the top of the aquifer, had strontium-90 concentrations ranging from undetected to 8.6 (±2.8) pCi/L. This vertical distribution of strontium-90 is consistent with that observed elsewhere in the 100 Area (e.g., 100-N Area; see discussion in Chapter 6.0). Groundwater characterization samples from the Ringold Formation upper mud unit in adjacent well 199-B2-15 did not contain detectable strontium-90.

Well 199-B2-12, screened in a water-bearing zone of the Ringold Formation upper mud unit, consistently has not had detectable strontium-90; however, its shallow counterpart, well 199-B3-47, has levels above the DWS.

Strontium-90 concentrations exceeded the DWS in two of the new aquifer tubes installed in 2010. Shallow tube C7724 and mid-depth tube C7725 had concentrations of 8.8 and 18 pCi/L, respectively. The deep tube at this location did not have detectable strontium-90. These results are consistent with previous results from nearby aquifer tube site 06.

4.1.2 Tritium

Strontium-90 and tritium continued to exceed the DWSs in 100-B/C Area groundwater.

The unconfined aquifer beneath the 100-B/C Area is contaminated with tritium at concentrations exceeding the DWS (20,000 pCi/L) in several wells (Figure 4-7). Tritium was present in effluent discharged to former cribs near the B Reactor (e.g., 116-B-5 Crib) and near the Columbia River. The former 118-B-1 Burial Ground in the southwestern 100-B/C Area was another source of contamination.

In the northern 100-B/C Area, wells 199-B3-47 and 199-B5-2 had tritium concentrations above the DWS in September 2010. The concentrations increased sharply in well 199-B5-2 between July and September (Figure 4-8). The concentration in September was 69,000 pCi/L, which was the maximum concentration detected in the 100-B/C Area in 2010.

Tritium concentrations in a portion of the southern 100-B/C Area exceed the DWS (maximum of 28,000 pCi/L in well 199-B8-8). Because the area has few monitoring wells, this plume is not well defined. The tritium concentration in well 199-B8-6, which is located near the 118-B-1 Burial Ground (formerly a source of tritium contamination), was above the DWS in May but not in July or September (Figure 4-9). Wells 199-B8-7 and 199-B8-8 had tritium concentrations above the DWS before the wells were decommissioned in 2010. Concentrations in well 199-B5-6, screened at the bottom of the unconfined aquifer, showed tritium levels below the DWS (6,500 to 7,400 pCi/L), but concentrations are higher near the top of the aquifer.

A characterization sample from adjacent shallow well 199-B4-14 had a concentration of 19,000 pCi/L.

Vertical characterization data from recently drilled wells indicate that tritium concentrations decrease with depth in the aquifer in most locations (wells 199-B2-14, 199-B5-6, and 199-B5-5) (Figure 4-10). Well 199-B8-9, located near the former C Reactor, shows a different pattern. At this location, tritium concentrations were the highest near the middle of the aquifer, with maximum concentrations of 17,000 pCi/L. Screen depth for this well was chosen based on the distribution of hexavalent chromium.

4.1.3 Chromium

Sources of hexavalent chromium included cribs near the reactor buildings, trenches and retention basins near the Columbia River (e.g., 116-B-1, 116-B-11, 116-C-1, and 116-C-5), and pipelines from the reactor buildings to these near-river facilities. During remediation activities in recent years, additional chromium sources were identified in the western 100-B/C Area: the 100-C-7 site and associated pipelines in the south, and the 100-B-27 sodium dichromate spill site in the northwest.

Hexavalent chromium is of potential concern to salmon and other aquatic life. The aquatic water quality standard for hexavalent chromium is 10 µg/L (WAC 173-201A-040, "Water Quality Standards for Surface Waters of the State of Washington"). The state groundwater cleanup level for hexavalent chromium is 48 µg/L (WAC 173-340-720[4][b][iii], "Model Toxics Control Act – Cleanup," "Ground Water Cleanup Standards"). The DWS for total chromium is 100 µg/L. Chromium concentrations exceeded 10 µg/L beneath a large portion of the 100-B/C Area and have occasionally exceeded 48 µg/L in one well.

New wells indicate that the chromium plume extends farther west than previously known.

Figure 4-11 illustrates the portion of the plume with concentrations greater than 10 µg/L in September 2010. The map differs from the 2009 map (Figure 13-8 in DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*) in several ways: (1) different contour levels are illustrated; (2) a specific sampling period is represented rather than an annual average; and (3) data are included from wells screened anywhere in the unconfined aquifer, not just in the upper portion. As a result of these changes, the plume area at 20 µg/L has increased slightly. The plume width at the river shore has not changed significantly since at least 2005 (Figure 2.2-9 in PNNL-15670).

New wells 199-B5-5 and 199-B5-6 are screened in the lower portion of the unconfined aquifer and had concentrations above 30 µg/L in 2010. Data from these wells indicate that the 20 µg/L contour is farther west than previously known. Well 199-B2-13, located west of the 100-B/C Area near the Columbia River, has historically had chromium concentrations above 10 µg/L; however, in 2010, the concentrations dropped below that level. Aquifer tubes along the western shoreline were not sampled in 2010. Concentrations of hexavalent chromium in these tubes previously have been below 10 µg/L.

In the southern 100-B/C Area, waste site investigations identified chromium contamination in the deep vadose zone at the 100-C-7 waste site. Chromium concentrations in wells 199-B8-7 and 199-B8-8 were less than 20 µg/L in January 2010, which is the last time these wells were sampled. The wells were decommissioned in 2010 to allow remediation of the 100-C-7 waste site. A new well pair, 199-B5-6 and 199-B4-14, is located downgradient of the waste site. The chromium concentration in deeper well 199-B5-6 was approximately 35 µg/L in 2010. The shallow well was drilled in 2010, and routine sampling began in 2011.

The highest chromium concentration in the 100-B/C Area in 2010 was 68.5 µg/L (unfiltered total chromium) in well 199-B3-47, downgradient of the 116-B-11 retention basin. This result was within the range observed since 1999 (Figure 4-12).

The highest chromium concentration in 100-B/C Area groundwater in CY 2010 was 69 µg/L in a well monitoring the top of the unconfined aquifer.

Vertical distribution of chromium in the unconfined aquifer varies. Vertical profiles of four wells were presented in the 2009 annual report (Figure 13-10 of DOE/RL-2010-11). Well 199-B8-9, drilled near C Reactor in 2010, had low chromium concentrations throughout the aquifer. Information regarding the vertical distribution in the wells completed in 2011 will be presented in an upcoming RI report.

Chromium contamination appears to be limited to the unconfined aquifer. Deep monitoring well 199-B2-12, which is screened in the Ringold Formation upper mud unit and located adjacent to shallow well 199-B3-47, does not have detectable chromium. Well 199-B2-15 was drilled into the Ringold Formation upper mud unit in 2010, and routine monitoring began in 2011. A characterization sample of water from the aquitard did not contain detectable hexavalent chromium.

Two of the three new aquifer tube clusters are within the central portion of the chromium plume. The highest concentrations in 2010 were 24.3 µg/L in tube C7719 and 34.8 µg/L in tube C7725. The levels are similar to those observed in nearby aquifer tubes in the past. New tubes C7780, C7781, and C7782 had concentrations ranging from undetected to 10.5 µg/L.

4.1.4 Nitrate

Nitrate concentrations exceeded the 45 mg/L DWS in two 100-B/C Area wells in the late 1990s but have subsequently declined (Figure 4-13). The wells are located near the 116-C-5 retention basin and 116-B-1 Trench. The concentration in well 199-B3-47 has increased in recent years; the maximum concentration in this well in 2010 was 44 mg/L in July. Other wells in the 100-B/C Area had concentrations below 20 mg/L in 2010.

4.1.5 Additional Contaminants of Potential Concern

Table 4-1 lists the groundwater COPCs identified in DOE/RL-2008-46-ADD3. The table lists the maximum concentrations detected in groundwater in 2010. The data are provided for information only; an upcoming RI report will include a full analysis of the COPC data.

Most metals were detected in few wells or were detected at concentrations near detection limits. Exceptions include chromium and hexavalent chromium (Section 4.1.3), as well as manganese. The elevated manganese values (greater than 50 µg/L) were from characterization samples collected during drilling. The drilling process can create chemically reducing conditions in the borehole, which increases the solubility of manganese.

With two exceptions, organic analytes were detected in few wells. Chloroform was detected in many samples, but most of the results were flagged as estimates (near the detection limit). The maximum concentration was 4.8 µg/L in a characterization sample. Trichloroethene was also detected in many samples, with most of the results flagged as estimates. The highest trichloroethene concentration was 3.3 µg/L in well 199-B5-6.

Radionuclides detected in 100-B/C Area groundwater include strontium-90 and tritium (Sections 4.1 and 4.2), technetium-99, and uranium. Except for one result that is flagged as a probably error, technetium-99 concentrations were less than 30 pCi/L. This contamination is believed to have originated in the 200 Area. Uranium concentrations were also low and are consistent with natural background concentrations.

4.2 CERCLA Groundwater Activities

In 2010, CERCLA activities associated with groundwater included RIs and routine groundwater monitoring.

4.2.1 Remedial Investigation Activities

In 2010, a RI/feasibility study (FS) work plan addendum (DOE/RL-2008-46-ADD3) and the sampling and analysis plan (DOE/RL-2009-44) were released. These documents are related to the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46). The documents describe the data to be collected to support selection of final remedies under CERCLA, and the approach integrates the data needs for waste sites and groundwater. The data and results will be reported in an upcoming RI/FS report, which will lead to the selection of alternatives for final action site cleanup.

Table 4-2 lists the RI groundwater data needs. The status of RI activities for 2010 is summarized below.

4.2.1.1 Horizontal and Vertical Extent of Contamination

The work plan addendum (DOE/RL-2008-46-ADD3) identified a data gap associated with the nature and extent of contamination in the unconfined aquifer. Vertical and horizontal distribution of contamination had not been determined in some locations nor for all of the COPCs. To fill this data gap, DOE installed ten new monitoring wells in 2009 and 2011 (DOE/RL-2009-44; DOE/RL-2009-61, *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit*). Data from the new wells were combined with data from older wells to create the contaminant plume maps presented in Section 4.1 of this chapter. Vertical contaminant distribution is also discussed in Section 4.1 and in last year's annual report (DOE/RL-2010-11). Section 4.1.5 summarizes the results of sampling for the full list of COPCs.

4.2.1.2 Porewater and Aquifer Tubes

One of the RI tasks called for sampling of Columbia River porewater at locations where hexavalent chromium contamination was previously detected in a 2009 investigation (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*). Ten sites that were previously sampled, as well as two additional sites located upstream of the 100-B/C Area facilities, were sampled in November 2010. Chromium concentrations were lower during the November 2010 sampling event than in the previous study. Only three of the sites had chromium concentrations above 10 µg/L. The maximum concentration was 13.6 µg/L (a split sample had 10 µg/L) compared to a maximum of 112 µg/L shown in the earlier study. *Columbia River Pore Water Sampling in 100-BC Area, November 2010* (SGW-49368) presents the results of the recent study and additional evaluation of all three sampling rounds.

Samples of porewater from the Columbia River bed contained lower concentrations of hexavalent chromium than shown in an earlier study.

Three new clusters of aquifer tubes were installed and sampled in 2010 to improve monitoring coverage. Locations of the tubes (C7718, C7719, and C7720; C7724, C7725, and C7726; and C7780, C7781, and C7782) are shown in Figure 4-1. The results of initial sampling were consistent with previous data from nearby wells and aquifer tubes. Sampling of a larger set of 100-B/C Area aquifer tubes was scheduled for the fall of 2010 but was delayed until 2011.

4.2.1.3 Uppermost Aquitard

Before 2009, only two wells in the 100-B/C Area had been drilled deep enough to reach the uppermost aquitard, informally named the Ringold Formation upper mud unit. Of the eight wells drilled in 2009 and 2010, seven wells reached the aquitard (two additional wells were in progress at the time this report was prepared). Sediment samples from the aquitard are undergoing physical and chemical testing. Slug tests have been conducted in the two wells screened in the aquitard, and the results will be discussed in upcoming reports.

4.2.1.4 Geologic and Hydrogeologic Data

Data from the new wells were combined with older data and used to create geologic cross sections and maps (elevation of the top of the aquitard and the top of Ringold Formation unit E gravels). The introductory paragraphs of this chapter briefly summarize the hydrogeologic framework of the 100-B/C Area. Soil and water samples were collected throughout the thickness of the unconfined aquifer. These samples are being analyzed to determine physical and chemical properties, which will be used to support numerical modeling.

Pressure transducers have been installed in selected wells to determine vertical and horizontal hydraulic gradients and how these vary in response to changing river stage. This information will support contaminant fate and transport studies.

4.2.1.5 Spatial and Temporal Distribution of Groundwater Contamination

Groundwater chemistry data were needed to reduce uncertainty in determining risks due to groundwater contamination. Eighteen monitoring wells in the 100-B/C Area were sampled in spring, summer, and fall to characterize spatial and temporal variation. The samples were analyzed for 36 COPCs identified in Table 1-3 of DOE/RL-2009-44. The well network was sampled in May, July, and September 2010, and the results will be used to assess risks to human health and the environment. Table 4-1 lists the COPCs and their maximum concentrations in 2010.

4.2.2 CERCLA Groundwater Monitoring

Routine groundwater sampling requirements are defined in the groundwater sampling and analysis plan (DOE/RL-2003-38), as modified by *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) change notices TPA-CN-240 and TPA-CN-293. Scheduled well sampling occurred as planned during the reporting period (Appendix A).

The sampling and analysis plan will be revised to incorporate newly installed wells after the wells are completed. The wells will be sampled quarterly for the first year.

4.3 Conclusions and Recommendations

Groundwater beneath the 100-B/C Area is contaminated with chromium, tritium, and strontium-90 at concentrations above water quality standards.

The RI/FS work plan addendum was implemented in 2010 to collect additional data needed to support final CERCLA cleanup decisions. New wells are helping to define the extent of contamination both areally and vertically.

Routine groundwater monitoring continued in 2010 and was coordinated with RI/FS sampling. After new wells are completed and early monitoring data are evaluated, the sampling and analysis plan for routine groundwater monitoring should be revised to incorporate the new information.

Table 4-1. Contaminants of Potential Concern for 100-B/C Area

Contaminant	No. of Analyses	No. of Detections	Maximum Concentration in CY 2010[a]	Data Flag
Metals				
Antimony, unfiltered	177	15	37.4	B
Antimony, filtered	163	6	5.94	BD
Arsenic, unfiltered	155	84	5.6	BC
Arsenic, filtered	169	89	18	BD
Beryllium, unfiltered	178	3	0.116	BD
Beryllium, filtered	163	4	0.147	BDC
Cadmium, unfiltered	164	1	0.325	BDC
Cadmium, filtered	175	4	4	B
Chromium, unfiltered	150	127	68.5	--
Chromium, filtered	158	136	56.1	--
Cobalt, unfiltered	163	38	1.45	D
Cobalt, filtered	178	38	8	B
Copper, unfiltered	162	48	8	B
Copper, filtered	176	43	6	B
Hexavalent chromium, unfiltered	122	99	57	--
Hexavalent chromium, filtered	79	72	58	--
Lead, unfiltered	154	8	25	B
Lead, filtered	171	3	0.318	BD
Manganese, unfiltered	103	48	220	--
Manganese, filtered	103	45	188	--
Mercury, unfiltered	98	0	ND	--
Mercury, filtered	114	2	0.174	BD
Nickel, unfiltered	106	42	12	BC
Nickel, filtered	121	24	7	B
Selenium, unfiltered	155	73	4.89	BD
Selenium, filtered	171	91	8.31	BD
Thallium, unfiltered	156	5	125	BC
Thallium, filtered	170	3	79	BCN
Zinc, unfiltered	106	47	165	D
Zinc, filtered	120	54	178	C
Anions				
Nitrate	166	163	44,200	--
Organics				
1,1,2,2-Tetrachloroethane	155	0	ND	--
1,1-Dichloroethene	155	0	ND	--
Benzene	155	2	6.5	--
Carbon tetrachloride	155	3	4.3	J
Tetrachloroethene	155	0	ND	--
Trichloroethene	155	58	3.3	--
Total petroleum hydrocarbons, diesel range	107	2	86 mg/L	J

Table 4-1. (Cont.)

Contaminant	No. of Analyses	No. of Detections	Maximum Concentration in CY 2010[a]	Data Flag
Chloroform	155	54	4.8	J
Vinyl chloride	155	0	ND	--
Radionuclides				
Carbon-14	108	0	ND	--
Cesium-137	148	1	2.04	--
Cobalt-60	148	0	ND	--
Europium-155	148	0	ND	--
Iodine-129	131	0	ND	--
Nickel-63	108	1	3.61	--
Radium-228	135	1	37.4	--
Strontium-90	158	29	72.9	--
Technetium-99	108	53	600[b]	Y
Tritium	159	151	69,000	--
Uranium, unfiltered	89	89	68[b]	--
Uranium, filtered	26	19	3.34	D

Note: The contaminants of potential concern are from DOE/RL-2008-46-ADD3. Wells are those listed in the routine groundwater sampling and analysis plan (DOE/RL-2003-38, as modified by Tri-Party Agreement change notices TPA-CN-240 and TPA-CN-293), as well as those specified in DOE/RL-2008-046-ADD3. Includes data from characterization samples collected during drilling. Excludes data flagged as "Y."

a. Except where otherwise noted, units are pCi/L for radionuclides and µg/L for others.

b. Suspected error.

B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit

C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration

D = analyte reported at a secondary dilution factor

J = estimated value; constituent detected at a level less than the contract required detection limit and greater than or equal to the method detection limit

N = spike and/or spike duplicate sample recovery is outside control limits

ND = not detected

Y = result is suspect; review had insufficient evidence to show result valid or invalid

Table 4-2. 100-B/C Area Remedial Investigation Groundwater Activities in 2010

Data Need*		Activity	Status
4	Data are needed to identify groundwater contaminants and define the extent of contamination horizontally and vertically.	Install well 199-B2-16 to define contaminant plumes near the river.	Sample ready February 2011.
		Install well 199-B3-51 to provide information on chromium and stronium-90 distribution within the unconfined aquifer in a cluster with existing wells 199-B3-47 and 199-B2-12.	Sample ready April 2011.
		Install well 199-B4-14 to create a shallow/deep pair with 199-B5-6 to characterize and monitor vertical distribution of contaminants.	Sample ready January 2011.
		Install well 199-B5-8 to define southern extent of contamination.	Sample ready April 2011.
		Install well 199-B8-9 to define western extent of contamination near C Reactor.	Sample ready January 2011.
		Install well 199-B2-15 to monitor the aquitard.	Sample ready February 2011.
		Sample new and existing wells for COPCs to determine nature and extent of contamination	Existing wells sampled in 2010; new wells in progress.
5	Data are needed to confirm results of previous porewater sampling, to observe concentration trends over time, and to better define areas of contamination under the river. Data from the aquifer tube network are needed to monitor concentrations over time and with depth near the river.	Collect Columbia River porewater samples from sites where chromium contamination was previously detected.	Sampled November 2010; reported in SGW-49368.
		Install and sample three new aquifer tube clusters.	Installed March 2010; sampled September 2010.
		Sample existing aquifer tubes.	Eight tubes sampled in 2011.
6	Only one well has been completed within the aquitard unit. Data are needed to evaluate the integrity of the aquitard, or fate and transport within the aquitard.	Collect samples of the uppermost aquitard from new monitoring wells. Screen one well in the aquitard (199-B2-15).	Completed (see data need 4).
		Collect split-spoon samples of the Ringold upper mud unit from new wells and determine hydrologic properties.	Completed (see data need 4).
7	Geological characterization, physical, and hydraulic property data are needed to support modeling and analysis.	Collect soil and water samples throughout the thickness of the unconfined aquifer in new wells; determine chemical and hydrologic properties.	Completed in early 2011.
		Update hydrogeologic interpretations based on geologic information from new and existing wells.	Completed in early 2011.
		Install pressure transducers in selected wells to define vertical and horizontal gradients.	Completed in early 2011.
		Conduct slug tests in new and selected older wells to refine horizontal hydraulic conductivity estimates for the unconfined aquifer and uppermost aquitard.	Completed in eight wells in 2010 and early 2011.
8	Groundwater chemistry data are needed to reduce uncertainty in determining risks due to groundwater contamination.	Collect and analyze groundwater samples from eighteen monitoring wells at three river stages to characterize spatial and temporal variation.	Samples collected May, July, and September 2010.

* From DOE/RL-2008-46-ADD3, Table ES-1. Data needs 1, 2, and 3 pertain to the vadose zone and are not included here.

Figure 4-1. Facilities, Groundwater Monitoring Wells, and Shoreline Monitoring Sites (Aquifer Tubes) in the 100-B/C Area

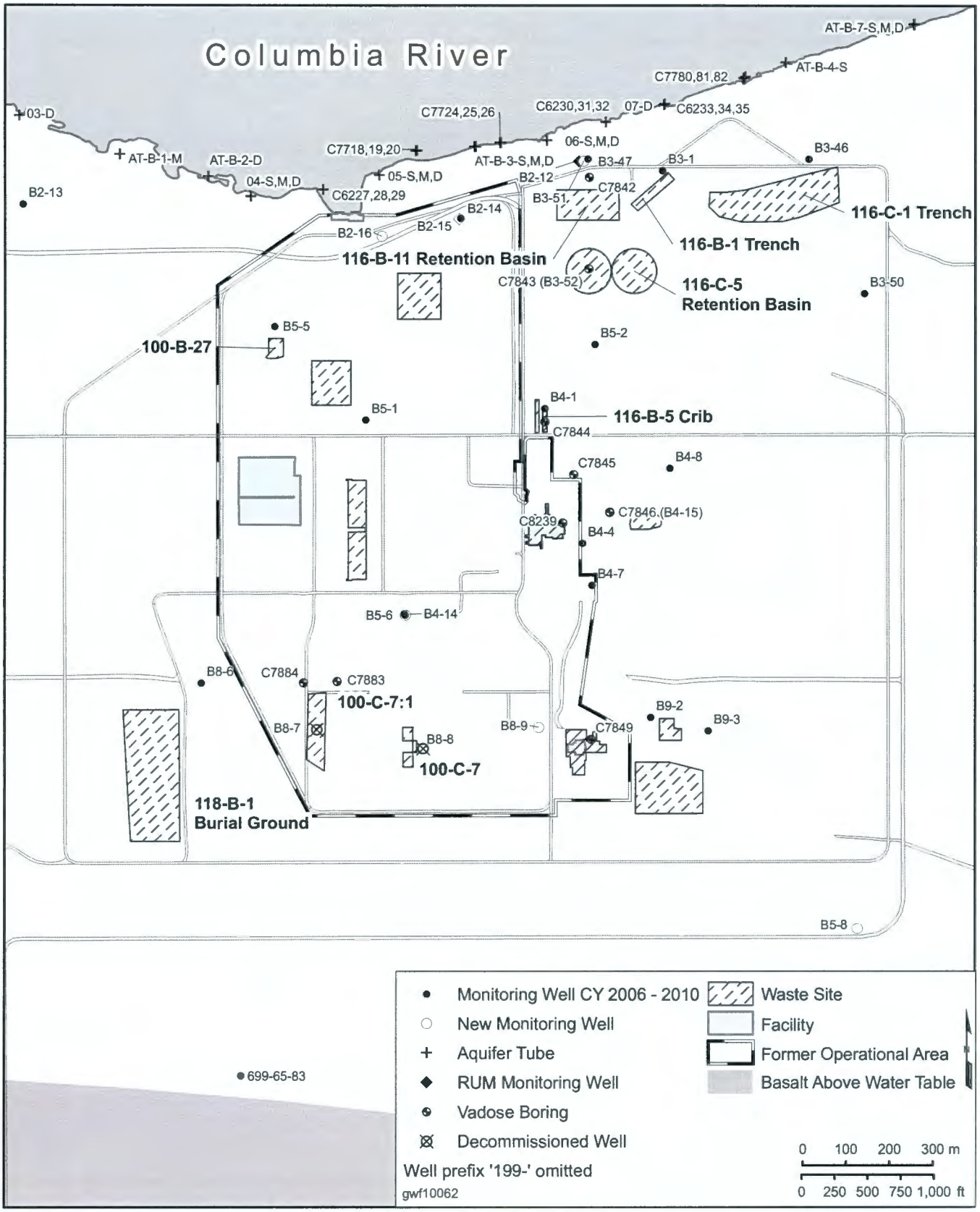


Figure 4-2. Stratigraphic and Hydrogeologic Units of 100-B/C Area

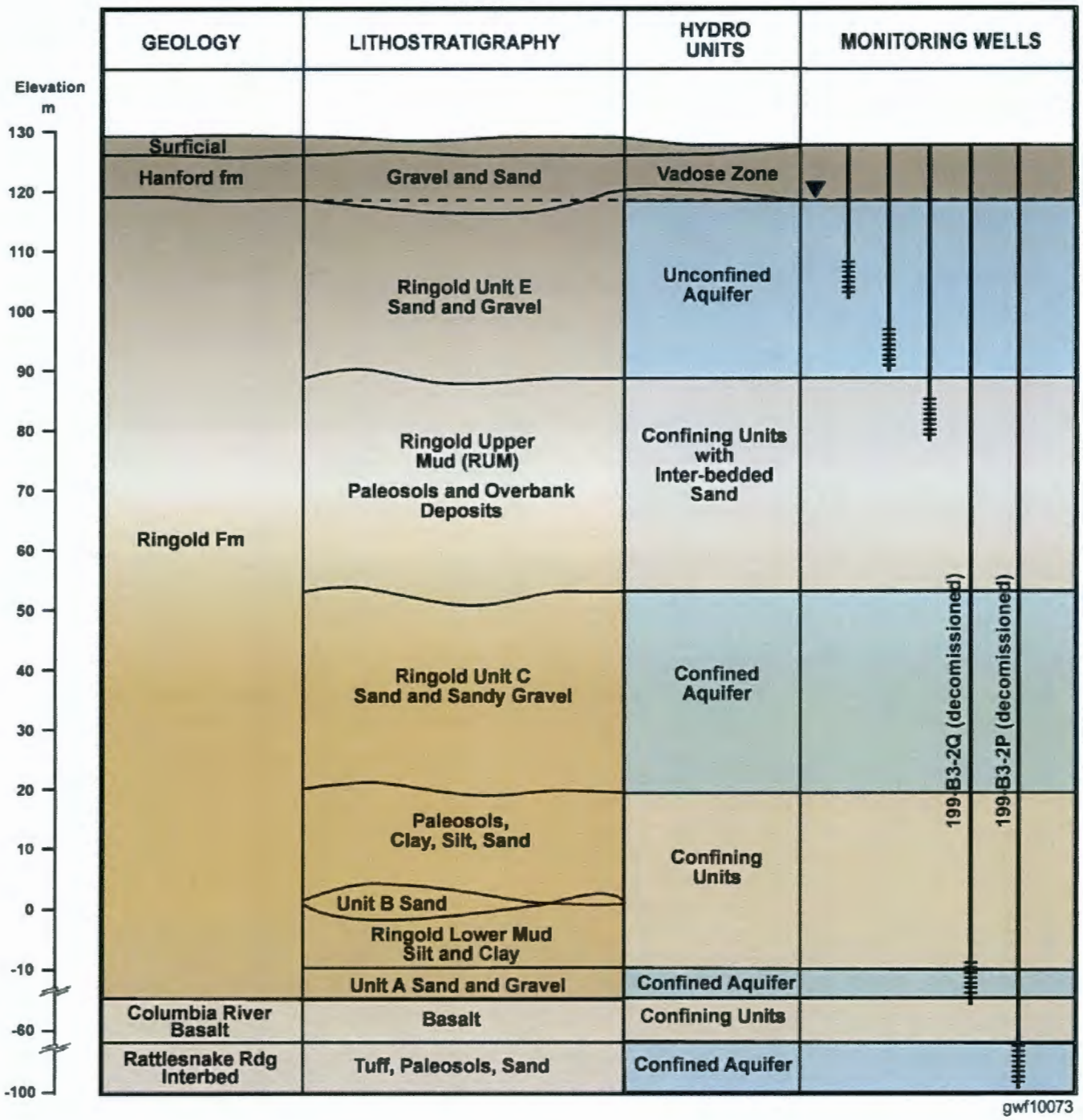


Figure 4-3. 100-B/C Area Water Table Map, March 2010

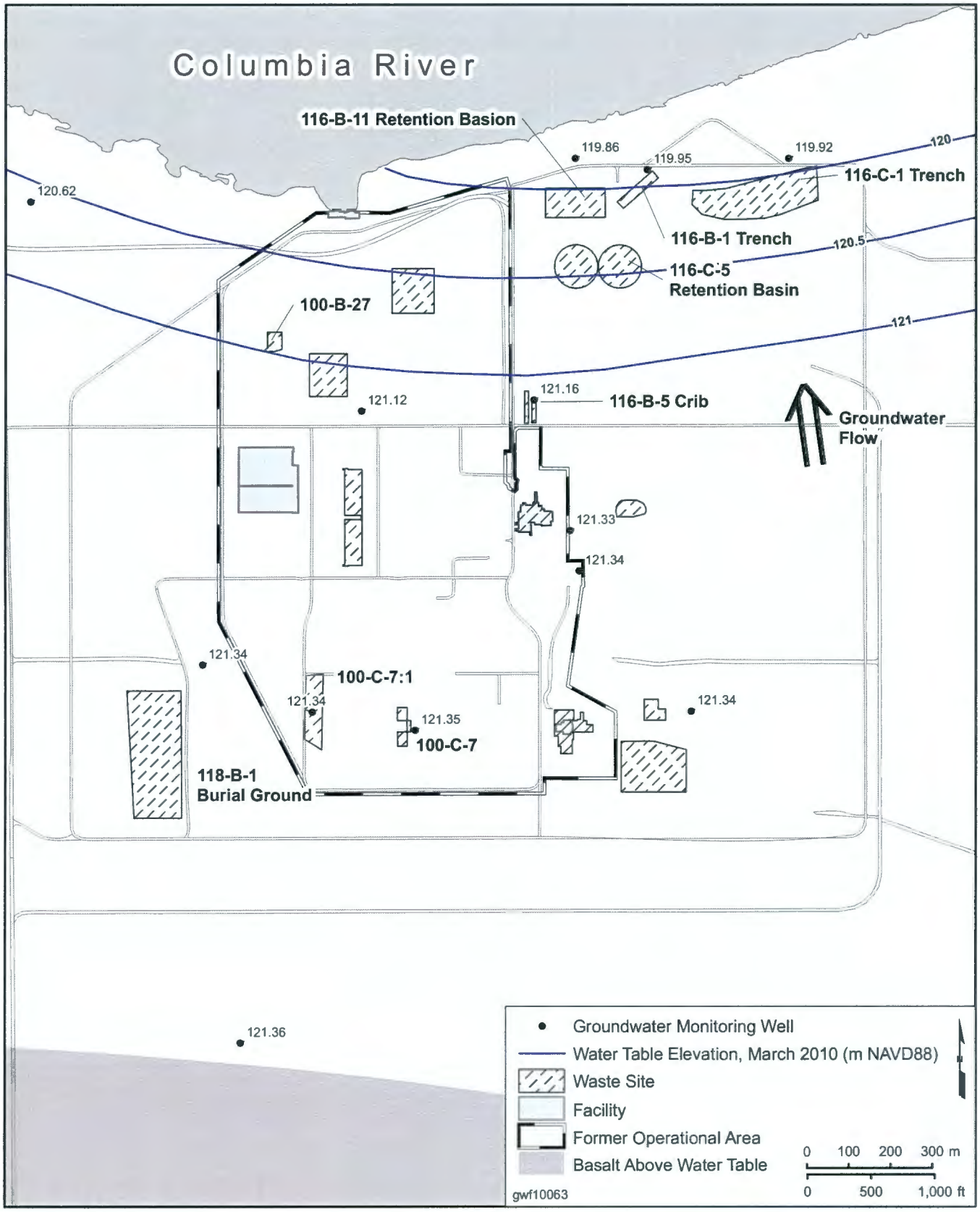


Figure 4-4. Strontium-90 Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010

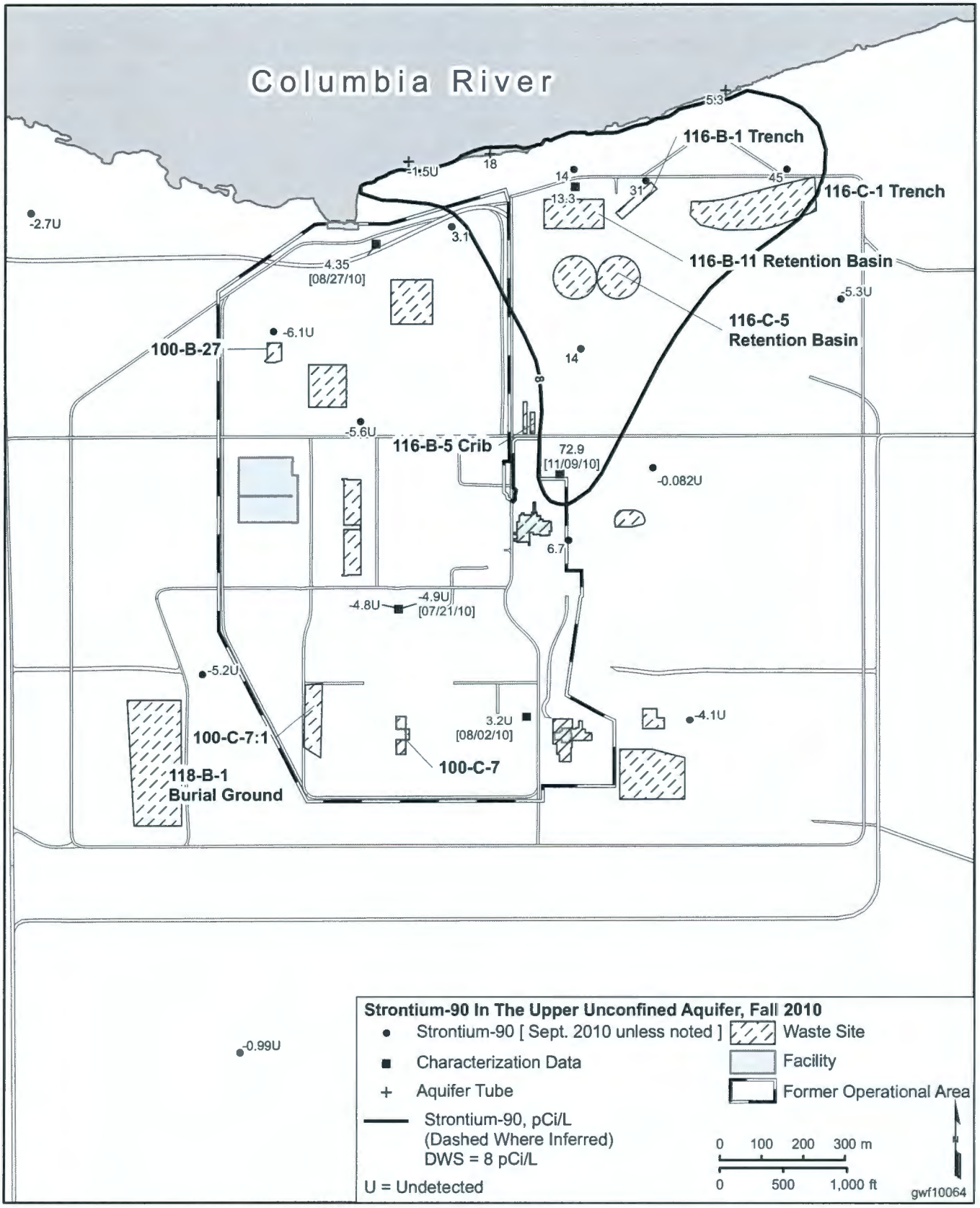


Figure 4-5. Strontium-90 Concentrations in Central 100-B/C Area Wells

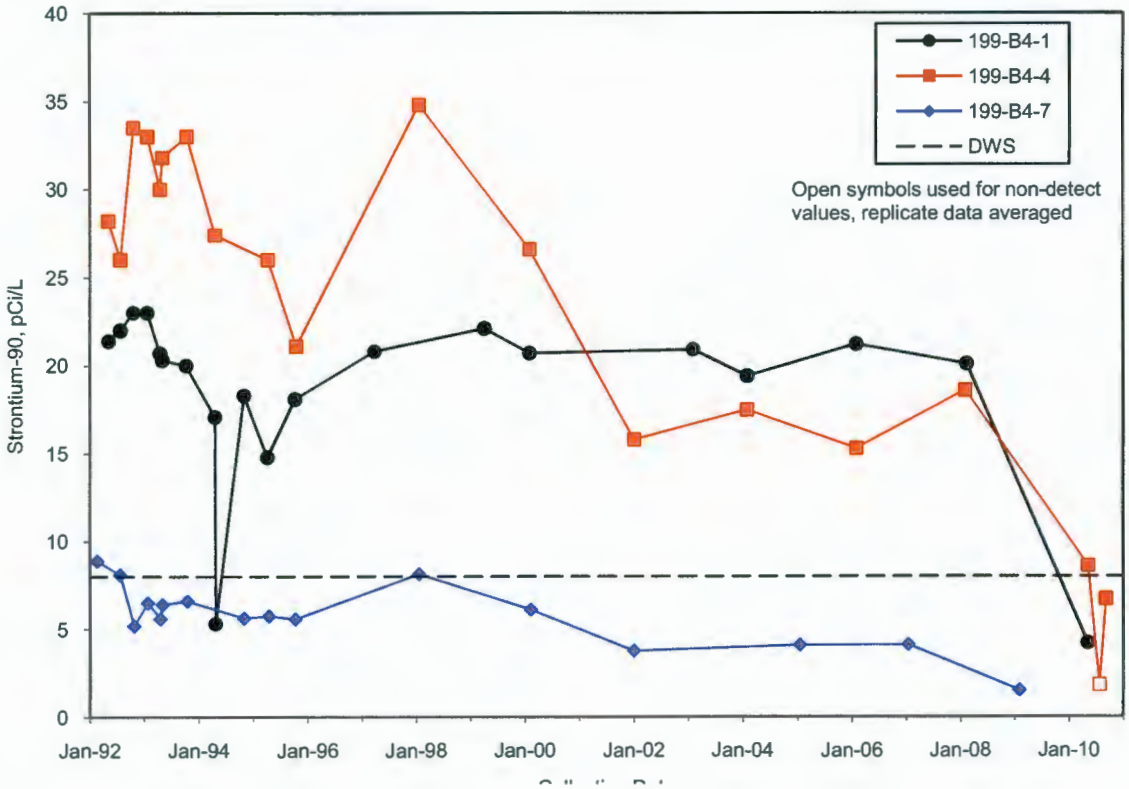


Figure 4-6. Strontium-90 Concentrations in Northern 100-B/C Area Wells

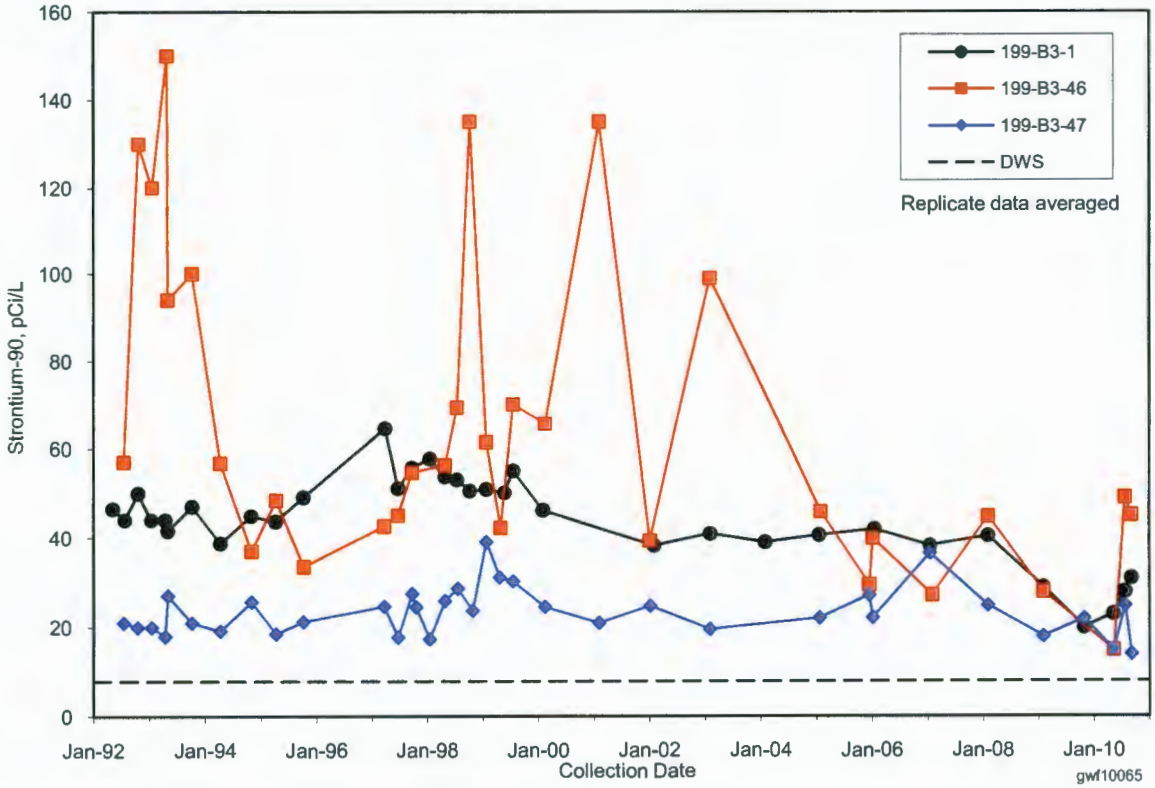


Figure 4-7. Tritium Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010

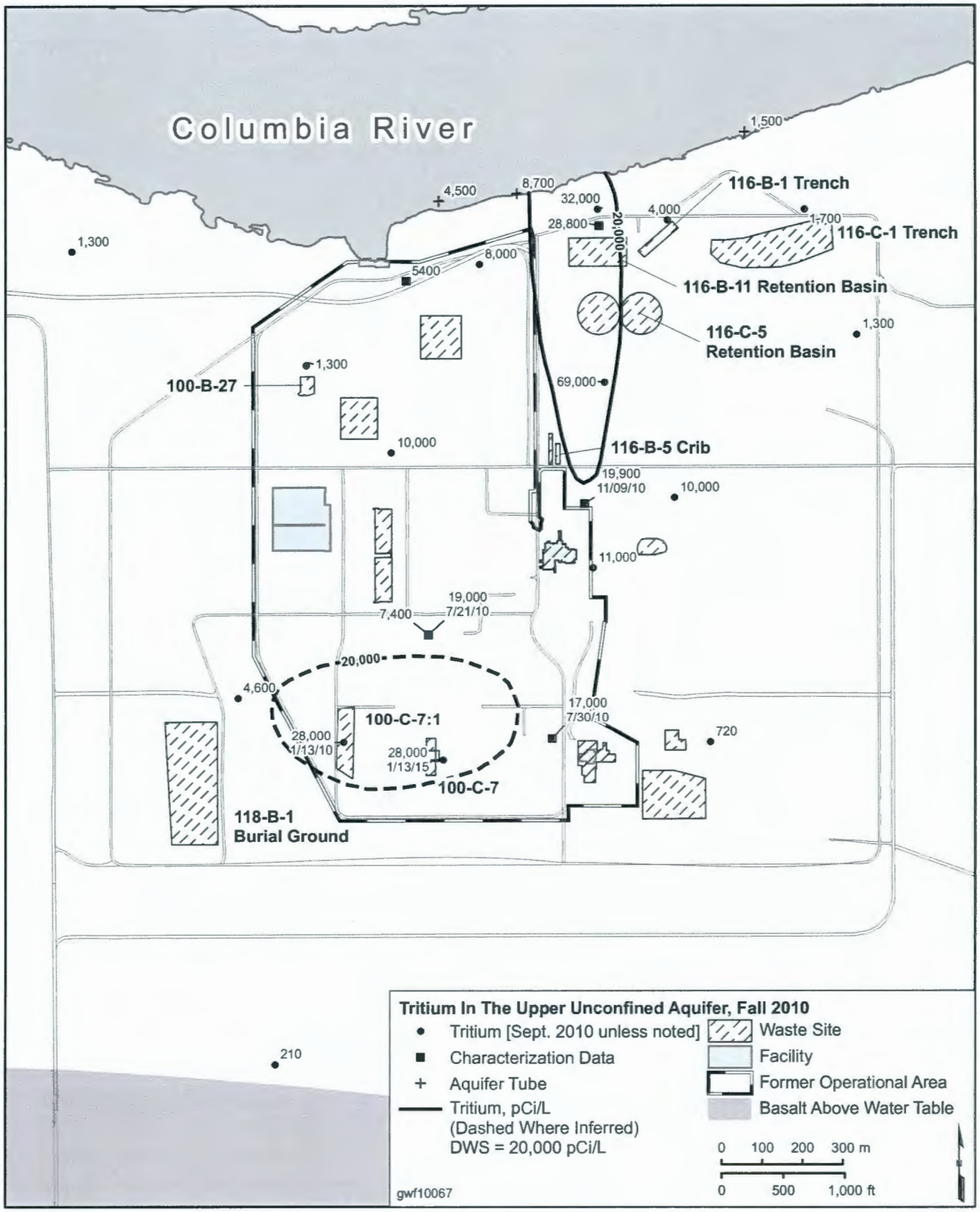


Figure 4-8. Tritium Concentrations in Northern 100-B/C Area Wells

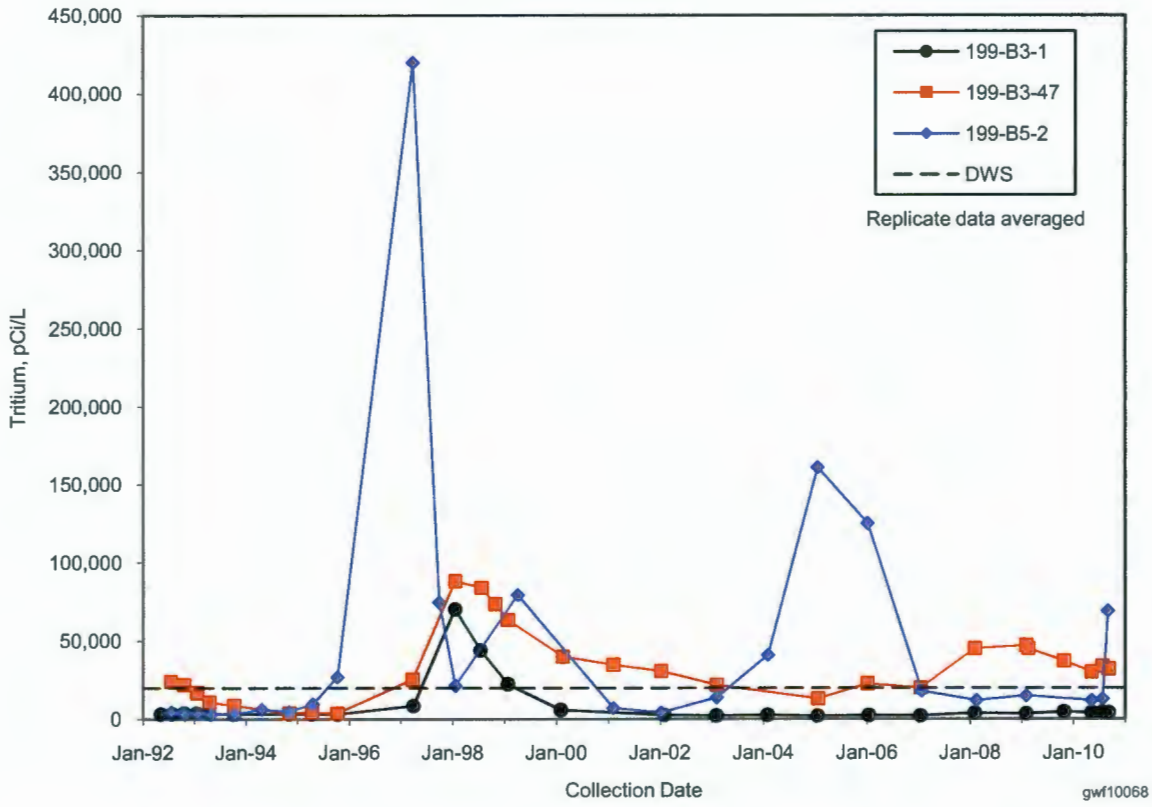


Figure 4-9. Tritium Concentrations in Southern 100-B/C Area Wells

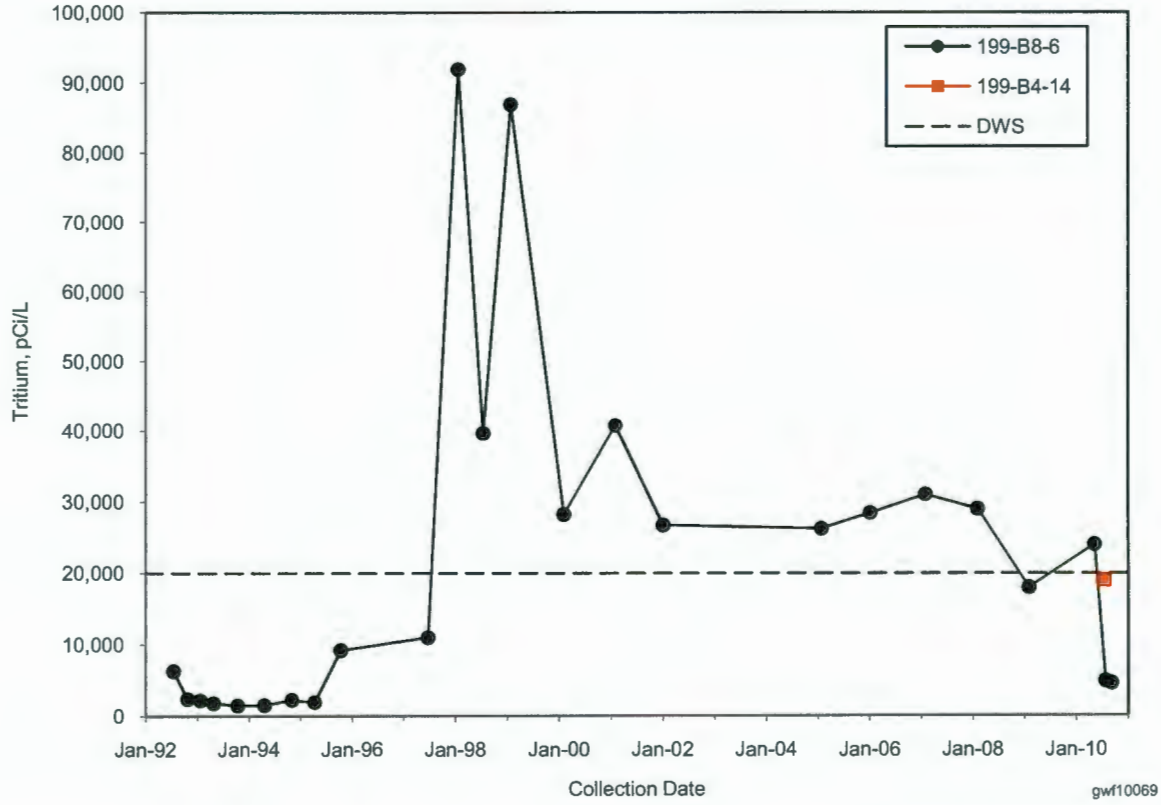


Figure 4-10. Tritium Concentration Profile in New Wells

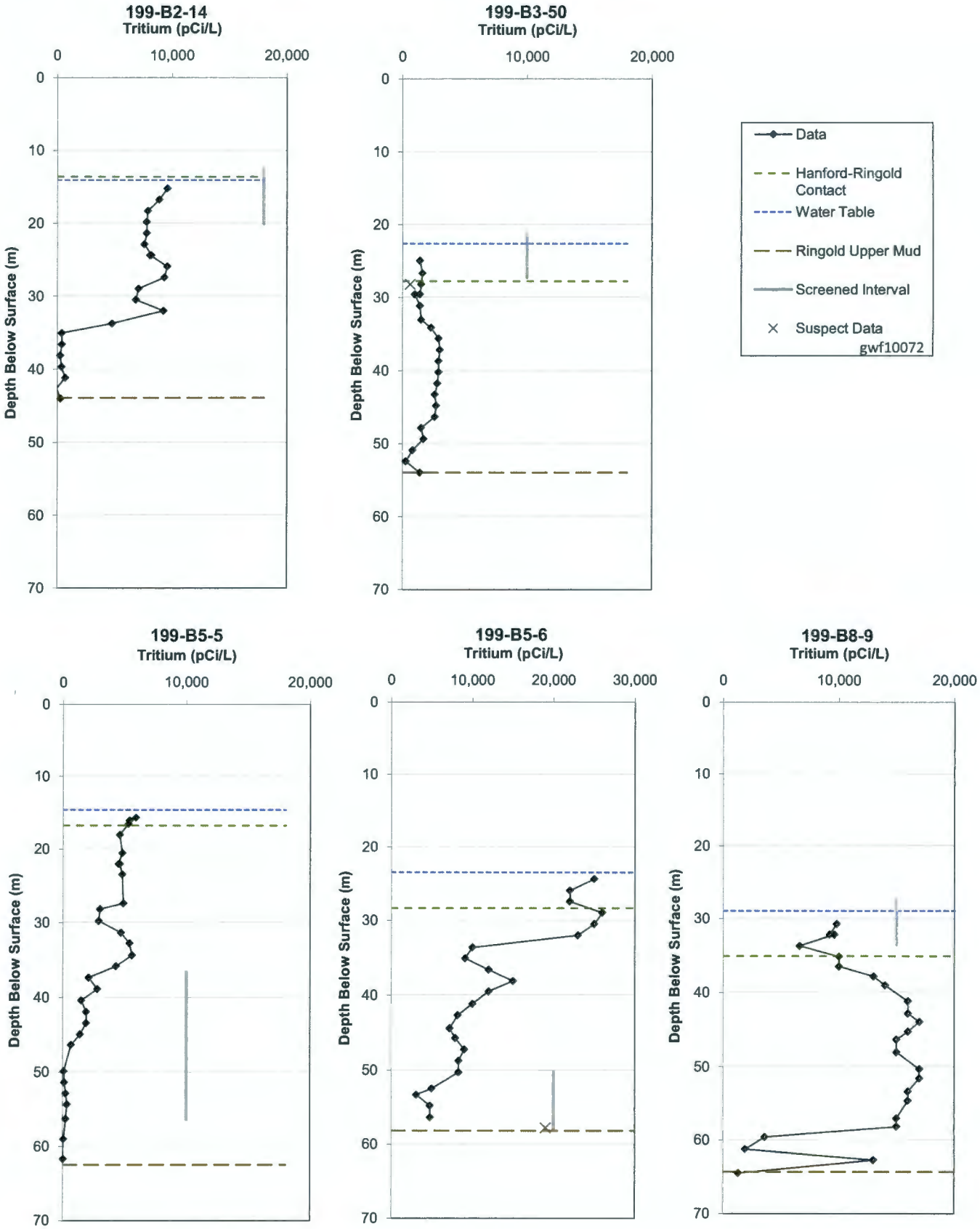


Figure 4-11. Chromium Concentrations in the 100-B/C Area Unconfined Aquifer, Fall 2010

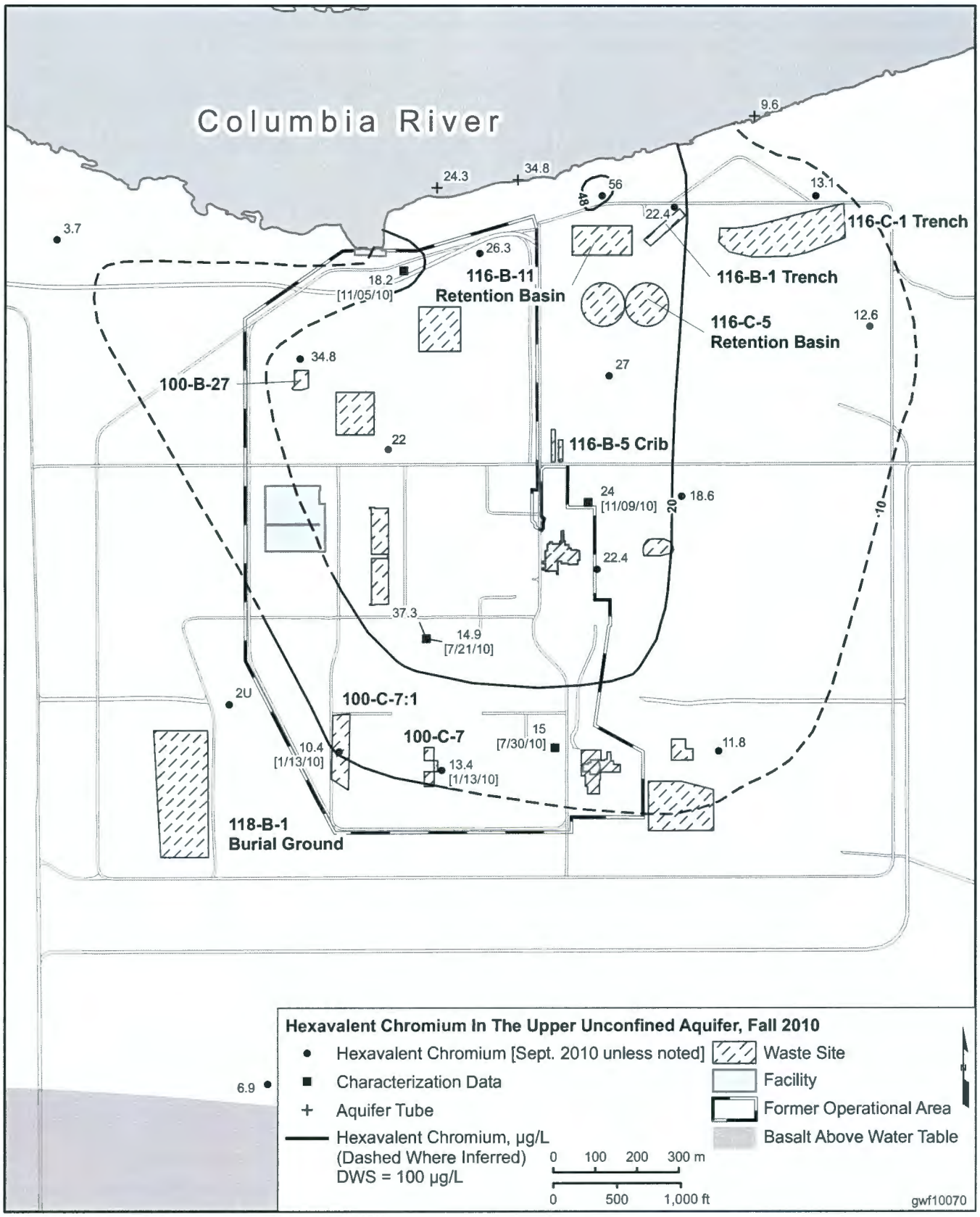


Figure 4-12. Chromium Concentrations in Well 199-B3-47, Northeastern 100-B/C Area

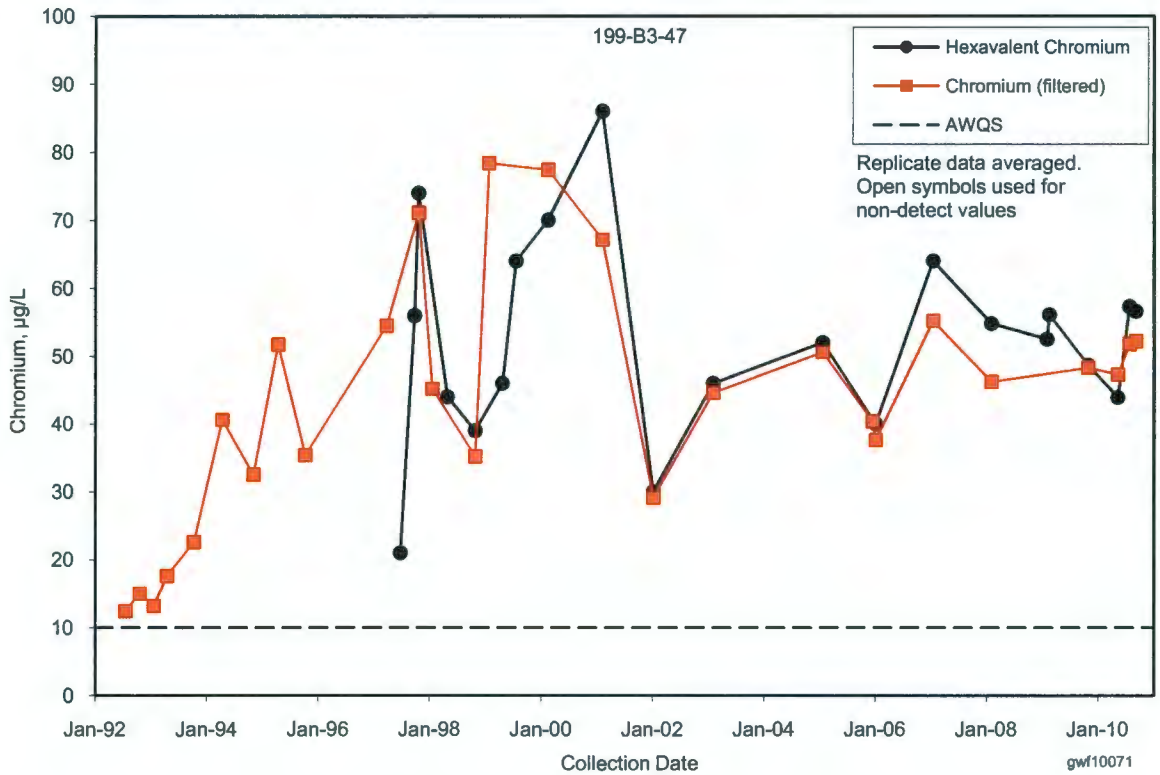
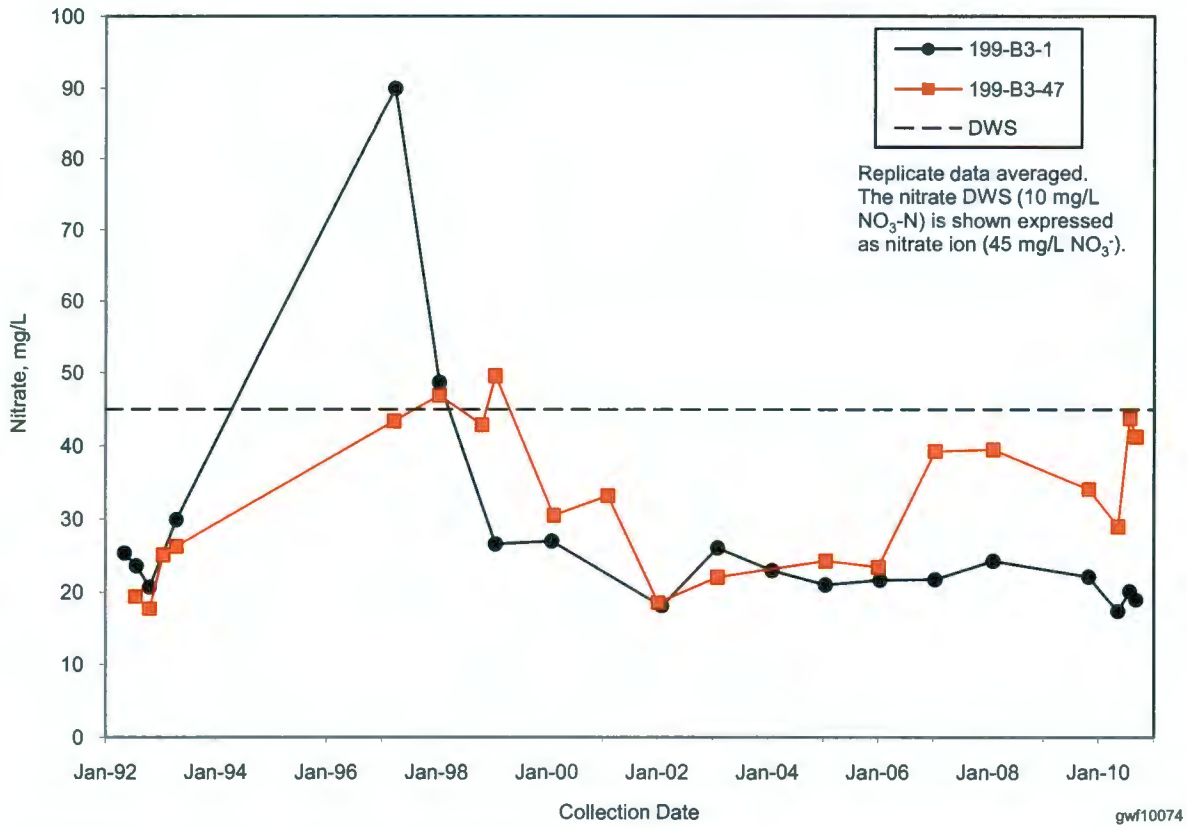
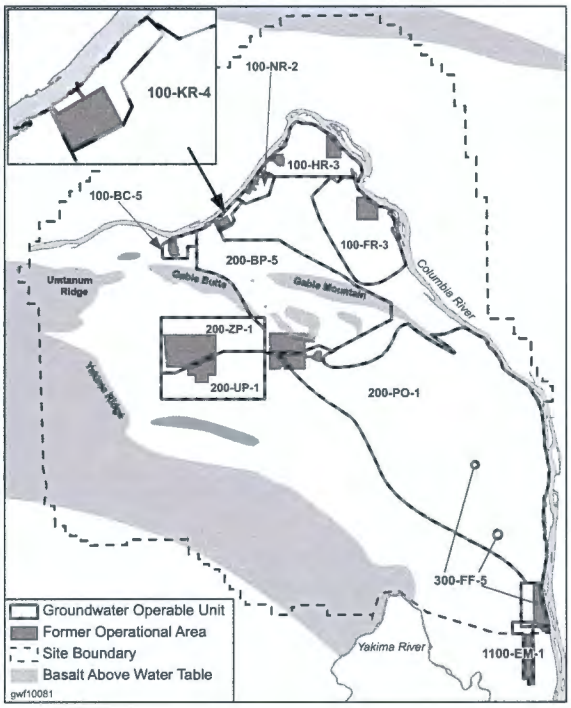


Figure 4-13. Nitrate Concentrations in Northern 100-B/C Area Wells



5.0 100-KR-4 Operable Unit

D.E. Erb/J. Blount



The 100-KR-4 Operable Unit (OU) is located along the Columbia River in the north-central portion of the Hanford Site (Figure 5-1). The 100-KR-4 OU, as defined in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (DOE/RL-2008-46-ADD2), comprises the groundwater affected by hexavalent chromium releases associated with past operation of the deactivated KE and KW Reactors and from the associated support facilities and waste sites within the 100-K Area (Figure 5-2).

The Washington State ambient water quality standard for protection of freshwater aquatic life from hexavalent chromium in the Columbia River is 10 µg/L. As defined in the current interim action Record of Decision (ROD) (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*), the remedial action goal (compliance concentration) for hexavalent chromium is 20 µg/L in compliance wells. The compliance concentration of 20 µg/L hexavalent chromium is based on the estimated 1:1 mixing of groundwater (and the associated hexavalent chromium) with infiltrated river water within a hydrologic mixing zone that separates the groundwater aquifer from the hyporheic zone of the river. The net concentration of hexavalent chromium entering the hyporheic zone of the river after this mixing process should be less than the 10 µg/L aquatic standard. The federal drinking water standard (DWS) for total chromium is 100 µg/L; Washington State has a groundwater cleanup level for hexavalent chromium of 48 µg/L (WAC 173-340 "Model Toxics Control Act – Cleanup").

Although hexavalent chromium is currently the only groundwater contaminant of concern (COC) for the 100-KR-4 OU, other groundwater constituents are monitored on a routine basis. Strontium-90 and tritium are listed in the interim ROD (EPA/ROD/R10-96/134) as target analytes. Carbon-14 and nitrate are target analytes monitored under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring program because of their detection above their DWSs in certain wells or due to a previous qualitative risk assessment (DOE/RL-94-48, *100-KR-4 Operable Unit Focused Feasibility Study*). Trichloroethene and chloroform have been determined by preliminary remedial investigation (RI)/feasibility study (FS) risk assessment calculations to be contaminants of potential concern (COPCs). Other contaminants detected at concentrations below risk-based levels are discussed in this chapter due to concerns over their potential future impact to groundwater. For ease of discussion, all of the contaminants (other than hexavalent chromium) addressed in this chapter (e.g., strontium-90, nitrate, tritium, trichloroethene, carbon-14, and technetium-99) are hereafter denoted as "contaminants of interest."

To mitigate the risks associated with hexavalent chromium contamination in the 100-KR-4 OU, three CERCLA interim action ion exchange-based pump-and-treat systems have been installed, and all three systems operated during calendar year (CY) 2010. The original 100-KR-4 treatment system (referred to as KR4), which

was the first of the systems installed, began operations in October 1997. This system was designed to capture and treat groundwater contaminated with hexavalent chromium near the former 116-K-2 Trench. When the KR4 system was installed, the extent of hexavalent chromium contamination was thought to be limited to the area around the 116-K-2 Trench and, to a lesser extent, around the KW and KE Reactor sites. Over time, however, additional groundwater characterization efforts demonstrated that elevated levels of hexavalent chromium were more extensive in the KW Reactor area than previously recognized and that contaminated groundwater also extended substantially farther to the northeast (downriver) than originally believed. The northeastern extent of the hexavalent chromium contamination associated with the 100-KR-4 OU was ultimately determined to extend past the southwestern boundary of the 100-NR-2 OU (Figure 5-2).

The Second CERCLA Five-Year Review Report for the Hanford Site (DOE/RL-2006-20) determined that the more recently identified areas of hexavalent chromium groundwater contamination also required remediation. This finding led to the development of plans to add two additional pump-and-treat systems (KW and KX) to substantially expand the remedial treatment capacity beyond that provided by the KR4 treatment system alone. The KW system was subsequently installed and began operating in January 2007 to remediate the contaminated groundwater in the KW Reactor area. The KX system began operations in February 2009 and treats groundwater contaminated with hexavalent chromium in the area between the northern section of the 116-K-2 Trench and the N Reactor fence line. The extraction and injection wells that comprise the well fields for these systems during CY 2010, as well as the associated monitoring wells and other monitoring locations, are shown in (Figure 5-2). A separate and much smaller hexavalent chromium plume, located downgradient of the KE Reactor area, is also treated by the KX system. Each system is a critical component of the overall remedial approach implemented to prevent hexavalent chromium in the 100-KR-4 OU from reaching the Columbia River at concentrations greater than the 10 μg/L aquatic water quality criterion.

The monitoring and extraction wells installed during the initial stages of the KR4 and KW pump-and-treat systems were designed to penetrate the upper section of the unconfined aquifer. Virtually all of the wells installed in the last 3 to 4 years in the 100-KR-4 OU (including the new KW and KX system wells) have fully penetrated the aquifer and have been screened over an interval selected on the basis of analytical results obtained during drilling. Thus, the well fields of each system include some extraction wells screened over the full vertical extent of the groundwater contamination.

Specific areas of concern occur at the downgradient KW system, where extraction wells 199-K-132 and 199-K-138 penetrate only the upper 6.1 to 7.6 meters of the ~26-meter-thick aquifer. A new well will be drilled during CY 2011 to address the lack of deep well control in this area. Vertical profiling of hexavalent chromium concentrations (and selected other constituents of interest) will be conducted during drilling activities to determine the vertical extent of contamination in this portion of the KW plume. The data will be used to guide the selection of the screened interval when this borehole is completed as a monitoring or extraction well. In preparation for the final ROD, an RI/FS was initiated in 2010 at the 100-KR-4 OU and will continue into 2011. Information has been collected that will further delineate the nature and extent of contamination, support the refinement of the existing conceptual site model, and contribute to the selection of the final remedy.

Hexavalent chromium, as sodium dichromate, was added as an anti-corrosion agent to cooling water that passed through the KE and KW Reactors during operation from 1955 to 1971. Typical sodium dichromate concentrations in the cooling water during the early years of reactor operations were 2,000 μg/L (~700 μg/L as hexavalent chromium), then decreased to 1,000 μg/L in the mid-1960s, and then 500 μg/L (~170 μg/L as hexavalent chromium) in the last stages of operations. After a single pass through the reactors, spent cooling water was discharged to the 107-KE and KW retention basins (Figure 5-2) to allow short-lived radionuclides to decay and the water to cool. The water was then discharged to the Columbia River. Infiltration and overland flow of contaminated cooling water from leaks at the 107-KE/KW retention basins and piping resulted in contamination of the vadose zone beneath these structures. The 107-KE and –KW Retention Basin sites were cleaned up and closed out in 2004 and 2005.

The 116-K-1 Crib and 116-K-2 Trench were constructed to receive radiologically contaminated water associated with fuel rod failures in the reactors and percolate it into the vadose zone. A pre-operational failure at the 116-K-1 Crib led to construction of the 116-K-2 Trench; contaminated cooling water was never purposely discharged to the 116-K-1 Crib. Valves beneath and downstream of the 107-KE and KW retention basins partially failed and led to discharges to both structures, although the 116-K-2 Trench received the overwhelming majority of cooling water. The 116-K-2 Trench is estimated to have received spent cooling water (contaminated with hexavalent chromium and short-lived radionuclides) at a rate of 18,900 to 37,900 liters per minute for up to 16 years (1955 through 1971), for a total of 160 to 320 billion liters. The 116-K-1 Crib received an estimated 30 million liters of cooling water during 16 months of operation (1955 through 1956). Photographs from the mid-1960s show water ponded in the 116-K-1 Crib.

Historical process information suggests that small volumes of high-concentration solutions (up to 70% by weight) of sodium dichromate were released to the 100-K Area by leaks and spills during the transfer of sodium dichromate from railcars to storage tanks at the 183.1-KE and -KW headhouses. The current and historical presence of hexavalent chromium concentrations in groundwater around the 183.1-K headhouses greatly exceed the concentrations found in reactor cooling water in and groundwater beneath the 116-K-2 Trench. Mobile residuals from the high-concentration sodium dichromate solutions may potentially remain in the vadose zone and may represent a potential future source of groundwater contamination. Characterization data from the RI/FS has revealed low concentrations of hexavalent chromium in the vadose zone at three wells, two of which were drilled adjacent to the two 183.1-KE and KW headhouses. After remediation of the vadose zone is complete and natural vegetation cover has been re-established, any residual vadose source term and the driving force necessary to transport it to the water table (i.e., infiltrating precipitation) will be greatly reduced.

In addition to hexavalent chromium, groundwater contaminants such as tritium, strontium-90, and carbon-14 may be associated with other 116-K liquid waste sites or with the 118-K-1 Burial Ground. These radionuclides were generated as neutron activation or fission products during reactor operations. These sites were active during reactor fuels storage operations and are discussed below. Other target analytes such as nitrate, technetium-99, trichloroethene, and chloroform have no obvious relation to particular waste sites but may be related to unidentified processes.

The unconfined aquifer in the 100-KR-4 OU ranges from 5.2 meters to more than 32 meters in thickness in wells. This aquifer is primarily made up of low to

moderately permeable sands and gravels of the Ringold Formation unit 5 (unit E). The Ringold unit 5 is disconformably overlain by the coarse, flood-deposited gravels and interbedded sand and silt lenses of the Hanford formation. The Hanford formation comprises the bulk of the vadose zone in the 100-KR-4 OU, although near the northeast end of the 116-K-2 Trench, the Hanford formation locally supports the unconfined aquifer at high river stage. The vadose zone ranges from less than 0.3 meters in thickness near the Columbia River to 32 meters in thickness southeast of the 183.1-KE headhouse. The contact between the Ringold unit 5 and Hanford units is a contrast between the denser, less permeable, locally cemented Ringold unit 5 and the more open, coarser-grained Hanford formation. The maximum Hanford formation thickness detected during RI characterization was 19.8 meters. The silt- and clay rich Ringold Formation upper mud unit (RUM) disconformably underlies the Ringold unit 5; this unit retards the downward migration of contaminated groundwater and is considered to form the base of the unconfined aquifer.

Long-term groundwater flow in the vicinity of the 100-K Area is generally to the northwest, toward the Columbia River (Figure 5-3). At any given time, however, the hydraulic gradient and groundwater flow direction within the aquifer proximal to the river is strongly influenced by short-term (e.g., daily) and longer term (e.g., seasonal) fluctuations in river stage. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer.

Groundwater in the shallow unconfined aquifer typically has a pH generally ranging between 7.5 and 8.5 and an average dissolved oxygen concentration of ~8.0 mg/L. This groundwater can be classified as predominantly calcium-bicarbonate-type water but, due to anthropogenic activities, it also contains notable but variable concentrations of sulfate and nitrate. Mineral saturation/solubility calculations indicate that the groundwater in the unconfined aquifer is saturated, or nearly saturated, with respect to calcium carbonate (calcite).

Daily and seasonal changes in the stage of the Columbia River in the 100 Area are largely controlled by the scheduled releases of water by the upstream Priest Rapids hydroelectric dam. Seasonal high water levels in the river during the spring and summer are due to increased runoff associated with the melting of snow pack in the mountains. The river stage affects the hydraulic gradient in the 100-KR-4 OU, which steepens toward the Columbia River during seasonal periods of low river flow (i.e., in the fall). During the spring when the river stage is high, the groundwater gradient toward the river flattens and eventually reverses as river water infiltrates into the aquifer. The reversal is observed inland based on the hydraulic conductivity of the local geology. The effect is most pronounced after the seasonal river stage has peaked. The daily to seasonal water-level fluctuations are also thought to promote a minor flow component parallel to the river in near-shore areas that gradually transport groundwater contaminants downriver before discharging to the river. This effect would be most pronounced during seasonal high river stage when the gradient along the river is locally reversed. This process may have contributed, in part, to the migration of the chromium plume from the 116-K-2 Trench past the boundary of the 100-NR-2 OU (Figure 5-2).

The substantial influx of river water into the aquifer during the spring and summer (high river stage) also affects the concentrations of hexavalent chromium and other contaminants of interest in many parts of the unconfined aquifer. The concentrations of these contaminants can be much lower in groundwater samples collected from near-shore wells (and to a lesser extent at upgradient wells) during the spring or

summer than at other times of the year. The concentrations of these constituents in groundwater tend to attain their maximum annual values in the fall of each year with the onset of low river stage conditions. The hydraulic effects of the pump-and-treat systems at the 100-KR-4 OU are superimposed on these seasonal fluctuations, and the efficiency of the treatment system (i.e., mass of hexavalent chromium captured per unit volume of water extracted) typically decreases during high river stage and reaches a maximum during low river stage.

This chapter summarizes the CY 2010 groundwater monitoring results, discusses the nature and extent in groundwater of hexavalent chromium and other constituents of interest, and summarizes the CERCLA characterization activities and pump-and-treat operations for the 100-KR-4 OU for the period of January 1 through December 31, 2010 (CY 2010).

5.1 Contaminant Monitoring

This section summarizes and presents the CERCLA analytical results obtained from groundwater monitoring wells supporting the 100-K Area pump-and-treat remedial action and other areas in the 100-KR-4 OU. The analytical results presented in this chapter are from unfiltered samples analyzed at the Waste Sampling and Characterization Facility laboratory or offsite laboratories. The following documents define the sampling strategies that were implemented for CY 2010:

- DOE/RL-96-84, Rev. 0, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*
- DOE/RL-96-90, Rev. 0, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*
- DOE/RL-2006-52, Rev. 2, *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*
- DOE-RL-2006-75, Rev. 1 (reissue), *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System.*

Plume areas (square kilometers) in the 100-KR-4 Operable Unit:

Carbon-14, 2,000 pCi/L — *
Chromium, 100 µg/L — 0.02
Chromium, 20 µg/L — 0.61
Nitrate, 45 mg/L — 0.143
Strontium-90, 8 pCi/L — 0.04
Trichloroethene, 5 µg/L — 0.03
Tritium, 20,000 pCi/L — 0.164

**** No annual average plume created this year.***

Most monitoring locations in the 100-KR-4 OU are sampled in the spring during high river stage and in the fall at low river stage. However, owing to the variable effects of the high river stage on groundwater contaminant concentrations during the spring, only the fall data has been used to evaluate the year-to-year changes in concentrations of hexavalent chromium and the other constituents of interest. Separate data tables are presented that summarize the available fall 2010 data for each contaminant. The relevant fall 2008 and 2009 data are also presented to allow a comparison of the fall results for the monitoring locations over a 3-year period. The calculated percent increase or decrease in contaminant concentrations at each monitored location between both CY 2008/CY 2009 and CY 2010 is also presented.

As discussed in Chapter 1.0, the fall 2010 sampling event was delayed by a work stoppage. Although sampling activities resumed on November 8, 2010, the completion of the fall sampling event was further delayed by weather and holidays. As a result, only 33 of 61 wells originally scheduled were sampled during the fall timeframe. In addition, only 9 of the 68 aquifer tubes at the 100-KR-4 OU were sampled within the required timeframe. To increase the robustness of the data set,

analytical data from September 2010 were used (where available) as supplemental data for those locations not sampled in October, November, or December 2010. Data collected prior to September 1 and after December 31 were not used in the fall 2010 data set, as the data were deemed not to be sufficiently representative of fall groundwater conditions. All of the analytical results presented in this chapter have undergone appropriate quality assurance/quality control evaluations and were obtained from samples collected from properly installed and developed monitoring and extraction wells or aquifer tubes. Data tables and plume maps provided in this report use only unfiltered analytical results from laboratory analyses collected during routine sampling. Vertical profile data collected while drilling RI/FS boreholes during CY 2010 were not used.

The spring and fall 2010 data collected at the 100-KR-4 OU were used to construct updated spring and fall plume maps for hexavalent chromium and other selected contaminants. Due to the work stoppage, the abundance and geographic distribution of plume data collected during fall 2010 alone were not sufficient to construct a new hexavalent chromium plume map. As an alternative approach, the data from the fall sampling event were used to revise and update the fall 2009 plume contours presented in *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* (DOE/RL-2010-11). Consequently, the fall 2010 plume maps for hexavalent chromium at the 100-KR-4 OU are based on modifications to fall 2009 plume contours using the available fall 2010 data.

The construction of the fall 2010 plume maps for the other contaminants of interest was also affected by these sampling issues; therefore, the fall 2010 plume maps for these constituents were also constructed using 2010 data to guide the modification of the existing fall 2009 plume maps. The paucity of fall 2010 data were more problematic for updating the distributions of some of these other constituents of interest (e.g., carbon-14 and strontium-90), as the distributions of these contaminants are generally far more limited than hexavalent chromium and are defined by fewer monitoring locations. Consequently, the absence of fall 2010 data for a few key monitoring locations greatly hindered the revision of the plumes for these constituents.

The monitoring results and plume maps for hexavalent chromium and other groundwater contaminants of interest at the 100-KR-4 OU are discussed in the following sections:

- Hexavalent chromium, Section 5.1.1
- Tritium, Section 5.1.2
- Strontium-90, Section 5.1.3
- Carbon-14, Section 5.1.4
- Nitrate, Section 5.1.5
- Volatile organic compounds (e.g., trichloroethene and chloroform), Section 5.1.6
- Other results, including technetium-99, total petroleum hydrocarbons, special sampling for nickel-63, etc., Section 5.1.7.

5.1.1 Hexavalent Chromium Monitoring Results

The groundwater distribution of hexavalent chromium within the 100-KR-4 OU during the spring and fall of 2010 is presented in Figure 5-4. The distribution of hexavalent chromium in the OU can be considered to comprise four separate plumes (KR4, K North, K East, and K West) that can be differentiated by geographic distribution and by the location and nature of probable source areas. The KR4 and

the K North plumes are located on the southwestern and northeastern ends of the 116-K-2 Trench, the original source area. These two plumes are currently being remediated by the KR4 and KX pump-and-treat systems (Figure 5-2). The K East plume is located downgradient of the KE Reactor and appears to be confined to the area near KX extraction wells 199-K-141 and 199-K-178. The source of this plume is likely leakage that occurred from the 183.1-KE headhouse serving the KE Reactor. The fourth hexavalent chromium plume, the K West plume, is located near the KW Reactor and supporting water treatment facilities. The sources of this plume likely include leaks and spills of high-concentration sodium dichromate solutions during unloading or storage at the 183.1-KW headhouse. The K West plume is currently being remediated by the KW pump-and-treat system.

5.1.1.1 116-K-2 Trench Area (KR4 and K North Plumes)

Reactor coolant discharges to the 116-K-2 Trench between 1955 and 1971 resulted in a groundwater mound that substantially raised the water table over a very large section of the OU (up to 4 meters at well 699-78-62, ~1,170 meters inland from the trench, near well 199-K-172). This extensive mound of contaminated water created a large dilute groundwater plume (the 116-K-2 plume), which has been partially remediated by pump-and-treat operations that began in 1997. These remedial activities divided the original plume, which once fully encompassed the 116-K-2 Trench, into a southwest segment (hereafter referred to as the KR4 plume) and a northeast segment (hereafter referred to as the K North plume) that are centered at opposite ends of the 116-K-2 Trench (Figure 5-4).

The K North plume extends ~1.4 kilometers along the Columbia River from the northeastern third of the 116-K-2 Trench to the southern fence line of N Reactor. This northern section of the K North plume is believed to extend inland from the river at least as far as monitoring well 199-K-182 (~1 kilometer), where a hexavalent chromium concentration of 80.5 µg/L was detected in September 2010 (Table 5-1). The plume is unbounded around this well. The southern section of the K North plume is believed to extend inland to the vicinity of extraction well 199-K-171, which is ~1.9 kilometers from the river (Figure 5-2).

The KR4 plume is the smaller of the two 116-K-2 Trench plumes and is found at wells in the area between the southwestern end of the 116-K-2 Trench and the northeastern corner of the fence line around the K Reactors. This plume extends ~0.6 kilometers inland from the river to the vicinity of monitoring well 199-K-111A, located adjacent to the 118-K-1 Burial Ground (Figure 5-2). The sources for this plume are the original trench plume, possibly combined with chromium from the KE headhouse.

The following observations regarding hexavalent chromium distribution associated with the 116-K-2 Trench are based on the data collected from this area during the fall sampling events between CY 2008 and CY 2010 (Table 5-1):

- Hexavalent chromium concentrations were less than 20 µg/L in 14 of 32 wells sampled in fall 2010.
- Hexavalent chromium concentrations decreased between fall 2009 and fall 2010 (results compared included nondetect qualifiers) in 21 of 23 wells sampled during both of these years. When the 2010 data are compared to available 2008 data, concentrations in 26 of 28 wells decreased between fall 2008 and fall 2010.
- The hexavalent chromium concentration at well 199-K-111A currently defines the upgradient extent of the KR4 plume. The concentration of hexavalent chromium at this well during fall 2010 was 46.4 µg/L, an increase of 54.7% since

fall 2008. An upward trend continued in early 2011. This increase may reflect the mobilization of hexavalent chromium contamination in the vadose zone by the infiltration of substantial amounts of dust-suppression water that was used during remediation activities at the 118-K-1 Burial Ground.

- The maximum fall 2010 hexavalent chromium concentration of 139 µg/L was observed in KR4 plume well 199-K-18, which is a 27.6% decrease from 192 µg/L in fall 2009. Hexavalent chromium concentrations increased at this well from the startup of KR4 pump-and-treat operations in 1997 through June 2010, when the trend reached 203 µg/L. It is possible that the effects of a recirculation cell created between the pump-and-treat extraction wells and injection wells is finally being observed in this well. Also, operations of downgradient extraction wells 199-K-145 and 199-K-162 are likely removing the mass of chromium around monitoring well 199-K-18.
- Well 199-K-145, located downgradient of well 199-K-18 (in the KR4 plume), is the only well downgradient of the 116-K-2 Trench with hexavalent chromium concentrations higher during fall 2010 than observed in fall 2008 (field data values of 37 µg/L and 62 µg/L, respectively). All other extraction wells showed declining concentrations of hexavalent chromium. The well was shut down in October 2010 to support upgrades to the KR4 pump-and-treat system. Upon resuming operation in January 2011, hexavalent chromium concentrations were ~25% lower.
- Four aquifer tubes were sampled downgradient of the 116-K-2 Trench plume area during fall 2010. However, only tube AT-K-3-D, at the leading edge of the KR4 plume, is located along a section of shoreline where the discharge of hexavalent chromium had been previously measured. Concentrations of hexavalent chromium in this aquifer tube decreased 9.3%, from 62.8 µg/L to 56.9 µg/L, between fall 2009 and fall 2010.
- Well 199-K-22, located downgradient of the 116-K-2 Trench, was not sampled in fall 2010. This well has had detected chromium concentrations above 100 µg/L since the start of treatment. A slowly decreasing trend was observed between 2008 and 2010, and concentrations dropped below 100 µg/L in 2011.
- Groundwater samples collected between 2008 and 2010 from monitoring wells (199-K-19, 199-K-21, and 199-K-117A) and extraction wells (199-K-119A, 199-K-120A, 199-K-125A, and 199-K-127) in the area between the Columbia River and the central section of the 116-K-2 Trench indicate that the central portion of the hexavalent chromium groundwater contamination historically associated with the trench has been remediated to less than 20 µg/L.
- The hexavalent chromium concentrations in extraction wells 199-K-149 and 199-K-150 (near the northern boundary of the K North plume) decreased from 82 to 8 µg/L and from 70 to 2 µg/L, respectively. The northern boundary of the K North plume appears to have shifted southeast since 2008 due to hydraulic influence of these extraction wells and injection wells 199-K-159 and 199-K-160.

5.1.1.2 KW Reactor Area

Wells 199-K-137 and 199-K-165 (in the central portion of the K West plume, just upgradient of the KW Reactor) were characterized in fall 2008 by hexavalent chromium concentrations of 1,390 and 2,530 µg/L, respectively. Data from fall 2010 are not available for upgradient wells 199-K-173 and 199-K-35 (formerly located between the former 183-KW headhouse and sedimentation basin, decommissioned

in May 2010). Hexavalent chromium concentrations peaked at 771 µg/L in well 199-K-35 (February 2010) and 968 µg/L in well 199-K-173 (August 2010). The presence of elevated concentrations in the KW plume extends upgradient of the 183.1-KW headhouse based on preliminary groundwater vertical profile data collected during installation of the borehole for new RI/FS well 199-K-195 (Figure 5-2). The maximum hexavalent chromium concentrations of 1,970 and 4,890 µg/L were found in an interval ~6 to 9 meters below the groundwater table. Below that interval, hexavalent chromium concentrations dropped to nondetect levels before increasing to 753 µg/L at a sampling interval 3.3 meters above the RUM.

These concentrations are above the normal hexavalent chromium concentrations found in plumes sourced by operational coolant water (700 to 170 µg/L). This suggests that the likely source of the K West plume was leaks and spills of concentrated sodium dichromate solutions and not the discharge of coolant water. Newly installed well 199-K-195 was sampled in April 2011 and a hexavalent chromium concentrations of 3,300 µg/L was detected. The well was decommissioned in late April to permit continued waste site remediation efforts around the former 183.1-KW headhouse. Table 5-2 provides the fall sampling data for the K West plume and the KW Reactor area in general for CY 2008 through CY 2010. The table also includes the percent change in hexavalent chromium concentrations occurring between 2009 and 2010 and between 2008 and 2010 for those wells with data from these years. The following observations on the hexavalent chromium distribution are primarily based on the data presented in Table 5-2:

- Fall 2010 hexavalent chromium concentrations were less than 20 µg/L in six of twelve monitoring locations that were sampled.
- Hexavalent chromium concentrations decreased from 2008 to 2010 in all ten of the wells monitored in this area during both of these years.
- Hexavalent chromium concentrations decreased or were unchanged from 2009 to 2010 in eleven of twelve wells monitored during both of these years.
- The maximum hexavalent chromium concentration in the K West plume during fall 2010 was 321 µg/L in extraction well 199-K-165. In November 2008 (just prior to converting this former monitoring well to an extraction well), a concentration of 2,530 µg/L was recorded in this well (Table 5-2).
- Hexavalent chromium concentrations in downgradient extraction wells 199-K-132 and 199-K-138 have declined steadily, to 16.8 and 20.6 µg/L, respectively.

5.1.1.3 KE Reactor Area

The KE Reactor area hexavalent chromium plume has been monitored since the early 1990s when a number of CERCLA wells were installed upgradient and downgradient of KE Reactor. An initial plume was observed at well 199-K-36, located at the 183.1-KE headhouse, where hexavalent chromium concentrations spiked as high as 1,300 µg/L between 1998 and 2003. This plume may have been the result of localized spills or leaks of concentrated sodium dichromate solutions at the 183.1-KE headhouse and possibly by an influx of contaminated groundwater from the 116-K-2 Trench. None of the groundwater samples collected in the KE Reactor area between 2008 and 2010 contained high hexavalent chromium concentrations (e.g., greater than 700 µg/L) that have recently been observed at some monitoring locations in the KW Reactor area. Beginning in the late 1970s, the KE sedimentation basins and the downgradient KE and KW clear wells were used for N Reactor fuel storage. Leaks are suspected to have diluted any of the KE Reactor area groundwater

chromium plumes present in the last two decades. Table 5-3 presents hexavalent chromium data collected during the fall sampling events of CY 2010, CY 2009, and CY 2008. For those wells where sufficient data were collected, the table also presents the percent change in hexavalent chromium concentrations that occurred between 2009 and 2010 and/or between 2008 and 2010. The following observations address the general hexavalent chromium distributions within the KE plume and the KE Reactor area and are primarily based on the data presented in Table 5-3:

- Pump-and-treat operations during CY 2010 appear to have reduced the areal extent of the KE plume and the overall hexavalent chromium concentrations within the plume.
- Fall 2010 hexavalent chromium concentrations were less than 20 µg/L in seven of the eleven wells sampled and in the only aquifer tube sampled in the KE plume area.
- Hexavalent chromium concentrations decreased or were unchanged in four of the eight wells sampled in both fall 2008 and fall 2010. Concentrations decreased in four of the eleven wells sampled in both 2009 and 2010.
- The maximum reduction in hexavalent chromium concentrations in the plume between fall 2008 (421 µg/L) and fall 2010 (38 µg/L) was observed at extraction well 199-K-141.

5.1.2 Tritium Monitoring Results

Tritium is highly mobile and is a common contaminant in groundwater beneath the K Reactor area. Tritium forms by neutron activation during reactor operations and by fission in fuel rods. Tritium is associated with the 116-KE-1 and 116-KW-1 gas condensate cribs, located just east of the KE and KW Reactor buildings. Tritium is also associated with the 116-KE-3 and 116-KW-2 Cribs, which received shielding water from the fuel storage basins of the respective reactors. Leaks occurring from buried silos in the 118-K-1 Burial Ground is a third source (PNNL-14031). Figure 5-5 presents tritium activity plume maps for the spring and fall of 2010. The DWS for tritium is 20,000 pCi/L.

5.1.2.1 116-K-2 Trench Tritium Plume

The source of the 116-K-2 Trench tritium plume is the silos buried within the central portion of the 118-K-1 Burial Ground. The fall 2010 sampling results, as well as the 2008 and 2009 results, are summarized in Table 5-4 and highlights are presented below:

- Fall 2010 tritium concentrations were less than the DWS in fifteen of eighteen wells sampled.
- Well 199-K-18 increased from 29,000 to 230,000 pCi/L between fall 2008 and fall 2010. A new, nearby RI/FS well, 199-K-192, encountered tritium concentrations of 1,400,000 to 350,000 pCi/L in the upper 6.2 meters of the unconfined aquifer. Downgradient of well 199-K-18, extraction wells 199-K-120A and 199-K-162 had decreased tritium concentrations below 8,000 pCi/L, while 199-K-145 increased to 63,000 pCi/L.
- Tritium concentrations decreased or were unchanged from 2008 to 2010 in six of ten wells and from 2009 to 2010 in twelve of thirteen wells.
- At well 199-K-157, the maximum fall 2010 tritium concentration was 27,000 pCi/L. However, tritium concentrations have decreased more than 90% in this well since 2008 (320,000 pCi/L). Another well displaying an increase

in tritium for the period of 2008 to 2010 was 199-K-111A, which increased more than 300% from 2008 to 2010 (from 6,000 pCi/L in 2008 to 26,000 pCi/L in 2010). Concentrations remained at this level in 2011.

- In the K North plume, a large increase in tritium from 2008 to 2010 was 203 pCi/L (nondetect) to 5,200 pCi/L in extraction well 199-K-163, upgradient of the northeast end of the 116-K-2 Trench. This well is located north of the KR4 pump-and-treat system injection field.
- During drilling of RI/FS well 199-K-192, a tritium concentration of 1,400,000 pCi/L was encountered in groundwater profiling samples collected near the top of the aquifer. Concentrations decreased to 14,000 pCi/L at 15.2 meters below the groundwater table. Minor tritium concentrations were detected in temporary wells 199-K-200 and 199-K-201.
- Tritium taken up by KR4 extraction wells around monitoring well 199-K-18 passes through the treatment system with no uptake on the ion-exchange resins, and it is injected at wells upgradient of the 116-K-2 Trench. Downgradient monitoring and extraction wells 199-K-119A, 199-K-125A and 199-K-127 have been sampled for tritium since the start of pump-and-treat operations. All three wells steadily increased from low concentrations to between 7,500 to 8,300 pCi/L in 2010; however, the concentration in only well 199-K-127 has not begun to decline.

5.1.2.2 KW Reactor Area Tritium Plume

The source of the elevated tritium in the KW Reactor area is likely the 116-KW-1 gas condensate crib, located on the east side of the KW Reactor. An inventory of 56.5 Ci of tritium (decayed through 1986) was reported for this crib. None of the samples collected from this area during fall 2010 indicated tritium above the 20,000 pCi/L DWS. Although none of the KW Reactor area tritium exceedances could be mapped, the wells sampled and the results obtained are shown in Figure 5-5. The results for 2008, 2009, and 2010 are summarized in Table 5-5. Pertinent observations are as follows:

- The maximum fall 2010 tritium concentration of 7,500 pCi/L was observed in well 199-K-132.
- Tritium concentrations increased from 2008 to 2010 in six of seven wells, with a maximum increase of 215% (to 4,100 pCi/L) in well 199-K-34.
- Well 199-K-106A was characterized by an 85% decrease in tritium from 2008 to 2010 (from 21,000 pCi/L in 2008 to 3,200 pCi/L in 2010). Tritium at this well had previously been as high as 2.24 million pCi/L in 2005. Tritium then trended downward to 430,000 pCi/L in April 2009 before experiencing a significant decline to 3,900 pCi/L in the next quarterly sampling.
- The highest tritium concentration in characterization samples from the four new KW Reactor area RI/FS wells (199-K-183, 199-K-184, 199-K-185, and 199-K-195) was 8,800 pCi/L at well 199-K-184.

5.1.2.3 KE Reactor Area Tritium Plume

The source of the small zone of tritium contamination identified as the KE Reactor area tritium plume was likely the 116-KE-1 gas condensate crib, located on the east side of the KE Reactor. The fall 2010 results, as well as the 2008 and 2009 results, are summarized in Table 5-6 and highlights are presented below:

- Tritium concentrations exceeded the 20,000 pCi/L DWS in only two of the nine wells sampled in the KE Reactor area during fall 2010 (wells 199-K-29 and 199-K-111A).
- The tritium concentrations in well 199-K-29 increased from 7,100 pCi/L in fall 2008 to 130,000 pCi/L in fall 2010. This result is being verified because it is much higher than the tritium activity trend for the well; the value is also more in line with the tritium trend at well 199-K-30.
- Tritium concentrations in well 199-K-30 decreased significantly from 2008 (410,000 pCi/L), to 2009 (140,000 pCi/L), and 2010 (16,000 pCi/L). The result from 2010 is the only reported tritium value below the DWS since the start of sampling in 1992.
- Monitoring wells 199-K-30 and 199-K-29 have been decommissioned to permit access for demolition of the 117-KE filter facility. Monitoring for this area of the plume will be conducted in the future at new monitoring well 199-K-189, which was installed as part of the RI/FS investigation. Groundwater profiling data collected during installation of this borehole found tritium concentrations ranging between 140,000 and 1,600 pCi/L near the top of the aquifer, 0 to 12.2 meters below the water table.

5.1.3 Strontium-90 Monitoring Results

Strontium-90 in the environment is the result of fuel rod failures in the reactor or in the fuel storage basins. At the KE and KW Reactors, at least 270 fuel rod failures were reported during operations (PNWD-2161 HEDR, *Fuel Element Failures in Hanford Single-Pass Reactors 1944-1971*). Cooling water contaminated by the failures were reserved in an empty 107-KE or –KW retention basin while the fuel rod was changed out and then discharged to the 116-K-2 Trench. Strontium-90 has also been released to 100-KR-4 OU groundwater via discharges to the 116-KW-2 and 116-KE-3 fuel storage basin cribs, or by the basins themselves. The DWS for strontium-90 is 8 pCi/L, and plume maps showing the distribution of strontium-90 exceedances in the groundwater of the 100-KR-04 OU are provided in Figure 5-6. The following discussion summarizes the nature and extent of the strontium-90 plumes associated with the 116-K-2 Trench, the KW Reactor, and the KE Reactor.

5.1.3.1 116-K-2 Trench Strontium-90 Plumes

Strontium-90 results collected from wells in the 116-K-2 Trench area during the fall monitoring events in CY 2008, CY 2009, and CY 2010 are shown in Table 5-7. Notable observations for strontium-90 distribution in the 116-K-2 Trench area are as follows:

- Strontium-90 concentrations were below the DWS of 8 pCi/L in thirteen of the eighteen locations sampled during fall 2010. Of the remaining five locations, strontium-90 was detected at concentrations above the 8 pCi/L DWS in two locations, and the detection limit for strontium-90 was above the 8 pCi/L DWS in the remaining three locations.
- The two monitoring wells identified with exceedances of strontium-90 in the 116-K-2 Trench area during the fall of CY 2010 were 199-K-19 (12 pCi/L) and 199-K-21 (17 pCi/L) (Figure 5-2). Well 199-K-19 defines the small plume located downgradient of the southeastern end of the trench, and well 199-K-21 defines the plume located downgradient of the central area of the trench (Figure 5-6).

- The strontium-90 concentration at well 199-K-19 increased from 7.5 to 12 pCi/L (60%) between fall 2009 and 2010, while the concentrations at well 199-K-21 decreased from 22 to 17 pCi/L (23%) during the same period (Table 5-7).
- Strontium-90 was detected in groundwater at new temporary RI/FS monitoring well 199-K-200 at concentrations of 130 to 190 pCi/L in early 2011. New RI/FS well 199-K-192 detected strontium-90 at a concentration of 19 pCi/L at the top of the aquifer. Strontium-90 is not detected at well 199-K-18, which is downgradient of the other two wells.

5.1.3.2 KW Reactor Area Strontium-90 Plume

The source of the KW Reactor area strontium-90 plume is assumed to be the former 116-KW-2 Crib, which received effluent from the 105-KW fuel rod basin (KW Basin). The fall 2010 results, as well as the 2008 and 2009 results, are summarized in Table 5-8 and highlights are presented below:

- Fall strontium-90 concentrations were less than the 8 pCi/L DWS in four of six wells sampled.
- Two DWS exceedances for strontium-90 were observed in the fall 2010 data. At well 199-K-107A, a fall 2010 strontium-90 concentration of 14 pCi/L was reported, essentially unchanged from 13 pCi/L observed in the well in fall 2009. The strontium-90 concentration at well 199-K-34 decreased from 36.4 pCi/L in 2008, to 16 pCi/L in October 2009, but then rose to 45 pCi/L in December 2010. The strontium-90 concentration in this well increased to 50 µg/L in January 2011.

5.1.3.3 KE Reactor Area Strontium-90 Plume

The source of the KE Reactor area strontium-90 plume is assumed to be effluent that was discharged from the 105-KE fuel rod basin (KE Basin) to the 116-KE-3 Crib. The strontium-90 results collected from wells sampled in the KE Reactor area during the fall of CY 2008, CY 2009, and CY 2010 are presented in Table 5-9. All seven of the monitoring wells sampled in this area during the fall of CY 2010 had strontium-90 concentrations that were less than the 8 pCi/L maximum DWS (Table 5-9). Former monitoring well 199-K-109A had the highest strontium-90 concentration measured in this area over the previous 3 years (1,120 pCi/L in March 2008). Well 199-K-109A was decommissioned in April 2008 to support demolition of the KE Basin; data have not been collected from the suspected core of this plume since that time. New monitoring well 199-K-189 was installed in the vicinity of decommissioned well 199-K-109A, and data collected in 2011 will be used to update the KE Reactor area strontium plume map. Based on the current absence of a nearby alternative location to well 199-K-109A, the CY 2008 data from decommissioned well 199-K-109A were used to produce an estimated plume boundary for strontium-90 exceedances in the KE Reactor area for the spring and fall of 2010 (Figure 5-6). Additional observations for this plume area include the following:

- The maximum strontium-90 concentration measured in wells in this area during the fall of CY 2010 was 4.4 pCi/L in well 199-K-32A.
- The maximum strontium-90 increase from 2009 to 2010 was 17% in well 199-K-32A. The fall 2009 result was 3.8 pCi/L, which increased to 4.4 pCi/L in 2010.
- Strontium-90 concentrations in well 199-K-141 (a KX system extraction well located downgradient of the KE Basin and former well 199-K-109A) increased from nondetect values when first drilled, to 5.9 pCi/L in July 2010, and to

12 μg/L in January 2011, before declining to 9.7 pCi/L when resampled in February 2011. Gross beta activity also increased. Verification samples taken in early March 2011 confirmed this trend. Verification sampling results are being evaluated for possible impact to operations.

5.1.4 Carbon-14 Monitoring Results

Carbon-14 is a neutron activation product of nitrogen, which was used as a blanket cover gas. The gas helped to cool the reactor and also removed water vapor from leaks in the core. In 1961, nitrogen replaced a helium-carbon dioxide blend as the cover gas. Carbon-14 in groundwater in the 100-KR-4 OU originates from two major sources: the 115-KE and 115-KW gas condensate facilities, and the 116-KE-1 and 116-KW-1 gas condensate cribs. Each crib has an estimated 110 Ci inventory of carbon-14. The DWS for carbon-14 is 2,000 pCi/L. Figure 5-7 presents plume maps for the spring and fall of 2010. The following discussion provides the carbon-14 results for the KW and KE Reactor areas for CY 2010.

5.1.4.1 KW Reactor Area Carbon-14 Plume

The suspected source of carbon-14 detected in wells around the KW Reactor is the 115-KW gas condensate facility and the 116-KW-1 gas condensate crib (Figure 5-2). The fall 2010 results, as well as the 2008 and 2009 results, are summarized in Table 5-10 and highlights are as follows:

- Well 199-K-106A, which was not sampled in fall 2010, is located downgradient of the 116-KW-1 gas condensate crib. Carbon-14 concentrations have trended above the 2,000 pCi/L DWS at this location since 1995, and the result from the fall of 2009 was 3,970 pCi/L (Table 5-10). The June 2010 carbon-14 concentrations at this well were 10,100 pCi/L. Sampling at former downgradient monitoring well 199-K-33, active until March 2003, detected carbon-14 concentrations of between 6,300 and 16,000 pCi/L between 1992 and 2003.
- The highest carbon-14 concentration during the fall of 2010 was 2,590 pCi/L observed at monitoring well 199-K-34, located west of well 199-K-106A.
- The maximum carbon-14 concentration at an extraction well was 2,350 pCi/L in 199-K-132. For the remainder of the extraction wells in the KW system, carbon-14 concentrations did not exceed 540 pCi/L. Monitoring wells 199-K-107A and 199-K-108A yielded carbon-14 concentrations of 625 and 265 pCi/L in fall 2010. These wells are cross-gradient and upgradient, respectively, of the source waste site (the 116-KW-1 Crib). Groundwater contaminated with carbon-14 is extracted by downgradient extraction wells and is passed through the KW treatment system. Some removal of carbon-14 using DOWEX-21K® (registered trademark of Dow Chemical Company, Midland, Michigan) resin is observed. The December 2010 sampling results indicated carbon-14 at a concentration of 700 pCi/L present in the influent tank of the ion-exchange system, and 580 pCi/L was observed in the effluent tank. Most of the carbon-14 remaining in the treated effluent is reinjected upgradient of the KW Reactor area carbon-14 plume via wells 199-K-158, 199-K-174, and 199-K-175.
- Although not collected as part of the fall sampling event, vertical profile data were collected through the unconfined aquifer during the installation of four new RI/FS wells installed in the KW Reactor area during CY 2010 and CY 2011 (199-K-183, 199-K-184, 199-K-185, and 199-K-195) (Figure 5-2). Only vertical profile samples collected from well 199-K-185, downgradient of the 107-KW retention basins, had carbon-14 concentrations exceeding the DWS, reaching a maximum

of 2,390 pCi/L in a sample collected near the top of the aquifer. This well replaced former well 199-K-33, in which the carbon-14 trend exceeded the DWS by three to eight times. Samples from well 199-K-184 yielded a maximum carbon-14 concentration of 1,640 pCi/L. The carbon-14 concentrations in the vertical profile samples collected during borehole installations for wells 199-K-183 and 199-K-185 did not exceed 900 pCi/L.

5.1.4.2 KE Reactor Area Carbon-14 Plume

The suspected source of the carbon-14 detected in wells around the KE Reactor is the 115-KE gas condensate facility and the 116-KE-1 gas condensate crib. The CY 2010 results, as well as the 2008 and 2009 results, are summarized in Table 5-11 and highlights presented below:

- Fall 2010 carbon-14 concentrations were less than the 2,000 pCi/L DWS in six of eight wells sampled.
- The maximum fall 2010 carbon-14 concentration was 4,110 pCi/L in monitoring well 199-K-30. The only other well displaying carbon-14 above the DWS was 199-K-29 at 3,120 pCi/L. Both values were on-trend when the wells were decommissioned.
- The carbon-14 concentration in well 199-K-30 decreased from 6,130 pCi/L in fall 2008 to 5,830 pCi/L in fall 2009, and again to 4,110 pCi/L in fall 2010.
- Extraction well 199-K-178 (downgradient of the 116-KE-1 Crib) yielded a fall 2010 concentration of 226 pCi/L. Downgradient monitoring wells 199-K-32A and 199-K-142 maintained relatively low carbon-14 concentrations of 192 and 242 pCi/L, respectively. These values were generally consistent with the range of values observed for these wells in 2008 and 2009. Five new RI/FS wells (199-K-189,199-K-186, 199-K-187, 199-K-188, and 199-K-190) were installed during 2010 in the KE Reactor area (Figure 5-2). Groundwater profiling samples collected during installation of these boreholes yielded carbon-14 concentrations up to 1,200 pCi/L in a sampling interval 3.1 meters below the top of the aquifer at well 199-K-189, while the maximum carbon-14 concentrations observed in wells 199-K-186, 199-K-187, 199-K-188, and 199-K-190 ranged from 60 to 716 pCi/L.

5.1.5 Nitrate Monitoring Results

Nitrate is present in most 100-KR-4 OU wells at concentrations below the DWS (45 mg/L). The source of nitrate is unknown but may be associated with reactor or water plant operations, decontamination activities, or septic systems. The following discussion presents the nitrate plumes (Figure 5-8) around the 116-K-2 Trench area, the KW Reactor area, and the KE Reactor area.

5.1.5.1 116-K-2 Trench Nitrate Plume

The fall 2010 results for the 116-K-2 Trench nitrate plume, as well as the 2008 and 2009 results, are summarized in Table 5-12 and highlights are presented below:

- The maximum fall 2010 nitrate concentration was 60.6 mg/L in well 199-K-18, followed by 26.7 mg/L in well 199-K-19. Nitrate trends at both wells have been decreasing since 2008. Although the data suggest that the 116-K-2 Trench is the source for this plume, some nitrate may also be derived from the 118-K-1 Burial Ground or the septic system for the KE Reactor (located northeast of the structure).
- Nitrate concentrations decreased in the five wells sampled in both 2008 and 2010.

- Nitrate concentration decreased in ten of twelve wells sampled in both 2009 and 2010. The maximum decreases were 70% at extraction well 199-K-161 and 56% in monitoring well 199-K-117A.
- Monitoring well 199-K-21 was the only well with an increase in nitrate concentrations from 2009 to 2010 (from 10.7 to 14.8 mg/L). However, concentrations decreased in this well between 2008 and 2010 (from 17.7 to 14.8 mg/L).

5.1.5.2 KW Reactor Area Nitrate Plume

The source for the KW Reactor area nitrate plume appears to be the 116-KW-1 gas condensate crib. The fall 2010 results, as well as the 2008 and 2009 results, are summarized in Table 5-13 and highlights are as follows:

- The fall 2010 nitrate concentrations were less than the 45 mg/L DWS in six of seven wells sampled.
- The maximum fall 2010 nitrate concentration was 73.9 mg/L in well 199-K-106A. It and former downgradient monitoring well 199-K-33 have usually ranged two to three times above the DWS
- The maximum observed reduction in nitrate concentration between 2008 and 2010 ranged from 193 mg/L to 22.4 mg/L (88.4%) in extraction well 199-K-166.
- Nitrate increased from 2008 to 2010 in four of seven wells sampled in both years, with a maximum increase of 21.2% in extraction well 199-K-132 (from 28.3 to 34.3 mg/L).

5.1.5.3 KE Reactor Area Nitrate Plume

The fall 2010 results for the KE Reactor area nitrate plume, as well as the 2008 and 2009 results, are summarized in Table 5-14 and highlights are as follows:

- Fall 2010 nitrate concentrations were less than the 45 mg/L DWS in eight of nine wells sampled.
- The maximum reported nitrate concentrations from the KE Reactor area in fall 2010 were 46.5 mg/L in monitoring well 199-K-29 and 25.1 mg/L in monitoring well 199-K-30. It is suspected that, based on proximity to the 116-KE-1 gas condensate crib and the nitrate trends at the two wells, the data have been reversed. The laboratory and field records are being checked for evidence that the samples may have been interchanged. Although trends do not differ significantly, the relative proximity of wells 199-K-30 versus 199-K-29 to the 116-KE-1 gas condensate crib makes the reported results problematic.
- Nitrate concentrations decreased from 2008 to 2010 in five of seven wells sampled in both years. The maximum decrease was 68.5% in monitoring well 199-K-30, from 79.7 mg/L in 2008 to 25.1 mg/L in 2010.
- The maximum increase in nitrate from 2008 to 2010 was 27.1% in monitoring well 199-K-36, increasing from 22.1 mg/L in 2008 to 28.1 mg/L in 2010.

5.1.6 Volatile Organic Compounds Monitoring Results

Trichloroethene is a chlorinated organic compound found around the KW Reactor area at concentrations slightly above the 5 µg/L DWS in a few wells. The spring and fall 2010 plumes are presented in Figure 5-9 and highlights are summarized below:

- Sampling conducted at seventeen wells in the 100-K Area for the risk assessment phase of the ongoing RI/FS indicated the presence of trichloroethene.

- Contaminant trends for trichloroethene were the highest at wells downgradient of the 116-KW-1 gas condensate crib (35 µg/L in 1995 at well 199-K-106A and 20 µg/L in 1994 at the now decommissioned well 199-K-33), which suggests that the source was likely the 116-KW-1 Crib. Since startup of KW pump-and-treat activities, the distribution of trichloroethene has spread away from these two wells.
- Most wells downgradient of the 116-KW-1 gas condensate crib have had one or more detections of trichloroethene exceeding the DWS, whereas most wells upgradient of the crib have detections below the DWS.

Chloroform is another chlorinated organic compound that has been detected at monitoring locations within the 100-KR-4 OU. Although the detected concentrations are well below the 80 µg/L DWS, some concentrations are above the risk assessment action level of 0.71 µg/L. The distribution of chloroform within the KW plume area is summarized below:

- Chloroform was detected at well 199-K-151, near the southwestern boundary of the N Reactor Area. Additional detections were found in wells near the head end of the 116-K-2 Trench and downgradient of the 116-KE-1 Crib.
- The chloroform levels at monitoring well 199-K-151 ranged up to 6.3 µg/L; however, no known source waste site has been identified.
- Well 199-K-18 had chloroform concentrations up to 2.1 µg/L during the three risk assessment sampling events. Previous results from 1992 and 1993 had concentrations estimated between 6 and 8 µg/L.
- Chloroform concentrations at well 199-K-32A during 2010 were as high as 2.3 µg/L and follow a series of 1992 to 1993 results ranging between 11 and 17 µg/L.
- Wells 199-K-29 and 199-K-30, downgradient of the 116-KE-1 gas condensate crib, reached levels of 19 and 14 µg/L, respectively, in 1992 and 1993.
- Other wells examined during the 100-K Area risk assessment sampling had chloroform concentrations generally below the detection limit of 1 µg/L.

5.1.7 Other Contaminants of Interest

5.1.7.1 Technetium-99

Technetium-99 is a long-lived fission product generated during100-K Area reactor operations. Technetium-99 concentrations at upgradient KW system extraction and monitoring wells (e.g., 199-K-173 and 199-K-165) ranged between 14 and 37 pCi/L in January 2011, while concentrations at downgradient extraction and monitoring wells (e.g., 199-K-107 and 199-K-132) ranged between 13 and 35 pCi/L in November 2010. Sampling at well 199-K-31, located upriver from the KW pump-and-treat area, had a detected technetium-99 concentration of 48 pCi/L in December 2010. Overall, technetium-99 concentrations in 100-KR-4 OU groundwater during CY 2010 were ~6% (or less) of the 900 pCi/L DWS.

5.1.7.2 Total Petroleum Hydrocarbons

As noted in the CY 2009 annual groundwater report (DOE/RL-2010-11), several wells in the KW Reactor area encountered total petroleum hydrocarbons (diesel and gasoline) while being drilled. Well 199-K-167 and replacement well 199-K-173 both encountered a diesel-saturated interval in vadose zone sediments at depths of ~8.5 to 9.1 meters below ground surface. Analytical results at wells around and downgradient of the 166-KW fuel storage vault have occasionally reported low detections of total

petroleum hydrocarbons (diesel or gasoline). The results at wells 199-K-165 and 199-K-168 showed detections, typically in the uppermost aquifer sample taken while the well was being drilled. Sampling during CY 2010 did not detect any of the total petroleum hydrocarbons in these wells.

While drilling RI/FS well 199-K-186, downgradient of the 166-KE fuel storage vault, a zone of diesel-saturated sediments was found at a depth of 12.8 to 14.6 meters below ground surface. Total petroleum hydrocarbons were not been reported in groundwater samples. Well 199-K-110A, located north of the 166-KE fuel bunker, detected a low concentration of diesel fuel in December 2010. An estimated ("J" qualified result close to detection levels with large analytical errors) concentration of 78 µg/L was reported.

5.1.7.3 Nickel-63

Nickel-63 is an activation product with a half-life of 101 years and a DWS of 50 pCi/L. Small amounts of nickel-63 were released to the environment in the 100-K Area as a result of KE and KW Reactor operations. A one-time nickel-63 sampling event was performed from March through July 2010 at wells downgradient of the 116-K-2 Trench at the request of Washington Closure Hanford. Concern regarding the presence of nickel-63 in the soil column led to sampling of the monitoring and extraction wells downgradient of the trench; wells 199-K-106A and 199-K-30, downgradient of the 116-KE-1 and 166-KW-1 Cribs, were also sampled. Most results were nondetects; however, nickel-63 was detected at a few wells, including 4.24 and 4.42 pCi/L at wells 199-K-18 and 199-K-30, respectively.

5.2 CERCLA Groundwater Activities

A variety of activities were underway at the 100-KR-4 Groundwater OU during CY 2010. Following approval of the 100-K Area RI/FS work plan (DOE/RL-2008-46-ADD2) and the *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study* (DOE/RL-2009-41), a series of drilling and sampling tasks supporting characterization were initiated (Section 5.2.1). The remedial process optimization (RPO) project was developed in greater detail in CY 2010; however, the design and implementation await a determination of the remedial approach following the final ROD (Section 5.2.2) before proceeding. Planning for implementation of the Phase 3 RPO requirements began in CY 2010.

Two of the three pump-and-treat systems (KX and KW) were operated with minimal interruptions for the entire year, and the third system (KR4) operated with minimal interruptions until shutdown in the fourth quarter CY 2010 for a system upgrade. Section 5.2.3 discusses system performance for the three pump-and-treat systems.

All remediation work performed at the 100-KR-4 OU is conducted in accordance with CERCLA requirements, as presented in the following documents:

- **DOE/RL-96-84, Rev. 0 and Rev. 0A, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*:** The work plan describes the design and operation requirements for the original KR4 pump-and-treat system.
- **DOE/RL-96-90, Rev. 0, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*:** This document established the initial operational,

monitoring, and sampling requirements for the 100-KR-4 OU to demonstrate satisfactory operations and control of the plume by the KR4 treatment system.

- **DOE/RL-2006-20, Rev. 1, *The Second CERCLA Five-Year Review Report for the Hanford Site*:** This document identified the need for the following:
  - Determine the southeastern extent of the chromium groundwater plume inland from the 116-K-2 Trench (Action 3-1). Three wells (199-K-153, 199-K-154, and 199-K-163) were installed in November 2008 to address this issue. Hexavalent chromium was detected at concentrations between 50 and 150 µg/L and extended the 50 and 100 µg/L contours further to the southeast.
  - Remediate the small hexavalent chromium plume reaching the Columbia River as detected at near-shore aquifer tubes (Action 4-1). The 379-liter-per-minute-capacity KW pump-and-treat system began operation in January 2007. The KW system capacity was expanded to 757 liters per minute in April 2009.
  - Expand the 100-K Area treatment capacity by 379 liters per minute to enhance remediation of the chromium plume between the 116-K-2 Trench and the N Reactor perimeter fence line (Action 5-1). The 2,271-liter-per minute-capacity KX treatment system was constructed and began operation in February 2009, reaching full treatment capacity in May 2009.
  - Add wells between the 116-K-2 Trench and the N Reactor perimeter fence line for groundwater extraction, and connect to the pump-and-treat system (Action 5-2). Wells 199-K-138, 199-K-149, and 199-K-150 were drilled in late 2007 and early 2008. Along with existing wells 199-K-130 and 199-K-131, the five wells were converted to extraction wells and connected to the KX treatment system, thus completing the required action.
- **DOE/RL-2006-52, Rev. 1 and Rev. 2, *The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*:** Revision 1 established the initial operational, monitoring, and sampling requirements for the 379-liter-per-minute-capacity KW pump-and-treat system. Revision 2 addressed the addition of new extraction and injection wells and the additional 379-liter-per-minute capacity from the added treatment train at the KW system.
- **DOE/RL-2006-75, Rev. 1 (reissue), *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design and Remedial Action Work Plan for the Expansion of the 100-KR-4 Pump-and-Treat System*:** This document established the initial operational, monitoring, and sampling requirements for the 2,271-liter-per-minute-capacity KX pump-and-treat system. This document will be reissued as a new document to incorporate changes from Phase 3 well additions.
- **DOE/RL-2008-46, Rev. 0, *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan*;** and ***DOE/RL-2008-46-ADD 2, Rev. 0, Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan: 100-KR-1, 100-KR-2 and 100-KR-4 Operable Units*:** These documents provide the basis for vadose zone and groundwater characterization needed to support preparation of the RI/FS and proposed plan in order to reach a final ROD for the 100-K Area.
- **DOE/RL-2009-41, Rev. 0, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*:** This document provided specific

sampling and analytical requirements for testing at thirteen groundwater wells and two boreholes planned for the 100-KR-4 OU.

- ***Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Change Notice 273 (TPA-CN-273):** This change notice addressed a number of changes required to improve operations at the KR4 and KX pump-and-treat systems, as follows:
  - Realign wells between the two systems to contain the impact of a tritium plume potentially impacting groundwater quality at KX injection wells
  - Standardize sampling of extraction, compliance, and monitoring wells at the KR4 and KX systems
  - Identify five new wells with locations for the KR4 and KX systems, as well as the sampling requirements, proposed uses, and general well design in support of RPO
  - Delete requirements to prepare a semiannual report on the status of the pump-and-treat systems for the first half of each CY.

During CY 2010, Tri-Party Agreement Change Notice 357 was prepared and approved. This change notice modified the sampling and analysis plan to address the following:

- Relocate one well planned in a culturally sensitive area southeast of the 116-K-2 Trench to a location near the KE Reactor.
- Require additional soil sampling requirements for the seven wells within the K Reactor area fence line. Sampling is required at 1.5-meter intervals while drilling through the vadose zone at wells 199-K-185, 199-K-190, 199-K-186, 199-K-184, 199-K-188, and 199-K-195.
- Permit construction of well 199-K-188 (and 199-K-195) as temporary wells (polyvinyl chloride casing), which are located in areas expected to undergo structural demolition (183.1-KE headhouse and 183.2-KE sedimentation basin) and waste site soil remediation within one year or less following well installation. The wells will be removed during remediation as needed to complete surface-based remediation activities.
- Incorporate revisions to gamma energy analysis analyte list for soil and groundwater samples to conform to lists in other RI/FS sampling and analysis plans.

5.2.1 Remedial Investigation/Feasibility Study Activities

Drilling and sampling activities required by DOE/RL-2008-46-ADD2 and implemented through the sampling and analysis plan (DOE/RL-2009-41) began in CY 2010. The sampling and analysis plan was altered by Tri-Party Agreement Change Notice 357. The results of RI/FS characterization activities are preliminary and are not presented in this document. An upcoming RI/FS report will include data and conclusions.

A drilling program including thirteen wells and two boreholes, initiated in May 2010, was ~80% complete by the end of CY 2010 and was completed mid-March 2011. Groundwater and vadose zone soil sampling at 1.5-meter intervals as specified for the borings inside the reactor area was performed. For wells outside the reactor area, soil samples were taken at intervals of 4.6, 3, 1.5, and 0.6 meters above the estimated water table and at 1.5 meters below the water table.

Groundwater was sampled for the following general classes of analytes: metals, volatile organic compounds, and anions, as well as hexavalent chromium, carbon-14, strontium-90, and tritium. In addition, six field performance analyses are performed prior to groundwater sampling: pH, specific conductance, temperature, dissolved oxygen, oxidation-reduction potential, and turbidity. Soil was analyzed for metals, hexavalent chromium, and the following radionuclides: gross alpha, gross beta, gross gamma, cesium-137, cobalt-60, europium-152, europium-154, and strontium-90. Batch leaching followed by testing for metals, mercury, and hexavalent chromium was planned for selected locations. In addition, physical properties testing of split-spoon soil samples was performed at major formation or lithology changes, as well as at 3 and 1.5 meters above the Hanford/Ringold contact and 1.5 meters below the Hanford/Ringold contact.

All boreholes were geophysically logged, and slug tests were conducted in all groundwater wells following construction and development. For each well, screen placement was based on the vertical profile data for hexavalent chromium concentrations. Most wells will be used for monitoring, but some wells were constructed to accommodate potential future use as extraction or injection wells. Three aquifer tubes at one location downgradient of the KW Reactor were installed and samples were taken at low and intermediate river stages during CY 2010. A series of three sampling events to collect data for the 100-K Area RI/FS risk assessment was completed at seventeen wells during CY 2010. Preparation of the RI/FS report began in CY 2010, and Draft A is scheduled for submittal to the regulatory agencies in September 2011.

5.2.2 Remedial Process Optimization Activities

The RPO activities were implemented for the 100-KR-4 interim action in CY 2009. This process is intended to improve treatment system performance to meet the Tri-Party Agreement milestones described below. The goal of these milestones is to improve remediation of the hexavalent chromium plume and other plumes that have been determined to impact groundwater and the Columbia River. The key proposed milestones are as follows:

- ***Milestone M-016-110-TO-1:*** Take action necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area OUs so ambient water quality standards are achieved in the hyporheic zone and river water column (December 31, 2012).
- ***Milestone M-016-110-TO-2:*** Take actions necessary to remediate hexavalent chromium plumes so hexavalent chromium will meet the DWS (December 31, 2020).
- ***Milestone M-016-110-TO-4*:** Implement remedial actions selected in all 100 Area groundwater RODs so contamination above DWSs or ambient water quality standards does not enter the Columbia River unless otherwise specified in a CERCLA decision (December 31, 2016).

The RPO activities have included use of groundwater flow and fate and transport modeling to (1) identify those areas of the 100-KR-4 OU where hexavalent chromium contamination will likely continue to discharge to the Columbia River under the current operating scenarios for the KW, KX, and KR4 pump-and-treat systems; and (2) perform system design modeling to identify modifications to the current extraction and injection well configurations that will minimize, as much as is possible, the discharge of hexavalent chromium into the Columbia River. Additional modeling has been conducted to identify upgradient changes to the remedial system (including

implementation of alternate treatment technologies) that could be implemented to increase mass removal and decrease cleanup times for the 100-KR-4 OU. The RPO efforts are planned as four phases:

- Phase 1 addressed well realignments to the KR4/KX treatment systems to address tritium issues (completed in CY 2009).
- Phase 2 addressed the drilling of five additional wells for use at the KR4 and KX treatment systems (completed in CY 2010).
- Phase 3 will install four new wells for plume control in 2011: three extraction and/or monitoring wells at the KR4 treatment system, and one extraction well at the KW treatment system.
- Phase 4 will address the requirements presented in the final ROD and implemented in the remedial design report/remedial action work plan.

An evaluation of four long-term remediation alternatives continued through mid-year in CY 2010:

1. No action/monitored natural attenuation
2. Continued pump-and-treat actions with existing treatment systems
3. Expanded extraction and injection well fields for the pump-and-treat systems with other actions (bioremediation).
4. An advanced aggressive pump-and-treat with other actions (bioremediation).

Groundwater Modeling Results

The RPO fate and transport modeling conducted under the current system design conditions indicates that, despite the overall effectiveness of the existing remedial systems and well field designs, hexavalent chromium may continue to discharge to the Columbia River after CY 2012 in some areas of the 100-KR-4 OU at concentrations above the ambient water quality criterion of 10 µg/L. Plume areas that may continue to discharge to the river include the KW Reactor plume and the plume areas at either end of the 116-K-2 Trench. Phase 3 wells are designed to intercept key known or suspected plume discharge sites near the southwest end of the 116-K-2 Trench and at the KW plume. Remediation of some plume areas downgradient of the 116-K-2 Trench will, however, be challenging due to the presence of sensitive cultural sites. The RPO modeling has been continued in support of the RI/FS, and further results will be presented in the report (DOE/RL-2010-97) when it is issued in September 2011.

5.2.3 100-KR-4 OU Pump-and-Treat Systems (KR4, KX, and KW)

The primary COC in groundwater at the 100-KR-4 OU is hexavalent chromium, and three pump-and-treat systems have been implemented to remediate the groundwater and to protect the Columbia River in the 100-K Area. The boundaries of the 100-KR-4 OU were originally defined by the expected extent of contaminated groundwater underlying the 100-KR-1 and 100-KR-2 Source OUs. Over time, additional characterization efforts demonstrated that hexavalent chromium groundwater contamination (likely originating from the 116-K-2 Trench source area) has migrated to the northeast, past the southern boundary of the 100-NR-2 OU (Figure 5-4). The following three pump-and-treat systems and their respective injection/extraction well fields, comprise the primary interim actions implemented for the remediation of the hexavalent chromium groundwater contamination associated with the 100-KR-4 OU:

- KR4 treatment system (capacity of 1,136 liters per minute)
- KX pump-and-treat system (capacity of 2,271 liters per minute)
- KW pump-and-treat system (capacity of 757 liters per minute).

The following discussion briefly summarizes the performance of each system and any notable system modifications implemented during CY 2010. The *CY 2010 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations* (DOE/RL-2011-25) provides additional information concerning the operation and performance of the 100-KR-4 OU pump-and-treat systems.

5.2.3.1 KR4 Pump-and-Treat System

The original 100-KR-4 OU pump-and-treat system (now referred to as the KR4 system) has been operating since 1997 and has treated the hexavalent chromium plume associated with the 116-K-2 Trench. This ion-exchange system includes ten extraction wells and five injection wells located as shown in Figure 5-10. Over time, the central portion of the plume has been remediated to concentrations below 20 µg/L, but the plumes at either end of the trench continue to require treatment. Overall, chromium concentrations decreased between CY 2009 and CY 2010 in the area being remediated by the KR4 extraction well system. A summary of operational parameters and system performance for CY 2010 is provided in Table 5-15.

Changes in CY 2010

New injection well 199-K-179 was placed into service for the KR4 system in early January 2010. Former KX extraction wells 199-K-144, 199-K-145, and 199-K-162 were realigned to the KR4 system in February 2010 and began pumping downgradient of well 199-K-18. Former injection well 199-K-124A, taken out of service in August 2009, is currently used as a monitoring well. Extraction wells 199-K-113A and 199-K-114A were turned off during high river stage (July through mid-August) due to low hexavalent chromium concentrations. The KR4 system was shut down on October 5, 2010, for system upgrades and maintenance, then remained offline for the remainder of CY 2010.

Treatment System Performance

Key operational and system highlights for the KR4 pump-and-treat system for CY 2010 are as follows:

- A total of 336.9 million liters of groundwater were treated and ~7.2 kilograms of hexavalent chromium were removed. The average flow rate during CY 2010 was 641 liters per minute, which is lower than the system design capacity of 1,136 liters per minute. From startup of the KR4 system through CY 2010, more than 5.64 billion liters of water have been treated and over 354.7 kilograms of hexavalent chromium have been recovered.
- The mass removal efficiency for CY 2010 was approximately 90.6%, which is higher than the 86.9% removal efficiency in CY 2009.
- The average influent hexavalent chromium concentration of 24.1 µg/L for CY 2010 was lower than the CY 2009 average of 31.3 µg/L.
- The average effluent hexavalent chromium concentration for CY 2010 of 2.0 µg/L was lower than the 3.9 µg/L reported in CY 2009.
- The total system availability for CY 2010 was 74.9%, which is lower than the 86.9% reported in CY 2009. The lower system availability is due to shutdown of the system from early October to January 2011 for upgrades. Similarly, the

scheduled system availability of 75.2% (a 0.3% difference) was lower than the 99.4% availability in 2009.

- The KR4 system has been effective in remediating the hexavalent chromium plume at the 116-K-2 Trench. Most of the plume has been remediated, with the exception of the hot spots at either end of the trench. Declining influent concentrations threaten to reduce the mass removal efficiency. Wells with higher hexavalent concentrations need to be connected to the KR4 system.

Monitoring Results

The remedial performance of the KR4 pump-and-treat system (i.e., the extent and effectiveness of plume capture) can be illustrated by evaluating the hexavalent chromium data from selected monitoring locations including, but not limited to, compliance monitoring wells 199-K-18, 199-K-20, and 199-K-117A and active extraction/compliance wells 199-K-114A and 199-K-129 (Figure 5-10). Recently collected data and long-term concentration trend data for these and other monitoring locations relevant to evaluating the performance of the KR4 system are discussed below.

The KR4 monitoring wells 199-K-125A and 199-K-119A are located downgradient of the central area of the 116-K-2 Trench. Both were former extraction wells but were taken offline in 2009. The concentrations of hexavalent chromium in these KR4 wells steadily decreased from ~40 µg/L in 2004 to below the field and laboratory detection limits (less than 2 µg/L) by January 2010 (Figure 5-10 and Table 5-1).

The general effectiveness of KR4 system extraction wells located in the central section of the 116-K-2 Trench area is clearly demonstrated by the progressive reduction in hexavalent chromium concentrations in downgradient compliance monitoring wells 199-K-20, 199-K-21, and 199-K-117A. The concentrations in wells 199-K-20 and 199-K-21 declined from ~50 to 60 µg/L, to ~5 to 6 µg/L, between 2004 and 2008 (Figure 5-10). The hexavalent chromium concentrations in nearby monitoring well 199-K-117A decreased from ~10 µg/L in 2004 to below the detection (2 µg/L) by 2008 (Figure 5-10 and Table 5-1). The effective remediation of the central area of the 116-K-2 Trench area has resulted in the division of the original 116-K-2 Trench plume into two plume remnants, referred to as at the KR4 plume and the K North plume. The effectiveness of the treatment is partly attributed to the higher hydraulic conductivity of the aquifer sediments in the central portion of the 116-K-2 Trench as compared to those at the ends of the trench.

Since KR4 system startup, monitoring well 199-K-22 has defined the 100 µg/L hexavalent chromium contour of the K North plume. The addition of extraction wells 199-K-154 and 199-K-163 temporarily increased the size of this plume. New temporary RI/FS well 199-K-201 has better defined the extent of this plume with +100 µg/L concentrations of hexavalent chromium in early 2011. Startup of these extraction wells are thought to have begun reducing the hexavalent chromium concentrations in well 199-K-22, as a +25% decrease was observed by April 2011.

The KR4 system extraction/compliance monitoring wells 199-K-114A and 199-K-113A are located near the Columbia River in the K North plume, at the northern end of the 116-K-2 Trench (Figure 5-10). Both of these wells appear to show a subtle decrease in hexavalent chromium concentrations in samples collected during the summer to early fall of 2010 relative to previous years. Concentrations in both wells remained below 10 µg/L during low river stage when concentrations of hexavalent chromium in near-shore plume wells are generally highest.

The KR4 system extraction/compliance well 199-K-129 is located near the Columbia River in the central area of the K North plume, further north than wells 199-K-114A and 199-K-113A (Figure 5-10). The long-term concentration trend for hexavalent chromium in this extraction well has gradually decreased from a high of ~60 µg/L in early 2004 to a low of 10 to 20 µg/L in late 2010. If the concentrations of hexavalent chromium in KR4 extraction wells 199-K-114A, 199-K-113A, and 199-K-129 continue to decrease during 2011, the interim action objective of protecting the river may be also achieved along this southern section of the K North plume.

Former compliance well 199-K-18 is located near the southern end of the 116-K-2 Trench (Figure 5-10). This well has defined the 100 µg/L contour for the hexavalent chromium KR4 plume. With the drilling of wells 199-K-145 and 199-K-162, this well is no longer the most downgradient well in the area. Hexavalent chromium concentrations in this well steadily increased from ~35 µg/L in 1997, to ~140 µg/L in 2004, and to ~200 µg/L by June 2010 (Figure 5-10). However, the concentrations in well 199-K-18 declined steadily during the remainder of 2010, reaching a concentration of 139 µg/L by December 2010 (Table 5-1). Hexavalent chromium concentrations had declined to 50% of the original peak values by early 2011. This abrupt reversal in the long-term increasing concentration trend for hexavalent chromium in this well likely reflects the February 2010 startup of three nearby KR4 extraction wells, 199-K-162, 199-K-145, and 199-K-120A. Of these three new extraction wells, the concentrations of hexavalent chromium measured at well 199-K-145 averaged ~60 µg/L during 2010, which was substantially higher than concentrations extracted by wells 199-K-162 and 199-K-120A. In the latter two wells, concentrations decreased below 10 µg/L soon after startup.

Although aquifer tubes are not official compliance points for treatment system performance, samples collected from these tubes are helpful for locating areas where hexavalent chromium may be discharging to the Columbia River at concentrations greater than 20 µg/L. Aquifer tube location AT-K-3-D is downgradient of monitoring well 199-K-18 and extraction wells 199-K-162, 199-K-145, and 199-K-120A. This aquifer tube has had concentrations ranging from ~32 to 85 µg/L since it was first sampled in 2004 (Figure 5-10); the December 2010 results were near the middle of that range. Given the recent startup of upgradient extraction wells 199-K-162, 199-K-145, and 199-K-120A and the abrupt decrease in concentrations in monitoring well 199-K-18 during 2010 (see discussion above), the concentrations of hexavalent chromium reaching this aquifer tube (and, therefore, the Columbia River) are expected to decrease substantially in this section of the KR4 plume within the next 1 to 2 years.

5.2.3.2 KX Pump-and-Treat System

The 2,270-liter-per-minute-capacity KX ion-exchange pump-and-treat system includes a well field that currently consists of twelve extraction wells and nine injection wells (Figure 5-2). The treatment system underwent acceptance testing in November 2008 and became fully operational in February 2009. A summary of operational parameters and the system performance for CY 2010 is provided in Table 5-16. The KX well field was primarily designed to remediate contaminated groundwater located between the northern end of the 116-K-2 Trench and the N Reactor fence line. Consequently, twelve of the fourteen KX system extraction wells are located in this area (Figure 5-11). A secondary objective of this the system is to remediate contaminated groundwater located downgradient of the KE Reactor, and two KX extraction wells have been dedicated for this purpose.

System Changes in CY 2010

High hexavalent chromium concentrations were observed at wells 199-K-153 and 199-K-171 in CY 2008 and CY 2009. These wells were realigned from monitoring and injection wells, respectively, to extraction wells during CY 2010 and were brought online in mid-March. In addition, two wells that previously served as extraction wells (199-K-149 and 199-K-150) were taken out of service in June 2010 due to low hexavalent chromium concentrations in groundwater. The wells are being converted to monitoring wells and may be converted to injection wells in 2011. New extraction well 199-K-178 and new injection well 199-K-180 were also put into service in mid-March 2010. Well 199-K-180 was completed in January 2010 and was sampled at that time. Hexavalent chromium concentrations did not exceed 6.5 μg/L, and the well was determined suitable for injection of treated water. Well 199-K-161 was shut down from July to September 2010 due to low hexavalent chromium levels during high river stage.

Treatment System Performance

Key operational and system highlights for the KX pump-and-treat system for CY 2010 include the following:

- A total of 904.5 million liters of groundwater were treated and ~39.8 kilograms of hexavalent chromium were removed. The average flow rate in CY 2010 was 1,720 liters per minute, which is 76% of the system design capacity of 2,271 liters per minute. Since startup, the KX system has treated more than 1.56 billion liters of water and removed 83.7 kilograms of hexavalent chromium.
- The mass removal efficiency for CY 2010 was 94.0%, which is slightly lower than 96.3% reported in CY 2009.
- The average influent hexavalent chromium concentration for CY 2010 of 47.2 μg/L was ~20% lower than the CY 2009 average of 58.4 μg/L. This is due to the generally lower mass within the original KX plume and the declining concentrations at some KX extraction wells.
- The average effluent hexavalent chromium concentration for CY 2010 of 2.8 μg/L was slightly higher than 2.1 μg/L reported in CY 2009.
- The total system availability for CY 2010 was 96.8%, which is slightly lower than the 98.1% availability reported in CY 2009. The scheduled system availability was higher, at 99.2% versus the 94.5% scheduled availability in 2009.

Monitoring Results

The fall 2010 chromium plume map and long-term concentration trends for the compliance and other selected wells relevant to evaluating the remedial performance of the KX pump-and-treat system are shown in Figure 5-11.

Concentrations of hexavalent chromium at extraction/compliance wells 199-K-150 and 199-K-149, at the northeast end of the KX system well field, remained below 10 and 20 μg/L, respectively, during CY 2010 (Figure 5-11). The low levels of hexavalent chromium in these well are likely maintained by continued injection of treated effluent at injections wells located further to the east and northeast (Figure 5-2). A rebound study was conducted using field analytical techniques to determine if residual hexavalent chromium remains accessible in the aquifer. When concentrations remained low during this study, the two wells were taken offline. Consideration is being given to converting the two wells to injection wells in CY 2011 for better control of this lobe of the plume. In addition, the hexavalent chromium

trend at nearby well 199-K-131 declined to 35 µg/L in fall 2010, with similar values noted in spring 2010.

Extraction/compliance well 199-K-130 remained above 20 µg/L, although the hexavalent chromium trend in this well is decreasing. Extraction/compliance well 199-K-148, with all hexavalent chromium analyses greater than 20 µg/L, trended downward during the first half of CY 2010. Subsequently, this well showed an increasing concentration trend, with the highest value in November 2010 at 52.6 µg/L, nearly 40% greater than the low value observed in August 2010. In CY 2011, hexavalent chromium concentrations at this well again declined. The performance of extraction wells 199-K-147, 199-K-146, and 199-K-161 is difficult to assess for CY 2010 because downgradient aquifer tube sampling was not performed in this area during the year. Previous sample analyses from downgradient aquifer tubes yielded nondetects to very low levels of hexavalent chromium. Hexavalent chromium concentrations were generally above 20 µg/L at wells 199-K-146 and 199-K-147 but were above 20 µg/L at well 199-K-161 only through April and May 2010. In general, hexavalent chromium trends at most wells downgradient of the inland extraction wells 199-K-163 and 199-K-154 (operational on May 28, 2010) dropped by 50% to 90% compared to fall 2010 data. Because this area overlaps with long-standing extraction by KR4 pump-and-treat system wells, the lower concentrations at both wells and aquifer tubes ensure improved control of the local chromium plume.

The KX system extraction wells 199-K-163 and 199-K-154, upgradient of the distal end of the 116-K-2 Trench, had fall 2010 concentrations of 54 and 85 µg/L, respectively. The relatively slow decline in elevated concentrations of hexavalent chromium observed in these extraction wells over the last several years (Figure 5-11) suggests that a substantial remnant of the 116-K-2 Trench coolant water plume remains in this portion of the aquifer. This, combined with lower hydraulic conductivities of the aquifer as demonstrated at well 199-K-22, may combine to explain the slow decrease in hexavalent chromium concentrations.

Two KX extraction wells are located within the KE Reactor area plume, directly downgradient of the KE Reactor. The hexavalent chromium concentration of 48 µg/L in fall 2010 at extraction well 199-K-178, located within the plume, was substantially lower than baseline sampling results (118 µg/L) observed shortly after the well was drilled in CY 2009. New well 199-K-181 was installed as a compliance well downgradient of the KE Reactor. Although the new well was not sampled in the fall of 2010, hexavalent chromium analyses from August 2009 through August 2010 were all less than 20 µg/L. This compliance well, together with wells 199-K-32A and 199-K-142, provides limits for the plume extending downgradient from the reactor, indicating that the plume has not spread laterally.

5.2.3.3 KW Pump-and-Treat System

The KW pump-and-treat system became operational in January 2007 and was designed to treat the hexavalent chromium plume located near the KW Reactor (Figure 5-12). The current well field configuration for the system consists of seven extraction wells and three injection wells (Figure 5-2). A summary of the operational parameters and system performance for the KW system during CY 2010 is provided in Table 5-17.

Changes in CY 2010

During CY 2010, extraction well 199-K-139 (previously taken out of service) was restarted on April 8 to replace proximal extraction well 199-K-140, which

yielded both low groundwater flows and low concentrations of hexavalent chromium. Well 199-K-140 remained available for sampling during 2010.

Treatment System Performance

Key operational and system highlights for the KW pump-and-treat system for CY 2010 are as follows:

- More than 387.15 million liters of groundwater were treated and ~54.14 kilograms of hexavalent chromium were removed. The average flow rate of 736 liters per minute is very close to the design capacity of 757 liters per minute. Since startup of operations, the KW system has treated over 1.05 billion liters of groundwater and has removed 137.4 kilograms of hexavalent chromium.
- The mass removal efficiency for CY 2010 was 96.9%, which is slightly higher than the mass removal efficiency for CY 2009 of 95.8%.
- The average influent hexavalent chromium concentration for CY 2010 of 144.0 µg/L was slightly lower than the average concentration of 155.4 µg/L reported for CY 2009.
- The average hexavalent concentration for the effluent during CY 2010 of 4.4 µg/L was very similar to the average effluent concentration of 4.2 µg/L reported for CY 2009.
- The total system availability for CY 2010 was 99.7%, which is slightly higher than the system availability of 98.6% reported in CY 2009. The scheduled system availability was 99.6%, which compared favorably to the CY 2009 scheduled availability of 95.6%. A total of 29.3 hours of scheduled downtime and 6.2 hours of unscheduled downtime contributed to the system's operational efficiency.

Monitoring Results

The remedial performance of the KW pump-and-treat system has been evaluated using the 2008 to 2010 hexavalent chromium data presented in Table 5-2 and the long-term concentration trends for selected KW pump-and-treat system monitoring locations (Figure 5-12).

Extraction/compliance wells 199-K-132 and 199-K-138 are located downgradient of the KW Reactor, near the leading edge of the KW Reactor area plume (Figure 5-12). Chromium concentrations at wells 199-K-132 and 199-K-138 were ~120 and 75 µg/L in January 2007 (Figure 5-12). Since startup of the KW pump-and-treat system, concentrations in these wells have steadily declined. The measured concentrations in these wells during November 2010 were 16.8 and 20.6 µg/L, respectively (Table 5-2). Although data from a single aquifer tube location are not definitive, the long-term data trend at aquifer tube AT-K-1-D is consistent with the inference that the leading edge of the KW Reactor area plume is being captured by these two extraction wells (Figure 5-12).

The concentrations in upgradient extraction wells 199-K-168, 199-K-139, 199-K-137, and 199-K-166 have either declined to a substantial degree or remained at near the 20 µg/L standard during CY 2010 (Figure 5-12). An exception to this general trend was observed at extraction well 199-K-165, located just upgradient of extraction wells 199-K-137 and 199-K-166. The hexavalent chromium concentration observed in this well in late 2008 was 2,850 µg/L. After extraction operations began at well 199-K-165 in early 2009, however, the concentrations declined precipitously to below 200 µg/L during the spring and summer of 2009. Since that time, concentrations in this extraction well have steadily increased, with values of 232 and 321 µg/L measured in the fall 2009 and fall 2010, respectively (Table 5-2). Concentrations in

early 2011 have declined. The hexavalent chromium trend in this extraction well is consistent, as it is the closest extraction well to the 183.1-KW headhouse, which is the putative source area for the leaks and spills of concentrated sodium dichromate that are believed to have created this plume.

Two monitoring wells, 199-K-35 and 199-K-173, located upgradient of the above-described extraction wells, demonstrated sharp spikes in hexavalent chromium concentrations that began in late CY 2009 and continued into CY 2010 (Figure 5-12). Well 199-K-35 was converted from an injection well to a monitoring well in late November 2009, and hexavalent chromium concentrations rapidly increased in samples collected from the well, reaching the maximum observed value of nearly 800 µg/L in early 2010, before declining to ~260 µg/L in April. After the April 2010 sampling event, well 199-K-35 was removed from service to facilitate demolition and soil remediation activities around the 183.1-KW headhouse and 183.2-KW sedimentation basins. Monitoring well 199-K-173 exhibited two separate spikes in hexavalent chromium concentrations during 2010, with concentrations briefly exceeding 900 µg/L at the peak of each spike (Figure 5-12). Peaks in chromium trends at downgradient extraction wells 199-K-165 and 199-K-166 roughly coincide in time but with lesser magnitudes to the trend observed at well 199-K-173.

One possible explanation for the abrupt development of these concentration spikes in the upgradient monitoring wells is the mobilization of residual source materials in the vadose zone by the heavy use of dust-suppression water during the demolition and remediation activities conducted near the 183.1-KW headhouse. Another possible explanation is that the startup of a new upgradient injection well 199-K-175 in April 2009 (Figure 5-2) and terminating injection of treated effluent at well 199-K-35 in late November 2009 may have accelerated the downgradient transport of a residual hot spot in the aquifer zone upgradient of well 199-K-35. The timing of the changes in these local injection activities appears to be consistent with the rapid downgradient transport of elevated hexavalent chromium concentrations such as those observed in wells 199-K-35 and 199-K-173.

5.2.3.4 Capture Zone Analysis

A. Spiliotopoulos and R. Shannon

The remedial performance of the KW, KR4, and KX pump-and-treat systems (i.e., extent and effectiveness of plume capture) is assessed by (1) evaluating the changes in hexavalent chromium concentrations over time in selected monitoring and extraction wells associated with the KR4, KW, and KX well fields; and (2) using two different methods of analysis to estimate the extent of plume capture by the three pump-and-treat systems under CY 2010 operating conditions.

To appropriately evaluate the effectiveness of plume capture in the 100-KR-4 OU, it was necessary to evaluate the combined effects the KR4, KW, and KX pump-and-treat systems (Figure 5-13), as well as the effectiveness of the capture zones for each individual treatment system (Figure 5-14). A brief discussion regarding the extent and effectiveness of the combined (OU-wide) capture zone (Figure 5-13) is provided below. More detailed descriptions of the methods used and the results of the capture zone evaluation are presented in the CY 2010 annual summary report (DOE/RL-2011-25).

Figure 5-13(a) and (b) depicts separate representations of the combined site-wide capture zone for the 100-KR-4 OU that were calculated independently based on the results of groundwater modeling analysis and high-frequency water-level mapping,

respectively. The data inputs and assumptions for these different methods of capture zone analysis are not the same, and the depictions of the extent and aggregate performance of the capture zones generated by the two methods will be different. For example, the groundwater modeling approach (Figure 5-13[a]) depicts areas of current and future capture zone effectiveness of the 100-KR-4 OU systems based on the actual operating conditions of the systems during all of CY 2010. This includes the fourth quarter of CY 2010, when the KR4 system was shut down for upgrades. This approach is useful for evaluating the extent that periods of reduced extraction during 2010 would, if not remedied, reduce the long-term capture efficiency of the affected system. Conversely, Figure 5-13(b) presents the areas where the extent of plume capture is based (with the exception of small-duration stoppages) on the hydraulic conditions imposed on the aquifer while the systems were actually operating during CY 2010. This approach to capture zone mapping does not include the hydraulic effects of long-term, nonroutine shutdown events such as that occurring at the KR4 system during 2010. Consequently, the capture zone performance illustrated in Figure 5-13(b) provides a better representation of the long-term effectiveness of the capture zones for the treatments systems, assuming that the current operating conditions will continue in the future.

A comparison of Figure 5-13(a) and (b) shows many similarities and some key differences in the estimates of capture zone effectiveness obtained using these two different methods for the 100-KR-4 OU. Both approaches indicate that the northern and southern areas of the capture zone distributions have a capture efficiency of upgradient groundwater of between 80% and 100%. However, the groundwater model-based capture effectiveness/efficiency map (Figure 5-13[a]) suggests that the central area of the overall capture zone distribution (KR4 plume area) will capture the upgradient plume with a much lower efficiency (e.g., 50% to 70%) than predicted in Figure 5-13(b). This difference primarily reflects the fact that the model-based analysis treats the reduced annual average extraction rates in this area during CY 2010 (including the planned 3-month shutdown at the KR4 system) as the standard operating conditions over the full multi-year simulation period. Consequently, the substantially higher overall capture efficiencies (e.g., 80% to 100%) for the composite capture zone presented in Figure 5-13(b) are believed to represent a more realistic estimate of the long-term capture efficiency of the overall system. As previously discussed, Figure 5-14(a), (b), and (c) includes the chromium plume and breaks out the capture zones for each of the three treatment systems as calculated by the high-frequency capture method described above.

5.2.4 Calcium Polysulfide Treatability Test

During the summer of 2005, a treatability test was conducted in the northern section of the 100-KR-4 OU to evaluate the practicality of treating hexavalent chromium in the aquifer with calcium polysulfide. The study concluded that hexavalent chromium concentrations in groundwater in the treated area were significantly reduced after the test. The results demonstrated that this method could be an effective alternative to pump-and-treat systems (DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*).

During the treatability test, groundwater from central extraction well 199-K-126 was mixed with calcium polysulfide and injected into four wells (199-K-133, 199-K-134, 199-K-135, 199-K-136) radially arrayed at a distance of 30 meters from the extraction well (Figure 5-2). Calcium polysulfide and emulsified vegetable oil circulated through the aquifer, reducing hexavalent chromium and the aquifer materials, creating a persistent zone of chemical reduction.

Each of the five wells was sampled quarterly through 2009 and once in 2010. Hexavalent chromium in the injection wells remained at detection limits (~3 µg/L), indicating that the zone of reduction has persisted for over the 5-year period following test completion. Dissolved oxygen and nitrate also remained low throughout CY 2010, which is another indication that reducing conditions persist in the aquifer.

Hexavalent chromium concentrations in well 199-K-126 increased to ~40 µg/L (about one-half the concentration in groundwater outside the treated area) one year after the test was completed and remained near that level in CY 2010. Dissolved oxygen and nitrate were also slightly lower in the extraction well compared to pre-test measurements.

5.3 100-K Basins

Groundwater monitoring at the 105-KE (KE Basin) and 105-KW (KW Basin) fuel storage basins (Figure 5-2) has been conducted since the late 1970s; however, the monitoring frequency was decreased as fuel has been removed from the basins. Furthermore, with demolition of the KE Basin and 115-KE gas recirculating building and 117-KE filter house support structures, as well as ongoing remediation of the surrounding contaminated soil, all of the close-in wells monitoring these structures have been decommissioned. Replacements have not been drilled. Regulatory drivers include a K Basin interim remedial action under CERCLA, environmental restoration program OU activities under CERCLA, and site-wide environmental surveillance associated with the *Atomic Energy Act of 1954*. Monitoring requirements are presented in several documents (most recently, PNNL-14033, *Groundwater Monitoring and Assessment Plan for the 100-K Fuel Rod Storage Basins*). PNNL-14033 addresses sampling of monitoring wells at waste sites associated with the K Basins and includes wells associated with the 115-K gas recirculation buildings, 116-KE-1 and 116-KW-1 Cribs, and the K Basins drain cribs (116-KE-3 and 116-KW-2).

The basins received and stored highly radioactive irradiated fuel rods, first from the respective reactors and then, beginning around 1978, fuel rods from the N Reactor. Other miscellaneous fuel discovered during remedial actions at other reactor basins was also stored here. Each basin held ~4.9 million liters of shielding water that was highly contaminated with long-lived radionuclides (e.g., strontium-90 and cesium-137), some of which are mobile in the environment (e.g., tritium). In addition, each basin was connected to a crib (116-KE-3 and 116-KW-2) designed to receive basin overflow water. These cribs were active into the early 1970s. The cribs, as well as leaks around the KE Basin, affected the adjacent vadose zone and groundwater. Trend data from decommissioned well 199-K-109A, downgradient of the 116-KE-3 Crib, indicate significant but declining concentrations of tritium and strontium-90 in the aquifer over the past two decades. A trend above the DWS was observed in early 2011 at downgradient KX extraction well 199-K-141, as strontium-90 concentrations increased to between 8.2 and 12 pCi/L. Based on groundwater monitoring data from downgradient wells, no indication of serious leaks at the KW Basin has been noted.

The fuel rods in the K Basins were removed by 2008 and sludge was pumped from the KE Basin to the KW Basin through CY 2009. Demolition of the KE Basin, substructure, and crib was completed in 2009. Contaminated soil around the basin and crib was remediated in CY 2009 and CY 2010, continuing to the present. Prior to demolition and remediation, two downgradient groundwater monitoring wells around the KE Basin (199-K-27 and 199-K-109A) were decommissioned in March 2008.

The KW Basin has been emptied of fuel rods but remains a depository for sludge from KE and KW Basins. The KW Basin and the 116-KW-2 Crib are scheduled for removal after 2015.

Based on reported contamination in the basin shielding water, the COCs at the monitoring wells include tritium, carbon-14, technetium-99, and other less mobile radionuclides such as strontium-90 and cesium-137. Tritium is considered to be the primary indicator of water loss from the fuel rod basin/crib system. Strontium-90 and, in particular, cesium-137 are not nearly as mobile as tritium in groundwater.

The previous KE and KW Basins sampling and analysis schedule complemented other 100-KR-4 OU groundwater sampling schedules. The K Basins monitoring plan (PNNL-14033) focused on the following objectives:

- Characterizing groundwater conditions between the KE and KW Basins and the Columbia River, and providing a status of current conditions and attenuation of plumes
- Distinguishing between groundwater contamination associated with KE and KW Basins and the contamination from other past-practice sources to help guide operational and remedial action decisions
- Maintaining a strategy for the potential expansion of monitoring capabilities to respond to future basin-related issues.

The monitoring plan (PNNL-14033) specified at least an annual sampling frequency for radionuclides, anions, and groundwater field parameters at all KE and KW Basins monitoring wells and downgradient aquifer tubes. A few close-in monitoring wells were designated for quarterly analysis for tritium and radionuclide screening test (gross alpha and gross beta). Although the basins are no longer filled with shielding water, a continuing sampling program is being maintained. Previous leakage at the KE Basin and the use of dust-suppression water during basin and vadose zone remediation warrant continued monitoring at downgradient wells for the foreseeable future. Based on current findings at extraction well 199-K-141 (Section 5.1.3.3), a quarterly sampling frequency should be initiated.

At this time, the four close-in downgradient wells around the KE Basin are no longer in existence. One new RI/FS well, 199-K-189, is located cross-gradient from the KE Basin and monitors an area less affected by historic discharges to the basin or the 116-KE-1 Crib. New wells are needed to replace those lost during remediation.

5.3.1 KE Basin

Two key monitoring wells downgradient of the KE Basin, 199-K-27 and 199-K-109A, were decommissioned and removed in April 2008 to provide access for demolition and remediation of the KE Basin and crib. These wells were replaced by downgradient wells 199-K-141 and 199-K-142, which are 120 meters closer to the Columbia River (Figure 5-2). High chromium concentrations in well 199-K-141 led to its conversion as an extraction well for the KX pump-and-treat system in 2009.

Tritium was routinely monitored at well 199-K-109A, reaching 420,000 pCi/L in October 1997 and then decreased to 13,000 pCi/L in March 2008. For well 199-K-27, tritium concentrations reached 628,000 pCi/L in March 1994 and declined to between 3,000 and 8,000 pCi/L for its last 16 months. Tritium concentrations for well 199-K-142 have ranged between 100 and 1,200 pCi/L since the start of sampling in April 2007. At downgradient well 199-K-141, tritium has trended between 400 and 4,800 pCi/L from April 2007 to February 2010. Sampling in July 2010 and January 2011 yielded similar tritium concentrations of 8,400 pCi/L.

Strontium-90 was routinely detected at well 199-K-109A at concentrations up to 18,600 pCi/L shortly after monitoring began in 1994. When the well was removed from service in 2008, strontium-90 concentrations of 910 to 1,120 pCi/L were detected. Strontium-90 was rarely detected at well 199-K-27 and it has not been detected at well 199-K-142. At well 199-K-141, strontium-90 has trended up from 18 months of mostly nondetects to 5.9 pCi/L in July 2010, and then to 12 pCi/L in January 2011.

Tritium concentrations at well 199-K-30 have fluctuated significantly above the 20,000 pCi/L DWS. Tritium reached a concentration of 3,320,000 pCi/L in 1993 in well 199-K-30 and has been below 100,000 pCi/L only three times in over 110 sampling events. One of those results, 16,000 pCi/L from a sample in December 2010 is the lowest tritium value reported for the well. In a similar number of samples, tritium at well 199-K-29 had not exceeded 100,000 pCi/L until sampling in December 2010, when the concentration reached 130,000 pCi/L. These two sample values are likely reversed, and the data set is being reviewed to ensure that the sample corresponds to the correct well.

5.3.2 KW Basin

The key downgradient monitoring wells around the KW Basin, 199-K-34 and 199-K-107A, currently remain intact. Extraction wells 199-K-139 and 199-K-168 (~55 meters downgradient of the 116-KW-2 Crib and well 199-K-107A) are also included. For CY 2010, tritium concentrations at the four wells ranged between 1,000 and 4,000 pCi/L and have not exceeded 10,000 pCi/L since sampling began in 1992. During CY 2010, tritium at downgradient extraction wells 199-K-132 and 199-K-138 ranged between 1,200 pCi/L and 7,500 pCi/L, respectively. These higher concentrations are attributed to a tritium plume associated with the 116-KW-1 gas condensate crib and well 199-K-106A. Tritium at this well reached a concentration of 2,240,000 pCi/L in 2005, was at 430,000 pCi/L in April 2009, and declined to 3,200 pCi/L in September 2010.

Strontium-90 concentrations at the KW Basin have consistently been above the 8 pCi/L DWS at wells 199-K-34 and 199-K-107A. Well 199-K-34 has typically trended between 16 and 40 pCi/L since 1992, while well 199-K-107A has trended slightly higher over the same timeframe. Extraction well 199-K-139, which is screened over the upper 7.6 meters of the aquifer, has had regular strontium-90 detections, but the concentrations have been below the DWS.

5.4 Conclusions

The following conclusions are presented for the 100-KR-4 OU:

- The hexavalent chromium groundwater plumes are generally well defined around the 116-K-2 Trench and the KE and KW Reactors. A data gap for the upgradient plume extent around well 199-K-171 will be closed after results are available from a new RI/FS well drilled in CY 2011. Uncertainty regarding the upgradient extent of chromium around well 199-K-182 persists, as concentrations exceeding 75 μg/L are routinely found. Several interior areas of plumes are unbounded. The 116-K-2 Trench plume, located in the area between wells 199-K-163/154 and 199-K-171, is not well characterized due to intermediate culturally sensitive areas that preclude drilling and remediation activities. An area around the 183.1-KW headhouse and 183.2-KW sedimentation basin has yielded unusually high spikes

of hexavalent chromium in groundwater. The cause for the spikes is not well understood and requires further investigation.

- The pump-and-treat systems continue to remove significant amounts of hexavalent chromium from the unconfined aquifer. During CY 2010, more than 101 kilograms of chromium were removed from over 1.63 billion liters of groundwater. Since startup of the respective pump-and-treat systems, more than 575 kilograms of chromium have been removed from 8.38 billion liters of water. Contaminant trends at most extraction and monitoring wells have declined; for a few other wells, hexavalent chromium concentrations have at least remained relatively constant. Only one extraction well, 199-K-145, has shown an increasing chromium trend, and this well is located downgradient of one of the two "hot spot" wells around the 116-K-2 Trench.
- Wells 199-K-18 and 199-K-22 are two prominent hexavalent chromium hot spots along the 116-K-2 Trench, with maximum CY 2010 concentrations at 203 and 143 µg/L, respectively, in the first half of the year. These hot spots are believed to be the result of injected treated water mounding at the center of the 116-K-2 Trench pushing the residual plume laterally toward both ends of the trench combined with low-conductivity sediments in the aquifer. At both wells, concentrations declined between CY 2009 and CY 2010, by 30% at well 199-K-18 and by 20% at well 199-K-22. Declining trends continued in 2011. These trends appear to be in response to pumping at nearby extraction wells. As a result, the size of the 100 µg/L contour around the two wells has decreased.

  It is possible that chromium at well 199-K-18 may have been augmented by process sewer discharges at the head end of the trench and may possibly include residual chromium from the KE Reactor area. Chromic acid and nitric acid were used during reactor decontamination and disposed to the 116-K-2 Trench and, thus, may contribute to the local plume.
- The impact of the hexavalent chromium plume along the Columbia River cannot be assessed for CY 2010 due to the absence of aquifer tube data that resulted from sampling delays. The fall 2010 depiction of the chromium plume along the Columbia River is largely based on the fall 2009 plume and has been modified only where fall 2010 data permit. Fall 2010 data (September through December 2010) are available for key aquifer tubes AT-K-1-D (2 µg/L, nondetect) and AT-K-3-D (57.7 µg/L).
- Leaks and spills during unloading of concentrated sodium dichromate at the 183.1-KE and -KW headhouses are not documented but are suspected as possible sources for more concentrated hexavalent chromium observed in CY 2009 at upgradient KW Reactor area extraction wells 199-K-137 and 199-K-165, as well as the spikes in CY 2010 observed at wells 199-K-35 and 199-K-173. During waste site remediation around the 183-KW headhouse and sedimentation basin, evidence of significant chromium within the 4.6- to 5.2-meter-deep excavations has been very limited. Data from a new RI/FS well have not indicated significant amounts of chromium in the vadose zone at either headhouse, but several spikes were observed in groundwater at the 183-KW headhouse.
- Tritium at concentrations below the 20,000 pCi/L DWS is widespread across the 100-KR-4 OU. Concentrations above the DWS are confined to plumes that appear to be derived from the 118-K-1 Burial Ground and the 116-KE-1 gas condensate crib. Tritium trends at the 116-KW-1 gas condensate crib were well

above the DWS from 2000 to early 2009, but were below 11,000 pCi/L in 2010. Tritium trends at wells associated with the 116-KE-1 Crib have routinely been above the DWS; these wells were recently decommissioned. Final sampling results indicated that well 199-K-29 was significantly above the DWS, while well 199-K-30 was below the DWS. Trends at the two wells are the reverse of their final sampling results, and the data are under review.

The tritium plume likely associated with the 118-K-1 Burial Ground is somewhat above the DWS at downgradient well 199-K-111A (32,100 pCi/L in September 2010) and well 199-K-157 (30,000 pCi/L in September 2010). The tritium concentration at well 199-K-18 has risen sharply in 2010, reaching to 230,000 pCi/L in December. Within the upper 16.8 meters of the aquifer in a new RI/FS well, 199-K-192, tritium concentrations ranged from 1.4 million pCi/L at the top of the aquifer to 27,000 pCi/L. These trends may be a response to dust-suppression water usage at the burial ground that began with remediation in CY 2009. (Note that of downgradient extraction wells 199-K-145, 199-K-162, and 199-K-120, only well 199-K-145 exceeded the DWS in early 2011 results.) Tritium at aquifer tube AT-K-3-D was at 6,000 pCi/L in December 2010. This plume appears to be moving under the influence of the burial ground remediation and is being captured and recirculated by the KR4 extraction wells.

- The distribution of strontium-90 correlates to the 116-K-2 Trench and the 116-KE-3 and 116-KW-2 fuel storage basin overflow cribs. Trends at wells immediately downgradient of the 116-KW-2 Crib have ranged between three to seven times the 8 pCi/L DWS. Wells further downgradient have detected strontium-90 concentrations below the DWS. Former well 199-K-109A, downgradient of the 116-KE-3 Crib, has ranged between two to more than three orders of magnitude higher than the DWS between 1994 and 2008, before the well was decommissioned. Strontium-90 at downgradient KE extraction well 199-K-141 began climbing in July 2010 and was at 12 pCi/L in early January 2011.
- Carbon-14 in groundwater is closely tied to discharges at the 116-KE-1 and 116-KW-1 gas condensate cribs and is present above the 2,000 pCi/L DWS at wells downgradient of the two cribs. The KW plume is more widespread and is being stretched by pumping at extraction well 199-K-132. Previous aquifer tube data did not indicate that carbon-14 is reaching the Columbia River (the tubes were not sampled in CY 2010). The 116-KE-1 Crib plume is confined to wells near the crib. Final samples prior to decommissioning indicate that carbon-14 is above the DWS at both wells 199-K-29 and 199-K-30 but has not moved further downgradient than has been shown in previous years.
- Nitrate is found above its DWS of 45 mg/L in a few wells but is present in most 100-KR-4 OU wells at low, but detectable, concentrations. Elevated but decreasing nitrate concentrations during CY 2010 were observed at well 199-K-18 (60.6 mg/L in December 2010) near the 116-K-2 Trench and at well 199-K-106A (73.9 mg/L in September 2010) near the 116-KW-1 gas condensate crib. A similar plume is likely present downgradient of the 116-KE-1 gas condensate crib, but nitrate concentrations appear to be reversed between the two monitoring wells.
- Trichloroethene has been occasionally found in most wells within the KW Reactor area at concentrations near or slightly above the 5 μg/L DWS. The plume appears to be focused at well 199-K-106A, just downgradient of the 116-KW-1 gas condensate crib; however, process history does not support routine use of

trichloroethene. The widespread but low concentrations of trichloroethene around this treatment system also suggest an upgradient source to the south of the K Reactor fence line.

- Chloroform has been reported at concentrations well below the 80 µg/L DWS but at levels of interest from the preliminary results of the RI/FS process. One remote well, 199-K-151, had a concentration of 7.1 µg/L in September 2010; the waste site source is not known for this well. Chloroform concentrations between 1 and 2 µg/L were reported at wells 199-K-11, 199-K-18, and 199-K-32A. No common waste site fits this well distribution.
- Total petroleum hydrocarbon (diesel) has been found in the vadose zone at wells 199-K-167 and 199-K-173 and at RI/FS well 199-K-188 near the 166-KW and 166-KE fuel storage bunkers. Diesel was detected in several wells downgradient of the KW bunker during vertical profile sampling while drilling several extraction wells in CY 2008. Sampling at downgradient wells in CY 2009 and CY 2010 did not detect total petroleum hydrocarbons in downgradient wells. Groundwater detections were not observed at well 199-K-188 during drilling; however, analytical results from well 199-K-110A returned an estimated value of 78 µg/L ("J" qualified) in December 2010.

5.5 Recommendations

Recommendations for groundwater monitoring are discussed in this section and are proposed for implementation:

- The hexavalent chromium plume is not bounded by well data around monitoring well 199-K-182, where chromium concentrations have consistently ranged between 75 and 81 µg/L. This well is scheduled to be converted to an extraction well during CY 2011. Additional wells upgradient of well 199-K-182 (i.e., to the south and southeast) are needed to bound the hexavalent chromium plume at well 199-K-182.
- Unknown plume conditions exist beneath the culturally sensitive area between extraction wells 199-K-171 and 199-K-163/199-K-154. The plume depiction does not suggest hexavalent chromium concentrations over 50 µg/L, but concentrations at the three wells ranged between 50 and 100 µg/L during CY 2010. The data uncertainty hinders accurate modeling of plume behavior and the estimation of needs for future remediation requirements. Data from this area must be gathered to assess the horizontal and vertical distribution of hexavalent chromium.
- Complete the Phase 3 well drilling program and realign new and existing wells to increase capture efficiency.
- The RI characterization at wells 199-K-188 and 199-K-195 has not fully clarified the hexavalent chromium distribution in the vadose zone and aquifer at the 183.1-KE and -KW headhouse structures. Little or no indication of chromium is seen in vadose zone samples or in groundwater at the KE headhouse. At the KW headhouse, chromium above operational levels was detected at both shallow and deep locations within the aquifer. Further characterization is needed to understand the lateral and vertical distribution of hexavalent chromium around both headhouses.
- Monitoring wells 199-K-29 and 199-K-30, downgradient of the 116-KE-1 gas condensate crib, were decommissioned in December 2010 following sampling and borehole logging. These wells have tracked the above-DWS carbon-14

and tritium activity trends for this crib. Similarly, previously decommissioned wells 199-K-27 and 199-K-109A, downgradient of the KE Basin and the 116-KE-3 Crib, tracked movement of strontium-90 and tritium. Only one well, 199-K-189, now lies downgradient but relatively close to the three waste sites; however, it is not well positioned to monitor plumes from the multiple waste sites. An increasing strontium-90 trend at well 199-K-141 suggests that a plume is moving toward the Columbia River. Replacement wells for 199-K-109A, 199-K-29, and 199-K-30 are needed to provide close-in coverage of mobile radionuclides.

- At least four existing wells or new RI/FS wells have been, or will be, removed to support remediation of soil waste sites, particularly around the 183.1-KE and -KW headhouses. These wells need to be replaced quickly to provide continuing coverage of groundwater plumes near these probable source sites. Sampling at the wells should be designed to provide quality analytical data on the vertical distribution of hexavalent chromium in the vadose zone and the aquifer.
- For appropriate existing wells, newly installed RI/FS wells, or Phase 3 RPO wells, passive sampling (used at the 100-D Area in 2010) should be implemented to provide a better understanding of vertical contaminant profiles across the aquifer. Vertical distribution of hexavalent chromium or other analytes observed in RI wells during drilling should be confirmed in an undisturbed setting and expanded to suitable monitoring wells at other locations.
- Few compliance wells are active within the 100-KR-4 OU groundwater monitoring network; however, additional wells are needed to meet the Tri-Party Agreement 2012 milestones listed in Section 5.2.2. Most wells located close to the Columbia River are used as extraction and compliance wells; however, there is a lack of wells further downgradient to determine the adequacy of remediation. Aquifer tubes are relied upon to indicate contaminant levels near the river but do not penetrate the full thickness of the aquifer to ensure a good data set. Cultural resources interfere with locating wells closer to the river in key areas.
- Evaluate the effectiveness of the 100-K Area pump-and-treat systems with respect to the 2012 Tri-Party Agreement Milestone M-016-110-TO1 target criteria. Groundwater concentration trends and hydraulic head data should be used with capture zone analyses and additional modeling to maximize capacity of existing treatment systems.

Table 5-1. Hexavalent Chromium Concentrations at the 116-K-2 Plume Wells and Aquifer Tubes, CY 2008 to CY 2010

Well or Aquifer Tube Name	Well Use[a]	Fall 2008, Filt. and Unfilt. Cr^{+6}		Fall 2009 Sample, Unfiltered Cr^{+6}		Fall 2010 Sample, Unfiltered Cr^{+6}		% Change in Cr^{+6} Conc. (Negative = Increase)	
		Date Collected	Conc. (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	2008 to 2010	2009 to 2010
199-K-18	C	10/23/08	156	10/22/09	192	12/8/10	139	10.9	27.6
199-K-19	P	10/23/08	28.7	10/18/09	13.7	12/3/10	7.3	74.6	46.7
199-K-20	C	10/27/08	5.5	10/28/09	2.3 (B)[b]	--[c]	--	--	--
199-K-21	P	10/23/08	6.7	10/18/09	6 (N)	12/3/10	5.5	17.9	8.3
199-K-22	P	10/23/08	108	10/22/09	120	--	--	--	--
199-K-37	P	10/27/08	71.2	10/22/09	56.7	12/3/10	27.1	61.9	52.2
199-K-111A	P	--	--	10/21/09	30.0	12/7/10	46.4		-54.7
199-K-113A	E/C-KR4	10/6/08	64	10/21/09	58	9/8/10	3	95.3	94.8
199-K-114A	E/C-KR4	10/6/08	85	10/21/09	62.9	--	--	--	--
199-K-115A	E/C-KR4	10/6/08	91	10/21/09	84.4	9/8/10	17	81.3	79.9
199-K-116A	E/C-KR4	12/1/08	54.5	10/21/09	25.3	--	--	--	--
199-K-117A	C	10/6/08	2 (U)	10/22/09	2 (U)	12/3/10	2 (U)	NC[d]	NC
199-K-119A	E/C-KR4	11/4/08	7	--	--	12/8/10	2 (U)	Dec[e]	--
199-K-120A	E/C-KR4	11/4/08	38	--	--	10/4/10	9	94.7	--
199-K-125A	C	11/4/08	12	--	--	--	--	--	--
199-K-126[f]	M	--	--	10/21/09	36.6	9/22/10	27.2	--	25.7
199-K-127	E/C-KR4	11/4/08	14	--	--	10/4/10	7	50.0	--
199-K-129/ K-112A	E/C-KR4	11/4/08	43	10/21/09	45.2	9/8/10	22	48.8	51.3
199-K-130	E/C-KX	11/18/08	49	10/20/09	49.7	11/22/10	37.5	23.5	24.5
199-K-131	E/C-KX	11/18/08	79	10/20/09	58	9/7/10	37	53.2	36.2
699-78-62	M	--	--	--	--	--	--	--	--
199-K-121A	I-KR4	--	--	--	--	--	--	--	--
199-K-122A	I-KR4	--	--	--	--	--	--	--	--
199-K-123A	I-KR4	--	--	--	--	--	--	--	--
199-K-124A	I-KR4	--	--	--	--	12/7/10	6.1	--	--
199-K-128	I-KR4	--	--	--	--	--	--	--	--
199-K-143	I-KR4	--	--	--	--	--	--	--	--
199-K-144	E/C-KR4	10/7/08	34	--	--	10/4/10	25	26.5	--
199-K-145	E/C-KR4	11/20/08	37	12/7/09	59	10/4/10	62	-67.6	-5.1
199-K-146	E/C-KX	11/24/08	58	10/20/09	44.8	10/4/10	21	63.8	53.1
199-K-147	E/C-KX	11/19/08	52	10/20/09	37.9	11/22/10	31.5	39.4	16.9
199-K-148	E/C-KX	11/12/08	146	10/20/09	85.3	11/22/10	52.6	64.0	38.3
199-K-149	E/C-KX	11/13/08	82	10/20/09	27.2	10/25/10	8	90.2	70.6
199-K-150	E/C-KX	11/19/08	70	10/20/09	8.8	10/11/10	2	97.1	77.3
199-K-151	P	11/24/08	60.7	10/22/09	26.4	9/20/10	7.9	87.0	70.1
199-K-152	P	9/24/08	75.5	10/22/09	69.9	9/21/10	59.4	21.3	15.0
199-K-153	M	9/24/08	38.4	--	--	11/22/10	30.2	21.4	--
199-K-154	E/C-KX	9/24/08	97.5	10/12/09	94	11/22/10	85.2	12.6	9.4
199-K-156	I-KX	--	--	--	--	--	--	--	--

Table 5-1. (Cont.)

Well or Aquifer Tube Name	Well Use[a]	Fall 2008, Filt. and Unfilt. Cr^{+6}		Fall 2009 Sample, Unfiltered Cr^{+6}		Fall 2010 Sample, Unfiltered Cr^{+6}		% Change in Cr^{+6} Conc. (Negative = Increase)	
		Date Collected	Conc. (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	2008 to 2010	2009 to 2010
199-K-157	P	9/24/08	64	10/29/09	51.5	12/7/10	30.2	52.8	41.4
199-K-159	1-KX	--	--	--	--	--	--	--	--
199-K-160	1-KX	--	--	--	--	--	--	--	--
199-K-161	E/C-KX	11/19/08	106	10/21/09	85.9	11/22/10	14.1	86.7	83.6
199-K-162	E/C-KR4	--	--	--	--	9/14/10	8	--	--
199-K-163	E/C-KX	9/24/08	128	10/12/09	96	11/22/10	52.2	59.2	45.6
199-K-164	I-KX	--	--	--	--	--	--	--	--
199-K-169	I-KX	--	--	--	--	--	--	--	--
199-K-170	I-KX	--	--	--	--	--	--	--	--
199-K-171	E-KX	9/5/08	79	--	--	11/22/10	53	32.9	--
199-K-172	I-KX	9/5/08	15	--	--	--	--	--	--
199-K-179	I-KX	--	--	--	--	--	--	--	--
199-K-180	I-KX	--	--	--	--	--	--	--	--
199-K-182	P	--	--	--	--	--	--	--	--
199-N-16	P	--	--	--	--	--	--	--	--
199-N-71	P	--	--	--	--	--	--	--	--
199-N-72	P	--	--	--	--	--	--	--	--
19-D[g]	AT	--	--	11/17/09	2 (U)	--	--	--	--
21-M	AT	--	--	11/18/09	2 (U)	--	--	--	--
22-M/D[h]	AT	--	--	11/21/09	7	--	--	--	--
23-D	AT	--	--	11/23/09	2 (U)	--	--	--	--
26-D	AT	--	--	--	--	--	--	--	--
C6246	AT	--	--	11/16/09	16	--	--	--	--
C6249	AT	--	--	11/17/09	20	--	--	--	--
C6250	AT	--	--	11/17/09	24.5	--	--	--	--
C6251	AT	--	--	11/21/09	3.5 (B)	--	--	--	--
C6252	AT	--	--	11/21/09	2.3 (B)	--	--	--	--
C6253	AT	--	--	11/21/09	49.4	--	--	--	--
C6254	AT	--	--	11/21/09	2 (U)	--	--	--	--
C6255	AT	--	--	11/21/09	5.4	--	--	--	--
C6256	AT	--	--	11/21/09	30.1	--	--	--	--
C6257	AT	--	--	11/21/09	2 (U)	--	--	--	--
C6258	AT	--	--	11/21/09	2 (U)	--	--	--	--
C6259	AT			11/21/09	2 (U)				
C6260	AT	--	--	11/23/09	2 (U)	--	--	--	--
C6263	AT	--	--	11/21/09	2 (U)	12/28/10	2(U)	--	--
C6264	AT	--	--	11/21/09	2 (U)	12/28/10	2(U)	--	--
C6265	AT	--	--	11/21/09	2 (U)	12/28/10	2(U)	--	NC
DK-04-2	AT	--	--	11/21/09	2 (U)	12/28/10	2(U)	--	NC

Table 5-1. (Cont.)

Well or Aquifer Tube Name	Well Use[a]	Fall 2008, Filt. and Unfilt. Cr^{+6}		Fall 2009 Sample, Unfiltered Cr^{+6}		Fall 2010 Sample, Unfiltered Cr^{+6}		% Change in Cr^{+6} Conc. (Negative = Increase)	
		Date Collected	Conc. (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	Date Collected	Unfilt. Cr^{+6} (mg/L)	2008 to 2010	2009 to 2010
AT-K-3-D	AT	--	--	11/01/09	62.8	12/17/10	56.9	--	9
AT-K-4-M	AT	--	--	11/23/09	2 (U)	--	--	--	--
AT-K-5-D	AT	--	--	11/23/09	45.6	--	--	--	--
AT-K-6-M	AT	--	--	--	--	--	--	--	--

a. Well use: C = compliance, E = extraction, I = injection; M = monitoring, P = performance, X = KR4 expansion well, use to be determined. Column also lists the applicable pump-and-treat system where appropriate.

b. Laboratory qualifiers: B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit, D = analyte reported at a secondary dilution factor, U = not detected in sample; value shown is the detection limit.

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

d. Change in hexavalent chromium concentration is not calculated (NC) when "U" (nondetect) values are used in the calculation. Where both values have a "U" qualifier, the values are assumed to not have changed significantly.

e. Where contaminant concentration comparisons involve one nonqualified result and one nondetect (U) result, the percent change was not calculated but rather and increase (inc.) or decrease (dec.) in concentration between years was noted.

f. Hexavalent chromium results from well 199-K-126 have been influenced by the calcium polysulfide treatability test that changed the color of groundwater and so strongly influenced the colorimetric EPA Method 7196 results. High out-of-trend results from this well have been rejected because of lingering calcium polysulfide influence.

g. Aquifer tube (AT) nomenclature regarding relative depth: D = deepest, M = middle, and S = shallowest.

h. Hexavalent chromium data from site AT 22 include sample results from either the middle or deep tubes in cluster as only one is sampled each year.

Table 5-2. Hexavalent Chromium Concentrations at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008 Unfilt. Cr^{+6}		Fall 2009 Unfilt. Cr^{+6}		Fall 2010 Sample Unfilt. Cr^{+6}		% Change in Cr^{+6} Conc. (Negative = Increase)	
		Date Collected	Conc. (µg/L)	Date Collected	Conc. (µg/L)	Date Collected	Conc. (µg/L)	2008 to 2010	2009 to 2010
199-K-34	M	10/27/08	44.1	10/22/09	36.8	12/7/10	5.1	88.4	86.1
199-K-35	M	--[b]	--	12/22/09	188	Decommissioned	--	--	
199-K-106A	M	10/6/08	4.8	10/22/09	2.1 (B)[c]	--	--	--	--
199-K-107A	M	10/6/08	172	10/22/09	29.3	12/3/10	14.4	91.6	50.9
199-K-108A	M	10/6/08	81.5	10/22/09	5.2	12/8/10	2(U)	Dec.[d]	Dec.
199-K-31	M	--	--	10/22/09	5.6	12/8/10	5.6	--	0.0
199-K-132	E	10/23/08	41	10/20/09	20	11/22/10	16.8	59.0	16.0
199-K-137	M	10/28/08	1,390	10/26/09	211	11/1/10	109	92.2	48.3
199-K-138	E	10/28/08	40.5	10/12/09	38	11/22/10	20.6	49.1	45.8
199-K-139	E	10/31/08	124	11/10/09	117	11/15/10	25	79.8	78.6
199-K-140	E	10/28/08	14.1	10/20/09	13	--	--	--	--
199-K-165	E	11/10/08	2,530	10/20/09	232	11/15/10	321	87.3	-38.4
199-K-166	E	11/10/08	101	10/20/09	56.1	11/22/10	30.5	69.8	45.6
199-K-167	--	--	--	--	--	--	--	--	--
199-K-168	E	11/10/08	241	10/20/09	130	11/15/10	57	76.3	56.2
199-K-173	M	12/1/08	7.3	10/21/09	104	--	--	--	--
199-K-174	I	--	--	--	--	--	--	--	--
199-K-175	I	--	--	--	--	--	--	--	--
AT-K-1[e]	AT	--	--	11/1/09	7.5	12/17/10	2 (U)	--	74

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

c. Laboratory qualifiers: B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit, C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration, D = analyte reported at a secondary dilution factor, U = not detected in sample; value shown is the detection limit.

d. Where contaminant concentration comparisons are both "U" (nondetect) then no percent change was calculated (NC), where comparisons involve one nonqualified result and one undetected (U) result, the percent change was not calculated but rather an increase (inc.) or decrease (dec.) in concentration between years was noted.

e. Change in hexavalent chromium concentration at site AT-K-1 included sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-3. Hexavalent Chromium Concentrations at the KE Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008 Unfiltered Cr^{+6}		Fall 2009 Unfiltered Cr^{+6}		Fall 2010 Sample Unfiltered Cr^{+6}		% Change in Cr^{+6} Conc. (Negative = Increase)	
		Date Collected	Conc. (µg/L)	Date Collected	Conc. (µg/L)	Date Collected	Conc. (µg/L)	2008 to 2010	2009 to 2010
199-K-32A	P	10/27/08	13.1	10/22/09	11.8	12/3/10	9.0	42	23.7
199-K-32B	M	10/27/08	6.8	10/18/09	5.1	12/8/10	3.8(B)[b]	57.4	43.1
199-K-30	M	10/27/08	3.3	10/18/09	2.1 (B)	12/2/10	7.5	-127.3	-257.1
199-K-29	M	--[c]	--	--	--	12/2/10	2 (U)	--	--
199-K-23	M	10/27/08	2 (U)	--	--	--	--	--	--
199-K-11	M	10/6/08	2 (U)	10/28/09	2 (U)	12/3/10	5.3	Inc.[d]	Inc.
199-K-110A	M	--	--	10/18/09	2 (U)	12/8/10	2 (U)	NC[d]	NC
199-K-36	M	10/27/08	21.4	10/22/09	20.0	12/3/10	34.2	-59.8	-71.0
199-K-141	E-KX	10/28/08	421	11/23/09	91	10/4/10	38	91.0	58.2
199-K-142	M	10/28/08	5.8	10/22/09	3.3 (B)	12/8/10	4	3131.0	-21.22
199-K-178	E-KX	--	--	11/5/09	117	11/17/10	23.8	--	79.7
199-K-181	C	--	--	11/5/09	8.6	--	--	--	--
C6242	AT	--	--	11/18/09	2 (U)	--	--	--	--
C6243	AT	--	--	11/18/09	4.8 (B)	--	--	--	--
C6244	AT	--	--	11/18/09	5.2	--	--	--	--
C6245	AT	--	--	11/16/09	14.8	--	--	--	--
C6246	AT	--	--	11/16/09	16	--	--	--	--
C6247	AT	--	--	11/16/09	15.7	--	--	--	--
19-D	AT	--	--	11/17/09	2 (U)	--	--	--	--
AT-K-2-D[e,f]	AT	--	--	11/1/09	3.4 (B)	12/17/10	2 (U)	--	41.22

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring. P = performance. Column includes applicable pump-and-treat system where appropriate.

b. Laboratory qualifiers: B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit, U = not detected in sample; value shown is the detection limit.

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

d. Where contaminant concentration comparisons are both "U" (nondetect) then no percent change was calculated (NC), where comparisons involve one nonqualified result and one nondetect (U) result, the percent change was not calculated but rather an increase (inc.) or decrease (dec.) in concentration between years was noted.

e. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

f. Change in hexavalent chromium concentration at site AT-K-2 included sample results from both the middle and the deep tube in the cluster because all tubes were not sampled each year.

Table 5-4. Tritium Activities at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010

Well or Aquifer Tube Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Activity (Negative = Increase)	
		Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	2008 to 2010	2009 to 2010
199-K-18	C	10/23/08	29,000	10/22/09	43,000	--[b]	--	--	--
199-K-19	P	10/23/08	2,900	10/18/09	3,900	12/3/10	4,800	-65.5	-23.1
199-K-20	C	10/27/08	5,400	10/28/09	6,100	--	--	--	--
199-K-21	P	10/23/08	240	10/18/09	5,800	12/3/10	58 (U)	Dec.[c]	Dec.
199-K-22	P	10/23/08	250	10/22/09	27 (U)[d]	--	--	--	--
199-K-37	P	10/27/08	188 (U)	10/22/09	680	12/3/10	300	-59.6	55.9
199-K-113A	E/C-KR4	--	--	10/21/09	170 (U)	--	--	--	--
199-K-114A	E/C-KR4	--	--	10/21/09	50 (U)	--	--	--	--
199-K-115A	E/C-KR4	--	--	10/21/09	56 (U)	--	--	--	--
199-K-116A	E/C-KR4	--	--	10/21/09	4,600	--	--	--	--
199-K-117A	C	10/6/08	200 (U)	10/22/09	41 (U)	12/3/10	-29 (U)	NC[c]	NC
199-K-119A	E/C-KR4	--	--	--	--	12/8/10	6,700	--	--
199-K-120A	E/C-KR4	--	--	--	--	--	--	--	--
199-K-118A/ 199-125A	C	--	--	--	--	--	--	--	--
199-K-126	M	--	--	--	--	--	--	--	--
199-K-127	E/C-KR4	--	--	--	--	--	--	--	--
199-K-129/ 199-K-112A	E/C-KR4	--	--	10/21/09	-22 (U)	--	--	--	--
199-K-130	E/C-KX	--	--	10/20/09	2,500	11/22/10	1,900	--	24.0
199-K-131	E/C-KX	--	--	10/20/09	3,300	--	--	--	--
699-78-62	M	11/23/08	1,700	11/23/08	1,700	--	--	--	--
199-K-121A	I-KR4	--	--	--	--	--	--	--	--
199-K-122A	I-KR4	--	--	--	--	--	--	--	--
199-K-123A	I-KR4	--	--	--	--	--	--	--	--
199-K-124A	I-KR4	--	--	--	--	12/7/10	6,900	--	--
199-K-128A	I-KR4	--	--	--	--	--	--	--	--
199-K-144	E/C-KR4	10/7/08	200,000	--	--	--	--	--	--
199-K-145	E/C-KR4	--	--	--	--	--	--	--	--
199-K-146	E/C-KX	--	--	10/20/09	150 (U)	--	--	--	--
199-K-147	E/C-KX	--	--	10/20/09	2,100	11/22/10	810	--	61.4
199-K-148	E/C-KX	--	--	10/20/09	3,800	11/22/10	2,500	--	34.2
199-K-149	E/C-KX	--	--	10/20/09	1,900	--	--	--	--
199-K-150	E/C-KX	--	--	10/20/09	7,800	--	--	--	--
199-K-151	P	11/24/08	4,500	10/22/09	1,200	9/20/10	940	79.1	21.7
199-K-152	P	12/8/08	800	10/22/09	280	9/21/10	150 (U)	81.3	46.4
199-K-153	M	12/1/08	0.9 (U)	--	--	11/22/10	740	--	--
199-K-154	E-KX	9/24/08	58.7 (U)	11/9/08	32 (U)	11/22/10	190 (U)	NC	NC
199-K-156	I-KX	--	--	--	--	--	--	--	--
199-K-157	P	11/18/08	320,000	10/29/09	290,000	12/7/10	27,000	91.6	90.7
199-K-159	I-KX	--	--	--	--	--	--	--	--

Table 5-4. (Cont.)

Well or Aquifer Tube Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Activity (Negative = Increase)	
		Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	2008 to 2010	2009 to 2010
199-K-160	I-KX	--	--	--	--	--	--	--	--
199-K-161	E/C-KX	--	--	10/21/09	108 (U)	11/22/10	83 (U)	--	NC
199-K-162	E/C-KR4	--	--	--	--	--	--	--	--
199-K-163	E/C-KX	11/9/08	203 (U)	--	--	11/22/10	5,200	Inc.	--
199-K-164	I-KX	--	--	--	--	--	--	--	--
199-K-169	I-KX	--	--	--	--	--	--	--	--
199-K-170	I-KX	--	--	--	--	--	--	--	--
199-K-171	E-KX	9/5/08	670	--	--	11/22/10	2,300	-243.3	--
199-K-172	I-KX	9/5/08	-9.5 (U)	--	--	--	--	--	--
199-K-179	I-KX	--	--	11/5/09	7,500	--	--	--	--
199-K-180	I-KX	--	--	--	--	--	--	--	--
199-K-182	P	--	--	12/28/09	5,800	9/20/10	4,100	--	29.3
199-N-16	P	--	--	10/18/09	300	--	--	--	--
199-N-72	P	--	--	--	--	9/19/10	1,600	--	NC
199-N-71	P	--	--	10/21/09	1,050	12/5/10	1,000	--	4.8
19-D/M[e,f]	AT	--	--	11/17/09	130 (U)	--	--	--	--
21-M	AT	--	--	11/18/09	100 (U)	--	--	--	--
22-M/D	AT	--	--	11/21/09	71 (U)	--	--	--	--
23-D	AT	--	--	11/23/09	-220 (U)	--	--	--	--
26-D	AT	--	--	8/19/08	1,900	--	--	--	--
C6246	AT	--	--	--	--	--	--	--	--
C6250	AT	--	--	11/17/09	1,700	--	--	--	--
C6253	AT	--	--	11/21/09	620	--	--	--	--
C6256	AT	--	--	11/21/09	240	--	--	--	--
C6259	AT	--	--	11/21/09	730	--	--	--	--
C6260	AT	--	--	--	--	--	--	--	--
DK-04-2	AT	--	--	11/21/09	620	--	--	--	--
AT-K-3-D/M	AT	--	--	11/1/09	5,400.0	--	--	--	--
AT-K-4-M	AT	--	--	11/23/09	37 (U)	--	--	--	--
AT-K-5-D/M	AT	--	--	11/23/09	300	--	--	--	--
AT-K-6-M	AT	--	--	--	--	--	--	--	--

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. Change in tritium concentration not calculated = (NC) when both values include "U" (nondetect) qualifier. If one value has a "U" qualifier and the second value is unqualified, the change in concentration is shown as increase (inc.) or decrease (dec.).

d. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

e. Aquifer tube (AT) nomenclature indicates relative depth: D = deep, M = middle, S = shallow.

f. Change in tritium concentration at some aquifer tube clusters may include sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-5. Tritium Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Activity (Negative = Increase)	
		Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	2008 to 2010	2009 to 2010
199-K-34	P	10/27/08	1,300	10/22/09	4,400	9/20/10	4,100	-215.4	6.8
199-K-35	I	--[b]	--	--	--	--	--	--	--
199-K-106A	P	10/6/08	21,000	10/22/09	2,300	9/13/10	3,200	84.8	-39.1
199-K-107A	P	10/6/08	760	10/18/09	1,200	12/3/10	1,300	-71.1	-8.3
199-K-108A	P	10/6/08	920	10/22/09	220 (U)[c]	--	--	--	--
199-K-31	M	10/27/08	1,300	10/22/09	1,500	12/8/10	1,600	-23.1	-6.7
199-K-132	E	10/28/08	6,000	10/20/09	8,200	11/22/10	7,500	-25.0	8.5
199-K-137	E	10/28/08	1,600	10/20/09	940	--	--	--	--
199-K-138	E	10/28/08	1,200	10/20/09	1,100	11/22/10	1,500	-25.0	-36.4
199-K-139	E	10/30/08	1,500	11/10/09	1,600	--	--	--	--
199-K-140	M	10/28/08	1,600	10/20/09	1,700	--	--	--	--
199-K-165	E	11/10/08	684	10/20/09	970	--	--	--	--
199-K-166	E	11/10/08	1,190	10/20/09	2,600	11/22/10	1,400	-17.6	46.2
199-K-167	Abandoned	--	--	--	--	--	--	--	--
199-K-168	E	10/29/08	1,370	10/20/09	970	--	--	--	--
199-K-173	P	9/27/08	910	10/21/09	1,200	--	--	--	--
199-K-174	I	--	--	--	--	--	--	--	--
199-K-175	I	--	--	--	--	--	--	--	--
AT-K-1-D/M[d,e]	AT	--	--	11/1/09	100 (U)	--	--	--	--

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. U = not detected in sample; value shown is the detection limit.

d. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

e. Change in tritium concentration at site AT-K-1 included sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-6. Tritium Activities at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		Change in Tritium Activity, Negative = Increase	
		Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	Date Collected	H-3 (pCi/L)	2008 to 2010	2009 to 2010
199-K-32A	P	10/27/08	4,200	10/22/09	3,900	12/3/10	2,500	40.5	35.9
199-K-32B[b]	M	10/27/08	140 (U)[c]	10/18/09	-29 (U)	--[d]	--	--	--
199-K-30	M	10/27/08	410,000	10/18/09	140,000	12/2/10	16,000	96.1	88.6
199-K-29	M	9/29/08	7,100	--	--	12/2/10	130,000	-1731.0	--
199-K-27	Decommissioned	--	--	--	--	--	--	--	--
199-K-23	M	10/27/08	120 (U)	--	--	--	--	--	--
199-K-11	M	10/6/08	140 (U)	10/28/09	66 (U)	12/3/10	330	-135.7	-400.0
199-K-109A	M	--	--	--	--	--	--	--	--
199-K-110A	M	10/6/08	160 (U)	10/18/09	96 (U)	12/8/10	140 (U)	NC[e]	NC
199-K-111A	P	10/6/08	6,000	10/21/09	7,515	12/7/10	26,000	-333.3	-246.0
199-K-36	M	10/27/08	172 (U)	10/22/09	48.4 (U)	12/3/10	130 (U)	NC	NC
199-K-141	E-KR4	10/28/08	4,300	--	--	--	--	--	--
199-K-142	P	10/28/08	1,200	10/22/09	290	12/8/10	117 (U)	90.3	59.7
199-K-178	E-KR4	--	--	10/8/09	3,100	11/17/10	1,100		64.5
199-K-181	C	--	--	10/8/09	340	--	--	--	--
C6241	AT	--	--	11/15/09	550	--	--	--	--
C6244	AT	--	--	11/18/09	2,100	--	--	--	--
18-S[f]	AT	--	--	11/18/09	160 (U)	--	--	--	--
19-D	AT	--	--	--	--	--	--	--	--
AT-K-2-M	AT	--	--	--	--	--	--	--	--

a. Well and aquifer tube use: M = monitoring, AT = aquifer tube, P = performance, E = extraction. Column includes applicable pump-and-treat system where appropriate.

b. Well 199-K-32B is screened within the Ringold upper mud unit and well 199-K-32A is screened within Ringold unit E.

c. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

d. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

e. Change in tritium concentration is not calculated (NC) when both results include "U" (nondetect) qualifiers. If one compared result includes a "U" qualifier and the second is unqualified, the change in concentration is shown as increase (inc.) or decrease (dec.).

f. Aquifer tube nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-7. Strontium-90 Activities at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010

Well or Aquifer Tube Name	Well Use[a]	Fall 2008		Fall 2009		Fall 2010		Change in Sr-90 Conc.	Change in Sr-90 Activity
		Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	2008 to 2010 (%) (Negative = Increase)	2009to 2010 (%) (Negative = Increase)
199-K-18	C	10/23/08	-1.38 (U)[b]	10/22/09	-6 (U)	--	--[c]	--	--
199-K-19	P	--	--	10/18/09	7.5	12/3/10	12	--	-60.0
199-K-20	C	10/27/08	3.05	10/28/09	-1.5 (U)	--	--	--	
199-K-21	P	10/23/08	26.7	10/18/09	22	12/3/10	17	36.3	22.7
199-K-22	P	10/23/08	6.78	10/22/09	-4.2 (U)	--	--	--	--
199-K-37	P	--	--	10/22/09	-7.7 (U)	12/3/10	-3.1 (U)	--	NC[d]
199-K-113A	E/C-KR4	--	--	10/21/09	5.9	--	--	--	--
199-K-114A	E/C-KR4	--	--	10/21/09	8.7	--	--	--	--
199-K-115A	E/C-KR4	--	--	10/21/09	6.1	--	--	--	--
199-K-116A	E/C-KR4	--	--	10/21/09	1.4	--	--	--	--
199-K-117A	C	10/6/08	0.18 (U)	10/22/09	-3.1 (U)	12/3/10	-1.2 (U)	NC	NC
199-K-119A	E/C-KR4	--	--	--	--	12/8/10	1.2 (U)	--	--
199-K-120A	E/C-KR4	--	--	--	--	--	--	--	--
199-K-125A	C	--	--	--	--	--	--	--	--
199-K-127	M	--	--	--	--	--	--	--	--
199-K-129/ 1990K-112A	E/C-KR4	--	--	10/21/09	-0.1 (U)	--	--	--	--
199-K-130	E/C-KR4	--	--	10/20/09	0.1 (U)	11/22/10	-11 (U)	--	NC
199-K-131	E/C-KX	--	--	10/20/09	-3 (U)	--	--	--	--
699-78-62	E/C-KX	--	--	--	--	--	--	--	--
199-K-121A	I-KR4	--	--	--	--	--	--	--	--
199-K-122A	I-KR4	--	--	--	--	--	--	--	--
199-K-123A	I-KR4	--	--	--	--	--	--	--	--
199-K-124A	I-KR4	--	--	--	--	12/7/10	-0.18 (U)	--	NC
199-K-143	I-KR4	--	--	--	--	--	--	--	--
199-K-144	E/C-KR4	--	--	--	--	--	--	--	--
199-K-145	E/C-KR4	--	--	--	--	--	--	--	--
199-K-146	E/C-KX	--	--	10/20/09	-2.5	--	--	--	--
199-K-147	E/C-KX	--	--	10/20/09	4.4	11/22/10	-4.9 (U)	--	NC
199-K-148	E/C-KX	--	--	10/20/09	0.69	11/22/10	-7.2 (U)	--	Dec.[e]
199-K-149	E/C-KX	--	--	10/20/09	-5.1 (U)	--	--	--	--
199-K-150	E/C-KX	--	--	10/20/09	-2.8 (U)	--	--	--	--
199-K-151	P	11/28/08	-7.2 (U)	10/22/09	-6.4 (U)	9/20/10	-4.7 (U)	--	NC
199-K-152	P	9/24/08	3	10/22/09	-7.2 (U)	9/21/10	-5.5 (U)	--	NC
199-K-153	M	9/24/08	-1.2 (U)	--	--	11/22/10	-10 (U)	--	--
199-K-154	E-KX	9/24/08	0.53 (U)	--	--	11/22/10	-8.1 (U)	--	--
199-K-156	I-KX	--	--	--	--	--	--	--	--
199-K-157	P	11/18/08	0.6 (U)	10/29/09	2.6	12/7/10	-0.45 (U)	NC	Dec.
199-K-159	I-KX	--	--	--	--	--	--	--	--
199-K-160	I-KX	--	--	--	--	--	--	--	--
199-K-161	E/C-KX	--	--	10/21/09	14.8	11/22/10	-2.2 (U)	--	--
199-K-162	E/C-KR4	--	--	--	--	--	--	--	--
199-K-163	E/C-KX	11/9/08	-0.953 (U)	--	--	11/22/10	-6.7 (U)	NC	--

Table 5-7. (Cont.)

Well or Aquifer Tube Name	Well Use[a]	Fall 2008		Fall 2009		Fall 2010		Change in Sr-90 Conc.	Change in Sr-90 Activity
		Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	2008 to 2010 (%) (Negative = Increase)	2009to 2010 (%) (Negative = Increase)
199-K-164	I-KX	--	--	--	--	--	--	--	--
199-K-169	I-KX	--	--	--	--	--	--	--	--
199-K-170	I-KX	--	--	--	--	--	--	--	--
199-K-171	E-KX	9/5/08	-0.49 (U)	--	--	11/22/10	-7.2 (U)	NC	--
199-K-172	I-KX	9/5/08	-2 (U)	--	--	--	--	--	--
199-K-179	I-KX	--	--	11/5/09	-5.5 (U)	--	--	--	--
199-K-180	I-KX	--	--	--	--	--	--	--	--
199-K-182	P	--	--	--	--	9/20/10	-1.8 (U)	--	--
19-D/M[f,g]	AT	--	--	11/17/09	-1 (U)	--	--	--	--
21-M	AT	--	--	11/18/09	2.1 (U)	--	--	--	--
22-M/D[f]	AT	--	--	--	--	--	--	--	--
23-D	AT	--	--	--	--	--	--	--	--
C6246	AT	--	--	11/16/09	-2.7 (U)	--	--	--	--
C6250	AT	--	--	--	--	--	--	--	--
C6253	AT	--	--	--	--	--	--	--	--
C6256	AT	--	--	--	--	--	--	--	--
C6259	AT	--	--	11/21/09	-7 (U)	--	--	--	--
C6260	AT	--	--	--	--	--	--	--	--
DK-04-2	AT	--	--	--	--	--	--	--	--
AT-K-3-D/M[f]	AT	--	--	11/17/09	-1.7 (U)	--	--	--	--
AT-K-4-M	AT	--	--	11/23/09	-9.2 (U)	--	--	--	--
AT-K-5-D/M[f]	AT	--	--	11/23/09	0.14 (U)	--	--	--	--
AT-K-6-M	AT	--	--	--	--	--	--	--	--

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P= performance. Column includes applicable pump-and-treat system where appropriate.

b. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

d. Change in strontium-90 concentration not calculated (NC) when "U" (undetected) values are compared.

e. Where contaminant concentration comparisons involve one nonqualified result and one undetected (U) result, the percent change was not calculated but rather an increase (inc.) or decrease (dec.) in concentration between years was noted.

f. Aquifer tube (AT) nomenclature indicates relative depth: D = deep, M = middle, S = shallow.

g. Change in strontium-90 concentration at some aquifer tube clusters may include sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-8. Strontium-90 Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Sr-90 Activity (Negative = Increase)	
		Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	2008 to 2010	2009 to 2010
199-K-34	P	10/27/08	36.4	10/22/09	16	12/7/10	45	Dec.[b]	Dec.
199-K-35	I	--[c]	--	--	--	--	--	--	--
199-K-106A	P	--	--	10/22/09	6.3	--	--	--	--
199-K-107A	P	--	--	10/18/09	13	12/3/10	14	--	-7.7
199-K-108A	P	11/18/08	-2 (U)[d]	10/22/09	-11 (U)	--	--	--	
199-K-31	M	--	--	10/22/09	-2.4 (U)	12/8/10	-0.87 (U)	--	NC
199-K-132	E	--	--	10/20/09	-3.2 (U)	11/22/10	-6 (U)	--	NC
199-K-137	E	10/28/08	-0.686 (U)	10/20/09	-1.8 (U)	--	--	--	--
199-K-138	E	10/28/08	-0.602 (U)	10/20/09	-0.36 (U)	11/22/10	-9.2 (U)	NC[b]	NC
199-K-139	E	10/30/08	0.717 (U)	11/10/09	5.3	--	--	--	--
199-K-140	M	10/28/08	0.478	10/20/09	-1(U)	--	--	--	--
199-K-165	E	11/10/08	-1.89 (U)	10/20/09	-1.6 (U)	--	--	--	--
199-K-166	E	11/10/08	-1.41 (U)	10/20/09	-0.31 (U)	11/22/10	-8.8 (U)	NC	NC
199-K-167	Abandoned	--	--	--	--	--	--	--	--
199-K-168	E	11/10/08	-1.87 (U)	10/20/09	-1.4 (U)	--	--	--	--
199-K-173	P	12/1/08	0.78 (U)	10/21/09	-6 (U)	--	--	--	--
199-K-174	I	--	--	--	--	--	--	--	--
199-K-175	I	--	--	--	--	--	--	--	--
AT-K-1-D/M[e,f]	AT	--	--	--	--	--	--	--	--

a. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance. Column includes applicable pump-and-treat system where appropriate.

b. Change in strontium-90 concentration not calculated (NC) when both values are undetected (U); when and the other value is unqualified and one value is nondetect (U), the change is shown as increase (inc.) or decrease (dec.).

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

d. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

e. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

f. Change in strontium-90 concentration at site AT-K-1 included sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-9. Strontium-90 Activities at the KE Reactor Wells and Aquifer Tubes

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Sr-90 Activity (Negative = Increase)	
		Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	Date Collected	Sr-90 (pCi/L)	2008 to 2010	2009 to 2010
199-K-32A	P	--[b]	--	10/22/09	3.8	12/3/10	4.4	--	72.5
199-K-32B[c]	M	--	--	10/18/09	2.3	--	--	--	--
199-K-30	M	--	--	10/18/09	-2.8 (U)[d]	12/2/10	-2.8 (U)	--	NC[e]
199-K-29	M	--	--	--	--	12/2/10	-5 (U)	--	--
199-K-27	Decommissioned	--	--	--	--	--	--	--	--
199-K-23	M	10/27/08	0.406 (U)	--	--	--	--	--	--
199-K-11	M	--	--	10/28/09	-0.76 (U)	--	--	--	--
199-K-109A	Decommissioned	3/19/08	1120	--	--	--	--	--	--
199-K-110A	M	--	--	10/18/09	-4.6 (U)	--	--	--	--
199-K-111A	P	--	--	12/22/09	-3.2 (U)	12/7/10	1.5	--	Inc.
199-K-36	M	--	--	10/22/09	-0.81 (U)	12/3/10	-14 (U)	--	NC
199-K-141	E-KR4	10/28/08	-0.498 (U)	--	--	--	--	--	--
199-K-142	P	10/28/08	-1.42 (U)	10/22/09	-3.4 (U)	9/21/10	-4.2 (U)	NC	NC
199-K-178	E-KR4	--	--	10/8/09	3.2	11/17/10	2.66	--	--
199-K-181	C	--	--	11/5/09	-11 (U)	--	--	--	--
C6241	AT	--	--	--	--	--	--	--	--
C6244	AT	--	--	11/18/09	2.3 (U)	--	--	--	--
18-S[f]	AT	--	--	--	--	--	--	--	--
19-D	AT	--	--	11/17/09	-1 (U)	--	--	--	--
AT-K-2-M	AT	--	--	--	--	--	--	--	--

a. Well and aquifer tube use: C = compliance, M = monitoring, P = performance, E = extraction, AT = aquifer tube. Column includes applicable pump-and-treat system where appropriate.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. Well 199-K-32B is screened within the Ringold upper mud unit and well 199-K-32A is screened within Ringold unit E.

d. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

e. Change in strontium-90 concentration is not calculated (NC) when both values have "U" qualifier. When one value is nondetect (U) and the second value is unqualified, the change is noted as an increase (inc.) or decrease (dec.).

f. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-10. Carbon-14 Activities at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in C-14 Activity (Negative = Increase)	
		Date Collected	C-14 (pCi/L)	Date Collected	C-14 (pCi/L)	Date Collected	C-14 (pCi/L)	2008 to 2010	2009 to 2010
199-K-34	M	10/27/08	4,680	10/22/09	1,910	12/7/10	2,590	--	--
199-K-35	M	--[b]	--	--	--	--	--	--	--
199-K-106A	M	10/6/08	2,860	10/22/09	3,970	--	--	--	--
199-K-107A	M	10/6/08	302	10/18/09	282	12/3/10	625	--	--
199-K-108A	M	10/6/08	2,210	10/22/09	946	12/8/10	265	--	--
199-K-31	M	10/27/08	240	10/22/09	565	12/8/10	396	-65.0	29.9
199-K-132	E	10/28/08	2,630	10/20/09	2,320	11/22/10	2,350	10.6	-1.3
199-K-137	M	10/28/08	1,830	10/20/09	950	--	--	--	--
199-K-138	E	10/28/08	192 (J)[c]	10/20/09	285	11/22/10	396	-106.3	-38.9
199-K-139	E	10/30/08	387	11/10/09	347	--	--	--	--
199-K-140	E	10/28/08	878	10/20/09	514	--	--	--	--
199-K-158	M	--	--	--	--	--	--	--	--
199-K-165	E	11/10/08	330	10/20/09	154	--	--	--	--
199-K-166	E	11/10/08	506	10/20/09	290	11/22/10	399	21.1	-37.6
199-K-168	E	10/29/08	643	10/20/09	290	--	--	--	--
199-K-173	P	12/1/08	215	10/21/09	582	--	--	--	--
199-K-174	I	--	--	--	--	--	--	--	--
199-K-175	I	--	--	--	--	--	--	--	--
AT-K-1-D[d]	AT	--	--	11/1/09	35.2	--	--	--	--

a. Well use: E = extraction, M = monitoring, P = performance, I = injection. Column includes applicable pump-and-treat system where appropriate.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. Laboratory qualifiers: J = estimated value; constituent detected at a level less than the contract required detection limit and greater than or equal to the method detection limit.

d. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-11. Carbon-14 Activities at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in C-14 Activity (Negative = Increase)	
		Date Collected	C-14 (pCi/L)	Date Collected	C-14 (pCi/L)	Date Collected	C-14 (pCi/L)	2008 to 2010	2009 to 2010
199-K-32A	P	10/27/08	205	10/22/09	166	12/3/10	192	6.3	-15.7
199-K-32B[b]	M	--[c]	--	10/18/09	1.01 (U)[d]	12/8/10	3.43 (U)	--	NC[e]
199-K-30	M	10/27/08	6,130	10/18/09	5,830	12/2/10	4,110	33.0	29.5
199-K-29	M	--	--	--	--	12/2/10	3,120	--	--
199-K-23	M	--	--	--	--	--	--	--	--
199-K-11	M	10/6/08	106	10/28/09	108	12/3/10	131	-23.6	-21.3
199-K-110A	M	--	--	10/18/09	152	--	--	--	--
199-K-36	M	--	--	10/22/09	91	12/3/10	65.1	--	28.5
199-K-141	E-KR4	10/28/08	84.4	--	--	--	--	--	--
199-K-142	P	10/28/08	291	10/22/09	209	12/8/10	242	16.8	-15.8
199-K-178	E-KR4	--	--	10/8/09	200	11/17/10	226	--	-13.0
199-K-181	P	--	--	10/8/09	270	--	--	--	--
C6241	AT	--	--	11/15/09	158	--	--	--	--
C6244	AT	--	--	11/18/09	126	--	--	--	--
C6247	AT	--	--	11/16/09	295	--	--	--	--
18-S[f]	AT	--	--	11/18/09	22.6	--	--	--	--
19-D	AT	--	--	11/17/09	-0.451 (U)	--	--	--	--
AT-K-2-M	AT	--	--	11/1/09	188	--	--	--	--

a. Well and aquifer tube use: E = extraction, M = monitoring, P = performance. Column includes applicable pump-and-treat system where appropriate.

b. Well 199-K-32B is screened within the Ringold upper mud unit and well 199-K-32A is screened within Ringold unit E.

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

d. Laboratory qualifiers: U = not detected in sample; value shown is the detection limit.

e. Change in carbon-14 concentration not calculated (NC) when both results include "U" (nondetect) qualifier. When one compared result includes "U" qualifier, and the second result is qualified, the change in concentration is shown as increase (inc.) or decrease (dec.).

f. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-12. Nitrate Concentrations at the 116-K-2 Wells and Aquifer Tubes, CY 2008 to CY 2010

Well or Aquifer Tube Name	Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		Change in Nitrate Concentration	
		Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	2008 to 2010	2009 to 2010
199-K-18	C	10/23/08	66.0	10/22/09	73	12/08/10	60.6	9.5	16.9
199-K-19	P	10/23/08	38.6	10/18/09	30.4	12/3/10	26.7	30.8	12.1
199-K-20	C	10/27/08	15.2	10/28/09	15.0	--	--	--	--
199-K-21	P	10/23/08	17.7	10/18/09	10.7	12/3/10	14.8	16.4	-37.6
199-K-22	P	10/23/08	16.5	10/22/09	21.4	--	--	--	--
199-K-37	P	10/27/08	10.2	10/22/09	10.4	12/3/10	6.77	33.6	34.9
199-K-113A	E/C-KR4	--[b]	--	10/21/09	9.38	--	--	--	--
199-K-114A	E/C-KR4	--	--	10/21/09	9.20	--	--	--	--
199-K-115A	E/C-KR4	--	--	10/21/09	11.0	--	--	--	--
199-K-116A	E/C-KR4	--	--	10/21/09	15.9	--	--	--	--
199-K-117A	C	10/6/08	6.02	10/22/09	4.36	12/3/10	1.92	68.1	56.0
199-K-129	E/C-KR4	--	--	10/21/09	8.81	--	--	--	--
199-K-130	E/C-KX	--	--	10/20/09	11.9	11/22/10	11.9	--	0.1
199-K-131	E/C-KX	--	--	10/20/09	13.4	--	--	--	--
199-K-143	I-KR4	--	--	--	--	--	--	--	--
199-K-144	E/C-KR4	--	--	--	--	--	--	--	--
199-K-145	E/C-KR4	--	--	--	--	--	--	--	--
199-K-146	E/C-KX	--	--	10/20/09	8.63	--	--	--	--
199-K-147	E/C-KX	--	--	10/20/09	10.5	11/22/10	11.4	--	-7.7
199-K-148	E/C-KX	--	--	10/20/09	14.6	11/22/10	13.8	--	5.5
199-K-149	E/C-KX	--	--	10/20/09	22.3	--	--	--	--
199-K-150	E/C-KX	--	--	10/20/09	16.2	--	--	--	--
199-K-151	P	--	--	10/22/09	9.60	9/20/10	6.6	--	31.3
199-K-152	P	--	--	10/22/09	8.45	9/21/10	7.61	--	10.0
199-K-153	M	--	--	--	--	11/22/10	10.4	--	--
199-K-154	E-KX	--	--	--	--	11/22/10	10.4	--	--
199-K-156	I-KX	--	--	--	--	--	--	--	--
199-K-157	P	--	--	10/29/09	41.9	12/7/10	22.3	--	46.8
199-K-159	I-KX	--	--	--	--	--	--	--	--
199-K-160	I-KX	--	--	--	--	--	--	--	--
199-K-161	E/C-KX	--	--	10/21/09	12.5	11/22/10	2.64	--	79.0
199-K-162	E/C-KR4	--	--	--	--	--	--	--	--
199-K-163	E/C-KX	--	--	--	--	11/22/10	14.3	--	--
199-K-164	I-KX	--	--	--	--	--	--	--	--
199-K-169	I-KX	--	--	--	--	--	--	--	--
199-K-170	I-KX	--	--	--	--	--	--	--	--
199-K-171	E-KX	--	--	--	--	11/22/10	14.2	--	--
199-K-179	I-KX	--	--	11/5/09	12.3	--	--	--	--
199-N-16	P	--	--	10/18/09	--	--	--	--	--
199-N-71	P	11/8/08	--	10/21/09	--	12/5/10	12.8	--	--
199-N-72	P	11/18/08	--	--	--	9/19/10	38.4	--	--

Table 5-12. (Cont.)

Well or Aquifer Tube Name	Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		Change in Nitrate Concentration	
		Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	2008 to 2010	2009 to 2010
699-78-62	M	--	--	--	--	--	--	--	--
C6248	AT	9/30/08	--	--	--	--	--	--	--
C6250	AT	9/30/08	--	11/17/09	--	--	--	--	--
C6251	AT	11/6/08	--	--	--	--	--	--	--
C6253	AT	11/6/08	--	--	--	--	--	--	--
C6256	AT	11/5/08	--	11/21/09	--	--	--	--	--
C6259	AT	11/10/08	--	11/21/09	--	--	--	--	--
C6260	AT	11/10/08	--	--	--	--	--	--	--
18-S	AT	10/28/98	--	11/18/09	--	--	--	--	--
19-D/M[c,d]	AT	10/30/00	--	11/17/09	--	--	--	--	--
AT-K-3-D/M[c,d]	AT	--	--	11/1/09	--	--	--	--	--

a. Well use: C = compliance, M = monitoring. Column includes applicable pump-and-treat system where appropriate.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. Aquifer tube (AT) nomenclature indicates relative depth: D = deep, M = middle, S = shallow.

d. Change in nitrate concentration at some aquifer tube clusters may include sample results from both the middle and deep tube in cluster because all tubes not sampled each year.

Table 5-13. Nitrate Concentrations at the KW Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Nitrate Conc. (Negative = Increase)	
		Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	2008 to 2010	2009 to 2010
199-K-34	M	10/27/08	53.1	10/22/09	53.1	12/7/10	32.6	38.6	38.6
199-K-35	M	--[b]	--	12/22/09	31.9	--	--	--	--
199-K-106A	M	10/6/08	89.9	10/22/09	96.1	9/13/10	73.9	17.8	23.1
199-K-107A	M	10/6/08	22.2	10/18/09	22.0	12/3/10	23.2	-4.5	-5.0
199-K-108A	M	10/6/08	69.1	10/22/09	61.5	--	--	--	--
199-K-31	M	10/27/08	24.0	10/22/09	24.1	12/8/10	24.6	-2.5	-2.0
199-K-132	E	10/28/08	28.3	10/20/09	31.7	11/22/10	34.3	-21.2	-8.2
199-K-137	M	10/28/08	16.5	10/20/09	26.4	--	--	--	--
199-K-138	E	10/28/08	21.3	10/20/09	--	11/22/10	22.1	-3.4	--
199-K-139	E	10/30/08	--	11/10/09	24.8	--	--	--	--
199-K-140	E	10/28/08	--	10/20/09	21.2	--	--	--	--
199-K-158	M	--	--	--	--	--	--	--	--
199-K-165	E	9/11/08	17.4	10/20/09	17.2	--	--	--	--
199-K-166	E	9/25/08	193	10/20/09	20.0	11/22/10	22.4	88.4	-11.9
199-K-168	E	--	--	10/20/09	18.9	--	--	--	--
199-K-173	P	9/27/08	17.4	10/21/09	19.1	--	--	--	--
199-K-174	I	--	--	--	--	--	--	--	--
199-K-175	I	--	--	--	--	--	--	--	--
AT-K-1-D[c]	AT	--	--	11/1/09	--	--	--	--	--

a. Well use: E = extraction, M = monitoring. Column includes applicable pump-and-treat system where appropriate.

b. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

c. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-14. Nitrate Concentrations at the KE Reactor Wells and Aquifer Tubes, CY 2008 to CY 2010

Well Name	Well Use[a]	Fall 2008		Fall 2009 Sample		Fall 2010 Sample		% Change in Nitrate Conc. (Negative = Increase)	
		Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	Date Collected	Nitrate (mg/L)	2008 to 2010	2009 to 2010
199-K-32A	P	10/27/08	20.9	10/22/09	20.7	12/3/10	19.0	9.1	8.3
199-K-32B[b]	M	10/27/08	10.4	10/18/09	10.3	--[c]	--	--	--
199-K-30	M	10/27/08	79.7	10/18/09	31.1	12/2/10	25.1	68.5	19.2
199-K-29	M	--	--	--	--	12/2/10	46.5	--	--
199-K-23	M	10/27/08	63.7	--	--	--	--	--	--
199-K-11	M	10/6/08	69.1	10/28/09	49.1	12/3/10	39.7	42.5	19.1
199-K-110A	M	10/6/08	9.96	10/18/09	13.2	12/8/10	10.8	-8.4	18.2
199-K-111A	P	10/6/08	42.9	10/21/09	43.4	12/7/10	37.1	13.5	14.5
199-K-36	M	10/27/08	22.1	10/22/09	23.5	12/3/10	28.1	-27.1	-19.6
199-K-141	E-KR4	10/28/08	30.0	--	--	--	--	--	--
199-K-142	P	10/28/08	31.1	10/22/09	22.5	12/8/10	1.42	54.6	37.0
199-K-178	E-KR4	--	--	10/8/09	17	11/17/10	13.9		18.2
199-K-181	P	--	--	10/8/09	17.6	--	--	--	--
C6241	AT	--	--	--	--	--	--	--	--
C6244	AT	--	--	--	--	--	--	--	--
C6247	AT	--	--	--	--	--	--	--	--
18-S[d]	AT	--	--	--	--	--	--	--	--
19-D	AT	--	--	--	--	--	--	--	--
AT-K-2-M	AT	--	--	--	--	--	--	--	--

a. Well and aquifer tube use: M = monitoring. Column includes applicable pump-and-treat system where appropriate.

b. Well 199-K-32B is screened within the Ringold upper mud unit and well 199-K-32A is screened within Ringold unit E.

c. Blank cells (marked as "--") indicate that the sample was not collected, the analysis was not performed, or a change in concentration could not be calculated.

d. Aquifer tube (AT) nomenclature regarding relative depth: D = deep, M = middle, S = shallow.

Table 5-15. KR4 Pump-and-Treat System Operation Parameters, CY 2010

Total processed groundwater	**CY 2009**	**CY 2010**
Total amount of groundwater treated since October 1997 startup (million L)	5.31	5.65
Total amount of groundwater treated (million L)	317.5	336.9
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since October 1997 startup (kg)	347.5	354.7
Total amount of hexavalent chromium removed (kg)	14.98	7.21
Summary of operational parameters		
Removal efficiency (% by mass)	86.9%	90.6%
Regenerated resin installed (m^3)	29.4	45
New resin installed (m^3)	0	0
Number of resin vessel changeouts	--	20
Summary of system availability[a,b]		
Total possible run-time (hours)	8,760	8,760
Scheduled downtime (hours)	53.6	2,170.4
Planned operations (hours)	8,706.4	6,589.6
Unscheduled downtime (hours)	1,089.8	22.1
Total time online (hours)	7,616.6	6,567.5
Total availability (%)	86.9%	74.0%
Scheduled system availability (%)	99.4%	75.2%[c]

a. Scheduled system availability [(total possible run-time – scheduled downtime) ÷ total possible run-time].

b. Total availability [(total possible run-time – scheduled and unscheduled downtime) ÷ total possible run-time)].

c. The relatively low system availability in CY 2010 is due to system shutdown for upgrades and maintenance during the last 3 months of the year.

Table 5-16. KX Pump-and-Treat System Operational Parameters, CY 2009 and CY 2010

Total processed groundwater	**CY 2009**	**CY 2010**
Total amount of groundwater treated since the February 2009 startup (million L)	656	1,561
Total amount of groundwater treated (million L)	590	904
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since November 2008 startup (kg)	44	84
Total amount of hexavalent chromium removed (kg)	38	40
Summary of operational parameters		
Removal efficiency (% by mass)	96.3	94.0
Regenerated resin installed (m^3)	61.2	147
New resin installed (m^3)	97.4	52
Number of resin vessel changeouts	--	65
Summary of system availability[a,b]		
Total possible run-time (hours)	7,968.0	8,616
Scheduled downtime (hours)	152.2	68.6
Planned operations (hours)	7,816	8,547
Unscheduled downtime (hours)	288	215
Total time online (hours)	7,523	8,333
Total availability (%)	98.1%	96.7
Scheduled system availability (%)	94.5	99.2

a. Scheduled system availability [(total possible run-time – scheduled downtime) ÷ total possible run-time].

b. Total availability [(total possible run-time – scheduled and unscheduled downtime) ÷ total possible run-time)].

Table 5-17. KW Pump-and-Treat System Operation Parameters, CY 2009 and CY 2010

Total processed groundwater	**CY 2009**	**CY 2010**
Total amount of groundwater treated since January 2007 startup (million L)	667	1,054
Total amount of groundwater treated (million L)	298	387
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since January 2007 startup (kg)	83.28	137.42
Total amount of hexavalent chromium removed (kg)	49.25	54.14
Summary of operational parameters		
Removal efficiency (% by mass)	95.8%	96.9%
Regenerated resin installed (m^3)	24.9	93
New resin installed (m^3)	24.9	27
Number of resin vessel changeouts	--	41
Summary of system availability[a,b]		
Total possible run-time (hours)	8,760	8,760
Scheduled downtime (hours)	268.8	29.3
Planned operations (hours)	8,491.2	8,730.7
Unscheduled downtime (hours)	118.0	6.2
Total time online (hours)	8,372.2	8,724.5
Total availability (%)	95.6%	99.6%
Scheduled system availability (%)	98.6%	99.7%

a. Scheduled system availability [(total possible run-time – scheduled downtime) ÷ total possible run-time].

b. Total availability [(total possible run-time – scheduled and unscheduled downtime) ÷ total possible run-time)].

Figure 5-1. 100-K Area Location Map

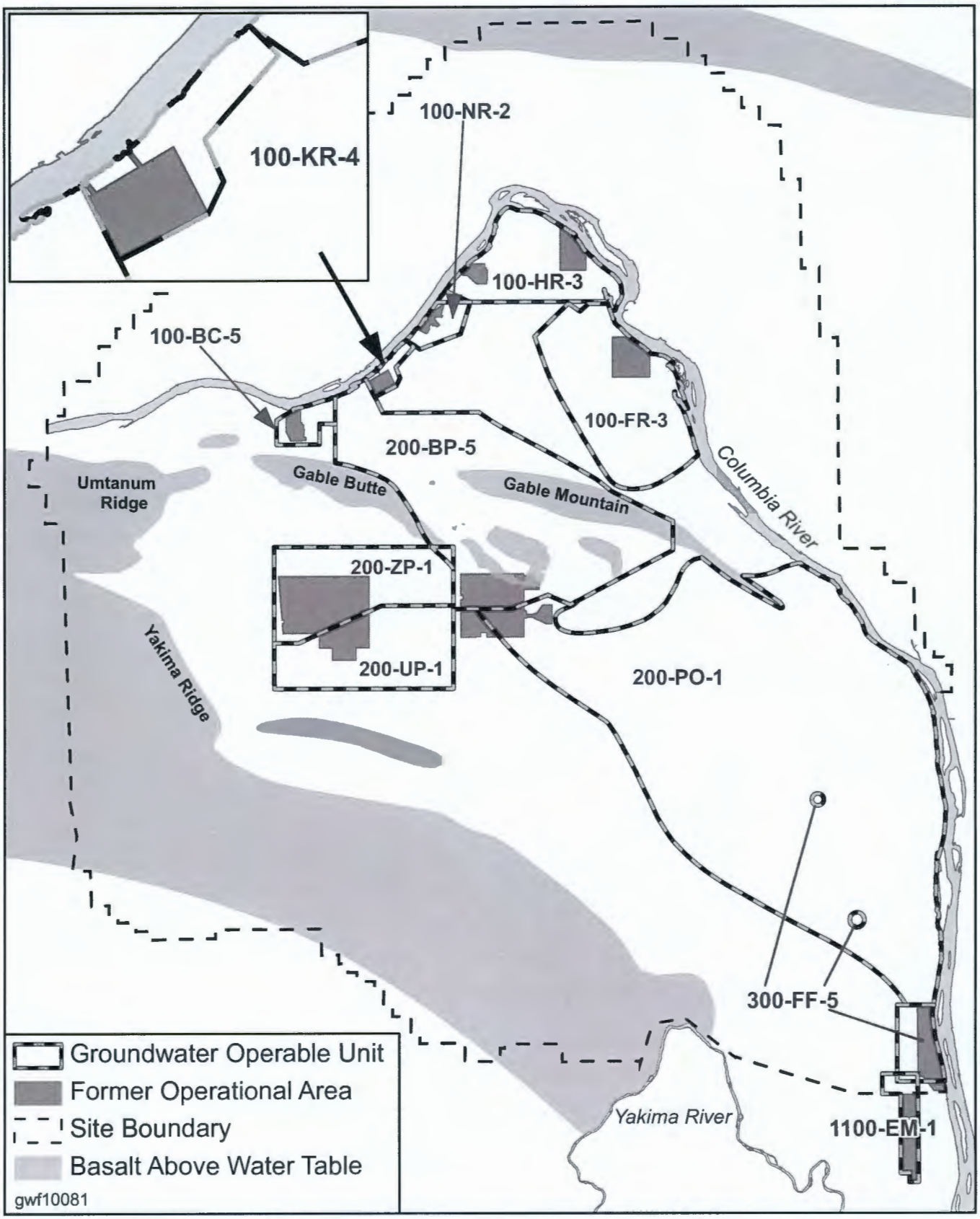
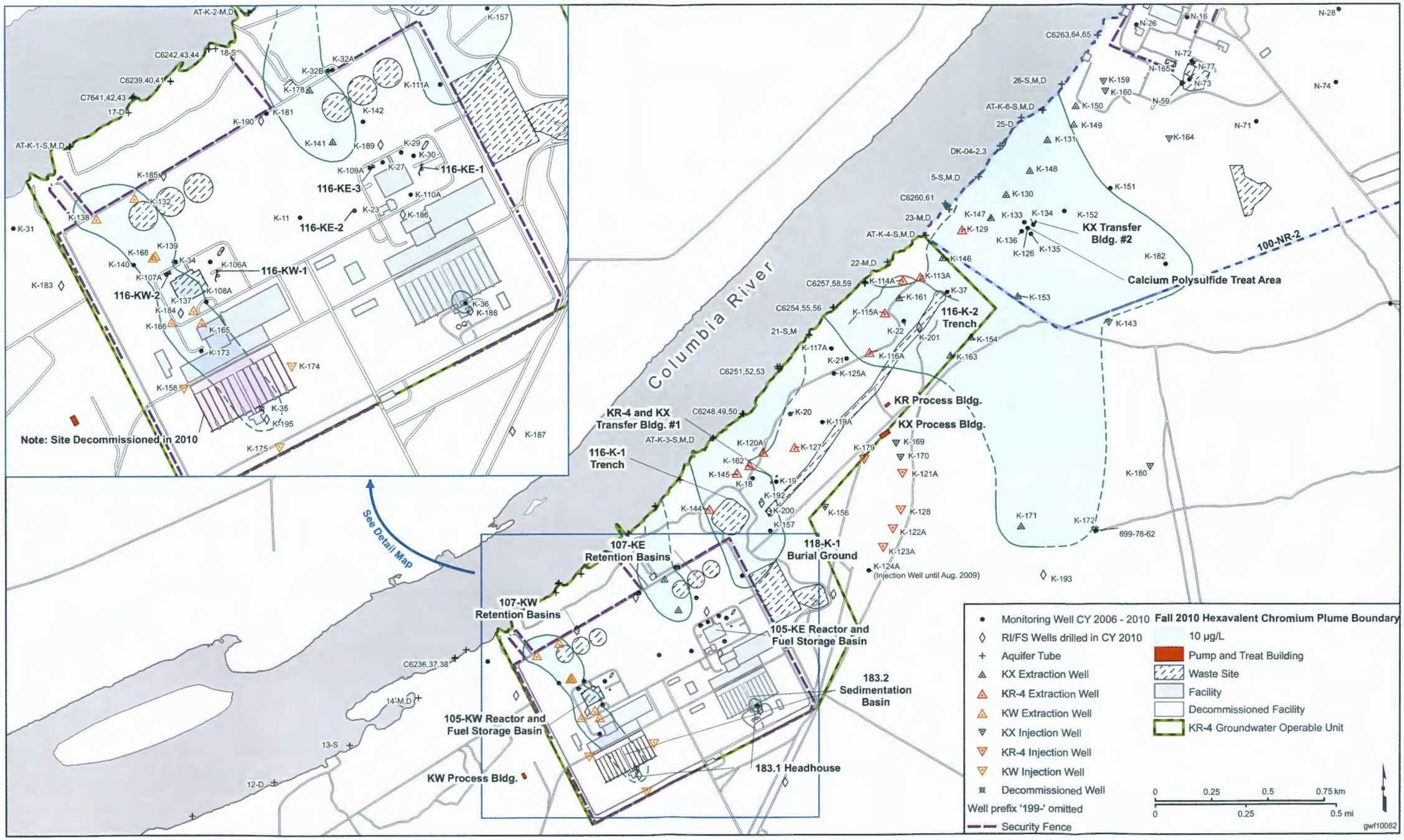
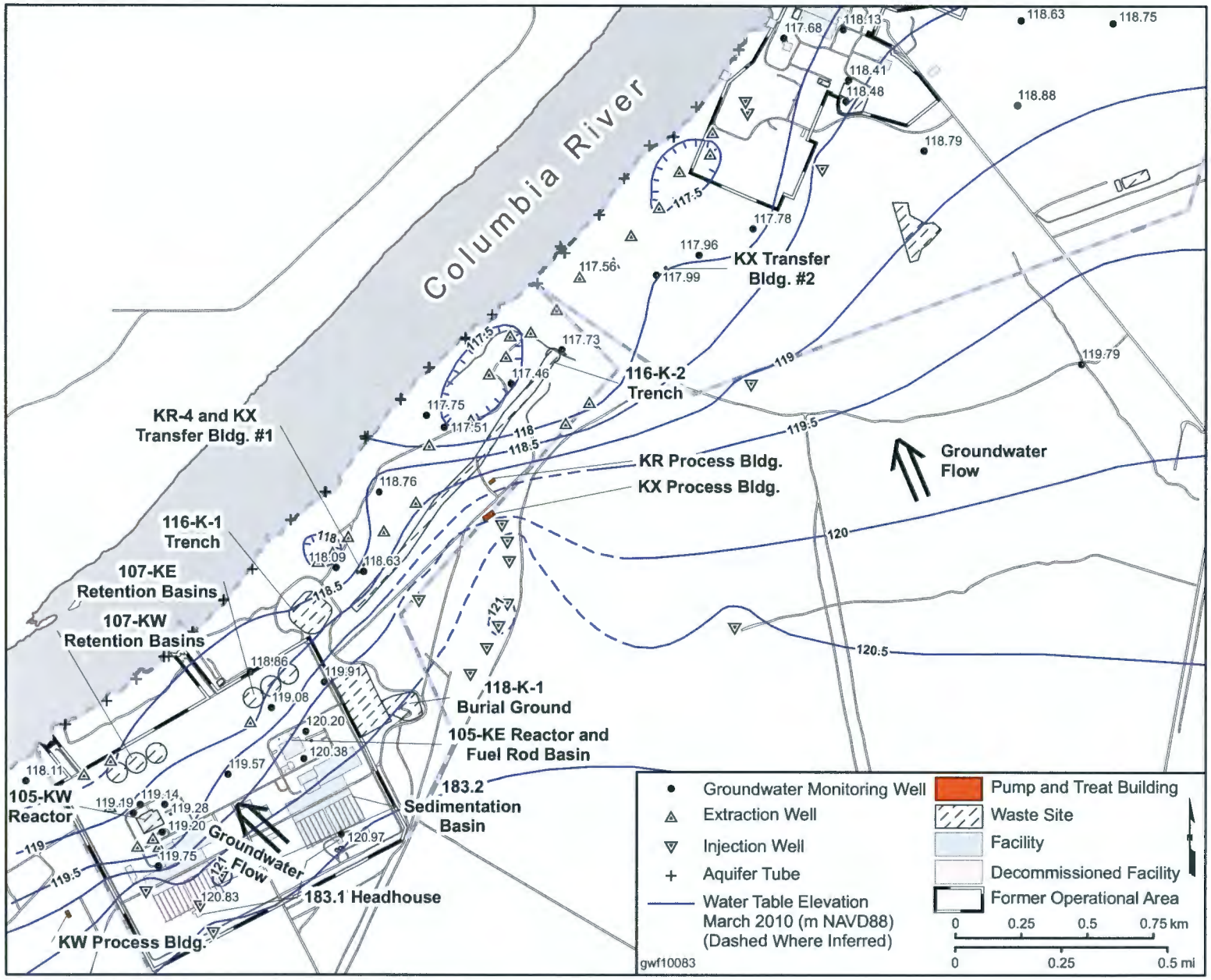


Figure 5-2. Overview of 100-KR-4 Operable Unit Wells and Facilities



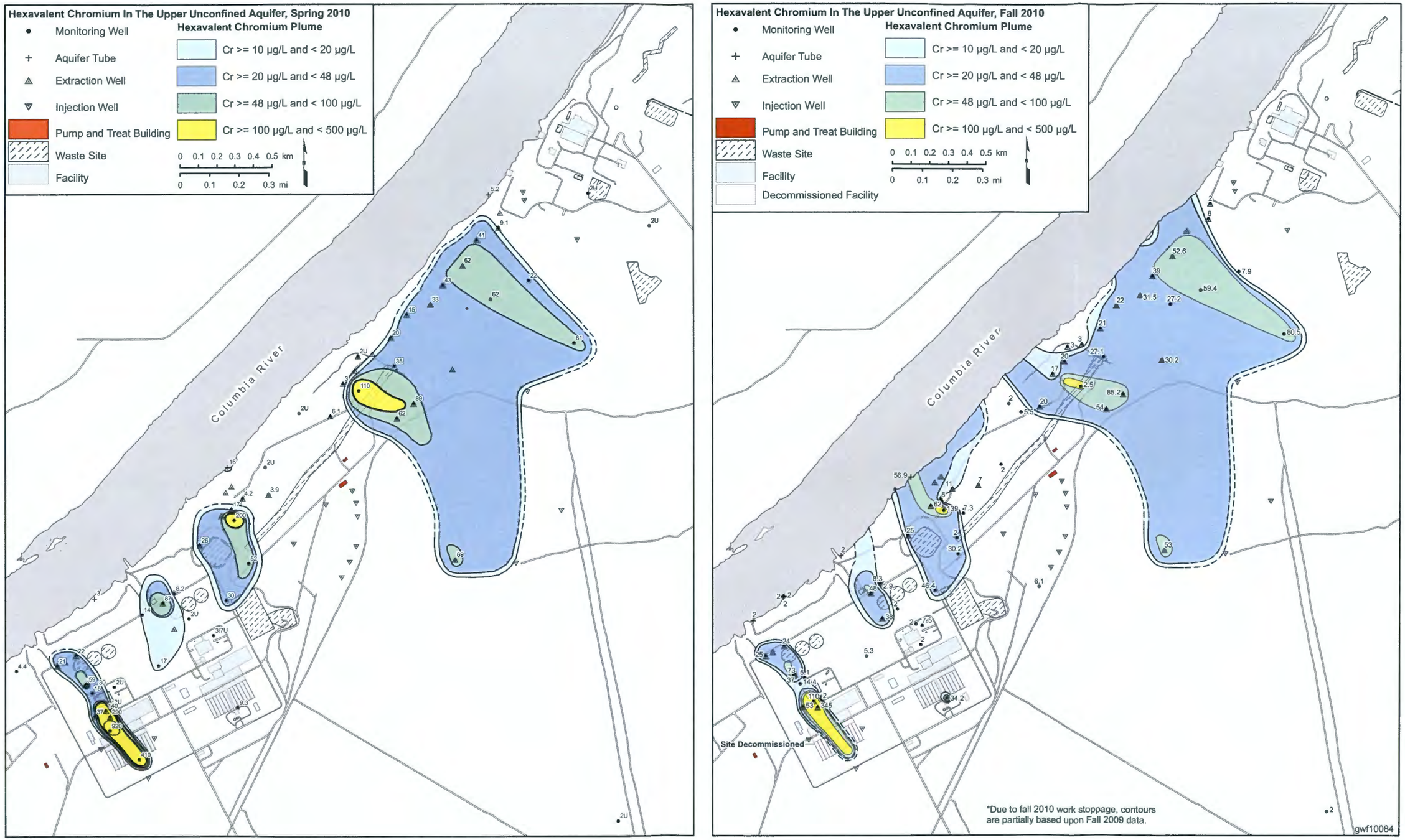
This page intentionally left blank.

Figure 5-3. Water-Level Contours at the 100-KR-4 Operable Unit



This page intentionally left blank.

Figure 5-4. Spring and Fall 2010 Hexavalent Chromium Plume Map

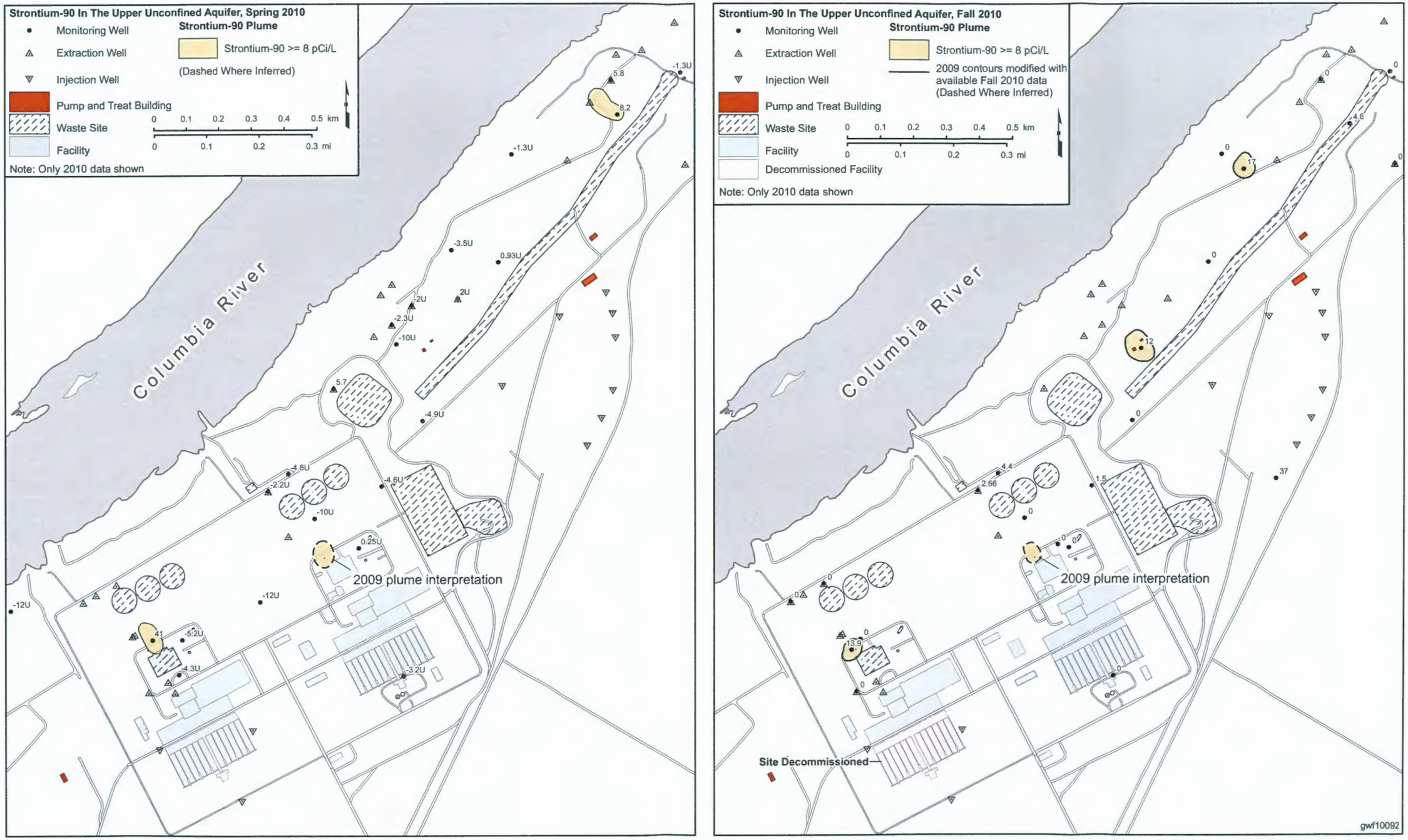


This page intentionally left blank.

Figure 5-5. Spring and Fall 2010 Tritium Plume Map

This page intentionally left blank.

Figure 5-6. Spring and Fall 2010 Strontium-90 Plume Map



This page intentionally left blank.

Figure 5-7. Spring and Fall 2010 Carbon-14 Plume Map

This page intentionally left blank.

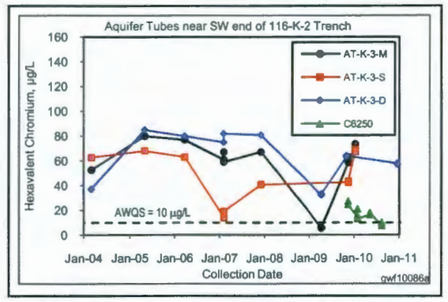
Figure 5-8. Spring and Fall 2010 Nitrate Plume Map

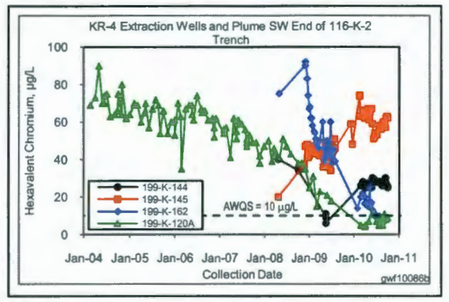
This page intentionally left blank.

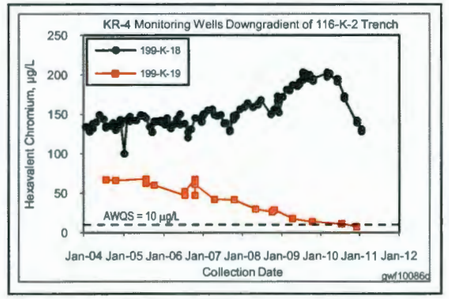
Figure 5-9. Spring and Fall 2010 Trichloroethene Plume Map

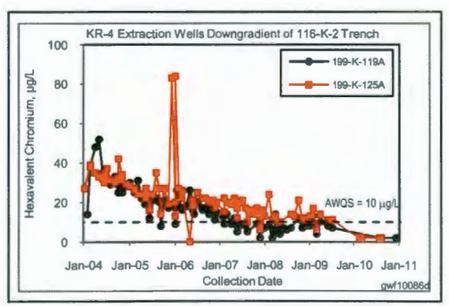
This page intentionally left blank.

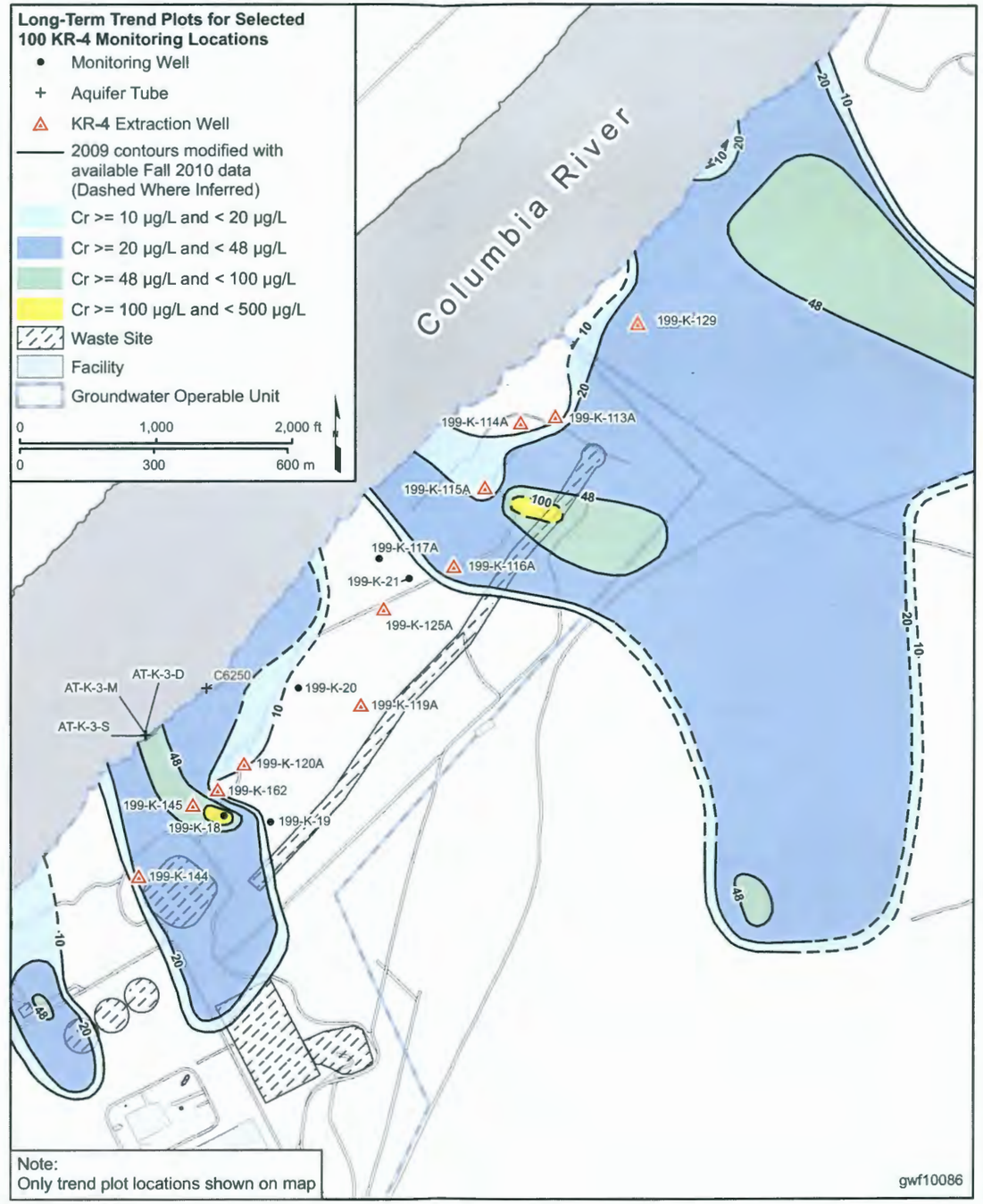
Figure 5-10. Fall 2010 Hexavalent Chromium Plume Map for KR4 Pump-and-Treat System

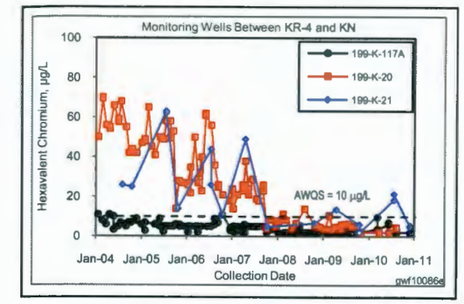


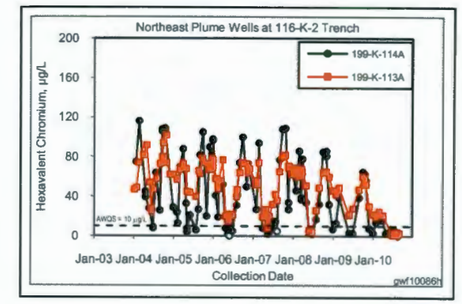


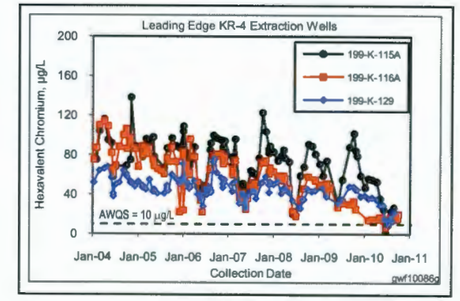






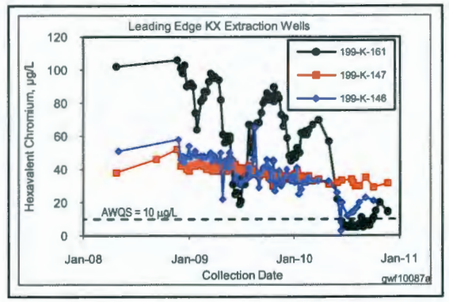


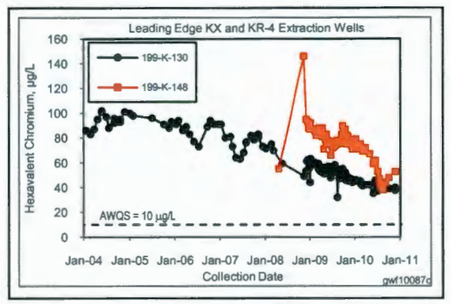


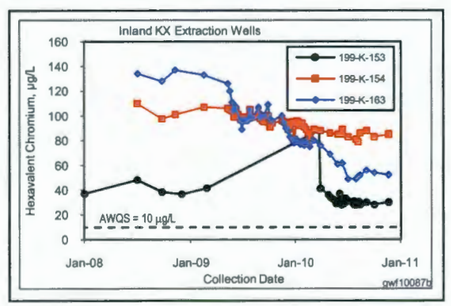


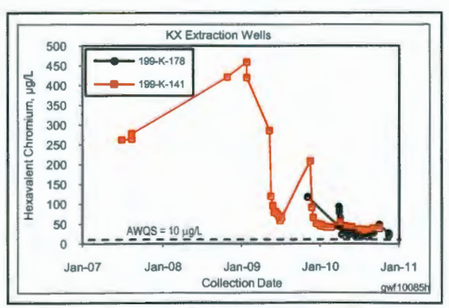
This page intentionally left blank.

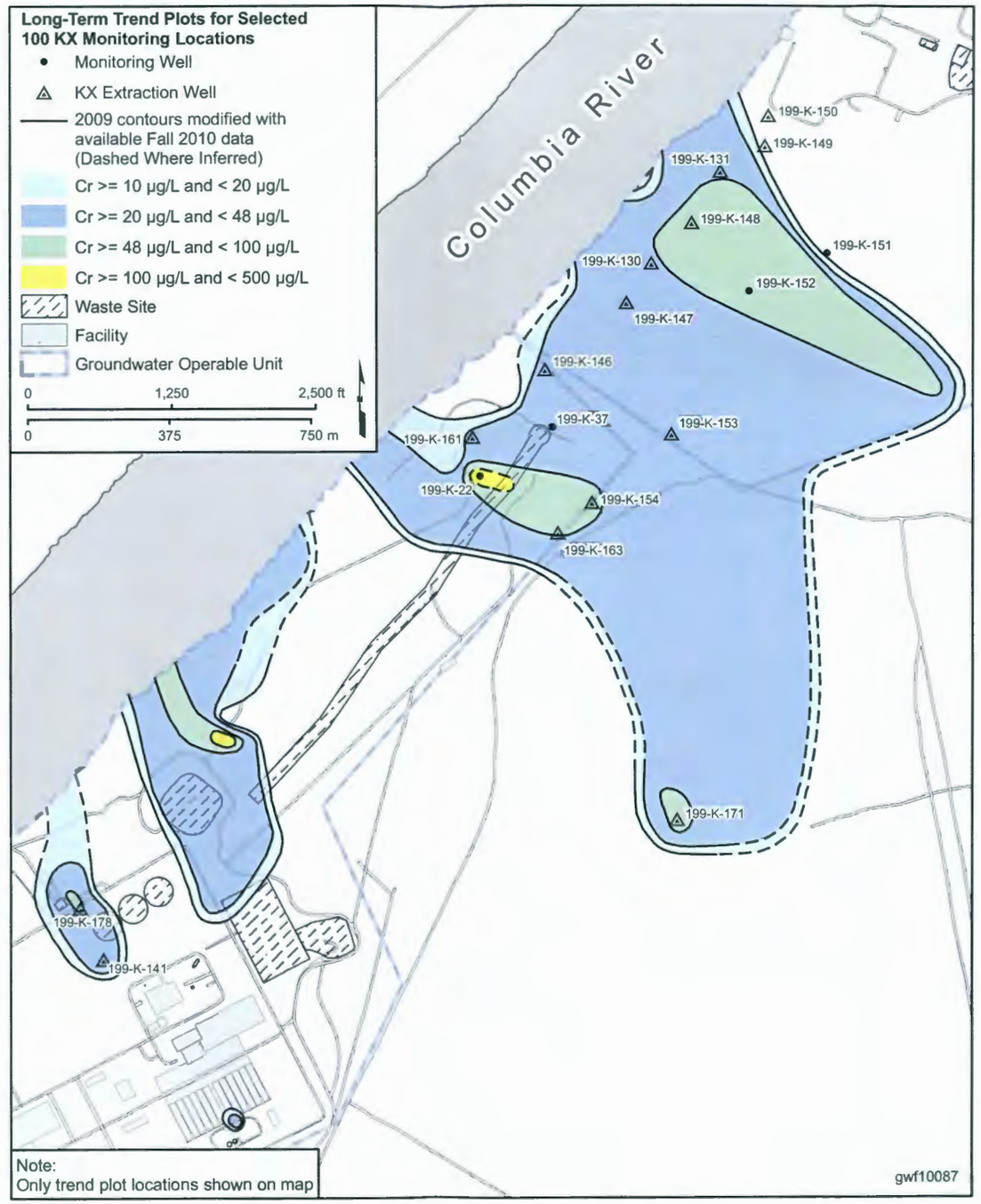
Figure 5-11. Fall 2010 Hexavalent Chromium Plume Map for KX Pump-and-Treat System

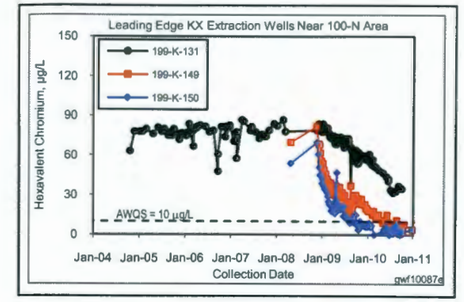


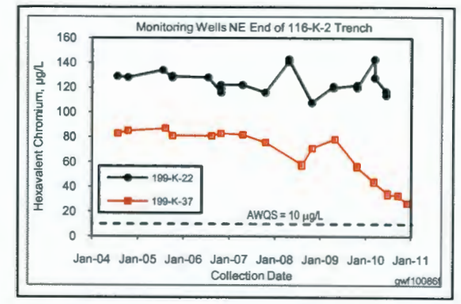


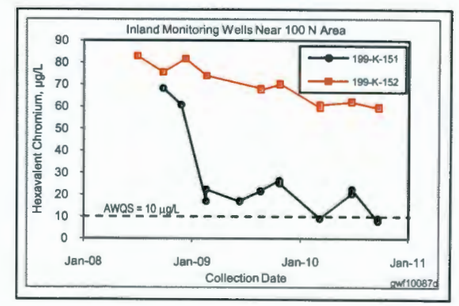






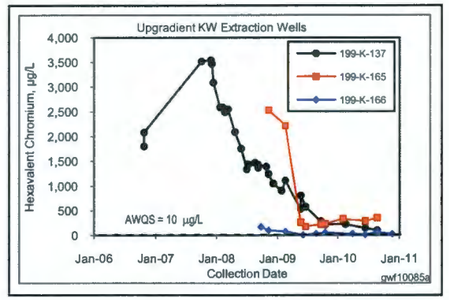


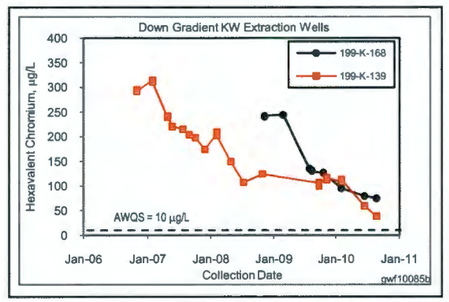


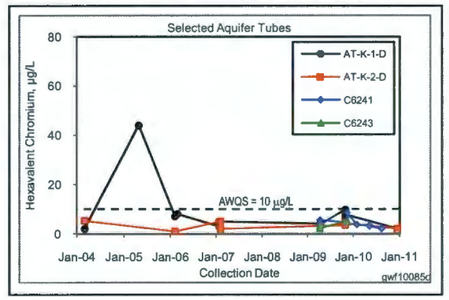


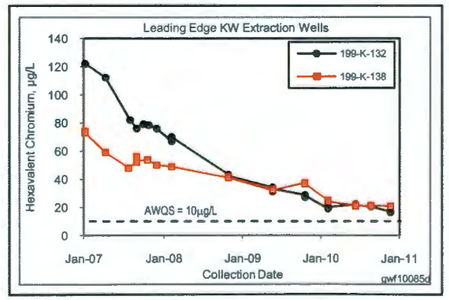
This page intentionally left blank.

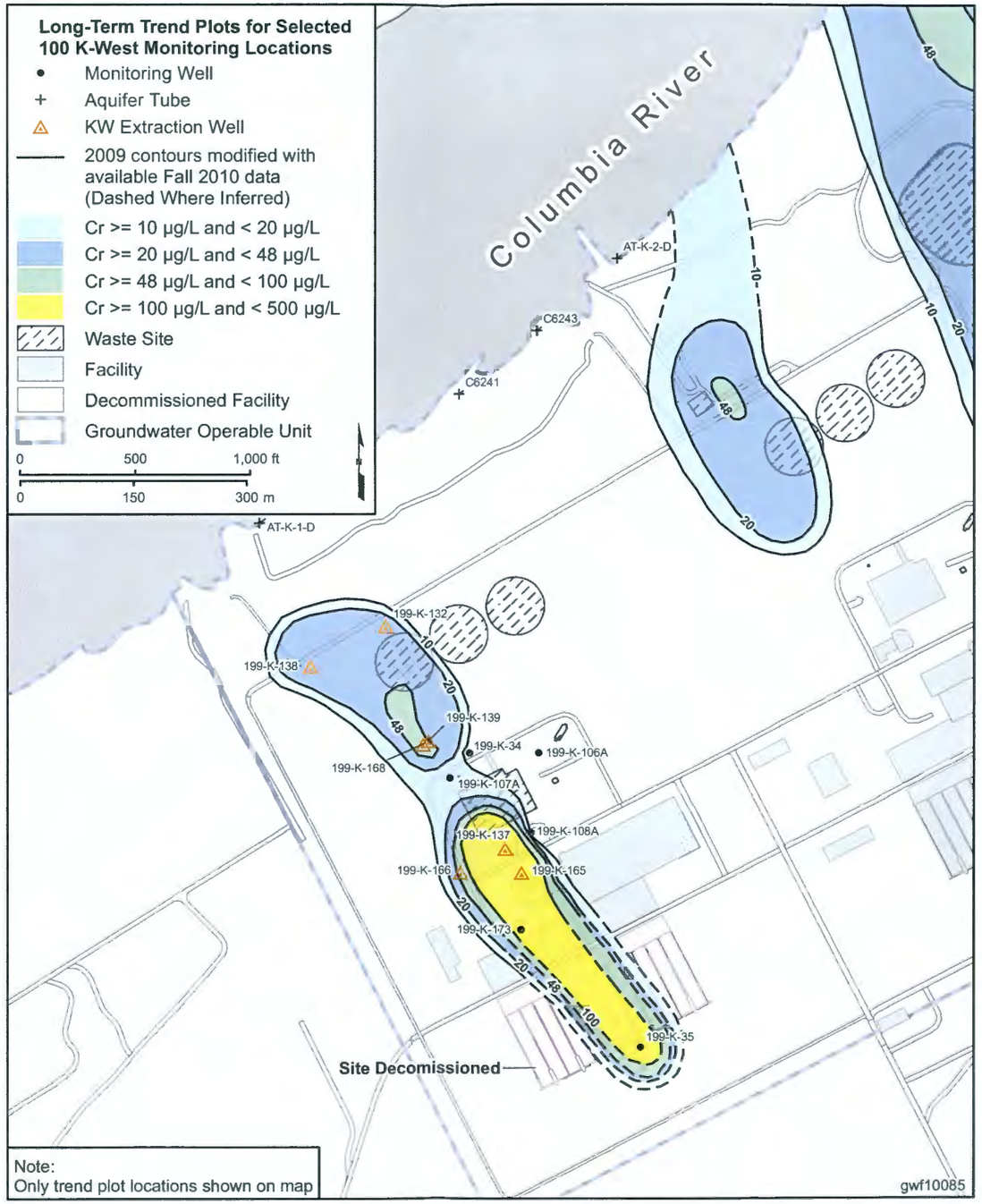
Figure 5-12. Fall 2010 Hexavalent Chromium Plume Map for KW Pump-and-Treat System

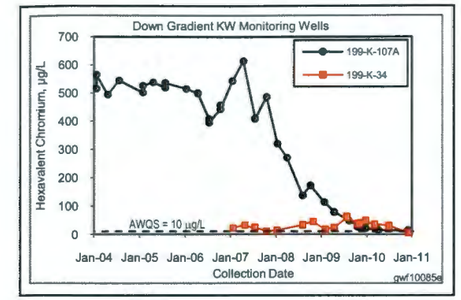


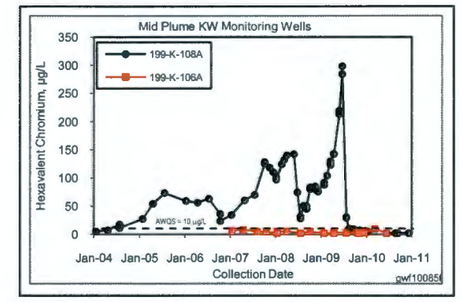


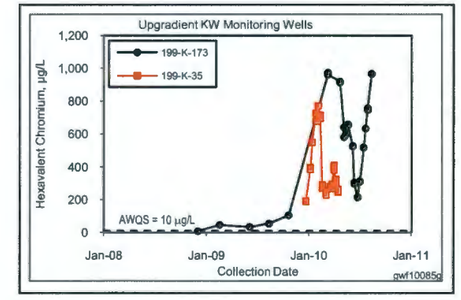












This page intentionally left blank.

Figure 5-13. Composite Capture Zone Efficiency/Effectiveness Maps for 100-KR-4 Operable Unit Pump-and-Treat Systems

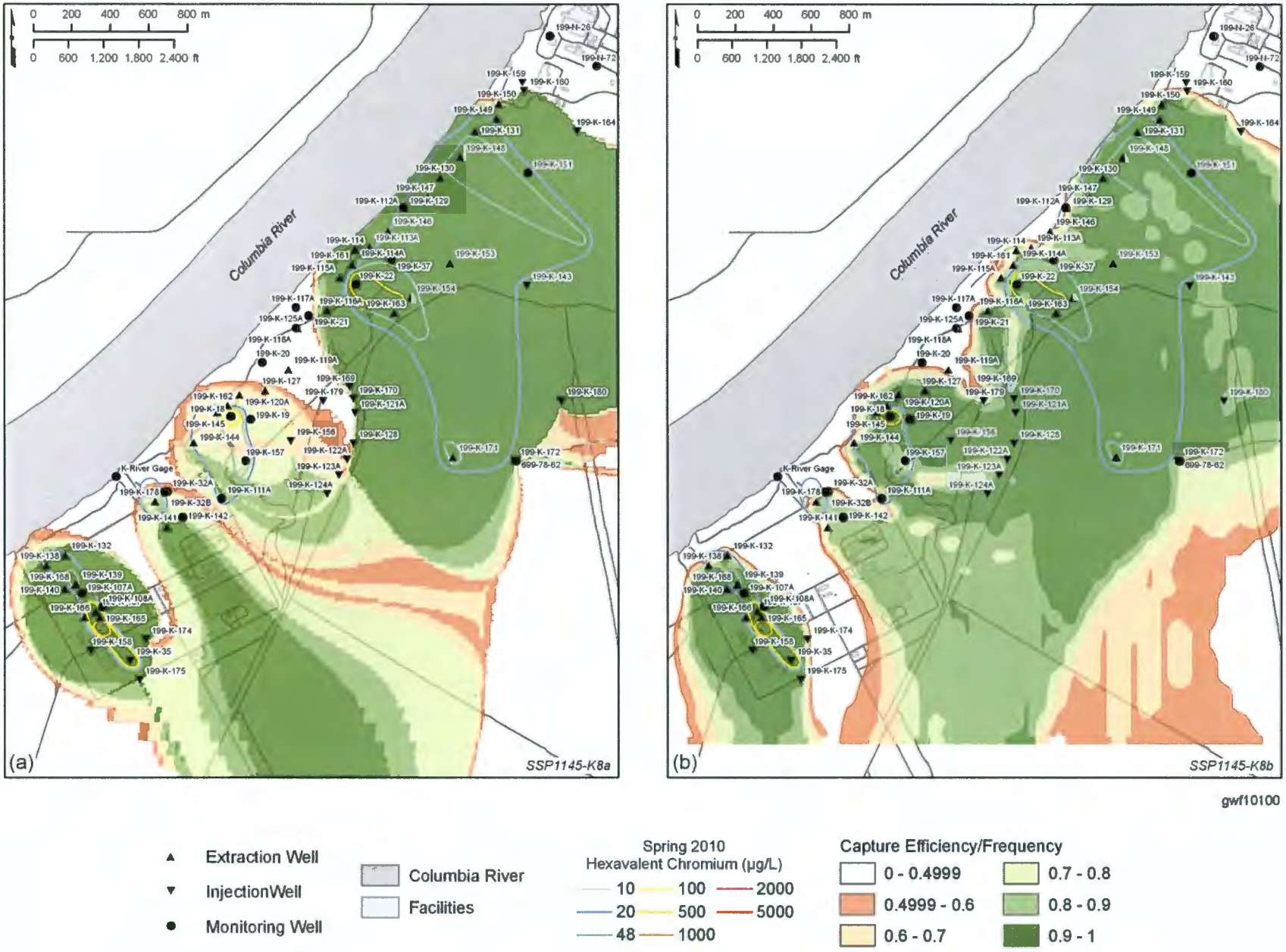
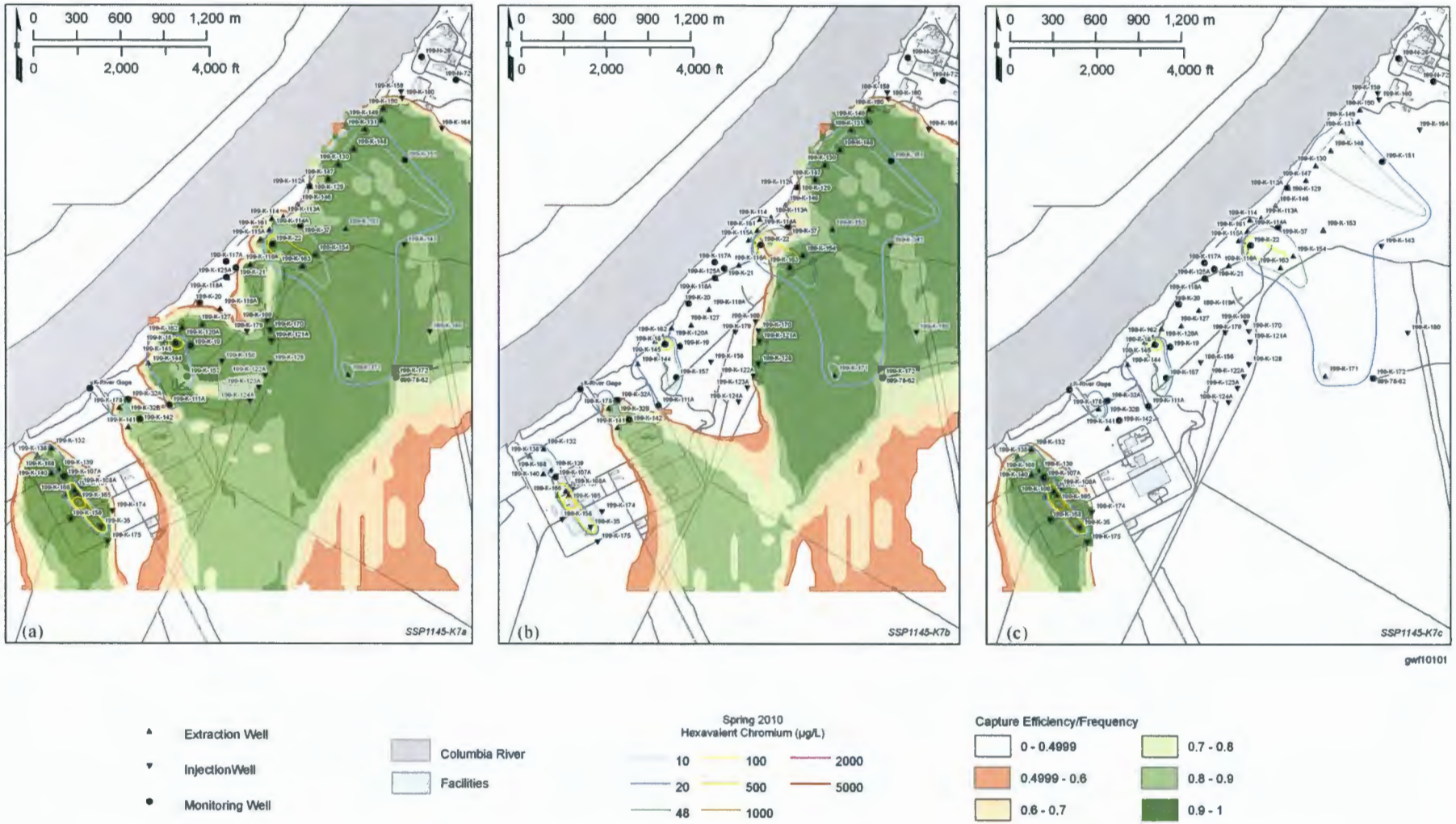
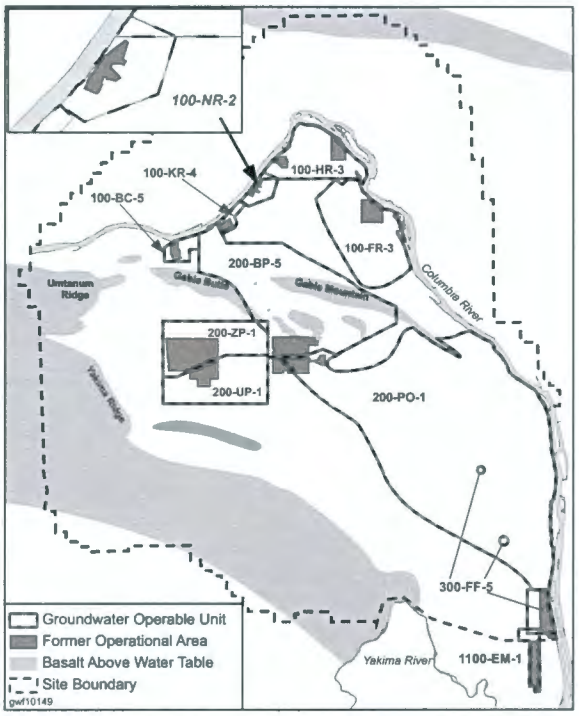


Figure 5-14. Individual Capture Zone Efficiency/Effectiveness Maps for the 100-KR-4 Operable Unit Pump-and-Treat Systems



6.0 100-NR-2 Operable Unit

D.J. Alexander



This chapter describes the groundwater conditions and contaminant distributions for the 100-NR-2 groundwater interest area and focuses on the 100-N Area and its associated facilities and operations. The 100-NR-2 Operable Unit (OU) is part of this groundwater interest area and encompasses the groundwater affected by contaminant releases from facilities and waste sites in the 100-N Area. Figure 6-1 shows the facilities and wells in the OU, and Figure 6-2 shows the shoreline monitoring locations and sites related to the apatite barrier tests performed to date at the 100-N Area.

A brief discussion on the conceptual model for the 100-NR-2 OU is provided below. Section 6.1 discusses the contaminant plumes and concentration trends in the vicinity of the 100-N Area. Strontium-90 is the contaminant of concern (COC) for a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) interim action (EPA/541/R-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). Several ongoing remedial investigation (RI) activities are working toward development of a final Record of Decision (ROD). The CERCLA activities completed during this reporting period are discussed in Section 6.2. Section 6.3 identifies the groundwater monitoring activities at the four facilities covered by the *Resource Conservation and Recovery Act of 1976* (RCRA) and the *Atomic Energy Act of 1954* (AEA) for calendar year (CY) 2010. Section 6.4 provides conclusions and recommendations for the 100-NR-2 OU. This chapter covers the period from January 1, 2010, through December 31, 2010, which is referred to in the following discussion as CY 2010.

The U.S. Department of Energy (DOE) has identified 185 waste sites in the 100-N Area; one site is closed out, 17 sites are interim closed out, one site requires no action, 10 sites are not accepted, and 27 sites were rejected, totaling 56 sites of the 185 sites (~30% of the sites) that will not need to be considered further as part of the *Integrated 100 Area Remedial Investigation Study/Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2008-46-ADD5). The high-volume waste sites include the 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities (LWDFs) and the 120-N-1 percolation pond.

The main COC in the 100-N Area is strontium-90. The areal extent of the strontium-90 plume has remained relatively unchanged from 1996 to the present. Strontium-90 contamination is found in portions of the vadose zone that were saturated during discharge operations and in the underlying aquifer extending to the Columbia River. Other contaminants in 100-N Area groundwater include tritium, nitrate, petroleum hydrocarbons, sulfate, and chromium.

The 100-N Area is underlain by the Hanford formation, the Ringold Formation unit 5, and the Ringold Formation upper mud unit. The uppermost unit, the Hanford formation, is 6 to 23 meters thick and underlies most of the area. In a few places along the shoreline lower roadway, the Hanford formation is absent due to excavation and

fill that was placed to build the road. Unit 5 of the Ringold Formation (also known as Ringold unit E) underlies the entire area and is 5 to 20 meters thick. The Ringold Formation upper mud unit also underlies the entire area and is 17 to 29 meters thick. Most of the monitoring wells in the 100-N Area are completed in the upper portion of the unconfined aquifer, which is predominately in the Ringold Formation unit 5. At high Columbia River levels, the aquifer can rise into the Hanford formation in wells along the shoreline and nearby inland wells. Three wells monitor the base of the unconfined aquifer (199-N-69, 199-N-70, and 199-N-121). Another well, 199-N-80, is completed in a fine-grained sandy unit in the Ringold Formation upper mud unit, ~12 meters below the water table. The aquifer monitored by these deeper wells is essentially free of strontium-90 contamination (i.e., nondetected or at levels barely above detection). Nitrate concentrations are higher in the upper aquifer wells than in deep wells. Tritium concentrations are about the same or lower in the deep wells. The Ringold Formation upper mud unit is the confining unit forming the base of the unconfined aquifer. Further information on the geology and hydrology of the 100-N Area is provided in Chapters 2.0 and 4.0 of the RI study/work plan (DOE/RL-2008-46-ADD5).

Groundwater flow is primarily to the north and northwest,toward the Columbia River, with flow influenced by fluctuations in the river level and the river's seasonal variations. The river stage can change daily (±1.5 meters) and seasonally (±2.4 meters) for sustained periods, which changes the saturated zone thickness and causes flow reversals (PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*). Figure 6-3 provides the March 2010 water table map for the 100-N Area. In the spring, the river level is higher than during the remainder of the year and water moves into the aquifer from the river, affecting water levels in shoreline and nearby inland wells. The water level within the soil column is elevated, and portions of the vadose zone (above average water table) are rewetted.

Vertical gradients are difficult to measure in the unconfined aquifer at the 100-N Area. The difference in water levels in well pairs 199-N-81/199-N-70 and 199-N-119/199-N-121 was only a few hundredths of a meter during CY 2010, within measurement error. The screen depths differ by ~5 to 6 meters.

Some wells for the adjacent 100-KR-4 OU pump-and-treat operation are installed in the western and southern portion of the 100-N Area. Injection wells are located between the 100-N Area (proper) and the extraction wells for the 100-KR-4 pump-and-treat systems. Placement of the injection wells was planned to put a "clean" water area between 100-N Area groundwater and the 100-K Area chromium plume further south. The wells and the pump-and-treat systems that are supported are discussed in detail in Chapter 5.0.

6.1 Groundwater Contaminants

Plume areas (square kilometers) in the 100-NR-2 Operable Unit:

Nitrate, 45 mg/L — 0.569

Strontium-90, 8 pCi/L — 0.579

Tritium, 20,000 pCi/L — 0.034

Petroleum Hydrocarbons, 1,000 µg/L — 0.009

Wells and aquifer tubes within the 100-NR-2 OU (Figures 6-1 and 6-2) are sampled for constituents of concern identified in the interim action ROD (EPA/541/R-99/112), which include strontium-90, tritium, nitrate, sulfate, petroleum hydrocarbons, manganese, iron, and chromium. Figure 6-2 shows the locations of current performance monitoring sites at the apatite permeable reactive barrier (PRB) and other planned remediation activities (see discussion in Section 6.2).

Field parameters are obtained whenever a well or an aquifer tube is sampled. Field parameters include pH, temperature, specific conductance, and turbidity on all wells/aquifer tubes. Two other parameters collected for wells/aquifer tubes under the influence of the diesel plume and the apatite barrier include dissolved oxygen and oxidation-reduction potential.

Strontium-90 is the principal COC in the 100-NR-1 OU. The plume has not changed much since 1996.

6.1.1 Strontium-90

The majority of the strontium-90 remaining in the unsaturated and saturated zones in the 100-N Area is present in the vadose zone above the aquifer. Far more strontium-90 is contained within the unsaturated zone than in the groundwater. Strontium-90 has a much greater affinity for sediment than for water (i.e., a high distribution coefficient), so its rate of transport in groundwater to the Columbia River is considerably slower than the actual groundwater flow rate. The relative velocity of strontium-90 to groundwater is ~1 to 100.

Soil data have been collected from wells and borings within and around the 116-N-1 (1301-N) and 116-N-3 (1325-N) LWDFs, as well as along the Columbia River shoreline. Strontium-90 is generally distributed in a layer around the current water table, mostly in the upper portion of the Ringold Formation unit 5. This layer is thickest around the LWDFs (up to 12.2 meters) and thins toward the Columbia River (1.5 to 6.1 meters). Strontium-90 concentrations in soil from wells/borings near the LWDFs show a decreasing trend with distance and depth from the LWDFs. The majority of strontium-90 contamination within the LWDFs was retained within the facilities (nearer the head end and immediately below the base). The LWDFs were interim remediated in 2005 and 2006, and contaminated concrete and soil were removed to a depth of 4.6 meters. The sites were backfilled in 2006 (DOE/RL-2006-76, *Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*).

Strontium-90 concentrations in soil samples collected from the wells/borings further from the LWDFs along the 100-N Area shoreline indicate that the majority of strontium-90 is located in the top of the Ringold Formation unit 5 and the bottom of the Hanford formation. The water table near the Columbia River is located in the top of the Ringold Formation unit 5 during low river-level conditions (July through March), but the water table can rise up into the Hanford formation when river levels are elevated (late March/April to June). This causes the strontium-90 contamination to smear vertically within the areal extent of the plume (PNNL-16891). The majority of the contamination in soil along the Columbia River is in the immediate vicinity of the current apatite PRB, between wells 199-N-123 to 199-N-121 (PNNL-16894, *Investigation of the Strontium-90 Contaminant Plume Along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*).

The size and shape of the strontium-90 plume in groundwater has varied little over the years due to the way strontium and strontium-90 act in the environment. The plume currently has nearly the same areal extent and shape as in 1996, prior to startup of 100-N Area pump-and-treat operations. Effluent discharge totals of strontium-90 to 116-N-1 and 116-N-3 LWDFs from 1964 through 1993 were slightly more than 2,997 curies. As of 2010, this amount was ~1,325 curies, corrected for radioactive decay (DOE/RL-2008-46-ADD5). The 2010 value does not reflect any contamination that was removed during the 2005/2006 excavation of the 116-N-1 and 116-N-3 LWDFs; therefore, some of the remaining 1,325 curies have been removed to the Environmental Restoration Disposal Facility. In a previous calculation for the 116-N-1 Crib and Trench sediments (BHI-00368, *Data Quality Objectives Workshop*

Results for 1301-N and 1325-N Characterization), the strontium-90 inventory was estimated at 500 curies, assuming an average strontium-90 concentration from soil analyses, distributed through a 1-meter-thick crib/trench/vadose zone interface (DOE/RL-2008-46-ADD5). Of the inventory remaining, ~99% is absorbed on the soil in the vadose zone and upper aquifer and 1% is actually in groundwater (PNNL-16891). The plume extends from beneath the 116-N-1 and 116-N-3 LWDFs to the Columbia River at levels exceeding the drinking water standard (DWS) of 8 pCi/L (Figure 6-4). Concentrations exceeding 100 pCi/L are limited to the upper ~3 meters of the aquifer (PNNL-16436, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*). Concentrations in several wells and aquifer tubes exceeded the DOE's derived concentration guideline of 1,000 pCi/L (which is the reference value given for conducting radiological environmental protection programs at DOE facilities per DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, Chapter 3).

The highest strontium-90 concentrations along the Columbia River in soil and groundwater are found near the current apatite PRB and immediately downriver to the northeast. This area is the focus of increased monitoring and remediation activities. Figure 6-5 depicts the strontium-90 concentrations at the 100-N Area shoreline in the area affected by the current apatite PRB. Figures 6-6 and 6-7 show the effects of the apatite PRB on strontium-90 concentrations. The barrier helped to reduce strontium-90 concentration in its immediate vicinity, including wells within the barrier itself, on both sides of the injection wells on each end of the barrier, and monitoring wells downgradient of the barrier. It also includes one well upgradient of the barrier; 199-N-46 has shown a decrease in strontium-90 concentration from a high in September 2006 of 6,040 pCi/L to 530 pCi/L in April 2010. Prior to apatite PRB installation, strontium-90 concentrations in this well were consistently above 1,000 pCi/L; however, since December 2008, the concentration has been below 650 pCi/L. Strontium-90 concentrations in all of the wells and aquifer tubes are less than those reported in last year's annual report (DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*). Several of the wells were nondetect for strontium-90 in 2010. All but one monitoring point are below 1,000 pCi/L; tube NVP2-116.0m remained at 1,200 pCi/L as of December 2010. Some variability in concentration is based on the depth of well completion but, overall, the values are well below pre-treatment levels. The effects of the apatite PRB are discussed in greater detail in Section 6.2.4.

Strontium-90 in monitoring wells near the former 116-N-1 LWDF and the former 116-N-3 LWDF show no obvious long-term decline in concentrations, but concentrations do vary significantly in relation to water levels within the wells (Figures 6-8 and 6-9, respectively). Water levels were significantly higher below the LWDFs in the 1980s and early 1990s, when discharges were still occurring. As the water level decreased, strontium-90 remained in the vadose zone above the water table. Therefore, when the water table rises beneath the former LWDFs, strontium-90 from the vadose zone is remobilized and the concentrations in groundwater increase. Levels have been consistent for the last few years, with the increase and decrease of strontium-90 concentrations mirroring changes in the water table elevation. Seven wells are showing increasing strontium-90 concentration trends: three wells are former 100-N Area pump-and-treat extraction wells (199-N-75, 199-N-103A, and 199-N-105A); three wells (199-N-2, 199-N-67, and 119-N-14) are downgradient of the 116-N-1 LWDF; and the fourth well, 199-N-122, is a monitoring well in the apatite PRB. Well 199-N-122 is located in one of the most contaminated portions

of the shoreline. The concentrations in all seven of these wells have increased since the pump-and-treat system shutdown in 2006. Six of the seven wells have higher concentrations now than in 1996, before the pump-and-treat system was started. It appears that the increase may be due to a rebound effect that has been occurring since pump-and-treat operations ceased. Another possible explanation is that higher river levels in the last few years have caused the lower vadose zone to be rewetted and allowed remobilization of strontium-90 from these contaminated sediments. As the river level and aquifer levels decrease, this contamination is smeared back down into the aquifer and could cause higher concentrations in the monitoring wells over time. This effect will be studied further in next year's report to determine if it is contributing to the uptrend observed in these six wells. Well 199-N-122 is the only exception, because it was not drilled and installed until October 2005, and the concentration of this well is under the influence of the apatite PRB. As the development of apatite continues along the barrier, changes occur in strontium-90 concentrations due to interaction with nearby treated wells and changes in river stage, remobilizing strontium-90 from rewetted contaminated sediment above the water table. All other wells in the 100-N Area that were monitored in 2010 are showing slight downward strontium-90 trends.

Figure 6-6 shows the screened intervals of aquifer tubes and near-shore wells in a cross section parallel to the Columbia River and illustrates strontium-90 concentrations with depth. Strontium-90 concentrations greater than the DWS are present only above ~115 meters in elevation (i.e., the top 2 to 3 meters of the aquifer). Although few aquifer tubes are completed at elevations less than 115 meters, the majority of the aquifer tubes completed below this elevation are in the area where strontium-90 concentrations along the river are known to be highest. Therefore, if the lower elevation tubes in this area are free of strontium-90 contamination, it is likely the adjacent areas along the river shore will also be free of strontium-90. Appendix C provides additional information on 100-N Area aquifer tube sampling. Figure 6-7 depicts the same information for the apatite PRB area. Some of the strontium-90 values shown in these graphs were calculated as half of a gross beta value where strontium-90 data were not available. This is an accurate representation of potential strontium-90 values, as there are no other competing beta emitters to consider, and previous studies performed at the 100-N Area have confirmed that this is a reliable calculation (PNNL-16894).

Figure 6-10 shows the strontium-90 depth profiles through the "NVP" cluster of aquifer tubes for the three sampling periods in CY 2010. The highest concentrations were at the elevation of 116.0 to 116.3 meters. Along the river shore in the 100-N Area, the 116.0 meter elevation (±1 meter) is the elevation where the aquifer intersects the river. During the porewater sampling conducted by Washington Closure Hanford (WCH) (from 2008 through 2009) and CHPRC (in 2010) along the 100-N Area shoreline, the majority of the groundwater detections were in this elevation range. The elevated strontium-90 values also correlate with higher conductivity readings in most cases for the sample collected. However, not every higher strontium-90 value has a corresponding higher conductivity value; in several samples from both elevations, conductivity increased and strontium-90 concentrations decreased.

Figure 6-11 shows the historical ranges and the March/April 2010 strontium-90 concentrations in 100-N Area aquifer tubes. The aquifer tubes located from Array-3A to Array-6A have historically had the highest and the widest ranges of concentrations. All of these tubes are completed at the 116.0 meter elevation, which is the elevation where most of the highest strontium-90 concentrations are found and the elevation

where groundwater most often intersects the Columbia River (see discussion in previous paragraph). The variability in concentrations in these four tubes is due to the effects of ongoing apatite PRB remediation (Section 6.2.4).

Figure 6-12 shows strontium-90 and gross beta concentrations over time in tube NVP2-116.0, where concentrations are typically the highest of any of the aquifer tubes. The top panel in the figure shows peaks in concentrations caused by mobilization of strontium-90 following chemical injections in 2007 and 2008 (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). The lower panel in the figure shows the trend without the larger peaks, so smaller trends are more discernable. Strontium-90 concentrations increased in early 2009 and subsequently dropped to ~1,000 pCi/L by December 2009. Fluctuations in concentrations also occurred in CY 2010, but the overall trend from 2006 through 2010 was downward. Gross beta values were greater than 5,000 pCi/L in early 2006 before apatite injections began. As of December 2010, the gross beta concentration had decreased to 2,600 pCi/L and the strontium-90 concentration had decreased to 1,200 pCi/L.

Samples were collected in five sets of aquifer tubes as part of the RI/feasibility study (FS) work in the 100-N Area (TPA-CN-353), which are discussed in Section 6.2.8.

6.1.2 Tritium

The source of the tritium in groundwater at the 100-N Area is from past-practice disposal operations associated with the N Reactor. Liquid effluent disposed to the 116-N-1 and 116-N-3 LWDFs contained tritium. Tritium is nonreactive with subsurface sediments, so tritium in effluent wastewater migrated quickly through the vadose zone without leaving residuals. Unlike strontium-90, tritium is present throughout the entire thickness of the unconfined aquifer. Concentrations in wells 199-N-69 and 199-N-70, which are completed at the base of the unconfined aquifer, are similar to nearby wells completed in the upper unconfined aquifer (DOE/RL-2010-11). The tritium concentration in well 199-N-80, completed in a confined aquifer in the Ringold Formation, was 13,000 pCi/L in 2010, which is less than the CY 2009 reported value of 16,000 pCi/L.

The tritium plume has diminished since 1991, when effluent discharge to the 116-N-3 LWDF ceased. The plume currently covers the area beneath both the 116-N-1 and 116-N-3 LWDFs and stretches north and northeast to the Columbia River shoreline. Figure 6-13 shows the data averages for CY 2010, and Figure 6-14 shows the tritium concentration between the wells near 116-N-1 (199-N-14) and 116-N-3 (199-N-32) LWDFs. The overall trend for tritium concentration near these former disposal facilities is slowly decreasing. In CY 2010, tritium concentrations were below the 20,000 pCi/L DWS in all wells. The highest tritium concentration in a 100-N Area well was 17,500 pCi/L in well 199-N-32 (Figure 6-14).

Nitrate concentrations continued to exceed the DWS in several wells and in some wells downgradient of the 116-N-1 LWDF in 2010.

6.1.3 Nitrate

The source of the nitrate plume at the 100-N Area is not well known. Based on information gathered to date, it is not believed that the source of nitrate contamination is from any past-practice effluent disposal at the 100-N Area. However, efforts continue to identify the source(s) of the plume, which include evaluating facility effluent streams, septic systems, and disposal sites (DOE/RL-2008-46-ADD5). Data collected from the 100-N Area RI/FS effort will be used to further identify the possible sources of the nitrate plume, including any sources located within the 100-N Area.

Nitrate concentrations exceed the 45 mg/L DWS in eighteen wells in the 100-N Area (Table 6-1). The majority of these wells are found near the 116-N-1 and 116-N-3 LWDFs. The nitrate plume lies under the former 116-N-1 and 116-N-3 LWDFs, under portions of the southwest 100-N Area (the reactor and associated buildings), and extending to the Columbia River below well 199-N-21. Figure 6-15 shows the average nitrate concentrations in the upper unconfined aquifer of the 100-N Area.

Figure 6-16 provides nitrate trend plots for two wells near the former 116-N-1 LWDF and includes the entire recorded history for these two wells. Figure 6-17 provides the nitrate trend plot for a well near the 116-N-3 LWDF. At both sites, nitrate concentrations were high in the mid- to late 1980s, declined sharply in the early1990s, and have been generally increasing since that time. As shown in Figure 6-16, both wells 199-N-2 and 199-N-67 showed increased concentrations in CY 2010. As shown in Figure 6-17, well 199-N-32 showed an overall decrease in CY 2010.

Figure 6-18 shows the nitrate concentrations for three wells near the 120-N-1 percolation pond and includes the entire recorded history for these wells. (Note that well 199-N-59 went dry and was replaced by well 199-N-165 in 2008.) Nitrate concentrations at this location have also increased since the early 1990s. During the 120-N-1 percolation pond's period of use from 1977 to 1990, only low levels of nitrate (~1 mg/L) were detected in the pond's effluent stream (DOE/RL-96-39, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*). When monitoring began in 1987, the nitrate concentrations in groundwater were low at 1 to 4 mg/L. Nitrate levels have exceeded the 45 mg/L DWS in well 99-N-59 (1998 to 2008) and also in replacement well 199-N-165 (but only for the first sample in 2009). Nitrate levels in well 199-N-72 exceeded the DWS from 2005 through 2008 (DOE/RL-2008-66). The source of the nitrate plume and the reason for the increasing concentrations are unknown.

Wells 199-N-18 and 199-N-16 have variable nitrate trends that are believed to be related to chemical reduction and biodegradation of hydrocarbons (DOE/RL-2010-11). The lower concentrations are believed to be caused by chemical reduction of nitrate due to biodegradation of petroleum hydrocarbons near the well (Section 6.1.4). Other chemical constituents and parameters that support the interpretation of chemical reduction in and around well 199-N-18 include low dissolved oxygen, low pH, detectable nitrite, and elevated concentrations of iron and manganese.

Aquifer tubes C6132 and C6322 had nitrate concentrations greater than the DWS in 2009, at 46 and 64.6 mg/L, respectively. Aquifer tube C6132 was not sampled in CY 2010. Aquifer tube C6320 had a value of 48.3 mg/L in September but decreased to 11.6 mg/L in December. Aquifer tubes C6317, C6318, and C6319 had respective values of 17, 41.7, and 753 mg/L (data flagged as suspect) in August and values of 31.7, 44.7, and 40.7 mg/L in September.

6.1.4 Petroleum Hydrocarbons

Petroleum hydrocarbon from a 1960s diesel fuel tank spill (UPR-100-N-17) continues to be detected in 100-N Area groundwater. The full nature and extent of subsurface hydrocarbon impacts in the UPR-100-N-17 waste site has not been determined (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). The petroleum hydrocarbon plume in groundwater (shown in Figure 6-19; data from spring through fall of CY 2010) is confined to a relatively small region in the 100-N Area and is centered on well 199-N-18 with a concentration of 420,000 µg/L.

The diesel plume in the 100-N Area has been further defined due to increased groundwater and vadose zone work. The groundwater plume has a limited extent and stems directly from spills in and around the former 166-N Tank Farm facility.

This represents a substantial increase from the CY 2009 value of 16,000 µg/L and may be due in part to two activities: (1) this well did not have as much active removal of free product in CY 2010 as in previous years, and (2) WCH began testing bioventing on the vadose zone in the area immediately east and southeast of this well. These activities are discussed later in this section. In a sample taken at well 199-N-18 on December 5, 2010, the concentration had decreased to 41,000 µg/L. Total petroleum hydrocarbon-diesel detections occurred in seven other nearby wells at the following concentrations:

- Well 199-N-167 at 4,600 µg/L
- Well 199-N-169 at 1,100 µg/L
- Well 199-N-170 at 360 µg/L
- Well 199-N-171 at 2,800 µg/L
- Well 199-N-172 at 25,000 µg/L
- Well 199-N-173 at 2,100 µg/L
- Well 199-N-96A at 200 µg/L.

Wells 199-N-167, 199-N-169, 199-N-170, 199-N-171, and 199-N-172 are part of the system installed to test bioventing techniques on the vadose zone in the area near the main diesels spills that occurred in the 100-N Area. Wells 199-N-96A and 199-N-173 are located immediately downgradient of the spill area and these other wells.

The DOE continued passive remedial actions to remove free product from well 199-N-18. Passive remediation involves the use of a polymer "smart sponge" that selectively absorbs petroleum products from the surface of the water within the well. Every 2 months, two of the sponges are lowered into the surface of the aquifer in well 199-N-18 and left in place to soak up the diesel fuel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of "product," or diesel fuel contamination, removed from the well. Table 6-2 shows the results of this remediation activity since it began in 2003. Removal of product from well 199-N-18 continued in CY 2010 in accordance with the interim action ROD (EPA/541/R-99/112); however, this did not occur during the entire CY. In mid-June 2010, one of the smart sponges came apart inside the well (the package containing the polymer was breached), which created a slime coating everything in the well, and made sampling or product removal very difficult. Well maintenance staff was able to remove a great deal of the sponge material, but the removal process smeared the material inside the well casing as it was removed. In July, the well was sampled before the well maintenance crew could finish cleaning the well. The diesel contamination value from this sampling event (July 9, 2010) is reflected on the plume map as the highest value measured in the well in CY 2010. The well was cleaned further with some success, but it was decided to replace well 199-N-18 based on the *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27). This decision was made for two main reasons: (1) low water level in the well makes sampling difficult and requires the use of a bailer, and (2) the inability to completely remove the smart sponge material from the well will cause long-term potential for interference with sampling and the quality of samples that can be collected. Well 199-N-18 will be kept for continued product removal because that particular process is not affected by the residual smart sponge material on the well casing. Smart sponges were reinstalled in well 199-N-18 in January 2011 and product removal from the well continues.

Low levels of hydrocarbon contamination have previously been observed in wells 199-N-3, 199-N-16, 199-N-19, and 199-N-96A (PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*). Previous detections in the 1990s were also found in wells 199-N-17 and 199-N-20 (both have been decommissioned). Wells that did not have detectable levels of diesel-range total petroleum hydrocarbons in CY 2010 were 199-N-3, 199-N-19, 199-N-21, 199-N-56, and 199-N-57. These wells bound the area of the diesel spill contamination and are indicators that the extent of contamination in groundwater is most likely limited to the area northwest and southeast of well 199-N-18.

When the apatite PRB expansion wells were drilled in 2009 and 2010, three of the wells in the vicinity of 199-N-173 and 199-N-96A had detections of petroleum hydrocarbon odors and staining of soils immediately above and into the water table.

- Well 199-N-346 (C7442), a monitoring well located between wells 199-N-173/ 199-N-96A and the two barrier wells on the uppermost end of the PRB expansion
- Well 199-N-201 (C7326)
- Well 199-N-200 (C7327).

These three wells have not been included in the plume map for this report, as they have only been sampled once and were not sampled at the same time. Shallow well 199-N-200 (completed in the Hanford formation) only contains water during high river stage. With the expansion of the apatite PRB scheduled within the next couple of years, these wells and others in the vicinity of wells 199-N-173 and 199-N-96A will have more samples taken and provide additional information on the extent of the petroleum hydrocarbon plume along the 100-N Area shoreline below well 199-N-18. The borehole logs for these wells are provided in the borehole summary report for the 171 wells installed for the apatite PRB expansion (SGW-47791, *Borehole Summary for the Installation of One Hundred and Seventy One Wells at 100-NR-2 Operable Unit, FY 2009-2010*).

Aquifer tubes near wells 199-N-173 and 199-N-96A along the 100-N Area shoreline are also sampled for petroleum hydrocarbons. In CY 2010, three of four aquifer tubes sampled near the intersect of the plume and the Columbia River showed detections of total petroleum hydrocarbon-diesel. Upstream aquifer tube C6320 was nondetect for total petroleum hydrocarbon-diesel. Aquifer tubes adjacent to the shoreline next to the above-mentioned wells had the following detections: C6135 at 910 µg/L and 116mArray-0A at 570 µg/L. The downstream aquifer tube 116mArray-1A had a detection at 220 µg/L; this aquifer tube was nondetect during the CY 2009 sampling events. It should be noted that these samples were collected in mid-September when the river level was low. It is possible that diesel contamination is more likely to be upwelling into the river under these conditions, as groundwater flow is into the river.

6.1.5 Sulfate

Wastewater from the former 120-N-1 percolation pond introduced sulfate and sodium into 100-N Area groundwater. The sulfate plume in the 100-N Area is depicted in Figure 6-20. The highest sulfate concentrations in CY 2010 were in well 199-N-18 at 504 mg/L and well 199-N-165 at 161 mg/L. Well 199-N-165 is used to monitor the 120-N-1 and 120-N-2 RCRA facilities. Wells located downgradient of the percolation pond (199-N-41, 199-N-56, 199-N-57, 199-N-64, and 199-N-105A) also had elevated sulfate levels. One other well near the 120-N-1 and 120-N-2 facilities also had elevated sulfate (well 199-N-72 at 123 mg/L). The contamination beneath

these facilities is residual from previous flow conditions that carried sulfate from the 120-N-1 percolation pond inland. Current groundwater flow conditions are carrying this plume to the north and northwest toward the Columbia River (DOE/RL-2010-11).

Only well 199-N-18 had sulfate values exceeding the 250 mg/L secondary DWS. In CY 2009, this well had a very low sulfate concentration (0.265 mg/L). The sulfate concentrations may be elevated in the well because of the excess diesel that is present in the well. Very little product removal was performed in well 199-N-18 during CY 2010 (see discussion in Section 6.1.4). Elevated sulfate concentrations were also detected at other wells near 199-N-18, namely 199-N-19 and 199-N-21.

Manganese and iron continue to be detected in areas where diesel biodegradation is believed to be occurring.

6.1.6 Manganese and Iron

Manganese concentrations in groundwater continued to be elevated in wells affected by the diesel plume. Figure 6-21 shows filtered manganese and iron concentrations in the 100-N Area from the fall of CY 2010. Several wells exceeded the secondary DWS of 50 µg/L for manganese:

- Well 199-N-16 at 748 µg/L
- Well 199-N-18 at 10,400 µg/L
- Well 199-N-32 at 70.5 µg/L
- Well 199-N-57 at 61 µg/L
- Well 199-N-167 at 1,270 µg/L
- Well 199-N-169 at 219 µg/L
- Well 199-N-170 at 142 µg/L
- Well 199-N-171 at 1,170 µg/L
- Well 199-N-172 at 3,240 µg/L
- Well 199-N-173 at 4,460 µg/L.

All of these wells, with the exception of 199-N-32 and 199-N-57, are under the influence of the current diesel plume. Well 199-N-16 is showing the effects of diesel degradation from three separate diesel spills that occurred in the area of the well (all from the 184-N day tank): UPR-100-N-19 in 1984, UPR-100-N-21 in 1986, and UPR-N-42 in 1987. In 2007, this well had detectable levels of total petroleum hydrocarbon-diesel; it did not have detectable levels in 2008 or 2009, but once again had detectable levels in CY 2010.

Several wells also exceeded the 300 µg/L secondary DWS for iron: 199-N-18 at 50,100 µg/L; 199-N-32 at 341 µg/L; 199-N-57 at 465 µg/L; 199-N-172 at 2,950 µg/L; and 199-N-173 at 834 µg/L. Well 199-N-26 did not exceed the secondary DWS of manganese but did exceed the iron 300 µg/L secondary DWS at a concentration of 366 µg/L. With the exception of wells 199-N-26, 199-N-32, and 199-N-57, all of these wells are under the influence of the diesel plume and/or the effects of diesel biodegradation. Natural biodegradation of hydrocarbons creates reducing conditions, which increases the solubility of metals (e.g., manganese and iron). The sources of the two metals may be the actual well casing or the aquifer sediments.

Aquifer tube 116mArray-0A had elevated levels of manganese (4,860 µg/L) and iron (1,130 µg/L). Aquifer tube C6135 also had elevated levels of manganese (2,250 µg/L) and iron (1,070 µg/L). These aquifer tubes also had detections of total petroleum hydrocarbon-diesel.

6.1.7 Chromium

Chromium above the 100 µg/L DWS is present in only one well at the 100-N Area. The majority of the remaining chromium detections were at or just above the 13 µg/L detection limit for chromium.

Chromium was reported as present in the effluent discharged to the 116-N-1 LWDF but was found at low concentrations in the waste stream. Sodium dichromate was only used in the 100-N Area from 1964 to 1973 and in lesser amounts than at the other 100 Area reactors because of the design of the N Reactor cooling system and the use of corrosion-resistant metals (e.g., zircaloy) in the fuel and facility (DOE/RL-2008-46-ADD5). The chromium fraction of the sodium dichromate used in the 100-N Area was ~24,704 kilograms. Given the mobility and nonsorbing nature of chromium in solution, the high continuous discharge rates while chromium was delivered to the 116-N-1 LWDF, and the fact that discharges continued for another 10 years after sodium dichromate use ceased, the mobile portion of discharged chromium was thoroughly flushed from the subsurface and into the Columbia River by the end of the reactor's operational period (DOE/RL-2008-46-ADD5). Together, all of the dangerous waste discharged to the LWDFs collectively made up only 0.002% of the total volume of wastes, according to the RCRA Part A Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*). Chromium was never detected in samples of the effluent waste stream from the 116-N-1 LWDF. Levels in wells monitoring the unconfined aquifer were low when the facility was in use.

Continued monitoring of wells in the 100-N Area shows sporadic, low-level detections of chromium throughout the area. Even in wells where chromium is detectable, nearby wells often do not show any detection. There is no reason to believe that a continuing source for chromium groundwater contamination exists in the 100-N Area based on available data from all wells being monitored. Any possible source of the contamination has dissipated, being flushed from the aquifer through years of high-volume effluent disposal and the high mobility of chromium when in solution (see Chapter 4 in DOE/RL-2008-46-ADD5 for further description of the use of sodium dichromate at the 100-N Area). Work on the 100-N Area RI/FS includes samples taken from the vadose zone, Hanford formation, Ringold Formation, and into the Ringold Formation upper mud unit at several locations. If a source of deep chromium contamination is found, it will be addressed and discussed in the 100-N Area RI report.

Two wells in the 100-N Area had dissolved (filtered) chromium concentrations above the DWS of 100 µg/L (199-N-80 and 199-N-18). Well 199-N-80, which is completed in a thin, confined aquifer in the Ringold Formation, had filtered chromium concentrations during the reporting period of 172, 192, and 176 µg/L in samples taken on September 20, 2010. These values are similar to the values reported in 2007, 2008, and 2009 for this well of 172, 172, and 169 µg/L, respectively. This well has shown very little change in chromium concentration over time. A down-hole camera survey performed in 2001 showed visible corrosion along the length of the well screen (33.7 to 42.7 meters depth) in this well. Corrosion of the stainless-steel well screen is likely the contributor of chromium to the groundwater sampled from this well. Stainless-steel corrosion is caused by sulfur impurities present in the metal. These small sulfur inclusions cause depletion of the chromium from the surrounding metal and a "pit" is created in the metal where this process is occurring ("Why Stainless Steel Corrodes" [Ryan et al., 2002]). In a stainless-steel well where this corrosion is occurring, chromium and sulfate are released into solution; when a groundwater sample is taken, similar trends are noted in chromium and sulfate concentrations. Figure 6-22 shows the trend plot for chromium and sulfate in well 199-N-80. The two

trends mirror each other and are a strong indicator that the elevated chromium is from the stainless-steel corrosion occurring in the well. Hexavalent chromium samples collected in CY 2010 show that the concentration of filtered chromium and hexavalent chromium are essentially the same, which is another indicator that the chromium source is from corrosion in the well. The chromium released by corrosion is in hexavalent form, as it is the soluble and mobile species of chromium. Soil and groundwater samples taken from wells drilled near 199-N-80 as part of the RI/FS process will be sampled in the lower Ringold Formation and the Ringold Formation upper mud unit. Analyses of both hexavalent chromium and total chromium are planned as part of this process. Results from the RI/FS work will be discussed in the RI report.

Well 199-N-18 had filtered total chromium results of 159 and 127 μg/L for samples taken in December 2010 when the diesel concentration was 41,000 μg/L in the well. Hexavalent chromium results for that date were much lower (36.4 μg/L and less than 2 μg/L in unfiltered and filtered samples, respectively). The data are being reviewed because of the inconsistencies. Samples taken in July 2010 (when the diesel concentration was an order of magnitude higher at 420,000 μg/L) had chromium concentrations considerably lower (at or near the detection limit). Well 199-N-18 has had very few chromium detections in the past (from 1989 through 2006). As of 2007, chromium has been detected in the well, with levels increasing as diesel levels increased. It is possible that the effects of diesel degradation may be interacting with the carbon-steel casing of the well and causing elevated levels of chromium, in addition to iron and manganese. Monitoring for chromium and hexavalent chromium will continue at this well.

Figure 6-23 shows unfiltered and filtered detectable total chromium results from the fall 2010 for the 100-N Area. Well 199-N-74 had detections of total and hexavalent chromium at 25 to 30 μg/L. The source of the chromium in this well is unknown; it is possible that the chromium may be migrating in from somewhere to the south of the 100-N Area or from the 100-K Area to the west. As part of the 100-N Area RI/FS work plan, a new well is being drilled between wells 199-N-74 and 199-K-182 (to the west) to determine if detectable chromium exists between the two wells.

The remaining detectable levels of total chromium in the 100-N Area are all low, at just above the 13 to 14 μg/L detection limit for chromium in most samples. Detection levels for chromium vary in the data set for the 100-N Area depending on which method was used and which laboratory performed the analysis. The majority of the samples are analyzed at the Waste Sampling and Characterization Facility using U.S. Environmental Protection Agency (EPA) Method 6010, which has a detection limit of 13 to 14 μg/L. The other samples are analyzed at the Test America St. Louis Laboratory using EPA Method 6010 with a detection limit of 3.10 to 3.3 μg/L. Hexavalent chromium results were less than 10 μg/L in 2010, except in the wells discussed above.

Two wells in the 600 Area that were sampled for the 100-N Area RI/FS had elevated levels of hexavalent chromium. Well 699-77-54, located ~3 kilometers southeast of the 100-N Area, had concentrations between ~20 and 25 μg/L. Well 699-87-55, located between the 100-N and 100-D Areas, had concentrations between 10 and 20 μg/L.

Total chromium concentrations were below the current 13 to 14 μg/L detection limit (for Waste Sampling and Characterization Facility samples) in 100-N Area aquifer tube samples in CY 2010.

6.2 CERCLA Activities

This section summarizes the CERCLA activities during the reporting period related to 100-NR-2 OU groundwater. For purposes of the RI/FS, the groundwater and source OUs were combined into the 100-N River Corridor unit, which has a slightly different configuration than the groundwater OU. The principal COC in the 100-N Area is strontium-90, which is currently the focus of most remediation efforts at the OU. The CERCLA activities in 2010 included performing interim action groundwater monitoring, performing continued monitoring of the existing apatite PRB, reporting conclusions for the initial phytoextraction study, planning infiltration testing, and continuing work to characterize the diesel plume.

6.2.1 CERCLA Decision Documents

In 1996, the overall pace of Hanford Site cleanup along the Columbia River was accelerated. An expedited response action to address strontium-90 contamination in groundwater was implemented at N-Springs. In 1999, the interim action ROD was issued (EPA/ROD/R10-99/112), which was specific to the 100-N Area OUs.

The RI/FS (DOE/RL-2008-46-ADD5) and the sampling and analysis plan (DOE/RL-2009-42, *Sampling and Analysis Plan for the 100N Decision Unit Remedial Investigation Feasibility Study*) for the 100-N Area were issued in March 2011 and December 2010, respectively.

The *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision* (DOE/RL-2009-54) was issued in June 2010.

The *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27, Rev. 1 Draft A) was submitted to the Washington State Department of Ecology (Ecology) on March 25, 2011.

6.2.2 Status of the Five-Year Review Action Items

The Second CERCLA Five-Year Review Report for the Hanford Site was published in 2006 (DOE/RL-2006-20). The review identified two actions pertaining to the 100-N Area, and DOE made progress on both actions in 2010.

- **Action 6-1.** *Implement the treatability test for the PRB using apatite sequestration (DOE/RL-2005-96, Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit) and issue the treatability test report.* ***Complete.***
  - This action was satisfied by installing the apatite PRB in 2006 and implementing the initial pilot test injections in 2006, 2007, and 2008. The *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injections for In Situ Strontium-90 Immobilization* (PNNL-17429) discusses progress at the PRB through the low-concentration injections completed in 2007. In the *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization* (PNNL-19572), progress is discussed through the completion of the high-concentration injections in 2008, the coring activities in 2009, and performance monitoring results. Section 6.2.4 provides additional information on the apatite PRB.
- **Action 7-1.** *Perform additional data collection to support risk assessment, provide previously collected data, and collect additional porewater data from new and existing aquifer tubes.* ***Complete.***

- Water samples continued to be collected from aquifer tubes in 2010. Section 6.1 discusses significant results, and data are included in the electronic files accompanying this report.
- River upwelling samples were collected in December 2010 as part of the RI/FS work plan and the results are discussed in Section 6.2.7. These results will also be included in the 100-N Area RI report.

The remedial action objectives in the 100-NR-2 OU (EPA/541/R-99/112) are as follows.

- ***Protect the Columbia River from the adverse impact of groundwater contamination by limiting exposure pathways, reducing or removing sources, controlling groundwater movement, or reducing the concentration of contaminants.***
- ***Protect the unconfined aquifer by implementing remedial actions that reduce the concentration of contaminants.***
- ***Obtain information to evaluate technologies to remove strontium-90 and evaluate the impact to ecological receptors.***
- ***Prevent destruction of sensitive wildlife habitat and minimize the disruption of cultural resources. In 2006, Ecology added a requirement for the pump-and-treat system to be put on standby and an alternative in situ treatment technology to be tested.***

6.2.3 Interim Action Monitoring

A pump-and-treat system operated from 1995 until March 2006 in the 100-N Area as part of the CERCLA interim action (EPA/541/R-99/112). The system removed ~1.8 curies of strontium-90 from the aquifer. Because strontium-90 binds strongly to the sediment, the pump-and-treat system was not effective in cleanup of the aquifer. One of the requirements of the interim action ROD was to evaluate alternative technologies for groundwater cleanup. Therefore, Ecology, EPA, and DOE approved Tri-Party Agreement Change Control Form M-16-06-01 in 2006, which required placing the pump-and-treat system in cold-standby status and constructing a PRB. Based on the treatability test results, the apatite technology is showing promise as a remediation option. As a result, the DOE proposed in June 2009 to amend the existing interim remedial action ROD for the 100-NR-1 and 100-NR-2 OUs (EPA/541/R-99/112) to include as an interim remedial action for expanding the existing apatite PRB to a total length of ~762 meters in the aquifer and the vadose zone. Regulatory approval of the amendment to the interim action ROD was issued in September 2010 and allows for proposed expansion to the apatite PRB and permanent decommissioning of the 100-NR-2 pump-and-treat facility.

Implementation of the interim remedy apatite barrier expansion will be conducted under a revision to the 100-NR-2 OU interim action remedial action/remedial design work plan (DOE/RL-2001-27) that was submitted as Rev. 1 Draft A to Ecology in March 2011.

Plans to optimize this apatite barrier technology prior to full-scale expansion will initially move forward under two approved design optimization studies: the barrier expansion design optimization study (DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*), and the jet injection design optimization study (DOE/RL-2010-68, *Jet Injection Design Optimization Study for the 100-NR-2 Groundwater Operable Unit*).

Wells and constituents monitored for the 100-NR-2 OU are defined in (1) the remedial design report/remedial action work plan (DOE/RL-2001-27) and modifications thereto (TPA-CN-256), (2) *100-N Area Integrated Groundwater Sampling and Analysis Plan* (DOE/RL-2009-58), and (3) the strontium-90 treatability teat plan for the 100-NR-2 OU (DOE/RL-2005-96) and modifications thereto (TPA-CN-271). The CERCLA sampling is conducted mainly in September, with selected wells also monitored in March. Sampling under RCRA is conducted quarterly or semiannually, as required. Analytical results from these other monitoring programs are presented in this report where the data are useful for assessing rebound or defining plumes. The wells, constituents, and sampling frequencies for interim action monitoring are shown in Appendix A. During 2010, two wells were unable to be sampled as scheduled in September due to (1) a breaker that tripped twice on a pump (unable to sample for well 199-N-106A), and (2) not enough water remained in well 199-N-46 for sampling because the well was pumped dry before a sample could be taken.

The monitoring results for each of the constituents of interest are discussed in further detail in Section 6.1.

6.2.4 Permeable Reactive Barrier

The DOE agreed to construct and evaluate the effectiveness of a PRB for strontium-90 using apatite sequestration technology as part of the of the CERCLA RI/FS process, which is consistent with the interim remedial action ROD for the 100-NR-1 and 100-NR-2 OUs (EPA/541/R-99/112) and the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Change Control Form M-16-06-01. Strontium-90 sequestration using this technology occurs by injecting a calcium-citrate-phosphate solution into the aquifer. After the solution is injected, biodegradation of the citrate results in apatite (a calcium phosphate mineral [$Ca_5(PO_4)^3(F, Cl, OH)$]) precipitation. Strontium-90 ions in groundwater substitute for calcium ions via cation exchange and eventually become "trapped" as part of the mineral matrix during apatite crystallization (PNNL-16891).

Apatite (a naturally occurring calcium phosphate mineral) is being used to form a PRB along the 100-N Area shoreline. This barrier allows free movement of groundwater through the treated zone, but strontium-90 is substituted for calcium and is bound up within the mineral matrix. The strontium-90 that is part of the mineral matrix does not reach the river and will naturally decay in place.

The apatite treatability test site covers ~90 meters along the Columbia River shoreline (Figure 6-2). Forty-five monitoring points are associated with this site, including injection/barrier wells, monitoring wells, and aquifer tubes. Sixteen wells comprise the actual PRB. Four monitoring wells are parallel to the PRB, between the river and the injection/barrier wells. Two pilot test sites (PT#1 and PT#2) are located at each end of the PRB (around the two end injection/barrier wells) and contain smaller diameter monitoring wells surrounding the individual end injection/barrier wells (Figure 6-2).

Strontium-90 contamination in the 100-N Area is primarily absorbed to sediments by ion exchange (99% absorbed and 1% in solution in the groundwater) in the lower vadose zone and upper portion of the unconfined aquifer. Although primarily absorbed, strontium-90 is still considered a high-mobility risk because it is mobilized by seasonal river stage increases; water level increases remobilize strontium-90 absorbed to sediments not previously in contact with groundwater (PNNL-16891). Apatite-forming solution injections were made to the Hanford formation and Ringold Formation over a period of 3 years (from 2006 through 2008). Table 6-3 summarizes the timeline and injection history for the apatite PRB.

A report on the treatability test (PNNL-19572) was issued in September 2010 to document the work completed to date on development of a high-concentration amendment formulation and field-scale testing of the solution. The high-concentration

amendment solution was formulated to maximize apatite formation within the targeted treatment zone while minimizing the short-term increases in strontium-90 concentration associated with injecting high ionic strength solutions. (An interim report, *100-NR-2 Apatite Treatability Test FY09 Status: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization: Interim Report* [PNNL-SA-70033] was issued in 2009, which was discussed in the CY 2009 annual report [DOE/RL-2010-11]). PNNL-19572 provides details regarding the high-concentration apatite amendment formulation, PRB emplacement operations, and barrier performance assessment, including aqueous monitoring results and sediment core analysis.

6.2.4.1 Performance Monitoring at the Existing Permeable Reactive Barrier

Performance monitoring at the existing apatite barrier was performed quarterly (usually in February, May, August, and November) through August 2010. This phase of monitoring was required by the original test plan and continued for 2 years following the final injections in July 2008. In August 2010, quarterly sampling was completed with a sampling event that covered all 45 of the original monitoring points (including the 16 injection wells, 21 monitoring wells, and 7 of the 8 original aquifer tubes). Until August 2010, sampling included four sets of wells that were monitored along the length of the PRB, including all four of the main monitoring wells, paired injection/barrier wells (with one well screened in the Ringold Formation only and one well screened across both the Hanford and Ringold Formations), and smaller diameter monitoring wells (completed in both the Hanford and Ringold Formations on the two ends of the PRB). Table 6-4 lists the wells that were sampled, formations monitored, screen depth, and their locations. These wells were chosen to cover portions of the whole barrier and to allow for both areal and vertical distribution of sampling points. Figure 6-2 depicts the four main monitoring locations along the PRB (PT#1 end, mid-upper, mid-lower; and PT#2 end).

Wells were sampled for a minimum of gross beta and/or strontium-90 during each of the four quarterly sampling events. Duplicate samples were collected during each sampling event. Split samples were collected at a minimum frequency of twice per year. Once each year (2008 through 2009) during low river conditions in October/November, samples were collected from each well for a full suite of analyses, including strontium-90, gross beta, metals/cations, and anions. The last scheduled monitoring event under the original test plan (DOE/RL-2005-96) occurred in August 2010 and included a full suite of analyses on all PRB sampling points, including the injection and monitoring wells and the aquifer tubes. Table 6-5 includes a full list of all constituents sampled during performance monitoring for this reporting period. Future performance monitoring at the existing barrier will be twice a year and is scheduled to coincide with the highest and lowest river levels, likely occurring in May/June and October/November, respectively. The full suite of analytes will be collected for each event for all monitoring points, including duplicate and split samples, as required. Appendix A provides lists of the well and constituents, as well as a status of monitoring during the reporting period.

Since injections ceased at the PRB in July 2008, a general, steady decline has been observed for strontium-90 and gross beta in the sampled wells, with very few exceptions. As of August 2010, the strontium-90/gross beta values were considerably less in all wells and aquifer tubes monitored along the PRB. All of the wells have shown ~90% decline in gross beta from the measured pre-injection values.

PNNL has prepared a follow-up document to the final high-concentration report (PNNL-19572) issued for the apatite PRB. The *100-NR-2 Apatite Treatability Test: An Update on Barrier Performance* (PNNL-20252) discusses an additional year of performance monitoring data than the previous report, as well as noting changes in trends for strontium-90 concentrations along the treated barrier. While in some areas the strontium-90 concentrations have slightly increased, the aqueous concentrations over the entire length of the barrier are generally being maintained at levels well below the pre-treatment levels (PNNL-20252).

Nearly all of the wells are showing a 90% decline in the amount of detectable gross beta 2 years after injections of apatite-forming chemicals ceased.

Figure 6-24 provides the trend plot for gross beta concentration in the mid-upper portion (Figure 6-2) of the existing apatite PRB. This set of three wells consists of a monitoring well (199-N-146) and two injection wells (well 199-N-164 screened only in the Ringold Formation, and well 199-N-142 screened across the Hanford formation and Ringold Formation). The high-concentration apatite injection solution had a higher ionic strength than groundwater (3.6 mM calcium, 9.0 mM citrate, and 40 mM phosphate, respectively). Therefore, all three wells showed high strontium-90 concentrations following the injections in 2008. When the fluid is initially injected, it temporarily mobilizes cations and anions, causing their concentrations in groundwater to increase. Over time, the concentration of gross beta begins to steadily decline, which is the most evident in monitoring well 199-N-146. The injection wells show more fluctuation in gross beta values, but all three wells show much lower concentrations of gross beta than prior to injections in CY 2008.

Figure 6-25 provides the trend plot for gross beta concentration in the mid-lower portion (Figure 6-2) of the existing apatite PRB. The set of three wells consists of a monitoring well (199-N-122) and two injection wells (199-N-160 screened only in the Ringold Formation, and 199-N-145 screened across the Hanford formation and Ringold Formation). All three wells showed high concentrations following the injections in CY 2008. Over time, the concentration of gross beta begins to steadily decline, which again is most evident in monitoring well 199-N-122. Again, the injection wells show more fluctuation in gross beta values, but all three wells show much lower concentrations of gross beta than prior to injections in CY 2008.

Figure 6-26 shows the trend plot for gross beta concentration across the highest concentration portion of the strontium-90 plume along the existing apatite PRB. Wells 199-N-122 and 199-N-147 are monitoring wells located upriver and downriver of aquifer tube NVP2-116.0 (Figure 6-2), respectively. After the 2008 high-concentration injections, tube NVP2-116.0 had the highest gross beta concentrations of all monitoring points along the PRB, as evidenced by the spike in July/August 2008. Even with the higher values in this portion of the PRB, the reduction in gross beta concentration is prominent for all three locations.

As of the end of CY 2010, the entire PRB has shown indications of a slight upward trend in some wells. At some point, additional injections will need to occur in the existing PRB, based on data presented in the two reports on the initial low-concentration and high-concentration injections (PNNL-17429; PNNL-19572). Injections for the existing barrier will occur as budget and schedule allow within the next few years. Twice yearly, performance monitoring (high and low river stage) will continue for the existing PRB until those injections occur, at which time a revised performance monitoring schedule will be initiated.

6.2.4.2 Core Samples

During the fall of 2009, three monitoring wells were drilled in the PT#2 site of the existing PRB for the purpose of collecting core sample data. These monitoring wells

Core sample data has shown the formation of apatite in the treated sediments.

were drilled and cored from ground surface to a depth of ~7.6 meters. Figure 6-27 shows the location of these core wells in relation to the other wells in the PT#2 site. Core samples were collected to determine the radial and vertical extent of injection fluid penetration from well 199-N-137 and whether the calcium-citrate-phosphate injection fluid is forming apatite in the soil matrix as predicted. The well locations were chosen to examine the vertical and areal distribution of injection chemicals in the sediment around injection well 199-N-137 at 1.5 meters, 3.1 meters, and 4.6 meters distance from the injection well. Results of these core samples were reported in September 2010 (PNNL-19572). The objectives of the core analysis were to characterize the following:

- Phosphate mass with depth and different radial distance from the injection well(s)
- Strontium-90 distribution absorbed on sediment and incorporated into apatite.

Considering the 10 mM (low concentration) and 40 mM (high concentration) phosphate injections conducted in the area where these cores were taken, an average apatite loading of 1.9 milligrams of apatite per gram of sediment (0.608 milligrams of phosphate per gram) was expected. The Hanford formation received an average of 0.559 (±0.253) milligrams of phosphate/g (92% of the mass that would be expected for full concentration arrival), and the Ringold Formation received an average of 0.268 (±0.113) milligrams of phosphate per gram (44% of the mass that would be expected for full concentration arrival). The average phosphate for the three boreholes (both Hanford and Ringold formations) was 0.415 (±0.232) milligrams of phosphate per gram of sediment. Although the boreholes were located at different distances from injection well 199-N-137, the average phosphate concentration was relatively constant at 0.376 milligrams per gram at 1.5 meters (well 199-N-368), 0.420 milligrams per gram at 3.1 meters (well 199-N-369), and 0.406 milligrams per gram at 4.5 meters (well 199-N-370). The relatively uniform distribution of average phosphate concentration with radial distance from the wells demonstrates one benefit of the calcium-citrate-phosphate injection formulation. The amount of phosphate present at different depths is related to the amount of total strontium-90 located at a given depth. Phosphate concentrations are high where total strontium-90 is high, and the concentrations low where total strontium-90 is low. One reason for this relationship may be the grain size of the sediments involved, as zones of finer grained material with higher surface area and more cation-exchange sites will have more strontium-90 absorbed on the sediments. Overlap in treatment zones between the injection wells (199-N-137 and 199-N-159) also contributed to higher phosphate concentrations.

Analysis of ion-exchangeable Ca^{2+} and Sr^{2+} from field cores shows significant depletion of both cations (95% lower for strontium and 47% lower for calcium); ion exchange during the initial calcium-citrate-phosphate solution injection has altered the cations on the sediment ion-exchange sites from their natural condition. The much greater depletion of ion-exchangeable Sr^{2+} compared to Ca^{2+} is likely due to the incorporation of strontium into the apatite mineral matrix. In the next few years, ion-exchangeable Ca^{2+} and Sr^{2+} will be replenished as upgradient groundwater (with Ca^{2+}, Sr^{2+}, and strontium-90) invades the apatite laden zone. However, because the sediments are being amended with a relatively small amount of apatite, the total ion-exchangeable strontium-90 on both sediment and apatite will only be slightly larger than for natural sediments. The real value of the apatite amendment is the permanent incorporation of strontium and strontium-90 into the apatite structure, which allows the strontium-90 to decay in place (PNNL-19572).

6.2.4.3 Proposed Extension of Existing Apatite Permeable Reactive Barrier

Apatite PRB extensions will increase the amount of 100-N Area shoreline treated to sequester strontium-90 up to 762 meters.

During the fall of 2009 and spring of CY 2010, 171 wells were installed to extend the existing apatite PRB (DOE/RL-2009-32, *100-NR-2 Groundwater Operable Unit Sr-90 Plume Rivershore Sampling and Analysis Plan*). The wells were installed on both the upriver and downriver ends of the existing barrier. The extensions cover the entire length of ~762 meters of where the strontium-90 plume intersects the Columbia River along the 100-N Area shoreline (Figure 6-4). Beginning at the upper (PT#1) end of the existing apatite PRB, the new injection/barrier wells alternate at depth completions of 4.6 meters (vadose) and 7.6 meters (top of unconfined aquifer) and continue to near monitoring well 199-N-173. Starting on the downriver (PT#2) end of the existing apatite PRB, the new injection/barrier wells also alternate depth completions of 4.6 meters (vadose) and 7.6 meters (top of unconfined aquifer) and continue to just southwest of monitoring well 199-N-92A. These wells are in line with the existing injection/barrier wells, to the extent that topography, position of the lower road bed, and other existing wells will allow. Approximately every 26 to 27 meters, a new 7.6-meter-deep monitoring well was installed in the top of the unconfined aquifer between the injection/barrier wells and the Columbia River. The injection/barrier wells will allow further injections of apatite-forming chemicals or other chemicals, as determined by ongoing apatite PRB testing. Future plans include injecting wells along an additional 182.8 meters of PRB, 91.4 meters upriver and downriver on both ends of the existing PRB, under a design optimization study (DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*) and the 100-NR-2 OU remedial design/remedial action work plan (DOE/RL-2001-27, Rev. 1, when issued).

The injections will be performed using a two-step process, where the deeper Ringold Formation wells are injected first and then the overlying Hanford formation wells are injected. This allows the injections to overlay each other and maximizes the coverage in both the upper unconfined aquifer and lower vadose zones. The planned formulation for these injections is the high-concentration calcium-citrate-phosphate solution amendment tested in 2008. The goals of the study are as follows (DOE/RL-2010-29):

- Refine the application of high-concentration calcium-citrate-phosphate solution over a large scale
- Test the effectiveness of high-concentration calcium-citrate-phosphate injection in previously untested sediment to compare with areas that received sequential injections of low- and then high-concentration injections
- Test the new well design installed under DOE/RL-2009-32 to evaluate the adequacy of injection solution delivery to the target zone
- Test and optimize operation of the new injection system to verify that the system can deliver the designed injection solution flow volume at multiple well locations
- Determine if the new well design and injection system can complete chemical injections at various river stages, thereby eliminating the need for injections during specific river levels
- Evaluate that the PRB can achieve up to a 90% reduction in strontium-90 flux to the Columbia River

- Further evaluate the impact the high-concentration calcium-citrate-phosphate solution has on the release of strontium-90 and other metals from previously untreated sediments to groundwater.

6.2.5 Other Strontium-90 Treatment Technologies

Several different types of strontium-90 treatment technologies are also being evaluated at the 100-N Area in addition to the existing PRB. It is necessary to look at several types of treatment to effectively treat the entire zone of contamination. The existing PRB has treated groundwater and the lower vadose zone, but it has not treated the upper vadose zone and near-shore riparian zone. The technologies discussed below are an effort to address these previously untreated areas.

6.2.5.1 Jet Injection Tests

Jet injection tests performed in December 2009 showed promise as a potential remediation technology for strontium-90.

Jet injection technology has been used extensively in many environmental remediation locations to place grout and other materials into the subsurface. This technology was used to test the injection of apatite-forming chemicals and pre-formed apatite into the subsurface at the 100-N Area. Apatite-forming chemical injections to date at the 100-N Area have treated predominantly the lower vadose zone and upper portion of the aquifer along the 100-N Area shoreline. Advantages to using jet injection technology at the 100-N Area included the following: (1) injections could be performed regardless of river level, (2) injections could treat the upper vadose zone that previous injections have left untouched, and (3) injections could be performed with apatite-forming chemicals and/or pre-formed apatite (DOE/RL-2005-96, Addendum 3). The objectives of the jet injection test were as follows:

- Evaluate the ability of jet injection technology to deliver different apatite material/ apatite-forming chemical solutions into the vadose zone and upper unconfined aquifer within three distinct treatment zones along the 100-N Area shoreline
- Evaluate the ability of the jet injection technology to deliver apatite-forming solutions to install a PRB in the vadose zone containing 3.4 milligrams of apatite per gram of sediment (1.1 milligram of phosphate per gram of sediment).

In December 2009, jet injection tests were performed in three plots located along the 100-N Area shoreline, just upriver from the existing apatite PRB (Figure 6-28) (SGW-47062, *Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100-NR-2 Operable Unit*). Each test plot was ~3.1 meters (width) by 6.1 meters (length) by 7.6 meters (depth) in size, and injections were made in six locations within each plot to determine if phosphate and apatite could be placed into the vadose zone and upper aquifer using the jet injection technology. The first plot was injected with a phosphate-only solution, the second plot was injected with a phosphate-only solution followed by a suspension of fishbone apatite, and the third plot was injected with a suspension of fishbone apatite only. The three plot sites were laid out along the planned route for extension of the apatite PRB, with the site of one to two of the planned injection/barrier wells located within a given plot. One well each was eventually located in the phosphate-only and apatite-only plots, and two wells were located within the phosphate and apatite plot. These wells were continuously cored from ground surface to a depth of 7.6 meters. The cores were sent to PNNL for analysis (similar to the core collected previously from the PT#2 site). In addition, water samples were obtained from two nearby aquifer tubes (116.0mArray-1A and 116.0mArray-2A) before, during, and after the jet injections.

The treatability test report (SGW-47062) was issued in CY 2010 and reported that both objectives of the test were met. Jet injection technology was successfully used

to emplace three different media in the vadose zone and upper unconfined aquifer. Collection and analysis of post-injection sediment cores enabled the evaluation of apatite emplacement within a vertical sediment column. Apatite emplacement at concentrations equal to or greater than 4 milligrams of apatite per gram of sediment was observed in the sediment cores in all three test plots (SGW-47062; PNNL-19524). Until future groundwater samples are taken at the wells installed in the test area, the results of the groundwater tests will not be available.

Future plans to optimize this apatite-barrier technology prior to full-scale expansion will initially move forward under two approved design optimization studies: (1) barrier expansion (DOE/RL-2010-29), and (2) jet injection (DOE/RL-2010-68).

6.2.5.2 Infiltration Gallery Tests

Apatite injections treat the strontium-90 contamination in the aquifer and lower portions of the vadose zone, but strontium-90 is also absorbed in the upper portion of the vadose zone. PNNL conducted a study of apatite infiltration to treat vadose zone contamination under the DOE Environmental Management Technology (EM-22) program. The study took place in the fall of 2010 at the infiltration gallery test site located ~5 meters past the downriver end of the existing apatite PRB (Figure 6-2). Two tracer tests were conducted using sodium bromide tracer, and the results were as follows:

- Application rate of tracer at 0.7 centimeters per hour
- Tracer arrivals at water table (10 to 12 feet below the base of the infiltration gallery) after ~5 days
- Advancement rate was 2 feet per day.

The test that was performed was with sodium bromide tracer solution only; it is not indicative of the amount of time actual reactive apatite-forming solutions would take to infiltrate, or if they would infiltrate at all. Additional information on the infiltration test and the data from test implementation are provided in *100-NR-2 Apatite Treatability Test: Fall 2010 Tracer Infiltration Test* (PNNL-20322).

6.2.5.3 Phytoextraction

Phytoextraction is a potential remediation technology along the riparian zone of the Columbia River.

Phytoextraction of strontium-90 is being considered as a potential remediation technology (polishing step) along the riparian zone of the Columbia River as part of an apatite PRB to reduce transport of strontium-90 to the river. The process uses coyote willows (*Salix exigua*) to extract strontium-90 from the vadose zone soil and aquifer sediments (phytoextraction) and to filter strontium-90 (rhizofiltration) from the shallow groundwater along the riparian zone of the Columbia River (PNNL-19120, *100-N Area Strontium-90 Treatability Demonstration Project: Phytoextraction Along the Riparian Zone – Field Treatability Study*). The initial test plot was installed in the 100-K Area to allow testing under uncontaminated conditions (i.e., no strontium-90) and to test the methodology along an area of shoreline where the slope was gentle and no large areas of rock (rip-rap) were present (e.g., in the 100-N Area).

The results of the test performed at the 100-K Area from 2007 through 2009 are summarized below:

- During the 3 years of testing, the trees survived multiple flooding events (including total immersion), no trees were uprooted or displaced, and most survived the entire 3-year period.

- Biomass (leaves, twigs, and smaller branches) production followed a typical growth curve for the first 2 years and went to a logarithmic/exponential rate in the third year.
- No intrusion of large or small herbivores occurred at the test plot over the 3-year period. The site had chain-link fencing (with smaller mesh screening around the bottom 0.61 meters of fencing, which also extended underground) surrounding the plot.
- Observed calcium and strontium concentrations found in harvested biomass suggest that the trees could prove effective in removing strontium-90 in the riparian zone.
- Harvested biomass is controlled and disposed of per approved radiological and waste management procedures.

Further information on this study and the results are provided in PNNL-19120. Plans to test this technology along the 100-N Area shoreline were initiated in CY 2010 but will not continue until a decision is made regarding whether the technology will be tested further.

6.2.6 Characterization of Petroleum Contamination

Data collection continues in areas affected by the diesel spill. By 2010, the plume was well defined and potential remediation technologies identified and/or being tested.

PNNL performed work for CH2M HILL Plateau Remediation Company (CHPRC) Soil and Groundwater Remediation Project (S&GRP) to evaluate the nature and extent of the diesel plume at the 100-N Area and to investigate potential remediation technologies. The study included soil, riverbed, and groundwater samples from select locations to collect as much data as possible to make initial remediation decisions (PNNL-18645, Rev. 1, *Summary of TPH Monitoring Conducted at 100-NR-2 2008 Through 2010*). The results of the monitoring investigation are summarized below:

- Samples collected from the top of the aquifer indicate the presence of total petroleum hydrocarbon-diesel range.
- Total petroleum hydrocarbon-diesel range decrease and then disappears with depth.
- High levels of manganese and iron are found in wells with total petroleum hydrocarbon-diesel range detections, which indicates microbial activity.
- Dissolved oxygen levels were low in wells with total petroleum hydrocarbon-diesel range detections, an indicator of reducing conditions and microbial activity.
- Naturally occurring bacteria present in the soil along the shoreline and inland at the 100-N Area are capable of using diesel-range hydrocarbons as their sole carbon source (i.e., the bacteria can break down and degrade diesel contamination into more natural byproducts).
- The large decrease in concentration between well 199-N-18 (the plume hot spot) and shoreline well 199-N-173 indicates that microbial degradation of diesel is occurring between these two wells.
- The extent of vadose zone contamination is not as well known as the extent of groundwater contamination. Ongoing work performed by WCH on the bioremediation site and bioventing study will be included in the 100-N Area RI report.

The S&GRP has also been collecting additional groundwater data in the area affected by the diesel contamination. Five wells (199-N-173, 199-N-96A, 199-N-18, 199-N-172, and 199-N-167) were sampled in August and September 2009 for multiple analyses, including metals, cations, anions, volatile organic analytes,

semivolatile organic analytes, and field parameters (pH, temperature, conductivity, dissolved oxygen, oxidation-reduction potential, and turbidity) (Figure 6-19). In April 2010, additional samples were taken from the five wells used for the WCH 100-N Area bioremediation project, which were the UPR-100-N-17 wells completed in groundwater (199-N-167, 199-N-169, 199-N-170, 199-N-171, and 199-N-172) (WCH-370, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project [UPR-100-N-17]*). In addition, the CERCLA monitoring program for the 100-N Area added total petroleum hydrocarbon-diesel range, polyaromatic hydrocarbons, and volatile and semivolatile organic analyte compound analyses to all wells and aquifer tubes in the known diesel plume area.

Well 199-N-18 has historically had floating diesel product, which still remains at this time. None of the other wells exhibited floating product, but an oily sheen and diesel-like smell were noted when wells 199-N-167, 199-N-169, 199-N-170, 199-N-171, and 199-N-172 were sampled. Samples from well 199-N-173 provided additional data on where the diesel plume intersects the Columbia River. Well 199-N-96A is located immediately downriver from well 199-N-173. Samples collected from the five wells listed above allowed the diesel plume to be plotted with a greater degree of accuracy. Prior to 2008, several other wells had detectable levels of total petroleum hydrocarbon-diesel, including 199-N-3 (in 1994), 199-N-19 (in 2005), 199-N-20 (in 1994), and 199-N-21 (in 1994), but none of these wells had detectable levels in recent years (year in parentheses notes the last year detected).

WCH is conducting bioventing pilot tests to evaluate contaminant removal rates and the distribution of air flow within the contaminated zone. The tests will consist of soil vapor measurements, respirometry tests, and air injection tests. Soil vapor monitoring is performed to determine the baseline concentrations of oxygen, carbon dioxide, and volatile hydrocarbons. Air injection tests will be performed to evaluate soil permeability and a consistent supply of adequate oxygen to the contaminated soil. The respirometry tests are performed to provide estimates of in situ biodegradation rates (WCH-323, *Sampling and Analysis Instruction for Installation of UPR-100-N-17 Bioremediation Wells and Performance of Bioventing Pilot Tests*). This work began at the UPR-N-17 site (as listed in the Waste Information Data System database) in the fall of 2010 and continues into 2011. A draft report on the tests progress was issued in early 2011 but was not yet available for use in this report.

6.2.7 River Sediment Porewater Sampling

WCH Studies. WCH performed porewater sampling in river sediments along the 100-N Area shoreline in 2008 and 2009, and the results from the sampling events were published in November 2010 (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Release to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*; WCH-381, *Data Quality Assessment Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*). The study was performed in three phases:

- **Phase I, Technology Demonstration:** Testing the Trident™ probe technology in Hanford Reach conditions.
- **Phase II, Delineating Eight Areas of Suspected Groundwater Plume Upwelling:** Overall rationale for selecting the eight areas to be studied is provided in the *Remedial Investigation Work Plan for Hanford Site Releases*

to the Columbia River (DOE/RL-2008-11). Constituents of interest for the 100-N Area were strontium-90 and total petroleum hydrocarbons.

- Phase IIa: Collecting in situ porewater measurements of specific conductance (conductivity) and temperature to determine the location of the groundwater/ riverwater interface. Conductivity values above 160 µS/cm indicated groundwater upwelling.
- Phase IIb: Included screening analysis for key Hanford Site indicator contaminants (e.g., hexavalent chromium, strontium-90, uranium, and tritium) from areas identified in Phase IIA as having groundwater upwelling.

- **Phase III, Groundwater Plume Upwelling Characterization:** More extensive characterization of upwelling conditions through porewater, sediment, and surface water sampling at locations selected from review of Phase II results.

In the 100-N Area under Phase IIa, a total of 97 locations were sampled. The maximum conductivity measured was 1,058 µS/cm and the maximum temperature measured was 6.9 degrees Celsius. Under Phase IIb, thirty sample locations were selected for strontium-90 analysis based on the Phase IIa results. Ten of those thirty locations were also sampled for total petroleum hydrocarbons. Five of the thirty locations had strontium-90 detections above the minimum detectable limit. All five of these samples also exceeded the DWS for strontium-90 (8 pCi/L), with concentrations ranging from 10.7 to 72.3 pCi/L. Two of these samples were taken from outside the area where the known strontium-90 plume intersects the Columbia River, near the outfall structure for the 100-N Area (located on the river below the N Reactor/109-N heat exchanger and associated buildings). None of the ten samples collected for total petroleum hydrocarbon analysis had detections. Under Phase III, four sample locations (T100N1A, T100N2A, JT100N3A, and T100N5Ring) and one additional sediment only sample location (T100N3A) were selected. Conductivity values ranged from 359 to 895 µS/cm, which are strong indicators of a groundwater sample being taken. Site T100N1A yielded the maximum porewater conductivity (895 µS/cm). Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all nondetects. All hexavalent chromium porewater samples were nondetects, with the exception of one detection of 26 µg/L at station T100N1A. Strontium-90 concentrations ranged from 8 to 55 pCi/L, with the maximum concentration at the 100-N outfall station. Tritium detections ranged from 1,100 to 12,000 pCi/L, with the maximum at station T100N5Ring.

S&GRP Studies. Based on the results of the WCH sampling activities, S&GRP performed follow-up porewater sampling at selected sites. A sampling and analysis plan was developed for the scope of work (DOE/RL-2010-69, *Sampling and Analysis Plan for the 100-NR-2 Operable Unit River Pore Water Investigation*), which included (1) collecting porewater samples from ten locations along a near-shore transect that is near and somewhat downriver of the 100-N outfall and spillway; (2) collecting porewater samples at three locations in the area of sample station T100N1A, where hexavalent chromium was detected during Phase III WCH sampling; and (3) analyzing porewater samples for strontium-90, hexavalent chromium, contaminants of potential concern, and additional analytes of interest to define the contamination extent and support a contaminant transport evaluation. Figure 6-29 shows the sample locations along the 100-N Area shoreline.

- **Sample point T100N1A:** Location where hexavalent chromium was detected during Phase III WCH sampling. Three samples were collected in the immediate vicinity at sample stations T100N1A-1, T100N1A-2, and T100N1A-3. Hexavalent

chromium was not detected at any of the three locations, so the detection found in Phase III at location T100N1A was not repeatable. Strontium-90 and tritium were detected at all three locations; these points are located offshore of the area where the known strontium-90 and tritium groundwater plumes intersect the river. Table 6-6 provides the sample results for strontium-90, tritium, and hexavalent chromium.

- **Transect sample points:** Locations along shoreline near 100-N outfall and spillway structure; eleven samples were collected along this transect, and one sample was a duplicate sample (Figure 6-29). Strontium-90 was detected only at locations N Transect 10 and N Transect 8, which are both near the 100-N outfall structure. Tritium was detected at all ten locations. All ten transect locations were nondetect for hexavalent chromium. Table 6-6 provides the samples results for strontium-90, tritium, and hexavalent chromium.

The strontium-90 detected near the 100-N outfall appears to be an isolated occurrence, as indicated by the transect sample results. Based on the construction of the outfall and its location relative to the N Reactor building and fuel storage basin, it is believed that past leaks from these or other nearby buildings entered groundwater flowing toward the Columbia River, and then followed the engineered fill around the concrete outfall structure. When this structure was built in the late 1950s/early 1960s, it extended over half way into the river channel. Concrete was poured, gravel or other clean fill was placed on either side of the structure, and it was then backfilled. Figure 6-30 depicts the geologic/hydrologic setting and generalized potential pathways the contamination may have taken to show up where detected in the river near the outfall. The 100-N Area RI/FS work plan (DOE/RL-2008-46-ADD5) includes a data gap evaluation associated with the fuel storage basin located on the river side of the N Reactor building. A characterization borehole (which would be completed as a groundwater monitoring well) may be reinstalled near the 118-N reactor fuel storage basin after remediation activities allow. As part of ongoing cleanup for the 100-NR-1 OU, contamination on the riverside of the reactor and associated buildings (e.g., fuel storage basin) is being excavated and the activities are being documented. Any additional data that become available regarding the source of this contamination will be provided in future annual reports and in the 100-N Area RI report.

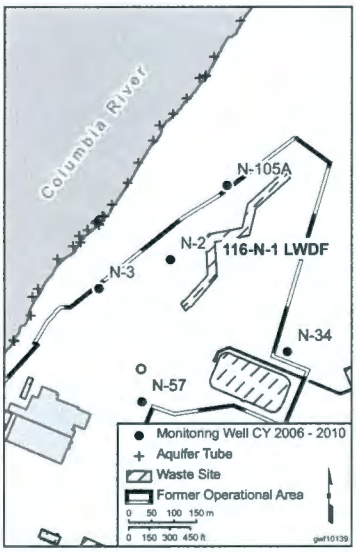
6.2.8 Remedial Investigation/Feasibility Study Aquifer Tube Sampling

Strontium-90 detected near the 100-N outfall during WCH sampling activities has also been addressed through the RI/FS work plan with the installation of two new sets of three aquifer tubes (one set adjacent to the downriver side of the outfall structure [C7934/35/36], and one set midway between the outfall structure [C7937/38/39] and existing aquifer tube set C6320/21/22) (CHSGW1007-29) (Figure 6-31). As part of the RI/FS sampling and analysis plan, three rounds of sampling (high, low, and transition river stages) on each of four sets of aquifer tubes were initiated in July 2010 and were completed in December 2010 (TPA-CN-353). In addition to the four sites listed in TPA-CN-353, one other site (C6317/18/19) was also sampled for two of the three rounds. Strontium-90 was not detected at the set furthest upriver of the 100-N outfall (C6263/64/65) or at one of the three sets downriver (C7937/38/39). Strontium-90 was detected in one of the sets upriver of the outfall structure (C6317/18/19) but only in tube C6317 (shallow tube). Strontium-90 was also detected in the set nearest the 100-N outfall (C7934/35/36), which is in the same area as the porewater detections listed in the previous section (N Transect 10 and

N Transect 8). The set of tubes furthest downriver (C6320/21/22) had strontium-90 detections in all three tubes but at low levels (less than 10 pCi/L). Strontium-90, tritium, and chromium results are shown in Table 6-7. These results will also be included in the final RI/FS report.

6.3 RCRA Facility Monitoring

M.J. Hartman



This section describes the monitoring results for the 116-N-1 and 116-N-3 LWDFs, the 120-N-1 percolation pond, and the 120-N-2 surface impoundment. Groundwater is monitored at these facilities to meet the requirements of RCRA and WAC 173-303 ("Dangerous Waste Regulations") for dangerous waste constituents. Groundwater data for these facilities are available in the Hanford Environmental Information System database and in the data files accompanying this report. Appendix B includes well and constituent lists, maps, flow rates, and statistical tables for the 100-N Area RCRA units.

6.3.1 116-N-1 (1301-N) Liquid Waste Disposal Facility

The 1301-N LWDF (waste site 116-N-1) was an unlined crib and trench used for disposal of liquid effluent from the 1960s through 1985. The waste site has been excavated to remove shallow vadose zone sediment (where most of the radionuclide contamination resided) and was backfilled with clean fill.

Groundwater flows to the northwest beneath the 116-N-1 LWDF and discharges to the Columbia River. The hydraulic gradient in March 2010 was 0.0016, with an estimated flow rate between 0.03 and 0.60 meter per day (Appendix B, Table B-1).

6.3.1.1 Network Evaluation and Compliance Status

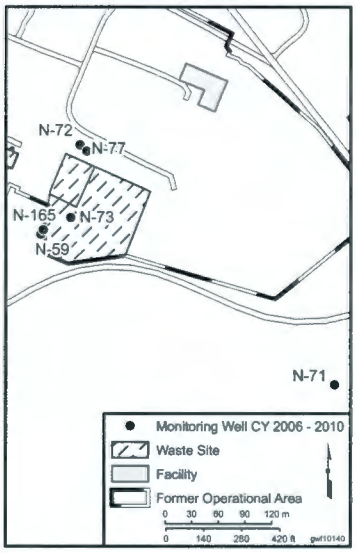
Two upgradient wells (199-N-34 and 199-N-57) and three downgradient wells (199-N-2, 199-N-3, and 199-N-105A) monitor the 116-N-1 LWDF (Appendix B, Table B-3). No changes to the monitoring network are planned until implementation of an integrated groundwater monitoring program (CERCLA, RCRA, and AEA) for the 100-N Area.

This facility is included in the Hanford Facility RCRA Permit (WA7890008967). The Permit states that RCRA monitoring during closure activities will follow the requirements of *100-N Pilot Project: Proposed Consolidated Groundwater Monitoring Program* (BHI-00725). That plan and a supplemental plan (PNNL-13914, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*) are similar to an interim status indicator evaluation program (40 CFR 265.93[b], "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), as referenced by WAC 173-303-400 ("Dangerous Waste Regulations," "Interim Status Facility Standards").

6.3.1.2 Groundwater Contaminants

Upgradient and downgradient wells are scheduled for sampling twice each year for RCRA contamination indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters. The wells were sampled as scheduled during the reporting period and there were no critical mean exceedances.

6.3.2 120-N-1 (1324-NA) Percolation Pond and 120-N-2 (1324-N) Surface Impoundment



The 1324-NA percolation pond and the 1324-N surface impoundment (waste sites 120-N-1 and 120-N-2) were used to treat and dispose corrosive, nonradioactive waste from 1977 to 1990. Both facilities have been remediated and backfilled.

Groundwater flows to the northwest beneath the 120-N-1 and 120-N-2 facilities, discharging to the Columbia River. The hydraulic gradient in March 2010 was 0.0024, with an estimated flow rate between 0.05 and 0.88 meter per day (Appendix B, Table B-1).

6.3.2.1 Network Evaluation and Compliance Status

Upgradient well 199-N-71 and downgradient wells 199-N-72, 199-N-73, 199-N-77, and 199-N-165 monitor the 120-N-1 percolation pond and 120-N-2 surface impoundment (Appendix B, Table B-3). Well 199-N-77 is screened at the base of the unconfined aquifer and statistical comparisons are not performed on data from this well. No changes to the monitoring network are planned until implementation of an integrated groundwater monitoring program for the 100-N Area.

Both of these units are included in the Hanford Facility RCRA Permit. The Permit states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. BHI-00725 and a supplemental plan (PNNL-13914) are similar to an interim status indicator evaluation program (40 CFR 265.93[b], as referenced by WAC 173-303-400). The two units are monitored as a single site (waste management area) because of their proximity and similar waste types.

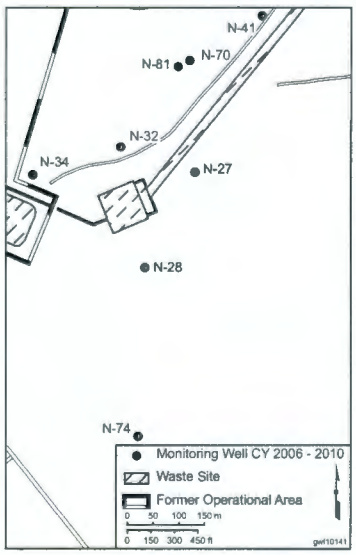
6.3.2.2 Groundwater Contaminants

During the reporting period, all of the monitoring wells for this site were sampled as scheduled, twice for RCRA contamination indicator parameters and groundwater quality, and once for site-specific parameters (Appendix B, Table B-3).

Average specific conductance values in downgradient wells 199-N-72, 199-N-73, and 199-N-165 continued to exceed the critical mean value of 752 µS/cm at least once in CY 2010. A previous groundwater quality assessment indicated that the high specific conductance is caused by the nonregulated constituents sulfate and sodium (WHC-SD-EN-EV-003, *Results of Groundwater Quality Assessment Monitoring at the 1301-N and 1324-N/NA Facilities*). Recent data indicate that this conclusion remains valid (DOE/RL-2008-01, Appendix B).

The average total organic carbon concentration exceeded the critical mean value of 865 µg/L in well 199-N-73 in September 2010, but the value was below the limit of quantitation of 990 µg/L. No other critical mean exceedances occurred during the reporting period.

Specific conductance increased sharply in well 199-N-73 in September 2010 (Figure 6-32). The change was caused by increases in calcium, sodium, nitrate, sulfate, and other ions. Nearby wells did not show a similar increase, and the cause of the change is unknown.



6.3.3 116-N-3 (1325-N) Liquid Waste Disposal Facility

The 1325-N LWDF (waste site 116-N-3) was an unlined crib and trench used to dispose liquid effluent from 1983 through 1991. The waste site was excavated to remove shallow vadose zone material (which contained the highest concentrations of radionuclides) and was backfilled.

Groundwater flows to the north beneath the 116-N-3 LWDF, turns to the northwest, and discharges to the Columbia River. The hydraulic gradient in March 2010 was 0.0012, with the groundwater flow rate estimated between 0.03 and 0.46 meter per day (Appendix B, Table B-1).

6.3.3.1 Network Evaluation and Compliance Status

The 116-N-3 LWDF is included in the Hanford Facility RCRA Permit. The Permit states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. BHI-00725 and a supplemental plan (PNNL-13914) are similar to an interim status indicator evaluation program (40 CFR 265.93[b], as referenced by WAC 173-303-400).

Upgradient well 199-N-74 and down-gradient wells 199-N-32, 199-N-41, and 199-N-81 monitor the 116-N-3 LWDF. Well 199-N-28 is monitored for supporting information but its data are not evaluated statistically. No changes to the monitoring network are planned until implementation of an integrated groundwater monitoring program for the 100-N Area.

6.3.3.2 Groundwater Contaminants

All five wells in the RCRA network were sampled as planned during the reporting period, twice for RCRA contamination indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (Appendix B, Table B-3).

Average specific conductance values in downgradient well 199-N-41 continued to exceed the critical mean value of 513 µS/cm during the reporting period, which is a continuation of previous exceedances noted from 1999 through 2009. The DOE notified Ecology of the original exceedance and submitted an assessment report (00-GWVZ-054, *Results of Assessment at the 1325-N Facility*), which concluded that the exceedance was caused by past discharges of nonregulated contaminants to the 120-N-1 percolation pond. Recent data indicate that this conclusion remains valid (DOE/RL-2008-01, Appendix B). No other critical mean exceedances occurred during the reporting period.

6.4 Conclusions and Recommendations

The conclusions and recommendations for the 100-NR-2 OU are presented below:

- Strontium-90 in groundwater within the 100-N Area is well characterized, with the plume varying little since before interim remedial actions (mainly pump-and-treat operations) began in 1996 to the present. Strontium-90 has a much greater affinity for sediment than for water (high distribution coefficient), so its rate of transport in groundwater to the Columbia River is considerably slower than the actual groundwater flow rate. The relative velocity of strontium-90 to groundwater is ~1 to 100 (between 0.0005 and 0.009 meters per day).
- Current work at the existing apatite PRB is promising and should provide an effective barrier between the strontium-90 plume and the Columbia River. Strontium-90 and gross beta concentrations in the existing apatite PRB, in both aquifer tubes and wells, are generally decreasing. Many sites have shown more than 90% reduction in gross beta concentrations.
- The jet injection test successfully demonstrated that the vadose zone and upper unconfined aquifer can be treated using this technology in conjunction with groundwater injections.

- Future activities planned for the 100-N Area shoreline include expansion of both the existing apatite PRB and installation of further jet-injected PRB, as well as further phytoextraction testing.
- Tritium is present beneath much of the 100-N Area and along the Columbia River. The concentrations in the plume are decreasing and no locations were above the DWS of 20,000 pCi/L in CY 2010. This reflects no continuing source of tritium contamination in the 100-N Area and attenuation through radioactive decay of the remaining tritium contamination.
- Nitrate continues to be an issue at the 100-N Area, with concentrations above the DWS of 45 mg/L in several locations. Data from the Waste Information Data System database and historical documents are being examined to determine if any potential sources of the nitrate plume may have been missed. Nitrate is also being investigated as part of the RI/FS process planned at the 100-N Area.
- A plume map has been generated showing the current extent of the diesel contamination in groundwater in the 100-N Area. The plume appears localized, with well 199-N-18 having the highest detections of total petroleum hydrocarbon-diesel. Several other nearby wells and aquifer tubes have detections of total petroleum hydrocarbon-diesel. The plume extends to the northwest to the Columbia River. WCH is continuing bioventing pilot testing, and S&GRP will take additional groundwater samples in support of that work during 2011.
- Sulfate levels are elevated in the 100-N Area, but only one well exceeded the secondary DWS of 250 mg/L. The highest value was found in well 199-N-18, and the cause is uncertain. Monitoring of this well will continue to determine if the sulfate concentration remains elevated in 2011. Well 199-N-165 had the second highest sulfate concentration; this well monitors a known source of the sulfate contamination in the 100-N Area. Most of the sulfate values are well below the regulatory limits.
- Manganese and iron are elevated in wells associated with the diesel plume, which is a side effect of the reducing conditions created by the biodegradation of diesel.
- Chromium is elevated in only two wells at the 100-N Area: well 199-N-80, which has known screen corrosion (exceeds the DWS of 100 µg/L); and well 199-N-74, which is being monitored to determine if the chromium detection trend continues. The RI/FS process is also investigating this well and trying to determine the source of the contamination. No evidence exists of any chromium groundwater contamination source in the remainder of the 100-N Area.
- The RI/FS work plan (DOE/RL-2008-46-ADD5) for the 100-N Area was issued in March 2011. The RI/FS sampling and analysis plan (DOE/RL-2009-42) was issued in December 2010. Drilling of the eight RI/FS wells for the 100-N Area began in March 2011. Spatial/temporal sampling was completed at the 100-N Area in February 2011, with the final well sampled near the end of the month. Data from the sampling is currently being evaluated.
- Eight new aquifer tubes were installed in the 100-N Area; two sets of three each (C7934/C7235/C7936 and C7937/C7938/C7939) near the 100-N outfall structure and two tubes at location N116mArray-7A (C7881/C7882) to replace this array which became unusable.
- Three rounds of RI/FS sampling were performed at four sets of aquifer tubes in the vicinity of the 100-N outfall structure.

Groundwater monitoring in the 100-NR-2 groundwater interest area includes the following activities:

CERCLA and AEA Monitoring (Appendix A) —

- ***Forty-three wells are scheduled for biannual or yearly sampling as part of the integrated monitoring plan for the 100-N Area (CERCLA, RCRA, AEA). Two wells were not sampled as planned.***
- ***Eighteen wells were sampled quarterly for performance monitoring of the apatite PRB. All forty-five wells/aquifer tubes were sampled in August 2010. Sampling will be performed twice each year for the next few years.***
- ***Fifteen wells and twenty-eight aquifer tubes are scheduled for quarterly to annual sampling under a shoreline groundwater monitoring plan.***

Facility Monitoring (Appendix B) —

- ***Five wells are scheduled for semiannual sampling for the 116-N-1 LWDF to meet RCRA and AEA requirements. The wells were sampled as planned.***
- ***Five wells are scheduled for semiannual sampling for the 120-N-1 percolation pond and 120-N-2 surface impoundment to meet RCRA and AEA requirements. The wells were sampled as planned.***
- ***Five wells are scheduled for semiannual sampling for the 116-N-3 LWDF the meet RCRA requirements. The wells were sampled as planned.***

Table 6-1. Nitrate Concentrations in Wells in the 100-N Area Exceeding the Drinking Water Standard (45 mg/L)

Well Name	Concentration (mg/L)	Nearest Facility	Well Name	Concentration (mg/L)	Nearest Facility
199-N-2	224 (D)	116-N-1	199-N-57	60.6 (D)	105-N
199-N-3	94.3 (D)	116-N-1	199-N-67	500 (D)	116-N-1
199-N-14	50 (D)	116-N-1	199-N-69	61.1 (D)	116-N-1
199-N-19	89.4 (D)	105-N	199-N-75	49.6 (D)	116-N-1
199-N-21	64.6 (D)	105-N	199-N-76	66.4 (D)	116-N-1
199-N-26	50.5 (D)	---	199-N-99A	47.8 (D)	116-N-1
199-N-28	52.2 (D)	116-N-3	199-N-103A	73.9 (D)	116-N-1
199-N-32	70.8 (D)	116-N-3	199-N-105A	109 (D)	116-N-1
199-N-56	51.4 (D)	105-N	199-N-121	45.2 (D)	116-N-1

D = analyte reported at a secondary dilution factor

Table 6-2. Hydrocarbon Product Removal from Well 199-N-18 (2003 to Present)

Year	Product Removed (g)	Notes
2003	~1,200 (see notes below)	Estimate provided per information given in note below; data records lost when original work package was lost in the field.
2004	3,475	Changed out twice per month.
2005	780	Changed approximately every 2 months.
2006	1,370	Changed every 2 months.
2007	1,294	Changed every 2 months.
2008	920	Changed every 2 months.
2009	1,380	Changed approximately every 2 months.
2010	225.5	Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.
	Total	**10,644.5 g (~10.64 kg) removed through end of 2010**

Notes:

1. DOE/RL-2004-21, *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal started in October 2003.

2. DOE/RL-2005-18, *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for FY 2004 (October 2003 through October 2004) was approximately 0.4 kilograms per month, so an estimate is provided for the 3 months missing in CY 2003.

Table 6-3. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Timeline

Dates		Injection Wells[a]	Description of Test/Injection	Injection Chemistry
2006[b]	May 3	N-138	Tracer test at the pilot test #1 location (upriver end of PRB)	NaBr
	May 31 to June 1	N-138	Pilot test #1 location (upriver end of PRB) — Hanford/ Ringold injection at high river level	4 mM Ca, 10 mM citrate, 2.4 mM PO4
	Sept. 27 to Sept. 28	N-137	Pilot test #2 location (downriver end of PRB) — Ringold Formation injection at low river level	2 mM Ca, 5 mM citrate, 2.4 mM PO4
2006 – 2007	9/28/06 to 2/28/07	N/A	Performance monitoring	N/A
2007[d]	Feb. 28 to Mar. 2	N-136, N-142, and N-145[c]	Low concentration injections into Ringold Formation at low river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
	Mar. 2 to Mar. 5	N-140 and N-144	Low concentration injections into Ringold Formation at low river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
	Mar. 20 to Mar. 23	N-137 and N-141	Low concentration injections into Hanford formation and Ringold Formation at high river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
	Mar. 23 to Mar. 25	N-139 and N-143	Low concentration injections into Hanford formation and Ringold Formation at high river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
	June 5 to June 6	N-142, N-136, and N-144	PT#3, Phases I and II — Hanford formation injections at high river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
	June 8 to June 10	N-138	PT#3, Phase III — Hanford formation injections at high river level	1 mM Ca, 2.5 mM citrate, 10 mM PO4
2007 – 2008	6/10/07 to 6/4/08	N/A	Performance monitoring	N/A
2008	June 4 to June 6	N-138, N-137, and N-159	High-concentration injection #1 — Hanford formation and Ringold Formation at higher river levels	3.6 mM Ca, 9.0 mM citrate, 40 mM PO4
	June 26 to June 28	N-145, N-161, and N-141	High-concentration injection #2 — Hanford formation and Ringold Formation at higher river levels	3.6 mM Ca, 9.0 mM citrate, 40 mM PO4
	June 30 to July 3	N-143, N-163, and N-139	High-concentration injection #3 — Hanford formation and Ringold Formation at higher river levels	3.6 mM Ca, 9.0 mM citrate, 40 mM PO4
	July 14 to July 17	N-136, N-160, N-142, and N-164	High-concentration injection #4 — Hanford formation and Ringold Formation at lower river levels	3.6 mM Ca, 9.0 mM citrate, 40 mM PO4
	July 22 to July 24	N-144, N-162, and N-140	High-concentration injection #5 — Hanford formation and Ringold Formation at lower river levels	3.6 mM Ca, 9.0 mM citrate, 40 mM PO4
	7/24/08 to 12/31/08	N/A	Performance monitoring	N/A
2009	January to December	N/A	Performance monitoring	N/A
2010	January to August	N/A	Performance monitoring	N/A

a. Well names are prefixed by "199-".

b. Original apatite PRB wells installed in 2005, including 199-N-136, 199-N-137, 199-N-139, 199-N-139, 199-N-140, 199-N-141, 199-N-142, 199-N-143, 199-N-144, and 199-N-145 (screened across lower Hanford formation and upper Ringold Formation), on 9.1-meter spacing between wells. Also installed two additional monitoring wells (199-N-146 and 199-N-147). Monitoring wells 199-N-122 and 199-N-123 were in place before PRB installation. All monitoring wells are screened across the lower Hanford formation and upper Ringold Formation.

c. Well 199-N-145 replaced well 199-N-142 part way through injection due to problems with well 199-N-142.

d. Six additional injection wells were installed in fall 2007 along existing the apatite PRB, including 199-N-159, 199-N-160, 199-N-161, 199-N-162, 199-N-163, 199-N-164, and 199-N-165 (screened in upper Ringold Formation), on 4.6-meter spacing between wells. Wells installed in lower portion of existing PRB, between wells 199-N-141 and 199-N-137.

N/A = not applicable

PT = pilot test

Table 6-4. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Monitoring Locations (Includes Barrier Wells, Monitoring Wells, and Aquifer Tubes)

Well Name/ID	Well Type	Geological Unit(s), Screened Interval	Screened Interval (ft bgs)	Location in PRB
N116mArray-2A/C5256	AT	--	--	Upriver end of PRB — pilot test #1 site
APT-1/C5269	AT	--	--	
199-N-138/C5044	IBW	Hanford/Ringold Formations	7.8 to 24.8	
199-N-123/C4955	MW	Hanford/Ringold Formations	9.99 to 29.97	
199-N-126/C5032	MW	Ringold Formation	22.3 to 27.3	
199-N-127/C5033	MW	Hanford formation	12.7 to 17.7	
199-N-128/C5034	MW	Ringold Formation	21.6 to 26.6	
199-N-129/C5035	MW	Hanford formation	12.1 to 17.1	
199-N-130/C5036	MW	Ringold Formation	22.5 to 27.5	
199-N-131/C5037	MW	Hanford formation	12.5 to 17.5	
199-N-132/C5038	MW	Ringold Formation	22.2 to 27.2	
199-N-133/C5039	MW	Hanford formation	12.7 to 17.7	
N116mArray-3A/C5257	AT	--	--	Upper half of PRB
199-N-139/C5045	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-140/C5046	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-146/C5052	MW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-141/C5047	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-164/C6182	IBW	Ringold Formation	17.14 to 24.14	
N116mArray-4A/C5258	AT	--	--	
199-N-142/C5048	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-163/C6181	IBW	Ringold Formation	17.35 to 24.35	
199-N-143/C5049	IBW	Hanford/Ringold Formations	7.0 to 24.0	Upper half of PRB
199-N-162/C6180	IBW	Ringold Formation	17.20 to 24.20	Lower half of PRB
199-N-122/C4954	MW	Hanford/Ringold Formations	7.06 to 26.92	
199-N-144/C5050	IBW	Hanford/Ringold Formations	7.0 to 24.0	
NVP2-116.0m/C5251	AT	--	--	
199-N-161/C6179	IBW	Ringold Formation	17.25 to 24.25	
199-N-145/C5051	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-160/C6178	IBW	Ringold Formation	17.20 to 24.20	
199-N-136/C5042	IBW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-159/C6177	IBW	Ringold Formation	17.11 to 24.11	
N116mArray-6A/C5259	AT	--	--	
199-N-137/C5043	IBW	Hanford/Ringold Formations	7.0 to 24.0	Downriver end of PRB — pilot test #2 site
199-N-147/C5116	MW	Hanford/Ringold Formations	7.0 to 24.0	
199-N-148/C5326	MW	Ringold Formation	19.7 to 24.7	
199-N-149/C5317	MW	Hanford formation	11.0 to 16.0	
199-N-150/C5318	MW	Hanford formation	11.0 to 16.0	
199-N-151/C5319	MW	Ringold Formation	20.0 to 25.0	
199-N-152/C5320	MW	Lower Ringold Formation	28.2 to 33.2	
199-N-153/C5321	MW	Hanford formation	10.9 to 15.9	
199-N-154/C5322	MW	Ringold Formation	19.1 to 24.1	

Table 6-4. (Cont.)

Well Name/ID	Well Type	Geological Unit(s), Screened Interval	Screened Interval (ft bgs)	Location in PRB
199-N-155/C5323	MW	Hanford formation	11.0 to 16.0	Downriver end of PRB — pilot test #2 site
199-N-156/C5324	MW	Ringold Formation	19.0 to 24.0	
APT-5/C5386	AT	--	--	
N116mArray-7A/C5260*	AT	--	--	
C7881 (N116mArray-7A replacement)*	AT	--	--	

* N116mArray-7A was monitored for the apatite PRB from June 2006 through September 2009. It became unusable in 2009 and was replaced at the same location with C7881.

Table 6-5. 100-NR-2 Operable Unit Apatite Permeable Reactive Barrier Performance Monitoring Constituents

Analysis	Constituents
Strontium-90	Strontium-89/90
Gross beta	Gross beta
Inductively coupled plasma (ICP) metals	Aluminum, antimony, arsenic, barium, calcium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, strontium, vanadium, and zinc
Ion chromatography (IC) anions	Chloride, fluoride, nitrate in nitrogen, nitrite in nitrogen, phosphate in phosphorous, and sulfate

Table 6-6. Porewater Sampling Results for Strontium-90, Tritium, and Hexavalent Chromium

Location	Strontium-90 (pCi/L) (DWS = 8 pCi/L)	Tritium (pCi/L) (DWS = 20,000 pCi/L)	Hexavalent Chromium — Unfiltered (µg/L) (DWS = 100 µg/L)
N Transect 1	-0.13 (U)	410	0.002 (U)
N Transect 2	-2.6 (U)	260	0.002 (U)
N Transect 3	-5 (U)	540	0.002 (U)
N Transect 4	-2.5 (U)	760	0.002 (U)
N Transect 5	-3 (U)	-82 (U)	0.002 (U)
N Transect 6	-4.1 (U)	670	0.002 (U)
N Transect 7	-1.4 (U)	800	0.002 (U)
N Transect 7 — Duplicate	-3.8 (U)	690	0.002 (U)
N Transect 8	3.2	740	0.002 (U)
N Transect 9	-5.5 (U)	4,300	0.002 (U)
N Transect 10	18	4,000	0.002 (U)
T100N1A-1	100	1,700	0.002 (U)
T100N1A-2	77	1,200	0.002 (U)
T100N1A-3	95	2,600	0.002 (U)

Note: Yellow-shaded cells indicate detection; orange-shaded cells indicate concentration above DWS. The DWS for strontium-90 = 8 pCi/L; DSW for tritium = 20,000 pCi/L; DWS for chromium = 100 µg/L.

U = not detected in sample; value shown is the detection limit

Table 6-7. Remedial Investigation/Feasibility Study Aquifer Tube Sampling Results for Strontium-90, Tritium, and Hexavalent Chromium

Location C6263 (Shallow)								
August 17, 2010			September 13, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-6 (U)	2,500	2.01 (BD) 14 (U)	-5.6 (U)	2,400	2.93 (BD) 14 (U)	-2.6 (U) -1.1 (U)	2,400 3,000	2.74 (BD) 14 (U)
Location C6264 (Middle)								
August 17, 2010			September 13, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-8.1 (U)	2,100	1.23 (BD) 14 (U)	-3.7 (U)	2,700	2.19 (BD) 24 (B)	-0.86 (U)	3,400	2.41 (BD) 14 (U)
Location C6265 (Deep)								
August 17, 2010			September 13, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-7.6 (U)	1,000	1.34 (BD) 14 (U)	-8.1 (U) -4 (U)	1,400 1,400	1.81 (BD) 14 (U) 1.92 (BD) 14 (U)	-2.2 (U)	3,100	2.74 (BD) 14 (U)
Location C6317 (Shallow)								
August 12, 2010			September 13, 2010			December 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
0.06 (U) 3.2	2,500 2,600	2.52 (BD) 14 (U) 1.96 (BD) 14 (U)	-2 (U) 0.93 (U)	1,600 1,400	2.15 (BD) 14 (U) 2.47 (BD) 14 (U) 2.88 (BD) 14 (U)	---	---	---
Location C6318 (Middle)								
August 12, 2010			September 13, 2010			December 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-7.8 (U)	750	5.04 (BD) 14 (U)	-3.1 (U)	730	5.03 (BD) 14 (U)	---	---	---

Table 6-7. (Cont.)

Location C6319 (Deep)								
August 12, 2010			September 13, 2010			December 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-3.1 (U)	870	4.06 (BD) 14 (U)	-1.8 (U)	990	4.15 (BD) 14 (U)	---	---	---
Location C7934 (Shallow)								
July 17, 2010			September 12, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
220	7,600	9.46 (BD) 13 (U)	300	9,800	8.37 (BD) 14 (U)	320	11,000	6.32 (BD) 14 (U)
Location C7935 (Middle)								
July 17, 2010			September 12, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
200	6,000	4.78 (BD) 13 (U)	300	9,400	8.45 (BD) 14 (U)	300	12,000	6.33 (BD) 14 (U)
Location C7936 (Deep)								
July 17, 2010			September 12, 2010			December 28, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
39	6,200	5.12 (BD) 13 (U)	69	4,300	5.32 (BD) 14 (U)	84	5,000	5.8 (BD) 14 (U)
Location C7937 (Shallow)								
July 15, 2010			September 12, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-2.2 (U)	-5.4 (U)	2.21 (BD) 13 (U)	-3.7 (U)	950	4.69 (BD) 14 (U)	0.04 (U) -3.7 (U)	84 (U) 140 (U)	1 (UD) 14 (U) 1 (UD) 14 (U)

Table 6-7. (Cont.)

Location C7938 (Middle)								
July 15, 2010			September 12, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-4.2 (U)	180	4.63 (BD) 13 (U)	-4.6 (U)	850	6.32 (BD) 14 (U)	-1.4 (U)	16 (U)	4.99 (BD) 15 (B)
Location C7939 (Deep)								
July 15, 2010			September 12, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-3.9 (U)	650	2.3 (BD) 13 (U)	-3.1 (U)	730	3.7 (BD) 14 (U)	-0.7 (U)	210	2.76 (BD) 14 (U)
Location C6320 (Shallow)								
August 11, 2010			September 9, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
5.4	220	12.6 (BD) 14 (U)	9.5	740	3.45 (BD) 14 (U)	1.2 (U)	380	1.6 (BD) 14 (U)
Location C6321 (Middle)								
August 11, 2010			September 9, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
5.8	390	2.27 (BD) 14 (U)	5.5	840	2.96 (BD) 14 (U)	3.6	410	1.65 (BD) 14 (U)
Location C6322 (Deep)								
August 11, 2010			September 9, 2010			December 27, 2010		
Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)	Sr-90 (pCi/L)	Tritium (pCi/L)	Chromium (unfiltered)
-4 (U)	710	3.95 (BD) 14 (U)	-0.23 (U)	1,200	5.71 (BD) 14 (U)	1.6	890	3.67 (BD) 14 (U)

Notes:

1. B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit, D = analyte reported at a secondary dilution factor, U = detected in sample; value shown is the detection limit.

2. Yellow-shaded cells indicatedetection; orange-shaded cells indicate concentrations above DWS. The DWS for strontium-90 is 8 pCi/L; the DWS for tritium is 20,000 pCi/L; and the DWS for chromium is 100 µg/L.

Figure 6-1. Facilities and Groundwater Monitoring Wells in the 100-N Area

Figure 6-2. Aquifer Tubes, Monitoring Wells, and Apatite Permeable Reactive Barrier Monitoring Locations on the 100-N Area Shoreline

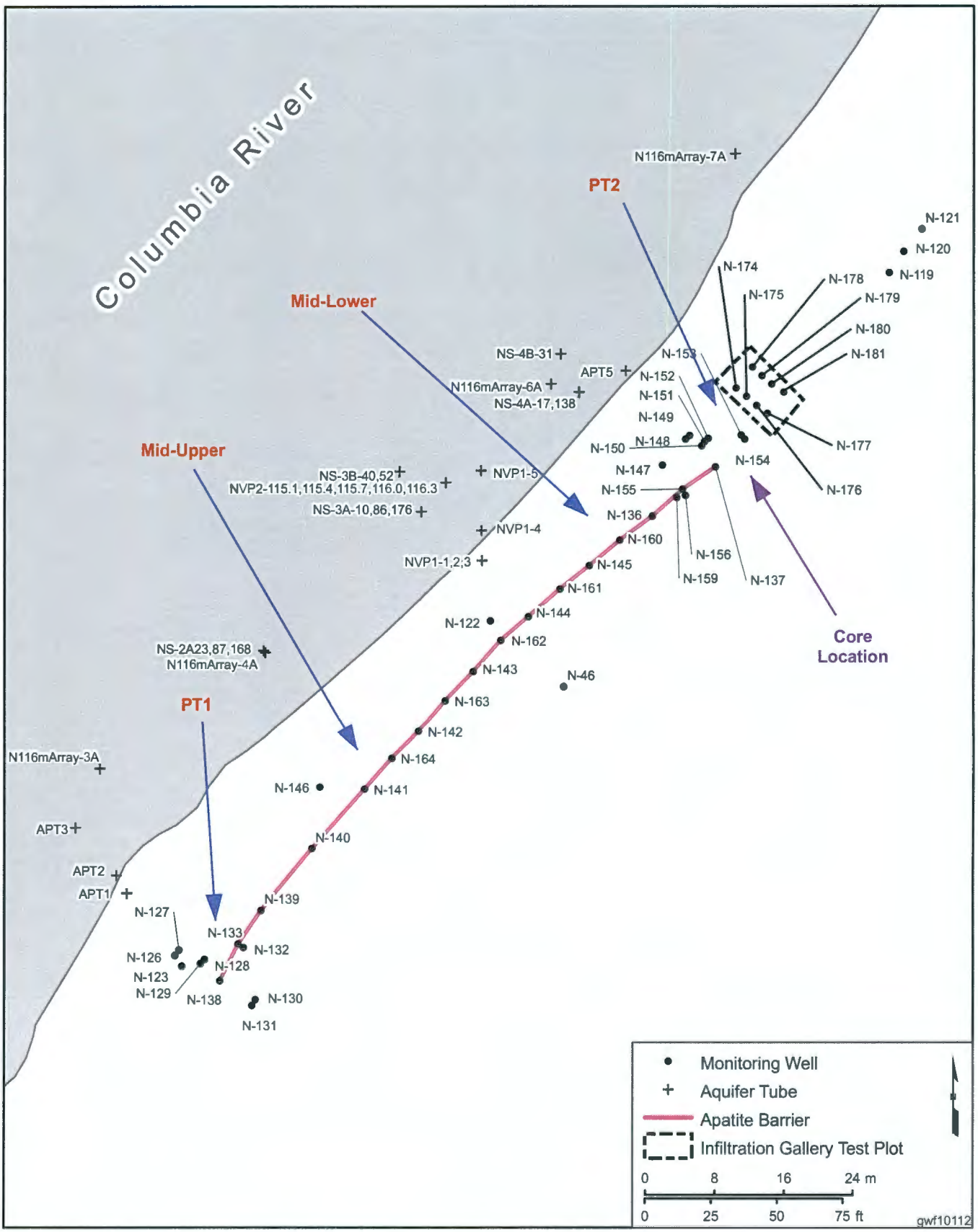


Figure 6-3. 100-N Area Water Table Map, March 2010

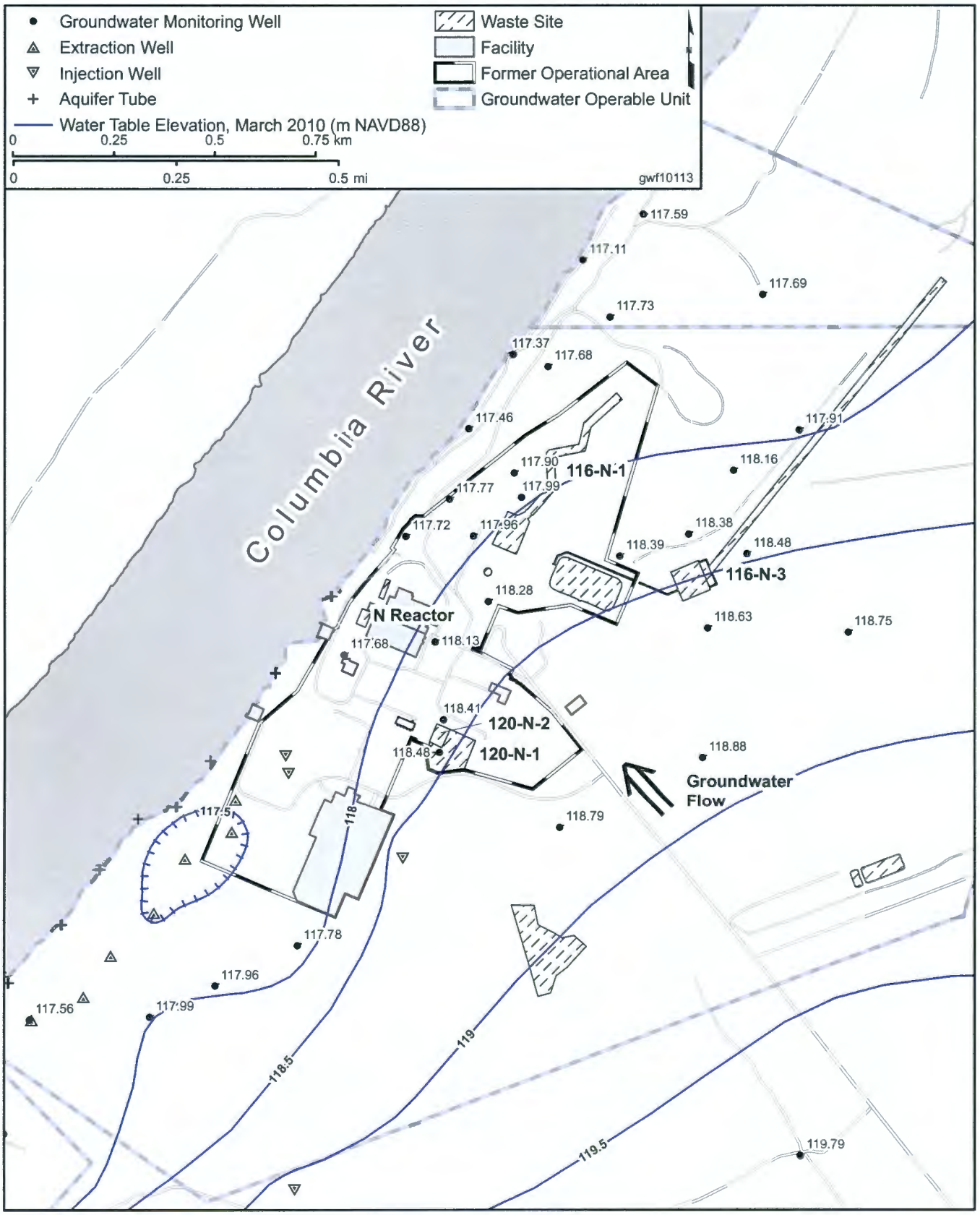


Figure 6-4. Average Strontium-90 Concentrations in the 100-N Area, Upper Portion of Unconfined Aquifer

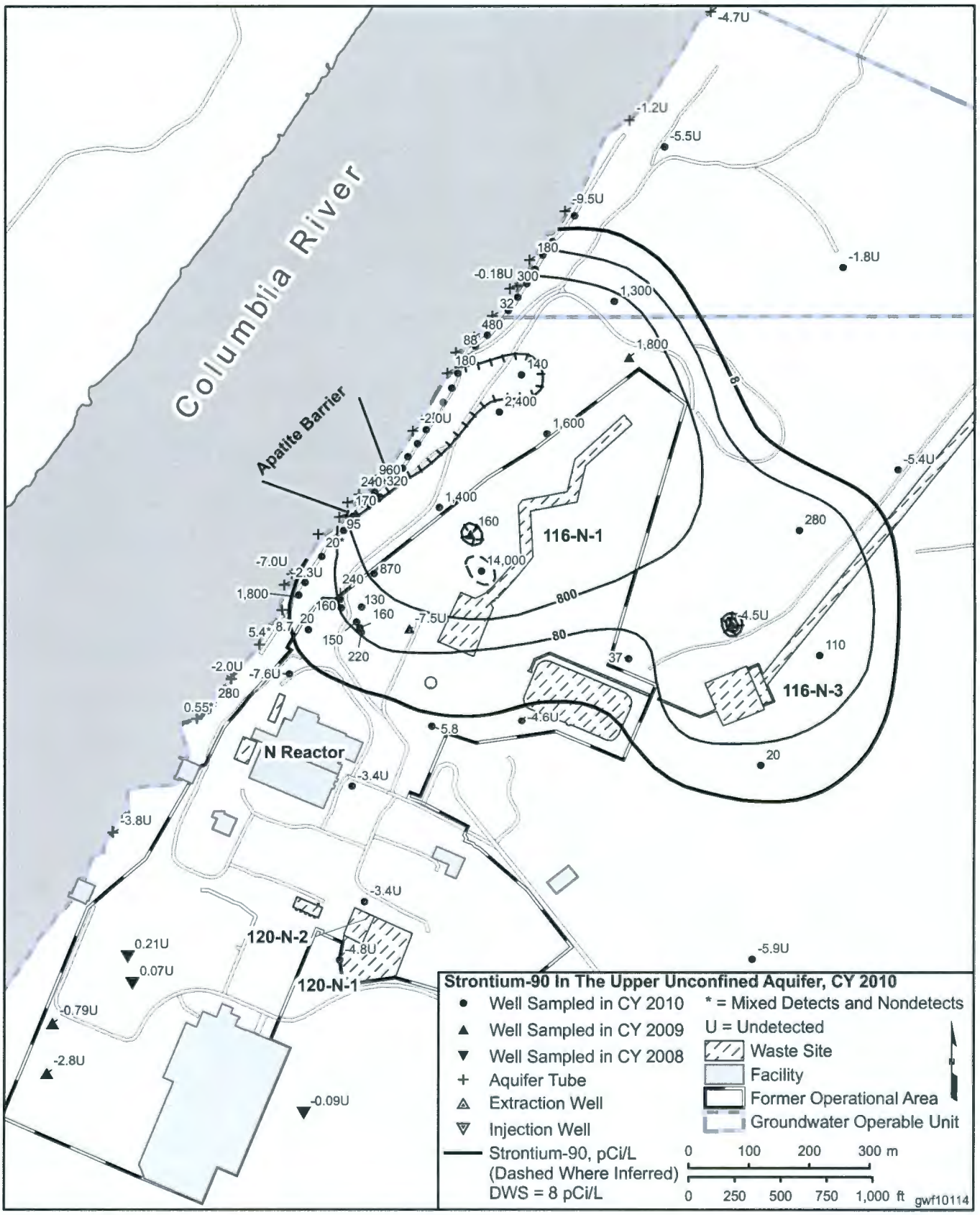


Figure 6-5. Strontium-90 in Groundwater at the Apatite Permeable Reactive Barrier Study Area, Fall 2010, Upper Portion of Unconfined Aquifer

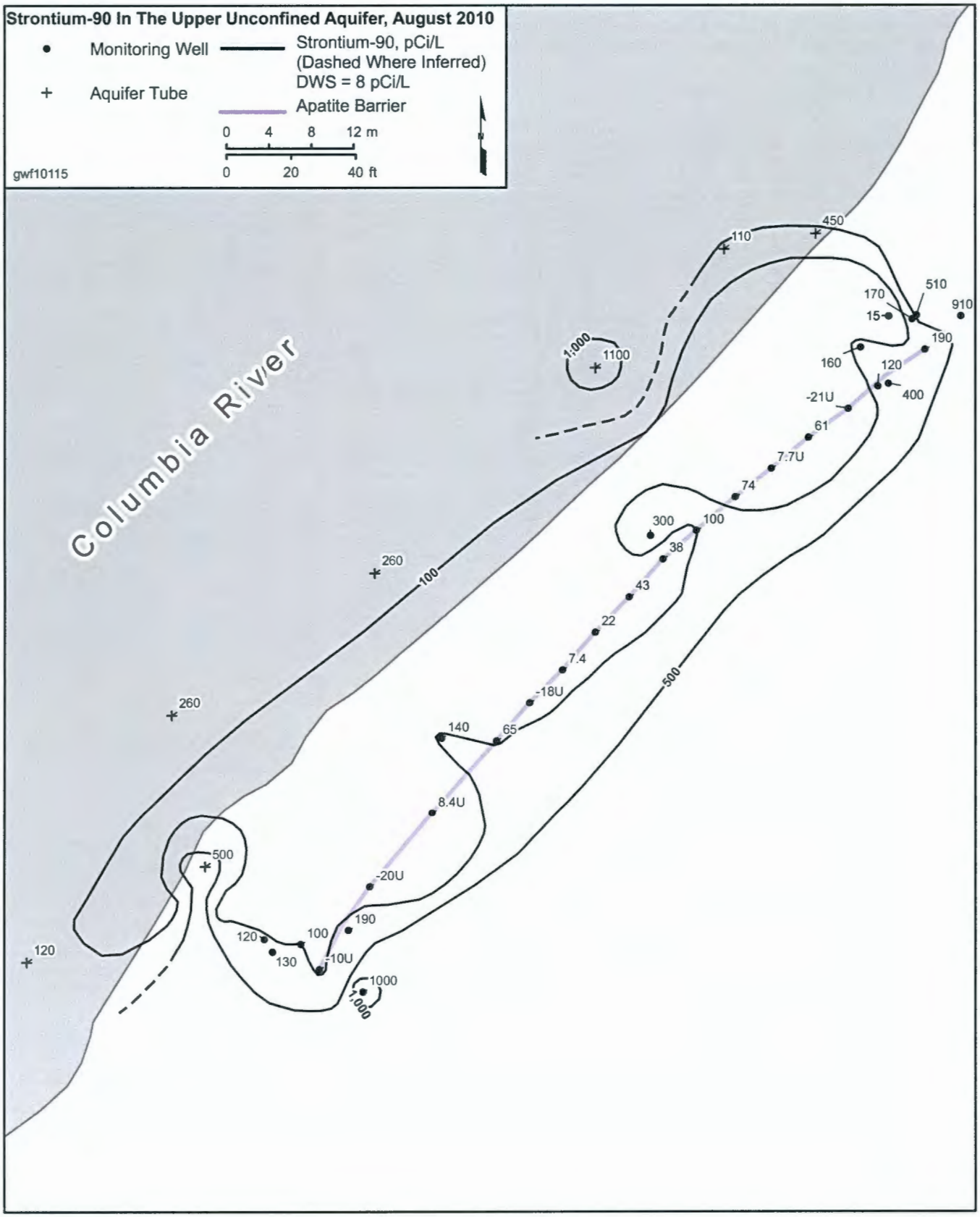


Figure 6-6. Strontium-90 Concentrations and Water Levels near 116-N-1 Liquid Waste Disposal Facility

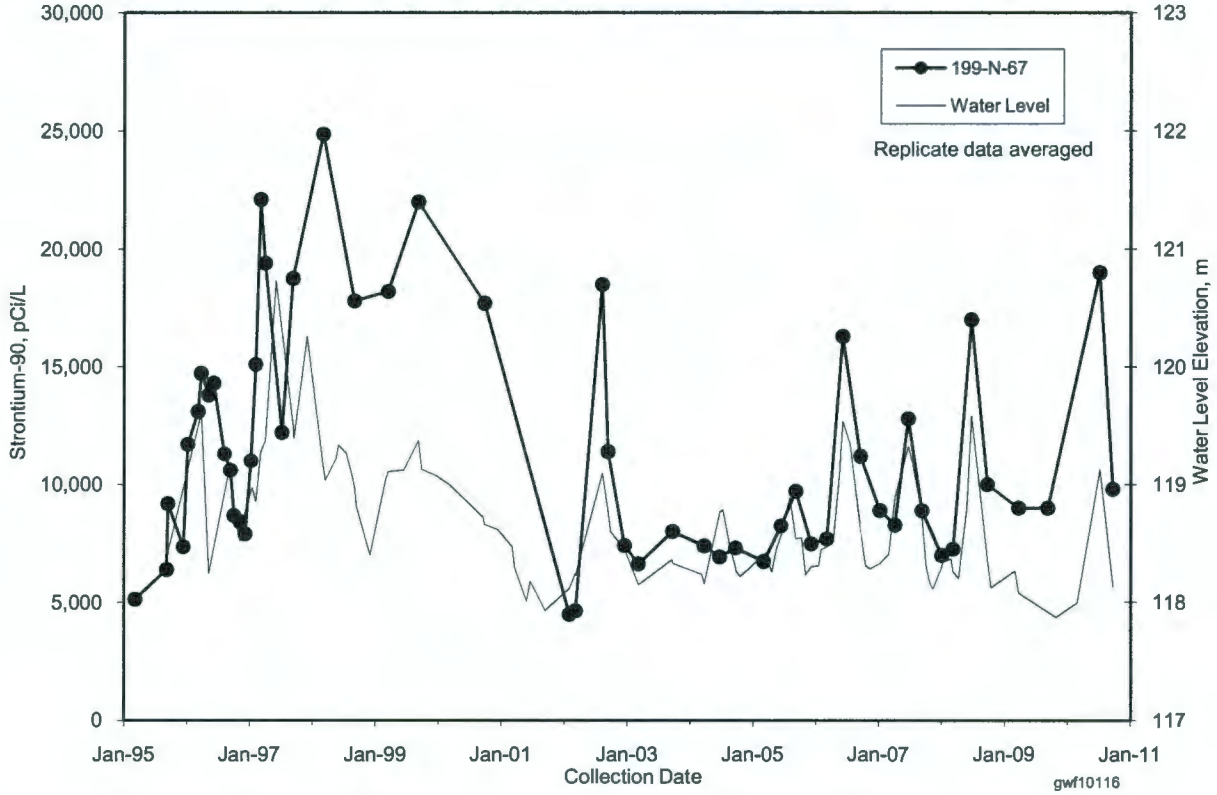


Figure 6-7. Strontium-90 Concentrations and Water Levels near 116-N-3 Liquid Waste Disposal Facility

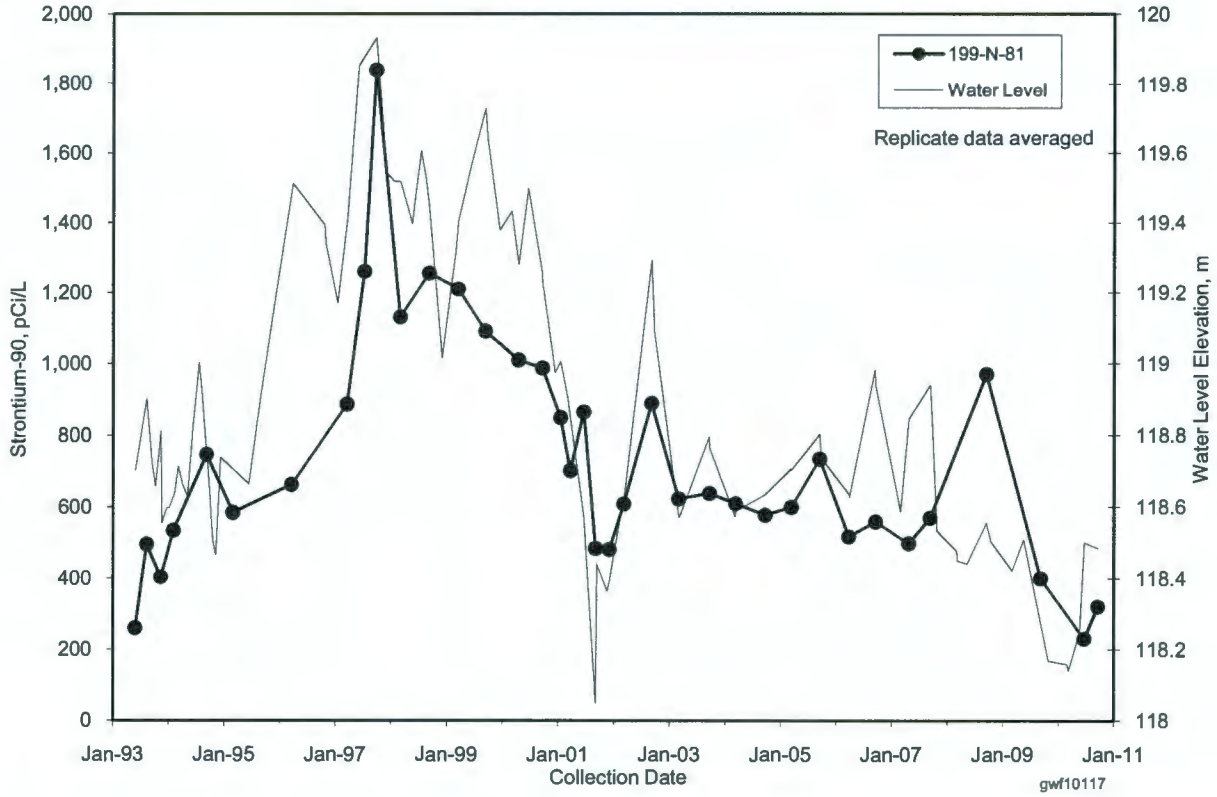


Figure 6-8. Cross Section of Wells and Aquifer Tubes and Strontium-90 Concentrations with Depth Along the 100-N Area Shoreline

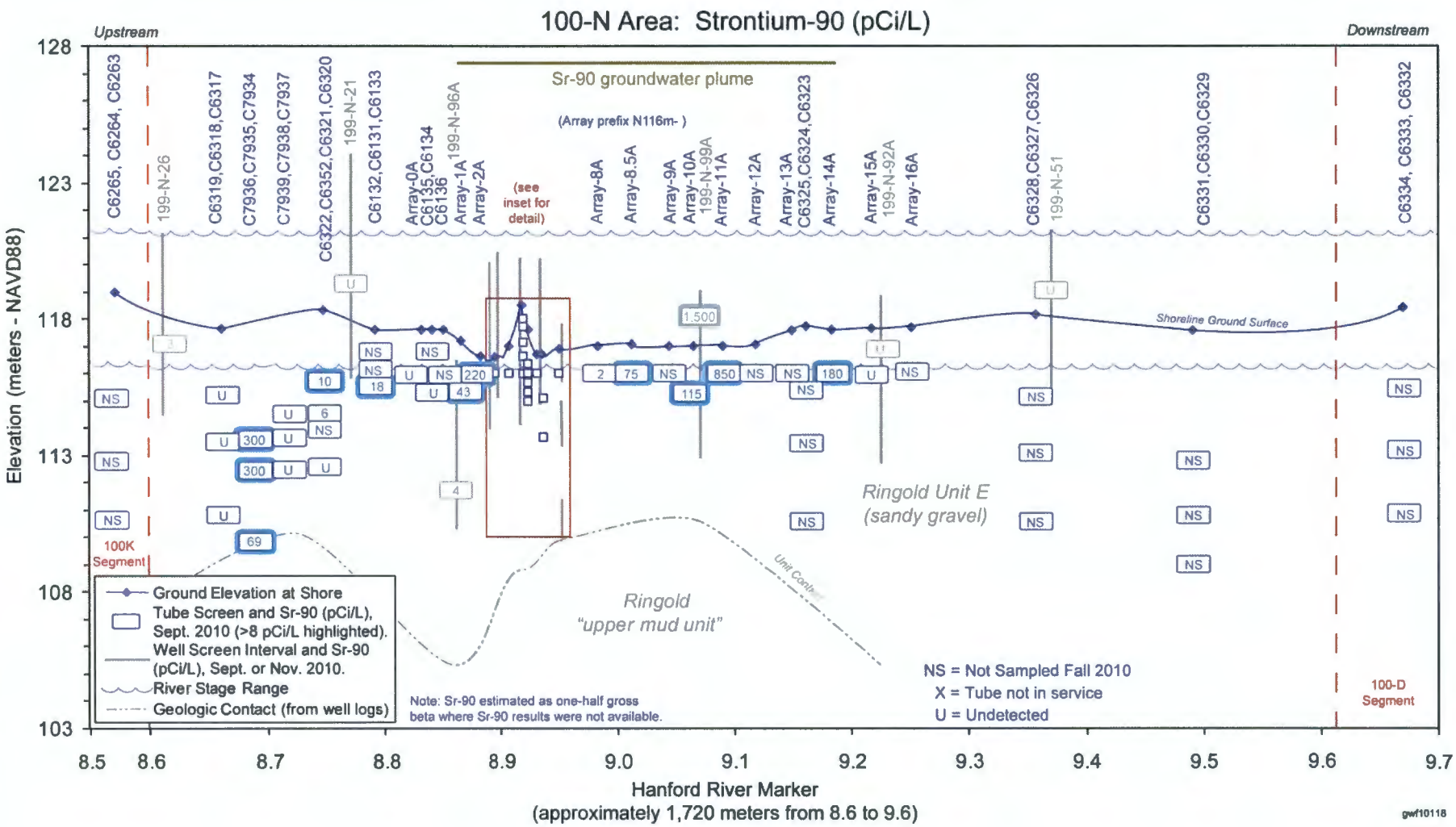


Figure 6-9. Cross Section of Wells and Aquifer Tubes and Strontium-90 Concentrations with Depth Along the Apatite Permeable Reactive Barrier, 100-N Area Shoreline

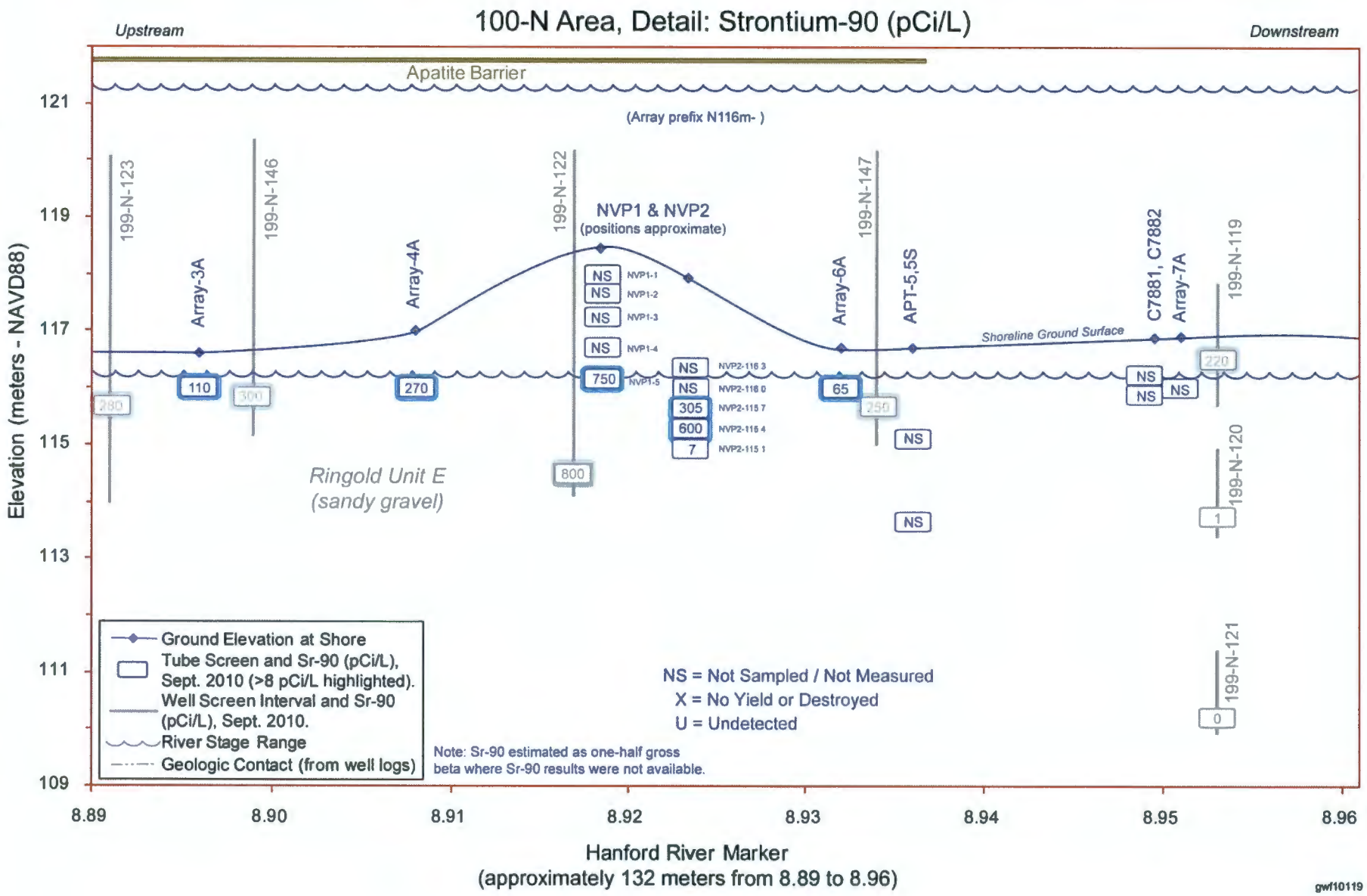


Figure 6-10. Strontium-90 Vertical Profile in the NVP2-Series Aquifer Tubes

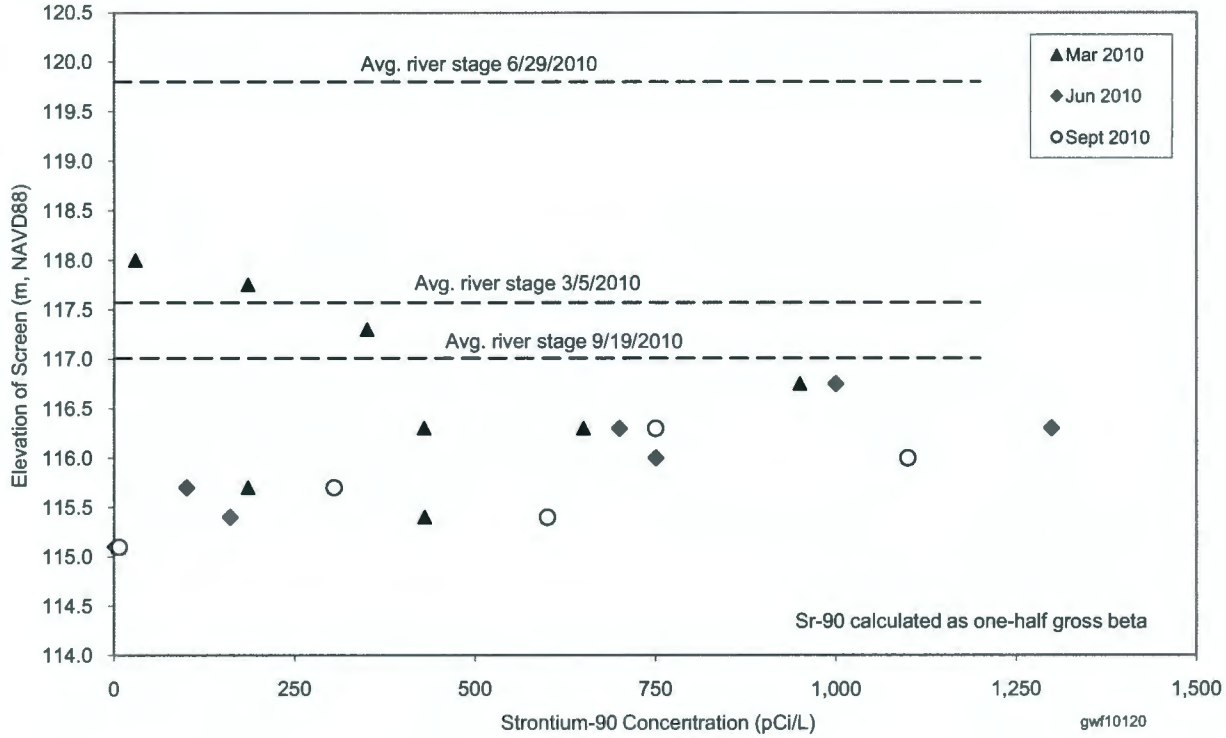


Figure 6-11. Strontium-90 Concentration in Aquifer Tubes in 100-N Area

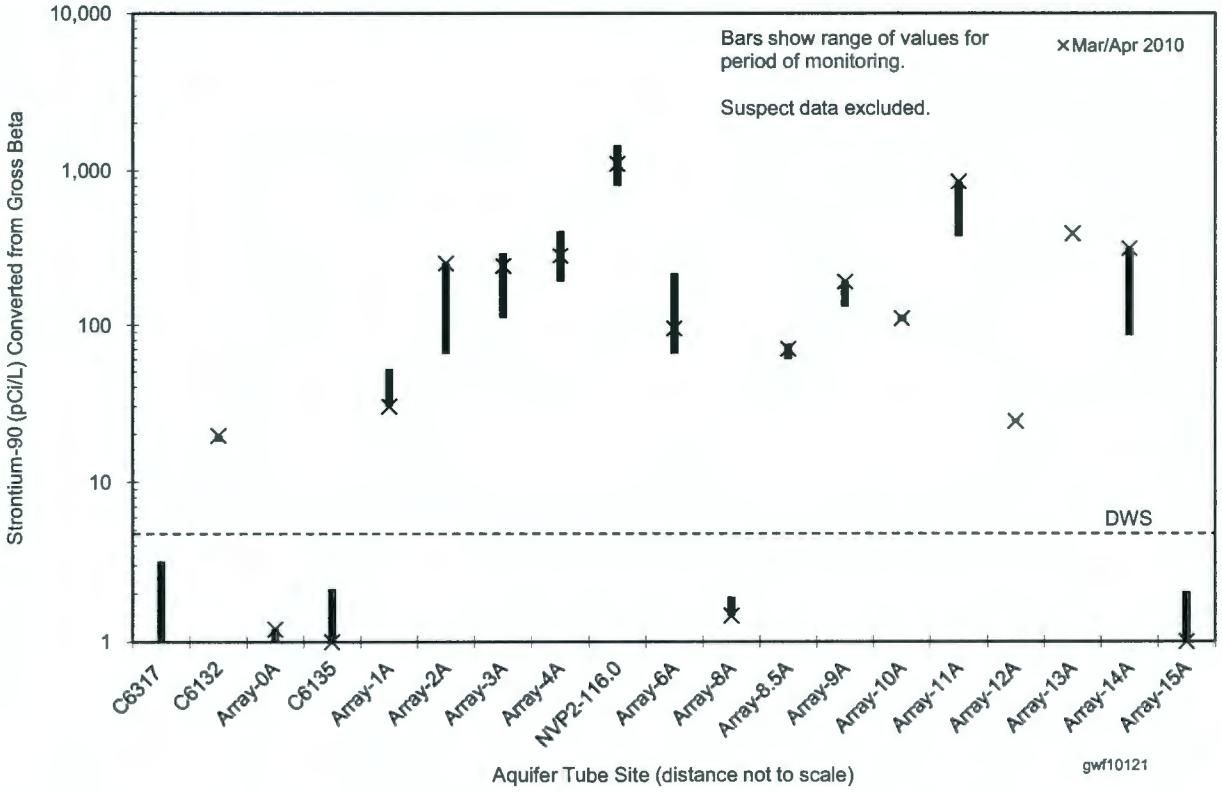
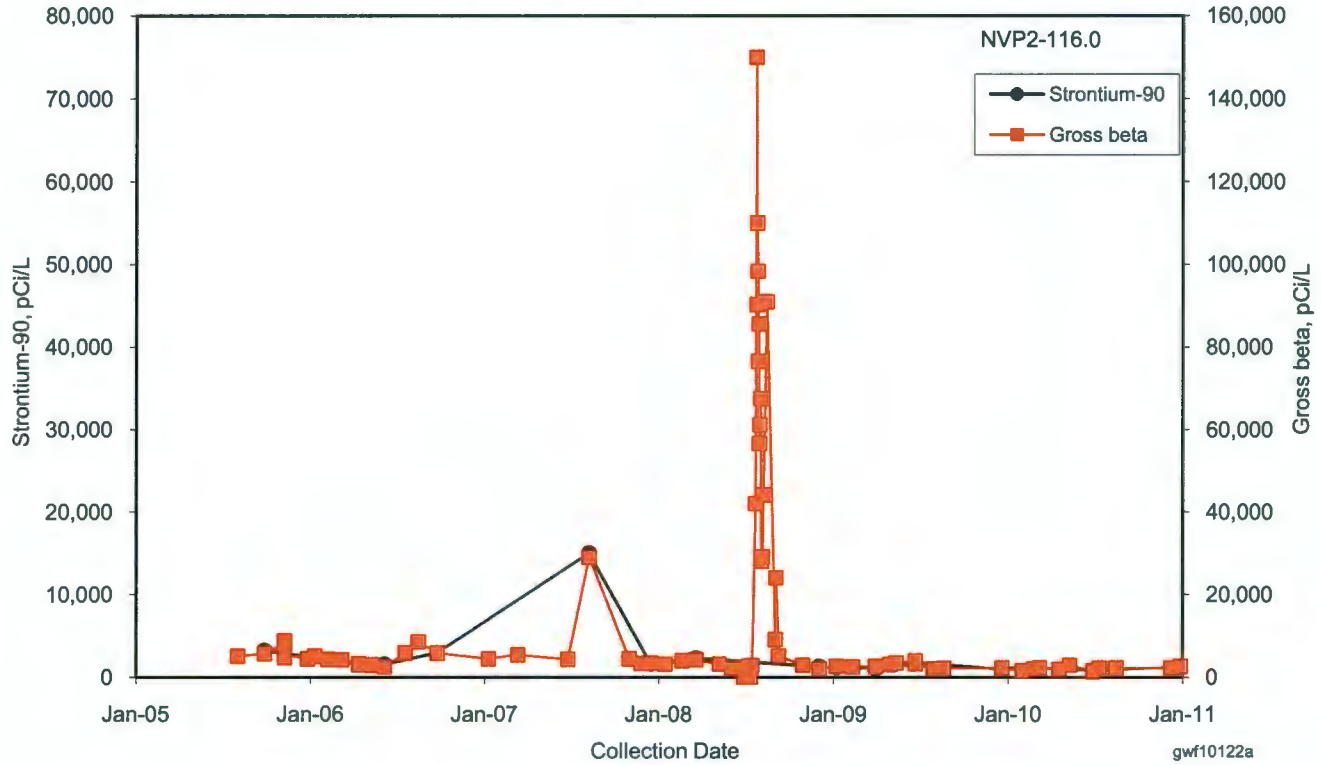
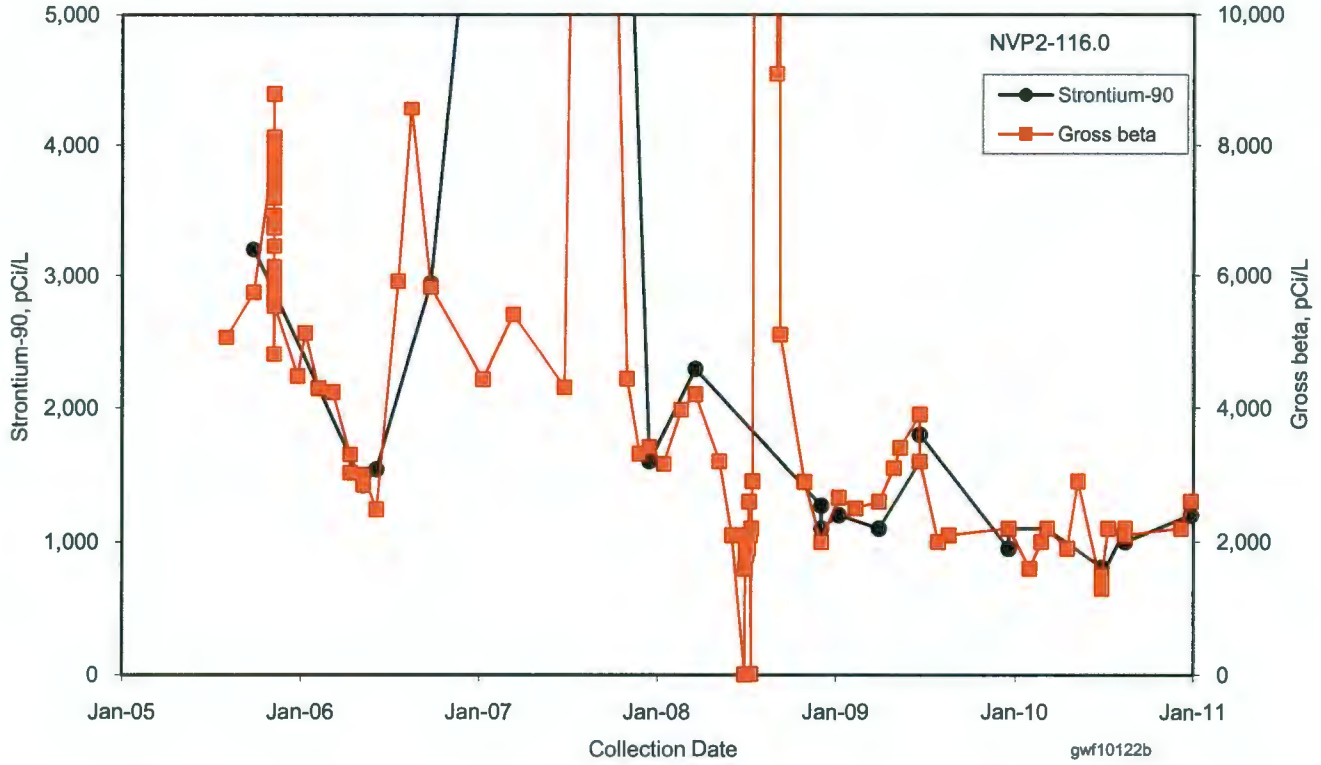


Figure 6-12. Strontium-90 and Gross Beta Concentrations in Aquifer Tube NVP2-116.0m





gwf10122

Figure 6-13. Average Tritium Concentrations in the 100-N Area, Upper Unconfined Aquifer

Figure 6-14. Tritium Concentrations near 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities

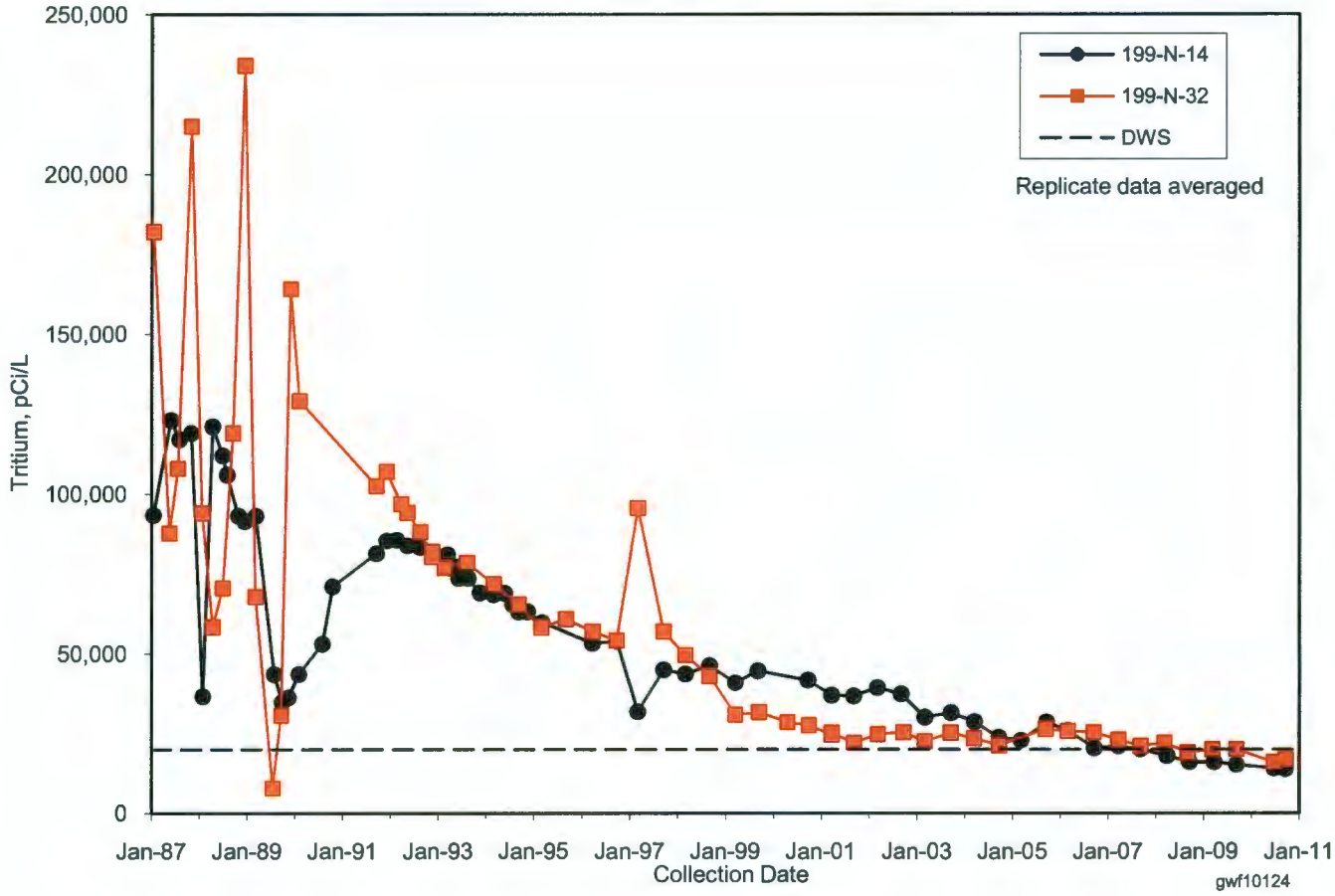


Figure 6-15. Average Nitrate Concentrations in the 100-N Area, Upper Unconfined Aquifer

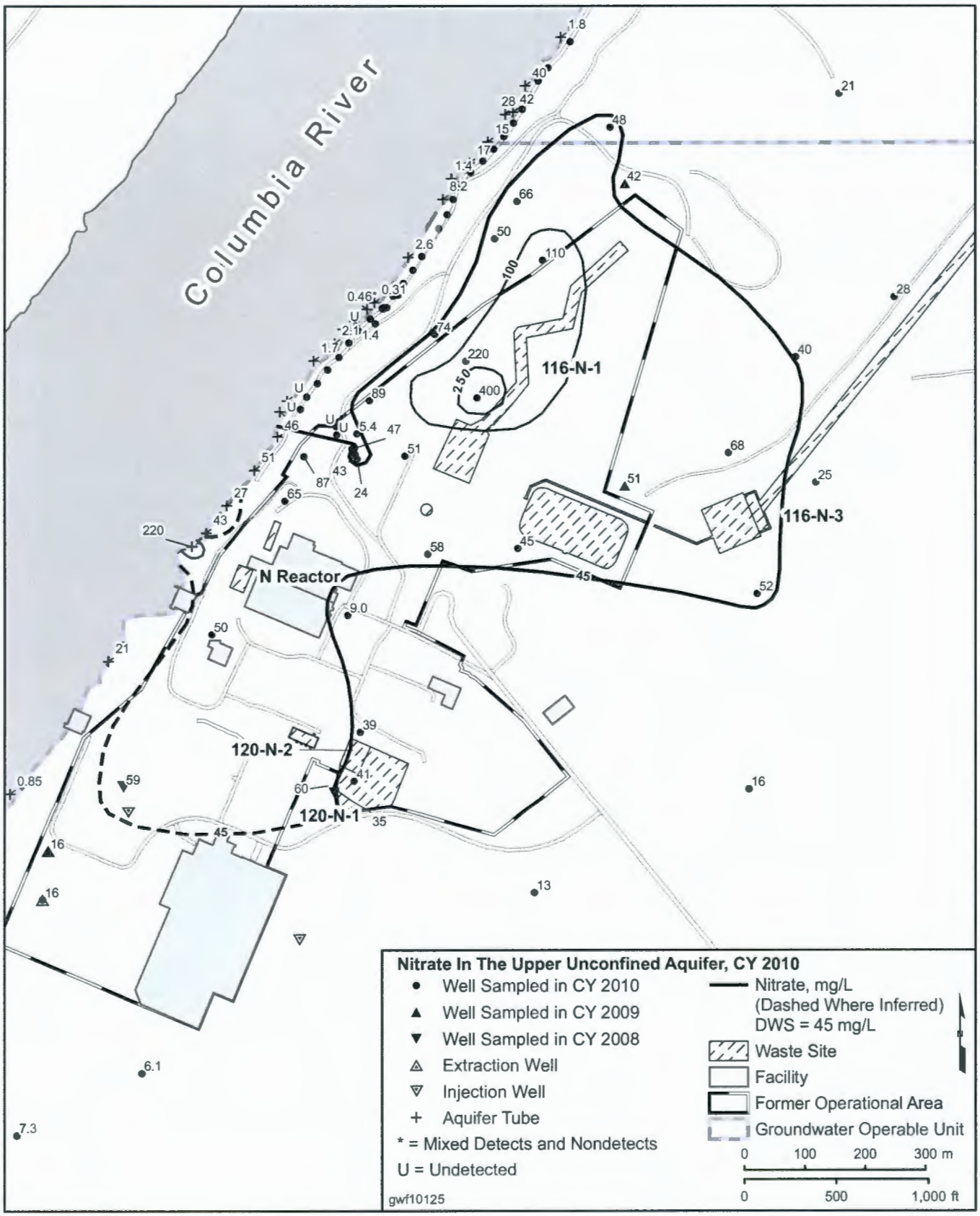


Figure 6-16. Nitrate Concentrations for the 116-N-1 Liquid Waste Disposal Facility

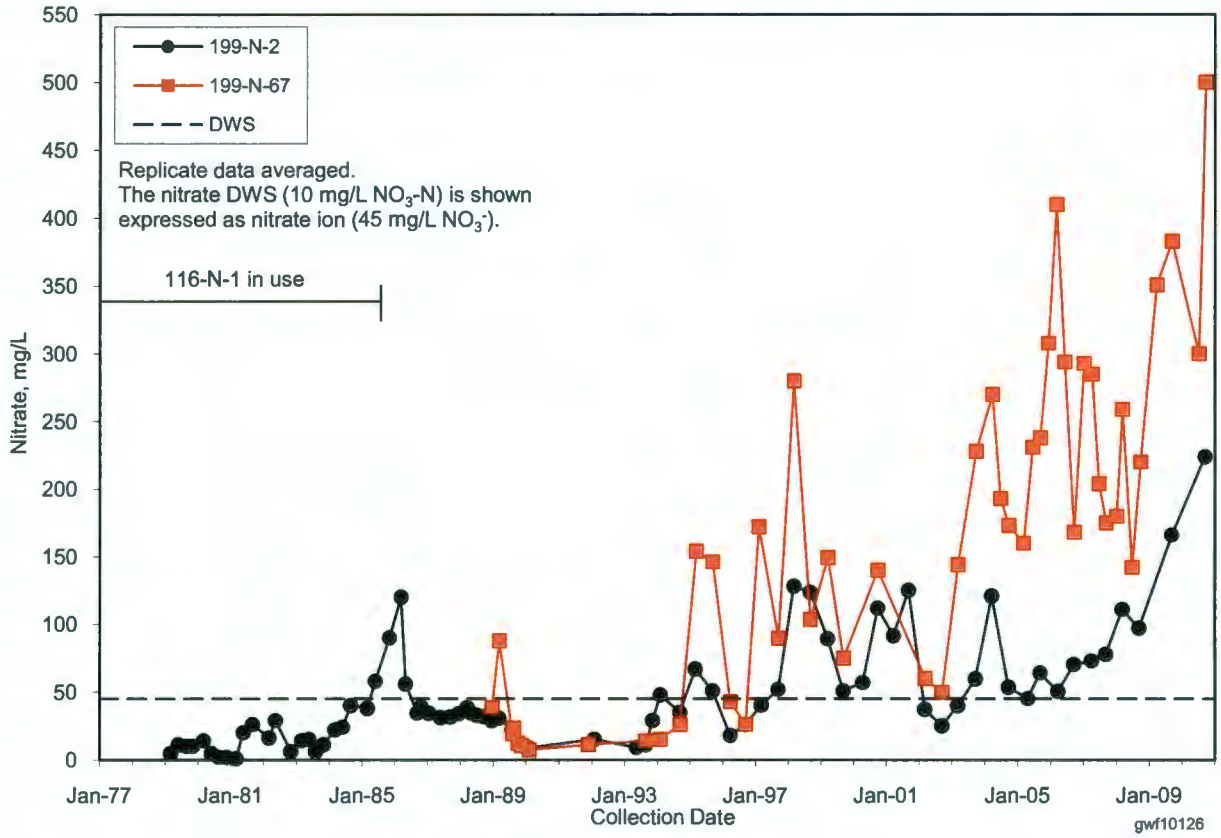


Figure 6-17. Nitrate Concentrations for the 116-N-3 Liquid Waste Disposal Facility

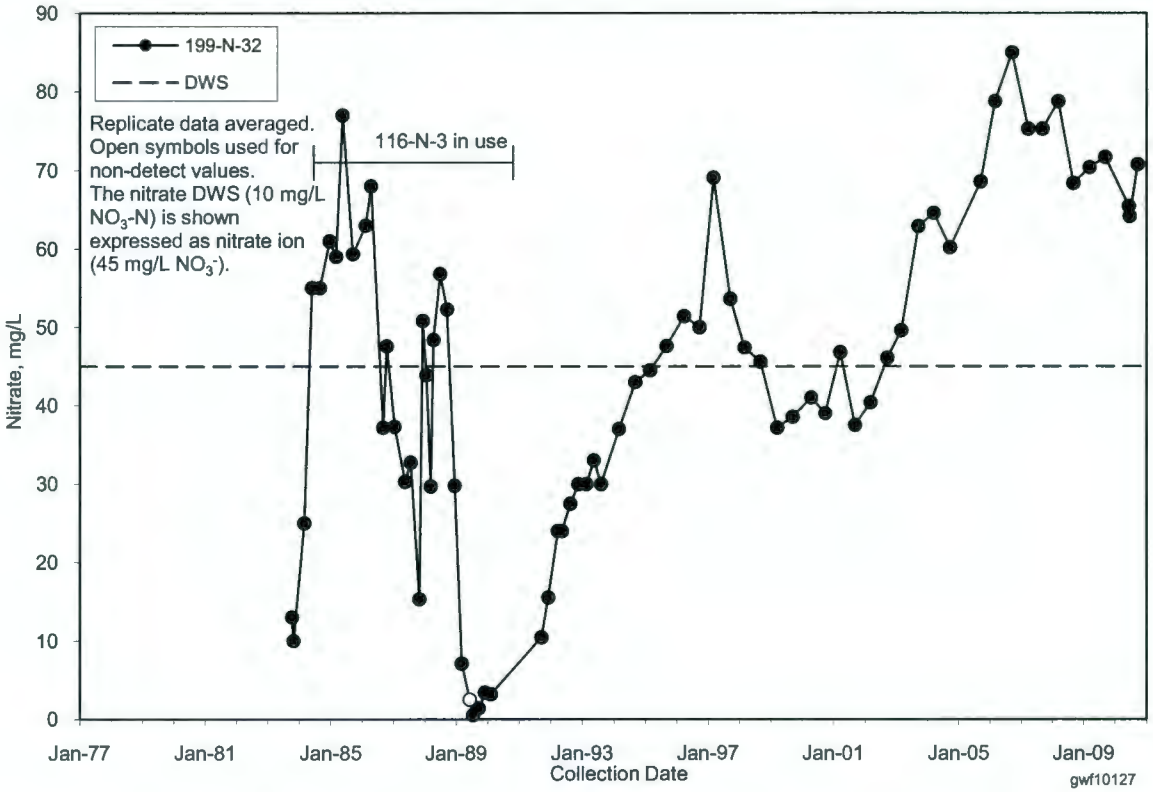


Figure 6-18. Nitrate Concentrations for the 120-N-1 Percolation Pond

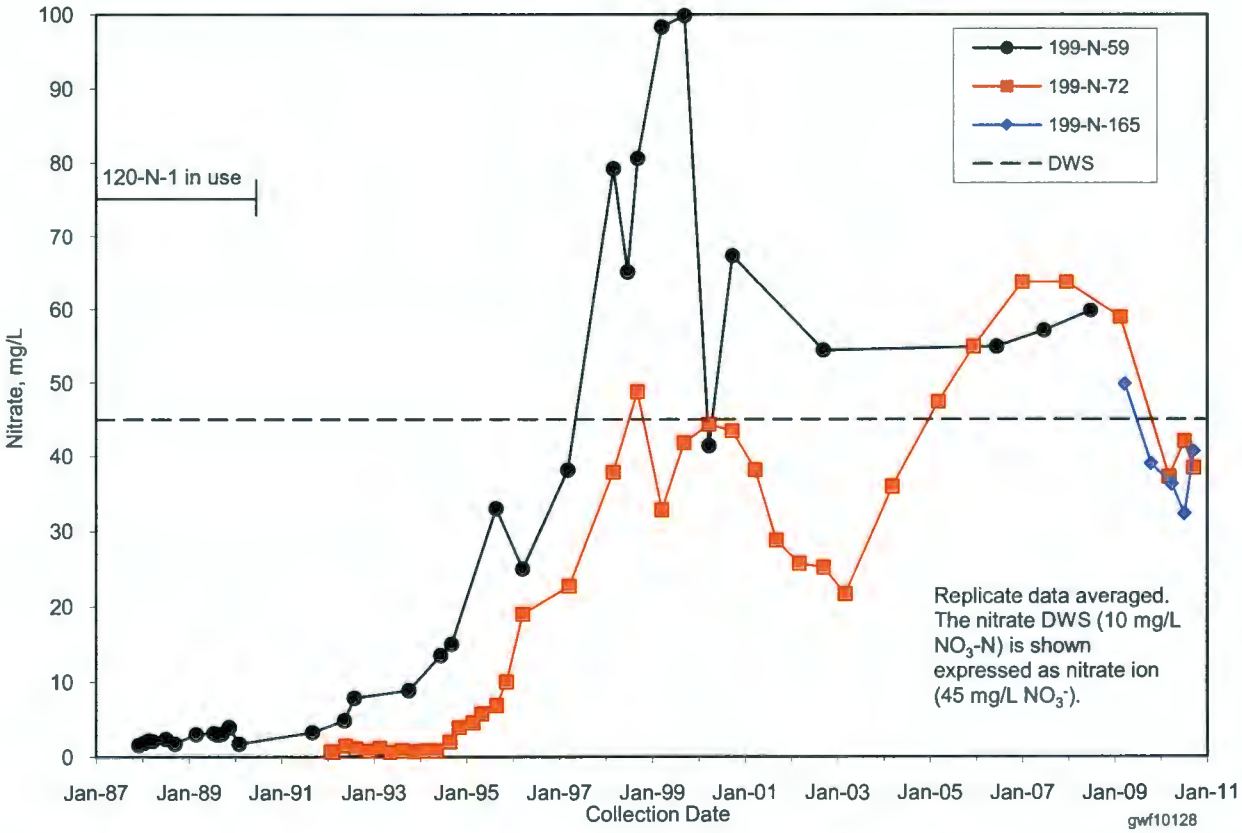


Figure 6-19. Total Petroleum Hydrocarbon-Diesel Range Concentrations in 100-N Area, April Through December 2010, Upper Unconfined Aquifer

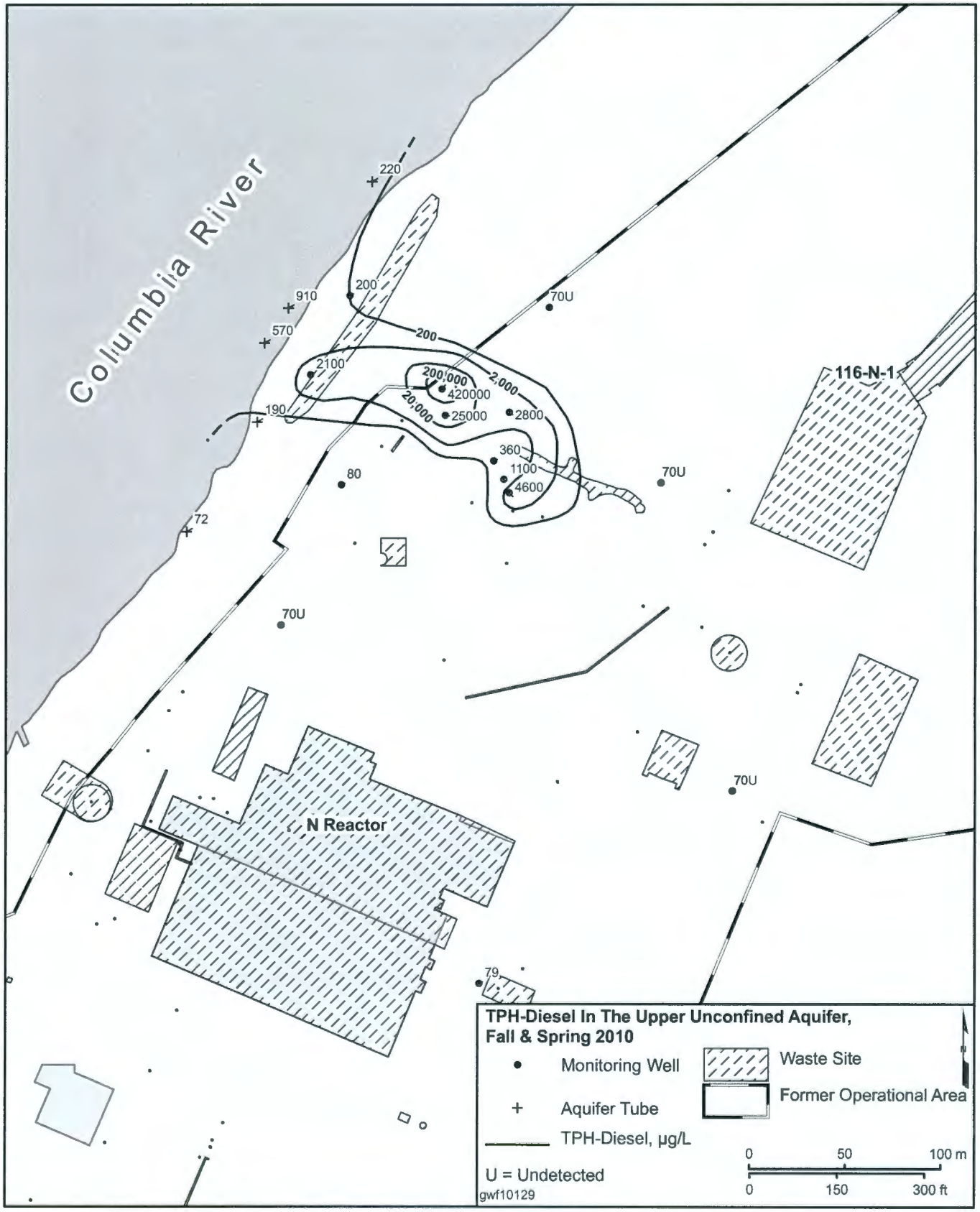


Figure 6-20. Sulfate Concentrations in 100-N Area, Upper Unconfined Aquifer

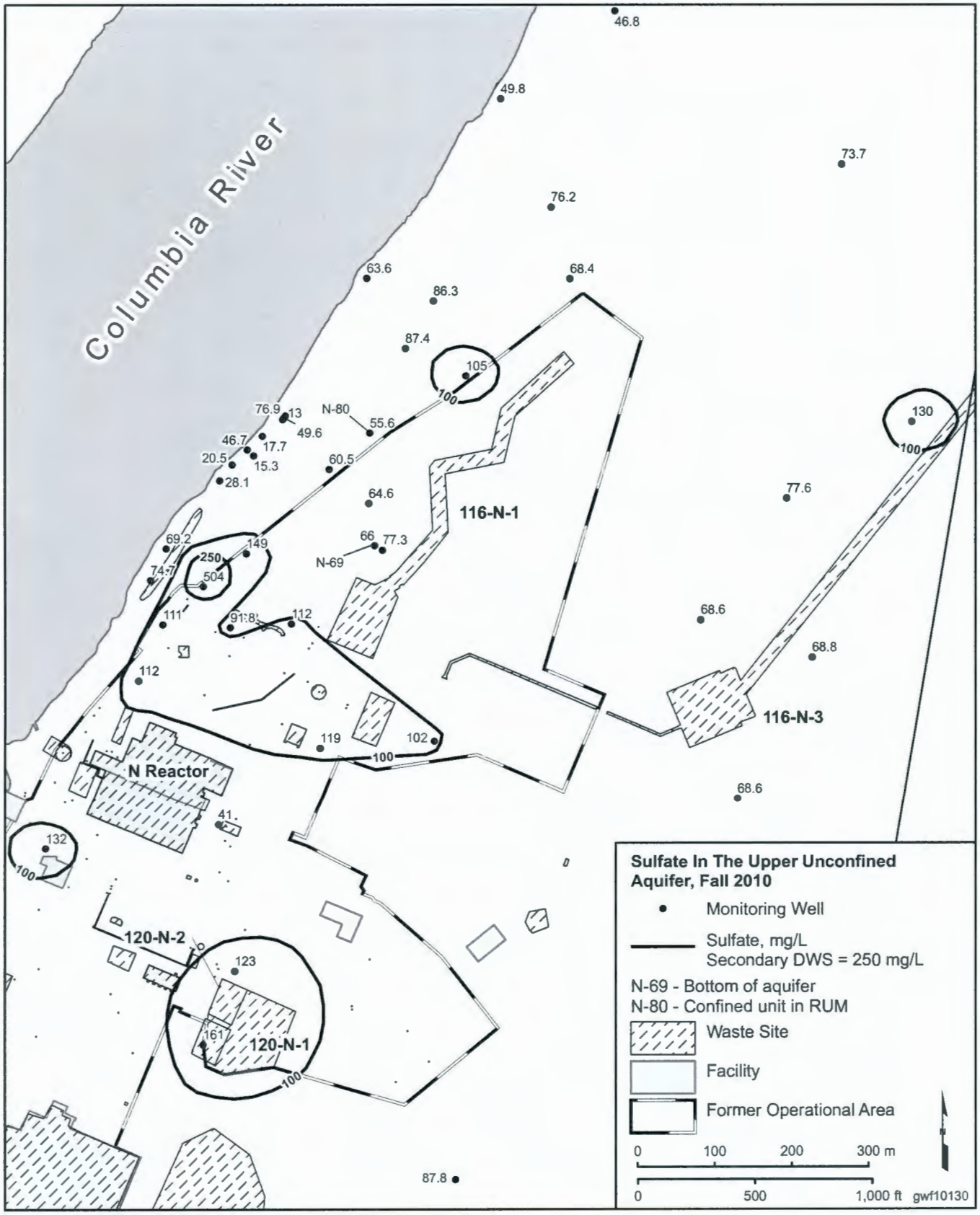


Figure 6-21. Manganese and Iron Detections in 100-N Area, Upper Portion of Unconfined Aquifer

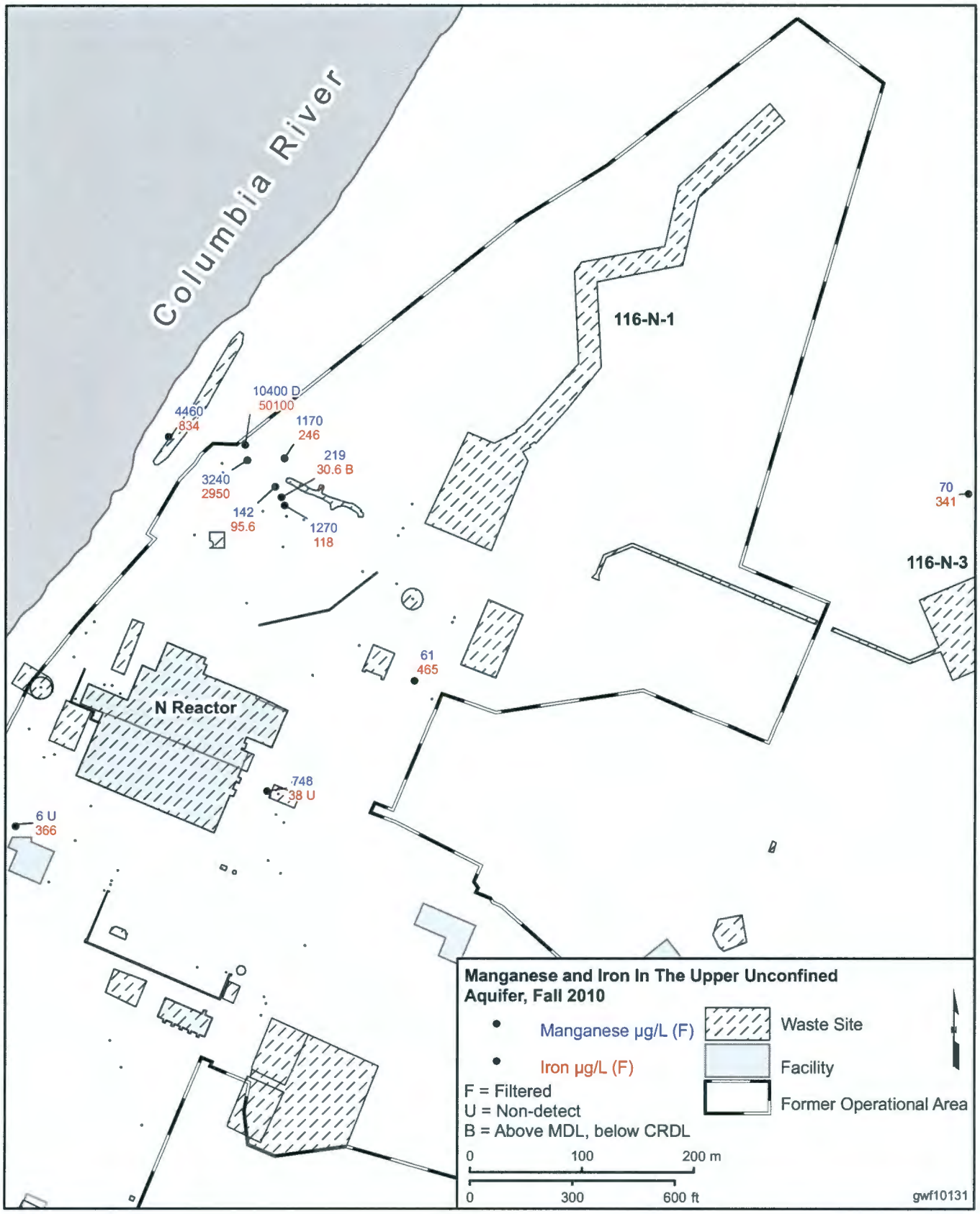
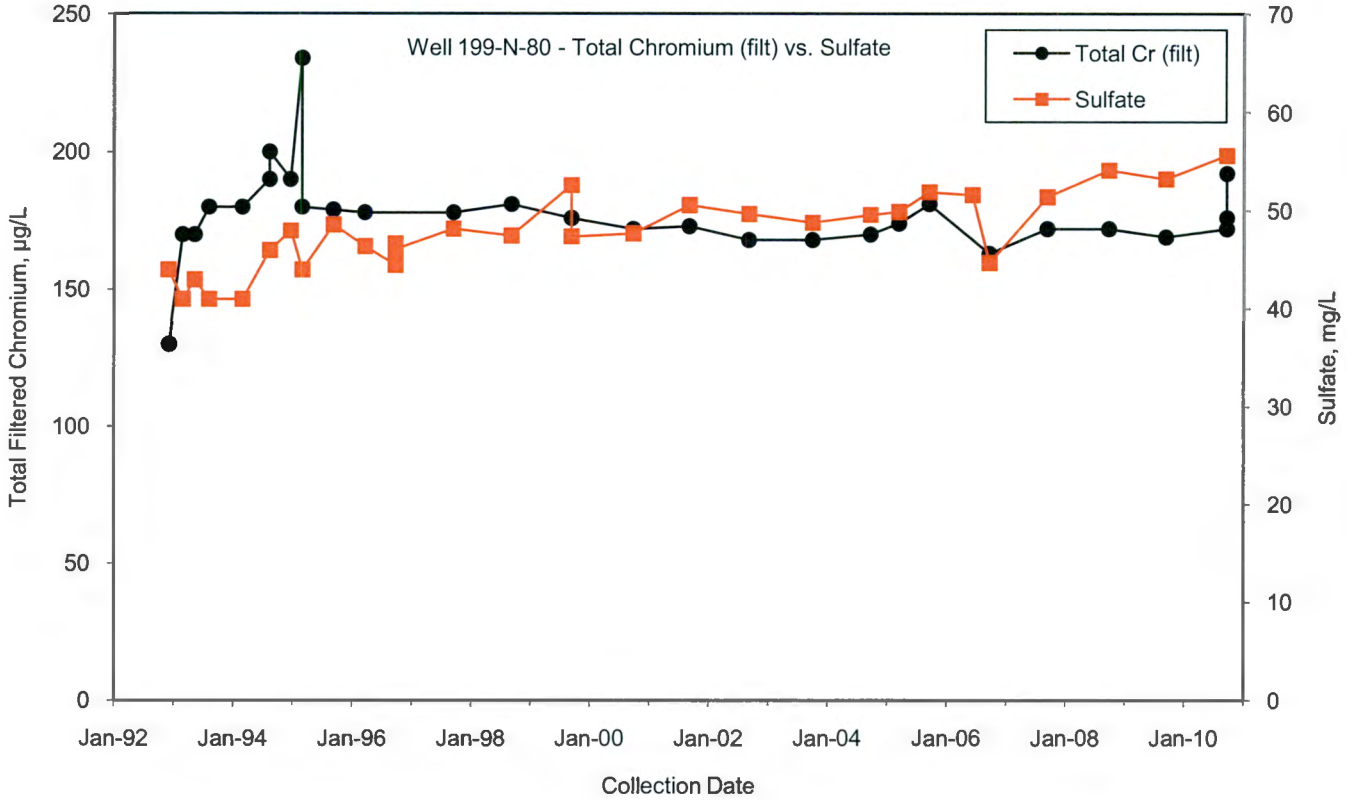


Figure 6-22. Filtered Total Chromium and Sulfate Trend Plot for Well 199-N-80



gwf10142

Figure 6-23. Chromium Detections in 100-N Area, Upper Portion of Unconfined Aquifer

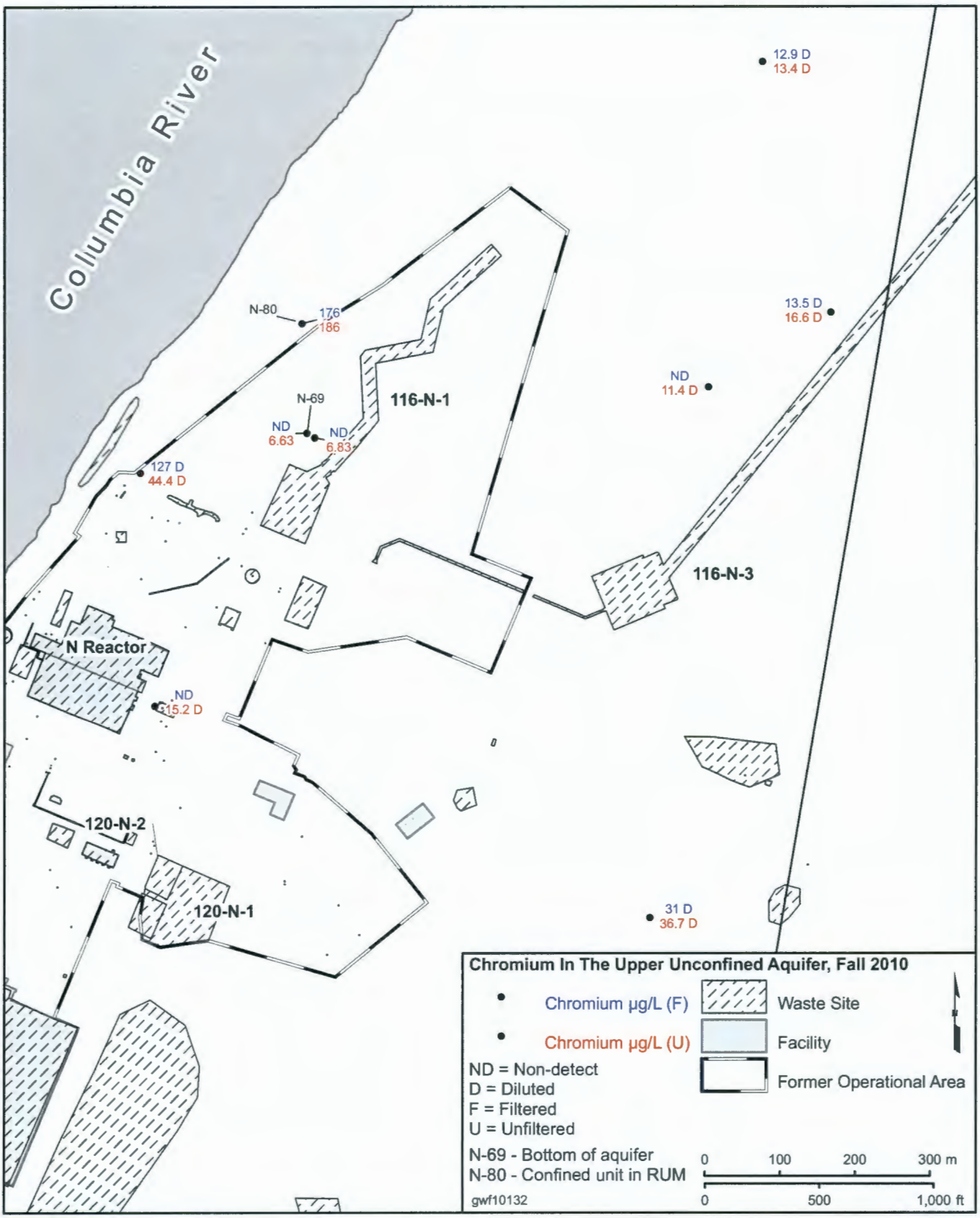


Figure 6-24. Gross Beta Trend Plot for Middle Upper Section of Apatite Permeable Reactive Barrier

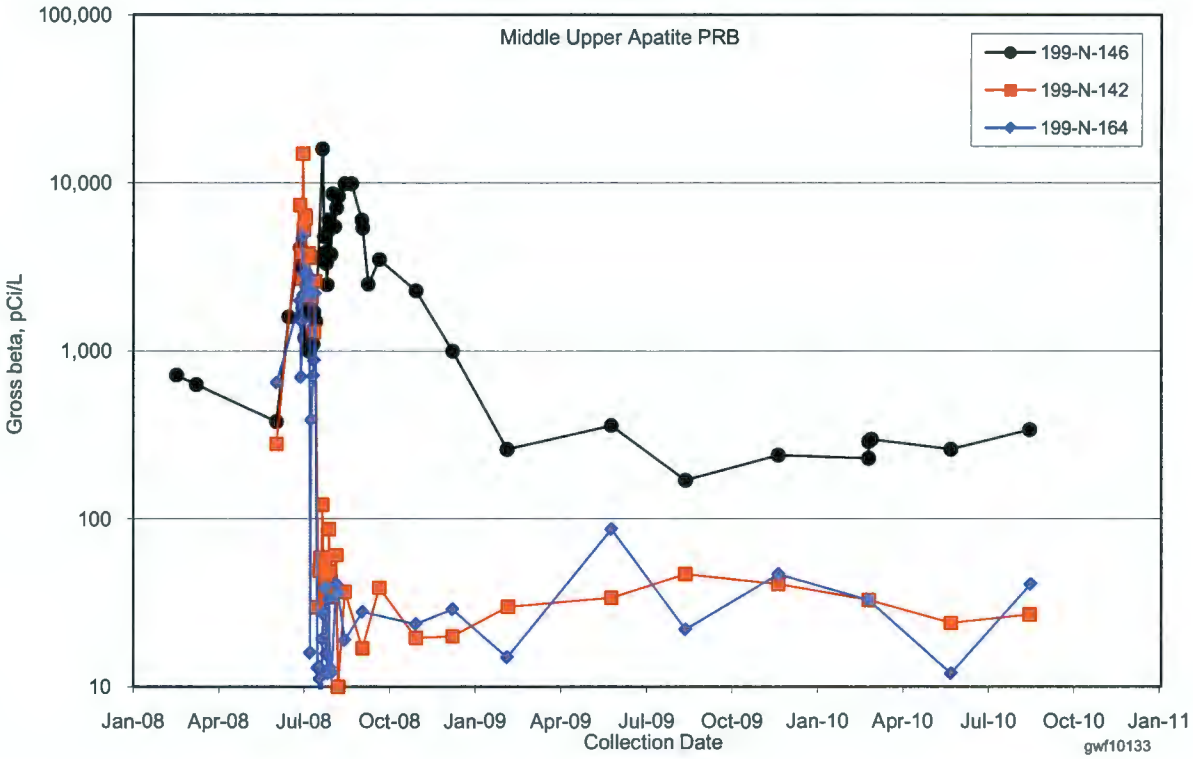


Figure 6-25. Gross Beta Trend Plot for Middle Lower Section of Apatite Permeable Reactive Barrier

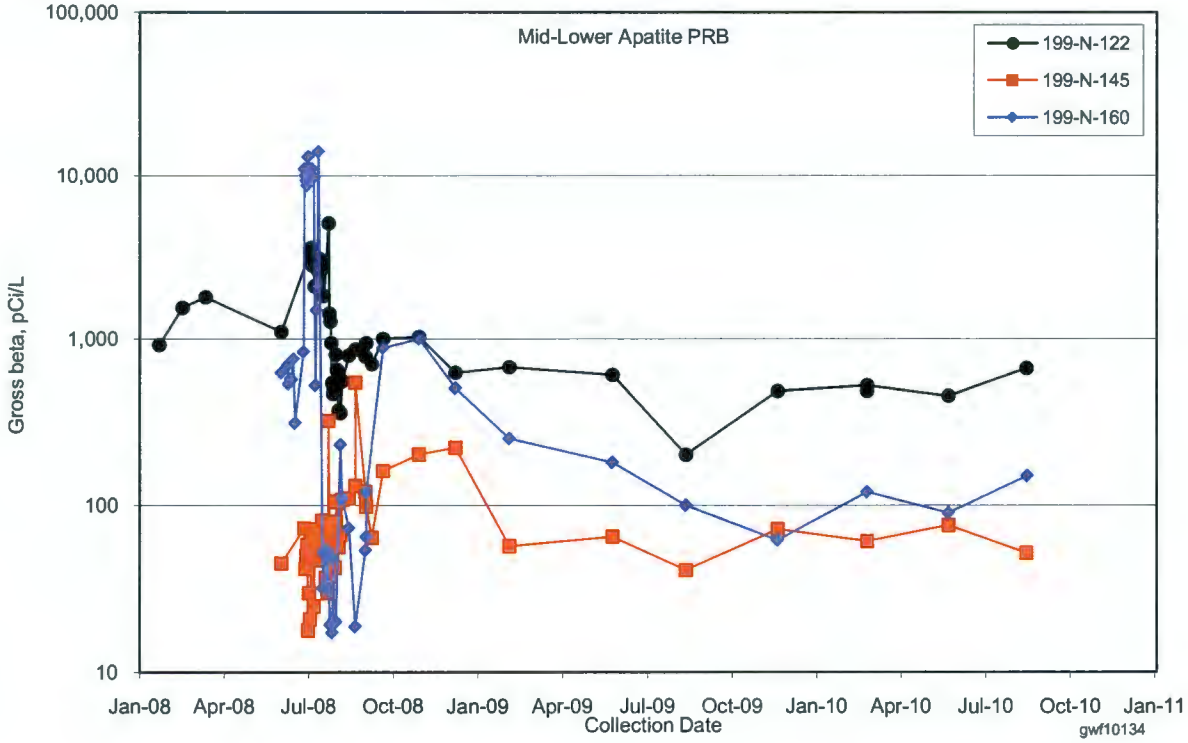


Figure 6-26. Gross Beta Trend Plot for the Highest Strontium-90 Concentration Portion of Apatite Permeable Reactive Barrier

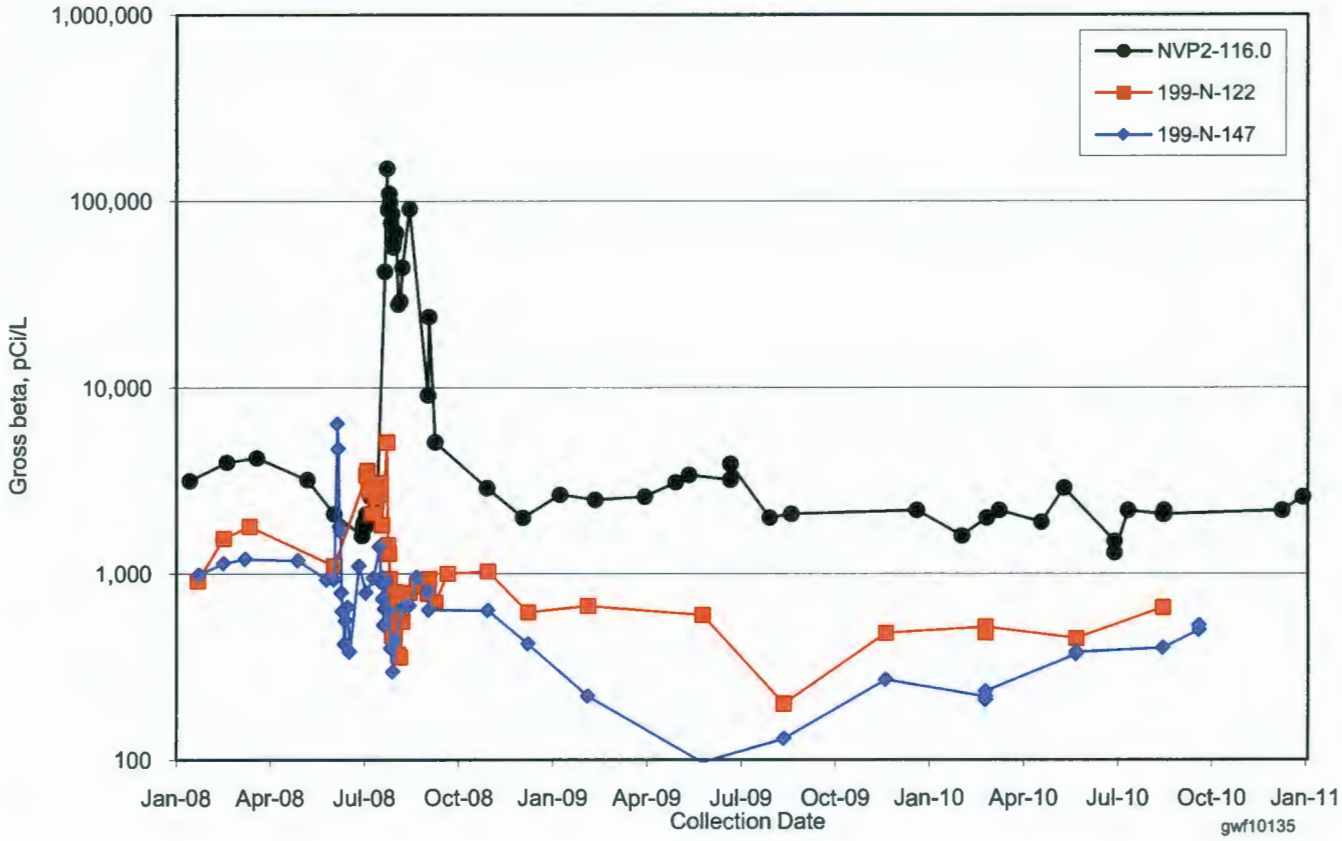


Figure 6-27. Location of Core Wells at the Pilot Test #2 Site, Apatite Permeable Reactive Barrier

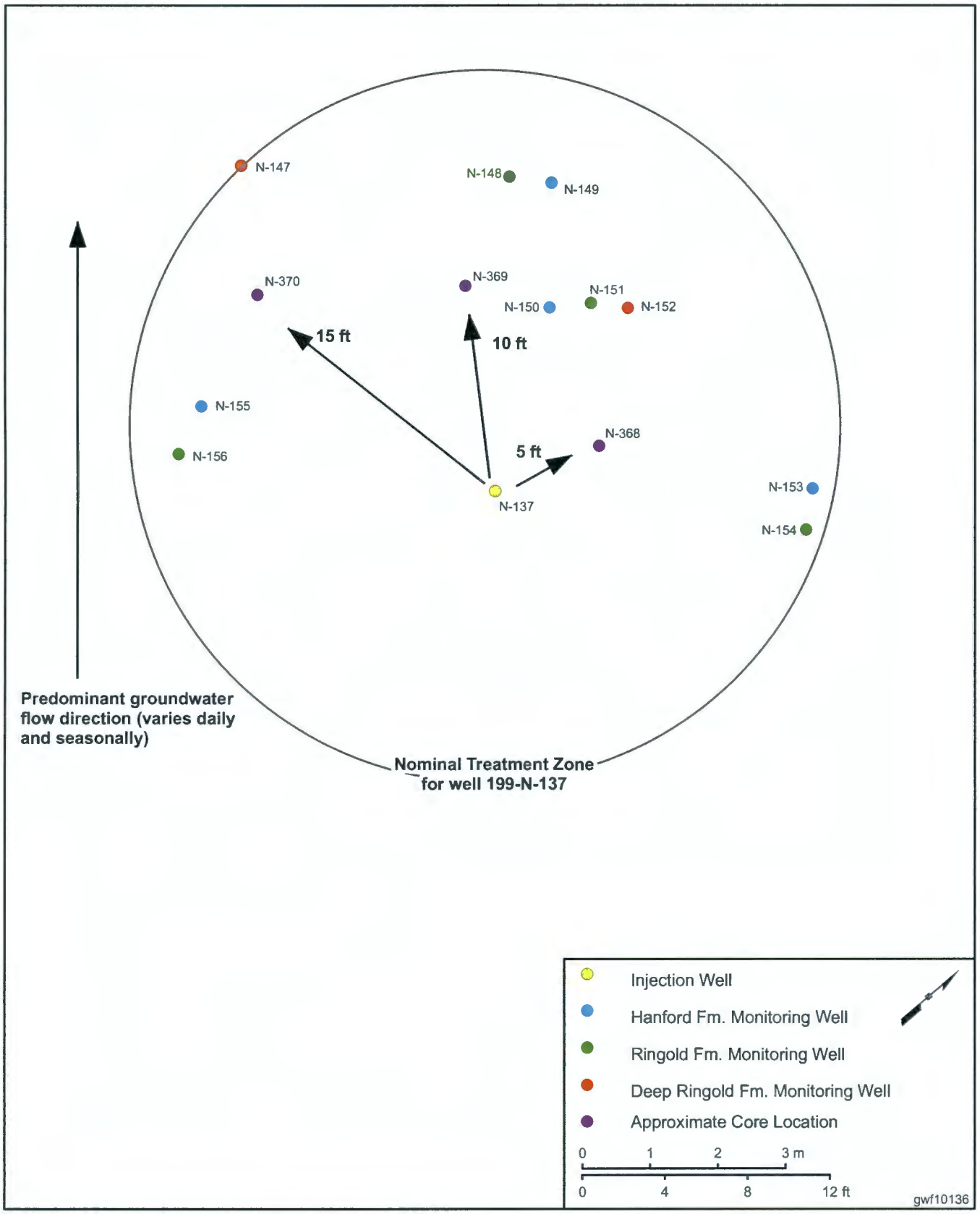


Figure 6-28. Location of Jet Injection Test Plots and Core Wells Along 100-N Area Shoreline

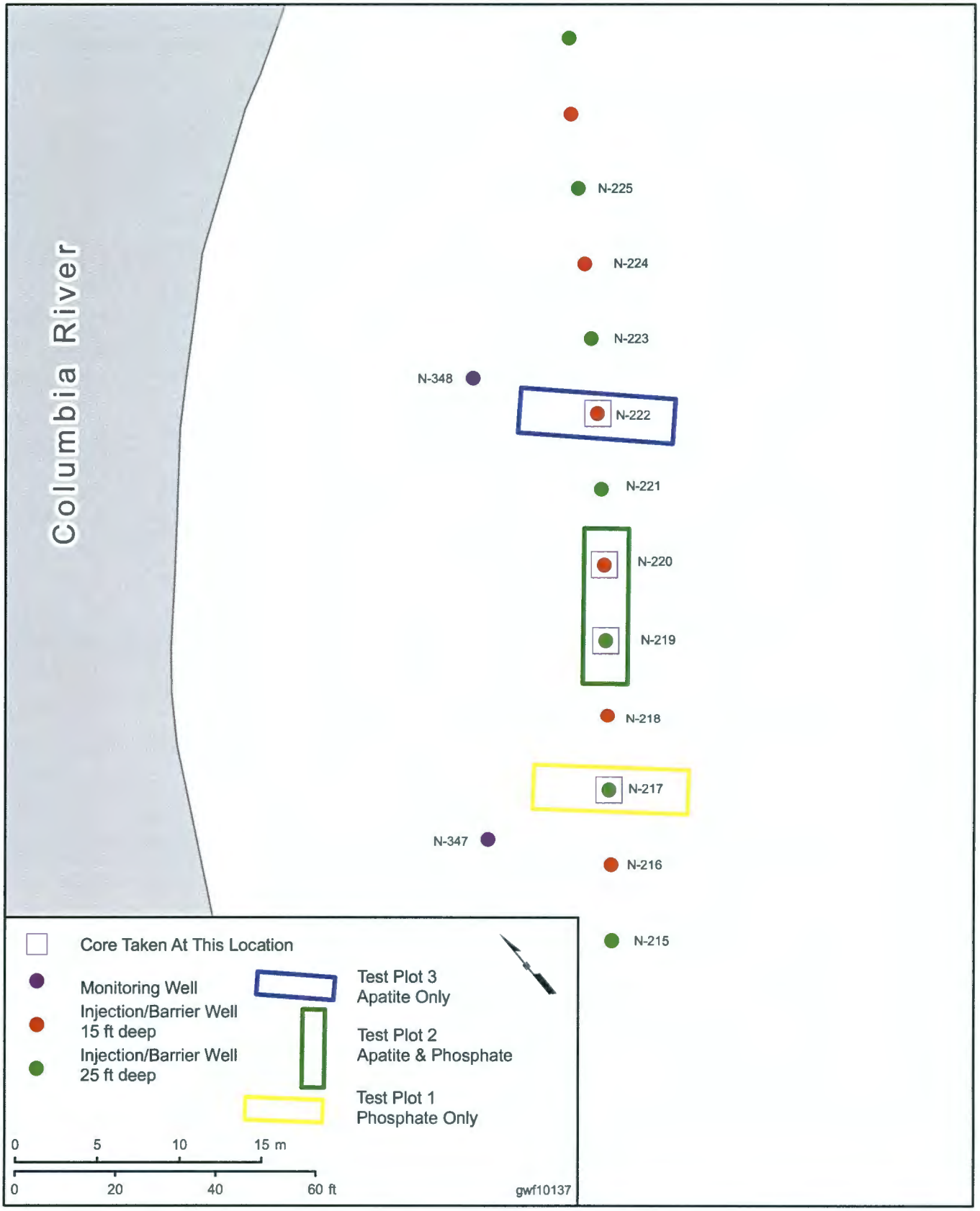


Figure 6-29. 100-N Area Follow-Up River Porewater Sampling Locations, November/December 2010

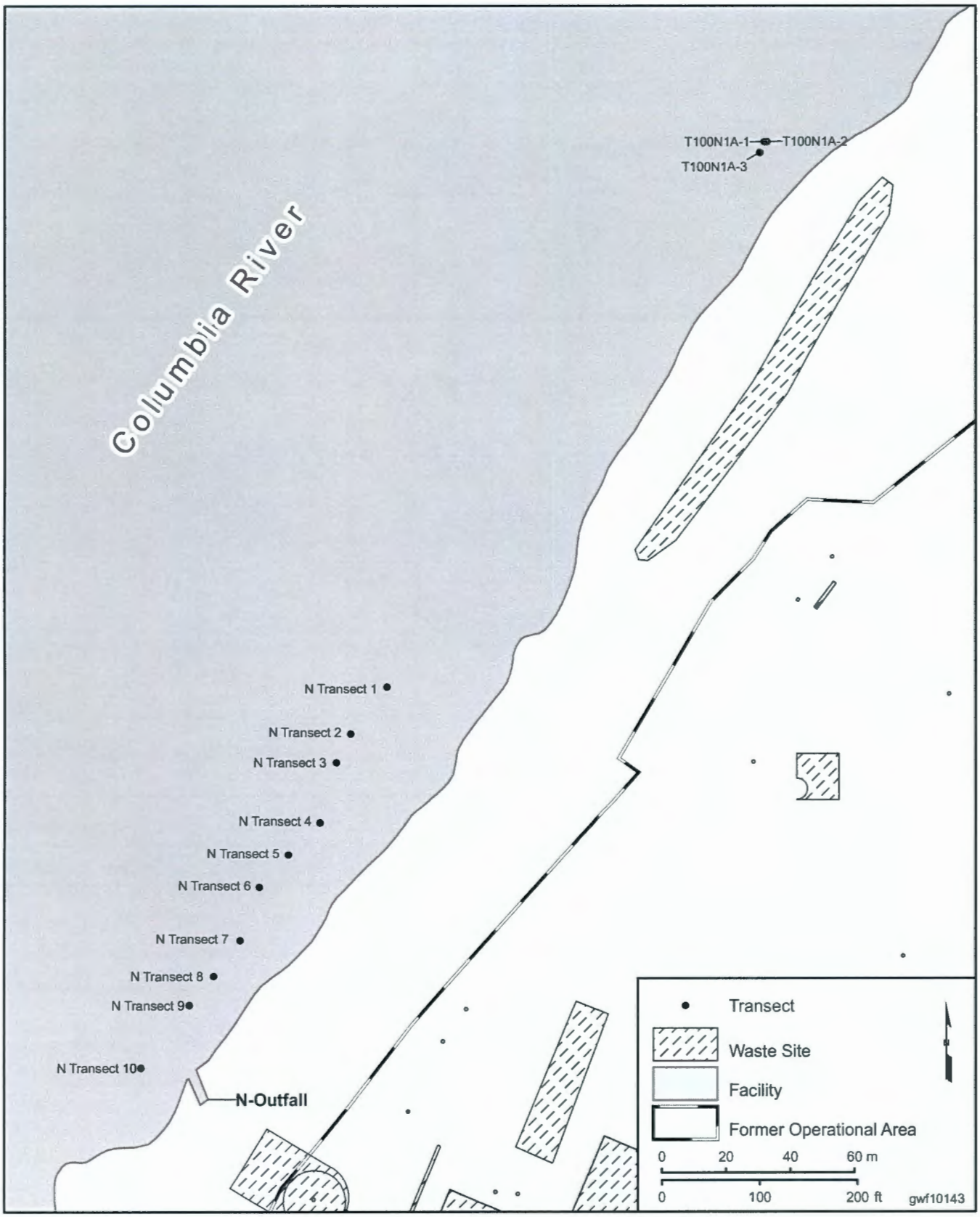


Figure 6-30. Potential Contaminant Source Pathways for 100-N Outfall Structure Strontium-90

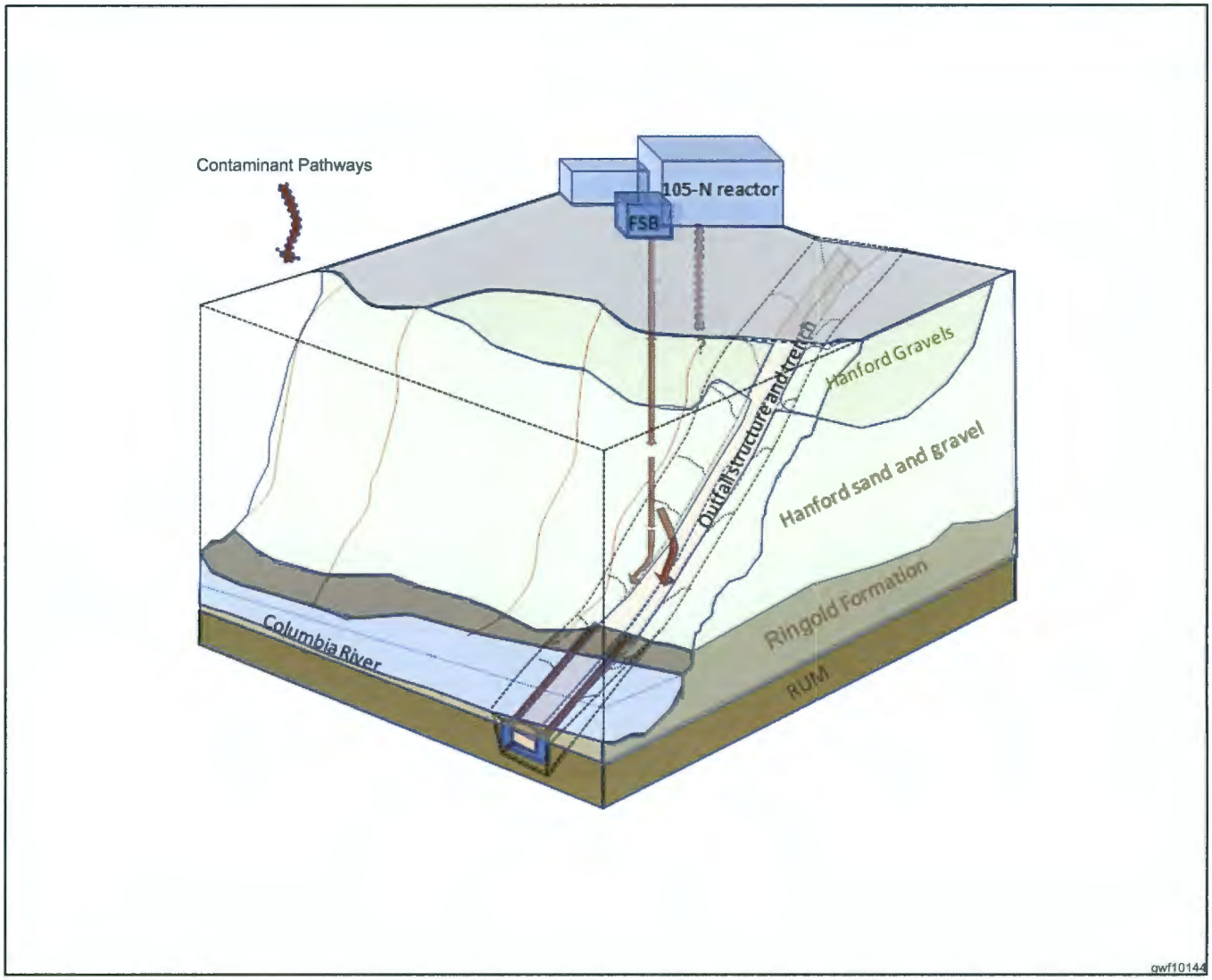


Figure 6-31. Remedial Investigation/Feasibility Study Aquifer Tube Sampling Locations

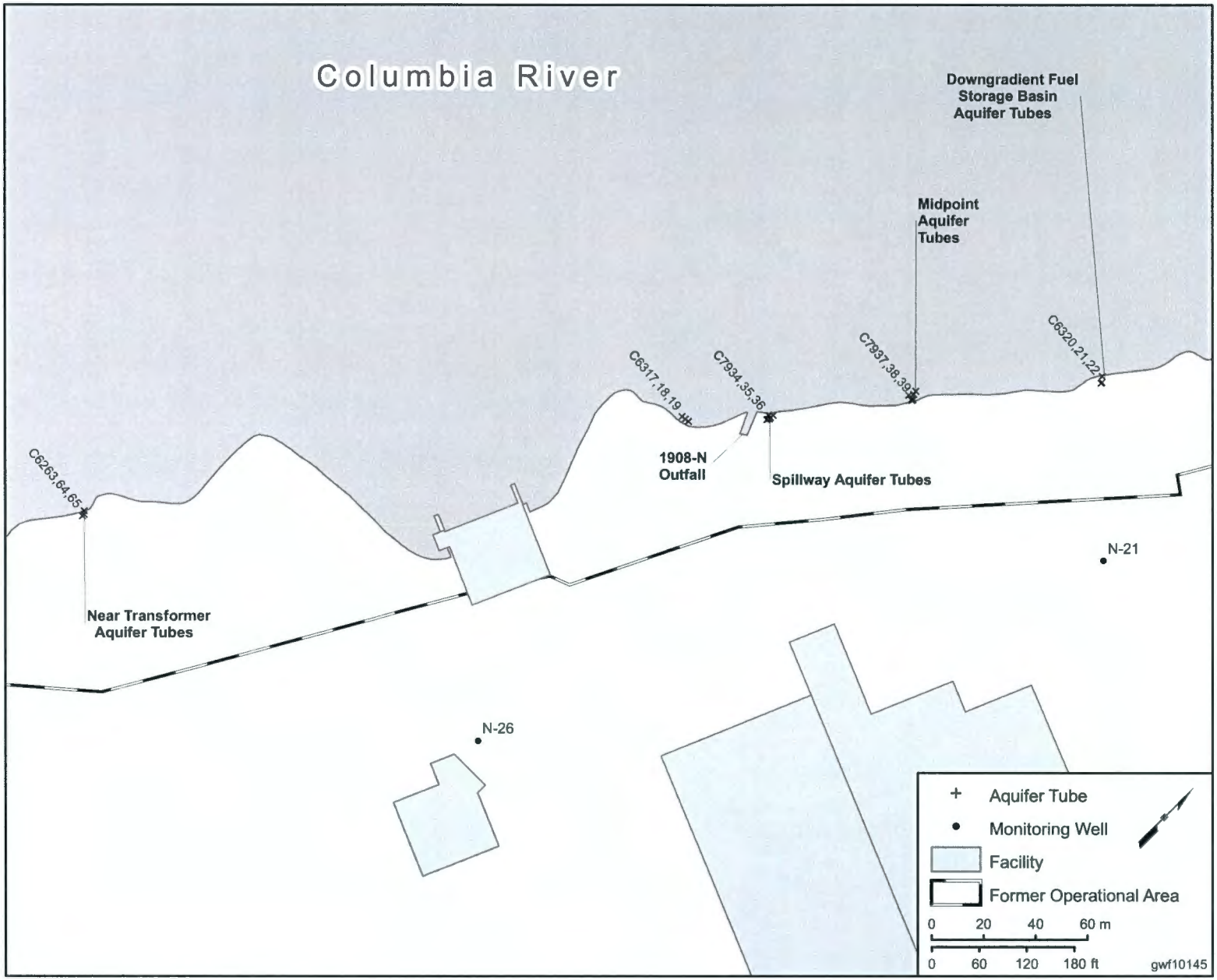
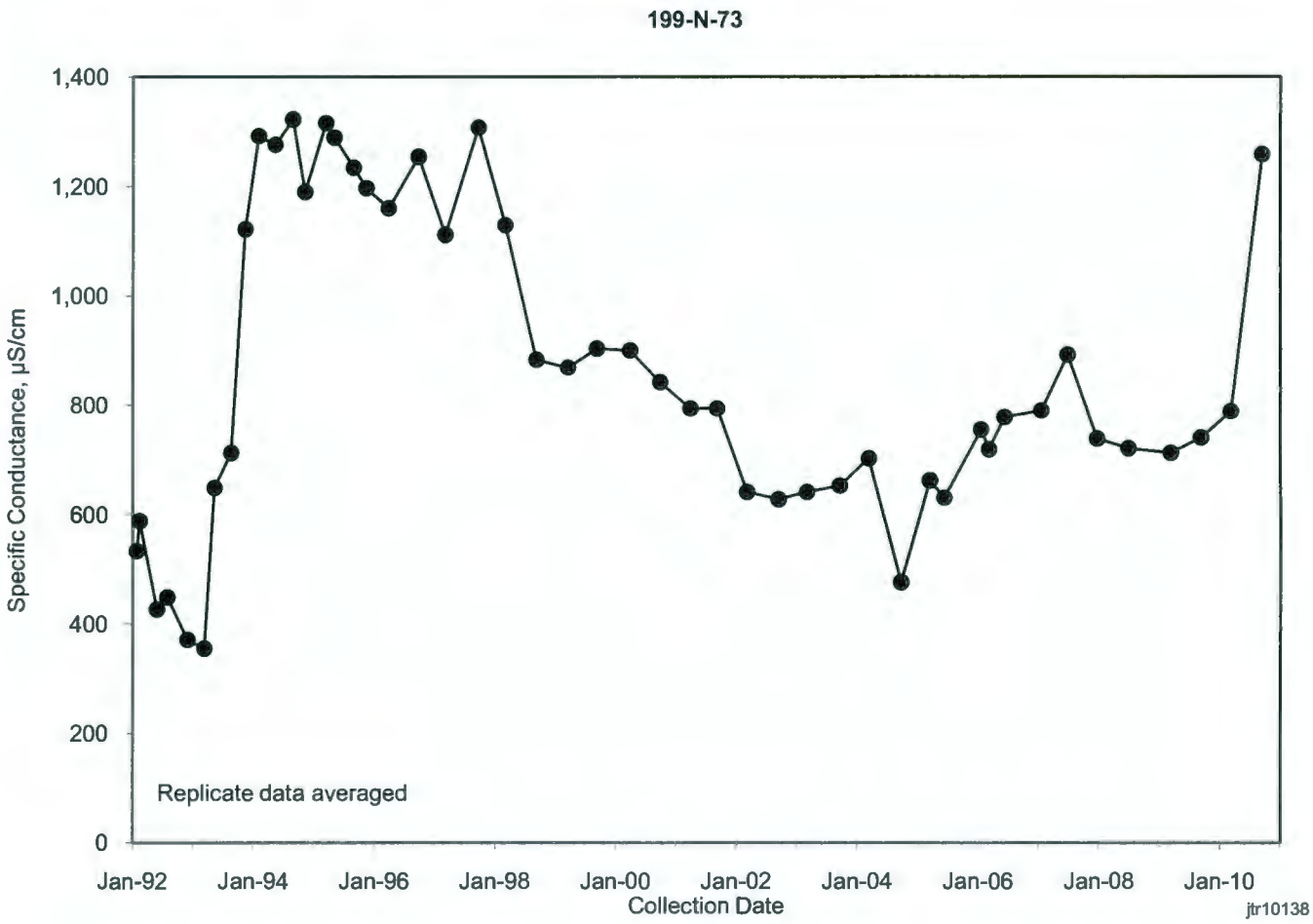


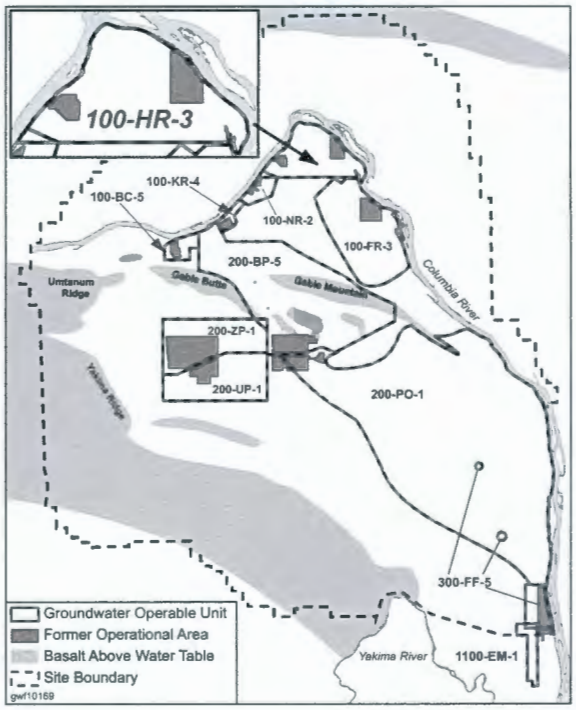
Figure 6-32. Specific Conductance in Well 199-N-73



7.0 100-HR-3 Operable Unit

J.L. Smoot/J.A. Eluskie

This chapter describes the hydrogeology and contaminant distribution within the 100-HR-3 Operable Unit (OU), which includes groundwater underlying the 100-D Area, 100-H Area, and the region between known as the horn area. Figures 7-1, 7-2, and 7-3 show the facilities, wells, and shoreline monitoring sites in the 100-D Area, 100-H Area, and horn area, respectively.



Groundwater underlying the 100-D and 100-H Area is monitored to meet the requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); the *Atomic Energy Act of 1954*; and the *Resource Conservation and Recovery Act of 1976* (RCRA) at the 116-H-6 (183-H) solar evaporation basins (a RCRA unit). No RCRA sites are located in the 100-D Area, and no active waste disposal facilities are located in either the 100-D or the 100-H Areas.

In calendar year (CY) 2010, three CERCLA interim action remedies operated in the 100-HR-3 OU. These included the original HR-3 pump-and-treat system in the 100-H Area, which treats groundwater from both the 100-D and 100-H Areas; the DR-5 pump-and-treat system in the 100-D Area; and the In Situ Redox Manipulation (ISRM) barrier, also in the 100-D Area. The new DX pump-and-treat system entered acceptance testing in the fourth quarter of the CY and became operational in 2011.

A summary of 100-HR-3 OU operations for CY 2010 is provided below:

- Hexavalent chromium is the principal contaminant of concern (COC) in groundwater. New wells have helped to define the core of the hexavalent chromium plume, with concentrations over 69,000 µg/L in some groundwater samples collected in the south 100-D Area plume.
- The DR-5 and HR-3 pump-and-treat systems continued to operate at normal capacity of ~132 liters per minute and ~757 liters per minute, respectively. The two pump-and-treat systems removed a combined 106 kilograms of hexavalent chromium from the 100-HR-3 OU in CY 2010; however, concentrations in groundwater remained above the remedial action goal of 20 µg/L.
- Expanded pump-and-treat systems are being implemented in both the 100-D (DX system) and 100-H (HX system) Areas to meet remedial action objectives. During CY 2010, the DX pump-and-treat facility was completed and operations began at the end of the reporting period. In December 2010, the DX system treated an additional 55.3 million liters of groundwater, with 18.4 kilograms of hexavalent chromium removed. The DR-5 system is being shutdown in CY 2011 for realignment of its wells to the DX pump-and-treat system. The HR-3 system also will be shut down in CY 2011 for realignment of its wells to the HX pump-and-treat system.
- The size of the 100-H Area hexavalent chromium plume has been significantly reduced since the start of pump-and-treat operations in 1997. However, because the HR-3 system has been realigned to treat water further north, contaminated groundwater has flowed into the southern portion of the area that is being targeted

by planned HX system extraction in that area. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River, particularly to the north of the remediated zone, as well as in the vicinity of well 199-H4-11. In contrast, the size of the 100-D Area hexavalent chromium plume has not been affected significantly by pump-and-treat operations. The new DX and HX pump-and-treat systems will help facilitate remediation efforts by expanding the capture zone in the 100-D and 100-H Areas, and, for the first time, in the horn area.

- The ISRM barrier continued to convert hexavalent chromium to a non-toxic, immobile form (trivalent chromium) within a portion of the aquifer. Concentrations in some downgradient wells remained above the remedial action goal of 20 μg/L due to breakthrough along the northeast segment where the barrier is not working effectively. Therefore, new DX extraction wells were installed downgradient of the barrier to treat this area.
- In CY 2010, the remedial investigation (RI)/feasibility study (FS) field work was initiated, with a planned completion date of April 2011. At the end of CY 2010, progress was underway and more than 50% of the work was completed. The results will be provided in Draft A of the RI report in fiscal year (FY) 2012.

In the 100-HR-3 OU, the groundwater system comprises several hydrostratigraphic units. Figure 7-4 shows a hydrogeologic cross section of the 100-D and 100-H Areas. From shallowest to deepest, these units include the following:

- Surface deposits, which consist of recent localized surficial deposits and backfill overlying the Hanford formation beneath the 100-D and 100-H Areas
- Vadose (unsaturated) zone, which are predominantly Hanford formation gravels; the vadose zone is 2 to 30 meters thick beneath the 100-D and 100-H Areas
- Unconfined aquifer, which is predominantly Ringold Formation unit E gravels in the 100-D Area and predominantly Hanford formation underlying the horn area and 100-H Area
- Uppermost aquitard, which includes the Ringold Formation upper mud unit (RUM) (clay and silt)
- Confined and semiconfined, discontinuous, water-bearing lenses and/or aquifers in the Ringold Formation, separated by fine-grained deposits (overbank and paleosol)
- Confined aquitards and aquifers in basalt beneath the Ringold Formation.

Groundwater generally enters the 100-HR-3 OU from the south, with most of the flow moving toward lower elevations of the 100-H Area. A much smaller portion of regional flow moves directly toward the 100-D Area. Underlying the 100-D Area, groundwater generally flows toward the Columbia River. Inland from the Columbia River and beneath the eastern portions of the 100-D Area, groundwater generally flows northeast. Northeast of the 100-D Area, groundwater flows east-northeast across the horn area and toward the 100-H Area. Groundwater below the 100-H Area discharges northeast and east to the Columbia River. Figure 7-5 presents a spring groundwater contour map of the area that was developed using data from CY 2010. This map represents average CY 2010 groundwater flow conditions beneath the 100-HR-3 OU. Groundwater levels are measured across the Hanford Site in March during a time when flows in the Columbia River are close to the annual average rate. While the river stage is very dynamic, this is assumed to represent a nominal average groundwater flow condition.

Groundwater flow in the 100-D and 100-H Areas is significantly influenced by Columbia River stage. The river stage fluctuates regularly in seasonal and shorter cycles (e.g., daily river stage changes) due to a combination of natural and anthropogenic influences. During the latter part of the year when the river stage is relatively low (e.g., September 2010; see Figure 7-6), natural groundwater flow is toward the river; when the river stage is high (e.g., June 2010; see Figure 7-7), groundwater can flow away from or parallel to the river. The high river stage can rise more than 3 meters above the low river stage and can fluctuate several feet over short periods (i.e., hours to days) based on operations at the upstream Priest Rapids Dam. Changing river stage can influence groundwater elevations over one kilometer inland from the river in the 100-HR-3 OU. In addition, because the hydraulic head is lower at the 100-H Area, regional flow from the south tends to move across the horn area toward the 100-H Area.

Other significant influences on groundwater flow are historical leakage from the 182-D reservoir and drawdown or mounding from the groundwater extraction and injection well network. Administrative controls are in place to minimize future leakage from the 182-D reservoir. The zone of uncontaminated groundwater near the 182-D facility suggests long-term contaminant mixing and diversion of contaminated groundwater from the mounding caused by the leaks. In response to the reservoir leakage information, a specific issue was included in *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20) for the U.S. Department of Energy (DOE) to provide direction to its operating contractor to conduct changes to reservoir operation to minimize leakage. Those actions were completed and documented during closeout of the 5-year review issue. These leaks and their impact to groundwater flow have significantly diminished since the reduction of storage volume in the reservoir in 2004.

Groundwater flow is influenced by the stage of the Columbia River.

The primary sources of contamination in the 100-HR-3 OU were the support systems for the three water-cooled nuclear reactors (D, DR, and H Reactors) and the structures and processes associated with the reactors. These operations generated large quantities of liquid and solid waste contaminated with radionuclides, hazardous chemicals, or both. Most contaminant sources can be characterized as high-volume, low-concentration wastes emplaced under high hydraulic head or low-volume, high-concentration wastes emplaced under low hydraulic head. Wastes released to the environment created secondary sources of contamination beneath ponds, ditches, cribs, burial grounds, and unplanned release sites where contaminants may be retained in the subsurface (vadose zone) and released to the aquifer over long periods.

Ongoing characterization and remediation of waste sites in the 100-D and 100-H Areas began in 1996 under the authority provided by the interim action Records of Decision (RODs) and RCRA closure and monitoring plans. Remediation consists mainly of removal and disposal of soil, debris, and waste material and then backfilling the remediated waste site. A portion of the 100-D and 100-H Area waste sites (i.e., trenches, pits, and burial grounds) have already been remediated and dispositioned. The remediation status of each waste site and the data gaps are described in detail in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (DOE/RL-2008-46-ADD1). The RI/FS characterization workscope identified in this document was initiated in 2010. The data collected for the RI/FS characterization will be published in Draft A of the RI report in FY 2012.

7.1 Groundwater Contaminants

Plume Areas (7.0 square kilometers) in the 100-HR-3 Operable Unit:
Chromium, 100 µg/L — 0.728
Chromium, 20 µg/L — 6.96
Nitrate, 45 mg/L — 0.76
Tritium, 20,000 pCi/L — 0.026

Hexavalent chromium is the principal COC in groundwater in the 100-D and 100-H Areas. The co-contaminants are strontium-90, technetium-99, tritium, uranium, and nitrate. This section describes the distribution and trends of these groundwater contaminants beneath the 100-D and 100-H Areas. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90) and associated Tri-Party Agreement change notice define the sampling protocols implemented for CY 2010. The contaminant monitoring results are presented in the following subsections.

7.1.1 Hexavalent Chromium

The remedial action goal for hexavalent chromium for 100-HR-3 OU groundwater interim actions is 20 µg/L in a near-shore compliance well for both the pump-and-treat systems, and the ISRM barrier system; these systems are given an allowance for a 1:1 attenuation factor to meet the 10 µg/L ambient water quality criteria in the hyporheic zone, as determined by the following:

- EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*
- EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*
- *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site Benton County, Washington* (EPA et al., 2009b).

Figures 7-8 and 7-9 show the distribution of hexavalent chromium in 100-HR-3 OU groundwater during spring and fall 2010, respectively. Note that the fall 2010 map includes only a partial data set due to the stop work that occurred at that time, which affected sample collection. The isoconcentration contours were drawn based on 2010 data, where available; however, in areas where data are sparse, historical isoconcentration contours were used to aid in completing the map.

Hexavalent chromium is the principal COC in the 100-D Area.

7.1.1.1 Horn Area Hexavalent Chromium Plume

The hexavalent chromium plume underlying the horn area is believed to have originated in the 100-D Area and has subsequently migrated toward the 100-H Area. A significant portion of the horn area mass may have resulted from the routing of cooling water to the 116-DR-1&2 Trench during the last months of operation (i.e., 1967) at 105-D.

In CY 2010, groundwater sampling results show that hexavalent chromium is present in groundwater beneath the horn area; however, the plume did not change significantly compared to CY 2009. Higher concentrations of hexavalent chromium are restricted to the area immediately adjacent to the 100-D Area. Injection wells in the 100-H Area create a hydrologic barrier on the northeastern side of the plume that prevents the plume from extending eastward into the northern portion of 100-H Area, as illustrated in Figures 7-8 and 7-9.

The central core of the horn area plume had concentrations between 50 and 90 µg/L in wells 699-98-43, 699-98-46, 699-97-41, 699-97-45, 699-97-43B, 699-96-52B, and 699-95-45. Well 699-97-41 is located northeast of the 100-H Area on the edge of the horn area. Thus, hexavalent chromium concentrations in these wells were largely unchanged between CY 2009 and CY 2010.

Three wells in the horn area monitor the RUM: 699-97-43C, 699-97-45B, and 699-97-48C. Wells 699-97-43C and 699-97-45B were sampled during CY 2010 with no detection of hexavalent chromium in groundwater samples. Well 699-97-48C reported a high hexavalent chromium concentration of 42.3 µg/L in December 2010; which is slightly higher than the CY 2009 concentration of 38.7 µg/L.

7.1.1.2 Southern 100-D Area Hexavalent Chromium Plume

Underlying the 100-D Area, hexavalent chromium in the unconfined aquifer occurs in two distinct plumes often referred to as the southern and northern plumes. Historical handling activities of 70% sodium dichromate solution at the 100-D Area (100-D-12 and former railcar unloading station) are the likely sources of the southern plume. The southern plume lies south and west of the 183-DR filter plant. In CY 2010, the plume configuration did not change compared to CY 2009. In addition, despite removing more than 326 kilograms of hexavalent chromium through pump-and-treat operations, the groundwater plume size and average concentrations beneath the 100-D Area have not markedly decreased over the past decade. The new DX facility, with a treatment capacity of 2,300 L/min (600 gpm), will help facilitate hexavalent chromium removal from the 100-D Area groundwater.

The 100-D Area hexavalent chromium plume for spring 2010 is shown in Figure 7-10. The figure also shows hexavalent chromium concentration plots for selected wells within the plume. Maximum hexavalent chromium levels generally coincide with low river-stage conditions that occur in the late fall to early spring. Among the wells in the southern hexavalent chromium plume, the highest concentrations in groundwater samples were found in wells 199-D5-99 and 199-D5-122, with concentrations as high as 11,900 µg/L (February 2010) and 69,700 µg/L (August 2010), respectively. For well 199-D5-99, hexavalent chromium concentrations are considerably lower than measured in CY 2009 (49,300 µg/L); however, hexavalent chromium concentrations in groundwater samples from well 199-D5-122 have increased from the CY 2009 value of 59,600 µg/L.

Hexavalent chromium concentrations in 100-D Area groundwater are the highest on the Hanford Site. For CY 2010, three remediation systems operated to reduce the amount of hexavalent chromium reaching the Columbia River.

Wells that monitor the aquifer in the central 100-D Area (199-D5-33, 199-D5-36, and 199-D5-44) continue to have low hexavalent chromium concentrations. These wells are located between the southern and northern hexavalent chromium plumes. In CY 2010, hexavalent chromium was not detected in groundwater samples from these wells, which may be the result of infiltration of clean water from the 182-D reservoir, leaking raw water pipes, or injection of treated water into wells 199-D5-41 and 199-D5-42. Repairs and operational changes have reduced the amount of infiltration from the 182-D reservoir, but hexavalent chromium concentrations have not fully rebounded in the aquifer beneath this area.

In 100-D Area aquifer tubes, concentrations of hexavalent chromium in 2010 were at the lower end of the historical range (Figure 7-11). The highest hexavalent chromium concentration detected in an aquifer tube was 294 µg/L in Redox-1-3.3, which is located downgradient of the ISRM barrier. Hexavalent chromium concentrations downgradient of the ISRM barrier have decreased since the late 1990s but continued to remain above the cleanup standard in CY 2010.

A cluster of four new aquifer tubes (C7645, C7646, C7647, and C7648) were installed as part of the RI/FS upstream of the ISRM barrier in April 2010 to define the extent of hexavalent chromium and strontium-90 southwest of the 100-D Area. Groundwater samples collected from these new tubes during the last half of CY 2010 showed hexavalent chromium concentrations ranging from nondetect to 8.9 µg/L.

7.1.1.3 Northern 100-D Area Hexavalent Chromium Plume

The northern hexavalent chromium plume extends north from the D Reactor to the Columbia River. Operationally, the northern plume is located downgradient of the former sodium dichromate distribution system, which contained less concentrated solutions than the initial 70% solution brought in by railcar at 100-D-12. Figure 7-12 shows hexavalent chromium concentrations within the northern plume. The figure also shows hexavalent chromium concentration plots for selected wells within the plume. In CY 2010, the northern hexavalent chromium plume had not changed significantly compared to CY 2009. Among the wells in the northern hexavalent chromium plume, the highest concentrations in groundwater were found in wells 199-D5-125 and 199-D5-126, with concentrations as high as 2,310 and 2,150 µg/L, respectively. This is largely unchanged from the CY 2009 concentrations of 2,350 µg/L (199-D5-125) and 1,970 µg/L (199-D5-126). These wells were added in the first quarter of FY 2009 and are located in the center of the plume. Some increase in concentration was observed in the vicinity of well 199-D8-88; this well is now extracting water to the DX system and concentrations are expected to decrease under the influence of the pump-and-treat system.

Well 199-D5-15 monitors groundwater near a potential source of the northern hexavalent chromium contamination. Hexavalent chromium concentrations were low from 1999 to 2003 because of mixing with nearby leaking water lines, which were repaired in 2004 (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*). Concentrations began to increase in 2004 and reached a maximum of 2,450 µg/L in May 2007. Hexavalent chromium in this well subsequently declined to ~1,000 µg/L in 2008 and remained below 700 µg/L during CY 2010, with a maximum concentration of 659 µg/L. Hexavalent chromium concentrations in wells 199-D5-14 and 199-D5-16 (downgradient of well 199-D5-15) also increased in 2008 but steadily decreased during the reporting period. Vadose zone soil sampling conducted during the 100-D Area chromium source investigations (DOE/RL-2009-92, *Report on Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*; DOE/RL-2010-40, *Report on Investigation of Hexavalent Chromium Source in the Northern 100-D Area*) discovered small amounts of hexavalent chromium in the vadose zone in a few locations but did not identify a large source capable of producing the high concentrations seen in some groundwater monitoring wells. Another theory for the northern plume is that it was split off from the south plume hydraulically via leakage from the 182-D reservoir and associated piping.

Hexavalent chromium concentrations in aquifer tubes downgradient of the northern plume have declined since the late 1990s. Only two of the five aquifer tube clusters used to monitor the northern plume were sampled in CY 2010. The only aquifer tube with a groundwater sample above the remedial action goal was tube 36-M with a concentration of 22.1 µg/L.

7.1.1.4 100-H Area Hexavalent Chromium Plume

The size of the hexavalent chromium plume in the unconfined aquifer underlying the 100-H Area has been significantly reduced since pump-and-treat operations began in 1997. However, in CY 2010, this plume did not change significantly compared to CY 2009. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River. The new HX pump-and-treat system will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater.

In CY 2010, groundwater in the 100-H Area predominantly contained less than 20 µg/L hexavalent chromium; however, several wells upgradient of the 100-H Area continued to have hexavalent chromium concentrations above the remedial action goal. Figure 7-13 shows hexavalent chromium concentrations in groundwater underlying the 100-H Area. The highest hexavalent chromium concentration for CY 2010 was 91.8 µg/L in well 199-H1-43. This well is downgradient of well 699-97-43B, which has had the highest concentration since 2007. In CY 2010, well 699-97-43B had a maximum hexavalent chromium concentration of 85.2 µg/L, which is a decrease from the previous reporting period (sampled in November 2008) of 91.5 µg/L. An increase in hexavalent chromium was noted in the southern portion of the area near well 199-H3-5, which is one of the original injection wells for the HR-3 pump-and-treat system. Since shutdown of these wells, some encroachment of the horn plume has occurred in this area. Well 199-H3-5 will be added to the HX pump-and-treat system.

Hexavalent chromium concentrations in 100-H Area have declined due to remediation efforts and natural processes.

Monitoring wells 199-H3-2C and 199-H4-12C, and piezometer 199-H4-15CS are screened within the first water-bearing layer within the RUM. In CY 2010, groundwater samples collected from these wells/piezometer continued to show elevated hexavalent chromium concentrations. In CY 2009, these wells/piezometer were used for a series of aquifer tests to gather data on the presence of deep chromium in the RUM (SGW-47776, *Aquifer Testing and Rebound Study in Support of the 100-H Deep Chromium Investigation*). Preliminary observations from the tests are summarized in Section 7.2.5. For CY 2010, the following observations were noted:

- Well 199-H3-2C (fully screened across the first water-bearing layer in the RUM) is located on the western side of the 100-H Area, upgradient of the 100-H Area waste sites. Hexavalent chromium concentrations in groundwater samples from this well have increased over the last several years to ~50 µg/L in FY 2007 and 2008. During the 2009 aquifer test, the highest value observed was 112 µg/L. The highest hexavalent chromium concentration detected in CY 2010 was 41 µg/L. Adjacent well 199-H3-2A, completed in the unconfined aquifer, had much lower hexavalent chromium concentrations of less than 16 µg/L.
- Well 199-H4-12C (fully screened across the first water-bearing layer in the RUM) is located near the Columbia River, downgradient of the 183-H solar evaporation basins and adjacent to extraction well 199-H4-12A (screened in the unconfined aquifer). Well 199-H4-12C showed declining hexavalent chromium concentrations during FY 2008, decreasing to ~80 µg/L. During CY 2009, the concentrations ranged between 80 and 100 µg/L until early November 2009, when concentrations increased to a maximum of 121 µg/L as a result of aquifer testing. The highest hexavalent chromium concentration in CY 2010 was 140 µg/L.
- Piezometer 199-H4-15CS is adjacent to an extraction well. Hexavalent chromium concentrations in this piezometer were steady at levels near 100 µg/L until November 2009, when the concentration increased to 115 µg/L as a result of aquifer testing (Section 7.3.6). The highest hexavalent chromium concentration in CY 2010 was 129 µg/L. Hexavalent chromium in shallower piezometers 199-H4-15A and 199-H4-15B were much lower at 31 and 28 µg/L, respectively.
- Concentrations in the RUM rose slightly as a result of the pumping during the test but have remained at relatively constant levels. It appears that the erosional forces that removed the Ringold Formation unit E east of the 100-D Area have also scoured off portions of the RUM to the extent that groundwater mounding

of reactor cooling water (less than or equal to 700 µg/L) provided sufficient hydraulic head to drive relatively large volumes of cooling water into the RUM in the vicinity of the retention basins. Concentrations decrease inland and no hexavalent chromium is found in this layer to the west into the horn area.

- Hexavalent chromium concentrations in aquifer tubes in the main 100-H Area were below 20 µg/L, with the exception of tube C7650. Aquifer tube C7650 was installed as part of the RI/FS downgradient of the 116-H-7 waste site in April 2010 to define the extent of the hexavalent chromium and strontium-90 contamination. Groundwater samples collected from this new tube during the last half CY 2010 had concentrations of hexavalent chromium ranging from 6.6 to 30.8 µg/L.
- Concentrations greater than 20 µg/L were also observed along the horn area, reflecting the plume as it intercepts the Columbia River. The highest concentration upstream of the 100-H Area was 42.2 µg/L in aquifer tube C5641. Appendix C provides additional information on 100-H Area aquifer tube sampling.

7.1.2 Strontium-90

7.1.2.1 100-D Area

In the 100-D Area, only one groundwater sample collected in CY 2010 had a strontium-90 concentration exceeding the drinking water standard (DWS) of 8 pCi/L (RI/FS borehole characterization sample from well 199-D3-5 at 8.5 pCi/L); however, groundwater samples collected from the well the previous day had a maximum detection of only 4.5 pCi/L and neither sample reported any gross beta. The areas near the former retention basins in the north and near the D Reactor in the central 100-D Area have historically had strontium-90 detections in groundwater. Well 199-D8-68, near the former retention basins, has had concentrations ranging from 2 to 14 pCi/L since 1998; however, in 2010, concentrations were 3 pCi/L.

Only one groundwater sample exceeded the DWS for strontium-90 in groundwater at the 100-D Area.

During CY 2010, none of the 100-D Area aquifer tubes were sampled for strontium-90.

7.1.2.2 100-H Area

The distribution of strontium-90 in groundwater underlying the 100-H Area has not significantly changed in recent years. Strontium-90 concentrations in groundwater continued to exceed the 8 pCi/L DWS in several wells located to the southeast. The highest strontium-90 concentration detected in groundwater was 28 pCi/L in well 199-H4-13, downgradient of the 116-H-7 retention basin. A value of 160 pCi/L was sampled at well 199-H1-20 in the northern portion of the horn area. However, this value is suspect because the corresponding value of gross beta was zero and the well location is far outside the expected extent of strontium-90. The data will continue to be evaluated.

During CY 2010, none of the 100-H Area aquifer tubes were sampled for strontium-90.

7.1.3 Technetium-99 and Uranium

7.1.3.1 100-D Area

In CY 2010, technetium-99 and uranium concentrations in groundwater underlying the 100-D Area were less than their respective DWSs of 900 pCi/L and 30 µg/L, respectively. The highest detected technetium-99 concentration was 190 pCi/L in an RI/FS borehole characterization sample from well 199-D3-5, which is far below the DWS. However, a duplicate of this sample was analyzed as undetected. Further

technetium-99 analyses will be conducted during FY 2011. The highest concentration of uranium in groundwater was 5.82 µg/L in well 199-D6-3 (also an RI/FS borehole characterization sample). This value is much lower than both the Hanford Site background for uranium (9.85 µg/L) and the DWS of 30 µg/L.

During CY 2010, none of the 100-D Area aquifer tubes were sampled for technetium-99 or uranium.

Technetium-99 and uranium concentrations in groundwater were below their respective DWS in both the 100-D and 100-H Areas.

7.1.3.2 100-H Area

In CY 2010, technetium-99 and uranium concentrations in groundwater underlying the 100-H Area were less than their respective DWSs. Although a groundwater sample from well 199-H6-4 had a technetium-99 concentration of 68 pCi/L, this radionuclide has not historically been detected in this area. This well represents the southernmost point of the 100-H Area. Technetium-99 in this area may be the result of groundwater mounding during reactor operations. Additional analyses will be conducted in 2011 in this area. Samples from surrounding wells were below the laboratory detection limit, and this well will be sampled in the future to determine the validity of this result. In addition, values of 68 and 29 pCi/L were reported from duplicate samples at well 199-H4-12A, and the discrepancy is being addressed by the laboratory.

In CY 2010, uranium was positively detected in all groundwater samples analyzed from the 100-H Area. The maximum concentration was identified in the groundwater sample collected from well 199-H4-3 at 12.2 µg/L. This is a decrease from CY 2009; however, the value is below both the Hanford Site background for uranium and the DWS.

During CY 2010, none of the 100-H Area aquifer tubes were sampled for technetium-99 or uranium. However, in CY 2009, three 100-H Area aquifer tubes (AT-H-1-D, AT-H-2-D, and AT-H-3-D) were sampled for technetium-99 and uranium. Technetium-99 was not positively detected in any sample. Uranium was detected at low levels in all three aquifer tubes, with the maximum concentration of 1.67 µg/L in aquifer tube AT-H-3-D.

7.1.4. Tritium

7.1.4.1 100-D Area

In CY 2010, tritium concentrations in groundwater underlying the 100-D Area were less than the DWS of 20,000 pCi/L. The groundwater sample collected from well 199-D6-3 (RI/FS borehole characterization sample) had a tritium concentration of 20,000 pCi/L, which is at the DWS. This well is located on the east side of the 100-D Area, east of the reactor area, along the flow direction extending into the horn area. The reactor area is likely the tritium source.

Tritium concentrations in groundwater were at or below the DWS in the 100-D Area, but a zone at the DWS was noted east of the reactor area at well 199-D6-3.

In addition, tritium was detected in several aquifer tubes in the southern portion of the 100-D Area shoreline at concentrations approaching the DWS. This may represent migration of tritium from the 100-N Area. In general, tritium concentrations in groundwater underlying the 100-D Area are declining; however, further monitoring in this area is warranted to confirm the 100-N Area as a source for tritium in the southwest portion of the 100-D Area.

7.1.4.2 100-H Area

In CY 2010, tritium concentrations in groundwater underlying the 100-H Area were generally less than 5,000 pCi/L, with the exception of a concentration of 9,000 pCi/L at well 199-H3-3. These concentrations are below the DWS. In addition,

Tritium concentrations in groundwater were below the DWS in the 100-H Area.

groundwater samples collected from wells in the horn area had tritium concentrations ranging between 2,000 and 4,500 pCi/L. Therefore, since the horn area is upgradient of the 100-H Area, it is not anticipated that tritium concentrations will increase above the DWS in future sampling events. In general, tritium concentrations in groundwater underlying the 100-H Area and horn area are declining.

7.1.5 Nitrate and Nitrite

7.1.5.1 100-D Area

In CY 2010, nitrate concentrations in groundwater underlying the northern 100-D Area increased compared to CY 2009. The plume has two lobes, and nitrate concentrations continue to exceed the DWS (45 mg/L) in both lobes. A groundwater sample collected from well 199-D5-15 had the maximum detected concentration (99.2 mg/L). The RI/FS wells 199-D5-133 and 199-D6-3 were drilled during CY 2010 and also showed elevated nitrate, with maximum concentrations of 81 and 77.9 mg/L, respectively (RI/FS borehole characterization samples). Figure 7-14 shows the distribution of nitrate in groundwater underlying the 100-D Area. Potential sources of nitrate include nitric acid used during operations, as well as nitrate derived from septic systems.

The southern portion of the nitrate plume is intercepted by the ISRM barrier, which chemically reduces the nitrate. During CY 2009, a maximum nitrate concentration of 95 mg/L was detected in groundwater from well 199-D2-6 (southern 100-D Area); however, in CY 2010, the concentration in groundwater from this well decreased to 69.5 mg/L. Nitrate concentrations in 100-D Area aquifer tubes were less than 45 mg/L.

In CY 2010, nitrite was detected in groundwater samples collected from several wells near the ISRM barrier. However, the measured concentrations were less than the DWS of 3.3 mg/L.

7.1.5.2 100-H Area

In CY 2010, nitrate concentrations in groundwater underlying the 100-H Area were below the DWS of 45 mg/L. The highest concentration (44.3 mg/L) was observed in an RI/FS borehole characterization sample collected from well 199-H6-3 in the southern 100-H Area. This well is located upgradient of aquifer tube 51, which has historically had elevated nitrate concentrations. Aquifer tube 51 was not sampled for nitrate in CY 2010, and the highest value in CY 2009 was 46 mg/L. Aquifer tubes in the southern 100-H Area and further downstream have had concentrations near or above the 45 mg/L DWS in recent years; however, these sites were not sampled in CY 2010.

7.1.6 Sulfate

7.1.6.1 100-D Area

In CY 2010, sulfate concentrations in groundwater underlying much of the southern 100-D Area remained greater than 100 mg/L. Excluding wells influenced by the ISRM barrier, concentrations were below the secondary DWS (250 mg/L), with a maximum concentration of 202 mg/L in well 199-D6-3 (RI/FS borehole characterization sample). Sulfate concentrations in water samples from 100-D Area aquifer tubes are generally low, except downgradient of the ISRM barrier. Previous injections of sodium dithionite solution at the barrier increased sulfate concentrations to levels above the secondary DWS in the ISRM barrier and in some downgradient wells and aquifer tubes. The highest concentration in CY 2010 was 776 mg/L in aquifer tube DD-43-3, which is the highest sulfate concentration ever detected in an

aquifer tube. Aquifer tube DD-42-4 also had results above the 250 mg/L secondary DWS in CY 2009, with a maximum concentration of 616 mg/L in 2010. This could represent migration of sulfate from the vicinity of the ISRM barrier due to low river stage.

7.1.6.2 100-H Area

In CY 2010, sulfate concentrations in groundwater underlying the 100-H Area were below the secondary DWS (250 mg/L). The maximum concentration detected was 83.6 mg/L in a sample collected from well 199-H4-46.

7.1.7 Gross Beta

7.1.7.1 100-D Area

Historical groundwater samples collected from wells in the ISRM barrier have contained detectable amounts of gross beta, which was primarily caused by naturally present potassium-40 in the pH buffer used during injection (PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). In CY 2010, three wells in the IRSM barrier were sampled for gross beta analysis. The three groundwater sample results were all below the DWS of 50 pCi/L, with a maximum concentration of 19 pCi/L in well 199-D4-84. Well 199-D4-19 was not sampled in CY 2010, but a maximum gross beta value of 140 pCi/L was detected in November 2009. A value of 27 pCi/L was reported at well 199-D5-40; however, the value in this well has consistently been less than 10 pCi/L for many years. Further review of the data is being conducted.

7.1.7.2 100-H Area

Strontium-90 is present in groundwater underlying the 100-H Area, which causes gross beta concentrations in groundwater to exceed the 50 pCi/L DWS. In CY 2010, the groundwater sample collected from well 199-H4-13 had the highest gross beta concentration (69 pCi/L) detected.

7.2 CERCLA Groundwater Activities

This section summarizes the CERCLA activities in the 100-D and 100-H Area, including groundwater remedial actions.

An interim remedial action ROD for the 100-HR-3 OU was issued in April 1996 (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*) pursuant to listing of the Hanford Site on the National Priorities List in 1989 for CERCLA. The goal of the resulting interim remedial action is to prevent discharge of hexavalent chromium to the Columbia River.

The interim action goal was changed from 22 µg/L to 20 µg/L in August 2009 by the explanation of significant difference for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009b). The explanation of significant difference sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality criterion of 10 µg/L. As indicated in the ROD, an attenuation factor of 1:1 is expected before the groundwater would reach the aquatic receptor point of concern within the river substrate, ensuring that the ambient water quality criterion of 10 µg/L in the river substrate will be met.

The remedial action objectives for the 100-HR-3 OU are as follows (EPA/ROD/R10-99/039; EPA/AMD/R10-00/22):

- ***Protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.***
- ***Protect human health by preventing exposure to contaminants in the groundwater.***
- ***Provide information that will lead to the final remedy. The COC is hexavalent chromium.***

The second CERCLA 5-year review (DOE/RL-2006-20) was published in November 2006. The review identified six actions for the 100-D Area and one action for the 100-H Area:

- **Action 8-1.** *Complete a field study to investigate additional sources of chromium groundwater contamination within the 100-D Area. Complete additional geologic and geochemical investigations of the vadose zone in the 100-D Area (March 2009).*

  Investigations were conducted for both the southern and northern plume (SGW-38757, *Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*; DOE/RL-2010-40). In addition, several boreholes and wells will be installed as part of the RI/FS (DOE/RL-2008-46-ADD1).

- **Action 9-1.** *Perform additional characterization of the aquifer in the horn area and evaluate the need to perform remedial action to meet the remedial action objectives of the 100-D Area ROD for interim action (September 2009).*

  This action was previously completed and is summarized in the *Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit* (DOE/RL-2008-42).

- **Action 9-2.** *Incorporate the horn area into the 100-HR-3 OU interim ROD (EPA/ROD/R10-99/039) if Action 9-1 indicates that the horn area contains a plume requiring immediate remediation (September 2009).*

  The DOE has completed the remedial process optimization (RPO) evaluation of the pump-and-treat system and is currently implementing the results (SGW-40044, *100-HR-3 Remedial Process Optimization Modeling Technical Memorandum*). The DOE installed additional extraction and injection wells throughout the horn area in FY 2009 and FY 2010 as part of RPO (Section 7.2.2).

- **Action 10-1.** *Direct the operating contractor to further minimize leaks from the 182-D reservoir.*

  Other local influences on groundwater flow are leakage from the 182-D reservoir and the groundwater extraction and injection from the pump-and-treat systems. The zone of uncontaminated groundwater near the 182-D facility suggests long-term contaminant mixing and diversion of contaminated groundwater from the mounding caused by the reservoir leaks. In response to the reservoir leakage information, a specific issue (Action 10-1) was included in the second CERCLA 5-year review (DOE/RL-2006-20) (see discussion in Section 7.3.1) for DOE to provide direction to its operating contractor to conduct changes

to the operation of the reservoir to minimize leakage. Those actions were completed and documented in the closeout of the 5-year review issue. The leaks and their impact on groundwater flow have significantly diminished since the reduction of storage volume in the reservoir in 2004, to the point that influences on groundwater flow from reservoir leakage are indistinguishable from those created by nearby pump-and-treat activities (PNNL-SA-50369, *Project Work Plan Hanford 100-D Area Treatability Demonstration: Accelerated Bioremediation Through Polylactate Injection*).

These actions were previously completed.

- **Action 11-1.** *Initiate limited iron amendments to evaluate whether this enhances ISRM barrier performance (September 2007).*

  Section 7.2.4 provides a summary of the results for this action. Results of the iron amendment tests are documented in *Treatability Test Report on Mending the In Situ Redox Manipulation Barrier Using Nano-Size Zero Valent Iron* (DOE/RL-2009-35).

- **Action 11-2.** *Expand groundwater pump-and-treat extraction within the 100-D Area by 378.5 liters per minute to enhance remediation of the chromium plume (no due date).*

  The DOE installed additional extraction and injection wells in FY 2009 as part of the RPO (SGW-38338, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document*; SGW-40044; Section 7.2.2). The DX system became operational on December 16, 2010.

- **Action 12-1.** *Perform additional characterization of the 100-H Area aquifer below the initial aquitard (September 2009).*

  The DOE installed three wells in the horn area, screened in the RUM (DOE/RL-2008-42) (Section 7.1.1.1), and continued to monitor three wells in the 100-H Area (Section 7.1.1.4).

  Section 7.2.5 presents the summary of the aquifer tests performed in CY 2009 to gather data and provide additional information on the deep hexavalent chromium contamination in the 100-H Area (SGW-47776).

  Five wells (three in the 100-H Area and two in the 100-D Area) were installed as part of the RI/FS work plan. The wells will be drilled through the RUM and screened within the first water-bearing layer encountered (DOE/RL-2008-46-ADD1).

  A non-significant change to the ROD was issued in 2010 (Holten, 2010), which identifies that DOE no longer will maintain the ISRM barrier but will instead meet remedial action objectives with the pump-and-treat expansion.

7.2.1 Remedial Investigation Activities

In CY 2010, the RI/FS work plan addendum for the 100-D and 100-H Area (DOE/RL-2008-46-ADD1) and the sampling and analysis plan (DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*) were issued. The documents identify the data to be collected to support selection of final remedies under CERCLA, using an approach that integrates the data needs for waste sites and groundwater. A total of ten boreholes, fifteen groundwater wells, five test pits, and six aquifer tubes were proposed for installation in CY 2010/2011 under the work plan. In addition, 53 existing groundwater wells were scheduled for three sampling rounds for temporal spatial analysis. The results of the sampling and analysis for these

53 wells are not discussed in this report. Field work is scheduled to be completed by April 2011. At the end of CY 2010, progress was underway and the following work was completed:

- Seven of fifteen wells were drilled and sampled.
- Two of ten boreholes were drilled and sampled.
- Two of five test pits were installed.
- All aquifer tubes were installed and sampled.
- Three sampling rounds for temporal spatial analysis of 53 wells was completed (the first sample round occurred in 2009). Note that the analytical results for these wells are included in discussions, tables, and figures within this report.

The scheduled RI/FS activities were not completed before preparation of this annual report. The complete data set from these investigations will be fully evaluated and reported in the RI/FS report, which will lead to the selection of alternatives for final cleanup action. The RI/FS report is scheduled for completion in CY 2011. These highlights include observations based on data collected during CY 2011. Preliminary highlights of RI/FS findings are briefly summarized below.

- ***Soil — 100-D and 100-H Areas:***
  - Preliminary soil sampling results indicate that total chromium concentrations are much higher than hexavalent chromium concentrations. Concentrations of other contaminants of potential concern do not show significant concentration variation from previous investigations.
- ***Groundwater — 100-D Area:***
  - Hexavalent chromium concentrations in borehole characterization groundwater samples from RI/FS wells are generally within expected values, exceeding the ambient water quality criterion value of 10 µg/L and *Model Toxics Control Act* (MTCA) (WAC 173-340, "Model Toxics Control Act – Cleanup") value of 48 µg/L. The only unexpected concentrations are associated with well 199-D3-5, which is near the former 116-D-1A Burial Ground. This well was installed to define the southwestern extent of hexavalent chromium in the unconfined aquifer but actually shows higher-than-expected hexavalent chromium concentrations on top of the RUM.
  - Generally, hexavalent chromium concentrations are homogeneous throughout the unconfined aquifer. However, in groundwater samples from wells 199-D5-133 and 199-D3-5, hexavalent chromium concentrations are higher at the water table and on top of the RUM, respectively. This could be an artifact of sampling with depth during drilling, but stratification is occasionally observed in some wells. These observations could be explained by density-driven flow during initial contamination by concentrated solutions that have slowly dissipated, leaving a remnant at the base of the aquifer followed by more recent leaching of hexavalent chromium during recent vadose zone remediation. Alternatively, the concentration profile could represent a higher hydraulic conductivity zone in the center of the aquifer, allowing clean water from upgradient to flow through the middle of the aquifer more quickly than the top or bottom portions.
  - Nitrates in borehole water samples from the unconfined aquifer exceeded the DWS (45 mg/L) in wells 199-D5-141, 199-D5-134, 199-D5-140, 199-D6-3,

199-D5-132, 199-D5-133, and 199-D3-5. This is consistent with previous extent of the nitrate plume.

- Strontium-90 concentrations in groundwater samples collected from boreholes were all below the DWS of 8 pCi/L, excluding well 199-D3-5. Well 199-D3-5 is located downgradient of former waste burial site 118-D-2. Further strontium-90 analysis is warranted.
- Technetium-99 concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-D Area.
- Tritium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (20,000 pCi/L) for all samples collected from the 100-D Area, except in well 199-D3-5 in the southwest portion of the 100-D Area, suggesting a possible source in the 100-N Area.
- Uranium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (30 µg/L) for all samples collected from the 100-D Area.
- Zinc concentrations in borehole groundwater samples collected from wells 199-D5-134 (unconfined aquifer and RUM), 199-D5-133, 199-D5-140, and 199-D6-3 exceeded the action level of 91 µg/L. Concentrations in the remaining "D" wells were below the action level.
- Two RUM wells were installed within the north and south hexavalent chromium plumes. The borehole samples collected from each of these wells within the RUM showed impact within the first water-bearing layer at concentrations exceeding the ambient water quality criterion but below the MTCA standard; however, hexavalent chromium concentrations in lower, water-bearing layers were below the laboratory method detection limits. Nitrate, strontium-90, technetium-99, and tritium are all below their respective DWSs. Uranium concentrations were low, and the zinc concentration appeared to be elevated in the sample from the first water-bearing layer at 331 µg/L.

- ***Groundwater — 100-H Area:***
  - Hexavalent chromium concentrations in borehole groundwater samples from RI/FS wells in the unconfined aquifer are generally rather low. Samples collected from wells 199-H6-4, 199-H6-3, 199-H3-7, 199-H3-6, 199-H3-9, and 199-H2-1 are either below or slightly elevated above the ambient water quality criterion.
  - Total chromium concentrations in groundwater from borehole samples are generally higher than the hexavalent chromium concentrations in the same sample. However, none of the groundwater samples collected from the unconfined aquifer exceeded the MTCA value. The total chromium should include both trivalent and hexavalent chromium, so the difference should represent the portion of total chromium that is trivalent chromium. Because hexavalent chromium should be a subset of total chromium, situations where hexavalent chromium is greater than total chromium suggest problems with the laboratory analysis.
  - Strontium-90 was detected above the DWS in only the borehole groundwater sample from well 199-H3-6. The remaining wells were below the minimum detection limit.

- Nitrate concentrations in borehole groundwater samples were below the DWS for all samples collected from the 100-H Area.
- Technetium-99 concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-H Area.
- Tritium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-H Area.
- Uranium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (30 µg/L) for all samples collected from the 100-H Area.
- Zinc concentrations in borehole groundwater samples collected from wells 199-H2-1 (unconfined aquifer and RUM) and 199-H6-3 exceeded the action level of 91 µg/L. The remaining "H" wells were below the action level.
- The northern extent of hexavalent chromium in the first water-bearing layer in the RUM is defined by well 199-H2-1 because the sample was below the ambient water quality criterion. However, the groundwater sample from 199-H3-9 collected within the first water-bearing layer in the RUM had the highest concentration of hexavalent chromium identified in groundwater underlying the 100-H Area.

7.2.2 Pump-and-Treat Systems

The DOE will expand and optimize the pump-and-treat systems in the 100-HR-3 OU to enhance treatment of the hexavalent chromium plumes in the 100-D Area, 100-H Area, and horn area.

During CY 2010, two pump-and-treat systems operated to remediate hexavalent chromium in groundwater. The HR-3 pump-and-treat system was the initial system and extracts water from both the 100-D and 100-H Areas. The DR-5 system supplements the HR-3 pump-and-treat system to improve hexavalent chromium control in the 100-D Area. The new DX pump-and-treat system entered acceptance testing in the fourth quarter of CY 2010 and became operational in 2011. The DX system will eventually incorporate some of the HR-3 and DR-5 wells into the system.

Expansion of pump-and-treat operations continues in the 100-HR-3 OU along the Columbia River, including, for the first time, the horn area. The current HR-3 and DR-5 pump-and-treat systems are being phased out by expanded systems (DX/HX) to improve overall system run-time, reduce individual well downtime, and capture and treat additional contaminated groundwater as a result of the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) requirements specified in CERCLA 5-year reviews (Section 7.2).

An RPO evaluation began in 2008 to determine the how to optimize remediation of hexavalent chromium in the 100-HR-3 OU groundwater by 2012 (SGW-38338). RPO is a systematic approach for evaluating existing remediation systems with the goal of improving their effectiveness and reducing overall site cleanup costs without increasing risks. In the long run, efficient use of RPO reduces the operations and management burden. The RPO review recommended implementing additional pump-and-treat system capacity to address the hexavalent chromium groundwater concentrations that exceed cleanup levels established in the interim ROD and interim ROD amendment (EPA/AMD/R10-00/122). The new DX and HX pump-and-treat system will substantially increase the rate of groundwater cleanup in the 100-HR-3 OU.

Seventy new RPO extraction/injection wells were installed within the 100-HR-3 OU to further aid in groundwater remediation activities (Figures 7-15 and

7-16). To accommodate the additional extraction well production needed to capture the full extent of the plume in the 100-D Area and western portion of the horn area, the DX system was completed at the end of CY 2010. The DX system will be capable of treating up to 2,300 liters per minute of groundwater. Pilot testing of the facility began in December 2010 and, after one month of operation, treated approximately 55.3 million liters of groundwater and removed an additional 18.4 kilograms of hexavalent chromium. Construction of the HX system (3,000 liters per minute) is progressing ahead of schedule, with the system startup anticipated in December 2011.

Groundwater from the 100-D Area portion of the HR-3 pump-and-treat system continued to be piped to the 100-H Area for treatment. As an outcome of the RPO, the DOE has begun consolidating extraction, treatment, and injection within the two areas to reduce water movement across the horn area (DOE/RL-2009-09, *Sampling and Analysis Plan for Installation of 100-HR-3 Groundwater Operable Unit Remedial Process Optimization Wells*). The results of operational monitoring and additional details about the pump-and-treat systems for CY 2010 are presented in the pump-and-treat system annual performance report (DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*).

The total dissolved mass of hexavalent chromium remaining in the unconfined aquifer underlying the 100-HR-3 OU was estimated using the fall 2009 isoconcentration map. The areal extent of the average hexavalent chromium concentrations within each contour interval was multiplied by an assumed average porosity value of 15% by an average aquifer thickness of approximately 7.5 meters. The results indicate that approximately 1,125 kilograms of hexavalent chromium remained in the aquifer. These results will be used to provide better perspective on pump-and-treat system performance in the 100-HR-3 OU.

7.2.2.1 HR-3 Pump-and-Treat System

M. Tonkin

The HR-3 pump-and-treat system extracts groundwater through wells in the northern plume (100-D Area) and in the 100-H Area plume. The extracted groundwater is transferred through an above-ground pipeline to a treatment building in the 100-H Area. Hexavalent chromium is removed from extracted groundwater using ion-exchange resins, and the treated water is then discharged to three injection wells, which are screened in the unconfined aquifer underlying the 100-H Area. Figure 7-17 presents a capture efficiency/frequency map of the HR-3 system for CY 2010 and the spring 2010 hexavalent chromium concentration contours. The capture maps describe the zone of influence of the pump-and-treat system with respect to the extraction/injection well locations. By overlaying these maps with the map showing the extent of the plume, the ability of the system to capture the plume can be assessed. The capture is discussed in detail in the annual pump-and-treat report (DOE/RL-2011-25).

The HR-3 system has used up to twelve extraction wells (ten wells in the unconfined aquifer and two wells in the RUM). In CY 2010, well 199-H3-2C and 199-H4-12C (RUM wells) were added to the HR-3 pump-and-treat system. These wells previously monitored a water-bearing layer within the RUM, which showed elevated concentrations of hexavalent chromium. The configuration of the extraction network has varied at times, depending on need (i.e., not all extraction wells are operated simultaneously). The HR-3 pump-and-treat system also includes three

injection wells in the 100-H Area. The existing treatment capacity for the HR-3 pump-and-treat system is 1,100 liters per minute.

The HR-3 pump-and-treat system treated 268 million liters of water during CY 2010, removing 31 kilograms of hexavalent chromium.

In CY 2010, the HR-3 pump-and-treat system extracted 267.9 million liters of groundwater from the 100-HR-3 OU. This is a 51% increase in volume when compared to 177.3 million liters processed in CY 2009. The system removed 31 kilograms of hexavalent chromium during CY 2010, bringing the total removal to 392.9 kilograms since 1997, in addition to the 30 kilograms removed by a pilot-scale system in the early 1990s. The hexavalent chromium removed in CY 2010 was an increase of 95% in mass removed when compared to the 15.9 kilograms processed in CY 2009. The average removal efficiency for CY 2009 was 96.0%, which is slightly higher than the 95% reported in CY 2010.

Wells 199-D8-54A and 199-D8-71 are the two specified compliance points for the HR-3 pump-and-treat system in the 100-D Area. Well 199-D8-54A was sampled eleven times during the reporting period because it was an extraction well, with concentrations ranging from 25 to 109 μg/L. Well 199-D8-71 was sampled twice during the reporting period, in March and May of CY 2010. The highest hexavalent chromium concentration detected in groundwater from this well was 130 μg/L, which is slightly lower than CY 2009, with a maximum detected concentration of 136 μg/L. Hexavalent chromium concentrations in these compliance wells exceeded the 20 μg/L remedial action goal during CY 2010, which is unchanged from the previous reporting period.

In CY 2010, a small area of hexavalent chromium exceeded 50 μg/L across the eastern boundary of the 100-D Area. The zone appeared to have a north-south axis, with wells 199-D8-69 and 199-D8-70 (compliance wells) located in the portion of the zone with hexavalent chromium concentrations between 50 and 100 μg/L in CY 2010. The compliance wells continued to show variable hexavalent chromium concentrations, with the lowest concentrations in the early summer when the river stage was high (Figure 7-12). Most concentrations in these compliance wells exceeded the 20 μg/L remedial action goal during CY 2010, which is unchanged from the previous reporting period. The highest concentrations detected were 64.5 and 82.7 μg/L in wells 199-D8-69 and 199-D8-70, respectively.

In the 100-H Area, one compliance well (199-H4-5) was scheduled for monthly sampling to evaluate the performance of the HR-3 pump-and-treat system; however, this well could only be sampled for 8 of the 12 months, due to the safety issues discussed earlier. None of the samples exceeded the 20 μg/L remedial action goal, and the maximum hexavalent chromium concentration detected was 10 μg/L.

Four additional wells in the 100-H Area are designated as dual-purpose wells. Well 199-H4-3 is designated as an extraction/performance well, and wells 199-H4-4, 199-H4-63, and 199-H4-64 are designated as extraction/compliance wells. All four wells had at least one sample above the remedial action goal of 20 μg/L for hexavalent chromium during CY 2010. Well 199-H4-64 had the maximum detected concentration of 26 μg/L; the concentration in this well has decreased from CY 2009 (61 μg/L).

The size of the hexavalent chromium plume in the unconfined aquifer underlying the 100-H Area has been significantly reduced since the start of pump-and-treat operations in 1997; however, in CY 2010, this plume did not change significantly compared to CY 2009. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River. The new HX

pump-and-treat system will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater.

7.2.2.2 DR-5 Pump-and-Treat System

A second pump-and-treat system, DR-5, began operating at the end of July 2004 to treat increasing hexavalent chromium concentrations in 100-D Area wells southwest of the original pump-and-treat system. The DR-5 pump-and-treat system extracts, treats, and injects groundwater in the 100-D Area and has a treatment capacity of 190 liters per minute. Groundwater is extracted from four wells and treated in the 100-D Area at the DR-5 treatment facility using a metal anion-exchange system with onsite regeneration. Treated groundwater is then injected into wells 199-D5-41 and 199-D5-42. The system has been modified (e.g., pumping rate changes, extraction wells added or subtracted) several times throughout the years to increase the rate of remediation and widen the capture zone. In CY 2010, four extraction wells and two injection wells were operating on different schedules. Figure 7-18 presents a capture efficiency/frequency map for the DR-5 system for CY 2010 and shows the spring 2010 hexavalent chromium concentration contours.

During CY 2010, the DR-5 pump-and-treat system operated with various configurations. In February 2010, extraction well 199-D5-104 and injection well 199-D5-41 were added to the DR-5 system to aid in addressing the 100-D Area south plume. Injection well 199-D5-42 was taken offline in February for rehabilitation and then added back online in September 2010.

The DR-5 pump-and-treat system currently consists of four extraction wells: two of the wells (199-D5-20 and 199-D5-92) are located in the northern hexavalent chromium plume (100-D Area), and two wells (199-D5-39 and 199-D5-104) are located in the southern hexavalent chromium plume (100-D Area). The DR-5 system also includes two injection wells (199-D5-41 and 199-D5-42) in the 100-D Area.

During CY 2010, the DR-5 pump-and-treat system extracted 44.6 million liters of groundwater from the 100-D Area, which is an 8% decrease in volume when compared to 48.6 million liters processed in CY 2009. The system removed 74.9 kilograms of hexavalent chromium during the reporting period, bringing the total removal to 326.2 kilograms since 2004. The amount of hexavalent chromium removed in CY 2010 was an increase of 70% in mass removed when compared to 44.2 kilograms processed in CY 2009. The average removal efficiency for CY 2010 was 99.8%, which is essentially the same as the 99.9% reported in CY 2009.

During CY 2010, the DR-5 pump-and-treat system removed 75 kg of hexavalent chromium from the aquifer.

Currently there are no compliance wells for the DR-5 pump-and-treat system; however, the system is monitored on a regular basis. The sampling frequencies and constituents are listed in Appendix A. Appendix A, Table A-8 lists the deviations from required sampling for both pump-and-treat systems. New compliance wells are planned to monitor the expanded pump-and-treat systems in 100-D and 100-H Areas.

For CY 2010, the areal extent of the southern hexavalent chromium plume in the 100-D Area did not change significantly relative to CY 2009. In addition, despite removing over 326 kilograms of hexavalent chromium through pump-and-treat operations, average concentrations beneath the 100-D Area have increased dramatically since the hot spot was identified 3 years ago. The new DX facility, with a treatment capacity of 2,300 liters per minute, will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater. In addition, drilling and installation of new characterization and monitoring wells has aided in defining the extent of contamination.

7.2.3 In Situ Redox Manipulation System

A permeable reactive barrier for in situ chemical treatment of the hexavalent chromium in the southern plume (100-D Area) was emplaced as an interim remedial action in accordance with the interim ROD amendment (EPA/AMD/R10-00/122) beginning in 2000 (Figure 7-19). The reduction-oxidation treatment zone is ~680 meters long (aligned parallel to the Columbia River) and ~100 to 200 meters inland, and it consists of 65 wells spaced across almost the entire width of the southern hexavalent chromium plume. The treatment zone was designed to reduce the hexavalent chromium concentration in groundwater to no more than 20 µg/L at seven compliance wells located between the treatment zone and the Columbia River.

The ISRM barrier has reduced hexavalent chromium concentrations in the aquifer near the Columbia River.

The permeable reactive barrier uses ISRM technology to create a treatment zone in which ferric iron (iron III) is reduced to ferrous iron (iron II) within the aquifer matrix. This is accomplished by injecting sodium dithionite into the aquifer through wells, then withdrawing the unreacted reagent and reaction products (predominately sulfate) through the same wells and pumping this to the ISRM evaporation pond. The sodium dithionite serves as a reducing agent for iron, producing a reducing-type environment in the aquifer. As the groundwater migrates through the treatment zone, the mobile hexavalent chromium is reduced to the less toxic, immobile trivalent chromium, which precipitates from solution. Dissolved oxygen and some nitrate are also removed from the groundwater as it passes through the permeable reactive barrier.

The ISRM barrier (Figure 7-20) intersects the southern hexavalent chromium plume and has largely cut off the highest concentration portion of the plume and prevented it from extending to the Columbia River. Figure 7-21 shows hexavalent chromium concentration plots for the ISRM compliance wells. The 2010 hexavalent chromium concentrations were all below the 20 µg/L remedial action goal in the southernmost compliance well 199-D4-86, with a maximum measurement of 14.3 µg/L. The compliance monitoring wells in the northwest portion of the ISRM barrier generally contained higher concentrations of hexavalent chromium during the reporting period. The northernmost well, 199-D4-83, had levels of hexavalent chromium up to 109 µg/L during CY 2010, which is an increase from the CY 2009 maximum concentration of 95.8 µg/L. Groundwater in well 199-D4-39, also near the northeast end of the barrier, had a hexavalent chromium concentration of 798 µg/L in CY 2010; this level was slightly elevated from the range of 515 to 783 µg/L observed in CY 2009. Concentrations remained above the remedial action goal in well 199-D4-38 and 199-D4-84, downgradient from the central portion of the ISRM barrier, with maximum concentrations of 116 and 69µg/L, respectively.

The sample frequencies and constituents are listed in Appendix A. Table A-7 in Appendix A lists the deviations from planned sampling for the ISRM barrier. The results of operational monitoring and additional details about the ISRM barrier for CY 2010 will be published in the annual pump-and-treat performance report (DOE/RL-2011-25).

The dissolved oxygen concentrations are monitored as required by the ROD amendment (EPA/AMD/R10-00/122) and the remedial design report/remedial action work plan (DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*). The sodium-dithionite injection process reduced dissolved oxygen in the groundwater at the barrier to low levels. Low levels of dissolved oxygen are monitored to assess changes as groundwater approaches the Columbia River, as well as to ensure that the dissolved oxygen levels have recovered sufficiently before water discharges into

the river. Low dissolved oxygen is a hazard to aquatic organisms. The dissolved oxygen profile in the vicinity of the ISRM treatment zone is generally characterized by relatively high dissolved oxygen concentrations upgradient of the treatment zone, dropping significantly through the treatment zone, and recovering to higher dissolved oxygen concentrations as groundwater flow approaches the river. A comparison was made between several wells in a line located upgradient of the ISRM (199-D4-15 and 199-D4-20), wells within the ISRM (199-D4-3 and 199-D4-19), and wells downgradient of the ISRM (199-D4-23 and 199-D4-84).

Since minimal data were collected in the fall of 2010, the dissolved oxygen sampling results from April through July were compared. The east line of wells moving from upgradient to downgradient (199-D4-15 at 8,920 μg/L; 199-D4-3 at 3,860 μg/L; and 199-D4-23 at 4,640 μg/L) show a reduction in oxygen of approximately 50%, with a slight increase occurring as moving downgradient. The west line of wells moving from upgradient to downgradient (199-D4-20 at 4,140 μg/L; 199-D4-19 at 1,220 μg/L; and 199-D4-84 at 1,620 μg/L) show a reduction in oxygen of approximately 70%, with a slight increase occurring as moving downgradient. Based on these results, it is evident that the ISRM barrier continues to create conditions that are favorable to hexavalent chromium reduction. This system, together with the downgradient DX pump-and-treat system extraction wells, will aid in meeting remedial action goals.

7.2.4 Zero-Valent Iron Injection

The ISRM barrier was completed in 2002 to intercept hexavalent chromium contamination in the unconfined aquifer. A 20-year service life was anticipated for the barrier, but some minor loss of barrier integrity was noted within 18 months of completion. In 2004, an independent technical panel recommended injection of micron-sized zero-valent iron to renew reducing conditions in the aquifer and mend portions of the barrier.

In 2007 and 2008, several zero-valent iron materials were evaluated in the laboratory to test their ability to move into the aquifer and chemically reduce groundwater. The compound RNIP-M2™ (trademark of Toda Kogyo Corporation, Hiroshima, Japan) was judged superior, and approximately 370,000 liters of iron slurry containing 2,400 kilograms of RNIP-M2 were injected into well 199-D4-26 within the ISRM barrier over a 5-day period in August 2008. Information from a network of monitoring wells and a post-injection verification well show that the iron was communicated greater than 7 meters into the aquifer. This is a sufficient radius of influence to form a continuous permeable reactive barrier if adjacent ISRM wells are injected.

Groundwater samples collected from the area influenced by the injection have hexavalent and total chromium values at or near detection limits and low dissolved oxygen and nitrate. Samples from a monitoring well 60 meters downgradient from the injection well showed decreasing concentrations of hexavalent chromium and dissolved oxygen in CY 2010, indicating that the reducing zone created in the ISRM barrier by the iron injection test is influencing the groundwater in a fairly large area.

Additional information on the iron injection test is provided in DOE/RL-2009-35.

7.2.5 Characterization of Hexavalent Chromium Within the Ringold Upper Mud Unit

In response to the 5-year review (Action 12-1), an investigation was conducted on the deep hexavalent chromium contamination in the sediments of the RUM (SGW-47776). The second 5-year review noted that groundwater samples from one

deep well extending below the aquitard (i.e., RUM) exceeded both the groundwater standard of 48 µg/L (Ecology Publication 94-06, *Model Toxics Control Act Cleanup Regulation 173-340 WAC*) and the federal DWS of 100 µg/L for hexavalent chromium. The extent of hexavalent chromium contamination in this zone is not well understood. Action 12-1 from the review was to "perform additional characterization of the aquifer below the initial aquitard"; therefore, field characterization and aquifer testing were performed in the 100-H Area to address this milestone. The purpose of aquifer testing was to (1) gather data to help refine the conceptual model for the source of contamination in the RUM, (2) examine the potential hydraulic connection between the RUM and the unconfined aquifer, (3) evaluate the hydraulic properties of the first water-bearing layer within the RUM, and (4) evaluate the extent of hexavalent chromium contamination in the upper mud unit.

The aquifer tests were conducted in late CY 2009. The three wells used for the aquifer pumping tests (199-H3-2C, 199-H4-12C, and 199-H4-15CS) exhibit hexavalent chromium contamination in confined groundwater. The results indicated persistent hexavalent chromium concentrations over the duration of testing, suggesting a large-scale emplacement of hexavalent chromium consistent with a high-volume, low-concentration source such as reactor cooling water that mounded up in this area with sufficient hydraulic head to drive water into this sandy layer in the RUM. The concentration decreases upgradient toward the horn area, suggesting a limit on the eastward extent of contamination. This is consistent with the results of the horn area investigation (DOE/RL-2008-42), which found locations in the same horizon in the horn area with no hexavalent chromium contamination.

The results suggest that the most likely explanation for the origin of the hexavalent chromium in the RUM underlying the 100-H Area is from contaminated cooling water that passed through the H Reactor. The cooling water contained up to 1,000 µg/L of hexavalent chromium, which was subsequently discharged to the ground in large quantities. This water formed a mound that provided sufficient hydraulic driving force to push into the upper RUM and mix with existing groundwater in the unit, resulting in concentrations of one-tenth to one-thirtieth of the original cooling water. Concentrations decline inland, consistent with a reactor mound. The areal extent and relatively high continuous concentrations rule out localized contamination during well drilling.

Concurrent with the testing in the RUM layer, pumping was stopped in the overlying unconfined aquifer. Evaluation of the hexavalent chromium concentration versus time in the unconfined aquifer showed no clear concentration trends for hexavalent chromium in unconfined aquifer monitoring wells subsequent to temporary shutdown of the 100-HR-3 pump-and-treat system. Therefore, there is no support for any significant rebound of hexavalent chromium concentrations. This type of information will be needed in the future to assess whether the remedy is sufficient.

7.2.6 Horizontal Direction Drilling — Technology Demonstration

A technology demonstration of horizontal directional drilling was conducted in the 100-D Area to evaluate the capability of this technology in difficult geological conditions and to determine the feasibility of emplacing a horizontal well to intercept a groundwater hexavalent chromium plume. The primary goals of this demonstration were to drill through the 25-meter-thick vadose zone and emplace a 90-meter-long screen in the unconfined aquifer. Secondary objectives were to minimize the loss of drilling fluid to the vadose zone and aquifer and to place the screen within

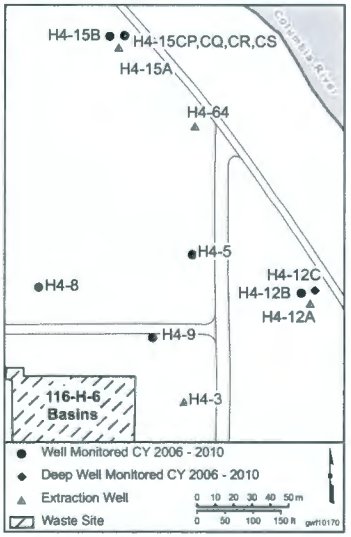
1.5 meters of the middle of the aquifer. The field demonstration was performed from November 2009 through January 2010.

The drilling and construction of a blind entry horizontal well involved using a down-hole hammer to advance approximately 53.3 meters of casing at a 16-degree angle from horizontal (true vertical depth of 15.2 meters) to penetrate and case-off the full thickness of the Hanford formation. At this point, the drilling method would switch to mud rotary drilling to advance a directional borehole for a total distance of ~207 meters, sufficient to emplace a 90-meter string of slotted well screen at a total vertical depth of 27.4 meters below ground surface.

This test did not result in successful installation of a horizontal groundwater well. Despite best efforts, only 24.7 meters of surface casing was installed at a 16-degree angle from horizontal. The bottom of the casing was 8.17 meters below ground surface. The principal impediments to casing installation were difficulty in removing cuttings from the nearly horizontal casing and inability of the down-hole hammer to advance through the unconsolidated Hanford formation. Attempts to drill beyond the casing with the directional drilling equipment were unsuccessful due to nearly 100% loss of drilling fluids to the Hanford formation. Therefore, the drilling methods used were not capable of advancing casing to a depth sufficient to begin horizontal drilling. The down-hole hammer system could not advance casing or a boring any further than 7.1 meters below ground surface (true vertical depth) due to difficulties removing cuttings with insufficient air return flow. The results and analysis of this technology demonstration may be useful to project planners, scientists, and contractors who are considering similar types of projects at the Hanford Site.

7.3 RCRA Groundwater Monitoring of 183-H Solar Evaporation Basins

The 183-H solar evaporation basins (waste site 116-H-6) included four sedimentation and flocculation basins remaining from operation of the 183-H water treatment facility. The four basins received combined radioactive and dangerous (mixed) waste for storage and treatment from the 300 Area fuel fabrication facilities from July 1973 until November 1985. By the fall of 1996, the waste remaining in the basins was removed, the basins were demolished, and the underlying contaminated soil was removed and replaced with clean fill.



Clean closure of the site was not achieved because fluoride and nitrate levels in soil below the 4.6-meter-deep excavation exceed the Method B cleanup levels of WAC 173-340. Therefore, the unit was closed under the partial-closure option, with specified measures for post-closure care.

The Hanford Facility RCRA Permit requires annual monitoring of the facility, which includes sampling four wells (199-H4-3, 199-H4-8, 199-H4-12A, and 199-H4-12C) for total chromium, fluoride, nitrate, technetium-99, and uranium. Although not regulated under RCRA, technetium-99 and uranium were included in the monitoring plan for completeness and were incorporated by reference in the RCRA Permit. The sample frequencies and constituents are listed in Appendix B. Table B-7 in Appendix B documents the deviations from planned sampling for the RCRA site.

All four quarters of CY 2010 are included in this report. The four-quarter period includes one RCRA sampling event (December 2010). The RCRA wells were sampled as scheduled per the RCRA recovery schedule for the constituents of interest listed

in the groundwater monitoring plan (PNNL-11573, *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*). The wells were originally scheduled for sampling in November 2010; however, due to safety concerns pertaining to all groundwater sampling, the wells were sampled in December 2010.

In CY 2010, the concentrations of most contaminants (e.g., nitrate, fluoride, technetium-99, and uranium) at the 183-H solar evaporation basins remained below applicable concentration limits. Total chromium concentrations were below the 122 µg/L RCRA Permit concentration limit in three wells, but concentrations in well 199-H4-12C in December 2010 were above this level (128 and 133 µg/L in filtered and unfiltered samples, respectively). The levels in this well have declined from ~300 µg/L in the early 1990s, and concentrations had been stable for the past several years before increasing since November 2009. Because none of the other 183-H solar evaporation basin co-contaminants were elevated in well 199-H4-12C, it is likely that the total chromium in this well has an alternate source (i.e., H Reactor coolant water that entered the RUM). Well 199-H4-12C began operating as an extraction well in August 2010. Table 7-1 shows the maximum concentration of each permit constituent and the corresponding well detected among the monitoring network.

7.4 Conclusions and Recommendations

The conclusions and recommendations for the 100-HR-3 OU are presented in this section.

7.4.1 Conclusions

The DR-5, HR-3, and ISRM remedies have contributed to meeting the remedial action objectives; however, the old pump-and-treat systems were undersized, and the ISRM barrier experienced some breakthrough in a high-concentration zone. The DX pump-and-treat system is now operational, with the HX pump-and-treat system scheduled to be online later in 2011. These additional remedies are much more robust and will reduce hexavalent chromium concentrations in groundwater before reaching the Columbia River.

The conclusions with respect to each remedial action objective are discussed below.

- **Remedial action objective #1.** *Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.*

  100-D Area:

  - During CY 2010, the DR-5 pump-and-treat system extracted 44.6 million liters of groundwater from the 100-D Area, which is an 8 percent decrease when compared to 48.6 million liters processed in CY 2009. The system removed 74.9 kilograms of hexavalent chromium during the reporting period, for a total of 326.2 kilograms removed since 2004.
  - The CY 2010 hexavalent chromium concentrations were above the 20 µg/L remedial action goal in both compliance wells 199-D8-69 and 199-D8-70. Well 199-D8-69 has since been converted into an extraction well for the DX pump-and-treat system, which should reduce the hexavalent chromium concentrations within this portion of the unconfined aquifer.
  - Overall, the ISRM barrier continues to help reduce hexavalent chromium in the aquifer. However, during periods of low flow, hexavalent chromium values above the remedial action goal were observed in some downgradient wells.

However, downgradient DX pump-and-treat system extraction wells now compensate for ISRM breakthrough, which will reduce hexavalent chromium concentrations in groundwater before reaching the river.

100-H Area:

- In CY 2010, the HR-3 pump-and-treat system extracted 267.9 million liters of groundwater from the 100-HR-3 OU, which is a 33% increase in volume compared to 177.3 million liters processed in CY 2009. The system removed 31 kilograms of hexavalent chromium in CY 2010, bringing the total amount removed since 1997 to 392.9 kilograms.
- The CY 2010 hexavalent chromium concentrations were less than the 20 µg/L remedial action goal in two of four original compliance wells, 199-H4-5 and 199-H4-13. A May 2010 groundwater sample from well 199-H4-11 had a hexavalent chromium concentration of 21.6 µg/L, but the March and December concentrations were less than 20 µg/L. The groundwater sample from well 199-H4-10 fluctuated between slightly exceeding and being beneath the remedial action goal. Groundwater samples from all four compliance wells continue to show decreasing hexavalent concentration trends.
- The CY 2010 hexavalent chromium concentrations were greater than the 20 µg/L remedial action goal in HR-3 pump-and-treat system extractions wells 199-H4-64 (26 µg/L) and 199-H4-15A (31 µg/L). Wells 199-H4-15A and 199-H4-64 will be incorporated as extraction wells in the new HX pump-and-treat system to continue remediation.
- Aquifer testing of the first water-bearing layer within the RUM indicates that hexavalent chromium concentrations were higher in RUM wells 199-H4-12C and 199-H4-15CS (~100 µg/L) than in unconfined wells 199-H4-12A and 199-H4-15A. Well 199-H3-2C had hexavalent chromium levels of ~30 to 40 µg/L. The source of the hexavalent chromium in the RUM at the 100-H Area is believed to be from contaminated H Reactor cooling water discharged to the ground in sufficient quantities to form a mound.

Horn area:

- Characterization wells and aquifer tubes completed during the past several years indicate that a low-concentration hexavalent chromium plume originating from the 100-D Area underlies the horn area. The last of the RPO wells were installed in 2010 to remediate groundwater underlying this area.

- **Remedial action objective #2.** *Protect human health by preventing exposure to contaminants in the groundwater.*

The interim remedial action ROD (EPA/ROD/R10-96/134) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas
- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls was presented in the *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions* (DOE/RL-2004-56). The findings of this report indicate that institutional controls were maintained to prevent public access, as required.

- **Remedial action objective #3.** *Provide information that will lead to a final remedy.*
  - Since 1997, a significant mass of hexavalent chromium has been removed from groundwater underlying the 100-HR-3 OU (719 kilograms). However, the overall areal extent of the 100-D Area hexavalent chromium plume has not been affected significantly by pump-and-treat operations. The new DX pump-and-treat system will help facilitate the remediation effort by expanding the capture zone, thereby drawing a larger volume of contaminated groundwater for treatment. In addition, drilling and installation of new characterization and monitoring wells has aided in defining the extent of contamination.
  - Preliminary RI results indicate that the conceptual site model for the 100-HR-3 OU remains unchanged. Most of the hexavalent chromium is already contained in the groundwater; therefore, the proposed DX/HX system will capture and treat residual contaminants.
  - Contaminant concentrations in aquifer tubes have been reduced.
  - The ISRM technology is not fully functional for the purpose it was emplaced. Hexavalent chromium concentrations still exceed remedial action objectives in compliance wells downgradient after multiple years of operation. However, downgradient extraction wells for the DX pump-and-treat system were added to reduce hexavalent chromium concentrations before reaching the river and reduce concentrations to a level that are manageable by the ISRM barrier.

7.4.2 Recommendations

Recommendations for the 100-HR-3 OU are as follows:

- Understand the operation of the newly designed and constructed DX and HX pump-and-treat systems. Extract and inject at the design rates and then vary the rates to understand the possible range of operation. Identify opportunities to optimize the performance and operation of existing components of the DX system that began operations at the end of CY 2010 and at the HX system that will begin operations in the fourth quarter of CY 2011.
- Update the groundwater model with actual well flow rates and pump-and-treat system data from the DX system startup late in CY 2010 for future analysis.
- Revise the remedial design/remedial action work plan to reflect upgrades to the DX and HX pump-and-treat systems, and obtain concurrence from Ecology on the associated monitoring well network and analyte list.
- Initiate installation of a compliance well network for the DX and HX pump-and-treat systems consisting of approximately eleven additional monitoring wells located primarily along the 100-D and 100-H Area shorelines for river protection monitoring, plus several wells interior to the plume for groundwater cleanup monitoring. Include these wells in future sampling events.
- Initiate pumping at the DX system in CY 2011 from the 100-D Area hot spot using wells 199-D5-99 and 199-D5-122.

Additional recommendations include the following:

- Evaluate the response of the 100-D Area hot spot to pumping of the larger volumes in the DX system.
- Evaluate the response of the 100-D Area hot spot to the 100-D-100 excavation of the overlying vadose zone sediments in the adjacent monitoring wells.
- Continue to pump the contaminated zone in the RUM in the 100-H Area after the HX system begins operations. Consider adding wells to the network based on the refined nature and extent developed in the 100-D and 100-H Areas RI/FS. Until system startup, monitor for potential rebound in concentrations in groundwater within the zone of influence of the HR-3 system.
- The timing of pump-and-treat system shutdowns will be planned to minimize contaminant flux to the Columbia River by scheduling outages during high river stage times of the year (i.e., spring and summer).
- Evaluate changes in concentrations in the 100-H Area during transition from HR-3 system to the HX system in CY 2011 while the pumps are shut down to determine whether any concentration rebound is occurring.
- Evaluate the effectiveness of the new DX and HX pump-and-treat systems with respect to 2012 Tri-Party Agreement Milestone M-016-110-TO1 target using groundwater concentration data, hydraulic head data, capture zone analyses, and further modeling to integrate the model with the data.
- Continue to review and modify the groundwater cleanup strategy for the interim actions and evaluate alternatives.

Table 7-1. Concentration Limits for 183-H Solar Evaporation Basins

Constituent	Concentration Limit	Maximum Concentration Detected in CY 2010
Dangerous Waste Constituents		
Chromium (total, filtered samples)[a]	122 µg/L; local background when compliance monitoring plan was written (1996); upgradient sources	133 µg/L (199-H4-12C)
Nitrate	45 mg/L; DWS (as NO_3)	37.7 mg/L (199-H4-3)
Fluoride	4,000 µg/L[b]	128 µg/L (199-H4-3)
Other 183-H Waste Indicators		
Technetium-99	900 pCi/L	94 pCi/L (199-H4-12A)
Uranium (total; chemical analysis)	20 µg/L; proposed DWS when monitoring plan was written (1996)	12.2 µg/L (199-H4-3)

a. Chromium results discussed here represent hexavalent chromium, which can be measured either by analyses specifically for the hexavalent species or from total chromium measured in filtered samples. Dissolved chromium in Hanford Site groundwater is nearly all hexavalent.

b. The *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967) erroneously gives the value 1,400 µg/L as the U.S. Environmental Protection Agency's maximum contaminant level (DWS) for fluoride. The actual limit is 4,000 µg/L.

Figure 7-1. Facilities, Wells, and Shoreline Monitoring Sites in the 100-D Area

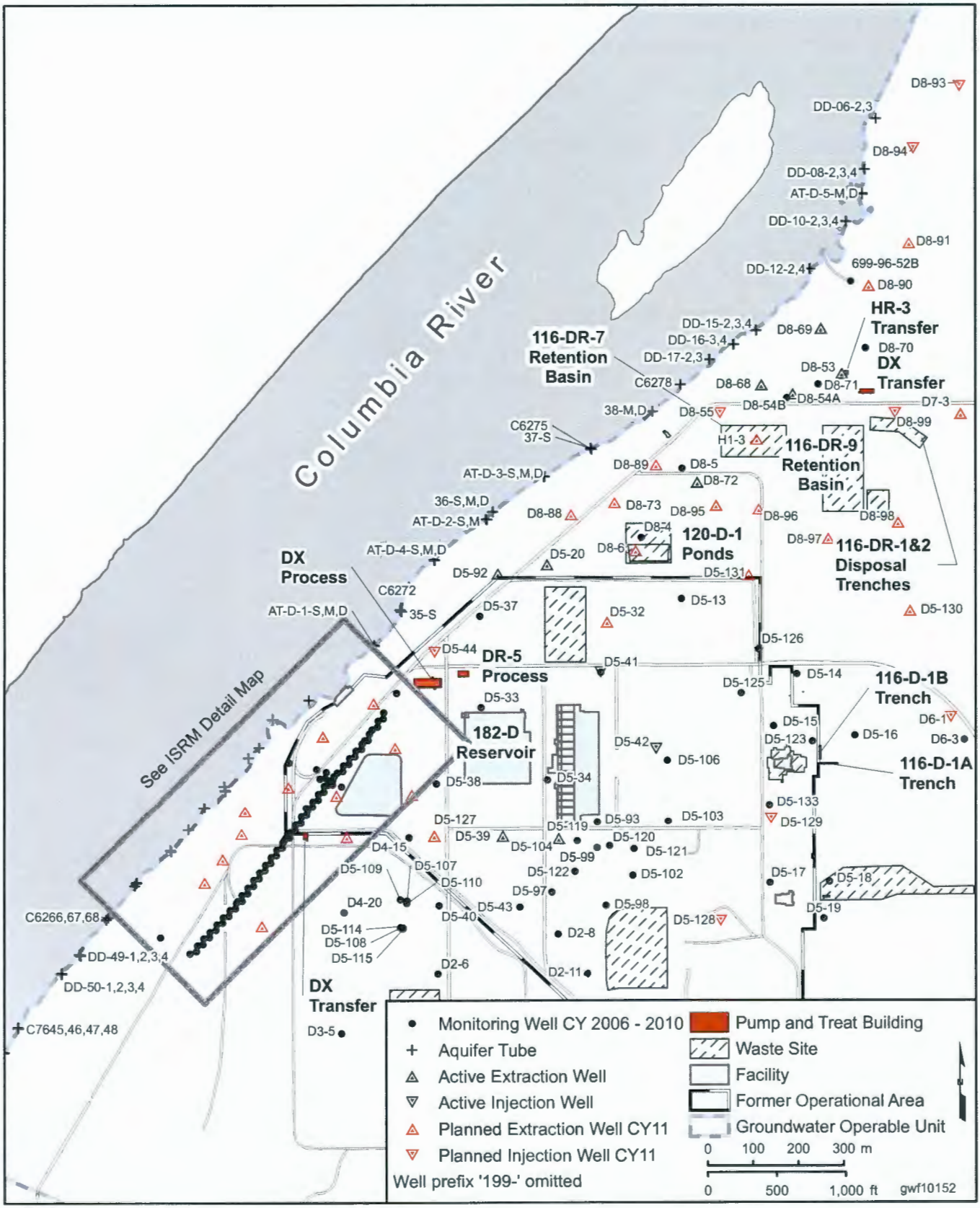


Figure 7-2. Facilities, Wells, and Shoreline Monitoring Sites in the 100-H Area

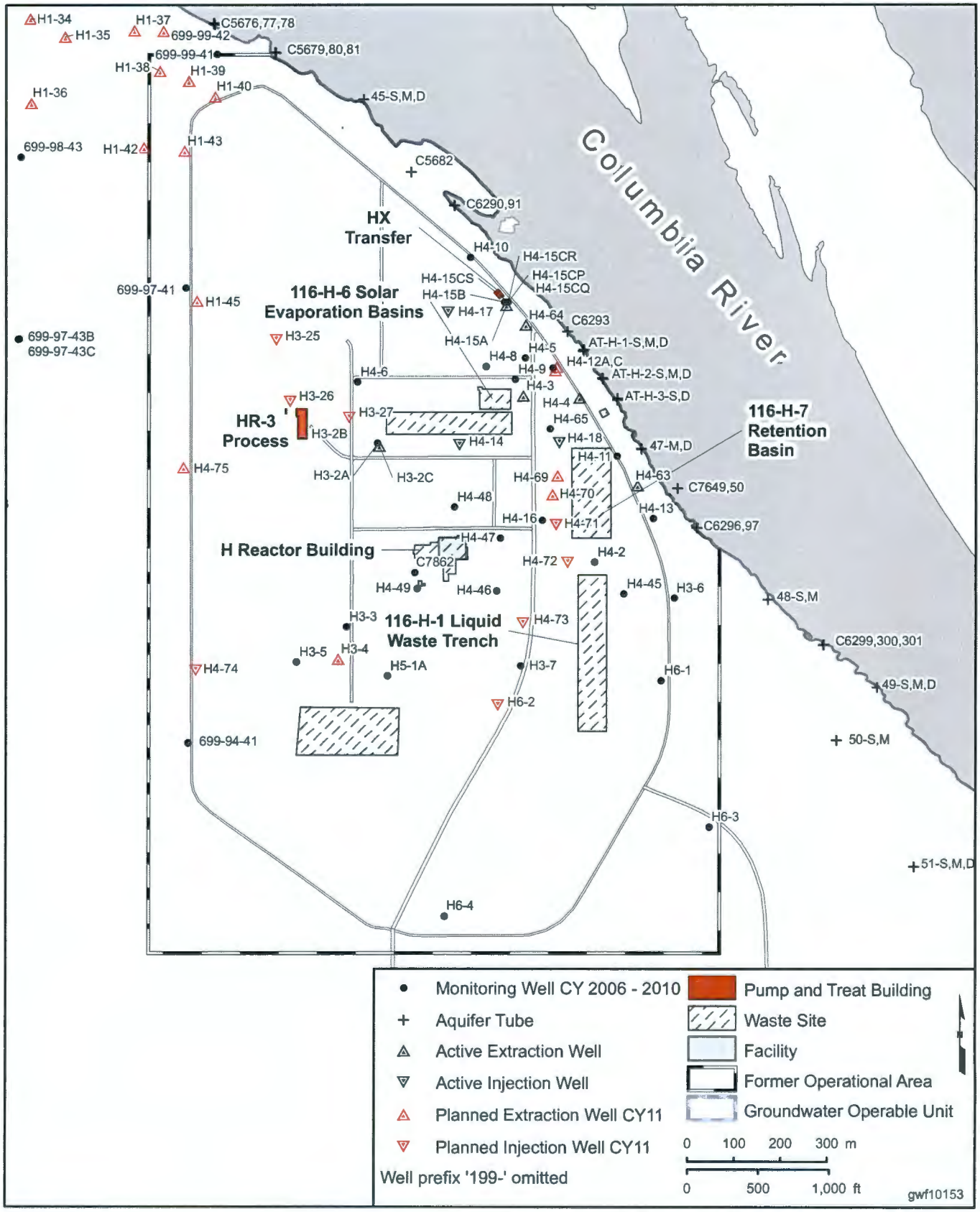


Figure 7-3. Facilities, Wells, and Shoreline Monitoring Sites within the Horn Area of the 100-HR-3 Operable Unit

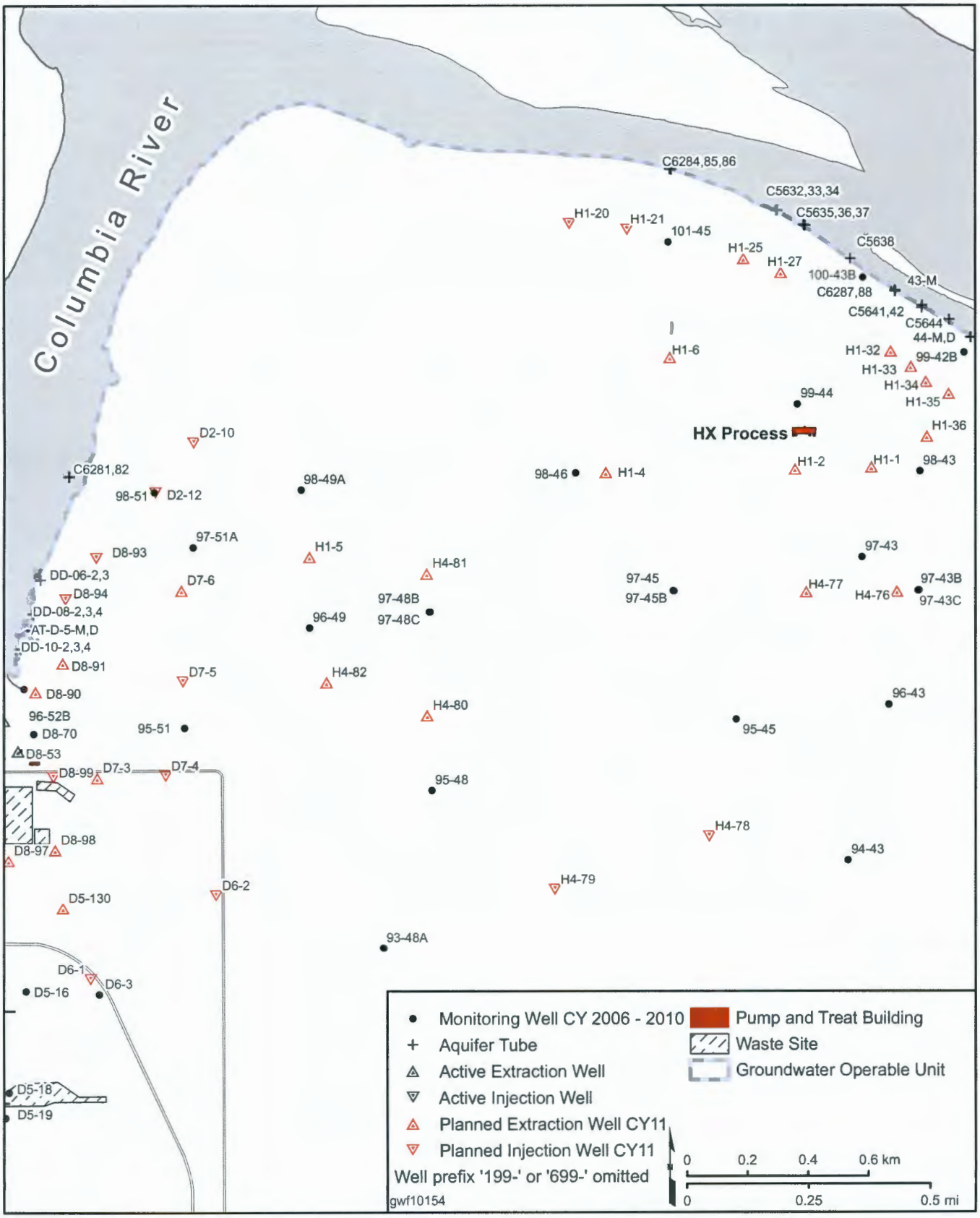


Figure 7-4. Conceptual Cross Section of the 100-D and 100-H Areas

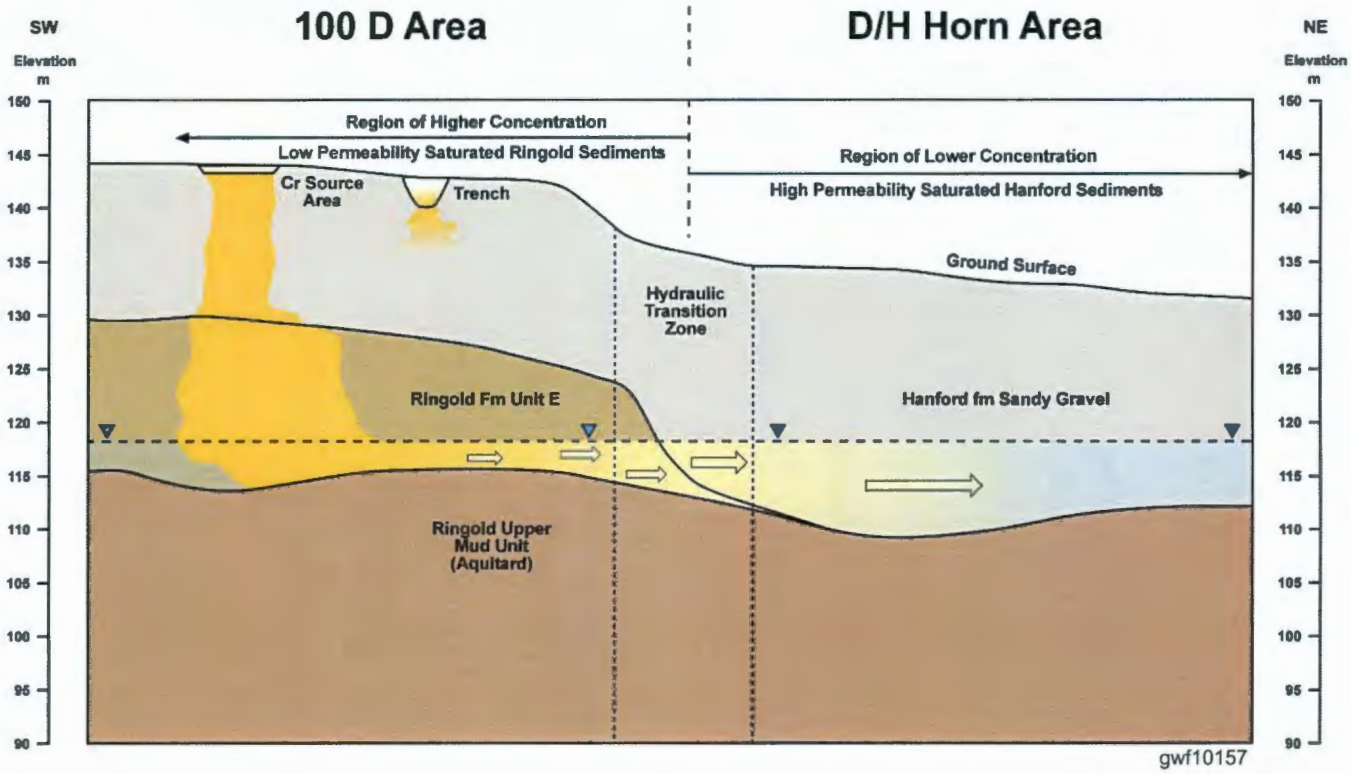
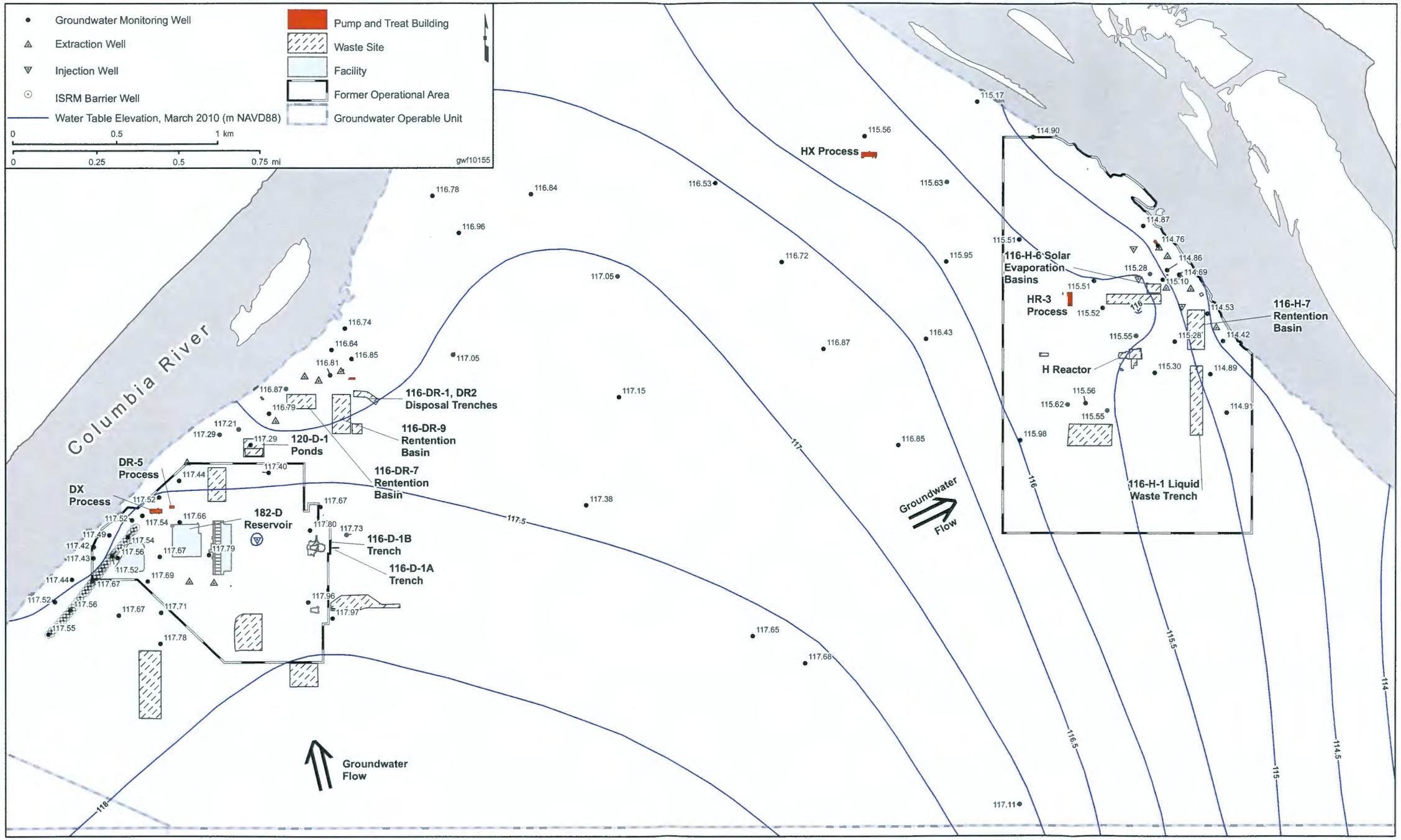
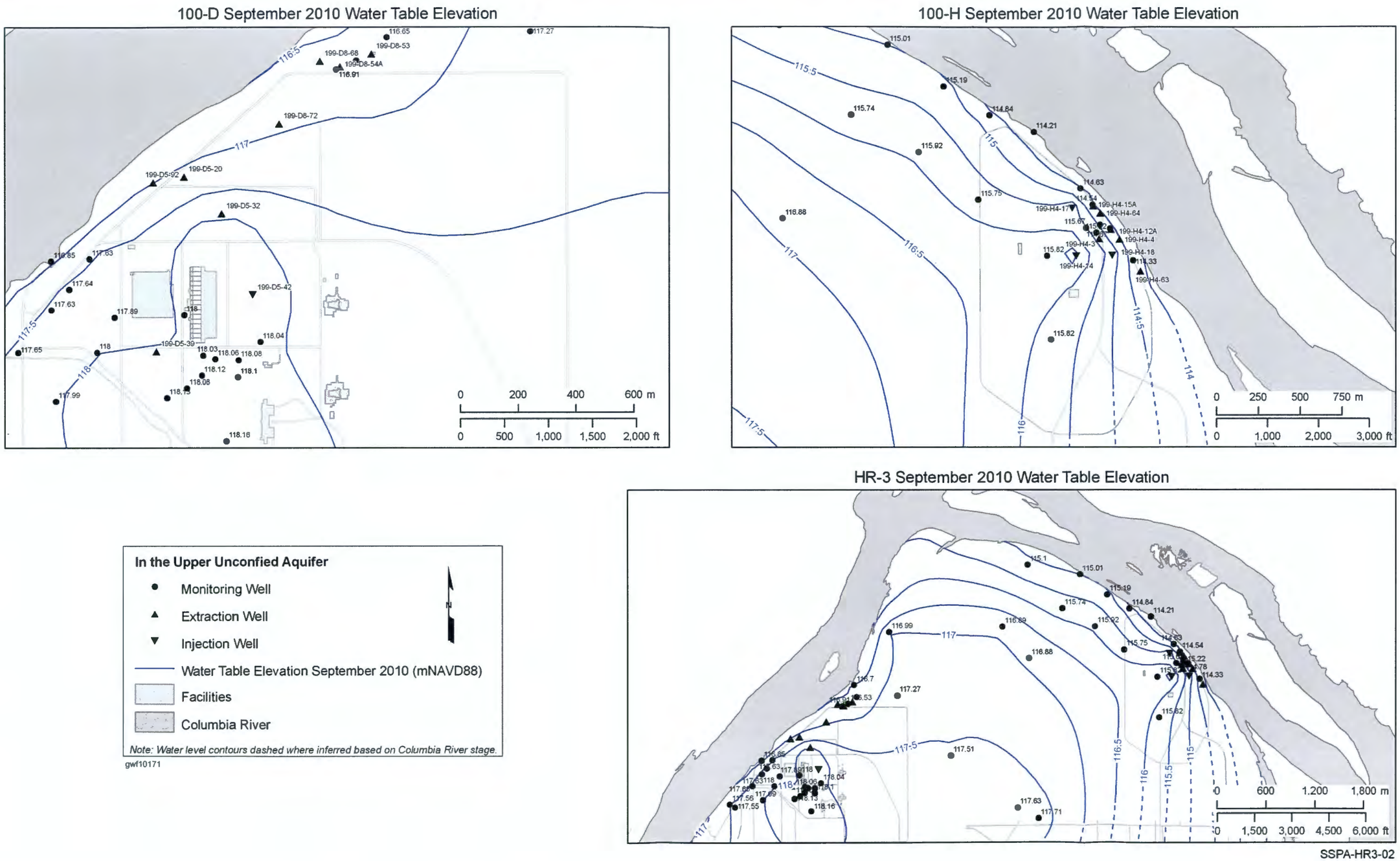


Figure 7-5. 100-HR-3 Operable Unit Water Table Elevation Map, March 2010



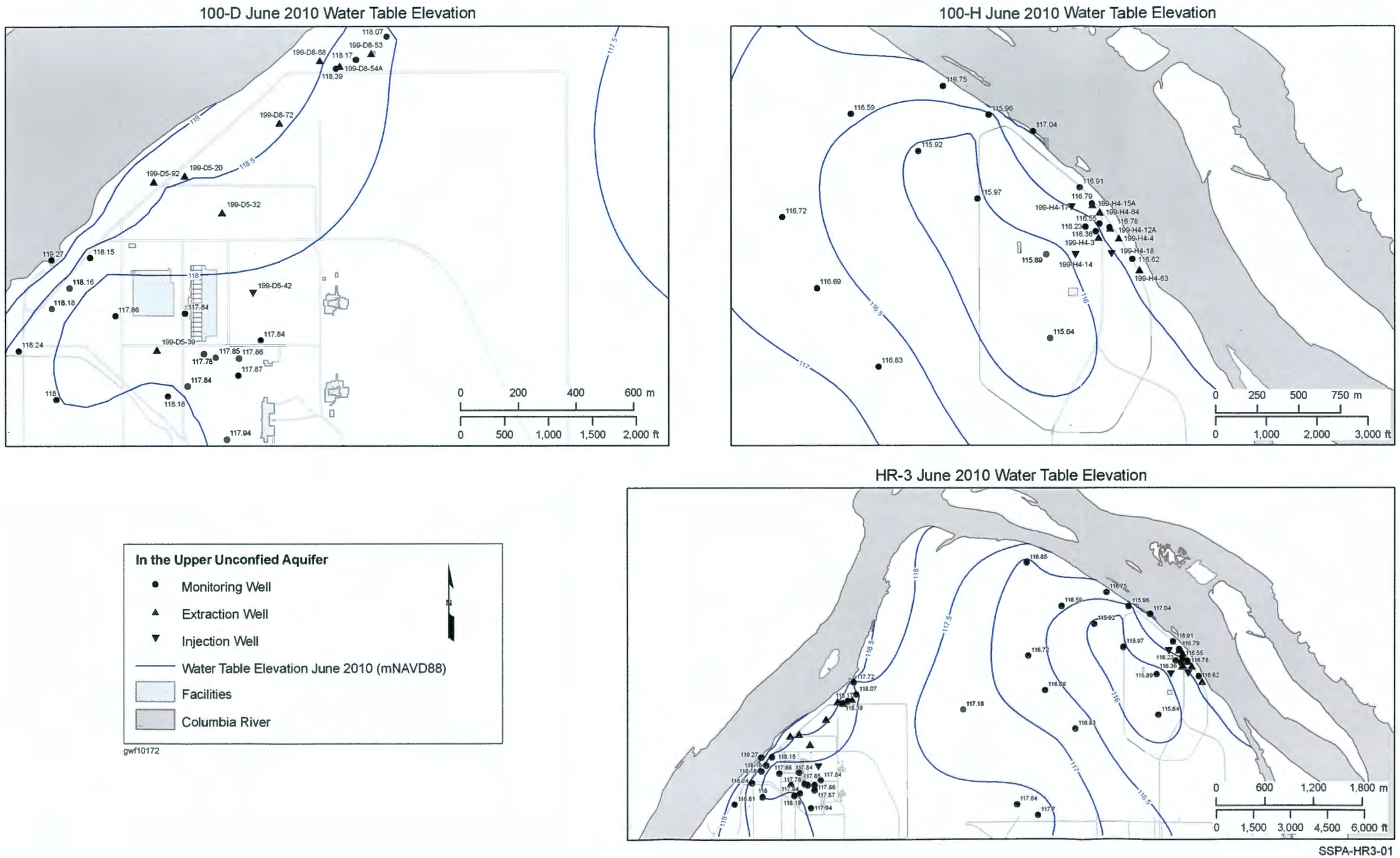
This page intentionally left blank.

Figure 7-6. 100-HR-3 Operable Unit Water Table Elevation Map, September 2010



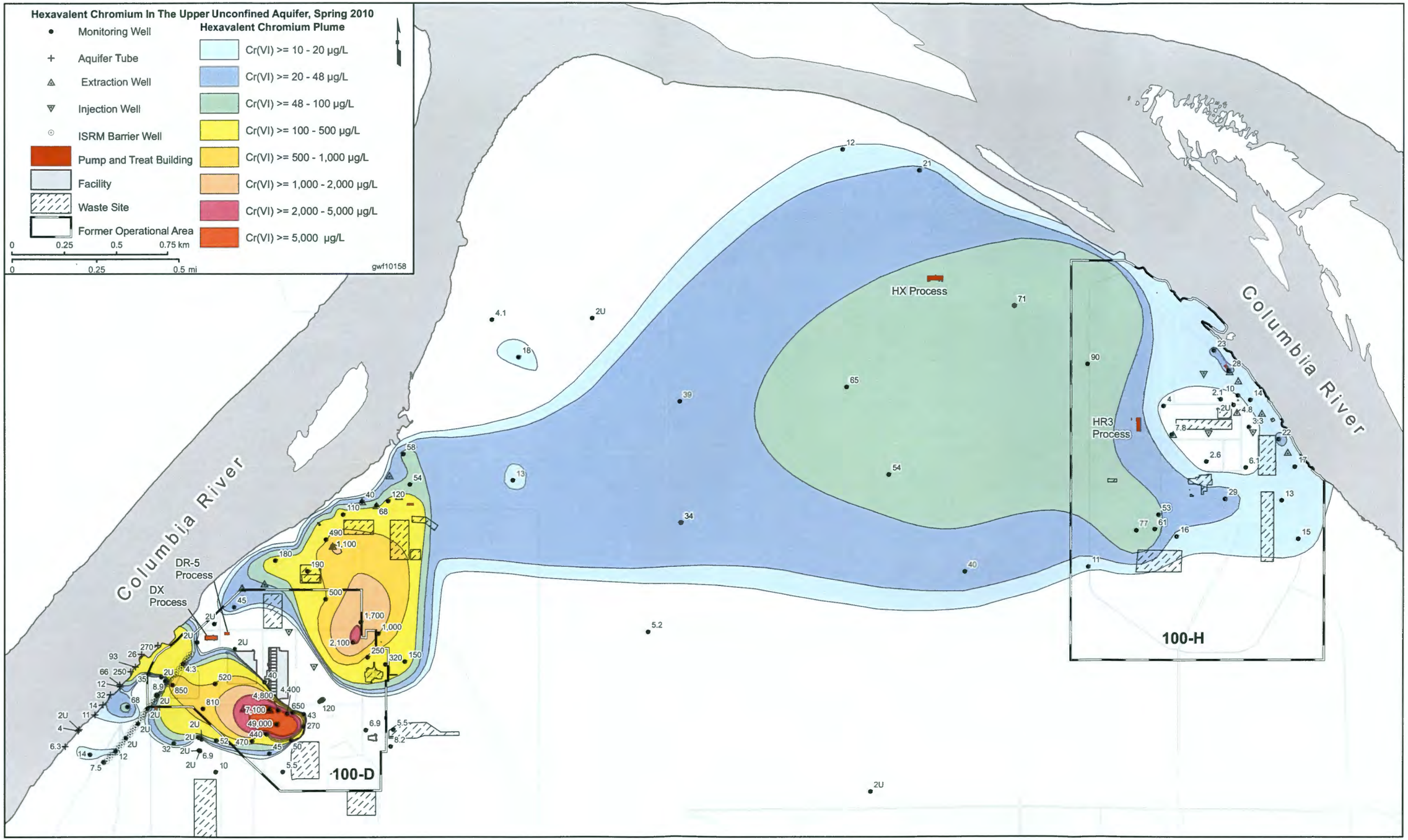
This page intentionally left blank.

Figure 7-7. 100-HR-3 Operable Unit Water Table Elevation Map, June 2010



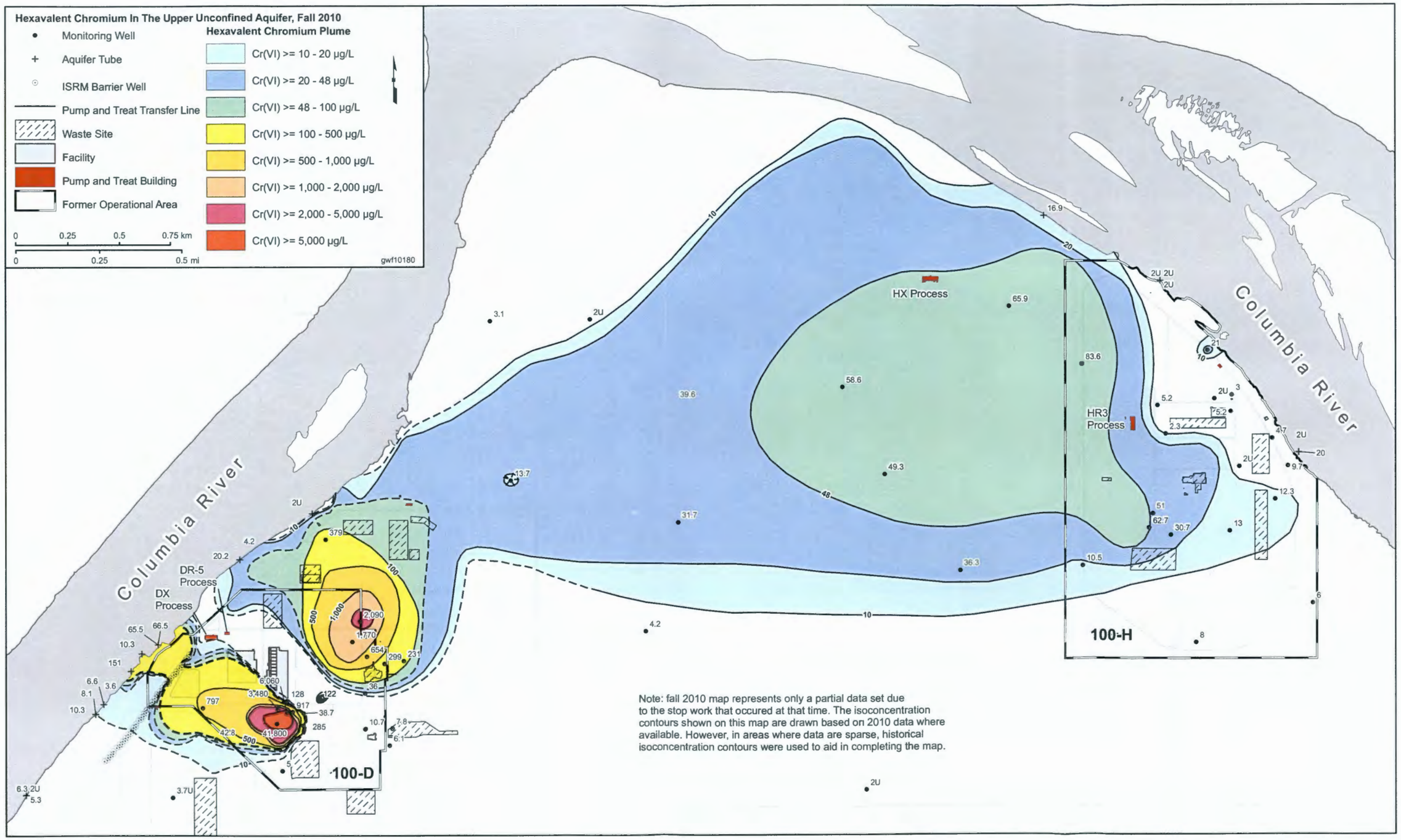
This page intentionally left blank.

Figure 7-8. 100-HR-3 Operable Unit Hexavalent Chromium Map, Spring 2010



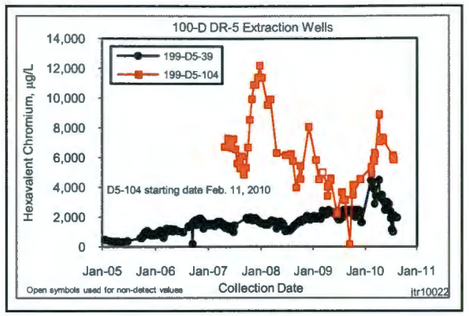
This page intentionally left blank.

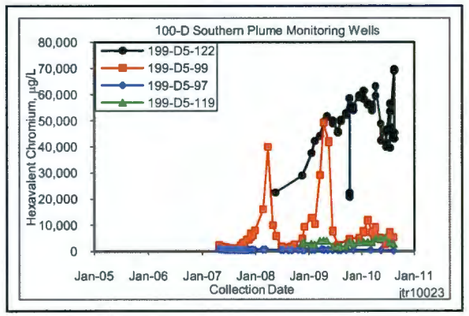
Figure 7-9. 100-HR-3 Operable Unit Hexavalent Chromium Map, Fall 2010

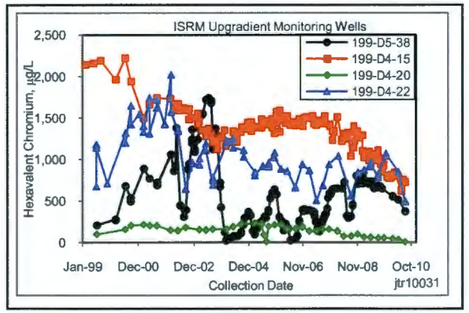


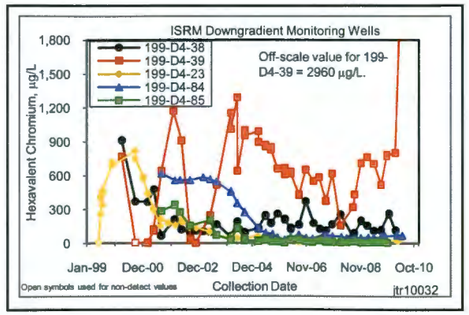
This page intentionally left blank.

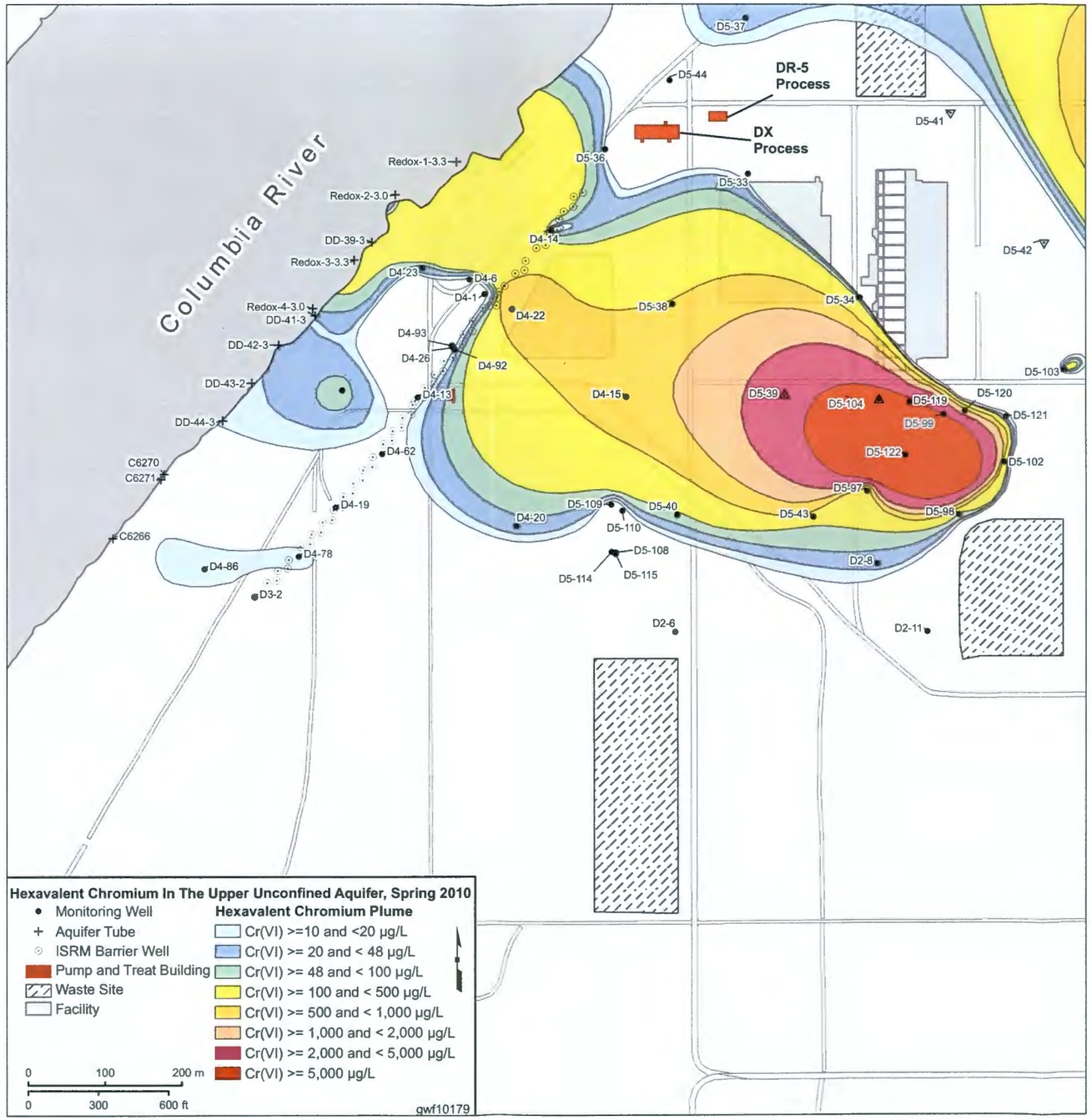
Figure 7-10. 100-D Area Hexavalent Chromium Trend Plots (South Plume)

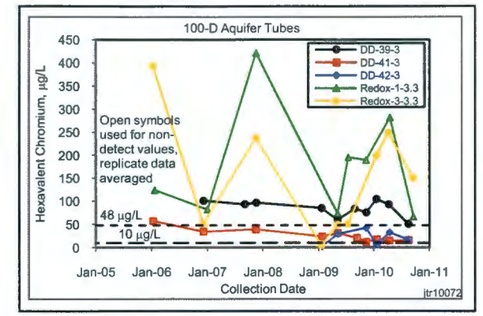






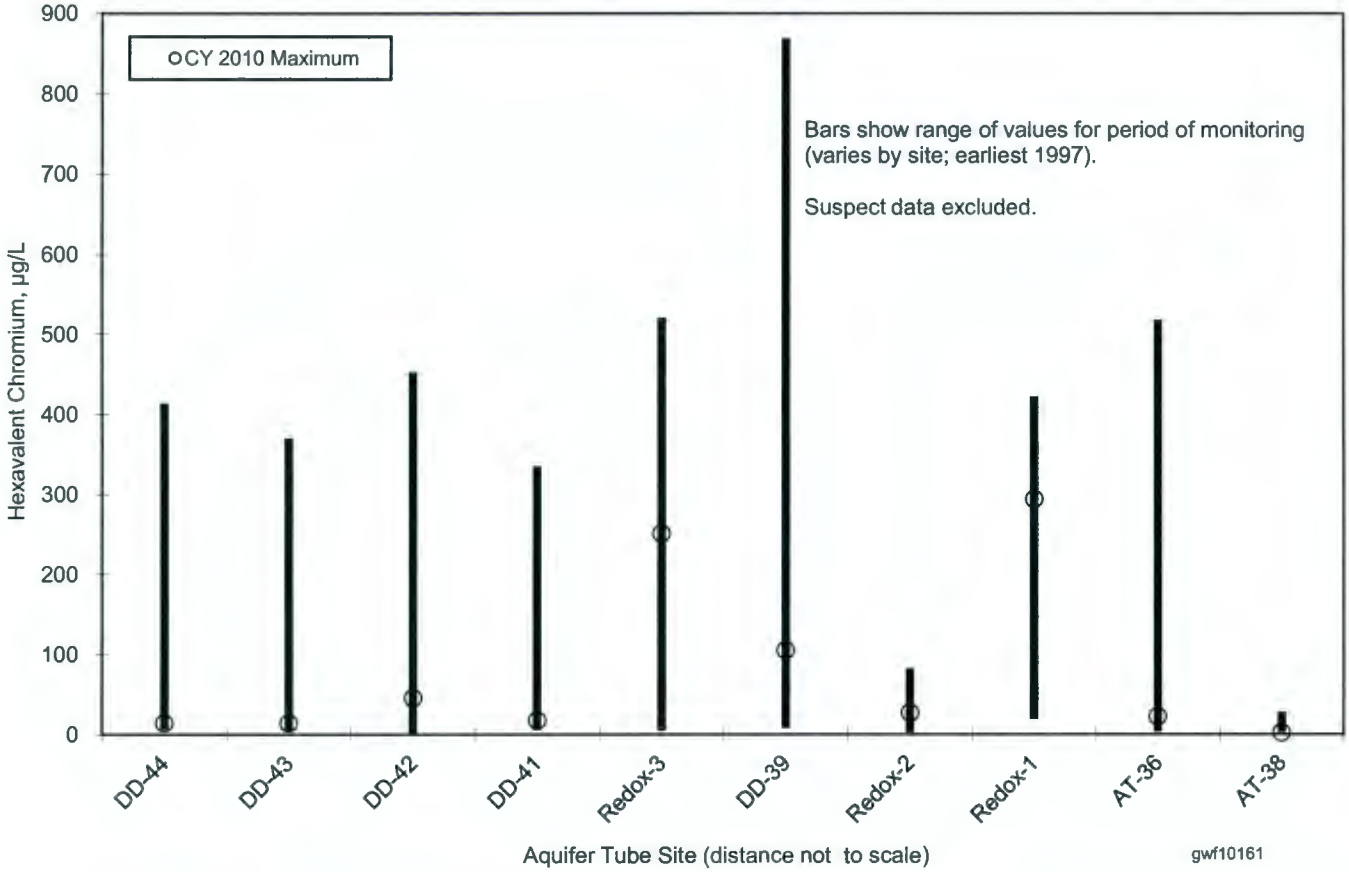






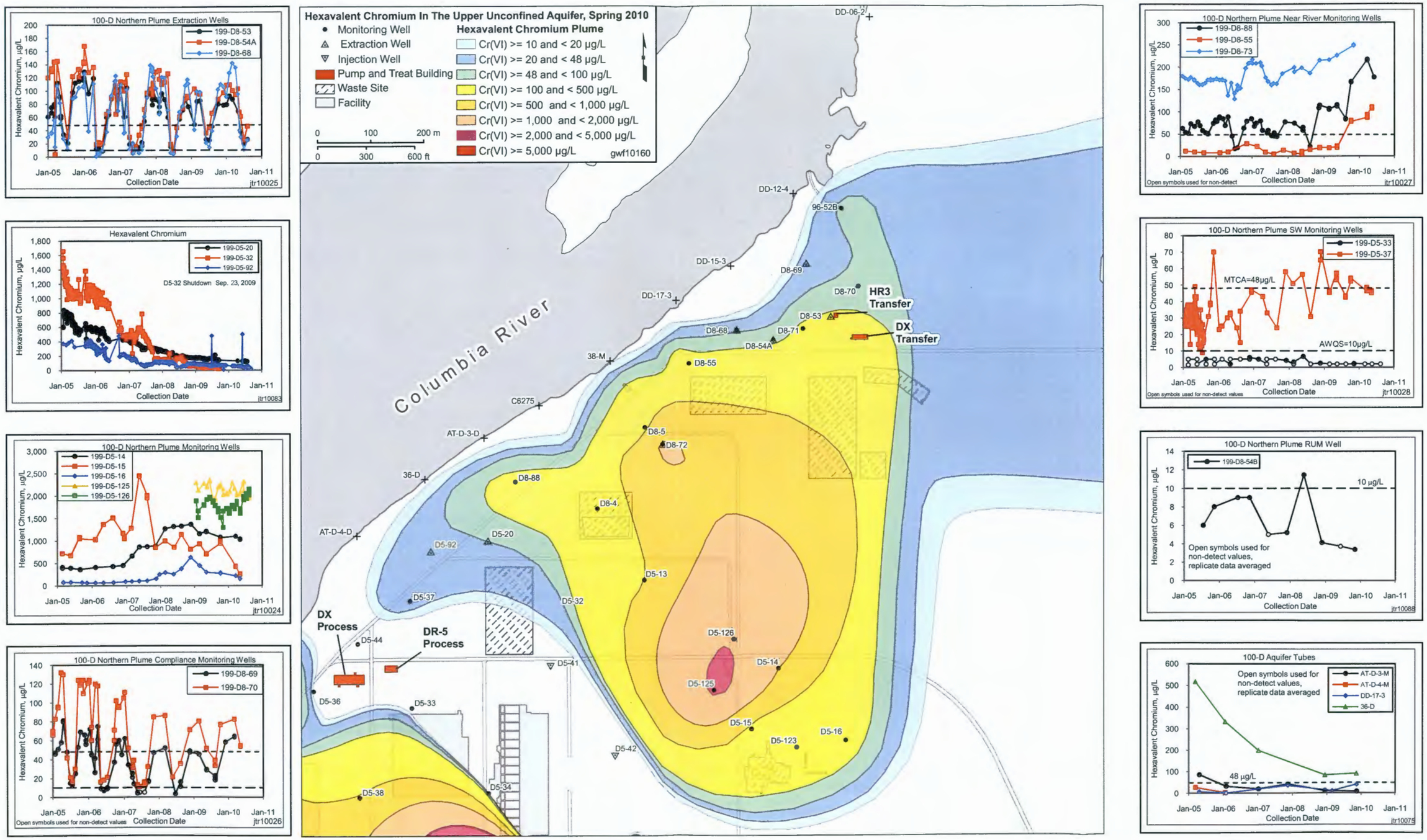
This page intentionally left blank.

Figure 7-11. 100-D Area Aquifer Tubes



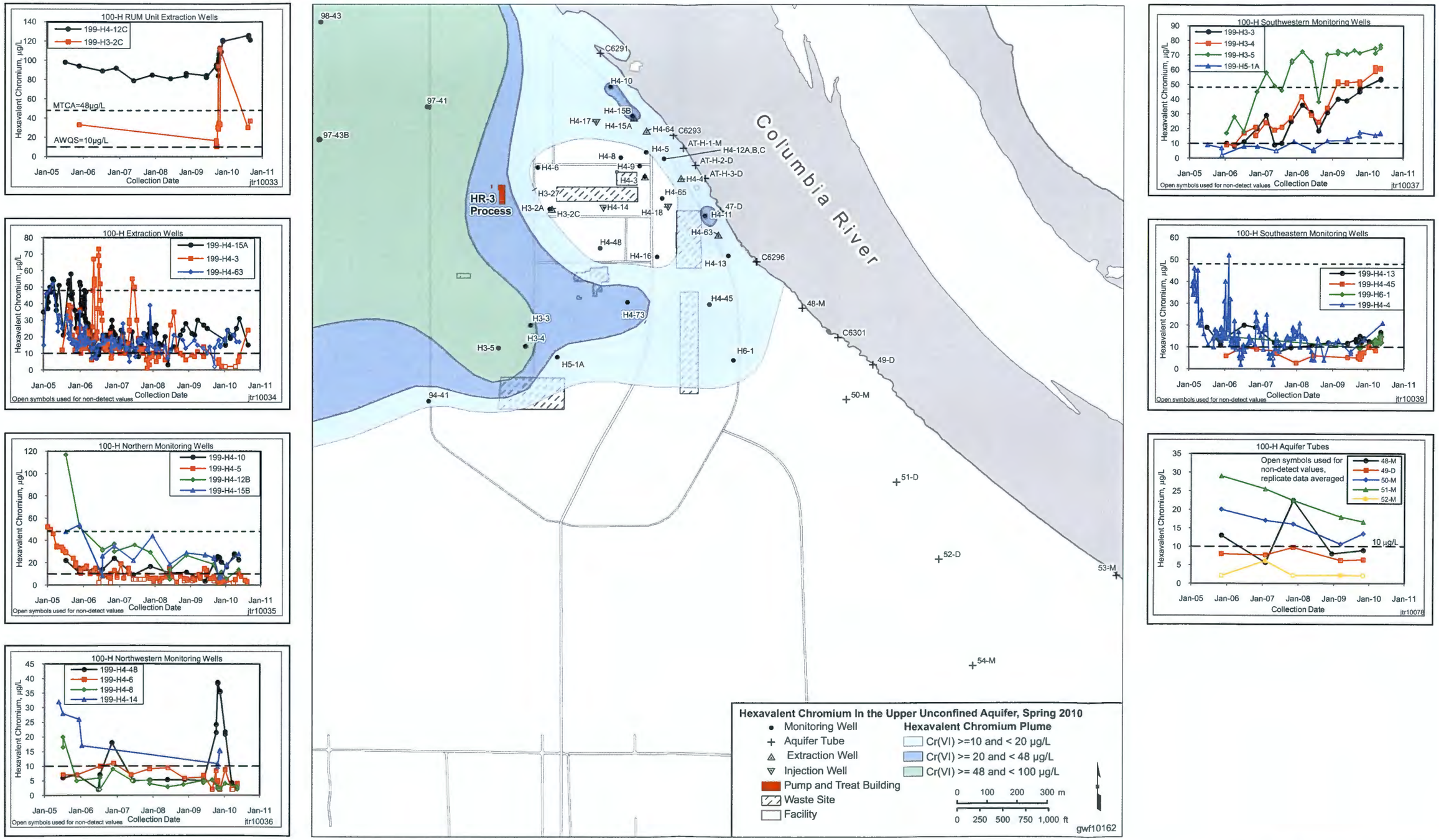
This page intentionally left blank.

Figure 7-12. 100-D Area Hexavalent Chromium Trend Plots (North Plume)



This page intentionally left blank.

Figure 7-13. 100-H Area Hexavalent Chromium Trend Plots



This page intentionally left blank.

Figure 7-14. 100-D Area Nitrate Map, Spring 2010

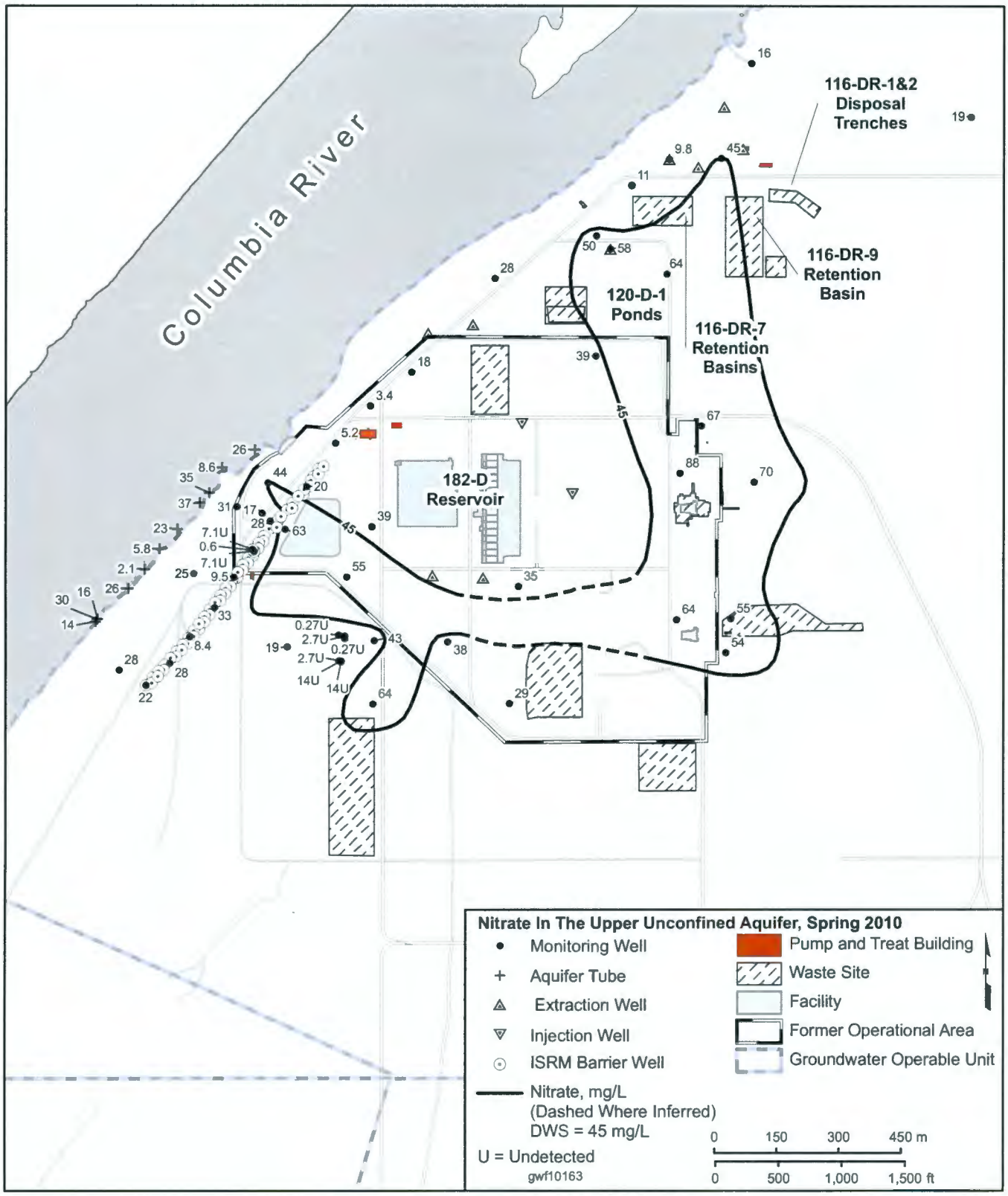


Figure 7-15. Injection/Extraction Well Locations in the 100-D Area

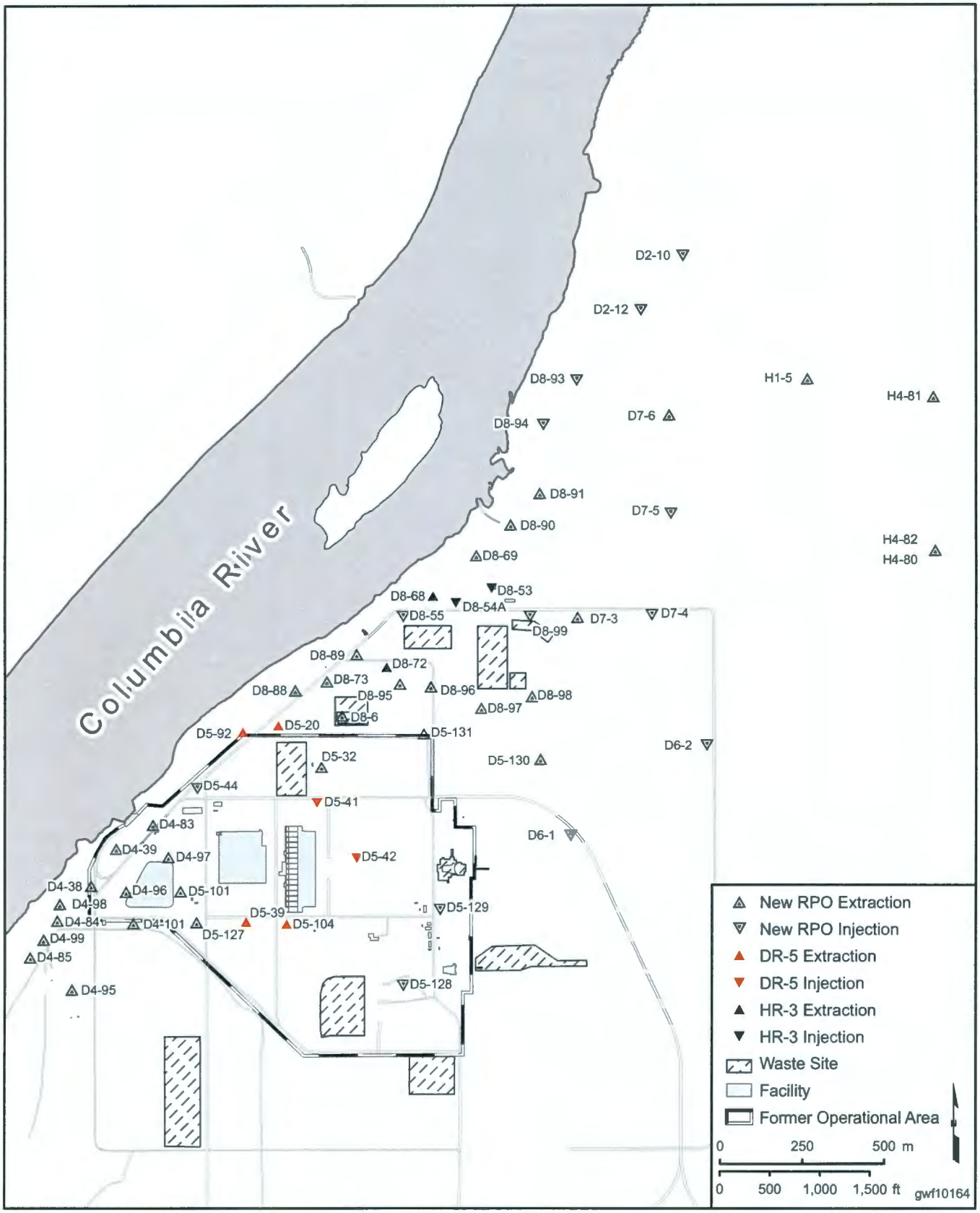


Figure 7-16. Injection/Extraction Well Locations in the 100-H Area

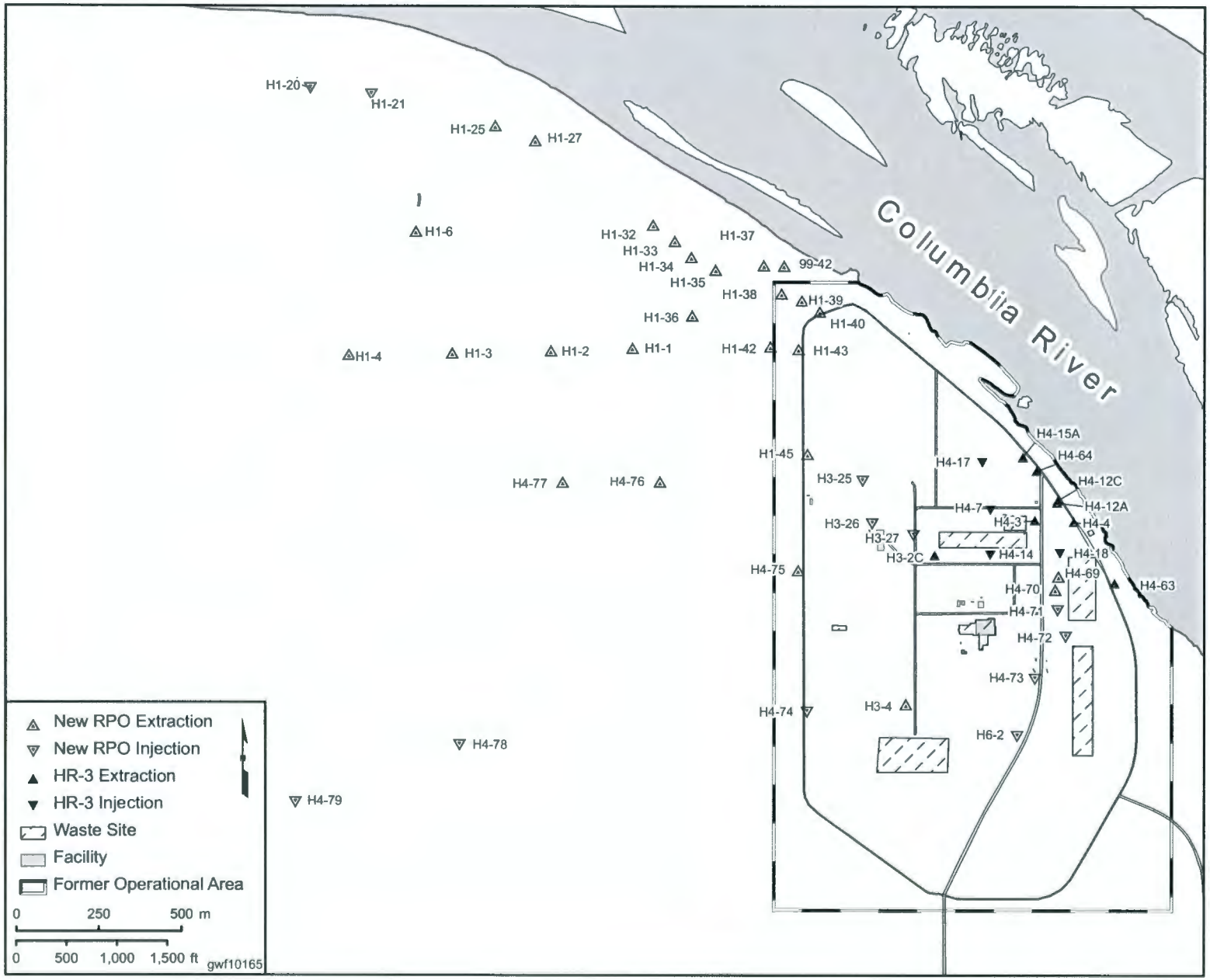


Figure 7-17. HR-3 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010

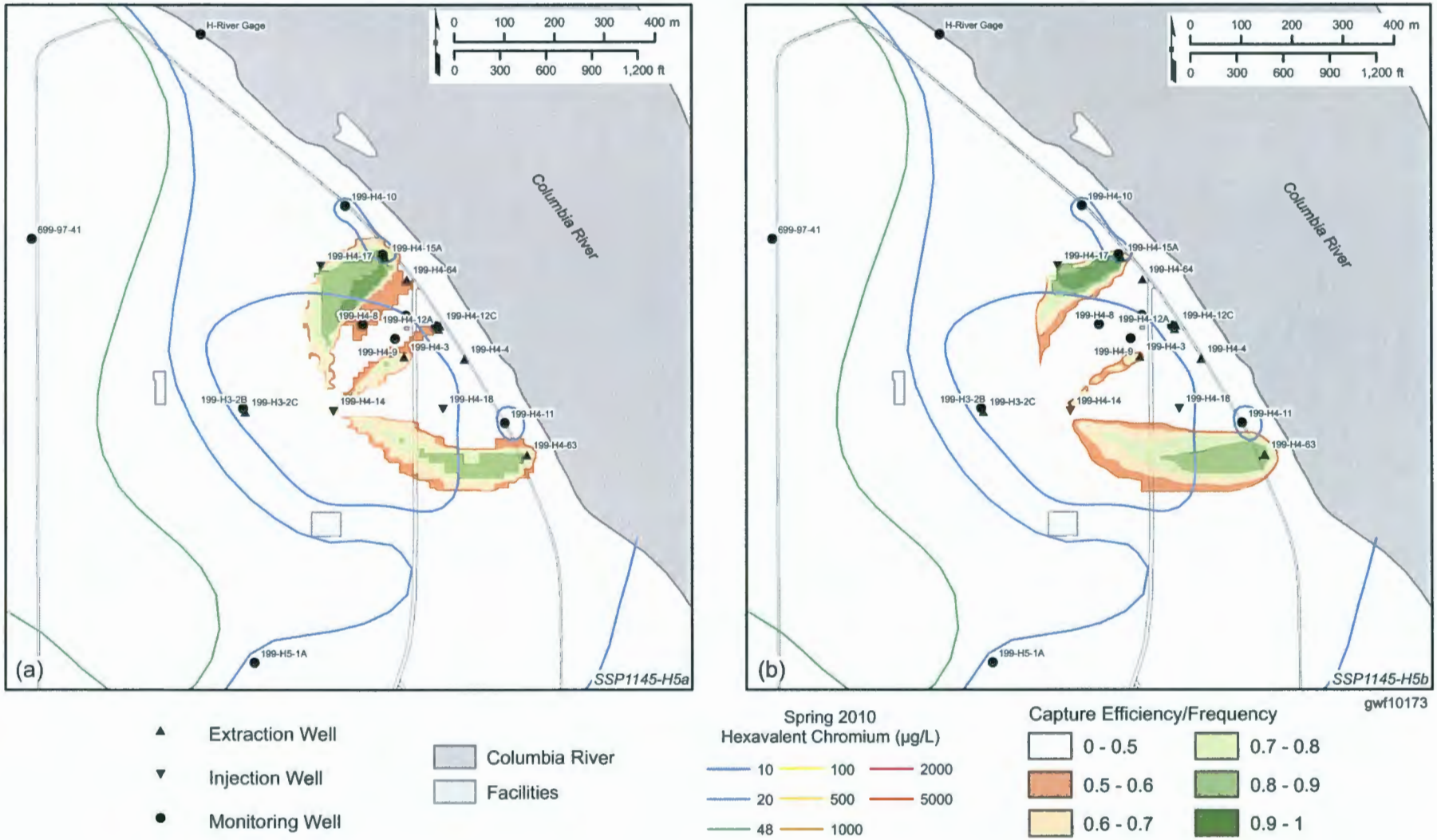


Figure 7-18. DR-5 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010

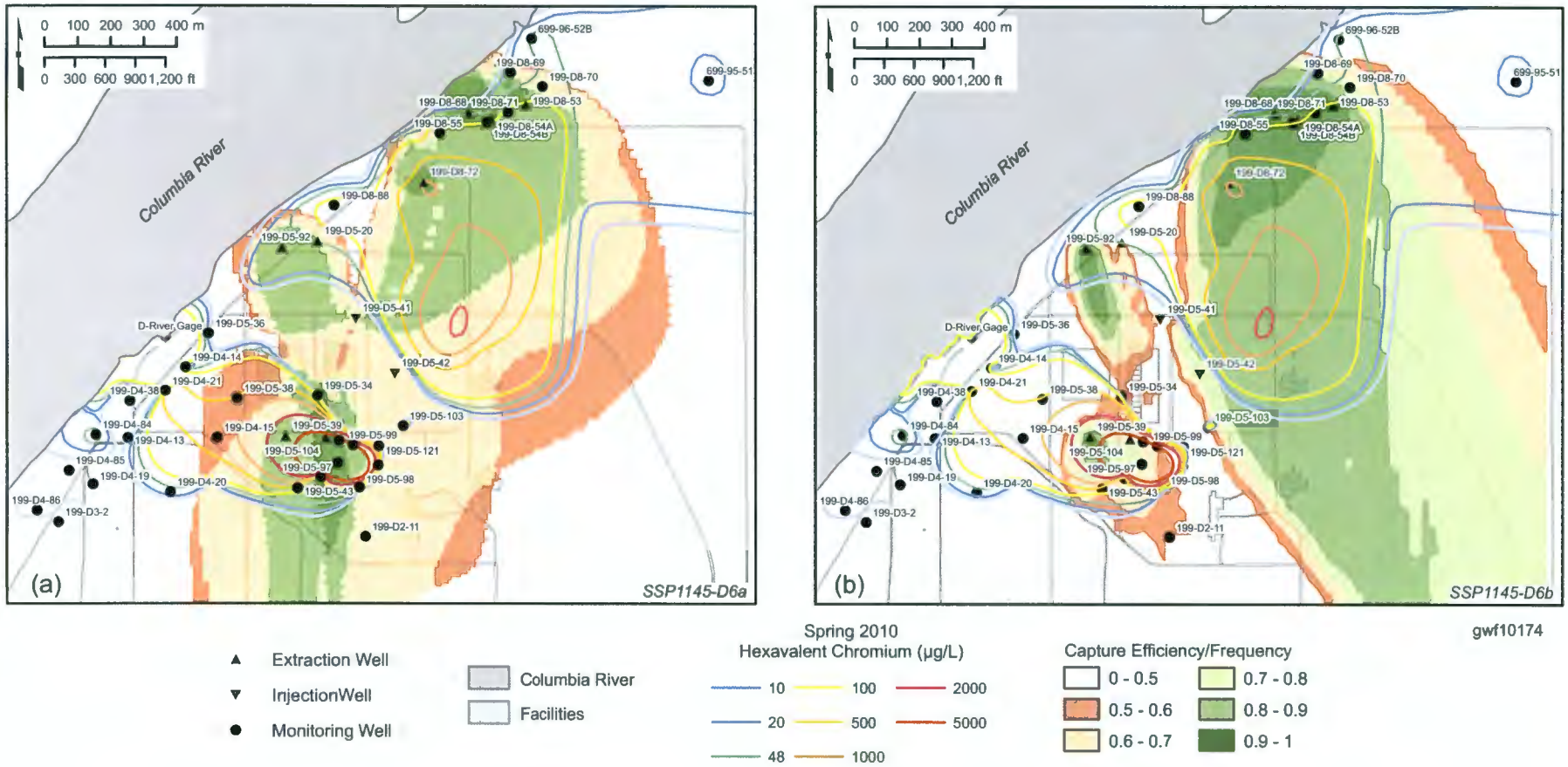


Figure 7-19. In Situ Redox Manipulation Detail Map

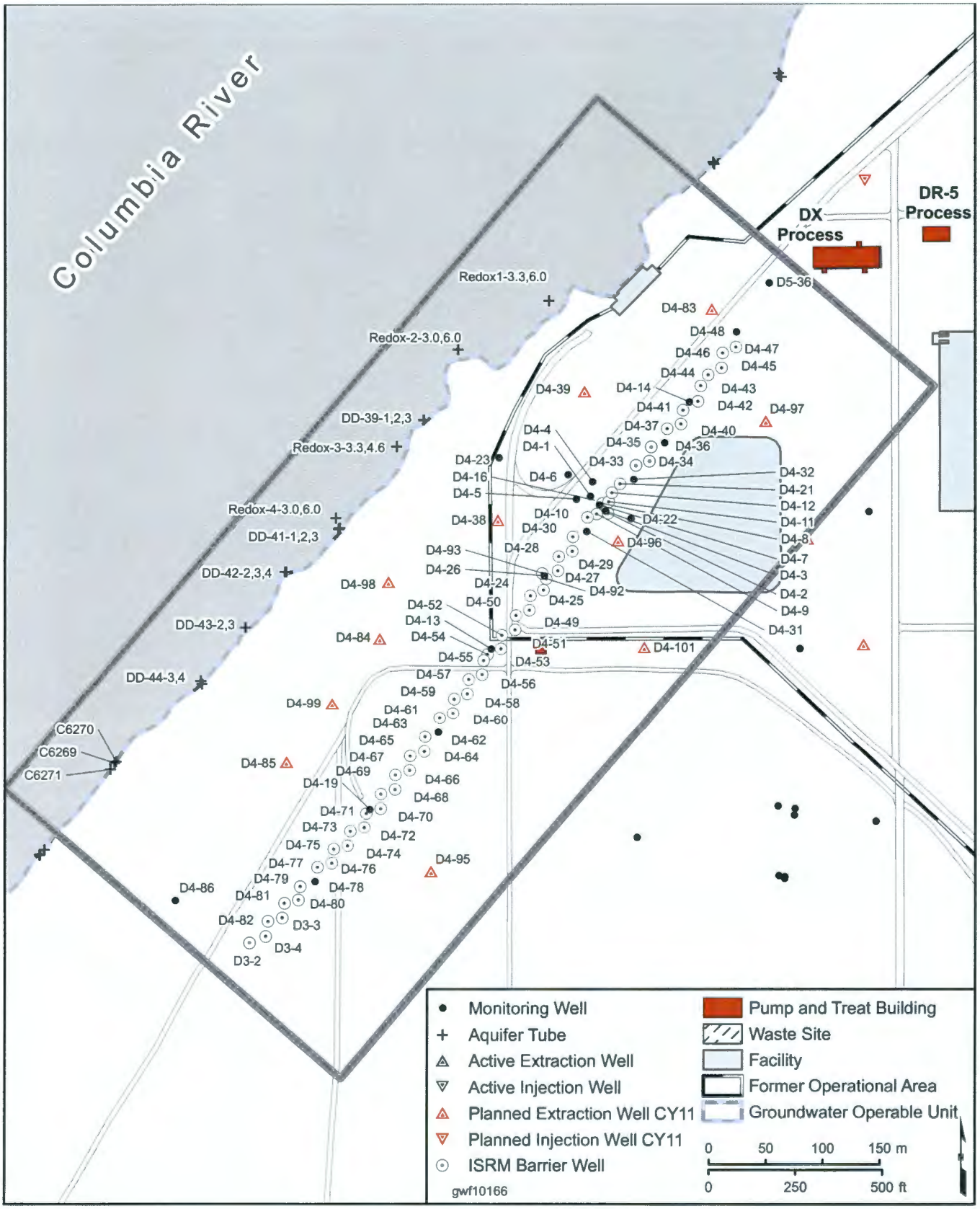


Figure 7-20. In Situ Redox Manipulation Map

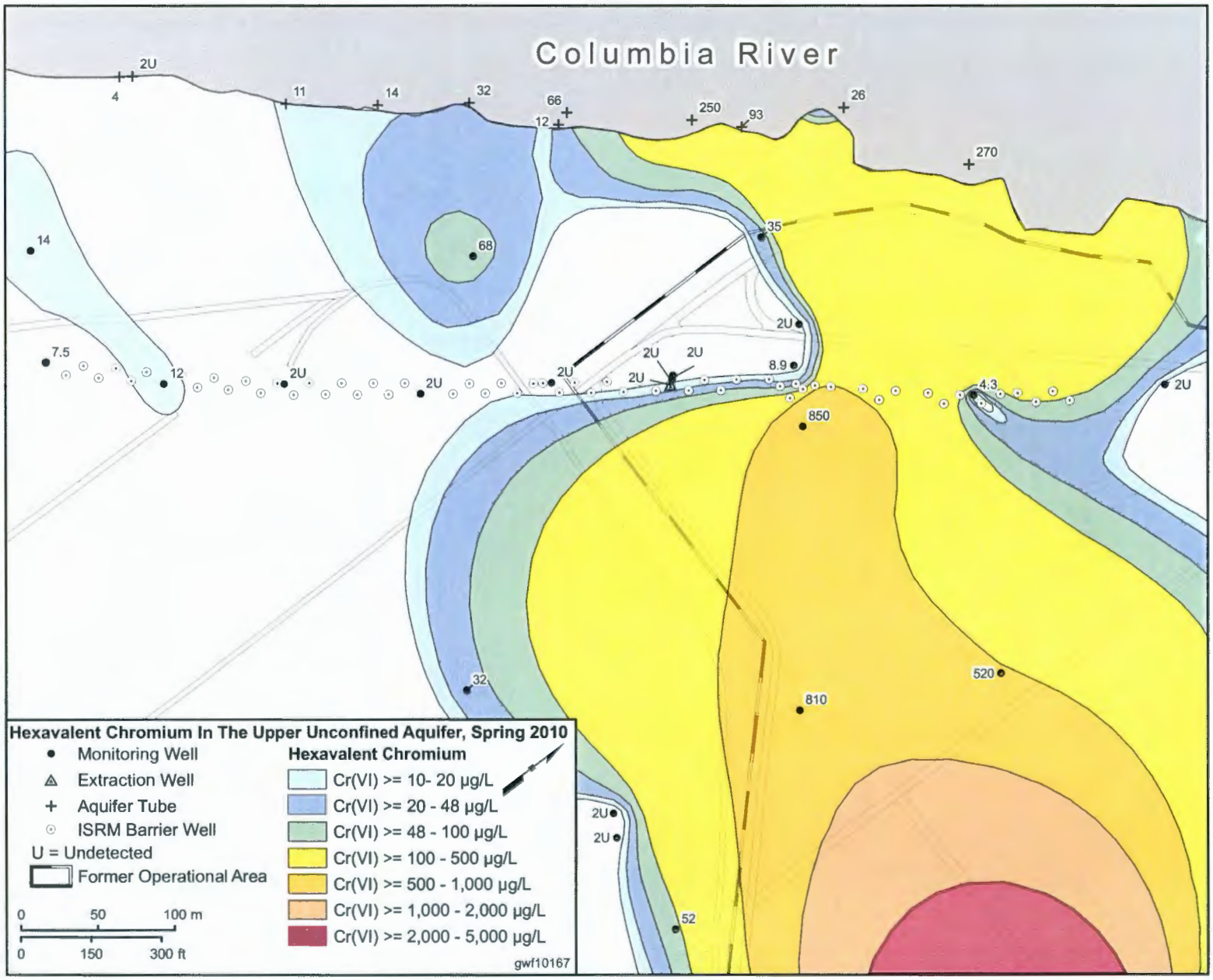
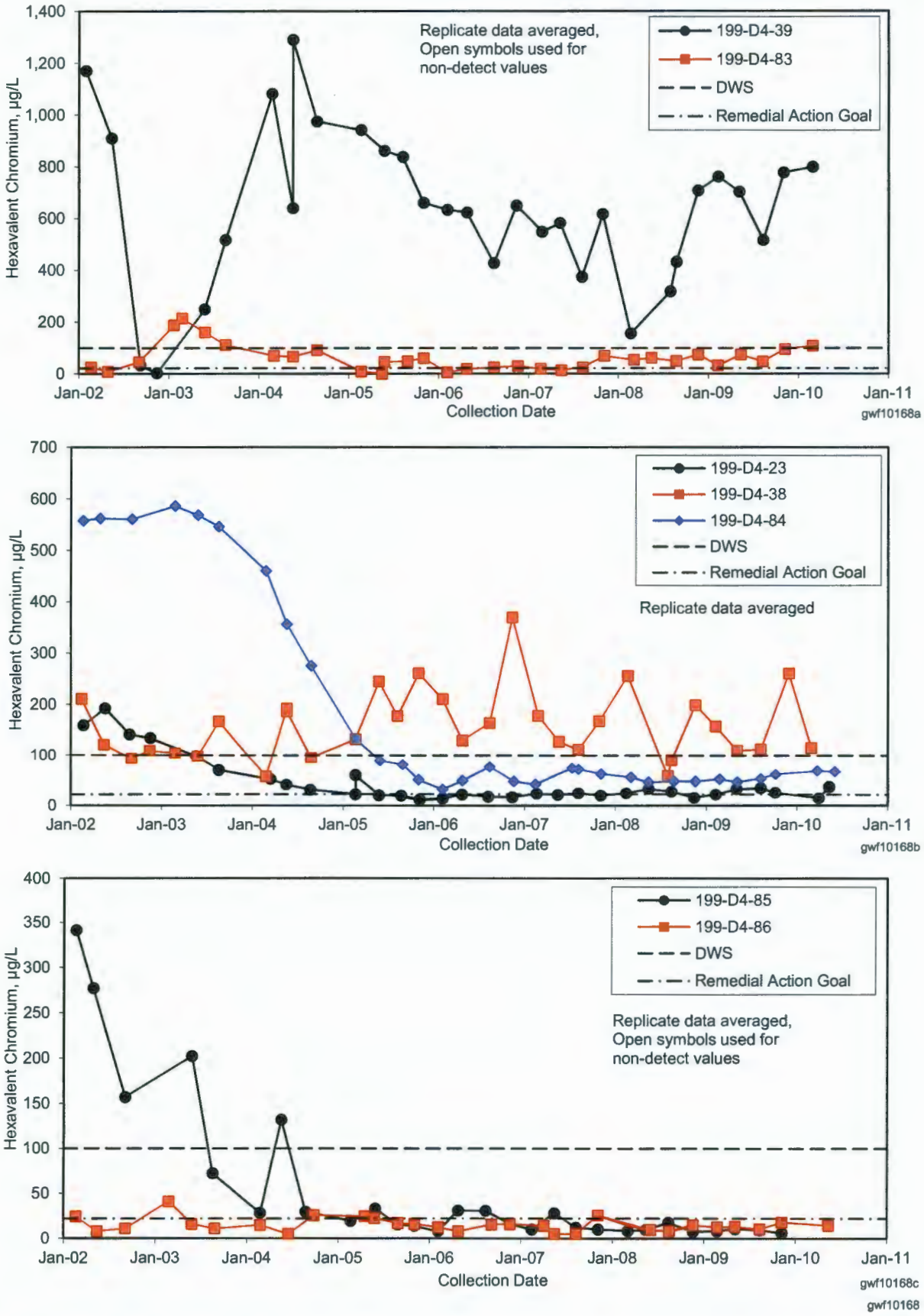


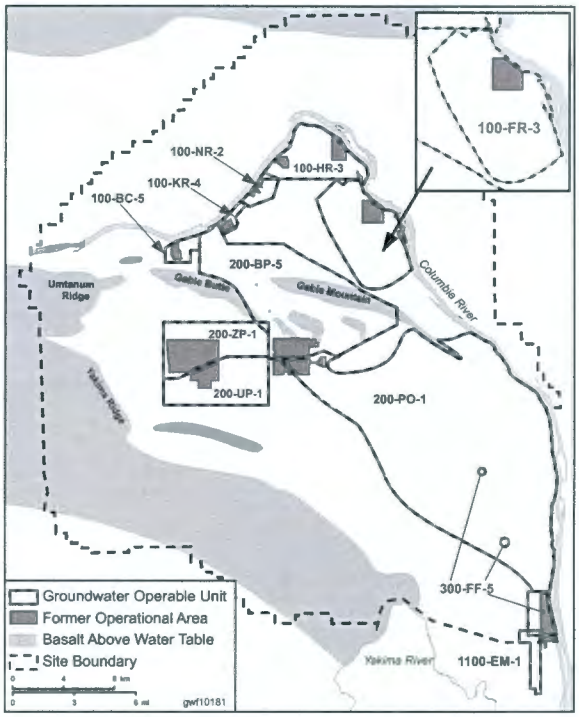
Figure 7-21. Chromium Trend Plots for Compliance Wells



8.0 100-FR-3 Operable Unit

M.J. Hartman

This chapter describes the groundwater flow and contaminant distribution in the 100-FR-3 Operable Unit (OU), which includes the 100-F Area. Figure 8-1 shows the facilities, wells, and shoreline monitoring sites in the 100-F Area.



Groundwater monitoring under the *Atomic Energy Act of 1954* is fully integrated with *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring. Most of the former liquid waste sites in the 100-F Area have been excavated and backfilled. No active waste disposal facilities or *Resource Conservation and Recovery Act of 1976* sites are located in the 100-F Area. Previous assessments have not resulted in any interim remedial measures for groundwater. The area is undergoing a CERCLA remedial investigation (RI) that will provide data to support final cleanup decisions.

Some of the main concepts associated with the 100-FR-3 OU include the following.

- The primary sources of contamination were the structures and processes associated with the operation of F Reactor from 1945 to 1965.
- Processes associated with reactor operations generated large quantities of liquid and solid waste. During operations, effluents were released directly to temporary surface impoundments, cribs, ditches, and the Columbia River. Solid waste was placed in unlined burial grounds.
- Numerous facilities and systems, used until 1976, were established for biological experiments at the 100-F Area. These activities generated large quantities of contaminated animal and plant waste (both solid and liquid).
- Over the past decade, the U.S. Department of Energy (DOE) has remediated these waste sites, usually by excavating contaminated soil. Fifteen sites remain to be remediated (DOE/RL-2008-46-ADD4, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*).
- The groundwater system comprises the following hydrostratigraphic units (Figure 8-2):
  - Vadose (unsaturated) zone, which is predominantly Hanford formation gravels; up to 13 meters thick beneath the 100-F Area
  - Unconfined aquifer, consisting of Hanford gravels, 1 to 8 meters thick
  - Uppermost aquitard, which consists of the Ringold Formation upper mud unit (clay and silt)
  - Series of confined and semiconfined aquifers in the Ringold Formation separated by fine-grained, overbank and paleosol deposits
  - Basalt aquitard and basalt-confined aquifers (shallowest is the Rattlesnake Ridge interbed).
- The groundwater is currently contaminated with hexavalent chromium, nitrate, strontium-90, and trichloroethene at levels above aquatic water quality criteria

Of more than 100 waste sites identified in the 100-F Area, only fifteen remain to be remediated.

or drinking water standards (DWSs). However, based on data from near-river wells, aquifer tubes, and river porewater samples, these plumes do not appear to reach the Columbia River at levels above the standards.

Near the Columbia River, the direction of groundwater flow beneath the 100-F Area varies with Columbia River stage. Figure 8-3 shows the water table in March 2010, when the river was at a moderate level. The map indicates a flow direction toward the east-northeast (toward the river) in the northern portion of the 100-F Area and toward the southeast (approximately parallel to the river) in the southern portion. Figure 3-2 in Chapter 3.0 illustrates the regional water table in this area. The shoreline topography in this area is low and flat, and the shore is submerged during high river stage (spring and early summer). During periods of high river stage the groundwater gradient in the 100-F Area can reverse and river water flows into the aquifer in the eastern 100-F Area.

Additional information on 100-F Area history, waste sites, and hydrogeology is provided in DOE/RL-2008-46-ADD4.

8.1 Groundwater Contaminants

This section summarizes the distribution of groundwater contamination in the 100-FR-3 OU. Routine monitoring requirements are described in the *100-FR-3 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-49). Under this plan, wells are sampled for the contaminants of concern selected using the data quality objectives process (PNNL-14287, *Data Quality Objectives Summary Report -- Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units*) (Appendix A, Table A-10). The contaminants of concern for routine monitoring are nitrate, strontium-90, tritium, trichloroethene, uranium, gross alpha, and hexavalent chromium. Most of the wells are sampled once per year or once every other year.

Plume areas (square kilometers) in the 100-FR-3 Operable Unit:
Chromium, 20 µg/L — 0.09
Nitrate, 45 mg/L — 12.70
Strontium-90, 8 pCi/L — 0.12
Trichloroethene, 5 µg/L — 0.68

Additional monitoring requirements were active in 2010, as described by DOE/RL-2008-46-ADD4 and the *Sampling and Analysis Plan for the 100-F/IU-2/IU-6 Decision Unit Remedial Investigation/Feasibility Study* (DOE/RL-2009-43). These documents identify additional contaminants of potential concern (COPCs) to be evaluated during the ongoing RI (Table 8-1). Nineteen wells were sampled three times in 2010 to investigate spatial and temporal variability of the COPCs. Three new monitoring wells were installed in 2010 to support the RI. Data from all of these sources are discussed in this section.

A subset of 100-F Area aquifer sampling tubes is scheduled for annual sampling in the fall. The fall 2010 sampling was delayed until early 2011. Only about half of the tubes were sampled before the rising river submerged the tubes.

8.1.1 Nitrate

A large nitrate plume with concentrations above the DWS extends southward from 100-F Area.

A large nitrate plume extends southward ~5 kilometers from the 100-F Area, although data are limited south of the 100-F Area (Figure 8-4). The plume evidently originated from various sources in the 100-F Area in the past, and moved southward when flow directions were influenced by groundwater mounds from effluent disposal. The plume did not change significantly between 2009 and 2010.

In 2010, wells in the main 100-F Area continued to show levels of nitrate exceeding the DWS (45 mg/L). The highest concentration in a routine sample was 133 mg/L in well 199-F5-4, located in the central 100-F Area. Concentrations have

increased in this well since 2007 (Figure 8-5). However, concentrations in other wells (e.g., well 199-F7-3) are generally steady or declining. Characterization samples collected during drilling of new well 199-F5-54 had a maximum nitrate concentration of 152 mg/L at the top of the aquifer. The concentration declined to 63 mg/L at the bottom of the aquifer, 7.7 meters below the water table.

Aquifer tubes were not sampled in 2010. Nitrate concentrations have occasionally exceeded the DWS in tube 75-D, approximately 2 kilometers south of the 100-F Area.

8.1.2 Strontium-90

A strontium-90 plume with concentrations above the 8 pCi/L DWS is present in the eastern 100-F Area (Figure 8-6). In 2010 (as in 2009), strontium-90 concentrations exceeded the DWS in only one well, 199-F5-1, located near the 116-F-2 Trench. Concentrations are declining in this well (Figure 8-7). A few other wells had detectable strontium-90, but the concentrations were below the DWS. Data from aquifer tubes and porewater samples indicate that the plume does not reach the Columbia River at concentrations above the DWS.

Strontium-90 concentrations exceed the DWS in one 100-F Area well.

Strontium-90 is detected intermittently at concentrations below the DWS in a well in the southwestern 100-F Area. Well 199-F8-7 was installed adjacent to the 118-F-6 Burial Ground in fiscal year 2008 because a grab sample of groundwater during waste site excavation contained strontium-90 at a concentration of hundreds of picocuries per liter. This grab sample was thought to be unrepresentative of groundwater conditions because it was potentially affected by surface contamination from the waste site. During 2010, strontium-90 concentrations in well 199-F8-7 ranged from below detection limits to 4.2 pCi/L.

Strontium-90 shows vertical stratification in the only shallow/deep well pair in the 100-F Area. Deep well 199-F5-43B, which monitors a water-producing zone in the Ringold Formation upper mud unit, consistently has no detectable strontium-90. Its shallow counterpart screened in the unconfined aquifer, well 199-F5-43A, has typically had strontium-90 detections of 2 to 4 pCi/L. In 2010, strontium-90 was detected in one of three samples from well 199-F5-43A. The deeper well was not sampled during 2010.

Characterization samples from three new wells drilled during 2010 were analyzed for strontium-90. A single sample from well 199-F5-53 detected strontium-90 at 1.16 (±0.45) pCi/L near the top of the aquifer. A sample from the same depth, analyzed by a different laboratory, did not have detectable strontium-90 (the result was reported as -4.6 [±3.1] pCi/L). Strontium-90 was not detected in water samples from the other new wells.

The 100-F Area aquifer tubes were not sampled in 2010. Previous results indicated concentrations below the DWS.

8.1.3 Chromium

Hexavalent chromium is of potential concern to salmon and other aquatic life. The aquatic water quality criterion for hexavalent chromium is 10 µg/L. Figure 8-8 illustrates the chromium concentrations in the unconfined aquifer in fall 2010. Only two wells had concentrations above 20 µg/L, and several other wells had concentrations above 10 µg/L. The concentration increased briefly in well 199-F5-46 in May, to a maximum of 92.9 µg/L (Figure 8-9); this well has had variable chromium concentrations in the past. The plume continues to decrease in size (comparing Figure 8-8 to Figure 2.7-8 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*; and Figure 17-9 in DOE/RL-2010-11, *Hanford Site Groundwater*

Hexavalent chromium concentrations in groundwater exceed the aquatic water quality criterion, but concentrations entering the river are lower.

Monitoring and Performance Report for 2009: Volumes 1 & 2). Data from aquifer tubes and Columbia River porewater samples indicate that concentrations of hexavalent chromium entering the river are below the aquatic standard.

The 100-F Area aquifer tubes were not sampled in 2010. The only aquifer tubes with concentrations above 10 µg/L in 2009 were in tube C6303 (a deep tube near the known groundwater plume) at 14.7 µg/L and tube 75-D (~2 kilometers downstream) at 11.3 µg/L. A shallow tube adjacent to tube C6303 had concentrations below 10 µg/L. No known hexavalent chromium sources exist near aquifer tube 75-D, so it is likely that the contamination moved southward from the 100-F Area.

Columbia River porewater samples were collected near the 100-F Area in 2009 and early 2010. The 2009 results were summarized in last year's annual report (single detection of hexavalent chromium at 8 µg/L) (Section 17.3 in DOE/RL-2010-11). During a later phase of the study in early 2010, hexavalent chromium was detected at the same location at 20 µg/L, but the result had a data validation qualifier of "J," indicating that it was an estimate. Total chromium of the sample was lower (9.18 and 4.01 µg/L in unfiltered and filtered samples, respectively). Staff collected additional porewater samples in February 2011, and all results were less than 3 µg/L. An upcoming report will provide additional information.

8.1.4 Trichloroethene

Trichloroethene concentrations in the unconfined aquifer underlying southwestern 100-F Area exceed the DWS (5 µg/L) but are declining overall. The plume appears to have originated west of the 100-F Area (Figure 8-10). A soil vapor investigation (DOE/RL-95-99, *100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report*) helped to define the area of contamination but did not identify the contamination source, which is believed to lie west of 100-F Area. Trichloroethene concentrations in this plume increased slightly in 2009 and 2010 (Figure 8-11). The highest concentration was 20 µg/L in well 199-F7-1 in May 2010. The monitoring wells are screened across the entire aquifer thickness, which is less than 3 meters in this location.

Wells in other portions of the 100-F Area also detect trichloroethene at concentrations that fluctuate around the DWS (the annual averages in 2010 were below the DWS). In the central 100-F Area, wells 199-F5-4, 199-F5-45, 199-F5-46, and 199-F5-48 had concentrations ranging from less than 1 to 7.9 µg/L. Well 199-F8-4 in the southeastern 100-F Area has concentrations near the detection limit (1 µg/L).

8.1.5 Tritium

Tritium concentrations in groundwater beneath the 100-F Area have not exceeded the DWS (20,000 pCi/L) in recent years. At lower concentrations, a plume extends to the southeast from the southern 100-F Area.

Historically, tritium concentrations in groundwater samples from well 199-F8-3 in the southern 100-F Area have exceeded the DWS. In the mid-1990s, concentrations at this well were ~180,000 pCi/L, and concentrations began to decline in the late 1990s. Because the decline began before most of the waste sites were remediated, the decline was likely caused by plume movement, dispersion, and radioactive decay. In 2010, the maximum tritium concentration in a groundwater sample was from well 199-F8-3 at 3,800 pCi/L.

8.1.6 Uranium and Gross Alpha

Uranium concentrations in groundwater underlying the 100-F Area remained below the DWS (30 µg/L). Five wells were sampled for uranium during the reporting

period, and the maximum concentration was 15.4 µg/L in well 199-F8-2 in the central 100-F Area (Table 8-2).

Gross alpha was analyzed in most of the 100-F Area wells that were sampled during the reporting period. New well 199-F5-54 had the highest concentration, 13 pCi/L, in a characterization sample from the top of the aquifer (Table 8-2). The concentration decreased with depth to less than 3 pCi/L at the bottom of the aquifer, at 7.7 meters below the water table. The DWS for gross alpha is 15 pCi/L.

8.1.7 Additional Contaminants of Potential Concern

Table 8-1 lists the COPCs for groundwater that were identified in DOE/RL-2008-46-ADD4. The table lists the maximum concentrations detected in groundwater in 2010; these data are provided for information only. An upcoming RI report will include a full analysis of the COPC data.

Most metals were detected in only a few samples or were detected at concentrations near detection limits. Exceptions include arsenic, chromium, hexavalent chromium, manganese, and zinc. The chromium results are discussed in Section 8.1.3. Relatively low levels of arsenic (approximately 10 µg/L and less) were detected in samples from wells throughout the 100-F Area. Arsenic is a natural component of Hanford Site groundwater and also was introduced to the environment in pesticides used before the Hanford Site was established. The RI will evaluate whether arsenic is a significant contaminant in 100-F Area groundwater. The elevated manganese and zinc values were from characterization samples collected during drilling. The drilling process can create chemically reducing conditions in the borehole, which increases the solubility of some metals.

Fluoride, nitrate, and sulfate are three anions frequently detected in 100-F Area groundwater. Fluoride and sulfate were detected at levels far below their secondary DWS (2 and 250 mg/L, respectively). Nitrate contamination is discussed in Section 8.1.1.

With two exceptions, organic analytes were detected in few wells. Chloroform was detected in many samples, and all but one of the results are flagged as estimates (near the detection limit). Trichloroethene contamination is discussed in Section 8.1.4.

Radionuclides detected in 100-F Area groundwater include carbon-14, plutonium-239/240, strontium-90 (Section 8.1.2), and tritium (Section 8.1.5). Well 199-F8-3 had the highest carbon-14 concentrations, ranging from 50 to 71 pCi/L (the DWS is 2,000 pCi/L). Plutonium-239/240 detections were sporadic, and total analytical error was nearly as large as the reported results. During data validation, it was noted that many of the plutonium-239/240 results were associated with laboratory contamination. The RI work plan did not identify uranium (Section 8.1.6) as a COPC.

8.2 CERCLA Groundwater Activities

In 2010, CERCLA activities associated with groundwater included RIs and routine groundwater monitoring.

8.2.1 Remedial Investigation Activities

In 2010, the RI/feasibility study (FS) work plan addendum (DOE/RL-2008-46-ADD4) and draft sampling and analysis plan (DOE/RL-2009-43) were issued. The documents are related to the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46) and describe the data to be collected to support selection of final remedies under CERCLA. The approach integrates the data needs for waste

sites and groundwater. The data and results will be reported in a RI/FS report, which will lead to selection of alternatives for final remedial action decisions.

Table 8-3 lists the RI groundwater data needs. The RI activities for 2010 are summarized below.

8.2.1.1 Horizontal and Vertical Extent of Contamination

The work plan addendum (DOE/RL-2008-46-ADD4) identified a data gap associated with the nature and extent of contamination in the unconfined aquifer. Vertical and horizontal distribution of contamination had not been determined in some locations nor for all of the COPCs. To fill this data gap, DOE installed three new monitoring wells in 2010 (DOE/RL-2009-43). Data from the new wells were combined with data from older wells to create the contaminant plume maps presented in Section 8.1 of this chapter. Vertical contaminant distribution is also discussed in Section 8.1. Section 8.1.7 summarizes the sampling results for the full list of COPCs.

8.2.1.2 Aquifer Tubes

One data gap called for continuing to sample existing aquifer tubes. A subset of tubes was scheduled for sampling in fall 2010, but sampling was delayed into early 2011 due to the fourth quarter sampling stop work. Eighteen of 32 tubes were sampled before rising river stage prevented further sampling.

8.2.1.3 Uppermost Aquitard

The aquifer beneath the 100-F Area is thin, and many of the wells were drilled to the top of the uppermost aquitard. Thus, the elevation and continuity of the aquitard were well known before the RI began; however, hydraulic properties of the aquitard were not well known and only one well was screened in the unit. Samples of the aquitard were collected from the three new wells for laboratory analyses. One well was screened in a water-producing zone of the aquitard. Slug tests were conducted in this well and an older well screened in the aquitard. The results will be discussed in upcoming reports.

8.2.1.4 Geologic and Hydrogeologic Data

Data from the new wells were combined with older data and used to create geologic cross sections and a map of the top of the aquitard. The introductory paragraphs of this chapter briefly summarize the hydrogeologic framework of the 100-F Area. Soil and water samples were collected throughout the thickness of the unconfined aquifer. These samples are being analyzed to determine physical and chemical properties that will be used to support numerical modeling.

Pressure transducers were installed in selected wells to determine vertical and horizontal hydraulic gradients and to determine how these gradients vary over time (i.e., changing river stage). This information will support studies of contaminant fate and transport.

8.2.1.5 Spatial and Temporal Distribution of Groundwater Contamination

Groundwater chemistry data were needed to reduce uncertainty in determining risks due to groundwater contamination. Nineteen monitoring wells in the 100-F Area were sampled at three river stages to characterize spatial and temporal variation. The samples were analyzed for 37 COPCs identified in Table 1-3 of DOE/RL-2009-43. The well network was sampled in May, July, and September/November 2010. The results will be used to assess risks to human health and the environment. Table 8-1 lists the COPCs and detections in 2010.

8.2.1.6 CERCLA Groundwater Monitoring

Groundwater sampling requirements are defined in the groundwater sampling and analysis plan (DOE/RL-2003-49) and *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) change notice TPA-CN-228. All of the wells scheduled for sampling during the reporting period were sampled successfully (Appendix A, Table A-10).

The sampling and analysis plan will be revised to incorporate newly installed wells after well completion. The wells are being sampled quarterly for the first year.

8.3 Conclusions and Recommendations

Groundwater beneath the 100-F Area is contaminated with hexavalent chromium, nitrate, strontium-90, and trichloroethene at levels above the DWSs or aquatic water quality criteria.

The RI/FS work plan addendum was implemented in 2010 to collect additional data needed to support final CERCLA cleanup decisions. New wells are helping define the extent of contamination areally and vertically.

Routine groundwater monitoring continued in 2010 and was coordinated with RI/FS sampling. After new wells are completed and early monitoring data are evaluated, the sampling and analysis plan for routine groundwater monitoring should be revised to incorporate the new information.

In early 2011, river porewater will be sampled and analyzed for chromium to determine whether the hyporheic zone is contaminated at levels exceeding the 10 µg/L aquatic water quality standard.

Table 8-1. Contaminants of Potential Concern for 100-F Area Groundwater

Contaminant	No. of Analyses	No. of Detections	Maximum Concentration in CY 2010[a]	Data Flag
Metals				
Antimony, unfiltered	139	2	4.3	B
Antimony, filtered	119	0	ND	--
Arsenic, unfiltered	137	60	11.6	D
Arsenic, filtered	117	50	10.9	D
Beryllium, unfiltered	139	1	0.11	BD
Beryllium, unfiltered	119	0	ND	--
Cadmium, unfiltered	139	1	0.247	B
Cadmium, filtered	119	1	0.059	B
Chromium, unfiltered	137	85	98.2	--
Chromium, filtered	118	69	93	--
Cobalt, unfiltered	139	30	4.82	D
Cobalt, filtered	119	26	4.4	D
Copper, unfiltered	136	59	7	BC
Copper, filtered	115	40	7	BC
Hexavalent chromium, unfiltered	79	29	91.9	--
Hexavalent chromium, filtered	62	31	92.9	--
Lead, unfiltered	136	7	2.11	B
Lead, filtered	117	1	0.441	BD
Manganese, unfiltered	77	20	234	--
Manganese, filtered	60	1	116	D
Mercury, unfiltered	76	0	ND	--
Mercury, filtered	60	0	ND	--
Nickel, unfiltered	78	23	36	--
Nickel, filtered	60	8	30	--
Selenium, unfiltered	133	52	5.38	BD
Selenium, unfiltered	117	41	5.36	BD
Thallium, unfiltered	138	0	ND	--
Thallium, filtered	117	1	1.1	B
Zinc, unfiltered	78	25	77.4	D
Zinc, filtered	60	10	100	D
Anions				
Fluoride	78	45	610	--
Nitrate	77	77	152,000	--
Sulfate	78	77	136,000	--
Organics				
1,1-Dichloroethene	78	0	ND	--
Carbon tetrachloride	78	1	1.8	J
Chloroform	78	32	1.9	--
Styrene	75	10[b]	0.52	JBT
Tetrachloroethene	78	3	1.1	--

Table 8-1. (Cont.)

Contaminant	No. of Analyses	No. of Detections	Maximum Concentration in CY 2010[a]	Data Flag
Trichloroethene	78	29	20	--
Vinyl chloride	78	0	ND	--
Radionuclides				
Americium-241	76	5	0.087	--
Carbon-14	76	10	70.7	--
Cesium-137	75	0	ND	--
Cobalt-60	75	0	ND	--
Europium-154	75	0	ND	--
Iodine-129	75	0	ND	--
Plutonium-238	73	4	0.3	--
Plutonium-239/240	76	20	1.12	--
Strontium-90	76	9	19	--
Technetium-99	76	6	40	--
Thorium-230	76	0	ND	--
Tritium	77	46	3,800	--

Note: Contaminants of potential concern are from DOE/RL-2008-46-ADD3. Wells are listed in the routine groundwater sampling and analysis plan (DOE/RL-2003-38, as modified by Tri-Party Agreement change notices TPA-CN-240 and TPA-CN-293), as well as those specified in DOE/RL-2008-46-ADD4. Includes data from characterization samples collected during drilling. Excludes data flagged as "Y."

a. Except where otherwise noted, units are pCi/L for radionuclides and µg/L for others.

b. All of the styrene detections were associated with blank contamination and are not considered representative of groundwater conditions.

B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit

C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration

D = analyte reported at a secondary dilution factor

J = estimated value; constituent detected at a level less than the contract required detection limit and greater than or equal to the method detection limit

ND = not detected

T = spike and/or spike duplicate sample recovery is outside control limits

Table 8-2. Maximum Concentrations of Gross Alpha and Uranium in 100-F Area Groundwater, CY 2010

Well	Maximum Gross Alpha (µg/L)	Maximum Uranium (µg/L)
199-F1-2	U	--
199-F5-1	U	--
199-F5-4	U	--
199-F5-42	U	--
199-F5-43A	U	--
199-F5-44	U	--
199-F5-45	8.4	13.3
199-F5-46	5.6	11.3 (D)
199-F5-48	U	11.1 (D)
199-F5-52	U	--
199-F5-53	U	--
199-F5-54	13 (G)	--
199-F5-6	5.5	--
199-F6-1	2.1	--
199-F7-1	U	--
199-F7-2	5.1	--
199-F7-3	6.8	--
199-F8-2	6.6	15.4
199-F8-3	U	--
199-F8-4	10	--
199-F8-7	3.3 (G)	6.76 (D)

D = analyte reported at a secondary dilution factor

G = record has been reviewed and determined to be correct

U = not detected in sample

Table 8-3. 100-F Area Remedial Investigation Groundwater Activities in 2010

Data Need*		Activity	Status
4	Data are needed to identify groundwater contaminants and define the extent of contamination horizontally and vertically.	Install well 199-F5-52 to define the chromium plume to the northwest.	Sample ready January 2011.
		Install well 199-F5-53 to monitor the Ringold Formation upper mud unit.	Sample ready January 2011.
		Install well 199-F5-54 to define the strontium-90 plume to the southeast.	Sample ready January 2011.
		Sample new and existing wells for COPCs to determine nature and extent of contamination.	Existing wells sampled 2010; new wells in 2011.
5	Data from the aquifer tube network are needed to monitor concentrations over time and with depth near the river.	Sample existing aquifer tubes.	Eighteen sampled early 2011.
6	Data are needed to evaluate the integrity of the aquitard, or fate and transport within the aquitard.	Collect samples of the uppermost aquitard from new monitoring wells. Screen one well in the aquitard (199-F5-53).	Completed (see data need 4).
		Collect split-spoon samples of the Ringold Formation upper mud unit from new wells and determine hydrologic properties.	Completed (see data need 4).
7	Geological characterization, physical, and hydraulic property data are needed to support modeling and analysis.	Collect soil and water samples throughout the thickness of the unconfined aquifer in new wells; determine chemical and hydrologic properties.	Completed (see data need 4).
		Update hydrogeologic interpretations based on geologic information from new and existing wells.	Completed in 2010.
		Install pressure transducers in selected wells to define vertical and horizontal gradients.	Completed early 2011.
		Conduct slug tests in new and selected older wells to refine horizontal hydraulic conductivity estimates for the unconfined aquifer and uppermost aquitard.	Completed early 2011.
8	Groundwater chemistry data are needed to reduce uncertainty in determining risks due to groundwater contamination.	Collect and analyze groundwater samples from nineteen monitoring wells at three river stages to characterize spatial and temporal variation.	Samples collected May, July, and September/November 2010.

* From DOE/RL-2008-46-ADD4, Table ES-1. Data needs 1, 2, and 3 pertain to the vadose zone.

Figure 8-1. Facilities and Groundwater Monitoring Wells in the 100-F Area

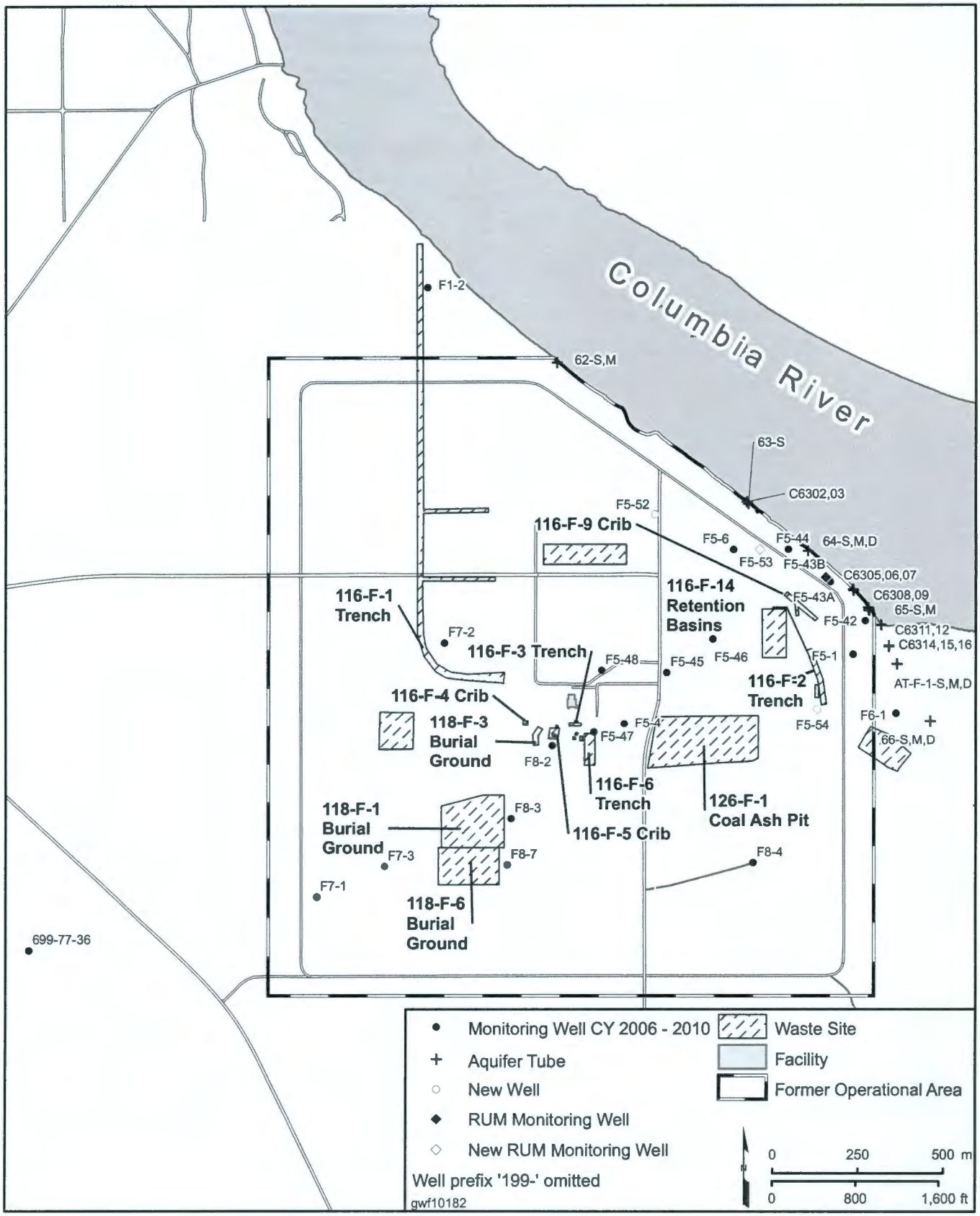
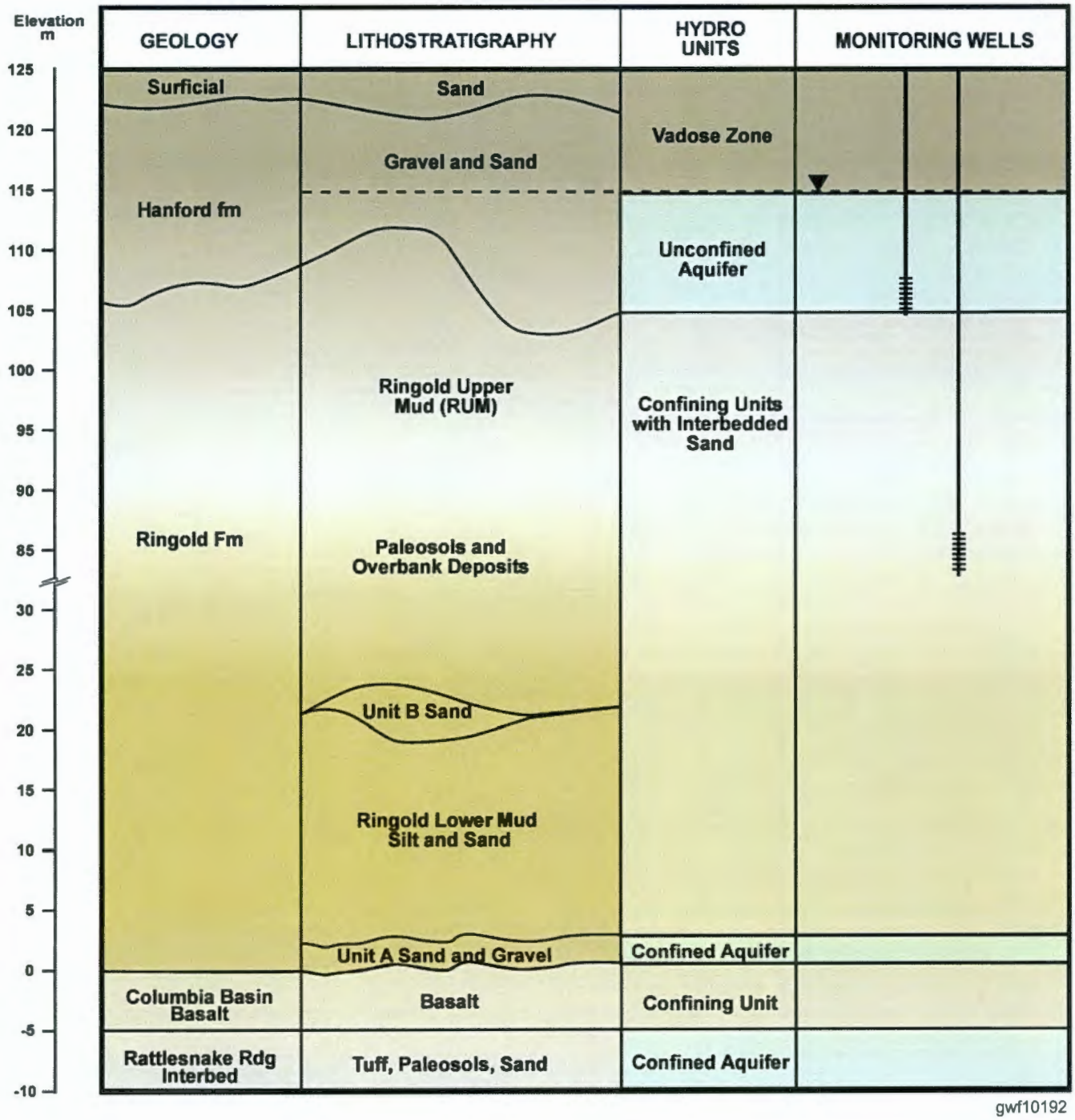


Figure 8-2. Stratigraphic and Hydrogeologic Units in 100-F Area



gwf10192

Figure 8-3. 100-F Area Water Table Map, March 2010

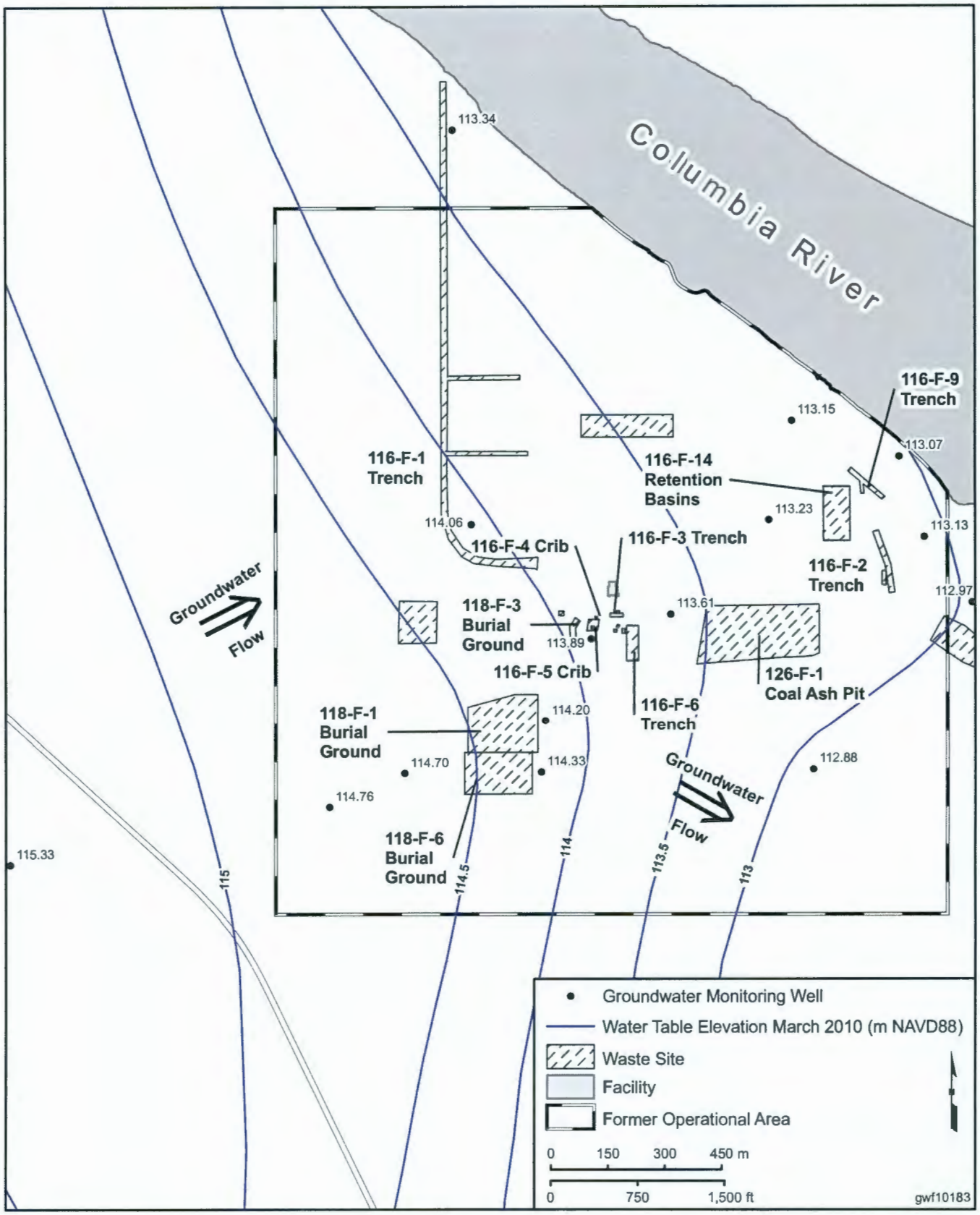


Figure 8-4. Nitrate Concentrations in 100-F Area and Vicinity, Unconfined Aquifer, Fall 2010

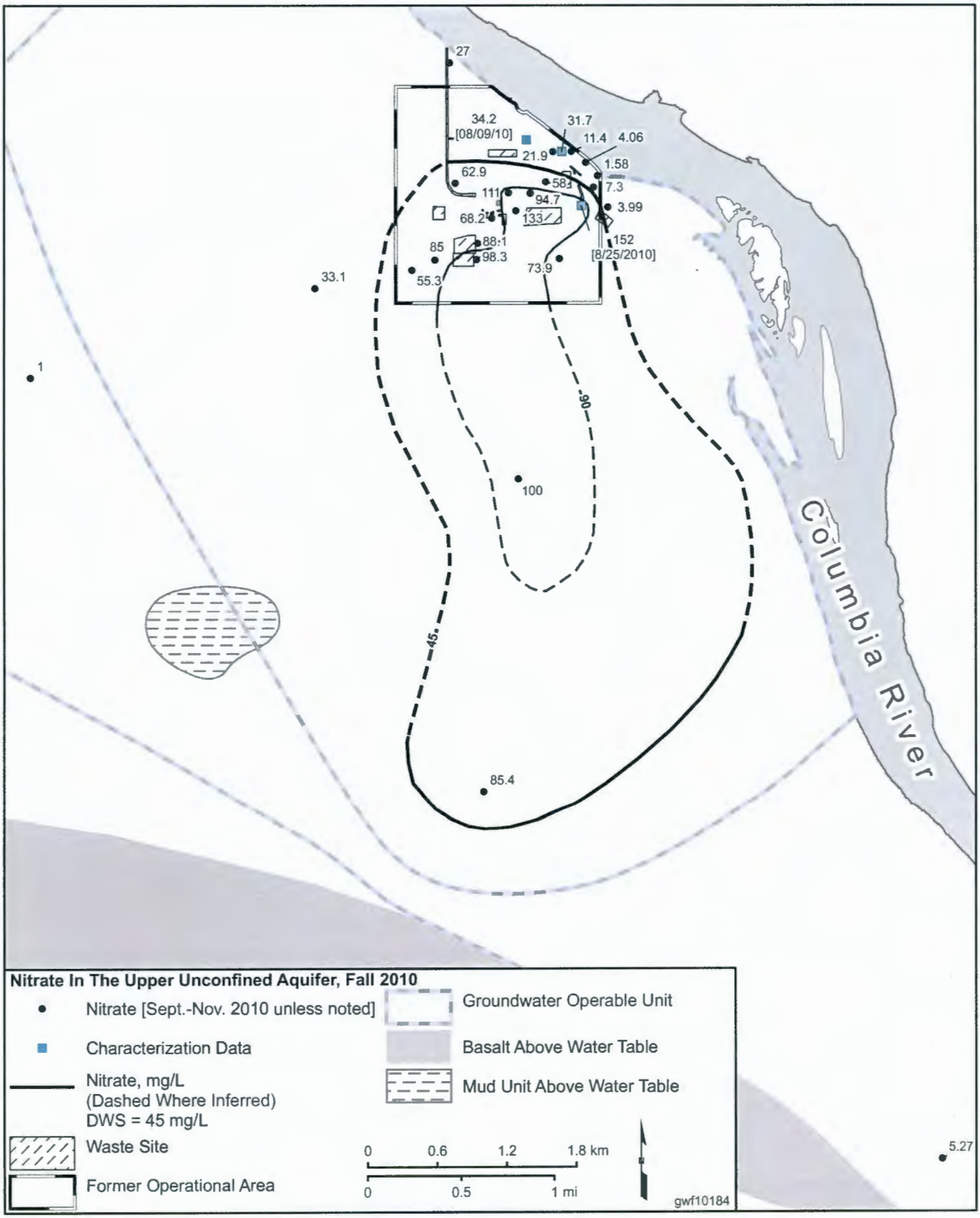


Figure 8-5. Nitrate Concentrations in Central (199-F5-4) and Southwestern (199-F7-3) 100-F Area

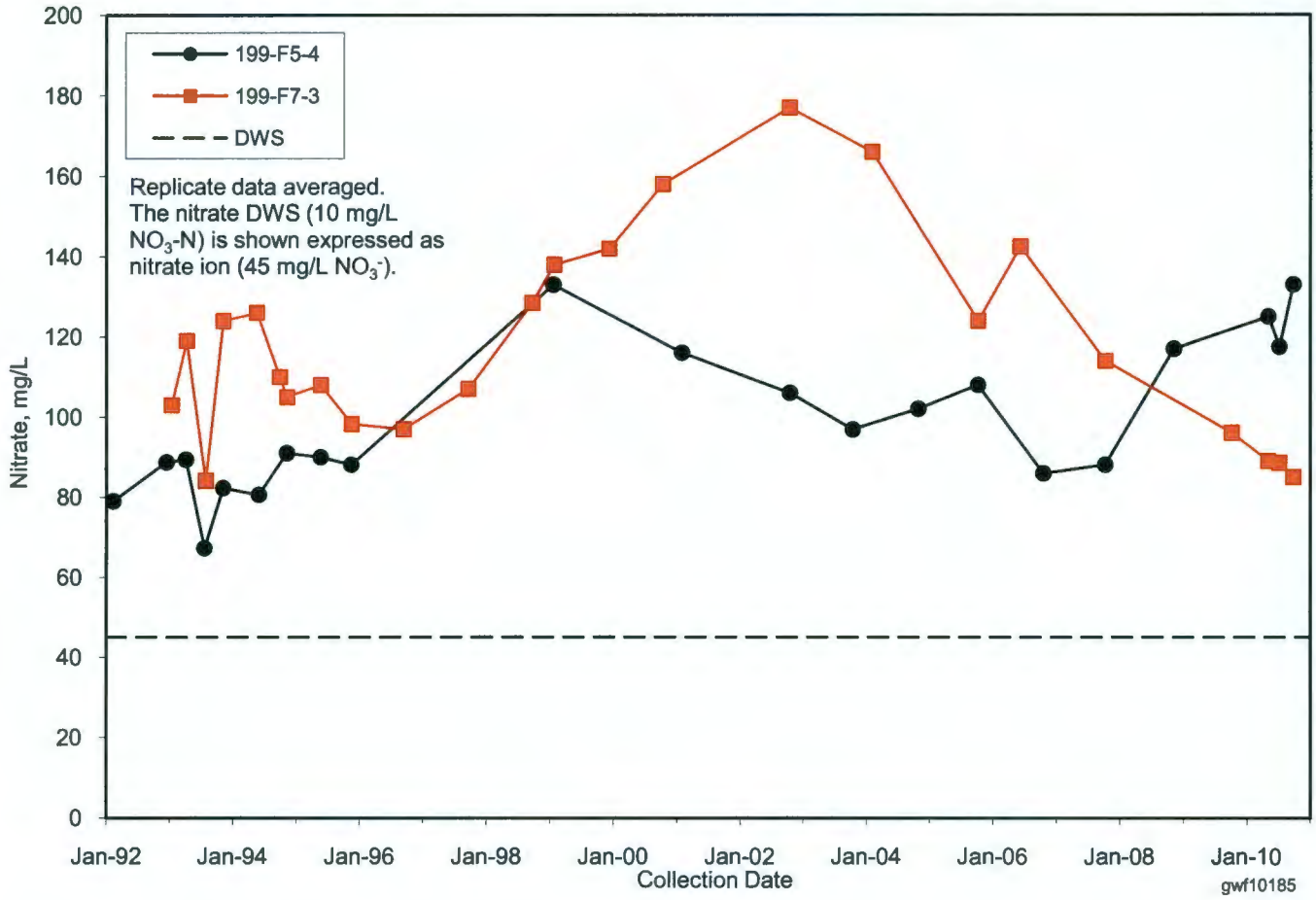


Figure 8-6. Strontium-90 Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010

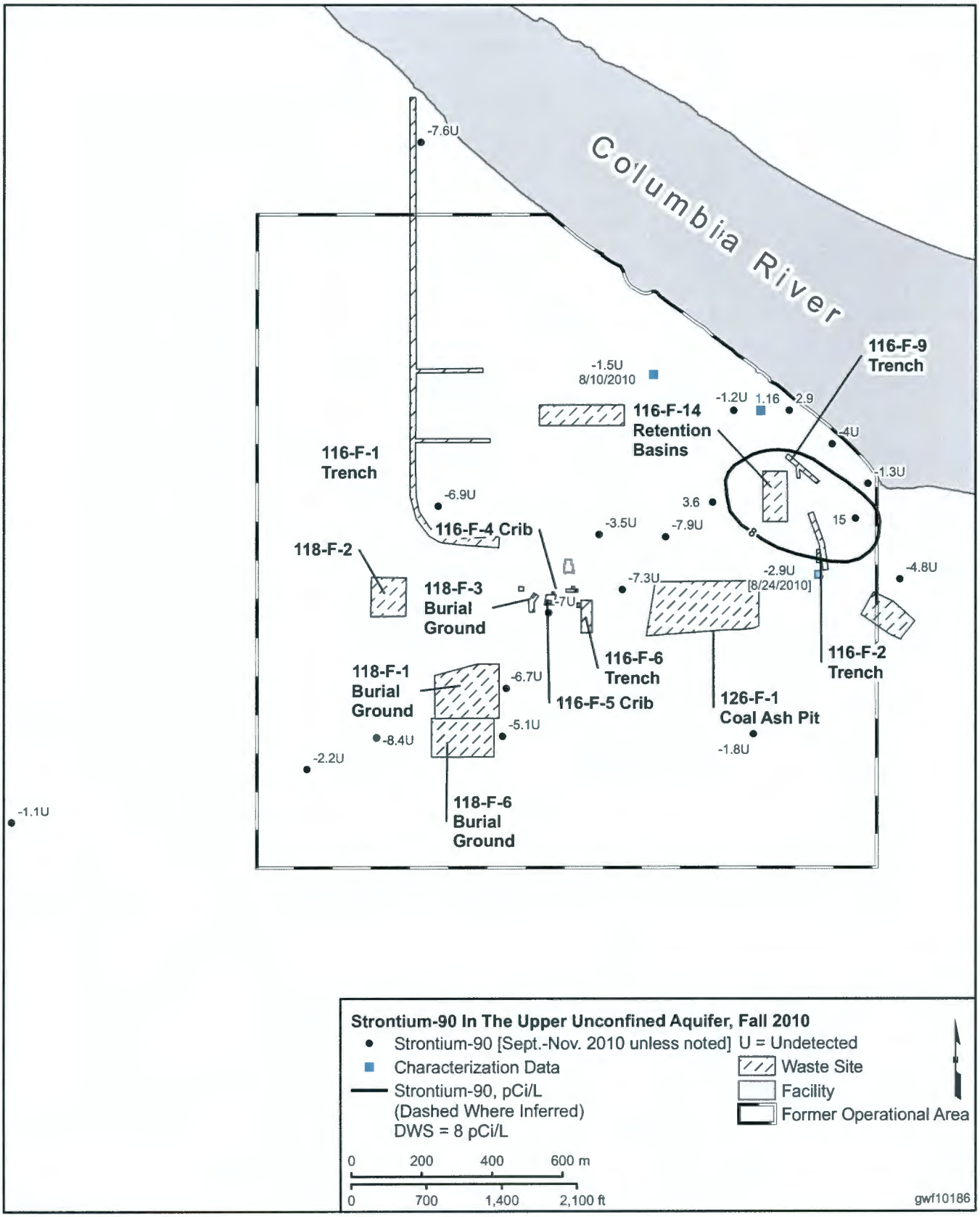


Figure 8-7. Strontium-90 Concentrations in Wells Monitoring the Eastern 100-F Area

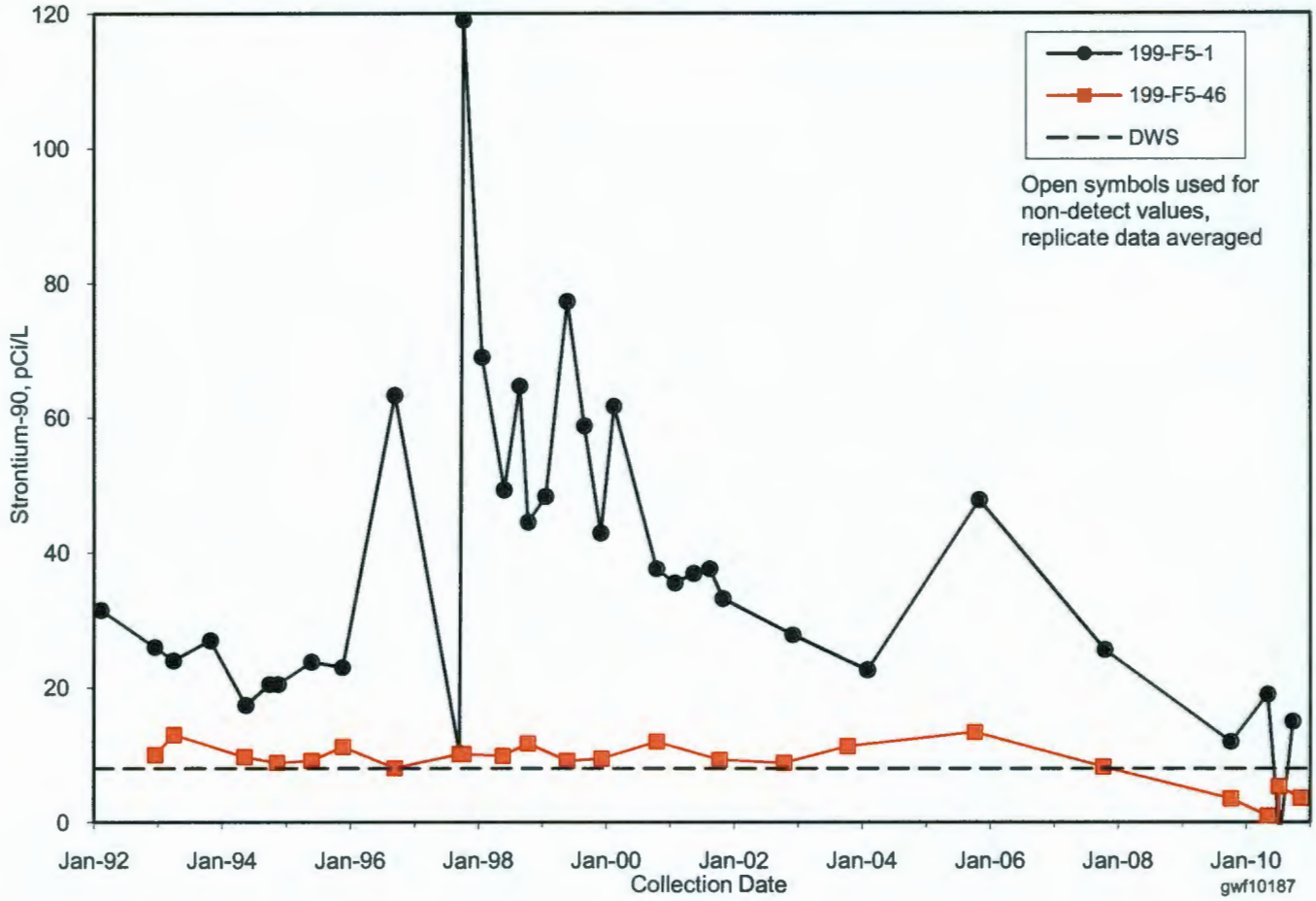


Figure 8-8. Chromium Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010

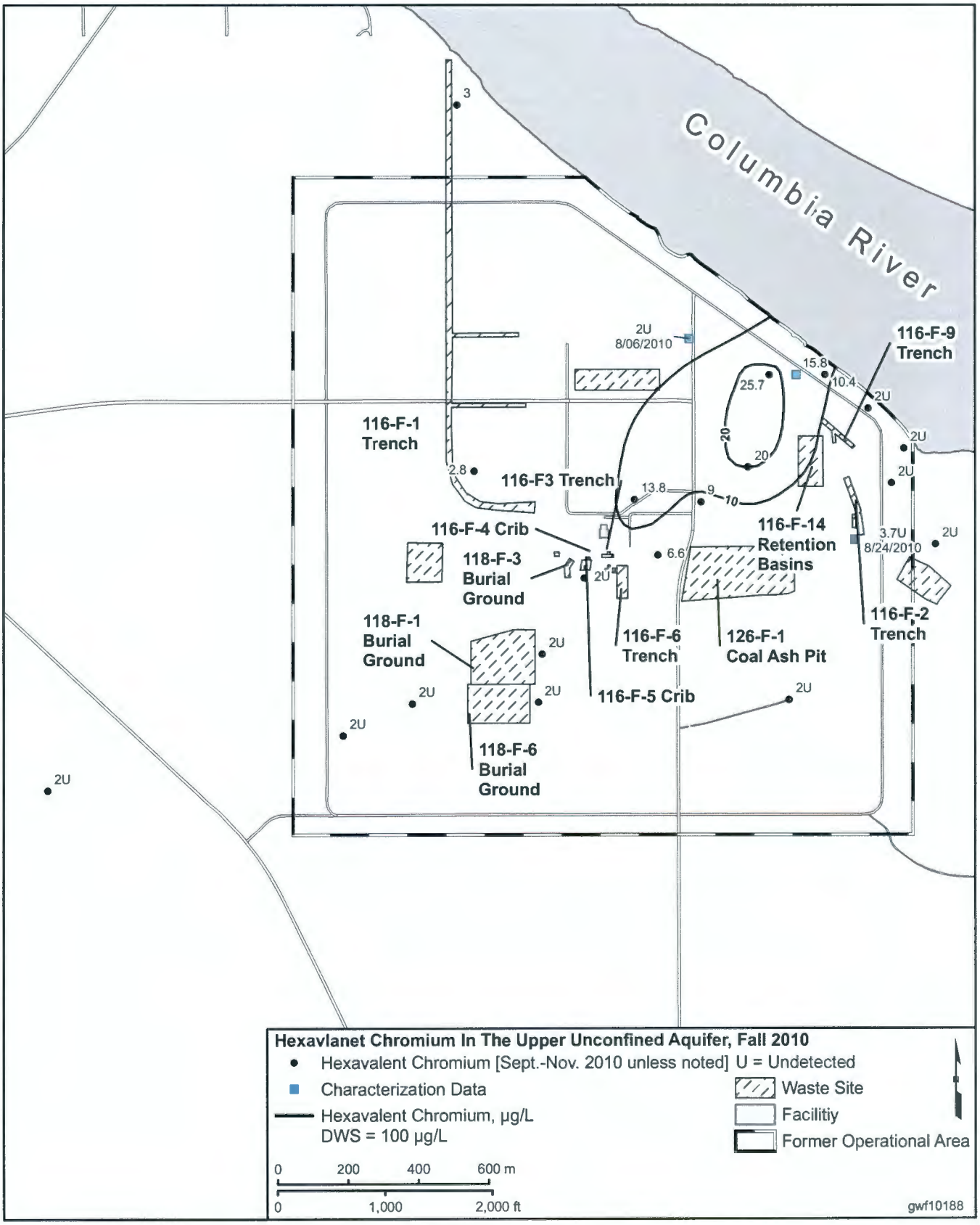


Figure 8-9. Chromium Concentrations in Wells Monitoring the Eastern 100-F Area

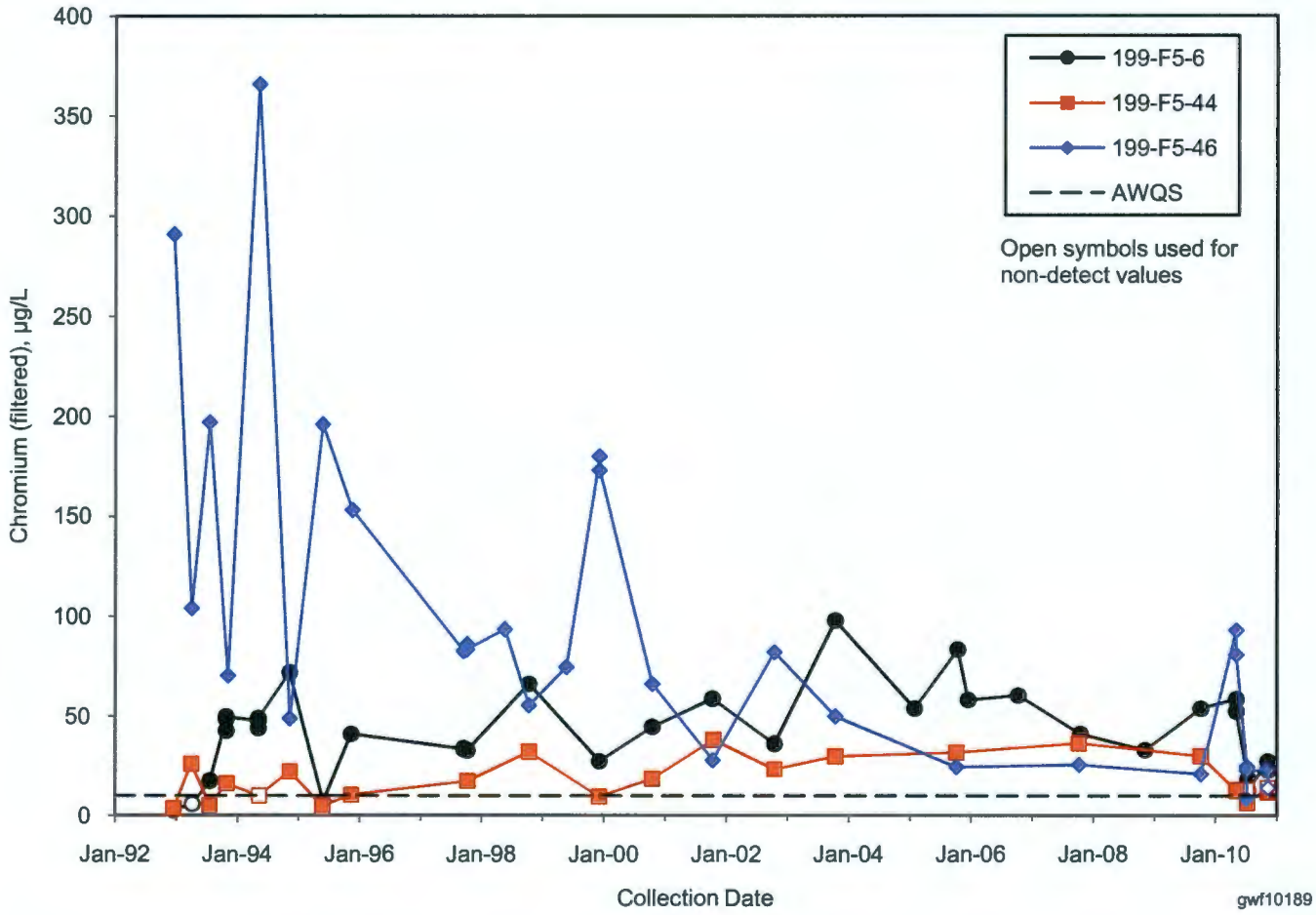


Figure 8-10. Trichloroethene Concentrations in 100-F Area, Unconfined Aquifer, Fall 2010

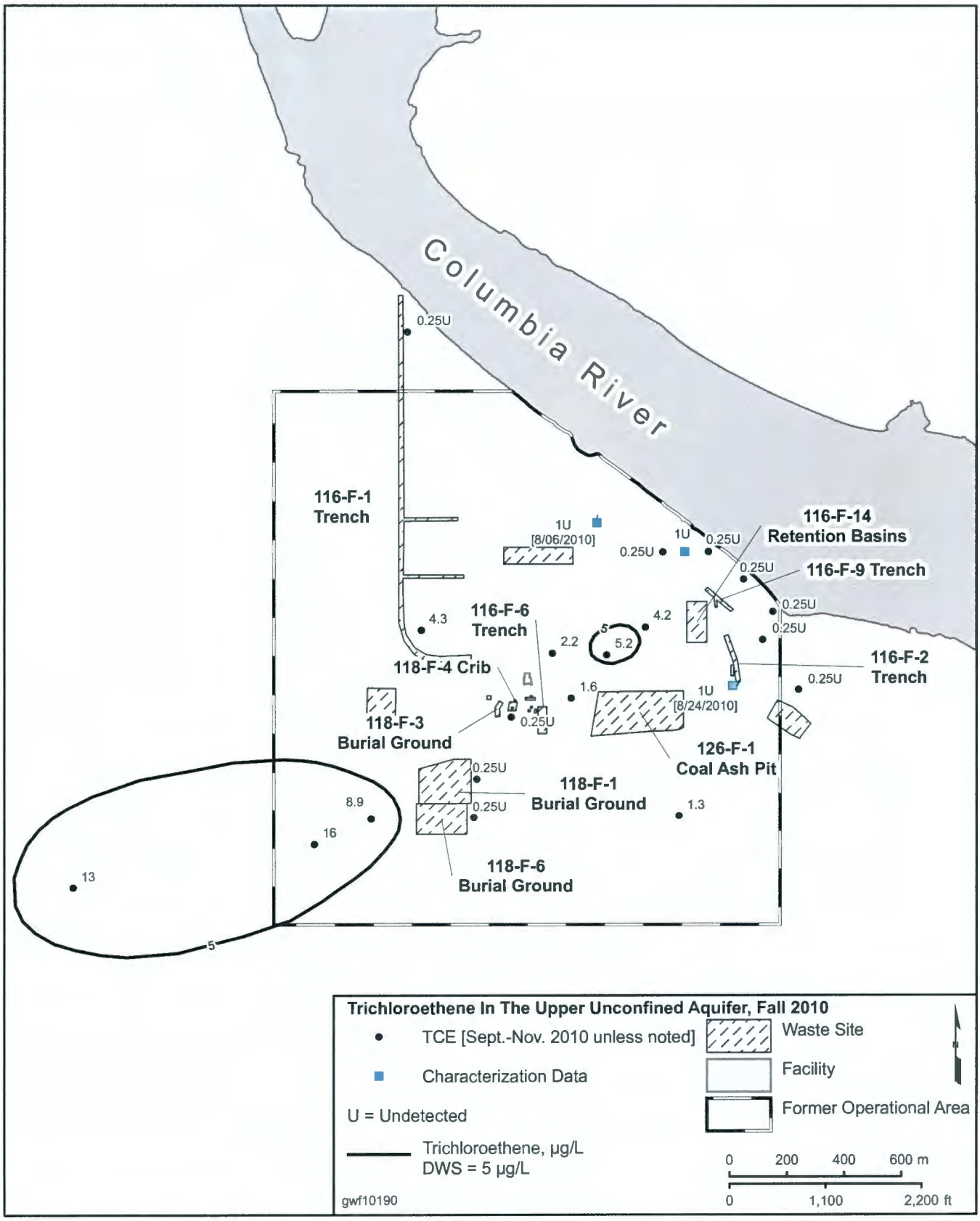
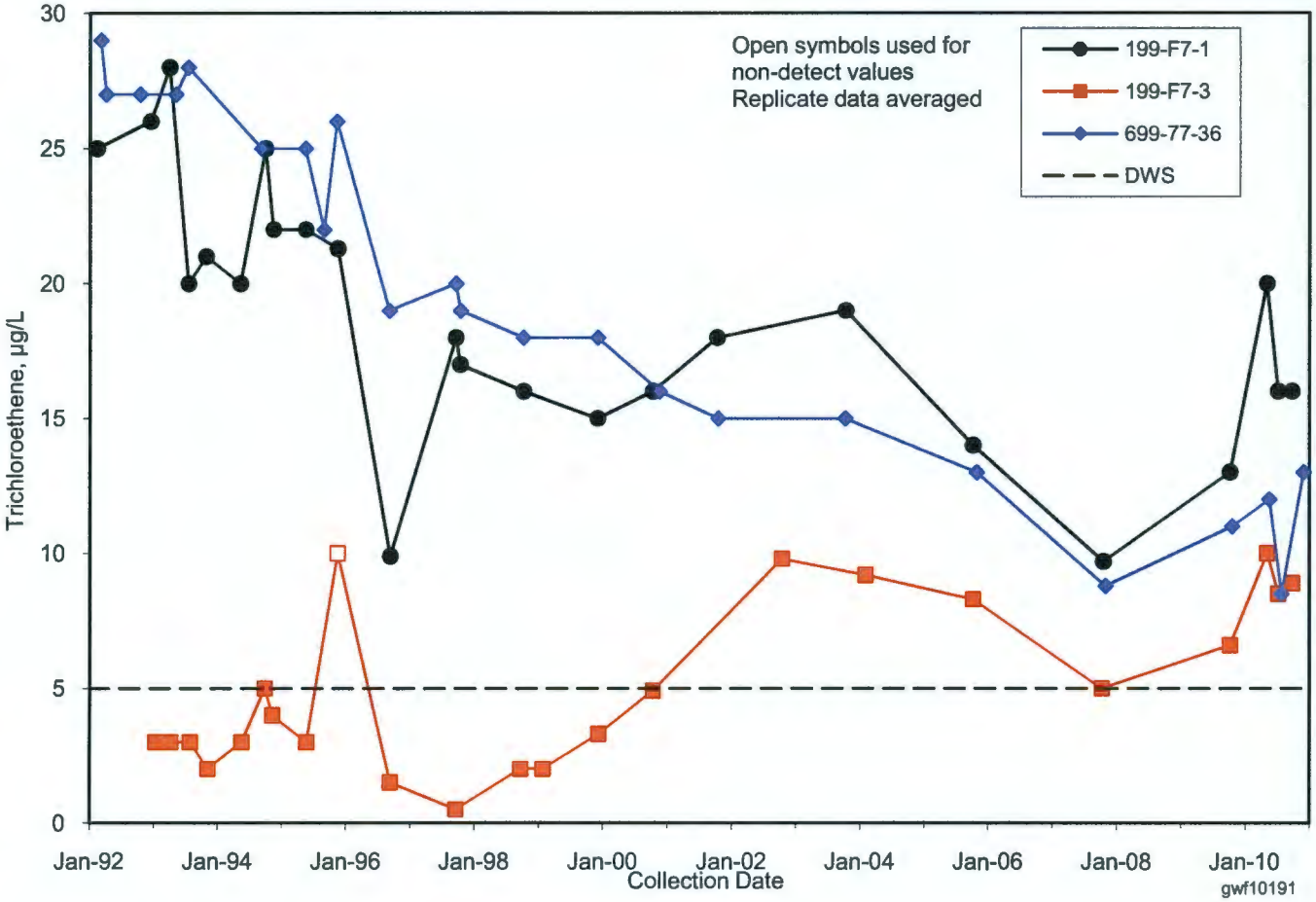


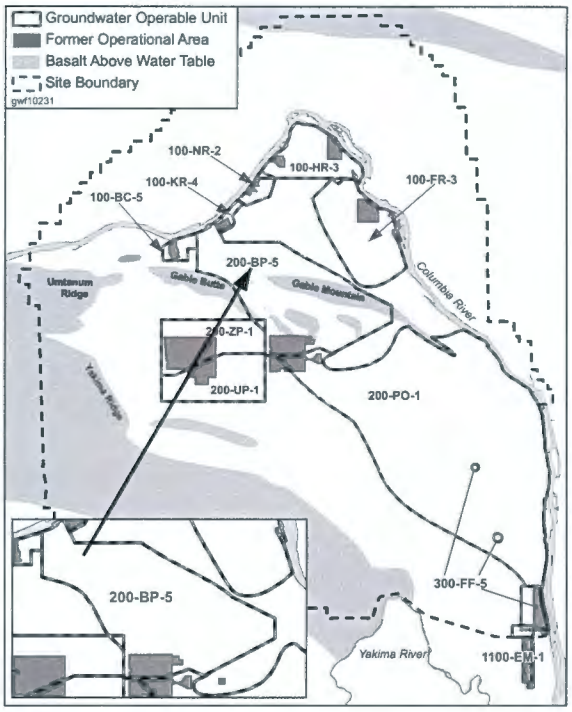
Figure 8-11. Trichloroethene Concentrations in Wells Monitoring Southwestern 100-F Area



9.0 200-BP-5 Operable Unit

G.S. Thomas

The groundwater flow and contaminant distributions in the 200-BP-5 Operable Unit (OU) are discussed in this chapter, which includes portions of the 200 East Area and adjacent 600 Area (Figure 9-1). The reporting period covers the timeframe from January 1, 2010, through December 31, 2010, referred to as calendar year (CY) 2010.



Figures 9-2 and 9-3 identify the waste sites, waste management units, and wells in the 200 East Area and 600 Area, respectively, within the 200-BP-5 OU. These figures identify the well names in subsequent figures discussed in this chapter.

The groundwater in the 200-BP-5 OU is monitored to track local and regional contaminant plumes associated with past-practice sites in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the *Atomic Energy Act of 1954* (AEA). The main CERCLA sites monitored in the 200-BP-5 OU include the following:

- 216-A-25 Pond (Gable Mountain Pond)
- BY Cribs and other proximal waste sites (B Complex)
- 216-B-5 injection well
- B Plant waste sites (including the 216-B-9, 216-B-12, and 216-B-62 Cribs).

In addition, the 200-BP-5 OU monitoring network is supplemented by several wells associated with sites that are monitored in accordance with the *Resource Conservation and Recovery Act of 1976* (RCRA). The RCRA sites in the 200-BP-5 OU include the following:

The groundwater in the 200-BP-5 OU is monitored to track local and regional contaminant plumes.

- Single-shell tank farms at Waste Management Area (WMA) B-BX-BY and WMA C
- Low-Level Waste Management Areas (LLWMAs) 1 and 2
- Liquid Effluent Retention Facility (LERF)
- 216-B-63 Trench
- 216-B-3 Pond (B Pond).

Note that the B Pond is partially in the 200-BP-5 OU and partially in the 200-PO-1 OU. Discussion on the B Pond site is provided with the 200-PO-1 OU in Chapter 10.0. Wells monitoring the B Pond within the 200-BP-5 OU are discussed for applicable contaminants of concern (COCs) in Section 9.1.

Ten COCs were initially defined in the *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49) and are the main constituents discussed in Section 9.1. One of the constituents, cobalt-60, has decreased below the drinking water standard (DWS) due to radiological decay and natural attenuation. Several RCRA wells that supplement the 200-BP-5 OU monitoring network near treatment, storage, and disposal (TSD) units are also used to interpret local changes in contaminant distribution. Section 9.3 discusses the WMA monitoring results associated with RCRA sites. The conclusions and recommendations associated

with findings during CY 2010 are provided in Section 9.4. The remainder of this introduction provides an overview for the following:

- Conceptual model for groundwater contaminant increases and decreases
- Location of contamination in the upper most confined aquifer
- Remedial investigation (RI) activities completed in CY 2010
- Geologic framework within the OU
- Groundwater flow regime in the north portion of the 200 East Area.

The groundwater contaminant plume contours in the 200-BP-5 OU did not show a significant difference when compared to last year.

The groundwater contaminant plumes within the 200-BP-5 OU for the most part did not show a significant difference compared to last year. This is attributed to the low groundwater hydraulic gradient discussed in Chapter 3.0. However, continued contaminant loading from the vadose zone near certain waste sites and/or facilities caused groundwater contaminant concentrations to increase. An example of this was in the northeast and north central portions of the 200 East Area where nitrate, sulfate, and technetium-99 concentrations/activities increased. More specifically, increasing groundwater contaminant trends near the C Tank Farm and the 216-B-2 Ditches indicated contaminant loading. At WMA C, a RCRA assessment determined that the dangerous waste constituent cyanide impacted groundwater. The driver for the assessment was the significant increase in specific conductance primarily associated with nitrate and sulfate increases in 2009. Significant technetium-99 increases were observed along the west side of the C Tank Farm in CY 2010. At the 216-B-2 Ditches, nitrate and sulfate increases are at least partially thought to be associated with contaminant loading from the vadose zone. Conversely, groundwater samples in wells where the groundwater flow appeared to increase (e.g., near the BY Cribs) showed a decrease in contaminant concentrations. The decreased contaminant concentrations appear to be associated with increased groundwater flow and dispersion rather than decreased contaminant loading from the vadose zone. The increased flow in this area appears to be associated with the reversal of the groundwater flow (back to the north) in 2009 and significant discharges at the Treated Effluent Disposal Facility (TEDF) in CY 2010. This apparent relationship between groundwater flow rate and concentrations of contaminants is an important part of the conceptual model for contaminant transport in the 200-BP-5 OU and is supported by evidence discussed later in this introduction and in Sections 9.1.1, 9.1.3, and 9.1.10.

Most of the groundwater contamination in the 200-BP-5 OU from past Hanford Site operations is present in the unconfined aquifer. The only exceptions are at well 299-E33-12 in the upper basalt-confined aquifer, the Rattlesnake Ridge interbed, near the BY Cribs; and in well 699-43-41G in a semiconfined aquifer beneath B Pond. The main source of contamination in well 299-E33-12 was associated with the lack of a proper annular seal that allowed contaminants from the BY Cribs to travel down the wellbore and into the confined aquifer. Placement of an annular seal in this well in 1979 has apparently remedied the intercommunication between the unconfined and the underlying confined aquifer at well 299-E33-12. Further discussion of contaminant extent at well 299-E33-12 is provided in Section 9.1.3.1. The semiconfined aquifer beneath B Pond is mainly discussed in Chapter 10.0; where appropriate, contaminants within the 200-BP-5 wells are discussed in Section 9.1.

Active groundwater remediation is currently not underway in the 200-BP-5 OU.

Active groundwater remediation is currently not underway in the 200-BP-5 OU. However, the evaluation of a pump-and-treat technology for possible future remediation of the uranium and technetium-99 contaminant plumes at the B Complex was drafted in a treatability test plan in 2010 in accordance with *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989)

Milestone M-015-082. The purpose of the test is to evaluate whether a pumping rate of 189 liters per minute can be sustained in the thin unconfined aquifer where uranium and technetium-99 plumes reside. The treatability test is planned at two locations during CY 2012 (providing the availability of sufficient funding): (1) a site along the west side of the BY Tank Farm, and (2) in well 299-E33-343 adjacent the northwest corner of the B Tank Farm. Other CERCLA activities completed in CY 2010 included installing the last three remedial investigation (RI) wells and depth-discrete sampling at fourteen existing 200-BP-5 OU wells. The RI wells were installed near the 216-B-12 Crib, 216-B-6 injection well, and the 216-C-1 Crib. The investigation was integrated with the corresponding waste site OUs to investigate both the vadose zone and groundwater. The depth-discrete sampling at the existing wells was completed mainly to investigate the vertical extent of existing contaminant plumes. Both investigations were performed in accordance with the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18). Upon completion of the work, an RI report was initiated. The CERCLA activities completed during this reporting period are discussed further in Section 9.2.

The geology of the 200-BP-5 OU consists of sediments of the Hanford formation and Ringold Formation overlying the Saddle Mountains Basalt. The uppermost basalt member of the Saddle Mountains Basalt in the 200-BP-5 OU is generally the Elephant Mountain Member. This member defines the base of the unconfined aquifer in the OU, with the exception of the Gable Mountain/Gable Butte Gap area (Gable Gap) and further north. In the Gable Gap area, portions of the Elephant Mountain, Pomona, Esquatzel, and Asotin members of the Saddle Mountains Basalt were removed by erosion, exposing and interconnecting the lower permeability Ringold, Rattlesnake Ridge interbed, and Selah interbed groundwater to the unconfined aquifer. An excellent cross section of this area is provided in Figures A-2 and A-4 of the *Hydrogeologic Model for the Gable Gap Area, Hanford Site* (PNNL-19702). Groundwater elevations in the interbeds south of the Gable Gap area (e.g., upgradient) are higher than the overlying unconfined aquifer water table, indicating an upward hydraulic gradient and flow regime. Therefore, groundwater contamination migrating from the 200 East Area as far as the Gable Gap area is constrained to the unconfined aquifer within the highly permeable Hanford formation. North of Gable Gap, a high-angle reverse fault shifted basalt upward across the Ringold Formation unit 8 (e.g., Ringold lower mud), which defines the base of the unconfined aquifer north of the fault.

The unconfined aquifer is mainly contained within moderate to low-permeability Ringold Formation sediments along the southwestern boundary of the OU. The Ringold sediments extend from the southerly portion of the LLWMA-1, east of B Plant near well 299-E28-6, and into the 200-PO-1 OU as defined in the *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington* (PNNL-12261, plate maps 3, 4, and 5). Two 200-BP-5 OU RI wells were drilled through the Ringold Formation to basalt near B Plant in CY 2010. Based on these wells, the aquifer thickness in this area is ~18.3 meters and it lies entirely within the Ringold Formation.

North and east of this area, cataclysmic flooding eroded some to all of the Ringold Formation sediments and deposited sediments of the Hanford formation. Due to past folding of the underlying basalts, the aquifer thins to the north-northeast. Along the northern boundary of the 200 East Area, the aquifer becomes very thin or is absent. East of the 200 East Area, the Ringold sediments are again present throughout the

aquifer. Most of the sediments east of the 200 East Area are comprised of the Ringold lower mud unit (PNNL-12261, unit 8). This unit creates a semiconfined aquifer where it overlies the silty, sandy, gravelly Ringold sediments (unit 9) and the Elephant Mountain Basalt. The Ringold lower mud unit is mainly the only saturated unit that extends north to Gable Mountain and groundwater contaminants are generally west of this unit. An exception is beneath both the Gable Mountain Pond and B Pond were a few contaminants still reside.

The saturated glaciofluvial Hanford formation and/or Cold Creek units are deposited in an eroded channel between the Ringold Formation sediments discussed above (i.e., to the east and west). Some remnant Ringold Formation sediments are present within paleochannels north of the 200 East Area, as discussed in PNNL-19702. The saturated Hanford sediments are thickest within the southerly portion of the 200-BP-5 OU and thin as the sediments extend to the northwest toward Gable Gap. Previous folding of the underlying basalts causes the aquifer to thin to apparently a couple meters or less between the 200 East Area and Gable Gap. The saturated Hanford sediments extending northwest of the 200 East Area is thought to be the primary groundwater flow path from the northwest portion of the 200 East Area to Gable Gap. It is worth noting that the more permeable Hanford sediments are juxtaposed with the remnant Ringold Formation paleochannel sediments. It appears that groundwater contaminants migrate primarily within the more permeable Hanford sediments as opposed to the Ringold sediments. The thinnest part of the saturated Hanford sediments is thought to be northwest of well 699-49-57A (Figure 9-3). A cross section of this area is provided in Figure A.5 of PNNL-19702; the primary flow path is shown between wells 699-50-59 and 699-50-56 in Figure A.5. Geophysical methods have been used in this area, but the aquifer thickness remains uncertain.

In general, groundwater moves into the 200-BP-5 OU from the southwest (Figure 9-4). As it approaches the more permeable Hanford sediments, some of the flow is diverted to the north-northwest toward Gable Gap. The flow to the north is limited by multiple contributing factors including permeability, the width and thickness of the Hanford sediments, heterogeneity of the saturated sediments, groundwater gradient, high Columbia River spring runoff elevations, and discharges to the TEDF.

Discharges at the TEDF have been shown to cause groundwater elevations to increase in the 200 East Area.

Discharges at TEDF have been shown to cause groundwater elevations to increase within the 200 East Area (Figure 9-5). The groundwater elevation increases appear to coincide with the statistically significant gradient measurements at LLWMA-1 to the north over the past 2 years. The statistically significant northward groundwater gradient measurements at LLWMA-1 occurred in July 2009 and June 2010. As seen in Figure 9-5 the flow reversal to the south at LLWMA-1 due to the high Columbia River spring runoff in 2008 occurred when TEDF discharges were absent. The data suggest a delicate balance between TEDF discharges and the Columbia River surface elevation. In fact, the flow return to the north at LLWMA-1 was not statistically determined until after the large-volume discharges at TEDF in spring 2009. Figure 9-5 shows how the groundwater elevation in the 200 East Area rose in response to these discharges. By July 2009, the groundwater measurements at LLWMA-1 showed a statistically north groundwater flow direction (Figure 9-6). During CY 2010, the TEDF discharges were significant in both the spring and fall, apparently causing increased northward groundwater flow at LLWMA-1 and WMA B-BX-BY. The assumed flow divide during most of CY 2010 was thought to be south of B Plant but may have fluctuated based on the schedule and volume of water discharged at the TEDF.

The remaining groundwater flow into the 200-BP-5 OU from the southwest moves generally northeast-east before diverting to the southeast, possibly west of WMA C. This appears to be consistent with the flow direction noted south of the Plutonium-Uranium Extraction Facility, near the Integrated Disposal Facility.

The groundwater gradient within the north central and northeast portion of the 200 East Area is too flat to be measured at this time. This is the location where the aquifer is cut off to the north by basalt rising above the water table. Consequently, the average groundwater flow appears to be very slow (less than 0.1 meter/day) in this area, as discussed in later sections (e.g., Sections 9.1.1.6, 9.3.2, and 9.3.5).

Plume areas (square kilometers) in the 200-BP-5 Operable Unit:

Cyanide, 200 µg/L — 0.345
Iodine-129*, 1 pCi/L — 6.2
Nitrate*, 45 mg/L — 6.14
Strontium-90, 8 pCi/L — 0.37
Technetium-99*, 900 pCi/L — 2.4
Tritium, 20,000 pCi/L — 0.495
Uranium, 30 µg/L — 0.347

**** Includes plume area that overlaps into the ZP-1 and PO-1 Operable Units.***

9.1 Groundwater Contaminants

This section summarizes the distribution of groundwater contamination in the 200-BP-5 OU, as required by the sampling and analysis plan (DOE/RL-2001-49). The COCs defined in DOE/RL-2001-49 include nitrate, iodine-129, technetium-99, uranium, strontium-90, cyanide, cobalt-60, cesium-137, plutonium-239/240, and tritium (the following subsections discuss the contaminants in this order). Each subsection includes discussion of the following: (1) areal extent of contamination exceeding the DWSs, (2) probable source, (3) groundwater flow direction at that site, (4) relevant geologic information, and (5) any RI activities conducted during fiscal year (FY) 2010 to address the contaminant at that location. Cobalt-60 and mercury have been included in previous reports, but their concentrations did not exceed the DWSs this year; therefore, these constituents are not discussed. Note, however, that cobalt-60 and mercury are still monitored in accordance with the previously mentioned sampling plan. Sulfate, although not identified in DOE/RL-2001-49 as a COC, is discussed because it exceeded the secondary DWS in several wells.

Contaminant distribution maps presented in this section show annual averages. Some wells provide four quarters of data, some wells provide two quarters of data, other wells provide one value per year, and some wells provide one value every 3 years. The 200-BP-5 OU well network is divided into the 200 East Area wells (Figure 9-2) and the 600 Area wells (Figure 9-3). Additional wells sampled in CY 2010 included the sixteen 200-BP-5 OU RI wells associated with the RI/feasibility study (FS) (DOE/RL-2007-18), wells associated with RCRA TSD sites, and wells associated with the 100-F/IU-2/IU-6 RI.

Elevated concentrations of constituents of interest in the 200-BP-5 OU occur in the following regions and are discussed in the following subsections:

- B Complex (e.g., WMA B-BX-BY and surrounding waste sites)
- 216-B-62 Crib and north along the west side of LLWMA-1
- Grouped wells 699-53-55A, B, and C (located near Gable Mountain Gap and Gable Mountain Pond)
- Gable Gap, Gable Mountain Pond, and B Pond
- B Plant
- 216-B-5 injection well
- WMA C
- LLWMA-2.

Discussions on flow rates are limited to areas where multiple observations (e.g., gradient, trend plots, and ion chemistry) correlate to each other. This approach with multiple lines of evidence is necessary to ensure consistency due to low groundwater gradient (~1.5 x 10^{-5} based on regional water-level measurements).

9.1.1 Nitrate

Nitrate analyses were performed on groundwater samples at least once from 141 wells across the 200-BP-5 OU. Sampling at three wells (299-E28-5, 299-E28-6, and 299-E28-18) was missed due to a work stoppage in the fourth quarter of CY 2010.

Figure 9-7 shows the average annual distribution of nitrate above the DWS (45 mg/L). Eight areas had nitrate concentrations above the DWS in CY 2010, as discussed below.

9.1.1.1 Wells at the B Complex and Extending Northwest Beyond Well 699-49-57A

The highest nitrate concentrations in the 200-BP-5 OU continued to be reported from wells associated with the BY Cribs.

The highest nitrate concentrations in the 200-BP-5 OU continued to be reported from wells associated with the BY Cribs. Three wells monitoring the groundwater beneath the BY Cribs had a maximum concentration of 1,540 mg/L (299-E33-3, 299-E33-7, and 299-E33-341), reported in May, February, and August, respectively. The concentrations are lower than last year and may be associated with an increased groundwater flow rate due to the increased TEDF discharges during CY 2010 versus CY 2009. This assumes that the contaminant infiltration rate from the vadose zone into the unconfined aquifer is constant, which is unknown; however, an increased flow rate is consistent with contaminant trend comparisons between wells near the BY Cribs and wells within the plume to the northwest. Figure 9-7 shows the majority of the nitrate plume from this area extending to the northwest. Based on the *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B Complex* (PNNL-19277), the plume to the northwest appears to be associated with the following waste sites/ facilities in this area: BY Cribs, 241-BX-102 unplanned release, 216-B-57 Crib, 216-B-8 Crib, 216-B-7A&B Crib, and possibly the 216-B-11A&B french drain.

The average groundwater flow rate extending from the BY Cribs to the northeast corner of LLWMA-1 was determined at ~0.78 meter/day based on the average of ten groundwater-level measurements between wells 299-E33-38 and 299-E33-34 during CY 2010 and early 2011. The two wells used to determine the flow rate are consistent with various three-point calculations in the area, plume migration, ion chemistry comparisons, and trend plot comparisons. The groundwater elevation data and calculation for these two wells are provided in Table 9-1. The average horizontal groundwater gradient between these wells was 2.08 x 10^{-5}. The ion chemistry and contaminant trend plot comparisons are discussed further in Section 9.1.3.1.

Nitrate concentrations decreased significantly in wells just south of the BY Cribs (299-E33-9, 299-E33-13, and 299-E33-31) during CY 2010. For example, concentrations at well 299-E33-31 decreased from ~900 mg/L in February to 584 mg/L by the end of December. The decrease in well 299-E33-13 was not as significant as the decrease in well 299-E33-31, but by early January 2011, nitrate concentrations had decreased by more than 150 mg/L.

Farther south, along the north side of the B Tank Farm, nitrate concentrations did not change much. It is assumed that the flow in this area is slower because the aquifer is thicker. PNNL-19277 indicates that nitrate from the 241-BX-102 unplanned release and the 216-B-7A&B Crib releases have impacted, and most likely continue

to impact, groundwater in this area. Consequently, the infiltration rate from a perched contaminated water horizon ~3.05 meters above the aquifer must nearly match the flow rate for concentrations to remain nearly constant. This conceptualization is based on the consistent nitrate concentrations in wells 299-E33-343 and 299-E33-345 and the much lower nitrate groundwater concentrations to the south.

Along the southern side of WMA B-BX-BY, nitrate concentrations increased in most wells until August, and then showed large decreases in December. The reason is unclear for the significant increase in nitrate concentrations in 2010 in certain wells such as well 299-E33-339 (along the south boundary of the BX Tank Farm) when the flow is presumed to be north. Nitrate concentrations further south in well 299-E28-8 were much lower (34 to 39.9 mg/L) than concentrations in well 299-E33-339 (145 to 201 mg/L) and decreased during the year. In addition, concentrations to the east and west were also much lower than concentrations at well 299-E33-339. In last year's annual report (DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*), the elevated nitrate in this well was attributed to a south groundwater flow direction and the specific gravity of infiltrating residual liquid waste from the vadose zone to the north. The south groundwater flow explanation from last year was carried over from a groundwater flow reversal that was initiated in 2008. The groundwater flow reverted back to north in mid-2009 based on statistical groundwater level measurements at LLWMA-1. Continued northerly groundwater flow from mid-2009 through the end of 2010 is consistent with statistical evaluations of the flow regime in this area (Figure 9-6). Therefore, the north groundwater flow regime in 2010 does not correlate with the increasing nitrate through August 2010 near well 299-E33-339. It is possible an unknown source of infiltrating nitrate may be the cause of the increase. Another possible explanation (also discussed in DOE/RL-2010-11) is associated with residual vadose zone contamination with a high specific gravity entering the groundwater. The groundwater results from an investigation completed in CY 2010 associated with this theory are provided in the following discussion.

A density driven conceptual model was previously considered for contaminants associated with the BY Cribs that may preferentially sink and move along the bottom of the aquifer. This conceptual model is further explained in *Potential for Groundwater Contamination from High Density Wastes Disposed at the BY Cribs, 200-BP-1 CERCLA Operable Unit* (WHC-SD-EN-TA-003). One reason for evaluating this theory was not only the specific gravity of the waste associated with the BY Cribs, but also the specific gravity (1.25 grams per cubic centimeter [g/cc]) of the metal waste released by the 241-BX-102 tank overfill event in 1951 (HW-23043, *Flow Sheets and Flow Diagrams of Precipitation Separations Process*). Based on discussion in WHC-SD-EN-TA-003, the density of the waste released to the BY Cribs was possibly 1.21 g/cc, indicating similar density as that associated with the metal waste. Another reason for investigating this theory was the nitrate, cyanide, technetium-99, and other contaminants characteristic of the BY Cribs found in the confined aquifer at well 299-E33-12 in the 1950s. These contaminants migrated into the confined aquifer due to poor well construction. Note that a higher hydraulic head has continually been present in the confined aquifer versus the unconfined aquifer, indicating an upward flow regime between the confined and unconfined aquifers (see Section 9.1.3.1). The contaminants that entered the confined aquifer have persisted to the present day, approximately six decades later. During the late 1950s after well 299-E33-12 was drilled, the nitrate concentrations exceeded 4,000 parts per million (ppm). The highest nitrate concentrations currently observed

In well 299-E33-49, down the basalt dip from the 241-BX-102 unplanned release and BY Cribs, a nitrate concentration an order of magnitude higher was reported from a sample collected at the bottom of the aquifer versus a sample collected ~2 meters above the bottom of the aquifer (e.g., 371 mg/L versus 54 mg/L, respectively).

in the confined aquifer remain at well 299-E33-12 and are just under the DWS, at ~42 ppm. The highest nitrate concentrations currently in the unconfined aquifer are beneath the BY Cribs at just above 1,000 ppm. However, well 299-E33-4 (also beneath the BY Cribs) had nitrate concentrations as high as 17,800 ppm in 2008; this well has not been sampled since because the aquifer is too thin for sampling at this location. According to "Numerical Simulation of the Effects of Variable Density in a Contaminant Plume" (Koch and Zhang, 2005), concentrations of ~4,000 ppm were shown to have a density effect on plume migration in a porous media. Based on these factors, the nitrate in well 299-E33-339 may be associated with residual liquid waste from the BY Cribs or the 241-BX-102 unplanned release, or both. Depth-discrete groundwater samples were collected in January and February at wells 299-E33-339 and 299-E33-49 to further investigate this conceptual model.

Depth-discrete groundwater samples collected in January and February found no significant variation in nitrate concentration with depth in well 299-E33-339. However, further to the west in well 299-E33-49, also down the basalt dip from the 241-BX-102 unplanned release and BY Cribs, a nitrate concentration an order of magnitude higher was reported from a sample collected at the bottom of the aquifer versus a sample collected ~2 meters above the bottom of the aquifer (e.g., 371 mg/L versus 54 mg/L, respectively). Even lower nitrate concentrations were reported at shallower depths in the aquifer at this well. Although the concentration of nitrate at the bottom of the aquifer collected from this well does not appear sufficient for a density plume, the stratification of the contamination is interesting. It could be speculated that the depth-discrete results at well 299-E33-49 may represent the disperse fringe of such a plume rather than the center of a possible density plume.

The ratio for technetium-99 to nitrate was also compared to groundwater results at wells near both the BY Cribs and the infiltration point of the 241-BX-102 unplanned release. The ratio of technetium-99 to nitrate at well 299-E33-49 was 33.2, which is between the ratios of the two sources (e.g., BY Cribs at ~18 and 299-E33-343 at ~55 in CY 2010). Thus, the elevated contamination at wells 299-E33-339 and 299-E33-49 may have been associated with various sources. Figure 9-8 provides one conceptual model of a possible density plume extending from the BY Cribs. The location of the cross section provided in Figure 9-8 is shown on Figure 9-2. In conclusion, the elevated nitrate concentrations at wells 299-E33-339 and 299-E33-49 may be associated with some unknown release near these wells (as stated above) or possibly associated with a density plume, or a combination of sources. Although the depth-discrete data do not provide sufficient information to conclude a source for the elevated nitrate concentrations observed at wells 299-E33-339 and 299-E33-49, no known sources of technetium-99 activities to the south of these wells exist to source the activities found in these wells. Thus, it is possible that a portion of some density plume from the north migrated south of these wells in the past and is now moving back to the north in accordance with the northerly flow regime.

The 2010 nitrate concentration reported at well 699-49-57A, located north of 200 East Area, was 269 mg/L, which is 46 mg/L higher than in April 2009 (223 mg/L). This was the first significant nitrate increase since 2006 in this well.

As discussed in previous annual reports, the nitrate plume from WMA B-BX-BY and surrounding waste sites extends to the northwest beyond the 200 East Area. The primary stratigraphic unit north of the B and BX Tank Farms and to the northwest toward well 699-49-57A is interpreted as the Cold Creek unit/Hanford formation. A recent interpretation of sediments from the two new RI wells 699-48-50B and 699-50-56, north of the 200 East Area, were used to define a low-permeability paleochannel of Ringold sediments in this area (Figure 6.3 in PNNL-19702). This paleochannel apparently runs in a northwest direction just north of the Cold Creek/Hanford formation, north of the 200 East Area. The lower permeability of

the Ringold sediments versus the Cold Creek/Hanford sediments creates an apparent preferential flow path toward well 699-49-57A and to the northwest. The nitrate concentration reported at well 699-49-57A was 269 mg/L, which is 46 mg/L higher than in April 2009 (223 mg/L). This was the first significant nitrate increase since 2006 in well 699-49-57A. The estimated northerly extent of the 45 mg/L (DWS) contour is between wells 699-49-57A and 699-55-60A (Figure 9-7).

The future flow path between wells 699-49-57A and 699-55-60A is in question due to the continuing water table decline and the apparent limit of aquifer thickness. Historical groundwater elevation plots between wells north and south of this basalt high indicate that groundwater flow through this paleochannel may be "cut off" at a certain elevation as the water table declines (Figures 9-9 and 9-10). Figure 9-9 shows the conceptual model of the aquifer thickness extending between wells 699-49-57A and 699-55-60A. The location of the cross section in Figure 9-9 is shown in Figure 9-3. Figure 9-10 shows the water-level trends at wells 299-E33-18 and 699-60-60. Well 299-E33-18 is located just north of the B Tank Farm, and the water level began to increase significantly in the latter part of 1955, when the water level at well 699-60-60 reached ~121.6 meters. Well 699-60-60 is located north of well 699-55-60A and the basalt high (Figure 9-9). As of September 2010, the groundwater elevation in well 699-60-60 was 121.76 meters. Based on data discussed in this subsection, the groundwater near WMA B-BX-BY appears to continue moving to the northwest.

9.1.1.2 216-B-62 Crib and North to Low-Level Waste Management Area 1

For the past 10 plus years, nitrate has been detected at levels exceeding the 45 mg/L DWS in well 299-E28-18, which monitors the 216-B-62 Crib (Figure 9-7). Nitrate concentrations were over 200 mg/L in the mid-1970s to early 1980s and have recently been approaching these levels again. Samples for this well were not collected during 2010 due to the work stoppage; however, increases were expected based on increases in wells 299-E28-26 to the north and the increasing nitrate trend in well 299-E28-18 (Figure 9-11).

Nitrate concentrations near the 216-B-12 Crib were reported as high as 828 mg/L.

The source of nitrate for wells 299-E28-18 and 299-E28-21 was initially thought to be the 216-B-62 Crib; however, the only waste site with significant nitrate inventory in this area is the 216-B-12 Crib (Appendix C of RPP-26744, *Hanford Site Soil Inventory Model, Rev. 1*). Supporting evidence for identifying the 216-B-12 Crib as the source is the elevated nitrate detected in CY 2010 in the aquifer to the southeast of this crib. Depth-discrete analytical results for nitrate at 7.6 meters below the water table during drilling of new 200-BP-5 RI well 299-E28-30 were 828 mg/L (Figure 9-12).

Figure 9-12 provides a conceptualization of the nitrate plume at depth extending toward well 299-E28-26. The location of the cross section in Figure 9-12 is shown in Figure 9-2. The rational for this model is based on the following: (1) the apparent widespread nature of elevated nitrate beneath the 216-B-12 Crib based on results from wells 299-E28-18, 299-E28-30, and 299-E29-54; (2) the dominant north-northwest flow over the past couple decades since termination of discharges to Gable Mountain Pond; (3) the northerly gradient determination in this area (discussed in Chapter 3.0, Section 3.2); and (4) the nitrate trend concentration increases at well 299-E28-26 to the northwest along the south side of LLWMA-1 (Figure 9-11). Another supporting factor is the increased tritium activity in well 299-E28-26, which is a co-contaminant associated with nitrate from the 216-B-12 Crib. The model is discussed in more detail below.

The conceptual model is based on several factors, beginning with the sharp increase in nitrate in the early 1970s shortly after discharges resumed to the 216-B-12 Crib. The nitrate trend plots for wells 299-E28-9 and 299-E28-16, both located near the 216-B-12 Crib, show the change in concentrations between 1960 and present (Figure 9-13). The nitrate trend plots for these wells and the information provided previously in this subsection indicate nitrate infiltration into the groundwater from the 216-B-12 Crib occurred as early as the 1970s. Continued infiltration from the vadose zone through the late 1970s, and possibly into the 1980s, is thought to have driven contamination into the deeper aquifer sediments based on the depth-discrete groundwater samples collected at new 200-BP-5 RI wells 299-E28-30 and 299-E29-54. Although the extent of infiltration into the aquifer during the 1970s and 1980s is unknown, similar depth-discrete profiles at wells 299-E28-30 and 299-E29-54 indicate that contamination migrated to the east in the past. The vertical concentration profile for new well 299-E28-30 is provided in Figure 9-12. Wells to the south (299-E28-6, 299-E28-13, and 299-E28-17) do not provide nitrate results near the concentrations seen in well 299-E28-18 or in the depth-discrete sample results from wells 299-E28-30 and 299-E29-54. Wells 299-E28-30 and 299-E29-54 share the same contaminants (nitrate, tritium, and uranium) with elevated concentrations of these contaminants at the same depths.

The model continues with the termination of discharges to the Gable Mountain Pond, which caused residual contaminants to migrate to the northwest. Vertical heterogeneity in the aquifer sediments allowed preferential migration from the more permeable sediment horizons. This is likely best displayed in the variability associated with the depth-discrete results at wells 299-E28-30 and 299-E29-54. Only well 299-E28-30 is shown in Figure 9-12, but the vertical distribution in 299-E29-54 is similar. Continuing with the model description, the continued flow to the north over the past couple decades has created contaminant spreading to the north. It is assumed that elevated contaminant concentrations in the tighter sediment horizons have leached into the Hanford sediments to the north (Figure 9-12).

The primary stratigraphic units represented in Figure 9-12 are discussed in this paragraph. The Ringold Formation unit 9A appears just above the aquifer near well 299-E28-30 and extends throughout most of the saturated thickness overlying a thin layer of Ringold unit 9B (mud) and an approximate 6.1 meters of Ringold unit 9C (PNNL-12261, plate maps 3, 4, and 5). North of well 299-E28-30, the Ringold unit 9A is truncated by glaciofluvial Hanford sediments that overlie the Ringold unit 9C. The change in hydraulic conductivity of these two formations ranges from an order of magnitude to several orders of magnitude (PNNL-12261). It is believed that nitrate is migrating from the Ringold unit toward the Hanford sediments and is the reason for continued elevated concentrations to the north beneath the 216-B-62 Crib and along the southeast side of LLWMA-1.

A 450 mg/L contour map is provided around well 299-E28-30 in Figure 9-14 because the annual average plume map (Figure 9-7) does not show this plume configuration. The reason the plume is not shown in Figure 9-7 is because the annual average plume maps are designed to show elevated plumes within the upper portion of the aquifer. The 450 mg/L contour map is based on vertical sampling data collected at ~7.6 meters into the aquifer in CY 2010 at wells 299-E28-30 and 299-E29-54. The vertical sampling data for these two wells are also not posted on the annual average maps because vertical sampling data during drilling are not always comparable to routine samples from completed and developed wells. However, comparative duplicate sample results for wells 299-E28-30 and 299-E29-54 at

~7.6 meters in the aquifer indicate that the elevated nitrate results reported above are good. Therefore, a 450 mg/L contour map was added so this area would be noted as having elevated nitrate contamination (greater than ten times the DWS). Data from two adjacent wells (e.g., 299-E28-13 and 299-E28-18) were also used to construct the contour because these wells are screened 6+ meters into the aquifer.

Over the past couple of decades, the prevailing groundwater flow direction near LLWMA-1 has been to the northwest (see Chapter 3.0, Section 3.2). Nitrate concentrations in wells along the western boundary of LLWMA-1 ranged from 46.9 to 82.3 mg/L during 2010, with the highest concentrations in well 299-E32-7. High concentrations were also found in well 299-E28-27 (the southeast corner of LLWMA-1) where concentrations ranged between 95.2 and 100 mg/L in CY 2010.

9.1.1.3 Grouped Wells 699-53-55A, B, and C Near Gable Mountain/ Gable Butte Gap

The cluster of wells 699-53-55A, B, and C are located in an area where a basalt window exists, west of Gable Mountain Pond (Figure 9-7). The term "basalt window" was applied because of the irregular erosion of the Elephant Mountain Member of the Saddle Mountains Basalt exposing and interconnecting the underlying Rattlesnake Ridge interbed. The three wells are screened across the bottom, middle, and top of the unconfined aquifer in this area, respectively (Figure 9-15). The location of the cross section in Figure 9-15 is shown in Figure 9-3. The aquifer is ~42.7 meters thick, comprised of ~21.3 meters of Hanford sediments, overlying ~21.4 meters of Rattlesnake Ridge interbed. Well 699-53-55A is screened below the base of the aquifer, which is more than 42.7 meters beneath the water table within the Pomona basalt but appears to be hydraulically connected to the bottom of the Rattlesnake Ridge interbed through a sand and gravel pack around the screen that appears to extend above the top of the Pomona basalt. Well 699-53-55B is screened ~15.3 to 21.3 meters below the water table, and well 699-53-55C is screened across the upper portion of the aquifer.

The difference in hydraulic conductivity between these two units is significant, with the Hanford formation ranging between ~500 to 2,700 meters per day versus the Rattlesnake Ridge interbed ranging from 0.01 to 10 meters per day. The range of the hydraulic conductivities for the Hanford formation in this area is based on a 4-day aquifer constant discharge test at well 699-55-50 and an 8-day aquifer constant discharge test at well 699-62-43 documented in *Hydraulic Characteristics of Hanford Aquifers* (HW-48916). The range of the hydraulic conductivity for the Rattlesnake Ridge interbed was derived from various test described in *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site* (RHO-RE-ST-12P).

Nitrate concentrations were slightly higher in wells 699-53-55B&C than last year (141 and 143 mg/L versus 142 and 151 mg/L for 2009 and 2010, respectively). The 2010 nitrate concentration in well 699-53-55C is the highest concentration historically reported in this well. The nitrate concentrations exceeding the DWS are limited to the Hanford formation sediments, as displayed in the cross section in Figure 9-15.

The nitrate plume at wells 699-53-55B&C is considered to have originated at the BY Cribs.

The source of the nitrate plume at wells 699-53-55B&C originated at the BY Cribs. During the early 1990s, the BY Cribs nitrate plume was shown centered around well 699-50-53A, ~1,000 meters south of well 699-53-55 (DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*). Groundwater sample results at well 699-53-50A in the early 1990s reported nitrate concentrations exceeding

600 mg/L. A recent geologic study of the area revised the basalt surface interpretation east of well 699-50-53A (PNNL-19702). The new interpretation used previous conceptual interpretations of folding and erosion and later deposition associated with formation of a paleochannel during the early to late Pleistocene to extend a channel between wells 699-50-53A and 699-53-55C (Figure 6.3 in PNNL-19702). As a result, the depositional sediments associated with the paleochannel provide a reasonable pathway for migration of the nitrate plume from well 699-50-53A to wells 699-53-55B&C. A distinctive characteristic linking the contamination in wells 699-50-53A and 699-53-55C (other than technetium-99, nitrate, and cyanide) is the lack of iodine-129. The contaminant plume near well 699-49-57A contains iodine-129; the lack of iodine-129 at wells 699-50-53A and 699-53-55C provides the rationale for separating the two plumes. Data from the 1950s indicate that the nitrate plume from the BY Cribs migrated to well 699-50-53A during this time. Continued migration northward was apparently hydraulically blocked by Gable Mountain Pond discharges until 1987, when discharges to the pond were terminated. After Gable Mountain Pond discharges terminated, the preferential pathway from the 200 East Area to Gable Gap was to the northwest through well 699-49-57A. Thus, when iodine-129 began migrating to the north shortly after discharges to Gable Mountain Pond were terminated from sites in the northern portion of the 200-PO-1 OU, it appears the iodine-129 stayed in the pathway toward well 699-49-57A; mixing between this plume and the plume at 699-50-53A has not been seen. Further discussion on the iodine-129 plumes is provided in Section 9.1.2.

The water-level elevations are currently consistently higher in well 699-53-55A than well 699-53-55B (indicating upward groundwater movement), while nitrate concentrations continue to increase in well 699-53-55A. Nitrate concentrations in upgradient wells within the Rattlesnake Ridge interbed have been and are significantly lower than the concentration in this well for CY 2010. Well 699-53-55A has an outer casing wall that is perforated from 49.7 to 94.5 meters below ground surface (bgs) where it terminates near the Pomona basalt. A 3.05-meter-thick cement cap is located at 81.4 meters bgs. The cement cap is located between the outer 8-inch casing and an inner 2-inch casing. A sand pack is located beneath the cement cap, extending 2.4 meters into the top of the Pomona basalt. A gravel pack is below the sand pack, which extends to the screen associated with the 2-inch casing, assumed to be 100.6 to 102.1 meters bgs. It is uncertain why nitrate is increasing in this well when upgradient wells have had (and continue to have) much lower concentrations, and the most prominent source of elevated nitrate would have to migrate downward through the low-permeability Rattlesnake Ridge interbed sediments against an upwelling flow regime. An alternative migration pathway to the pump may be through perforations in the outer 8-inch casing of well 699-53-55A, which extend from the upper portion of the aquifer. After entering through these perforations, elevated nitrate concentrations may slowly migrate toward the pump during purging, either through a fractured cement plug or compromised 2-inch inner casing joints; regardless, it appears that the elevated concentrations in well 699-53-55A are from faulty well control rather than from the bottom of the aquifer within the Rattlesnake Ridge interbed sediments. Decommissioning of this well is recommended.

The plume configuration within the Hanford sediments is currently defined to extend toward the northwest based on nitrate concentrations in wells 699-55-57, 699-57-59, and 699-59-58 (Figure 9-7). Use of well elevations to triangulate a groundwater gradient in this area appears to be affected by possible errors associated with well elevation surveys, measurement error, and in some cases possibly well

deviation from vertical as wells have not been gyroscopically surveyed. Triangulation results generally derive a west flow direction from well 699-53-55C rather than a northwest flow direction as defined by the nitrate concentrations in the wells discussed above. Determining a flow rate with suspect well elevations is not recommended and, therefore, is not provided in this area.

9.1.1.4 Gable Mountain Pond Area

The highest average nitrate concentration reported near Gable Mountain Pond was from well 699-53-48A at 141 mg/L. This well is located beneath the southeastern portion of the inactive pond that has been dry since the late 1980s (Figure 9-7). The nitrate concentration in this well decreased ~32 mg/L since last year. During the past 2 years, concentrations did not change much in this well; however, the concentration decreased significantly during the prior 10 years. The stabilization of the nitrate concentrations over the past couple of years may have been associated with the high spring Columbia River elevations over the past couple years starting in 2008 and extending to 2009. Sampling of this well has been completed in June since 2005. In addition, this well screen only extends ~ 0.3 to 0.6 meters into the aquifer characterized as broken basalt.

Further to the northwest in well 699-54-49, nitrate concentrations are lower and have remained about the same over the previous 5 years. For this reporting period, the nitrate concentration in well 699-54-49 was 46.9 mg/L, which is the same concentration observed last year. Still further to the northwest in well 699-55-50C (located near the northwest end of Gable Mountain Pond), the nitrate concentration was 6.82 mg/L for the reporting period. This concentration is consistent, but slightly lower, compared to the concentrations reported over the previous 6 years. Based on these results, no change was observed in the plume configuration in this area. It should be noted that well 699-54-45A (located east of Gable Mountain Pond and screened in the Ringold Formation mud unit) continues to be reported at near detectable concentrations for nitrate (0.81 mg/L) and constrains the eastern boundary of the plume.

The flow rate near Gable Mountain Pond may range between 10 to 53 meters per year.

As depicted in Figure 9-7, the basalt rises above the water table along the south side of Gable Mountain Pond, confining the plume in this direction. The aquifer to the east is contained within the Ringold Formation mud unit and portrays a groundwater flow direction to the west. Beneath the east side of Gable Mountain Pond, the Ringold Formation mud unit is truncated by the highly permeable Hanford formation. Groundwater elevation measurements in July 2010 between wells 699-55-50C and 699-57-59 provided a gradient of 1.1×10^{-5} to the west. Based on the range of hydraulic conductivity (Section 9.1.1.3), the flow rate in this area may range between 10 to 53 meters per year. These wells have not been surveyed with the accuracy as described in Chapter 3.0, Section 3.2; therefore, the flow rate is an approximation.

9.1.1.5 B Plant Area

As discussed in Section 9.1.1.2, elevated nitrate was detected in three wells near B Plant: 299-E28-6, 299-E28-17, and 299-E29-54. The contaminants in these wells are considered to have originated at the 216-B-12 Crib because of the lack of nitrate inventory from other waste sites. Eight other waste sites in the area have a combined total of 2,229 kilograms of nitrate (Appendix C in RPP-26744). The only other waste site in the area with significant inventory is the 216-B-6 injection well with an inventory of 58,373 kilograms of nitrate, which is small compared to the 2,860,615 kilograms of nitrate received at the 216-B-12 Crib.

9.1.1.6 216-B-5 Injection Well and 216-B-9 Crib

Only well 299-E28-25 was sampled near the 216-B-5 injection well for nitrate during the reporting period. The other three results are associated with sampled collected during CY 2008 and CY 2009. The 59.8 mg/L concentration in well 299-E28-25 is consistent with results from the previous 3 years and much less than the FY 2006 result of 166 mg/L, which was flagged as suspect. Nitrate concentrations at well 299-E28-25 have shown an increasing trend since 1995, when groundwater flow in the area appeared to be faster. Further north, well 299-E28-2 reported results similar to those of previous years, with an increasing trend similar to well 299-E28-25. Because of the lack of results to the northwest and southeast of well 299-E28-25, it is difficult to determine the exact extent of nitrate near the 216-B-5 injection well and whether the elevated concentration in well 299-E28-25 is associated with migration from a distal source, proximal source, or a combination of both. Due to the consistent concentrations in this well, the nitrate plume configuration was not changed in this area from last year. Additional wells have been added to the sampling schedule for 2011 to better define the extent of the plume around this waste site.

The highest quarterly nitrate concentration at WMA C for CY 2010 was reported from well 299-E27-14 at 101 mg/L.

9.1.1.7 Waste Management Area C Area

Groundwater analyses from four wells at WMA C had nitrate concentrations exceeding the DWS in CY 2010. Two of the wells, 299-E27-14 and 299-E27-24, are located on the southeast side of the WMA. The highest quarterly nitrate concentration for CY 2010 was from well 299-E27-14 at 101 mg/L (Figure 9-16). This well is screened across the upper 2.6 meters of the aquifer. The next highest nitrate concentration, 73 mg/L, was collected at new well 299-E27-24, located ~61 meters south of well 299-E27-14. The sample was collected just above the basalt during depth-discrete sampling while drilling. Well 299-E27-24 is now screened across the lower 6.1 meters of the aquifer, with the top of the screen ~9 meters below the water table. The position of the well screen was based on elevated cyanide concentrations found in the deeper portion of the aquifer during drilling. Finding cyanide at the base of the aquifer supports the concept of downward contaminant migration. The base of the well screen is just above the basalt, ~15.5 meters below the water table. December 2010 sample results from this well returned a nitrate concentration of 68.2 mg/L.

Nitrate concentrations began to increase in well 299-E27-14 in fall 1998. Concentrations have continued to trend upward since that time (Figure 9-16). It is postulated that the increased nitrate concentrations are associated with infiltration from the vadose zone beneath the C Tank Farm. A determination was made during an ongoing groundwater assessment at WMA C that groundwater has been impacted by the C Tank Farm based on the presence of the dangerous waste constituent cyanide (Section 9.3.4). The assessment was initiated because of the statistically significant increase of specific conductivity at well 299-E27-14. The sharp fluctuations in the nitrate trend at well 299-E27-14 appear to indicate a nearby point of infiltration (Figure 9-16). Additional evidence of a local source of infiltration is the lower nitrate concentrations in upgradient wells to the north of well 299-E27-14. A third line of evidence is the lower nitrate concentration reported in the downgradient well 299-E27-24, ~61 meters south of well 299-E27-14.

As previously discussed, the highest nitrate concentration in well 299-E27-24 was found at the bottom of the aquifer. This determination was based on depth-discrete groundwater samples collected at 3.9, 10, and 15.5 meters in the aquifer during

drilling. The increased nitrate with depth is not uncommon in the other WMA C wells. Depth-discrete samples collected during drilling or using the SPYDER sampler in existing wells have shown increased nitrate with depth in all seven of the deep wells at WMA C; the SPYDER sampler is discussed in additional detail in Section 9.1.3.3. The other two wells with elevated nitrate concentrations exceeding the DWS in CY 2010 were also associated with groundwater samples collected at 9.1 meters or more below the water table.

9.1.2 Iodine-129

Iodine-129 analyses were performed on groundwater samples at least once from 96 wells across the 200-BP-5 OU. Sampling at five wells (299-E28-5, 299-E28-6, 299-E28-18, 299-E33-16, and 299-E33-26) was missed due to the work stoppage. Sampling at well 299-E33-7 was missed due to insufficient water, and sampling at well 299-E33-43 was missed due to scheduling oversight. The missed well results did not affect the plume configuration, as most of these wells are adjacent to other wells with data available for CY 2010. Sampling at well 299-E28-6 was missed, with no proximal well; however, the well has been below the DWS and was assumed to be below the DWS this year. Figure 9-17 shows the distribution of iodine-129 above the 1 pCi/L DWS. The plume did not change significantly from 2009.

Sources in the northern portion of the 200-PO-1 OU are likely responsible for the widespread distribution of iodine-129 within the 200-BP-5 OU.

A historical evaluation of iodine-129 in the 200 East Area was completed during preparation of the draft 200-BP-5 RI in 2010, which provided an understanding of the most likely sources and current distribution. Three sources (216-A-10 Crib and vicinity, 216-A-29 Ditch, and the southeast end of the 216-B-3 Pond) in the northern portion of the 200-PO-1 OU are likely responsible for the widespread distribution of iodine-129 within the 200-BP-5 OU. Historical review of the plume indicates groundwater migration from the southern portion of the 200 East Area to the northwest and into Gable Gap during the late 1980s and early 1990s. A potential source of iodine-129 in the 200-BP-5 OU is the 241-BX-102 unplanned release site. Observations over the past several years indicate little change in plume configuration. Since the primary sources are associated with the 200-PO-1 OU, the order of discussion below follows a sequence of the nearest sites (e.g., southerly) to the furthest sites (e.g., northerly) to portray the decreased activities with distance. Five primary areas are discussed regarding iodine-129 activities above the DWS during this monitoring period:

- Wells monitoring WMA C
- Wells monitoring B Pond
- Wells monitoring LLWMA-2 and west of LERF
- Wells at the B Complex and extending northwest beyond well 699-49-57A
- Wells monitoring the 216-B-5 injection well and 216-B-9 Crib.

9.1.2.1 Waste Management Area C Area

All of the wells at WMA C sampled for iodine-129 had reported activities exceeding the DWS. The highest activity this year was in well 299-E27-13 (6.14 pCi/L), located on the west side of the tank farm. The activities in the four wells sampled this year ranged from 4.23 to 6.14 pCi/L. Historically, activities have fluctuated, but not much decrease has been noted over the past two decades.

9.1.2.2 B Pond Area

Eleven wells are located near the B Pond in the 200-BP-5 OU. Four of these wells had detectable iodine-129 concentrations during CY 2010. The highest activity was

in well 699-45-42 (1.96 pCi/L), which was a significant decrease from 3.16 pCi/L reported last year. This well, and all of the 200-BP-5 OU wells monitoring B Pond, is located on the east side; the higher concentrations are located on the west side of the pond in the 200-PO-1 OU. The other three results were below the 1 pCi/L DWS.

9.1.2.3 Low-Level Waste Management Area 2

Elevated iodine-129 activities have been detected in the wells along the south side of LLWMA-2 since monitoring began in the early 1990s. The highest activity was in well 299-E27-10 when sampling began. Since 2003, the highest activity has been in well 299-E27-9 until this year, when higher activity was reported in well 299-E27-8, west of well 299-E27-9. The highest activity result in this well was 2.48 pCi/L from the December sampling event, which is an increase of 0.5 pCi/L since October 2009. Historically, activities have not shown much fluctuation or decrease within wells 299-E27-8, 299-E27-9, and 299-E27-11.

Last year, the most probable source for the iodine-129 was considered to be the inactive 216-B-2-1 and 216-B-2-2 Ditches. However, review of iodine-129 inventory versus liquid volume (RPP-26744) indicates that any iodine-129 from these ditches should not be detectable in the groundwater.

9.1.2.4 216-B-5 Injection Well and 216-B-9 Crib Area

The highest iodine-129 activity (1.71 pCi/L) at this location during this reporting period was ~1 meter from the 216-B-5 injection well at well 299-E28-25. The activity in this well has shown a constant decreasing trend since monitoring began for iodine-129 in this well in 1994. Well 299-E28-25 is a key well for defining the western edge of the 1 pCi/L isopleth because wells to the west have lower activity than the DWS, including the depth-discrete results at well 299-E29-54 at B Plant. One elevated concentration was noted in the depth-discrete samples collected during drilling at well 299-E28-30 (adjacent the 216-B-12 Crib), but the result was the only detected value and is suspect at this time. Higher activity is found to the north near WMA B-BX-BY.

9.1.2.5 Wells at the B Complex and Extending Northwest Beyond Well 699-49-57A

The highest iodine-129 activity in WMA B-BX-BY was from new investigation/monitoring well 299-E33-343 (4.38 pCi/L in May 2010), located adjacent the northwest corner of B Tank Farm and northeast of the 241-BX-102 tank release. Last year it was difficult to discern what source(s) contributed to this plume; however, based on evaluation during the RI, the majority of iodine-129 is considered to be from past sources south of the 200-BP-5 OU. The 241-BX-102 unplanned release may also contribute due to the iodine-129 activity in the perched water zone and the inventory associated with the unplanned release versus other nearby sources. Historically, the activity in this area (as portrayed in wells 299-E33-16 and 299-E33-18) has fluctuated but has not shown much decrease.

The iodine-129 groundwater plume continues from WMA B-BX-BY and extends toward the northwest to Gable Gap (see Section 9.1.1.1 for details on flow regime). The 1 pCi/L (DWS) leading contour is shown between wells 699-57-59, 699-59-58, and 699-61-62 (Figure 9-17). The 1 pCi/L iodine-129 contour (Figure 9-17) extends further west than supported by the average activities from well 699-55-60A (see Figure 9-3 for location of well 699-55-60A). The rationale for extending the contour west and northwest of this well is based on the screen position of well 699-55-60A, the erosion of the basalt at depth near well 699-55-60A, and the iodine-129 activity

in wells to the north. Well 699-55-60A is screened deeper in the aquifer (5.18 to 17.37 meters) than wells to the north. It is interpreted that the activity in this well is associated with the dispersed portion of the plume at depth. The thickness of the aquifer contributes to this interpretation, as the aquiver may be only a couple of meters or less within the paleochannel northwest of well 699-49-57A and thickens to more than 33.5 meters near well 699-55-60A. Therefore, the 1 pCi/L contour is continued through this area based on higher interpreted activity near the water table.

9.1.3 Technetium-99

Technetium-99 analyses were performed on groundwater samples at least once from 130 wells across the 200-BP-5 OU. All of the 200-BP-5 OU required wells were sampled at least once in accordance with DOE/RL-2001-49.

The distribution of technetium-99 above the 900 pCi/L DWS was limited to three isolated regions in the 200-BP-5 OU during CY 2010 (Figure 9-18):

- Wells at the B Complex and extending northwest beyond well 699-49-57A
- Grouped wells 699-53-55A, B, and C near Gable Gap
- Wells at WMA C.

9.1.3.1 Wells at the B Complex and Extending Northwest Beyond Well 699-49-57A

The highest technetium-99 activity in the 200-BP-5 OU continued to be reported in wells monitoring the BY Cribs.

The highest technetium-99 activity in the 200-BP-5 OU continued to be reported in wells monitoring the BY Cribs. Five wells were sampled beneath or adjacent to the BY Cribs in CY 2010: 299-E33-3, 299-E33-7, 299-E33-38, 299-E33-341, and 299-E33-342. Three of the wells were sampled quarterly: 299-E33-38, 299-E33-341, and 299-E33-342. The highest activity (38,000 pCi/L) was at well 299-E33-7 in February 2010; this value was 1,000 pCi/L higher than the previous year and was the highest activity ever reported at this well. Activities for wells at the BY Cribs (sampled quarterly) were lower at the end of the year versus the beginning of the year. The decreases ranged from 2,000 to ~9,000 pCi/L and appear to be associated with increased groundwater flow compared to the last couple of years when the flow was apparently slower due to changing flow direction in 2008 and 2009.

The density of the liquid waste received by the BY Cribs appears to have been a reason for past contaminant migration into the upper basalt-confined aquifer, the Rattlesnake Ridge interbed, at well 299-E33-12. Past reports attribute the source of contamination in well 299-E33-12 with the BY Cribs and poor well construction during early Hanford Site operations. A higher hydraulic head has continually been present in the confined aquifer versus the unconfined aquifer, indicating an upward flow regime between the confined and unconfined aquifers (Figure 9-19). Cobalt-60, iron, nitrate, and technetium-99 previously exceeded their respective DWSs in well 299-E33-12. The well seal was remediated in 1979 and appears to have sealed the intercommunication between aquifers. Technetium-99 is currently the only contaminant that still exceeds the DWS (1,200 pCi/L). Two new 200-BP-5 RI wells, 299-E33-50 and 299-E33-340, were installed to assess the groundwater in the Rattlesnake Ridge interbed in the upgradient and downgradient directions, respectively, from well 299-E33-12. Neither of the new wells exhibited technetium-99 activites exceeding the DWS in CY 2010. Technetium-99 activities in downgradient well 299-E33-340 ranged between nondetect and 26.6 pCi/L. The technetium-99 activity in this well decreased during the year. The previous high level of technetium-99 in this well appeared to be associated with leakage from the unconfined aquifer during drilling rather than from migration associated with well 299-E33-12.

Technetium-99 in well 299-E33-50 during CY 2010 was reported at an activity of 250 pCi/L in one sample and 46.1 pCi/L in a duplicate sample. Based on 3 years of previous results at well 299-E33-50 with no result above 43 pCi/L (in nine samples), the 250 pCi/L result was flagged as suspect. Suspect results are re-evaluated for possible changes when future results become available. Based on the current history of results in these three wells, the original contaminants near well 299-E33-12 appear localized and are dispersing under natural hydraulic conditions.

Near the B and BX Tank Farms, technetium-99 trends for wells 299-E33-41, 299-E33-339, and 299-E33-343 are similar over the last 3 years since well 299-E33-343 was installed. In May 2009, the elevated activity in well 299-E33-339 was attributed to infiltration of residual waste from the 241-BX-102 unplanned release and south flow due to a flow reversal. Activity in each of these wells was highest in the early part of the year and continued to decrease throughout the year (Figure 9-20). The technetium-99 trend appears to be consistent with the perceived flow direction to the north during CY 2010. The technetium-99 trend shows a significantly smaller increase in well 299-E33-339 in early CY 2010 than the nitrate trend. More specifically, the technetium-99 increase in early 2010 was about six times less than the peak in mid-2009. By comparison, the nitrate peak in early 2010 was nearly the same concentration as seen in the peak of 2009. The nitrate trend for well 299-E33-339 is discussed in Section 9.1.1.1. Because sources of high nitrate to the north of well 299-E33-339 are also associated with technetium-99, depth-discrete samples were collected from wells 299-E33-339 and 299-E33-49 along the south side of the BX Tank Farm to investigate a possible density conceptual model. The conceptual model and the results of the investigation are briefly discussed below.

In CY 2010, depth-discrete sampling was completed in wells 299-E33-339 and 299-E33-49 to evaluate a density theory based on the high specific gravity waste from the BY Cribs and 241-BX-102 unplanned release. The specific gravity of the neutralized metal waste was documented as 1.25 g/cc (HW-23043), which was slightly higher than the density of the waste released to BY Crib (at 1.21 g/cc) (WHC-SD-EN-TA-003). The conceptual model being investigated was associated with the specific gravity of the residual metal waste and/or BY Crib waste possibly causing the contaminants to sink when reaching the aquifer.

Depth-discrete groundwater samples did not find significant variation in technetium-99 activities with depth in well 299-E33-339. However, further to the west in well 299-E33-49, an activity an order of magnitude higher was reported for a sample collected at the bottom of the aquifer versus a sample collected ~2 meters above the bottom of the aquifer (e.g., 12,300 to 346 pCi/L, respectively); even lower activity was reported in the shallower samples at this well. Although the nitrate and technetium-99 analytical results from the bottom of the aquifer collected from well 299-E33-49 do not appear sufficient for a density plume, the stratification of the contamination is interesting (see discussion in Section 9.1.1.1 for nitrate stratification). It could be speculated that the depth-discrete results at well 299-E33-49 may represent the disperse fringe of such a plume rather than the center of a possible density plume.

The ratio for technetium-99 to nitrate was also compared to groundwater results at wells near both the BY Cribs and the 241-BX-102 unplanned release. The technetium-99 to nitrate ratio at well 299-E33-49 was 33.2, which is between the ratios at the two sources (e.g., BY Cribs ~18, and 299-E33-343 ~55 in CY 2010). Thus, the elevated contamination at wells 299-E33-339 and 299-E33-49 may have been associated with various sources. Figure 9-8 provides one conceptual model of

a possible density-driven flow regime extending from the BY Cribs. The conceptual model shown in Figure 9-8is associated with nitrate results, not the technetium-99 results. The technetium-99 trend associated with standard monitoring results at wells 299-E33-339 and 299-E33-49 did not increase, which differed from the nitrate concentrations discussed above. Therefore, the elevated nitrate concentrations at wells 299-E33-339 and 299-E33-49 may be associated with some unknown release near these wells (Section 9.1.1.1). However, the technetium-99 to nitrate ratio at depth in well 299-E33-49 could also indicate a density plume from a northerly source. Evidence for this conclusion is strengthened by the lack of technetium-99 activity from sources to the south. In conclusion, the depth-discrete data do not provide sufficient data to conclude a source for the elevated nitrate or technetium-99 observed at wells 299-E33-339 and 299-E33-49; however, it does not appear to be associated with sources to the south.

The average groundwater flow rate near the B Complex for CY 2010 ranged between 0.75 and 0.78 meters per day.

The technetium-99 plume from the B Complex extends to the northwest beyond the 200 East Area boundary. The northwest average flow gradient from the BY Cribs to the northwest was determined as 2.08×10^{-5}, which is slightly less than the derived regional gradient of 1.5×10^{-5} (Chapter 3.0, Section 3.2). The calculated average flow rate for CY 2010 was 0.78 meters per day (Section 9.1.1.1 provides details on these calculations). Technetium-99 trend results between wells 299-E33-38 and 299-E33-26 were used to confirm the groundwater gradient direction and flow rate (Figure 9-21). Three specific activity changes are correlated in the trend plots. The last correlated change is the peak in February 2009 in well 299-E33-38 and the peak in well 299-E33-26 in February 2010. The ratio of the correlated activities for the three specific activity changes between these wells ranged from ~54% to 63%. The distance between these wells is ~273 meters, and the average flow rate for the most recent correlation is ~0.75 meters per day. This result agrees with the calculated Darcy velocity of 0.78 meters per day.

The apparent increasing flow rate to the northwest in CY 2010 since the reversal back to the north in mid-2009 is reflected in technetium-99 activity increases in well 699-49-57A, located ~1.3 kilometers northwest of the BY Cribs. Activity levels in this well returned to levels consistent with those seen prior to the initial groundwater flow reversal to the south (4,800 pCi/L versus 4,900 pCi/L). The 900 pCi/L (DWS) leading contour is found between wells 699-49-57A and 699-55-60A (Figure 9-18). Further discussion of the flow pathway is provided in Section 9.1.1.1.

9.1.3.2 Grouped Wells 699-53-55A, B, and C Near Gable Gap

The wells cluster 699-53-55A, B, and C is located in an area where a basalt window exists, west of Gable Mountain Pond (now dry) (Figure 9-18). The term "basalt window" was applied because of the irregular erosion of the Elephant Mountain Member of the Saddle Mountains Basalt exposing and interconnecting the underlying Rattlesnake Ridge interbed. The three wells are screened across the bottom, middle, and top of the unconfined aquifer in this area, respectively. Figure 9-15 provides a cross section of the well screen locations but shows nitrate rather than the technetium-99 activities. The aquifer is ~42.7 meters thick, comprised of ~21.3 meters of Hanford sediments overlying ~21.4 meters of Rattlesnake Ridge interbed. Well 699-53-55A is screened below the base of the aquifer, which is more than 42.7 meters beneath the water table within the Pomona basalt, but appears to be hydraulically connected to the bottom of the Rattlesnake Ridge interbed through a sand and gravel pack around the screen that appears to extend above the top of the Pomona basalt. Well 699-53-55B is screened ~15.3 to 21.3 meters below the water table, and well 699-53-55C is screened across the upper portion of the aquifer.

During the reporting period, technetium-99 groundwater activities was reported as slightly lower at well 699-53-55B than at well 699-53-55C (2,700 and 2,800 pCi/L, respectively), which is a 200 pCi/L increase in well 699-53-55B and a 200 pCi/L decrease in well 699-53-55C from CY 2009. The increased activity reported in CY 2010 in well 699-53-55A (130 pCi/L) versus CY 2009 (110 pCi/L) is not considered representative of the deeper aquifer but may instead be associated with poor well construction (see Section 9.1.1.3). Decommissioning of this well is recommended.

The increasing technetium-99 activity at wells 699-53-55B&C has been linked to high technetium-99 activities (up to 30,000 pCi/L) reported in well 699-50-53A before the well went dry in the mid-1990s. The pathway between the two wells was based on similar contaminants at both locations and a revised interpretation of the geology in the area (PNNL-19702). Section 9.1.1.3 provides additional information regarding the transport conceptual model and geologic discussion for the area.

9.1.3.3 Waste Management Area C Area

Seven wells at WMA C were reported with technetium-99 activities exceeding the DWS. Four wells (299-E27-4, 299-E27-13, 299-E27-23, and 299-E27-155) are located along the west to southwest side of the C Tank Farm, and three wells (299-E27-14, 299-E27-21, and 299-E27-24) are located along the south-southeast side of the tank farm. Higher average technetium-99 activities were reported in the west-southwest WMA C wells compared to the south-southeast wells. The highest activity during the reporting period was in well 299-E27-23 (20,800 pCi/L). Figure 9-18 shows the estimated distribution of technetium-99 near the groundwater table in this area. The sample results from the two deep wells (299-E27-24 and 299-E27-155) and depth-discrete sample analyses within two long-screened wells (299-E27-4 and 299-E27-21) within the aquifer are not shown in Figure 9-18 because of the mapping criteria established for this annual report. Based on the elevated results with depth, the technetium-99 plume appears more widespread with depth.

The peak technetium-99 concentration at well 299-E27-23 was determined during depth-discrete sampling at ~9 meters in the aquifer.

The peak technetium-99 activity at well 299-E27-23 was determined during depth-discrete sampling at ~3-meter intervals in the aquifer. Although the highest activity was ~9 meters beneath the water table in well 299-E27-23, the activity was nearly constant at each depth (19,900 pCi/L at 3 meters and 20,500 pCi/L at 6 meters). Depth-discrete samples were also collected at wells 299-E27-4, 299-E27-7, and 299-E27-21. The results from these wells showed increases in technetium-99 with depth. For example, well 299-E27-4 had activities of 727 and 761 pCi/L in the first two intervals but 7,260 pCi/L in the lowest sample interval. Sample collection was completed via low-flow groundwater sample extraction with tubing that extended from the pump to the well screen (e.g., SPYDER sampler; discussed in PNNL-19129, *Discrete Sampling Test Plan for the 200-BP-5 Operable Unit*). The sampling flow rate was calculated between 1.6 to 3.4 milliliters per minute. The tubing was designed to slide against the well screen to maximize water collection from the sand pack. Longer purging durations were completed to draw water from the formation.

The depth-discrete groundwater data, as well as data from routine sampling at wells 299-E27-13 and 299-E27-155, were used to create more detailed technetium-99 isopleth contours for 3 and 9 meters in the aquifer (Figure 9-22). One reason that plume configuration was completed in this manner was based on ion chemistry. The ion chemistry between wells 299-E27-4, 299-E27-21, and 299-E27-23 is similar. In contrast, the ion chemistry in wells 299-E27-155 and 299-E27-14 is significantly different, with higher calcium, chloride, magnesium, and sulfate concentrations

(Figure 9-23). This plume configuration suggests a generally south to southeast flow direction. If the flow is to the southeast, it also follows that technetium-99 may have infiltrated from the vadose zone near wells 299-E27-4 and 299-E27-23. However, vadose zone investigations have not found evidence for significant vadose zone contamination in this area to support this conceptual model. Therefore, an alternative conceptual model is provided below.

The alternative (and not necessarily exclusive) conceptual model is based on the ratio of technetium-99 to nitrate concentration in the wells along the west and southwest side of C Tank Farm. The technetium-99 result was divided by the corresponding nitrate result to create a ratio at each well location for evaluation. Figure 9-24 provides a contour of the ratio results. The contours provide the basis for another model, which conforms to the previous southwest flow direction interpretations at WMA C. Using this basis, the technetium-99 activities associated with the depth-discrete sample results at ~9 meters below the water table were contoured (Figure 9-24). A bias is given to this conceptual model because of similar technetium-99 to nitrate ratios for wells along the east side of the C Tank Farm. The varying technetium-99 to nitrate ratios to the east may also indicate more than one source of groundwater contamination from WMA C. Additional discussion on previous ratio evaluations at WMA C is provided in *Hanford Site Groundwater Monitoring for Fiscal Year 2007* (DOE/RL-2008-01).

9.1.4 Uranium

Uranium analyses were performed at least once from 114 wells across the 200-BP-5 OU. Three wells (299-E28-5, 299-E28-6, and 299-E28-18) were not sampled due to a work stoppage.

Uranium contamination in the 200-BP-5 OU was limited to three isolated regions during 2010 (Figure 9-25):

- Wells at the B Complex and northwest beyond the 200 East Area
- Wells near B Plant, the 216-B-62 Crib, and north to LLWMA-1
- Wells near the 216-B-5 injection well.

9.1.4.1 B Complex and Northwest Beyond the 200 East Area

Well 299-E33-343 (adjacent the northwest corner of B Tank Farm) continues to record the highest groundwater uranium concentration in the 200-BP-5 OU. Groundwater concentrations peaked in February at 3,670 µg/L. During the year, uranium concentrations diminished, and the December 2010 result was 3,220 µg/L.

Uranium isotopic signatures from samples within the vadose zone and within the groundwater demonstrate that the 241-BX-102 tank release is the primary source of uranium in groundwater at WMA B-BX-BY.

Uranium isotopic signatures from samples within the vadose zone at boreholes 299-E33-45 and 299-E33-343 and within the groundwater demonstrate the 241-BX-102 tank release as the primary source of uranium in groundwater at WMA B-BX-BY (PNNL-19277). After uranium enters the groundwater near well 299-E33-343, it migrates predominantly to the northwest. The pathway extends mainly beneath the BY Tank Farm, toward well 299-E33-34 (located beneath the northeast corner of LLWMA-1). The northern extent of the 30 µg/L uranium contour (the DWS) is between wells 299-E33-34 and 699-49-57A (Figure 9-25).

Sharp uranium groundwater concentration peaks have been observed in wells 299-E33-41 and 299-E33-339 over the past couple years. A breakthrough location south of well 299-E33-343 was discussed in last year's annual report (DOE/RL-2010-11) as a possible explanation for the increased concentration at well 299-E33-339. Another explanation for the increase in uranium in this well, also provided last year, was migration due to the groundwater flow reversal and/or

density flow along the basalt at the bottom of the aquifer. Additional discussion of density flow is provided in Sections 9.1.1.1 and 9.1.3.1.

A depth-discrete groundwater sampling investigation completed in CY 2010 did not include uranium at well 299-E33-339 or 299-E33-49. Other constituents did not showed elevated levels at depth within the aquifer in well 299-E33-339; however, depth-discrete samples at well 299-E33-49 (located to the west of well 299-E33-339) did show significant increases in nitrate and technetium-99 concentrations at depth. The ratio of nitrate to technetium-99 at depth in well 299-E33-49 is between the results associated with the BY Cribs and the 241-BX-102 unplanned release. Therefore, it is not clear if uranium associated with the 241-BX-102 unplanned release is associated with the density theory discussed in Sections 9.1.1.1 and 9.1.3.1.

Uranium concentrations in well 299-E33-339 have decreased since May 2009, when the groundwater reversal to the south appeared to be waning and a northerly groundwater flow was being re-established (further discussed in Chapter 3.0, Section 3.2.1). Uranium concentrations have not increased since the return of a northwest groundwater flow, which would suggest that the uranium may not be associated with the density plume speculated for the nitrate and technetium-99 concentrations found at depth in well 299-E33-49. This would mean that the peak concentration in well 299-E33-339 in CY 2009 was likely associated with the flow reversal to the south between 2008 and 2009.

9.1.4.2 216-B-62 Crib and North to Low-Level Waste Management Area 1

Over the past 10 years, uranium has been detected at levels near the 30 µg/L DWS in well 299-E28-18, which monitors the 216-B-62 Crib located northwest of B Plant (Figure 9-25). Uranium concentrations were over 200 µg/L in the mid-1980s but decreased by the late 1980s to levels similar to those reported during CY 2010 (43.7 µg/L).

Elevated uranium appears to extend to the northwest, north, and northeast of the 216-B-12 Crib.

Well 299-E28-21 also monitors the 216-B-62 Crib but is located northwest of well 299-E28-18. Uranium concentrations have been decreasing at this well since initial high values were observed in the mid-1980s. The CY 2010 uranium concentration in well 299-E28-21 was 10.7 µg/L.

The source of uranium for these wells (299-E28-18 and 299-E28-21) was initially linked to the 216-B-62 Crib; however, the only waste site with significant uranium inventory is the 216-B-12 Crib located southeast of the 216-B-62 Crib (Appendix C in RPP-26744). Supporting evidence for the 216-B-12 Crib as the source of elevated uranium in the aquifer is provided by the elevated analytical results from depth-discrete samples collected during drilling near this crib. Approximately 35 µg/L of uranium was reported for a sample collected 7.6 meters below the water table. Elevated uranium is interpreted to extend to the northwest, north, and northeast from the 216-B-12 Crib at depth within the aquifer, similar to the discussion provided for nitrate in this area in Section 9.1.1.2. The depth-discrete uranium concentrations at the new RI well 299-E28-30 near the 216-B-12 Crib are not shown in Figure 9-25 (for the same reasons provided in Section 9.1.1.2 for nitrate).

The prevailing groundwater flow direction near LLWMA-1 has been to the north-northwest over the past couple of decades. Previous uranium groundwater concentrations were observed to migrate from near wells 299-E28-18 and 299-E28-21 to the north-northwest. The elevated uranium concentrations along the western side of LLWMA-1 show the northwest extent of the migration. In CY 2010, uranium concentrations in wells along the western boundary of LLWMA-1 ranged from less than 3 µg/L to 19.5 µg/L, and the highest concentration was in well 299-E32-7. Higher

concentrations are also found in well 299-E28-27 (southeast corner of LLWMA-1), where the December 2010 value was 27 µg/L.

9.1.4.3 216-B-5 Injection Well Area

The 216-B-5 injection well is located northeast of B Plant (Figure 9-25). A small uranium plume has been reported since groundwater monitoring began at the injection well approximately three decades ago. The highest uranium concentration (22.9 µg/L) for CY 2010 was at well 299-E28-25, located ~7 meters to the northwest of the injection well. Uranium concentrations have been decreasing at the monitoring well (near injection well 299-E28-23) and to the south (well 299-E28-24) over the past 3 years; however, concentrations in well 299-E28-25 to the northwest have increased during this timeframe. All results are currently below the DWS. The increasing concentrations in well 299-E28-25 is consistent with the conceived northwest flow direction.

9.1.4.4 B Plant Area

Elevated uranium concentrations are reported for two wells near B Plant: 299-E28-6 (average 39 µg/L in CY 2009) and 299-E28-17 (33.9 µg/L in CY 2010). The well distribution near these wells is sparse. New RI well 299-E29-54, installed just south of B Plant, reported a ~9 µg/L uranium concentration during drilling. It is uncertain how uranium is distributed in this area, with a lower concentration between the 216-B-12 Cribs and wells 299-E28-6 and 299-E28-17; therefore, the plume was separated into two parts (Figure 9-25).

9.1.5 Strontium-90

Strontium-90 analyses were performed at least once from 58 wells across the 200-BP-5 OU. Two 200-BP-5 OU wells (299-E28-5 and 299-E28-6) were not sampled due to a work stoppage.

Eight wells were reported with strontium-90 levels above detection.

Eight wells were reported with strontium-90 levels above detection limits. Seven of the eight wells were reported with strontium-90 activities above the 8 pCi/L DWS, with the results of two of these strontium-90 detections unexpected. Four of the wells are located near the 216-B-5 injection well, and two wells are located near the inactive/dry Gable Mountain Pond (Figure 9-26).

The two wells with unexpected strontium-90 detections, 299-E33-341 and 699-50-56, are located beneath the BY Cribs and to the northwest of the 200 East Area, respectively. The activity reported in well 299-E33-341 in February 2010 was 2.6 pCi/L (±3 pCi/L); therefore, the result is within the analytical error and is considered a false positive. This evaluation is consistent with the nondetect values previously and subsequently reported in this well and for wells proximal to this well. The analytical result reported in well 699-50-56 was inconsistent with the duplicate and had a quality control issue; therefore, the result is considered to be a laboratory error.

The highest strontium-90 concentration (4,200 pCi/L) for this reporting period was ~1 meter from the 216-B-5 injection well, in well 299-E28-23.

The highest strontium-90 activity (4,200 pCi/L) for this reporting period was in well 299-E28-23, ~1 meter from the 216-B-5 injection well. This was the only well above the U.S. Department of Energy (DOE)-derived activity guide of 1,000 pCi/L. Distal strontium-90 activities from the 216-B-5 injection well indicate a predominant history of northwest groundwater flow from the 216-B-5 injection well. This is demonstrated by the 1,700 pCi/L activity at well 299-E28-25 (~7 meters to the northwest) versus the lower activity of 350 pCi/L in well 299-E28-24 (~5 meters to the southeast). The predominant northwest transport of strontium-90 is further seen by the 180 pCi/L activity in well 299-E28-2 (~170 meters to the northwest).

Strontium-90 activity has been steadily decreasing at Gable Mountain Pond, and the highest concentration reported was 310 pCi/L in wells monitoring this area.

The next closest well to the northwest is well 299-E28-27, which has continued to report nondetect values.

The highest strontium-90 activity reported near Gable Mountain Pond was in well 699-53-47A (beneath the southeastern portion of the once active pond) at 310 pCi/L. The activity at this well has steadily decreased over the last 13 years from 1,320 pCi/L. Further northwest beneath the central portion of Gable Mountain Pond, well 699-54-49 reported activities of 160 pCi/L; the activities in this well have also decreased but more slowly when compared to the decrease observed in well 699-53-47A. One reason for the more significant decrease in strontium-90 activities in well 699-53-47A may be related to the well screen placement. The screen at this well only extends only ~0.5 meter into the aquifer, while well 699-54-49 is screened across the upper 3 meters of the aquifer. Combined with low infiltration and migration, this may explain the significant decreases at well 699-53-47A versus well 699-54-49. In addition, well 699-53-47B, which is adjacent to well 699-53-47A and extends throughout the aquifer, has not shown as significant decreases. This well is screened across the 1.75 meters of aquifer thickness in this location.

Strontium-90 activities at well 699-53-48A, located between wells 699-53-47A and 699-54-49, have also decreased significantly since 2005, with nondetect values reported in CY 2010. The strontium-90 activity reported for the well in 2005 was 741 pCi/L. This well monitors the bottom of the aquifer and extends ~2.9 meters beneath the groundwater surface within broken basalt and clay. Well 699-53-48A does not have perforations or screen, and the bottom of the casing underlies 1.8 meters of silt and clay. The well produces water at a rate of more than 7.6 liters per minute. Recent results appear to be good because the duplicate result was also nondetect. Based on the results for this well, the strontium-90 contours at Gable Mountain Pond have been modified.

Well 699-55-50C, located near the northwest end of the inactive Gable Mountain Pond, was again reported with a nondetect strontium-90 activity. The continued nondetect values in this well indicate limited movement of the strontium-90 plume to the northwest.

9.1.6 Cyanide

The maximum cyanide concentration in the 200-BP-5 OU in CY 2010 was located beneath the BY Cribs in well 299-E33-7 (1,590 µg/L).

Cyanide analyses were performed at least once from 81 wells across the 200-BP-5 OU. The distribution of cyanide above the 200 µg/L DWS originates beneath the BY Cribs and extends predominantly to the northwest beyond the 200 East Area boundary (Figure 9-27). Elevated cyanide concentrations, also originating from the BY Cribs, were found in well 699-53-55C at a maximum of 170 µg/L (west of Gable Mountain Pond).

The maximum cyanide concentration in the 200-BP-5 OU during CY 2010 was beneath the BY Cribs in well 299-E33-7 (1,590 µg/L), but this was 140 µg/L less than the value reported in CY 2009. The cyanide 200 µg/L (DWS) contour extends predominantly to the northwest beyond the 200 East Area boundary, between wells 299-E33-34 and 699-49-57A (Figure 9-27). The maximum cyanide concentration was formerly found in well 299-E33-4, which has not been sampled since 2008 due insufficient groundwater in the well.

Cyanide is also present to the south and east of the BY Cribs. Cyanide groundwater concentrations to the south and east of the BY Cribs began to decrease as groundwater flow returned to the northwest. Furthermore, cyanide along the south side of the BY Cribs has been elevated over the past 3 years in wells 299-E33-9, 299-E33-13, 299-E33-31, and 299-E33-44, while the flow regime had changed from

a dominate north flow to a south flow and back to a north flow regime. In CY 2010, the concentrations diminished significantly as apparent flow rates increased to the northwest. Density-driven contamination was considered as an alternative explanation for the increased concentration last year in these wells. During CY 2010, depth-discrete samples were collected in wells 299-E33-31 and 299-E33-342 south of the BY Cribs, and the cyanide concentrations in both these wells showed an increase with depth. For example, well 299-E33-342 had a concentration of 303 µg/L at ~0.76 meters in the aquifer versus 831 µg/L at the bottom of the aquifer. The concentrations in well 299-E33-31, although not as high, also increased at the bottom of the aquifer. Thus, the residual cyanide-bearing waste infiltrating into the aquifer appears to have sank through the aquifer initially and later dispersed with the flow in the direction of the groundwater gradient similar to the density theory discussed for nitrate and technetium-99 (Sections 9.1.1.1 and 9.1.3.1).

Cyanide concentrations associated with well 699-53-55C continued to decrease since the peak value in April 2009.

Elevated cyanide concentrations are also associated with well 699-53-55C, which has continued to decrease since the peak value in April 2009. Lower concentrations in January and July 2010 indicate a decreasing trend.

The current cyanide plume at well 699-53-55C has apparently migrated from near well 699-50-53A over the two past decades. In the early 1990s the cyanide concentrations at well 699-50-53A exceeded 1,000 µg/L. Concentrations at well 699-53-55C appear to now be decreasing after having increased for the past 7 years. Concentrations peaked in April 2009 at 195 µg/L and as of July 2010 had decreased to 158 µg/L. It appears that concentrations may not exceed the DWS due to the increased aquifer thickness near this well and the decreasing cyanide concentration trend. The aquifer residing in the Hanford sediments at well 699-53-55C is approximately 21.3 meters thick compared with the less than 1-meter-thick aquifer near well 699-50-53A in the early 1990s. This may be part of the reason that concentrations at well 699-53-55C have remained below the DWS while concentrations at well 699-50-53A exceeded the DWS. Well 699-53-55B, which is screened deeper in the aquifer, has slightly lower concentrations, indicating a possible despersed portion of the plume. Concentrations at well 699-53-55B had decreased to146 µg/L by May 2010.

9.1.7 Cesium-137

The 216-B-5 injection monitoring wells were the only wells with detections of cesium-137 in the 200-BP-5 OU.

Cesium-137 analyses were performed at least once from 91 wells across the 200-BP-5 OU. Wells 299-E28-5 and 299-E28-6 were not sampled due to a work stoppage.

Only three wells (near the 216-B-5 injection well) had detectable activities of cesium-137 within the 200-BP-5 OU, ranging from 35.4 to 2,180 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 injection well, had the highest activity at 2,180 pCi/L (see Figure 9-2 for well location). The reported activity is above the 200 pCi/L DWS and is less than the DOE-derived activity guide of 3,000 pCi/L. The current activity is ~60% of the average observed in the 1980s.

Cesium-137 has relatively low mobility in the subsurface and does not migrate significant distances, as can be observed by the much lower activity (79.2 pCi/L) from well 299-E28-24, which is located ~5 meters to the southeast of the 216-B-5 injection well. An even lower activity (35.4 pCi/L) is found ~7 meters to the northwest in well 299-E28-25. Based on historical comparisons, this plume appears to be decaying without much movement, as modeled and concluded in DOE/RL-95-59.

9.1.8 Plutonium-239/240

Plutonium-239/240 analyses were performed at least once from 31 wells across the 200-BP-5 OU. Wells 299-E28-5 and 299-E28-6 were missed due to a work stoppage; these two wells have historically been reported with nondetect values.

Six wells had detectable activities of plutonium-239/240. Three of the wells (299-E82-23, 299-E28-24, and 299-E28-25) are near the 216-B-5 injection well. Detectable activities in these wells have been continuous since sampling began in 1986 and 1987. The activities reported for CY 2010 ranged between 0.21 and 42.6 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 injection well, had the highest activity at 42.6 pCi/L. Plutonium-239/240 is nearly immobile in the subsurface, as reflected by the stable, low results in wells 299-E28-24 and 299-E28-25, which are located ~5 to 7 meters from the 216-B-5 injection well.

The other three wells with detected activities (299-E33-38, 699-48-50, and 699-50-56) were unexpected because these wells have not had previous plutonium-239/240 detections. Two of these wells had measurement errors greater than the reported detection and, therefore, are within measurement error and are considered false positives. Well 699-48-50 had a result slightly above to the total analytical error of 0.029 pCi/L. Previous results in this well have been nondetects, and wells between the 216-B-5 injection well and this well have been consistently nondetect; therefore, this result is suspect. The well will be sampled again in CY 2011.

9.1.9 Tritium

The highest tritium concentrations in 2010 were in new RI wells 299-E28-30 and 299-E29-54, located near the 216-B-12 Crib and B Plant, respectively.

Tritium analyses were performed at least once from 140 wells across the 200-BP-5 OU. Three wells (299-E28-5, 299-E28-6, and 299-E28-18) were missed due to a work stoppage. Tritium activities above the 20,000 pCi/L DWS are limited to three wells in the thin aquifer northwest and east of the 216-B-57 and 216-B-50 Cribs, respectively (Figure 9-28). Tritium was also reported above the DWS in samples collected at depth from two new 200-BP-5 RI wells drilled in CY 2010. Because these samples were collected at depths greater than 4 meters beneath the water table and also during drilling, the values are not shown in Figure 9-28.

The two wells with the highest tritium activities in CY 2010 were the two new RI wells, 299-E28-30 and 299-E29-54, located near the 216-B-12 Crib and B Plant, respectively. The highest activity, 150,000 pCi/L, was reported during sample collection while drilling at well 299-E29-54 and encountered ~18.3 meters below the water table. There was no duplicate; however, the sample was run twice with different dilution factors and provided consistent results. The next highest activity, 93,500 pCi/L, was reported during sample collection while drilling at well 299-E28-30, encountered at ~7.62 meters below the water table. The result is an average of two samples, one at 93,000 pCi/L and a duplicate sample at 94,000 pCi/L. The results are consistent with the significant tritium inventory associated with the 216-B-12 Crib (2,340 curies) versus the less than one curie for the other combined waste sites in this area (Appendix C of RPP-26744).

The high tritium activities in well 299-E28-30 coincide with the Ringold Formation unit 9A (PNNL-12261). The top of the Ringold unit 9A is interpreted to extend from just above the water table through most of the saturated thickness, overlying a thin layer of unit 9B and ~6.1 meters of unit 9C. North of this well, Ringold unit 9A is truncated by the glaciofluvial Hanford sediments which overlie the Ringold unit 9C. The change in hydraulic conductivity between these two formations ranges from an order of magnitude to several orders of magnitude (PNNL-12261). It is believed that tritium migrates north from Ringold units, causing elevated activities to the

north beneath the 216-B-62 Crib (similar to the nitrate discussion in Section 9.1.1.1). The elevated tritium is also interpreted as the source of elevated tritium along the southeast and west side of LLWMA-1.

A tritium contour is not provided around well 299-E28-30 because the results are based on vertical profiling data during drilling; therefore, the tritium contour is not shown in Figure 9-28. As stated in Section 9.1.1.2, vertical sampling data are not posted on annual average maps because vertical sampling data are not always comparable to routine samples from completed and developed wells.

The other two wells with tritium levels exceeding the DWS in CY 2010 were wells 299-E33-7 and 299-E33-26. These wells are adjacent to waste site 216-B-50 (part of the BY Cribs) and the 216-B-57 Crib, which were reported with high tritium inventories of 126.3 and 194.6 curies, respectively (Appendix C of RPP-26744). The maximum tritium activity was formerly reported in well 299-E33-4, which has not been sampled since 2008 due insufficient groundwater in the well. The activities in wells 299-E33-7 and 299-E33-26 have recently decreased and appear to be associated with an increase in the groundwater flow rate in this area. This also appears to be the reason for the smaller 20,000 pCi/L plume configuration.

During the past 10 years, elevated tritium levels within Gable Gap continue to decrease slightly faster than the decay rate; this was observed in wells 699-60-60 and 699-61-62. North of Gable Gap, the tritium activity decrease appears to match the decay rate over the past 8 to 10 years in wells 699-64-62 and 699-66-64. In well 699-66-58 to the northeast of well 699-64-62, the tritium activities have not decreased as much as the decay rate. To the east of well 699-64-62 in well 699-63-55, the activities appear to be decreasing slightly faster than the decay rate. Based on the data, it appears that tritium migrating north of Gable Gap may preferentially migrate along the north side of Gable Mountain and to the northeast.

9.1.10 Sulfate

Sulfate analyses, like nitrate, were performed at least once from 141 wells across the 200-BP-5 OU. The distribution of sulfate above the secondary DWS (250 mg/L) is limited to a three locations within the 200-BP-5 OU (Figure 9-29):

- BY Cribs and adjacent wells
- East side of WMA C
- Well 299-E27-10 at LLWMA-2.

9.1.10.1 BY Cribs and Adjacent Wells

High sulfate concentrations beneath the BY Cribs are not unexpected based on the large inventories of sulfate that were added in the initial phase of the bismuth phosphate process. The waste generated (referred to as metal waste) was eventually sent to the BY Cribs after further separation of various fission and metal products. Thus, considering previous vadose zone and groundwater sample results, the current groundwater results are consistent with the other COCs associated with the BY Cribs (e.g., cyanide, nitrate, and technetium-99).

9.1.10.2 East Side of Waste Management Area C

The sulfate concentration reported in well 299-E27-14 (southeast side of WMA C) is associated with WMA C. In 2010, the sulfate concentrations in well 299-E27-14 averaged 296 mg/L. Although sulfate exceeded the 250 mg/L (secondary DWS) in other WMA C wells, the plume configuration (Figure 9-29) only reflects the result at this well because it is associated with the upper aquifer.

Sulfate concentrations also exceeded the secondary DWS in well 299-E27-24, located ~61 meters to the south. In this well, the sample concentrations collected during drilling at depth-discrete intervals in the aquifer were higher in the lower portion of the aquifer. For example, the concentration at ~3.93 meters into the aquifer was 185 mg/L, at 10 meters was 248 mg/L, and at 15.6 meters was 345 mg/L. The bottom of the 6.1-meter well screen was placed at just above the basalt. The first sample from the completed well in December 2010 reported 301 mg/L. This concentration is slightly higher than the concentration reported in the depth-discrete sample (286 mg/L) collected in well 299-E27-7 during February. Further to the northeast, the concentrations at depth in well 299-E27-25 were just above the secondary DWS. The December quarterly sample result at well 299-E27-25 was 250 mg/L.

9.1.10.3 Well 299-E27-10 at Low-Level Waste Management Area 2

The sulfate concentration in well 299-E27-10 has continued to increase since the late 1990s (Figure 9-30). The highest concentration during CY 2010 was 361 mg/L, reported in February as part of a depth-discrete sample located in the bottom portion of the screened interval for this well. The sulfate concentration in this well appears to be associated with releases from the 216-B-2-1 and 216-B-2-2 Ditches. High sulfate concentrations were reported beneath the 216-B-2-2 Ditch during the 200-CW-3 OU RI (DOE/RL-2000-35, *200-CW-1 Operable Unit Remedial Investigation Report*). The *Borehole Summary Report for the 216-B-2-2 Ditch* (BHI-01177) reported four zones of elevated moisture at depth. In addition, the subsurface lithology has been described as having silt-rich interbeds capable of generating perched water conditions (WHC-SD-EN-TI-290, *Geologic Setting of the Low-Level Burial Grounds*); these interbeds appear to dip to the northeast. A possible contributor for the driving force to groundwater associated with the 216-B-2-1 and 216-B-2-2 releases may have been a subsequent release associated with the 216-B-2-3 Ditch, which was determined after water began entering an empty burial trench at LLWMA-2 in 1986. By May 1997, significant sulfate increases were reported in well 299-E34-7 (Figure 9-30). An increasing trend began in 1999 in well 299-E27-10, located to the southwest of well 299-E34-7. It is unknown whether the sulfate migrated through the aquifer toward well 299-E27-10 or infiltrated into the aquifer from the vadose zone near this location. However, both wells are north of the 216-B-2-1 and 216-B-2-2 Ditches, which is the prevailing dip direction of the vadose zone sediments.

Although the gradient at LLWMA-2 has suggested flow to the west along the southern boundary for nearly two decades, increased sulfate concentration observed in well 299-E27-10 has not been noted in well 299-E34-12, which is ~1,100 meters to the west. However, sulfate was found in the new WMA C well 299-E27-25. It appears that the sulfate in well 299-E27-10 is associated with the sulfate in wells 299-E27-25 and 299-E26-77. Therefore, the sulfate plume has been configured to include each of these wells (Figure 9-29).

9.2 CERCLA Groundwater Activities

The CERCLA groundwater activities for CY 2010 included routine groundwater monitoring, RI studies, and preparation of a treatability test plan to address technetium-99 and uranium contamination, as discussed below.

9.2.1 Routine Groundwater Monitoring

Routine CERCLA groundwater monitoring requirements are described in the *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*

(DOE/RL-2001-49). The monitoring network, constituent lists, and sampling frequency are provide in Appendix A of this report. The CERCLA monitoring data are used to define the extent of groundwater contamination. Each year, contours are revised for each COC identified in DOE/RL-2001-49. The certainty of the plume interpretation is also assessed to determine the effectiveness of the CERCLA and AEA monitoring program. The assessment determines if the selected analytical methods, sampling frequencies, and well locations are appropriate. In addition, the new contours are compared each year with previous contours to interpret groundwater flow and track concentration trends near contaminant sources. DOE/RL-2001-49 also provides the direction for the integrated use of RCRA analytical data.

A revision of DOE/RL-2001-49 was initiated after RI well installations were completed in spring 2010. Data from the new RI wells and the existing monitoring network help to provide a better understanding of several potential contaminant sources and the groundwater flow direction across the central portion of the 200 East Area. The groundwater flow across the central portion of the 200 East Area has been uncertain for several years due to small groundwater elevation differences and an apparent groundwater divide, limiting the use of conventional three-point analyses. As a result, groundwater chemistry is compared with contaminant plume configurations and groundwater gradient information to ensure defensible interpretations.

The overall CY 2010 contaminant concentrations/activities were slightly lower than last year beneath areas in the northwest portion of the 200 East Area where infiltration of contaminants (discussed in Section 9.1) has been occurring: BY Cribs, 241-BX-102 unplanned release, 216-B-7A&B Cribs, 216-B-8 Crib, and 216-B-57 Crib. This appears to be a result of increased flow to the northwest. Further east, wells near apparent infiltration sites had peak concentrations in CY 2010, which were primarily associated with wells 299-E27-14 and 299-E27-23 near WMA C and well 299-E27-10 near the 216-B-2 Ditches. These increases appear to be associated with limited groundwater migration and continued residual liquid waste infiltration into the aquifer.

In CY 2010, all but three wells were successfully sampled (Appendix A). Sampling at wells 299-E28-5, 299-E28-6, and 299-E28-18 was missed due to a work stoppage in late 2010. Iodine-129 samples were also missed in a few additional wells due to insufficient water in the wells or scheduling oversight (Section 9.1.2).

9.2.2 Remedial Investigation Activities

The scope of the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) was derived through the data quality objective process (WMP-28945, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process*). The work plan identified the need for fifteen additional wells to resolve the future impact to groundwater, improve the understanding of contaminant nature and extent within the aquifer, and refine the groundwater flow direction. Field work began in 2006 and continued through 2010.

The last three RI wells were drilled and installed early in CY 2010.

The last three RI wells ("K," "L," and "M"), identified in DOE/RL-2007-18 and WMP-28945, were drilled and installed early in CY 2010. The wells were located near the following: well 299-E28-30 ("K") near the 216-B-12 Crib west of B Plant, well 299-E29-54 ("L") near the 216-B-6 injection well south of B Plant, and well 299-E24-25 ("M") near the 216-C-1 Crib near the Semi-Works Facility. All analytical data from the RI-derived samples collected both in the vadose zone and groundwater were verified, a portion was validated, and the data have been included in the Hanford Environmental Information System database.

Three contaminants were reported above the DWS at new RI well 299-E28-30: nitrate, tritium, and uranium. Nitrate and tritium were also reported at levels exceeding the DWS at new RI well 299-E29-54. The highest results in well 299-E28-30 were at the second depth-discrete interval, ~7.6 meters below the water table. Elevated results were also reported at this depth in well 299-E29-54; however, the highest results for nitrate and tritium in this well were in the lowest sample ~18.3 meters beneath the water table. No constituents were found to exceed the DWS in well 299-E24-25. The results associated with wells 299-E28-30 and 299-E29-54 are discussed in more detail in Sections 9.1.1.2, 9.1.4.2, and 9.1.9.

Another RI activity completed in CY 2010 involved the collection of depth-discrete samples at fourteen existing wells within the 200-BP-5 OU. The samples were collected to evaluate the vertical extent of contamination beneath, adjacent, and downgradient of waste sites where continuing contaminant infiltration is thought to be occurring. The wells included the following:

- Well 299-E27-10 along the north side of the 216-B-2-2 Ditches
- Wells 299-E27-4, 299-E27-7, 299-E27-21, and 299-E27-23 at WMA C
- Wells 299-E33-49 and 299-E33-339 along the south side of the B and BX Tank Farms
- Wells 299-E33-343 and 299-E33-345 near apparent points of contaminant infiltration associated with the 241-BX-102 unplanned release and 216-B-7A&B Cribs discharges, respectively
- Wells 299-E33-31, 299-E33-39, and 299-E33-342 near the BY Cribs
- Well 699-50-56 located ~1.3 kilometers northwest of the BY Cribs
- Well 699-53-55C located ~1.6 kilometers north of the BY Cribs.

The nitrate and technetium-99 sample results are discussed in Sections 9.1.1 and 9.1.3. In general, depth-discrete results indicated that contaminant concentrations increase with depth, except in areas where infiltration appears to be occurring. For example, at well 299-E33-343, concentrations for the ions tested were nearly the same throughout the aquifer. This well is considered to be near the point of infiltration of contamination from the 241-BX-102 unplanned release because of the high concentrations of uranium compared to adjacent wells. Similar results were also found at well 299-E27-23 (near WMA C) where technetium-99 was significantly more concentrated than in the surrounding wells. Conversely, all but two of the remaining wells showed increased concentrations with depth. These wells were considered adjacent contaminant infiltration. Wells 699-50-56 and 699-53-55C were considered downgradient, and not much change in concentration was observed with depth. It appears that specific gravity of the residual vadose zone waste entering the aquifer plays a part in the initial downward movement of the contaminants. Another factor for high contaminant concentrations proximal to an infiltration source is slow groundwater movement, which relates to slow dispersion of the infiltrating contaminants.

Four major reports were prepared in CY 2010 for the 200-BP-5 RI/FS. Two of the reports were associated with a treatability test near WMA B-BX-BY: *200-BP-5 OU Data Quality Objectives Summary Report* (SGW-44329) and *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74). These two reports defined the boundary, location, data, infrastructure, and approach required to complete the treatability test. The submittal of the draft treatability test plan to the U.S. Environmental Protection Agency (EPA) completed Tri-Party Agreement

Milestone M-015-082. Another report initiated in CY 2010 was the *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit* (DOE/RL-2009-127), which is still in draft status and planned for final publication in 2011. The final report prepared this year was the *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit: November 2004 Through November 2009 Groundwater Data*, which evaluated 10,926 groundwater samples over the past 5 years to determine whether the data were of sufficient quality to support the baseline risk assessment and selection of remedial alternatives. The report concluded that the data were of the right type, quality, and quantity for use in the RI/FS process.

9.2.3 Treatability Test Plan

Two test sites were identified to evaluate the practicality of performing a groundwater pump-and-treat system for the extraction of uranium and technetium-99 contaminant plumes near WMA B-BX-BY. The sites were selected based on the proximity of the existing plumes, aquifer thickness, preliminary hydraulic conductivity, and ability for manpower to reach the site easily. One test site is located along the west side of the BY Tank Farm. This location is near the major source of technetium-99 (the BY Cribs), where the aquifer thickens due to the dip of the Elephant Mountain Member of the Saddle Mountains Basalt, and it is outside of waste site boundaries. This location was thought to be the closest site available to the BY Cribs that met the criteria for test locations. The location is also considered to be downgradient of the uranium plume source, the 241-BX-102 unplanned release.

The other site selected was existing well 299-E33-343, located adjacent the northwest corner of the B Tank Farm. This site was selected mainly due to high uranium concentrations at this well. The well is considered to be near the infiltration point of the uranium plume associated with the 241-BX-102 unplanned release. Because the well is an existing 4-inch monitoring well, test equipment will be evaluated for the ability to maintain a sustainable yield in accordance with test performance objectives. This well is also used to access spatial variability of hydraulic parameters and contaminant removal rates.

The treatability test is planned for early to mid-FY 2012 (based on available funding). Prior to the start of testing, the following activities are required: complete the design plan, level and prepare for site construction, drill and construct extraction and associated monitoring well along the west side of BY Tank Farm, construct a pipeline from both extraction wells to the cross-site line to the Effluent Treatment Facility, construct a utility distribution rack, and provide an electrical connection.

9.3 RCRA Treatment, Storage, and Disposal Unit Monitoring

This section describes the results of monitoring at individual units such as TSD units or tank farms. These units are monitored under RCRA requirements for dangerous waste constituents and under AEA for source, special nuclear, and byproduct materials. Data from unit-specific monitoring are also integrated into CERCLA groundwater investigations. Dangerous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for each unit. As previously discussed and pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy

RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

The 200-BP-5 OU contains six RCRA sites with groundwater monitoring requirements: LLWMA-1 and LLWMA-2, WMA B-BX-BY, WMA C, LERF, and 216-B-63 Trench. The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for this reporting period. Groundwater data are available in the Hanford Environmental Information System database and in the data files accompanying this report. Additional information (including well and constituent lists, maps, flow rates, and statistical tables) is included in Appendix B.

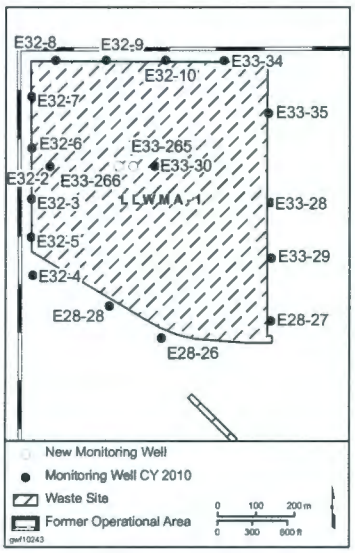
All of the existing LLWMA-1 wells were successfully sampled during the reporting period.

9.3.1 Low-Level Waste Management Area 1

G.S. Thomas

Groundwater monitoring at LLWMA-1, located in the northwestern corner of the 200 East Area, continued under RCRA and AEA requirements. In accordance with WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (as referenced by 40 CFR 265.93(b), "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), the well network was sampled semiannually for RCRA indicator and site-specific parameters (DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for LLBG WMA-1*). The AEA monitoring requirements were derived from the *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds* (DOE/RL-2000-72). All of the existing LLWMA-1 wells were successfully sampled in January/February and June/July during the reporting period. Two new wells were also added to the network and were sampled in September. Appendix B, Table B-19 provides a list of the wells and constituents monitored during CY 2010. Appendix B, Table B-20 provides a list of the indicator parameter comparison values for use in CY 2011. The indicator parameter comparison values for CY 2010 are provided in Appendix C, Table C-20 in DOE/RL-2010-11 and are discussed specifically in Section 9.3.1.2. The following subsections discuss the annual evaluation requirements for the monitoring network, compliance status, and groundwater results.

9.3.1.1 Network Evaluation and Compliance Status



The interim status monitoring requirements of 40 CFR 265, Subpart F ("Ground-Water Monitoring") and WAC 173-303-400 require upgradient and downgradient monitoring wells that ensure detection of statistically significant change in concentrations (e.g., above or below) of the derived critical means for the four indicator parameters at the limit of the WMA within the uppermost aquifer. This subsection discusses additions to the network, measures taken to determine groundwater flow, the results of statistical groundwater gradient measurements, correlation of the statistical measurements with observed contaminant migration, determination of flow direction and rate, and whether the network remains satisfactory for immediate detection of any statistical change in concentration within the LLWMA-1 monitoring network.

At the beginning of the reporting period, the LLWMA-1 groundwater monitoring network consisted of seventeen wells. Two additional LLWMA-1 monitoring wells (299-E33-265 and 299-E33-266) were added during the reporting period in accordance with the *Groundwater Monitoring Needs Assessment for Low-Level*

Burial Grounds Waste Management Areas (SGW-40037). The two new wells were installed to detect groundwater contamination that could emanate from the buried RCRA-regulated wastes associated with Trench 9 in the 218-E-10 Burial Ground (Figure 9-31).

Two new wells were installed to detect groundwater contamination that could emanate from buried RCRA-regulated wastes associated with Trench 9 in the 218-E-10 Burial Ground.

As discussed in Appendix A of SGW-40037, use of uncorrected water-level measurements to determine groundwater flow direction is problematic in the 200 East Area because the hydraulic gradient is very small (~1.5×10^{-5} based on regional water-level measurements). To increase the accuracy of water-level elevation determinations for LLWMA-1, six perimeter LLWMA-1 wells, three wells to the north, three wells to the south, and two wells to the east were resurveyed to a single bench mark, and gyroscopic surveys were conducted to determine well plumbness (deviation from vertical) (see Figure 3-4 in Chapter 3.0). Sixteen wells in the north central and northeastern portion of the 200 East Area were also resurveyed to the same marker and gyroscoped to more accurately determine the regional groundwater flow regime (Figure 3-6 in Chapter 3.0). Additional details of this work are provided in Chapter 3.0, Section 3.2.1.

Statistical monthly water-level measurement evaluations for the fourteen-well network were reduced to five monthly measurements in 2010 due to requirements associated with monitoring evaluations and the work stoppage. The statistical measurement evaluations were completed from the January, May, June, July, and September data. An additional set of measurements collected during in January 2011 was also included for this discussion. Each set of measurements was analyzed using trend-surface analyses (see discussion in Chapter 3.0, Section 3.2.1). Since the fall of 2008, statistically significant values for groundwater flow using this network have been limited to two summer results: one in July 2009 and one in June 2010 (Figure 9-6). Although the probability in almost all of the statistical measurements exceeded 5% (e.g., p values shown in Figure 9-6), since April 2009 the flow direction ("Dir." in Figure 9-6) value indicates a predominant northerly flow direction. April 2009 signifies the return of a predominant north flow regime from the flow reversal statistically determined in July 2008.

The use of water levels only to derive the flow direction and rate across LLWMA-1 is not recommended for 2010. Therefore, ion chemistry and contaminant trend plots were also evaluated before determining flow direction.

During the reporting period, the probability that the fitted trend surface results did not represent a good approximation of the overall groundwater gradient (i.e., the p value) ranged between 34% and 68%, except for one statistically significant gradient determination (with a p value of less than or equal to 5%) in June 2010. The higher the p value, the higher the probability that the azimuth direction provided in Figure 9-6 could be different from the true gradient. Evaluation of the corrected groundwater elevations indicates that the uncertainty was due to low groundwater elevations in the southerly wells 299-E28-17 and 299-E28-1 during the first part of the year (e.g., January and May). During the year, well 299-E28-17 consistently had low groundwater elevations, except in June and early January 2011. The only well with lower groundwater elevations was well 699-50-56, north of the 200 East Area. Unlike well 299-E28-17, well 299-E28-1 had one of the highest groundwater elevations in the summer (June through September) and in January 2011. If the two high elevations and two low elevations are removed, the flow direction is then based on 6 millimeters or less of water-level elevation change, which is within the measurement error. The flow regime depicted from the remaining wells is variable from month to month or is indeterminate; therefore, the use of CY 2010 water levels only to derive the flow direction and rate across LLWMA-1 is not recommended. Because of the small groundwater elevation differences and uncertainty regarding the measurements, ion chemistry and contaminant trend plots were also evaluated

to determine if correlation between these observation methods were in agreement before deciding the flow direction.

One area where the use of groundwater-level data maybe appropriate is between the south portion of the BY Cribs and the northeast corner of LLWMA-1. Between wells 299-E33-38 and 299-E33-34, the groundwater elevation was consistently higher in well 299-E33-38, except in August and September (see Section 9.1.1.1). More importantly, contaminant trend plots and ion chemistry in these wells and the well between these wells (e.g., 299-E33-26) all suggest a northwest groundwater flow direction. For example, comparable technetium-99 trend results between wells 299-E33-38 and 299-E33-26 indicate a northwest flow, as discussed further in Section 9.1.3.1 (Figure 9-21). Nitrate trend plots for these wells provide a similar comparison; furthermore, ion chemistry between the three wells is comparable. Since the ion chemistry and trend plots are consistent with the elevation differences between these wells, further evaluation between these wells regarding the flow is discussed below.

A range of groundwater gradient values for wells 299-E33-38 and 299-E33-34 was derived by subtracting the corrected groundwater elevations and dividing by the distance between these wells (Table 9-1). The calculations ranged between -3.73×10^{-6} and 1.96×10^{-7} for the 10-month evaluation, including early January 2011 (see Section 9.1.1.1). After removing the two high and low values, the range was from 1.00×10^{-5} to 2.16×10^{-6}. Summing and dividing by six produced an average of 2.08×10^{-5}, which is slightly less than the regional gradient of 1.5×10^{-5}. Multiplying the average by the upper hydraulic conductivity range of 7,500 meters per day (PNNL-14753, *Groundwater Data Package for Hanford Assessment*) and dividing by an effective porosity of 0.2 derived an average flow rate of 0.78 meters per day to the northwest. This flow rate correlates with the nitrate and technetium-99 trend changes in these wells, which indicates a flow rate of ~0.75 meters per day (Section 9.1.3.1). Because of the correlation between groundwater elevation differences, trend plots, and ion chemistry, the average gradient between the BY Cribs and northeast corner of LLWMA-1 is considered to be $\sim 2.08 \times 10^{-5}$ to the northwest.

Groundwater elevation differences beneath the remaining portion of LLWMA-1 are within the measurement error, as previously explained. In addition, conclusive evidence does not exist to indicate a particular flow direction in this area. Based on the review of previous groundwater flow through this area and the evidence of northwest flow further north, it is postulated that flow in this area is also to the north or northwest.

The LLWMA-1 monitoring network remains satisfactory for detection of any statistical change in concentration at the point of compliance.

In conclusion, the contaminant plume orientation along the north side of the WMA is consistent with the azimuth direction from statistical groundwater gradient measurements in this area. If the contaminant plumes orientation and statistical measurements are an indication of the general flow throughout the WMA, then the addition of the two new wells (299-E33-265 and 299-E33-266) provides even greater confidence for detection of potential groundwater contamination that could emanate from the buried RCRA-regulated wastes associated with Trench 9 in the 218-E-10 Burial Ground. Based on this information, DOE considers the network capable of the immediate detection of any statistical change in concentration at the point-of-compliance within the LLWMA-1 monitoring network.

9.3.1.2 Groundwater Contaminants

The groundwater in LLWMA-1 monitoring wells is sampled and analyzed for the parameters listed in Appendix B, Table B-19. In accordance with WAC 173-303-400

and 40 CFR 265.92, the LLWMA-1 network wells are monitored semiannually for RCRA groundwater quality and indicator parameters. The comparison criteria (critical mean) for the indicator parameters and the basis for deriving the critical mean are provided in Appendix C, Table C-20 of DOE/RL-2010-11, and specific comparisons are provided below. Water-level measurements are taken before each sampling event. During CY 2010, all groundwater sample analyses were completed as required (DOE/RL-2009-77, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*).

During the reporting period, the indicator parameter measurements for pH, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean).

During the reporting period, the indicator parameter measurements for pH, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the wells ranged from 7.73 to 8.17, which is within the lower and upper bound of the critical mean (7.48 to 8.43, respectively). Five wells had total organic carbon levels exceeding the critical mean (800 µg/L) in the June sampling event; however, verification sampling results were nondetect. The highest total organic halide concentration was reported just above the detection level in well 299-E33-29. The annual groundwater phenol results were all reported as nondetects for the January 2010 sampling event.

The elevated specific conductance in wells 299-E32-10 and 299-E33-34 is not cause for change of the interim status indicator evaluation groundwater monitoring conducted at LLWMA-1.

The indicator parameter specific conductance was reported below the critical mean of 912 µS/cm for all wells except 299-E32-10 and 299-E33-34. The exceedance of specific conductance in well 299-E33-34 was initially reported by DOE to the Washington State Department of Ecology in 1999. The most recent specific conductance levels are the highest respective levels reported for these two wells (1,165 and 2,325 µS/cm, respectively) and are influenced primarily by the nitrate plume migrating from the BY Cribs. The nitrate concentrations in these two wells ranged from 50% to 70% of the total anion milliequivalents per liter versus less than 35% in the other WMA wells. This indicates a difference in groundwater quality in this portion of the monitoring network compared to the remainder of the network. Thus, the elevated specific conductance in wells 299-E32-10 and 299-E33-34 is not cause for change of the interim status indicator evaluation groundwater monitoring conducted at LLWMA-1.

Nitrate and cyanide are the only groundwater quality parameters exceeding DWSs beneath LLWMA-1, with nitrate concentrations exceeding the DWS in nearly every well. As reported in previous annual reports, the sources of nitrate are east and south of LLWMA-1 (BY Cribs and WMA B-BX-BY, and the 216-B-12 Crib, respectively). The largest nitrate increase was in well 299-E33-34 where the reported concentration was 1,050 mg/L in July 2010. This value is the highest nitrate concentration ever reported in this well and for the monitoring network. Well 299-E33-34 also had the only cyanide concentration (340 µg/L) reported exceeding the DWS. Wells 299-E32-9 and 299-E32-10, located west of well 299-E33-34 along the northern boundary, also reported increased nitrate and cyanide concentrations. The increased concentrations are consistent with the contaminant trends noted in wells to the east of LLWMA-1. The next highest nitrate concentrations in the remaining LLWMA-1 monitoring wells (excluding wells 299-E32-9, 299-E32-10, and 299-E33-34) are found in monitoring well 299-E28-27 located in the southeast corner of LLWMA-1. The source of this contamination has been reported from the south and, because of results at new 200-BP-5 RI well 299-E28-30, is considered from the 216-B-12 Crib (Section 9.1.1.2).

9.3.1.3 Performance Assessment Monitoring

Performance assessment monitoring of radionuclides at LLWMA-1 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium specifically for performance assessment.

Technetium-99 concentrations have changed significantly in wells monitoring LLWMA-1 in the eastern, central, and northern portion of the WMA. The increased technetium-99 groundwater concentrations in the northeast wells (299-E32-9, 299-E32-10, and 299-E33-34) is the result of the technetium-99 plume migrating from the BY Cribs. Technetium-99 detected in wells 299-E33-28 and 299-E33-30 may be associated with sources in the WMA B-BX-BY and/or the 216-B-7A&B Cribs.

Elevated iodine-129 activities are also found predominantly in the eastern, central, and northern LLWMA-1 monitoring wells. The source of the iodine-129 appears to be locally from the east and regionally from the southeast when groundwater was strongly influenced by the B Pond groundwater mound in the late 1980s and early 1990s (Section 9.2.2).

Uranium concentrations at LLWMA-1 continue to increase and exceed the 30 µg/L DWS in well 299-E33-34. The uranium concentrations also exceeded the DWS in well 299-E32-10 (west of well 299-E33-34) for the first time during this reporting period. To the west of these wells, uranium concentrations are also increasing in wells 299-E32-9 and 299-E32-8, indicating prevailing flow direction to the west along the northern boundary of LLWMA-1. The increasing uranium concentration previously reported in well 299-E28-27, near the southeastern corner of LLWMA-1, appears to have stabilized over the past few years. The source appears to be the 216-B-12 Crib, based on depth-discrete groundwater sample results from a new 200-BP-5 RI well installed near this location and the predominant north flow direction over the past two decades.

Tritium was not reported above the DWS in any LLWMA-1 monitoring well in CY 2010. The highest activity continued to be in well 299-E33-34, which is the result of migration from wells to the southeast (Section 9.2.9).

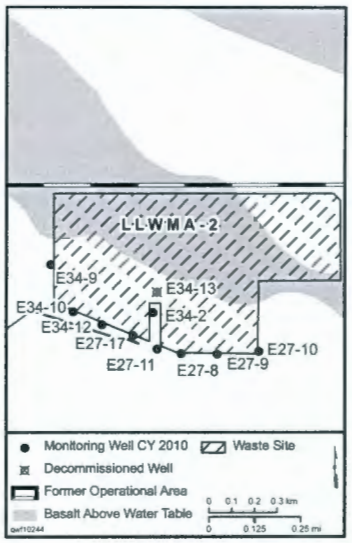
9.3.2 Low-Level Waste Management Area 2

G.S. Thomas

All of the LLWMA-2 wells were successfully sampled during this reporting period.

Groundwater at LLWMA-2 in the northeast corner of the 200 East Area continued to be monitored under RCRA and AEA requirements. In accordance with WAC 173-303-400 (as referenced by 40 CFR 265.93[b]), the well network was scheduled for semiannual sampling for RCRA indicator and site-specific parameters (DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for LLBG WMA-2*). The AEA monitoring requirements were derived from DOE/RL-2000-72. All of the LLWMA-2 wells were successfully sampled during this reporting period; however, due to a work stoppage in September 2010, the October sampling event was delayed until December. Appendix B, Table B-21 includes a list of the wells and constituents monitored during CY 2010. Appendix B, Table B-22 provides a list of the indicator parameter comparison values for use in CY 2011. The indicator parameter comparison values for CY 2010 are provided in Appendix C, Table C-22 of DOE/RL-2010-11 and are discussed specifically in Section 9.3.2.1 below. The following subsections provide annual evaluation requirements for the monitoring network, groundwater results, and compliance status.

9.3.2.1 Network Evaluation and Compliance Status



The interim status monitoring requirements of 40 CFR 265, Subpart F and WAC 173-303-400 require upgradient and downgradient monitoring designed to detect any statistically significant change in concentrations (e.g., above the derived critical mean for the four indicator parameters) of dangerous waste or dangerous waste constituents at the limit of the WMA within the uppermost aquifer. The flow direction for this WMA is uncertain due to the nearly flat groundwater table. An assessment of the groundwater monitoring needs was completed in 2008 and published in January 2009 (SGW-40037). The following discussion presents the changes implemented in 2010 in association with the assessment (SGW-40037). Also discussed are the additional measures taken to more accurately determine the groundwater gradient, the results of statistical groundwater gradient measurements, an evaluation of contaminant migration, and whether the network remains adequate for immediate detection of any statistical change in concentration within the LLWMA-2 monitoring network.

At the beginning of the reporting period, the LLWMA-2 groundwater monitoring network consisted of nine wells. One additional LLWMA-2 monitoring well, 299-E34-13, was drilled during the reporting period in accordance with SGW-40037 (Figure 9-32). The new well was located ~80 meters north of well 299-E34-2 as a new downgradient well of RCRA waste disposal site. In accordance with DOE/RL-2009-76, an additional well was also planned north of well 299-E34-13. During drilling of well 299-E34-13, groundwater was not observed prior to reaching basalt. Drilling then extended ~2.1 meters into the basalt to check for groundwater associated with the flow top. Groundwater was not observed in the well after 105 minutes, and examination of the basalt chips indicated no fractured flow top at this location. The lack of a fractured flow top is consistent with previous observations of basalt chips from adjacent wells 299-E34-2 and 299-E34-4. Drilling later continued to ~3.1 meters into the basalt to check for groundwater associated with fractures in the basalt. Groundwater was encountered; however, the groundwater infiltration rate was 0.4 meters over 1.5 hours (13.2 liters per hour). A sample of the groundwater was collected and analyzed, showing a calcium-sulfate chemistry (Figure 9-33). The sulfate was reported as 244 mg/L, and elevated nitrate was present at 40.3 mg/L. Because the well did not produce sufficient groundwater and the groundwater produced did not appear to be associated with the upper unconfined aquifer, the well was decommissioned and well 299-E34-14 was not drilled.

As discussed in Appendix B of SGW-40037, use of uncorrected water-level measurements to determine groundwater flow direction is problematic in the 200 East Area because the hydraulic gradient is very small (~1.5×10^{-5} based on regional water-level measurements). To increase the accuracy of water-level elevation determination for LLWMA-2, five wells along the perimeter of the WMA and three wells to the west-southwest were resurveyed to a single bench mark, and gyroscope surveys were performed (Figure 3-6 in Chapter 3.0). An additional fourteen-well network to the west was also resurveyed to the same marker and gyroscoped previously to more accurately determine the regional groundwater flow regime for the northwest 200 East Area (Figure 3-4 in Chapter 3.0). Additional information regarding this work is provided in Chapter 3.0, Section 3.2.2.

The hydraulic gradient at LLWMA-2 is currently too low to measure.

Monthly water-level measurements for the network were reduced to nine monthly measurements in 2010 due to a work stoppage. The monthly measurements were completed in January through September, as well as an additional set of measurements collected during early January 2011. Each set of measurements was analyzed using

trend-surface analysis (see Chapter 3.0, Section 3.2 for further discussion). Since March 2009, when the well network was resurveyed to a common bench mark, eleven statistically significant trend-surface results have been derived. However, to achieve statistically significant results at LLWMA-2, two to four of the eight wells used were removed from the analysis due to inconsistent groundwater elevations. The azimuth values derived for the statistically significant measurement generally portray a north-northeast flow direction. Groundwater movement to the north-northeast seems inconsistent based on the lack of groundwater in eight previous wells/borings spaced across the north portion of the WMA and the high groundwater elevations to the east. The northerly wells have little to no water due to groundwater elevation decreases. In addition, basalt chip observations indicate no apparent rubbly flow top in this area that could contain or transmit water. As described in Chapter 3.0, Section 3.2, the error in the water-level elevation determinations for LLWMA-1 was estimated to have a range of 0.012 meters; presumably, this error estimate would also apply to the LLWMA-2 measurements. The water-level elevations determined for LLWMA-2 exhibit an average range of 0.013 meters, which is nearly equal to the expected error. This likely accounts for the unsatisfactory trend-surface analysis results at this WMA. Thus, the hydraulic gradient at LLWMA-2 is currently deemed too low to measure.

Evaluation of contaminant history, along with knowledge of the geological setting and previous discharges from wastewater disposal sites, indicates that the groundwater is being influenced by infiltration of residual waste liquids from the unlined 216-B-2 Ditches (see Section 9.1.10.3 for further discussion of the 216-B-2 Ditches). Most of the WMA wells are located along the north side of the 216-B-2 Ditches, which transferred ~151 billion liters of water to B Pond during active operations (1945 through 1987). Wells 299-E27-9 and 299-E27-10 along the ditches have had significantly increased nitrate and sulfate concentrations. The concentration increases appear to indicate limited groundwater flow for the following reasons:

- Residual infiltration into the aquifer is considered to be small.
- Indeterminate regional groundwater gradient suggests little movement.
- Nitrate and sulfate concentration increases over the past decade and a half indicate limited dispersion.

These combined factors indicate slow groundwater flow in the area. The driving force of the elevated nitrate and sulfate concentrations appears to be residual moisture associated with blockage of the weir box at the east end of the 216-B-2-3 Ditch during the mid-1980s (Section 9.1.10.3). Figure 9-7 depicts a nitrate plume beneath this area, which appears to be centered beneath the weir box at the east end of the 216-B-2-3 Ditch where the blockage occurred. Comparison of groundwater chemistry and contaminant trends between wells 299-E27-10, 299-E27-9, and 299-E27-8 portrays a west-northwest flow direction over the past several years.

Based on current data trends and understanding of the surrounding wastewater disposal history, the LLWMA-2 monitoring network remains satifactory for immediate detection of statistical changes.

If flow is west-northwest, well 299-E34-2 is ideally located for monitoring downgradient of buried RCRA waste because the aquifer is bounded to the north by the basalt, as confirmed from drilling results for well 299-E34-13. In addition, wells 299-E27-11, 299-E27-17, 299-E34-12, 299-E34-10, and 299-E34-9 provide monitoring to the west-southwest. Therefore, based on current data trends and understanding of the surrounding wastewater disposal history, the LLWMA-2 monitoring network remains satisfactory for detection of statistical changes.

9.3.2.2 Groundwater Contaminants

The groundwater in LLWMA-2 monitoring wells is sampled and analyzed for the parameters listed in Appendix B, Table B-21. In accordance with WAC 173-303-400 and 40 CFR 265.92, the LLWMA-2 network wells are monitored semiannually for RCRA groundwater quality and indicator parameters. The critical mean for the indicator parameters and the basis for deriving the critical mean are provided in Appendix C, Table C-22 of DOE/RL-2010-11; however, specific comparisons are provided below. Water-level measurements are taken before each sampling event. During CY 2010, all groundwater sample analyses were completed as required (DOE/RL-2009-76).

During the reporting period, the indicator parameter measurements did not exceed the statistically derived background comparison values (e.g., critical mean), and the unit remains in indicator evaluation status.

During the reporting period, the indicator parameter measurements for pH, total organic carbon, total organic halides, and specific conductance were consistent with previous results and did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for each of the wells ranged from 7.87 to 8.3, which is within the lower and upper bound of the critical mean (6.85 to 8.56, respectively). The highest average total organic carbon concentration reported was 936 µg/L in December 2010 at well 299-E27-10. The highest average total organic halide concentration reported was slightly above detection at 8.05 µg/L also in December 2010 at well 299-E27-10. The annual groundwater phenol results were all reported as nondetects for the annual fall sample collection event. Samples from wells 299-E27-8 and 299-E27-17 were also collected and analyzed for phenols in April 2010, with no detected results.

The indicator parameter of specific conductance was reported below the critical mean of 1,278 µS/cm for all LLWMA-2 monitoring wells. The highest specific conductance level was reported in December 2010 for well 299-E27-10 (1,111 µS/cm).

Sulfate and nitrate are the only groundwater quality parameters that exceeded DWSs during the reporting period at LLWMA-2.

Sulfate and nitrate are the only groundwater quality parameters that exceeded DWSs during the reporting period at LLWMA-2. Elevated sulfate concentrations were limited to well 299-E27-10, with a high concentration of 335 mg/L from December 2010. Elevated nitrate concentrations were reported in well 299-E27-10 and for the first time well in 299-E27-9. The highest concentration was 58 mg/L in well 299-E27-10 for December 2010 sampling, while well 299-E27-9 had a value of 49.6 mg/L for December 2010 sampling.

9.3.2.3 Performance Assessment Monitoring

Performance assessment monitoring of radionuclides at LLWMA-2 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides that are not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium.

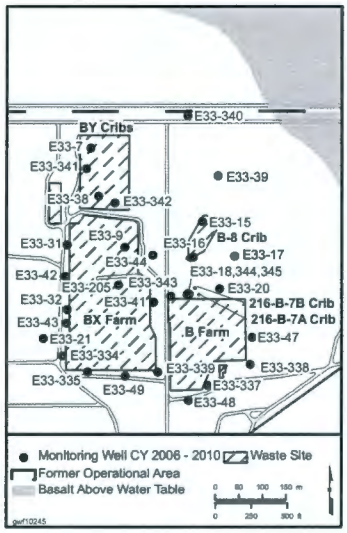
The technetium-99 concentrations increased slightly in well 299-E27-10 during the reporting period, with an activity of 84 pCi/L in December 2010. Other wells in the monitoring network have lower technetium-99 concentrations and only periodically report detected results. Iodine-129 concentration was most prominent in well 299-E27-8 at 2.48 pCi/L in December. Wells adjacent to well 299-E27-8 had elevated concentrations, but wells to the east were all below the DWS, with the exception of well 299-E34-12 at 1.06 pCi/L in April, which decreased to 0.72 pCi/L in December. The overall iodine-129 activity appears to be slowly decreasing in all LLWMA-2 wells. Tritium concentrations have also decreased over the past two decades, with maximum concentrations currently below 550 pCi/L (December 2010). Uranium concentrations in LLWMA-2 samples were less than 5 µg/L.

9.3.3 Waste Management Area B-BX-BY

C.J. Martin

Located in the north-central portion of the 200 East Area, this single-shell tank WMA consists of the B, BX, and BY Tank Farms; ancillary waste transfer lines; and diversion boxes. The three tank farms consist of a total of 36 underground tanks, ranging in capacity between 2 and 2.9 million liters, as well as four 208,000-liter tanks constructed between 1945 and 1949.

Groundwater monitoring is conducted at this WMA in accordance with WAC 173-303-400 (and by reference, 40 CFR 265, Subpart F) and the AEA. The WMA B-BX-BY is currently in a RCRA groundwater quality assessment program and is monitored quarterly, as detailed in the RCRA assessment plan (PNNL-13022, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site*). In addition to monitoring dangerous waste/dangerous waste constituents for RCRA assessment, the site is monitored for CERCLA and AEA purposes under the 200-BP-5 Groundwater OU program.



9.3.3.1 Network Evaluation and Compliance Status

The RCRA groundwater monitoring requirements include an annual evaluation of the network to determine if it remains adequate to monitor the WMA. The network must include upgradient and downgradient wells in the uppermost aquifer. The current network consists of 26 wells. The groundwater gradient beneath WMA B-BX-BY is virtually flat (i.e., the gradient is near zero), so the network includes wells on all sides of the WMA, which remains capable of monitoring the extent and concentration of contaminants throughout 2011.

Wells specified in the assessment plan (PNNL-13022) near the WMA and in nearby past-practice liquid disposal sites are sampled in an effort to differentiate tank-related contamination from that associated with the surrounding non-RCRA waste sites. Many of the wells are co-sampled for the 200-BP-5 OU under CERCLA guidance, although CERCLA sampling is generally performed at a lower frequency, and sampling is coordinated to avoid redundancy.

A site-wide sampling stop work was initiated on September 2010 and was not completely lifted until November 8, 2010. This impacted the collection of the fourth quarter samples at this WMA. The final quarter of sampling at wells 299-E33-7, 299-E33-9, and 299-E33-26 was not performed. Access to the BY Tank Farm had closed during the stop work, thus well 299-E33-9 could not be accessed for sampling. Well 299-E33-26 had pump problems that could not be resolved before the end of CY 2010. In well 299-E33-7, the groundwater elevation decreased in May to a nonpumpable level; the well is awaiting maintenance to lower the pump. Two other wells, 299-E33-15 and -E33-205, also missed complete sampling for the year. Due to scheduling conflicts, access to the BX Tank Farm had closed before well 299-E33-205 could be sampled in December, while well 299-E33-15 had electrical problems that were not resolved in time to collect the first quarter sample. By the end of CY 2010, all but four wells had been sampled for the fourth quarter as scheduled, and those four were sampled by the end of the first week of January 2011.

Determining the hydraulic gradient and flow direction using uncorrected water-level measurements to determine groundwater flow direction is problematic in the 200 East Area because the hydraulic gradient is very small (~1.5×10^{-5} based on regional water-level measurements). To improve the accuracy of water-level measurements in the northwest 200 East Area, a network of fourteen wells was

established at the nearby LLWMA-1, which included two wells from WMA B-BX-BY (299-E33-38 and 299-E33-339). Casing elevations were resurveyed and borehole deviation surveys were performed to correct for nonverticality of the wells. Resulting trend-surface analyses indicated a long-term average flow direction to the north-northwest (340 degrees azimuth), with a gradient of ~1.9×10^{-5} ($\pm 0.2 \times 10^{-5}$). The average flow rate appears to increase to the north as the aquifer thins and where trend plots and groundwater elevation differences indicate ~0.72 to 0.75 meters per day, as discussed further in Sections 9.3.1.1 and 9.1.1.1.

9.3.3.2 Groundwater Contaminants

In FY 1996, the groundwater monitoring program for WMA B-BX-BY shifted from indicator parameter evaluation to groundwater assessment because specific conductance in a downgradient monitoring well exceeded the critical mean value. Results from the ensuing investigation indicated that waste products from the WMA had entered and affected groundwater quality (PNNL-11826, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site*). Subsequent annual assessment reports have been included in the Hanford Site annual groundwater reports (e.g., DOE/RL-2010-11).

The groundwater in WMA B-BX-BY monitoring wells is sampled and analyzed for the parameters listed in Appendix B, Table B-30. In accordance with WAC 173-303-400 and 40 CFR 265.93, selected WMA B-BX-BY network wells are monitored quarterly for RCRA COCs and associated field/supporting parameters. Some of the wells listed in Appendix B, Table B-30 are sampled at other frequencies for selected constituents to provide additional information on contaminant movement and to differentiate tank-related contamination from contamination associated with the surrounding waste sites. Water-level measurements are taken before each sampling event. During CY 2010, most groundwater samples were collected as scheduled. Section 9.3.3.1 discusses the wells missed and the causes for missed sampling.

Additional parameters (i.e., alkalinity, dissolved oxygen, temperature, and turbidity) are measured as indicators of groundwater quality and general aquifer/well environmental conditions. Other anions sampled include chloride and sulfate to detect potential contamination from surrounding waste sites, as well as to provide input for charge-balance calculations.

The primary dangerous waste constituent found beneath WMA B-BX-BY is cyanide. However, based on leak inventories, the likely source of the cyanide beneath the WMA is the BY Cribs (RPP-26744). Certain non-RCRA-regulated constituents (e.g., nitrate, sulfate, and radionuclides) are also found within the boundaries of the WMA (DOE/RL-2010-11). In the past, elevated nitrite levels were also observed. These constituents are attributed to multiple sites, including WMA B-BX-BY and the surrounding cribs.

WMA B-BX-BY appears to be a significant source of AEA-regulated contamination in the 200-BP-5 OU.

Several non-RCRA contaminant plumes coincide with WMA B-BX-BY, and the sources of some of these plumes are likely from within the WMA. Nitrate, technetium-99, and uranium are observed under, and both northwest and southeast of, the BY Tank Farm. The proximity of these contaminants to the BY Tank Farm suggests a possible tank-related source. Technetium-99, nitrate, uranium, sulfate, tritium, cobalt-60, and cyanide occur together near the BY Cribs and, with the exception of uranium, are at high concentrations. Elevated concentrations of iron and manganese are present in the groundwater above DWSs (300 and 50 µg/L, respectively) under the BY Tank Farm. Near the 216-B-8 Crib, nitrate, nitrite, technetium-99, and uranium contamination coincide. In general, many of these

contaminants occur together in tank and crib waste, and their coincidence in groundwater monitoring is expected.

The results from well 299-E33-47 stand out as requiring an individual discussion for CY 2010. Since installation of well 299-E33-47 in 2003, the well (along with well 299-E33-338) has had contaminant concentrations that can be considered "background" when compared to other wells in the WMA B-BX-BY network. This trend continued through the first two quarters of CY 2010 (Figure 9-34). In the latter half of the year, the concentrations of most metals and anions show a dramatic increase (up to 91% for nitrate). The non-RCRA constituent technetium-99 also increased. The exact cause and meaning of these increases remains unknown. Some early possibilities include impact from density flow of contamination along the basalt surface (which dips toward well 299-E33-47 from the potential sources of the BY Cribs and 241-BX-102 tank release), impact from some unrecorded source, or a combination of both. For additional information regarding density flow, see Section 9.1.1.1.

Cyanide. Cyanide concentrations from scavenged waste disposed to the BY Cribs continued to increase in groundwater under the BY Cribs, with concentrations ranging up to 1,590 µg/L in well 299-E33-7. The cyanide plume extends a couple of kilometers to the northwest. Much lower cyanide concentrations north of the 216-B-8 Crib (in wells 299-E33-15 and 299-E33-39) also show continued increases, with a maximum of 159 µg/L in well 299-E33-39 during the reporting period. It is important to note that the 216-B-8 Crib and Tile Field did not receive scavenged waste.

Cyanide concentrations beneath the BY Tank Farm decreased during CY 2010 in wells 299-E33-9, 299-E33-31, and 299-E33-44, with a maximum concentration of 61.4 µg/L in well 299-E33-44. The concentrations reported in wells 299-E33-9, 299-E33-31, and 299-E33-44 appear to be sourced from the BY Cribs. In general, the elevated concentrations in these wells were reported in the 2009 annual report (DOE/RL-2010-11) and occurred during a prolonged groundwater gradient reversal to the south, which was determined by a low-level groundwater elevation study. This flow reversal would have resulted in periods of stagnation when contaminant concentrations would increase. As the flow returned to its normal direction toward the northwest, the elevated concentrations would decline as the contamination once again moved with the groundwater.

A contributing explanation for the elevated cyanide concentrations in these wells may be associated with density flow of contamination along the basalt surface, which dips to the south in this area. A depth-discrete groundwater sampling investigation was performed in CY 2010 and is discussed in Section 9.1.1.1.

Other wells with measurable cyanide concentrations include 299-E33-17 (north of the B Tank Farm and east of the 216-B-8 Tile Field) and well 299-E33-26 (west of the BY Cribs). The two new wells (299-E33-341 and -E33-342), located within the footprint of the BY Cribs also have measurable cyanide. Along with well 299-E33-38 (also in the BY Cribs), wells 299-E33-26, 299-E33-341, and 299-E33-342 each have approximately the same cyanide concentrations.

Only sporadic detection of cyanide has occurred in wells monitoring the B and BX Tank Farms. The maximum concentration measured at the B Tank Farm was 4.7 µg/L in well 299-E33-343, while the maximum concentration measured at the BX Tank Farm was 4.2 µg/L in well 299-E33-205.

Chromium. Chromium concentrations in wells around the BY Tank Farm and north of the B Tank Farm continue to show a slow increase. Well 299-E33-16,

beneath the 216-B-8 Crib, has the highest overall chromium concentration average at 86.9 µg/L. The 216-B-8 Crib is the likely source based on the inventory added to this waste site and the higher groundwater concentrations primarily reported in well 299-E33-16 versus other wells. The chromium received at this site was associated with the sodium dichromate used in the first-cycle decontamination process of plutonium (HW-10475, Hanford Technical Manual). In addition, this site received hydrochloric and citric acid (HW-17088, Underground Disposal of Liquid Wastes at the Hanford Works). The acid may have augmented the total chromium concentration by reaction with and mobilization of the native chromium in sediments within the vadose zone.

The maximum concentration this reporting period was 71.0 µg/L in well 299-E33-18, located between the B Tank Farm and 216-B-8 Crib. The highest tank farm average is 19.36 µg/L at the BY Tank Farm. All concentrations are well below the chromium DWS of 100 µg/L.

Nitrate. Nitrate is prevalent in WMA B-BX-BY as part of process wastes discharged to both tanks and cribs. Generally, nitrate extends along a northwestern-southeastern trend from the northern portion of the 216-B-8 Crib through the BY Cribs and the northeastern corner of LLWMA-1, and it extends to the north-northwest away from the WMA. DOE/RL-2008-01 provides an extensive history of the nitrate plume. No significant changes were observed in CY 2010, although many wells exhibited a general decrease in concentrations during the year. This is not unexpected, as the aquifer moves to re-establish equilibrium after the flow reversal and stagnation that occurred in late 2008/early 2009.

Overall, nitrate concentrations continued to increase beneath WMA B-BX-BY, the BY Cribs, and the 216-B-8 Crib. The maximum concentration for CY 2010 was beneath the BY Cribs at wells 299-E33-7 and 299-E33-341 (1,540 mg/L). The maximum concentration below WMA B-BX-BY was in well 299-E33-44 (753 mg/L), east of the BY Tank Farm and northwest of the B Tank Farm.

Nitrite. Historically, nitrite has been detected in only a few wells in the WMA monitoring network. Nitrite was detected in all of the newly installed wells throughout most of CY 2009 but has decreased to below detection in all but two wells. Well 299-E33-345 (north of the BX Tank Farm) had the highest nitrite concentration (2,650 µg/L) in March 2010. The DWS for nitrite is 3,300 µg/L. The concentration in this well increased sharply from below the detection limit at the start of the year (January), before beginning a declining trend to the end of CY 2010.

Well 299-E33-344, which was recently installed in a perched zone at WMA B-BX-BY, is co-located with well 299-E33-345 and has also shown measurable nitrite concentration, with at a maximum of 4,340 µg/L early in the reporting period. This well has maintained nitrite levels greater than 2,500 µg/L since its installation. Because of the higher concentration in this well, it is likely that the nitrite at well 299-E33-345 is from percolation of perched water.

Sulfate. Similar to nitrate, sulfate levels continued to increase in wells around WMA B-BX-BY, with a minor decrease in concentrations during CY 2010. The highest concentrations in wells monitored for WMA B-BX-BY were greater than 200 mg/L in wells in the northern portion of the BY Tank Farm network.

Eight wells exceeded the 250 mg/L secondary DWS for sulfate in CY 2010, four of which are directly associated with the tank farms. Well 299-E33-31 (in the northwestern corner of BY Tank Farm) had a maximum concentration of 264 mg/L in May, which was a decrease from 267 mg/L in 2009. Well 299-E33-44, opposite

well 299-E33-31 and east of the BY Tank Farm, had a CY 2010 maximum value of 290 mg/L in August. Well 299-E33-9, located in the BY Tank Farm, declined slightly from last year's maximum to a 300 mg/L concentration in September. Finally, new perched well 299-E33-344 had a December 2010 concentration of 529 mg/L.

Other wells that exceeded the DWS include well 299-E33-16 south of the 216-B-8 Crib and Tile Field at 351 mg/L in February; well 299-E33-26 west of the BY Cribs at 296 mg/L in August; and wells 299-E33-38, 299-E33-341, and 299-E33-342, all within the BY Cribs, at 309 mg/L in February, 273 mg/L in August, and 305 mg/L in December, respectively.

9.3.3.3 Performance Assessment Monitoring

Performance assessment monitoring of radionuclides at WMA B-BX-BY, under AEA authority, is designed to complement RCRA assessment monitoring and specifically at monitoring radionuclide materials not regulated under RCRA. The current monitoring plan (PNNL-13022) includes technetium-99 and uranium specifically for performance assessment.

Technetium-99. Technetium-99 occurs in wells throughout the WMA B-BX-BY network and is above the DWS of 900 pCi/L in all of the wells associated with the BY Tank Farm, BY Cribs, 216-B-8 Crib, and 216-B-7A/7B Cribs. Only one other well that is part of the network for WMA B-BX-BY was above the DWS. Well 299-E33-339 (between the BX and B Tank Farms) had a maximum concentration of 1,140 mg/L in March but dropped to below the DWS for May and August (799 mg/L and 609 mg/L, respectively).

The overall technetium-99 concentration trends showed the same character as nitrate of an overall increase with a minor decline in CY 2010. The maximum concentration was 31,000 pCi/L, detected in well 299-E33-38 in the southwestern corner of the BY Cribs. The highest value within the WMA B-BX-BY network of 18,000 pCi/L was in August in well 299-E33-18, which is located north of the B Tank Farm, between the tank farm and the 216-B-8 Crib. Similarly, high concentrations are also found in new wells 299-E33-343 and 299-E33-345, which are located slightly west of well 299-E33-18.

Technetium-99 contamination is attributed to discharges to the BY Cribs and the 216-B-7A&B and 216-B-8 Cribs. In CY 2009, mapping the extent of technetium-99 migration indicated some southward movement of this contaminant across the southern border of the BX and B Tank Farms, as indicated by detection in wells 299-E33-49 and 299-E33-339. This was likely related to periods of stagnation and reverse flow that occurred in late 2008/early 2009 (Figure 9-6). Further support of this is the steady decline in concentrations in both wells since their maximum in early 2009. No other suspected source of technetium-99 is present in this area to contribute to groundwater contamination.

Uranium. The source of the observed uranium contamination in WMA B-BX-BY is the 1951 overfill event of tank 241-BX-102. The highest average uranium value in CY 2010 was northwest of the B Tank Farm in newly installed well 299-E33-343 (3,670 µg/L). The next highest concentration was 1,140 µg/L in well 299-E33-9, located in the center of the BY Tank Farm and downgradient from well 299-E33-343.

The center of uranium contamination was historically believed to be under the BY Tank Farm based on well 299-E33-9 regularly having the maximum concentration. However, since early 2008, rapid increases in the uranium concentration in BX Tank Farm wells to the northeast (76% in well 299-E33-41) and southeast

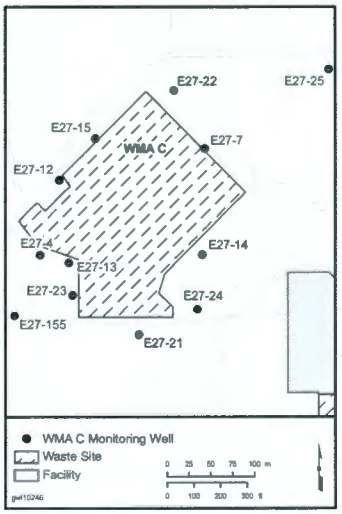
(99% in well 299-E33-339, and 78% in well 299-E33-49) seem to support the tank 241-BX-102 release as the source. In addition the uranium concentration in the perched well 299-E33-344 of 1,660 µg/L, northeast of tank 241-BX-102, may be a potential vadose zone source. The strongest support for a 241-BX-102 source comes from uranium isotope ratios. The comparison of these ratios conclusively links uranium in groundwater at this WMA with the uranium in the 241-BX-102 wastes. The methods used and results are detailed in depth in PNNL-19277.

The historic shape of the uranium plume has suggested groundwater flow to the northwest (Figure 9-25). This interpretation is consistent with the recent detailed water-level interpretation in the vicinity of LLWMA-1.

9.3.4 Waste Management Area C

G.S. Thomas

Groundwater monitoring at WMA C is conducted in accordance with WAC 173-303-400 (and by reference, 40 CFR 265, Subpart F) and the AEA. The WMA C is currently in a RCRA groundwater quality assessment program and is monitored quarterly, as detailed in the RCRA assessment plan for WMA C (DOE/RL-2009-77). Table 3-5 in DOE/RL-2009-77 includes the construction dates for the wells, screened interval, depth to water, screened water column, estimated depth to basalt, and percentage of screen in aquifer.



The objectives of groundwater assessment monitoring include determining if dangerous waste or dangerous waste constituents are in the groundwater, assessing the extent and rate of migration of dangerous waste or dangerous waste constituents in groundwater, and determining the levels of dangerous waste or dangerous waste constituents in groundwater. Cyanide is the only dangerous waste constituent determined to presently be impacting the groundwater at WMA C. Based on the small horizontal gradient at WMA C, no determination could be made for the rate of migration. However, using the analytical results associated with the WMA C monitoring network, an estimated extent of cyanide detection is provided in Section 9.3.4.1. Section 9.3.4.1 also includes discussion of multiple conceptual models for flow direction using the AEA constituent technetium-99. The levels of contamination are discussed in Section 9.3.4.2, as well as the assessment constituents being retained and excluded in accordance with the evaluation process in DOE/RL-2009-77.

All of the wells were successfully sampled during this reporting period, except for the December sampling event at well 299-E27-12. Appendix B, Tables B-31, B-32, B-33, and B-34 provide lists of the wells and constituents monitored for the assessment.

9.3.4.1 Network Evaluation and Compliance Status

At the beginning of the reporting period, the WMA C groundwater monitoring network consisted of ten wells. Two additional WMA C monitoring wells (299-E27-24 and 299-E27-25) were drilled during the reporting period in accordance with DOE/RL-2009-77. New well 299-E27-24 is ~61 meters south of well 299-E27-14, where specific conductance was verified as exceeding the critical mean in July 2009. The other well, 299-E27-25, is located to the northeast of the WMA as a new upgradient well.

Groundwater flow at WMA C has been reported to be southwesterly since at least 1997, with the exception of CY 2009 when the direction was indeterminate. In the

past, groundwater flow directions were based on well water-level elevations that did not account for vertical deviations of the wellbores. As has been previously discussed, the use of uncorrected water-level measurements to determine groundwater flow direction as problematic in the 200 East Area because the hydraulic gradient is very small (~1.5×10^{-5} based on regional water-level measurements). In March 2009, 22 wells were resurveyed to a common bench mark and gyroscoped in north-central and northeast regions of the 200 East Area to increase the accuracy of regional groundwater measurements. Presently determining a directional gradient is still uncertain. Using only the corrected groundwater elevations at WMA C to derive a gradient and flow direction is even more problematic due to the variability in the water-level elevation values. When attempting three-point evaluations, certain wells continually dominate the outcome and are inconsistent by comparison. Therefore, the use of water levels to derive the flow direction and rate is not recommended at this time.

Evaluation of groundwater chemistry provides another potential method for deriving approximate flow direction. This method was used for WMA C in FY 2007 (DOE/RL-2008-01). As discussed in Sections 9.1.1.7 and 9.1.3.3, the ion chemistry between wells along the west to south side of WMA C (299-E27-4, 299-E27-21, and 299-E27-23) have a distinct ion chemistry versus the wells to the east or west (Figure 9-23). The ion chemistry for the wells to the east and west (e.g., 299-E27-14 and 299-E27-155, respectively) have noticeably more calcium, chloride, magnesium, and sulfate than the wells mentioned above. Using the AEA constituent technetium-99 activities derived during depth-discrete sampling within the aquifer (as discussed in Section 9.1.3.1), a plume configuration was created (Figure 9-22). Figure 9-22 suggests a generally south to southeast flow direction. If the flow is to the southeast, it also follows that technetium-99 may have infiltrated from the vadose zone near wells 299-E27-4 and 299-E27-23. However, vadose zone investigations have not found evidence for significant vadose zone contamination in this area to support this conceptual model. Therefore, an alternative conceptual flow model is provided below.

The alternative (and not necessarily exclusive) conceptual model is based on the technetium-99 activity as compared with nitrate concentration in the wells along the west and southwest side of the C Tank Farm. The technetium-99 result was divided by the corresponding nitrate result to create a ratio at each well location for evaluation. Figure 9-24 provides a contour of the ratio results. The contours provide the basis for another model that conforms to the previous southwest flow direction interpretations at WMA C. Using this basis, the technetium-99 activities associated with the depth-discrete sample results at ~9 meters below the water table were recontoured (Figure 9-24). A bias is given to this conceptual model because of similar technetium-99 to nitrate ratios for wells along the eastern side of the C Tank Farm. The varying technetium-99 to nitrate ratios in wells to the southeast may also indicate more than one source of groundwater contamination from WMA C. Additional discussion on previous ratio evaluations at WMA C is provided in DOE/RL-2008-01.

Because no measurable gradient can be determined at WMA C, a flow rate is not provided. However, wells to the north and south of the C Tank Farm provide boundary conditions for the lateral extent of cyanide contamination. Wells to the south and southwest of C Tank Farm do not provide as clear of a definition for deriving the south lateral extent of cyanide contamination. Therefore, only an approximation of the extent of cyanide contamination to the south can be provided, and dashed contours are depicted in Figure 9-35 where bounding wells to the south are not present.

The vertical extent of cyanide contamination south of WMA C is the bottom of the aquifer where cyanide is observed in wells 299-E27-24 and 299-E27-155.

9.3.4.2 Groundwater Contaminants

This subsection discusses the analytical results for the dangerous waste constituent cyanide. Discussion is also included on the analytical methods approved to determine if dangerous waste constituents were present, the results of those analyses, and the rationale for exclusion of certain constituents.

During the reporting period, the dangerous waste constituent cyanide was detected in seven of the twelve network monitoring wells.

During the reporting period, the dangerous waste constituent cyanide was detected in seven of the twelve network monitoring wells, all at levels far below the 200 µg/L DWS (Figure 9-35). Nondetect values were reported in three of the four wells with screen intervals in the upper 1.5 meters of the aquifer. The other nondetect values were in wells to the north and northeast (299-E27-22 and 299-E27-25). The highest concentrations, ranging from 17.5 to 38.7 µg/L, were in well 299-E27-7, located on the east side of WMA C. The next highest concentrations were in well 299-E27-14, located to the south of well 299-E27-7, ranging from 16.2 to 20.6 µg/L. Well 299-E27-14 is the only well screened in the upper 1.5 meters of the aquifer that detected cyanide; the cyanide concentrations in this well have also been trending upward since 2006, when mainly nondetect results were reported previously. Further south in new well 299-E27-24, analytical results indicated the highest concentrations in the lower portion of the aquifer during drilling; therefore, the well was screened in the lower 6.1 meters of the aquifer. Only one quarterly sample was collected from this well in 2010; the concentration reported in December was 15.3 µg/L, which is consistent with the concentration reported in this portion of the aquifer during drilling. Based on the time difference when cyanide was detected at wells 299-E27-7 and 299-E27-14, the dispersive front of cyanide should not have been as concentrated in well 299-E27-24, assuming a southwest flow direction. Thus, the flow direction may be changing to a more southward direction. Also, because higher concentrations are found in the lower portion of the aquifer at well 299-E27-24, contamination appears to be preferentially moving downward through the aquifer beneath WMA C. This is consistent with the vertical head differences between wells screened in the upper portion of the aquifer (e.g., 299-E27-4 and 299-E27-23) and well 299-E27-155 screened in the lower portion of the aquifer.

Cyanide concentrations also ranged from 5.2 to 8.43 µg/L in the lower portion of the aquifer at well 299-E27-155, located to the southwest of the C Tank Farm. This well is located ~290 meters southwest of well 299-E27-7 and has had consistent cyanide concentrations ranging between 4 and 8.43 µg/L since monitoring began in January 2008; thus, flow to the southwest appears to have occurred in the past. Because cyanide has been consistently detected in wells 299-E27-7, 299-E27-14, and 299-E27-155 the cyanide plume is shown as extending beyond these wells (Figure 9-35).

As approved in DOE/RL-2009-77, a common subset of constituents from two lists of potential COCs were used to determine if dangerous waste or dangerous waste constituents have impacted the groundwater. The lists used and rationale for selection of the contaminant of potential concern are discussed in Section 2.7 of DOE/RL-2009-77. Based on the resulting list of constituents (Appendix B, Tables B-31, B-32, B-33, and B-34), the following analytical analyses were performed to determine if dangerous waste or dangerous waste constituents were present in the groundwater at WMA C:

- SW-846, Method 8260, "Volatile Organics"

- SW-846, Method 8270,"Semi-Volatile Organics"
- EPA Method 8081 "Pesticides"
- EPA/600 Method 200.8 and SW-845 Method 6010, "Metals"
- EPA/600 Method 335.2 "Cyanide"
- Sulfides-9030, "Sulfide"
- EPA/600 Method 300.0, "Anions"
- EPA Standard Method 2320 "Alkalinity."

According to DOE/RL-2009-77, a minimum of two quarterly sampling events are necessary to determine whether a constituent should be excluded from the assessment. The sampling events occurred in December 2009 and March 2010. In accordance with the evaluation process, if questions arose regarding a potential dangerous waste or dangerous waste constituent, then additional samples would be collected. Since the assessment began in December 2009, eight volatile organics and ten metals were detected above site-wide background concentrations during quarterly sampling events, requiring further evaluation as possible dangerous waste or dangerous waste constituents. The following two paragraphs discuss the additional evaluation of these constituents. The remaining constituents were excluded per the evaluation process outlined in DOE/RL-2009-77. Thus, the currently applicable tables of constituents being collected and analyzed are provided in Appendix B, Tables B-31 and B-32.

Volatile organic compounds have been sampled four times since the assessment began, and samples continue to be taken and evaluated. Three of the eight volatile organics (e.g., bromomethane, chloromethane, and tetrachloroethane) were detected in blank samples at concentrations near the reported value, which was also near the detection limit, and are therefore not considered representative of groundwater contamination.

- Carbon disulfide was detected in two wells (299-E27-13 and 299-E27-155) at 0.07 and 0.12 μg/L, respectively. The result in well 299-E27-13 was the only detect value in four samples since the assessment began, and the result was within the error margin of the laboratory method detection limit (0.05 μg/L). The result for well 299-E27-155 was the only detected result during the assessment for this well, and it was also the only detection in nineteen samples from the previous 3 years; in addition, the duplicate result was nondetect. Therefore, both carbon disulfide results are considered false positives.
- Acetone was detected in two wells (299-E27-23 and 299-E27-155) at 1.90 and 5.60 μg/L, respectively. The result in well 299-E27-23 was the only detect value in six samples since the assessment began, and the result is considered a false positive because the duplicate result was nondetect. The detected result in well 299-E27-155 also had a duplicate result reported as nondetect. In addition, the detected value was the only detected value in nineteen samples over the past 3 years when this well was first installed. Therefore, both acetone results are considered false positives.
- The constituent 2-hexanone was detected in well 299-E27-155. The result at this well was the only detected value in nine samples over the previous 3 years, and the result is considered a false positive because the duplicate result was nondetect.
- Carbon tetrachloride was detected in well 299-E27-13 once in four samples since the assessment began. The result, 0.22 μg/L, is less than five times the laboratory method detection limit (0.06 to 0.012 μg/L) and is being evaluated.

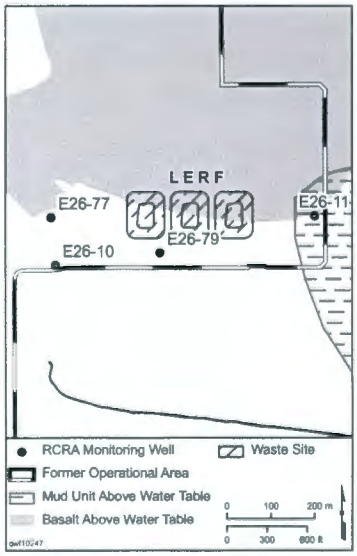
- Chloroform was detected in three wells: 299-E27-12, 299-E27-24, and 299-E27-155. Two results were reported in well 299-E27-12 (e.g., 0.15 and 0.13 in March and August, respectively) and were within the error margin of the laboratory method detection limit (0.10 µg/L). One result of 0.13 µg/L was reported in well 299-E27-24 in December and was within the error margin of the laboratory method detection limit. Chloroform was also detected once at 0.16 µg/L in nineteen analyses from well 299-E27-155 during the previous 3 years and was within the error margin of the laboratory method detection limit. Chloroform is being retained for further evaluation during 2011 in accordance with DOE/RL-2009-77.

The evaluation process of the metals in accordance with DOE/RL-2009-77 is discussed below. Seven of the ten metals detected above background concentrations during the assessment period were associated with one or more of the following: unfiltered results, filtered results associated with elevated concentrations in the quality control blank, and/or results during drilling from an uncased well (e.g., 299-E27-24 and 299-E27-25). Therefore, these seven constituents were excluded from further consideration. Below is a discussion of the other three metals detected above background concentrations.

- Cobalt was detected once during the assessment period in well 299-E27-7, with a concentration of 5.6 µg/L. Although this value is above the Hanford Site background concentration, it is the only detected cobalt concentration above background in the monitoring network since assessment began and only the second detect reported value in 61 sample results over the past 10 years in this well. Therefore, this cobalt result is not considered representative of the groundwater.
- Filtered nickel results were reported above Hanford Site background in seven WMA C monitoring wells. The filtered results in upgradient well, 299-E27-22, was also reported above background. Although the highest concentration was not in the upgradient well, regional wells have shown higher results than this well. Therefore, nickel is continuing to be evaluated but is not considered to be a dangerous waste constituent associated with the C Tank Farm at this time.
- Filtered vanadium results were reported above Hanford Site background in all but two of the WMA C monitoring wells. The filtered results in the two upgradient wells, 299-E27-22 and 299-E27-25, were also reported above background. Although the highest concentration was not in the upgradient well, regional wells have shown comparable results with the highest value at WMA C. Therefore, vanadium is continuing to be evaluated but is not considered a dangerous waste constituent associated with the C Tank Farm at this time.

9.3.5 Liquid Effluent Retention Facility

D.C. Weekes



Located on the eastern boundary of the 200 East Area, the LERF consists of three lined surface impoundment basins. Construction of the complex was completed in 1991. The basins are arranged side by side, with 18.2-meter separation between each basin. The dimensions of each basin (cell) are 100.5 meters by 82.2 meters, with a maximum fluid depth of 6.7 meters.

The latest stratigraphic interpretation beneath the LERF was constructed from the four original and two additional boreholes drilled for the groundwater monitoring network. Correlations were also made with data from nearby sites. The thickness

of the sediments near the LERF basins is ~61 meters. Three principal stratigraphic units present near the LERF are the Hanford formation, the Ringold Formation, and the Elephant Mountain Member of the Saddle Mountains Basalt. The vadose zone beneath the LERF is in the Hanford formation and portions of the Elephant Mountain Member where it occurs above the water table, as well as potentially some of the Ringold Formation or a paleosol resulting from the weathering of the Elephant Mountain Member flow top near well 299-E26-11. Perched water table conditions are not observed near the LERF basins. The uppermost aquifer directly beneath the LERF consists of thin aquifer(s) in the Hanford formation and Elephant Mountain Member flow top. The aquifer in the Hanford formation is unconfined; however, recent analysis of water-level data for barometric pressure responses indicates that the aquifer near well 299-E26-11 is semiconfined. Well 299-E26-11 is still considered capable of yielding representative samples from the same hydrostratigraphic unit as the other three wells associated with the LERF groundwater monitoring program.

Groundwater at LERF continued to be monitored under RCRA final status permit conditions. The LERF is a RCRA-regulated unit under the *Revised Code of Washington* (RCW) 70.105 ("Hazardous Waste Management") and is subject to groundwater monitoring requirements pursuant to WAC 173-303-645 ("Releases from Regulated Units"). The well network was sampled semiannually for RCRA indicator and site-specific parameters (PNNL-11620, *Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan*).

9.3.5.1 Network Evaluation and Compliance Status

The current groundwater monitoring network consists of one upgradient well (299-E26-11) and three downgradient wells (299-E26-10, 299-E26-77, and 299-E26-79), which are sampled semiannually. The initial groundwater monitoring network was installed at the LERF in 1990 before final construction of the complex. During CY 2008, two additional monitoring wells (299-E26-77 and 299-E26-79) were installed to replace two original network wells that went dry. Well 299-E26-77 is west of the basins (near dry well 299-E26-9), and well 299-E26-79 is south of the western edge of Basin 43. The other two monitoring wells are well 299-E26-10 (in the southwestern corner of the unit) and upgradient well 299-E26-11 (at the eastern end of the unit). All monitoring wells are compliant with WAC 173-160 ("Minimum Standards for Construction and Maintenance of Wells").

Work began in FY 2008 to better understand the groundwater flow direction beneath the LERF. Vertical elevation surveys and gyroscopic surveys were performed at three wells (299-E26-10, 299-E26-77, and 299-E26-79) in CY 2009 due to the flatness of the water table. Trend-surface analyses were applied to the measurements to determine gradient magnitudes and flow directions on two data sets: one data set without barometric corrections, and the second data set with barometric corrections. The two sets are very similar, so only the corrected set will be discussed. Since well 299-E26-11 is considered to be in the semiconfined aquifer and possibly not in direct hydraulic communication the other three wells, it shows ~0.8 meters higher head than the remainder of the wells and was excluded from the analyses. The semiconfined aquifer is in communication with the unconfined aquifer; however, it is a different hydrostratigraphic unit with different properties. Trend-surface analysis was performed for the three remaining wells in the network (exclusive of well 299-E26-11), and the data set corrected for barometric effects showed average groundwater flow direction to be south-southwest at 199 (±28) degrees) and the average gradient magnitude was 2.6×10^{-4} ($\pm 5.8 \times 10^{-4}$) m/m, with a calculated groundwater flow of ~0.02 meters per day (see Appendix B, Table B-1). This analysis

is similar to the CY 2009 groundwater flow direction of 199 degrees. The gradient magnitude increased from the CY 2009 value of 1.3×10^{-4} m/m.

The uppermost aquifer beneath the LERF is being evaluated as part of a groundwater evaluation plan. This plan will be part of a revision of the LERF operating permit that will form the basis for future groundwater monitoring at the unit. The results from drilling new wells suggest that the fractured basalt flow top makes up the basal portion of the unconfined aquifer. One new borehole will be drilled on the north side of the LERF in CY 2011 to determine whether sufficient water is available for installing a well to further delineate groundwater flow direction. It is anticipated that the water table is present within the basalt flow top.

9.3.5.2 Groundwater Contaminants

The constituents currently monitored are alkalinity, gross alpha, ammonium, anions, gross beta, metals, phenols, and volatile organics. Nitrate, total organic halogen, total organic carbon, tritium, and gross alpha- and gross beta-emitting isotopes are COCs.

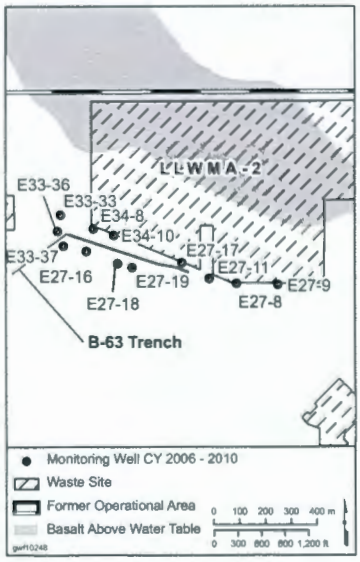
Analyses of samples collected during the reporting period indicate that all constituents in the permit were either undetected or below DWSs, except for nitrate. Specific conductance and sulfate results slightly increased in well 299-E26-10. Nitrate exceeds the DWS in wells 299-E26-10 and 299-E26-77, with maximum concentrations of 50.9 and 53.6 mg/L, respectively. Nitrate has been increasing in well 299-E26-10 since 2003 and in wells south and east of the LERF. The regional increase of anions and cations is evident in wells located in the central and eastern portions of the 200 East Area. Wells installed prior to LERF operations showed increasing nitrate from a regional plume.

9.3.6 216-B-63 Trench

C.J. Martin

Located southwest of LLWMA-2, the 216-B-63 Trench is one of three nonoperational TSD units in the 200-CS-1 Chemical Sewer OU that is currently undergoing closure negotiations. The 216-B-63 Trench is a regulated unit because it received nonradioactive dangerous waste regulated by 40 CFR 261 ("Identification and Listing of Hazardous Waste") after November 19, 1980. The 216-B-63 Trench is regulated as a surface impoundment, as defined in WAC 173-303-040 ("Dangerous Waste Regulations," "Definitions").

The groundwater beneath the 216-B-63 Trench is monitored in accordance with WAC 173-303-400 and 40 CFR 265.93(b) to detect the impact of potential dangerous waste/dangerous waste constituent to groundwater. A revised and updated groundwater monitoring plan for this unit was issued in June 2010 (DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*). The revised plan reduced the number of wells in the network from twelve to seven. Each well is sampled semiannually for contamination indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) and annually for groundwater quality parameters (i.e., alkalinity, metals, phenols, and anions) and site-specific constituents (DOE/RL-2008-60). Appendix B, Table B-12 lists the network wells and the groundwater constituents monitored.



The 216-B-63 Trench was an open, unlined, manmade excavation, ~427 meters in length. The trench boundary is located at the southwestern perimeter of LLWMA-2 (218-E-12B Burial Ground) in the 200 East Area. During its operational period,

the trench was ~1.2 meters wide, with an average depth of 3 meters, and it had an earthen shielding berm and a side slope of ~10:6. Operations at the 216-B-63 Trench began on March 22, 1970, when it received cooling water from both B Plant and in-tank solidification unit #2. From May 1970 until February 1992, the trench also received B Plant chemical sewer effluent. A total of ~970,000 liters per day of total flow reached the trench. The regulated discharges constituted a minor portion of this flow (less than 1,900 liters per day). The 216-B-63 Trench was removed from service in 1992. Interim stabilization measures were completed at the trench in November 1994, and the site was permanently isolated by filling the weir box at the head end of the ditch with concrete on December 12, 1994.

From 1945 to 1995, groundwater flow direction and hydraulic gradients near the 216-B-63 Trench were highly influenced by hydraulic mounding associated with discharges to the 216-B-3 Pond. Decommissioning of the ponds resulted in a dramatic decline in groundwater elevations throughout the 200 East Area, which has in turn lead to a region of essentially flat groundwater gradients across the 200 East Area. This lack of appreciable gradient results in high uncertainty in the groundwater flow rate and direction. As discussed for LLWMA-2 (Section 9.3.2.1), determining a gradient and flow direction in this area is problematic for the reporting period, therefore these parameters are considered indeterminate at the 216-B-63 Trench.

9.3.6.1 Network Evaluation and Compliance Status

The interim status monitoring requirements of 40 CFR 265, Subpart F and WAC 173-303-400 require upgradient and downgradient monitoring wells that ensure immediate detection of any statistically significant change in concentrations (e.g., above the statistically derived critical mean for the four indicator parameters) of dangerous waste or dangerous waste constituents at the limit of the TSD unit within the uppermost aquifer. These requirements also include an annual evaluation of the monitoring network to determine if it remains adequate to monitor the unit. The current network consists of seven wells that essentially surround the unit. This subsection discusses if the network remains capable of monitoring the 216-B-63 Trench in accordance with these requirements.

The present network remains satisfactory for the detection of potential releases from the 216-B-63 Trench throughout CY 2010.

Based on the current configuration of the monitoring network, the wells remain capable of detecting potential releases from the 216-B-63 Trench, regardless of the groundwater flow direction. Because the wells essentially surround the unit and are all sampled on the same frequency and for the same constituents, when a flow direction is determined, the wells to be used for the specified upgradient/ downgradient comparisons can be selected. Critical means for use during 2011 (Appendix B, Table B-13) were determined using upgradient wells based on historical flow directions.

Groundwater monitoring to date has indicated no impact from the 216-B-63 Trench; therefore, the site will remain under detection monitoring for indicator parameters.

To date, no dangerous waste subject to WAC 173-303 from the 216-B-63 Trench has contaminated groundwater; therefore, the site will continue in an interim status indicator evaluation monitoring program for the upcoming year. During CY 2010, all groundwater samples were collected and analyzed as scheduled, with the exception of the final sample from well 299-E27-16, as noted below.

A revised and updated monitoring plan (including the well network, COCs, sampling and analysis procedure, and a conceptual model) was completed and issued in June 2010.

9.3.6.2 Groundwater Contaminants

As required in accordance with WAC 173-303-400 and RCRA (40 CFR 295.93[b]) in regard to interim status facility indicator parameter monitoring, the required indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) are statistically compared between upgradient and downgradient wells using the most recent data. No statistical comparison values for any of the indicator parameters were exceeded at the 216-B-63 Trench during the reporting period.

Groundwater samples were collected and analyzed as scheduled in CY 2010 at all seven wells monitoring the 216-B-63 Trench, with the exception of the final sample from well 299-E27-16. A site-wide sampling stop work went into effect on September 27, 2010, and was completely lifted by November 8, 2010. This work stoppage impacted all groundwater sampling at the site. Six of the seven wells had been sampled before a RCRA recovery plan could be implemented. By the time the plan was implemented, the CY had ended, thus negating the ability to collect the second semiannual sample from this well.

The groundwater beneath the 216-B-63 Trench is monitored for detection of dangerous waste/dangerous waste constituent impact to groundwater. The seven wells in the groundwater monitoring network are sampled semiannually for contamination indicator parameters (i.e., pH, specific conductance, temperature, total organic carbon, and total organic halides). Required groundwater quality parameters (i.e., alkalinity, metals, phenols, and anions) are monitored annually (DOE/RL-2008-60). Additional parameters (i.e., dissolved oxygen, temperature, and turbidity) are measured as indicators of sample quality and general aquifer/well environmental conditions. Appendix B, Table B-12 provides a list of wells in the monitoring network, their locations, and the groundwater constituents monitored. Water-level measurements are taken before each sampling event.

Specific conductance is the only required parameter showing a trend. Specific conductance continues to increase, which is consistent with corresponding increases in major cations (e.g., calcium, magnesium, potassium, and sodium) and anions (e.g., chloride and sulfate) throughout the region. Well 299-E27-9, which is the furthest away from the actual trench, shows the most rapid increase. The increases associated with well 299-E27-9 are discussed in Section 9.3.2.2.

Concentrations of the indictor parameters remained steady in CY 2010. Total organic carbon and total organic halides were undetected in all network wells, with the exception of well 299-E34-10. Concentrations of both constituents in this well were just above the detection limit.

During the reporting period, no detected constituents were above their respective DWSs. No evidence of dangerous waste/dangerous waste constituents impacting groundwater was detected at the 216-B-63 Trench during CY 2009.

9.4 Conclusions and Recommendations

The conclusions and recommendations for the 200-BP-5 OU are presented in the following subsections.

9.4.1 Conclusions

Other than expansion of the nitrate plume south of LLWMA-2, no significant changes in the distribution of the ten contaminant plumes within the 200-BP-5 OU were observed during the monitoring period. This is mainly because groundwater

within the northern portion of the 200 East Area moves slowly. Eleven additional conclusions are as follows:

- The TEDF discharges during CY 2010 were associated with increased water levels across the 200 East Area and a statistically significant north groundwater flow gradient at LLWMA-1. The periodic TEDF discharges slow the southeast flow from the 200 East Area (Figure 9-5). Consequently, flow in the northwest corner of the 200 East Area diverted more prominently toward Gable Gap. An indicator of this result was the increased flow rate between wells 299-E33-26 and 299-E33-38, located at the BY Cribs and extending to the northwest. The flow between these two wells reverted back to the north in 2009 after a flow reversal in 2008. Between 2009 and 2010, the average flow rate was calculated at ~0.75 meters per day. The longevity of this pathway to Gable Gap is questionable due to the decreasing water levels and the decreasing aquifer thickness (Section 9.1.1.1). Although the aquifer thickness is questionable, the influence of this pathway to divert water to the north appears to reach the southern portion of B Plant.
- In the north-central and northeast portion of the 200 East Area, flow measurement methods indicate that groundwater flow is likely less than 0.1 meter per day.
- Groundwater monitoring within the 200 East Area has helped to identify areas where continuing contaminant infiltration from the vadose zone is impacting the groundwater. Contaminant infiltration at the following sites and associated contaminants are either confirmed or highly probable. (Note that B Pond and Gable Mountain Pond, which are both inactive, remain as contributors but are not summarized below.)
  - BY Cribs: Current cyanide, nitrate, sulfate, technetium-99, and tritium.
  - 241-BX-102 unplanned release: Current nitrate, technetium-99, uranium, and possibly iodine-129. The main source of iodine-129 in the 200-BP-5 OU appears to be associated with sites in the 200-PO-1 OU during the late 1980s and early 1990s, when the flow divide was further south.
  - 216-B-57 Crib: Current contributor of nitrate and tritium.
  - 216-B-8 Crib: Current contributor of nitrate with elevated chromium.
  - 216-B-7A&B Cribs: Current contributor of nitrate.
  - WMA C: Current contributor of cyanide, nitrate, sulfate, and technetium-99.
  - 216-B-2 Ditches: Current contributor of nitrate and sulfate.
  - 216-B-11A&B french drain: Possibly contributor of nitrate.
  - 216-B-12 Crib: Past contributor of nitrate, tritium, and uranium.
  - 216-B-5 injection well: Past contributor of cesium-137, plutonium-239/240, and strontium-90.
- Contaminants associated with high specific gravity wastes have apparently sunk through the aquifer in the past at well 299-E33-12. Depth-discrete sampling and analysis of groundwater near the BY Cribs and south of the BX Tank Farm found higher concentrations of several contaminants/constituents at depth (i.e., cyanide, chloride, nitrate, sulfate, and technetium-99). The depth-discrete results, although not conclusive, indicate possible density-type transport of various contaminants as far as the south side of the BX Tank Farm. This conclusion is based on the northern flow direction in this area and the lack of a known source of contaminant infiltration to the south.

- Depth-discrete sample results near WMA C found higher concentrations of several contaminants/constituents at depth. Unlike the possible density theory at the B Complex, the deep contamination at WMA C appears to be associated with a downward gradient based on the much lower head in well 299-E27-155 than the head in wells 299-E27-4 and 299-E27-23 screened higher in the aquifer (Section 9.3.4.1).
- Well 699-53-55A, located west of Gable Mountain Pond, appears to be poorly sealed and does not provide samples representative of groundwater in the Rattlesnake Ridge Interbed or upper Pomona basalt.
- Directly north of Gable Gap, groundwater seems to be moving very slowly or is stagnant near wells 699-64-62 and 699-66-64. Tritium activity has essentially decreased in accordance with the decay rate over the past 8 to 10 years in these wells. North and east of Gable Gap, however, preferential migration of tritium is apparent along the north side of Gable Mountain and to the northeast. This is based on the slight increase over the past 6 years in well 699-67-51, which was reported at 1,810 pCi/L in October 2004 and by November 2010 had increased to 2,600 pCi/L.
- None of the data from the RCRA TSD units in interim indicator evaluation monitoring suggested an impact to the groundwater during CY 2010. Indicator parameter results did not indicate a significant increase (above the critical mean), with one exception. The specific conductance critical mean was exceeded at LLWMA-1, but the increase is associated with an upgradient source; therefore, the status remains the same. In addition, the monitoring networks were determined to be satisfactory in all but one of the RCRA sites. The one exception was the LERF site, where an additional well is planned for installation in 2011.
- Cyanide was determined to be a dangerous waste constituent in groundwater that has a source at the C Tank Farm. The assessment of other constituents is continuing in accordance with DOE/RL-2009-77.
- Tri-Party Agreement Milestone M-015-082 was achieved with submittal of Draft A of the 200-BP-5 OU treatability test plan (DOE/RL-2010-74). Two test sites were identified to evaluate the practicality of implementing a groundwater pump-and-treat system for the extraction of uranium and technetium-99 contaminant plumes near WMA B-BX-BY. The test is planned for early to mid-FY 2012 (based on available funding).

9.4.2 Recommendations

The recommendations listed below are based on the evaluation of contaminant trends, data from new RI wells, spatial examination of contaminants, and evaluation of corrected groundwater-level measurements locally and regionally:

- Revise the 200-BP-5 OU sampling and analysis plan (DOE/RL-2001-49) to achieve the following:
  - Modify the sampling and analysis requirements for distal wells monitoring sources associated with low mobility contaminants. This will include reducing the monitoring frequency for contaminants such as cesium-137, plutonium-239/240, and strontium-90.
  - Include ion chemistry in key wells as an alternative means for evaluating flow direction. The major ions will be used (Section 9.1.1.2).
  - Incorporate key new 200-BP-5 RI wells.

  - Update well list by removing decommissioned wells.
  - Provide a new conceptual model based on revisions to the geologic framework.
  - Propose new well locations for refinement of plume configuration.
  - Include radionuclides that have been removed from RCRA monitoring plans.
- Decommission well 699-53-55A because it appears to be poorly constructed and provides a possible pathway for contaminant migration near the base of the Rattlesnake Ridge interbed.

Table 9-1. Monthly Corrected Groundwater Elevations in Northwest Corner of 200 East Area Used to Derive Groundwater Flow Direction and Rate

Well Name	1/21/10	2/25/10	3/8/10 and 3/16/10	4/29/10	5/23/10	6/30/10	7/13/10	8/10/10	9/15/10	1/4/11
299-E33-38*	121.9042	121.8682	121.8822	121.9372	121.8522	121.8512	121.8492	121.8332	121.8442	121.8532
299-E33-34*	121.8801	121.8631	121.8611	121.8401	121.8451	121.8501	121.8441	121.8331	121.8461	121.8501
Difference in elevation*	0.0241	0.0051	0.0211	0.0971	0.0071	0.0011	0.0051	0.0001	-0.0019	0.0031
Distance between wells*	509	509	509	509	509	509	509	509	509	509
Monthly gradient calculation (elevation over distance)	4.735E-05	1.002E-05	4.145E-05	1.91E-04	1.395E-05	2.161E-06	1.002E-05	1.965E-07	-3.733E-06	6.090E-06
Estimated direction	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Indeterminant	Southeast	Northwest
Range in gradient	-3.73E-06 to 1.96E-07									
Gradient range (after removing the two highest and lowest)	1.00E-05 to 2.16 E-06									
Average of the six remaining gradients	2.083E-05									
Average groundwater flow rate	0.781									

Notes:

1. Yellow-shaded cells indicate the two highest and lowest monthly gradients.
2. Calculation used to derive average groundwater flow rate: $V = [K(h_1\text{-}h_2)/L]/n$

   where:

   V = average groundwater flow

   K = hydraulic gradient (7500 m)

   h_1 = upgradient groundwater elevation

   h_2 = downgradient groundwater elevation

   L = distance between wells

   n = porosity (0.2).
3. $(h_1\text{-}h_2)/L$ = average of remaining gradients from above.

* All values are in meters.

Figure 9-1. Boundaries of 200-BP-5 Groundwater Operable Unit and Adjacent Operable Units

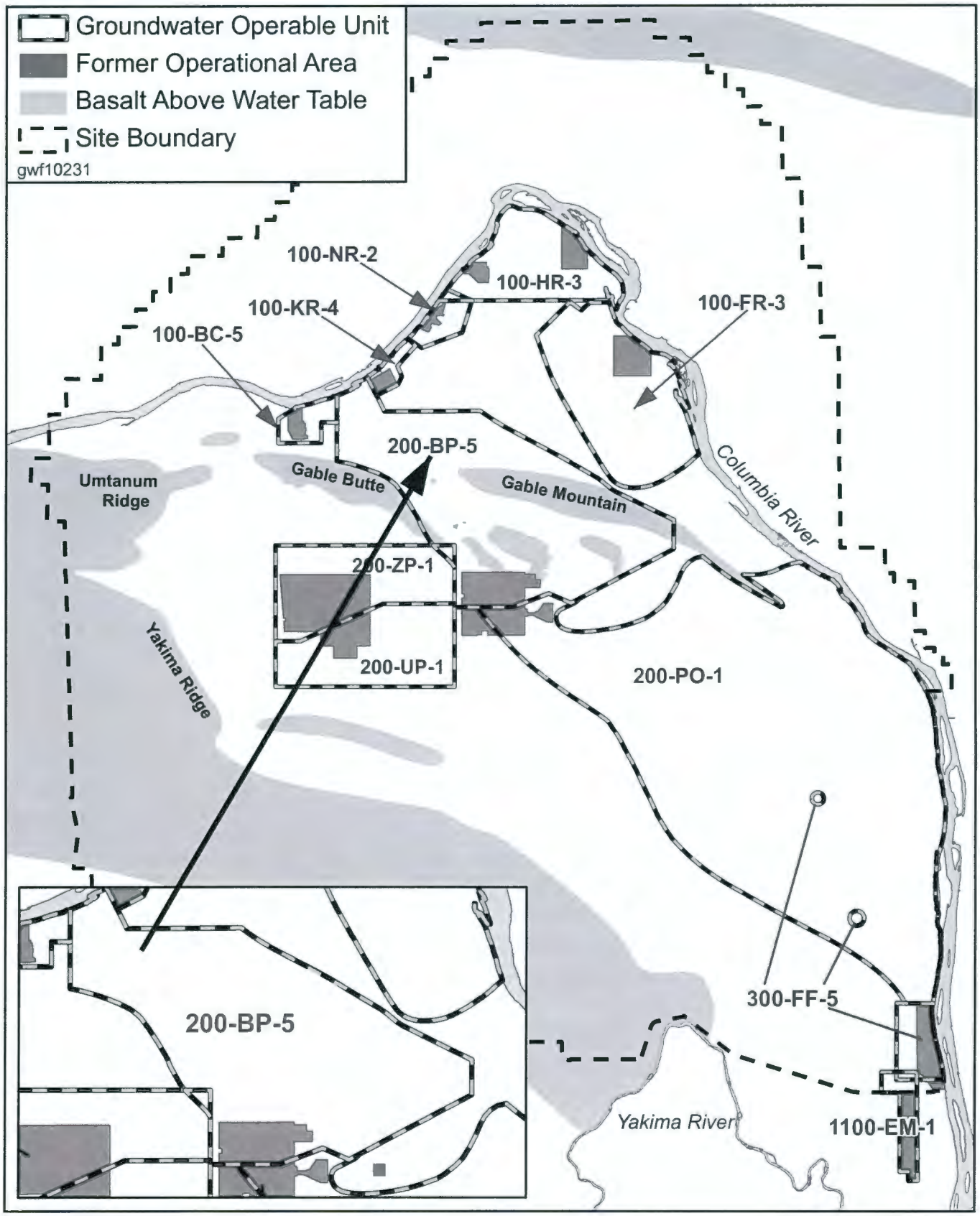
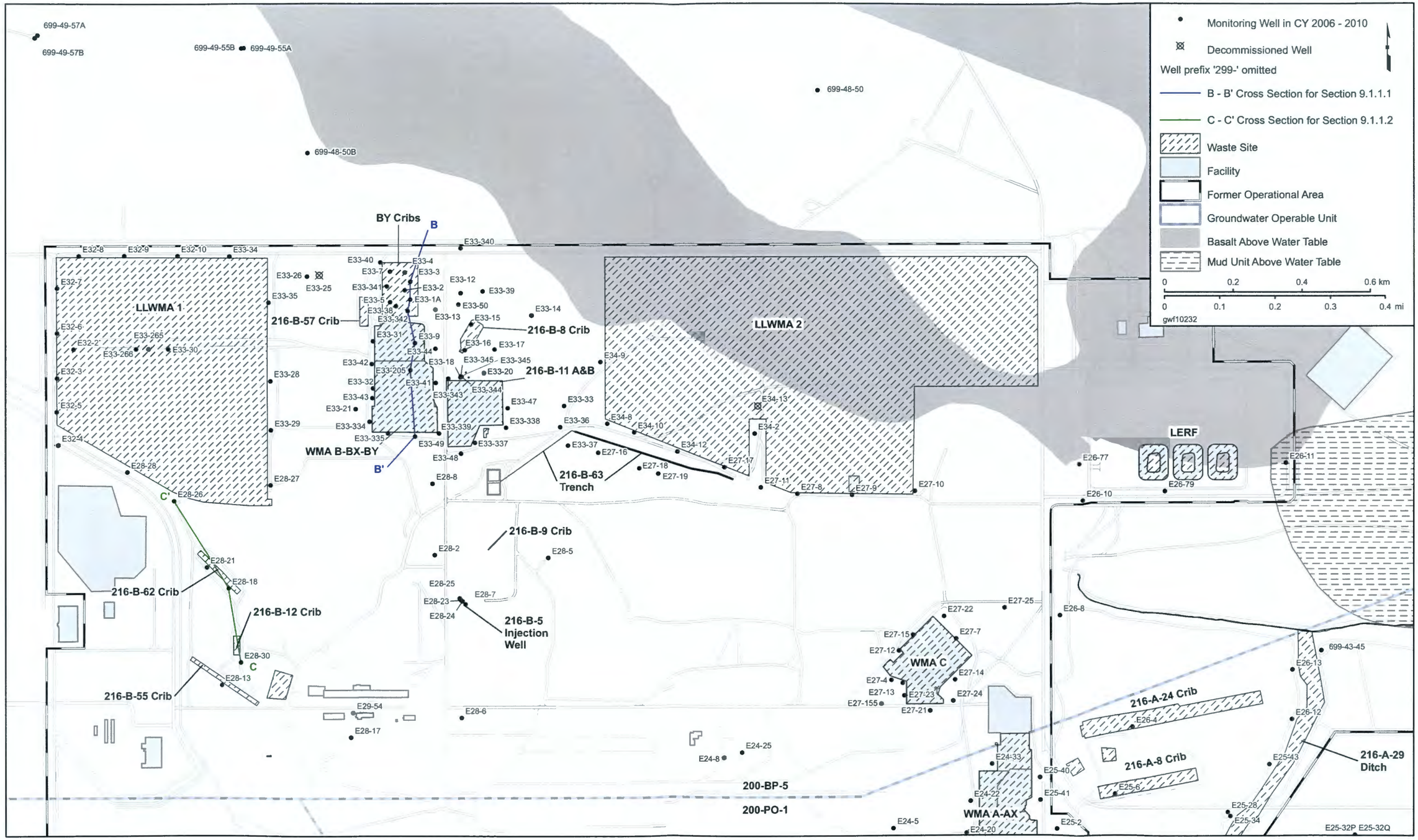
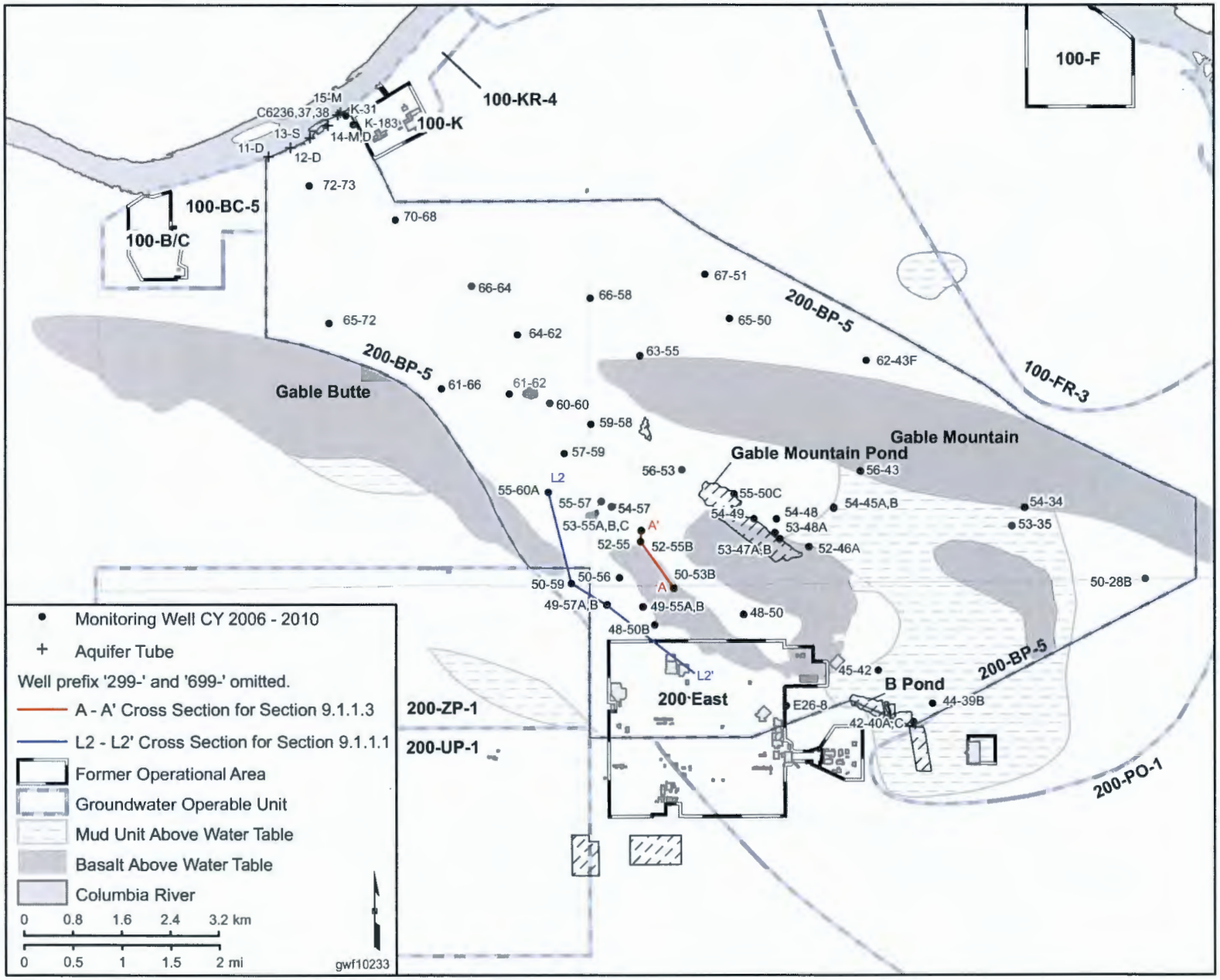


Figure 9-2. Facilities and Groundwater Monitoring Wells in 200-BP-5 Operable Unit Portion of 200 East Area



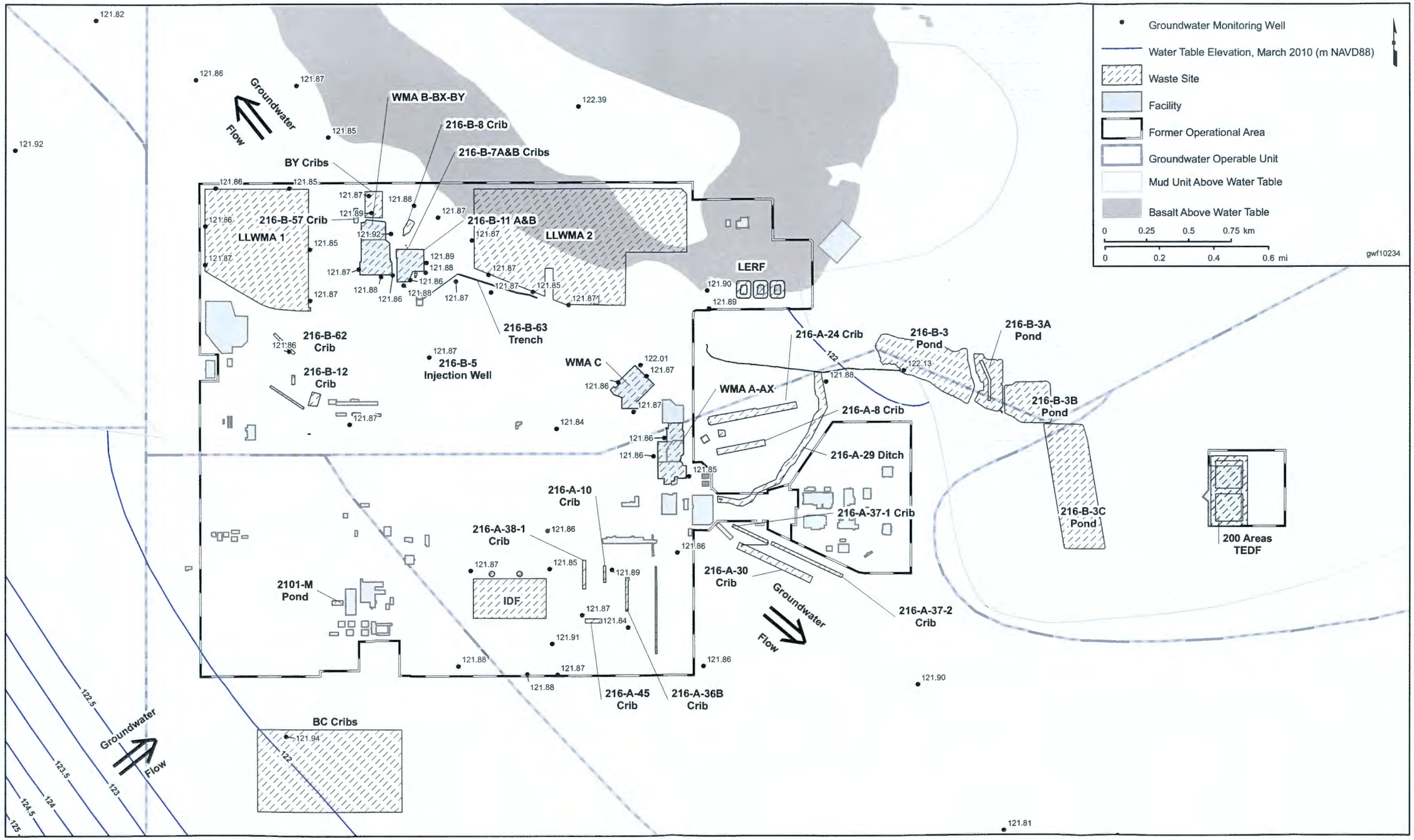
This page intentionally left blank.

Figure 9-3. Facilities and Groundwater Monitoring Wells in 600 Area Associated with 200-BP-5 Operable Unit



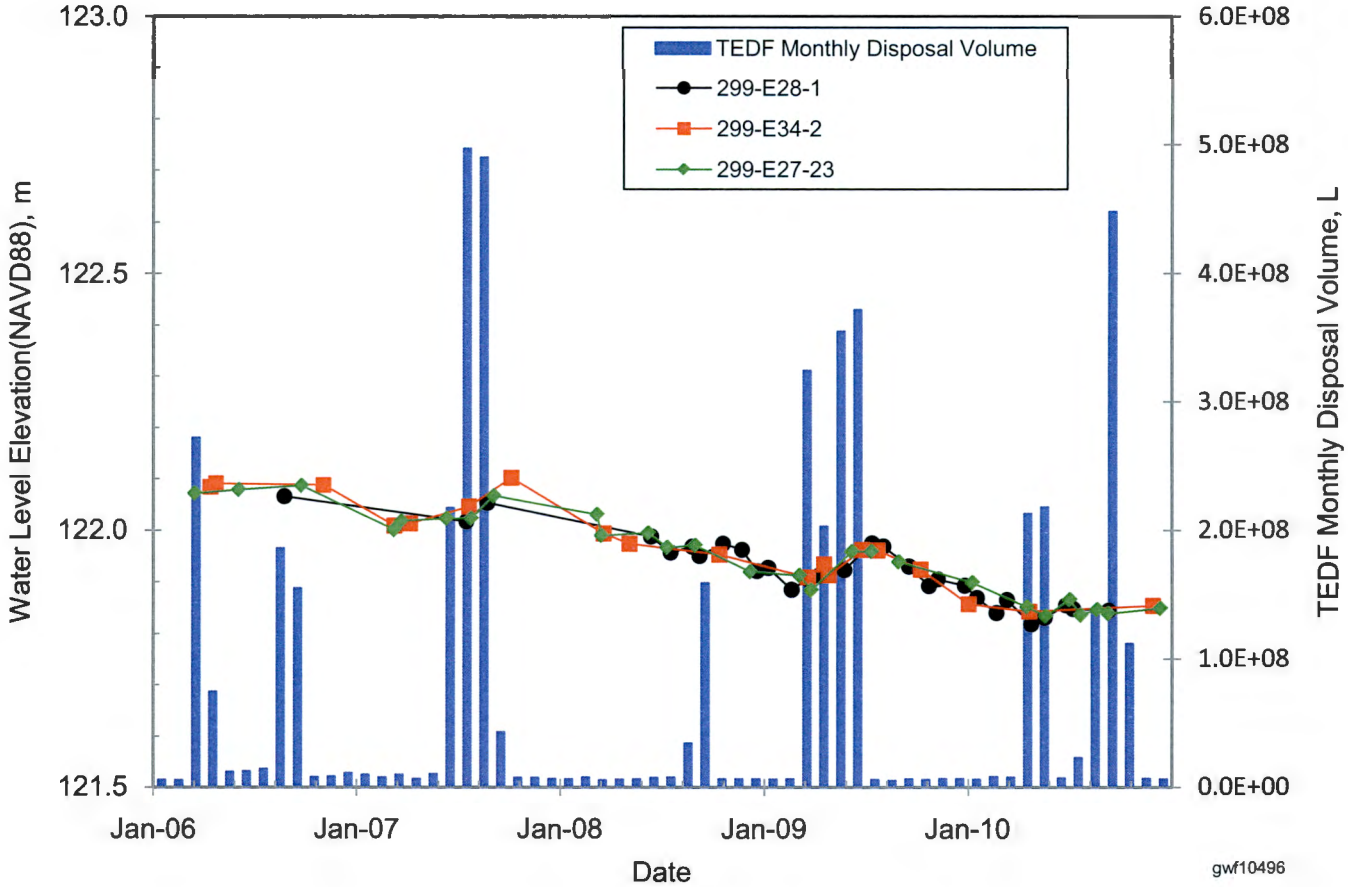
This page intentionally left blank.

Figure 9-4. 200 East Area Water Table Map, March 2010



This page intentionally left blank.

Figure 9-5. Comparison of Treated Effluent Disposal Facility Discharges with 200 East Area Groundwater Elevations

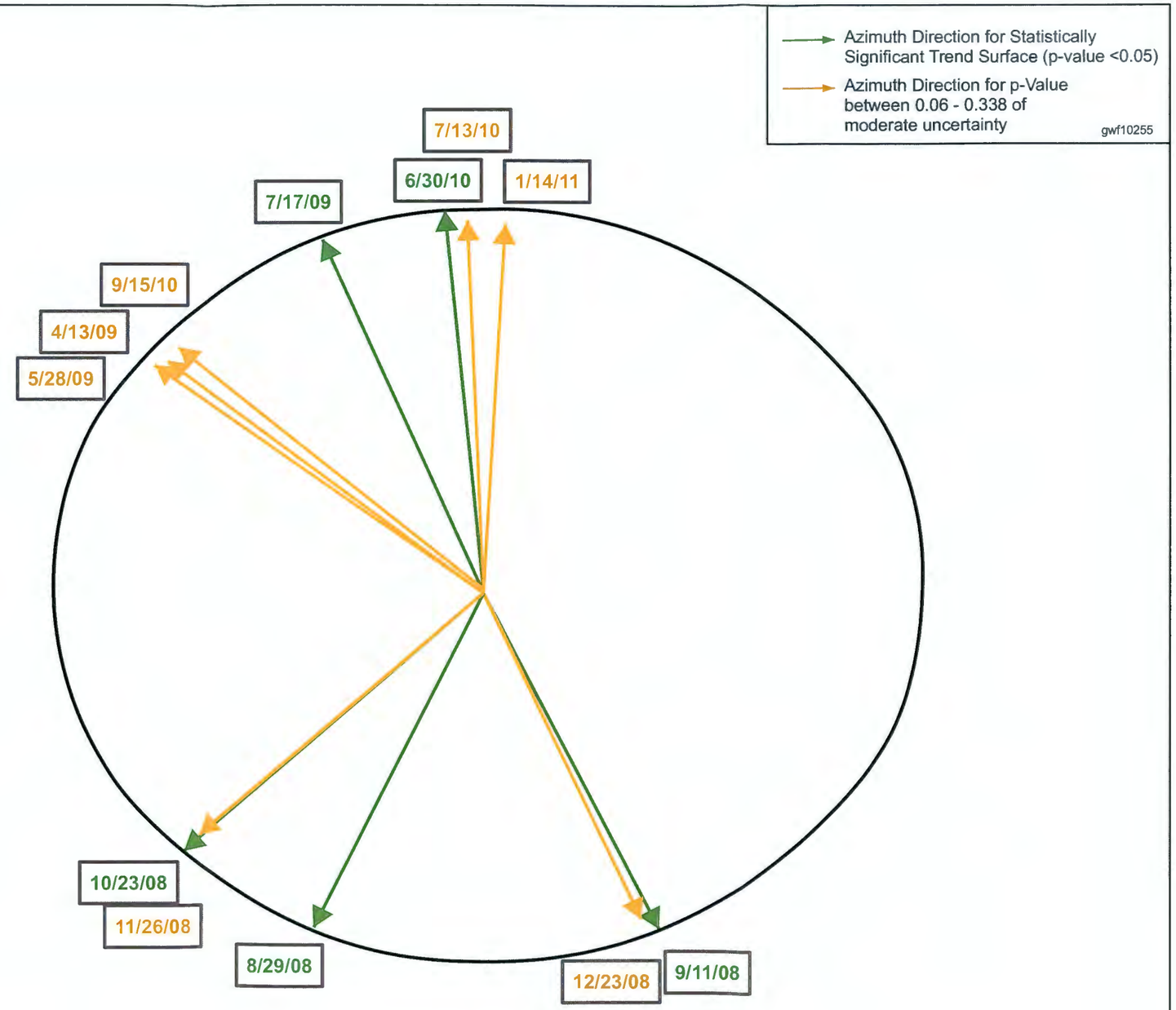


This page intentionally left blank.

Figure 9-6. Low-Level Waste Management Area 1 Historical Trend Surface Results and Associated Azimuth Directional Vectors

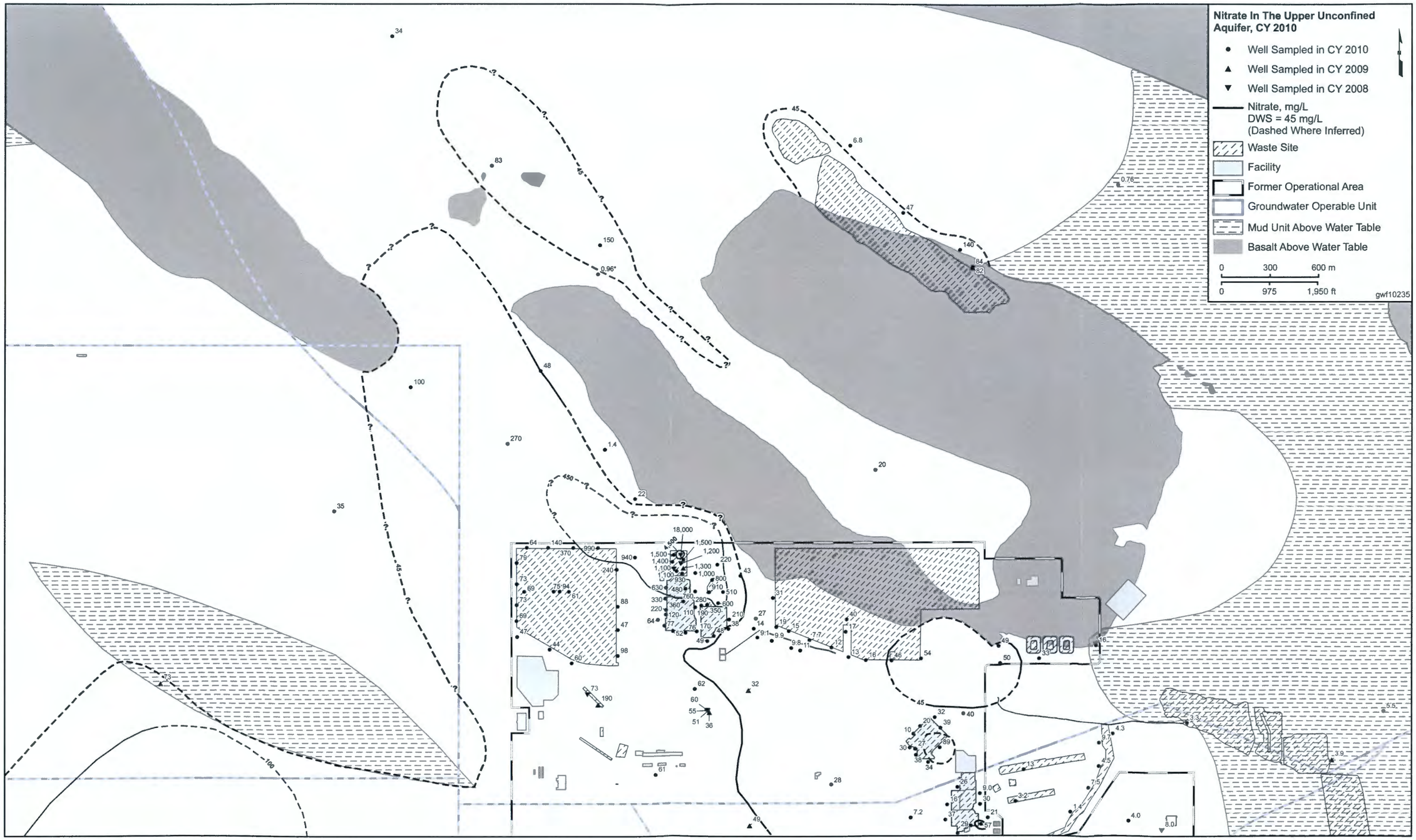
LLWMA-1 Trend Surface Results

Date	Mag.	Dir.	p-Value	Stat Sig?
9/1/2005	7.7E-06	312	0.020	Yes
9/12/2005	8.2E-06	329	0.017	Yes
10/11/2005	8.0E-06	356	0.005	Yes
10/25/2005	6.4E-06	320	0.060	No
11/23/2005	6.9E-06	336	0.017	Yes
12/29/2005	1.0E-05	13	0.014	Yes
2/2/2006	9.7E-06	350	0.011	Yes
3/8/2006	7.8E-06	332	0.070	No
6/8/2006	1.0E-05	347	0.0099	Yes
1/25/2007	7.3E-06	336	0.015	Yes
6/16/2008	8.1E-06	324	0.005	Yes
Averages:	**8.2E-06**	**338**		
7/21/2008	1.3E-06	97	0.964	No
8/29/2008	1.3E-05	213	0.004	Yes
9/11/2008	9.3E-06	156	0.001	Yes
10/23/2008	1.1E-05	226	0.038	Yes
11/26/2008	1.1E-05	225	0.127	No
12/23/2008	5.7E-06	160	0.289	No
1/12/2009	8.9E-07	130	0.945	No
2/23/2009	5.3E-06	149	0.516	No
3/24/2009	6.3E-07	106	0.974	No
4/13/2009	4.7E-06	316	0.271	No
5/28/2009	8.2E-06	310	0.234	No
7/17/2009	2.0E-05	335	0.013	Yes
9/21/2009	3.7E-06	8	0.573	No
10/27/2009	6.0E-06	100	0.578	No
11/12/2009	3.5E-06	259	0.893	No
1/21/2010	1.1E-05	243	0.675	No
5/23/2010	6.3E-06	358	0.502	No
6/30/2010	1.8E-05	353	0.021	Yes
7/13/2010	1.0E-05	357	0.338	No
9/15/2010	7.6E-06	315	0.065	No
1/4/2011	1.1E-05	002	0.144	No



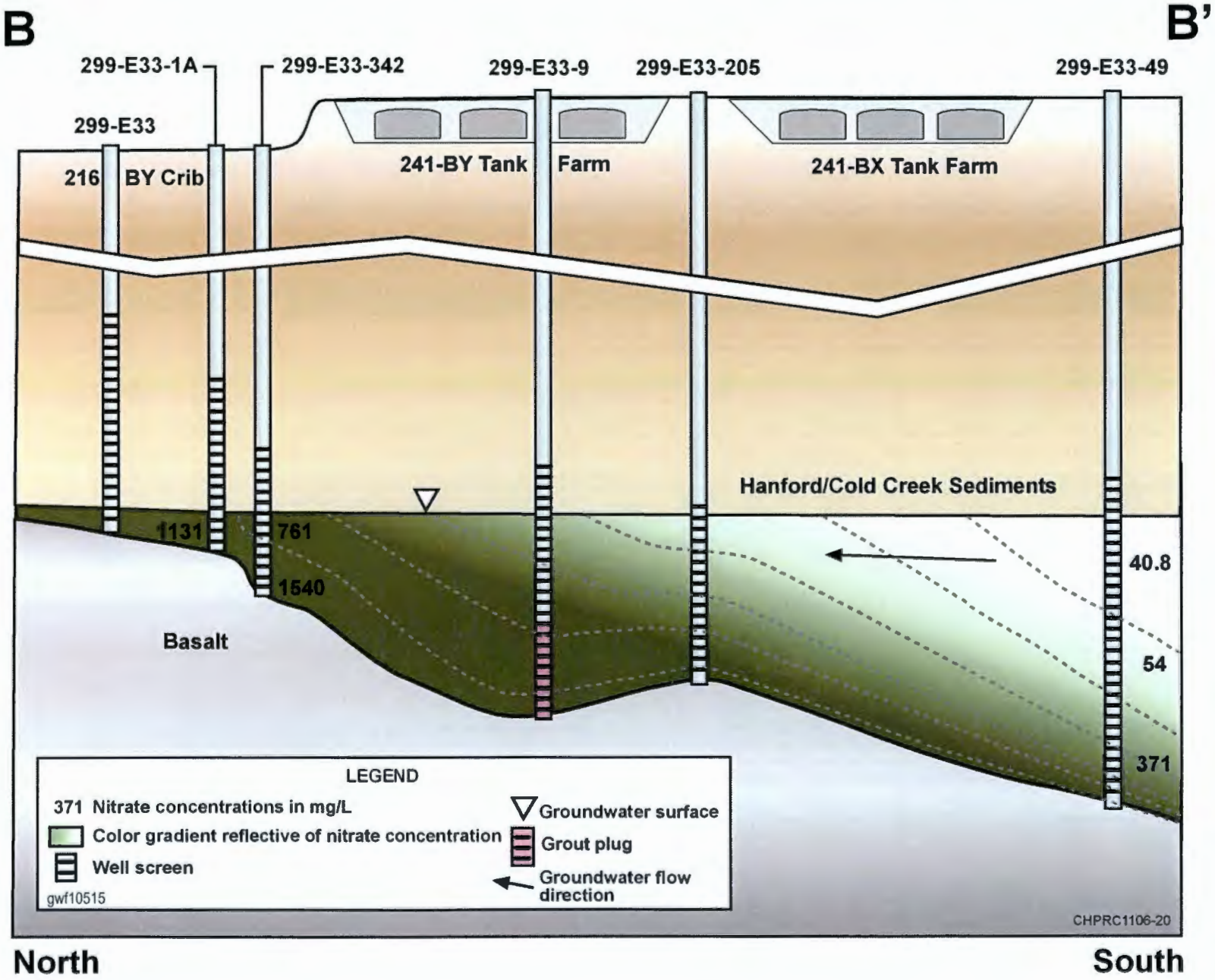
This page intentionally left blank.

Figure 9-7. Average Groundwater Nitrate Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



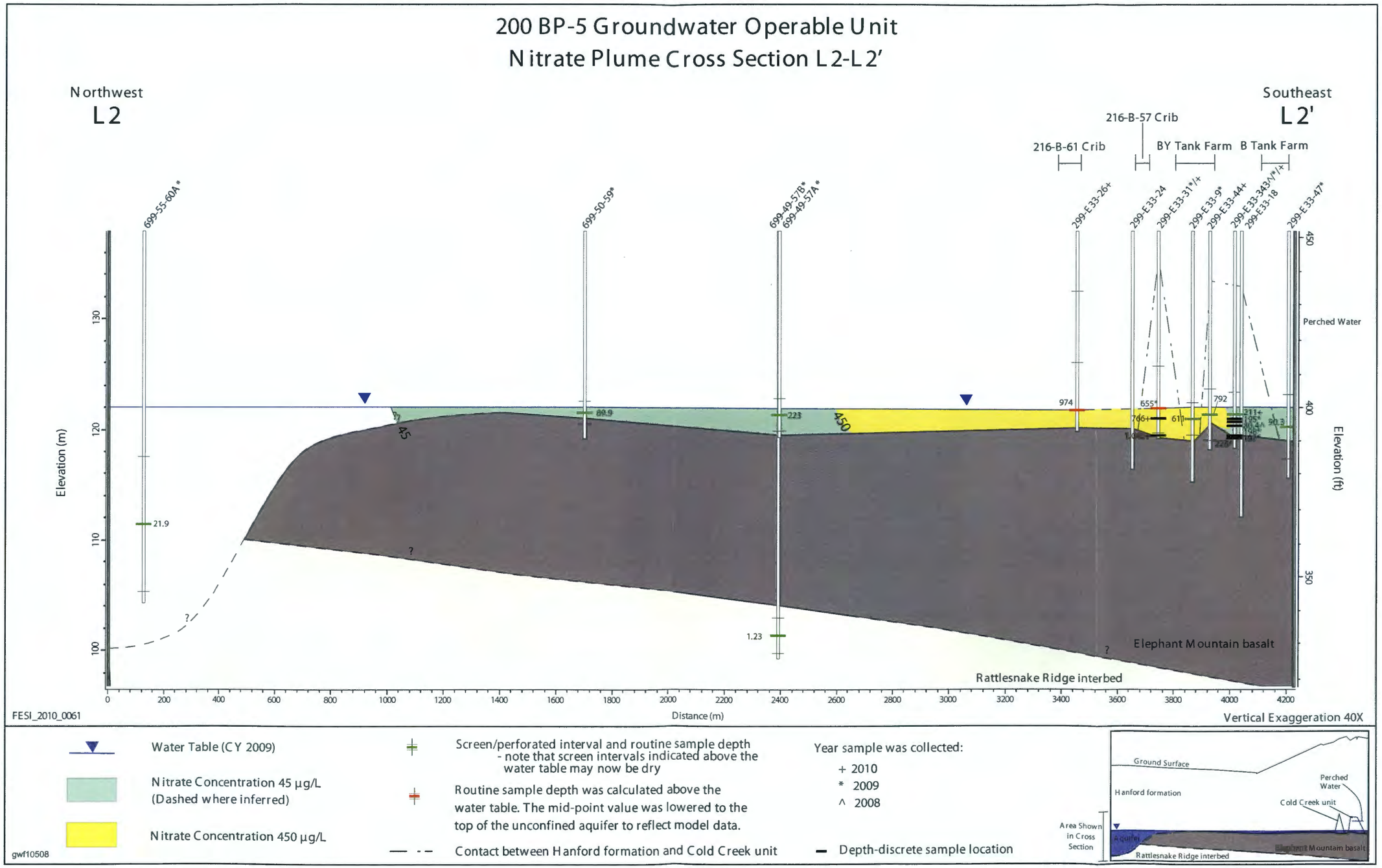
This page intentionally left blank.

Figure 9-9. Cross Section B-B' of the B Complex Conceptual Model Density Plume for Nitrate



This page intentionally left blank.

Figure 9-9. Cross Section L2-L2' of the Nitrate Plume and Top of Basalt Conceptualization from the B Complex to the Gable Gap



This page intentionally left blank.

Figure 9-10. Comparison of Historical Groundwater Elevation Trends for Wells 299-E33-18 and 699-60-60

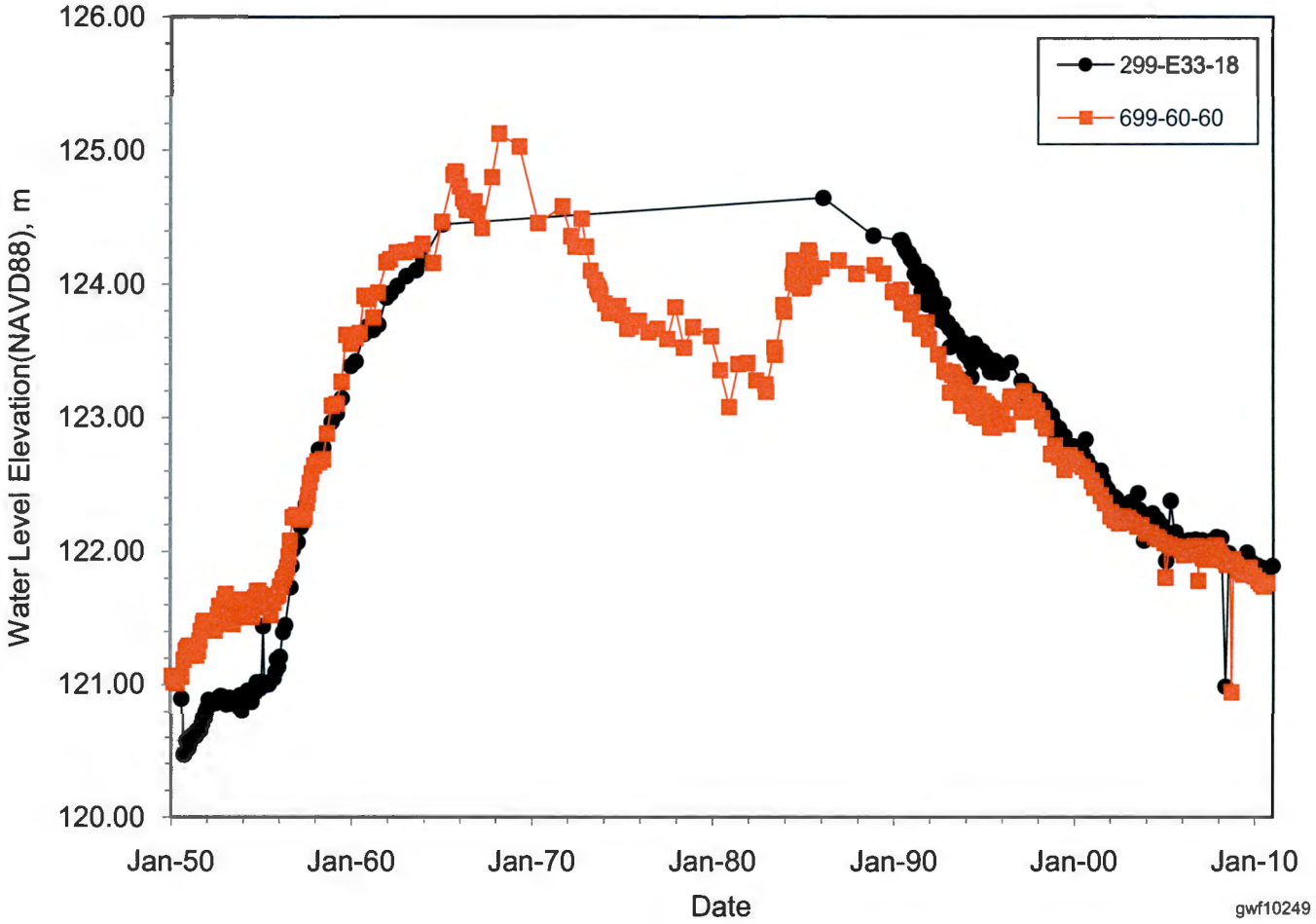


Figure 9-11. Nitrate Trend Plot of Wells 299-E28-18, 299-e28-26, 299-E28-27, 299-E28-28, and 299-E32-4

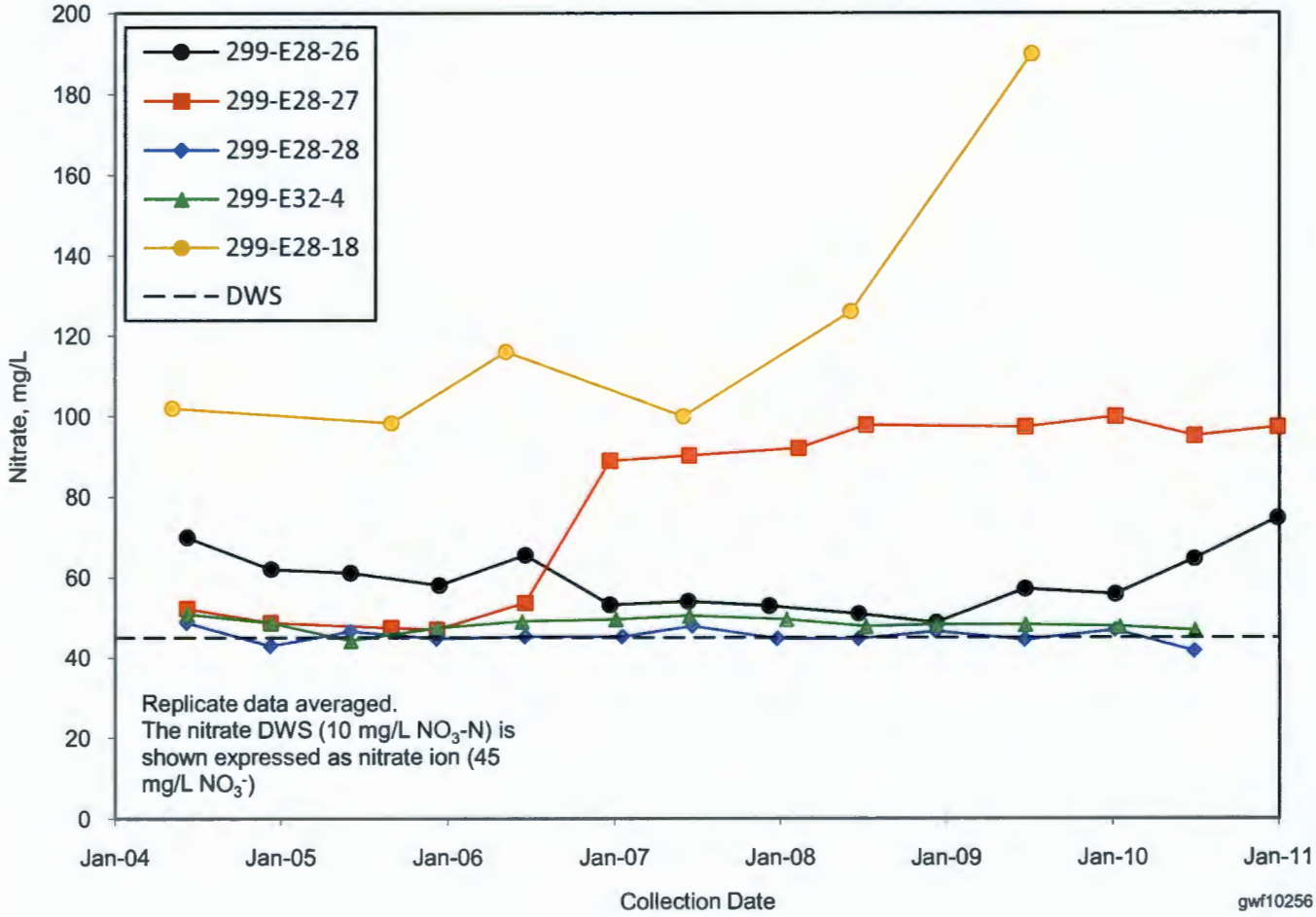
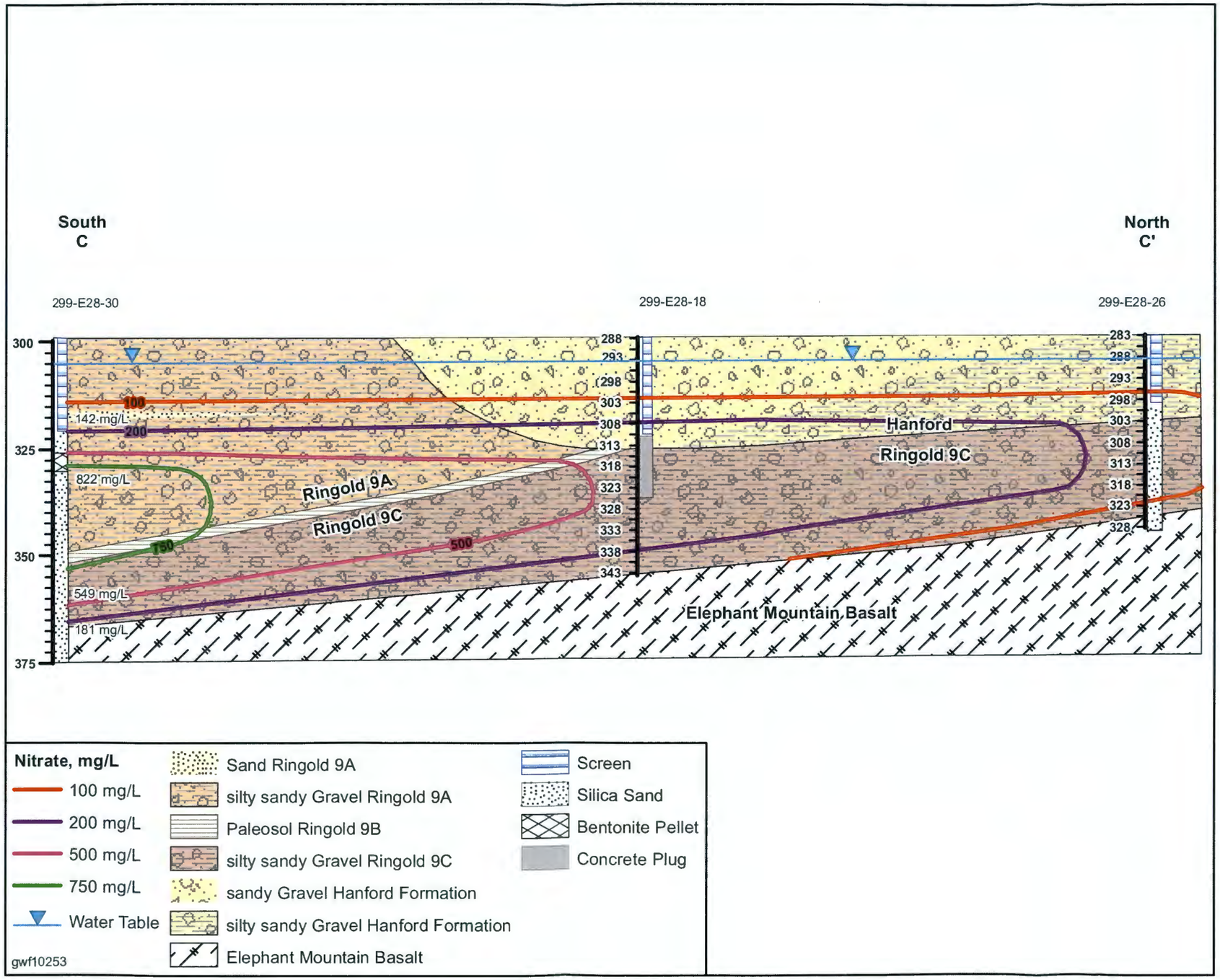


Figure 9-12. Cross Section C-C' for the Nitrate Distribution Conceptual Model for Wells 299-E28-18, 299-E28-26, and 299-E28-30



This page intentionally left blank.

Figure 9-13. Nitrate Trend Results for Wells 299-E28-9 and 299-E28-16

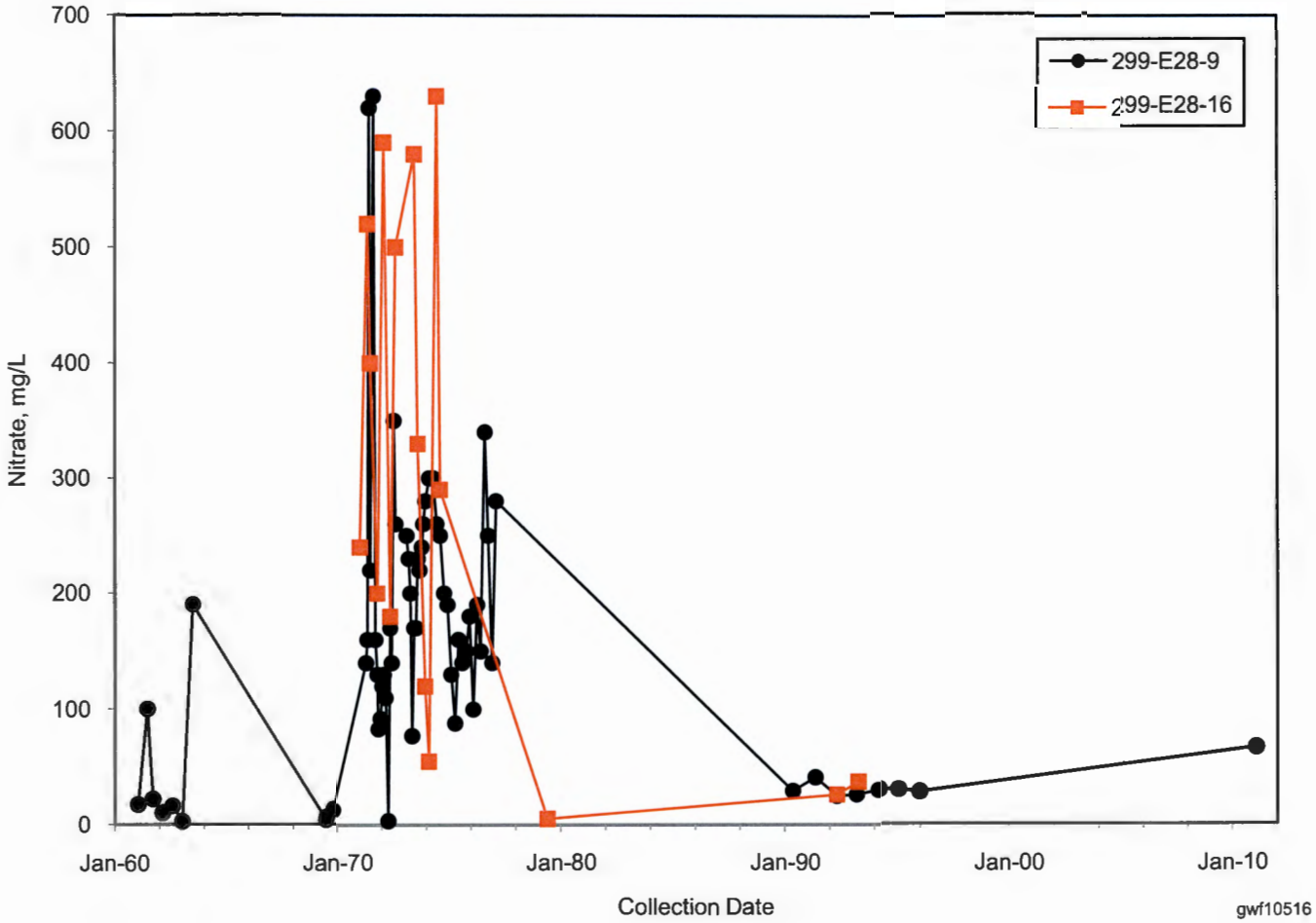


Figure 9-14. 450 mg/L Nitrate Contour Near Well 299-E28-30 at Approximately 7 meters Below Groundwater Table

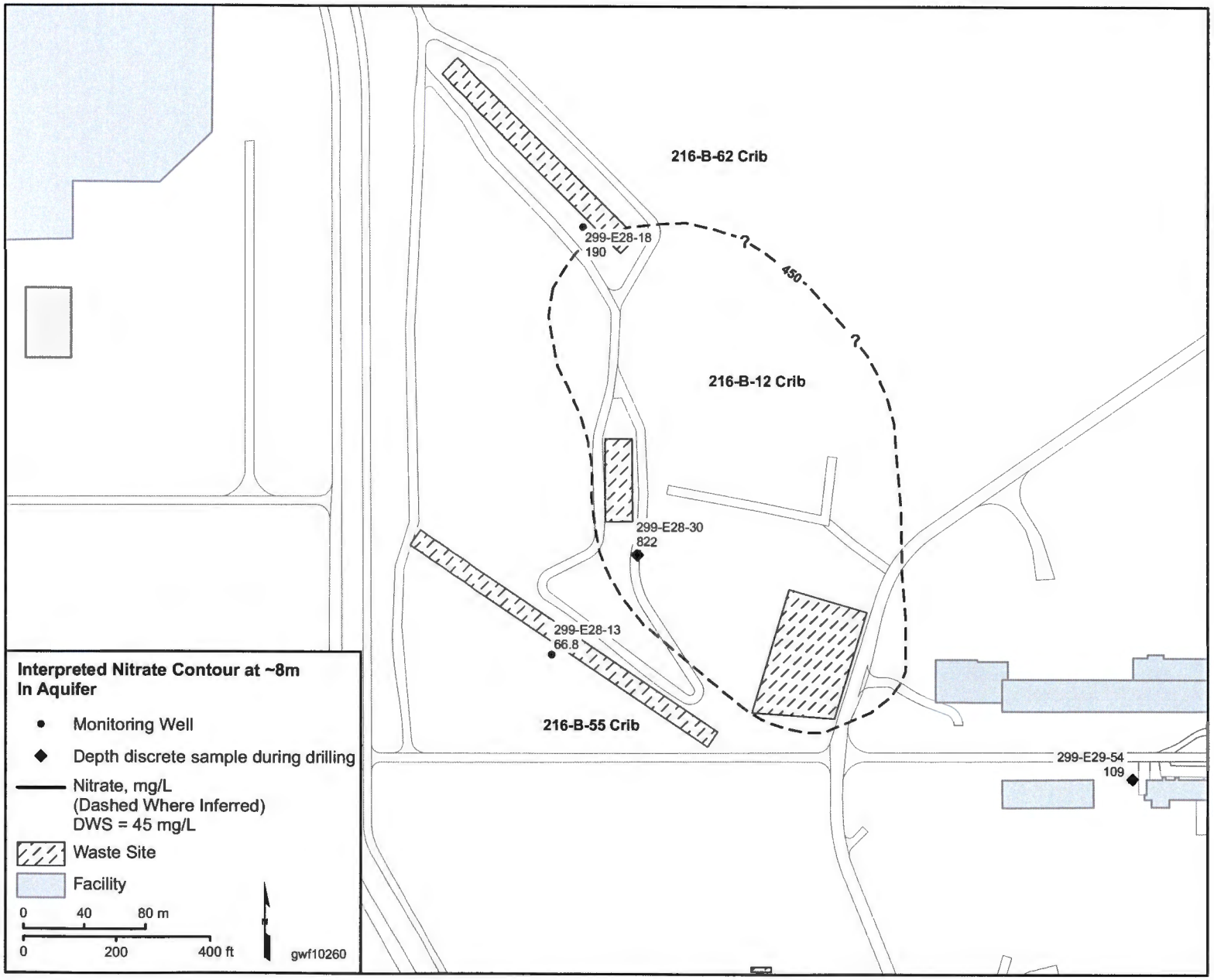


Figure 9-15. Cross Section A-A' of the Nitrate Contaminant Portrayal Through Wells 699-50-53A to 699-53-55A

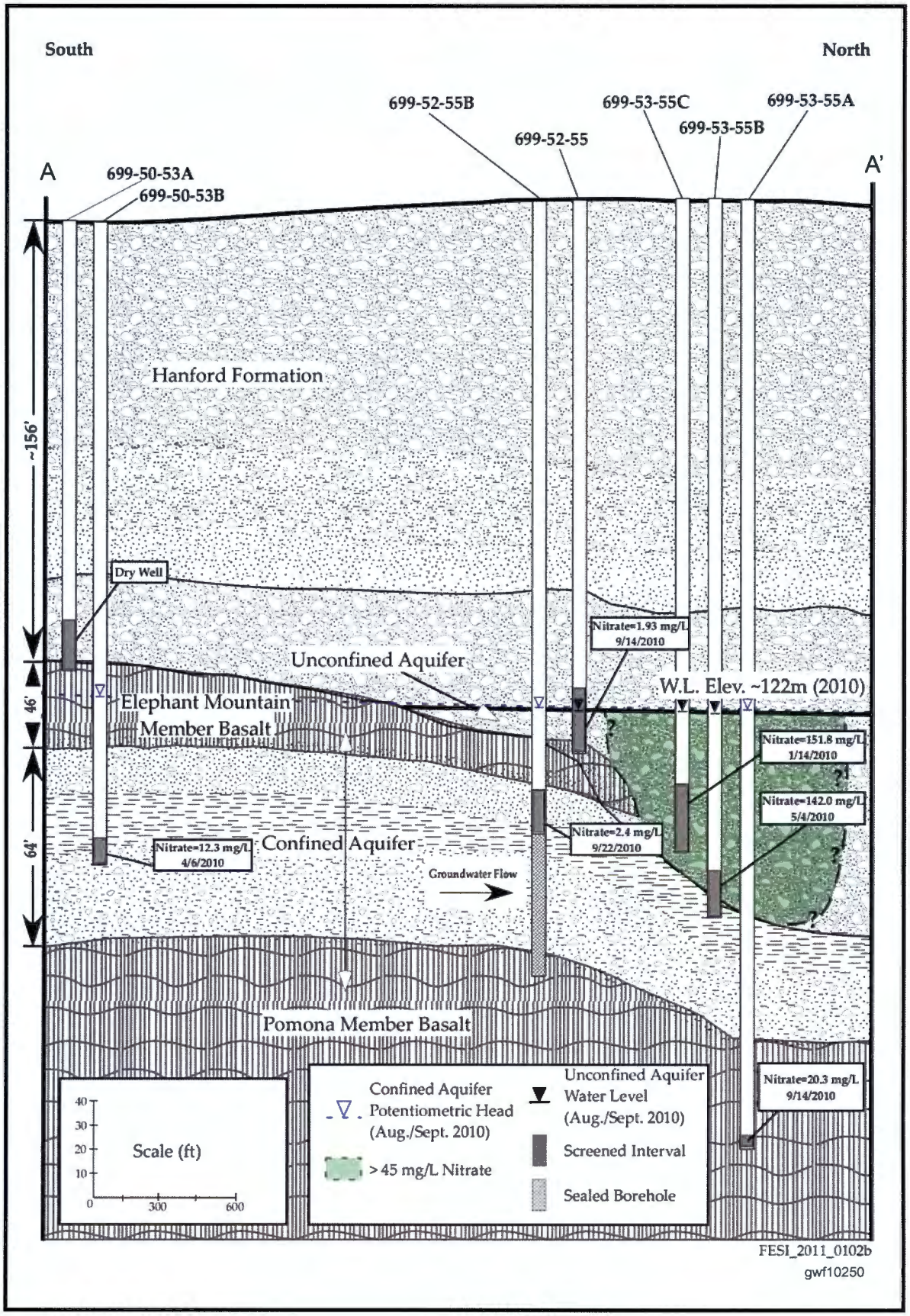


Figure 9-16. Nitrate Trend Plot at Waste Management Area C Monitoring Well 299-E27-14

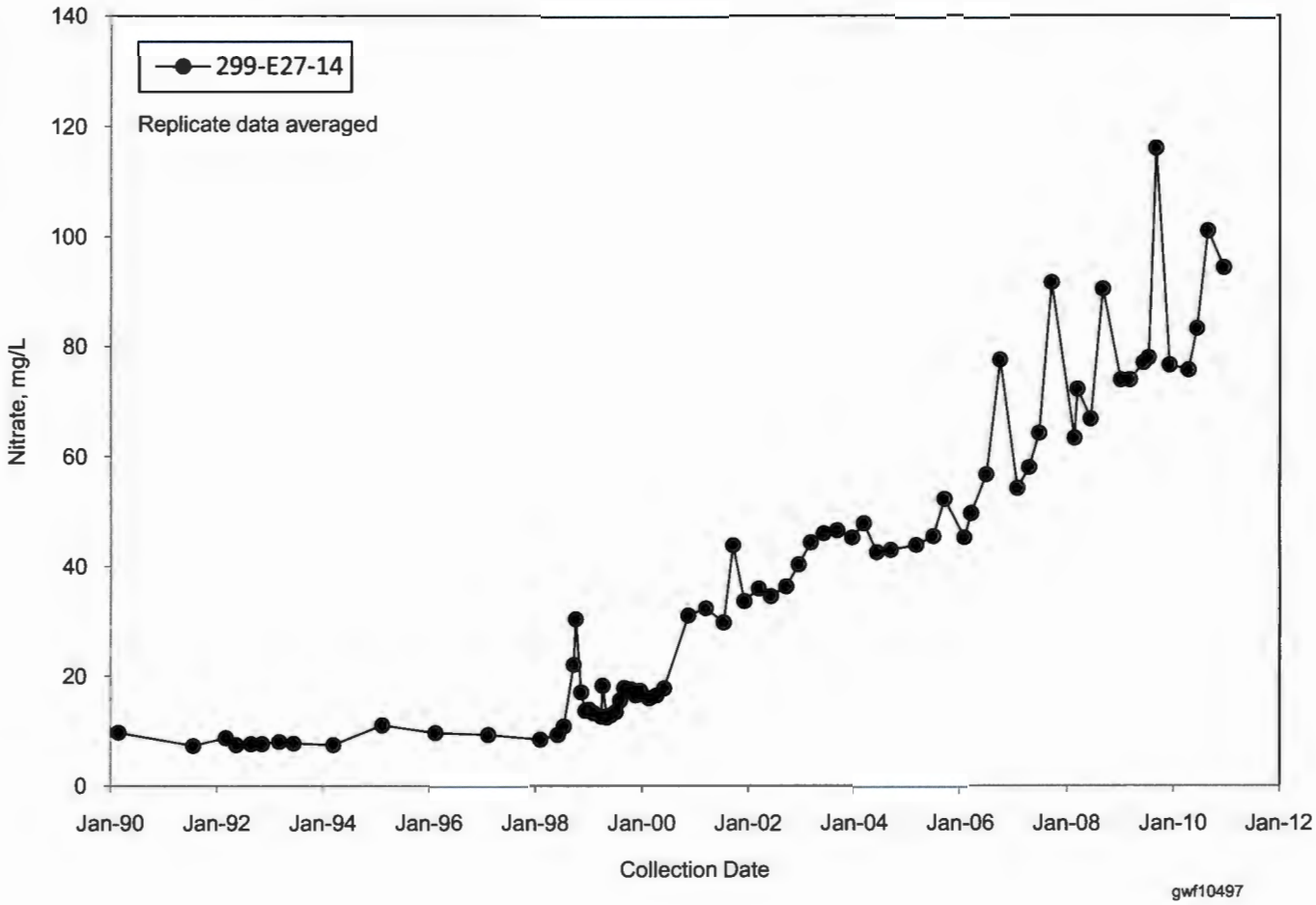
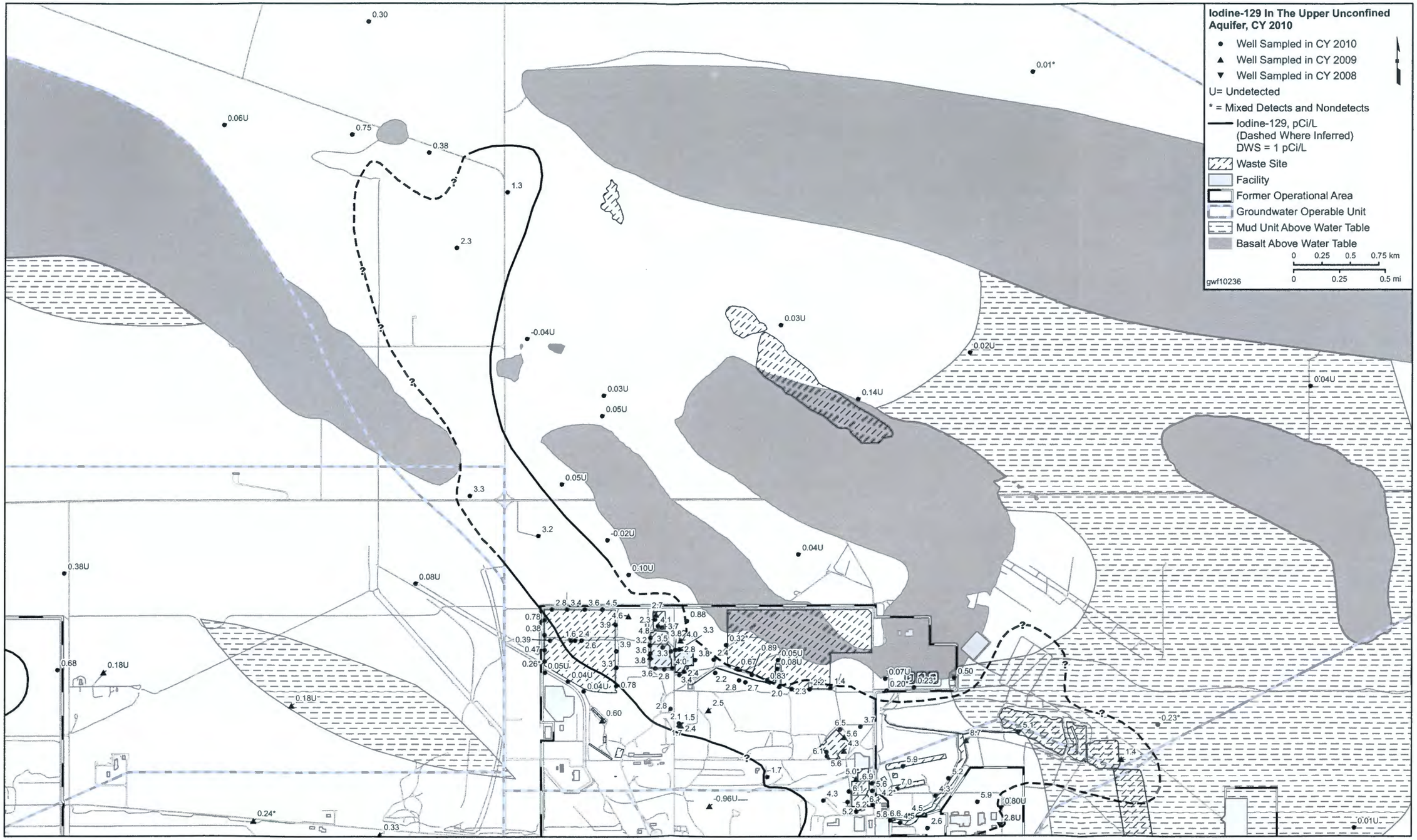
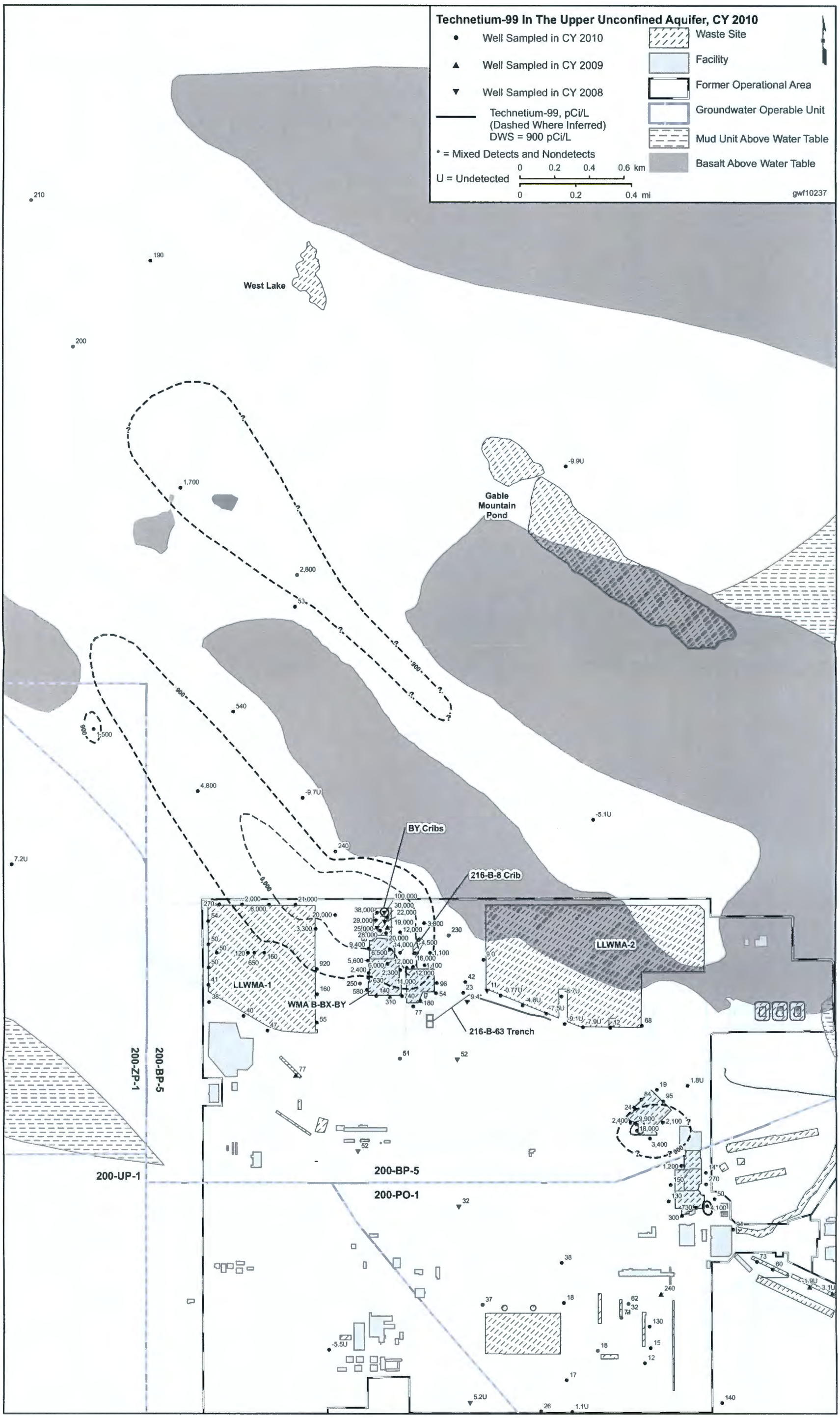


Figure 9-17. Average Groundwater Iodine-129 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



This page intentionally left blank.

Figure 9-18. Average Groundwater Technetium-99 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



This page intentionally left blank.

Figure 9-19. Groundwater Elevation Comparison Between the Confined and Unconfined Aquifers

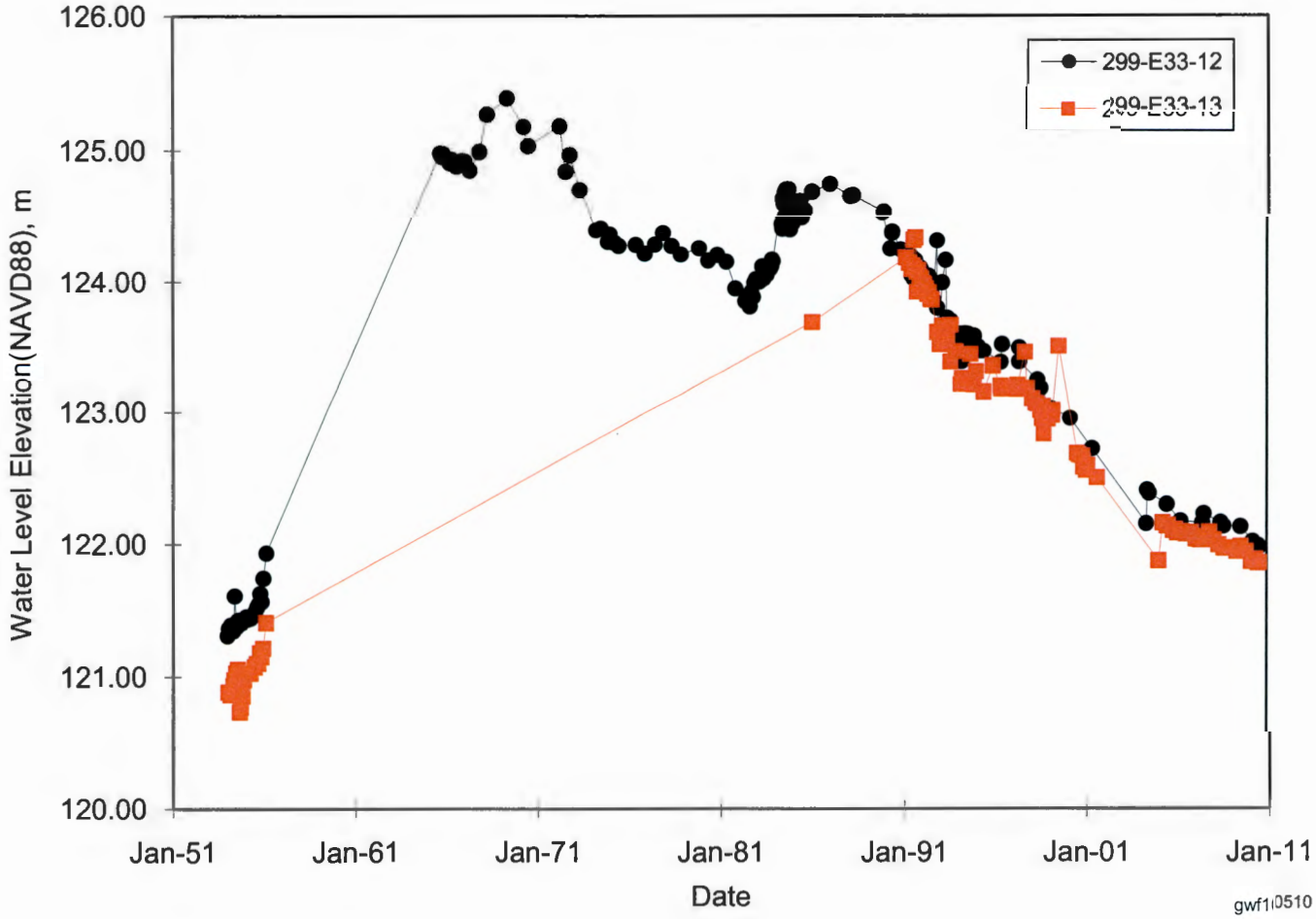


Figure 9-20. Technetium-99 Trend Plot Between Wells 299-E33-41, 299-E33-339, and 299-E33-343

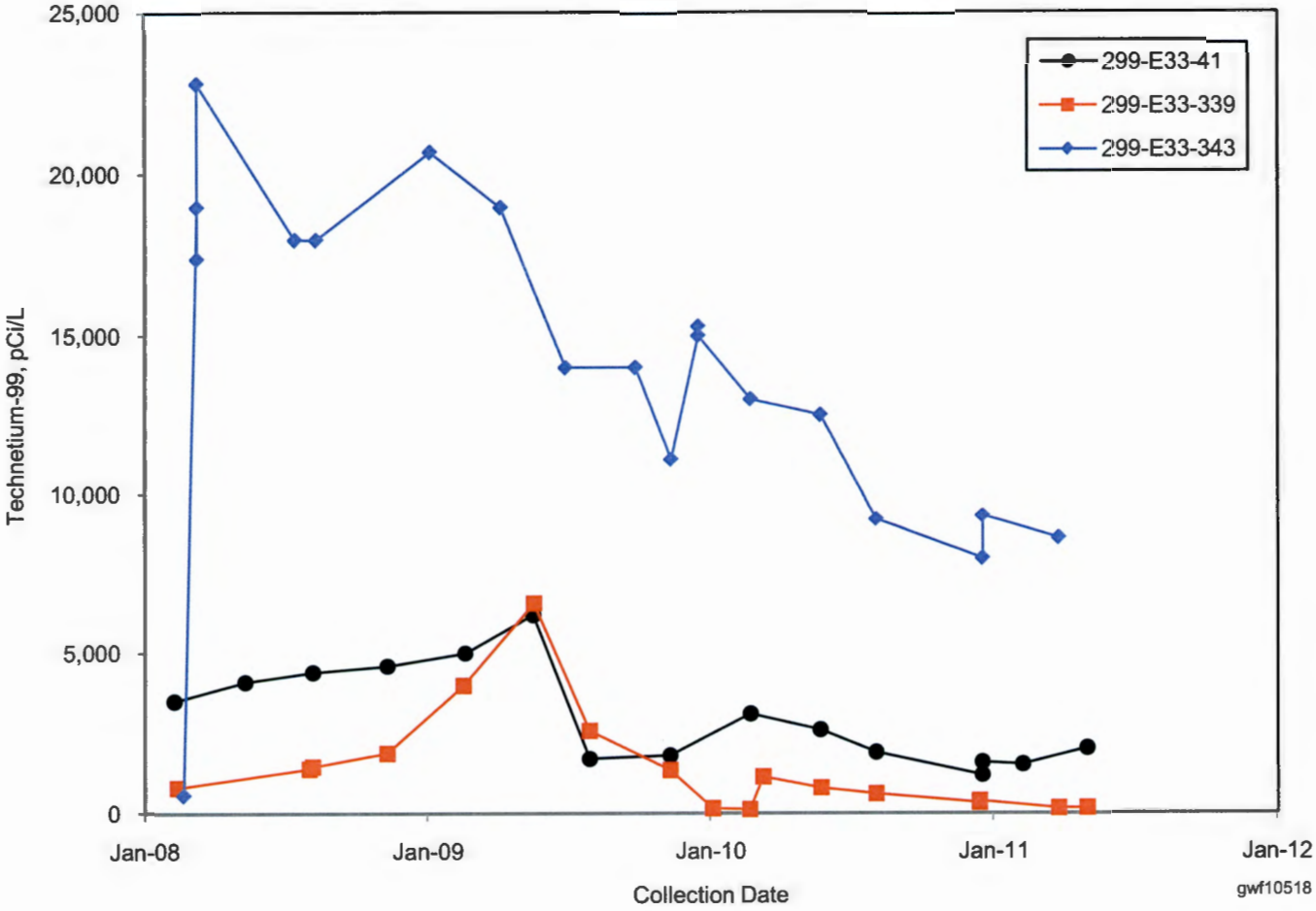
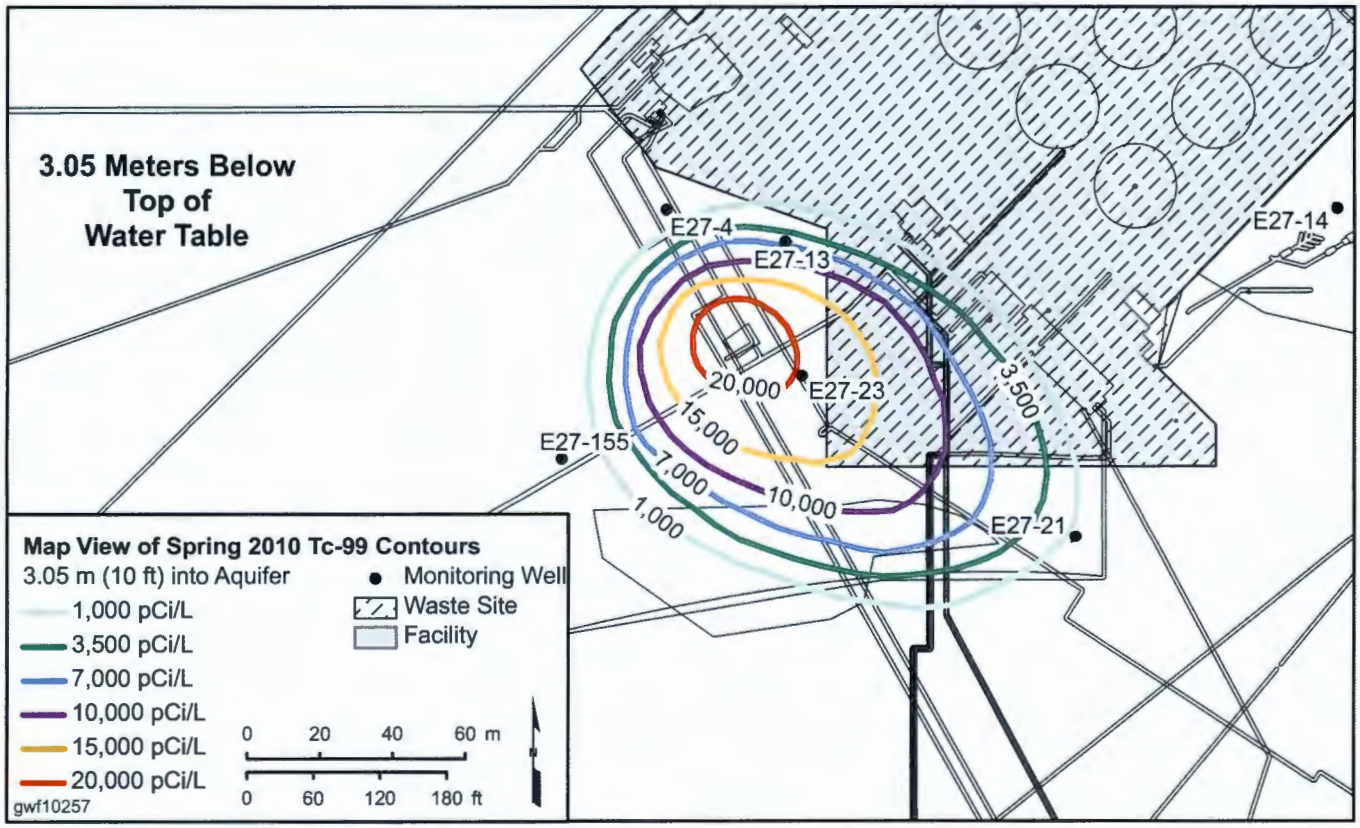


Figure 9-21. Trend Plot Comparison of Technetium-99 Between Wells 299-E33-26 and 299-E33-38

Figure 9-22. Map View of the Interpreted Technetium-99 Plume Associated with Depth-Discrete Sample Results at 3.05 and 9.14 meters Beneath Water Table Southwest of Waste Management Area C



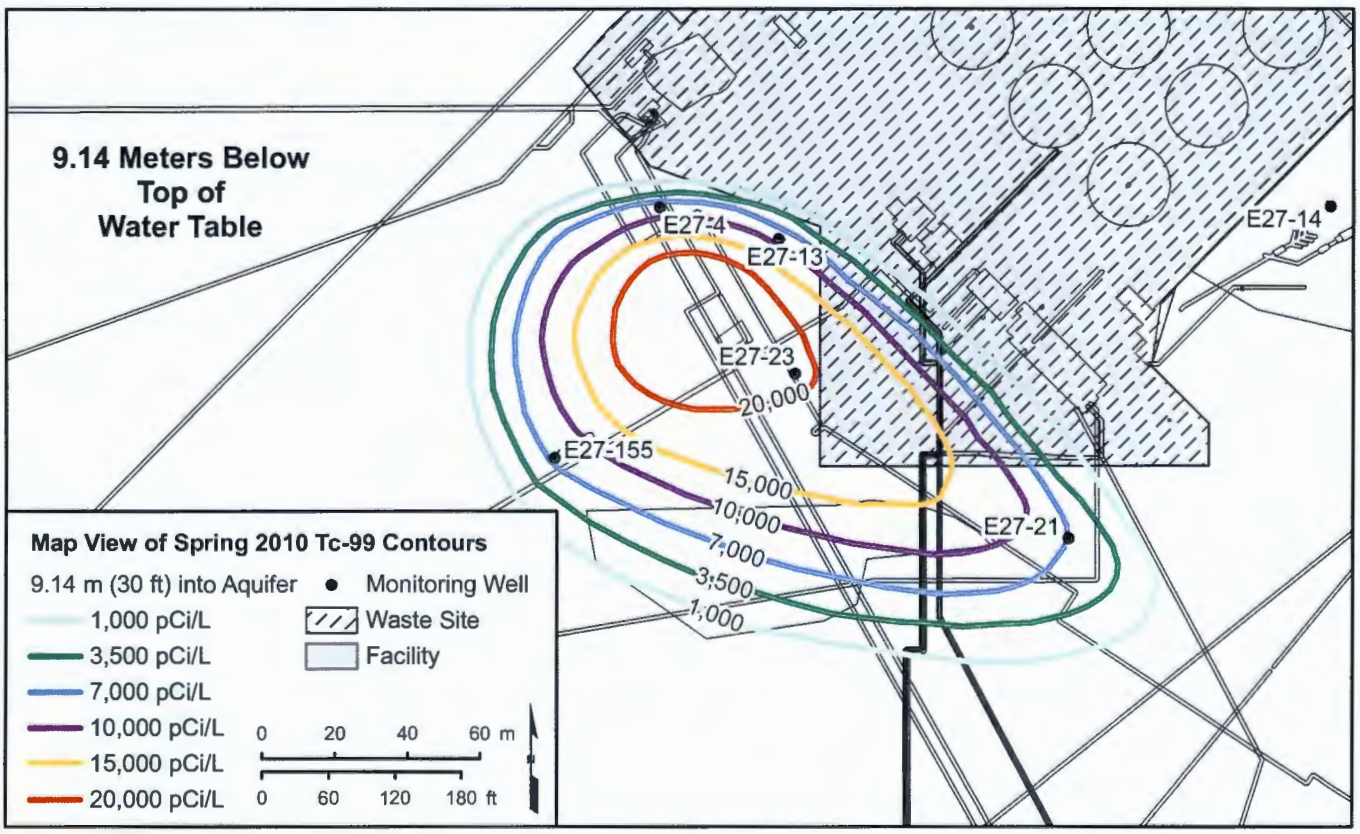
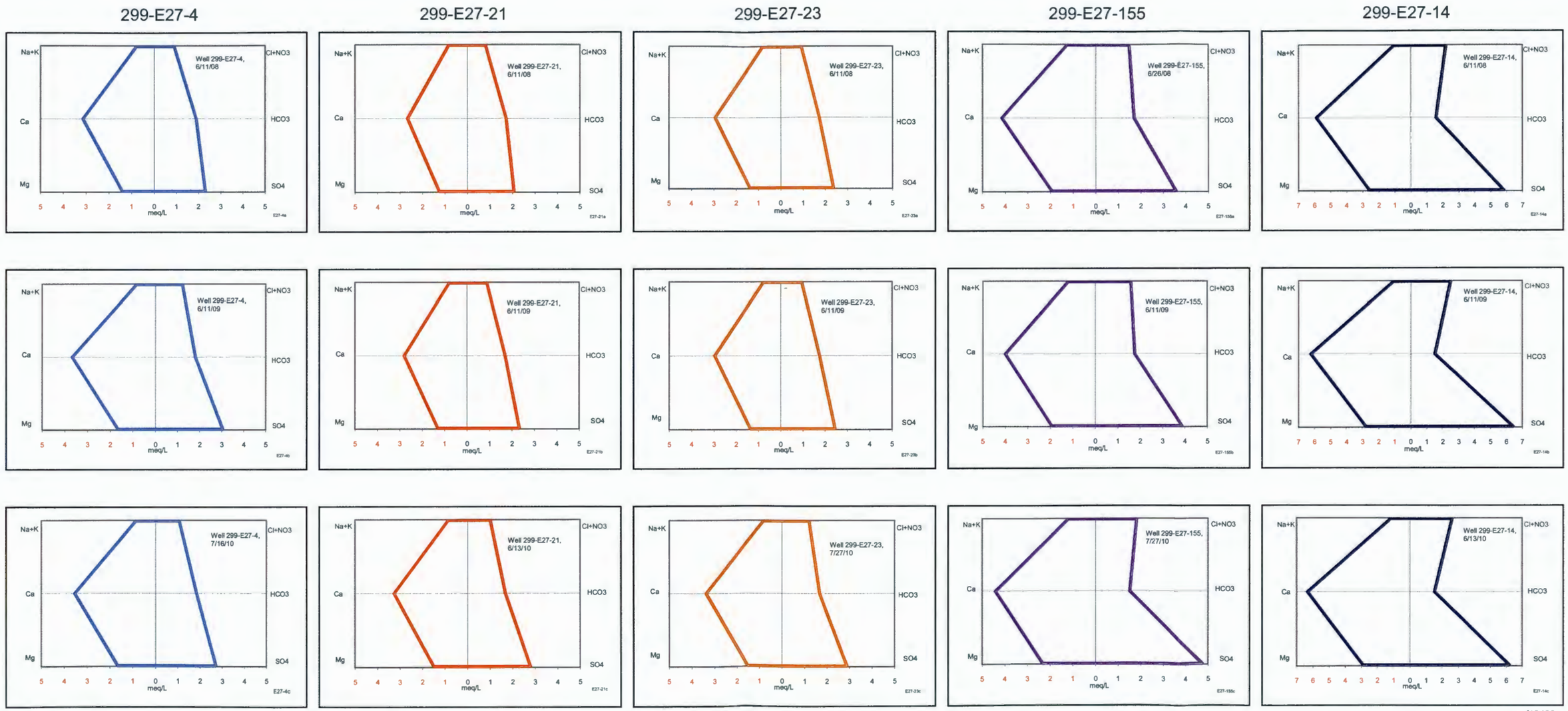


Figure 9-23. Comparison of Ion Chemistry for Five Waste Management Area C Wells



This page intentionally left blank.

Figure 9-24. Technetium-99 to Nitrate Ratio Contour Map at WMA C and Alternative Technetium-99 Contour Plume Map at WMA C

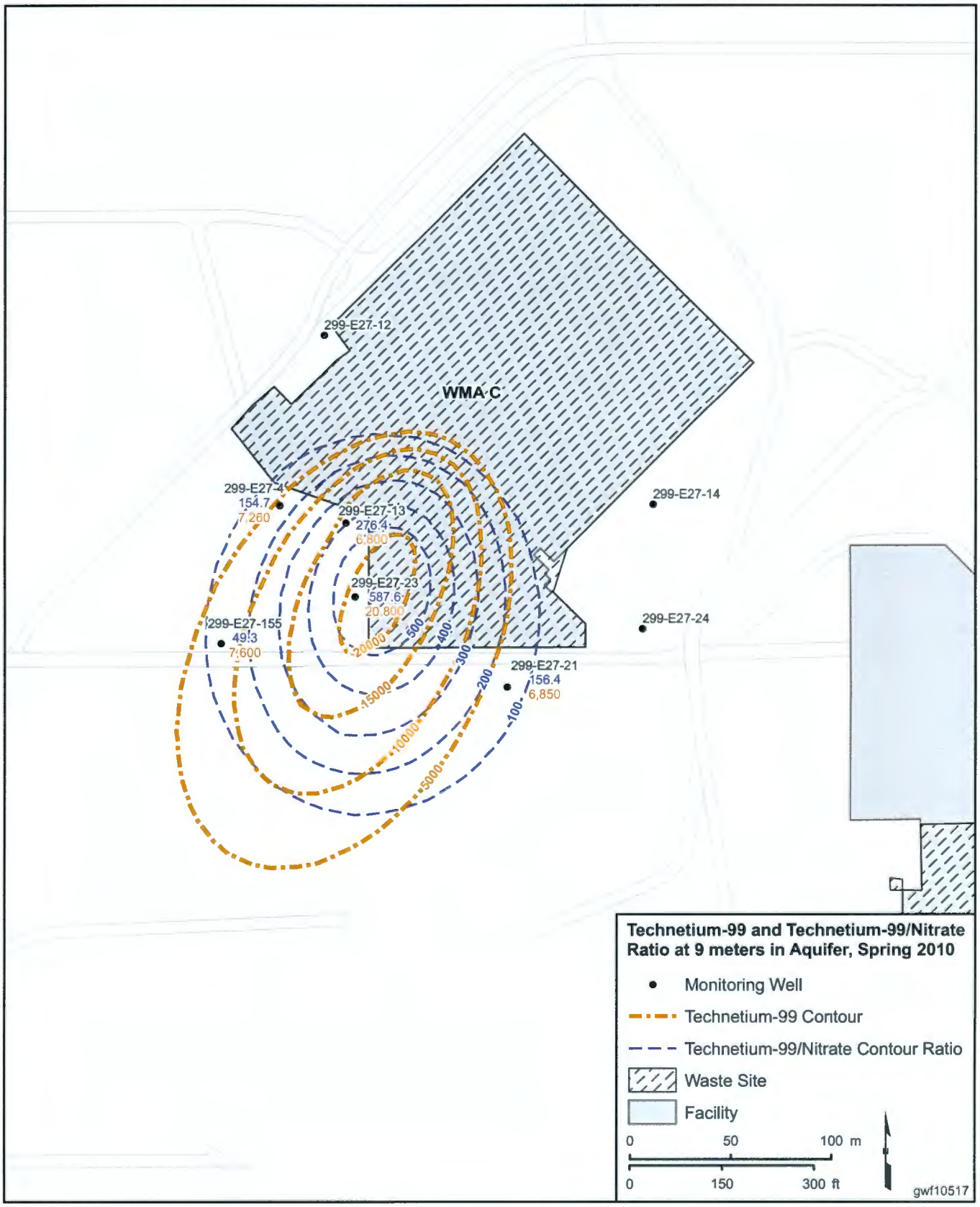


Figure 9-25. Average Groundwater Uranium Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010

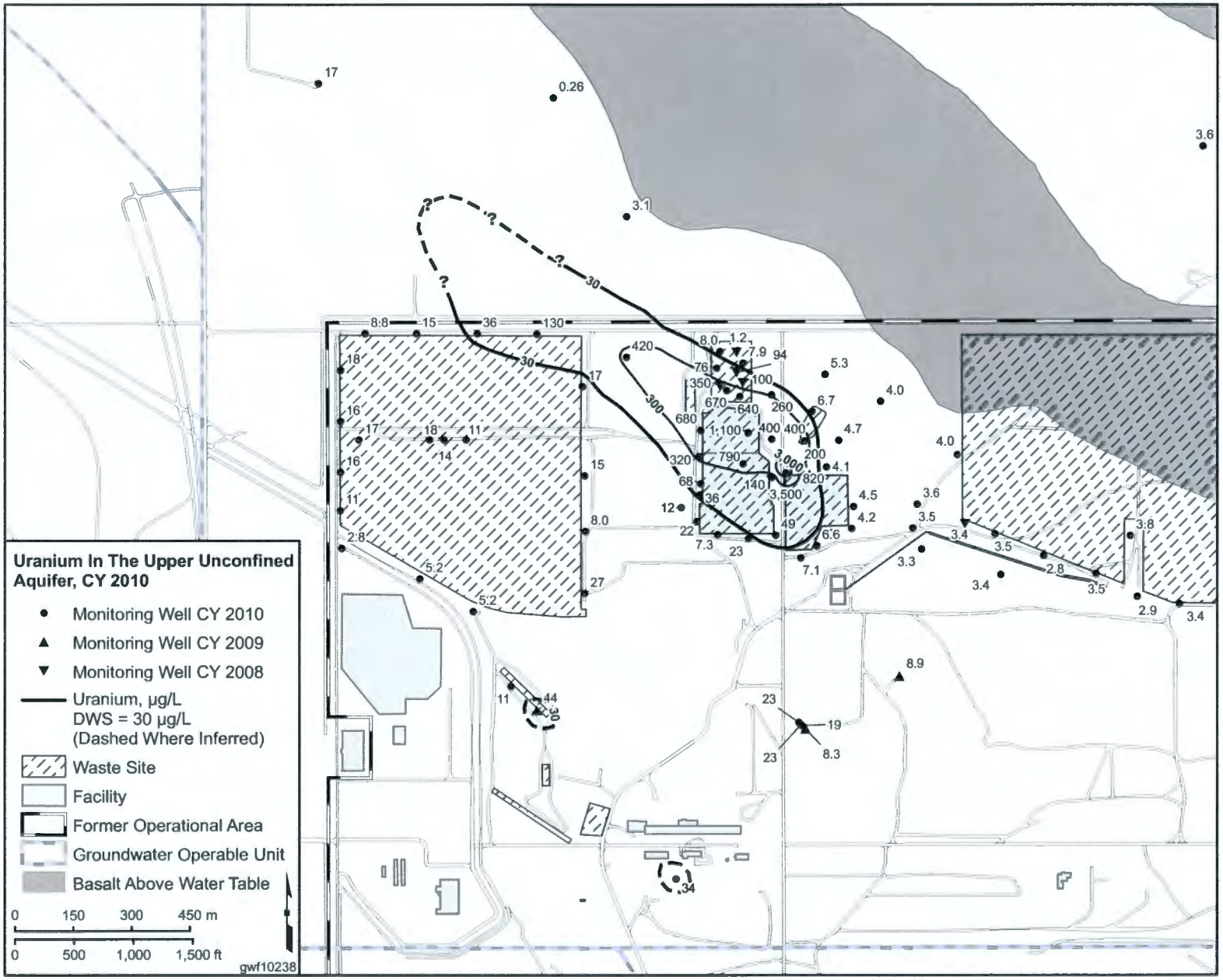
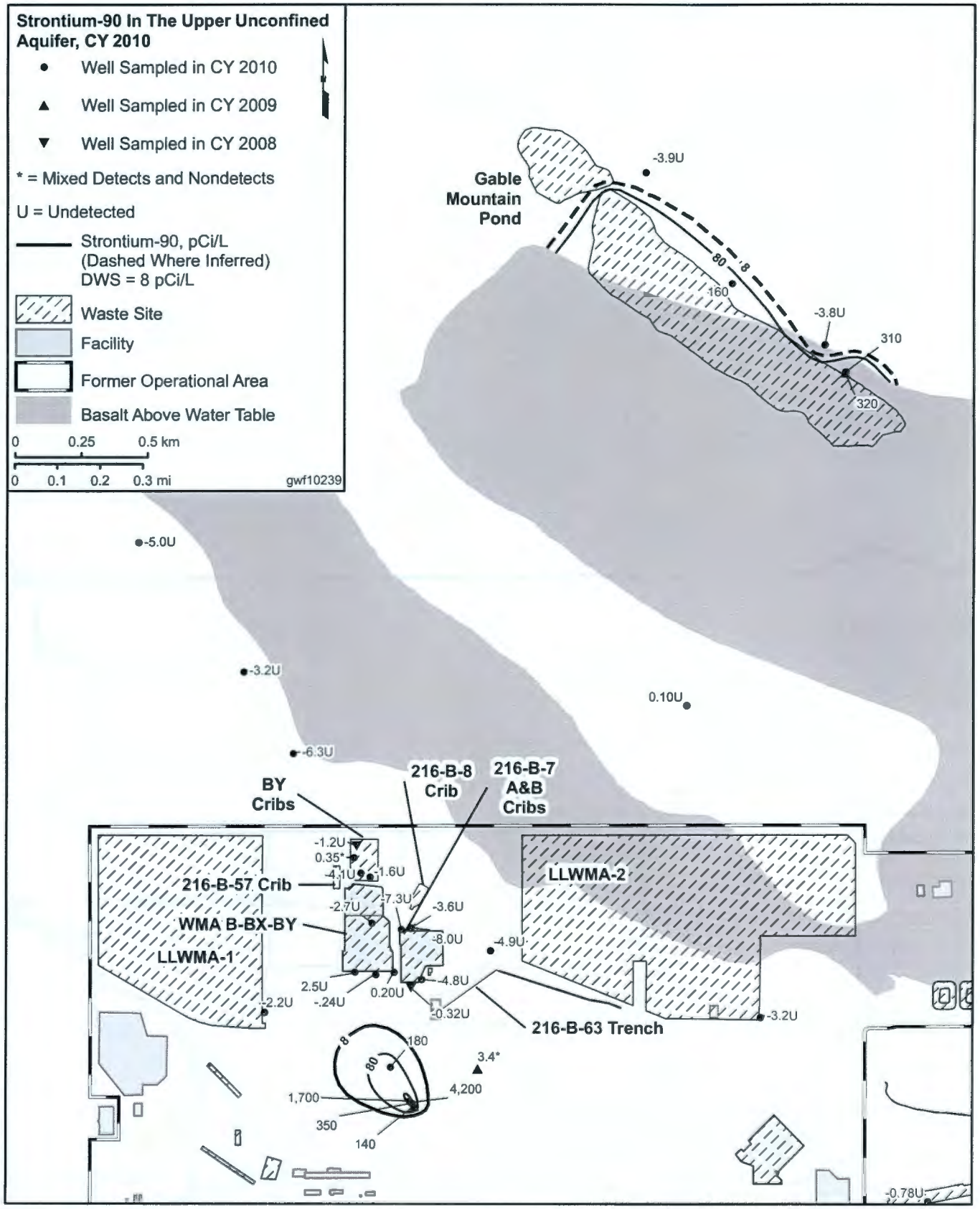
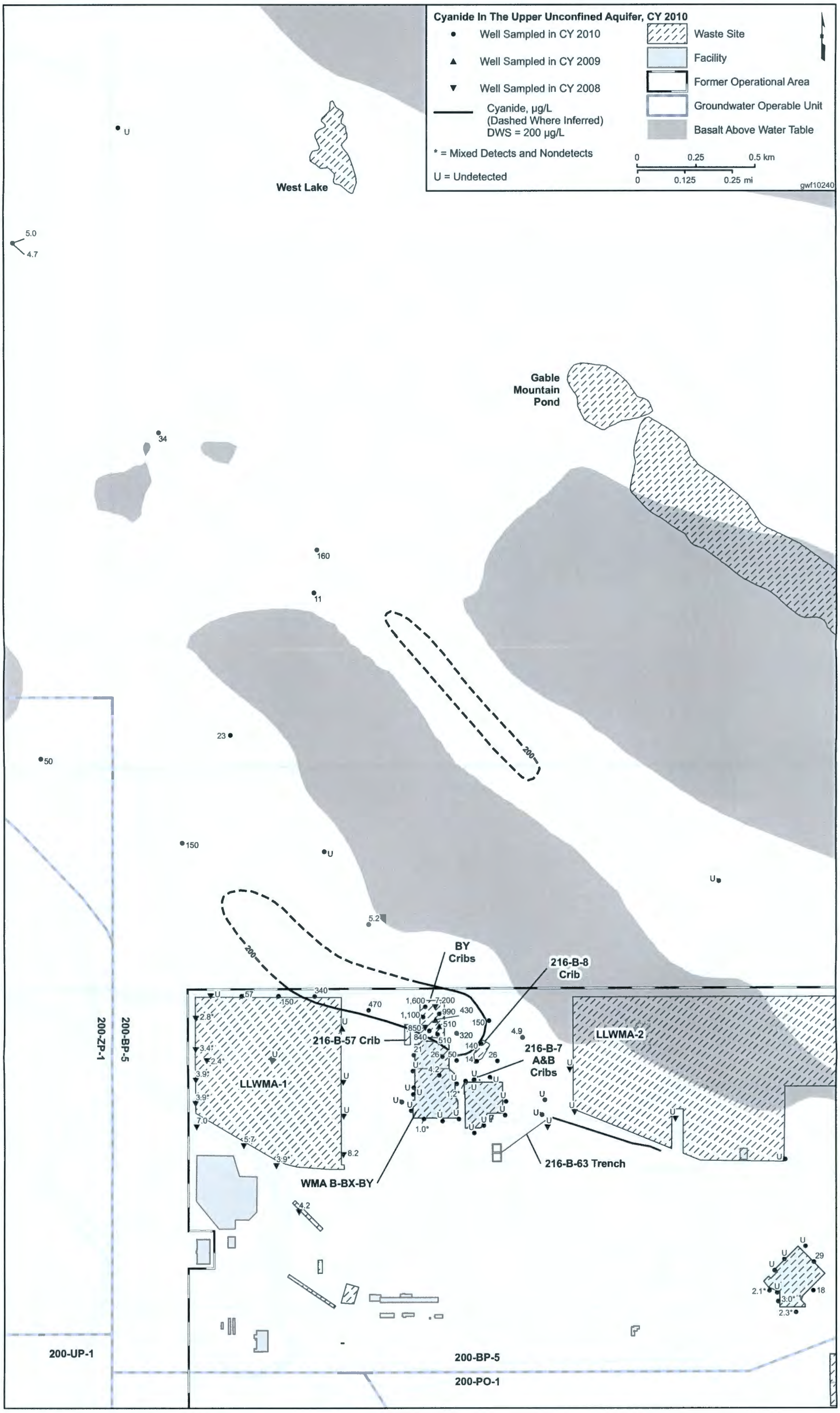


Figure 9-26. Average Groundwater Strontium-90 Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



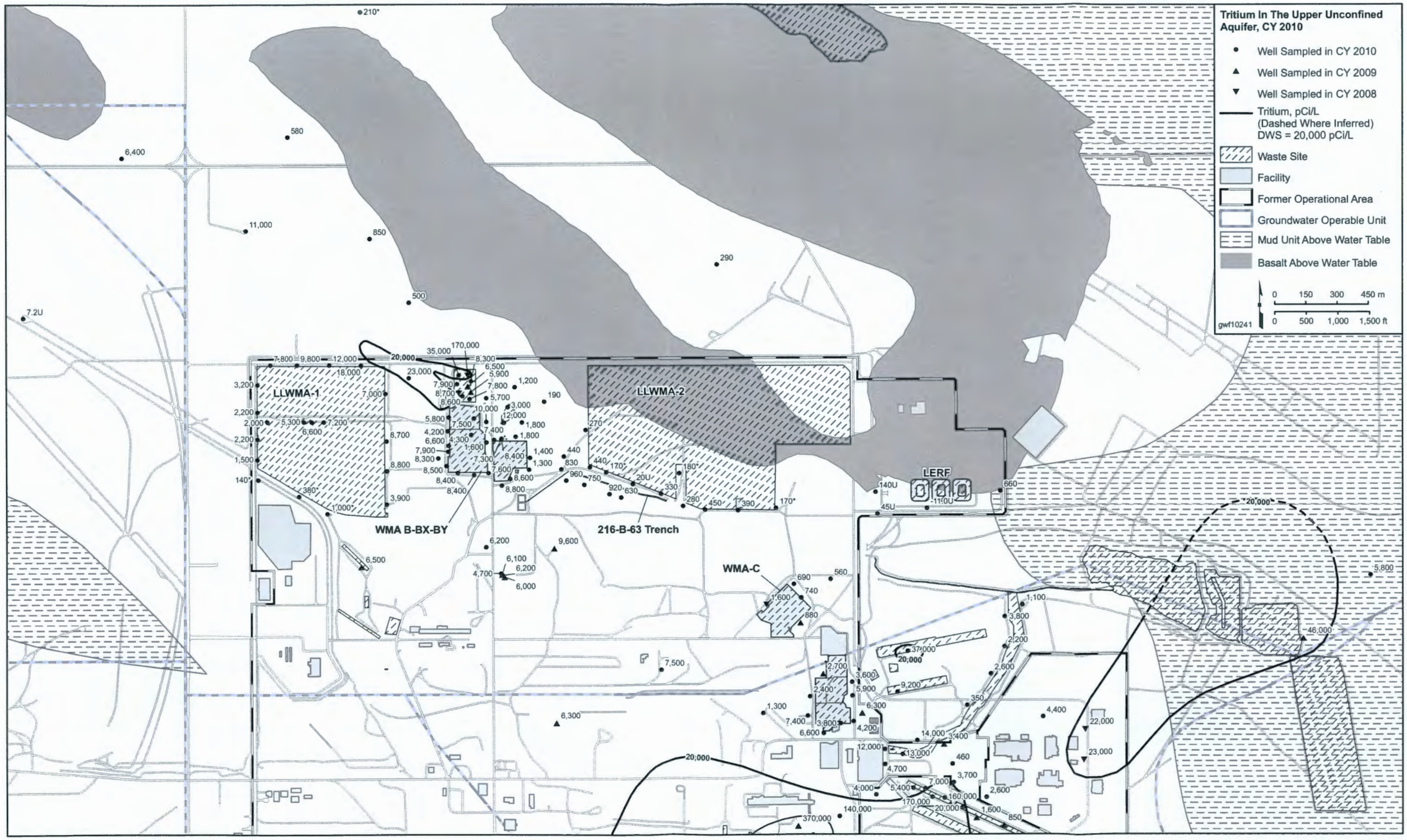
This page intentionally left blank.

Figure 9-27. Average Groundwater Cyanide Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



This page intentionally left blank.

Figure 9-28. Average Groundwater Tritium Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010



This page intentionally left blank.

Figure 9-29. Average Groundwater Sulfate Concentrations in 200 East Area and 600 Area in 200-BP-5 Operable Unit, CY 2010

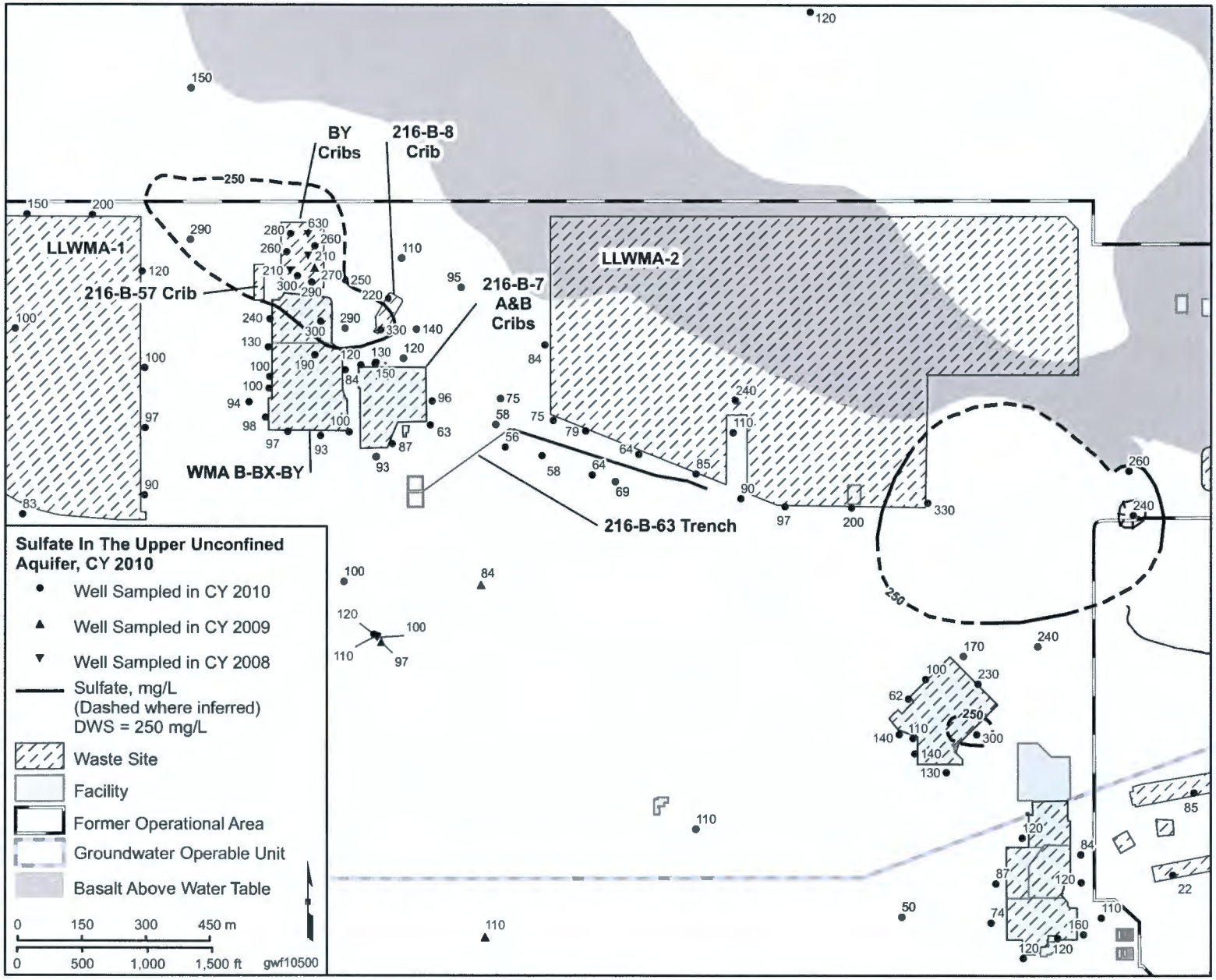


Figure 9-30. Trend Plot of Wells 299-E27-10 and 299-E34-7

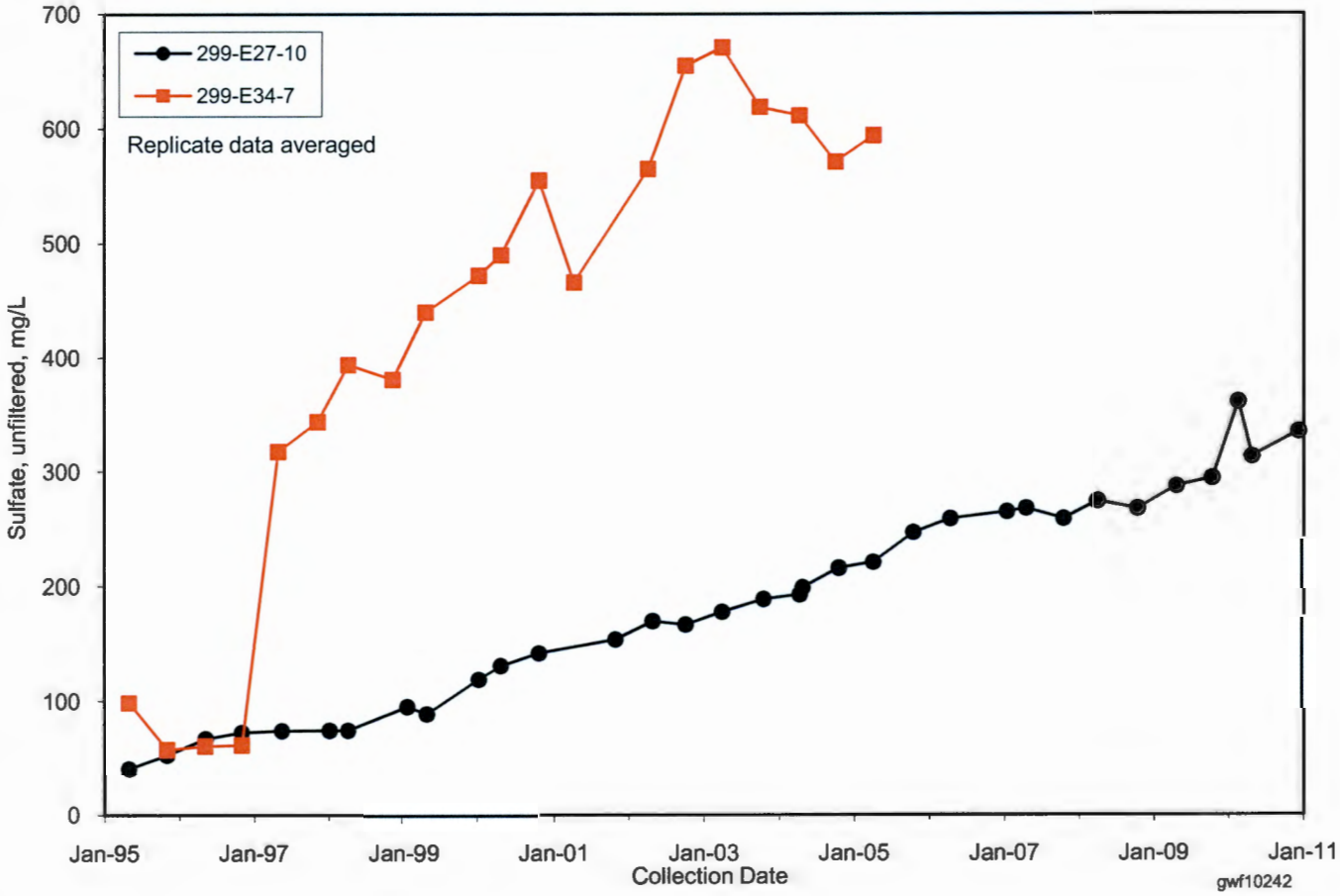


Figure 9-31. 216-E-10 Burial Ground Site Map and LLWMA-1 Well Network

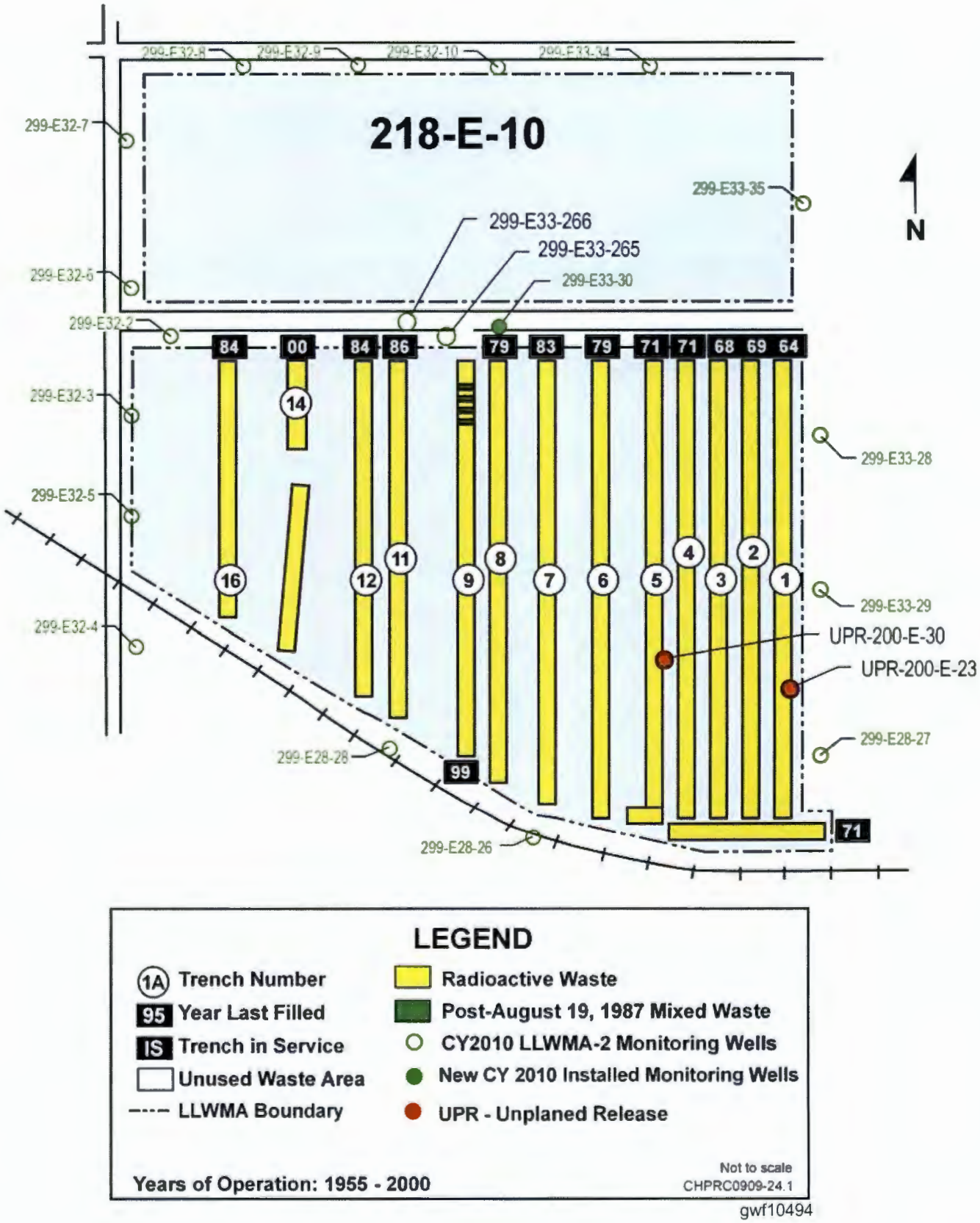
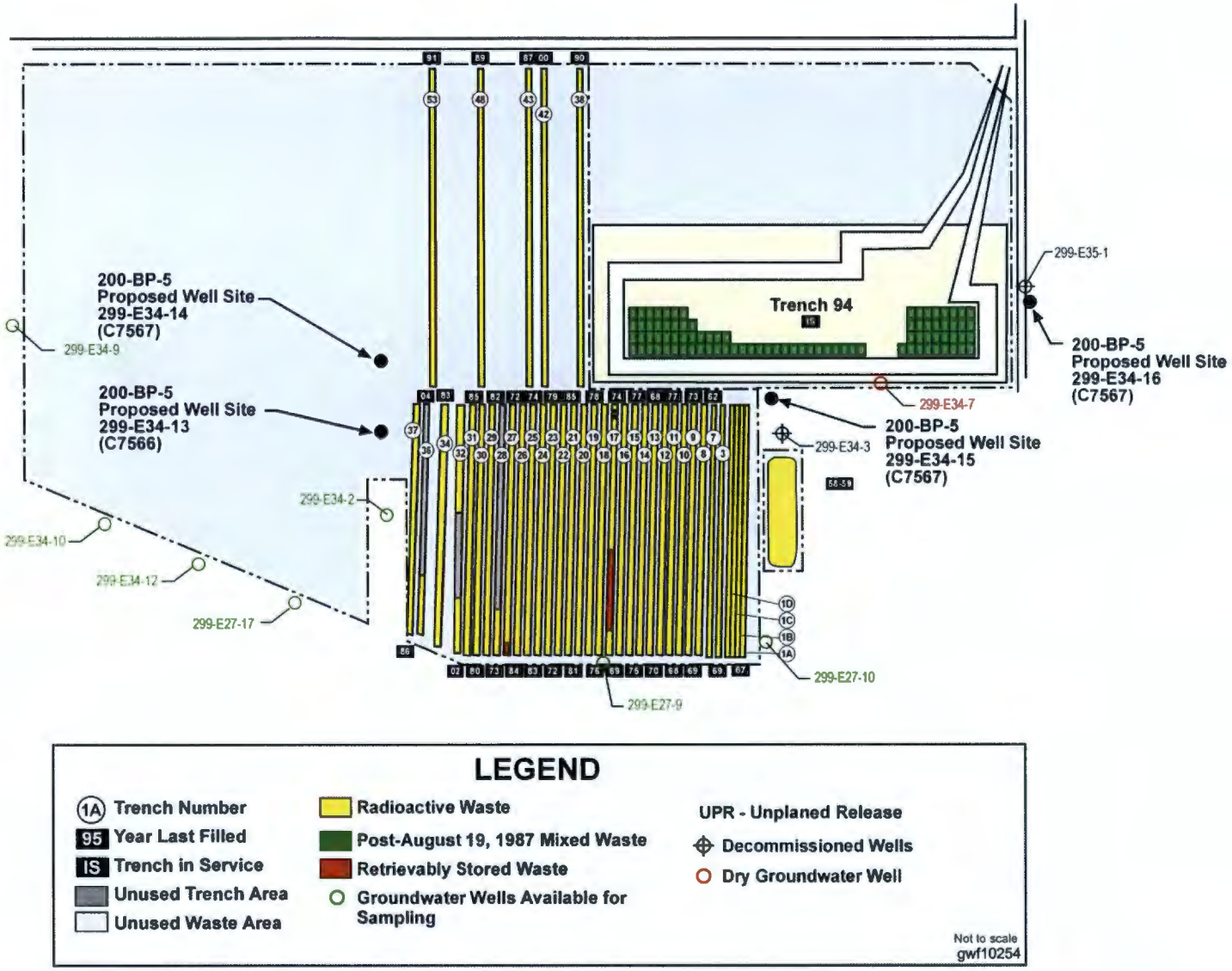


Figure 9-32. 216-E-12B Burial Ground Site Map and LLWMA-2 Well Network



Years of Operation (218-E-8): 1958-59
Years of Operation (218-E-12B): 1967 - Present

Figure 9-33. Ion Chemistry for Groundwater Sample at Well 299-E34-13

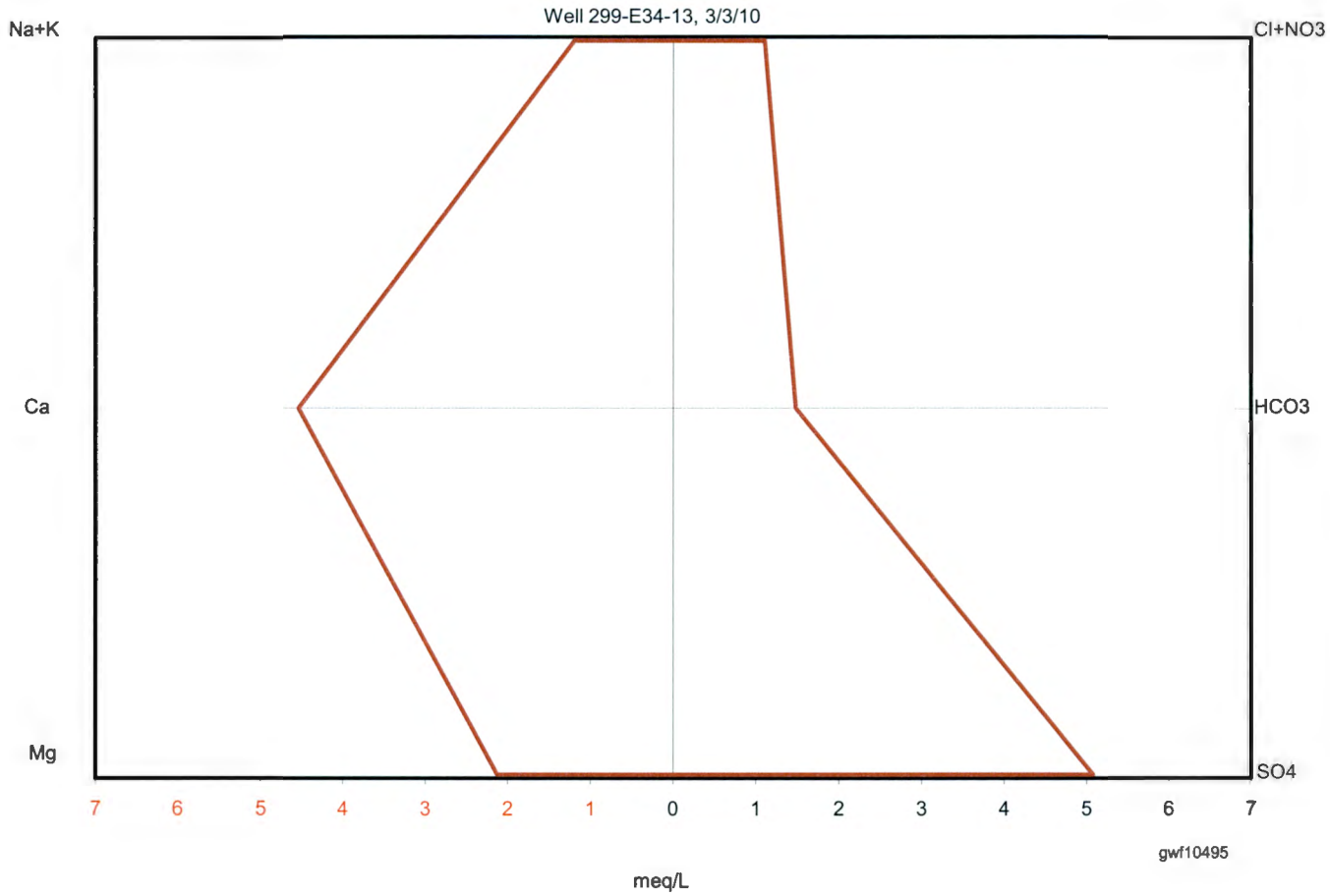


Figure 9-34. Trends of Selected Anions and Metals for Well 299-E33-47

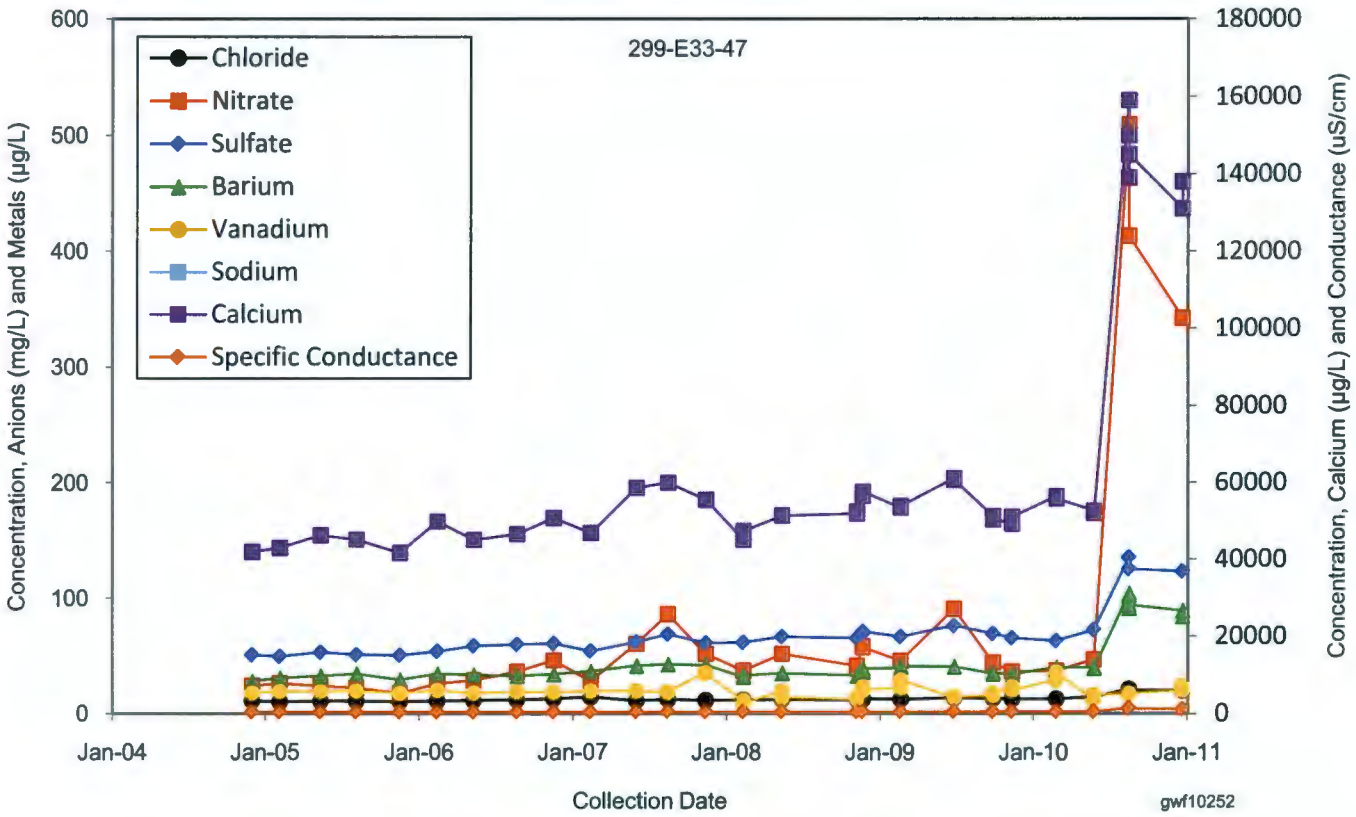
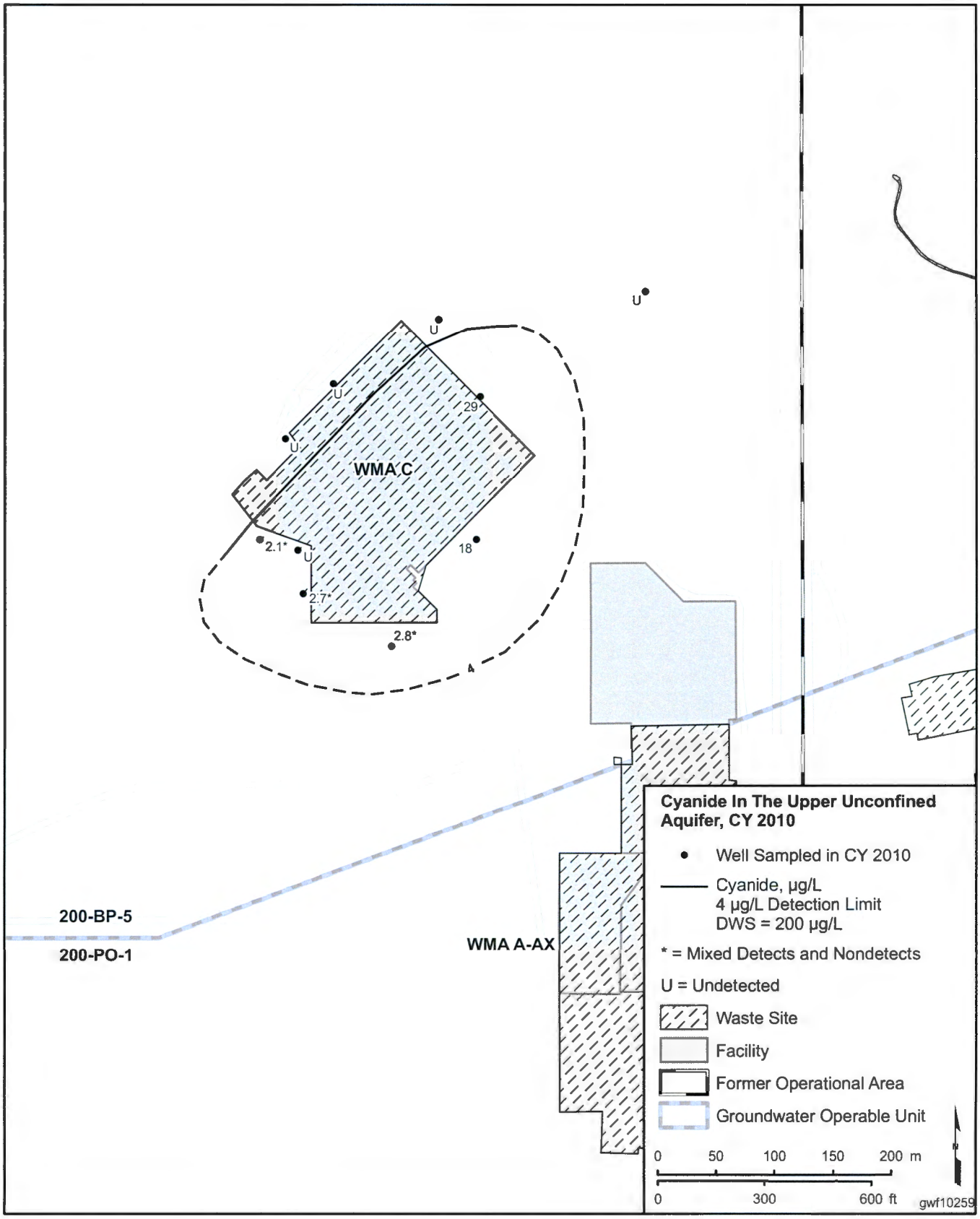


Figure 9-35. Interpreted Extent of Detectable Cyanide at Waste Management Area C

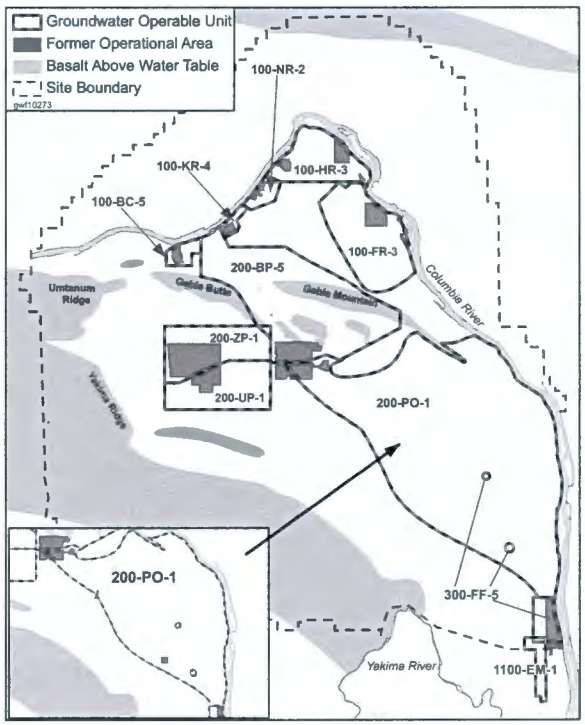


This page intentionally left blank.

10.0 200-PO-1 Operable Unit

J.W. Lindberg

This chapter describes groundwater flow and chemistry for the 200-PO-1 groundwater interest area, which includes the 200-PO-1 Operable Unit (OU). This area encompasses the southern portion of the 200 East Area and a large, triangular-shaped portion of the Hanford Site that extends to the Hanford town site to the east and to the 300-FF-5 groundwater interest area to the southeast. Although the 216-B-3 Pond (B Pond) straddles the boundary of two interest areas, it is considered part of the 200-PO-1 groundwater interest area. The BC Cribs and Trenches are located completely outside of the 200-PO-1 OU but are within the 200-PO-1 groundwater interest area. Potential groundwater contamination in the area is discussed in this chapter to ensure that potential groundwater impact from these cribs and trenches is not overlooked. The 51 wells located in the 200 East Area (near the major sources for groundwater contamination) are considered to be in the 200-PO-1 OU near-field area, while the 80 wells located in the 600 Area to the east and southeast are considered to be in the far-field area. In addition, 34 of the 61 *Resource Conservation and Recovery Act of 1976* (RCRA) (and *Washington Administrative Code*-permitted) wells in the 200-PO-1 OU are cooperatively sampled with the 200-PO-1 OU. Figure 10-1 shows the location of local facilities and wells used in near-field monitoring of the southern 200 East Area. Figure 10-2 provides the locations of wells used in the remainder of the 200-PO-1 OU far-field area and shoreline monitoring sites within the 600 Area. Figure 10-3 provides a water table map of the 200-PO-1 OU.



Active groundwater remediation is currently not taking place in the 200-PO-1 OU. A ROD has not yet been prepared.

Groundwater monitoring in the 200-PO-1 groundwater interest area is designed to meet the requirements of the *Atomic Energy Act of 1954* (AEA); the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); RCRA; and the *Washington Administrative Code*, as directed by U.S. Department of Energy (DOE) orders. Active groundwater remediation is currently not taking place in the 200-PO-1 OU. A Record of Decision (ROD) has not yet been prepared. The immediate goal for the 200-PO-1 OU is to monitor the contaminants of concern (COCs) and contaminants of potential concern (COPCs) under the CERCLA remedial investigation (RI)/feasibility study (FS) process until final cleanup decisions are made. A total of 131 wells are routinely monitored for AEA, CERCLA, and WAC requirements (51 near-field and 80 far-field wells). The OU has six RCRA units that are routinely monitored under separate groundwater monitoring plans. Some of the RCRA wells are sampled cooperatively with 200-PO-1 CERCLA sampling. The RCRA units and the number of monitoring wells include the following:

- Integrated Disposal Facility (IDF) (seven wells)
- RCRA Plutonium-Uranium Extraction (PUREX) Cribs (eleven wells)
- Waste Management Area (WMA) A-AX (single-shell tanks [SSTs]) (nine wells)
- 216-A-29 Ditch (nine wells)
- 216-B-3 Pond facility (four wells)
- Nonradioactive Dangerous Waste Landfill (NRDWL) (nine wells).

Facilities monitored under other WAC requirements include the Solid Waste Landfill (SWL) (nine wells) and the 200 Area Treated Effluent Disposal Facility (TEDF) (three wells). Water supply wells monitored under AEA include the three wells in the 400 Area and two new wells northwest of the 618-10 Burial Ground.

A detailed discussion of geology and hydrogeology within the 200-PO-1 OU is provided in the *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2009-85, Draft A), including geologic cross sections. The following four paragraphs summarize key characteristics of the aquifers and flow characteristics.

The suprabasalt aquifer system comprises the uppermost aquifer system in the 200-PO-1 OU. The aquifer system is primarily unconfined but due to its large extent and overall thickness (up to 215 meters), it includes localized semiconfined and confined intervals within the deeper portion of the suprabasalt sedimentary sequence. The suprabasalt aquifer system is primarily contained within the Ringold Formation, which is composed of silty, sandy gravel interspersed with thick, fine-grained (i.e., silty clayey) intervals such as the Ringold Formation lower mud unit. However, in some regions of the 200-PO-1 OU, the very uppermost portion of the unconfined aquifer is actually within the lower portion of the Hanford formation, which unconformably overlies the Ringold Formation. The younger, more permeable Hanford formation can create preferential groundwater flow (e.g., the southeast-trending paleo-channel cutting across the northern and eastern portions of the 200 East Area) because of the relatively higher hydraulic conductivity of the Hanford formation compared to the underlying Ringold Formation.

The Ringold Formation lower mud unit represents the base of the unconfined aquifer throughout the majority of the 200-PO-1 OU.

The Ringold lower mud unit represents the base of the unconfined suprabasalt aquifer throughout the majority of the 200-PO-1 OU, except where the Ringold lower mud unit is absent in the northern and central portions of the 200 East Area, where the uppermost basalt is the base of the aquifer.

The depth to the uppermost unconfined aquifer in the near-field area (area closest to the major waste sites in the 200-PO-1 OU in the southeastern portion of the 200 East Area) is more than 91 meters near the southern boundary of the 200 East Area, and it varies in depth to near zero meters below ground surface (bgs) at the Columbia River. Springs and seeps occur along the riverbanks where the aquifer flows in places laterally out of the ground directly into the river and/or down the sloping river shoreline into the Columbia River.

In the western portion of the 200-PO-1 OU (i.e. in the southern portion of the 200 East Area, where the main contaminant sources are located), the groundwater flow direction ranges from southeast to northeast in the unconfined aquifer before diverting primarily to the southeast upon exiting the 200 East Area (Figure 10-3) (see Chapter 3.0 for further discussion on the water table and groundwater flow). The southeasterly flow out of the 200 East Area is influenced by the higher groundwater elevations to the west, the large more permeable paleochannel (trending southeast) incised in the top of the underlying Ringold Formation, and the Ringold Formation lower mud unit situated above the water table in the vicinity of the 216-B-3 Pond. In the central to eastern portion of the OU, groundwater flow fans outward, flowing northeast, east, and southeast as it approaches the Columbia River. Based on the propagation of peak tritium concentrations from the southeast corner of the 200 East Area to the Columbia River, the apparent travel time for mobile contaminants is ~33 years (DOE/RL-2009-85, Draft A, Section 3.6.10). This

estimated travel time is based on historical water table conditions, and current travel times are expected to be slightly longer due to reduced hydraulic gradient.

Hydraulic head in the 200-PO-1 OU generally increases with depth, forming an upward gradient. In the 200 East Area, the hydraulic gradient between the aquifer below the Ringold lower mud unit and the overlying unconfined aquifer ranges from a few centimeters to ~1 meter, with the head decreasing upward. Along the Columbia River near well 699-20-E12, the vertical head difference is ~10 meters, with the 600 Area between the two areas having intermediate head differences. The exception to the general upward gradient is near B Pond where the heads decrease with depth, which is likely a condition remaining from the time period that the B Pond system was in operation. The *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington* (PNNL-12261) provides a detailed discussion of 200 East Area hydrogeology and groundwater flow characteristics.

Principal sources of groundwater contamination included cribs, ponds, pipelines, and potentially leaking SSTs.

Other important concepts associated with the 200-PO-1 OU include the following:

- Principal sources of groundwater contamination included cribs, ponds, pipelines, and SSTs that formerly leaked. These facilities are currently inactive, and pumpable liquids have been removed from the tanks; however, the waste sites have not yet been remediated and contamination remains in the vadose zone.
- Tritium, nitrate, and iodine-129 are the principal groundwater COCs because of their widespread plumes. The area of the iodine-129 plume above 1 pCi/L appears relatively stable, while the tritium and nitrate plumes are shrinking due to dispersion and (for tritium) also radioactive decay.
- Small plumes of strontium-90, technetium-99, and uranium in the 200 East Area exceed their respective drinking water standards (DWSs). Concentrations in the local plumes of strontium-90 and technetium-99 are stable to decreasing, but the small uranium plume may be increasing in size.
- The direction of groundwater flow in the 200 East Area is difficult to interpret because of the low hydraulic gradient. An effort to determine the hydraulic gradient near the PUREX Cribs and the IDF by improving the accuracy of the water-level measurements began during fiscal year (FY) 2008 and continued through 2010. This effort has yielded results that are in reasonable agreement with the interpreted movement of contaminant plumes.
- Most of the monitoring wells are screened at the top of the unconfined aquifer where the highest levels of groundwater contamination are detected. Twenty wells are screened (or have perforated casings) in deeper portions of the unconfined or confined aquifers. The deeper wells that were monitored during 2010 (or in 2009 for the basalt-confined aquifer wells) continued to show that groundwater contamination is either not detected at depth or that concentrations are much lower than near the water table (in the areas where the deeper wells are located).

10.1 Groundwater Contaminants

Major COCs in the 200-PO-1 OU include tritium, iodine-129, nitrate, strontium-90, technetium-99, and uranium.

This section describes the major COCs within the 200-PO-1 OU, which include tritium, iodine-129, nitrate, strontium-90, technetium-99, and uranium; other COPCs are also discussed. Most wells are screened (or casings perforated) in the upper portions of the unconfined aquifer at the water table. However, of the 124 wells that were scheduled for sampling during 2010, 16 wells are screened deeper in the unconfined aquifer (not at the water table), one well is screened below the Ringold

Plume areas (square kilometers) in the 200-PO-1 Operable Unit:

Iodine-129, 1 pCi/L — 54.74

Nitrate, 45 mg/L — 1.57

Strontium-90, 8 pCi/L — 0.013

Technetium-99, 900 pCi/L — 0.0035

Tritium, 20,000 pCi/L — 119.67

Tritium, 80,000 pCi/L — 1

Uranium, 30 µg/L — 0.09

lower mud unit, and 7 wells are screened in the basalt-confined aquifer below the Ringold Formation. When data from the deeper wells are discussed, the data will be identified or specifically mentioned as to their source from the deeper wells.

During 2010, many wells in the eastern portion of the 200-PO-1 OU were sampled for a relatively comprehensive list of analytes for the Decision Unit Risk Assessment Project. As a result, many of the wells in this area have additional results not normally scheduled for the 200-PO-1 OU. Some of the constituents were analyzed with lower than normal detection limits for wells in this area (e.g., tritium and technetium-99). The additional data provided more definition of the detectable boundaries in the distant areas of the 200 East Area plumes but did not affect concentrations or plume map contours near the DWSs.

The cribs, ponds, and ditches surrounding the PUREX Plant are responsible for most of the groundwater contamination in the 200-PO-1 OU. The PUREX Plant began operation in 1956, eventually replacing the Reduction-Oxidation (REDOX) Plant as the plutonium-separation facility. The first PUREX operational campaign was from 1956 to 1972. Following an 11-year shutdown, the PUREX Plant operation restarted in 1983, operating for 5 years until December 1988, when the mission for weapons production ended. Plant operation briefly restarted again in December 1989 to stabilize material in the system. The plumes that are present primarily contain those species associated with process condensates, including tritium, iodine-129, and nitrate. Some strontium-90 and technetium-99 are also associated with PUREX waste disposal, although technetium-99 is not found above the 900 pCi/L DWS in contaminant plumes from PUREX Cribs. Within the boundaries of the 200-PO-1 OU, technetium-99 exceeds the DWS only near WMA A-AX.

10.1.1 Tritium

The principal source for the large tritium plume is the PUREX Cribs.

The principal source for the large tritium plume extending from the southeastern portion of the 200 East Area to the Columbia River (Figures 10-4 and 10-5) is the PUREX Cribs. The highest concentrations of tritium in this plume remain near these cribs (Figure 10-5). The highest reported level of tritium during 2010 was 590,000 pCi/L for a sample collected April 2010 at well 299-E17-14 (near the 216-A-36B Crib).

Wells in the near-field area generally have higher tritium concentrations than wells in the far-field area because of their proximity to the tritium sources. However, like wells in the far-field areas, wells in the near-field area generally show decreasing to stable trends. Figure 10-6 shows tritium concentration trends in three wells at the PUREX Cribs (one well for each of the three PUREX Cribs). The wells shown had the highest tritium concentration for their respective cribs during 2010.

Concentrations of tritium generally continue to decline in the far-field area as the plume attenuates naturally due to radioactive decay, advection, and dispersion. The plume eventually discharges with normal groundwater flow to the river. Wells in the northeastern portion of the 200-PO-1 OU (699-35-9, 699-29-4, and 699-26-15A) previously had tritium concentrations greater than 80,000 pCi/L (Figure 5-4 in DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*). In 1997, the 80,000 pCi/L plume configuration was ~60 square kilometers in this area. In 2008, the 80,000 pCi/L plume configuration had decreased to ~18 square kilometers. Likewise, the tritium results for these wells has decreased from over 120,000 pCi/L in the mid-1990s to 69,000, 61,000,

and 58,000 pCi/L, respectively in 2010, eliminating concentrations greater than 80,000 pCi/L in this area (Figure 10-4).

The zone of lower tritium concentrations near the Energy Northwest complex (Figure 10-4) is likely an effect of a zone of lower hydraulic conductivity in the unconfined aquifer. In this area, the water table is within the upper portion of the Ringold Formation that may have a greater degree of local cementation. The small but concentrated tritium plume near the Energy Northwest complex is due to tritium from the 618-11 Burial Ground in the 300-FF-5 OU. Chapter 13.0 discusses tritium at the 618-11 Burial Ground, which is west of the Energy Northwest complex.

Wells screened (or casings perforated) in the middle or lower portions of the unconfined aquifer had tritium results ranging from nondetect to 62,000 pCi/L. The maximum concentration was at well 699-37-E4 (near the Columbia River, southeast of the Hanford town site). Other deep wells in the unconfined aquifer where tritium was above the 20,000 pCi/L DWS included well 699-31-11 (in the middle of the tritium plume) and wells 699-41-40 and 699-41-42 near B Pond. The tritium levels in those wells were 58,000, 36,000, and 22,000 pCi/L, respectively. In well 699-31-11, the well screen is 41 meters below the water table, but it was retrofitted from an older, carbon-steel well with potentially leaking seals or packers (well location in Figure 10-2). Wells 699-41-40 and 699-41-42 are in an area where the head decreases with depth, allowing downward flow.

Tritium was not detected in the three wells located near the TEDF, east of the 200 East Area. These wells are screened in the coarse basal Ringold unit 9 and below the Ringold lower mud unit, which locally confines the groundwater. Tritium was also not detected in four of the seven wells monitoring the basalt-confined aquifer. Three deep basalt-confined aquifer wells where tritium was detected were 699-42-40C, 699-S2-34B, and 699-S11-E12AP (Figure 10-2). The level was 3,500 pCi/L in well 699-42-40C near B Pond (where the head decreases with depth). At well 699-S2-34B near the Laser Interferometer Gravitational-Wave Observatory (LIGO) the concentration was 41.1 pCi/L. Well 699-S11-E12AP located near the Columbia River north of the 300 Area had a concentration of 33.8 pCi/L. Results from both the Ringold Formation and basalt-confined aquifers are discussed further in Chapter 15.0.

10.1.2 Iodine-129

The iodine-129 plume has changed very little over the past 15 years.

The iodine-129 plume (Figure 10-7) extends southeast into the 600 Area from the 200 East Area and appears to coincide with the northern portions of the tritium plume. The plume (above the 1 pCi/L isopleth line) has changed very little over the past 15 years, although the maximum concentrations have declined significantly (PNL-10698, *Hanford Site Ground-Water Monitoring for 1994*) and appear relatively stable.

The highest concentrations of iodine-129 in the 200-PO-1 OU are near the sources in the 200 East Area and B Pond area. The concentrations in this near-field area ranged from nondetect to 9.7 pCi/L at well 299-E17-19 (near the 216-A-10 Crib). The general trend was relatively stable for iodine-129 at this well (Figure 10-8), which is typical of the trend for iodine-129 at other wells near the PUREX Cribs.

It is likely that the sources of iodine-129 in the 200 East Area continue to contribute iodine-129 to the plume because of the persistence of the plume across the northern portions of the 200-PO-1 OU. With a low retardation factor, iodine-129 would be expected to disperse more quickly through natural processes if the plume were not continually replenished. Iodine-129 has a half-life of 15.7 million years and a low

distribution coefficient (ranging from 0 to 2 mL/g, depending on aquifer conditions, and averaging 0.2 mL/g) (PNNL-11800, *Composite Analysis of Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*; PNNL-14702, *Vadose Zone Hydrogeology Data Package for the 2004 Composite Analysis*).

Iodine-129 was detected in wells screened (or perforated) deeper in the unconfined aquifer, including wells near B Pond, the 216-A-37-1 Crib (299-E25-29Q), 216-A-29 Ditch (299-E25-28), near the Columbia River (699-37-E4), and in the central 600 Area in the possibly leaking well (699-31-11). The highest concentrations for the deeper unconfined aquifer wells were near B Pond where iodine-129 concentrations reached 3.4 pCi/L in well 699-41-42 (Figure 10-1). As noted for tritium, the hydraulic heads decrease downward in this area, allowing downward groundwater flow and downward movement of contaminants. The detection in well 699-37-E4 near the Columbia River was at a concentration of 0.168 pCi/L. Of the seven deep basalt-confined aquifer wells, iodine-129 was detected only in well 699-42-40C near the B Pond at 0.289 pCi/L.

The nitrate plume, with sources in the 200 East Area, appears to have dispersed over previous years, except near the PUREX Cribs.

10.1.3 Nitrate

The extent of the plume with nitrate concentrations elevated above background is similar to the tritium plume; however, the portion of this plume exceeding the 45 mg/L DWS is relatively small by comparison (Figure 10-9). During 2010, the highest nitrate concentration in the 200-PO-1 OU was at wells near the PUREX Cribs (Figure 10-10). Well 299-E17-19 (at the 216-A-10 Crib) had an average of 160 mg/L for samples collected during 2010. The average for well 299-E17-14 (216-A-36B Crib) was 110 mg/L. The nitrate plume, with sources in the 200 East Area, appears to be dispersing slightly over time when compared with previous years, except near the PUREX Cribs (PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*; DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*) and WMA A-AX. Another nitrate plume with offsite sources exists near the 300 Area.

Many of the wells near the PUREX Cribs in the southeastern portion of the 200 East Area have increasing nitrate concentrations. The trend at well 299-E17-19 (near the 216-A-10 Crib) is typical of wells with increasing trends (Figure 10-11). Increasing nitrate concentrations were also observed at WMA A-AX (Section 10.3.3.2). The cause of the increase in nitrate concentrations at many of the wells in the southeastern portion of the 200 East Area is unknown but may be the result of shifting groundwater flow directions related to cessation of wastewater discharges at B Pond or the discharge of wastewater at the TEDF. These same discharges may have diluted the nitrate concentrations while B Pond was active. Increasing concentrations near the PUREX Cribs and WMA A-AX may also be due to continued seepage from the vadose zone.

For the wells screened (or casings perforated) in the middle to lower portions of the unconfined aquifer, nitrate did not exceed the 45 mg/L DWS. The highest nitrate concentration reported in the deeper wells was at well 699-2-7 near the 400 Area Process Ponds, which is a local source of nitrate; the nitrate concentration was 36.3 mg/L. In the main water supply well in the 400 Area (well 499-S1-8J), nitrate concentrations averaged 0.44 mg/L during 2010. In the Ringold Formation confined aquifer beneath the TEDF, nitrate concentrations averaged 6.64 mg/L at well 699-42-37, 0.79 mg/L at well 699-41-35, and 0.17 mg/L at well 699-40-36. Nitrate concentrations were very low in all of the basalt-confined aquifer wells, with the exception of 6.15 mg/L in well 699-42-40C near B Pond.

10.1.4 Strontium-90

Well 299-E17-14 (at the 216-A-36B Crib) was the only well with strontium-90 detected during 2010 in the 200-PO-1 OU. In previous years, several other wells near the PUREX Cribs had detections of strontium-90. At well 299-E17-14, the trend appeared to be decreasing in 2008 and 2009 when the levels dipped lower than the previously stable concentration of 18 to 20 pCi/L, with concentrations of 14 and 11 pCi/L, respectively (the DWS for strontium-90 is 8 pCi/L). The 2010 result was 16 pCi/L. Strontium-90 was not detected in any of the deeper unconfined aquifer wells or basalt-confined aquifer wells.

10.1.5 Technetium-99

Technetium-99 continues to be detected at WMA A-AX at levels above the 900 pCi/L DWS.

Technetium-99 (also a beta-emitter) continues to exceed the DWS (900 pCi/L) at only one location within the 200-PO-1 OU, WMA A-AX. Technetium-99 is most concentrated at well 299-E25-93, located along the southern boundary of WMA A-AX, with results for 2010 ranging from 3,400 to 5,300 pCi/L. Technetium-99 is also above the DWS in WMA A-AX upgradient well 299-E24-33, with results ranging from 1,200 to 1,300 pCi/L in 2010. The trend at both wells has been relatively level since 2009 (Figure 10-12) (technetium-99 at WMA A-AX is also discussed in Section 10.3.3). Technetium-99 was detected in wells at the PUREX Cribs up to a concentration of 140 pCi/L. The technetium-99 activity from these areas extends throughout the northern and central portions of the area occupied by the large tritium plume, with concentrations up to 120 pCi/L. The only deep well with technetium-99 detected was well 699-31-11 in the central 600 Area (Figure 10-2). As previously stated, this well may be leaking and in hydraulic communication with groundwater in the upper portions of the unconfined aquifer. Although, there is no direct evidence, the suggestion of leakage was deduced from sampling results of other contaminants in this well and other nearby deep and shallow wells. The monitoring results at well 699-31-11 are similar for tritium, iodine-129, nitrate, and technetium-99, as is also the case with shallow wells in the area. The nearby deep well 699-25-33A (at a similar horizon in the aquifer) has much lower values for these constituents. Well 699-31-11 is a noncompliant well (WAC 173-160) with a vulnerable neoprene packer at 49 meters. Based on the construction details and history of this older, noncompliant well, it is not unexpected that the well may be leaking. The range for technetium-99 in well 699-31-11 was 86 to 97 pCi/L.

10.1.6 Uranium

In recent years, uranium concentrations have been increasing in wells near the PUREX Cribs.

Elevated uranium concentrations were found at three locations within the 200-PO-1 OU, the PUREX Cribs, the 618-10 Burial Grounds, and the 618-11 Burial Grounds. In recent years, uranium concentrations have been increasing in wells near the PUREX Cribs (Figure 10-13). Uranium concentrations at well 299-E17-14 have been relatively stable since 2006, with concentrations near the 30 µg/L DWS (Figure 10-14). In two nearby wells, concentrations have been higher in recent years, with the highest concentration at well 299-E24-23 (106 µg/L in 2009) (Figure 10-14); however, well 299-E24-23 was not sampled during 2010, so it is not known if the upward trend continued. The other well with a higher uranium concentration was 299-E25-36, with a concentration of 75.4 µg/L in 2010.

At the 618-10 and 618-11 Burial Grounds (within small "islands" of 300-FF-5 OU, in the 200-PO-1 OU), uranium concentrations reached the 14.4 µg/L background concentration at the 95th percentile (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*), but these areas are sites of known uranium

contamination in the 300-FF-5 OU. Elsewhere, including the deeper wells, uranium concentrations are lower than the background range (at the 95th percentile).

10.1.7 Other Constituents

Other constituents (i.e., arsenic, chromium, manganese, and vanadium) are COPCs at various source sites within the 200-PO-1 OU (DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*). Chromium, cobalt-60, cyanide, and uranium are COPCs at the BC Cribs and Trenches. Arsenic was detected in nearly every well sampled in the 200-PO-1 OU, but mostly at concentrations below the background concentration at the 95th percentile of 11.8 µg/L. Results exceeded background at five wells in the Energy Northwest area, with the highest concentrations in well 699-13-1A (13.8 to 14.9 µg/L). The volatile organic compounds (VOCs) were constituents of concern at the NRDWL and SWL in the central 600 Area.

Manganese exceeded the 50 µg/L secondary DWS in the 200-PO-1 OU during 2010 in only one well (699-32-22B).

In 2010, manganese exceeded the 50 µg/L secondary DWS in the 200-PO-1 OU in only one well (699-32-22B), with 71 µg/L for an unfiltered sample and 8 µg/L for a filtered sample collected at the same time. Well 699-32-22B is a deep basalt-confined aquifer well that is screened across a basalt interbed at a depth of 236 to 255 meters bgs. It is located along the southeast transect (see Section 10.2.2) (Figure 10-2). The result for the unfiltered sample is anomalous for this well and is an isolated occurrence; it is likely that this result is a sampling or laboratory error or may be due to deterioration of the well screen or casing.

Vanadium concentrations ranged from the method detection limit of 12 to 42.6 µg/L in well 299-E25-22, located near the 216-A-37-2 Crib. This result is typical for well 299-E25-22, and vanadium was detected in many wells throughout the 200-PO-1 OU. The 95th percentile background level for vanadium is 19 µg/L. A DWS has not been established for vanadium.

Groundwater monitoring is routinely conducted at three wells at the BC Cribs and Trenches (299-E13-5, 299-E13-11, and 299-E13-19). Well 299-E13-11 was not sampled as scheduled during 2010 because of difficulties in accessing the well. The recent results from the other two wells show that COPCs (i.e., chromium, cobalt-60, cyanide, and uranium), as well as the 200-PO-1 OU major COCs, were either not detected or were similar to background (upgradient) concentrations in the BC Cribs and Trenches.

Although not a COC in the 200-PO-1 OU, a fluoride concentration of 9.2 mg/L observed in well 699-S2-34B (the well at the LIGO) during 2010 was above the 4 mg/L primary DWS. This well is used for water supply. The results are typical of the historical trend for this well. The well is screened in the Frenchman Springs Member of the Wanapum Basalts, and this member generally has relatively low levels of fluoride. At the LIGO site, the Wanapum Basalts may have upwelling groundwater from the underlying Grande Ronde Basalt, which is known to have fluoride concentrations in the range of 8 to 10 mg/L (PNNL-13962, *Natural Gas Storage in Basalt Aquifers of the Columbia Basin, Pacific Northwest USA: A Guide to Site Characterization*).

The VOCs were constituents of concern at the NRDWL and SWL in the central 600 Area; however, the VOCs were not detected there in 2010 and were occasionally detected in PUREX Cribs wells. During 2010, the only detection of a VOC was tetrachloroethene in well 299-E24-16 at 2.8 µg/L; however, the result was flagged by the analytical laboratory as estimated only.

10.2 CERCLA Groundwater Activities

Groundwater monitoring at the 200-PO-1 OU supports the RI/FS process under the direction of a work plan and two sampling and analysis plans.

The 200-PO-1 OU makes up a large portion of the Hanford Site (Figure 10-2). The OU boundaries are generally defined by the 2,000 pCi/L tritium (200 East Area origin) plume contour, which is the largest contaminant plume in the OU. Wells at the BC Cribs and Trenches are also within the 200-PO-1 groundwater interest area, even though they are located outside the OU boundaries.

Groundwater monitoring at the 200-PO-1 OU supports the RI/FS process under the direction of a work plan and two sampling and analysis plans (one for routine groundwater sampling, and a second for short-term characterization to supplement routine groundwater monitoring). Work began on a draft RI report in 2009 following completion of RI activities. Draft A of the report was submitted for regulatory review in May 2010. The work plan, sampling and analysis plans, and RI report documents are briefly described below.

Under the direction of the "routine" sampling and analysis plan, 124 wells were scheduled to be sampled in 2010, and 116 of those wells were successfully sampled.

DOE/RL-2003-04, Rev. 1, ***Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit.*** This sampling and analysis plan (referred to as the "routine" sampling and analysis plan) provides the basis for routine sampling and analysis of 200-PO-1 COCs for CERCLA and AEA. Revision 1 of the routine sampling and analysis plan was approved in 2005 to provide groundwater data necessary to track the extent and concentration of known contaminant plumes. In 2008, the monitoring well list and groundwater analyte list were updated with additional wells and analytes. The monitoring well locations associated with the routine sampling and analysis plan are shown in Figure 10-1 (near-field wells) and Figure 10-2 (far-field wells). Appendix A, Tables A-14 and A-15 provide the well list and analyte list for the 200-PO-1 OU, respectively. The routine sampling results for 2010 are discussed in Sections 10.1 and 10.2.2. Of the 124 wells scheduled for sampling in the OU during 2010, 116 were successfully sampled. Eight well trips were unsuccessful due to a variety of reasons, including maintenance issues, wellhead damage, access problems, or insufficient water. Two wells were scheduled during the work stoppage in October 2010 and were not sampled prior to February 2011.

Work was completed for the "characterization" sampling and analysis plan in 2009, and the results were reported in the RI report in 2010.

DOE/RL-2007-31, Rev. 0, ***Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit.*** This work plan was issued in 2008 to further define the conditions within the 200-PO-1 OU. Data acquisition was designed to complement the routine sampling and analysis plan and to provide additional information regarding groundwater flow direction and rate, preferential pathways for contaminant migration, and contaminant mass transport. Appendix A of the work plan includes a RI sampling and analysis plan (referred to as the "characterization" sampling and analysis plan) that directed (1) sampling of additional wells to supplement the routine sampling and analysis plan, (2) opportunistic sampling of vadose zone boreholes when they reached groundwater, (3) sampling wells planned for decommissioning, and (4) sampling of eleven aquifer tubes. Work was completed for the characterization sampling and analysis plan in 2009, and the results were reported in the RI report (see below) and in the 2009 Hanford Site groundwater annual report (DOE/RL-2010-11).

DOE/RL-2009-85, Draft A, ***200-PO-1 Operable Unit Remedial Investigation Report.*** In 2009, work began on the RI report to document the completion of the RI studies in accordance with the work plan (DOE/RL-2007-31) for the 200-PO-1 OU, including the results of the two sampling and analysis plans (routine and characterization sampling). The report was completed in 2010 and was submitted

for review by the regulatory agencies prior to issuance. Results of the draft RI report are summarized in the following section.

The purpose for conducting the RI was to collect additional data to refine the nature and extent, to assess fate and transport, and to evaluate potential risks to human health and the environment from 200-PO-1 Groundwater OU contaminants.

10.2.1 Remedial Investigation Report

The RI was conducted in late 2008 and early 2009 and reported in DOE/RL-2008-85, Draft A, which was released for regulatory review in May 2010. Data that missed the deadline for inclusion in Draft A of DOE/RL-2008-85 were discussed in the 2009 annual Hanford Site groundwater report (DOE/RL-2011-11). The following is a summary of the results taken largely from the executive summary of DOE/RL-2008-85.

The purpose for conducting the RI was to collect additional data to refine the nature and extent, to assess fate and transport, and to evaluate potential risks to human health and the environment from 200-PO-1 OU contaminants. The information collected during the RI will also support development of the FS for the 200-PO-1 OU. The results and conclusions of the RI were largely based on data collected over a 5-year period, from 2004 through 2009.

Concentrations of tritium and iodine-129 within the primary plume have declined in the far-field area. These declining concentrations are due to natural attenuation as a result of radioactive decay and dispersion, cessation of liquid disposal operations, and a decreasing source of contaminants that resulted from the termination of PUREX Plant and B Plant operations.

In the near-field area (the 200 East Area), the extent of the strontium-90 and uranium plumes was found to be very small as a result of relatively low to moderate mobility of the contaminants in the aquifer. Prior to 2003, groundwater sampling in the area of the PUREX Cribs and WMA A-AX returned technetium-99 results up to a maximum concentration of 600 pCi/L. Since 2004, increasing technetium-99 concentrations have been detected, with concentration in one well (well 299-E25-93, installed in 2003) exceeding the 900 pCi/L DWS since the well was installed. In this area, a local source of technetium-99 and an upgradient source for technetium-99 are entering WMA A-AX from the northwest.

Computer simulation of the fate and transport of groundwater contamination was used to estimate future impact of current groundwater contamination in both the near-field and far-field regions.

In the far-field area (outside the 200 East Area), tetrachloroethene, trichloroethene, and carbon tetrachloride have been detected near the SWL and NRDWL in previous years and are being addressed through RCRA corrective action and final closure. Groundwater monitoring in the SWL and NRDWL wells since the early 1990s had shown decreasing trends in tetrachloroethene and trichloroethene concentrations.

Computer simulation of the fate and transport of 200-PO-1 groundwater contamination was used to estimate future impact of current groundwater contamination in both the near-field and far-field regions (ECF-200PO1-09-2007, *200-PO-1 Operable Unit Remedial Investigation Report – Far Field Contaminant Fate and Transport*; ECF-200PO1-10-0259, *Central Plateau MODFLOW Model Development*; ECF-200PO1-09-2352, *200-PO-1 OU Remedial Investigation Report – Near Field Groundwater Contaminant Fate and Transport Modeling)*. The simulation did not consider the effects of continuing vadose zone contribution to be addressed by overlying source OUs. The fate and transport simulation for the near-field (200 East Area) contaminants included the following results:

- The iodine-129 plume, beginning with an initial maximum concentration of less than 10 pCi/L, persists over the simulated timeframe (i.e., 1,000 years) due to moderate retardation and a long half-life. At the end of the simulation, the

maximum calculated iodine-129 concentration from all locations is less than 0.3 pCi/L.

- The technetium-99 plume increases initially, from ~53 pCi/L at 5 years to ~218 pCi/L at 10 years, and then gradually decreases to ~15 pCi/L at the end of the simulation.
- The tritium plume decreases from a maximum concentration of ~513,000 pCi/L to ~5,700 pCi/L after 50 years.
- The nitrate plume concentration declines gradually from a maximum of ~100 mg/L to ~3.5 mg/L within 300 years.
- The trichloroethene plume concentration declines from a maximum of ~0.5 μg/L to less than 0.04 μg/L within 100 years.
- The strontium-90 plume concentration declines from a maximum of 80 pCi/L to less than 0.02 pCi/L within 100 years.
- The uranium plume concentration declines from a maximum of 34 μg/L to less than 3 μg/L within 500 years.

The results of the transport model demonstrated that peak concentrations of contaminants that currently exist in the far-field region (e.g., tritium, iodine-129, and nitrate) generally decline over time and distance. Peak concentrations for COPCs that have not arrived in the far-field region (e.g., uranium, technetium-99, strontium-90, tetrachloroethene, trichloroethene, and carbon tetrachloride) are predicted to remain lower than those at the upstream boundary, suggesting decreasing risk.

The conceptual exposure model identified potentially complete human and ecological exposure pathways in the near-field, far-field, and river exposure areas.

A conceptual exposure model was also developed for the 200-PO-1 OU. This model identifies potentially complete human and ecological exposure pathways in the near-field, far-field, and river exposure areas. Potential human receptors, including Native American subsistence users, are assumed to be hypothetical future domestic groundwater users. Ecological receptors are limited to aquatic organisms in the Columbia River that may be exposed to contaminants in groundwater that discharges into the river. The following potential exposure routes were identified:

- Ingestion of contaminated water by drinking or from food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminants in groundwater
- External radiation exposure from radioactive contaminants in groundwater
- Potential exposure for the near-field and river exposure areas (consumption of fish from the affected portion of the Columbia River).

Based on results of the modeling and baseline risk assessment, it was concluded that it is appropriate to proceed with the FS.

The draft RI report (DOE/RL-2008-85) described the baseline risk assessment that was conducted to evaluate current and potential future risks to hypothetical human and ecological receptors. Table 10-1 provides the results of the baseline risk assessments for each of the near-field, far-field, and river exposure areas. The table also identifies the standards that are exceeded under current and estimated future groundwater conditions, as well as provides a summary of the quantified risk results that would be encountered if remedial action were not taken. Based on the information provided in the modeling and the results of the baseline risk assessment, it was concluded that it is appropriate to proceed with the FS for the 200-PO-1 Groundwater OU.

10.2.2 CERCLA Groundwater Monitoring

This section discusses the groundwater monitoring results for 2010 for the "routine" sampling and analysis plan (DOE/RL-2003-04) that were not previously

discussed in Section 10.1. Characterization activities for the "characterization" sampling and analysis plan were completed prior to 2010, and the results were reported in earlier documents. Most of the results for the primary groundwater plumes and COCs for the 200-PO-1 OU are discussed in Section 10.1, but specific details of the guard wells are discussed here (guard wells discussed in the following paragraph). Lists of wells and groundwater constituents analyzed for 200-PO-1 OU wells are provided in Appendix A, Tables A-14 and A-15.

Wells along the southeast transect are screened for a comprehensive list of analytes.

The 200-PO-1 OU routine sampling and analysis plan (DOE/RL-2003-04) specifies annual sampling of two lines of guard wells to screen for a comprehensive list of analytes (i.e., additional groundwater constituents than usually analyzed on samples collected from far-field wells). One of the lines of guard wells (the southeast transect) is located southeast of the 200 East Area (Figure 10-2) and ensures that unexpected contaminants do not migrate undetected from the 200 East Area. The other line (the river transect) is a line of wells located along the Columbia River to assess the concentration of any groundwater contaminants that may reach the river. The comprehensive list of analytes for samples collected from wells of both transects includes tritium, iodine-129, anions (including nitrate), gross alpha and beta, gamma scan, metals, strontium-90, and VOCs.

The only constituents exceeding DWSs in southeast transect wells were tritium and iodine-129.

Most of the anions and metals (e.g., fluoride and arsenic) detected in southeast transect wells during 2010 are naturally occurring or are typical of Hanford Site background values at the 95th percentile (DOE/RL-96-61). The only constituents exceeding their DWS were tritium and iodine-129, but their concentrations were consistent with their respective plumes. Technetium-99 was detected at levels above Hanford Site background at the 95th percentile (0.99 pCi/L) but was similar to other wells in the area. The highest result for technetium-99 during 2010 for southeast transect wells was 43 pCi/L at well 699-32-22A. Gross alpha and gross beta were as high as 5.3 and 48 pCi/L, respectively, in southeast transect wells, and both are typical for wells in this area. Chromium, cobalt, copper, nickel, and vanadium were all detected at levels above Hanford Site background levels, but their results were low enough to be flagged by the analytical laboratory as "estimated" only. Nitrate and sulfate exceeded Hanford Site background and are elevated due to 200 East Area liquid waste discharges. The highest reported levels were 41.7 and 58.5 mg/L, respectively. The VOCs bromomethane, chloromethane, and trichloroethene were detected at very low levels in well 699-46-21B, but like the metals, these results were flagged by the analytical laboratory as "estimated" only.

The only groundwater contaminant exceeding its DWS in the river transect wells was tritium.

Groundwater monitoring results for 2010 at the river transect were similar to those for the southeast transect although generally lower in concentrations due to greater distance from contamination sources. Most of the anions and metals (e.g., fluoride and arsenic) detected in river transect wells during 2010 are naturally occurring or are typical of Hanford Site background values (DOE/RL-96-61). The only constituent exceeding DWS was tritium (DWS of 20,000 pCi/L) with a high of 52,000 pCi/L at well 699-41-1A. This tritium result is typical for this area of the large tritium plume emanating from the 200 East Area, and the trend for this well is decreasing. Aluminum, bismuth, molybdenum, and sodium were detected at levels above Hanford Site background concentrations, but all sodium results were flagged as estimated by the analytical laboratory. Sodium was above Hanford Site background values and had a high of 42 mg/L in well 699-S3-E12. The trend in this well is slightly increasing to stable, and the reason for the elevated levels at this location is unknown. Other wells in the area have sodium concentrations ranging from 15 to 30 mg/L.

10.2.3 Geophysical Investigations

Geophysical investigations conducted during FY 2010 to support groundwater investigations consisted of ground-truthing previously collected airborne electromagnetic (AEM) surveys (SGW-47996, *Testing Ground Based Geophysical Techniques to Refine Electromagnetic Surveys North of the 300 Area, Hanford, Washington*) in the 200-PO-1 Groundwater OU and collecting seismic check shot information (SGW-47535, *Measurement of Compressional-Wave Seismic Velocities in 29 Wells at the Hanford Site*) to help refine interpretations of previously collected seismic reflection data in both the 200-BP-5 and 200-PO-1 OUs.

The airborne electromagnetic data were collected as part of the 200-PO-1 RI and were initially interpreted to define potential groundwater migration routes based on a presumed electrical-resistivity/sediment grain-size relationship where more electrically resistive zones correlate with coarser grained and more hydraulically conductive intervals. The FY 2010 surface-based geophysical investigations used electrical-resistivity and electromagnetic techniques to determine subsurface electrical properties along a ~5-kilometer-long profile north of the 300 Area where the airborne electromagnetic data showed potential groundwater migration pathways (Figure 10-15). Results from the ground-based geophysical surveys indicated that the airborne electromagnetic methods are capable of imaging clay and mud units within the Ringold Formation to at least 50 meters bgs, with consistent subsurface spatial distributions developed from both the airborne electromagnetic and ground-based data. The airborne electromagnetic methods, however, proved insensitive to more electrically resistive zones at the Hanford Site and their use restricted to delineating clay/mud-dominated intervals.

Seismic check shot surveys (SGW-47535) were collected in seventeen wells during FY 2010 to refine the interpretations of existing seismic reflection profiles, with specific emphasis on recent seismic profile data collected in the Gable Gap region (SGW-43746, *Landstreamer/Gimbaled Geophone Acquisition of High Resolution Seismic Reflection Data North of the 200 Areas – Hanford Site*). Check shot information provided a direct link between lithology and reflector character and also allowed for interpreting the top of basalt throughout the Gable Gap region. The definition of the top of basalt allowed for improved mapping of likely saturated regions above the basalt surface.

10.3 RCRA Groundwater Monitoring

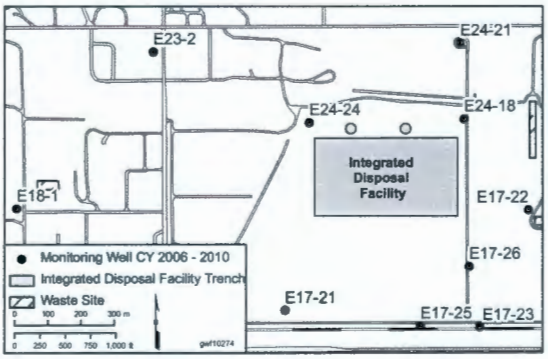
The 200-PO-1 OU contains six RCRA sites with groundwater monitoring requirements: IDF, PUREX Cribs, WMA A-AX, 216-A-29 Ditch, 216-B-3 Pond (B Pond), and NRDWL.

This section describes the results of monitoring at individual regulated units (i.e., treatment, storage, and disposal [TSD] units or tank farms [WMAs]). These facilities are monitored under RCRA requirements for dangerous waste constituents and under the AEA for source, special nuclear, and byproduct materials. Data from facility-specific monitoring are also integrated into the CERCLA groundwater investigations. Dangerous waste constituents and radionuclides are discussed jointly in this section to provide a comprehensive overview of groundwater contamination for each facility. Pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA and are regulated by DOE, acting pursuant to its AEA authority. Therefore, while this report may satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA Permit.

The 200-PO-1 OU contains six RCRA sites with groundwater monitoring requirements: IDF, PUREX Cribs, WMA A-AX, 216-A-29 Ditch, 216-B-3 Pond (B Pond), and NRDWL. The 200-PO-1 OU also includes the SWL (regulated by the Washington State Department of Ecology [Ecology] under WAC 173-350, "Solid Waste Handling Standards"), the TEDF (monitored under WAC 173-216, "State Waste Discharge Permit Program"), and three 400 Area water supply wells (monitored under the AEA). The monitoring results for these three sites are discussed in Section 10.4. This section summarizes the results of statistical comparisons, assessment studies, and other developments for 2010. Groundwater data are available in the Hanford Environmental Information System (HEIS) database. Appendix B provides additional information, including well location and constituent lists, maps, groundwater flow rates, and statistical tables.

10.3.1 Integrated Disposal Facility (Immobilized Low-Activity Waste)

D.C. Weekes



Current groundwater monitoring at the IDF is directed at obtaining background values for monitored constituents.

Construction of the IDF began in September 2004 and was completed in April 2006. The DOE submitted a Part B RCRA Permit application to Ecology, which was incorporated into the Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*) on April 9, 2006. The start date for IDF operations is estimated to be December 2016.

The objective of RCRA and operational monitoring at the IDF will be to determine whether the facility has impacted groundwater quality. The facility is not yet operational, and current monitoring is directed at obtaining baseline values for monitored constituents.

The IDF consists of an expandable, double-lined landfill with ~7 hectares of liner. The facility is located in the south-central portion of the 200 East Area (Figure 10-1). The landfill is divided lengthwise (north-south) into two distinct cells: (1) the east cell for the disposal of low-level radioactive waste, and (2) the west cell for the disposal of mixed waste. The facility is a RCRA-compliant landfill (i.e., a double, high-density, polyethylene-lined trench with leachate collection and leak detection system). The constructed liner is ~442 meters wide, 160 meters long, and up to 15 meters deep. The landfill will have four layers of waste containers, separated vertically by 0.9 meters of soil. The current waste disposal capacity is ~163,000 cubic meters.

The stratigraphy beneath the IDF consists of basalt bedrock overlain by the Ringold Formation, the Hanford formation, and Holocene deposits. The Elephant Mountain Member of the Columbia River Basalt Group forms the base of the suprabasalt aquifer and has no known or suspected erosional windows in the area of the facility. The Ringold Formation is 95 meters thick on the west side of the site and thins eastward. A northwest-southeast trending erosional channel or trough is scoured into the Ringold Formation in the northeast portion of the site. The Hanford formation is up to 116 meters thick beneath the site. Holocene eolian sand deposits cover the southern portion of the site.

The delineations of groundwater flow directions and water table gradients are difficult to calculate for the 200 East Area from water-level data because of a flat

water table. Work began in FY 2008 to better understand the groundwater flow direction beneath the IDF. Gyroscope surveys were completed on four of the monitoring wells and at well 299-E17-21 (wells 299-E17-26 and 299-E24-24 had gyroscope surveys completed in FY 2005). Vertical elevation surveys were performed in 2008 on all seven wells in the IDF water-level network, as well as some of the PUREX Cribs wells. Several sets of water-level measurements were made, and trend-surface analyses were applied to the measurements. The average groundwater flow direction was determined to be east at 80 (±17) degrees, with an average gradient of 2.0×10^{-5} m/m ($\pm 0.2 \times 10^{-5}$ m/m) (see discussion in Chapter 3.0, Section 3.2.2).

Based on the geometry of existing contaminant plumes and on regional water-level measurements, the groundwater flow direction is estimated to be toward the east to southeast at rates between 0.002 and 0.0075 meters per day (see Appendix B, Table B-1). The unconfined aquifer occurs in the fluvial gravels of the Ringold Formation and flood deposits of the Hanford formation.

All wells in the IDF groundwater monitoring network were initially sampled twice per quarter for one year (June 2005 through May 2006) to determine the baseline conditions. This was followed by semiannual sampling events in the remainder of 2006 and 2007 through 2010. Each semiannual sampling event included the collection of four time-independent samples from each well. All seven network wells were sampled as scheduled during 2010. Starting in 2011, sampling will be reduced to annually for each well in the network to maintain the baseline prior to operational status. This change was approved by a Permit modification.

All seven wells of the IDF well network were sampled as scheduled in 2010.

10.3.1.1 Network Evaluation and Compliance Status

The current groundwater monitoring network consists of three upgradient wells (299-E18-1, 299-E24-21, and 299-E24-24) and four downgradient wells (299-E17-22, 299-E17-23, 299-E17-25, and 299-E17-26). Appendix B, Table B-17 lists the network wells, their locations, and the groundwater constituents monitored. Groundwater flow direction has been changing since the network was initially planned and the current network is no longer considered adequate. A revised monitoring network has been provided in a plan that is undergoing Ecology review. All monitoring wells are in compliance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

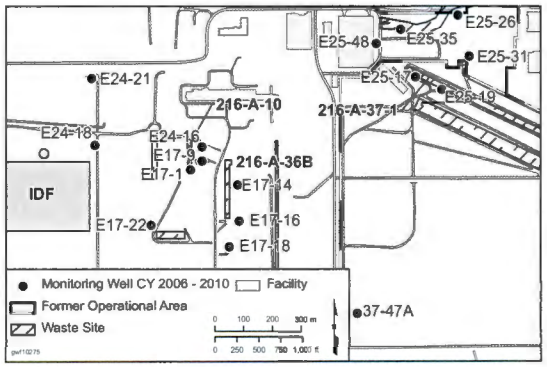
10.3.1.2 Groundwater Contaminants

Nitrate exceeded the DWSs (45 mg/L) during 2010 in wells at the IDF, and the results are comparable to previous years. The maximum nitrate concentration was 68.6 mg/L in well 299-E24-24. This well is in the regional 200 East Area nitrate plume that is presumed to originate from the PUREX Cribs east of the IDF (Section 10.3.2), contamination occurred possibly during an earlier time when groundwater flow direction was flowing radially outward from B Pond.

Nitrate exceeded its DWS in IDF wells during 2010.

10.3.2 216-A-10, 216-A-36B, and 216-A-37-1 (RCRA PUREX) Cribs

The RCRA PUREX Cribs are located in the southeastern portion of the 200 East Area and include the 216-A-10, 216-A-36B, and 216-A-37-1 Cribs (Figure 10-1), which are monitored under RCRA interim status to assess groundwater quality. Other nearby cribs also received PUREX waste (e.g., 216-A-45 Crib); however, these other cribs are not regulated as RCRA TSD units, but are instead monitored under CERCLA through the 200-PO-1 OU.



The objective of RCRA monitoring at the PUREX Cribs is to assess groundwater contaminated with dangerous waste constituents. Appendix B, Table B-28 lists the wells, their locations, and groundwater constituents monitored for the PUREX Cribs. Groundwater monitoring at the PUREX Cribs is conducted as described in the *Interim-Status RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 Cribs* (PNNL-11523). The eleven RCRA wells near the PUREX Cribs (see Appendix B, Figure B-4) monitor contaminant plumes in the near-field area, close to the cribs. More distant portions, or far-field area, of the contaminant plumes are monitored by the 200-PO-1 OU (see Appendix A). Section 10.1 discusses the concentration of major plumes in both the near-field and far-field areas.

The cribs, ponds, and ditches surrounding the PUREX Plant are responsible for most of the groundwater contamination in the 200-PO-1 OU.

The cribs, ponds, and ditches surrounding the PUREX Plant (including the RCRA PUREX Cribs) are responsible for most of the groundwater contamination in the 200-PO-1 OU. The groundwater contamination plumes from the PUREX Plant cribs primarily contain those species associated with PUREX process condensates, including tritium, iodine-129, and nitrate. Some strontium-90 and technetium-99 are also associated with PUREX waste disposal, although technetium-99 is not found above the 900 pCi/L DWS in contaminant plumes from the PUREX Cribs.

Groundwater flow direction near the 216-A-10 and 216-A-36B Cribs (the two cribs to the west) is likely toward the east (see Chapter 3.0, Section 3.2.2). After migrating beneath the two cribs, the flow veers toward the southeast as it leaves the 200 East Area. The gradient is 2.0×10^{-5} based on detailed analysis of the water table surface (Section 3.2.2). The groundwater flow rate is calculated to range between 0.001 and 0.6 meters per day. Near the 216-A-37-1 Crib, groundwater flow is estimated to be toward the southeast. Flow directions are influenced by (1) the northwest-southeast-trending paleo-channel with high permeability Hanford formation sediments cutting across the 200 East Area, (2) the Ringold lower mud unit at the water table east of the 200 East Area, and (3) the higher water table elevations to the west and north. These flow directions are supported mainly by the distribution of the tritium, nitrate, and iodine-129 plumes emanating from near these cribs and recent efforts to refine the water table map in the southeastern portion of the 200 East Area (Section 3.2.2). Appendix B, Table B-1, provides additional information on the flow direction and rate. The RCRA PUREX Cribs are located in a region where several groundwater contaminant plumes contain constituents exceeding DWSs. The similarities in effluent constituents disposed to these cribs, and other PUREX cribs such as the 216-A-45 Crib, make it difficult to determine the contribution of the individual cribs to these plumes.

The primary constituent of interest at the RCRA PUREX Cribs is nitrate.

The primary constituent of interest at the PUREX Cribs is nitrate because it is a breakdown product of nitric acid, which was disposed to the 216-A-10 Crib. Additional groundwater quality constituents required by WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (and by reference, 40 CFR 265.93[d][3] and [d][4]) include chloride, iron, manganese, phenols, sodium, and sulfate.

Sampling is required quarterly for RCRA sites in an interim status groundwater quality assessment program. Therefore, one well at each of the three PUREX Cribs is sampled on a quarterly schedule and the other wells are sampled semiannually (Appendix B provides details on well scheduling and specific analytes for PUREX Cribs groundwater samples). All scheduled groundwater samples were collected from wells at the PUREX Cribs during 2010.

10.3.2.1 Network Evaluation and Compliance Status

The PUREX Cribs well network is capable of meeting the groundwater monitoring objectives to assess the rate and extent of migration of groundwater contamination with dangerous waste constituents and determine their levels in the aquifer. The upgradient and downgradient wells of the near-field network are aligned appropriately, based on the recent determination of groundwater flow direction.

The PUREX Cribs remained in a RCRA interim status groundwater quality assessment program during 2010. However, the 216-A-10 Crib was officially closed March 30, 2010, and was removed from Part A of the Hanford Facility Dangerous Waste Permit. Two cribs, 216-A-36B and 216-A-37-1, will remain in RCRA interim status. Due to the relatively large distance between these two remaining cribs, different monitoring well networks were considered appropriate for these cribs, and two separate groundwater monitoring plans were written. The revised groundwater monitoring plans (DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*; DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*) are designed to bring the groundwater monitoring plans up to date with current protocols and incorporate the data quality objective process. An important update for the two remaining cribs (and the two new groundwater monitoring plans) includes returning the cribs to an indicator parameter evaluation program. The cribs were returned to indicator evaluation programs because groundwater constituents detected were not dangerous wastes or dangerous waste constituents. Groundwater monitoring under the two new plans began January 1, 2011.

The 216-A-10 Crib was officially closed March 30, 2010, and removed from Part A of the Hanford Facility Dangerous Waste Permit.

10.3.2.2 Groundwater Contaminants

The large nitrate plume emanating from the PUREX Cribs extends east and southeast to the Columbia River. Although concentrations remain elevated near the PUREX Cribs, the overall concentrations are decreasing because the plume is dissipating. The movement of nitrate in groundwater is nearly the same as the groundwater itself due to the very low distribution coefficient for nitrate (nearly 0 mL/g) (PNNL-11800; PNNL-14702). In the near-field, the nitrate DWS (45 mg/L) was exceeded at seven monitoring wells during 2010, including upgradient well 299-E24-18 (west of the 216-A-10 Crib). The highest concentrations were 172 and 138 mg/L in well 299-E17-19 (near the 216-A-10 Crib) and 125 and 124 mg/L in well 299-E17-14 (near the 216-A-36B Crib). Section 10.1.3 discusses the nitrate plume in the far-field area of the 200-PO-1 OU.

Nitrate concentrations are decreasing throughout most of the plume but remain elevated near the PUREX Cribs.

Nitrate trends vary depending on location. Near the 216-A-36B Crib (Figure 10-16), the nitrate concentration appears to be stable. At the 216-A-10 Crib, nitrate trends have been generally increasing (Figure 10-17). At the 216-A-37-1 Crib, nitrate has an increasing trend in most wells (Figure 10-18). Figure 10-10 shows the nitrate plume in the southeastern portion of the 200 East Area. Figure 10-9 shows the nitrate concentrations for the entire 200-PO-1 OU.

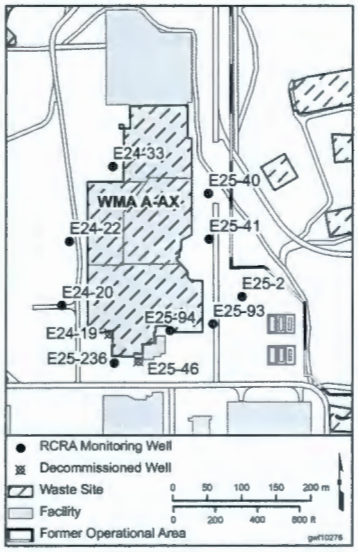
Groundwater quality constituents required by WAC 173-303-400 (i.e., chloride, iron, manganese, phenols, sodium, and sulfate) continue to be lower than their respective DWSs during 2010, except for the anomalously elevated iron and manganese values in wells with carbon-steel casings.

Groundwater quality constituents required by WAC 173-303-400 continue to be lower than their respective DWSs during 2010, except for iron and manganese anomalies in wells with carbon-steel casings.

10.3.3 Waste Management Area A-AX

The WMA A-AX is located on the east-central border of the 200 East Area (Figure 10-1) and consists of the A and AX Tank Farms, the 244-AR vault, and

Since 2006, WMA A-AX has been monitored under a RCRA interim status groundwater quality assessment program.



ancillary equipment (seven diversion boxes and waste transfer lines). The tank farms contain ten 3.79-million-liter tanks constructed from 1954 to 1964, and some of the tanks are suspected to have leaked. Since 2006, WMA A-AX has been monitored under a RCRA interim status groundwater quality assessment program (first determination). Appendix B, Figure B-4 provides a well location map and Table B-29 lists wells and monitored analytes for the WMA.

The WMA A-AX lies within the large northwest-southeast-trending paleochannel incised in the Ringold Formation by cataclysmic Pleistocene flooding and filled with ~11 meters of highly permeable Hanford formation sands and gravels between the remnant Ringold Formation gravel and the water table. Groundwater flow direction in the unconfined aquifer is most likely southeast, based on slightly higher heads to the northeast, the orientation of the paleochannel, and the configuration of the major contaminant plumes. Although the water table gradient is very low (2×10^{-5}) (see Chapter 3.0, Section 3.2.2), the hydraulic conductivity of the Hanford sediments is relatively high, allowing average flow velocities ranging from 0.1 to 0.4 meters per day (see Appendix B, Table B-1).

The current groundwater monitoring plan for WMA A-AX (PNNL-15315, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*) requires the analysis of nitrate, sodium, sulfate, total organic carbon, filtered chromium, and filtered lead in groundwater samples. Technetium-99 is analyzed under that monitoring plan only to help evaluate groundwater contamination sources within WMA A-AX. Appendix B, Table B-19 contains supporting information, including a list of the wells, constituents, and sampling frequencies for this site. In 2010, two of the wells were not sampled as scheduled in December 2010.

10.3.3.1 Network Evaluation and Compliance Status

With the installation of well 299-E25-236 in 2008, the groundwater monitoring well network was considered complete (PNNL-15315). The network currently has three upgradient wells and six downgradient wells and is considered capable of determining whether the facility has contributed dangerous wastes or dangerous waste constituents to groundwater. The locations of the current wells are appropriately oriented with a southeast groundwater flow direction.

An assessment report concluded that WMA A-AX had impacted groundwater quality with dangerous waste or dangerous waste constituents.

The WMA A-AX was placed in assessment monitoring in 2005 due to elevated specific conductance, and a "first determination" groundwater quality assessment plan (40 CFR 265.93[d][5]) was implemented in 2006 (PNNL-15315). The first determination plan continued to be implemented until replacement well 299-E25-236 was installed in 2008, and an additional year of monitoring data were collected and assessed from the completed well network. An assessment report of the findings was issued in August 2010 (SGW-47538, *Groundwater Quality Assessment Report for Waste Management Area A-AX: First Determination*), and it was concluded that the tank farm had impacted groundwater quality with dangerous waste or dangerous waste constituents (nickel). A new plan was written as required by 40 CFR 265.93(d)(7) that will continue the path forward in an interim status groundwater quality assessment program. The new plan, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX* (DOE/RL-2009-70), is under review by Ecology. Until the new plan is approved, groundwater monitoring at WMA A-AX will continue under the current groundwater monitoring plan (PNNL-15315).

Chemical analysis of split-spoon samples from the replacement well demonstrated that vadose sediments there could also corrode stainless-steel casings.

In 2008, when replacement well 299-E25-236 was installed, four split-spoon core samples were collected between the depths of 82 and 85.5 meters and chemically

analyzed (PNNL-SA-18197, *Analytical Data Report for Sediment Samples Collected from Well 299-E25-236 in the 200-PO-1 Operable Unit*). The results indicated that sediments were capable of generating porewater with sufficient chloride concentrations to cause corrosion of the stainless-steel well casing. The equivalent porewater concentrations of chloride ranged from 220 to 233 mg/L, which is higher than the 100 mg/L commonly considered concentrated enough to corrode stainless steel. Because bentonite was not present when well 299-E25-236 was drilled, chemical analysis of the split-spoon samples demonstrated that the vadose zone chemistry of the zone at 82 to 85.5 meters was affected by a Hanford Site waste stream (possibly from WMA A-AX). The stainless-steel casing in well 299-E25-236 is not expected to experience any significant corrosion because the 82- to 85.5-meter zone was sealed with Portland cement rather than bentonite.

10.3.3.2 Groundwater Contaminants

Only nitrate and technetium-99 exceeded their DWSs in WMA A-AX wells during 2010.

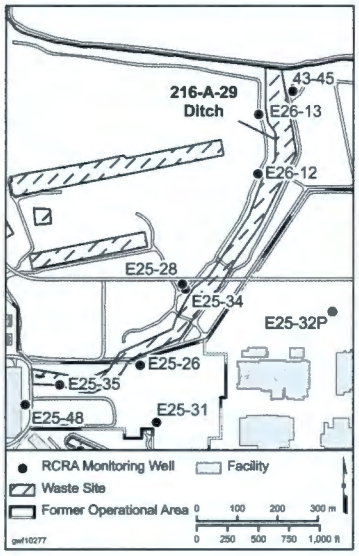
Only nitrate and technetium-99 exceeded DWSs (45 mg/L and 900 pCi/L, respectively) in WMA A-AX wells during 2010. Chromium and lead were detected, but chromium was detected only at very low levels (less than 18 µg/L) in two wells (one upgradient). The detections for lead (in the two wells) were below Hanford Site background levels at the 95th percentile (1.3 µg/L) (DOE/RL-96-61). Sodium and sulfate were detected in all of the WMA A-AX samples and are naturally occurring constituents in Hanford Site groundwater. Detected sodium was at or below background levels. Sulfate concentrations were well above Hanford Site background levels, but upgradient wells had concentrations similar to downgradient wells. Total organic carbon was detected in many of the network wells as isolated spikes. The highest of these spikes was 1,890 µg/L at well 299-E25-94. The cause of these spurious detections is unknown; however, total organic carbon concentrations at well 299-E25-236 increased continually throughout 2010, starting at 578 µg/L in January and ending the year at 2,520 µg/L in December (Figure 10-19). Like the isolated spikes in the other wells, the cause for the rising total organic carbon concentrations in well 299-E25-94 is unknown. Efforts to determine the source of the elevated total organic carbon will continue in 2011.

Most likely there is a nitrate source within WMA A-AX.

Figure 10-10 shows the nitrate concentrations near the WMA A-AX and southeastern 200 East Area. Two wells had nitrate concentrations exceeding the 45 mg/L DWS (Figure 10-20). The average nitrate concentration for well 299-E25-93 for 2010 was 58 mg/L, and the trend is rising. At well 299-E24-20, the average concentration for 2010 was 37 mg/L, although the last result (December 2010) was 45.2 mg/L. Upgradient well 299-E24-20 had a significantly lower average concentration, indicating a nitrate source within WMA A-AX. The trends for upgradient wells 299-E24-20, 299-E24-22, and 299-E24-33 have been relatively stable since 2007, but a slight increase has occurred in all three wells in the previous 2 years.

A technetium-99 source is likely located within WMA A-AX.

As with nitrate, technetium-99 is more concentrated at well 299-E25-93 than any other well in WMA A-AX, suggesting a local source (Figure 10-21). During the reporting period, the technetium-99 DWS (900 pCi/L) was exceeded in two wells (upgradient well 299-E24-33 and downgradient well 299-E25-93). Downgradient well 299-E25-93 had the highest concentrations, ranging from 3,400 to 5,300 pCi/L, with a stable to decreasing trend since 2006 (Figure 10-12). During 2010, upgradient well 299-E24-33 had a concentration range from 1,200 to 1,300 pCi/L. As with nitrate, a likely technetium-99 source is located near well 299-E25-93, but there is also an upgradient source (possibly WMA C).



The 216-A-29 Ditch is monitored as required by WAC 173-303-400 and 40 CFR 265.93(b) for detection of dangerous waste constituents impacting groundwater.

10.3.4 216-A-29 Ditch

C.J. Martin

The 216-A-29 Ditch is located just east of the 200 East Area fence line (Figure 10-1) and is planned for closure. The 216-A-29 Ditch is a regulated unit because it received nonradioactive dangerous waste regulated by 40 CFR 261, "Identification and Listing of Hazardous Waste," after November 19, 1980. The 216-A-29 Ditch is regulated as a surface impoundment, as defined in WAC 173-303-400.

The groundwater beneath the 216-A-29 Ditch is monitored as required by WAC 173-303-400 and 40 CFR 265.93(b) for detection of dangerous waste/dangerous waste constituents impacting groundwater. A revised and updated groundwater monitoring plan for this unit was issued in March 2010 (DOE/RL-2008-58, *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch*). The revised plan removed one older well and replaced it with a different well. The nine wells of the groundwater monitoring network are sampled semiannually for contamination indicator parameters and annually for groundwater quality parameters (i.e., alkalinity, metals, phenols, and anions) and site-specific constituents (DOE/RL-2008-58). Appendix B, Table B-8 lists the network wells, their locations, and the groundwater constituents monitored.

The 216-A-29 Ditch was excavated to convey liquid effluent from the PUREX chemical sewer (low-level contaminants) to the B Pond and was placed in service in November 1955. Flow from the chemical sewer (low-level contaminants) was continuous, with an average flow of ~3,671 liters per minute. The 216-A-29 Ditch received continuous discharge of corrosive waste and potentially hazardous spilled chemical materials from the PUREX Plant. The most significant chemical discharges included acidic and caustic effluents associated with backwashing for the regeneration of demineralizer columns. The ditch also received spills from the PUREX Plant chemical sewer (low-level contamination). A complete, estimated inventory of materials discharged to the 216-A-29 Ditch is provided in the *Groundwater Monitoring Plan for the 216-A-29 Ditch* (WHC-SD-EN-AP-045).

The 216-A-29 Ditch is currently backfilled with material from the ditch sides and spoils piles in the bottom. The portion of the 216-A-29 Ditch inside the 200 East Area security fence was brought to grade with clean material. The portion of the ditch outside of the 200 East Area security fence was topped with clean material in a series of eleven terraces progressing down the length of the ditch. Both areas have been revegetated and appropriately signed (the 216-A-29 Ditch is an underground radioactive material area).

The stratigraphy beneath the 216-A-29 Ditch is similar to that found at the nearby B Pond. However, in the area of the 216-A-29 Ditch, the contact between the Hanford/Cold Creek/Ringold Formation is difficult to identify. For this reason, many descriptions simply call out the lowest sediments as "undifferentiated Hanford/ Ringold Formation."

The uppermost aquifer beneath the 216-A-29 Ditch is unconfined and occurs within undifferentiated Hanford/Ringold Formation. The water table elevation near and beneath the 216-A-29 Ditch is ~122 meters above mean sea level.

Groundwater at 216-A-29 Ditch monitoring wells is sampled and analyzed for the parameters listed in Appendix B, Table B-8. In compliance with WAC 173-303-400(3) (and 40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and

Analysis," as incorporated by reference), the 216-A-29 Ditch network groundwater wells are monitored semiannually for total organic carbon, total organic halides, pH, and specific conductance. Wells are monitored annually for metals (including cadmium), and phenols. Alkalinity, anions, and water levels are also analyzed semiannually. Alkalinity (and metals and anions) is used to calculate a groundwater charge balance, while anions are included to detect potential nitrate contamination and to provide input for charge-balance calculations. During calendar year (CY) 2010, all but three groundwater samples were collected as scheduled. Well 299-E25-26 was not sampled during the year due to a lack of water in the well. Well 299-E25-28 was not sampled in April as scheduled due to pump problems. These issues were resolved during the second half of the calendar year. The April sampling event at well 699-43-45 was missed due to restrictions on access (impassable off-road conditions followed by wildfire/off-road travel closure). As with well 299-E25-28, the access restrictions did not clear until the second half of the year. Also, due to a site-wide sampling work stoppage, the second round of sampling originally scheduled for October did not occur until November and December. With the exception of the wells noted above, all wells were sampled twice during the calendar year as required.

10.3.4.1 Network Evaluation and Compliance Status

Historically, well 699-43-45 has served as an upgradient well for the 216-A-29 Ditch. With the apparent shift in groundwater flow direction from the southwest to the southeast continuing, this well is no longer upgradient of the unit. Wells 299-E26-12 and 299-E26-13, which have always been included in the network, will be the new upgradient wells starting in CY 2011.

Wells 299-E25-26, 299-E25-35, and 299-E25-48 are located south of the 216-A-29 Ditch and are downgradient of the inlet end of the ditch. Well 699-43-45 now monitors the distal end of the ditch, while well 299-E25-32P monitors downgradient of the middle of the ditch.

Well 299-E25-34 was removed from the network because it is now upgradient of the central portion of the ditch and is no longer needed.

The present network is capable of the detection of potential releases from the 216-A-29 Ditch throughout CY 2011.

The nine groundwater monitoring wells that currently comprise the 216-A-29 Ditch monitoring network are shown in Appendix B, Figure B-4. All but two of the groundwater monitoring wells (299-E25-26 and 299-E25-28) were constructed to meet the resource protection well standards of WAC 173-160.

The water table gradient at the 216-A-29 Ditch is estimated to be similar to that at the PUREX Cribs and IDF at 2 x 10^{-5} (see Chapter 3.0, Section 3.2.2) with a southeastern flow direction interpreted from plume maps. Based on the interpretation of a southeasterly flow direction, the current network was capable of the detection of potential releases from the 216-A-29 Ditch throughout CY 2010 and will continue to meet the needs of monitoring this unit throughout CY 2011. In accordance with requirements, the network will be re-evaluated annually, although it is not believed that any significant changes will be needed in 2011.

No dangerous waste subject to WAC 173-303 has been found to date at the 216-A-29 Ditch. Therefore, the site will remain under detection monitoring for indicator parameters.

To date, no dangerous waste subject to WAC 173-303 from the 216-A-29 Ditch has contaminated groundwater. Therefore, the site remains in an interim status indicator evaluation program, as specified in 40 CFR 265.92(b).

10.3.4.2 Groundwater Contaminants

As required under WAC 173-303-400 and RCRA (40 CFR 295.93[b]) for interim status facility indicator parameter monitoring, the required indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) are

statistically compared between upgradient and downgradient wells using the most recent data. Statistical evaluation of the first indicator evaluation monitoring results in January 1990 indicated that the specific conductivity (field) value in downgradient well 299-E25-35 was statistically greater than the background levels. Resampling later verified this measurement, and the required groundwater quality assessment plan was prepared and initiated for the 216-A-29 Ditch (WHC-SD-EN-AP-031, *Interim-Status Groundwater Quality Assessment Plan for the 216-A-29 Ditch*). The groundwater network was expanded to include new well installations and additional existing monitoring wells.

The results of the final groundwater assessment report (WHC-SD-EN-EV-032, *Results of Groundwater Quality Assessment Program at the 216-A-29 Ditch RCRA Facility*) issued in 1995 identified increased sulfate, sodium, and calcium as the cause of elevated specific conductivity in well 299-E25-35. Because these constituents are not regulated as dangerous wastes, it was concluded that groundwater had not been adversely impacted by discharges to the 216-A-29 Ditch. Subject to these findings, the 216-A-29 Ditch reverted to indicator parameter monitoring in 1994 under the *Groundwater Monitoring Plan for the 216-A-29 Ditch* (PNNL-13047).

Specific conductance continued to remain above the critical mean in downgradient wells at the 216-A-29 Ditch during CY 2010.

Specific conductance continued to remain above the critical mean in downgradient wells 299-E25-35 and 299-E25-48 and upgradient well 299-E26-13 during both semiannual sampling events. The continued trend of increasing specific conductance coincides with similar increases in sulfate, nitrate, and chloride in these wells. An example of the increases is provided for well 299-E25-32P in Figure 10-22. Wells 299-E25-28 (deep completion) and 299-E25-34 appear to be least affected by these trends. Well 299-E25-32P also exceeded the specific conductance critical mean for the first time (Figure 10-23). This was expected, as these constituents have been steadily increasing in this well.

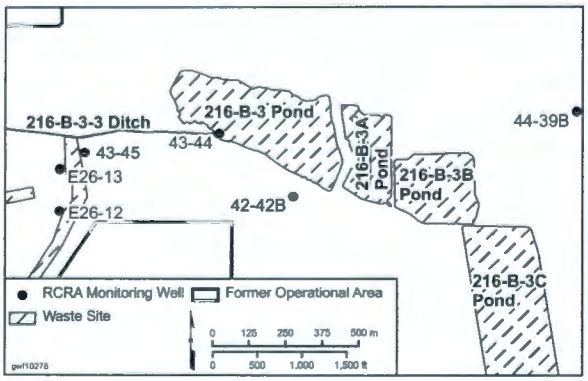
None of the increasing constituents exceed their respective DWSs. The remaining three contamination indicator parameters (i.e., pH, total organic carbon, and total organic halides) were below critical means for all wells in the 216-A-29 Ditch network during CY 2010. Appendix B, Table B-9 lists the critical mean values to be used for CY 2011 comparisons.

10.3.5 216-B-3 Pond

C.J. Martin

The B Pond is regulated as a surface impoundment, as defined in WAC 173-303-400.

The 216-B-3 Pond (B Pond) is an inactive, nonoperational TSD unit that will undergo closure. The B Pond is regulated as a surface impoundment, as defined in WAC 173-303-400. The original B Pond system included the main pond and three expansion ponds (Figure 10-1). The three expansion ponds have been subsequently clean closed, however, leaving the main pond and an adjacent portion of the 216-B-3-3 Ditch to be regulated under WAC 173-303-400.



The B Pond is located in a natural topographic depression that is diked on the eastern margin and covers ~14.2 hectares. The B Pond began receiving effluent in 1945 at the site of the main pond (initially referred to as the B-3 Pond). Discharges to B Pond were terminated in 1994.

The 216-B-3-1, 216-B-3-2, 216-B-3-3, and 216-A-29 Ditches were used to convey effluent from the production facilities in the 200 East Area to the main pond, where the water then evaporated

and infiltrated into the ground. These ditches were decommissioned and stabilized (backfilled) over the lifetime of the pond, mostly as a result of unplanned releases of dangerous waste (DOE/RL-89-28, *216-B-3 Expansion Ponds Closure Plan*). Details of the operation of these ponds and ditches are presented in the *B Plant Source Aggregate Area Management Study Report* (DOE/RL-92-05).

Discharge volumes to the B Pond averaged around 1.0×10^{10} liters per year, except for a short period in the mid-1980s. From 1986 to 1991, more than 6.4×10^{10} liters per year were discharge to the B-3 Pond, with a maximum discharge in 1988 of over 1.0×10^{11} liters. Total discharge to the facility since 1945 is estimated to have exceeded 1.0×10^{12} liters.

Beginning in April 1994, discharges to the main pond and 3A expansion pond ceased, and all effluents were re-routed to the 3C expansion pond via a pipeline. The main pond and 216-B-3-3 Ditch were then filled with clean soil as part of interim stabilization activities. Just before the effluent was diverted from the main pond, the 3A, 3B, and 3C expansion ponds were clean closed under RCRA. This determination indicates that no identifiable waste remains in the closed facilities; thus, only the main pond and an adjoining part of the 216-B-3-3 Ditch require groundwater monitoring under RCRA requirements.

In June 1995, portions of the effluent stream were re-routed to the permitted TEDF. The remaining streams were diverted from the 3C expansion pond to the TEDF by August 1997, ending all routine operation of the B Pond system. The 3C expansion pond is still maintained as an overflow contingency facility for the TEDF. Historic effluent feeds are described in greater detail in DOE/RL-92-05 and the *Groundwater Impact Assessment Report for the 216-B-3 Pond System* (WHC-EP-0813).

As discussed in Chapter 2.0, the lowermost stratigraphic unit beneath the B Pond is the subdivided lower portion of the Ringold Formation. In the area of the B Pond, only units 8 and 9 (including the lower mud unit) are present. The Ringold lower mud unit (unit 8) is not present in the northwestern portion of the B Pond, but it is up to 24 meters thick near the southern extreme of the 3C expansion pond and is generally thicker south and southeast of the main pond. This unit is particularly important to effluent infiltration and groundwater flow patterns near B Pond (see Chapter 3.0).

The lowermost confined aquifer in the B Pond/TEDF area appears to have been mostly isolated from a significant part of the B Pond effluent discharges and likely all of the TEDF discharges. The effluent was/is mostly intercepted by the intervening Ringold lower mud unit (unit 8) and diverted predominantly south along the upper surface of this fine-grained unit. Where the Ringold lower mud unit dips below the water table, the effluent entered the more permeable Hanford formation south and west of the main pond. This interpretation is supported by the fact that no hydrologic response to TEDF discharges has thus far been observed in the TEDF wells (completed in unit 9) since the facility began operation in 1995. Wells in this region, including those near the southern extreme of the 216-B-3C Pond, have shown only a general decline in head since installation in the early 1990s, with only a brief period of stasis in 1995 prior to TEDF operation.

Some B Pond effluent apparently entered unit 9 where the overlying Ringold lower mud unit has been removed by erosion. Groundwater sampling data indicate that the contamination associated with this effluent apparently did not migrate very far to the east and south, even though there was a hydraulic gradient in these directions due to groundwater mounding beneath the B Pond. Hydrostratigraphic research presented in PNNL-12261 indicates that a stratigraphic "trap" could exist near the south and

southeast extremities of the facility (e.g., south of the TEDF and 216-B-3C Pond) that may have prevented any appreciable groundwater movement in this direction. In addition, it is postulated that the north-south trending May Junction Fault (located to the east of the B Pond area, or the low-permeability Ringold Formation sediments just west of the fault, may represent a barrier to groundwater flow in unit 9, preventing any appreciable flow to the east. Within unit 9 in the area of B Pond, groundwater currently flows to the west-southwest and discharges to the unconfined aquifer along the erosional boundary of the confining units. Flow within unit 9 confined by the Ringold Formation lower mud unit is to the west with a gradient of 1.4×10^{-3}.

West of B Pond and within the unconfined aquifer, groundwater flow is to the southeast, with an estimated regional gradient of $\sim 2 \times 10^{-5}$ m/m (see Chapter 3.0, Section 3.2.2).

The groundwater in B Pond monitoring wells is sampled and analyzed for the parameters listed in Appendix B, Table B-10. In compliance with WAC 173-303-400(3) (and 40 CFR 265.92, as incorporated by reference), a revised and updated monitoring plan was issued in September 2010 (DOE/RL-2008-29). The B Pond network groundwater wells are monitored semiannually for interim status facility indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides). Wells are monitored annually for metals and phenols. Additional groundwater quality parameters (i.e., alkalinity, dissolved oxygen, temperature, and turbidity) are measured as indicators of sample quality and general aquifer/well environmental conditions. During CY 2010, all but one well had groundwater samples collected as scheduled. As noted above in the 216-A-29 Ditch discussion, the April sampling event at well 699-43-45 was missed due to restrictions on access (impassable off-road conditions followed by wildfire off-road travel closure). The access restrictions did not clear until the second half of the year. The site-wide sampling stop work delayed collection of the second semiannual sample at well 699-43-45 from November to December.

10.3.5.1 Network Evaluation and Compliance Status

Appendix B, Figure B-5 shows the locations of the four wells (699-44-39B, 699-42-42B, 699-43-44, and 699-43-45) in the groundwater monitoring well network for the B Pond system. The network consists of one upgradient well (699-44-39B) and three downgradient wells (699-43-45, 699-43-44, and 699-42-42B). None of these wells are anticipated to go dry within the foreseeable future.

The current network wells and hydraulic gradient configuration continue to allow for determination of groundwater flow directions and allow the specified upgradient/ downgradient comparisons to be made.

No dangerous waste subject to WAC 173-303 has been found to date from the B Pond. Therefore, the site will remain under detection monitoring for indicator parameters.

Using the water table map for the 200 East Area and the measured head differences between network wells, the direction of groundwater flow in the confined aquifer at B Pond is estimated to be southwesterly. The water table gradient at B Pond is estimated at 1.21×10^{-3}. Applying an average hydraulic conductivity of 1.0 meter per day and an estimated effective porosity of 0.25 yields an estimated groundwater flow velocity of 0.0048 meter per day (see Appendix B, Table B-1).

As noted above during CY 2010, all but one of the groundwater samples were collected as scheduled. To date, no groundwater contamination or dangerous waste subject to the requirements of WAC 173-303 beneath the B Pond site can be conclusively linked to past practices at the site. Therefore, the site remains under indicator parameter evaluation monitoring as specified in 40 CFR 265.92(b).

A revised monitoring plan (DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*) was completed and issued in September 2010.

10.3.5.2 Groundwater Contaminants

As required by RCRA regulations for interim status facility indicator parameter monitoring, the indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) are statistically compared between upgradient and downgradient wells using the most recent data. All but one of the wells were sampled as required during the reporting period.

During 2010, none of the indicator parameters exceeded their critical means at the B Pond facility.

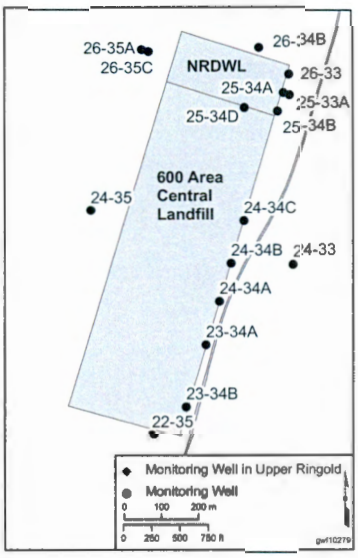
The B Pond has been monitored under interim status since 1988. Total organic carbon and total organic halides exceeded the critical means in two wells in 1990. Results of the groundwater quality assessment concluded that no dangerous constituents were present in the groundwater. The B Pond was returned to indicator evaluation monitoring in 1996 and continues in an indicator evaluation program.

Constituents continue to show stable trends. The major anions show a gradual increasing trend, but concentrations are an order of magnitude below DWSs.

During CY 2010, critical mean values for the indicator parameters were not exceeded in any of the downgradient wells. During the reporting period, no detected constituents were outside of historical ranges and were well below their respective DWSs.

10.3.6 Nonradioactive Dangerous Waste Landfill

The NRDWL is located southeast of the 200 East Area (Figure 10-2) next to the SWL. The objective of RCRA monitoring at the NRDWL is to determine if dangerous waste constituents from the landfill have contaminated groundwater (40 CFR 265.93[b], as referenced by WAC 173-303-400), through an interim status indicator evaluation monitoring program.



Groundwater at NRDWL is monitored under an interim status indicator evaluation monitoring program.

The NRDWL is underlain by ~40 meters of vadose zone composed mostly of sand, silty-sandy gravel, and gravel of the Hanford formation. The uppermost aquifer below the water table consists of ~9 meters of additional Hanford formation, 8 meters of the Cold Creek unit (a pre-Missoula gravel deposit), and 6 meters of undifferentiated Ringold Formation sandy gravel. Below the 6 meters of Ringold Formation sandy gravel is a low-permeability unit composed of silt and silty sand that forms the base of the unconfined aquifer locally. Two of the wells in the NRDWL network (one upgradient and the other downgradient) reach the top of this low permeability unit to sample groundwater from the lower portion of the local unconfined aquifer. Groundwater flow direction is southeast, as determined from the general direction of movement of major contaminant plumes originating in the 200 East Area.

The main groundwater constituents of interest at the NRDWL are the RCRA interim status indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides), and the groundwater quality parameters (i.e., chloride, iron, manganese, phenols, sodium, and sulfate) (see Appendix B, Table B-26 and PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*). The site-specific constituents nitrate and VOCs are also monitored. Groundwater quality parameters are monitored annually, and the indicator parameters and site-specific COCs are monitored semiannually. All wells were sampled as scheduled except for well 699-25-34A.

The main groundwater constituents of interest at the NRDWL are the RCRA interim status indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides).

10.3.6.1 Network Evaluation and Compliance Status

The NRDWL well monitoring network consists of nine wells (see Appendix B, Figure B-14), with two of the wells screened at the bottom of the unconfined aquifer, just above the low-permeability unit. The two deeper wells are monitored for information only and not used for upgradient/downgradient comparisons. Of the seven wells screened at the water table, two wells are upgradient (west and northwest) and five are downgradient (north, east, and south). The wells are located appropriately to accomplish the objectives of the interim status groundwater indicator parameter evaluation program.

Critical means for pH and specific conductance continued to be exceeded in NRDWL wells during 2010 but did not require verification sampling or regulator notification.

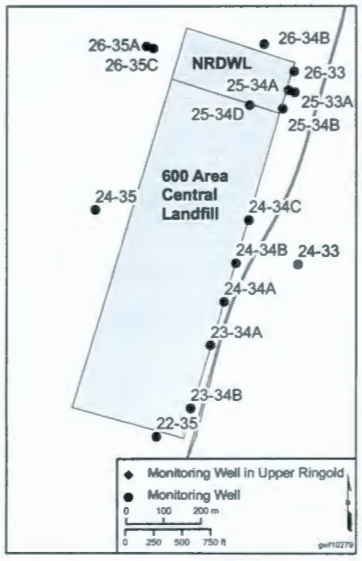
During 2010, a new combination RCRA groundwater monitoring plan was written for the NRDWL and the SWL (DOE/RL-2010-28, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*). Because the two landfills are adjacent to one another, combining the ultimate remedial action for the two landfills was considered a reasonable option to maximize available resources. In the new plan, NRDWL groundwater monitoring will move into RCRA final status under WAC 173-303-645, "Releases from Regulated Units." The plan is under review by Ecology. Until the plan is approved, NRDWL will continue to be monitored under the current groundwater monitoring plan (PNNL-12227).

10.3.6.2 Groundwater Contaminants

Critical means of two of the four indicator parameters (7.72 for pH and 593 µS/cm for specific conductance) were exceeded in NRDWL wells during 2010 but did not require verification sampling or regulator notification. The pH exceedances (7.85 to 7.91) were in the two deep wells screened at the base of the local unconfined aquifer, and these wells are not used for upgradient/downgradient comparisons. Specific conductance results that exceeded the 593 µS/cm critical mean were in wells 699-25-34A and 699-25-34B and ranged as high as 602 µS/cm in well 699-25-34A and 601 µS/cm in well 699-25-34B. Specific conductance exceedances occurred previously at NRDWL and were determined to be caused by nonhazardous groundwater constituents likely from the nearby SWL (DOE/RL-2008-01).

Compliance at the SWL is determined by comparing results from downgradient wells with statistically derived background threshold values from upgradient wells.

The VOCs, manganese, and phenols were not detected at NRDWL wells during 2010. Chloride, iron, sodium, and sulfate were detected at levels consistent with Hanford Site background values (i.e., less than the 95th percentile) (DOE/RL-96-61). The highest nitrate result was 21 mg/L, which is consistent with the large nitrate plume emanating from the 200 East Area (Figure 10-9).



10.4 Other Regulated Facilities

This section presents the results for non-RCRA facilities that require groundwater monitoring.

10.4.1 Solid Waste Landfill

The SWL is located south of the NRDWL (Figure 10-2). The landfill is regulated by Ecology in accordance with WAC 173-350. However, the groundwater monitoring plan (PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*) was written to accommodate the requirements WAC 173-304 ("Minimum Functional Standards for Solid Waste Handling"), which are similar to WAC 173-350 ("Solid Waste Handling Standards"). WAC 173-350 superseded WAC 173-304. WAC 173-304 constituents and site-specific constituents (including VOCs and filtered arsenic) are analyzed in groundwater samples collected quarterly. Compliance

is determined by comparing results from downgradient monitoring wells with statistically derived background threshold values from upgradient wells.

The groundwater flow direction is southeast, as inferred from the general direction of movement of major 200 East Area plumes. Hydrogeology is similar to that at the NRDWL (Section 10.3.6). The well network for the SWL includes two upgradient wells and seven downgradient wells. Appendix B, Table B-42 lists the network wells, their locations, and the groundwater constituents monitored. During 2010, the January, April, and July sampling events occurred as scheduled, but the October sampling event was delayed until December 2010 due to a work stoppage. In addition, three of the nine network wells (699-22-35, 699-24-34B, and 699-24-35) were not sampled in December 2010.

10.4.1.1 Leachate and Soil Vapor Monitoring

A leachate collection system (lysimeter) underlying one set of double trenches within the SWL is sampled quarterly and has detected contamination from the landfill in previous years. The leachate is analyzed for ammonia, metals, anions, total organic carbon, total organic halides, total dissolved solids, and VOCs. Most of the inorganic analytes were detected, but the VOCs were generally not detected. Most of the constituents detected in the leachate during 2010 were also analyzed in groundwater samples from the SWL well network. However, nine of these constituents were not analyzed in groundwater samples: boron, silicon, aluminum, lead, molybdenum, tin, uranium, thorium, and thallium.

The eighteen soil vapor monitoring stations at the SWL are monitored quarterly for methane, carbon dioxide, methylene chloride, 1,1-dichloroethane, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, 1,1,2-trichloroethane, tetrachloroethene, and ammonia. During 2010, only methane, carbon dioxide, 1,1,2-trichloroethane, and ammonia were detected in soil vapor samples. The methane results ranged from zero to 38 parts per million (ppm). Carbon dioxide ranged from 714 to 10,400 ppm (the typical concentration in air ~387 ppm; concentrations above 1%, or 10,000 ppm, are lethal). Two stations had detections of 1,1,2-trichloroethane (SWL-4 and SWL-6) in the January 2010 sampling event, ranging from 1.58 to 2.57 ppm. Ammonia ranged from zero to 159 ppm and was detected only in the September 2010 sampling event. Concentrations of ammonia, methane, and carbon dioxide at levels greater than normally found in air have possibly resulted from degradation of sewage discharged at the SWL. One of the known VOCs disposed at the SWL is 1,1,2-trichloroethane, which came to the site as catch tank liquid from the 1100 Area heavy equipment garage and bus shop.

10.4.1.2 Groundwater Monitoring Results

Each WAC 173-304 parameter is discussed separately below. A complete list of the results for required constituents at the SWL during 2010 and the background threshold values for 2011 are provided in Appendix B, Table B-44. The increased amount of detail in the discussions of individual groundwater constituents (compared to other sections of this report) is provided to meet the annual reporting requirements of the groundwater monitoring plan (PNNL-13024). Only the filtered results for the metals are presented because WAC 173-304 specifies that the groundwater samples be analyzed for the dissolved metals.

Ammonium. Results for ammonium ion (background threshold value 90 µg/L) in SWL wells during the reporting period ranged from less than the method detection limit (3.09 µg/L) to 51.3 µg/L (July 2010) in well 699-24-33. Ammonium ion was detected in the upgradient and downgradient wells. Detections of this groundwater

constituent have been sporadic in previous years at the SWL and continued during the reporting period.

Chemical oxygen demand remained below the background threshold value of 10 mg/L at all SWL wells during 2010.

Chemical Oxygen Demand. Chemical oxygen demand remained below the background threshold value of 10 mg/L at all SWL wells during 2010. Historically, chemical oxygen demand values are sporadic at the SWL. Elevated values of this parameter could be an indication of groundwater contaminated by sewage, which is known to have been discharged to the SWL trenches.

Chloride. Chloride ranged from 5.9 mg/L at downgradient well 699-23-34B to 7.5 mg/L at upgradient well 699-26-35A. The background threshold value of 7.8 mg/L was not exceeded during 2010. Chloride slightly increased in concentration in most SWL wells until about 2005 and has stabilized thereafter.

Coliform Bacteria. The background threshold value (of one colony per 100 milliliters of groundwater) was exceeded at one SWL well (699-24-34A) during 2010 with a concentration of 3.1 colonies per 100 milliliters. As with chemical oxygen demand, elevated levels of coliform bacteria have been detected sporadically at the SWL in previous years. Elevated levels of this constituent are expected with the known disposal of sewage at the SWL.

Filtered Iron. None of the filtered iron results exceeded the 160 µg/L background threshold value during 2010. The reported values ranged from less than 18 to 149 µg/L. Elevated filtered iron results have been reported above the background threshold value occasionally at SWL wells in recent years but are not typical of overall historical trends.

Filtered Manganese. Filtered manganese was not detected above the method detection level of 4 µg/L in SWL wells during 2010. The background threshold value was 18 µg/L.

Nitrate. The SWL is located on the western edge of the major nitrate plume emanating from the 200 East Area (Figure 10-9). Downgradient wells have levels of nitrate similar to the upgradient wells. During 2010, the highest level of nitrate at the SWL was 20.1 mg/L at downgradient well 699-23-34A, which was significantly lower than the 29 mg/L background threshold value.

Nitrite. There were no detections of nitrite at SWL wells during 2010. The background threshold value was 266 µg/L, and the analytical laboratory's required detection limit was 118 µg/L.

pH. Two wells at the SWL during 2010 had pH levels lower than the background threshold range (6.68 to 7.84): wells 699-23-34A and 699-23-34B. The lowest pH value reported was 6.63 at well 699-23-34A. The pH trends are relatively steady at the SWL wells.

Specific conductance values at all seven downgradient wells exceeded the 583 µS/cm background threshold value during 2010.

Specific Conductance. Specific conductance values at all seven downgradient wells exceeded the 583 µS/cm background threshold value during 2010. Specific conductance values at the two upgradient wells did not exceed the background threshold value. Five of the seven downgradient wells also had specific conductance values greater than the 700 µS/cm limit of WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)." The highest reported value during 2010 was 812 µS/cm at downgradient well 699-22-35. Specific conductance values at the SWL have remained relatively stable since 2001. Elevated specific conductance may be caused by increased concentrations of sulfate and other anions in groundwater at the SWL.

Sulfate. The results for sulfate reported ranged from 40.0 mg/L at upgradient well 699-26-35A to 49.2 mg/L at downgradient well 699-23-34A. Only well 699-23-34A had results exceeding the 47.2 mg/L background threshold value. The overall trend for sulfate concentrations at the SWL is stable to slightly increasing.

Temperature. Temperatures recorded at two of the downgradient wells exceeded the 20.7°C background threshold value during 2010. They were 22.6°C at well 699-24-34B and 20.8°C at well 699-24-34C. These were at two adjacent wells during July, and none of the other wells exceeded the limit. These exceedances appear to be anomalous and are not consistent with historical trends at these wells.

Total Organic Carbon. None of the SWL wells had total organic carbon results during 2010 that exceeded the 1,200 µg/L background threshold value. In previous years, elevated total organic carbon results have occurred occasionally. As with chemical oxygen demand and coliform bacteria, elevated total organic carbon could be due to the degradation of the sewage disposed at the site.

Filtered Zinc. During 2010, filtered zinc ranged from less than 4 µg/L (the analytical method detection limit) to a maximum of 9.2 µg/L at downgradient well 699-24-33. None of the SWL wells had filtered zinc values exceeding the 42.3 µg/L background threshold value.

Site-Specific Parameters. Disposed waste at the SWL has impacted groundwater with minor chlorinated hydrocarbon contamination. However, the concentrations of chlorinated hydrocarbons at the SWL have decreased over the years, and for the first time since groundwater monitoring began at the SWL, chlorinated hydrocarbons were not detected.

Most of the constituents detected in the leachate were also detected in groundwater but had results lower than the primary DWSs (or secondary DWSs, if appropriate) or the limits specified in WAC 173-200-40 ("Water Quality Standards for Ground Waters of the State of Washington," "Criteria"), except for arsenic and iron. Cobalt, copper, and manganese were not detected. The DWS for arsenic is 10 µg/L, but the WAC 173-200-40 limit is 0.05 µg/L. The results for filtered and non-filtered arsenic ranged from 1.1 to 3.4 µg/L, all exceeding the WAC 173-200-40 limit. However, results from downgradient wells were not significantly different than the results from upgradient wells. Although none of the filtered iron results exceeded the 300 µg/L DWS, this limit was exceeded in unfiltered samples from downgradient wells (699-24-34B and 699-24-33). Well 699-24-34B had the highest result at 786 µg/L.

Most of the constituents detected in the leachate of the SWL lysimeter were also detected in groundwater but at levels lower than the regulatory limits.

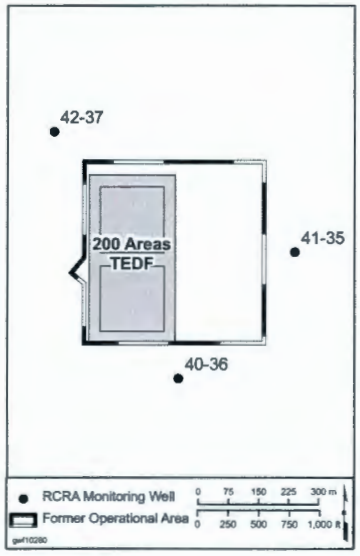
10.4.1.3 Compliance Status

During 2010, the SWL continued to be regulated by Ecology in accordance with WAC 173-304. Several background threshold values were exceeded, and their exceedances were reported.

A new RCRA groundwater monitoring plan was written in 2010, combining groundwater monitoring with that of the NRDWL (DOE/RL-2010-28). Because the two landfills are adjacent to one another, combining the ultimate remedial action for the two landfills was considered a reasonable option to maximize available resources. At the SWL, closure and post-closure groundwater monitoring is subject to WAC 173-350-500 ("Ground Water Monitoring"); however, compliance with groundwater monitoring requirements for the SWL will be achieved through deferral under WAC 173-350-710(8) ("Permit Application and Issuance") to equal or greater requirements within WAC 173-303-645. Some downgradient wells at the SWL continue to show higher coliform bacteria, specific conductance, sulfate, and lower

A new groundwater monitoring plan was written in 2010, combining groundwater monitoring at the SWL with that of the NRDWL.

pH. In previous years, some of the SWL wells also showed higher chemical oxygen demand. The lower pH is apparently a result of elevated levels of carbon dioxide in the vadose zone resulting from the degradation of sewage material disposed to the SWL (DOE/RL-93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993,* Section 5.3; PNL-7147, *Final Report: Soil Gas Survey at the Solid Waste Landfill*; WHC-SD-EN-TI-199, *Nonradioactive Dangerous Waste Landfill Soil Gas Survey: Final Data Report*). The coliform bacteria and specific conductance also may be related to sewage disposed at the SWL. Soil vapor analysis shows elevated levels of carbon dioxide, methane, and ammonia.



Groundwater monitoring results are used to demonstrate continued isolation of TEDF discharges from the locally confined aquifer below the Ringold Formation lower mud unit.

10.4.2 200 Area Treated Effluent Disposal Facility

The 200 Area TEDF is monitored under a Washington State waste discharge permit (WAC 173-216; PNNL-13032, *Groundwater Monitoring Plan for the Hanford Site 200 Areas Treated Effluent Disposal Facility*). The facility is located southeast of the B Pond RCRA facility (Figure 10-1) and has received effluent since June 1995. Three wells monitor the site on the northwest, east, and southeast.

Prior to startup of the TEDF, there was no continuous unconfined aquifer above the Ringold lower mud unit (unit 8) at that location. Therefore, the three groundwater monitoring wells installed at the facility were installed in the locally confined aquifer below the Ringold lower mud unit and are isolated from the effects of the effluent from the disposal facility by the relatively impermeable silts and clays of the lower mud unit (PNNL-14098, *Results of Groundwater Monitoring at the Hanford Site 200 Area Treated Effluent Disposal Site – FY-1999 through FY-2002*; PNNL-15479, *Groundwater Monitoring for the Hanford Site 216-B-3 Pond RCRA Facility*). When the wells were installed, a minor amount of perched water was encountered above the Ringold lower mud unit, and recent discharges to the ground at the facility have likely increased the amount of perched water. The quarterly analytical results from the three wells are used to demonstrate continued isolation of the locally confined aquifer below the Ringold lower mud unit from TEDF discharges.

Based on hydraulic head measurements during 2010 (i.e., gradient 5.3×10^{-4}) and estimates of effective porosity (0.25) and hydraulic conductivity (1.1 meters per day [PNNL-13032]), the groundwater flow in the confined aquifer beneath the TEDF is directed southwest at 213 degrees azimuth, at 2.0×10^{-3} meters per day. Historically, major ionic composition and extremely low tritium concentrations have indicated that groundwater in the Ringold Formation confined aquifer beneath this facility is isolated from the perched groundwater above the lower mud unit. The water quality (determined from wells screened below the lower mud unit) is largely unaffected by discharges from the TEDF. Hydraulic head continues to decline in the TEDF wells as a result of the dissipating pressure effect of historical discharges at the nearby B Pond facility.

The three monitoring wells at the TEDF are monitored quarterly for three constituents with enforcement limits (i.e., pH, cadmium, and lead) that are required by *State Waste Discharge Permit ST 4502* (Ecology, 2000b), as well as the indicator parameters specific conductance, gross alpha and beta, anions, metals, total dissolved solids, trace metals, and tritium.

10.4.2.1 Network Evaluation

The three wells of the TEDF meet the requirements of the State Waste Discharge Permit (Ecology, 2000b) and WAC 173-160. The three wells (699-40-36, 699-41-35, and 699-42-37) were in existence when the current revision of the State Waste Discharge Permit (ST 4502) was issued and are specifically mentioned as the wells

to be monitored. Results from the three wells continue to demonstrate isolation of the wastewater discharges from the locally confined aquifer below the Ringold lower mud unit.

10.4.2.2 Groundwater Contaminants

The groundwater monitoring results for three constituents (cadmium, lead, and pH) from the two downgradient wells are compared with specific enforcement limits (5 µg/L for cadmium, 10 µg/L for lead, and pH ranging from 6.5 to 8.5) set by the State Waste Discharge Permit. During 2010, all groundwater samples were collected as scheduled, and none of the enforcement limits were exceeded. Most concentrations for anions, metals, and radionuclide indicators have been below Hanford Site groundwater background levels (e.g., WHC-EP-0595, *Westinghouse Hanford Company Operational Groundwater Status Report, 1990-1992*; DOE/RL-96-61) since monitoring began at the site.

During 2010, all groundwater samples were collected as scheduled at the TEDF, and none of the enforcement limits were exceeded.

10.4.2.3 Compliance Status

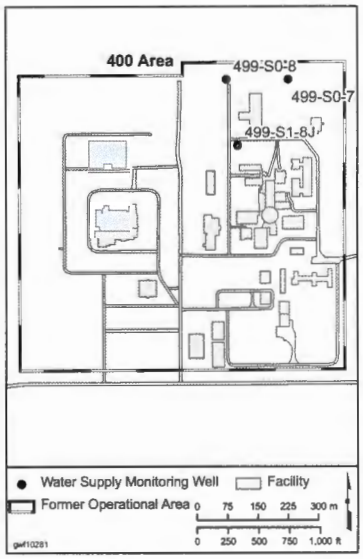
Groundwater monitoring results continue to demonstrate isolation of the wastewater discharges from the locally confined aquifer below the Ringold lower mud unit. Therefore, groundwater monitoring at the TEDF will continue under the State Waste Discharge Permit in accordance with WAC 173-216.

10.4.3 400 Area Water Supply Wells

Groundwater monitoring is conducted to determine if Hanford Site-wide groundwater contamination plumes are impacting groundwater pumped by the water supply wells.

Primary groundwater monitoring activities in the 400 Area involve monitoring of the area's three water supply wells in accordance with the AEA. Monitoring is conducted to provide information on the potential impact of site-wide contamination (primarily tritium, nitrate, and iodine-129) on the water supply wells, which provide drinking water and emergency supply water for the 400 Area (PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*, Section 8.6). This section discusses monitoring of the 400 Area water supply wells (specifically tritium) and the general aspects of groundwater chemistry in the 400 Area.

Each of the three 400 Area water supply wells (499-S1-8J, 499-S0-7, and 499-S0-8) have a pumping capacity of 757 liters per minute. The wells provide water to a common header that supplies storage tanks. The 400 Area water usage ranges from 757 liters per minute in the summer months to 95 liters per minute in the winter months. Table 10-2 provides the characteristics of the well screens for the three water supply wells. Well 499-S1-8J is the main water supply well, but occasionally wells 499-S0-7 and 499-S0-8 are used for water supply. During the first 6 months of 2010, water supply came from well 499-S0-8 and during the remainder of the year came from well 499-S1-8J.



Since 2009, the water supply wells have been on an annual sampling schedule for the 200-PO-1 OU. They were sampled twice during 2010 for AEA (July and November 2010) as well as other times during the year for the Washington State Department of Health and Decision Unit Risk Assessment Program. The samples were analyzed for VOCs, ammonium ion, metals, anions, gamma scan, gross alpha and beta, iodine-129, strontium-90, technetium-99, tritium, and uranium.

The Hanford Site water table map (Figure 10-3) indicates that flow in the unconfined aquifer is generally to the east-southeast across the 400 Area. The water table is located near the contact of the Ringold Formation and overlying Hanford formation and is ~49 meters bgs (WHC-EP-0587, *Groundwater Impact Assessment Report for the 400 Area Ponds*). Hanford formation sediments dominate groundwater

flow in the 400 Area due to their relatively high permeability compared to the sediments in the underlying Ringold Formation.

Elevated levels of tritium associated with the groundwater plume originating in the 200 East Area (as compared with Hanford Site background value of 119 pCi/L at the 95th percentile) were identified in the 400 Area wells (Figure 10-4). Well 499-S1-8J has lower tritium levels because it is screened at a greater depth (top of screen 61 meters below the water table) than the other two water supply wells (19 and 9 meters, respectively). Figure 10-24 compares the tritium concentrations in the three wells to that of the 400 Area drinking water supply. Tritium was measured at levels below the DWS (20,000 pCi/L) in all three water supply wells during the reporting period. The maximum tritium concentration in well 499-S1-8J during 2010 was 1,900 pCi/L. Tritium remained below the DWS and the 4 mrem/year dose equivalent in the drinking water supply (sampled at a tap) for all of the sampling events during 2010 (Figure 10-24). The reason for the anomalous tritium results from tap water samples in late 2009 and 2010 is unknown, but it may be due to higher than expected levels of tritium in well 499-S0-8. A composite sample from well 499-S0-8 during 2010 (four separate dates) had a tritium concentration of 5,560 pCi/L (red "X" in Figure 10-24). Subsequently, tap water sampling results have returned to their historical trend below 2,000 pCi/L.

None of the groundwater constituents detected in the 400 Area water supply wells were above DWSs, except possibly for aluminum.

Although many groundwater constituents were detected in samples collected during 2010, none of the constituents were above DWSs, except for aluminum (and even aluminum results were detected at values less than the contract-required detection limit but greater than the method detection limit). The highest aluminum result was 88 µg/L in well 499-S0-7. Other constituents detected included bromodichloromethane, bromoform, bromomethane, carbon disulfide, chloroform, chloromethane, cobalt, copper, dibromochloromethane, diethylphthalate, gross alpha, gross beta, iodomethane, lead, molybdenum, thallium, and tritium. All of these constituents, except for gross beta and tritium, were found in very low concentrations; most were either outliers or detected in such low concentrations as to be lower than the laboratory's contract-required detection limit. The gross beta results ranged up to 9.7 pCi/L in well 499-S0-8, which is typical for these wells.

10.5 Conclusions and Recommendations

The conclusions and recommendations for the 200-PO-1 OU are presented below.

10.5.1 Conclusions

The focus of 200-PO-1 OU CERCLA groundwater monitoring during the reporting period was to complete the RI report (DOE/RL-2009-85, Draft A) and continue monitoring the wells in the routine groundwater monitoring plan (DOE/RL-2003-04).

A conclusion of the RI was that the nature and extent of groundwater contamination was similar to earlier monitoring results.

The RI report concluded that the nature and extent of contamination was similar to earlier monitoring results and of the current routine monitoring plan (discussed below). However, the VOCs formerly detected at the SWL and NRDWL were assumed to continue to be detected based on the last 5 years of monitoring data, but in 2010 the VOCs were no longer detected. Based on the information provided in the modeling and the results of the baseline risk assessment, the RI report concluded that it is appropriate to proceed with the FS for the 200-PO-1 Groundwater OU.

Groundwater monitoring results continue to show tritium, iodine-129, and nitrate as the major plumes extending from the 200 East Area into the remainder of the 200-PO-1 OU, and also that small, more isolated plumes (including strontium-90

and uranium) are located near the PUREX Cribs and technetium-99 at WMA A-AX. All of these groundwater contaminants continue to exceed their respective DWSs, but only tritium exceeded its DWS in wells near the Columbia River.

For the sites within the 200-PO-1 OU that are monitored under RCRA, the *Washington Administrative Code*, or Washington State waste discharge permits, some of the sites will continue their current monitoring efforts, but other sites will undergo changes. Because waste has not been disposed at the IDF, monitoring at the facility will continue focusing on establishing baseline water conditions for the monitored constituents.

Monitoring at two of the PUREX Cribs (216-A-36B and 216-A-37-1) reverted to an interim status indicator evaluation program, while the 216-A-10 Crib is no longer monitored under RCRA. A new groundwater monitoring plan was written for each of the two cribs where RCRA monitoring continues.

The WMA A-AX will continue under interim status groundwater assessment monitoring program. However, the groundwater monitoring plan was changed from "first determination" to a full groundwater quality assessment plan to reflect the conclusion that the WMA has contaminated groundwater with nickel (a dangerous waste constituent). The new plan for WMA A-AX (DOE/RL-2009-70) was issued in 2010 and is undergoing review by Ecology.

The 216-A-29 Ditch and 216-B-3 Pond (both RCRA TSD units) were monitored under interim status indicator parameter evaluation programs during the reporting period. Significant increases were not detected in indicator parameters at downgradient wells, so it is concluded that these units are not contributing to groundwater contamination.

The RCRA groundwater monitoring at the NRDWL continued in an indicator parameter evaluation program.

Groundwater monitoring efforts at the SWL and the TEDF did not detect any significant changes in monitoring results compared to previous years. Monitoring will continue under the current *Washington Administrative Code* regulations.

During 2010, a new RCRA groundwater monitoring plan was written for the combination of the NRDWL and the SWL (DOE/RL-2010-28). Because the two landfills are adjacent to one another, combining the ultimate remedial action for the two landfills was considered a reasonable option to maximize available resources. In the new plan, NRDWL groundwater monitoring will move into RCRA final status under WAC 173-303-645. At the SWL, closure and post-closure groundwater monitoring is subject to WAC 173-350-500; however, compliance with groundwater monitoring requirements for the SWL will be achieved through deferral under WAC 173-350-710(8) ("Permit Application and Issuance") to equal or greater requirements within WAC 173-303-645. The new combination plan was written to meet WAC 173-350-500 requirements for the SWL and WAC 173-303-645 requirements for NRDWL.

Groundwater monitoring at the three water supply wells in the 400 Area continues to show that tritium levels remain well below the 20,000 pCi/L DWSs; thus, the monitoring plan will not change.

10.5.2 Recommendations

Only one recommendation is made for the 200-PO-1 OU for this reporting period. Efforts should continue to refine the water table map in the eastern and southeastern portions of 200 East Area and at the NRDWL/SWL area by decreasing the amount

Efforts should continue to refine the water table map in the eastern and southeastern portions of the 200 East Area and at the NRDWL/SWL area.

of measurement error in determining water table elevations at the wells. The water table gradient in these areas is so low that errors in measuring the depth to water can be larger than the differences in water table elevations between wells.

During FY 2008 and the reporting period, wells at IDF and PUREX Cribs were resurveyed to a known datum and measured for deviation from vertical. Trend-surface analyses were conducted to separate local from regional variability and to determine any regional trends on the water table surface. Although the FY 2008 results were not definitive, continued work during 2009 and 2010 produced some significant results (see Chapter 3.0). It is recommended that this work, which was previously performed only at the IDF and PUREX Cribs, be extended to the north at WMA A-AX and the 216-A-29 Ditch and southeast toward the NRDWL and SWL facilities to more precisely define groundwater flow direction in these areas.

Table 10-1. Summary of Groundwater Conditions in 200-PO-1 Operable Unit Exceeding Standards and Basis for Feasibility Study

Exposure Area	Final COPC	Groundwater Standard[a]	Current Exceedance[b]	Year Maximum Projected Concentration Achieves Groundwater Standard
Near field	Iodine-129	1 pCi/L	Yes	2709
Near field	Technetium-99	900 pCi/L	Yes	2034
Near field	Strontium-90	8 pCi/L	No	2034
Near field	Tritium	20,000 pCi/L	Yes	2059
Near field	Trichloroethene	0.49 µg/L	Yes	2059
Near field	Nitrate	45,000 µg/L/ 25,600 µg/L	Yes	2309/ 2509
Near field	Uranium	30 µg/L	No	2209
Far field	Iodine-129	1 pCi/L	Yes	2709
Far field	Tritium	20,000 pCi/L	Yes	2084
Far field	Carbon tetrachloride	0.34 µg/L	Yes	2034
Far field	Tetrachloroethene	0.081 µg/L	Yes	2059[c]
Far field	Trichloroethene	0.49 µg/L	Yes	2059[d]
Far field	Nitrate	45,000 µg/L/ 25,600 µg/L	Yes	2309/ 2509
River	Tritium	20,000 pCi/L	Yes	2084
River	Nitrate	45,000 µg/L/ 25,600 µg/L	Yes	2309/ 2509

a. Standard exceeded; MCL established by the *Safe Drinking Water Act of 1974*. Groundwater cleanup standard in accordance with WAC 173-340-720.

b. Current exceedance:

Yes = Calculated groundwater exposure point concentration currently exceeds the applicable standard(s). The exposure point concentration is the 90th percentile value for each COPC calculated from the current groundwater data set.

No = Calculated groundwater exposure point concentration does not currently exceed the MCL; WAC 173-340-708 risk threshold of 1×10^{-5} for multiple hazardous substances or the upper National Contingency Plan threshold of 1×10^{-4}, or a noncancer hazard index of 1.

c. Represents the year that the 1×10^{-6} risk level is achieved.

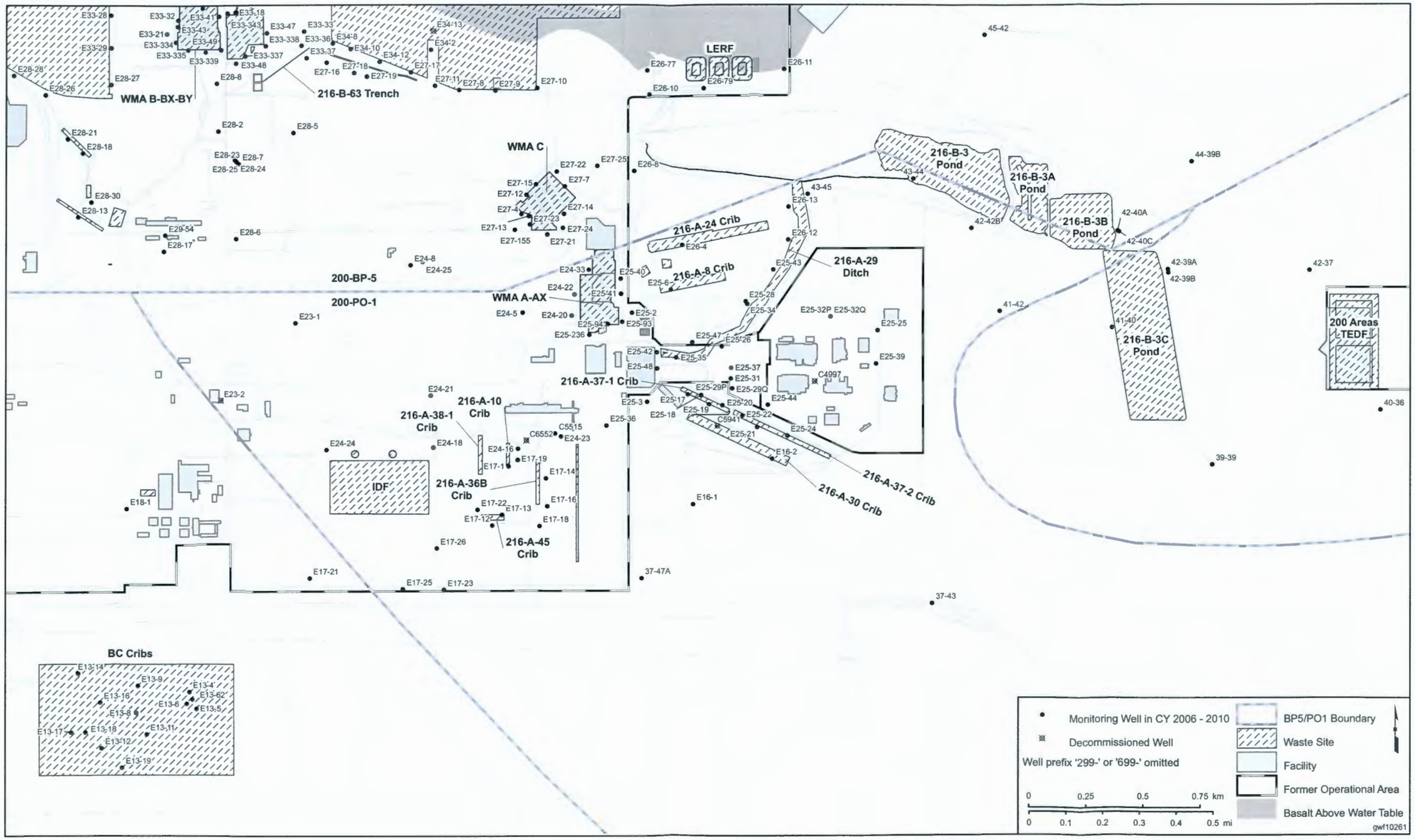
d. Represents the year that the MCL of 5 µg/L is achieved.

Table 10-2. Well Screen Characteristics of the Three 400 Area Water Supply Wells

Well	Elevation Top of Screen (m)	Elevation Bottom of Screen (m)	Water Table to Screen Distance (m)
499-S1-8J	57	48	61
499-S0-7	100	46	19
499-S0-8	110	81	9

Notes: Depth to water in all three wells approximately 49 meters. Water table elevation approximately 118 meters.

Figure 10-1. Facilities and Wells in 200 East Area (Near-Field)



This page intentionally left blank.

Figure 10-2. Map of 200-PO-1 Operable Unit Boundaries, Far-Field Wells, Shoreline Monitoring Sites, and Transects

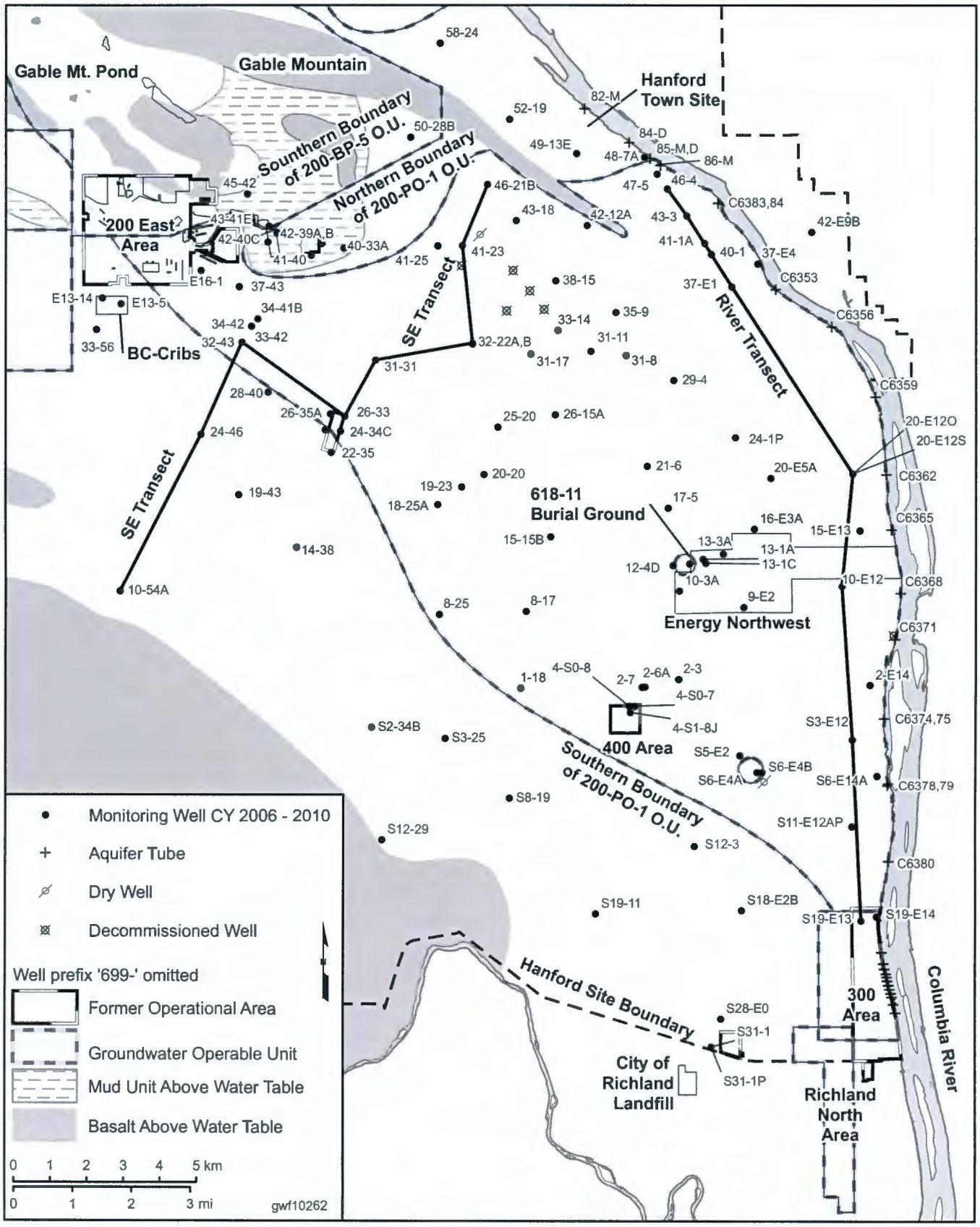


Figure 10-3. Water Table Map for the 200-PO-1 Operable Unit, March 2010

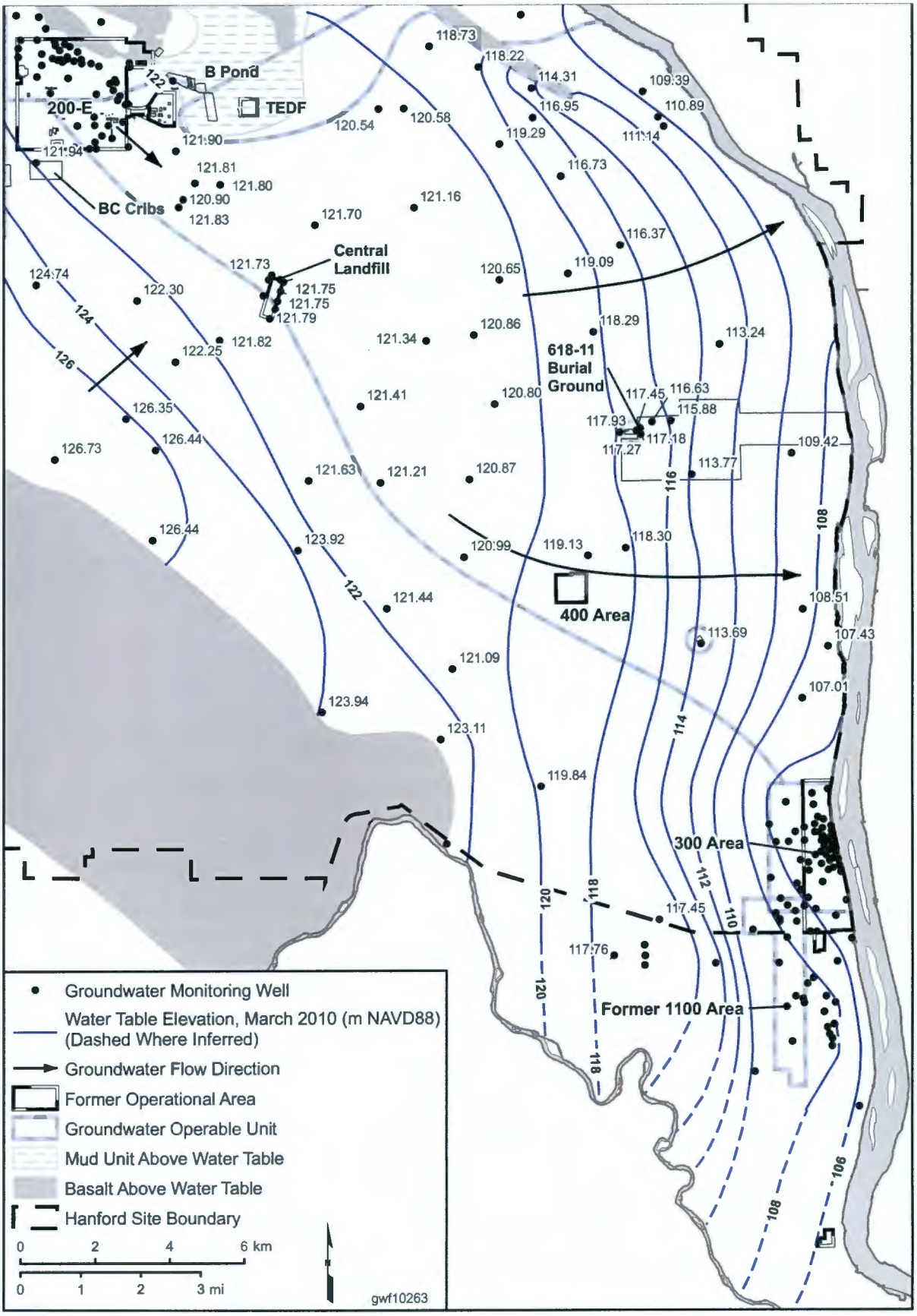
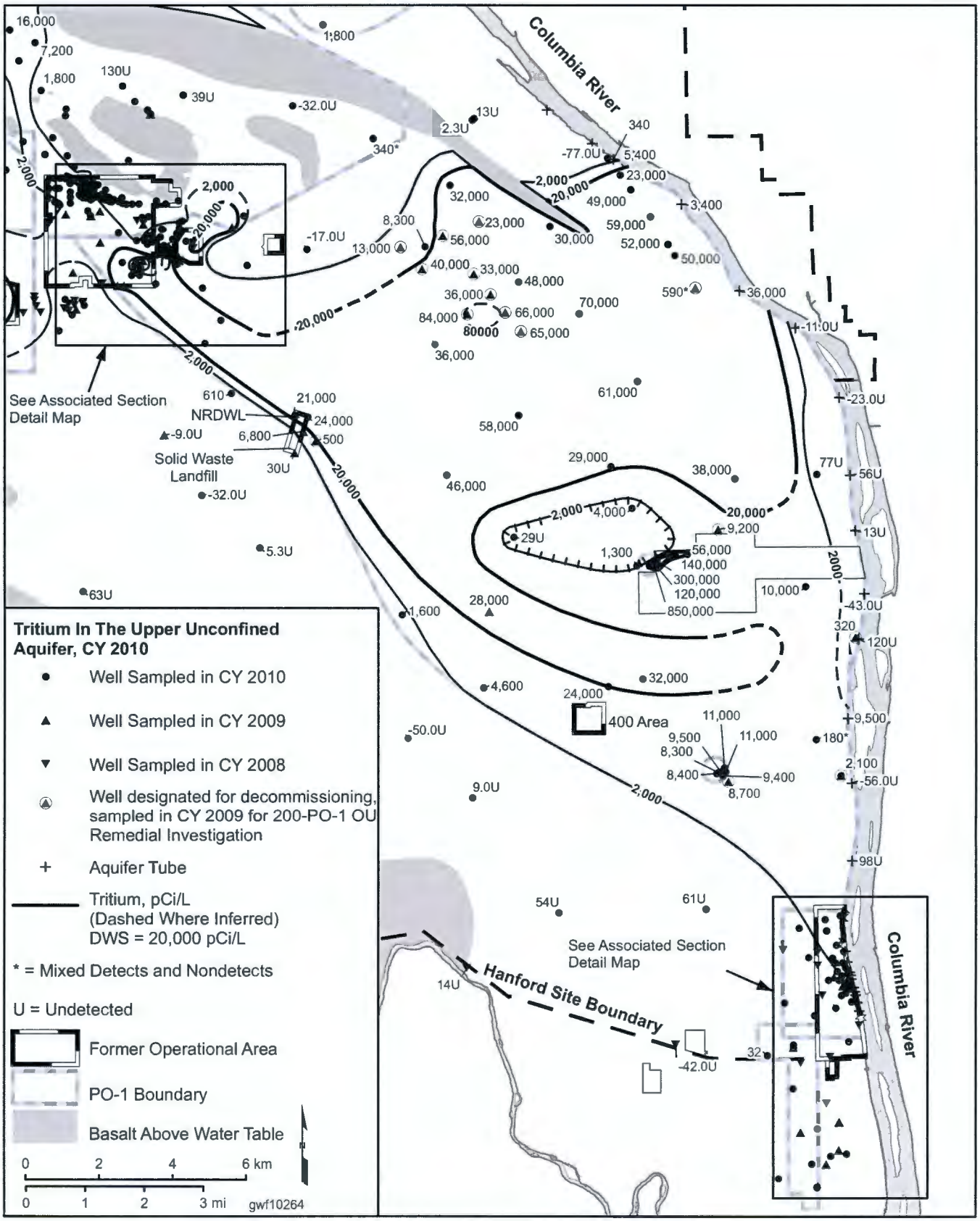
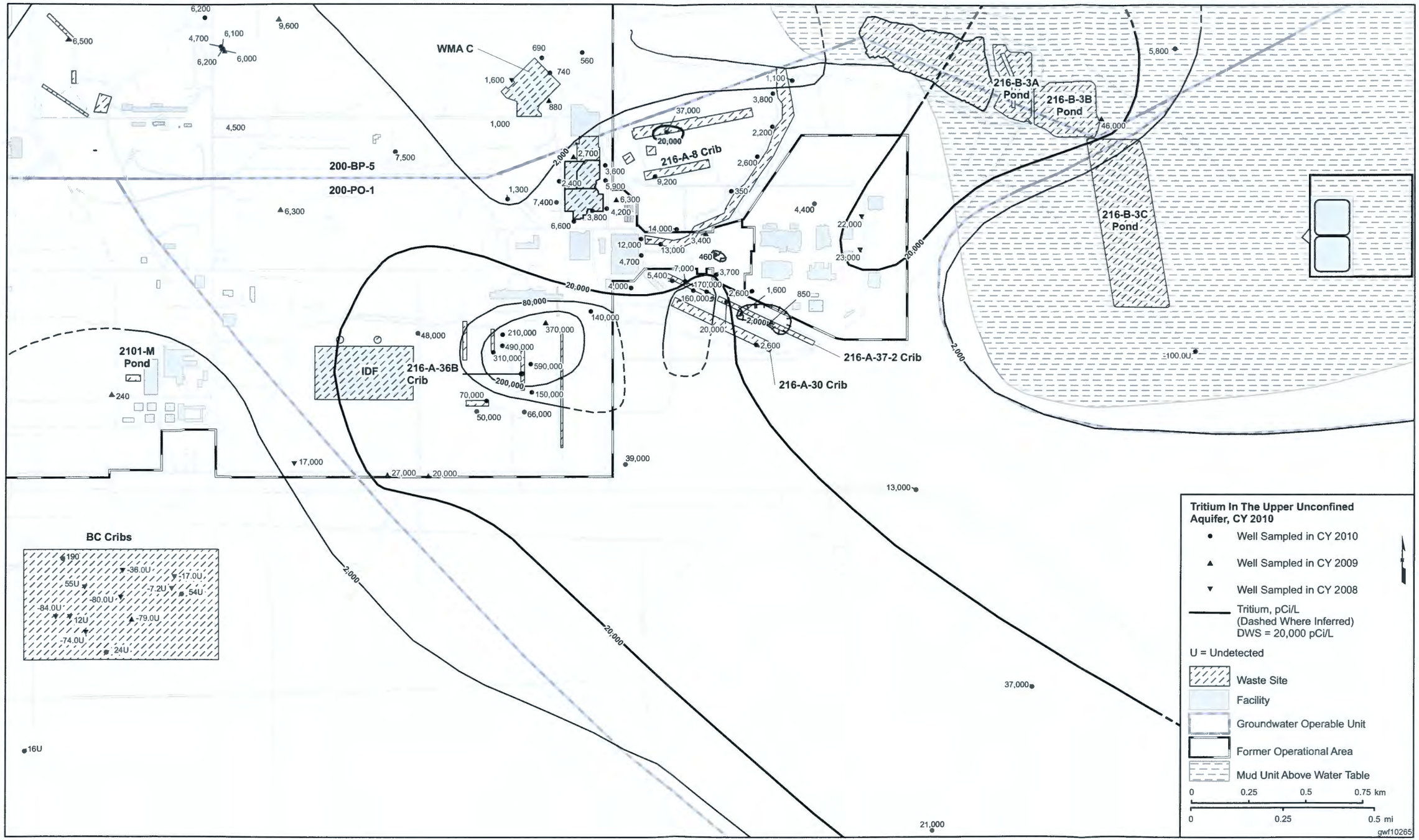


Figure 10-4. Tritium Plume Map for 200-PO-1 Operable Unit



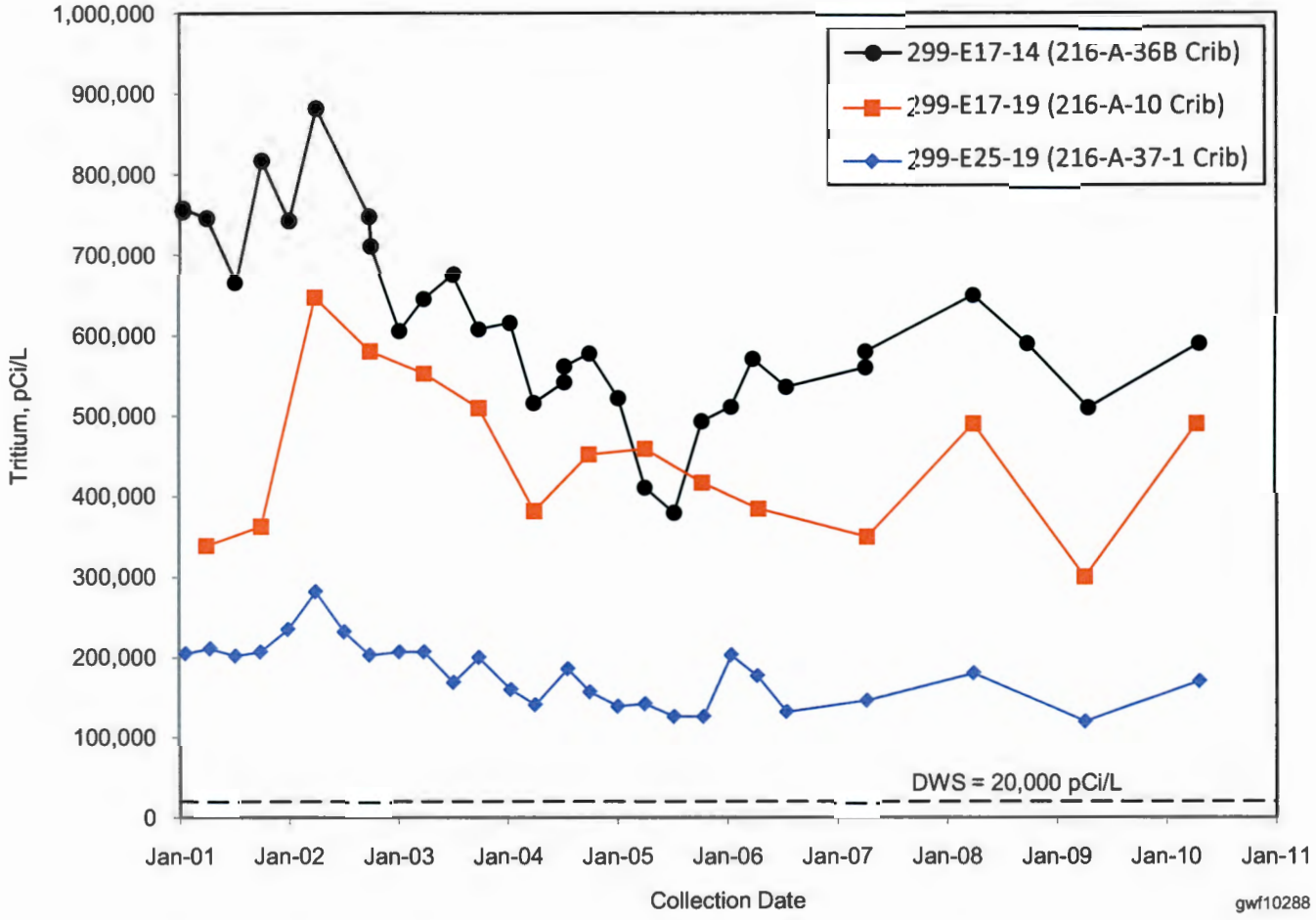
This page intentionally left blank.

Figure 10-5. Tritium Plume Map (Near-Field)



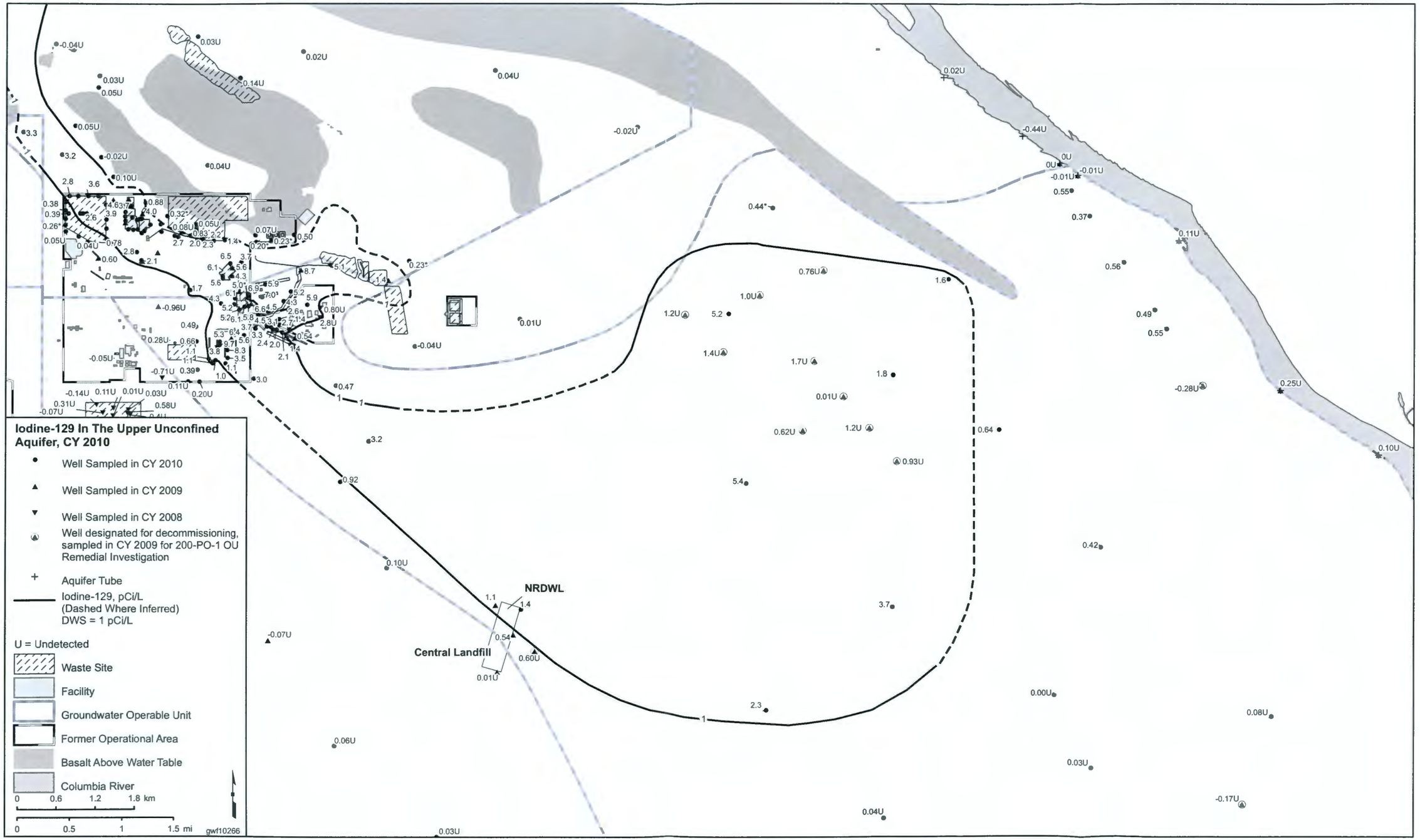
This page intentionally left blank.

Figure 10-6. Tritium Concentrations in PUREX Cribs



This page intentionally left blank.

Figure 10-7. Iodine-129 Plume Map for 200-PO-1 Operable Unit



This page intentionally left blank.

Figure 10-8. Iodine-129 Concentration in Well 299-E17-19 at the 216-A-10 Crib

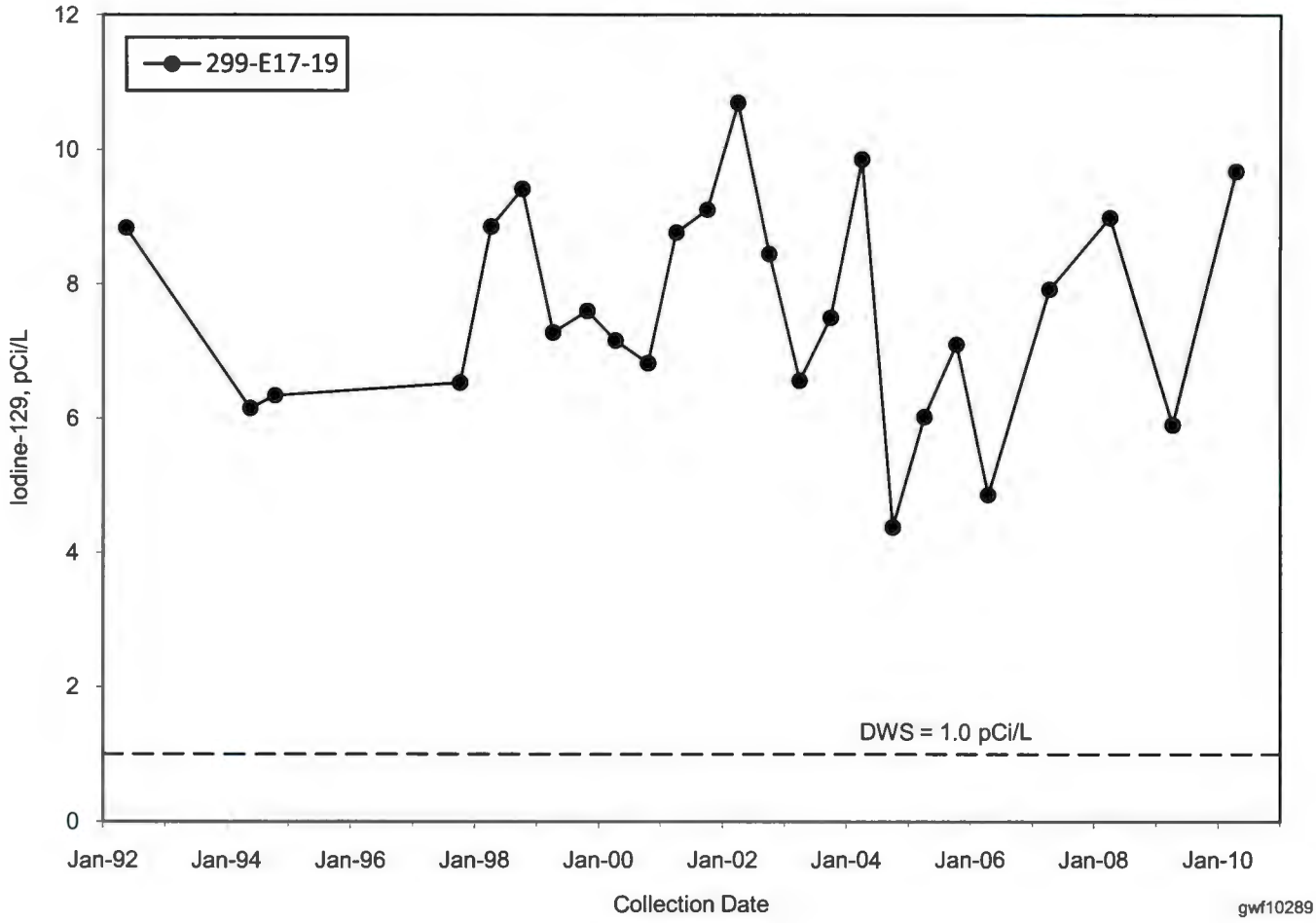


Figure 10-9. Nitrate Plume Map—200-PO-1 Operable Unit (Far-Field)

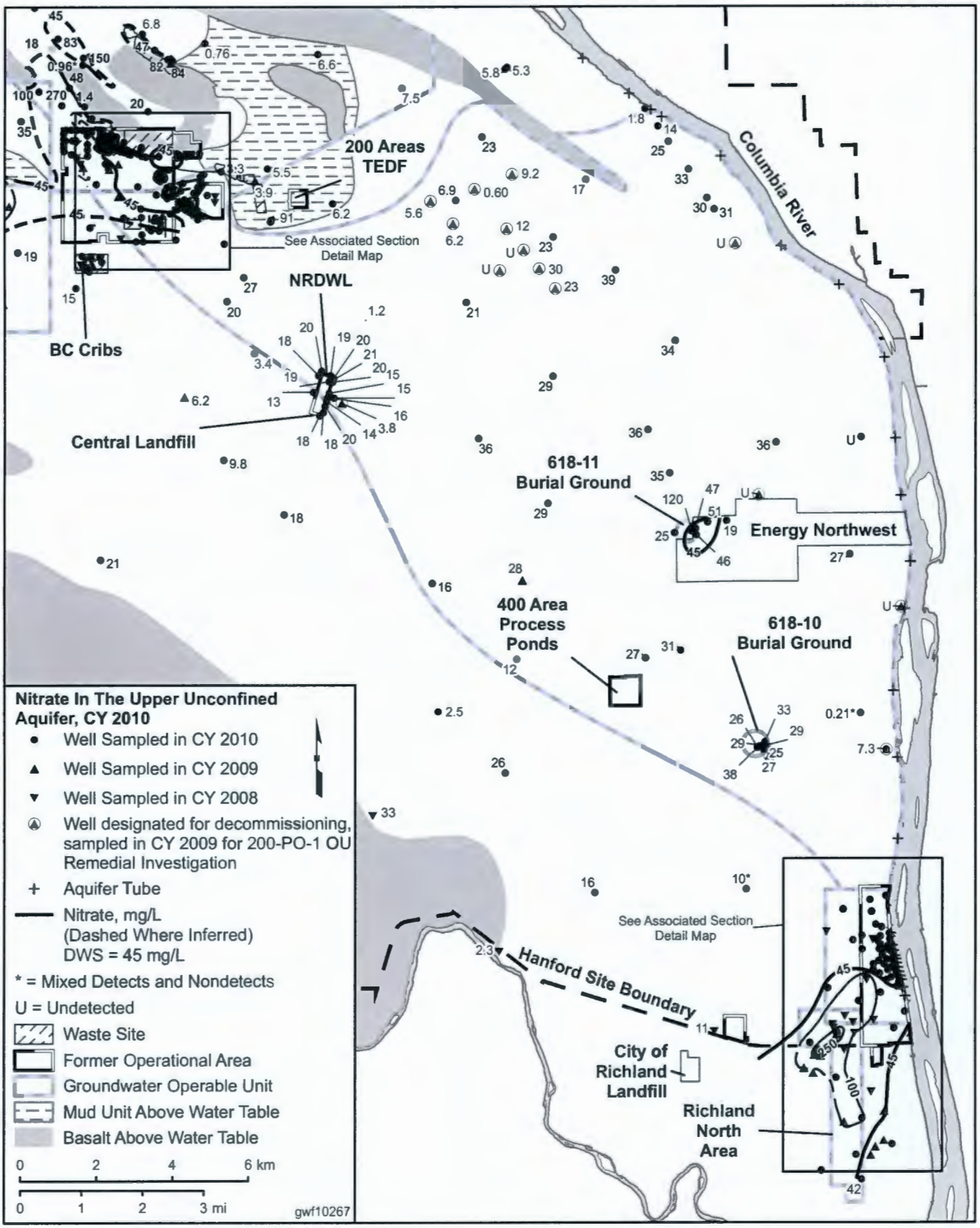


Figure 10-10. Nitrate Plume Map — 200 East Area (Near-Field)

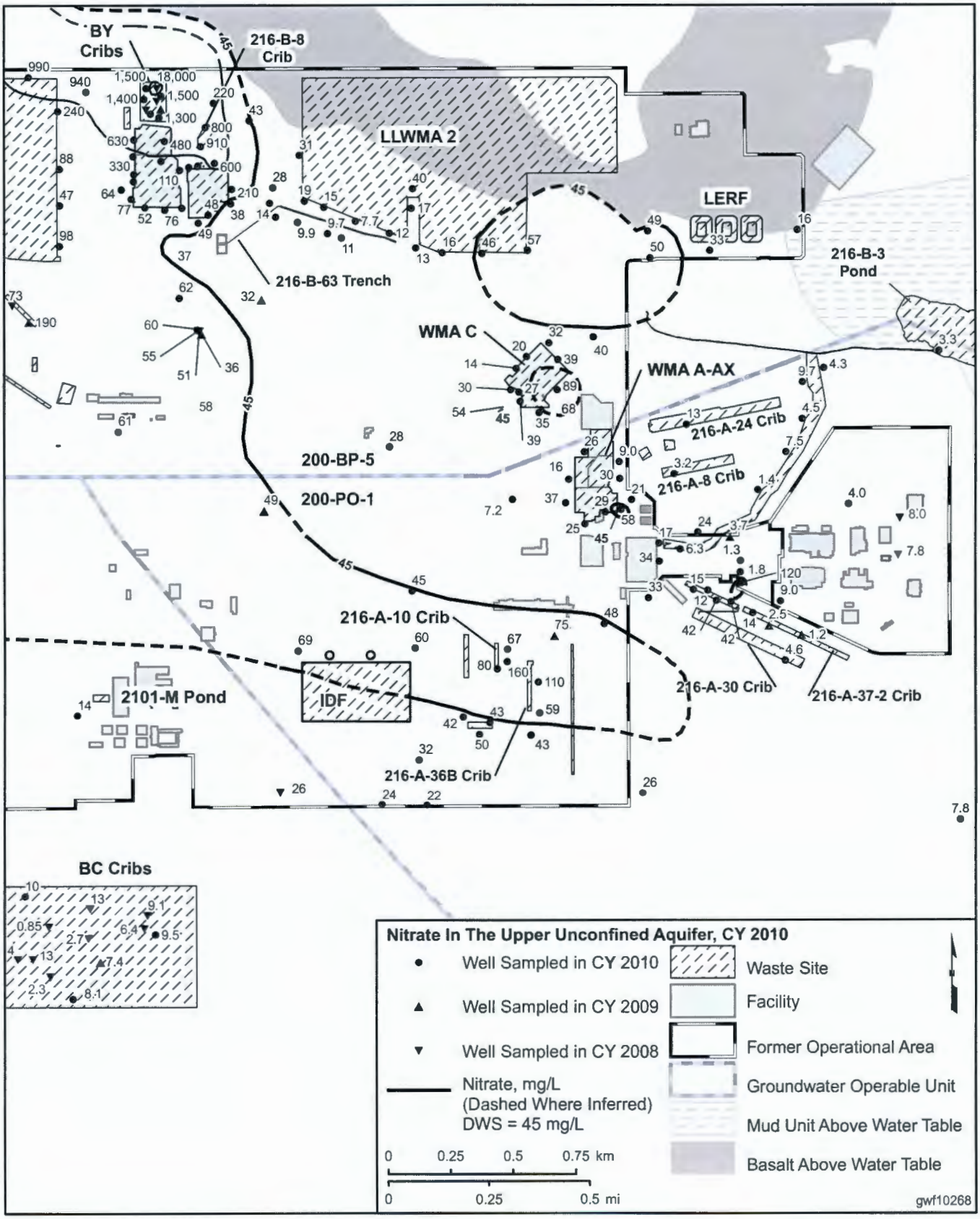


Figure 10-11. Nitrate Concentration in Well 299-E17-19 Near the 216-A-10 Crib

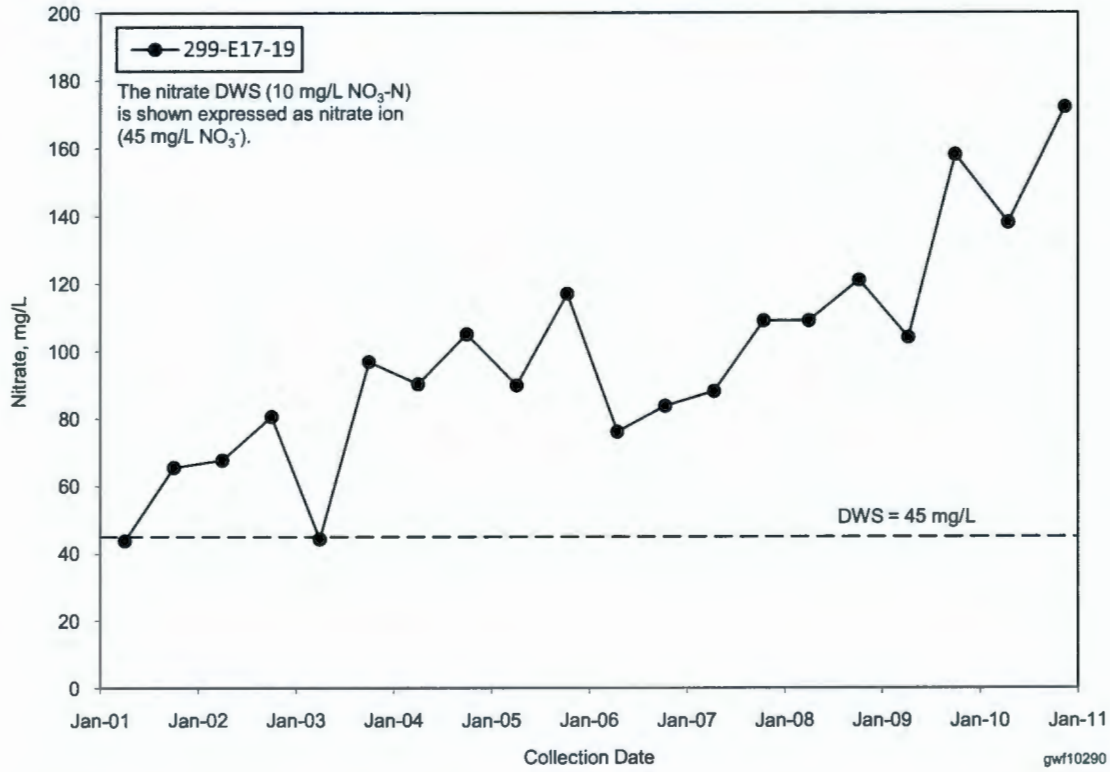


Figure 10-12. Technetium-99 Concentrations in Wells at Waste Management Area A-AX

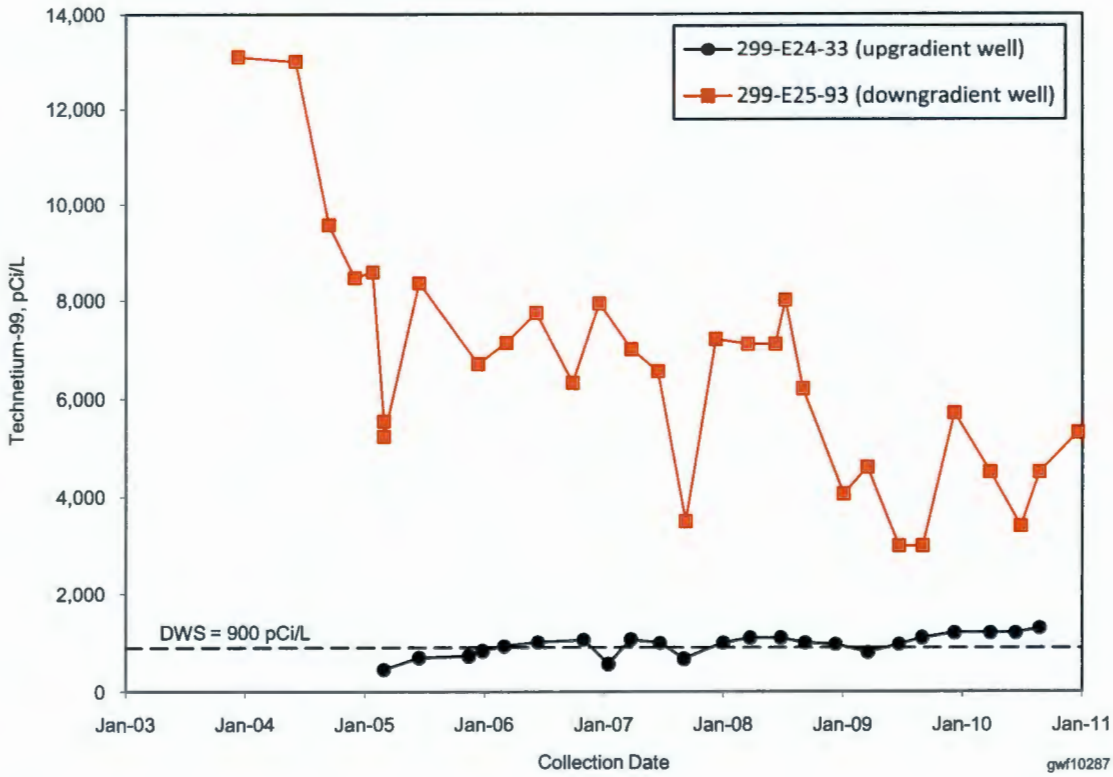


Figure 10-13. Local Plume Map for Uranium Near the PUREX Cribs

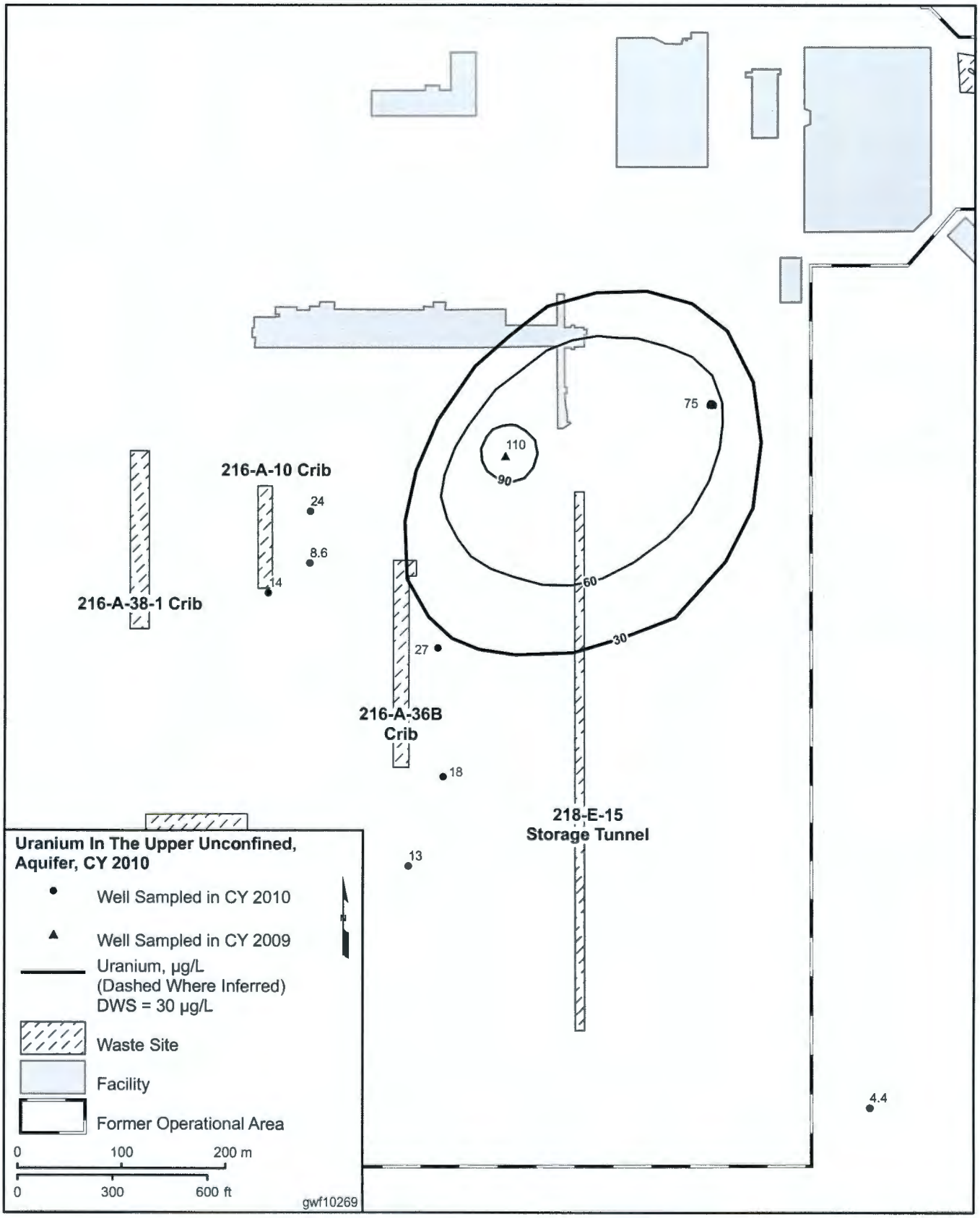


Figure 10-14. Uranium Concentration Near the PUREX Cribs

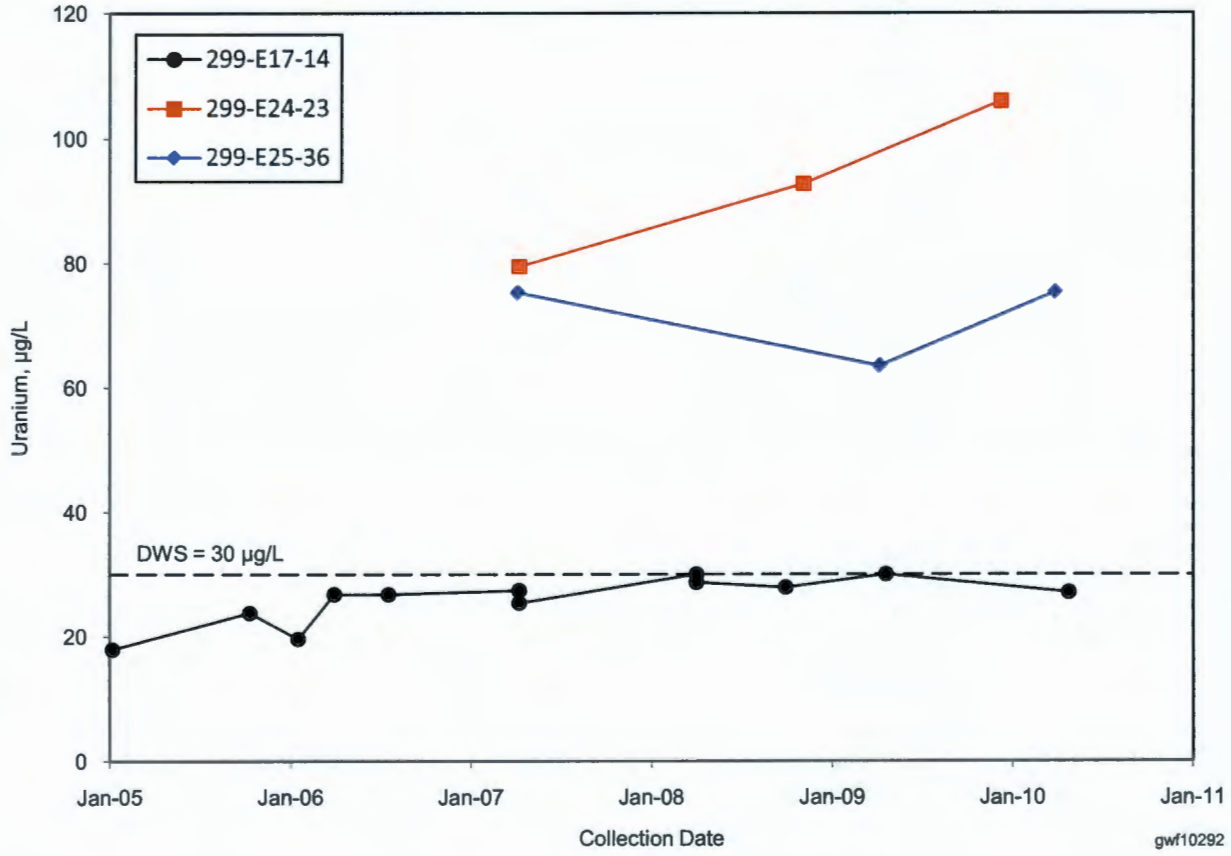


Figure 10-15. Cross Section of the Airborne Electromagnetic Geophysical Survey North of the 300 Area

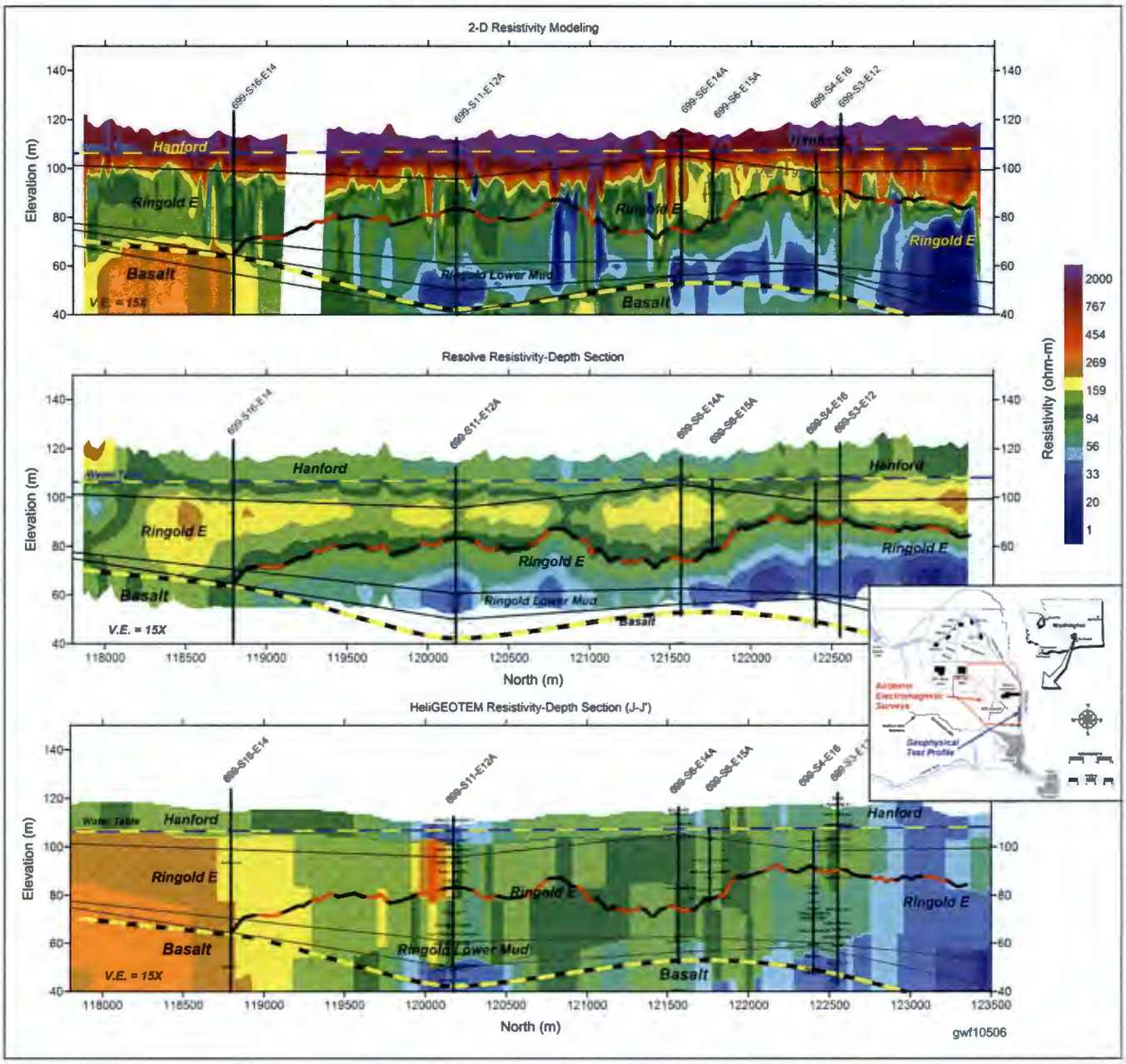


Figure 10-16. Nitrate Concentrations in Wells at 216-A-36B Crib

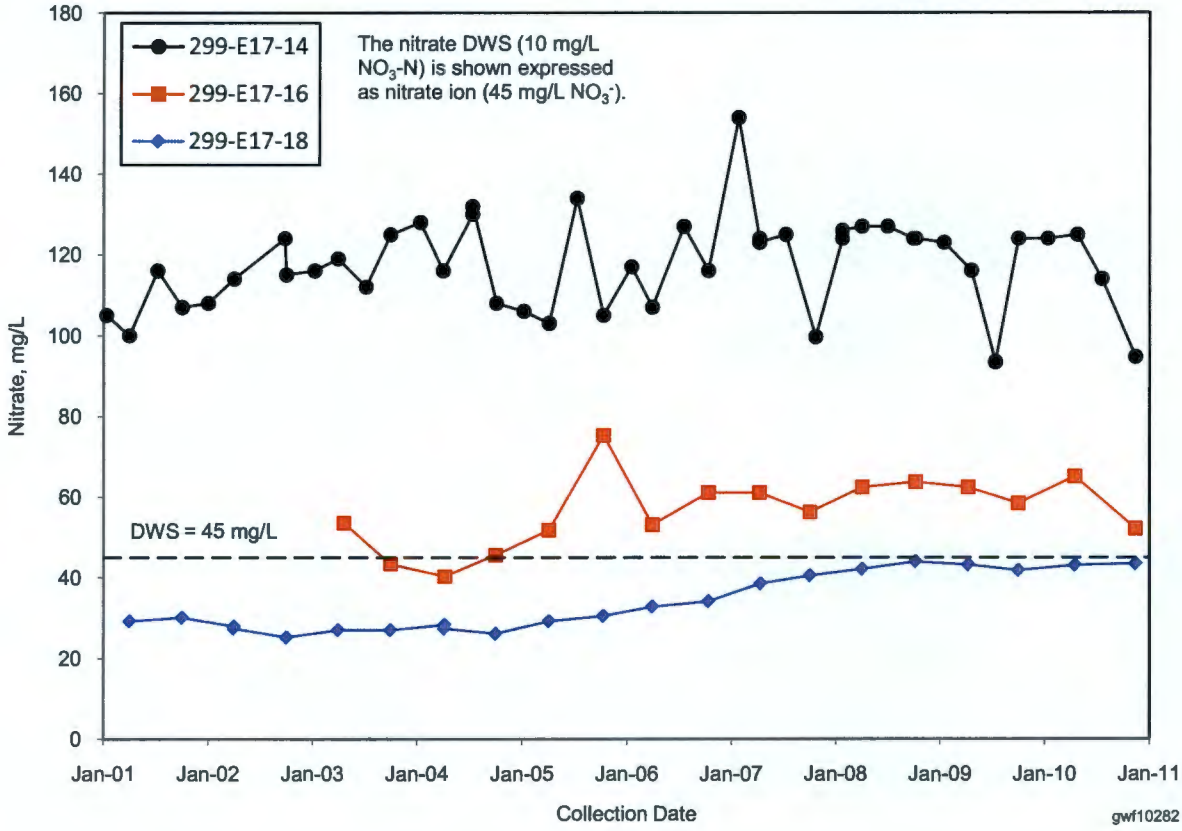


Figure 10-17. Nitrate Concentrations in Wells at 216-A-10 Crib

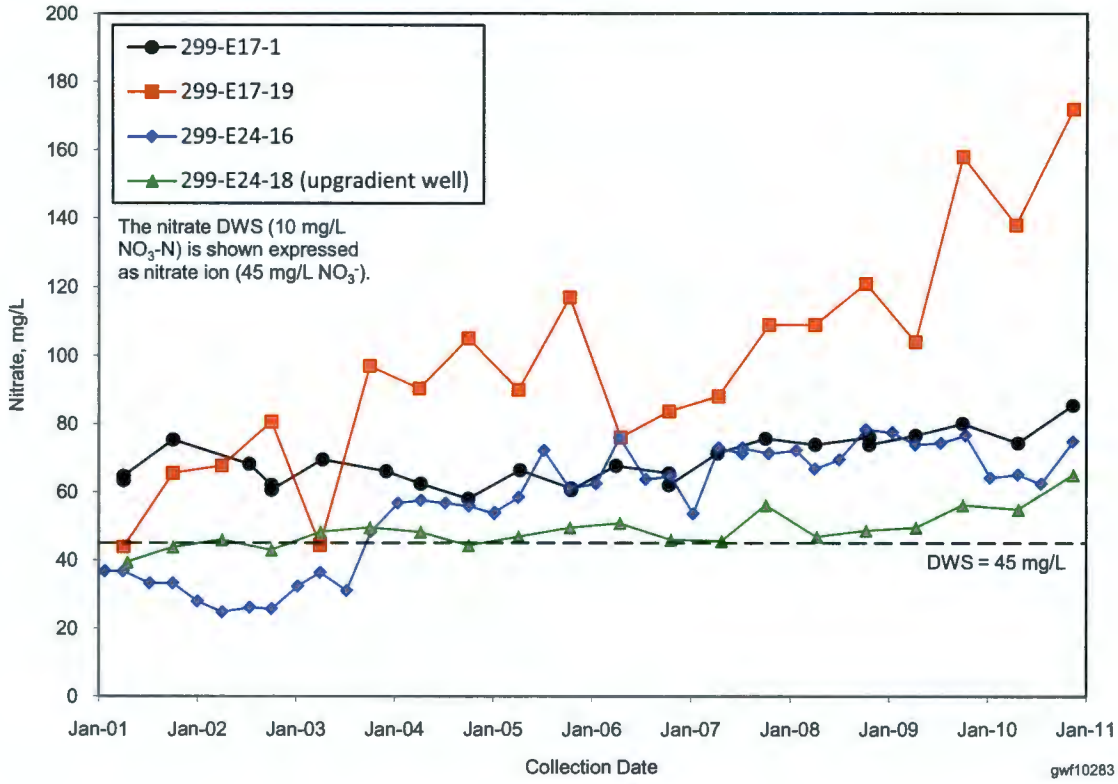


Figure 10-18. Nitrate Concentrations in Wells at 216-A-37-1 Crib

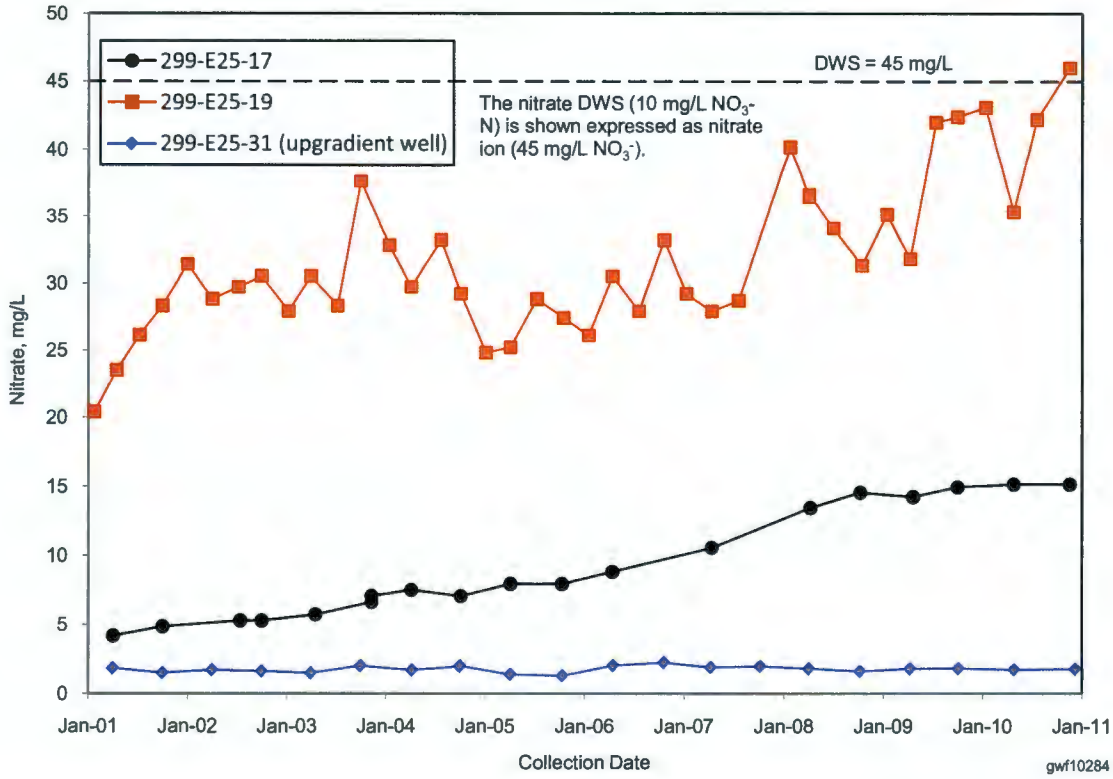


Figure 10-19. Total Organic Carbon Concentrations in Wells at Waste Management Area A-AX

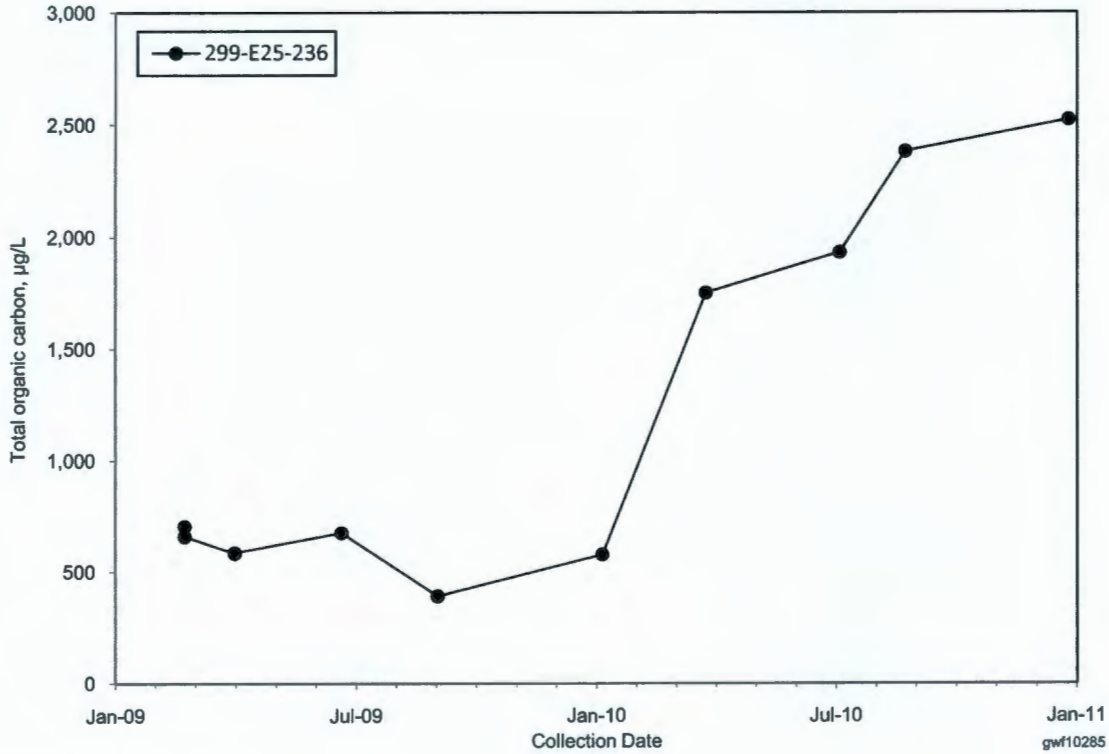


Figure 10-20. Nitrate Concentrations in Wells at Waste Management Area A-AX

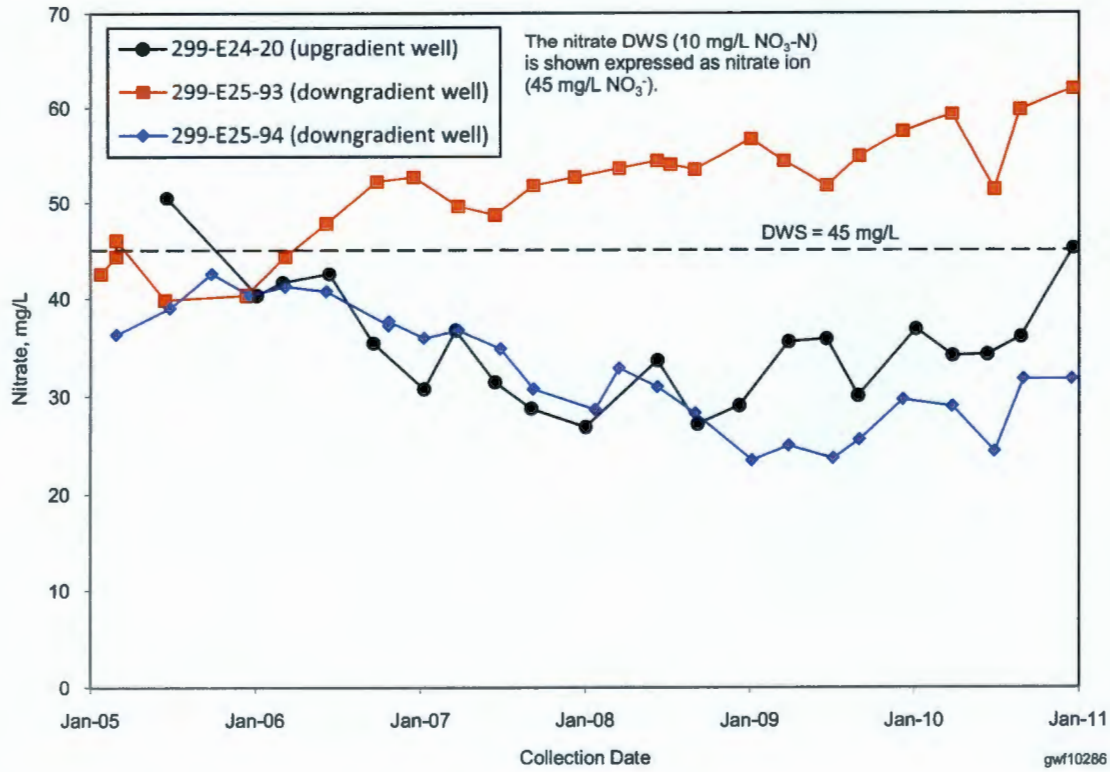


Figure 10-21. Technetium-99 Plume Map of Waste Management Area A-AX and Waste Management Area C

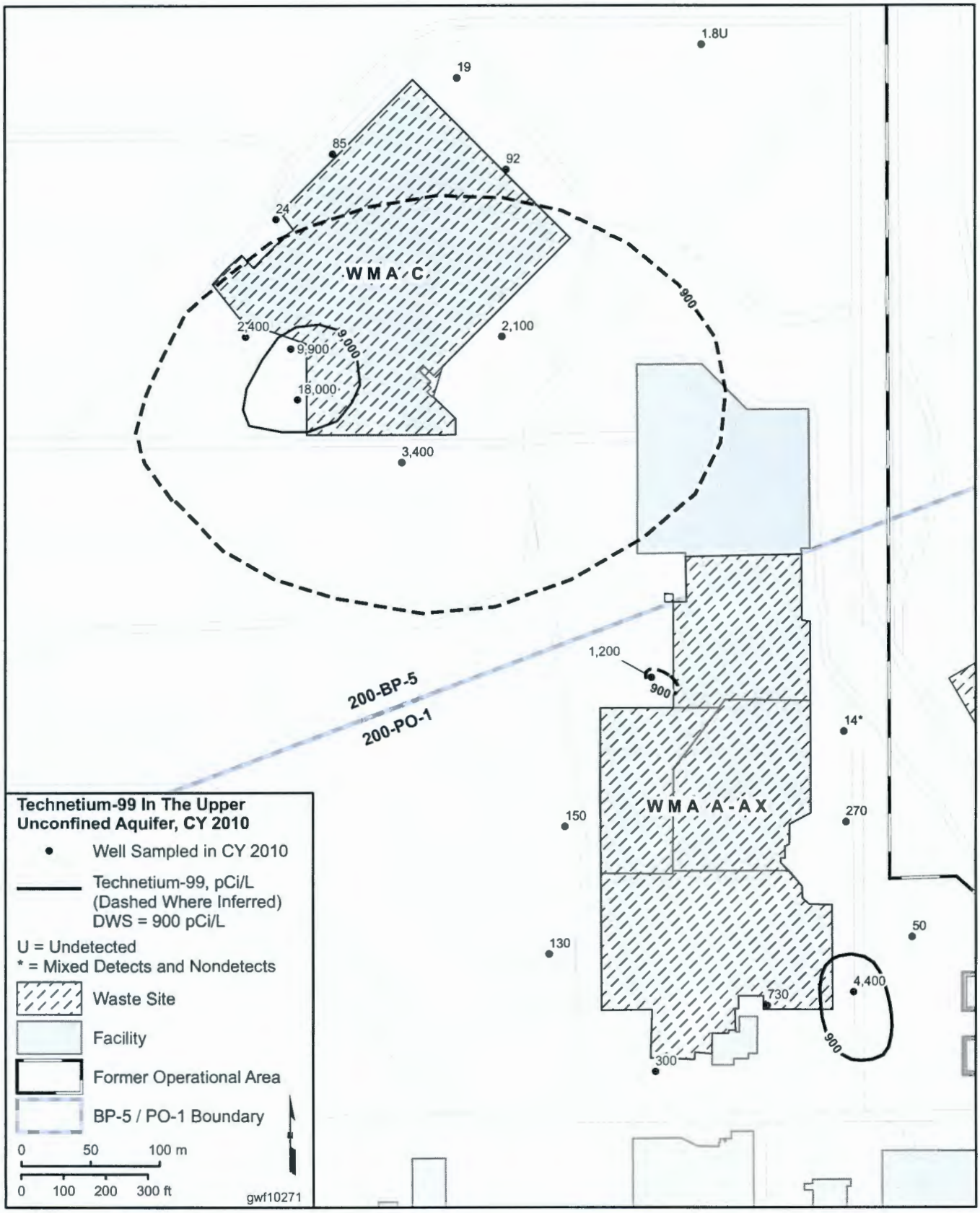


Figure 10-22. Major Anions and Specific Conductance in Well 299-E25-32P

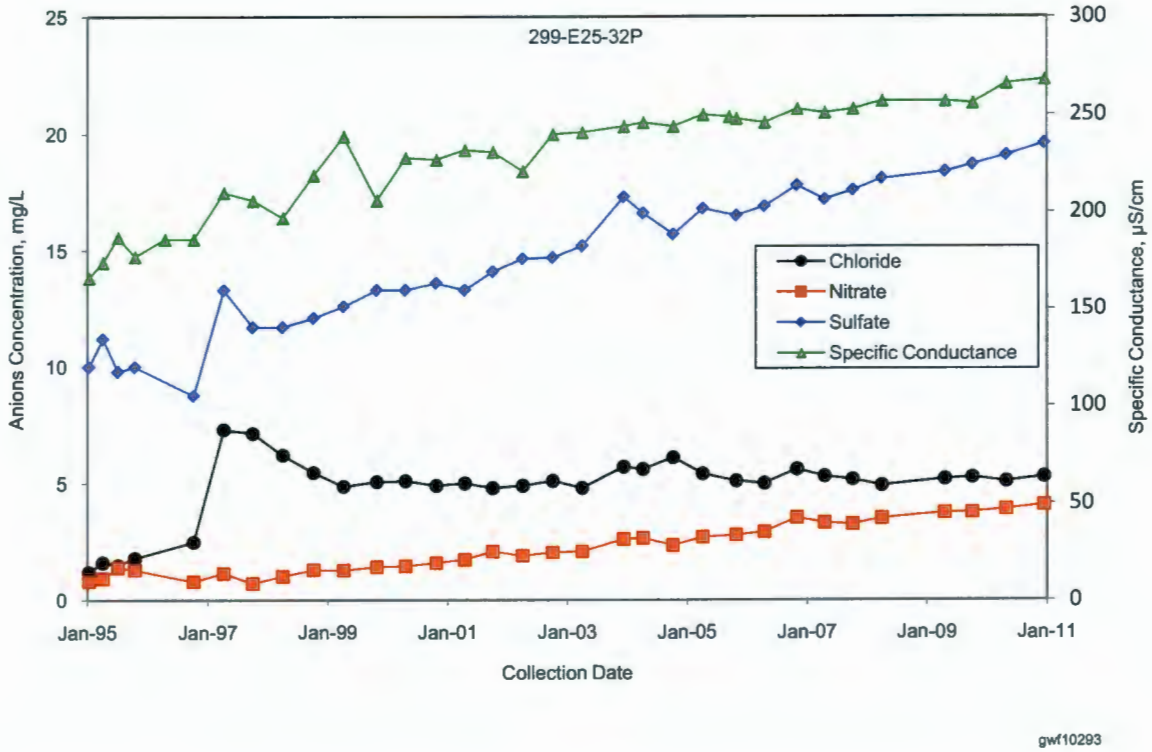


Figure 10-23. Specific Conductance in 216-A-29 Ditch Wells

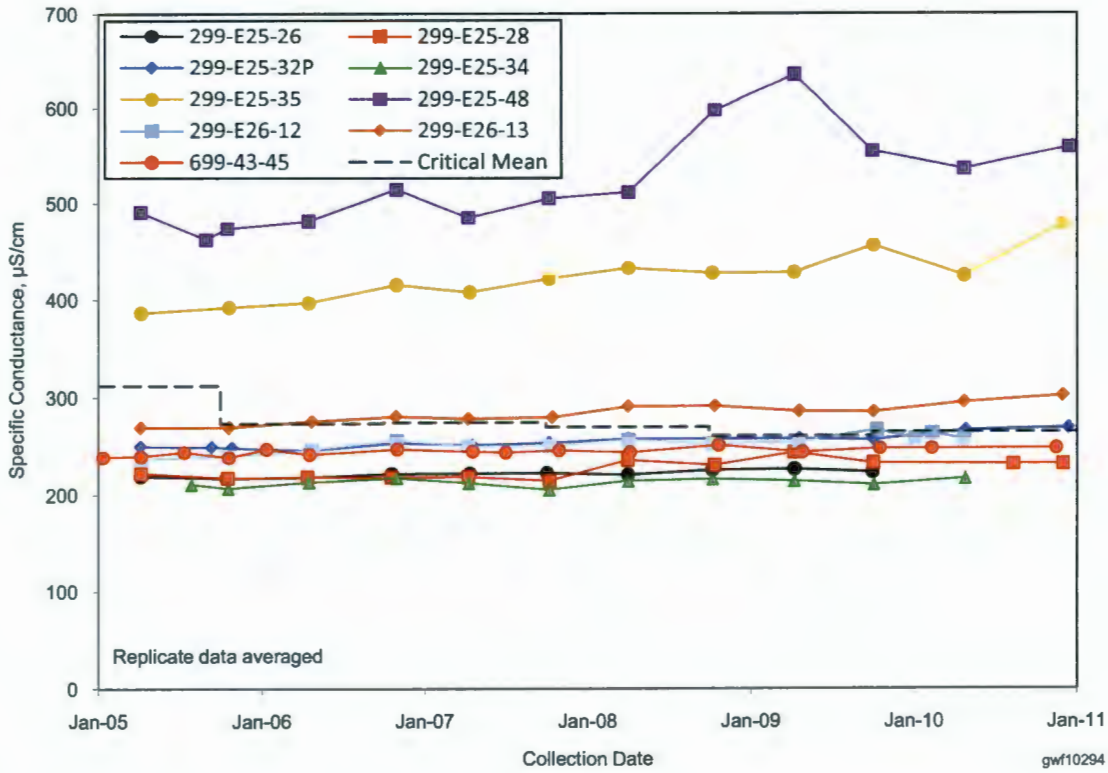
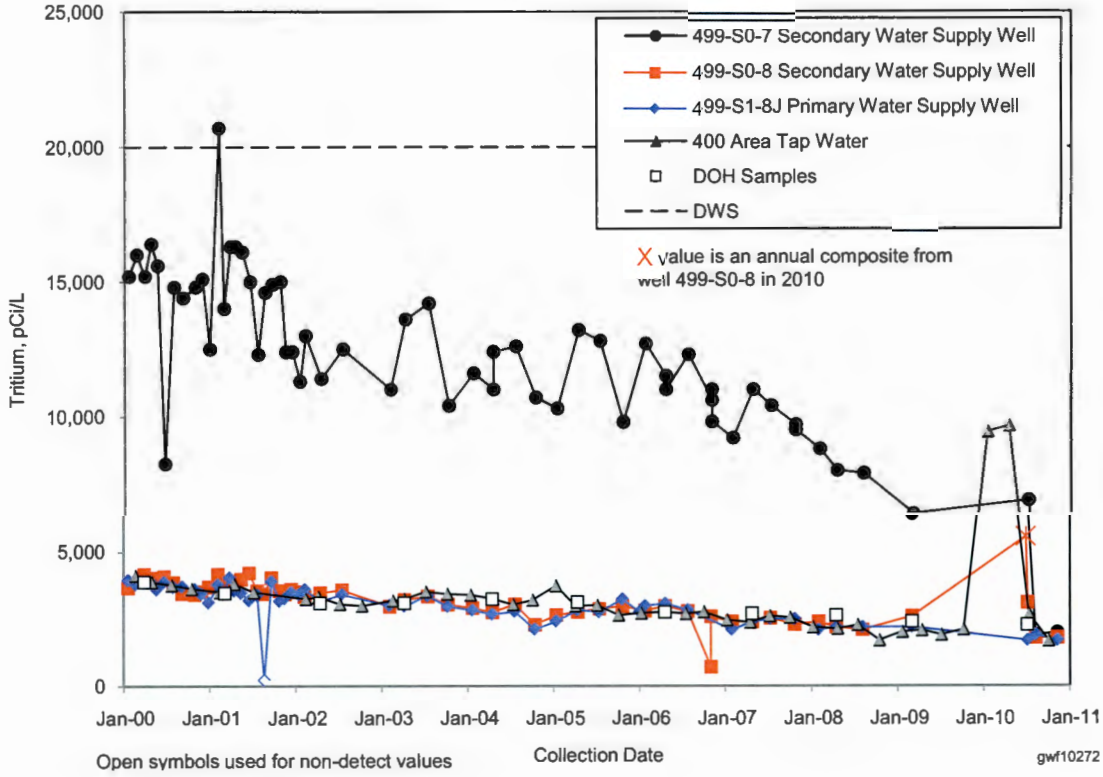


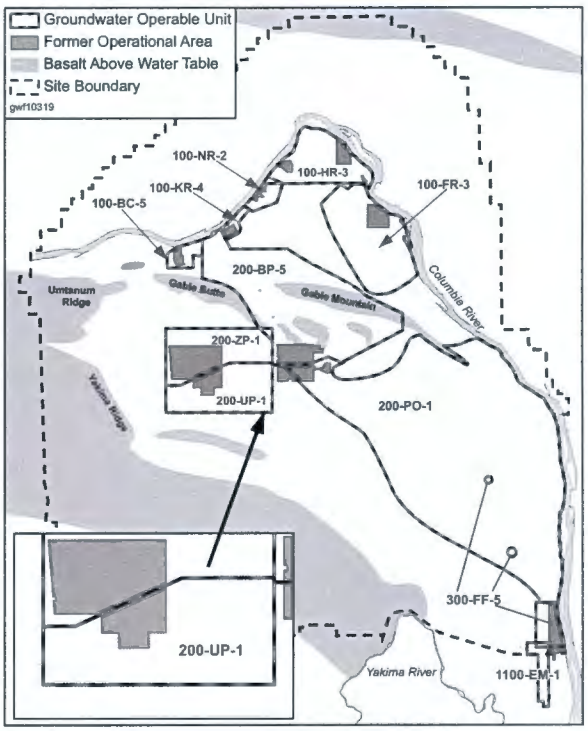
Figure 10-24. Tritium Concentrations in the Three 400 Area Water Supply Wells



This page intentionally left blank.

11.0 200-UP-1 Operable Unit

J.P. McDonald



The 200-UP-1 Operable Unit (OU) addresses groundwater contaminant plumes beneath the southern third of the 200 West Area and adjacent portions of the surrounding 600 Area. With the exception of the Environmental Restoration Disposal Facility (ERDF), most of the facilities and waste sites within the OU are associated with former operation of the Reduction-Oxidation (REDOX) Plant (plutonium separation) and U Plant (uranium recovery). The OU lies within the larger 200-UP-1 groundwater interest area, informally defined to facilitate sample scheduling, data review, and interpretation. Figure 11-1 shows facilities and wells in a large portion of the 200-UP-1 groundwater interest area. Groundwater wells in the remainder of the interest area are shown in Figure 3-1 in Chapter 3.0. The interest area and OU boundaries are shown in Figure 1-2 in Chapter 1.0.

Groundwater monitoring in the 200-UP-1 groundwater interest area is conducted under three regulatory drivers:

- The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) governs the 200-UP-1 OU and the ERDF. The CERCLA requirements for the OU are further subdivided into monitoring conducted to (1) characterize and track contaminants of concern (COCs) or contaminants of potential concern in the OU; and (2) evaluate the performance of a pump-and-treat system that removes technetium-99, uranium, carbon tetrachloride, and nitrate from groundwater near U Plant.
- *Resource Conservation and Recovery Act of 1976* (RCRA) (and RCW 70.105, "Hazardous Waste Management") interim status assessment monitoring for dangerous constituents is performed at single-shell tank Waste Management Areas (WMAs) S-SX and U. Evaluation monitoring for interim status indicator parameters under RCRA is performed at the 216-S-10 Pond and Ditch (S-10 unit).
- Monitoring of radionuclides is performed to meet the requirements of the *Atomic Energy Act of 1954* (AEA).

The scope of this chapter is the entire 200-UP-1 groundwater interest area, but the term "operable unit" is used frequently as a spatial reference because most of the waste disposal operations and groundwater plumes occur within the OU. The plume maps shown in this chapter are based on groundwater sampling results averaged over calendar year (CY) 2010. Plume cross sections shown in this chapter are the same as those published in Chapters 3 and 4 of the *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-2009-122) and are largely based on depth-discrete groundwater sampling during well installation between 2002 and 2008. Cross-section locations are shown in Figure 11-2.

Highlights. The following list summarizes the significant findings/accomplishments discussed in this chapter:

- The draft remedial investigation (RI)/feasibility study (FS) and proposed plan documents for the 200-UP-1 OU were released in September 2010, meeting

Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Milestone M-015-17A.

- The revised remedial design/remedial action work plan for the 200-UP-1 OU was released in January 2010. The work plan implements changes made to the interim action Record of Decision (ROD) by the explanation of significant differences issued during 2009.
- At the U Plant interim action pump-and-treat system targeting the uranium and technetium-99 plumes downgradient from the 216-U-1/2 Cribs, all technetium-99 sample results were below the 9,000 pCi/L remedial action objective, and all uranium sample results were below the 300 µg/L remedial action objective.
- Concentrations of mobile tank waste constituents in well 299-W22-44 at the S Tank Farm were relatively stable during the year, with maximum values of 275 mg/L for nitrate, 702 µg/L for chromium, and 18,000 pCi/L for technetium-99.
- Concentrations of mobile tank waste constituents in well 299-W23-19 at the SX Tank Farm exhibited slight decreases during the year, with maximum values of 1,180 µg/L for chromium, 491 mg/L for nitrate, and 65,000 pCi/L for technetium-99.
- An interim action pump-and-treat system targeting the technetium-99 plumes from WMA S-SX (Tri-Party Agreement Milestone M-016-120) was in the planning stage during 2010.
- New well 299-W22-89 was installed south-southeast of WMA S-SX; sample results reduced the uncertainty in the interpretation of the contaminant plume boundary from the SX Tank Farm.
- For RCRA indicator parameter evaluation monitoring at 216-S-10 Pond and Ditch, new critical mean values were calculated for pH, specific conductance, and total organic halides using sample results from the new upgradient well 699-33-76. The total organic carbon critical mean was not recalculated because the sampling results exhibited too much variability to be used for statistical evaluations (i.e., concentrations are presumed to be recovering from the drilling process). There were no indicator parameter exceedances at this site during 2010.
- The results of groundwater monitoring at the ERDF continued to indicate that the facility has not adversely affected groundwater quality.

Technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form substantial plumes within the 200-UP-1 OU.

Conceptual Model. Large-scale waste disposal at the 200-UP-1 OU began during the early 1950s when plutonium-separation operations began at the REDOX Plant and uranium-recovery operations began at U Plant. In general, the high-level radioactive waste was stored in underground storage tanks, and other liquid waste streams were disposed to ponds and cribs. Groundwater plumes of nitrate, tritium, and iodine-129 formed when the pond and crib waste reached the aquifer. These plumes expanded as effluent disposal operations continued. Effluent disposal to the ponds and cribs ceased during the 1990s. The groundwater plumes from these sources are currently dispersing naturally; however, constituents of lower mobility in the vadose zone beneath the ponds and cribs may potentially reach the water table in the future and affect groundwater quality.

Within the tank farms (WMA S-SX and WMA U), some of the underground single-shell storage tanks have leaked, contaminating the vadose zone beneath the tanks. Some of the contamination has migrated downward and reached the water table (e.g., PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*). Plumes of

nitrate, technetium-99, and chromium from the tank farms are currently found in the groundwater, and the plumes are generally growing in areal extent and exhibit increasing constituent concentrations. To minimize the probability of future leaks, all of the single-shell tanks at the Hanford Site have been interim stabilized, and the drainable liquid in each tank has been removed and transferred to double-shell tanks.

Plumes of tritium, nitrate, and iodine-129 from ponds and cribs are dispersing naturally, whereas plumes from the tank farms generally exhibit increasing concentrations and are growing in areal extent.

Currently, technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form extensive plumes within the region. These contaminants have sources within the OU, except for carbon tetrachloride which has migrated into the 200-UP-1 OU from the adjacent 200-ZP-1 OU. In addition to these constituents, other high-priority COCs for CERCLA monitoring include strontium-90, trichloroethene, chloroform, chromium, cadmium, and arsenic (DOE/RL-92-76, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*, Table A1-1).

Figure 2-2 in Chapter 2.0 shows the generalized stratigraphic column for the Hanford Site. The Columbia River Basalt Group forms the bedrock beneath the 200-UP-1 OU. The uppermost basalt flow is the Elephant Mountain Member of the Saddle Mountains Basalt. Geologic units at the 200-UP-1 OU above the basalt (in ascending sequence) are as follows:

- Semiconsolidated sand and gravel of the Ringold Formation unit 9
- Silt and clay of the Ringold lower mud unit 8
- Semiconsolidated sand and gravel of the Ringold unit 5
- Fine- to coarse-grained Cold Creek unit (CCU)
- Unconsolidated sand and gravel of the Hanford formation.

Groundwater within the interest area occurs as an unconfined aquifer, as well as under confining conditions beneath the Ringold lower mud unit (Ringold confined aquifer) and within and between the basalt flows (upper basalt-confined aquifer system and the lower basalt aquifers). The unconfined aquifer is the aquifer directly impacted by waste disposal operations in the southern 200 West Area (within the 200-UP-1 OU) and, therefore, is the only aquifer discussed in this chapter. The unconfined aquifer occurs within Ringold unit 5 and its base is the fine-grained Ringold lower mud unit. Depths from land surface to the water table range from 64 to 106 meters, with the largest depths occurring in the northeastern portion of the OU. The thickness of the unconfined aquifer within the OU is variable (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*, Plate 13). The aquifer is ~70 meters thick in the western portion of the OU. The elevation of the top of the lower mud unit increases to the northeast, and a portion of this unit is interpreted to occur above the water table north of the OU boundary (shown in Figure 3-2 in Chapter 3.0). Thus, the aquifer thickness approaches zero in the northeastern corner of the OU.

Groundwater flow in the unconfined aquifer is primarily to the east within the southern 200 West Area and east-northeast in the eastern portion of the interest area (Figure 11-3). Water levels have been declining in this area since the 1980s; within the southern portion of the 200 West Area, flow directions have generally changed from southeast to east since the 1980s. When the 216-U-10 Pond (U Pond) and the 216-U-14 Ditch were active, a groundwater mound formed resulting in radial flow in the northwestern portion of the interest area (e.g., see Figures 5 through 10 in PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site [1950-1970]*). Discharges to ground ceased in the mid-1990s,

and the groundwater flow has resumed its pre-Hanford flow direction toward the east. Between March 2009 and March 2010, the water table elevation declined by an average of 0.21 meters in the southern portion of the 200 West Area.

11.1 Groundwater Contaminants

Plume areas (square kilometers) in the 200-UP-1 Operable Unit:

Chromium, 100 µg/L — 2.292

Iodine-129, 1 pCi/L — 4.65

Nitrate, 45 mg/L — 6.3

Technetium-99, 900 pCi/L — 0.348

Tritium, 20,000 pCi/L — 7.842

Uranium, 30 µg/L — 0.437

*** Carbon tetrachloride included with the 200-ZP-1 Operable Unit***

The following sections provide an overview of the contaminant plumes and COCs for the 200-UP-1 groundwater interest area. The constituents discussed include technetium-99, uranium, tritium, iodine-129, nitrate, chromium, carbon tetrachloride, chloroform, trichloroethene, strontium-90, and others. The discussion provides a summary of the combined results of CERCLA, RCRA, and AEA monitoring performed in this area, with focus on the upper portion (i.e., approximately the upper 20 meters) of the unconfined aquifer. Information on the vertical distribution of contaminants in the aquifer is given where available.

The areal extent of the chromium, technetium-99, and uranium plumes (above their respective drinking water standards [DWSs]) with time is shown in Figure 11-4. The sharp increase in the chromium extent from 2008 to 2009 was due to a reinterpretation of the plume and does not reflect an actual change in plume size. The chromium extent has been relatively constant over time; much of the chromium above the DWS occurs in the 600 Area southeast of the 200 West Area. Technetium-99 has increased in areal extent. The technetium-99 plume extent has decreased substantially at the U Plant pump-and-treat system, but increases in plume size from the S and SX Tank Farms have caused the overall extent of technetium-99 to increase. The apparent decline in the areal extent of uranium is due mostly to refinements in plume interpretation as new monitoring wells were installed for the U Plant pump-and-treat system. The areal extent of uranium has changed little since 2003. The areal extent of the iodine-129, nitrate, and tritium plumes over time is shown in Figure 11-5. The nitrate plume size exhibits a slight decreasing trend, whereas the iodine-129 and tritium plume sizes have been relatively stable. Changes from year-to-year in the tritium plume extent is attributed mostly to differences in plume interpretation.

The relative mobility of the constituents in the 200-UP-1 OU groundwater is one factor that affects the size and distribution of the contaminant plumes, and an understanding of relative mobility is important for interpreting groundwater sampling results. Some constituents are fully dissolved in the groundwater and migrate with the groundwater flow, while others interact with the aquifer sediment to some degree (i.e., "sorb" by either adsorption or precipitation) and migrate at a slower rate than the groundwater flow. The degree of sorption for a particular constituent can be described by its distribution coefficient value, which is the ratio of the sorbed phase concentration to the dissolved phase concentration. Constituents that do not sorb at all have distribution coefficient values equal to zero, whereas sorbing constituents have distribution coefficient values greater than zero. The distribution coefficient values used for contaminant transport modeling performed for the 200-UP-1 RI are presented in DOE/RL-2009-122, Section 5.1.2.

The contaminants in the groundwater at the 200-UP-1 OU exhibit variable mobility. Tritium is highly mobile under all conditions (i.e., has a distribution coefficient value equal to 0 mL/g) because it is a hydrogen isotope that occurs as part of the water molecule. The mobility of other constituents depends, in part,

on geochemical conditions in the aquifer. The groundwater in the 200-UP-1 OU unconfined aquifer is generally oxidizing and has a pH of neutral to slightly basic (90% of the pH measurements during 2010 ranged between 7.6 and 8.4, with a median value of 7.85; dissolved oxygen ranged from 6,500 to 9,600 µg/L, with a median value of 8,300 µg/L). Under these conditions, constituents such as technetium-99, chromium, and nitrate do not sorb onto aquifer sediments to any appreciable degree and are highly mobile and migrate at the same rate as the groundwater flow (i.e., have distribution coefficient values equal to 0 mL/g). Other constituents, such as uranium and iodine-129, are considered moderately mobile (i.e., have distribution coefficient values between 0 and 1.0 mL/g). The mobility of uranium is complex and can be quite variable depending on geochemical conditions. Within 200-UP-1 OU groundwater, uranium forms complexes with carbonate and hydroxide ions, which limits its sorption ability and increases its mobility. For a comprehensive discussion of uranium geochemistry, including the factors that affect speciation and mobility, see *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site* (PNNL-17031). Organic constituents are also considered moderately mobile because they interact with organic material in the aquifer. Strontium-90 strongly sorbs to aquifer sediments and is considered only slightly mobile (i.e., has a distribution coefficient value greater than 1.0 mL/g).

11.1.1 Technetium-99

As stated previously, technetium-99 is highly mobile in the 200-UP-1 groundwater. Technetium-99 concentrations occur above the DWS of 900 pCi/L in three regions of the operable unit: (1) downgradient (east) from the 216-U-1/2 Cribs near U Plant, (2) at WMA S-SX, and (3) at WMA U (Figure 11-6). A technetium-99 plume originates from the 216-U-1/2 Cribs, which were active in the 1950s and 1960s. The plume extends ~1.5 to 2 kilometers east into the 600 Area, but the plume is mostly at levels below the DWS. When wastewater was disposed at the nearby 216-U-16 Crib in the mid-1980s, it migrated north along a caliche layer and mobilized the technetium-99 and uranium in the vadose zone soil column beneath the 216-U-1/2 Cribs, which added contaminant mass to the groundwater plume (DOE/RL-92-76, the 200-UP-1 RI/FS work plan, Section 2.3.3.1). This plume is separated into two parts: one downgradient from the 216-U-1/2 Cribs, and one east of the 200 West Area boundary. This separation was caused by capture of the high-concentration portion of this plume by the U Plant interim remedial action pump-and-treat system while the lower concentration portion that was not captured continued to migrate to the east.

A cross section of the 216-U-1/2 Cribs plume is shown in Figure 11-7 (cross-section locations are shown in Figure 11-2). Within the U Plant pump-and-treat area (near wells 299-W19-36 and 299-W19-43), the plume occurs largely in the upper portion of the aquifer. To the east of the 200 West Area boundary, the plume occurs throughout much of the aquifer thickness. Historically, the highest measured technetium-99 concentration in the 216-U-1/2 Cribs plume was 41,000 pCi/L in well 299-W19-24 (west of the 216-U-17 Crib) in October 1989.

The U Plant pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1995 until a rebound study began in early 2005. Groundwater extraction resumed in April 2007 following the rebound study. The pump-and-treat system has been successful in reducing technetium-99 concentrations in the aquifer. Throughout the year, technetium-99 concentrations were below the 9,000 pCi/L remedial action objective in both extraction wells (299-W19-36 and 299-W19-43) and all of the compliance wells. Technetium-99 concentrations

The maximum technetium-99 concentration during the year at SX Tank Farm well 299-W23-19 was 65,000 pCi/L.

exceeded the DWS in both extraction wells but were below the DWS for all of the compliance wells. The maximum concentration measured during the year at the pump-and-treat system was 7,100 pCi/L in extraction well 299-W19-36 (June 2010). Section 11.2.2 provides additional discussion of the pump-and-treat activities.

At WMA S-SX, a technetium-99 plume originates from the southwestern corner of the SX Tank Farm and another plume originates from the north-central portion of the S Tank Farm. The highest technetium-99 concentrations within the OU occur in the southern plume at well 299-W23-19 (located inside the SX Tank Farm). During the year, concentrations in this well were generally stable, fluctuating between 49,000 and 65,000 pCi/L (Figure 11-8). The southern plume from WMA S-SX represents a growing contamination issue because the plume is increasing in areal extent and concentrations are increasing in many of the downgradient wells. At far downgradient well 299-W22-86, the technetium-99 concentration increased to 10,000 pCi/L during August 2010. A cross section of this plume is shown in Figure 11-9. The plume occurs largely within the upper 20 meters of the aquifer.

Both the northern and southern technetium-99 plumes from WMA S-SX represent growing contamination issues. A pump-and-treat system is planned for these plumes.

The northern plume at WMA S-SX originates from the S Tank Farm. Concentrations began increasing substantially in this plume during late 2006. In near-field downgradient well 299-W22-44, the technetium-99 concentration was generally stable during the year, fluctuating between 17,000 and 18,000 pCi/L (Figure 11-10). Concentrations are increasing in far downgradient well 299-W22-26, where the technetium-99 concentration was 6,000 pCi/L in December 2010 (Figure 11-11). Most technetium-99 sample results in upgradient well 299-W23-20 were nondetects during the year, confirming the S Tank Farm as the source. The recent concentration increases in the northern plume indicate that it is also a growing contamination issue. Section 11.3.1 provides additional information regarding technetium-99 at this WMA. Future remediation of both the northern and southern plumes from WMA S-SX is being addressed by the 200-UP-1 OU CERCLA activities. An interim-action pump-and-treat system for both the north and south plumes was in the planning stage during 2010.

Technetium-99 concentrations in the downgradient wells at WMA U are elevated compared to concentrations in the upgradient well. This indicates the U Tank Farm is a source of technetium-99 contamination (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*); however, concentrations are lower than in the WMA S-SX plumes. Technetium-99 concentrations were greater than the DWS in four of the downgradient monitoring wells during the year, with maximum concentrations of 1,000 pCi/L at 299-W18-30; 2,200 pCi/L at 299-W19-42; 2,000 pCi/L at 299-W19-45; and 2,100 pCi/L at 299-W19-47. Concentrations have been relatively stable in wells 299-W18-30 and 299-W19-47 and slowly increasing in wells 299-W19-42 and 299-W19-45. Section 11.3.2 includes additional discussion regarding technetium-99 at this WMA.

11.1.2 Uranium

Uranium within the 200-UP-1 OU primarily occurs in a plume downgradient from the 216-U-1/2 Cribs (Figure 11-12) and is associated with the technetium-99 plume. The plume extends ~1.5 kilometers to the east at levels above the 30 µg/L DWS. Uranium sorbs to soil particles and is considered moderately mobile in the 200-UP-1 groundwater. The uranium originated from the 216-U-1/2 Cribs, which were active in the 1950s and 1960s. As with technetium-99, additional mass was added to the groundwater plume when effluent disposed at the nearby 216-U-16 Crib in the mid-1980s migrated north along a caliche layer in the vadose zone, mobilizing

the technetium-99 and uranium in the soil column beneath the 216-U-1/2 Cribs (DOE/RL-92-76, Section 2.3.3.1).

The U Plant interim remedial action pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1995 until a rebound study began in early 2005. Groundwater extraction resumed in April 2007 following the rebound study. The uranium plume map shown in Figure 11-12 depicts the average conditions during the year. Throughout the year, uranium sample results were below the current remedial action objective of 300 µg/L at all wells within the remedial action target area (i.e., baseline plume area). The maximum concentration measured within the baseline plume area during the year was 257 µg/L in extraction well 299-W19-43. Well 299-W19-37 had a uranium concentration of 322 µg/L in March 2008, but this well has since gone dry and can no longer be sampled. Concentrations at most wells, however, continue to exceed the DWS of 30 µg/L. Section 11.2.2 provides additional information regarding operation and performance of the U Plant pump-and-treat system.

All uranium sample results in the U Plant pump-and-treat area were below the 300 µg/L remedial action objective during the year, although the concentration at well 299-W19-18, upgradient from the remedial action target area, continued to exceed 300 µg/L.

Near the 216-U-1/2 Cribs, uranium continues to be elevated in well 299-W19-18. Concentrations had been declining in this well; however, between August 2008 and August 2009, the uranium concentration increased from 349 to 416 µg/L. During the year, this well was sampled once in March and the concentration was 417 µg/L. The persistence of elevated concentrations in this well over the past 10 years may be due to an ongoing source of uranium to the aquifer. Possible sources include continued leaching from the vadose zone beneath the 216-U-1/2 Cribs or desorption of uranium from the aquifer sediment. However, the uranium concentration may also result from the slow migration of this constituent compared to technetium-99. The cross section of the uranium plume (Figure 11-13) indicates the plume is limited to the upper ~20 meters of the aquifer (cross-section locations are shown in Figure 11-2). There have been no exceedances of the DWS in samples collected below 20 meters in depth.

Uranium concentrations are elevated in wells west and northwest of WMA S-SX near U Pond. Uranium concentrations exceed the DWS in only one well in this area, 299-W23-4 (near the 216-S-21 Crib), which had a peak concentration of 37 µg/L during the year.

11.1.3 Tritium

Disposal facilities associated with the REDOX Plant are the primary sources of tritium in the 200-UP-1 OU. The REDOX Plant operated from 1952 until 1967, although effluent releases continued after that time. A large tritium plume from the REDOX Plant cribs originates from the southern portion of the 200 West Area and extends ~5 kilometers toward the east and northeast at levels above the 20,000 pCi/L DWS. The large extent of this plume is due to the large number of sources, the long time span since releases began, and the high mobility of tritium in the aquifer. Two high-concentration areas occur within the region of tritium contamination: a large plume extending to the east and northeast from the 200 West Area, and a smaller plume extending ~550 meters to the east-southeast from the 216-S-25 Crib (Figure 11-14).

The tritium plume originating from the southern 200 West Area is attenuating naturally through dispersion and radiological decay.

Sample results in the eastern high-concentration area over the past 3 years have increased to 300,000 pCi/L (well 299-W22-20). Within the 20,000 pCi/L contour, concentrations are generally declining at eight wells, are relatively stable in one well, and are increasing in one well. The plume has localized portions with higher concentrations, which may account for increasing trends as these portions of the plume pass by wells. However, the plume exhibits declining concentrations overall,

and the areal extent has changed little in recent years, indicating natural attenuation by dispersion and radiological decay.

Only limited information is available on the vertical distribution of the large tritium plume. At the southern edge of this plume, depth-discrete tritium sampling was conducted at well 699-30-66 during drilling in 2004. Tritium was found at 18,000 pCi/L in the uppermost sample, 6.3 meters below the water table. The concentration was much lower (570 pCi/L) at 17.6 meters below the water table, and tritium was not detected in deeper samples. Depth-discrete tritium sampling was also conducted at well 699-36-70B when the well was drilled in 2004. This well is located along the western boundary of ERDF. Concentrations were 8,800 pCi/L at 1.5 meters below the water table; 1,200 pCi/L at 11.9 meters depth; 1,000 pCi/L at 22.9 meters depth; and 325 pCi/L at 46.3 meters depth. This information suggests that tritium occurs largely in the upper ~20 to ~25 meters of the aquifer, but this conclusion is tentative because vertical information is not available within the high-concentration regions of this plume.

Tritium occurs above the DWS in eight wells downgradient of the 216-S-25 Crib. Between 2000 and 2007, concentrations fluctuated between 150,000 and 500,000 pCi/L in a single well (299-W23-9) on the downgradient side of the crib, but this well went dry during FY 2007 and can no longer be sampled. Further downgradient, trends are generally stable in three wells, increasing in three wells, and declining in two wells. Radioactive liquid effluent was disposed to the 216-S-25 Crib from 1973 through 1980; in 1985, effluent from a pump-and-treat system at the 216-U-1/2 Cribs was disposed to this crib. In the vadose zone beneath the 216-S-25 Crib, tritium in the residual soil moisture may be migrating slowly to the water table. The plume has migrated under WMA S-SX, but the tank farms are not considered a direct source of tritium to the groundwater. Tritiated water in the tanks was removed by the 242-S evaporator and disposed to the 216-S-25 Crib. During the year, the tritium concentration in 299-W22-45 (downgradient from the SX Tank Farm) increased to above the DWS for the first time since this well was installed in 1992. The maximum sample result in this plume during the year was 71,000 pCi/L in well 299-W23-21, which is upgradient of WMA S-SX.

The tritium concentration in groundwater near the 216-S-21 Crib (west of WMA S-SX) continued to increase during the year, reaching 50,000 pCi/L in well 299-W23-4 (August 2010). This crib has previously been a major source of tritium. The peak tritium concentration in well 299-W23-4 occurred in 1963 and 1964 at 110 million pCi/L.

11.1.4 Iodine-129

Iodine-129 plumes in the 200-UP-1 OU originate from both U Plant and REDOX Plant disposal facilities (Figure 11-15), although the most substantial releases occurred from the REDOX facilities (based on estimated release inventories in RPP-26744, *Hanford Soil Inventory Model, Rev. 1*, Appendix C). One plume originates from the 216-U-1/2 Cribs, and a second plume originates from the southern portion of the 200 West Area. At the current level of monitoring detail, these plumes merge downgradient and become indistinguishable. This combined plume (as defined by the 1 pCi/L contour) extends to the east a distance of ~3.5 kilometers. Iodine-129 sorbs slightly to the aquifer sediments and is considered moderately mobile. This is likely one factor explaining the more limited extent of this plume in the 600 Area compared to tritium and nitrate which were released concurrently from the same sources. Sample results near the REDOX Plant cribs are above the DWS (1 pCi/L).

For example, well 299-W22-72, near the 216-S-7 Crib, had a maximum concentration during the year of 2.3 pCi/L (December 2010).

The highest concentrations of iodine-129 within the interest area, greater than ten times the DWS, occur in a 2-kilometer region extending eastward from the southeastern 200 West Area.

The highest concentrations of iodine-129 within the OU, greater than 10 times the DWS, occur in a region extending ~2 kilometers east into the 600 Area from the southeastern 200 West Area (Figure 11-15). Historically, the peak concentration in this area occurred in well 699-35-70, where the iodine-129 concentration was 37 pCi/L in March 2008. This well is now dry and can no longer be sampled. Within the larger plume (as delineated by the 1 pCi/L contour), concentrations are generally declining or stable, and dispersion is slowly reducing the areal extent of the plume above the DWS. Radiological decay is not a factor in the declining areal extent because iodine-129 has a long half-life (15.7 million years).

A cross section of the iodine-129 plume from the 216-U-1/2 Cribs is shown in Figure 11-16. The plume is interpreted to be shallow near the source, becoming deeper with increasing distance to the east. Information is not available on the vertical extent of the high-concentration portion of the iodine-129 plume from the southern portion of the 200 West Area.

11.1.5 Nitrate

Nitrate plumes are widespread within the 200-UP-1 interest area and originated from multiple sources.

Nitrate plumes in the 200-UP-1 OU originated from both the U Plant and REDOX Plant disposal facilities, although the U Plant sources were more substantial (based on estimated release inventories in RPP-26744, Appendix C). Potential sources of nitrate from U Plant include the 216-U-1/2, 216-U-8, and 216-U-12 Cribs. The nitrate plumes from these and other sources merge downgradient into a single, large plume that extends to the east and northeast a distance of ~4 kilometers (Figure 11-17). Like tritium, the nitrate plume is widespread within the OU, presumably due to the large number of sources, the time span since releases began, and the high mobility of nitrate. The high-concentration portion of the nitrate plume outside the 200 West Area occurs more to the north than the tritium and iodine-129 plumes. This is consistent with the U Plant cribs being the primary sources of nitrate, whereas the REDOX Plant disposal facilities to the south were the most important sources of the other plumes. With a few exceptions, concentrations throughout the large plume east of the 200 West Area are stable or declining. On the eastern edge of the plume, concentrations are stable in well 699-36-61A, increasing in well 699-40-62, and are declining in well 699-44-64.

The highest nitrate concentrations within the 200-UP-1 OU occur in extraction well 299-W19-43 at the U Plant pump-and-treat area, which had a maximum concentration of 1,080 mg/L during the year.

Within the U Plant pump-and-treat area, nitrate concentrations are highest in the two extraction wells, 299-W19-43 and 299-W19-36. The maximum concentrations during the year were 1,080 mg/L at well 299-W19-43 and 234 mg/L at well 299-W19-36. The maximum historical nitrate concentration value from well 299-W19-43 (1,930 mg/L in 2003) is higher than concentrations measured historically at the 216-U-1/2 Cribs in the 1970s and 1980s (~100 to ~300 mg/L). Thus, it appears that nitrate may have a local source near the pump-and-treat area.

A cross section of the nitrate plume from the 216-U-1/2 Cribs through the U Plant pump-and-treat area and into the 600 Area is shown in Figure 11-18. Similar to the technetium-99 and iodine-129 plumes in this area, nitrate occurs at shallow depths near the source and becomes fully mixed vertically throughout the aquifer between ~1.5 to ~2 kilometers downgradient from the source. The deeper occurrence of nitrate with distance from the source is most likely due to hydrodynamic dispersion.

During the year, nitrate concentrations exceeded the DWS in six of the eight network monitoring wells at the U Tank Farm, including the upgradient well 299-W18-40 due to an upgradient source. The maximum measured nitrate

concentration at the U Tank Farm during the year was 82 mg/L (December 2010) in well 299-W19-45. Concentrations are higher in the downgradient wells compared to the upgradient well, confirming that the U Tank Farm is a source of nitrate to the groundwater (Section 11.3.2).

Nitrate occurs in two small plumes associated with REDOX Plant disposal facilities: one plume near the 216-S-20 Crib, and the second plume near the 216-S-25 Crib and S-SX Tank Farms. Well 299-W22-20 (downgradient of the 216-S-20 Crib) had a nitrate concentration of 104 mg/L in September 2007.[1] The concentration in this well has been declining since a maximum value occurred in December 2005 (144 mg/L). At well 699-34-72 (located ~320 meters downgradient from the 216-S-20 Crib), the nitrate concentration was 33 mg/L in March 2010. From 1952 through 1972, this crib received waste from laboratory hoods and decontamination sinks in the 222-S Building, as well as laboratory waste from the 300 Area.

The nitrate plume originating from the 216-S-25 Crib merges with a nitrate plume from WMA S-SX (Section 11.3.1). Nitrate concentrations from the tank farm correlate with technetium-99 and chromium concentrations. In well 299-W23-19 in the southwestern corner of SX Tank Farm, the nitrate concentration exhibited a generally decreasing trend during the year, with concentrations fluctuating between 491 and 365 mg/L. A nitrate plume also originates from the S Tank Farm; the maximum concentration in this plume during the year was 275 mg/L in well 299-W22-44 (Figure 11-10). Depth-discrete sampling during drilling of well 299-W22-47 indicated that concentrations above the DWS in the southern plume are limited to the upper 21 meters of the aquifer.

High concentrations of chromium are found in two regions of the 200-UP-1 OU: at WMA S-SX and in the 600 Area (east and southeast of the 200 West Area).

11.1.6 Chromium

High concentrations of dissolved chromium are found in two regions of the 200-UP-1 OU: in two plumes at WMA S-SX and another plume in the 600 Area east and southeast of the 200 West Area (Figure 11-19). During the year, samples from seven wells at WMA S-SX had chromium concentrations that exceeded the 100 µg/L DWS, and concentrations in wells 299-W22-26 and 299-W22-86 exceeded the DWS for the first time during the year. The highest concentrations occurred at well 299-W23-19, where dissolved chromium concentrations were variable but exhibited a generally decreasing trend during the year (average of 990 µg/L in filtered samples) (Figure 11-8). This well is near the source of a chromium, technetium-99, and nitrate plume originating from the SX Tank Farm.

A second plume occurs in the northern portion of WMA S-SX, downgradient from the S Tank Farm. At near-field downgradient well 299-W22-44, dissolved chromium concentrations ranged between 556 and 702 µg/L during the year. Concentrations in this well have exhibited only a slight upward trend since 2008, much less than the sharp increasing trend between 2006 and 2008 (Figure 11-10). The other mobile tank waste constituents (technetium-99 and nitrate) have also increased substantially in this well since 2006. The downgradient extent of this plume, at the 100 µg/L contour level, reached well 299-W22-26 during the year (Figure 11-11). In general, chromium concentrations are increasing at WMA S-SX and the areal extent of both the northern and southern plumes is growing. Section 11.3.1 provides additional information on chromium at WMA S-SX.

---

1 Two subsequent sample results in well 299-W22-20 were substantially lower: 3.4 mg/L in August 2008 and 2.4 mg/L in August 2009. However, these results are believed to be nonrepresentative of the nitrate concentration in the aquifer because the well was going dry. This well is now dry and can no longer be sampled.

Dissolved chromium is frequently detected in wells east and southeast of the 200 West Area. In well 699-32-62, dissolved chromium concentrations have declined slowly since this constituent was first analyzed at this well in 1992 (from 254 µg/L in 1992 to 144 µg/L in 2010). Dissolved chromium is also elevated at well 699-30-66 (100 µg/L in June 2010), which is completed deep in the aquifer, just above the Ringold lower mud unit. Based on these results, chromium is interpreted to occur throughout the aquifer thickness in this region (a cross section of this plume is shown in Figure 11-20). The location of this plume is consistent with effluent disposal to the 216-S-20 Crib and/or the REDOX Plant ponds and ditches to the south of the 200 West Area during the 1950s. Chromium concentrations remain elevated in groundwater near both of these potential source locations. In well 699-34-72, downgradient from the 216-S-20 Crib, a chromium concentration of 30 µg/L was detected in a filtered sample collected during July 2008. In well 299-W26-13 at the 216-S-10 Pond, chromium was detected at 87 µg/L in a filtered sample in December 2010.

11.1.7 Chlorinated Hydrocarbons

Carbon tetrachloride concentrations exceed the 5 µg/L DWS in numerous wells within the 200-UP-1 OU. This constituent originates from disposal sites in the 200-ZP-1 OU.

Carbon tetrachloride occurs above the DWS (5 µg/L) in numerous wells within the 200-UP-1 OU, and the maximum concentration exceeded ten times the DWS in thirty wells during the year. The highest concentrations occur within and near the 200 West Area, with concentrations decreasing toward the east. At the water table, the plume is widespread in the southern portion of the 200 West Area and extends ~1 kilometer east into the 600 Area (Figure 12-4 in Chapter 12.0). The plume originated from waste disposal sites associated with the Plutonium Finishing Plant in the 200-ZP-1 OU. Concentration trends vary, with different wells exhibiting increasing trends, stable trends, or declining trends, and no clear spatial pattern is evident among the wells with increasing or decreasing trends.

A cross section of the carbon tetrachloride plume is shown in Figure 11-21. In the eastern portion of the plume, concentrations generally increase with depth in the unconfined aquifer. This indicates that the plume occurs at greater depths as it migrates east. The highest carbon tetrachloride concentration measured during the year was 1,200 µg/L in well 299-W14-71, which is screened from 40.7 to 45.2 meters below the water table, just above the Ringold lower mud unit. Chapter 12.0 provides additional information regarding carbon tetrachloride in the 200 West Area.

Within the U Plant pump-and-treat area, carbon tetrachloride concentrations at all wells exceeded the 5 µg/L DWS. The maximum concentration within the baseline plume area was 480 µg/L in extraction well 299-W19-36 (June 2010). Given the size of the carbon tetrachloride plume and the relatively low pumping rates, groundwater extraction is not having any discernable effect on carbon tetrachloride concentrations in this area.

Carbon tetrachloride and chloroform concentrations generally increase with depth in the eastern portion of the 200-UP-1 OU.

Chloroform is a degradation product of carbon tetrachloride and tends to occur in the same wells with carbon tetrachloride. Thus, some natural degradation of carbon tetrachloride may be occurring, although chloroform was likely introduced to the aquifer from the 2607-Z Tile Field (Chapter 12.0). During the year, 104 chloroform analyses were performed on samples from 53 wells within the 200-UP-1 groundwater interest area, and no exceedances of the DWS (80 µg/L for total trihalomethanes) were observed. The maximum concentration measured was 12 µg/L in well 299-W15-37, located north of the WMA U tank farm. Depth-discrete sampling during new well installation has indicated that concentrations tend to increase with depth, similar to carbon tetrachloride.

Trichloroethene is found in the 200-UP-1 OU above the DWS (5 µg/L) near the U Plant pump-and-treat system, as well as to the north at well 299-W14-71. Depth-discrete sampling results during well drilling have shown that trichloroethene concentrations also tend to increase with depth. During the year, 104 trichloroethene analyses were performed on samples from 53 wells within the interest area, and the DWS was exceeded in only 2 wells (299-W14-71 and 699-38-70B). Both of these wells are screened deep within the unconfined aquifer, just above the Ringold lower mud unit. None of the wells monitoring the upper portion of the aquifer had trichloroethene concentrations that exceeded the DWS. The maximum concentration measured during the year was 8.8 µg/L in well 299-W14-71.

11.1.8 Strontium-90

Strontium-90 in groundwater occurs in only one location within the OU (well 299-W22-10, downgradient from the 216-S-1/2 Cribs). This well was last sampled in FY 2006 with a result of 27 pCi/L, which was above the DWS (8 pCi/L). The 216-S-1/2 Cribs received highly acidic waste from the REDOX Plant between 1952 and 1956. In 1955, the waste is believed to have corroded the casing of nearby well 299-W22-3 (located ~25 meters south-southeast of the 216-S-1/2 Cribs), which allowed the effluent to bypass the soil column and flow down the well directly into groundwater (based on information from the Waste Information Data System database). This is the postulated pathway by which strontium-90 may have reached groundwater at this location.

During the year, twenty analyses for strontium-90 were performed on samples collected from seven wells within the groundwater interest area. Only one detection was noted (2.1 pCi/L in well 299-W22-83). This result is likely a false positive, as strontium-90 was not detected in three other samples collected from this well during the year.

11.1.9 Other Constituents

Arsenic and cadmium are listed as COCs for groundwater monitoring within the 200-UP-1 OU (DOE/RL-92-76). During the year, 30 analyses were performed for arsenic in more than 10 wells, and 316 analyses were performed for cadmium in 43 wells. No confirmed detections above the DWS (10 µg/L for arsenic and 5 µg/L for cadmium) were observed in either filtered or unfiltered samples.

The constituent 1,4-dioxane has historically been detected in well 299-W22-20, near the 216-S-20 Crib. The maximum sample result was 160 µg/L during January 2003. The last sampling of this well was in August 2009, when 1,4-dioxane was detected at 39 µg/L. This well has since gone dry, so no further samples can be collected. Well 699-34-72 was installed ~230 meters east-southeast of well 299-W22-20 in 2008. There were no detections of 1,4-dioxane in this well during 2009, but a low-level detection occurred during 2010 at 5.8 µg/L. The source of this constituent is thought to be the 216-S-20 Crib. The sample results at well 699-34-72 suggest that concentrations decrease rapidly in the aquifer downgradient from the crib.

Selenium-79 is present in groundwater downgradient from WMA S-SX. Eight wells are routinely sampled for selenium-79 in this area, and detections were found in all but the two upgradient wells during the year. The maximum concentration was 322 pCi/L in well 299-W23-19. A DWS has not been established for selenium-79, but the U.S. Department of Energy (DOE) established a derived concentration guide of 20,000 pCi/L (100 mrem/year dose).

11.2 CERCLA Groundwater Activities

This section describes activities for the 200-UP-1 OU involving the RI, the status of the U Plant interim action pump-and-treat system, extended well purging for technetium-99 in the SX Tank Farm plume, and closeout of actions related to the 2006 CERCLA 5-year review (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*). Monitoring within the OU is controlled by a sampling and analysis plan, which is incorporated into the RI/FS work plan for the 200-UP-1 OU (DOE/RL-92-76, Appendix A) and is a revision of the original plan issued in June 2002 (DOE/RL-2002-10, *Sampling and Analysis Plan for the 200-UP-1 Groundwater Monitoring Well Network*). Appendix A, Table A-12 presents monitoring information for the 200-UP-1 OU, including a well list, sampling frequency, and a list of analytes.

The second CERCLA 5-year review was published in November 2006 (DOE/RL-2006-20). Only one issue and associated action were identified for the 200-UP-1 OU:

- **Issue 18.** *The remedial action objective for uranium was ten times the WAC 173-340 ("Model Toxics Control Act – Cleanup") cleanup standard of 48 µg/L. Since that time, the U.S. Environmental Protection Agency has established a DWS of 30 µg/L. Other issues remain to be addressed in the ROD, including the limited quarterly pumping requirement at well 299-W23-19, adjusting the pumping requirement for 200-UP-1 because of limited flow within the extraction well network, and technetium-99 groundwater contamination at other locations within the OU.*
  - **Action 18-1:** Prepare an explanation of significant difference for 200-UP-1 OU interim action ROD (EPA/ROD/R10-97/048, *Declaration of the Record of Decision Hanford 200 Area 200-UP-1 Superfund Site Benton County, Washington*).
  - **Response.** The *Explanation of Significant Differences for the Interim Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Washington* (EPA et al., 2009a) was issued in February 2009, and the interim action ROD was modified as follows:
    - The remedial action objective for uranium was reduced to 300 µg/L.
    - The requirement to extract groundwater at a rate of 190 liters per minute from existing extraction wells was replaced by a requirement to extract groundwater from existing or new extraction wells in accordance with an approved remedial design/remedial action work plan until the concentration of uranium and technetium-99 are less than or equal to their respective remedial action objectives for four consecutive quarters.
    - A requirement was added to sample well 299-W23-19 at WMA S-SX for technetium-99 quarterly and to purge a minimum of 3,785 liters of water during each sample event until the technetium-99 concentration is less than or equal to 9,000 pCi/L for four consecutive quarters.
    - The national primary DWS of 30 µg/L for uranium was added as an applicable or relevant and appropriate requirement for the treatment of the extracted groundwater.
    - Institutional controls were revised.
    - The cost estimate for the remedial action was revised.

The remedial design/ remedial action work plan for the 200-UP-1 OU was revised during 2010 to implement the explanation of significant differences issued in 2009.

The revised *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36, Rev. 3) was prepared to address these changes. In addition, the work plan also included the preliminary design for a pump-and-treat system targeting both the north and south technetium-99 plumes at the S and SX Tank Farms (at concentrations greater than 9,000 pCi/L), with treatment to occur at the 200 West Area groundwater treatment facility. The conceptual design provided in the work plan (DOE/RL-97-36) called for a single extraction well within each plume, with each well pumping at a rate of 132 to 170 liters per minute. As the remedial design was completed, a three-well extraction system, pumping at ~76 to ~114 liters per minute each, was specified to best meet work plan objectives. The three extraction wells will be located near existing monitoring wells 299-W22-44, 299-W22-50, and 299-W22-86. Preparation of a sampling and analysis plan to support installation of the extraction wells was in progress at the end of the year.

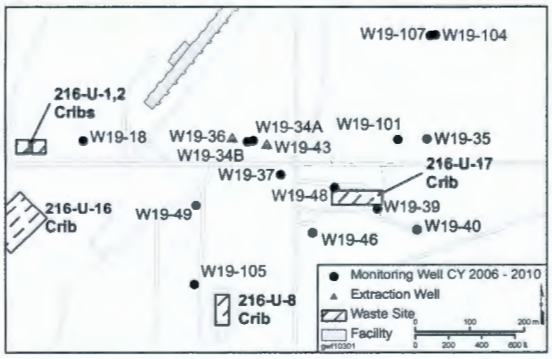
11.2.1 Remedial Investigation/Feasibility Study

An interim-action pump-and-treat system is being designed to address the technetium-99 plumes at the S and SX Tank Farms.

The draft RI/FS (DOE/RL-2009-122, Draft A) and proposed plan (DOE/RL-2010-05, *Proposed Plan to Amend the 200-ZP-1 Groundwater Operable Unit Record of Decision to Include the Remedial Actions for the 200-UP-1 Groundwater Operable Unit*, Draft A) were released during September 2010, meeting Tri-Party Agreement Milestone M-015-17A. By the end of the year, review comments had been received from the U.S. Environmental Protection Agency.

11.2.2 U Plant Pump-and-Treat System

E.J. Freeman, M.E. Caron, and M.J. Tonkin



Draft RI/FS and proposed plan reports were issued during 2010.

The U Plant pump-and-treat system is intended to reduce uranium and technetium-99 concentrations within the groundwater plume from the 216-U-1/2 Cribs. The *Record of Decision for the 200-UP-1 Interim Remedial Measure* (EPA/ROD/R10-97/048), as modified by the explanation of significant differences (EPA et al., 2009a), identifies the remedial action objectives that address plume concentrations and target locations for remediation. The primary COCs for the pump-and-treat system are uranium and technetium-99, and the co-contaminants are carbon tetrachloride and nitrate. Groundwater pumped from the two active 200-UP-1 extraction wells (299-W19-36 and 299-W19-43) is transported by pipeline to the Liquid Effluent Retention Facility (LERF) and is then processed at the Effluent Treatment Facility (ETF). This section provides a summary of system operation and monitoring results for 2010. For additional details, see the *Calendar Year 2010 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations* (DOE/RL-2011-26).

11.2.2.1 Changes in 2010

During the year, no configuration changes were made to the extraction wells and no new wells were drilled to supplement the monitoring network.

11.2.2.2 Extraction System Performance

The U Plant pump-and-treat system began formal operations in 1995 after a treatability test in 1994. In July 2003, after 9 years of operation, the system successfully reached the then-current remedial action objectives for uranium and technetium-99 concentrations (480 µg/L for uranium, and 9,000 pCi/L for technetium-99). Following a year of optimized operation, the system was shut down

The interim remedial action objectives for the 200-UP-1 pump-and-treat system are as follows (EPA/ROD/R10-97/048, as modified by EPA et al., 2009a):

- ***Reduce contamination in the area of highest concentrations of uranium and technetium-99 to below 300 µg/L for uranium and 9,000 pCi/L for technetium-99.***
- ***Reduce potential adverse human health risks through reduction of contaminant mass.***
- ***Prevent further movement of these contaminants from the highest concentration area.***
- ***Provide information that will lead to development and implementation of a final remedy that will be protective of human health and the environment.***

to conduct a year-long rebound study from January 2005 to January 2006. The system remained in hot-standby status until April 19, 2007, when it was restarted. Except for minor unplanned equipment malfunctions and regular planned outages, the system operated until August 6, 2008, at which time both extraction wells were shut down to support ETF system modifications and upgrades. The wells were restarted on November 17, 2008, and were operational except for minor unplanned and planned service outages until October 14, 2009, when the wells were again shut down due to work at the ETF. The wells were restarted in May 2010.

At the U Plant pump-and-treat system, extraction wells 299-W19-36 and 299-W19-43 operated approximately one-third of the time during 2010, but flow rates were low.

An ongoing issue with the U Plant pump-and-treat system is the low production from the extraction wells. Prior to the explanation of significant differences (EPA et al., 2009a), there was a requirement to pump at a combined extraction rate of 190 liters per minute. However, both extraction wells combined were pumping less than 30 liters per minute on average during operational periods in 2010. Both extraction wells were rehabilitated twice during 2010 with the goal of increasing production. The rehabilitation consisted of well screen acid washing during March/April, and then the use of AirBurst™ (trademark of Frazier Industries, Inc., Muskego, Wisconsin.) technology during August/September. With the latter technique, an air gun is used to generate a shock wave causing high-velocity movement of water within the well screen that removes encrusted scale, biomass, and sedimentation from the screen and surrounding formation. These efforts were generally not successful, resulting in an increase of less than an 8 liters per minute in total flow rate.

The two extraction wells operated for slightly more than one-third of the time during 2010. Extraction well 299-W19-36 operated from May 18 to July 6, 2010, and from September 20 to December 31, 2010. Extraction well 299-W19-43 operated from May 5 to August 26, 2010, and from October 21 to November 13, 2010. Well 299-W19-36 was online a total of 3,091 hours, with an average monthly operational percentage of 35.0%. Well 299-W19-43 was online a total of 3,292 hours with an average monthly operational percentage of 37.4%. Well 299-W19-36 had a total of 5,669 hours of downtime, while well 299-W19-43 had a total of 5,468 hours of downtime. Much of this downtime was related to ETF system modifications and well rehabilitation. Well 299-W19-36 also suffered a pump failure during the latter part of the year.

During operations, extraction well 299-W19-36 had a pumping rate ranging from less than 0.1 to 24.9 liters per minute. Including downtime, well 299-W19-36 had an annual average pumping rate of 5.2 liters per minute for the year. Extraction well 299-W19-43 had a pumping rate of less than 0.1 to 19.5 liters per minute during operations, for an annual average rate of 4.1 liters per minute. Together, the extraction

During the year, 4.9 million liters of water were extracted from the aquifer by the U Plant pump-and-treat system.

wells removed 4.9 million liters of water from the aquifer during 2010. This water was discharged to the ETF's liquid effluent retention basin #43. Table 11-1 presents the volume of water extracted and a summary of operational parameters for 2010.

11.2.2.3 Capture Zone Analysis

This section presents the estimated extent of capture for the U Plant pump-and-treat system during CY 2010. The capture analysis was performed using a water-level mapping method that incorporates drawdown in response to withdrawal of water from the extraction wells. The method is fully described in *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance* (SGW-42305).

Capture estimation followed a three-step procedure. First, weekly water-level maps (as numerical grids) were prepared using flow rates from the extraction wells and automated water-level data from a network of wells in the pump-and-treat system vicinity. The grids were generated only during periods of system operation (i.e., downtime periods were excluded). The grids were developed using universal kriging with an additional drift term in the kriging equation to represent the extraction wells (SGW-42305). Second, particle tracking was used for each grid to estimate the extent of capture. Finally, the results of the particle tracking were "rolled up" into a capture frequency map, which depicts the frequency with which each particle terminates at an extraction well across all the water-level grids. A frequency of 1.0 indicates that the particle is captured on every water-level grid; a frequency of zero indicates that a particle is not captured on any grid; and intermediate frequencies indicate that the particle is captured on some grids and not on others. A 0.5 contour on a capture frequency map indicates that particles on that contour were captured on 50% of the water-level grids. Thus, a capture frequency map can be thought of as capture probability. The advantage of capture frequency maps in depicting capture is that they incorporate uncertainty and/or variability in groundwater flow directions and varying flow rates from the extraction wells. Grid generation, particle tracking, and capture frequency map preparation were performed using the KT3D_H2O software ("KT3D_H2O: A Program for Kriging Water Level Data Using Hydrologic Drift Terms" [Karanovic et al., 2009]). The water table grids used in this analysis were two-dimensional and based on wells screened in the upper portion of the aquifer, so the resulting capture analysis is most applicable to the upper part of the aquifer.

In Figure 11-22, the CY 2010 capture frequency map for the U Plant pump-and-treat system is shown in relation to the uranium plume contours. The capture zone is represented by capture frequencies of 0.5 or greater. Due to the low flow rates from the extraction wells, the extent of capture is relatively small. The capture zone was larger in past years when pumping rates were greater. Thus, the system has been successful in reducing uranium plume concentrations to below 300 µg/L (and technetium-99 concentrations to below 9,000 pCi/L) when the capture zone was larger. In the future, however, it is clear that this system will not be very effective in capturing the uranium plume at lower concentrations as might be required for a final remedy.

11.2.2.4 Treatment System Performance

The ETF was offline from late 2009 until February 17, 2010, for system upgrades. The extraction wells were not brought back online until May 2010, following the acid wash rehabilitation. The mass of contaminants removed from the aquifer during 2010, as well as the totals since startup in March 1994, are listed in Table 11-2. During 2010, the U Plant pump-and-treat system removed 0.9 kilograms of uranium,

1.47 grams (0.025 curies) of technetium-99, 0.9 kilogram of carbon tetrachloride, and 2,092 kilograms of nitrate from the groundwater. Contaminant concentrations in the effluent after treatment at the ETF were below regulatory limits during all of 2010.

During the year, the U Plant pump-and-treat system removed 0.9 kilograms of uranium, 1.47 grams (0.025 curies) of technetium-99, 0.9 kilograms of carbon tetrachloride, and 2,092 kilograms of nitrate from the aquifer.

11.2.2.5 Contaminant Monitoring

This section discusses the contaminant monitoring results and plume changes from the previous year. Figures 11-23, 11-24, 11-25, and 11-26 show the uranium, technetium-99, carbon tetrachloride, and nitrate groundwater monitoring results for the year, as well as the long-term concentration trends from the U Plant pump-and-treat system wells (see Figure 11-1 for well locations).

The overall distribution of contaminants in 2010 was very similar to the distribution observed in 2009. The groundwater plume for uranium is shown in Figure 11-27 (based on average sample results for the year) and is generally similar to the plume from the previous year (DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009*, Figure 6-21). However, the area bounded by the 300 µg/L contour (the uranium remedial action objective) does not extend as far downgradient as it did in 2009, primarily because the concentration in extraction well 299-W19-43 has declined to below 300 µg/L (Figure 11-23). Throughout 2010, uranium sample results were below the current remedial action objective of 300 µg/L at all wells within the area targeted for remediation (i.e., the baseline plume area). The maximum concentration measured within the baseline plume area during the year was 257 µg/L in extraction well 299-W19-43. Well 299-W19-37 had a uranium concentration of 322 µg/L in March 2008, but this well has since gone dry and can no longer be sampled (this value is shown on the plume map in Figure 11-27 but is not used for contouring because the value is 2 years old). Concentrations at most wells continue to exceed the DWS of 30 µg/L. In general, the extent of the uranium plume above the DWS has not responded to pumping as well as the technetium-99 plume because, as described in Section 11.1, uranium sorbs to sediment grains and is only considered moderately mobile in the aquifer.

Uranium sample results within the U Plant pump-and-treat system area were below the 300 µg/L remedial action objective throughout the year.

The uranium plume immediately downgradient of the 216-U-1/2 Cribs remains stable, with no change between 2009 and 2010 noted in uranium concentrations in proximal downgradient well 299-W19-18 (416 µg/L in August 2009, and 417 µg/L in March 2010). Although the main mass of mobile uranium has already passed this near-source location, the stabilization of concentrations at an elevated level in this well suggests residual drainage from the vadose zone or continuing releases (i.e., desorption) from the aquifer sediments.

The technetium-99 plume is shown in Figure 11-28. Technetium-99 concentrations in all monitoring wells in the baseline plume area remained below the 9,000 pCi/L remedial action objective during 2010, and concentrations have been below the remedial action objective in all wells since late 2007 (i.e., the last sample result above the remedial action objective was 11,000 pCi/L in well 299-W19-36 from October 2007). The maximum concentration measured during 2010 was 7,100 pCi/L in extraction well 299-W19-36, collected on June 1, 2010. However, a sample collected 2 weeks later had a technetium-99 result of 5,500 pCi/L. Carbon tetrachloride exceeded the 5 µg/L DWS in all monitoring wells (maximum of 380 µg/L in 299-W19-36), and nitrate exceeded the 45 mg/L DWS in most wells (maximum of 1,080 mg/L in 299-W19-43). In general, the trends for technetium-99, carbon tetrachloride, and nitrate continue to be stable or slightly declining, with little change from 2009.

Technetium-99 sample results within the U Plant pump-and-treat system area were below the 9,000 pCi/L remedial action objective throughout the year.

11.2.3 Extended Purging of Well 299-W23-19

The feasibility of using well 299-W23-19 as a pump-and-treat extraction well to remediate the southern plume from the SX Tank Farm was investigated in 2001. After aquifer testing in this well, it was concluded that the production capacity was too small for a pump-and-treat system (RPP-10757, *Technetium-99 in Groundwater at Hanford Well 299-W23-19: Options Analysis and Recommended Action Report*, Section 6.0). To perform some remediation of the technetium-99, the practice of extended purging during sampling at well 299-W23-19 was agreed to by DOE and the Washington State Department of Ecology (Ecology) and began in 2003. This agreement was formalized in the explanation of significant differences for the 200-UP-1 OU (EPA et al., 2009a) (see Section 11.2). After samples are collected from this well each quarter, well purging is continued at a higher flow rate until a minimum of 3,785 liters of water are removed from the aquifer. This water is transferred to the ETF for treatment and disposal. This practice has the objective of reducing the technetium-99 concentration in the aquifer and will continue until four consecutive quarterly sample results are below 9,000 pCi/L, or until another remedy is implemented.

Table 11-3 presents the date, amount of water collected, and a calculation of the mass and activity of technetium-99 removed from the aquifer. A total of ~0.0012 curies (~0.07 grams) of technetium-99 were recovered during the year. Since the start of this treatment in 2003, ~0.0097 curies (~0.57 grams) of technetium-99 have been recovered.

11.3 Facility Monitoring

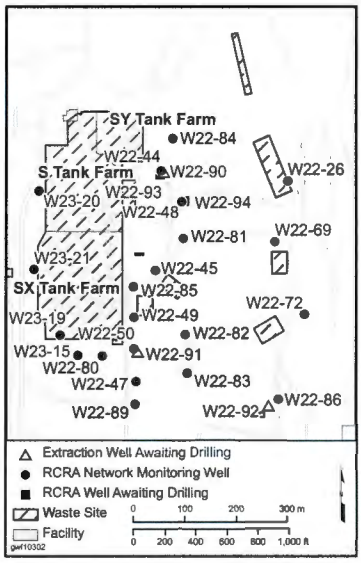
This section describes the results of monitoring for individual waste management or disposal facilities. Some of these facilities are monitored under RCRA requirements for dangerous waste constituents and AEA for source, special nuclear, and byproduct materials. Data from facility-specific monitoring also are integrated into the CERCLA groundwater investigations. As discussed in Chapter 1.0 pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are regulated by DOE, acting pursuant to its AEA authority.

Detailed groundwater monitoring is conducted at four facilities in the 200-UP-1 OU. Three of these sites are monitored in accordance with RCRA regulations. Interim status groundwater quality assessment monitoring was conducted at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring was conducted at the 216-S-10 Pond and Ditch (S-10 unit). Groundwater monitoring at the ERDF is conducted in accordance with a CERCLA ROD (EPA/ROD/R10-95/110, *Record of Decision: U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*). Groundwater data for these facilities are available from the Hanford Environmental Information System database and the data files accompanying this report.

11.3.1 Waste Management Area S-SX

The WMA S-SX consists of two tank farms: the S Tank Farm and the SX Tank Farm. The S Tank Farm consists of twelve tanks, each with a capacity of 2.9 million liters. The SX Tank Farm consists of fifteen tanks, each with a capacity of 3.8 million liters (RPP-7884, *Field Investigation Report for Waste Management Area S-SX*, Section 1.2). The WMA also includes ancillary equipment consisting of three

catch tanks, one receiver tank, six diversion boxes, associated piping, valve pits, and pumps (RPP-7884, Section 1.2). Both tank farms received waste generated from the reduction-oxidation process (REDOX Plant) in the 1950s and 1960s.



The stratigraphy beneath WMA S-SX consists of unconsolidated to semiconsolidated sediments overlying basalt bedrock of the Columbia River Basalt Group. The sedimentary units present, in descending sequence, are sand and gravel backfill, sand and gravel of the Hanford formation, fine-grained CCU (see Chapter 2.0, Section 2.1.3), sand and gravel of Ringold unit 5, fine-grained Ringold lower mud unit, and sand and gravel of Ringold unit 9 (which overlies the basalt). The water table occurs within Ringold unit 5, and the vadose zone beneath the WMA is ~68 meters thick. The base of the aquifer is the fine-grained Ringold lower mud unit. The water table elevation is ~135 m (North American Vertical Datum of 1988 [NAVD88]), and the unconfined aquifer is ~70 meters thick. A more detailed description of the geology of the WMA is provided in Section 2.2 of *Subsurface Conditions Description for the S-SX Waste Management Area* (HNF-4936) and Appendix B of *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site* (PNNL-12114). PNNL-13858 describes the hydrogeology of the entire 200 West Area and vicinity. See RPP-7884 for a discussion of vadose zone conditions beneath the waste management area.

Groundwater monitoring is conducted at WMA S-SX in accordance with WAC 173-303-400 ("Dangerous Waste Regulations," "Interim Status Facility Standards") and, by reference, 40 CFR 265, Subpart F ("Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring"), which requires monitoring to determine whether dangerous waste or dangerous waste constituents from the waste site have entered the groundwater. The WMA was placed into assessment status (40 CFR 265.93[d], "Preparation, Evaluation, and Response," as referenced by WAC 173-303-400) in 1996 at the direction of Ecology due to elevated specific conductance in downgradient monitoring wells. The first determination assessment found that multiple sources within the WMA had affected groundwater quality with elevated concentrations of nitrate and chromium in wells downgradient of the WMA (PNNL-11810, Section 5.0). The current objective of RCRA monitoring at WMA S-SX is to assess the nature and extent of groundwater contamination with dangerous constituents and determine their rate of movement in the aquifer. Groundwater monitoring under the AEA tracks radionuclides in the vicinity of the WMA.

Groundwater was monitored during 2010 in accordance with *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site,* Interim Change Notice 4 (PNNL-12114-ICN-4). A new monitoring plan was prepared during the year and issued in January 2011 (DOE/RL-2009-73, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX*). The major change was the reduction of the sampling frequency for all but four of the network monitoring wells from quarterly to semiannual or annual. The new monitoring plan will be implemented in 2011.

Appendix B includes a well location map (Figure B-16) and a list of the wells and constituents monitored for WMA S-SX (Table B-33). During the year, quarterly sampling was conducted in monitoring wells for the RCRA constituent chromium, supporting constituent nitrate, as well as the AEA constituent technetium-99. Alkalinity, as well as major anions and cations, were also sampled quarterly as supporting constituents. The monitoring wells were sampled annually for the AEA

constituent tritium, and a subset of wells were sampled annually for selenium-79. Annual sampling is also conducted in well 299-W23-19 for gross alpha and gross beta.

The planned sampling for all but two wells in the monitoring network was completed as scheduled during the year. The third quarter sampling for well 299-W22-85 was missed due to a maintenance issue, and the fourth quarter sampling for well 299-W23-20 was missed due to the sampling stop work (Section 1.2).

11.3.1.1 Network Evaluation and Compliance Status

For 2010, the monitoring network at WMA S-SX formally consisted of nineteen wells (two upgradient wells, sixteen downgradient wells, and one well within the WMA). One additional well (299-W22-26), located downgradient from the S Tank Farm, was informally added to the network in March 2008. In addition, a new monitoring well, 299-W22-89, was installed during the year ~50 meters south of well 299-W22-47 to bound the southern extent of the SX Tank Farm plume in this area. Both of these additional wells were formally added to the monitoring network in the new monitoring plan (DOE/RL-2009-73). DOE believes the revised well network is capable of monitoring the distribution of contamination at this WMA.

During the year, the water table elevation declined at an average rate of 0.22 meters per year in the monitoring wells, which was similar to the long-term rate of decline since 2006 of 0.26 meters per year. Analysis of water-level data collected during March 2010 indicated that the hydraulic gradient is 1.7×10^{-3} m/m nearly due east (88 degrees azimuth), and the groundwater flow rate (i.e., average linear velocity) ranges from 0.011 to 0.27 meters per day (4 to 100 meters per year), depending on the hydraulic conductivity and effective porosity selected. Using values of 6.1 meters per day for the hydraulic conductivity and 0.12 for the effective porosity (average values from multiple constant-rate pumping tests in wells at the WMA [PNNL-13514, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*; PNNL-14113, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*; PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*]), the groundwater flow rate most representative for this site is 0.088 meters per day (32 meters per year). This is consistent with a previous estimate of 0.096 meters per day (35 meters per year) based on the movement of chromium, nitrate, and technetium-99 between wells (PNNL-12114, Section 5.1.1).

The WMA S-SX will remain in interim status groundwater quality assessment monitoring in accordance with 40 CFR 265.93(d), as referenced by WAC 173-303-400 for CY 2011.

11.3.1.2 Groundwater Contaminants

Dangerous Waste and Supporting Constituents. Groundwater beneath WMA S-SX is contaminated with the dangerous waste constituent chromium and supporting constituent nitrate. This contamination is attributed to two general source areas within the WMA: (1) a source area in the S Tank Farm, and (2) a source area located to the south in the SX Tank Farm. Nitrate also has other sources in the vicinity, most notably the 216-S-25 Crib. Figures 11-29 and 11-30 show the nitrate and chromium plumes using average concentrations for CY 2010. Carbon tetrachloride also is present in groundwater beneath the WMA (Figure 12-4 in Chapter 12.0), but the sources are waste sites outside the 200-UP-1 OU in the vicinity of the Plutonium Finishing Plant.

In the plume downgradient from the S Tank Farm, concentrations of chromium and nitrate were largely stable during the year in well 299-W22-44

(Figure 11-10). Concentrations increased rapidly in this well between 2006 and 2008. Peak concentrations in this well during the year were 702 µg/L for dissolved chromium (December 2010) and 275 mg/L for nitrate (March 2010) (the DWSs are 100 µg/L for chromium and 45 mg/L for nitrate). Concentrations of these constituents continue to increase in well 299-W22-26 (further downgradient from the S Tank Farm). In this well, chromium increased to above the DWS during the year and had a peak concentration of 131 µg/L in December 2010. The peak nitrate concentration was 98 mg/L (December 2010). Concentrations of these constituents in upgradient well 299-W23-20 for the S Tank Farm were ~10 mg/L for nitrate and nondetect for chromium, indicating that the S Tank Farm is the source. Tank S-104 is the only tank within the S Tank Farm known to have had a leak/release (from an overfill event). A surface electrical-resistivity survey conducted during FY 2006 indicated that a portion of the vadose zone plume beneath tank S-104 at the 2- to 5-ohmmeter level had apparently reached groundwater (RPP-RPT-30976, *Surface Geophysical Exploration of S Tank Farm at the Hanford Site*, Figure 10). This is the likely source of the S Tank Farm groundwater plume.

Concentrations of mobile tank waste constituents in well 299-W22-44 at the S Tank Farm were relatively stable during the year, with maximum values of 275 mg/L for nitrate, 702 µg/L for chromium, and 18,000 pCi/L for AEA constituent technetium-99.

Groundwater beneath the SX Tank Farm in the southern portion of the WMA is also contaminated with chromium and nitrate. In groundwater, these constituents extend from the source area (near well 299-W23-19) toward the east-southeast ~450 meters at levels above the DWSs (Figures 11-30 and 11-29). Low-concentration areas are depicted in these plumes around wells 299-W22-80 and 299-W23-15. An in-well tracer test at well 299-W22-80 (PNNL-14113, Section 8.3) and time-series sampling during extensive purging indicated that relatively clean water may be migrating into the bottom of the well, moving up the wellbore, and diluting plume concentrations in the upper portion of the plume (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*, Section 2.9.3.2). A similar process is assumed to be occurring at well 299-W23-15. In the source area, concentrations of these constituents in well 299-W23-19 exhibited slight decreasing trends during the year, with peak concentrations of 1,180 µg/L for chromium (April 2010) and 491 mg/L for nitrate (July 2010) (Figure 11-8). At far downgradient well 299-W22-86, the chromium concentration increased above the DWS during the year, reaching a peak concentration of 124 µg/L in an unfiltered sample during December 2010.

Concentrations of mobile tank waste constituents in well 299-W23-19 at the SX Tank Farm exhibited slight decreasing trends during the year, with maximum values of 1,180 µg/L for chromium, 491 mg/L for nitrate, and 65,000 pCi/L for technetium-99.

When new well 299-W22-89 was installed ~50 meters south of 299-W22-47, depth-discrete groundwater samples were collected during drilling from near the water table to a depth of 30 meters at ~6.1-meter intervals. No substantial contamination was found at this location. Nitrate concentrations ranged from 8 mg/L near the water table to background levels (between 1 and 3 mg/L) at depth, and chromium was not detected at all (13 µg/L detection limit). Thus, this well has eliminated the uncertainty regarding the southern extent of the plumes in the near-source vicinity, and the interpretation of the plume contours did not appreciably change from that presented in previous years (Figures 6-22 and 6-23 in the 2009 annual groundwater report [DOE/RL-2010-11]).

AEA Constituents. Plumes of the AEA constituent technetium-99 occur in groundwater beneath and downgradient from WMA S-SX in association with chromium and nitrate (Figure 11-31). Technetium-99 is also attributed to releases from the tank farms. In the north plume from the S Tank Farm, concentrations were stable during the year at 17,000 to 18,000 pCi/L (Figure 11-10). At well 299-W22-26 further downgradient, concentrations continued to increase, reaching 6,000 pCi/L at the end of the year (Figure 11-11). This plume is interpreted to extend ~450 meters

downgradient from the likely source (tank S-104) at concentrations above the 900 pCi/L DWS.

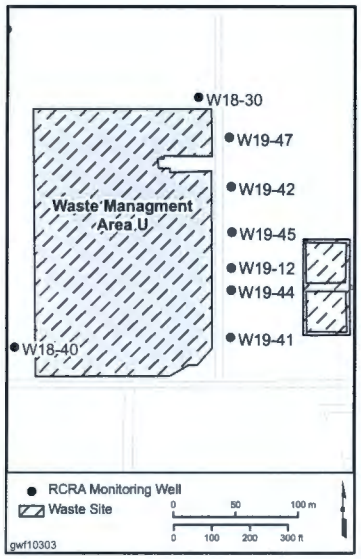
In the south plume from the SX Tank Farm, technetium-99 concentrations at well 299-W23-19 within the source area were generally stable during the year, fluctuating between 49,000 and 65,000 pCi/L. Extended purging during quarterly sampling is conducted in this well as a remedy under CERCLA for technetium-99 (Section 11.3.3). Technetium-99 was barely detectable in new well 299-W22-89. Results of the depth-discrete groundwater sampling during drilling ranged from nondetect to 12 pCi/L. Thus, similar to the situation with chromium and nitrate, the interpretation of the plume contours did not appreciably change from that presented in previous years (e.g., Figure 6-24 in DOE/RL-2010-11, the 2009 groundwater monitoring report). At far downgradient well, 299-W22-86, the technetium-99 concentration increased to 10,000 pCi/L during the year. This plume is interpreted to extend ~450 meters downgradient at concentrations above 9,000 pCi/L, and ~650 meters downgradient at concentrations above the DWS.

Remediation of the technetium-99 plumes from the S and SX Tank Farms will occur under CERCLA, and an interim action pump-and-treat remediation system was in the planning stage during 2010. Three extraction wells are scheduled to be installed during 2011 near existing wells 299-W22-44, 299-W22-86, and 299-W22-50, in support of Tri-Party Agreement Milestone M-016-120.

Other AEA constituents occurring in the groundwater beneath and downgradient from the WMA are selenium-79 and tritium. Eight wells are routinely sampled for selenium-79 in this area, and there were detections in all but the two upgradient wells during the year. The maximum concentration was 322 pCi/L in 299-W23-19. The concentrations are co-variate with technetium-99 indicating that the WMA is the source. There is no established DWS for selenium-79, but the DOE established a derived concentration guide of 20,000 pCi/L (100 mrem/year dose). The concentration equivalent to a 4 mrem/year dose is 800 pCi/L; all reported concentrations are below this value. The tritium originates from the 216-S-25 Crib, located just west (upgradient) of the SX Tank Farm (PNNL-13441, *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX [November 1997 through April 2000]*, Section 3.3) and was discussed in Section 11.1.3.

11.3.2 Waste Management Area U

The WMA U contains sixteen underground single-shell tanks constructed between 1943 and 1944. Twelve of the single-shell tanks have capacities of 2 million liters and four have capacities of 210,000 liters (RPP-35485, *Field Investigation Report for Waste Management Area U*, Section 1.2). The WMA also contains a variety of ancillary equipment used to manage tank waste during operations, including six diversion boxes, the 271-UR control house, the 244-UR process vault, the 244-U double-contained receiver tank, waste transfer lines, pits, and junction boxes.



The tank farm received waste from the bismuth phosphate process between 1946 and 1948, and from the REDOX process between 1954 and 1957 (WHC-MR-0132, *History of the 200 Area Tank Farms*). In 1952, some waste was retrieved and pumped to the 242-T evaporator, and between 1952 and 1957, the metal wastes (stored in nine of the 2-million-liter-capacity tanks) were transferred to U Plant for uranium recovery.

Groundwater monitoring is conducted at WMA U in accordance with WAC 173-303-400, and by reference 40 CFR 265, Subpart F, which requires monitoring to determine whether dangerous waste or dangerous waste constituents from the unit have entered the groundwater. The WMA U was placed into assessment

status in 2000 when specific conductance in groundwater monitoring wells downgradient of the WMA exceeded upgradient levels (PNNL-13185, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*, Section 1.1). An assessment of that finding determined that the WMA had affected groundwater quality based on elevated concentrations of nitrate and possibly chromium in wells downgradient of the WMA (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*, Section 6.0). Contaminant concentrations did not exceed their respective DWSs, and the affected area appeared to be limited to the southeastern corner of the WMA at that time. The current objective of RCRA monitoring at this WMA is to assess the nature and extent of groundwater contaminated with dangerous constituents and determine their rate of movement in the aquifer (40 CFR 265.93[d], as referenced by WAC 173-303-400). Groundwater monitoring under the AEA tracks radionuclides in the WMA and surrounding area. See RPP-35485 for a discussion of vadose zone conditions beneath the waste management area.

Groundwater was monitored during 2010 in accordance with the *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U*, Interim Change Notice 2 (PNNL-13612-ICN-2). A new monitoring plan was prepared during the year and issued during January 2011 (DOE/RL-2009-74, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*). The new plan will be the guiding document for groundwater monitoring at WMA U beginning in 2011.

During the year, quarterly sampling was conducted in the monitoring wells for the RCRA constituents chromium and nitrate, as well as the AEA constituent technetium-99. Alkalinity, as well as major anions and cations, were also sampled quarterly as supporting constituents. The monitoring wells were sampled annually for gross alpha, gross beta, and gamma emitters. The first quarter sampling of 299-W19-44 was missed due to a maintenance issue. Appendix B includes a well location map (Figure B-16) and a list of wells and constituents monitored for WMA U (Table B-36).

11.3.2.1 Network Evaluation and Compliance Status

The monitoring network at WMA U consists of eight wells sampled quarterly: one upgradient well and seven wells downgradient of the WMA. DOE believes the well network is currently capable of monitoring the distribution of contamination from the WMA; however, well 299-W18-30 is nearly dry. All new RCRA wells proposed for installation at the Hanford Site are negotiated annually by Ecology, DOE, and EPA under Tri-Party Agreement Milestone M-24-00. Two new replacement wells have been proposed for WMA U: one for 299-W18-30 and one for 299-W19-12, whose construction does not comply with the well construction standards found in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

Groundwater flow conditions at WMA U have varied over the past several decades due to changing wastewater disposal in areas surrounding the WMA, but flow has been generally to the east since 1996 (~80 degrees azimuth). The decline in monitoring well water levels has averaged 0.27 meters per year since 2006. Analysis of water-level data collected during 2010 indicated an average hydraulic gradient of 2.2×10^{-3} m/m in a direction of 87 degrees azimuth (east). The groundwater flow rate (i.e., average linear velocity) ranged from 0.018 to 0.20 meters per day (7 to 75 meters per year), depending on the hydraulic conductivity and effective porosity selected. Using values believed to be most representative, 6.12 meters per day for

the hydraulic conductivity and 0.17 for the effective porosity from a constant-rate pumping test conducted in well 299-W19-42 (PNNL-13378, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*, Section 7.4), the groundwater flow rate most representative for this site is 0.077 meters per day (28 meters per year).

The WMA U will remain in interim status groundwater quality assessment monitoring, in accordance with 40 CFR 265.93(d), as referenced by WAC 173-303-400 for CY 2011.

11.3.2.2 Groundwater Contaminants

Dangerous Waste and Supporting Constituents. The WMA U has been identified as the source of groundwater contamination limited to the downgradient (east) side of the site (PNNL-13282, Section 6.0). The dangerous waste constituent chromium and supporting constituent nitrate were originally found in the groundwater, but monitored chromium concentrations have decreased in the past to below the analytical detection limit, where concentrations remained during the year. While chromium is highly mobile in the aquifer, it generally migrates slower than nitrate in the vadose zone beneath the tank farms. This has been attributed to a reduction process where iron(II) minerals in the sediment are dissolved by tank fluids, and the iron then reacts with the soluble chromium(VI) reducing it to chromium(III), which precipitates as an insoluble iron-chromium hydroxide (Zachara et al., 2004 and Qafoku et al,. 2003, as referenced by PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*). The reason chromium was initially found in the groundwater is not known, but this vadose zone reaction and the relatively low tank leak volumes that occurred at WMA U may explain the present lack of chromium in the groundwater.

During the year, nitrate concentrations exceeded the DWS (45 mg/L) in at least one sample from six of the network monitoring wells: 299-W19-12, 299-W19-42, 299-W19-44, 299-W19-45, 299-W19-47, and upgradient well 299-W18-40. The nitrate plume is shown in Figure 11-32. During the year, the nitrate concentration exceeded the DWS for the first time in upgradient well 299-W18-40 (maximum of 53 mg/L in December 2010), indicating an upgradient source. The maximum nitrate concentration measured in a quarterly sample was 82 mg/L in well 299-W19-45 during December 2010. Because concentrations are higher in the downgradient wells compared to the upgradient well, the WMA is a source of nitrate to the aquifer. In the past, nitrate concentrations had generally exceeded the DWS only in the southern downgradient wells, but that has now changed. Nitrate occurs above the DWS in most of the downgradient monitoring wells; only the northernmost and southernmost wells (299-W18-30 and 299-W19-41) have nitrate concentrations below the DWS.

Carbon tetrachloride is found in groundwater beneath WMA U at concentrations above the DWS of 5 µg/L. Well 299-W18-30 is the only well from which samples are collected and analyzed for carbon tetrachloride (CERCLA sampling). A sample collected in July 2010 yielded a result of 140 µg/L. The regional carbon tetrachloride distribution (Figure 12-4 in Chapter 12.0) indicates that the carbon tetrachloride found in the groundwater beneath WMA U originates from liquid waste disposal sites within the 200-ZP-1 OU.

Sources within WMA U have contaminated the groundwater with nitrate and technetium-99.

AEA Constituents. During the year, measured technetium-99 concentrations exceeded the DWS (900 pCi/L) in at least one sample from each well along the north downgradient side of the WMA (299-W18-30, 299-W19-42, 299-W19-45, and 299-W19-47). Concentrations had been generally increasing in each of these four wells, but concentrations declined during the year in wells 299-W18-30, 299-W19-42,

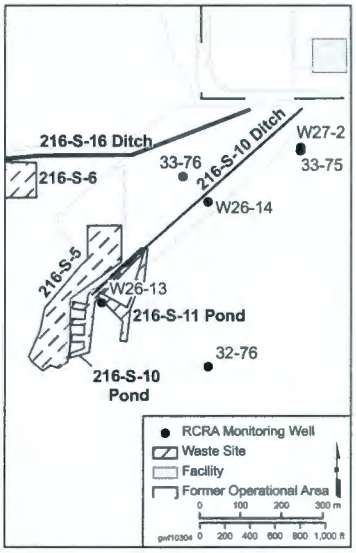
and 299-W19-47. The technetium-99 plume is also shown in Figure 11-32. The concentration in the upgradient well, 299-W18-40, was less than 50 pCi/L, indicating that the tank farm is the source of the technetium-99 contamination. The maximum technetium-99 concentration measured in a quarterly sample was 2,200 pCi/L in well 299-W19-42 during February 2010.

Technetium-99 concentrations are highest in the northern downgradient wells at WMA U, whereas nitrate concentrations are above the DWS in most of the downgradient wells.

11.3.3 216-S-10 Pond and Ditch

C.J. Martin

The 216-S-10 Pond and Ditch (referred to as the S-10 unit) is located off the southwestern corner of the 200 West Area, directly outside the perimeter fence (Figure 11-1). The site was active from 1951 through 1991 and received effluent primarily from the REDOX Plant chemical sewer. The groundwater beneath the S-10 unit is monitored under interim status regulations (40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis"; and 40 CFR 265.93[b], as referenced by WAC 173-303-400) to determine if dangerous waste constituents have impacted groundwater. A factor that complicates groundwater monitoring is adjacent non-RCRA waste disposal sites that have similar hydrogeologic controls and received similar waste streams during their operational life as at the S-10 unit. Hence, distinguishing between contamination contributions from these waste sites and the S-10 unit is difficult.



The S-10 unit was initially a single, open, unlined ditch (216-S-10 Ditch), ~1.2 meters wide at its base and 686 meters long. Discharge to the ditch was through a vitrified clay pipeline from the REDOX Plant. The 216-S-10 Pond was added to the southwest end of the 216-S-10 Ditch in 1954 to increase wastewater capacity. The 216-S-10 Pond covered ~2 hectares, and the shape resembled a backwards "E" with an extra leg, where each leg was a separate leaching trench. Wastewater discharged into the 216-S-10 Ditch flowed into the 216-S-10 Pond and evaporated or infiltrated into the ground. This infiltration created perched water in the vadose zone and created a groundwater mound on the underlying aquifer. In May 1954, increases in discharge to the S-10 unit necessitated the excavation of two additional ponds on the southeastern side of the 216-S-10 Ditch (i.e., 216-S-11 leach ponds). Wastewater flowed into the 216-S-11 Pond when levels in the 216-S-10 Ditch reached the elevation of the connecting ditch.

The conceptual model assumes that the large volume of wastewater discharged to the S-10 unit during its operational lifetime (6.6 x 10^9 liters) was sufficient to saturate the soil column down to groundwater beneath both the unlined ditch and the pond. Saturated conditions, combined with the fact that many of the COCs are known to be mobile (because they are anions or are non-charged chemical species), resulted in contaminants contained in the wastewater migrating through the soil column to groundwater. In addition, it is believed that several multi-valent metals (e.g., chromium and copper) were mobile via complexing agents or as oxymetallic anions (e.g., chromate and cuprate) and may have also migrated to the groundwater.

In September 1983, a documented dangerous waste discharge to the S-10 unit occurred (PNNL-15731, *Post-Closure RCRA Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*, Section 2.2). This waste was discharged to the pond and ditch and allowed to percolate into the soil column underlying the unit. In this incident, 416.4 liters of synthetic, double-shell tank slurry were discharged to the S-10 unit from the Chemical Engineering Laboratory. The waste consisted largely of

sodium nitrate (46%) and sodium hydroxide (41%), with small quantities of sodium phosphate, sodium fluoride, sodium chloride, and potassium chromate.

Groundwater is monitored at the S-10 unit in accordance with the *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch* (DOE/RL-2008-61). Most of the network wells are monitored semiannually for the contamination indicator parameters total organic halides, total organic carbon, pH, and specific conductance. Major dissolved anions, metals, mercury, alkalinity, turbidity, and temperature are also sampled semiannually as indicators of sample and analytical quality, as well as general aquifer/well background conditions. Phenols, Aroclor 1254, and benzo(a)pyrene have been identified as possible contaminants to the S-10 unit and are sampled annually. Additional groundwater monitoring for gross alpha and gross beta under the AEA is used to track the radionuclides beneath the unit and surrounding area. Groundwater samples from three wells installed in late CY 2008 (699-32-76, 699-33-75, and 699-33-76) were collected quarterly during CY 2010 to obtain data and establish baseline conditions. One upper aquifer well (299-W26-14) and one deep aquifer well (299-W27-2) are monitored annually for all the same constituents as listed above. Appendix B includes a well location map (Figure B-6) and a list of wells and constituents monitored for the S-10 unit (Table B-14).

During the year, groundwater samples were collected as scheduled, except during the fourth quarter. A site-wide sampling stop work went into effect on September 27, 2010, and was completely lifted by November 8, 2010. Wells 299-W26-13 and 299-W26-14 were sampled during the fourth quarter, but sampling of the remaining wells was cancelled due to the work stoppage.

11.3.3.1 Network Evaluation and Compliance Status

The declining water table in the 200 West Area has resulted in many wells going dry. Water levels in all of the original wells monitoring the upper aquifer at the S-10 unit have declined below their screened intervals. Prior to 2008, the monitoring network consisted of only two shallow downgradient wells and one deep downgradient well; all former upgradient wells were dry. The RCRA requirements for interim status monitoring specify a minimum of one upgradient and three downgradient monitoring wells to monitor the site. One new upgradient well (699-33-76) and two new downgradient wells (699-32-76 and 699-33-75) were installed in 2008. All three wells are screened across the upper portion of the aquifer. These three wells have been formally added to the network with issuance of the revised groundwater monitoring plan for this unit (DOE/RL-2008-61, the 216-S-10 monitoring plan).

Because the new wells underwent initial quarterly sampling in CY 2009 (with additional quarterly samples collected during CY 2010), it was anticipated that the new upgradient well (699-33-76) would be used for statistical comparisons during the year. However, extreme variability occurred in total organic carbon concentrations, which had a standard deviation greater than 2,300, leading to a critical mean in excess of 23,000 μg/L. Therefore, it was determined that a second year of data collection was needed to baseline the indicator parameters before being used as new background values. Thus, new background values were calculated for use in CY 2011 for the required upgradient/downgradient comparisons and are provided in Table B-15 in Appendix B. The existing critical mean total organic carbon was used for the CY 2010 comparison, while the calculated new values for pH, specific conductance, and total organic halide were used.

Groundwater flow conditions beneath the S-10 unit have varied greatly over the past several decades due to changing wastewater disposal practices on the site. Using the water table map for the 200-UP-1 OU (Figure 11-3) and measured head differences between network wells, the direction of groundwater flow near the S-10 unit is estimated to be to the east-southeast (110 degrees azimuth), which is consistent with flow over the past several years. Using an average hydraulic gradient of 2.2 x 10^{-3} m/m, a hydraulic conductivity range of 1.5 to 52 meters per day (range of hydrologic testing results), and an assumed effective porosity range of 0.1 to 0.2, the range of average linear velocities is 0.033 to 0.57 meters per day (12 to 209 meters per year). Using a best hydraulic conductivity value of 10.4 meters per day (constant-rate discharge test from well 299-W27-2 near the water table [WHC-SD-EN-DP-052, *Borehole Completion Data Package for the 216-S-10 Facility, CY 1992*]) and an assumed effective porosity of 0.15, the best-estimate average linear velocity is 0.15 meters per day (~56 meters per year). The rate at which the water table is declining remained constant at ~0.1 meters per year in all of the monitoring wells during 2010.

With the formal addition of the new wells to the monitoring network the S-10 unit is now in full compliance with the guiding regulations. The revised well network will continue to be evaluated annually to determine if it is capable of meeting the groundwater monitoring needs of the S-10 unit through the post-closure period. Based on the most recent determinations of groundwater flow direction, DOE believes the revised network is capable of detecting constituents migrating from the site into the uppermost aquifer.

To date, no dangerous waste subject to WAC 173-303 that can be directly linked to the S-10 unit has affected groundwater quality in the uppermost aquifer beneath the unit. The site will remain in detection monitoring for indicator parameters, as specified in 40 CFR 265.92 and 40 CFR 265.93(b) in CY 2011. A revised and updated monitoring plan, including the well network, COCs, sampling and analysis procedure, and a conceptual model, was completed and issued in March 2010 (DOE/RL-2008-61).

With the new wells installed at the S-10 unit, the monitoring well network will be capable of detecting potential releases from the site throughout CY 2011.

11.3.3.2 Groundwater Contaminants

As required by RCRA regulations (40 CFR 265.92 and 40 CFR 265.93[b], as referenced by WAC 173-303-400), the required indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) are statistically compared between the upgradient and downgradient wells of the formal monitoring network using the most recent data. As stated above, all parameters except total organic carbon from the new well were used to provide background values of contaminant indicator parameters in 2010. It is believed that the extreme variability in total organic carbon is the result of the aquifer re-establishing equilibrium after the impact of the well installation process. Values began to stabilize in CY 2010, and it is anticipated that the total organic carbon data from new upgradient well 699-33-76 will be available to calculate new critical means for use in the required upgradient/downgradient comparisons beginning in CY 2011.

No indicator parameter exceedances occurred during 2010 at the S-10 unit. With formal addition of the new wells to the network, well 699-32-76, downgradient of the 216-S-10 Pond, is close to exceeding the critical mean for specific conductance (Figure 11-33). This is not unexpected, as this well also has the highest concentrations of nitrate and sulfate, which are substantial contributors to specific conductance

No indicator parameter exceedances occurred at the S-10 unit during CY 2010.

(Figures 11-34 and 11-35, respectively). Additional investigations are ongoing at this unit to determine the cause of the high conductivity.

Hexavalent and total chromium are tracked because they are potential COCs associated with releases to the S-10 unit. Elevated total chromium concentrations at former upgradient well 299-W26-7 exceeded the DWS (100 µg/L) before the well went dry. The elevated total chromium may have been caused by short-term releases migrating through the vadose zone from past effluent releases to the 216-S-10 Pond or from nearby upgradient sources.

Although well 299-W26-7 was designated as an upgradient well, it is located very close to one lobe of the pond system and may have been affected by drainage spreading laterally in the vadose zone or by a mound on the water table when the S-10 unit was in operation. Although historical records document that the release in 1983 to the 216-S-10 Ditch contained hexavalent chromium, the assignment of chromium to the S-10 unit is complicated by the fact that a REDOX Plant disposal pond (located immediately upgradient of the S-10 unit) is also a potential source of chromium contamination. Because the S-10 unit cannot currently be ruled out as the source of the contamination, chromium remains a dangerous waste constituent for the unit. More recently, concentrations of both total and hexavalent chromium have continued to increase in well 299-W26-13, downgradient of the 216-S-10 Pond (up to 87 µg/L dissolved total chromium in December 2010). Total chromium and hexavalent chromium were also measured above the detection limits of 14 µg/L and 0.002 µg/L, respectively, in new well 699-32-76, which is downgradient of well 299-W26-13 and the 216-S-10 Pond (values of both constituents were less than 15 µg/L during 2010).

Concentrations of total chromium and hexavalent chromium continue to increase in well 299-W26-13, which is downgradient of the 216-S-10 Pond.

Nitrate concentrations were co-variate with chromium concentrations in older network wells 299-W26-7, 299-W26-9, 299-W26-10, and 299-W26-12 before the wells went dry. Former upgradient well 299-W26-7 had the highest nitrate concentrations. These and other data presented in the monitoring plan (DOE/RL-2008-61) suggest that the 216-S-10 Pond could be the source of the nitrate and chromium increase. Although chromium and nitrate were elevated in upgradient well 299-W26-7 before the well went dry, substantial concentrations of these constituents have not been detected in downgradient wells. Well 299-W26-13 (which replaced well 299-W26-9 and is located ~3 meters downgradient of the pond) shows the same covariate increases in nitrate and total chromium; chromium concentrations increased from 39 µg/L in June 2009 to 52 µg/L in June 2010 at the same time that nitrate increased from 19.1 to 21.2 mg/L. Neither constituent exceeds their respective DWS (i.e., 100 µg/L for chromium and 45 mg/L for nitrate). By comparison, new well 699-32-76 is over 300 meters downgradient of the pond and shows no increasing trend but has the same co-variate nature of chromium and nitrate, although concentrations are lower than at well 299-W26-13. By contrast, chromium in well 299-W26-14 (located away from the pond and centered along the ditch portion of the facility) remains essentially undetected. This difference may indicate a localized source near the pond.

Concentrations of barium, chloride, magnesium, and nickel in deep monitoring well 299-W27-2 continued to be significantly higher than in shallow wells during the year. Because nickel has not been detected in the shallow monitoring wells, the S-10 unit is not believed to be the source of these constituents.

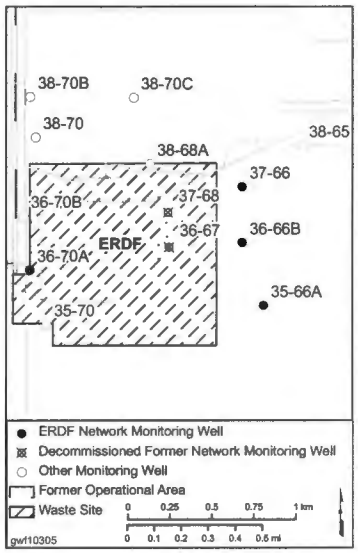
Carbon tetrachloride continued to be detected in all wells in the S-10 unit monitoring network. Concentrations in well 299-W27-2 have averaged above the DWS (5 µg/L)

since 2001. During 2010, concentrations fell below the DWS to 2.9 µg/L. New well 699-33-75, located near 299-W27-2, has the highest carbon tetrachloride results of any well in the S-10 unit network, with an average concentration of 22.3 µg/L during the year. Chloroform was previously detected in this well; however, since late CY 2009, concentrations have dropped below the 1.0 µg/L detection limit. The source of these constituents is believed to be liquid waste disposal sites at the Plutonium Finishing Plant because new upgradient well 699-33-76 also has measurable concentrations of carbon tetrachloride (average of 3.1 µg/L).

11.3.4 Environmental Restoration Disposal Facility

R.L. Weiss

The ERDF is a low-level radioactive mixed waste facility used for disposal of waste from surface remedial actions on the Hanford Site. The location of the ERDF is shown in Figure 11-1. Groundwater monitoring at the ERDF is regulated under a CERCLA ROD (EPA/ROD/R10-95/110), which states that groundwater monitoring will be conducted in accordance with RCRA regulations. The site was designed to meet RCRA standards, although it is not actually permitted as a RCRA facility. The ERDF began operation in July 1996. During CY 2010, ~1,791,000 tons of remediation waste were disposed at the facility.



Details of the leachate and groundwater monitoring programs associated with ERDF activities are provided in annual reports. The most recent report, *Groundwater and Leachate Monitoring and Sampling at ERDF, CY 2010* (WCH-455), was published in June 2011. A summary of the leachate monitoring and any potential impact the vadose zone might have on groundwater is provided in Section 11.3.4.1. The groundwater monitoring results for 2010 are discussed in Section 11.3.4.2.

11.3.4.1 Leachate Monitoring

The ERDF currently operates eight disposal cells, and two additional cells are under construction. Each disposal cell was constructed with a double-liner system to collect leachate from natural precipitation and water added as a dust suppressant. The collected leachate is sent to the ETF. The liners deliver the leachate to sumps beneath the cells, and the leachate is then pumped to two holding tanks where sampling occurs. Composite samples of leachate were collected in March and September 2010 and analyzed for selected metals, anions, selected organic compounds, total dissolved solids, gross alpha, gross beta, and selected radionuclides. Sampling in September 2010 included an expanded list of analytes (primarily for organic compounds) specified to be performed every 2 years. This expanded list is required to ensure that delisting criteria (necessary for the disposal path to the ETF) continue to be met. The analyses provide data for leachate delisting analyses and to assess whether additional analytes should be added to the routine ERDF groundwater monitoring program.

The results of leachate monitoring at the ERDF for 2010 indicated that the leachate could continue to be treated at the ETF and that no additional analytes need to be added to the groundwater monitoring program.

The composite leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. Evaluation of the reported constituents for the expanded analyte lists found no impact to the delisting criteria. The following is a summary of the analytes discussed in WCH-315:

- Bromide, which had been detected in recent years, was not detected in leachate samples in 2010.

- Chromium concentrations began declining during CY 2007. The chromium concentration averaged 29 µg/L in December 2006 but the 2010 average was ~20 µg/L.
- Potassium concentrations have declined from a maximum of ~26,000 µg/L to ~20,000 µg/L through 2010.
- Uranium concentrations, which have increased over the previous 3 years, reached a new maximum concentration of 3,060 µg/L in March 2010, but declined substantially to ~1,800 µg/L in September 2010.
- Nitrate concentrations remained steady through March 2010, averaging ~380 mg/L. A substantial decline to ~280 mg/L was seen in the September 2010 samples.
- Specific conductance remained steady during 2010.
- Total dissolved solids remained steady during 2010, averaging ~2,100,000 µg/L.
- Gross alpha concentrations averaged 1,450 pCi/L during 2010. Concentrations had been increasing, reaching a peak of 3,380 pCi/L in December 2008.
- Gross beta concentrations averaged 650 pCi/L during 2010. Similar to gross alpha, concentrations had been increasing, reaching a peak of 1,500 pCi/L in December 2008.

Gross alpha and gross beta in groundwater will be closely monitored in the future. However, based on the CY 2010 leachate concentrations, no additional analytes were recommended for the groundwater monitoring program.

11.3.4.2 Groundwater Monitoring

This section summarizes the 2010 groundwater monitoring results at the ERDF, which is described more fully in the ERDF 2010 annual groundwater and leachate monitoring report (WCH-455). The groundwater flow direction beneath the ERDF is toward the east-northeast. During 2008, former downgradient wells 699-36-67 and 699-37-68 were decommissioned to allow for expansion of ERDF to the east, and two new downgradient wells (699-37-66 and 699-36-66B) were constructed as replacements.

Groundwater at the ERDF is monitored in accordance with the *Groundwater Protection Plan for the Environmental Restoration Disposal Facility* (WCH-198). One upgradient well (699-36-70A) and three downgradient wells (699-37-66, 699-36-66B, and 699-35-66A) are sampled semiannually, typically in March and September. To detect impact to groundwater quality, sample results are compared to baseline conditions established when monitoring began in 1996 using a tolerance interval approach (WCH-198). All monitoring wells were sampled successfully during the year, although the September sampling was delayed until November due to the sampling stop work (Section 1.2). Appendix B includes a well location map (Figure B-21) and lists of the wells and constituents monitored for the ERDF (Table B-39).

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not adversely affected groundwater quality.

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not adversely affected groundwater quality. Several constituents (tritium, iodine-129, nitrate, and carbon tetrachloride) are present in the groundwater near or above DWSs, but these constituents are elevated in both the upgradient and downgradient wells. Figures 12-4 and 12-7 in Chapter 12.0, and Figures 11-14, 11-15, and 11-17 in this chapter indicate that these plumes originated in the 200 West Area and have migrated toward the ERDF.

The uranium concentrations in wells 699-36-70A and 699-35-66A are consistent with Hanford Site background levels. Both technetium-99 and gross beta are trending downward in upgradient well 699-36-70A. The technetium-99 concentration is an order of magnitude below the DWS (900 pCi/L), and gross beta is approximately one-half the DWS (50 pCi/L). The only analyses indicating upward trends are technetium-99 and gross beta (impacted by the technetium-99) in downgradient well 699-35-66A. The 2010 sample results showed maximums for this well but remained below historic maximums for other nearby wells. The maximum technetium-99 result remains ~10% of the DWS value. Nitrate levels are decreasing in upgradient well 699-36-70A and downgradient well 699-36-66B, but the levels remain stable in downgradient wells 699-37-66 and 699-35-66A. These trends will continue to be monitored.

Barium results for downgradient well 699-37-66 remain greater than in the other monitoring wells but are below the maximum concentrations encountered early in the monitoring program. Nitrate concentrations in this well remained more than twice the concentrations observed in the other monitoring wells and near the highest concentrations encountered in the monitoring program. However, these values are below the 226 mg/L tolerance limit established in the monitoring plan (WCH-198) and appear to be trending downward.

All vanadium results reported in 2010 are elevated relative to previous sampling (~30% higher). Maximum values were seen in the March 2010 results. Review of the analytical data shows no indications of issues with the analyses. A previous similar spike in vanadium was seen in sampling during August 1998. The vanadium results will be monitored closely during 2011.

No other analytical issues were identified during the 2010 sampling.

11.4 Conclusions and Recommendations

The conclusions and recommendations for the 200-UP-1 OU are presented below.

11.4.1 Conclusions

Within the 200-UP-1 OU, groundwater monitoring was conducted under CERCLA to track contaminants throughout the OU, to assess potential impact to groundwater from the ERDF, and to monitor the performance of the U Plant pump-and-treat system. Interim status groundwater quality assessment monitoring under RCRA was conducted at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring was conducted at the 216-S-10 Pond and Ditch. Monitoring of radionuclides at the RCRA sites was conducted under CERCLA and the AEA.

A major accomplishment during the year was release of the draft RI/FS (DOE/RL-2009-122, Draft A) and proposed plan (DOE/RL-2010-05, Draft A) for the 200-UP-1 OU in September 2010, meeting Tri-Party Agreement Milestone M-015-17A. In addition, the revised remedial design/remedial action work plan (DOE/RL-97-36, Rev. 3) was released in January 2010. This document was prepared to implement changes made to the interim action ROD by the explanation of significant differences issued during 2009 (EPA et al., 2009a). The work plan included a preliminary design for an interim action pump-and-treat system targeting both the north and south technetium-99 plumes at the S and SX Tank Farms in support of Tri-Party Agreement Milestone M-016-120.

Within the 200-UP-1 OU, technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater

and form extensive plumes within the region. Groundwater plumes of tritium, nitrate, and iodine-129 that originated from ponds and cribs are dispersing naturally, whereas plumes originating from the tank farms are generally growing in areal extent and exhibit increasing concentrations. The carbon tetrachloride plume has migrated into the 200-UP-1 OU from the adjacent 200-ZP-1 OU. Groundwater flow in the unconfined aquifer is primarily toward the east within the interest area, and the water table declined by an average of 0.21 meters in the southern 200 West Area between March 2009 and March 2010.

The U Plant interim action pump-and-treat system continued operation to remediate the uranium and technetium-99 plumes downgradient from the 216-U-1/2 Cribs. During the year, all technetium-99 sample results within the area targeted for remediation were below the 9,000 pCi/L remedial action objective, and all uranium sample results were below the 300 µg/L remedial action objective. The highest uranium concentration downgradient from the 216-U-1/2 Cribs occurred at well 299-W19-18 (417 µg/L in March 2010), which is located upgradient of the pump-and-treat area.

At WMA S-SX, concentrations of the mobile tank waste constituents in well 299-W22-44 (downgradient of the S Tank Farm) were generally stable during the year, with maximum values of 275 mg/L for nitrate, 702 µg/L for chromium, and 18,000 pCi/L for technetium-99. At well 299-W23-19 (near the source of the SX Tank Farm plume), concentrations of nitrate and chromium exhibited slight decreasing trends during the year, with maximum values of 491 mg/L for nitrate and 1,180 µg/L for chromium. The technetium-99 trend in this well fluctuated between 49,000 and 65,000 pCi/L. Chromium concentrations exceeded the 100 µg/L DWS in wells 299-W22-26 and 299-W22-86 during the year, indicating continued migration of these plumes toward the east. New well 299-W22-89 was installed in June 2010, south-southeast of the WMA, to bound the contaminant plumes from the SX Tank Farm. Substantial contamination was not found in the new well, which confirmed the existing interpretation of the plume extent.

The results of monitoring at WMA U, the 216-S-10 Pond and Ditch (S-10 unit), and the ERDF were similar to those of previous years. Results for WMA U continued to indicate that concentrations of technetium-99 and nitrate exceed their respective DWSs in many of the downgradient monitoring wells, but maximum concentrations only exceeded their respective DWSs by approximately a factor of two. There were no exceedances of any indicator parameter during the year at the S-10 unit. Sample results from new upgradient well 699-33-76 were used to revise the critical means for statistical evaluations of pH, specific conductance, and total organic halides. The total organic carbon results exhibited too much variability to be useful for statistical evaluations, so the critical mean for this parameter has not yet been revised. Sampling results at the ERDF have continued to indicate that the facility has not affected groundwater quality.

11.4.2 Recommendations

The following recommendations are made regarding CERCLA activities and future monitoring of the 200-UP-1 OU:

- The withdrawal of groundwater at the U Plant interim action pump-and-treat system should be discontinued. During 2010, all sample results within the pump-and-treat area were below the 300 µg/L remedial action objective for uranium and the 9,000 pCi/L remedial action objective for technetium-99. In addition, the flow rates from the two extraction wells (299-W19-36 and

299-W19-43) are low, and attempts to increase production by well rehabilitation during the year were not successful. It is not cost effective to operate at such low flow rates with very little capture of the contaminant plumes. If it is decided to continue operation of this system, a new extraction well should be installed.

- The monitoring plan for the 200-UP-1 OU should be revised after the RI/FS (DOE/RL-2009-122, Draft A) and proposed plan (DOE/RL-2010-05, Draft A) are finalized. The existing plan (DOE/RL-92-76, Rev. 1, Appendix A) was designed to gather information needed for the RI. Because the RI is complete, a new plan should be prepared that is optimized for long-term monitoring of the OU and assessment of the remedial actions.
- It is recommended that a replacement well for 699-35-70 be proposed through the Tri-Party Agreement Milestone M-24-00[2] process. This well went dry during the year, and the loss of this well has resulted in poor coverage of the high-concentration portion of the iodine-129 plume.

2 Wells proposed for installation at the Hanford Site are negotiated annually by Ecology, DOE, and EPA in accordance with Tri-Party Agreement (Ecology et al., 1989) Milestone M 24 00.

Table 11-1. 200-UP-1 Operable Unit Treatment System Summary

Total hours in the reporting period	8,760
Scheduled outages (hours)	1,356
Total time online (hours)	7,404
Total processed groundwater:	
Total groundwater processed during year (millions of liters)	4.9
Total groundwater processed since startup (March 1994) (millions of liters)	886.0
Summary of fiscal year 2008 operational parameters:	
Removal efficiency % by mass for uranium, average for year [(influent – effluent) / (influent)] x 100	100%

Table 11-2. 200-UP-1 Operable Unit Pump-and-Treat System Mass/Activity of Contaminants Removed from Aquifer

Contaminant	Mass/Activity Removed from the Aquifer[a]		
	CY 2009	CY 2010	Since Startup, March 1994
Uranium	2.37 kg	0.9 kg	220.3 kg
Technetium-99[b]	1.91 g (0.033 Ci)	1.47 g (0.025 Ci)	127.6 g (2.17 Ci)
Carbon tetrachloride	2.031 kg	0.939 kg	41.268 kg
Nitrate	4,931 kg	2,092 kg	49,667 kg

a. Mass/activity removed is calculated from volume extracted, not total volume treated.

b. For technetium-99, grams convert to curies at a ratio of 58.7 g/Ci.

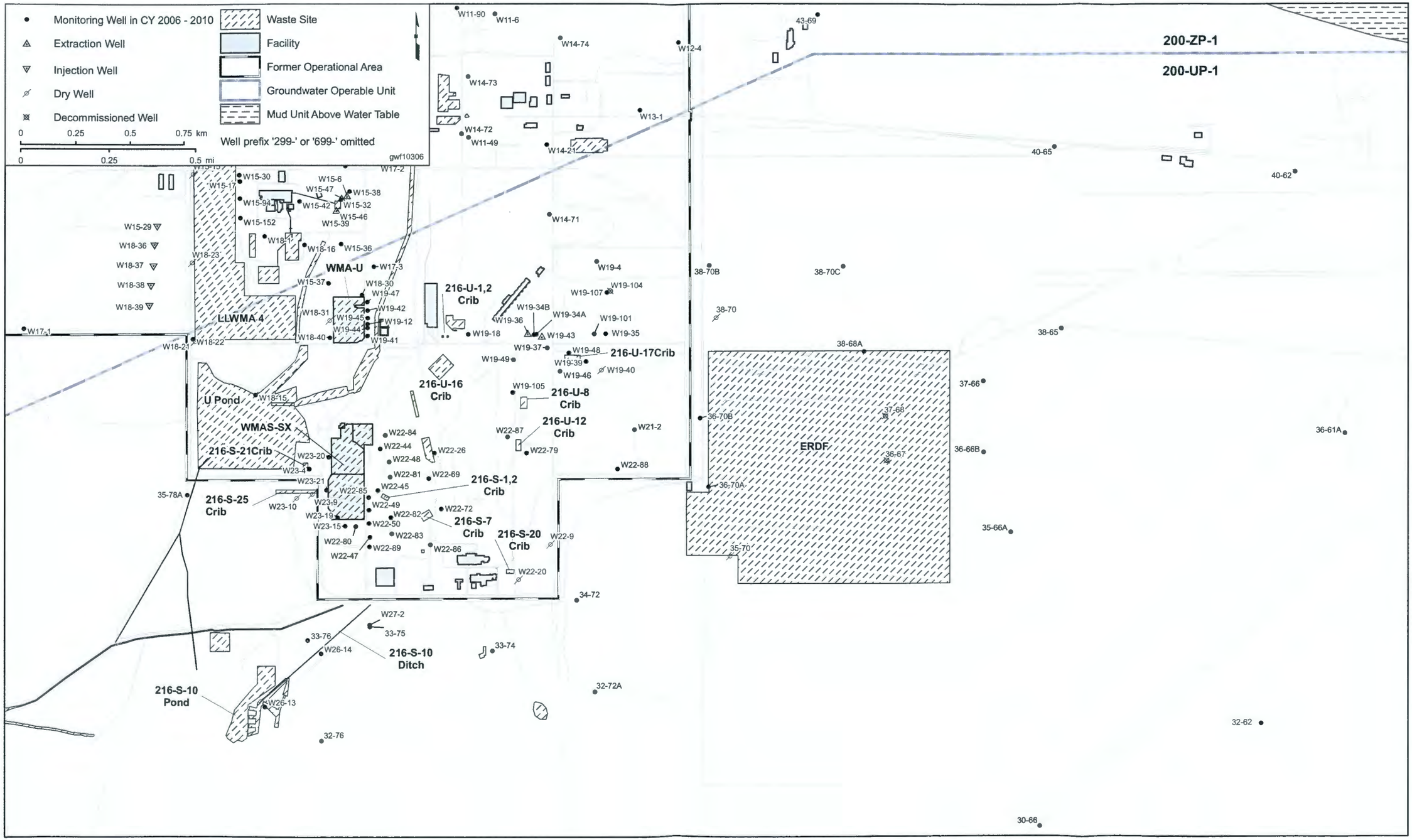
Table 11-3. Quantity of Treated Groundwater and Technetium-99 Removed from Aquifer During Extended Purging at Well 299-W23-19

Sample Date	Volume of Water Treated L (gal)	Technetium-99 Concentration (pCi/L)	Activity of Technetium-99 Removed (Ci)	Mass of Technetium-99 Removed (g)
4/23/10	6,011 (1,588)	55,000	3.3×10^{-4}	0.019
7/13/10	5,466 (1,444)	65,000	3.6×10^{-4}	0.021
9/13/10	6,246 (1,650)	49,000	3.1×10^{-4}	0.018
12/28/10	4,028 (1064)	53,000	2.1×10^{-4}	0.013
Totals	**21,751 (5,746)**	**N/A**	**1.2×10^{-3}**	**0.071**
Totals since startup*	**157,659 (41,650)**	**N/A**	**9.7×10^{-3}**	**0.573**

* Totals for all quarterly events since startup of extended purging in March 2003.

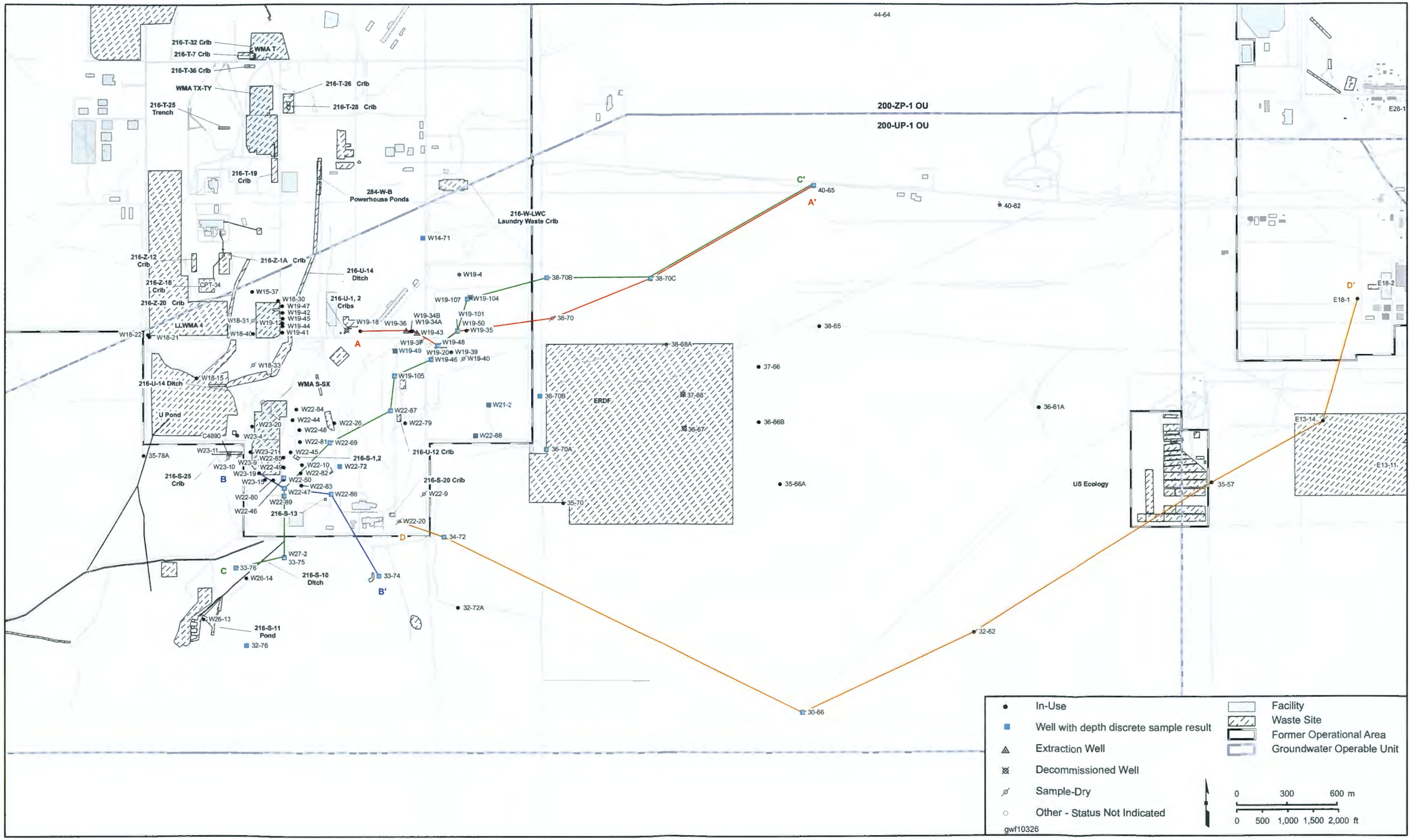
N/A = not applicable

Figure 11-1. Facilities and Groundwater Monitoring Wells in 200-UP-1 Operable Unit



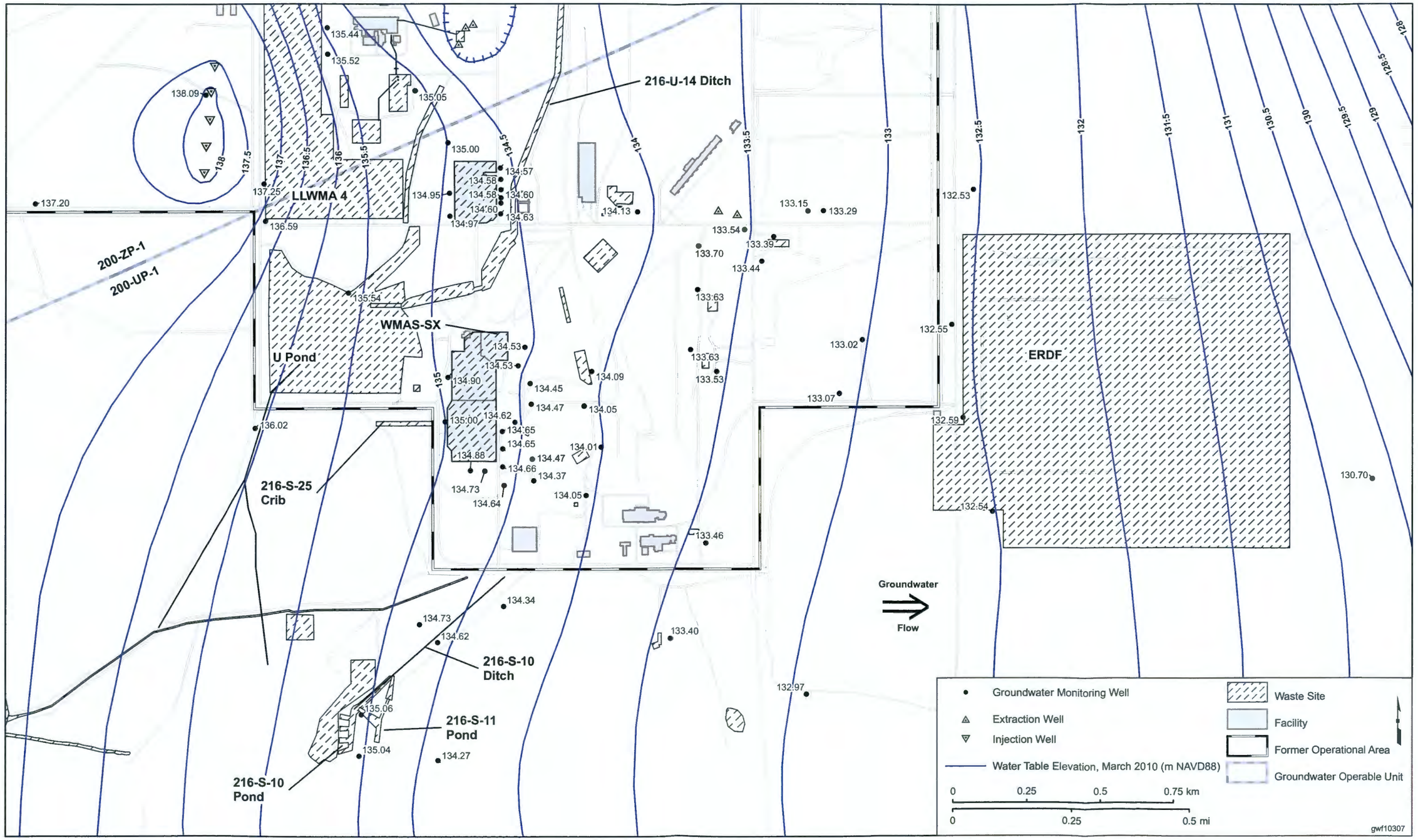
This page intentionally left blank.

Figure 11-2. Cross Section Locations for the 200-UP-1 Operable Unit



This page intentionally left blank.

Figure 11-3. Water Table Map for 200-UP-1 Groundwater Interest Area, March 2010



This page intentionally left blank.

Figure 11-4. Chromium, Technetium-99, and Uranium Plume Areas Above the Drinking Water Standard in the 200-UP-1 Groundwater Interest Area

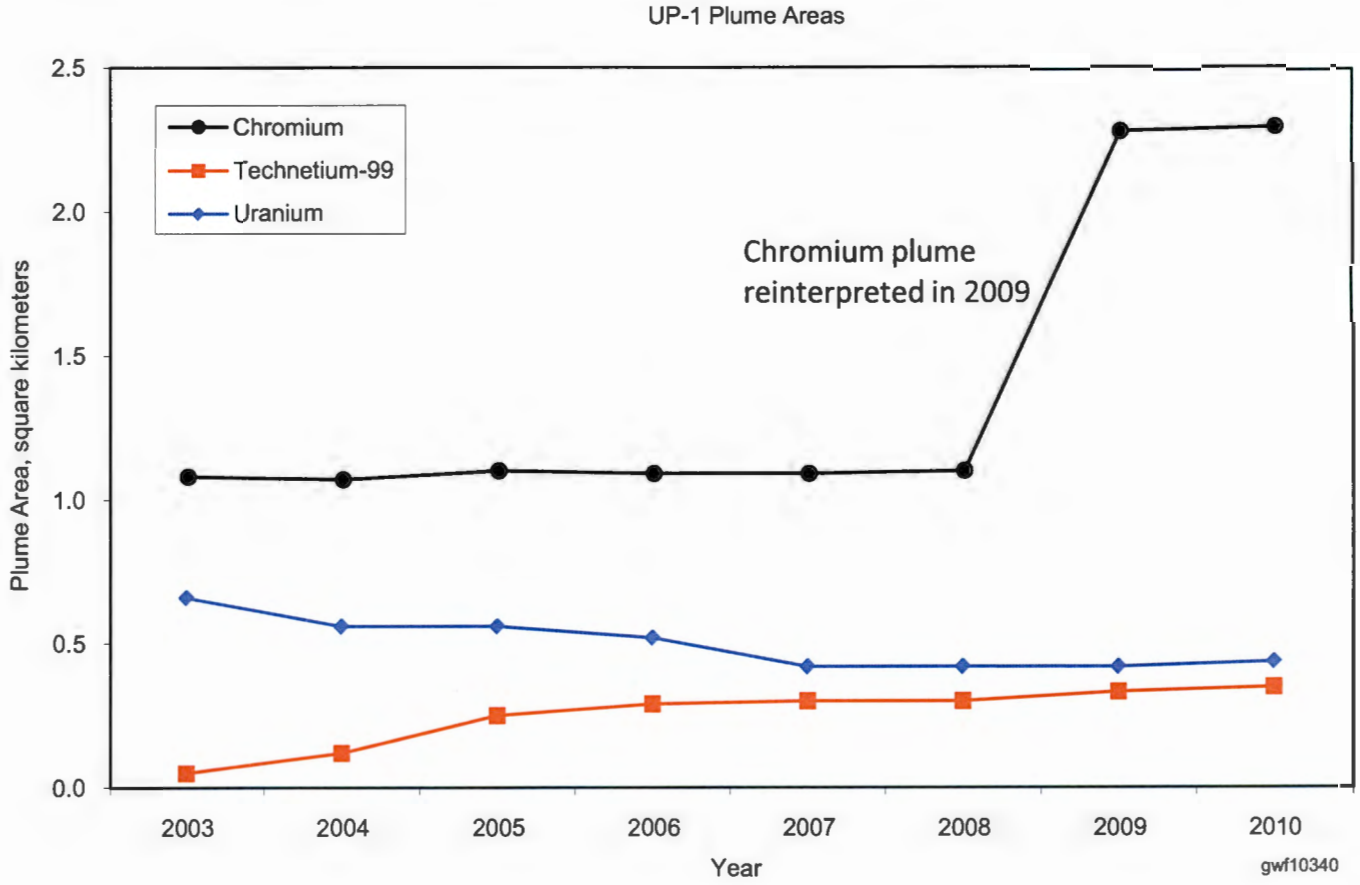


Figure 11-5. Iodine-129, Nitrate, and Tritium Plume Areas Above the Drinking Water Standard in the 200-UP-1 Groundwater Interest Area

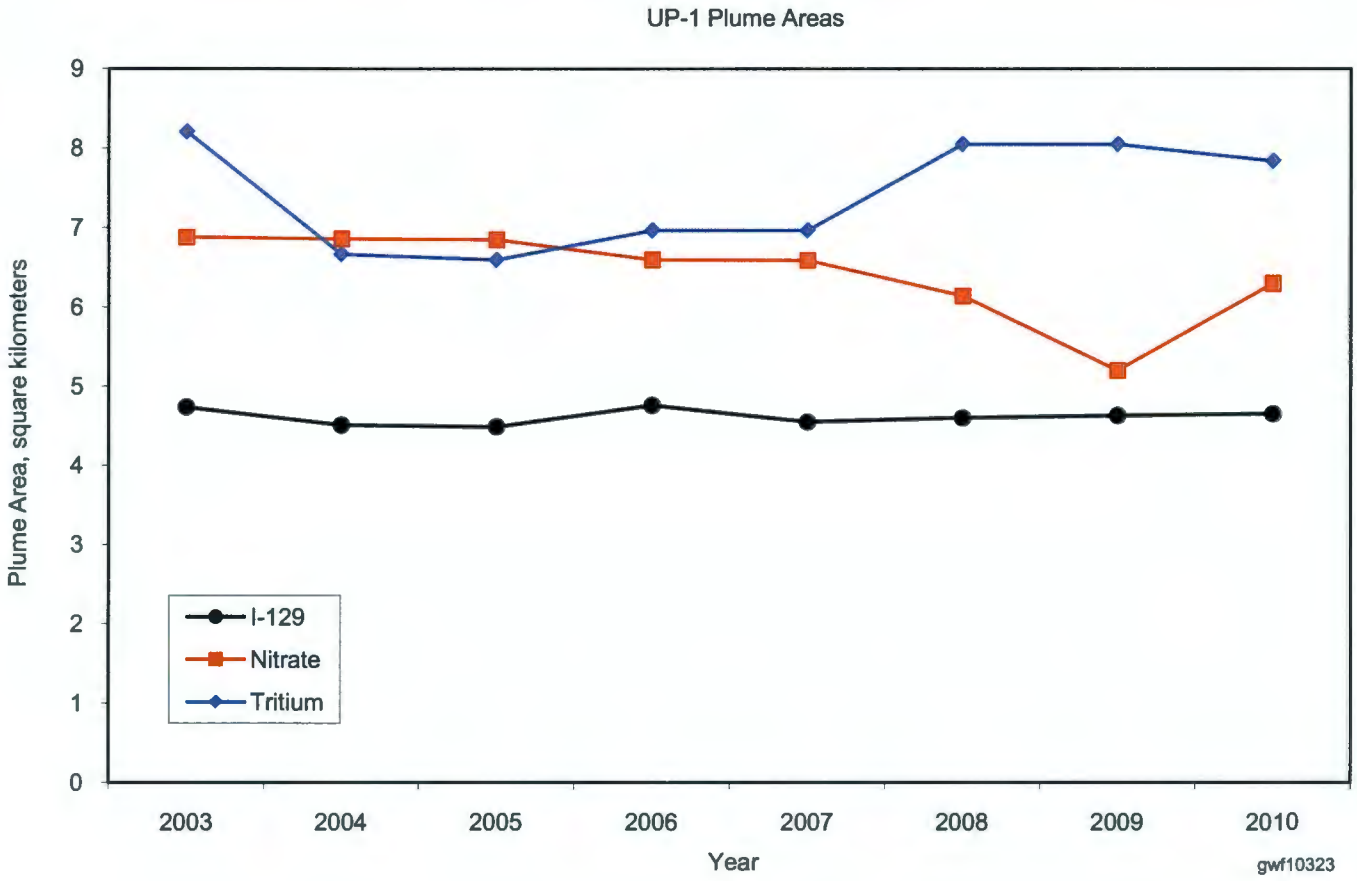
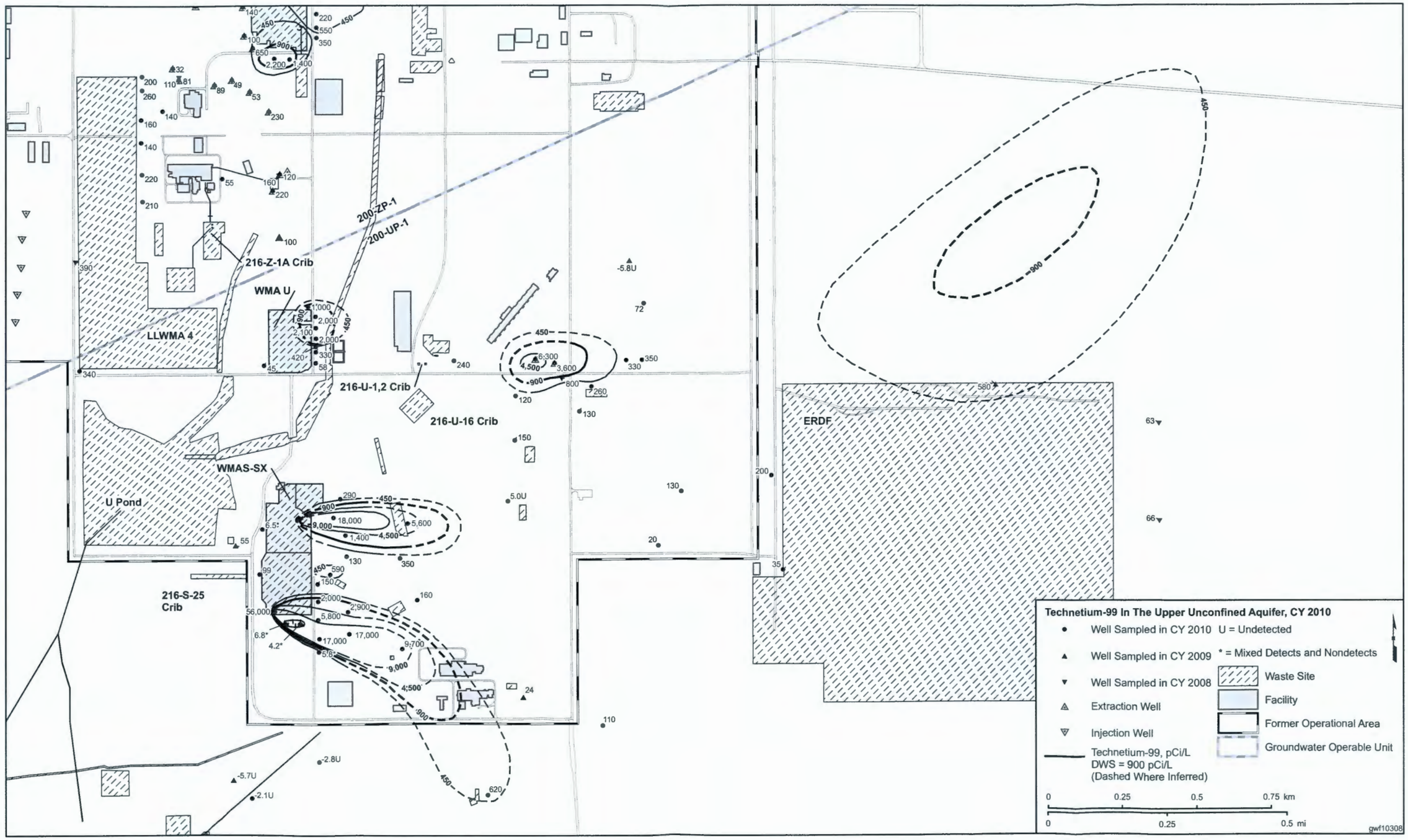
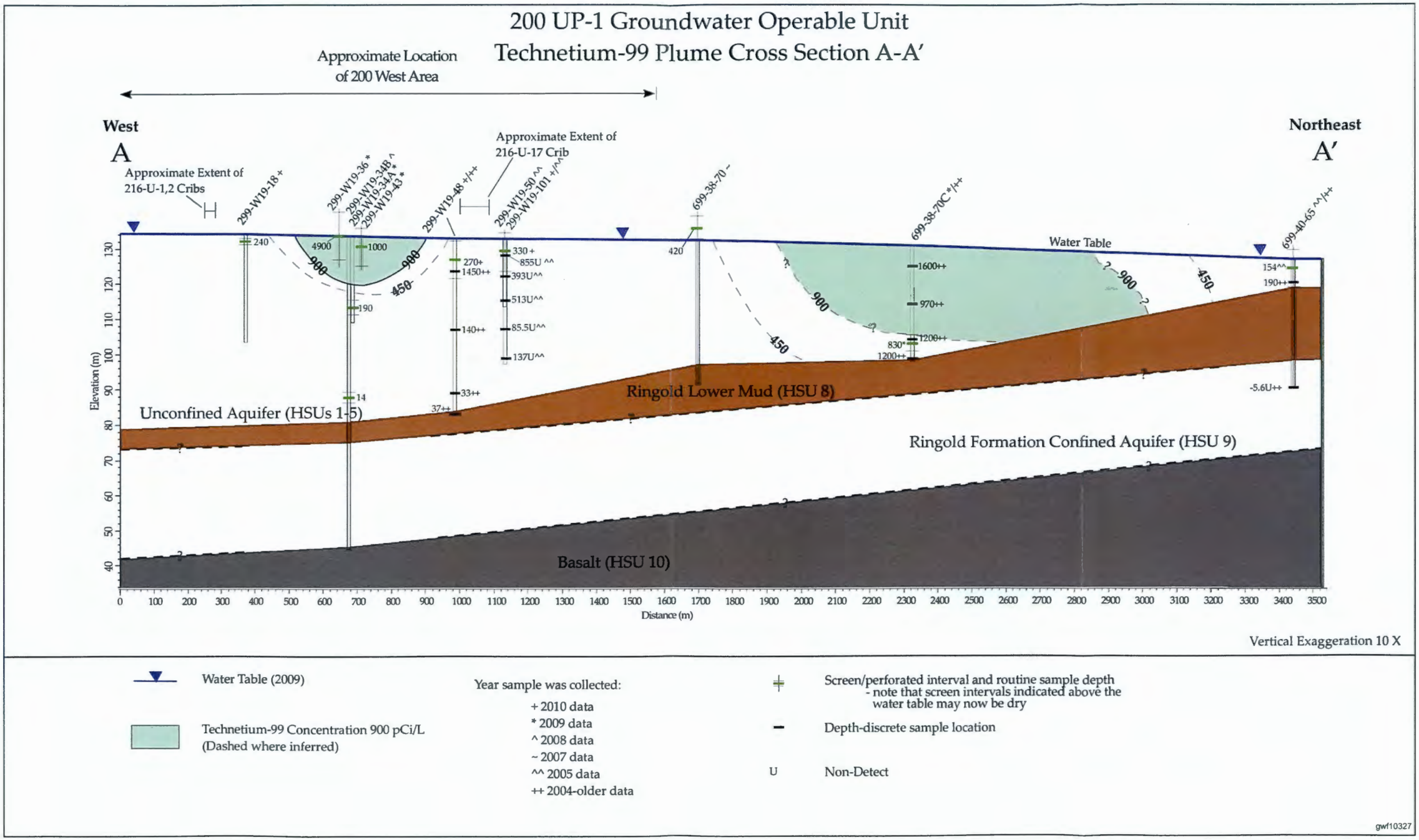


Figure 11-6. Average Technetium-99 Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer



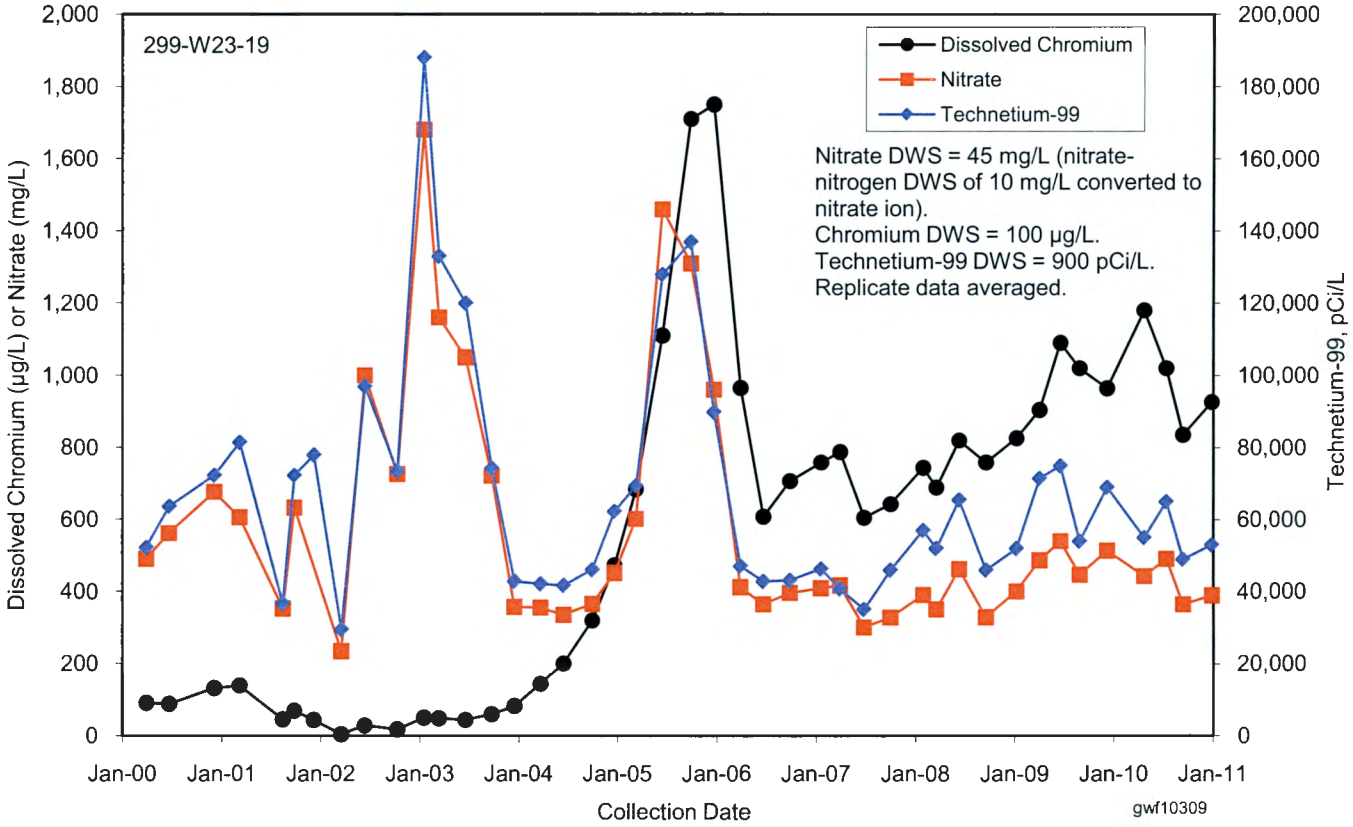
This page intentionally left blank.

Figure 11-7. Cross Section of the Technetium-99 Plume from the 216-U-1/2 Cribs



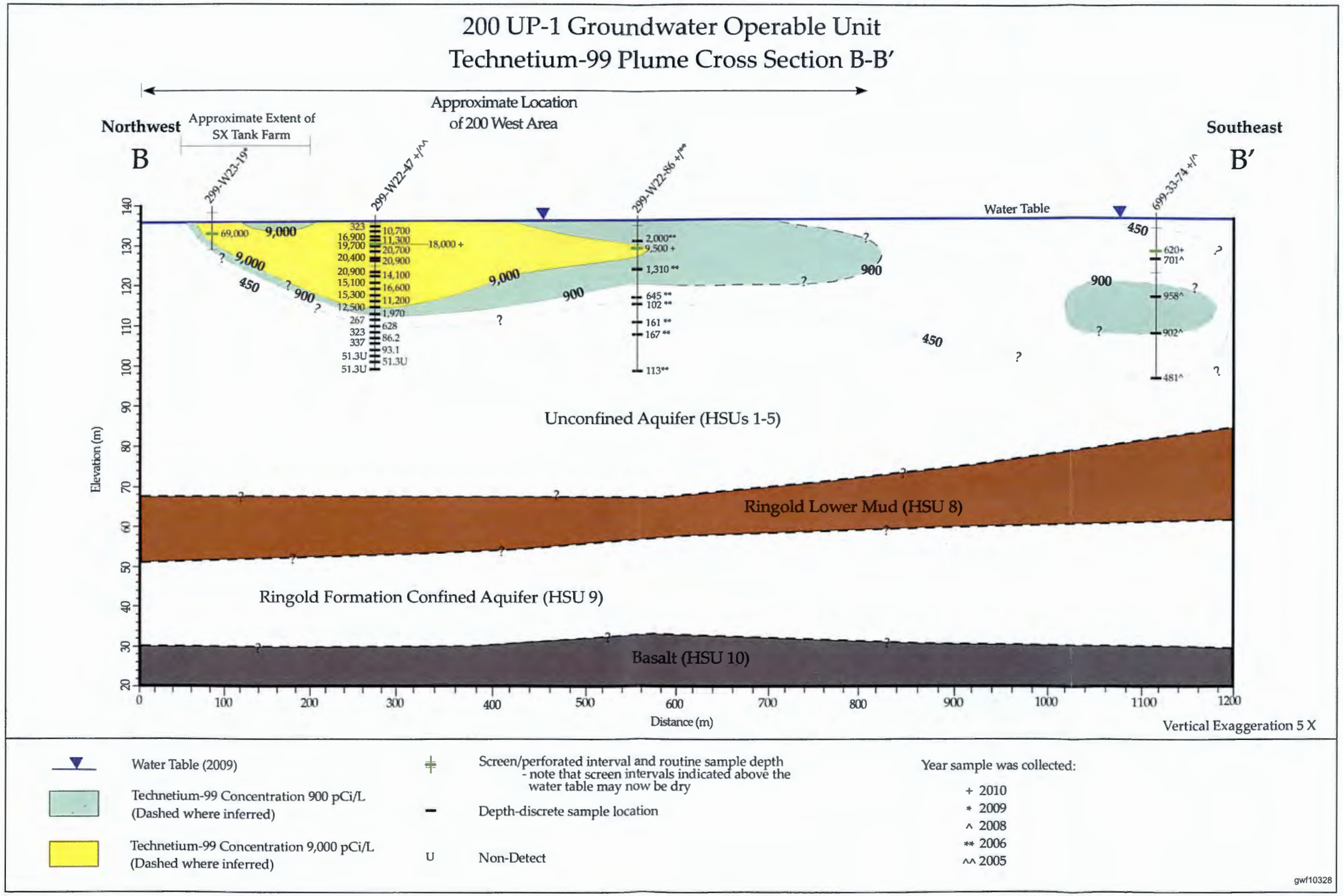
This page intentionally left blank.

Figure 11-8. Chromium, Nitrate, and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX



This page intentionally left blank.

Figure 11-9. Cross Section of the Southern Technetium-99 Plume from Waste Management Area S-SX



This page intentionally left blank.

Figure 11-10. Nitrate, Chromium, and Technetium-99 Concentrations in Well 299-W22-44 Downgradient from S Tank Farm

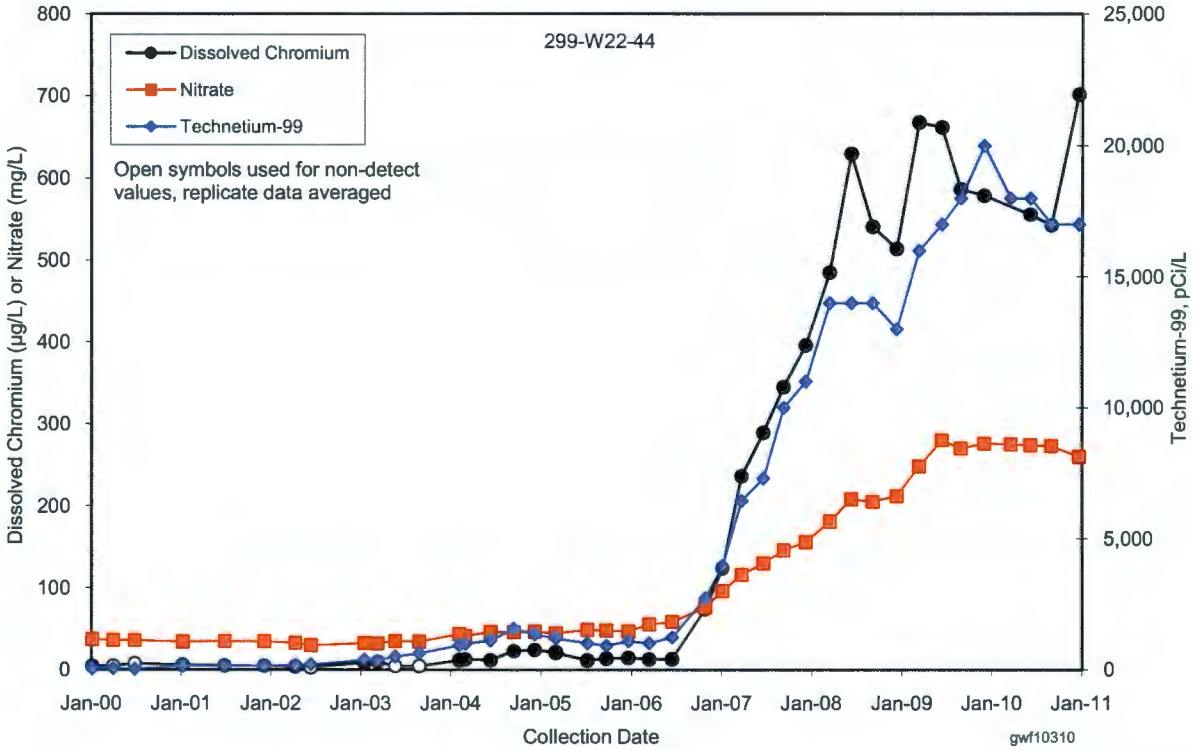


Figure 11-11. Nitrate, Chromium, and Technetium-99 Concentrations in Well 299-W22-26 Downgradient from S Tank Farm

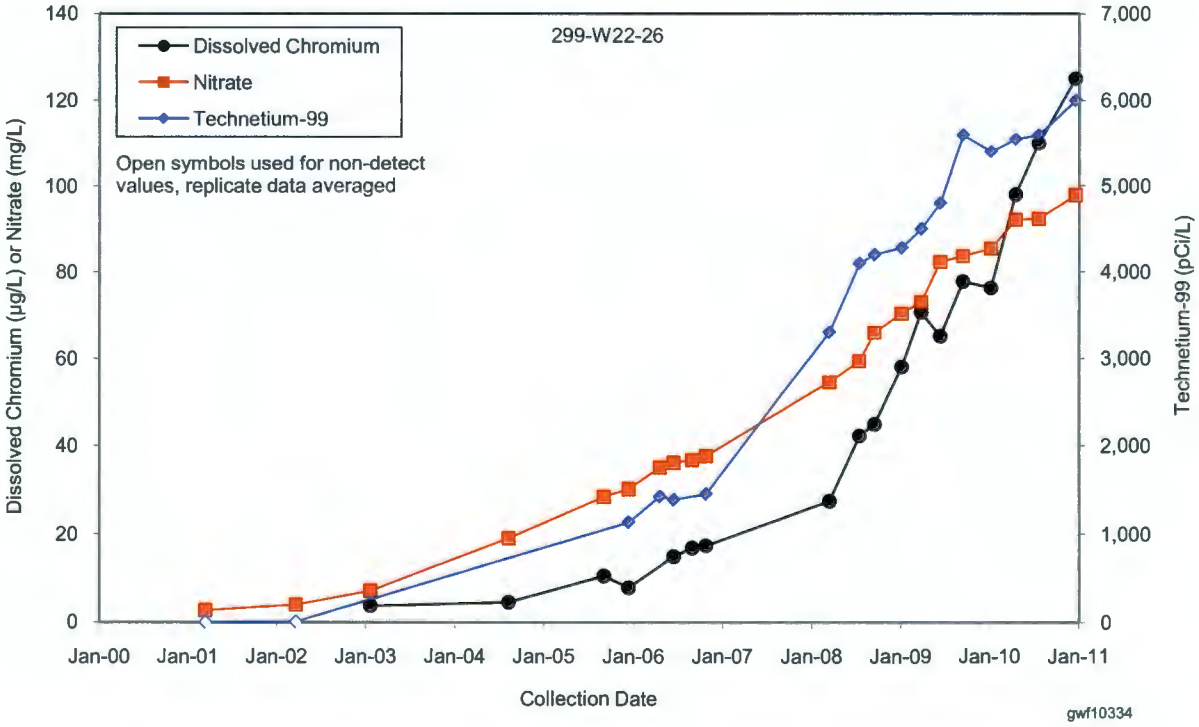


Figure 11-12. Average Uranium Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer

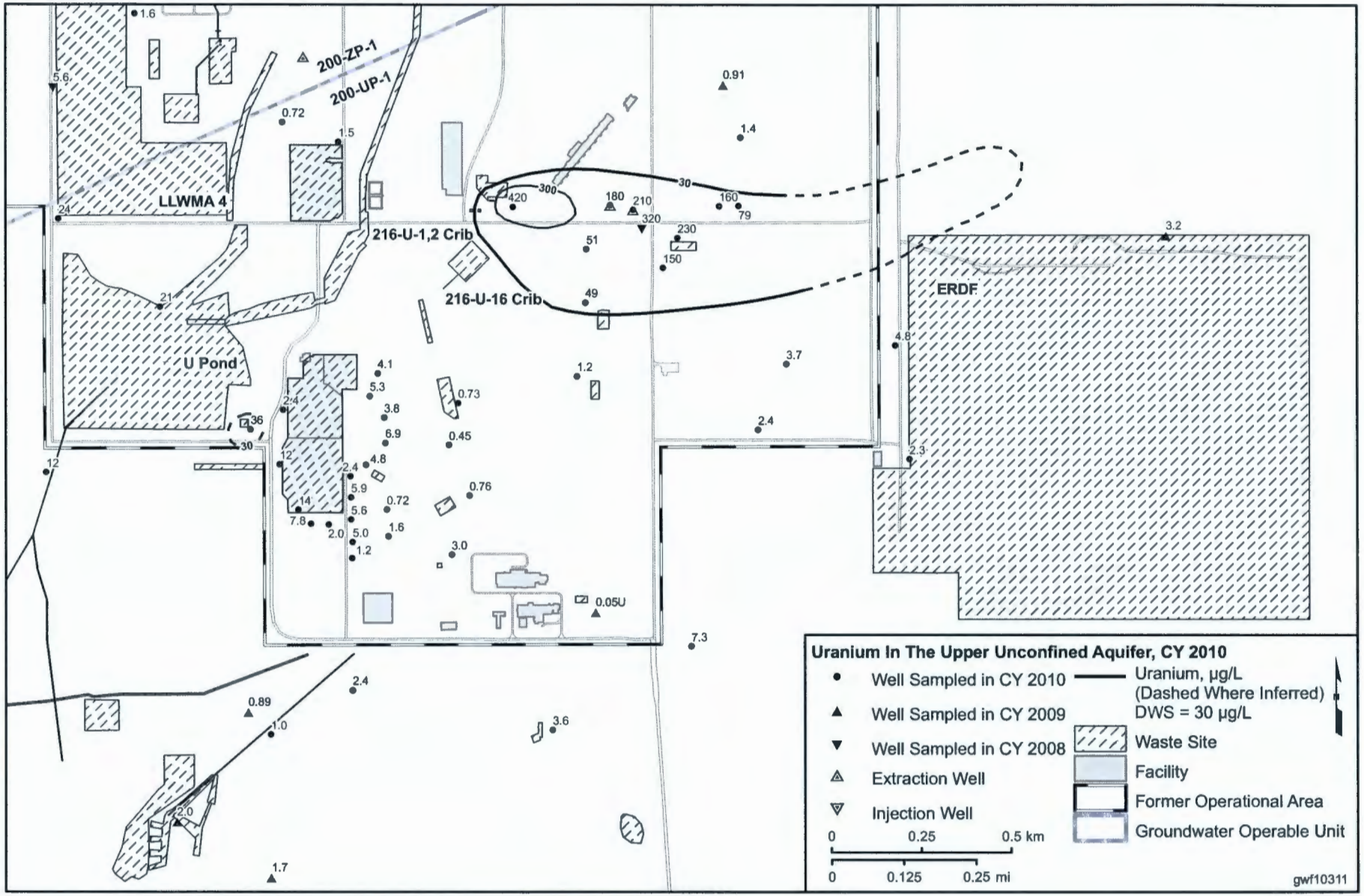
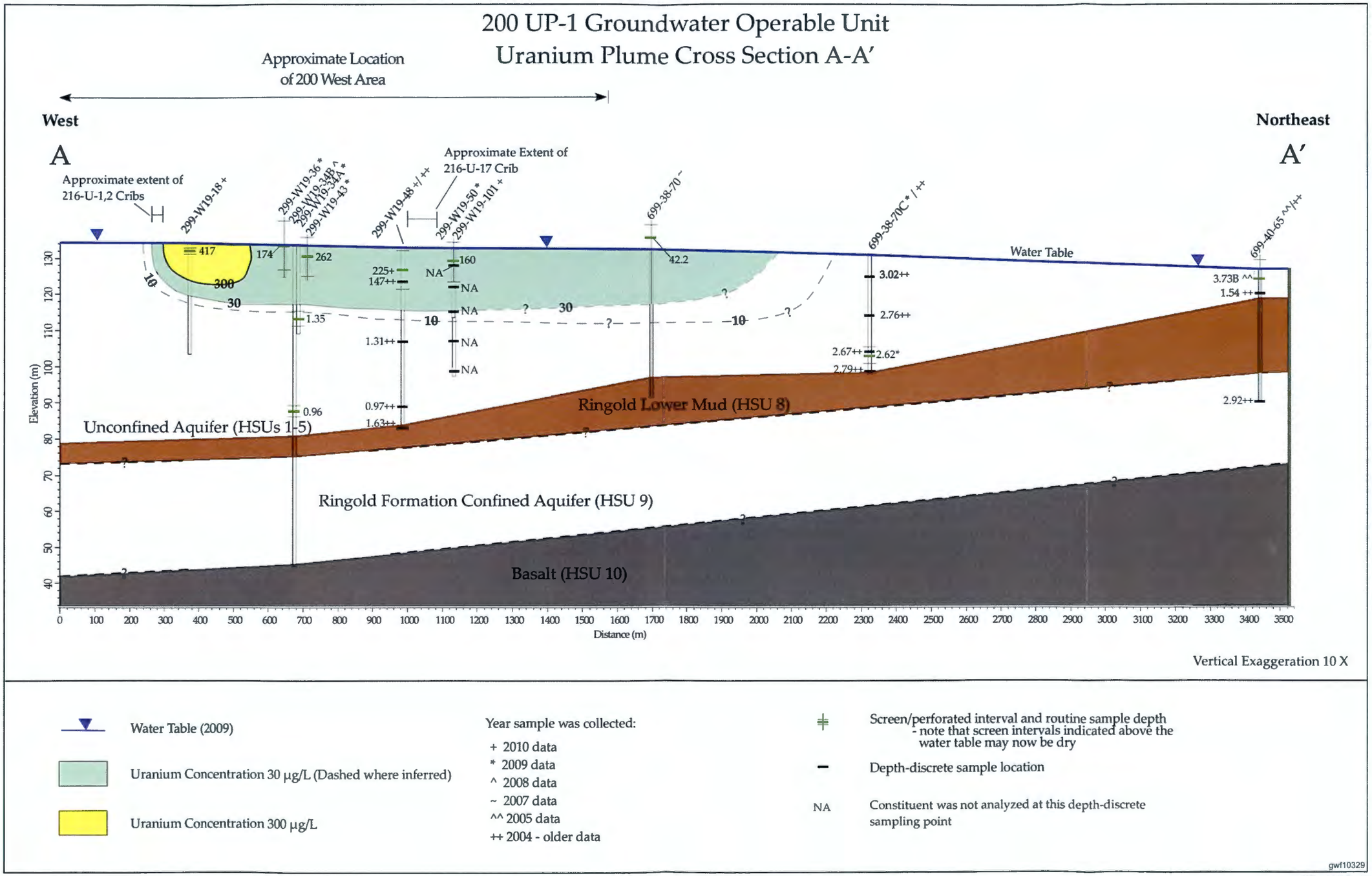
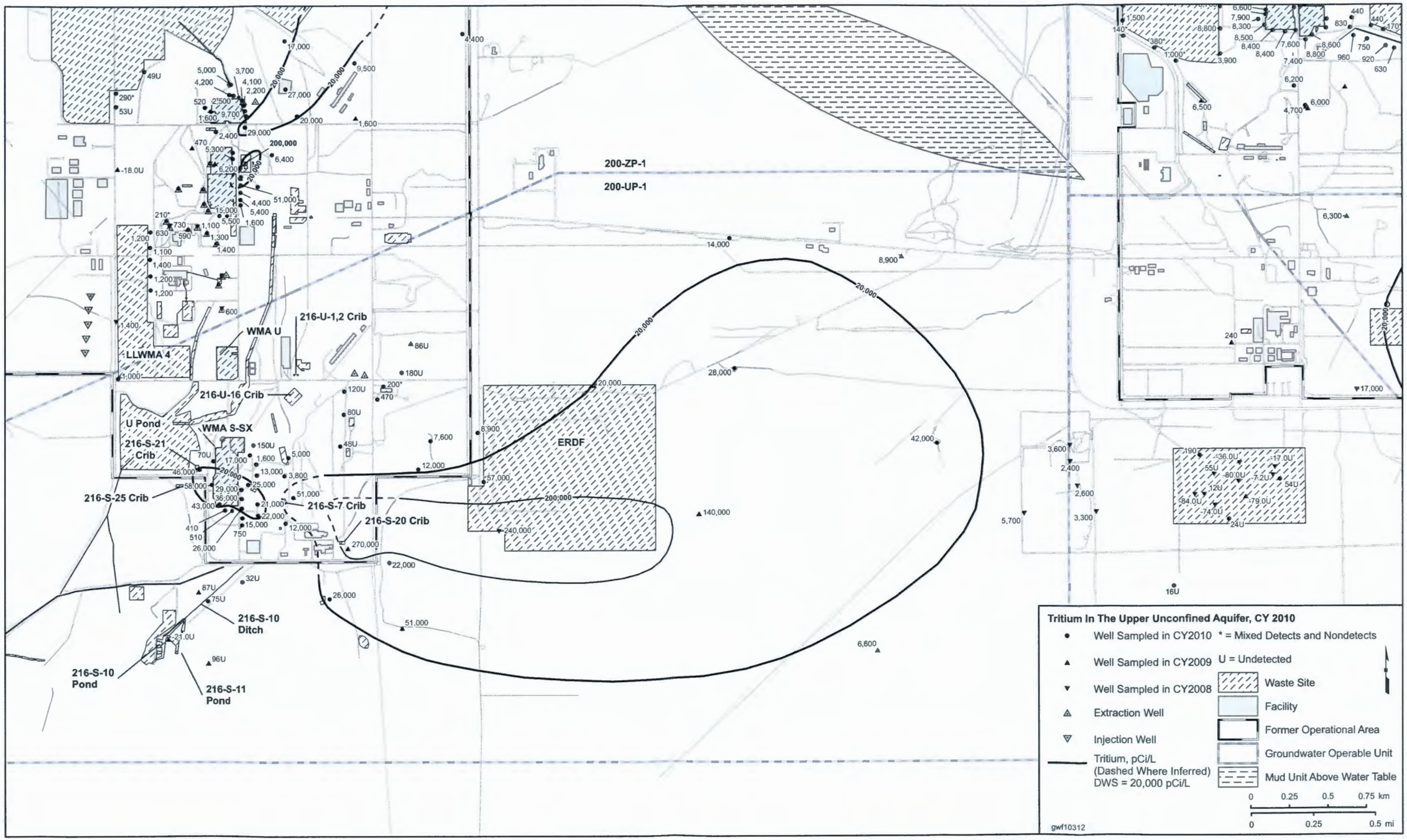


Figure 11-13. Cross Section of the Uranium Plume from the 216-U-1/2 Cribs



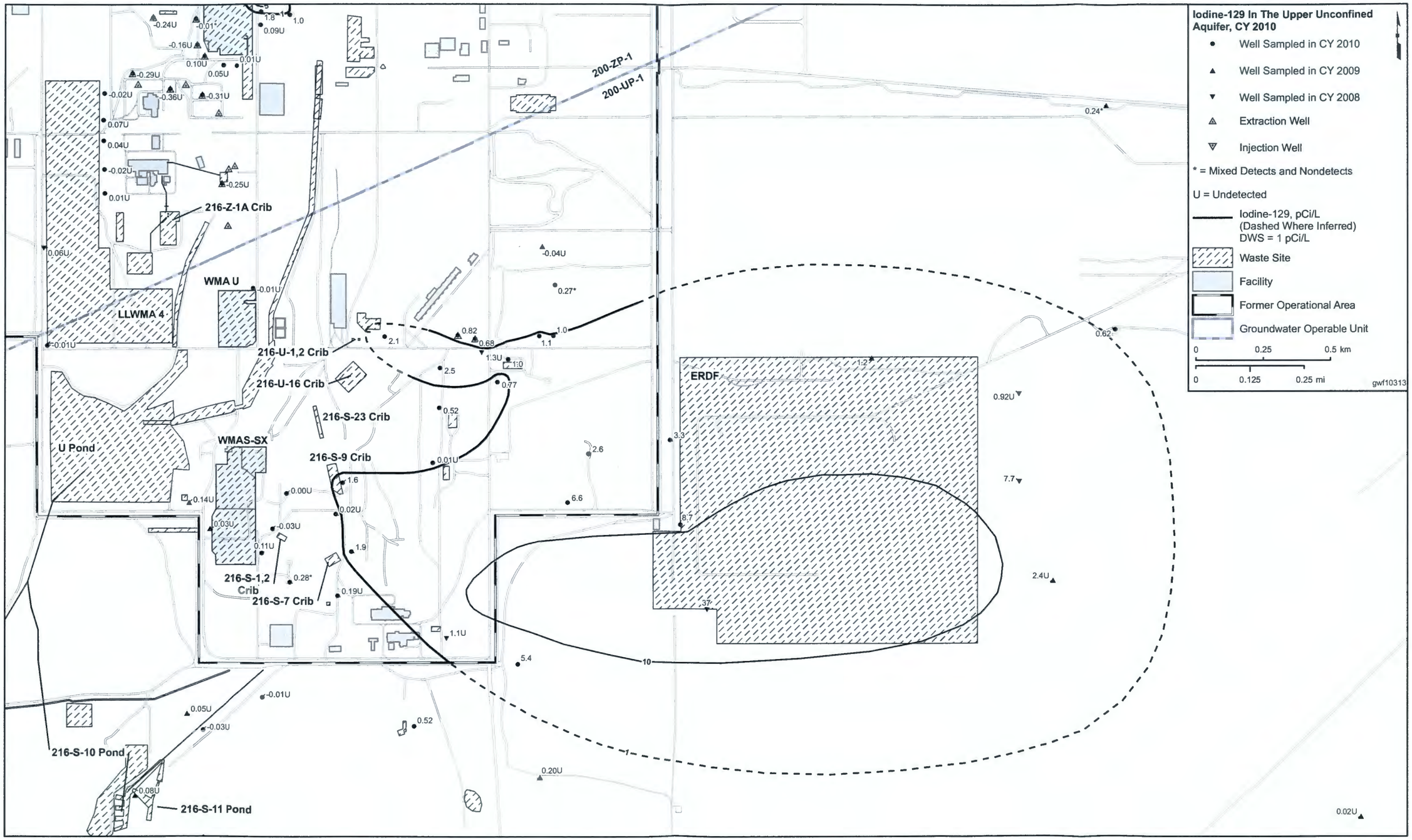
This page intentionally left blank.

Figure 11-14. Average Tritium Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer



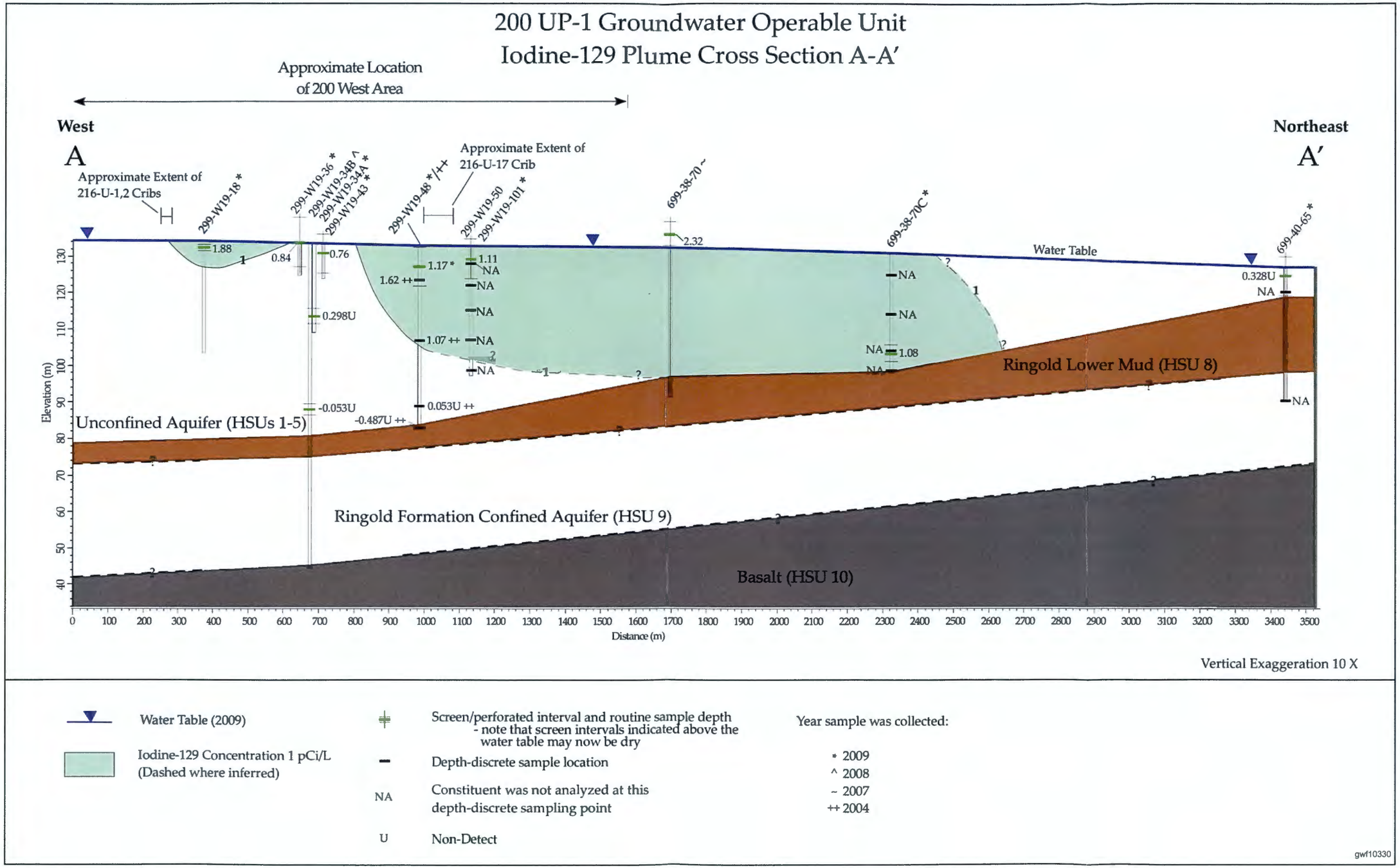
This page intentionally left blank.

Figure 11-15. Average Iodine-129 Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer



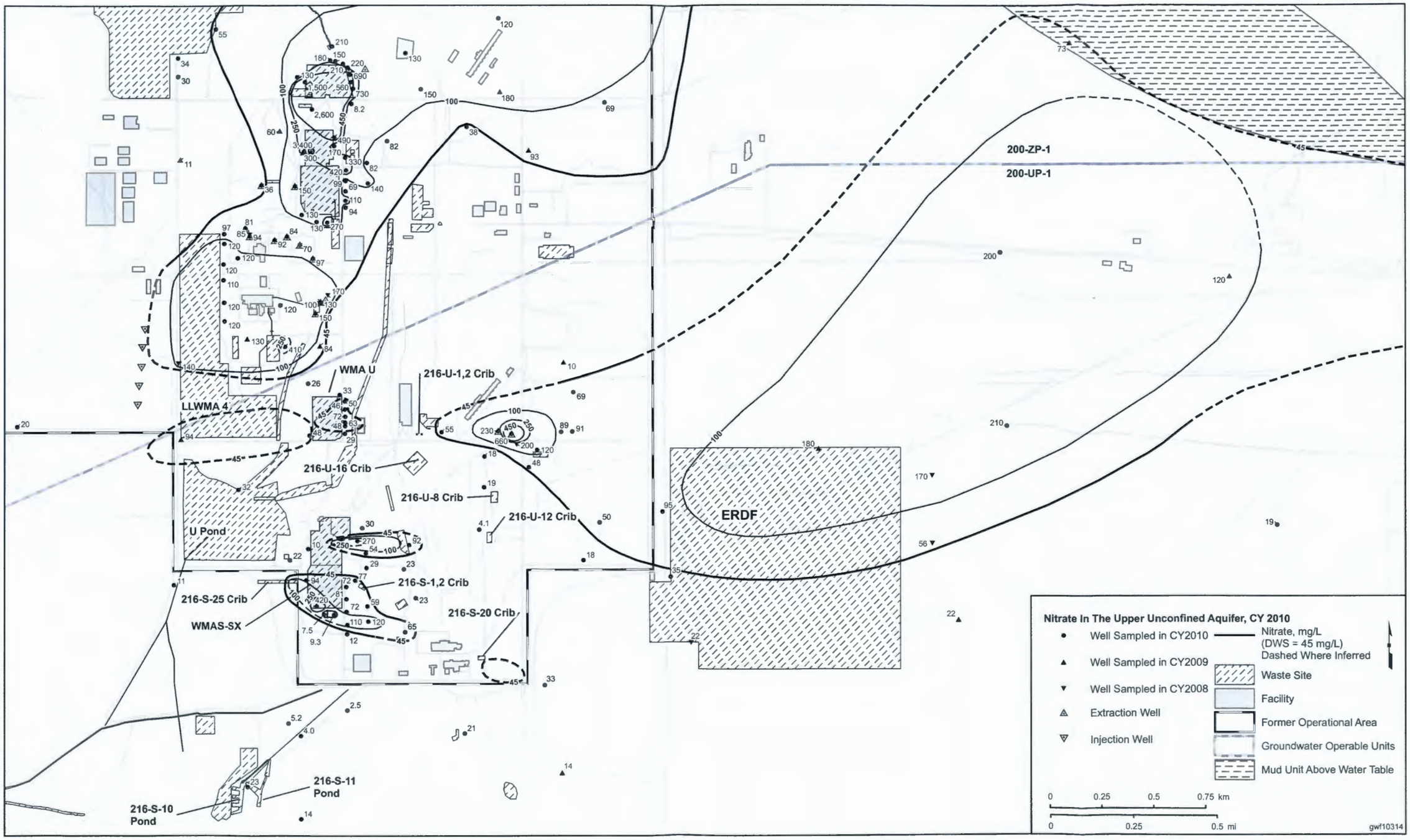
This page intentionally left blank.

Figure 11-16. Cross Section of the Iodine-129 Plume from the 216-U-1/2 Cribs



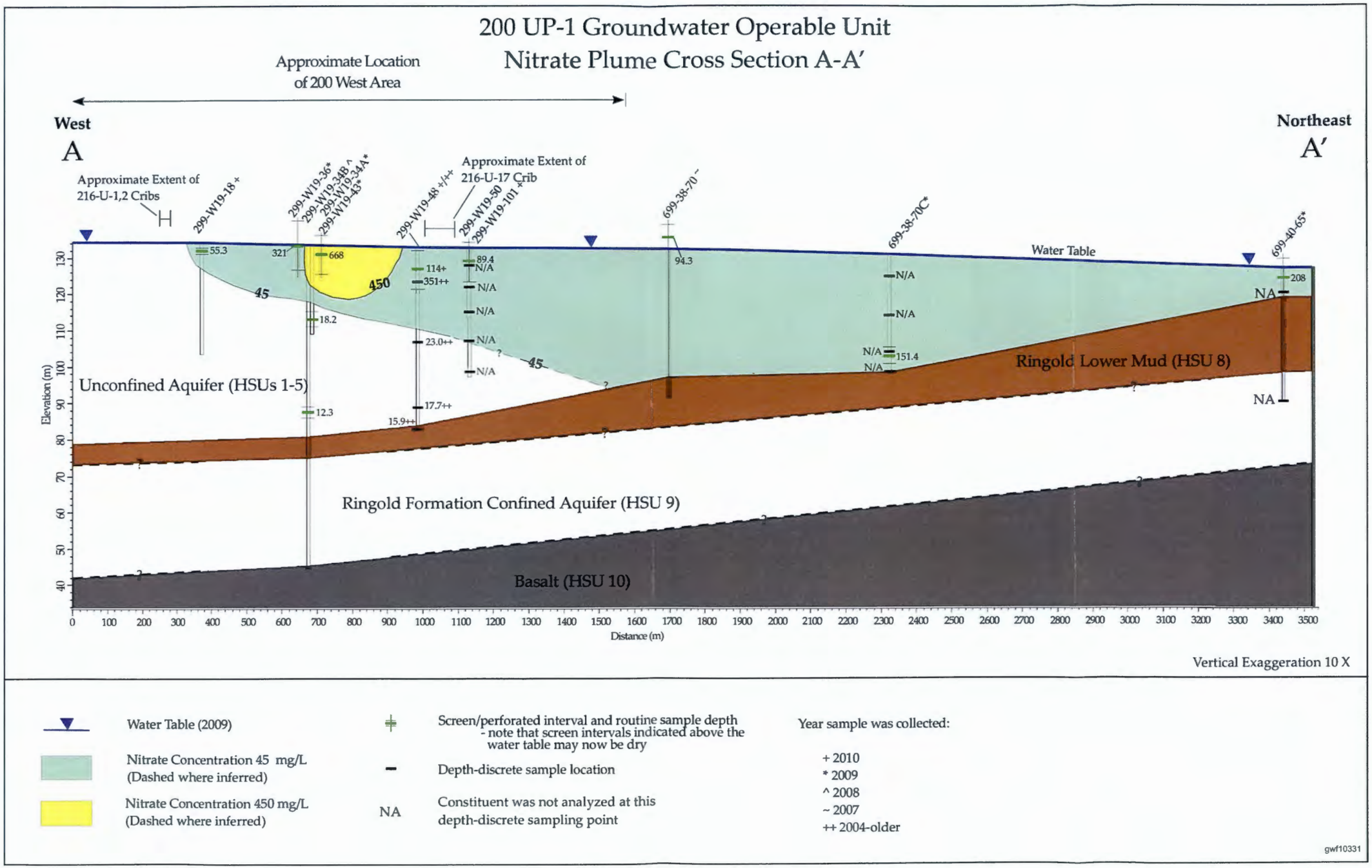
This page intentionally left blank.

Figure 11-17. Average Nitrate Concentrations in 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer



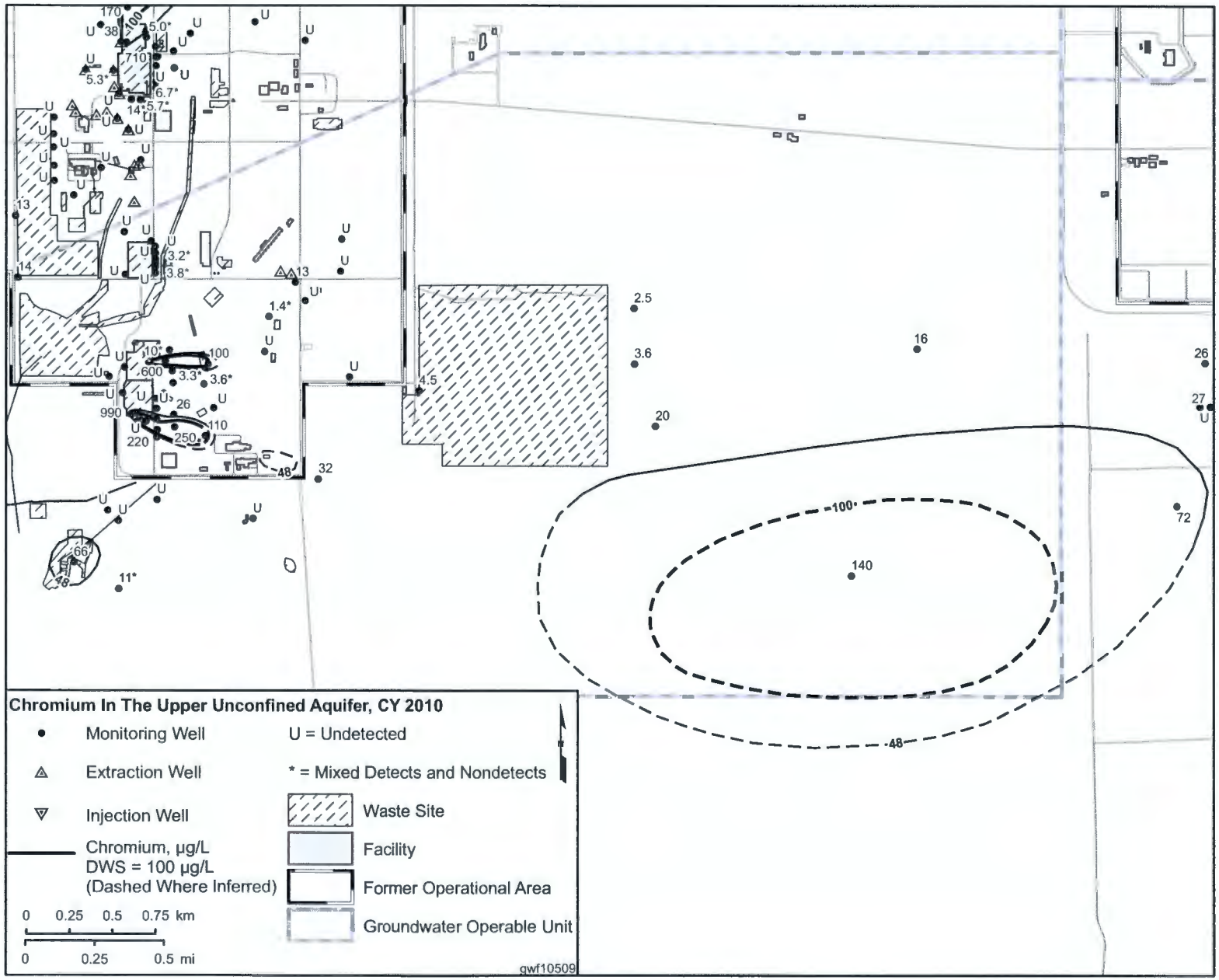
This page intentionally left blank.

Figure 11-18. Cross Section of the Nitrate Plume from the 216-U-1/2 Cribs



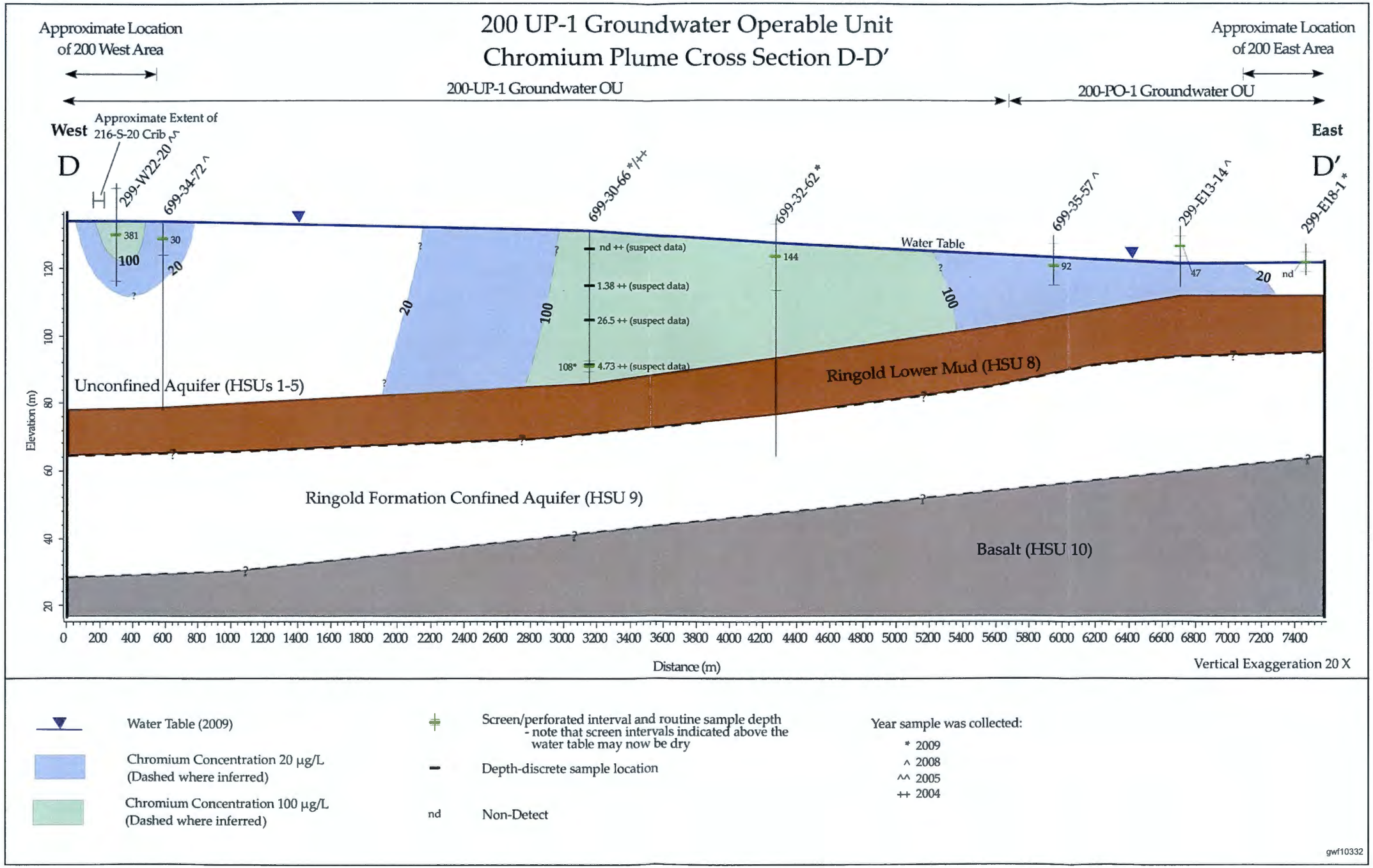
This page intentionally left blank.

Figure 11-19. Average Chromium Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer



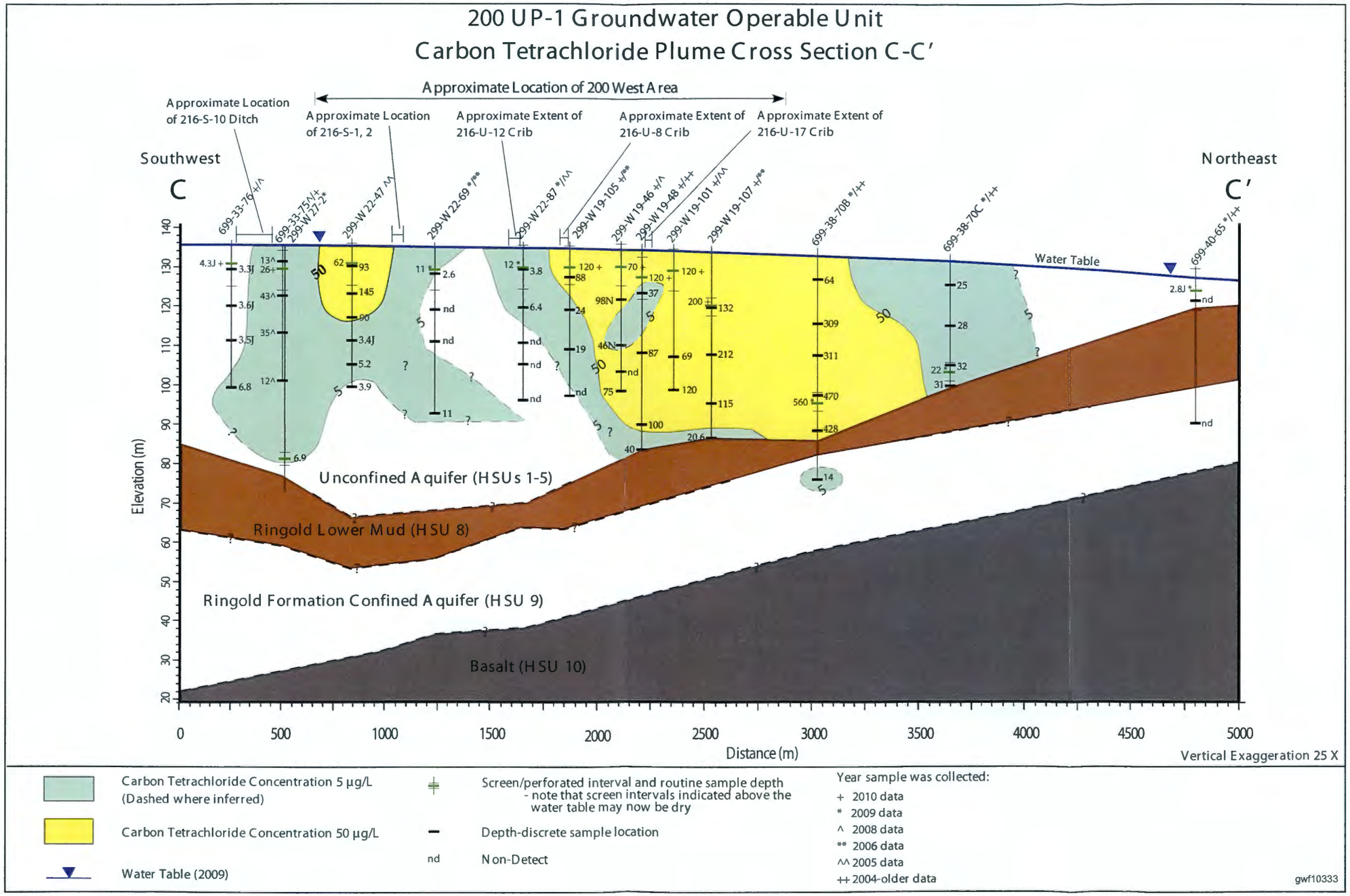
This page intentionally left blank.

Figure 11-20. Cross Section of the Chromium Plume East-Southeast of the 200 West Area



This page intentionally left blank.

Figure 11-21. Cross Section of the Carbon Tetrachloride Plume Within the 200-UP-1 Operable Unit



This page intentionally left blank.

Figure 11-22. 200-UP-1 Operable Unit Pump-and-Treat System Capture Frequency, CY 2010

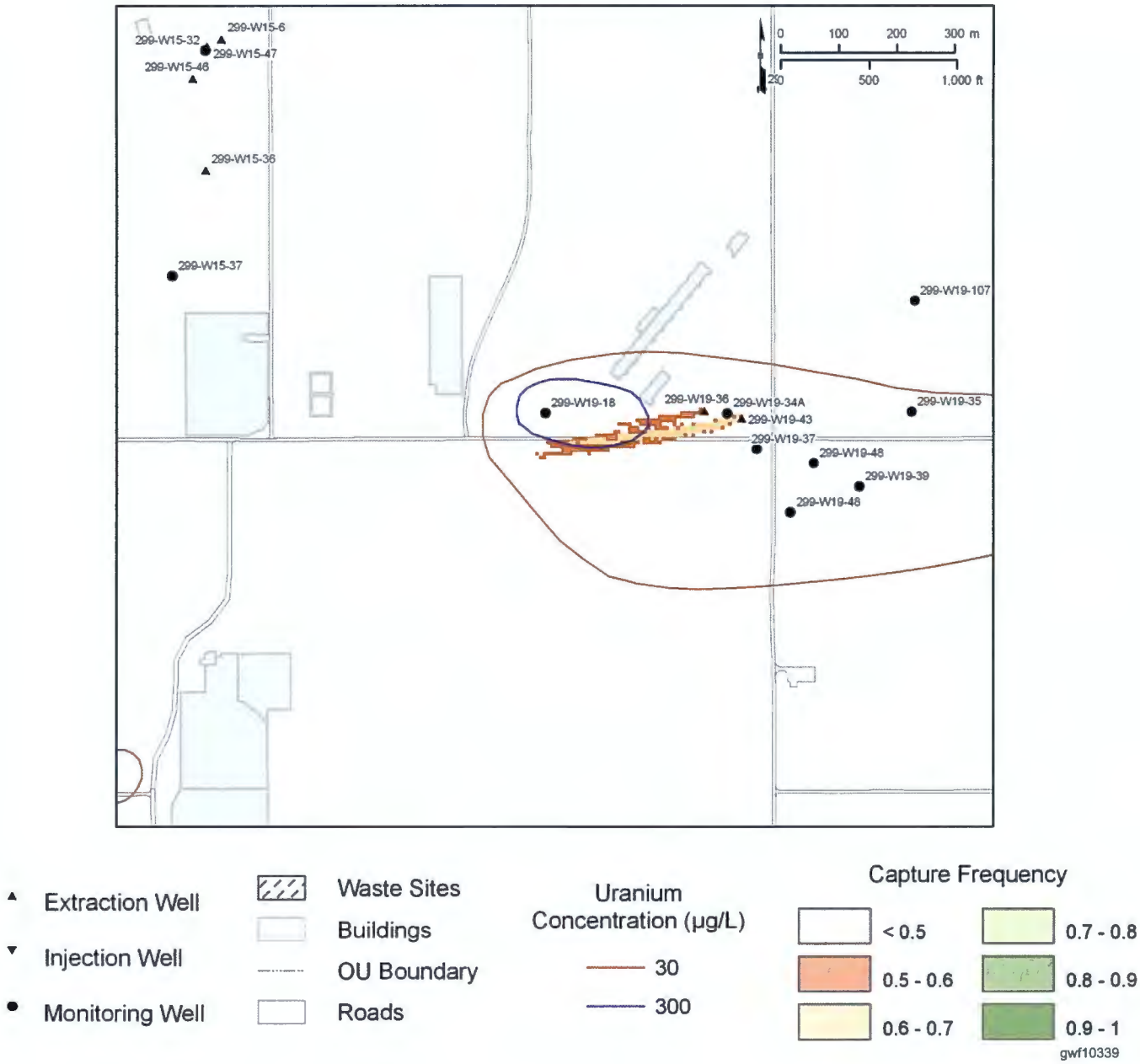


Figure 11-23. Uranium Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells

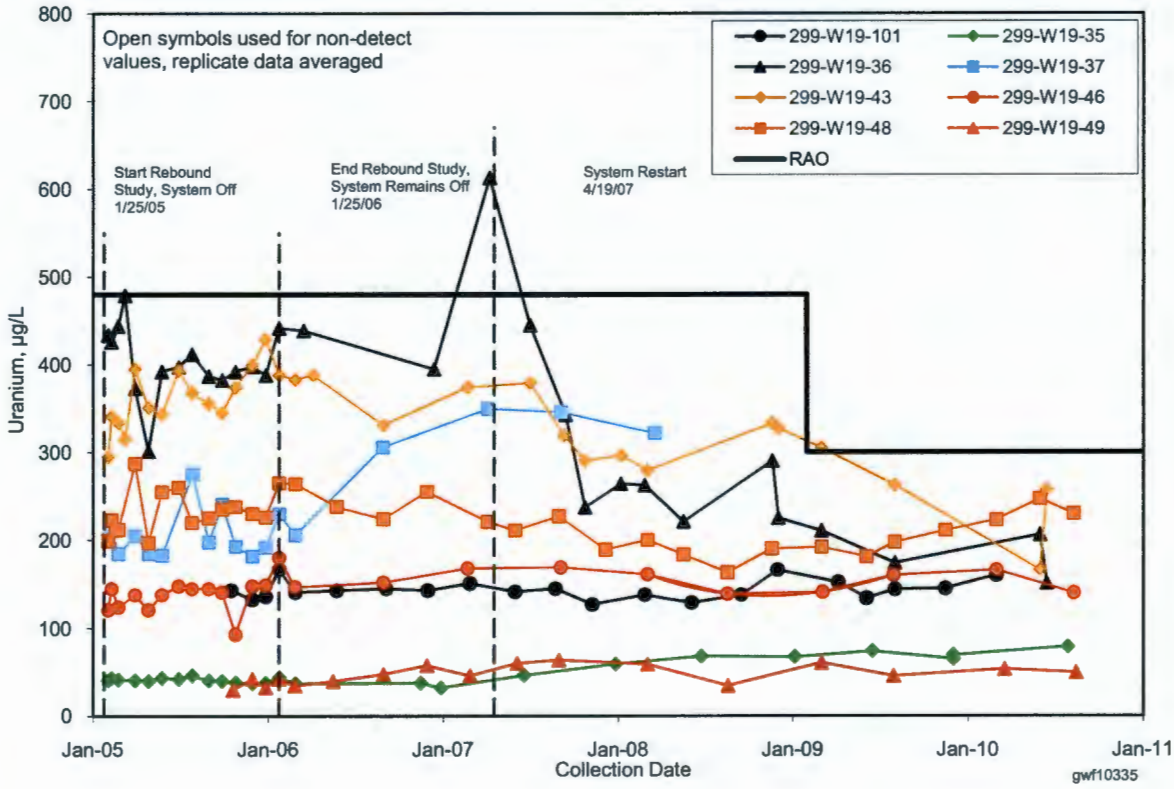


Figure 11-24. Technetium-99 Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells

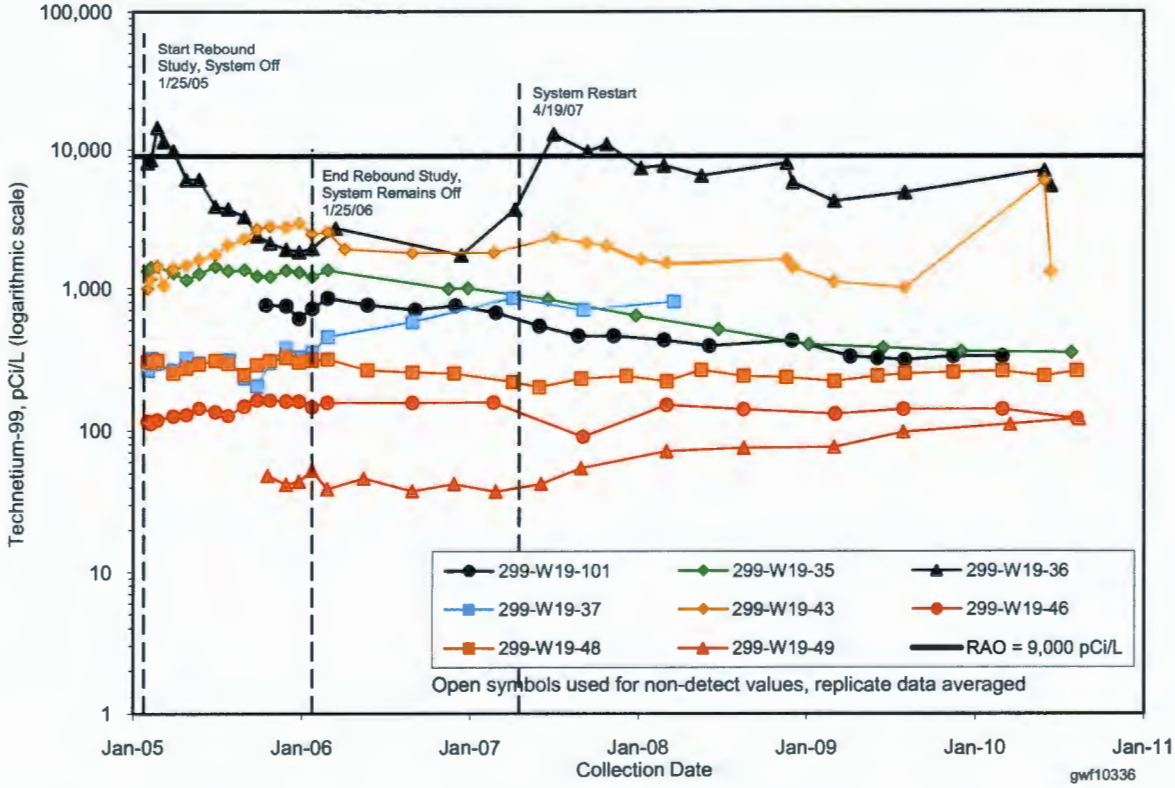


Figure 11-25. Carbon Tetrachloride Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells

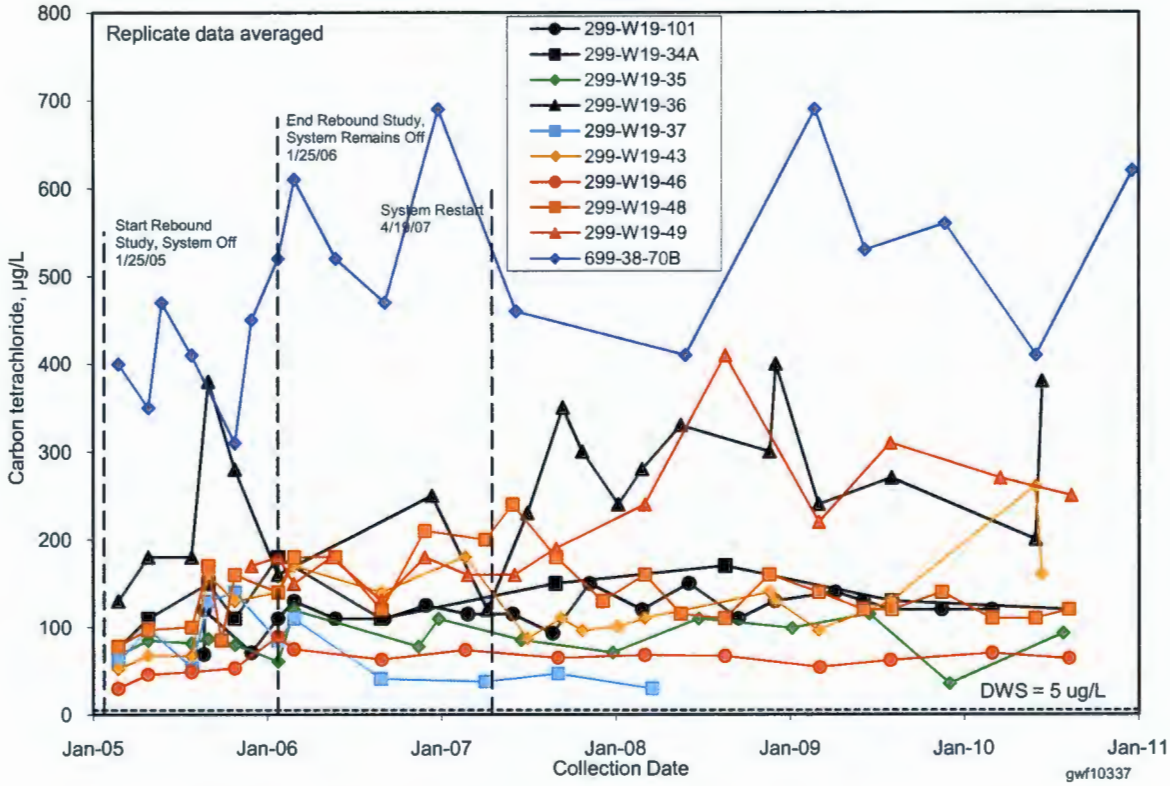


Figure 11-26. Nitrate Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Wells

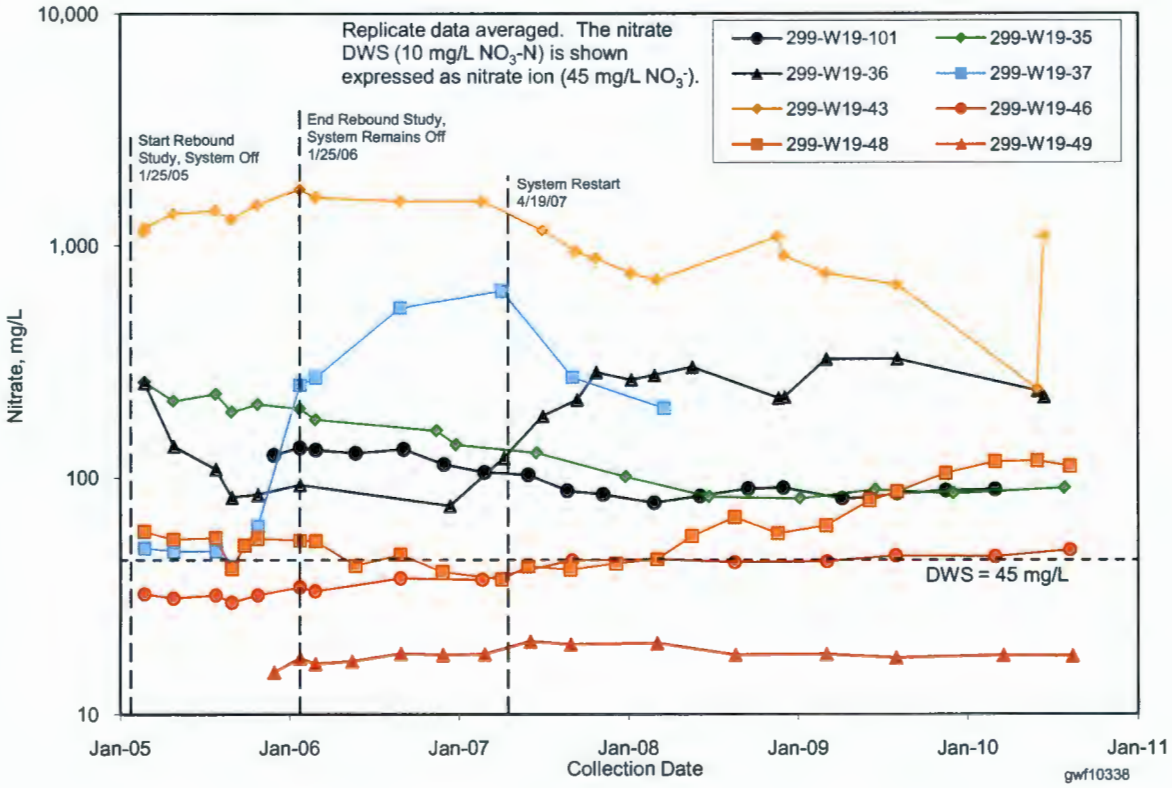


Figure 11-27. Average Uranium Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Area, Upper Portion of Unconfined Aquifer

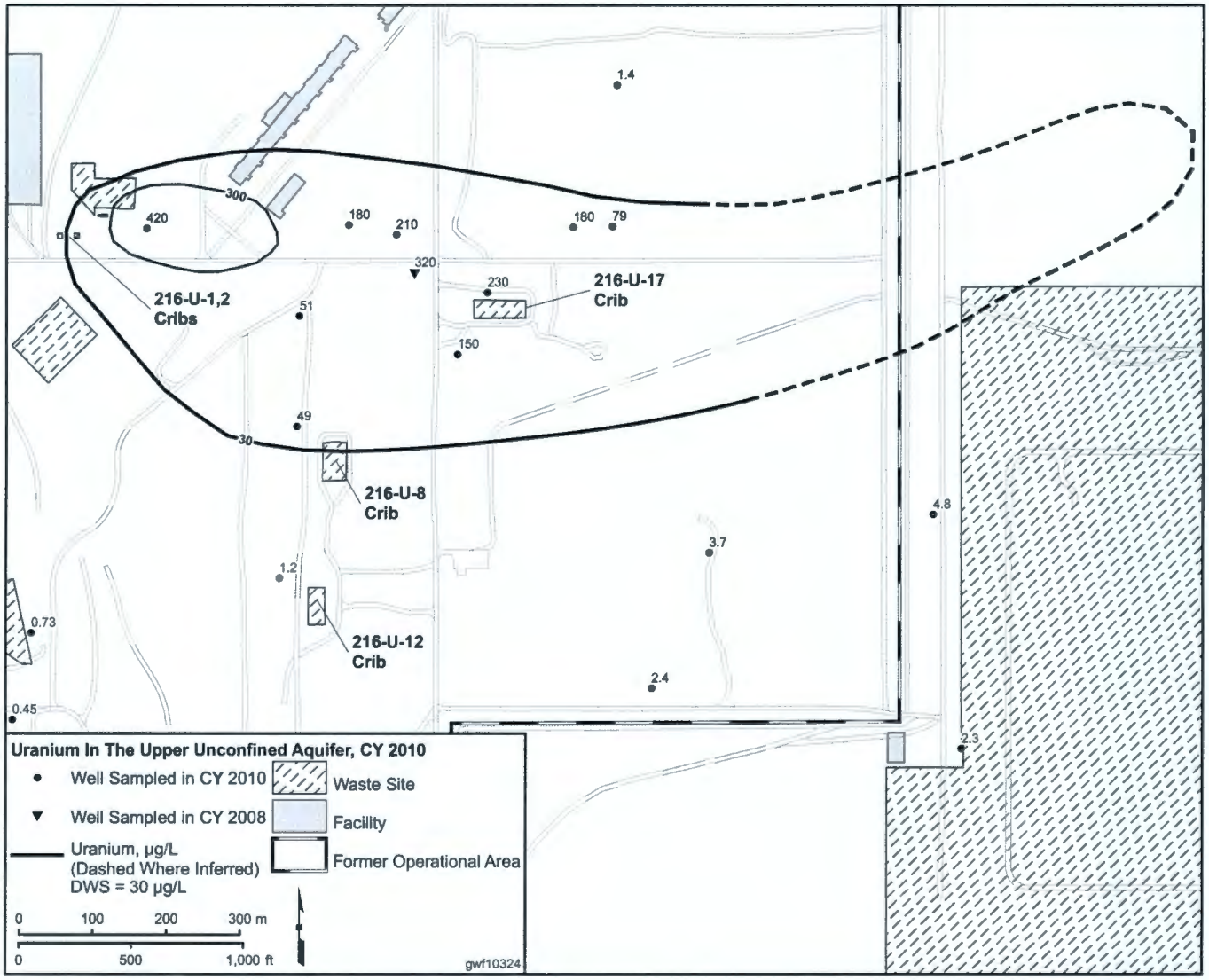


Figure 11-28. Average Technetium-99 Concentrations in 200-UP-1 Operable Unit Pump-and-Treat System Area, Upper Portion of Unconfined Aquifer

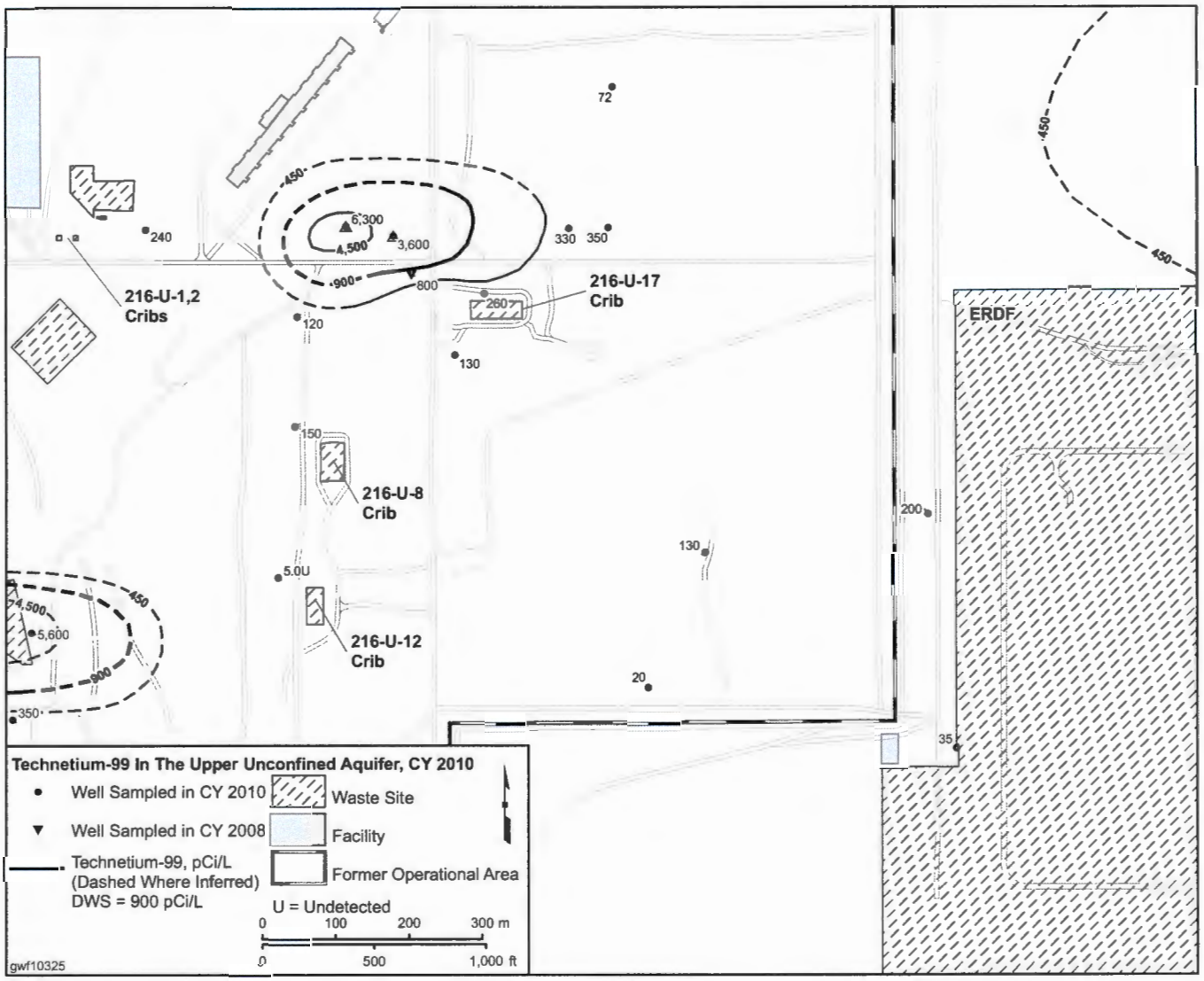


Figure 11-29. Average Nitrate Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer

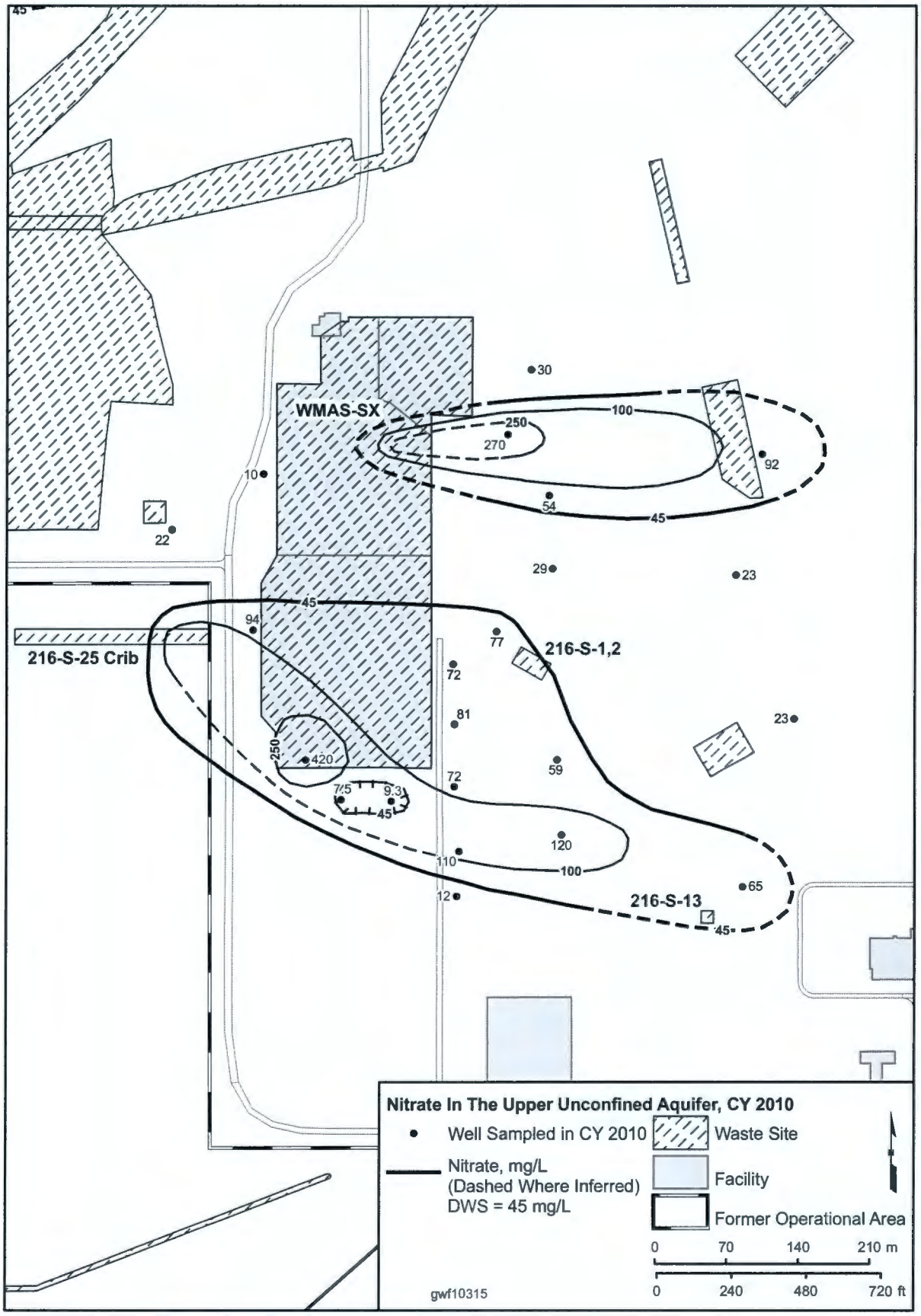


Figure 11-30. Average Chromium Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer

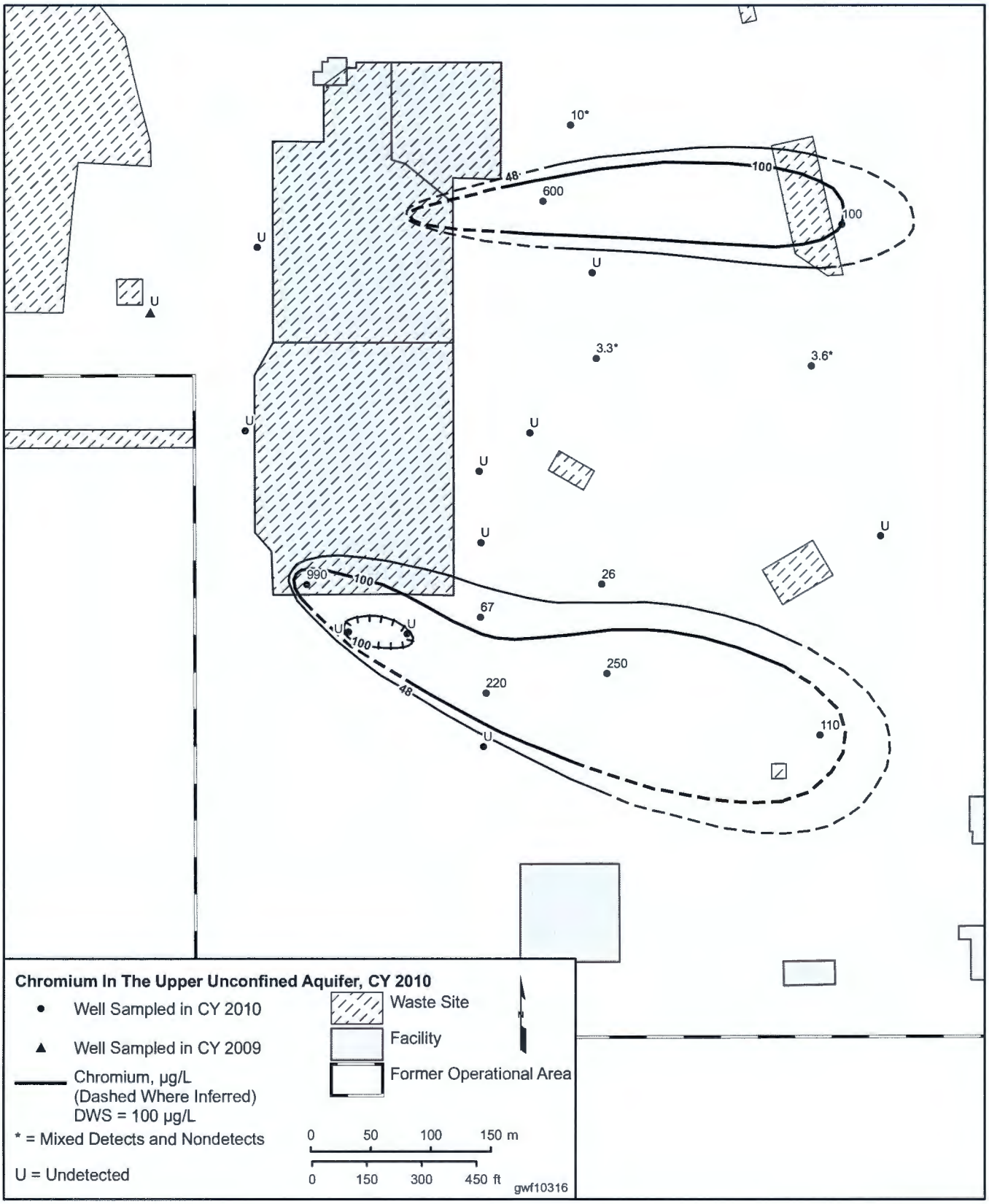


Figure 11-31. Average Technetium-99 Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer

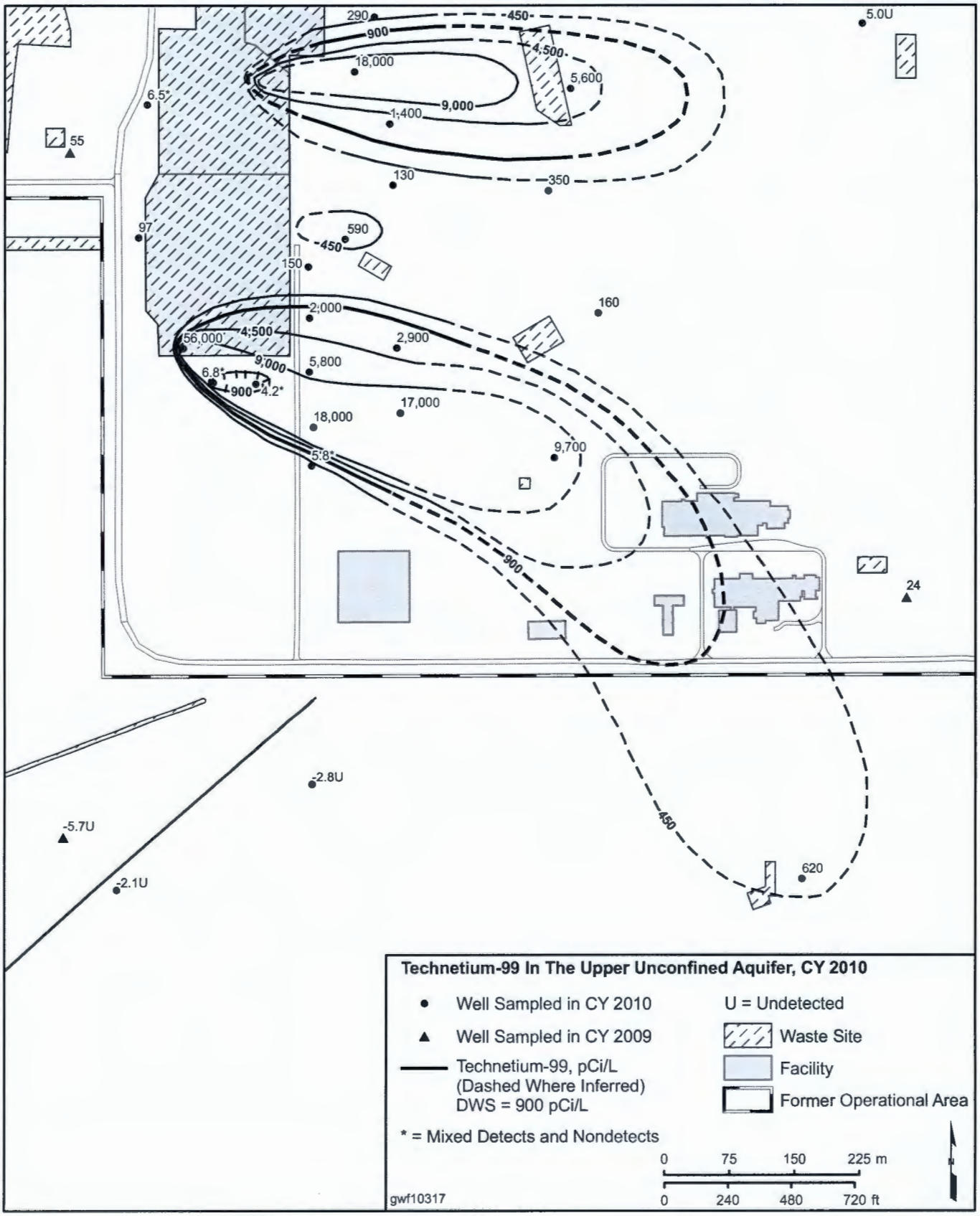


Figure 11-32. Average Nitrate and Technetium-99 Concentrations in Waste Management Area U, Upper Portion of Unconfined Aquifer

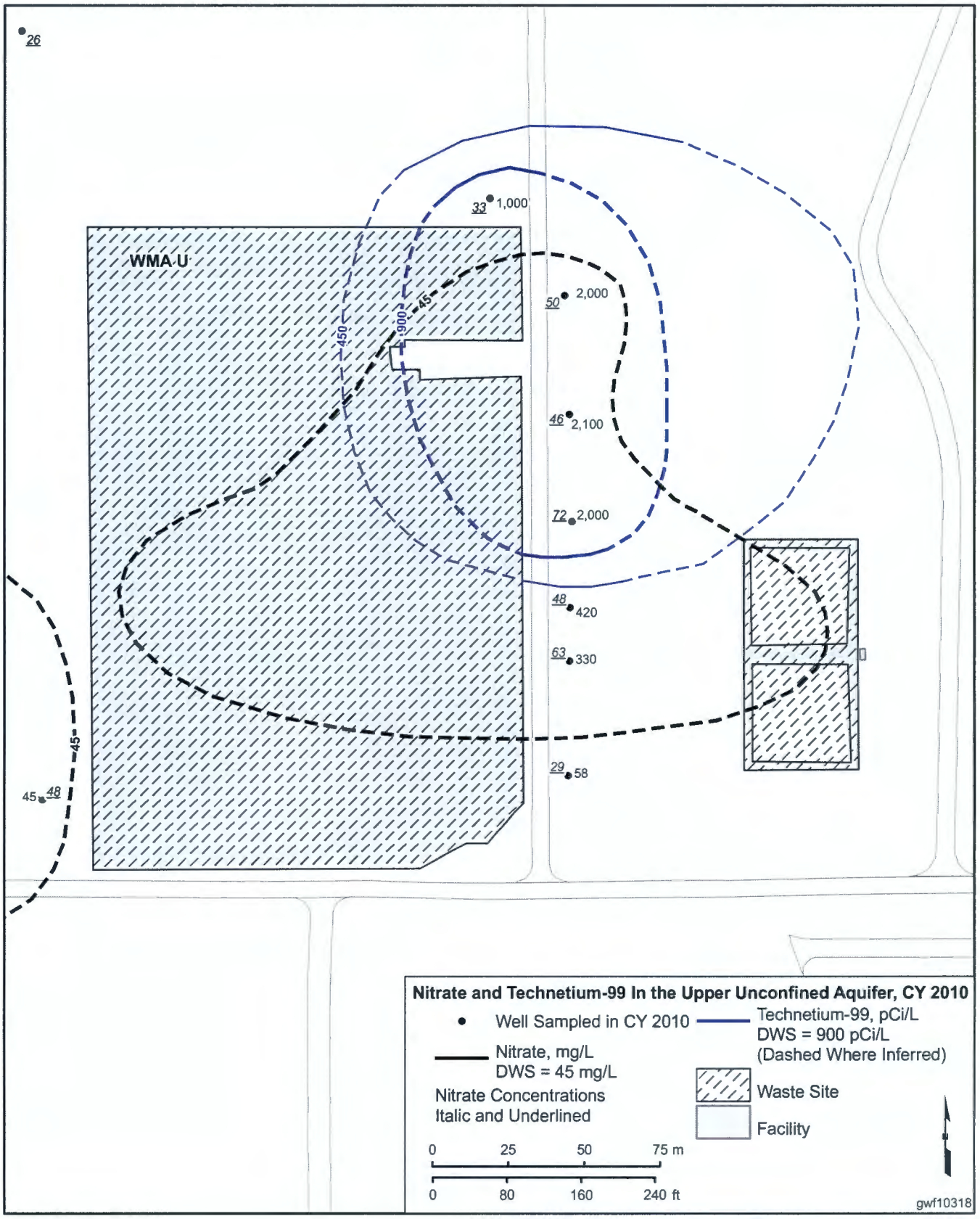


Figure 11-33. Specific Conductance in the 216-S-10 Pond and Ditch Monitoring Wells

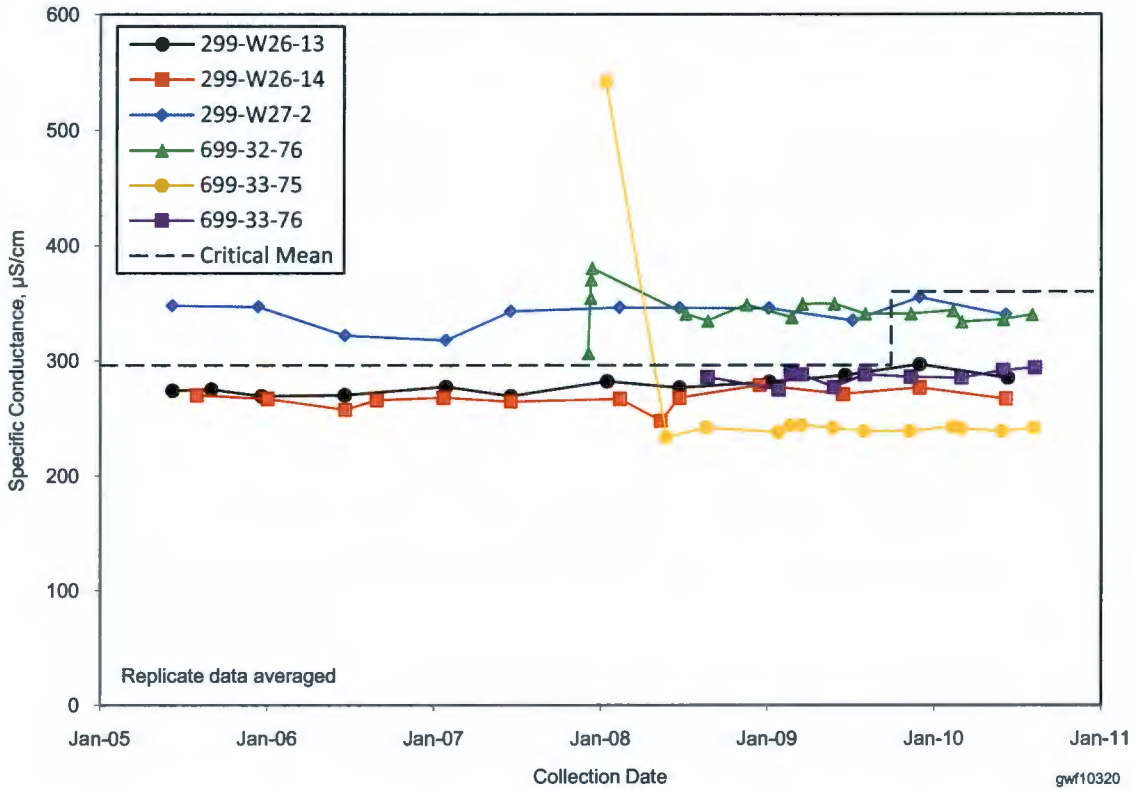


Figure 11-34. Nitrate Concentrations in the 216-S-10 Pond and Ditch Monitoring Wells

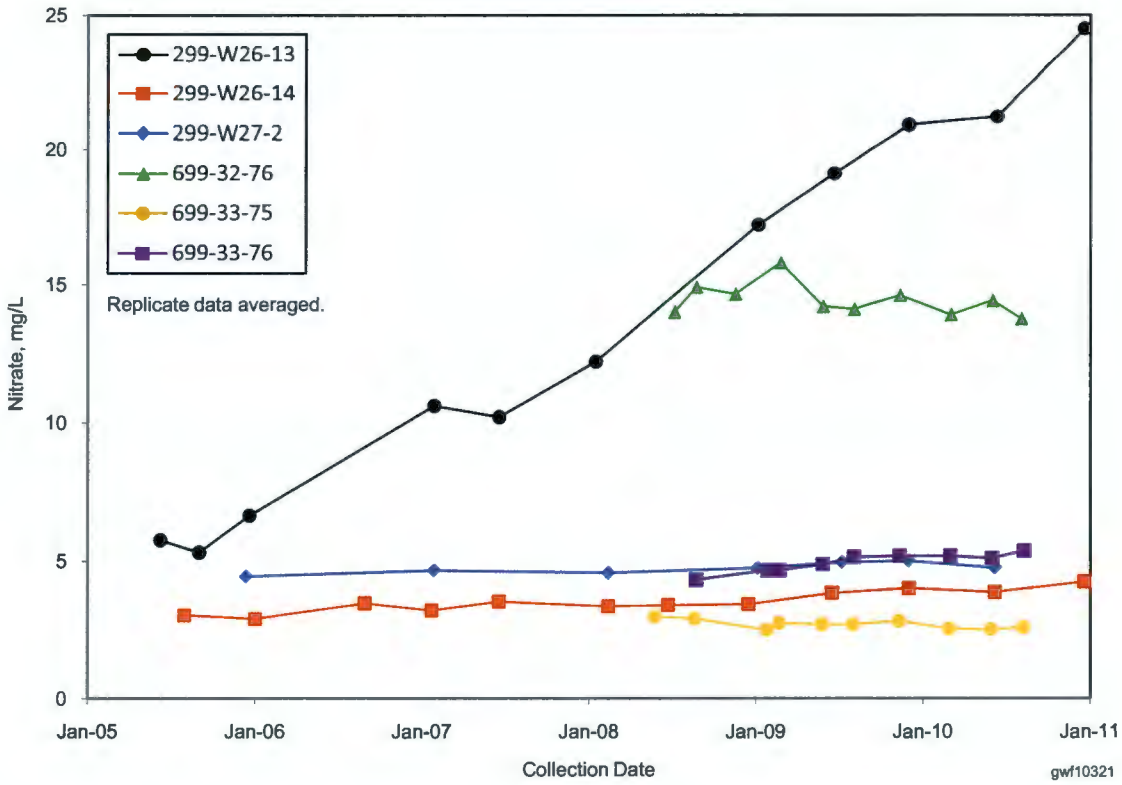
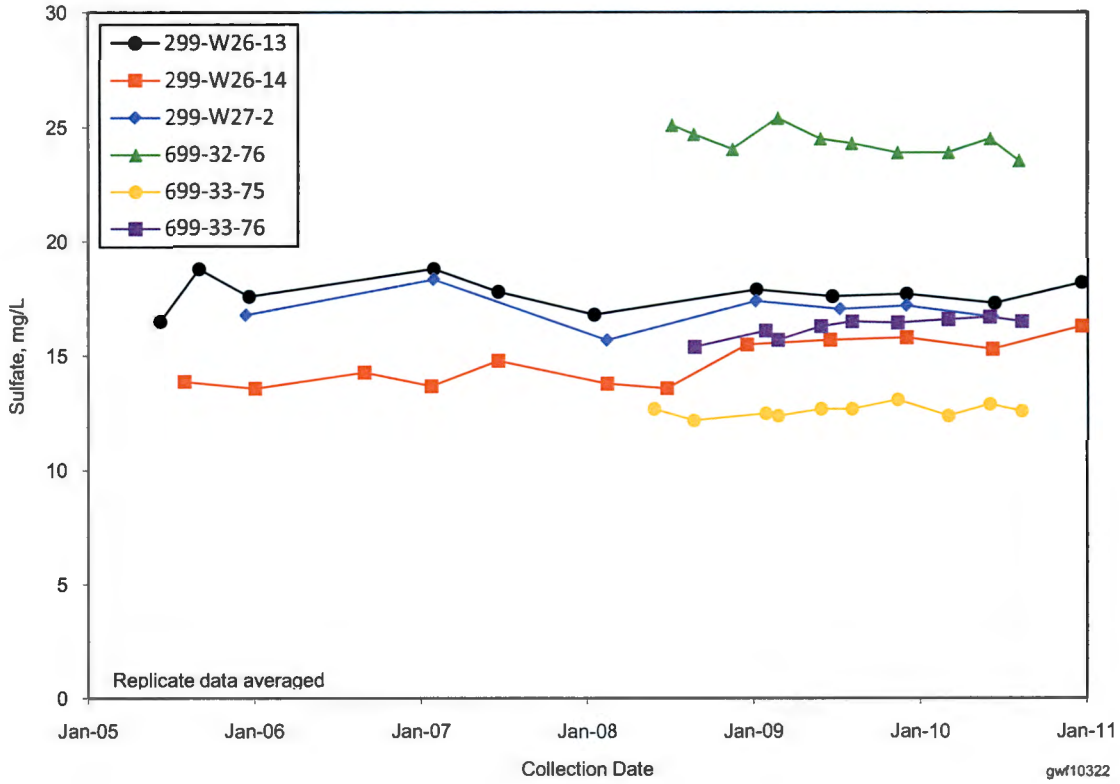


Figure 11-35. Sulfate Concentrations in the 216-S-10 Pond and Ditch Monitoring Wells

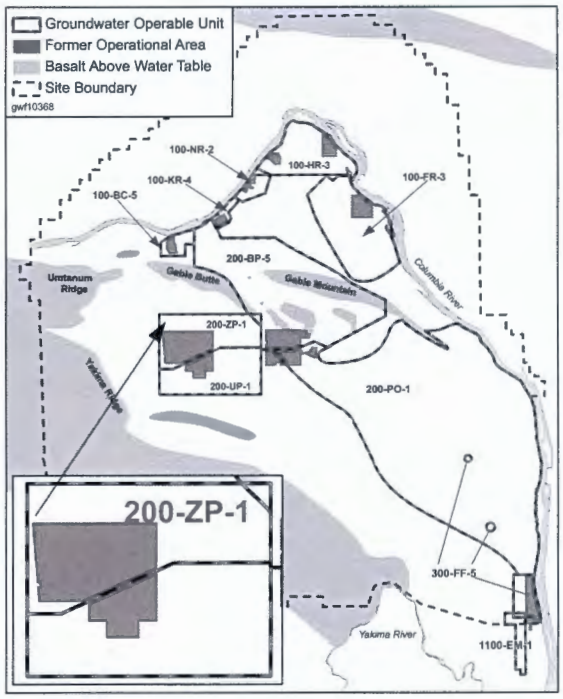


This page intentionally left blank.

12.0 200-ZP-1 Operable Unit

E.J. Freeman

The 200-ZP-1 Operable Unit (OU) activities focus on monitoring and remediation of groundwater contaminant plumes beneath the northern and central portions of the 200 West Area and the 600 Area (adjacent to the 200 West Area). The OU lies within the larger 200-ZP-1 groundwater interest area, informally defined to facilitate scheduling, data review, and interpretation (Figure 1-4 in Chapter 1.0). Figure 12-1 shows the extent of the OU, the facilities, and wells.



Groundwater is monitored to assess the performance of the interim action pump-and-treat system for carbon tetrachloride and technetium-99, to track other contaminant plumes, and to support four *Resource Conservation and Recovery Act of 1976* (RCRA) units and the State-Approved Land Disposal Site (SALDS). Data from facility-specific monitoring are also integrated into the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater investigations. Radionuclide monitoring for facilities is performed in accordance with the *Atomic Energy Act of 1954* (AEA).

The primary sections that comprise this chapter are organized as follows:

- Section 12.1 describes the waste facilities, hydrogeology, and groundwater flow characteristics for the 200-ZP-1 OU.
- Section 12.2 describes groundwater contaminants and compliance monitoring during the reporting period.
- Section 12.3 summarizes the CERCLA groundwater interim remedial action system performance for effective capture of carbon tetrachloride and technetium-99 within the OU.
- Section 12.4 addresses groundwater monitoring of RCRA facilities and the SALDS.
- Section 12.5 provides the conclusions and recommendations for the OU.

This chapter presents the calendar year (CY) 2010 activity for the 200-ZP-1 OU, from January 1, 2010, through December 31, 2010.

The main COC within the 200-ZP-1 OU is carbon tetrachloride associated with discharges to the 216-Z-1A, 216-Z-9, and 216-Z-18 Trenches.

12.1 Conceptual Model

This section provides a brief discussion of the conceptual site model, which affects estimates of contaminant distributions and migration rates and pathways. Elements that contribute to the conceptual model include waste site operations, hydrogeologic framework, and groundwater characteristics. Additional details on the conceptual model for the 200-ZP-1 OU can be found in Chapters 2 and 4 of the *Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2006-24)

Carbon tetrachloride is the primary contaminant of concern (COC) present in groundwater in the OU. The primary source of this COC is associated with discharges to the 216-Z-1A, 216-Z-9, and 216-Z-18 Cribs and Trenches. The contaminant

plume extends out from these waste sites along the primary flow direction to the north, northeast, and east, with the highest concentrations beneath the TX-TY Tank Farms. To a lesser extent, some migration of carbon tetrachloride has occurred to the south and southeast. Additional COCs within the 200-ZP-1 OU include trichloroethylene, technetium-99, chromium, nitrate, tritium, and iodine-129. Monitoring and remediation activities in the past have focused on wells screened in the upper 15 meters of the aquifer. Recent deeper drilling and well installations have confirmed the presence of relatively high contaminant concentrations at depth. This information is being incorporated into well designs and the remedial action process.

The Columbia River Basalt Group forms the bedrock beneath the 200-ZP-1 groundwater interest area. The uppermost basalt flow is the Elephant Mountain Member of the Saddle Mountains Basalt. Geologic units above the basalt (in ascending sequence) are the semiconsolidated sand and gravel of the Ringold Formation unit 9, the silt and clay of the Ringold lower mud unit 8, the semiconsolidated sand and gravel of Ringold unit 5, the fine- to coarse-grained Cold Creek unit (CCU), and unconsolidated sand and gravel of the Hanford formation. Groundwater within the interest area occurs as an unconfined aquifer, as well as under locally confining conditions, and as present beneath the Ringold lower mud unit (Ringold confined aquifer) and in the basalt flows and interbeds. The groundwater in the suprabasalt sediments is the only aquifer directly impacted by waste disposal operations in the central and northern 200 West Area. In those areas where the Ringold unit 8 is missing in the stratigraphic sequence, carbon tetrachloride has migrated below the elevation of the lower mud unit and into the confined aquifer.

The unconfined aquifer is contained within Ringold Formation sediments at the 200-ZP-1 OU and has been directly impacted by waste disposal operations in the central and northern 200 West Area. In particular, the aquifer occupies Ringold unit 5 and its base is generally the fine-grained Ringold lower mud unit, although in some areas the mud unit is missing and the bottom of the aquifer occurs at the top of the basalt. Depths from land surface to the water table range from 64 to 106 meters, with the greater depths occurring in the northeastern portion of the interest area. The thickness of the unconfined aquifer within the interest area is variable (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*). Moving east of the 200 West Area, the aquifer transitions into the Hanford formation, which is a much more transmissive unit. The lower mud unit rises to the northeast and subcrops above the water table.

Groundwater in the northern portion of the 200 West Area predominantly flows toward the east-northeast but is locally influenced by the 200-ZP-1 pump-and-treat system and from effluent discharges to the SALDS (Figure 12-2) just north of the 200 West Area. The groundwater flow rates, calculated using the Darcy relationship (SGW-38815, *Water-Level Monitoring Plan for Hanford Site Soil and Groundwater Remediation Project*), typically range from 0.0001 meter per day in fine-texture, low-permeability material to 0.5 meter per day in coarse-texture, higher permeability material within the 200-ZP-1 groundwater interest area. The water table was impacted by Hanford Site operations in the 200 West Area due to past discharge of wastewater to ponds, ditches, and trenches. Cessation of these discharges has resulted in the water table declining at a rate of ~0.21 to 0.35 meters per year (Figure 12-3). The flow direction in the northern portion of the groundwater interest area has shifted over the past decade, from a north-northeastern direction to a more easterly direction as the water table decline approaches new equilibrium groundwater levels.

Flow in the central portion of the 200 West Area (southern portion of the 200-ZP-1 groundwater interest area) is strongly influenced by operation of the 200-ZP-1 pump-and-treat system. The 200-ZP-1 pump-and-treat system currently has fourteen extraction wells located north of the 216-Z Cribs and Trenches and west of Waste Management Area (WMA) TX-TY (Figure 12-1). The treatment system removes carbon tetrachloride and other volatile organic compounds. Treated effluent is injected into the aquifer to the west of the area. A small groundwater mound is present in the area of the injection wells, while a region of drawdown occurs near the extraction wells, setting up a recirculation zone between the two areas. The injection wells are due west of Low-Level Waste Management Area 4 (LLWMA-4) and have affected groundwater flow direction and contaminant concentrations beneath that WMA.

12.2 Groundwater Contaminants

This section describes the major COCs for the 200-ZP-1 OU: carbon tetrachloride, trichloroethylene, nitrate, total chromium, hexavalent chromium, tritium, iodine-129, and technetium-99. Cribs, trenches, and underground tanks are the principal sources of groundwater contamination. Most of the sampling and analytical results that are used to define the contaminant plume are from monitoring and extraction wells completed in the upper 15 meters of the aquifer. As a result, previous plume maps have been biased toward the top of the unconfined aquifer. The plume maps discussed in this section represent the annual average concentration calculated from all sampling events at each well during the reporting period.

Plume areas (square kilometers) in the 200-ZP-1 Operable Unit:

Carbon Tetrachloride*, 5 µg/L — 11.459
Chromium, 100 µg/L — 0.05
Iodine-129, 1 pCi/L — 0.74
Nitrate, 45 mg/L — 5.808
Technetium-99, 900 pCi/L — 0.073
Trichloroethene, 5 µg/L — 0.107
Tritium, 20,000 pCi/L — 0.532
Uranium, 30 µg/L — 0

**** Also includes plume area beneath the 200-UP-1 Operable Unit***

The predominant COC in the 200-ZP-1 OU is carbon tetrachloride. By 2010, the 1,000 µg/L plume contour within the upper 15 meters of the aquifer had decreased in area from 0.53 square kilometers to 0.43 square kilometers. Carbon tetrachloride is purported to exist only in a soluble liquid phase (dissolved). Field studies conducted in 2006 and 2007 (DOE/RL-2006-58, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid [DNAPL] Source Term Interim Characterization Report*; and DOE/RL-2007-22, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid [DNAPL] Source Term Characterization Report Addendum*) investigated whether carbon tetrachloride was present as a free-phase, dense nonaqueous-phase liquid product. In both studies, only the water-soluble component was detected; therefore, it is believed that carbon tetrachloride no longer or minimally exists in free-phase, dense nonaqueous-phase form at the former disposal sites. Consequently, any current downward migration of this contaminant is thought to be the results of lithologic controls and/or a vertical hydraulic gradient induced by past liquid waste disposal operations.

Depth-discrete sampling of volatile organic analytes at new extraction wells in the 200-ZP-1 OU exhibit carbon tetrachloride reduction-oxidation degradation and chloroform accumulation at the contact between coarse and fine sediments.

12.2.1 Carbon Tetrachloride

Carbon tetrachloride is the principal COC for the 200-ZP-1 OU and is found at levels greater than the drinking water standard (DWS) (5 µg/L) under most of the 200 West Area (Figures 12-4 and 12-5). The main sources of carbon tetrachloride are the 216-Z Cribs and Trenches (three facilities) that received waste from the Plutonium Finishing Plant (PFP). Interim remediation of this plume began in 1994. The remedial action objectives for cleanup of the plume are described in the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA/ROD/R10-95/114).

The initial targeted capture zone for the interim action was an area where carbon tetrachloride concentrations were greater than 2,000 µg/L.

The extent of the shallow unconfined carbon tetrachloride plume is depicted in Figure 12-4. The 2,000 µg/L mass in the upper 15 meters is currently located along the western edge of WMA TX-TY. In the mid-1990s, the plume was centered in the area of the PFP. Within and adjacent to this area, fourteen extraction wells are operating to remove contaminated groundwater for subsequent treatment at the 200-ZP-1 interim treatment facility (Figure 12-1). After treatment for volatile organics, the remediated water is injected through a line of five wells oriented north to south, located west of LLWMA-4. The plume area at the 5 µg/L DWS extends to the boundaries of the 200 West Area to the north, south, and east. The main plume orientation indicates overall migration predominantly northeast to east. The overall extent of the plume for CY 2010 is similar to that observed in 2009 (~11.5 square kilometers).

In addition to shallow carbon tetrachloride contamination (upper 15 meters) in the unconfined aquifer (Figure 12-4), the distribution throughout the full extent of the unconfined aquifer is shown in Figure 12-5. This figure represents a revision of Figure 7-5 from the *Hanford Site Groundwater Monitoring and Performance Report 2009* (DOE/RL-2010-11). Figure 12-5 incorporates additional data from recent depth-discrete sampling during drilling, removes data older than 2005 from the analysis, accounts for spatially varying properties of the plume, and takes into consideration depositional characteristics of the sediments. These changes provide a similar configuration but a somewhat more contorted plume than the smoother plume presented in DOE/RL-2010-11. Also, the carbon tetrachloride that accounts for the greater than 2,000 µg/L area appears as fragmented zones rather than a large, coherent mass in the aquifer. This new conceptualization is consistent with the principles of groundwater flow in heterogeneous porous media.

During CY 2010, two monitoring wells and five extraction wells in the 200-ZP-1 performance monitoring network exceeded 2,000 µg/L. Groundwater wells 299-W15-40, 299-W15-11, and 299-W15-765 had the highest recorded concentrations at ~2,900 µg/L for CY 2010. Monitoring well 299-W15-50 averaged ~2,600 µg/L. Since 2002, well 699-48-71 (northeast and outside of the 200 West Area) has shown a continuing increase in carbon tetrachloride concentration. The concentration has exceeded the DWS since 2002 and is currently ~94 µg/L (Figure 12-6).

The carbon tetrachloride concentration distribution for the 200-ZP-1 OU plume map (Figure 12-4) has been based on groundwater wells in the upper 15 meters of the unconfined aquifer. As a result of drilling new groundwater extraction wells, carbon tetrachloride concentrations greater than 1,000 µg/L have recently been observed at depths greater than 15 meters at wells downgradient from the source zone. Figure 12-7 provides a visual "slice" through a three-dimensional conceptual model of the carbon tetrachloride plume at 94 m elevation above mean sea level. This "slice" is derived from concentrations measured in all groundwater wells screened above the basalt within the unconfined aquifer. The vertical distribution of carbon tetrachloride is developed from 200-ZP-1 groundwater wells along the A to A' transect shown in Figure 12-7. The vertical and laterally continuous carbon tetrachloride plume is represented in Figure 12-8. Both of these plume maps show that carbon tetrachloride has moved toward the east and vertically downward at increasing distances from the source zone. Additionally, overall concentrations are declining at greater distances due to dispersion and degradation.

Depth-discrete sampling is currently performed during the construction phase while drilling new groundwater injection and extraction wells. By the end of CY 2010, fourteen new extraction and four new injection wells were completed to support future operations of the 200 West Area pump-and-treat groundwater processing facility. The wells are oriented in a staggered line from west of WMA TX-TY to the eastern boundary of the 200 West Area (Figure 12-5) and are designed to locate the extraction wells within the greater than 1,000 µg/L carbon tetrachloride contour.

12.2.2 Trichloroethylene

Trichloroethylene is detected at levels above the DWS (5 µg/L) in the 200-ZP-1 groundwater interest area. The main trichloroethylene plume (Figure 12-9) is located north from the source area at the 216-Z Cribs and Trenches. There are three discrete plume lobes with concentrations above the DWS located (1) beneath WMA TX-TY, co-located with the high-concentration portion of the carbon tetrachloride plume; (2) beneath WMA T; and (3) directly east of WMA T. Each of these plumes is downgradient, along the centerline of the carbon tetrachloride plume. Trichloroethylene exceeded the DWS in sixteen performance monitoring wells, including six extraction wells (four wells adjacent to WMA TX-TY and two wells east of WMA T). The maximum reported concentration during CY 2010 was 12 µg/L east of WMA TX-TY at extraction well 299-W15-45. At well 299-W11-34P, ~300 meters east of WMA T, the trichloroethylene concentration was 10 µg/L for most of the reporting period. The trichloroethene plumes for both WMA TX-TY and WMA T are located within the capture zones for their respective interim pump-and-treat systems. The plume east of WMA T is downgradient and lies outside of any capture zone. However, this plume shows a declining trend and is also in the capture zone for the final remedy pump-and-treat extraction wells.

12.2.3 Nitrate

Nitrate concentrations were above the DWS (45 mg/L, as nitrate) beneath much of the 200-ZP-1 groundwater OU (Figure 12-10). Multiple sources of nitrate likely exist in this area, including the cribs near WMA T and the 216-Z Cribs and Trenches. Two discrete, high-concentration plumes (greater than 400 mg/L) are discernible in the 200-ZP-1 OU: (1) a plume located beneath WMA T, and (2) a diminishing plume centered at well 299-W18-16 (near the 216-Z Cribs and Trenches) (Figure 12-10). The 45 mg/L contour extends from the 216-Z Cribs and Trenches at the southwest to beyond the 200 West Area boundary to the northeast.

The northern high-concentration plume is located, in part, within the capture zone of the current WMA T pump-and-treat wells. The highest concentration at the WMA T wells for the reporting period was 2,830 mg/L at well 299-W10-4. The high value reported for the southern plume at well 299-W18-16 has declined from 708 mg/L in 2009 to 411 mg/L in 2010. In general, the nitrate plume remained stable during CY 2010 compared to 2009.

12.2.4 Chromium

Chromium contamination is found at levels above the DWS (100 µg/L) beneath the single-shell tank farms WMA T and WMA TX-TY (Figure 12-11). The hexavalent form of chromium is soluble and mobile in water. For the groundwater plume analysis, total chromium is used to characterize concentrations and plume extent. The maximum concentration during CY 2010 was ~731 µg/L at tank farm well 299-W14-13. The maximum concentration reported at CERCLA well 299-W10-4, south of WMA T, was 465 µg/L. The chromium plume path is oriented toward the northeast. A total of ten performance monitoring wells exceeded

the chromium DWS in CY 2010, and nine of these wells were adjacent to WMA T. The chromium-contaminated wells in the northeastern corner of WMA T are within the capture zone for the pump-and-treat system. The concentration in the extraction wells immediately downgradient of WMA T at the end of CY 2010 were 146 µg/L in well 299-W11-45 and 121 µg/L in well 299-W11-46. In general, the chromium plume remained stable during CY 2010 compared to values observed in 2009.

12.2.5 Tritium

Tritium concentrations exceed the 20,000 pCi/L DWS only at wells northeast of WMA T, WMA TX-TY, and near the SALDS.

Tritium concentrations exceeded the DWS of 20,000 pCi/L within the 200-ZP-1 OU at two locations: (1) adjacent to WMA T and WMA TX-TY, and (2) adjacent to the SALDS. The geometry and extent of the tritium plumes are shown in Figure 12-12. The highest concentrations occur east of WMA TX-TY at well 299-W14-13. The tritium concentration at this well was measured at 1.6 million pCi/L. The general configuration of the plume shows the tritium oriented along a northeast flow path. Possible sources include surface wastewater disposal sites and facilities associated with the tank farms. The main source of the tritium plume near WMA TX-TY and WMA T is unknown. Tritium concentrations at wells near the WMAs appear to be declining over the years, which suggest that the tritium source may be depleted. Another explanation may be a shift in the hydraulic gradient that is diverting the higher concentration part of the plume away from the observations wells.

The second source of tritium is associated with the active wastewater discharge site at the SALDS. These discharges are known to contain tritium and are permitted by the State of Washington (Permit ST 4500 [Ecology, 2000a]). The highest tritium concentrations in groundwater wells 299-48-77A, 299-48-77C, and 299-48-77D were 7,500 pCi/L, 88,000 pCi/L, and 180,000 pCi/L, respectively. The tritium is expected to decay below the DWS as it moves downgradient from this facility.

The tritium plume near the SALDS varies with discharge volumes and correlates to concentration loading received from the Effluent Treatment Facility (ETF).

12.2.6 Iodine-129

Iodine-129 concentrations at the 200-ZP-1 OU exceeded the 1 pCi/L DWS at four wells during CY 2010. The extent and geometry of the iodine-129 plume is shown in Figure 12-13. The maximum concentration of 39.6 pCi/L was at well 299-W14-13, adjacent to WMA TX-TY. Concentrations exceeded the DWS at wells 299-W11-34P, 299-W11-37, and 299-W11-7. The flow path of the iodine-129 plume can be traced to downgradient wells along a northeast trend. The highest iodine-129 concentrations associated with extraction wells occurred in wells 299-W11-45 and 299-W11-46 with concentrations of 0.95 pCi/L and 0.99 pCi/L, respectively. The detection limit for iodine-129 is ~0.5 pCi/L. In general, the iodine-129 plume remains stable compared to 2009 at ~0.74 square kilometers.

12.2.7 Technetium-99

The technetium-99 maximum concentration has steadily declined in extraction well 299-W11-46, from a high of 113,000 pCi/L in 2007 to 4,500 pCi/L in CY 2010.

Technetium-99 exceeded the 900 pCi/L DWS at eleven of the 200-ZP-1 OU groundwater wells. The highest concentration measured during CY 2010 was 10,000 pCi/L at well 299-W11-40, located at the east side of WMA T. Three distinct plumes are shown in Figure 12-14, which are centered at (1) the south end of WMA TX-TY, (2) the north end of WMA TX-TY, and (3) beneath WMA T. The second highest measured technetium-99 concentration during CY 2010 of 6,900 pCi/L was measured at well 299-W14-13, located on the east side of WMA TX-TY, at the north end. This well also accounted for the highest iodine-129 and highest tritium concentrations measured at the OU. The highest technetium-99

concentrations at extraction wells included 299-W15-765 (5,600 pCi/L), 299-W11-46 (5,000 pCi/L), and 299-W11-45 (4,000 pCi/L). Well 299-W15-3 had a concentration of 40,000 pCi/L when it was last measured in 2009.

The plume beneath WMA T has the same northeast trend as other contaminant plumes in the OU. The north plume is distinct at WMA TX-TY in that it appears to be oriented to the southeast. The reason for the plume's orientation is unknown. The southern WMA TX-TY plume does not show a discernible trend of flow direction. Overall technetium-99 concentrations at the monitoring wells remain stable in comparison to the observations for 2009.

12.2.8 Other Constituents

Other constituents detected in groundwater at concentrations above the preliminary target action levels include fluoride, antimony, arsenic, iron, and manganese. Chloroform and methylene chloride are monitored for the groundwater interest area as degradation products of carbon tetrachloride.

During CY 2010, the annual average chloroform concentrations in the 200-ZP-1 groundwater interest area remained below the 80 µg/L DWS (defined for total trihalomethanes). Concentrations are declining throughout the groundwater interest area. Possible chloroform sources include biodegradation of carbon tetrachloride and sanitary sewer discharges to the 2607-Z Tile Field. Chloroform also is found near WMA TX-TY and WMA T, as well as at depth below the water table to the northeast of these areas.

Uranium is another constituent of interest in groundwater that could potentially exceed the current DWS (30 µg/L). During CY 2010, the maximum uranium concentration of 26.3 µg/L was detected in groundwater well 299-W11-37. This well is located near the T Plant complex, and the uranium concentrations have been steadily declining over time. None of the groundwater wells in the 200-ZP-1 OU exceeded the DWS for uranium during CY 2010.

Fluoride contamination at levels greater than the primary DWS (4 mg/L) has historically occurred in a local area around T Tank Farm. Well 299-W10-8 (located at the northwestern corner of the tank farm) had the CY 2010 maximum fluoride concentration of 4.49 mg/L, which reflects a slight decrease in fluoride from a concentration of 4.89 mg/L in 2009. A possible source for the contamination is the historical surficial releases of lanthanum fluoride used in the bismuth phosphate process. This liquid may have infiltrated to the unconfined aquifer.

Antimony concentrations in several wells exceeded the DWS (6 µg/L) in CY 2010; however, antimony results have been problematic. Detections are typically very close to the reported detection limit and are sporadic. Most of the detections in CY 2010 and previous years are believed to be false-positive results.

During CY 2010, filtered arsenic was detected at levels above the 10 µg/L DWS in well 299-W10-4 located southwest of WMA T. The maximum concentration reported at this well was 12.0 µg/L, which is slightly higher than the maximum of 9.7 µg/L at this well in 2009. The Hanford Site filtered groundwater background for arsenic is 11.8 µg/L (95th percentile) (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*).

Iron was present at levels above the 300 µg/L secondary DWS in eleven groundwater monitoring wells. The maximum reported concentration of 2,400 µg/L (unfiltered) was at well 299-W10-4. Since well 299-W10-4 was constructed in 1952 and the casing is carbon steel, high iron content in the water may be an artifact of

casing degradation. Review of samples collected for multiple years at individual wells indicates that the iron concentration typically fluctuates over a wide range. The sample results for iron are suspect because iron is also a naturally occurring component of the aquifer sediment and is found in well materials. The background iron concentration for Hanford Site filtered groundwater is 55.3 µg/L (DOE/RL-96-61).

Methylene chloride was detected at levels above the 5 µg/L DWS in one well in the 200-ZP-1 groundwater interest area during CY 2010. The maximum concentration reported was at well 299-W17-1 (eastern boundary of LLWMA-4) at 5.9 µg/L. Methylene chloride (dichloromethane) can be a degradation product or impurity in carbon tetrachloride (tetrachloromethane), but it is also a common laboratory contaminant.

12.3 CERCLA Groundwater Activities

This section summarizes the CERCLA groundwater performance monitoring and interim remedial measures at the 200-ZP-1 OU, as outlined in the interim Record of Decision (ROD) (EPA/ROD/R10-95/114), and as implemented in the *200-ZP-1 Interim Remedial Measure Remedial Design Report* (DOE/RL-96-07) and the *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network* (DOE/RL-2002-17).

The performance monitoring network is intended to ensure that appropriate data are collected to evaluate remedy performance in the aquifer. A list of the performance monitoring network wells and sampling frequency is provided in Appendix A, Table A-11. The final design, installation, and operation of the remedial action monitoring network and treatment system are discussed in the *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78). Additional tasks performed during CY 2010 in support of the final ROD issued in 2008 (*Declaration of the Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* [EPA et al., 2008]) included the completion of eleven additional wells (seven extraction and four injection), which supplements the seven wells completed in 2009 and moves the project closer to a final network of at least sixteen injection and twenty extraction wells. These wells will support the new groundwater treatment facility, which is anticipated to be operational by December 2012. Construction activities for the new and expanded groundwater treatment facility continued in CY 2010.

Within the 200-ZP-1 OU, interim actions have been implemented to remediate carbon tetrachloride, chloroform, and trichloroethylene in the vicinity of the 216-Z liquid waste disposal cribs and trenches. The final remedy for the 200-ZP-1 OU addressed carbon tetrachloride and the other COCs throughout the vertical extent of the aquifer in accordance with the final ROD (EPA et al., 2008). The *Calendar Year 2010 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable unit Pump-and-Treat Operations* (DOE/RL-2011-26) provides a detailed status of the interim remediation from previous years. Interim remedial measures were implemented through operation of fourteen extraction wells and five injection wells to capture the high-concentration (greater than 2,000 µg/L) region of the carbon tetrachloride plume. Carbon tetrachloride and seven other constituents are removed from the contaminated groundwater at an interim treatment facility in the 200 West Area, and the treated effluent is then pumped back into the aquifer through a group of injection wells. This action creates a groundwater mound that increases the groundwater gradient of the plume toward the extraction wells.

In addition to carbon tetrachloride, monitoring and remediation of technetium-99 from sources within WMA T and WMA TX-TY have been implemented to address this constituent for both CERCLA and AEA programs. Remediation activities at this site include pumping of technetium-99-laden groundwater from wells 299-W11-45 and 299-W11-46. Effluent from these wells is transferred to the ETF via a cross-site transfer pipeline, where constituents are removed before the remediated water is discharged at the SALDS.

The plan and schedule for implementing all of the tasks applicable to the 200 West Area pump-and-treat system, as set forth in the final 200-ZP-1 ROD, were issued in the 200-ZP-1 pump-and-treat remedial design/ remedial action work plan (DOE/RL-2008-78) in March 2009.

12.3.1 CERCLA Decision Documents

The interim remedy for the 200-ZP-1 OU is defined in the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA/ROD/R10-95/114). The purpose of the ROD is to explain the cleanup alternatives that are used at the site. The primary COCs identified for interim remediation are carbon tetrachloride, trichloroethylene, and chloroform. The interim ROD identifies that the three remedial action objectives for the project are to (1) reduce contamination in the areas of highest concentration of the carbon tetrachloride plume, (2) prevent further movement of contaminants from high concentration areas, and (3) provide information to the final remedy that is protective of human health and the environment.

The second CERCLA 5-year review was published in November 2006 (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*), which provided a comprehensive evaluation of the status of groundwater and source OU investigations and cleanup actions. All findings pertinent to the 200-ZP-1 OU for the 200 Areas National Priority List (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan") were completed in fiscal year (FY) 2007.

Based on groundwater characterization activities and interim pump-and-treat operations, the final remedy for the 200-ZP-1 OU was developed and formalized in the final ROD (EPA et al., 2008). The list of COCs was expanded to include the major contaminant plumes exceeding DWSs. The COCs include carbon tetrachloride, trichloroethylene, iodine-129, technetium-99, nitrate, hexavalent chromium, total chromium, and tritium. The remedial action objectives identified in the ROD include (1) return the 200-ZP-1 OU groundwater to beneficial use, (2) apply institutional controls to prevent use of groundwater until the cleanup levels have been attained, and (3) protect the Columbia River from degradation and unacceptable impacts caused by contamination from the 200-ZP-1 OU. The remedial action objectives are achieved through four remedy components: (1) pump-and-treat of the contamination, (2) monitored natural attenuation, (3) flow-path controls, and (4) institutional controls.

The CERCLA cleanup process for the 200-ZP-1 OU is described in a series of regulatory documents, including the following:

- *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2003-55), prepared in FY 2004 and implemented in FY 2005
- *Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2006-24), published in October 2006
- *Feasibility Study Report for 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2007-28) and the *Proposed Plan for Remediation of 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2007-33), completed in July 2008
- *Declaration of the Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton county, Washington* (EPA et al., 2008)

Carbon tetrachloride mass was reduced through pumping and treating over 570.2 million liters of groundwater from fourteen extraction wells during CY 2010. This resulted in the removal of 700.7 kilograms of carbon tetrachloride. The large increase in mass removed and volume extracted relative to 2009 can be attributed to addition of extraction well 299-W15-225 during CY 2010.

- *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78), for implementing all of the tasks for design, installation, and operation of the 200 West Area pump-and-treat system (as set forth in the final 200-ZP-1 ROD), completed in July 2009.

12.3.2 Pump-and-Treat System for Carbon Tetrachloride

The main portion of the current 200-ZP-1 OU interim pump-and-treat system is located near the middle of the 200 West Area (Figure 12-1) and it removes carbon tetrachloride as the primary COC, with chloroform and trichloroethylene as secondary COCs. New extraction and injection wells to support the final remedy will cover this area, most of the northern portion of the 200 West Area and outside the 200 West Area to the east (Figure 12-5). The baseline groundwater plume is centered on an area of high carbon tetrachloride concentration that has its source from discharges to three waste sites located immediately south and east of the PFP. One of the remedial action objectives, as defined in the interim ROD (EPA/ROD/R10-95/114) identifies reducing contamination in the area of highest concentrations of carbon tetrachloride. The pump-and-treat system began operation in 1994 and includes fourteen extraction wells and five injection wells as of CY 2010. Groundwater extracted by the well network is processed through the 200-ZP-1 interim treatment system before being pumped back into the aquifer at the five active injection wells. Much of the groundwater beneath the 200 West Area and adjacent 600 Area has carbon tetrachloride concentrations exceeding the DWS of 5 µg/L.

This section provides a summary of the information contained in the annual performance report for 200-ZP-1 OU interim pump-and-treat operations (DOE/RL-2011-26). More detailed discussion can be found in that annual summary report. The production metrics and operational results of the pump-and-treat activities are also included in the following discussion.

12.3.2.1 Changes in 2010

During CY 2010, a range of activities was performed at the 200-ZP-1 pump-and-treat system to improve system operation and provide a better understanding of contaminant distribution and movement. A summary of the 200-ZP-1 pump-and-treat activities and developments for CY 2010 is as follows:

- Extraction well 299-W15-44 was removed from the pump-and-treat system and replaced by well 299-W15-225. The new extraction well increased production by ~946 liters per minute and now accounts for 52% of the water extracted from the fourteen-well network.
- A new heater/chiller unit was installed to moderate temperature variations at the plant. This improvement further enhances the operational efficiency of the system.
- Seven injection and four extraction wells were completed during CY 2010 compared to seven wells completed in CY 2009, for a total of eighteen wells. Ultimately, the pump-and-treat system will consist of at least sixteen injection and twenty extraction wells.
- Construction at the 200 West Area groundwater treatment facility proceeded expeditiously during CY 2010, with progress on the radiological process facility and biological treatment facility ongoing. Construction on this facility is scheduled for completion by the end of 2011.
- The design and balance of plant requirements were completed, as they pertain to the expanded 200 West Area pump-and-treat system, to meet *Hanford Federal*

Facility Agreement and Consent Order (Tri-Party Agreement) Milestone M-016-123 (Ecology et al., 1989).

- Several documents relevant to carbon tetrachloride pump-and-treat operations were completed, including the following:
  - DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*
  - DOE/RL-2009-124, *200 West Area Pump-and-Treat Facility Operations and Maintenance Plan*
  - DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*
  - DOE/RL-2010-72, *Sampling and Analysis Plan for Eight Remediation Wells in the 200-ZP-1 Operable Unit in Fiscal Year 2011*
  - DOE/RL-2010-78, *200 West Area Groundwater Pump-and-Treat Facility Extraction and Injection Well Maintenance Plan*
  - PNNL-19681, *Tc-99 Ion Exchange Resin Testing*
  - SGW-47662, *Test Plan for Technetium-99 Adsorption on Selected Resins from Hanford Site 200 West Area Groundwater*
  - SGW-46453, *Testing Guidelines for Technetium-99 Adsorption on Activated Carbon.*

12.3.2.2 Extraction System Performance

During CY 2010, fourteen extraction wells operated over a period of 336 days, with various combinations of extraction wells in operation from 3 to 319 days during the period. The average combined pumping rate was 1,181.9 liters per minute. The extraction system produced 570.2 million liters of contaminated groundwater in CY 2010, which is a 60% increase over the 356.4 million liters in CY 2009. The new extraction well, which is screened across most of the unconfined aquifer, pumped at a daily average rate of 939 liters per minute, which is well above the pumping rates achieved in other shorter screened extraction wells. The total volume of groundwater pumped since startup of the 200-ZP-1 treatment system in 1994 is ~5.0 billion liters.

12.3.2.3 Capture Zone Analysis

Estimates of the extent of the hydraulic capture produced by the 200-ZP-1 extraction wells were calculated using a water-level mapping method for the Hanford Site as described in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance.* Capture estimation using water-level maps follows a three-step process: (1) water-level maps are prepared using universal kriging, which enables a deterministic trend to be included in the map; (2) particle tracking is used to define (estimate) the extent of capture; and (3) a capture frequency map is used to depict capture estimates on the basis of numerous alternative water-level maps. A capture frequency map is generated that depicts the frequency with which each theoretical contaminant particle terminates at an extraction well, calculated over alternative water-level maps derived from discrete sampling events throughout the year. A frequency of 1.0 indicates that the particle is captured on every map; a frequency of zero indicates that a particle is not captured on any map; and intermediate frequencies indicate that the particle is captured using some maps and not on others.

Two capture frequency maps were generated: one with the addition of well 299-W15-225 and without operating well 299-W15-44, and one prior to operation

of well 299-W15-225. The addition of well 299-W15-225 in June 2010 increased overall water production by 40%. Figure 12-15(a) and (b) presents two ensemble depictions of capture calculated for each operational period (before and after well 299-W15-225) using capture frequency maps that are superimposed on the carbon tetrachloride plume contour map.

The width of the capture zone during the first period, prior to startup of well 299-W15-225, is wider at the southern lobe and exhibits greater capture at the northern lobe during the second time period. This phenomenon is contingent upon multiple factors, including (1) well screen penetration depth, (2) pumping rate, (3) injection well location relative to the extraction well, and (4) reduced pumping rate at extraction wells to the south of the new extraction well. The shallow extraction wells tend to capture flow over a broader area than deep well 299-W15-225. The development of a steeper gradient and narrower capture zone at the deep extraction well, combined with the orientation of the injection wells, increases and focuses the flow toward the deep well, so the particle capture is more tightly bound to the deep extraction well. The high flow upgradient at the injection wells and downgradient at the deep extraction well tends to dampen the aquifer response at the shallower, less-productive extraction wells. Consequently, the broad capture at the shallow wells is reduced. Further description of screen penetration and Hanford Site-specific effects on capture are discussed in "Variations in Capture-Zone Geometry of a Partially Penetrating Pumping Well in an Unconfined Aquifer" (Bair and Lahm, 1996) and DOE/RL-2011-26.

Figure 12-15(a) and (b) indicates that the current 200-ZP-1 OU extraction wells contain the high-concentration carbon tetrachloride present in the upper 15 meters of the aquifer. The successful retrieval of carbon tetrachloride from well 299-W15-225 with the longer screen interval indicates the presence of significant contamination deeper in the aquifer.

12.3.2.4 Treatment System Performance

The treatment system at the 200-ZP-1 OU uses an air-stripper column to remove carbon tetrachloride from the groundwater by separating it into a vapor phase. The carbon tetrachloride is then captured on granular activated carbon in canisters that are sent offsite for regeneration. Treated groundwater is returned to the aquifer through injection wells located south-southwest of the treatment facility.

The total amount of carbon tetrachloride removed in CY 2010 at the 200-ZP-1 OU was 700.7 kilograms (Table 12-1), which is a 72% increase in mass removed compared to 404.1 kilograms of removed in CY 2009. The increase in mass removal is a direct result of the increase in treated volume from 299-W15-225 in CY 2010 when compared to CY 2009.

Online availability in CY 2010 was 87.2% compared to 62.5% in CY 2009. The better performance measurement for CY 2010 largely relates to system upgrades and increased leak detection alarms in CY 2009 that spuriously caused additional downtime. Total availability was 88.5% in CY 2010. This calculation factors out scheduled downtimes and, therefore, emphasizes the impact of unscheduled outages. Treatment system availability is summarized in Table 12-2.

12.3.2.5 Compliance Monitoring

The areal extent of carbon tetrachloride and trichloroethylene plumes (Figures 12-4 and 12-9, respectively) are based on semiannual (or higher frequency) analytical data. A plume map was not generated for chloroform because the concentration has

not exceeded the 80 µg/L DWS since 1996. The compliance monitoring network consists of twelve active groundwater monitoring wells and the fourteen extraction wells that primarily penetrate the upper 15 meters of the unconfined aquifer. Trend plots for carbon tetrachloride, chloroform, and trichloroethylene concentrations at the monitoring and extraction wells during the current and previous three CYs are shown in Figures 12-16, 12-17, 12-18, and 12-19, respectively.

The CY 2010 contaminant monitoring highlights at the 200-ZP-1 pump-and-treat system for wells located in the upper 15 meters of the aquifer are summarized below:

- **Plume trends:**
  - The high-concentration portion of the carbon tetrachloride plume (greater than 2,000 µg/L to less than 3,000 µg/L) decreased in size and concentration from CY 2009 to CY 2010.
  - The area enclosed by the 1,000 µg/L contour for carbon tetrachloride shrank from 0.53 square kilometers in CY 2009 to 0.43 square kilometers in CY 2010. The most notable change in size occurred in the area near the pump-and-treat wells.
  - Chloroform concentrations declined in the main portion of the carbon tetrachloride plume shown in Figure 12-17. Monitoring wells did not exhibit chloroform concentrations greater than 17 µg/L during CY 2010.
  - The CY 2010 area of the trichloroethylene plume decreased compared to CY 2009. The area with highest concentrations continues to occur at extraction wells that were the original target of the interim action.
- **Extraction wells:**
  - In CY 2010, carbon tetrachloride concentrations in extraction wells generally exhibited a decreasing trend in comparison to CY 2009. Eight wells had measured carbon tetrachloride concentrations at or above 2,000 µg/L during 2009. In 2010, seven wells had concentrations of at least 2,000 µg/L. The maximum concentration reported for 2009 was 3,900 µg/L at pumping well 299-W15-50. The maximum concentration during CY 2010 was 2,900 µg/L at extraction wells 299-W15-40 and 299-W15-765.
  - Well 299-W15-6, which is screened in the lower unconfined aquifer near the 216-Z-9 Crib, has historically had carbon tetrachloride results ranging between 1,500 and 2,000 µg/L. The average CY 2010 concentration was within this range, from 1,725 µg/L to a high of 2,100 µg/L reported in December 2010.
  - Chloroform levels from extraction wells and monitoring wells have not exceeded the 80 µg/L DWS at any well since August 1996. Concentrations did not exceed 16 µg/L in CY 2010. Average trichloroethylene concentrations slightly exceeded the 5 µg/L DWS at three of the fourteen extraction wells, including 299-W15-40 (6.9 µg/L), 299-W15-44 (8.4 µg/L), and 299-W15-765 (5.9 µg/L). The maximum detected concentration was 12 µg/L at extraction well 299-W11-45.
- **Monitoring wells:**
  - The highest carbon tetrachloride concentrations measured in performance monitoring wells within the 200-ZP-1 OU occurred at 299-W15-50 and

299-W10-24, with maximum quarterly concentrations of 2,600 and 2,400 µg/L, respectively.

- The highest average trichloroethylene concentration, measured at monitoring well 299-W11-34P, was 10.0 µg/L.

- **Deep wells:**
  - The highest carbon tetrachloride concentrations were measured in deep wells 299-W13-1 and 299-W11-87, located near the eastern boundary of the 200 West Area. The highest reported value was 1,500 µg/L. These wells are screened deep in the unconfined aquifer, just above the Ringold lower mud unit. Maximum concentrations in the other eight deep monitoring wells ranged from 1 to 1,200 µg/L.
  - Chloroform concentrations at each of the ten deep wells were stable or decreasing, with average concentrations ranging from less than detect to 13 µg/L.
  - Trichloroethylene concentrations measured in the ten deep monitoring wells ranged from 1 to 8.8 µg/L. The 5 µg/L DWS was exceeded only at wells 299-W13-1, 299-W14-72, and 299-W14-71.

12.3.2.6 Vertical Distribution of Contamination Throughout the Unconfined Aquifer Sediments

The recent installation of wells supporting the final ROD and expansion of the pump-and-treat system has provided more detailed information on the vertical distribution of carbon tetrachloride. The new extraction and injection wells are installed using a drill-and-test procedure, which provides data on the contaminant concentrations down to the top of the basalt. These data provide a different perspective on the vertical distribution of carbon tetrachloride than the initial perspective when the interim action ROD was issued in 1994. A summary of this new information is as follows:

- Carbon tetrachloride concentrations appear widely distributed at depth.
- The deeper plume extends further northeast than had been previously mapped.
- Two high-concentration areas appear to be separated by a low concentration area in Figure 12-7. This separation is believed to be caused by dilution by leakage from the former 216-U-14 wastewater ditch, which is oriented north to south.

Using the carbon tetrachloride concentration from multiple wells that were sampled at regular vertical intervals, a three-dimensional conceptualization of the contaminant distribution was generated. Figure 12-7 provides the carbon tetrachloride plume in plan view for a "slice" through the conceptual plume at an elevation of 94 meters above mean sea level. This image shows the plume location relative to a new extraction well network and injection wells. The extraction wells are distributed within the carbon tetrachloride plume, along the flow direction; the injection wells are arranged along the perimeter of the plume, upgradient and downgradient to provide hydraulic containment. The transect line A-A' is the trace of a vertical profile through the carbon tetrachloride plume and is represented in Figure 12-8. In the vertical profile, the carbon tetrachloride has been shown to have migrated downgradient through an erosional window in the Ringold lower mud unit and is present beneath the mud unit at the eastern extent of the plume. The plume appears to be situated in the upper portion of the aquifer at wells to the west than at wells further downgradient, which suggests that the carbon tetrachloride

moved deeper into the aquifer as it moved to the east. The increasing depth to the east was likely caused by a downward hydraulic gradient, which is likely the result of surface discharges in the past (infiltration) to cribs, ditches and ponds, and/or through lithologic controls (flowing along higher hydraulic conductivity pathways). The plume depicted in Figures 12-7 and 12-8 shows regions of high concentration and changes in concentration out to 100 µg/L. The 100 µg/L concentration signifies the expected concentration to be achieved over the entire area to remove 95% of the carbon tetrachloride mass in groundwater.

12.3.2.7 Historical Plume Trends

The current carbon tetrachloride plume configuration indicates that the 200-ZP-1 pump-and-treat activities in CY 2010 and previous years were successful in reducing mass and the overall distribution of carbon tetrachloride in the upper 15 meters of the unconfined aquifer.

As has been the case for the previous few years, the southern end of the plume (historically defined by the 1,000 µg/L contour) was stable in CY 2010. A detailed discussion of changes in the size of the carbon tetrachloride plume since inception of the pump-and-treat remedy is provided in Appendix H of DOE/RL-2011-26.

12.3.3 Pump-and-Treat System for Technetium-99

A pump-and-treat test system specifically targeting technetium-99 began operating in September 2007 as part of a designed interim remedial activity. These wells are located on the eastern side of WMA T. The interim remedial activity was implemented as part of the general remedial guidance for the 200-ZP-1 OU based on the interim ROD (EPA/ROD/R10-95/114) and the *Technetium-99 Pump-and-Treat System to Support the 200-ZP-1 CERCLA Remedial Investigation/Feasibility Study Process* (DOE/RL-2007-23). The pump-and-treat test system at WMA T currently consists of two extraction wells (299-W11-45 and 299-W11-46) that deliver groundwater via a cross-site transfer line to the 200 Area Liquid Effluent Retention Facility (LERF). The contaminated groundwater is treated at the ETF. Treated groundwater is then transported by pipeline and disposed at the SALDS surface discharge site north of the 200 West Area. Groundwater monitoring well and extraction well trend plots for the technetium-99 plume in the area of WMA T are shown in Figures 12-20 and 12-21, respectively, for a 7-year interval through the end of 2010. The figures show that technetium-99 is below the DWS at the selected monitoring wells but remains above the DWS at the extraction wells.

Technetium-99 mass was reduced in the area of highest concentrations through pumping and treating more than 52.2 million liters of groundwater from two extraction wells during CY 2010. This resulted in the removal of 22,959 kilograms of nitrate, 16.35 grams of technetium-99, 6.25 kilograms of chromium, and 27.86 kilograms of carbon tetrachloride.

Technetium-99 is most commonly found in the 200 West Area in groundwater downgradient of the tank farms and the liquid disposal waste sites associated with tank farm or evaporator processes. Potential sources for technetium-99 include the 216-T-21 through 216-T-28 Cribs; the 242-T evaporator; and the T, TX, and TY Tank Farms. The following subsections address CY 2010 activities in regard to technetium-99 groundwater contamination at the 200-ZP-1 OU.

12.3.3.1 Changes in 2010

No major changes occurred in regard to the WMA T pump-and-treat system during CY 2010. The system operated throughout the year with occasional stoppages for maintenance and cross-site transfers from other facilities.

12.3.3.2 Extraction System Performance

During CY 2010, the two extraction wells produced 52.2 million liters of groundwater at a combined average annual rate of 99.3 liters per minute. The two extraction wells operated from February 17, 2010, through December 31, 2010.

Both wells were offline from January 1, 2010, through February 17, 2010, due to maintenance at the ETF. Well 299-W11-45 was online for 257 days, or 70.4% availability. Well 299-W11-46 was online for 289 days, for 79.1% availability. The monthly operational availability is listed in Table 12-3.

12.3.3.3 Capture Zone Analysis

Estimates of the extent of the hydraulic capture produced by the two technetium-99 extraction wells were calculated using a water-level mapping method at the Hanford site as described in SGW-42305. Capture estimation using water-level maps follows a three-step process: (1) water-level maps are prepared using universal kriging, which enables a deterministic trend to be included in the map; (2) particle tracking is used to define (estimate) the extent of capture; and (3) a capture frequency map is used to depict capture estimates on the basis of numerous alternative water-level maps. A capture frequency map is generated that depicts the frequency with which each theoretical contaminant particle terminates at an extraction well, calculated from alternative water-level maps derived from discrete sampling events throughout the year. A frequency of 1.0 indicates that the particle is captured on every map; a frequency of zero indicates that a particle is not captured on any map; and intermediate frequencies indicate that the particle is captured using some maps and not on others.

The two extraction wells adjacent to WMA T operated throughout CY 2010, with the exception of stoppages for maintenance and cross-site transfers from other facilities. The capture frequency map for these wells corresponds to the smaller northern plume near WMA T shown in Figure 12-15. The capture frequency map for the first half of the year in Figure 12-15(a) shows a much lower capture frequency than the capture frequency calculated for the second half of the year (Figure 12-15[b]). The difference between the two capture configurations is attributed to extraction well 299-W15-225 being brought online. Operation of this well increased drawdown to the south of WMA T and slightly changed groundwater flow direction in the northern portion of the 200 West Area. This change in hydraulic conditions helped to improve the overall capture of the WMA T extraction wells.

12.3.3.4 Treatment System Performance

Treatment of groundwater pumped from the two WMA T extraction wells resulted in removal of 16.35 grams of technetium-99, 27.86 kilograms of carbon tetrachloride, 22,959 kilograms of nitrate, 6.25 kilograms of chromium, and 245 grams of trichloroethylene. Table 12-4 summarizes the CY 2010 production data for the pump-and-treat system.

12.3.3.5 Compliance Monitoring

Technetium-99 within the 200-ZP-1 OU is found at levels significantly above the DWS (900 pCi/L) on the eastern (downgradient) side of WMA T and in two areas near WMA TX-TY (Figure 12-14). The size of the plume associated with WMA TX-TY appears to have expanded along the eastern margin of the tank farm, although concentrations have not concurrently increased. In fact, concentrations along the eastern margin of the WMA T have decreased somewhat due to groundwater extraction at pumping wells 299-W11-45 and 299-W11-46.

The maximum average concentration observed within the plume in CY 2010 was 7,833 pCi/L at monitoring well 299-W11-40, which is one of five wells located near WMA T. The other four wells ranged from 1,024 to 6,640 pCi/L in CY 2010. Concentrations in the extraction wells have been decreasing since pumping began in late CY 2007. Maximum concentrations recorded in CY 2010 were 4,000 pCi/L

at well 299-W11-45 and 5,000 pCi/L at well 299-W11-46. In both cases, the concentrations were lower than the highest concentrations observed in CY 2009 for these two wells, which were 6,400 and 8,600 pCi/L, respectively.

The technetium-99 plume on the north side of WMA TX-TY had a maximum annual concentration of 6,900 pCi/L. The concentration is higher than the CY 2009 values of 5,400 pCi/L. The small plume at the southern end of WMA TX-TY had a maximum average concentration of 2,233 pCi/L, which was observed at performance monitoring well 299-W15-41. Both of these plumes remained relatively stable from CY 2009 to CY 2010.

12.3.4 Vertical Distribution of Technetium-99 Throughout the Unconfined Aquifer Sediments

Data collected at uniform vertical locations during drilling of new injection and extraction wells included technetium-99 concentration data. A three-dimensional conceptual model of the technetium-99 distribution was developed using these data derived from drilling logs. Figure 12-22 shows a plan view of the plume for a "slice" through the plume at 127 meters above mean sea level. The figure shows multiple discrete lobes that originate from near each of the tank farms. Transect line A-A' represents the trace of a vertical profile oriented southwest to northeast through the northern plume near WMA TX-TY and WMA T. A second perspective is given in Figure 12-23 where the vertical extent of technetium-99 contamination is displayed through the slice plane. The technetium-99 plume appears to move deeper as it migrates further downgradient from the source. The leading edge of the plume at the water table appears to be moving out faster than contamination deeper in the aquifer. One explanation for this behavior is that as contamination reaches the groundwater table first and moves both vertically and laterally from there. As the technetium-99 migrates deeper into the aquifer, it starts moving laterally. In essence the deep contamination is following a longer flow path. The well traces shown in Figure 12-23 represent the position of each well relative to the plume, but only concentration data from wells within 500 meters of the section line (Figure 12-22) are used to describe the vertical distribution of the plume at this slice. The technetium-99 plume does not appear to be as significantly affected by vertical migration, as was the case for the carbon tetrachloride plume.

12.4 Facility Monitoring

This section describes the results of monitoring at individual units such as treatment, storage, and disposal units or tank farms (monitored under RCRA), as well as the SALDS (monitored under a state waste discharge permit). Some of the units monitored under RCRA requirements for dangerous waste constituents are also monitored under AEA for source, special nuclear, and byproduct materials. Data from facility-specific monitoring are also integrated into CERCLA groundwater investigations. The AEA and CERCLA monitoring results and discussions are addressed in Section 12.2 and are separate from the following RCRA-focused sections that satisfy RCRA reporting requirements.

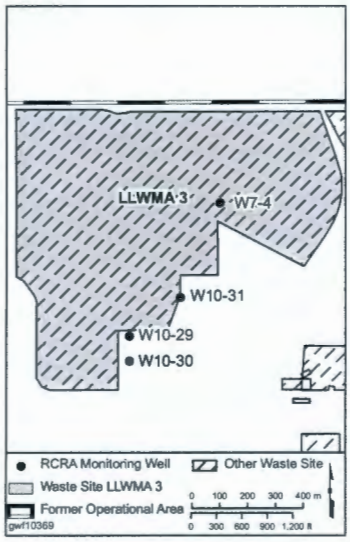
The 200-ZP-1 OU contains four RCRA sites with groundwater monitoring requirements: LLWMA-3, LLWMA-4, WMA T, and WMA TX-TY. The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for the reporting period. Groundwater data are available in the Hanford Environmental Information System database and in data files accompanying

this report. Additional information (including well and constituent lists, maps, flow rates, and statistical tables) is included in Appendix B.

12.4.1 Low-Level Waste Management Area 3

D.A. Gamon

Groundwater at LLWMA-3, located in the north-central corner of the 200 West Area, continued to be monitored under RCRA and AEA requirements. The LLWMA-3 consists of the 218-W-3A Burial Ground (20.4 hectares), 218-W-3AE Burial Ground (20 hectares), and 218-W-5 Burial Ground (37.2 hectares).



The 218-W-3A Burial Ground contains 57 unlined trenches that vary in length from 120 to 285 meters. The burial ground began operating in 1970 and has not received waste since 1998.

The 218-W-3AE Burial Ground contains eight unlined trenches varying in length from 325 to 380 meters, with bottom widths between 5 and 6 meters. The burial ground began operating in 1981 and received waste until July 2004.

The 218-W-5 Burial Ground contains ten unlined trenches and two lined trenches. The unlined trenches are between 160 and 350 meters long, 4.5 to 12 meters wide, and 5 to 6 meters deep. The lined trenches were constructed in 2000 and are 36 meters wide at the bottom, 9.1 meters deep, and 230 meters long. The burial ground began operating in 1986, and the two double-lined mixed waste trenches are the only trenches that continue to receive waste. All filled trenches are thought to contain 2.4 meters of soil cover.

In accordance with 40 CFR 265.93(b) ("Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), as referenced by WAC 173-303-400 ("Dangerous Waste Regulations," "Interim Status Facility Standards"), the well network was sampled semiannually for RCRA indicator and site-specific parameters (PNNL-14859, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*; DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*). The controlling interim status groundwater monitoring document was updated midway through CY 2010 with the release of DOE/RL-2009-68, which replaced PNNL-14859. All of the wells were successfully sampled during the reporting period, except 299-W7-4, which was added back into the monitoring network in the latter part of CY 2010 after access and safety issues were resolved.

Appendix B, Table B-23 includes a list of wells and constituents monitored. The following subsections provide the annual evaluation requirements for the monitoring network, groundwater results, and compliance status.

12.4.1.1 Hydrogeology

The LLWMA-3 is underlain from the ground surface to the top of the basalt by the Hanford formation, the CCU, and the Ringold Formation. The Ringold Formation at this location is mostly sand and gravel, with minor units of finer grained sediment. The top of the water table is situated in the Ringold Formation and depth to groundwater is ~74 to 78 meters below land surface. The Ringold lower mud unit is absent beneath the northernmost portion of the area. Underlying the sedimentary deposits is the Elephant Mountain Member of the Saddle Mountains Basalt. The suprabasalt sediments range in thickness from 145 to 160 meters, of which 60 meters (south area) to 75 meters (north area) is saturated. The CCU dips

gently to the south and rises to within 6 meters of the surface along the northern boundary of LLWMA-3.

The water table continued to decline beneath LLWMA-3 during the reporting period at ~0.3 meter per year in response to the greatly reduced discharge of wastewater to surface facilities around the 200 West Area. The groundwater flow direction in this portion of 200 West Area is northeast across LLWMA-3 based on the March 2010 water-level data (Figure 12-2).

The hydraulic conductivity in the unconfined aquifer beneath LLWMA-3 is on the order of 2.5 to 10 meters per day and the hydraulic gradient is ~0.0016. Using these values and assuming an average effective porosity of aquifer materials of 0.1, the groundwater flow rate is calculated at 0.04 to 0.16 meters per day (see Appendix B, Table B-1). A current groundwater map that includes LLWMA-3 is shown in Figure 12-2.

12.4.1.2 Network Evaluation

A new upgradient well, 299-W9-2, is planned to be constructed by mid- to late CY 2011, which will allow statistical evaluations to resume.

Groundwater monitoring activities at LLWMA-3 currently consist of water-level monitoring and chemical constituent monitoring. The LLWMA-3 is sampled semiannually from a network of four wells. Samples are analyzed for indicator parameters and supporting constituents semiannually and for anions, metals, and phenols annually. Water-level measurements are taken each time a groundwater sample is collected, and site-wide water-level measurements are collected annually, usually during the month of March.

The groundwater monitoring network at LLWMA-3 consists of four wells along the southeastern boundary (Figure 12-1). The network wells are screened at the water table. Due to water-level decline, the only previously existing upgradient well on the western side of the WMA (299-W9-1) did not have enough water in the screened interval and was technically dry by 2000; the LLWMA-3 has not had upgradient monitoring wells since that time. Three out of the four monitoring wells have adequate water columns in the screened interval (over 9 meters). Well 299-W7-4 has ~1 meter of water column available and will be sampled using a bailer method; it is estimated this well can be sampled for several years using this method.

New upgradient well 299-W9-2 is planned to be constructed by mid- to late CY 2011, which will allow statistical evaluations to resume. No other new downgradient wells are expected at LLWMA-3 until the effects on groundwater flow direction of the expanded 200-ZP-1 OU pump-and-treat system are known.

Appendix B, Figure B-12 shows the location of wells in the LLWMA-3 monitoring network. All wells were sampled as scheduled during the reporting period, except for well 299-W7-4, which was added back into the monitoring network under the new groundwater plan (DOE/RL-2009-68) too late to collect a sample during CY 2010.

12.4.1.3 Compliance Status

Interim status indicator evaluation groundwater monitoring at LLWMA-3 will continue in CY 2011. Statistical evaluations at LLWMA-3 are currently suspended but will resume after new upgradient well 299-W9-2 is constructed and sampled as per requirements.

12.4.1.4 Groundwater Contaminants

Groundwater at LLWMA-3 is monitored under RCRA and AEA requirements. This section addresses only the RCRA requirements in accordance with 40 CFR 265.93(b), as referenced by WAC 173-303-400. The well network was sampled semiannually

for indicator and site-specific parameters (PNNL-14859; DOE/RL-2009-68). Based on the results presented below, there is no evidence of LLWMA-3 contaminating groundwater downgradient of the WMA.

Indicator parameters are pH, specific conductance, total organic carbon, and total organic halides, which were sampled for semiannually at each network well during the reporting period.

The wells were on trend for pH during the reporting period. Well 299-W10-31 continued its increasing trend for specific conductance from 434 µS/cm in 2009 and 514 µS/cm in CY 2010. This increase may be related to increasing nitrate concentrations at this well likely caused by movement of the regional nitrate plume.

The highest annual average total organic carbon value was in well 299-W10-30 (2,058.8 µg/L), which was an increase from the previous year's sample results. During CY 2010, total organic carbon concentrations increased in well 299-W10-29 from 1,360 to 2,170 µg/L and decreased slightly in well 299-W10-31.

The highest annual average total organic halides value was in well 299-W10-31 (50 µg/L), which was a decrease from the previous year. Total organic halide values in the other network wells remained on trend.

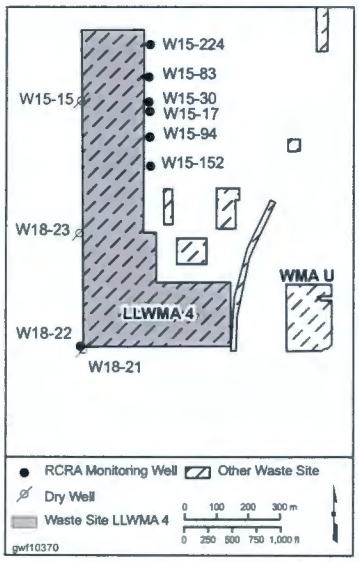
Carbon tetrachloride and associated trichloroethylene and chloroform concentrations in LLWMA-3 wells are consistent with those observed in regional plumes. Only carbon tetrachloride was detected at levels above the DWS. The highest annual average concentration was 85.0 µg/L in well 299-W10-31. Carbon tetrachloride concentrations in well 299-W10-31 have shown a decreasing trend since the well was constructed in FY 2006.

The nitrate distribution at LLWMA-3 is consistent with regional plumes (Section 12.2.3). The maximum annual average concentration during the reporting period (55.0 mg/L) was in well 299-W10-31. This value was an increase from 41.5 mg/L at the end of 2009, a continuation of the increasing trend for this well.

12.4.2 Low-Level Waste Management Area 4

D.A. Gamon

The LLWMA-4 is located in the 200 West Area, just west of the PFP and the U Tank Farm. The LLWMA-4 consists of the 218-W-4B and 218-W-4C Burial Grounds, which contain 28 unlined trenches. The 218-W-4B Burial Ground also contains twelve below-grade caissons at the southern end of the facility. The LLWMA-4 was used for disposal of low-level radioactive wastes and low-level mixed wastes beginning in 1967. The caissons in the 218-W-4B Burial Ground contain remote-handled, low-level waste, and retrievable transuranic waste. The dangerous chemicals in the low-level mixed waste portions of LLWMA-4 are regulated under RCRA and its implementing requirements WAC 173-303-400.



In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semiannually for contamination indicator parameters and supporting constituents (PNNL-14859; DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*). DOE/RL-2009-69 replaced PNNL-14859 midway through CY 2010 as the current and updated interim status groundwater monitoring plan. All of the wells were successfully sampled during the reporting period.

Appendix B, Table B-24 includes a list of wells, constituents monitored and the indicator parameter comparison values for CY 2011 are provided in Table B-25. The

following subsections provide annual evaluation requirements for the monitoring network, groundwater results, and compliance status.

12.4.2.1 Hydrogeology

The LLWMA-4 is underlain from the ground surface to the top of the basalt by the Hanford formation, the CCU, and the Ringold Formation. The vadose zone beneath LLWMA-4 is ~68 to 76 meters thick and consists of the Hanford formation, the CCU, the member of Taylor Flat of the Ringold Formation (lower unit 4), and the upper portion of unit 5 of the member of Wooded Island of the Ringold Formation. The water table is at ~136 to 137 meters in elevation and is entirely within Ringold unit 5. The Ringold lower mud unit is present everywhere beneath the LLWMA-4 and forms the bottom of the unconfined aquifer. The saturated thickness of the unconfined aquifer is ~69 meters in the south (at well 299-W18-22) and ~59 meters in the north (at well 299-W15-17). The thickness of the aquifer, as well as the groundwater flow direction and flow rate, are influenced by the 200-ZP-1 OU pump-and-treat system injection wells to the west of the LLWMA and the extraction wells located northeast of the LLWMA.

The water table continued to decline beneath the LLWMA-4 during the reporting period at ~0.3 meters per year in response to the greatly reduced discharge of wastewater to surface facilities around the 200 West Area. Previously, water levels in upgradient wells declined slower than levels in downgradient wells due to the effects of the upgradient 200-ZP-1 pump-and-treat system injection wells. The groundwater flow direction in this portion of 200 West Area is generally east but can be locally variable due to the effects of the 200-ZP-1 pump-and-treat system (Figure 12-1).

The hydraulic conductivity in the unconfined aquifer beneath LLWMA-4 is on the order of 2.5 to 10 meters per day and the hydraulic gradient is ~0.004. Using these values and assuming an average effective porosity of aquifer materials between 0.1 and 0.3, the groundwater flow rate is calculated at 0.1 to 0.4 meters per day (see Appendix B, Table B-1). A current groundwater map that includes LLWMA-4 is shown in Figure 12-2.

12.4.2.2 Network Evaluation

The general groundwater flow to the east at LLWMA-4 is largely affected by injection wells to the west and extraction wells to the northeast.

The monitoring network at LLWMA-4 currently does not include any upgradient wells but does include six downgradient wells. Upgradient wells 299-W15-15 and 299-W18-23 went dry in 2008, and upgradient well 299-W18-21 went dry in early 2010. Upgradient well 299-W18-22 (screened at the bottom of the unconfined aquifer) is located at the southwestern corner of LLWMA-4 and currently is not truly upgradient; the well was upgradient until the 200-ZP-1 pump-and-treat system began injecting water into five injection wells located just west (upgradient) of the LLWMA. This injection has caused groundwater to flow toward the southeast at the location of this well, which is no longer upgradient of the facility in relation to the existing downgradient wells located northeast of this well. No new wells are expected at LLWMA-4 until the effects of the enhanced 200-ZP-1 OU pump-and-treat system are known.

All other wells in the network, except for downgradient deep screened monitoring well 299-W15-17, are screened across or at the top of the water table. These water table wells all have adequate water columns in the screened interval (from 4 to 8 meters) available for sampling. The LLWMA-4 is sampled semiannually and analyzed for indicator parameters and supporting constituents. Anions, metals, and phenols are sampled for and analyzed annually. Site-wide water-level measurements

are collected annually, usually during the month of March. Water-level measurements are also taken at network monitoring wells during groundwater sample collection.

Appendix B, Figure B-13 provides the location of wells in the LLWMA-4 monitoring network. All wells were sampled as scheduled during the reporting period, except for well 299-W18-21, which went dry in early 2010.

12.4.2.3 Compliance Status

Interim status indicator parameter evaluation groundwater monitoring at LLWMA-4 will continue in CY 2011. Statistical evaluations will proceed for this reporting period using critical means calculated from the most recent data from well 299-W18-21 encompassing several previous years. Construction of an upgradient well is not expected until the effects of the enhanced 200-ZP-1 OU pump-and-treat system are known.

12.4.2.4 Groundwater Contaminants

Groundwater at LLWMA-4 is monitored under RCRA and AEA requirements. This section addresses only RCRA requirements in accordance with 40 CFR 265.93(b), as referenced by WAC 173-303-400. The well network was sampled semiannually for indicator and site-specific parameters (PNNL-14859; DOE/RL-2009-69). The indicator parameters are pH, specific conductance, total organic carbon, and total organic halides, which were sampled semiannually at each network well during the reporting period.

The wells were below the critical mean for pH during the reporting period, with well 299-W15-30 having the highest average value during the reporting period at 8.6. Specific conductance ranged from 366 to 559 µS/cm, and all wells were under the critical mean.

As in previous years, downgradient wells continued to exceed the statistical comparison value (critical mean) for total organic halides in most samples during the reporting period. The U.S. Department of Energy (DOE) previously reported the exceedance of the critical mean in well 299-W15-16 (now dry) to the U.S. Environmental Protection Agency and the Washington State Department of Ecology in August 1999. Well 299-W15-30 replaced 299-W15-16, and exceedance of the critical mean for total organic halides continued. These exceedances have also been iterated in previous annual groundwater reports. The elevated total organic halide concentrations are consistent with observed levels of carbon tetrachloride in the aquifer (Section 12.2.1).

Total organic carbon did not exceed the critical mean in any of the network monitoring wells during the reporting period. Well 299-W15-224, which exceeded the critical mean in 2009, had total organic carbon concentrations decrease drastically from the 2009 high of 2,210 µg/L to a low of 540 µg/L during CY 2010. However in July 2010, the average total organic carbon concentration in this well increased moderately to 887 µg/L, indicating that the unknown local organic source of carbon is still present. A current hypothesis for the source of organic carbon is that some type of microbial processes may be occurring in the monitoring wells not coming from other sources to include the monitored facility. This hypothesis will be further investigated in CY 2011.

Nitrate continued to exceed the DWS at all monitoring wells except deep downgradient well 299-W15-17 (24.5 mg/L) and deep upgradient well 299-W18-22 (18.7 mg/L). During CY 2010, concentrations ranged from 18.7 to 120 mg/L, with the maximum concentration in downgradient well 299-W15-152. Nitrate

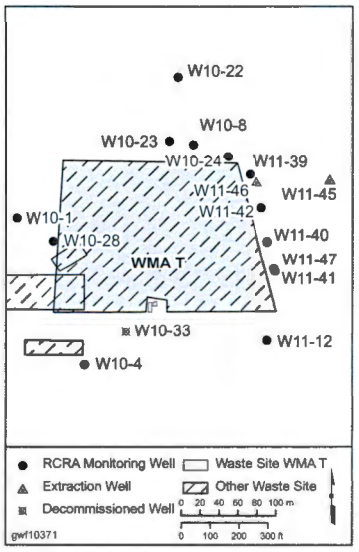
contamination is likely unrelated to waste disposal at the burial grounds. Some of the nitrate contamination is related to injection of treated water upgradient of the burial ground. The treatment system does not remove nitrate from the water, causing treated water with relatively high nitrate concentrations to mix with upgradient groundwater that is normally lower in nitrate. The nitrate plume observed at the LLWMA-4 monitoring wells reflects a cyclical process where nitrate is captured at the downgradient extraction wells and reinjected at the injection wells. The final remedy pump-and-treat facility scheduled to come online at the end of 2011 will remove nitrate from the waste stream.

Carbon tetrachloride concentrations display downward or stable trends in all wells in the network when compared with the historical data available. During the reporting period, carbon tetrachloride concentrations continued to decline in network wells. Well 299-W15-94 declined from 170 µg/L in FY 2009 to 75 µg/L in CY 2010. The maximum concentration of 100 µg/L was in downgradient well 299-W15-30. Known sources of carbon tetrachloride include the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib (DOE/RL-2006-20). Chloroform and trichloroethylene concentrations remained below the DWS in all LLWMA-4 wells. None of the wells had trichloroethylene concentrations above detection limits.

12.4.3 Waste Management Area T

D.A. Gamon

The WMA T, which includes the T Tank Farm, is located in the northern portion of the 200 West Area and was used for interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. The WMA is regulated under RCRA and its implementing requirements in WAC 173-303-400.



The WMA T was placed in assessment monitoring in 1993 because of elevated specific conductance (a RCRA indicator parameter) in one downgradient well. Assessment monitoring has continued at WMA T since that time and is currently controlled by *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T* (PNNL-15301). Currently, WMA T is in assessment monitoring due to concentrations of the dangerous constituent chromium exceeding the DWS in downgradient wells. The objectives for the continued assessment of groundwater quality at WMA T, as required by 40 CFR 265.93(d)(7)(i), are to determine the concentration and the rate and extent of migration of the hazardous waste or hazardous waste constituents in the groundwater. Appendix B, Table B-36 includes a list of wells and constituents monitored, and Table B-37 shows the indicator parameter comparison values for CY 2011. The following subsections provide annual evaluation requirements for the monitoring network, groundwater results, and compliance status. In 2008, an interim corrective measure, consisting of a surface barrier over a portion of the farm, was designed and constructed to reduce infiltration and subsequently migration of contaminants beneath the tank farm.

12.4.3.1 Hydrogeology

The vadose zone beneath WMA T is between ~70 and 76 meters thick and from ground surface to top of the underlying basalt consists of the Hanford formation, the CCU, the member of Taylor Flat of the Ringold Formation (the lower portion of unit 4), and the upper portion of unit 5 (the member of Wooded Island of the Ringold Formation). The water table is ~134.5 meters in elevation (March 2010). The unconfined aquifer beneath WMA T is estimated to be ~48 to 51 meters thick based on water levels and the depth of the Ringold lower mud unit, which serves as a

confining or semiconfining layer separating the unconfined aquifer from a confined, or partly confined, aquifer in the underlying Ringold unit 9.

Water levels in the unconfined aquifer increased as much as 13.5 meters (above the pre-Hanford natural water table) beneath WMA T due to artificial recharge from liquid waste disposal operations between the mid-1940s and 1995. During that time, the groundwater flow direction changed from eastward (the pre-Hanford direction) to southward, then northward, and finally back toward the east as a result of changes in waste management practices. More recently, two monitoring wells east of WMA T were converted to extraction wells to remove technetium-99 in the 200-ZP-1 OU, which will tend to enhance the eastward flow of groundwater. The shifts in groundwater flow direction have implications for contaminant distribution in the uppermost aquifer beneath WMA T as contaminant plumes react and adjust to the new hydraulic regime created by the local extraction wells

The water table continued to decline beneath WMA T monitoring wells during the reporting period at ~0.3 meter per year in response to the greatly reduced discharge of wastewater to surface facilities around the 200 West Area. The hydraulic conductivity in the unconfined aquifer beneath WMA T is on the order of 6.1 to 9.7 meters per day and the hydraulic gradient is ~0.002. Using these values and assuming an average effective porosity of aquifer materials of 0.1, the groundwater flow rate is calculated at 0.12 to 0.19 meters per day (see Appendix B, Table B-1). A time series depicting the water-level decline at select 200-ZP-1 groundwater wells is provided in Figure 12-3. An interim corrective measure, consisting of a surface barrier over a portion of the tank farm is designed to reduce infiltration and subsequently migration of contaminants beneath the tank farm.

The primary dangerous waste constituents found beneath WMA T in 2010 are chromium, carbon tetrachloride, and trichloroethylene. The source for the carbon tetrachloride and trichloroethylene was liquid disposal associated with processes at the PFP and not WMA T.

12.4.3.2 Network Evaluation

The network currently consists of two upgradient, two assessment, one far-field, and nine downgradient monitoring wells. The two assessment wells are not directly upgradient or downgradient and are used to help distinguish other contaminant plumes impinging on WMA T. Some of the wells in the monitoring network are also sampled for the 200-ZP-1 OU performance monitoring program. Sampling for WMA T and 200-ZP-1 OU is coordinated to eliminate duplicate well trips and analytes. Appendix B, Table B-34 lists the constituents at each well in the network to be analyzed for RCRA monitoring. The wells are sampled quarterly, semiannually, or annually each year. Appendix B, Table B-34 also indicates the purpose of each well and identifies whether the wells meet WAC requirements.

Water-level measurements are collected before each sampling event. A more comprehensive set of water-level measurements is made annually in the northern 200 West Area. Wells in the WMA T monitoring network are not expected to go dry for several years, as water columns in the screened intervals range from 1.5 to 17 meters. The well with only 1.5 meters of water column (299-W11-12) may be the exception, because it is an older well that was filling in with sediments and casing debris caused by the construction technique and well casing corrosion. The well recently underwent maintenance to clean out sediment and debris from the bottom of the well and scrub the perforated interval to allow better flow into the well. The well will be sampled via the bailer method for as long as possible.

The direction of groundwater flow is not expected to change greatly in the near future (CY 2011). However, with expansion of the 200-ZP-1 pump-and-treat system in the 200 West Area, groundwater flow direction and velocity at WMA T will be impacted. However, the magnitude and direction of these changes will not be known

until after the expanded system becomes operational and a performance monitoring and assessment of the system is completed, as defined in DOE/RL-2009-115. The groundwater flow direction in this portion of the 200 West Area is generally east but can be locally variable due to the effects of the active pump-and-treat systems.

Appendix B, Figure B-17 shows the location of wells in the WMA monitoring network. Some wells were not sampled as scheduled during the reporting period, including the following:

- Quarterly scheduled monitoring of well 299-W10-4 was not performed in April 2010 due to pump performance issues that required repairs to the well.
- Quarterly scheduled monitoring of well 299-W10-8 was not performed in October 2010 due to the site-wide sampling work stoppage (September 27 to November 8, 2010).
- Semiannually scheduled wells 299-W10-22 and 299-W11-7 were removed from the new groundwater assessment plan beginning CY 2010. Well 299-W10-22 is no longer downgradient of the WMA, and well 299-W11-7 is a far-field downgradient well not in the direct path of existing plumes. The new groundwater assessment plan (DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T)* will be implemented beginning in CY 2011.
- Quarterly scheduled monitoring well 299-W11-12 was not sampled during the January 2010 event due to falling water levels, which required the pump to be removed and debris in the well screen to be cleaned out. The well was not sampled for the October scheduled quarterly event due to the site-wide sampling work stoppage that occurred. Since that time, the well is being sampled using the bailer method.
- Extraction well/monitoring well 299-W11-45 was not sampled during the July scheduled quarterly event due to mechanical issues that required maintenance. The well was not sampled as scheduled during the October scheduled quarterly event due to the site-wide sampling work stoppage.

12.4.3.3 Compliance Status

Assessment status groundwater monitoring at WMA T will continue in CY 2011. A new assessment monitoring plan for WMA T was issued in February 2011 (DOE/RL-2009-66).

12.4.3.4 Groundwater Contaminants

An indicator evaluation groundwater monitoring program began at WMA T in 1989 (WHC-SD-EN-AP-012, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*). As stated in Section 12.4.3, the WMA was placed in assessment monitoring in 1993 when specific conductance values in downgradient well 299-W10-15 exceeded the upgradient critical mean value (WHC-SD-EN-AP-132). Elevated specific conductance in the well, principally resulting from elevated sodium and nitrate from an upgradient source, dropped below the critical mean in 1994. However, before the WMA could be returned to an indicator evaluation monitoring program, specific conductance in well 299-W11-27 (decommissioned) began to rapidly increase in late 1995 and exceeded the critical mean in early 1996. In well 299-W11-27, the increased specific conductance was accompanied by elevated nitrate, calcium, magnesium, sulfate, chromium, and total organic carbon.

The primary dangerous waste constituents found beneath WMA T during the reporting period were chromium, carbon tetrachloride, and trichloroethylene. The source for the carbon tetrachloride and trichloroethylene contamination was liquid waste disposal associated with processes at the PFP and not releases from WMA T (Sections 12.2.1 and 12.2.2); these constituents are monitored as part of the 200-ZP-1 OU. Nitrate and fluoride are also found in the groundwater beneath the WMA. Chromium is a dangerous constituent monitored under the RCRA assessment program.

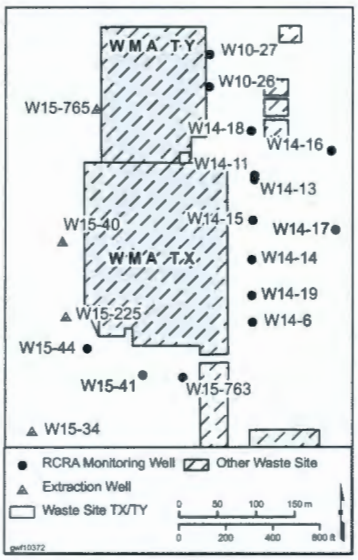
The highest chromium concentration in the upper portion of the aquifer during the reporting period was in assessment well 299-W10-4 (576 μg/L), located at the southwestern corner of the WMA. The highest chromium concentration found in wells screened deeper within the aquifer in WMA T was 168 μg/L in downgradient well 299-W11-47 (screened between 7.5 and 17 meters below the water table). The highest chromium concentration in downgradient extraction well 299-W11-46 (screened between 6 and 12 meters below the water table) was 124 μg/L. The highest chromium concentration in adjacent downgradient well 299-W11-39 (screened at the water table) was 56 μg/L.

Downgradient extraction well 299-W11-45 is ~80 meters downgradient of well 299-W11-46 and is screened between 8.5 and 13 meters below the water table. The highest chromium concentration for this well during the reporting period was 146 μg/L. The higher concentrations in the deeper screened wells show that the chromium plume at WMA T extends relatively deep in the aquifer downgradient of WMA T and is present laterally at least 80 meters downgradient (eastward) at concentrations above the DWS of 100 μg/L.

A local nitrate plume is located within the regional nitrate plume beneath WMA T (Figure 12-10). The plume retained the same general configuration as in CY 2009. During the reporting period, the highest average nitrate concentrations were in upgradient wells 299-W10-28 (1,458 mg/L) and 299-W10-4 (2,617 mg/L). The nitrate concentrations above the DWS in downgradient wells were between 82 and 695 mg/L. More than one source, including the WMA T, likely contributed to the nitrate plume beneath the WMA, but the higher upgradient concentrations indicate greater contributions from other sources.

12.4.4 Waste Management Area TX-TY

D.A. Gamon



The WMA TX-TY, which includes the TX and TY Tank Farms, is located in the northern portion of the 200 West Area and was used for interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. The WMA is regulated under RCRA and its implementing requirements in WAC 173-303-400.

The WMA was placed in assessment monitoring in 1993 because specific conductance values in downgradient wells 299-W10-17 and 299-W14-12 exceeded the upgradient background (critical mean) value (WHC-SD-EN-AP-132). The first assessment report (PNNL-11809, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site*) concluded the following: (1) elevated contamination in well 299-W14-12 was consistent with a source within the WMA, and (2) an upgradient source (the 216-T-25 Trench) was possible. Subsequent drilling and sampling of well 299-W15-40, located between the 216-T-25 Trench and the WMA, eliminated the 216-T-25 Trench as a possible source of high-level contamination upgradient

of the WMA. The second assessment report (PNNL-14004, *RCRA Groundwater Quality Assessment Report for Single-Shell Tank Waste Management Area TX-TY [January 1998 through December 2001]*) was not able to eliminate the WMA TX-TY as a source for the downgradient contamination. Continuation of the groundwater assessment was required, and PNNL-14004 describes the activities for continued assessment. The dangerous constituent monitored in this assessment program is chromium.

The objectives for the continued assessment of groundwater quality at WMA TX-TY, as required by 40 CFR 265.93(d)(7)(i), are to determine the rate and extent of migration of the dangerous waste or dangerous waste constituents in the groundwater and the concentrations of the hazardous waste or hazardous waste constituents in the groundwater. Appendix B, Table B-37 provides a list of wells, constituents monitored, and the indicator parameter comparison values for 2011 are presented in Table B-38. The following subsections provide annual evaluation requirements for the monitoring network, groundwater results, and compliance status.

12.4.4.1 Hydrogeology

The vadose zone beneath WMA TX-TY is between ~66 and 70 meters thick. The sediments from ground surface to top of the underlying basalt, in descending sequence, consist of the Hanford formation, the CCU, the member of Taylor Flat of the Ringold Formation (lower portion of unit 4), and the upper portion of unit 5 (the member of Wooded Island of the Ringold Formation). The water table is between ~134 and 134.5 meters in elevation based on CY 2010 water table elevations. The unconfined aquifer beneath WMA TX-TY is estimated to be between 48.5 and 56.5 meters thick, estimated from water levels and the depth of the Ringold lower mud unit, which serves as a confining or semiconfining layer separating the unconfined aquifer from a confined (or partly confined) aquifer in the underlying Ringold unit 9.

Water levels in the unconfined aquifer increased as much as 14 meters above the pre-Hanford natural water table beneath WMA TX-TY due to artificial recharge from liquid waste disposal operations active between the mid-1940s and 1995. During that time, the groundwater flow direction changed from eastward (the pre-Hanford direction) to southward, then northward, and finally back toward the east as a result of changes in waste management practices. Local groundwater levels continue to decline at a rate of ~0.4 meter per year due to cessation of artificial recharge from liquid waste disposal operations in the area.

More recently, extraction wells for the 200-ZP-1 OU pump-and-treat system have altered the flow direction and local hydraulic gradients. In 2005, upgradient wells were converted to extraction wells, shifting the flow southward in the southern portion of the WMA and likely shifting flow toward the northwest in the northern portion of the WMA. Possible stagnation points exist in the middle portion of the WMA east of the extraction wells, and some flow is currently eastward in the middle of the WMA. Therefore, it must be assumed the water table gradient is variable beneath WMA TX-TY due to influences from pump-and-treat system extraction wells. The shifts in groundwater flow direction have implications for contaminant distribution in the uppermost aquifer beneath WMA TX-TY.

12.4.4.2 Network Evaluation

The network currently consists of two upgradient, two mid-field, and eleven downgradient monitoring wells. Some of the wells in the monitoring network are also sampled for the 200-ZP-1 OU under CERCLA. Sampling for WMA TX-TY and the 200-ZP-1 OU is coordinated to eliminate duplicate well trips and analytes.

Given the current rate of water table decline (0.3 to 0.4 meter per year), well 299-W14-6 was expected to be dry in 2010 and in fact became "sample dry" in late CY 2010 (fourth quarter). Sample dry is when some groundwater remains in contact with the screened interval but a sample pump or bailer is unable to adequately remove water from the bottom of the well to ground surface for collection. Well 299-W15-41 has ~1.5 meters of water column available in the screened interval and should not go dry for several years. The remainder of the WMA TX-TY network wells have adequate water columns ranging from 6 to 14 meters.

The 200-ZP-1 OU pump-and-treat system is in the process of adding 36 extraction and injection wells. Once operational, this system is expected to further influence and change groundwater flow direction and velocity at WMA TX-TY. The magnitude and direction of the changes will not be known until after the expanded system becomes operational in 2012 and performance monitoring and assessment of the system is completed as defined in DOE/RL-2009-115.

Appendix B, Figure B-17 shows the location of wells in the WMA monitoring network. Some wells were not sampled as scheduled during the reporting period as follows:

- Quarterly scheduled monitoring well 299-W14-13 was not sampled during the April 2010 and the July 2010 due to pump performance issues requiring repairs by well maintenance staff. The well was not repaired before the October scheduled quarterly event due to the site-wide sampling work stoppage that occurred from September 27 through November 8, 2010.
- Quarterly scheduled monitoring well 299-W14-17 was not sampled during the April 2010 event due to pump performance issues that required repairs. The well was not sampled as scheduled during the October quarterly event due to the site-wide sampling work stoppage.
- Quarterly scheduled monitoring well 299-W14-18 was not sampled during the April event due to pump performance issues that required repairs.
- Quarterly scheduled monitoring well 299-W14-19 was not sampled during the April event due to pump performance issues that required repairs.
- Quarterly scheduled monitoring well/remedial extraction well 299-W15-44 was not sampled during the January and April 2010 events. The well was taken out of service as an extraction well (replaced by new extraction well 299-W15-225) and converted into a monitoring well.
- Quarterly scheduled monitoring well/remedial extraction well 299-W15-765 was not sampled during the April 2010 event. The well was nonoperational from March 27 to August 31, 2010. From March to May, aquifer testing occurred in the local area. From June to August, pump performance issues required troubleshooting and repairs to be made. The well was successfully sampled in early September to satisfy the July scheduled event.

12.4.4.3 Compliance Status

Assessment status groundwater monitoring at WMA TX-TY will continue in CY 2011. The new assessment monitoring plan for WMA TX-TY was finalized in January 2011 and will go into effect for CY 2011 (DOE/RL-2009-67, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY*).

12.4.4.4 Groundwater Contaminants

As stated in Section 12.4.4, the WMA was placed in assessment monitoring in 1993 because specific conductance values in downgradient wells 299-W10-17 and 299-W14-12 exceeded the upgradient critical mean value. For well 299-W14-12, the increased specific conductance was accompanied by elevated concentrations of calcium, magnesium, chromium, nitrate, and sulfate.

The dangerous waste constituent found in groundwater beneath WMA TX-TY during the reporting period is chromium. Other dangerous constituents found at the WMA during the reporting period included carbon tetrachloride and trichloroethylene, which are attributed to other waste sites (Sections 12.2.1 and 12.2.2). Nitrate and fluoride are also found in the groundwater beneath the WMA. Chromium is the dangerous constituent monitored under the RCRA assessment program.

Special sampling of well 299-W15-3 was performed in May 2009 at the request of the project scientist. This well was not sampled in CY 2010 but is included as pertinent information to assist in defining current groundwater contamination conditions at WMA TX-TY. The well is located in the TY Tank Farm, adjacent to tank TY-106 and ~32 meters due east of extraction well 299-W15-765. The well was drilled in 1952, is constructed of carbon steel, and is perforated from 61 to 72 meters below ground surface. Well 299-W15-3 was last sampled in 1991, with the results indicating that groundwater from the well has extremely high concentrations of most major and minor cations and anions, as well as some contaminants.

Of particular note from the CY 2009 sampling event was the technetium-99 concentration, which was 40,000 pCi/L and the highest technetium-99 concentration that has been found at WMA TX-TY. The nitrate concentration was also extremely high at 3,410 mg/L, which is just slightly less than the highest concentration found at well 299-W14-11 (3,600 mg/L) during drilling in CY 2005. The nitrate concentration in 1991 at well 299-W15-3 was only117 mg/L. Also noted were the very low tritium (5,100 pCi/L) and iodine-129 (0.42 pCi/L) concentrations and a relatively low chromium concentration (91.2 µg/L filtered). The tritium concentration has decreased in this well, as the concentration reported in 1991 was 45,000 pCi/L. Iodine-129 and chromium were not sampled historically at this well; therefore, comparison to the current values is not possible.

Tank TY-106 was declared a leaker in 1959 with a revised estimated amount leaked of 68,000 liters of tributyl phosphate process waste. Tank TY-106 is next to tank TY-105, which was declared a leaker in 1960 with a revised estimated leak amount ranging from 114,000 to 163,000 liters (RPP-RPT-42296, *Hanford TY-Farm Leak Assessments Report*) of tributyl phosphate process waste. Either one or both of these tanks could be a partial source of high contaminant concentrations in well 299-W15-3. The effects of the nearby extraction well may be concentrating contaminants as the hydraulic gradient is reversed and water levels decrease under the tanks.

During the reporting period, nitrate concentrations exceeded the DWS (45 mg/L) in all wells in the monitoring network. Figure 12-10 shows a plume map for nitrate in the area. Overall, the nitrate concentrations remain stable in most wells in WMA TX-TY. The highest nitrate concentration at the WMA during the reporting period was 593 mg/L in downgradient well 299-W10-27. The dissolved oxygen concentrations in this well have been decreasing since January 2010 (6.1 mg/L), down to 2.6 mg/L by August. This decreasing trend is being analyzed for evidence of possible changes in local contaminant plume behavior due to mixing of new contamination with existing groundwater, groundwater chemistry responses to

changes in the pump-and-treat operations schedule, natural attenuation, or other chemical reactions changing local groundwater chemistry.

The nitrate concentration in other downgradient wells was between 54 mg/L (299-W14-14) and 417 mg/L (299-W14-13). Much of the nitrate contamination is attributed to PFP operations, as well as past practice disposal to cribs and trenches in the area. Some nitrate contamination may be from WMA TX-TY, although distinguishing the different sources is difficult. Section 12.2.3 provides information on nitrate in the north-central 200 West Area.

In CY 2010, chromium was detected above the 100 µg/L DWS in some wells monitoring WMA TX-TY. The highest chromium concentration was 732 µg/L in downgradient well 299-W14-13, which was a slight decrease from CY 2009 concentrations (736 µg/L). The chromium concentration has been elevated in this well since it was drilled in 1998 and was elevated in the early 1990s in adjacent (but now dry) well 299-W14-12.

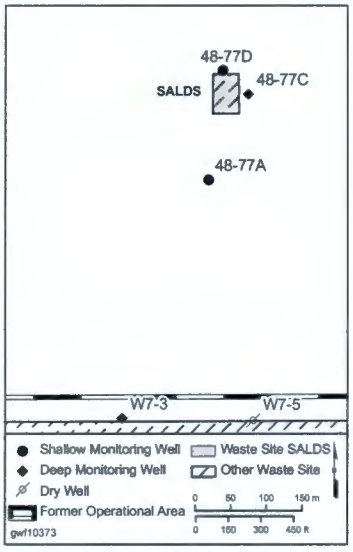
Well 299-W14-11 is located next to well 299-W14-13 but is screened between 11.6 and 14.6 meters below the water table. The highest chromium concentration in well 299-W14-11 was 178 µg/L, indicating that significant chromium contamination may exist deeper in the aquifer than shown by wells screened at the water table, although the highest concentrations appear to be near the water table in this area. The source for the chromium is assumed to be WMA TX-TY by default because no alternative sources have been identified.

Well 299-W14-15 is located south of well 299-W14-13, and its highest chromium concentration during the reporting period was 62.9 µg/L. Historically, chromium concentrations decrease rapidly in monitoring wells south of this well, and this observation continued during CY 2010.

Nitrate, technetium-99, and iodine-129 accompanied chromium, and all four contaminants showed the same trend during the reporting period (Figure 12-24). This may indicate that all four contaminants shared a common source and that part of the plume began passing through these wells between the end of FY 2009 and beginning of CY 2010 (Figure 12-24). Because well 299-W14-13 was offline for maintenance beginning in March, this trend could not be evaluated throughout the reporting period.

12.4.5 State-Approved Land Disposal Site

E.J. Freeman



The ETF processes contaminated aqueous waste from various Hanford Site facilities. The treated wastewater contains tritium that cannot be removed and is discharged to the SALDS. The SALDS operates on a state FY basis (i.e., September 1 to August 30), not on a federal FY basis (i.e., October 1 to September 30, which is observed by DOE). During CY 2010, 71.4 million liters of water were discharged to the SALDS compared to 82.6 million liters in CY 2009. The smaller volume in 2010 is the result of a lower ETF discharge rate when processing K Basin wastewater, which was not processed in CY 2009.

A state waste discharge permit *State Waste Discharge Permit ST 4500* (Ecology, 2000a) requires the monitoring of groundwater at this site. Quarterly monitoring is required for three wells proximal to the SALDS facility. The permit was issued in June 1995, and the site began operation in December 1995. Groundwater monitoring requirements are described in *Groundwater Monitoring and Tritium Tracking Plan for the 200 Area State-Approved Land Disposal Site* (PNNL-13121).

For all of the monitoring wells, the hydraulic head has declined an average of 0.38 meters per year. The average rate of decline includes increasing water levels at the three proximal wells adjacent to the SALDS area between March 2008 and March 2009. A less biased rate of decline can be calculated if water-level changes in the proximal wells are excluded. Numerical flow and transport modeling at this site was performed during FY 2009 (SGW-42604, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site Fiscal Year 2009*). The results of the modeling show that tritium will not reach downgradient wells before 2025; furthermore, tritium will decay before reaching the Columbia River.

A total of 71.4 million liters of tritiated water was discharge to SALDS during CY 2010 in compliance with State Waste Discharge Permit ST 4500.

12.4.5.1 Hydrogeology

The lithologic sequence beneath the SALDS facility is a major feature that regulates how effluent moves from the facility into the groundwater. The sediments at the surface consist of ~5 meters of highly permeable eolian sand. Beneath this sand is the CCU, which is sandy silty sediment that is also highly cemented. This unit has low permeability and is ~16 meters thick. Next in the sequence is the Ringold Formation, which comprises ~84% of the sediments beneath the SALDS. These sediments are moderately consolidated fluvial sand and gravel deposits through which effluent from the SALDS migrates for ~50 meters before contacting the water table. Beneath the Ringold sediments is the Elephant Mountain Member of the Saddle Mountains Basalt at ~132 meters, which serves as the base of the unconfined aquifer. The basalt and overlying sediments dip at ~3 degrees to the south.

Discharges from the SALDS facility drain through the eolian sands and are diverted to the south along the sloping CCU layer. The first arrival of tritium contamination was observed at well 699-48-77A, which is upgradient from the SALDS relative to the regional groundwater system. About one year after the first arrival of the tritium pulse at this well, the contaminant pulse (depicted as concentration at discrete times in Figure 12-25) moved from south to the northern wells downgradient in the flow system.

12.4.5.2 Network Evaluation

The state waste discharge permit stipulates the requirements for groundwater monitoring and establishes enforcement limits for concentrations of eleven constituents in three additional wells immediately surrounding the facility (Appendix B, Table B-43). Groundwater monitoring for tritium was conducted in twelve additional wells around the facility (Appendix B, Figure B-20).

Wells immediately surrounding the SALDS facility were sampled four times during CY 2010. Tritium-tracking wells were sampled annually or semiannually. Many of the wells in the tritium-tracking network south of the SALDS have gone dry since discharge began in 1995. Water-level measurements in the three wells nearest the facility indicated a small, localized groundwater mound centered on well 699-48-77A. Mounding is the result of treated effluent discharge that originates from the SALDS. This mound results in outward radial flow before the regional northeastward flow becomes dominant. This condition also places several wells south of the SALDS hydraulically downgradient from the facility.

12.4.5.3 Groundwater Contaminants

The primary COC at the SALDS is tritium. Additional parameters sampled include pH, specific conductance, metals, anions, total dissolved solids, and volatile organic analytes. A complete list of the SALDS monitoring wells sampled and

contaminant concentrations is provided in Appendix A of *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2010* (SGW-47923).

The maximum tritium activities decreased by an order of magnitude at well 699-48-77A, from 77,000 pCi/L in 2009 to 7,400 pCi/L at the end of 2010. Tritium concentration increased in well 699-48-77C from 67,000 pCi/L in 2009 to 88,000 pCi/L in 2010 and showed a slight decline at well 699-48-77D from 180,000 pCi/L at the end of 2009 to 150,000 pCi/L at the end of 2010. The decline in tritium concentration at well 699-48-77A and subsequent increases at the other proximal wells (Figure 12-25) signify migration of the plume through subsequent down-gradient wells after high-concentration discharges associated with ETF treatment of K Basins wastewater in FY 2007 moved through the groundwater. Concentrations of all chemical constituents with permit limits were within or below detection limits during the entire reporting period. Acetone, benzene, cadmium, chloroform, and tetrahydrofuran were below method detection limits in all samples. Three target metals were found at or near detection concentrations in well 699-48-77A. Maximum concentrations of lead, copper, and mercury were present at 0.171 μg/L, 4.19 μg/L, and less than detection, respectively. Concentrations of major anions and cations continued to be below the background levels observed prior to facility operation. The low concentrations are due, in part, to mixing with clean water discharged by the SALDS.

The decline in tritium concentration at well 699-48-77A showed a return to normal levels after a high-concentration discharge event associated with activities at the K Basins during FY 2008.

12.4.5.4 Compliance Status

Monitoring activities included those for tritium and additional constituents at twelve wells subject to *State Waste Discharge Permit ST 4500* (Ecology, 2000a). Groundwater contaminant data reported for CY 2010 confirmed that the SALDS was in compliance with the terms described in the state waste discharge permit.

12.5 Conclusions and Recommendations

The conclusions and recommendations for the 200-ZP-1 OU are presented in the following sections.

12.5.1 Conclusions

The 200-ZP-1 OU covers the northern and central region of the 200 West Area and the adjacent 600 Area. The 200-ZP-1 OU is tasked with performance monitoring and remedial actions for past-practice waste streams that have contaminated groundwater. The activities at the 200-ZP-1 OU are subject to regulatory compliance in accordance with RCRA, CERCLA, and the AEA. Activities covered by CERCLA include remediation and performance monitoring of the contaminant plume in groundwater that is subject to remediation. Within the OU, specific facilities that are regulated under RCRA include LLWMA-4, LLWMA-3, WMA T, and WMA TX-TY. The SALDS, which is a liquid waste disposal facility, is monitored in compliance with WAC 173-216, "State Waste Discharge Permit Program."

Pump-and-treat operations for the 200-ZP-1 OU include two remedial systems. One system that addresses volatile organic compound contamination, consists of fourteen extraction wells, a treatment plant, and five injection wells at the west side of LLWMA-4. The primary COCs are carbon tetrachloride, chloroform, and trichloroethylene. The second system that addresses high technetium-99 contamination consists of two extraction wells located at the northeast corner of WMA T that discharge wastewater to the LERF for storage before contaminants are

removed at the ETF. The primary COC from this waste stream is technetium-99. The effluent stream is treated for all known contaminants, except for tritium, which cannot be removed at the ETF. The tritiated waste stream is then discharged at the SALDS facility.

Operations at the 200-ZP-1 pump-and-treat interim action site removed 570.2 million liters of contaminated groundwater. The average pumping rate for the extraction well field during CY 2010 was 1,180 liters per minute. During the reporting period, extraction well 299-W15-44 was removed from the extraction network and was converted to a monitoring well; concurrently, new extraction well 299-W15-225 was connected to the extraction system. The addition of well 299-W15-225 increased pumping capacity by an average of 949 liters per minute and accounted for 52% of the total production. The total carbon tetrachloride mass removed by the pump-and-treat system during CY 2010 was 700.7 kilograms. During CY 2010, the system had a cumulative availability of 87%.

Pump-and-treat operations at the WMA T pump-and-treat system removed 52.2 million liters of contaminated groundwater. The average pumping rate for the two wells that make up this system was 99.3 liters per minute. Contaminant mass removed during CY 2010 included 16.35 grams of technetium-99; 27.86 kilograms of carbon tetrachloride; 22,959 kilograms of nitrate; and 6.25 kilograms of chromium. During CY 2010, the availability for well 299-W11-45 was 70% and well 299-W11-46 was 89%.

The 200-ZP-1 interim pump-and-treat system was designed to remediate contamination in the upper 15 meters of the unconfined aquifer to address the high-concentration area around the PFP. Performance monitoring for wells in this region of the aquifer show that the plume has decreased around the original targeted area. In general, the high-concentrations of the carbon tetrachloride plume also showed a decline in concentration.

Construction of a final remedy pump-and-treat system, which will extract COCs over a broader area and capture deeper contamination, is currently in progress. During CY 2010, four new injection and eleven new extraction wells were installed. Additionally, construction of the new treatment plant is well underway and will continue through the end of 2011, when the treatment facility is scheduled to become operational. The new pump-and-treat facility is expected to increase treatment capacity over the current system by five times.

Performance monitoring at the RCRA facilities indicates that conditions at these facilities remained stable during CY 2010. Both LLWMA-3 and LLWMA-4 remain in indicator evaluation monitoring, and WMA T and WMA TX-TY are in assessment monitoring. Waste streams released at the SALDS facility are in compliance with limits set forth in State Permit ST-4500.

Measurable progress was made during the reporting period to meet specific remedial action objectives specific to the interim ROD (Section 12.3.1). The results for each remedial action objective are discussed below:

- **Remedial action objective #1:** Prevent further movement of contaminants from the highest concentration area of the baseline plume.

  The shallow portion of the aquifer (upper 15 meters) in the area of the baseline carbon tetrachloride plume continues to be captured by the 200-ZP-1 pump-and-treat system. The pump-and-treat configuration was designed specifically to capture the high-concentration portion of the carbon tetrachloride plume in the area of the Z Plant. Five extraction wells are currently operating

within the 2,000 µg/L portion of the plume. Carbon tetrachloride north of the high-concentration area is generally moving to the northeast. The interim remedy does not explicitly address capture of carbon tetrachloride deeper than 15 meters below the water table or at concentrations less than 1,000 µg/L in the upper aquifer. Remediation of the broader plume is addressed by actions required under the final ROD for the 200-ZP-1 OU (EPA et al., 2008). The pump-and-treat system will be installed and operational by 2011 for remediating the broader plume.

- **Remedial action objective #2:** Reduce contamination in the areas of highest concentration of carbon tetrachloride.

  During CY 2010, 700.7 kilograms of carbon tetrachloride were removed from 570.2 million liters of groundwater. Since startup of the pump-and-treat operations, ~12,663 kilograms of carbon tetrachloride have been removed from over 4.9 billion liters of groundwater. The volume of water treated in CY 2010 was ~60% more than FY 2009. Reduction in carbon tetrachloride contamination within the highest concentration portion of the contaminant plume has been demonstrated by the contaminant removal volumes and a decrease in the extent of the high-level targeted area over the last 12 years.

- **Remedial action objective #3:** Provide information that will lead to development of a final remedy that will be protective of human health and the environment.

  The remedial design/remedial action work plan (DOE/RL-2008-78) was issued during CY 2009. The selected remedy for the 200-ZP-1 OU combines pump-and-treat, monitored natural attenuation, flow-path control, and institutional controls. The *Sampling and Analysis Plan for the First Set of Remedial Action Wells in the 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2008-57) was issued to support this final remedy. Data collected over the previous 12 years of pump-and-treat system operation were used to develop the final ROD (EPA et al., 2008).

12.5.2 Recommendations

The recommendations for the 200-ZP-1 OU are as follows:

- Perform aquifer testing in the new extraction well(s) to be installed to support the 200 West Area pump-and-treat system. Aquifer testing will improve estimates of hydraulic properties, help define optimum well spacing of future extraction wells, and provide better estimates for optimum design and operation of the remediation system.
- Collect additional depth-discrete groundwater samples during installation of new wells to assist in further defining the vertical distribution of contamination, appropriate length of well screens, and proper positioning of the screens within the aquifer.
- Apply modeling tools to assess the effectiveness of the current pump-and-treat well configuration to continue to support plume capture and assess efficiency of sampling frequency for the monitoring well network.
- Evaluate all extraction wells to determine any degradation in well efficiency. If well performance is found to have declined due to scale buildup on the screen and/or in the filter pack, well rehabilitation should be planned.
- Review the current performance monitoring well network to determine if sufficient coverage exists to detect plume extents. Many wells in the monitoring

well network have gone dry due to the regionally declining water table, and additional wells will go dry over the next 10 years. As the number of available wells decreases, the ability to effectively monitor remediation, contaminant concentrations, and changes in the plume configuration will be significantly impaired.

Table 12-1. 200-ZP-1 Operable Unit Pump-and-Treat Performance Summary, CY 2010

Total processed groundwater:	
Total groundwater processed in CY 2010 (L)	570,220,143
Total groundwater processed since startup (March 1994) (billions of L)	5.02
Carbon tetrachloride mass removed:	
Total mass of carbon tetrachloride removed in CY 2010 (kg)	700.7
Total mass of carbon tetrachloride removed since startup (March 1994) (kg)	12,646.8
Summary of FY 2008 operational parameters:	
Removal efficiency % by mass, average for year – [(influent – effluent) ÷ (influent)] x 100	99.9%

Table 12-2. 200-ZP-1 Operable Unit Treatment System Availability, CY 2010

Total possible hours run in a year	8,760
Scheduled outages (e.g., connecting new wells, maintenance, etc.) (hours)	127.8
Unscheduled outages (primarily shutdowns due to leak detection alarm shutdowns) (hours)	991
Total time on-line (hours)	7,641.2
Online availability ({total hours - total outage hours} ÷ total hours) x 100	87.2%
Total availability {total hours - total outage hours} ÷ {total hours – scheduled outage hours} x 100	88.5%

Table 12-3. Waste Management Area T Treatment System Availability, CY 2010

Month	Possible Hours	299-W11-45 Online Hours	299-W11-46 Online Hours	299-W11-45 Downtime Hours	299-W11-46 Downtime Hours	299-W11-45 Monthly Online Operational Percentages	299-W11-46 Monthly Online Operational Percentages
January 2010	744	0	336	744	408	0%	45%
February 2010	672	216	636	456	36	32%	95%
March 2010	744	720	720	24	24	97%	97%
April 2010	720	540	660	180	60	75%	93%
May 2010	744	720	696	24	48	97%	94%
June 2010	720	684	600	36	120	95%	83%
July 2010	744	696	696	48	48	94%	94%
August 2010	744	408	720	336	24	55%	97%
September 2010	720	36	624	684	96	5%	87%
October 2010	744	720	672	24	72	97%	90%
November 2010	720	696	684	24	36	97%	95%
December 2010	744	744	744	0	0	100%	100%
Total	**8,760**	**6,180**	**7,812**	**2,580**	**972**	**70.5%**	**89.2%***

* Average annual percentage.

Table 12-4. Waste Management Area T Pump-and-Treat Performance Summary, CY 2010

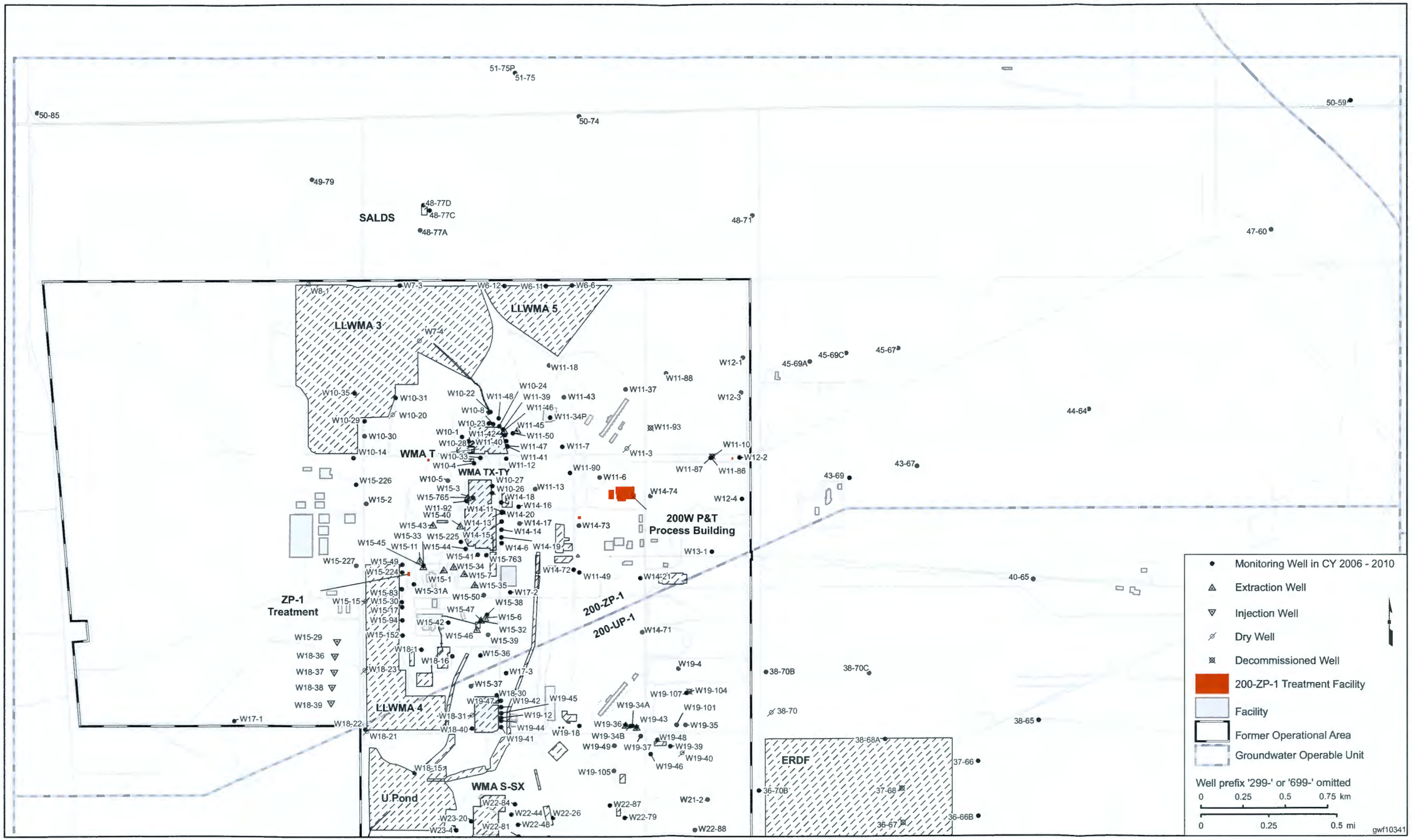
Total processed groundwater:						
Total groundwater processed in CY 2010 (L)					52,176,235	
Total groundwater processed since startup (July 2007) (millions of L)					174,753,016	
Reporting Period	**Extracted Volume (L)**	**Contaminants**				
		Tc-99 (kg)[a]	**Carbon Tetrachloride (kg)[a]**	**Nitrate (kg)[a]**	**Chromium (kg)[a,b]**	**TCE (g)[a]**
CY 2010						
January – March	9,704,187	6.75	9.30	4,496	0.84	37.04
April – June	13,570,205	3.93	5.33	5,858	1.77	121.67
July – September	12,578,147	0.62	7.25	5,613	1.66	17.27
October – December	16,323,926	5.05	5.98	6,992	1.98	69.05
Totals	**52,176,465**	**16.35**	**27.86**	**22,959**	**6.25**	**245.03**

a. Mass removed by the ETF is reported for both of the 200-UP-1 and 200-ZP-1 (241-T) OU pump-and-treat systems. Previously, an estimated mass removed was calculated using the most recent pre-treatment tank concentrations reported, multiplied by the gallons pumped at each well. Since more gallons were pumped than were treated, the percentage per pump-and-treat system was calculated and multiplied by the ETF mass removed to compute mass removed for each system. For CY 2010, it was determined that a more accurate method for determining mass removed was to multiply liters removed by the quarterly average concentration from each extraction well. Exceptions are for carbon tetrachloride, where the ETF values are used instead of calculated values as considerable volatilization takes place prior to treatment. In addition, where quarterly analytical data are not present, annual averages are used as a proxy to calculate masses.

b. Note that all hexavalent chromium is attributed to the 200-ZP-1/241-T extraction system. Chromium is not a target analyte at the 200-UP-1 OU.

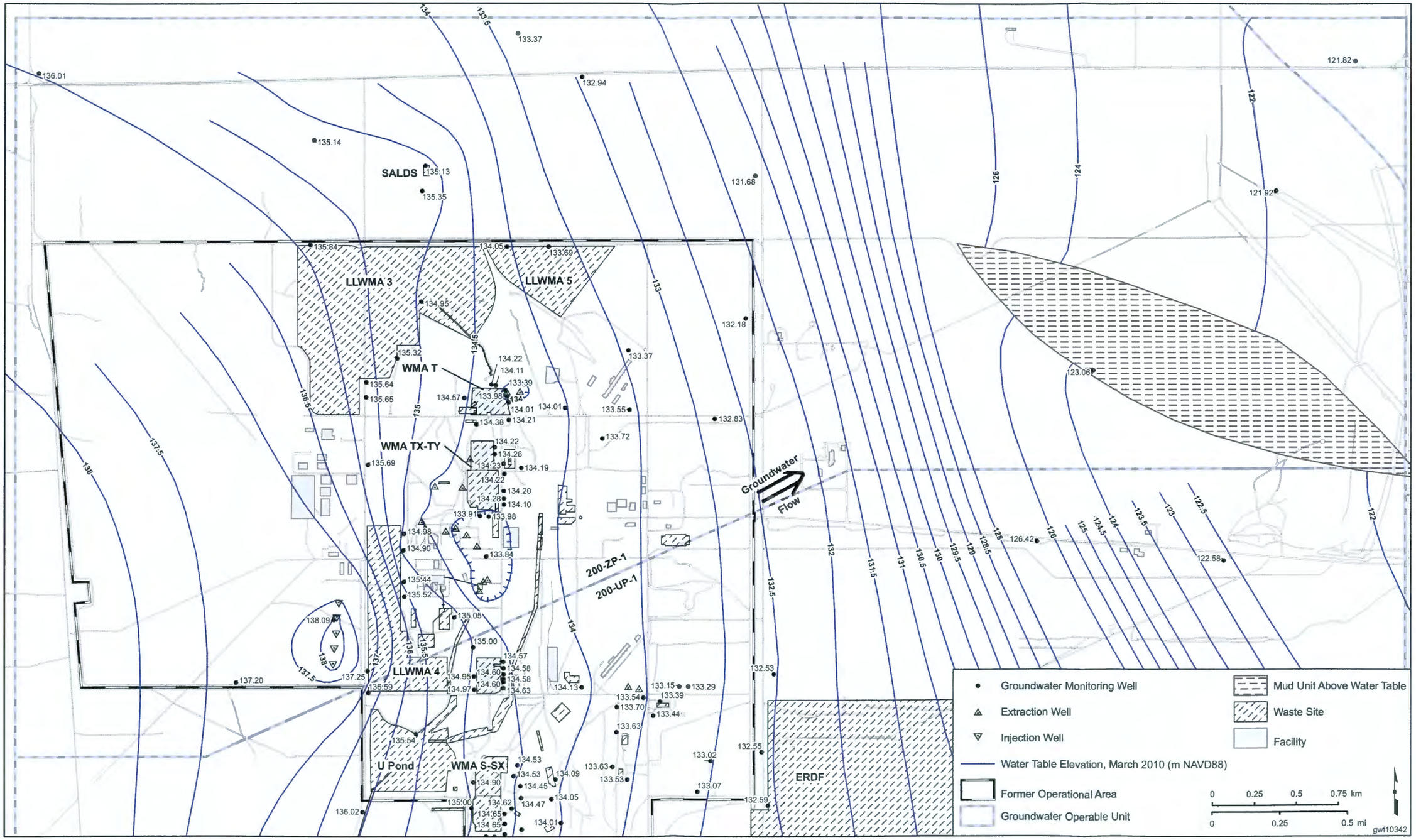
This page intentionally left blank.

Figure 12-1. Facilities and Groundwater Monitoring Wells in the 200-ZP-1 Operable Unit



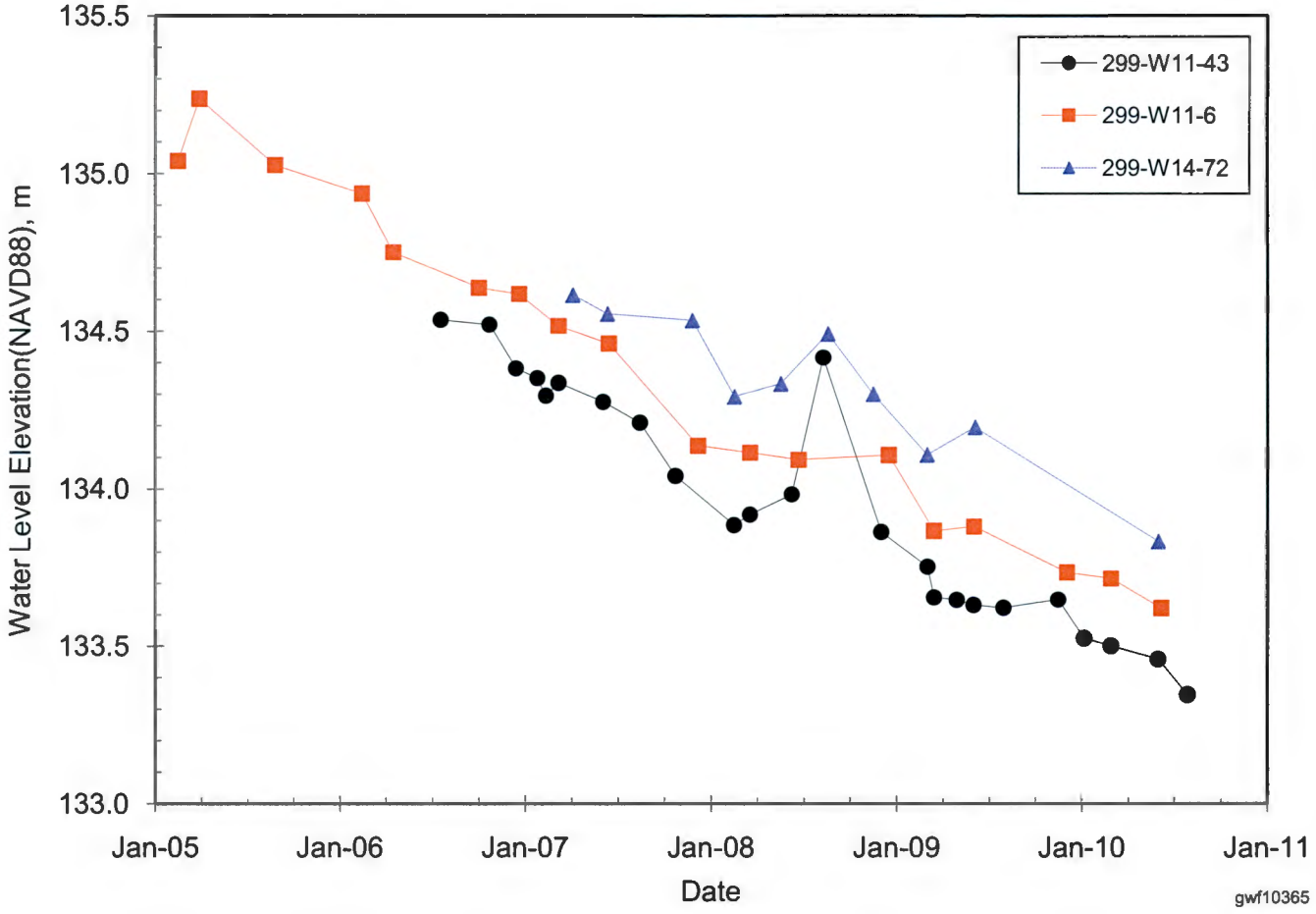
This page intentionally left blank.

Figure 12-2. 200 West Area Water Table Map, CY 2010



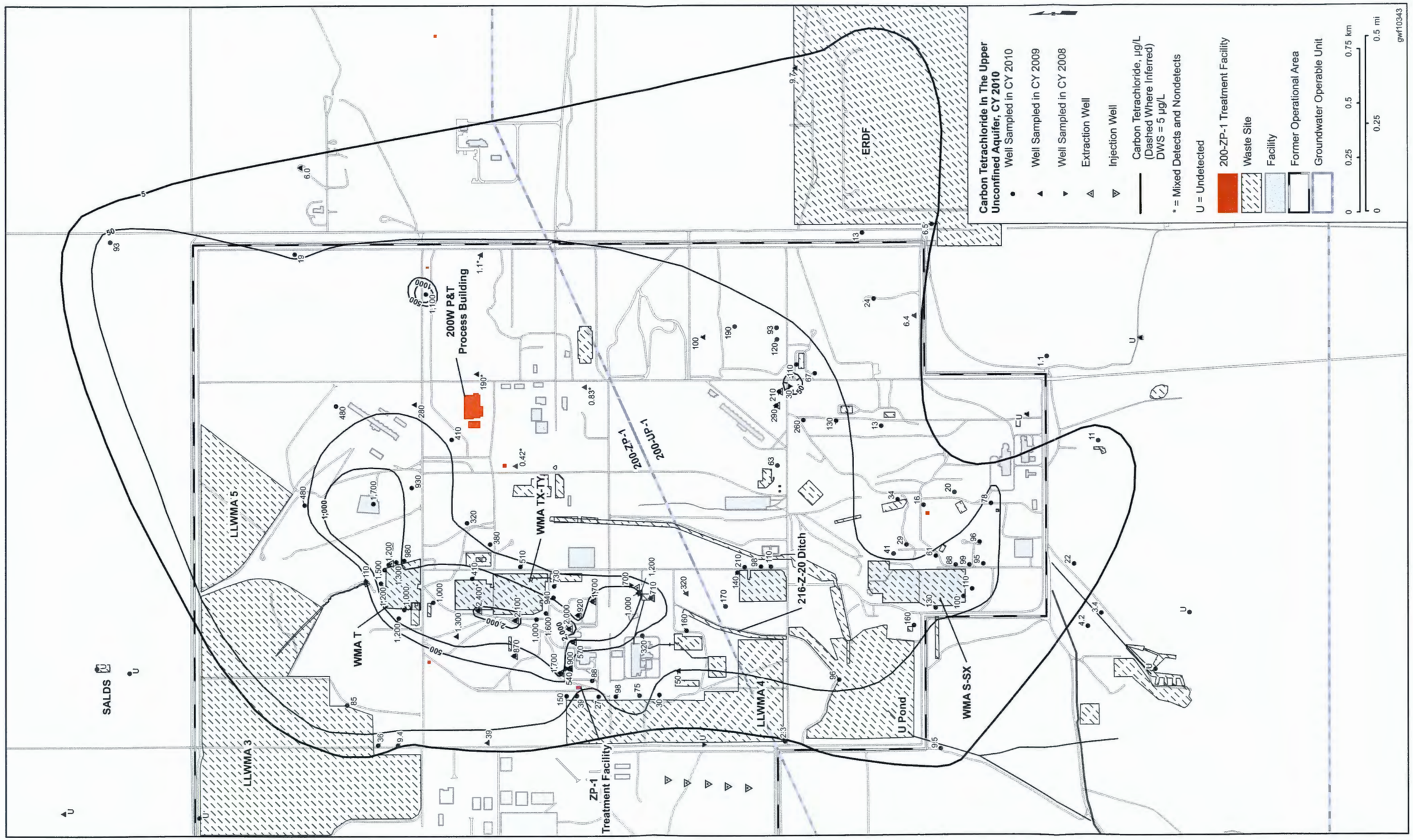
This page intentionally left blank.

Figure 12-3. Hydrograph for Selected Wells in Northern Portion of 200 West Area



This page intentionally left blank.

Figure 12-4. Average Carbon Tetrachloride Concentration in the 200 West Area, Upper Portion of Unconfined Aquifer



This page intentionally left blank.

Figure 12-5. Average Carbon Tetrachloride Concentration in 200 West Area Throughout the Unconfined Aquifer and Locations of the Final Remedy Extraction and Injection Wells

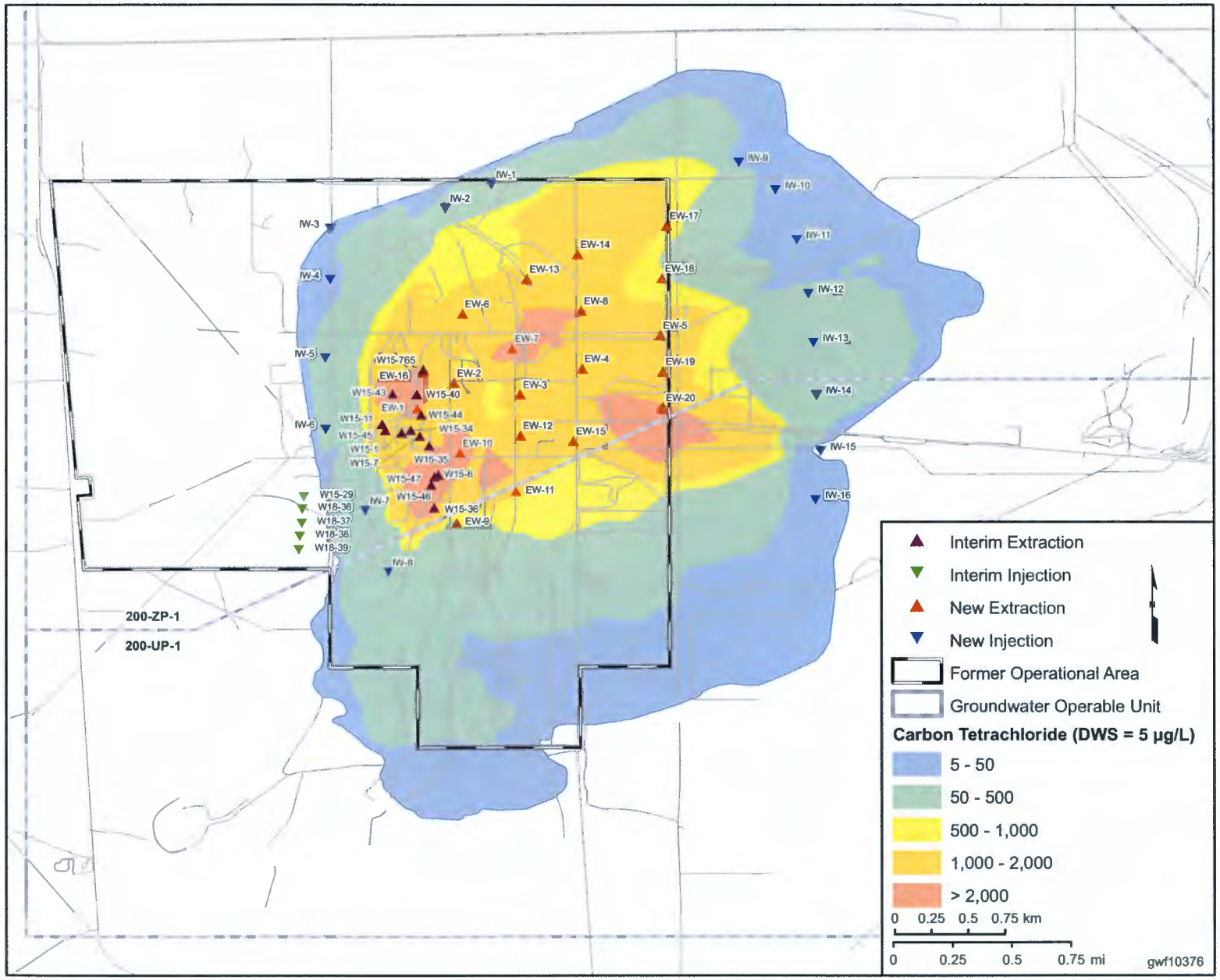


Figure 12-6. Carbon Tetrachloride Concentration in Well 699-48-71, Northeast of 200 West Area

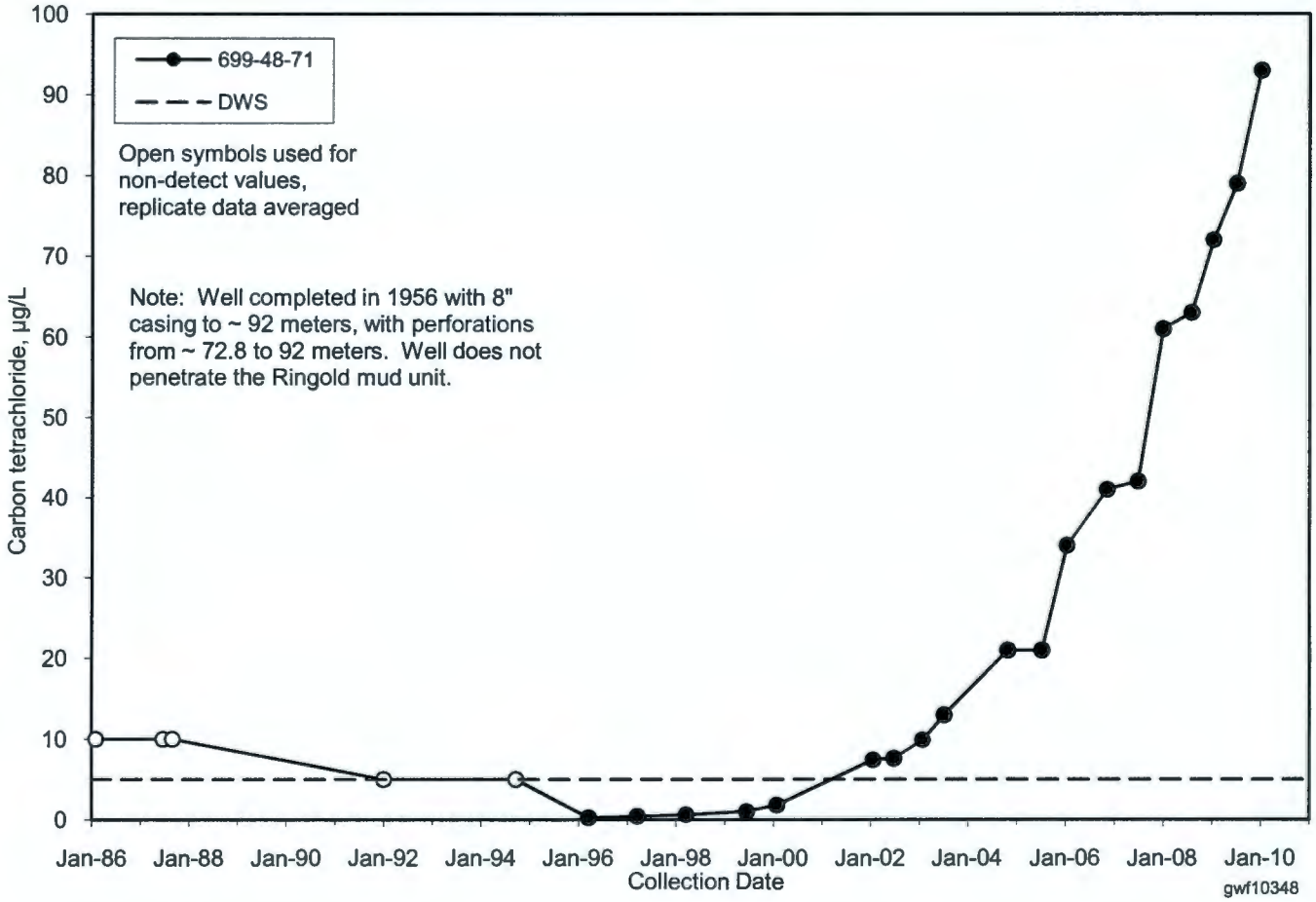


Figure 12-7. 200-ZP-1 Groundwater Operable Unit Carbon Tetrachloride Concentration Plan View at 94 m Elevation Above Mean Sea Level and Cross Section A A'

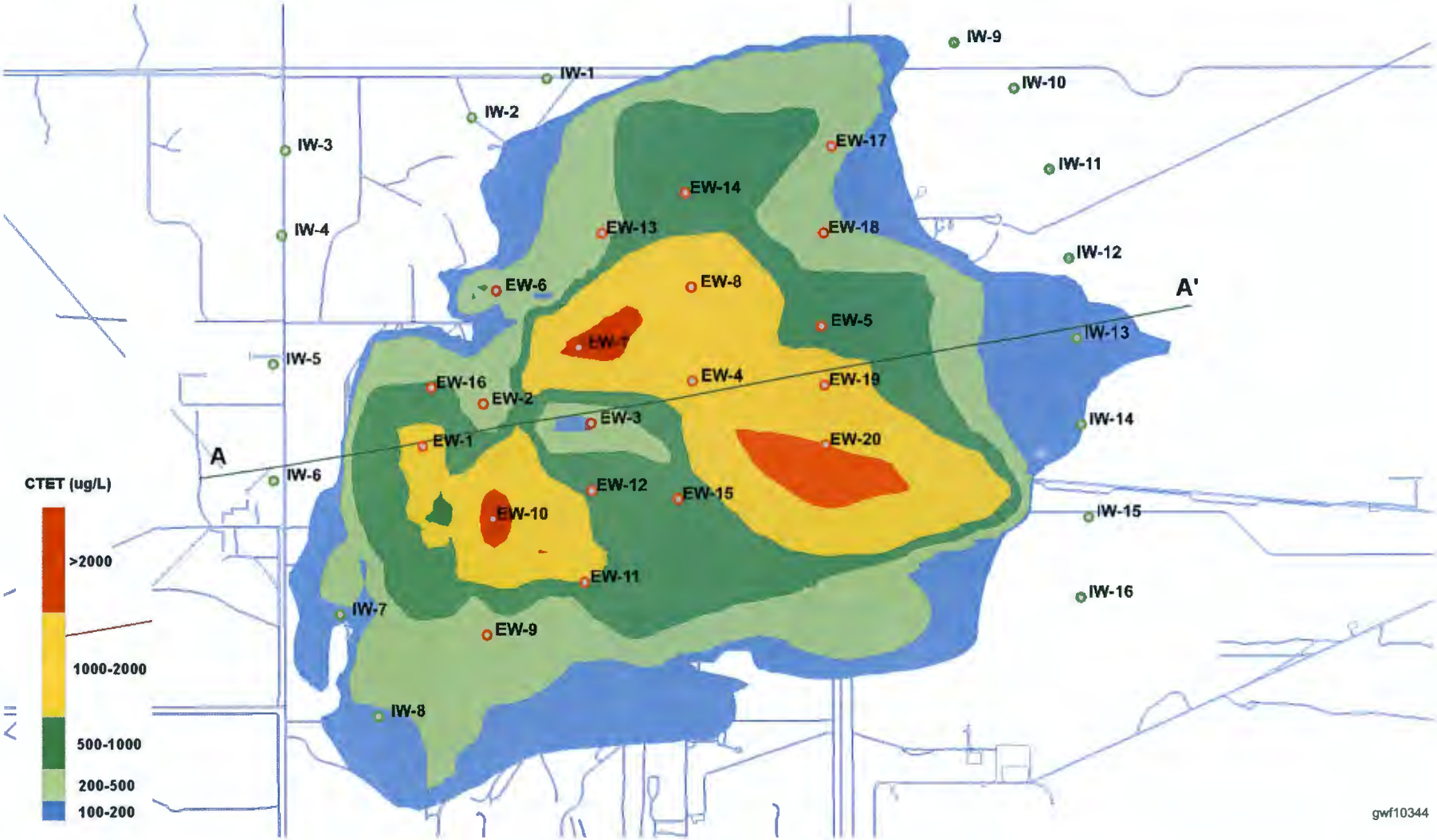


Figure 12-8. 200-ZP-1 Groundwater Operable Unit Carbon Tetrachloride Plume Cross-Section A-A'

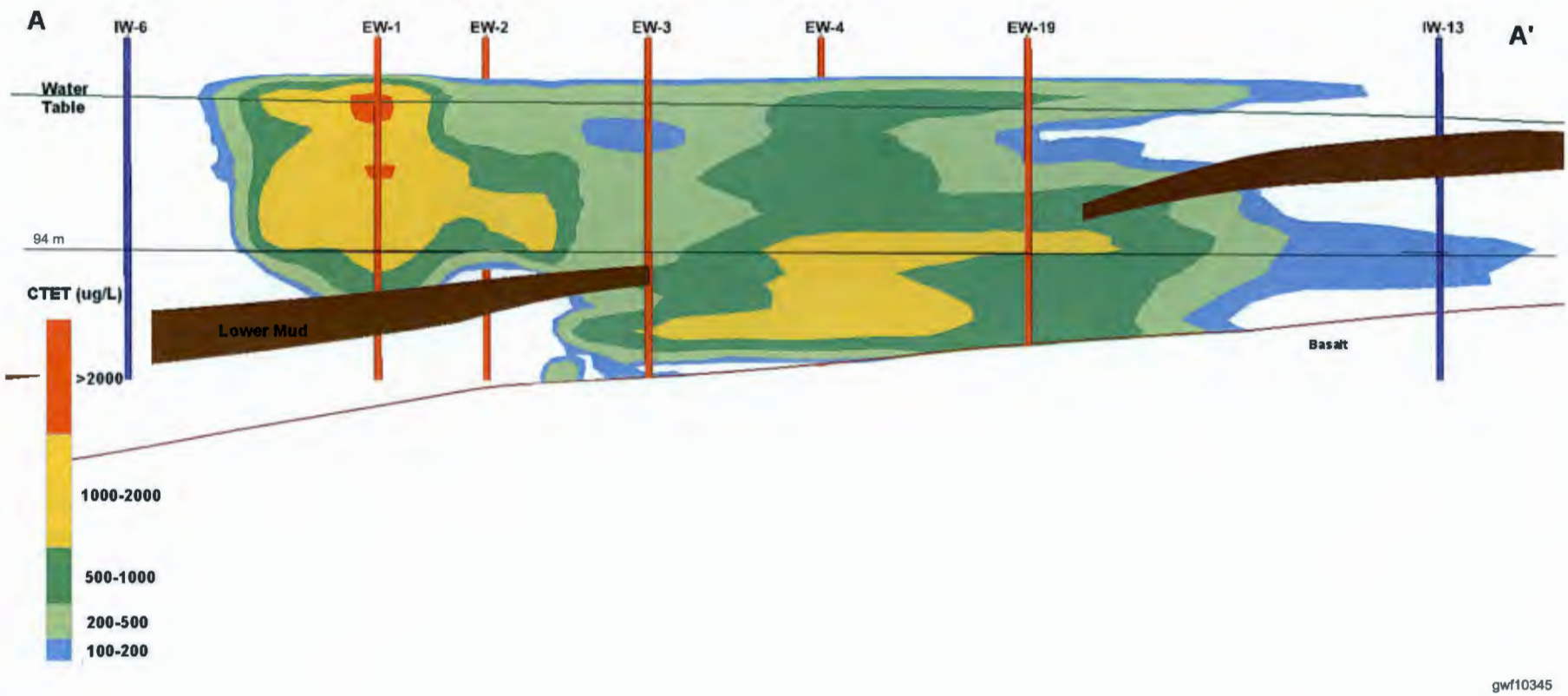


Figure 12-9. Average Trichloroethylene Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer

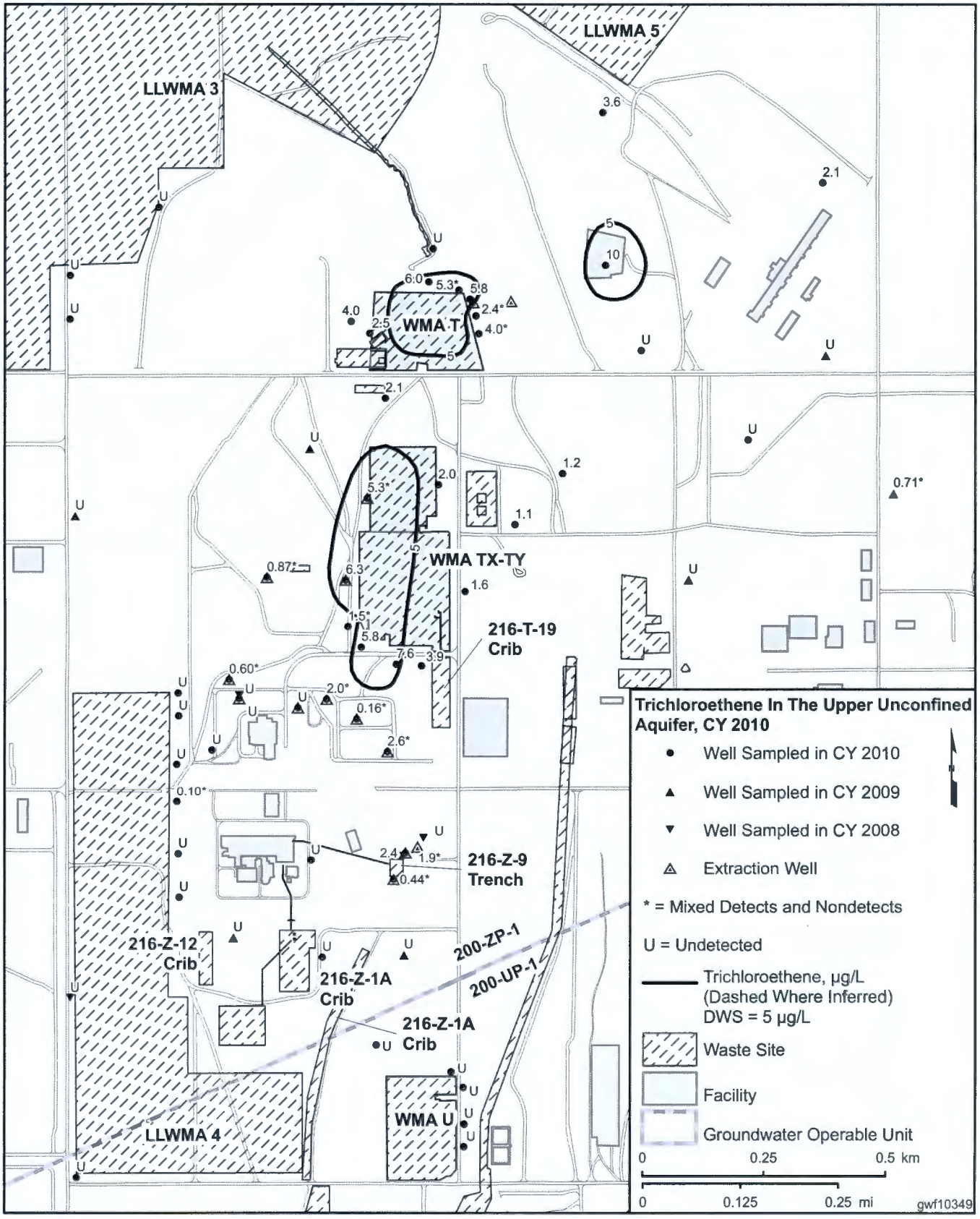


Figure 12-10. Average Nitrate Concentration in Central and Northern 200 West Area, Upper Portion of the Unconfined Aquifer

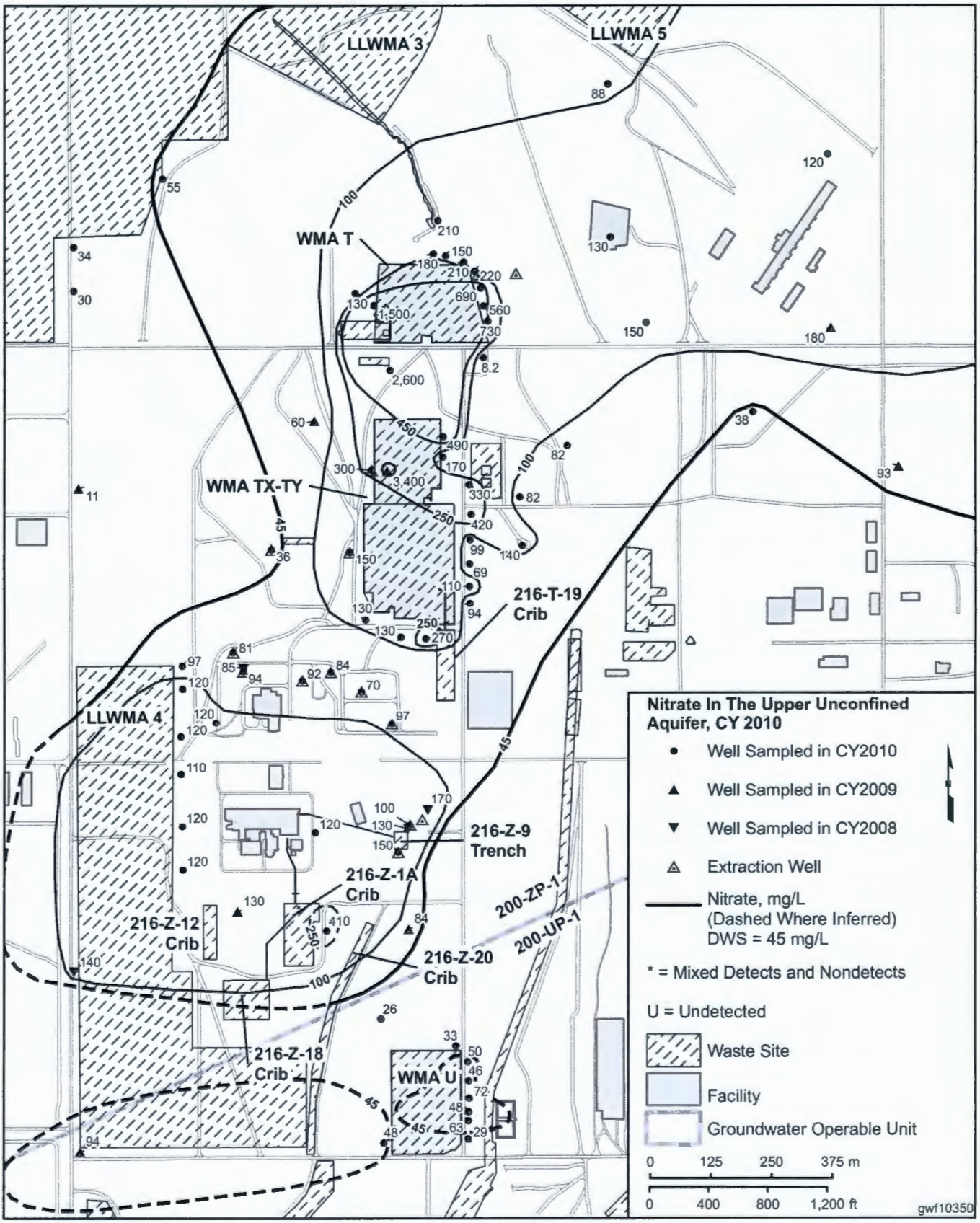


Figure 12-11. Average Filtered Chromium Concentration Northern 200 West Area, Upper Portion of Aquifer

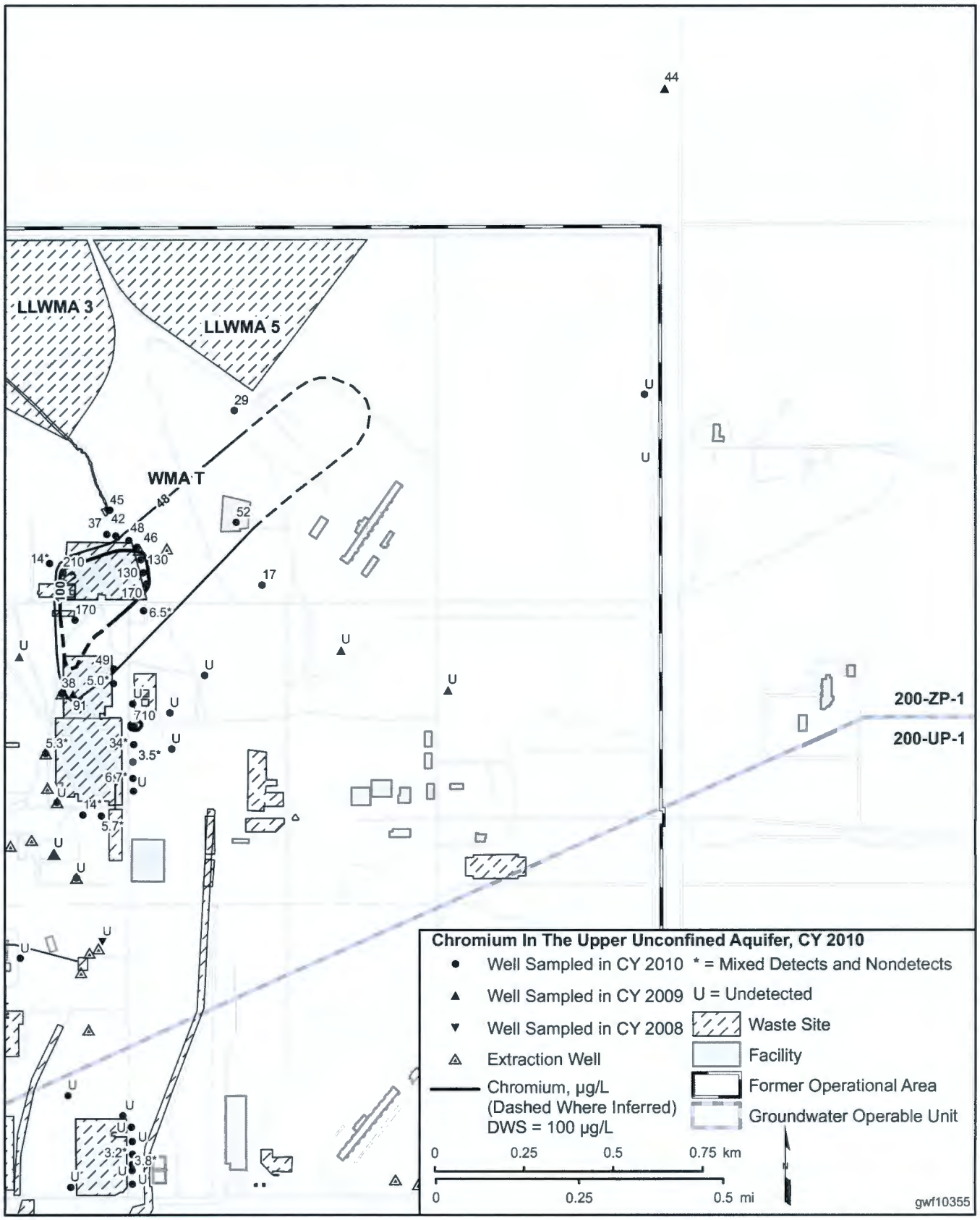


Figure 12-12. Average Tritium Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer

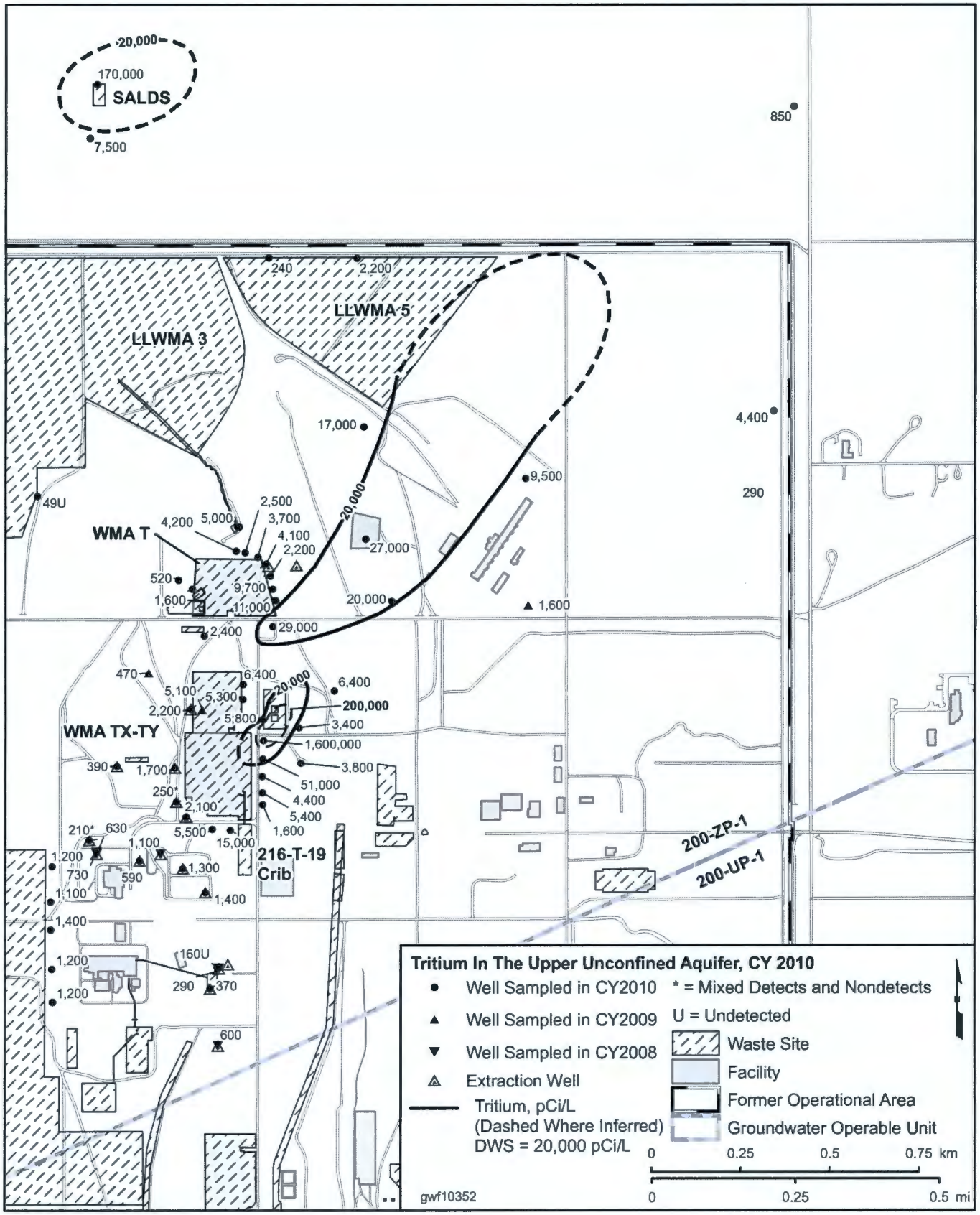


Figure 12-13. Average Iodine-129 Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer

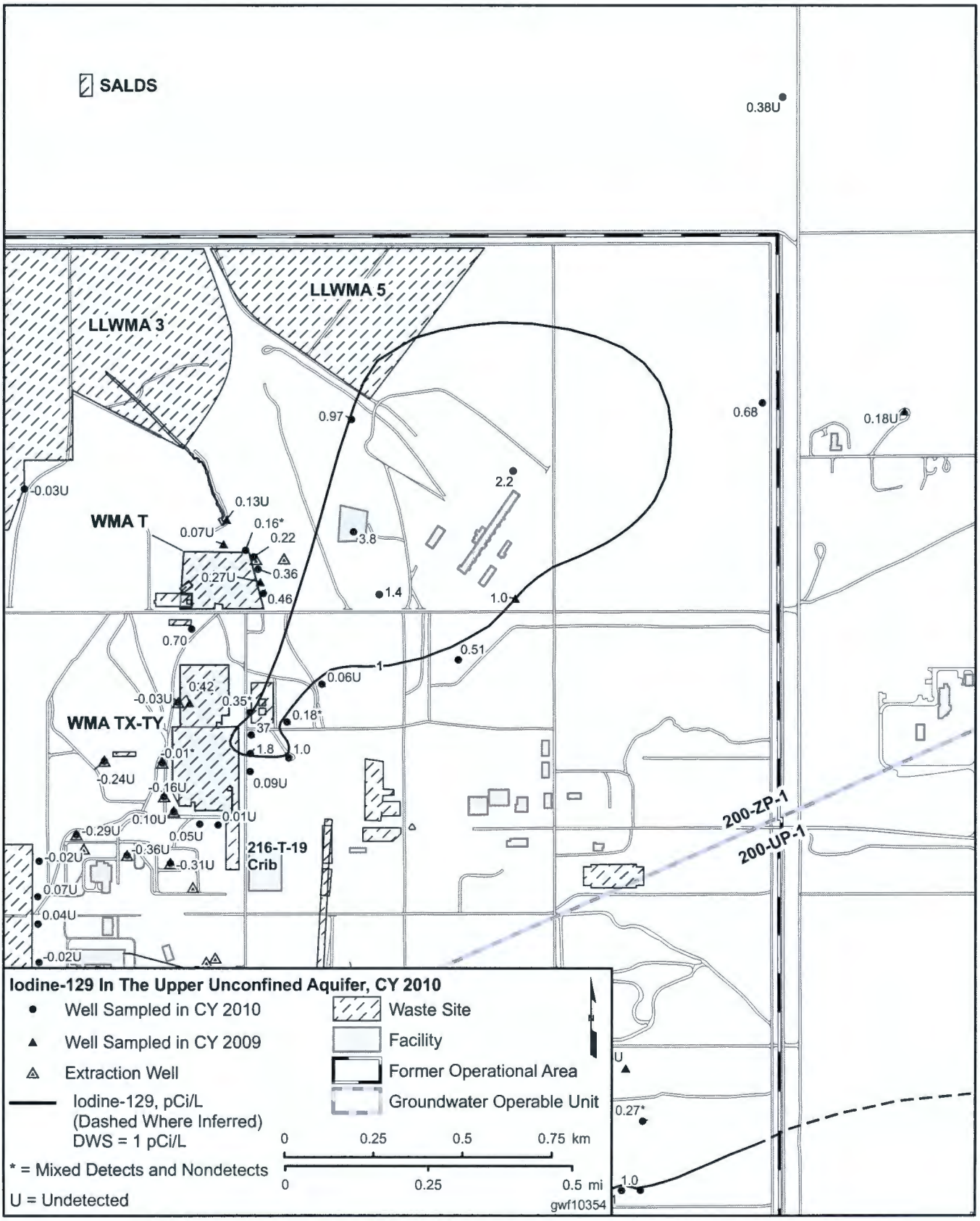


Figure 12-14. Average Technetium-99 Concentration in Central and Northern 200 West Area, Upper Portion of Unconfined Aquifer

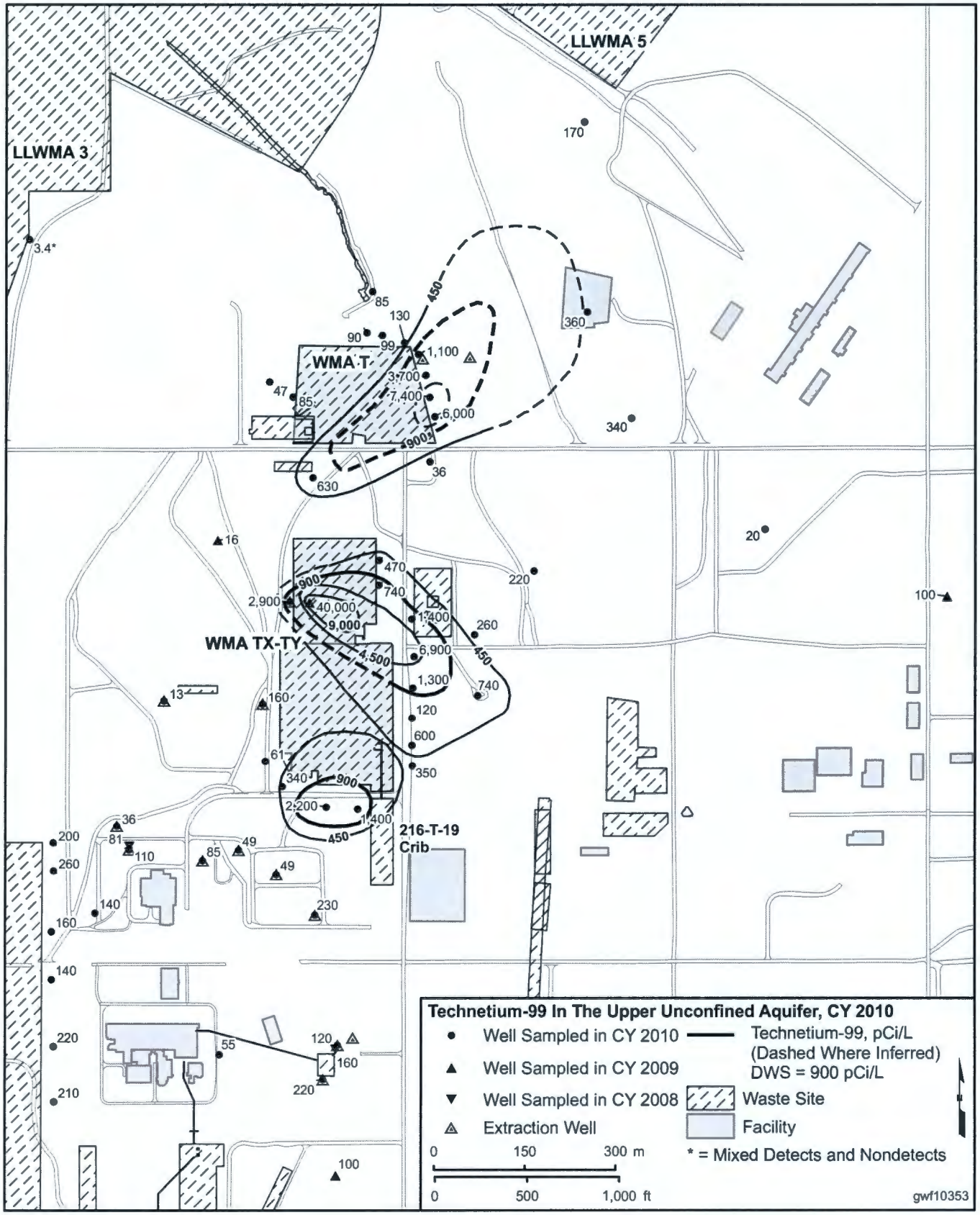


Figure 12-15. 200-ZP-1 Operable Unit Approximate Extent of Capture Overlaid with Contoured Extent of Carbon Tetrachloride, CY 2010

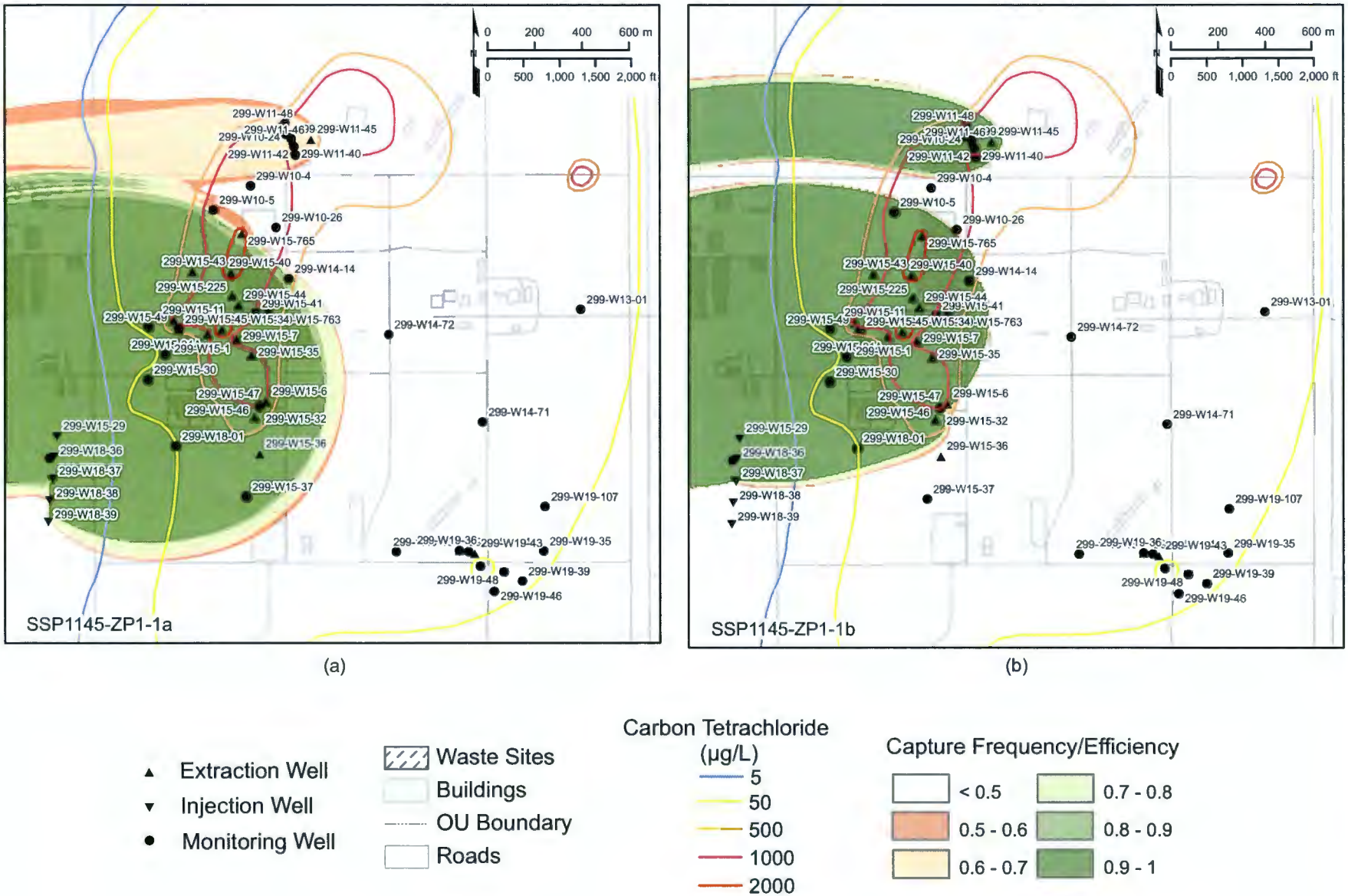


Figure 12-16. Carbon Tetrachloride Trend Plots for Monitoring Wells

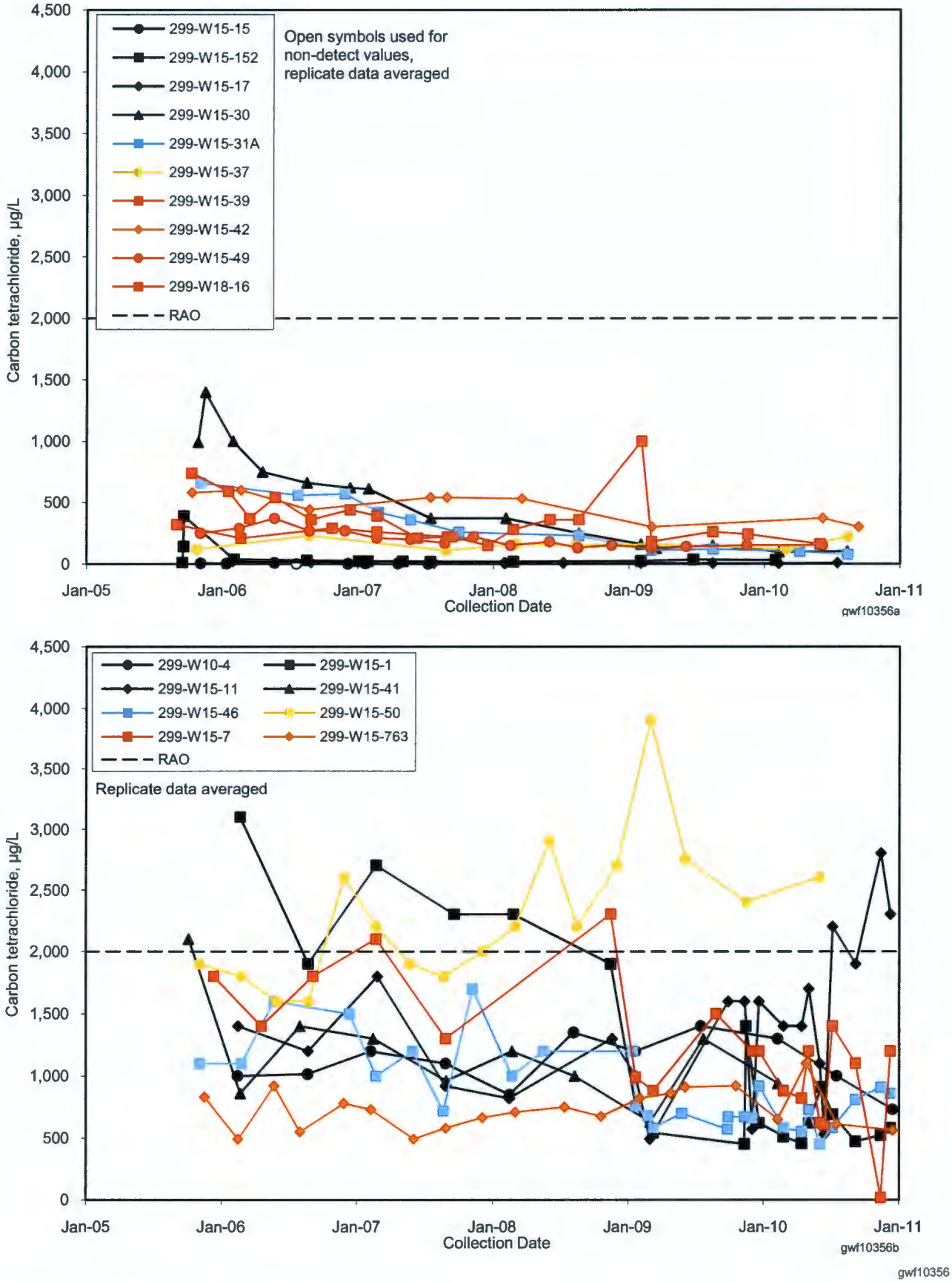
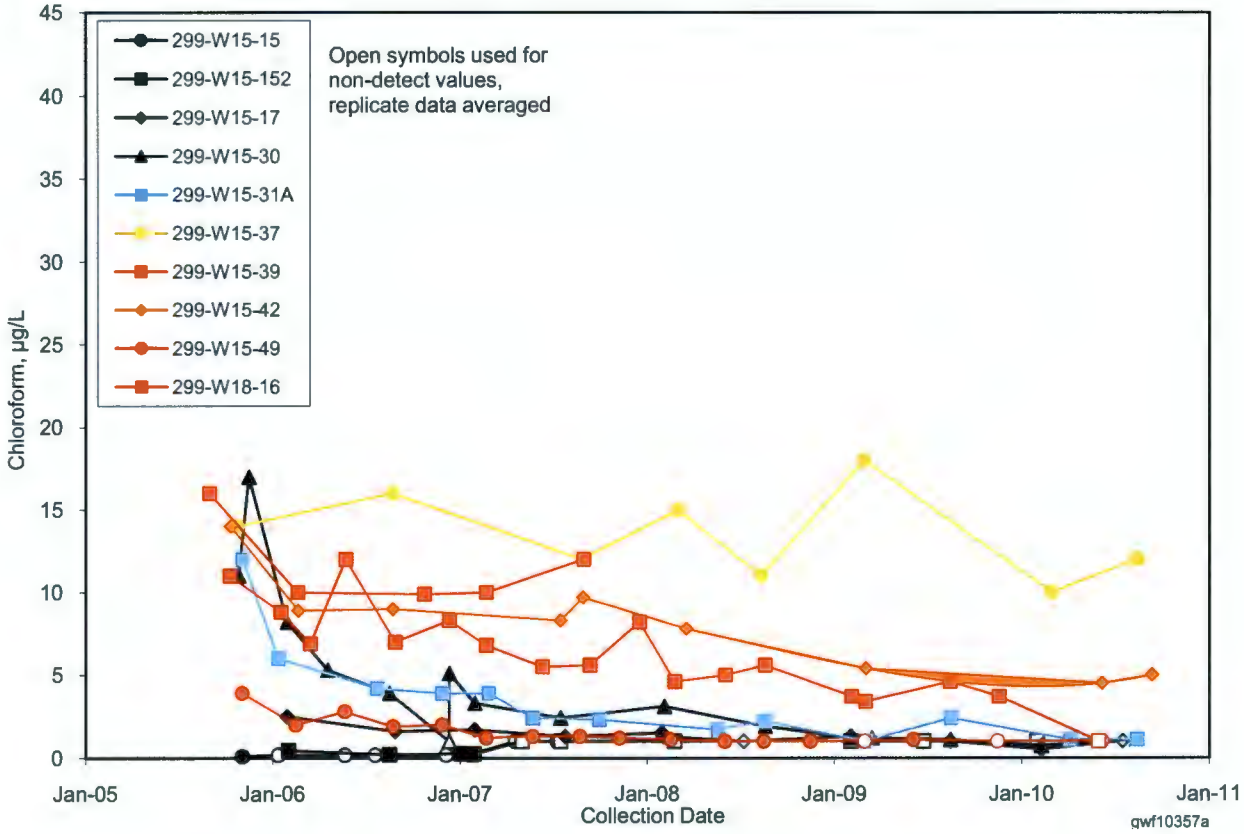
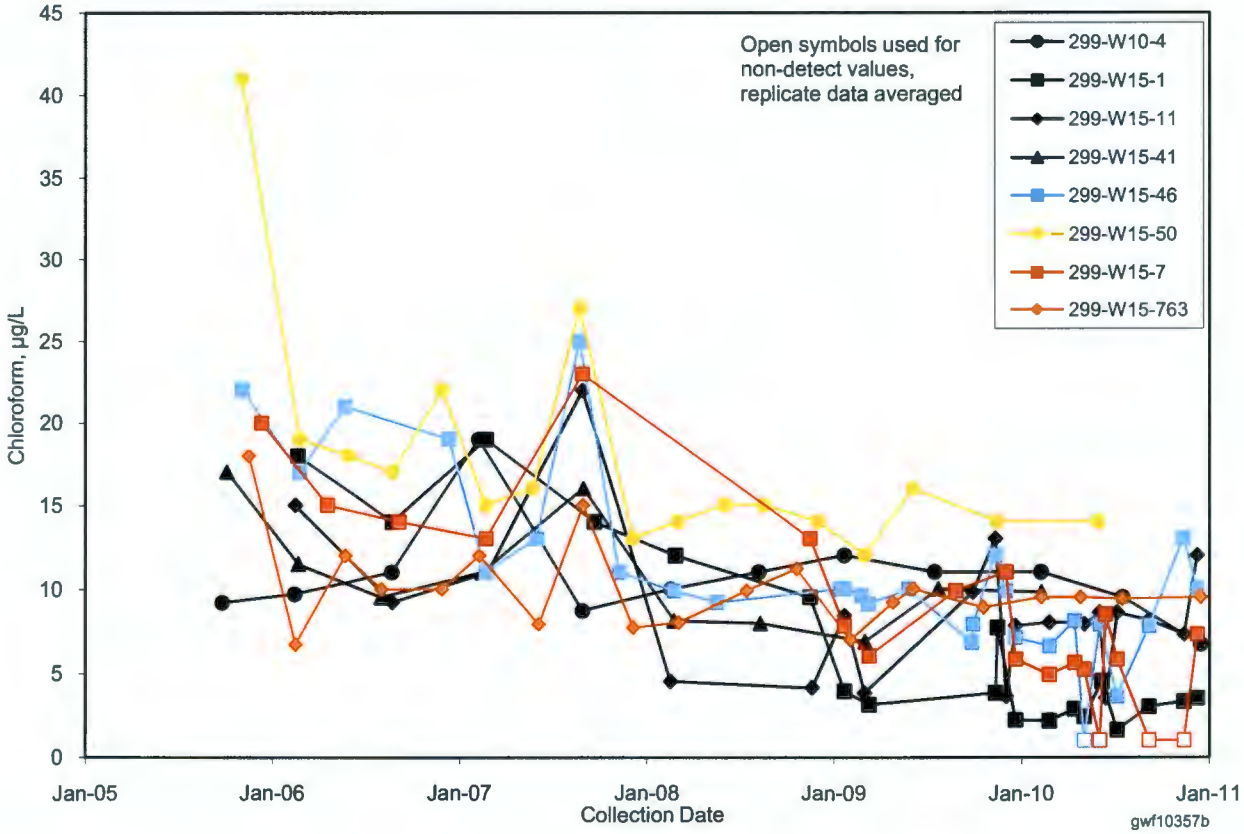


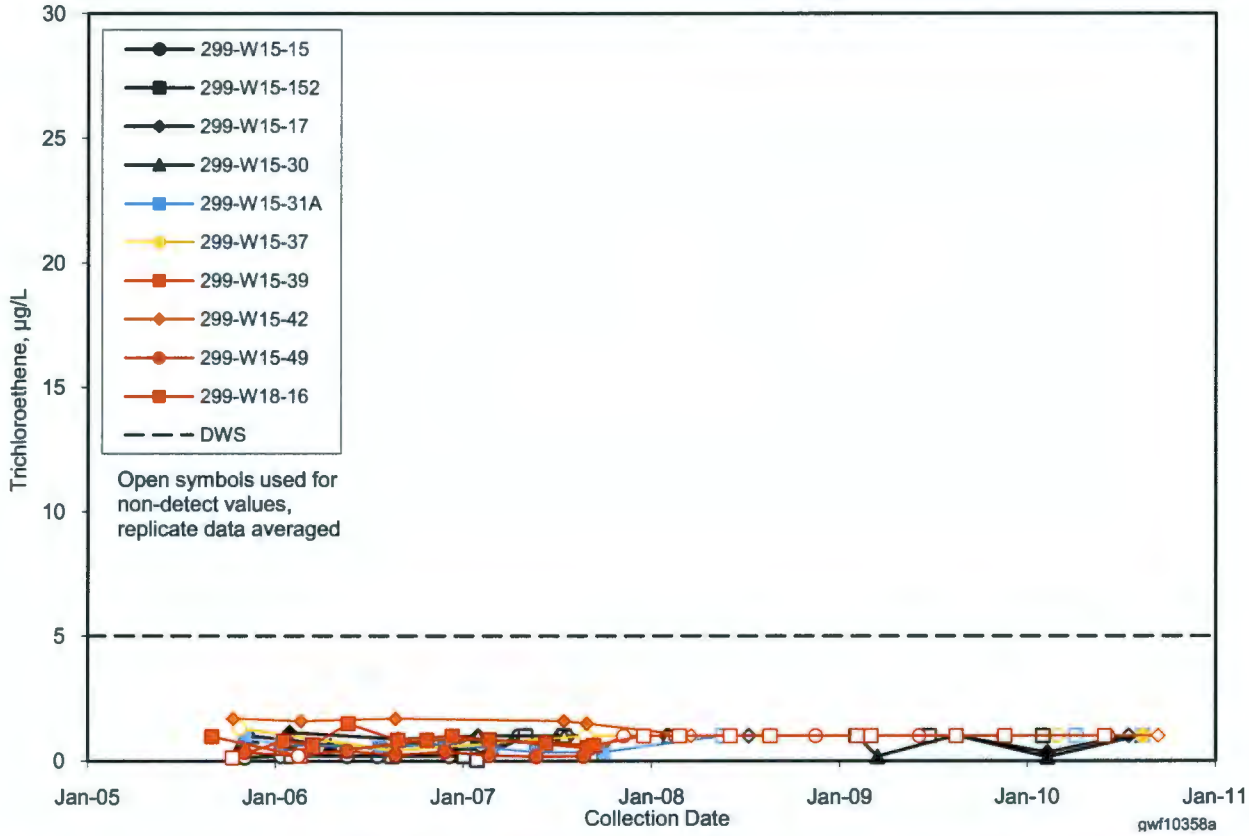
Figure 12-17. Chloroform Trend Plots for Monitoring Wells

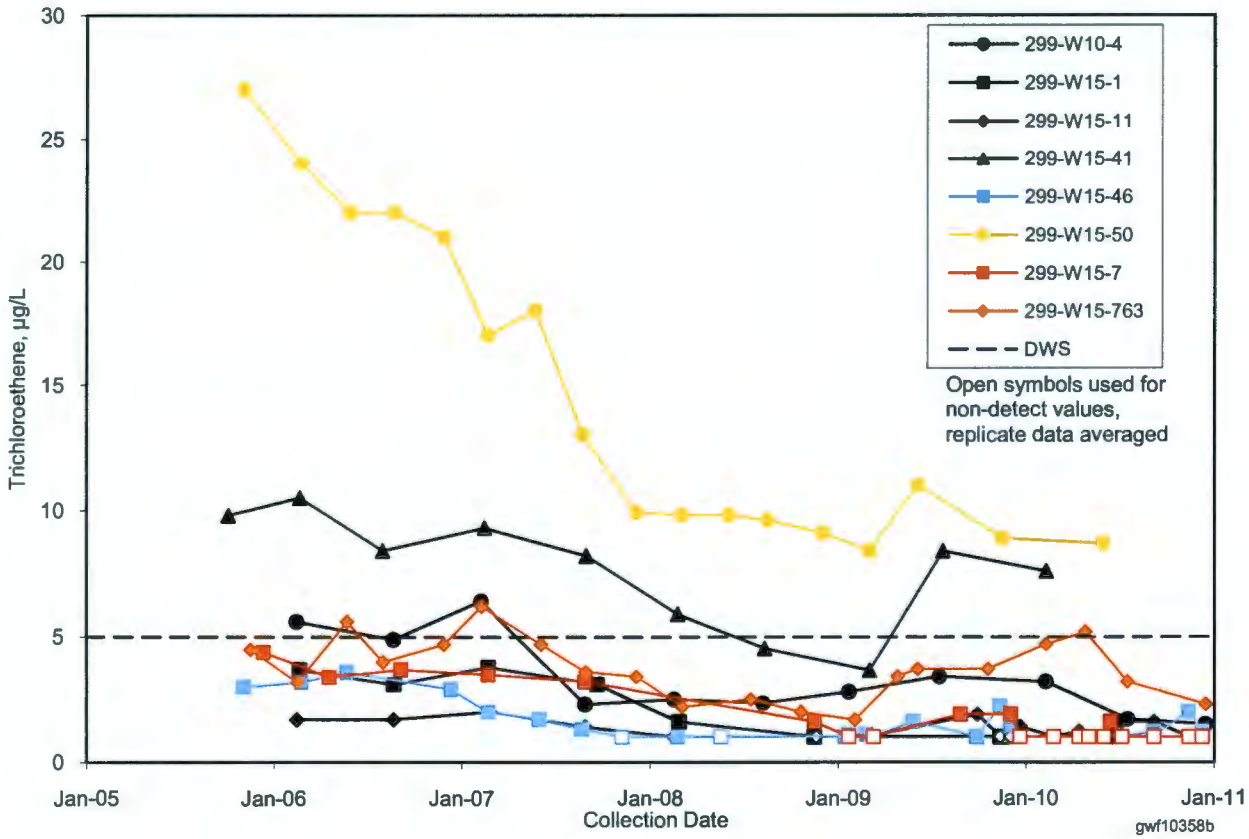




gwf10357

Figure 12-18. Trichloroethylene Trend Plots for Monitoring Wells





gwf10358

Figure 12-19. Carbon Tetrachloride Trend Plots for Extraction Wells

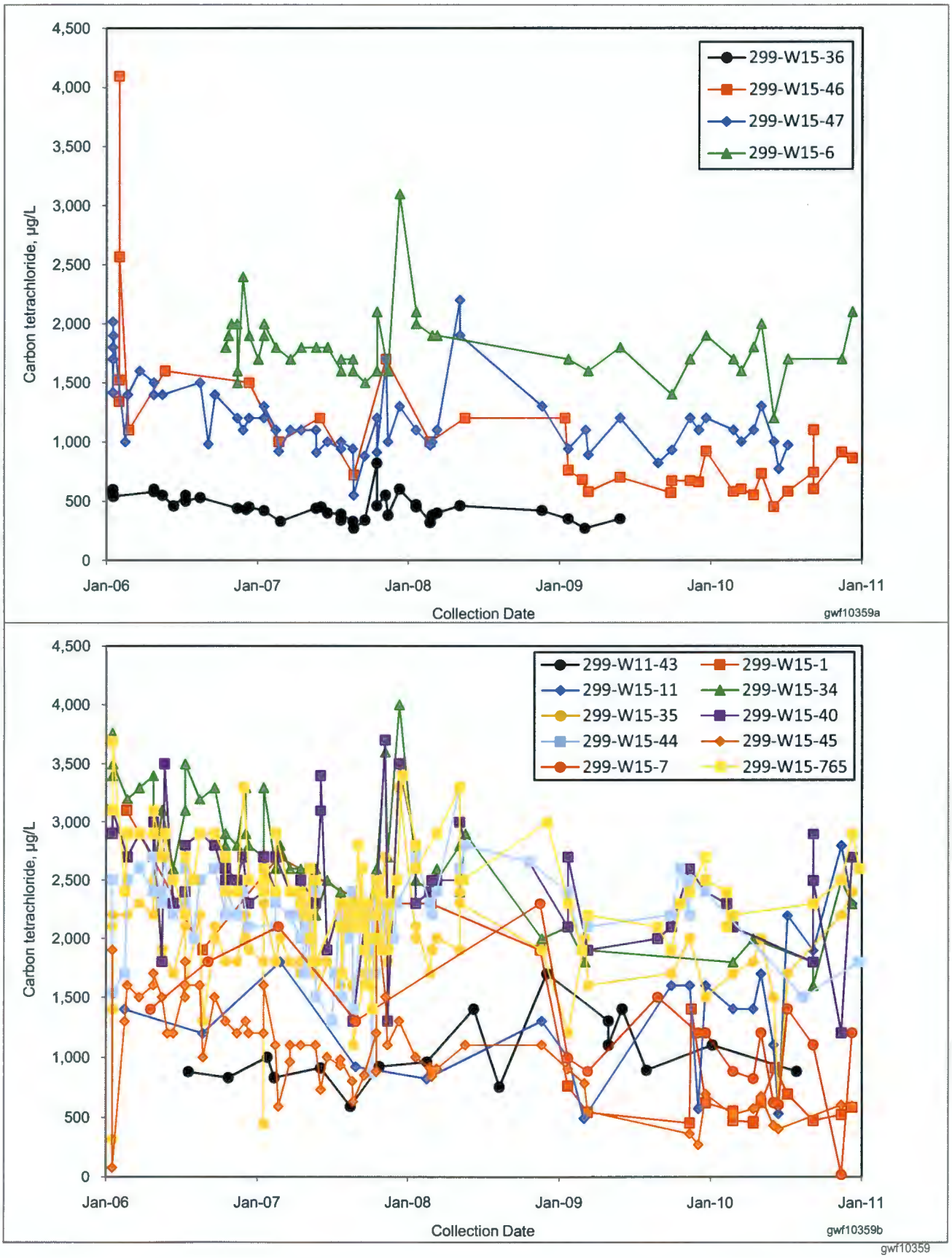


Figure 12-20. Technetium-99 Trend Plots for Monitoring Wells

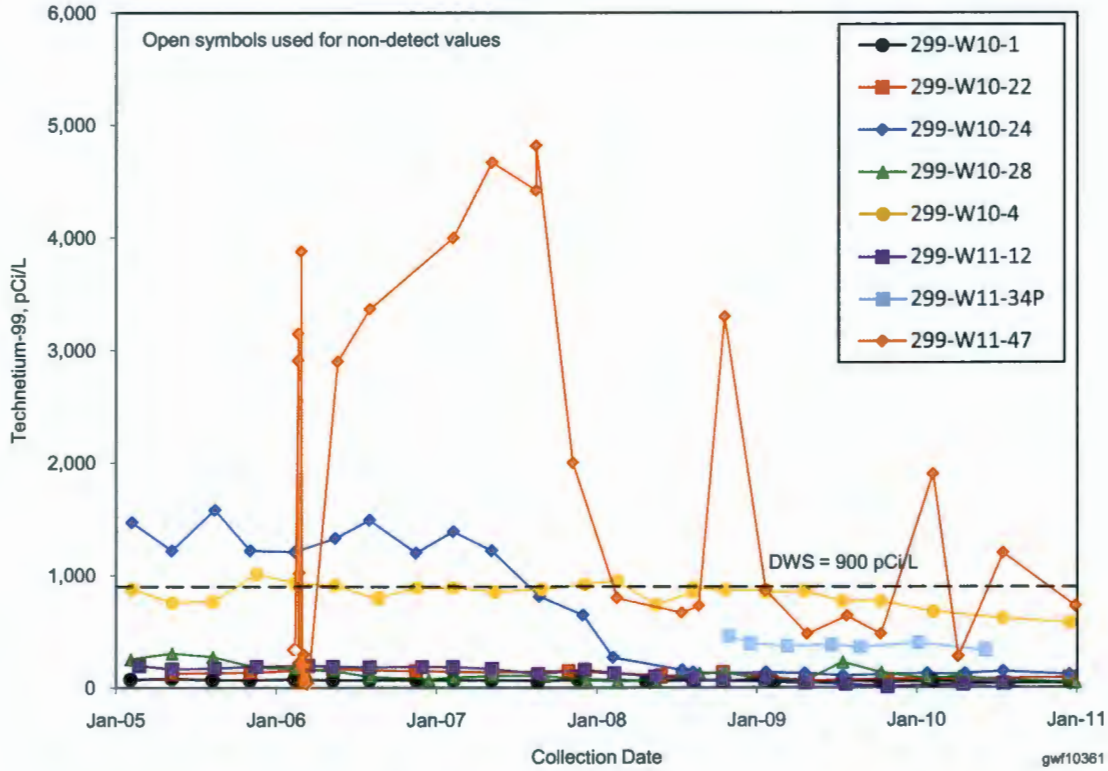


Figure 12-21. Technetium-99 Trend Plots for Extraction Wells

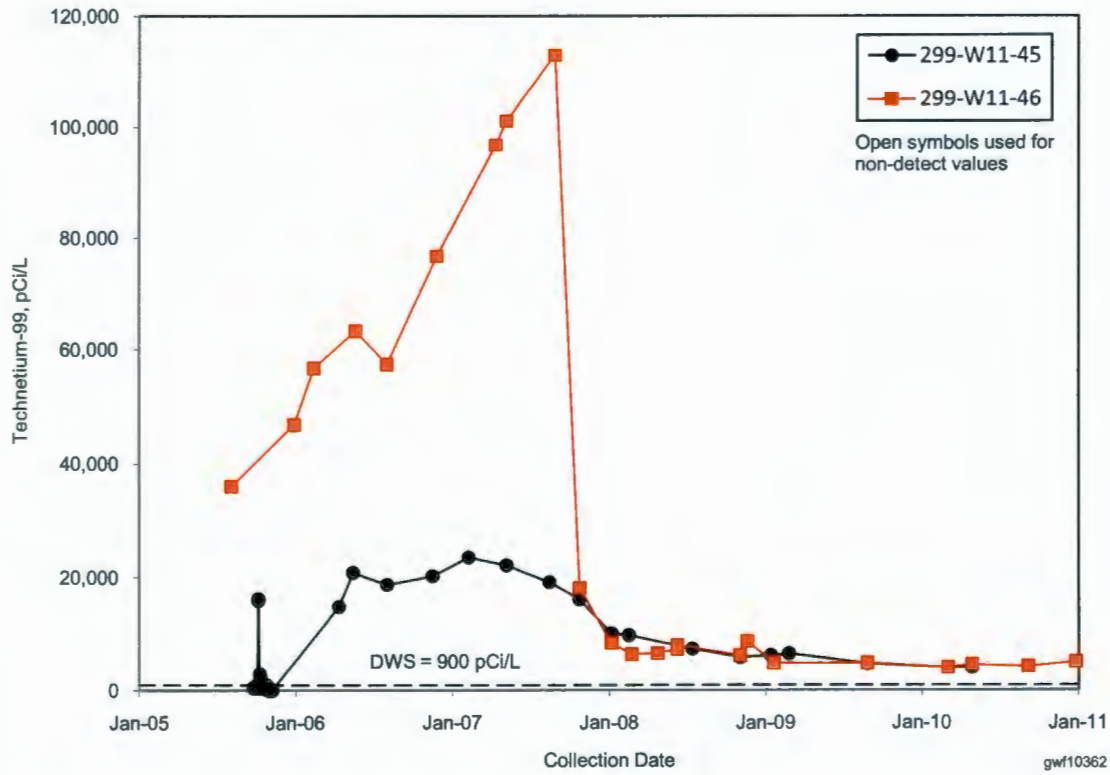
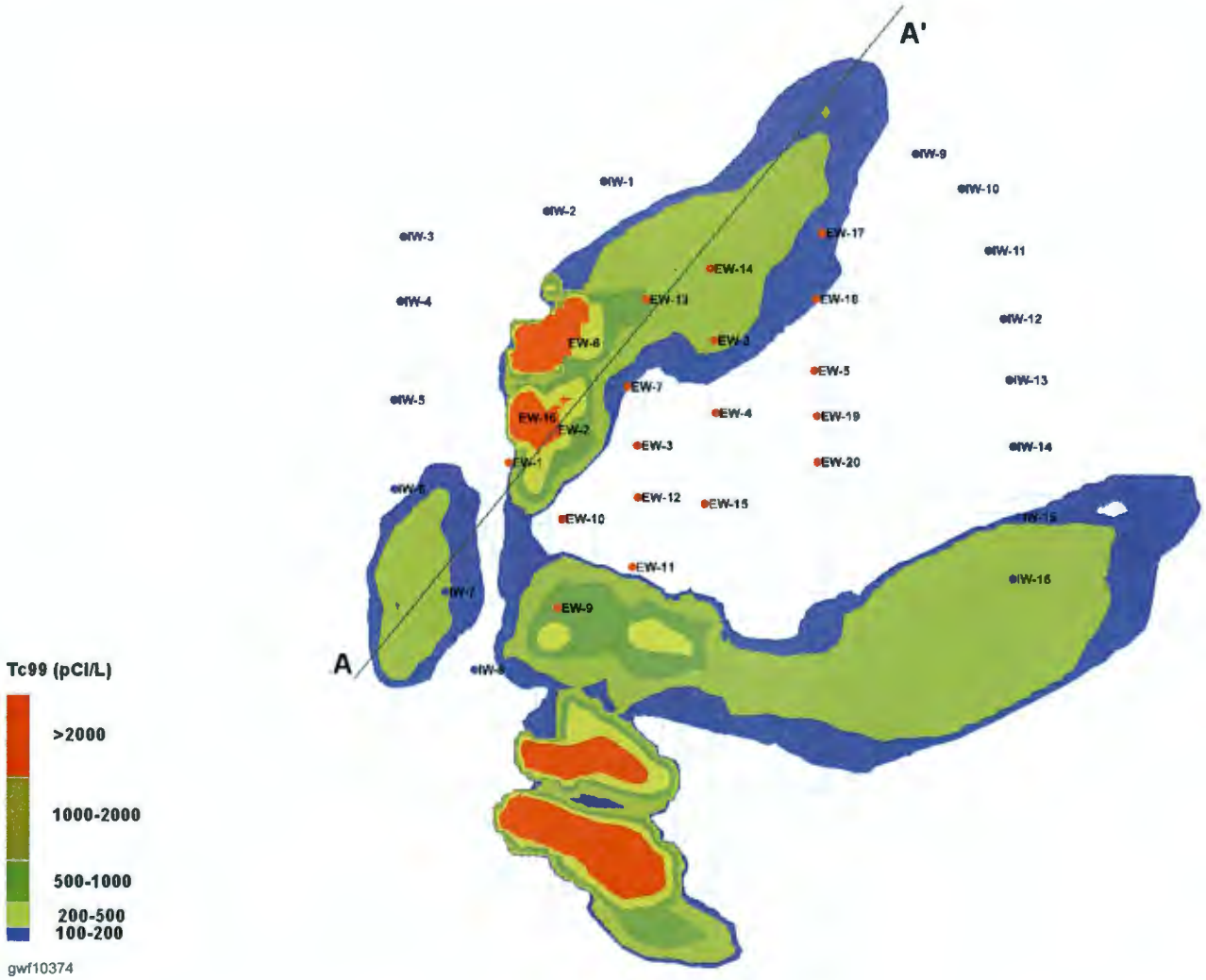


Figure 12-22. 200-ZP-1 Groundwater Operable Unit Technetium-99 Concentration Plan View at 127 m Elevation Above Mean Sea Level and Cross-Section A-A'



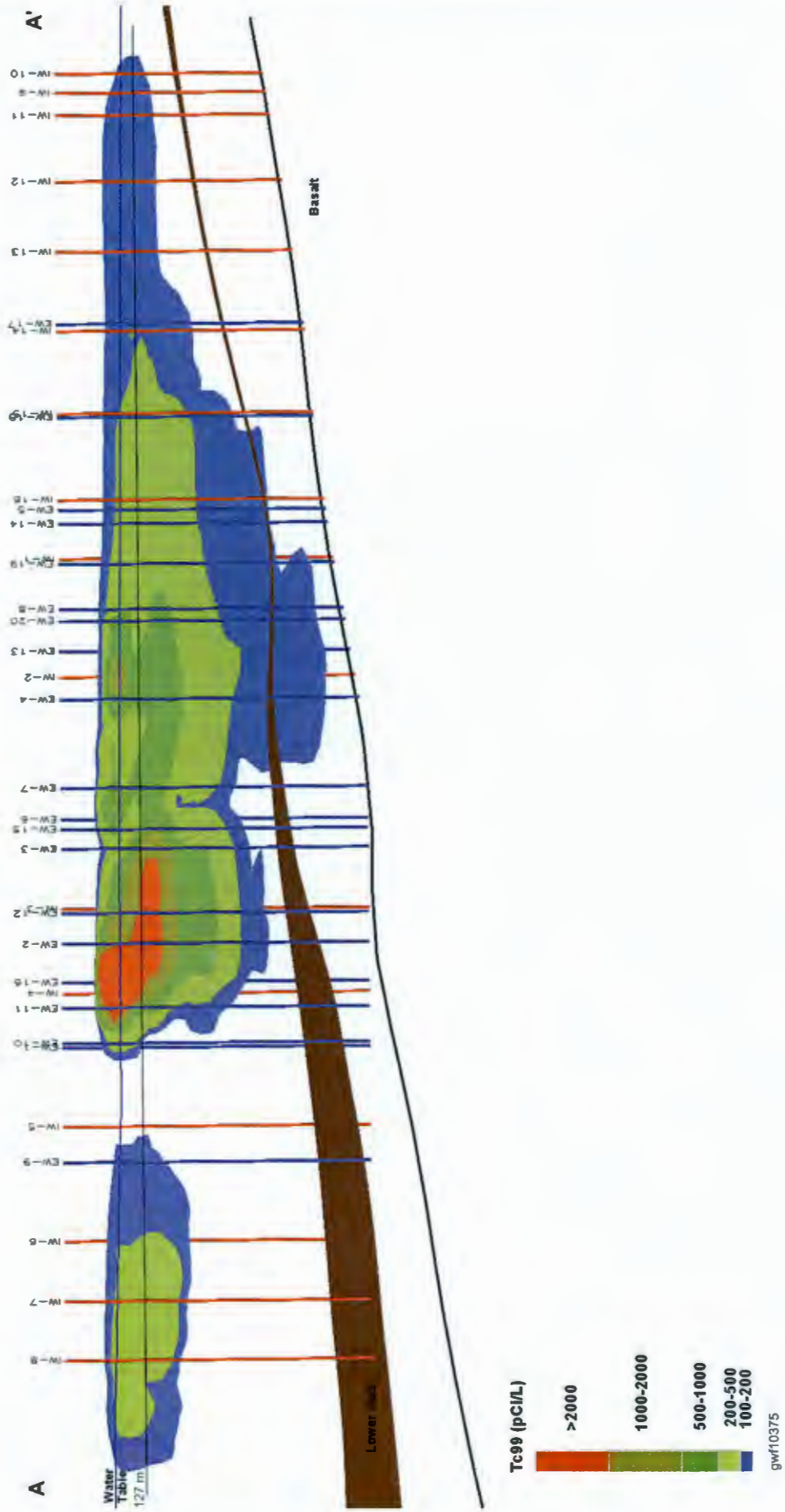


Figure 12-23. 200-ZP-1 Groundwater Operable Unit Technetium-99 Plume Cross-Section A-A'

Figure 12-24. Concentration of Selected Contaminants in Wells 299-W14-3 and 299-W14-5, Waste Management Area TX-TY

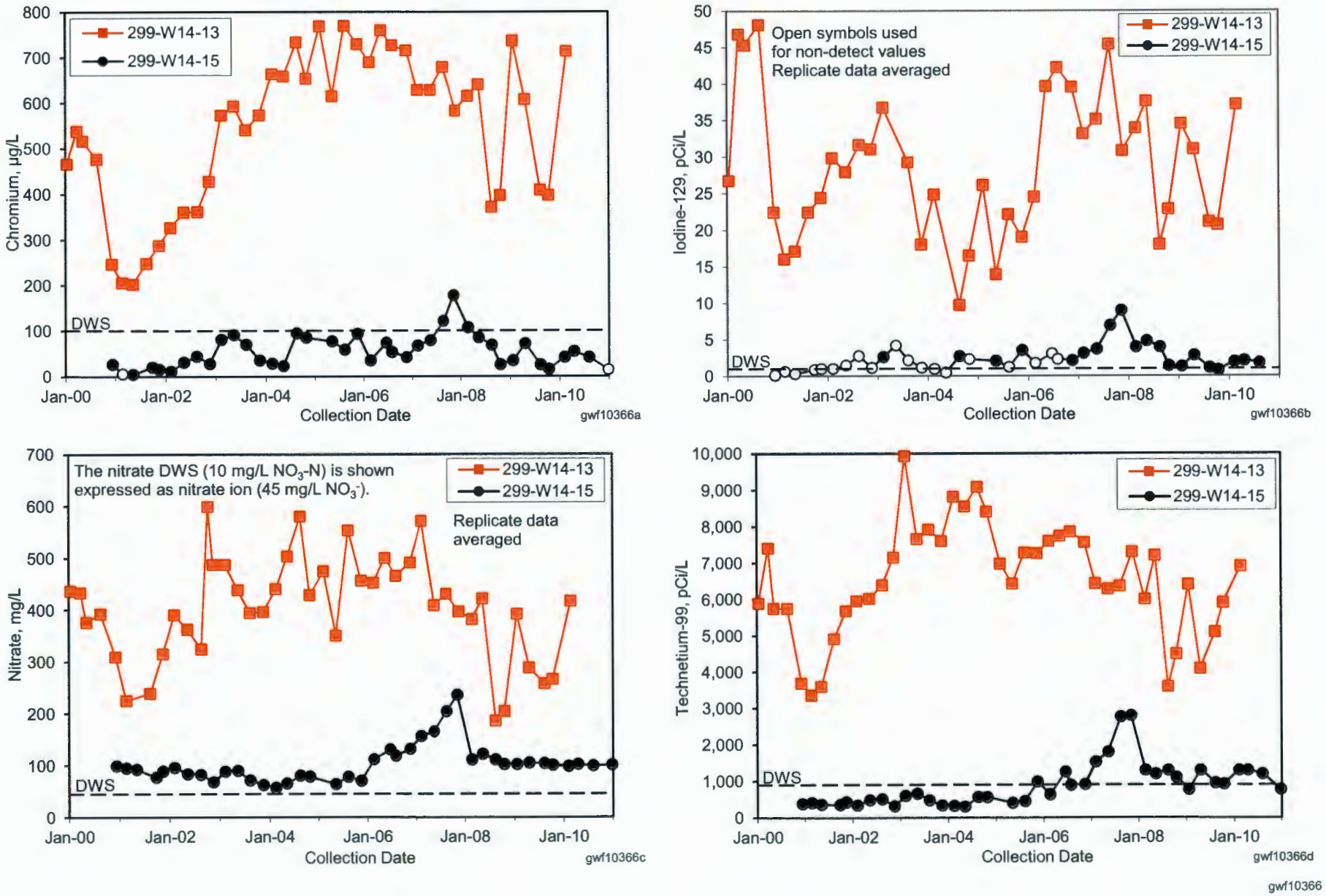
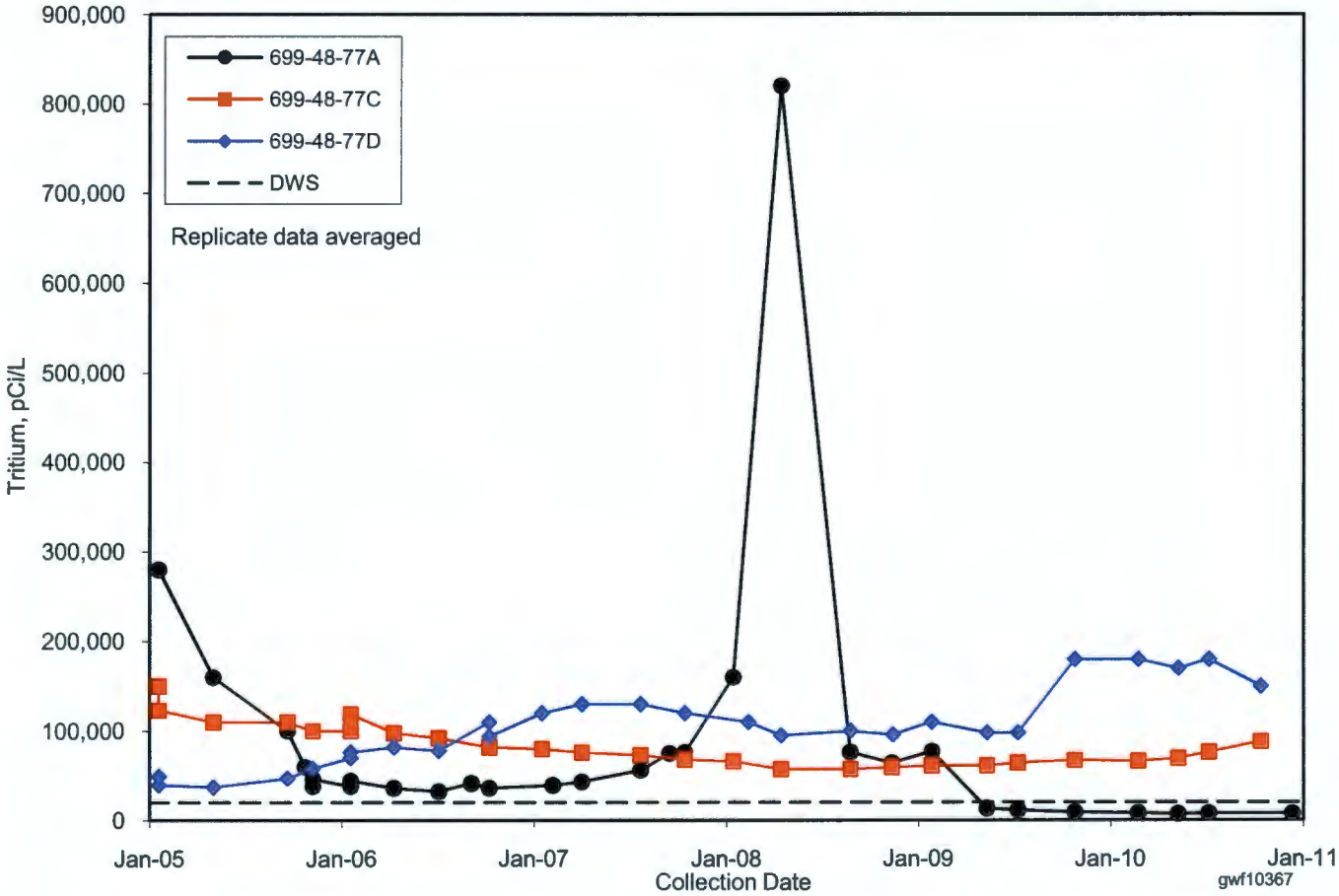
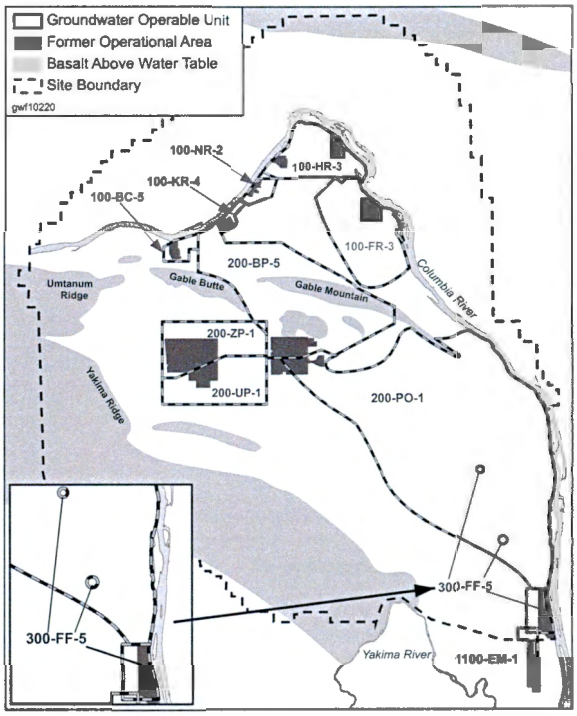


Figure 12-25. Tritium Concentrations in Wells Monitoring the State-Approved Land Disposal Site



13.0 300-FF-5 Operable Unit

R.E. Peterson



The 300-FF-5 Operable Unit (OU) is defined as groundwater that has been impacted by waste disposal or unplanned releases associated with the 300-FF-1 and 300-FF-2 OUs. The OU consists of several areas of contaminated groundwater beneath the southeastern portion of the Hanford Site, with subregions designated for the 300 Area, 618-11 Burial Ground, and 618-10 Burial Ground/316-4 Cribs (Figure 13-1). In addition to releases from 300-FF-1 and 300-FF-2, contaminated groundwater also migrates to this portion of the Hanford Site from waste sites not associated with those OUs and from sources not involving Hanford Site activities. The latter contamination is described as part of the 200-PO-1 OU (Chapter 10.0) and the 1100-EM-1 groundwater interest area (Chapter 14.0), respectively.

The principal origin for contamination currently observed in groundwater beneath the 300 Area involves historical routine disposal of liquid effluent associated with (1) fabrication of nuclear fuel assemblies, and (2) research involving the processing of irradiated fuel. The liquid wastes produced were discharged to ponds and trenches designed for infiltration to the underlying soil. Periodic spills and accidental releases from various facilities also occurred. Because nearly all of the principal liquid waste disposal facilities have been out of service for decades and most have been remediated by removing contaminated soil (DOE/RL-2004-74, *300-FF-1 Operable Unit Remedial Action Report*), the contamination remaining in the underlying vadose zone and aquifer can be characterized as residual.

Groundwater in the 300-FF-5 OU has been affected by liquid waste disposal and unplanned releases in the 300 Area and two outlying subregions.

Potential sources for groundwater contamination beneath the 300 Area that have not yet been remediated include the process sewer system and the 307 Process Trenches. Some release and/or remobilization of contamination may have occurred in more recent years because of continuing operations, excavation activities, removal of buildings, and processes potentially still active at some of the unremediated burial grounds (e.g., formation of a tritium plume in groundwater at the outlying 618-11 subregion). At the outlying subregions, intrusive investigative activities began at the 618-10 Burial Ground in August 2010, with excavation and removal activities planned to begin in March 2011. Remediation activities have not yet started at the 618-11 Burial Ground, but intrusive investigative work is underway.

The subregion of 300-FF-5 with the most significant groundwater issues is the 300 Area, where manufacturing and research activities associated with nuclear fuel were conducted during the Hanford Site's operational period. Large volumes of liquid effluent containing hazardous constituents were disposed to ponds and trenches designed for infiltration, with some contamination retained within the underlying vadose zone and a large portion reaching groundwater, followed by discharge to the Columbia River. Most of the contaminated sediment associated with these facilities has been removed and disposed at the Environmental Restoration Disposal Facility. The key issues for the 300 Area subregion are as follows:

- Persistent uranium contamination in the upper portion of the unconfined aquifer beneath most of the 300 Area. Evidence gathered during the interim action reveals

areas where contamination from the vadose zone may continue to resupply the groundwater plume.

- Persistent contamination by dichloroethene at one well, which monitors the lower portion of the unconfined aquifer. This volatile organic compound (VOC) is a degradation product of trichloroethene and tetrachloroethene, which were used extensively during the period of nuclear fuel manufacturing.
- Trichloroethene contamination of limited geographic extent, contained in a relatively finer grained sediment interval within the unconfined aquifer. Because of low groundwater yield, monitoring wells are not screened in this interval. The potential for further dispersal via the interval is limited because of the low permeability of the sediment. The source(s) for the compound and mechanisms by which it contaminated the finer grained interval are not clearly known.

Contaminants in groundwater beneath the 300 Area reflect past waste disposal associated with the fabrication of nuclear fuel for the plutonium-production reactors and research related to processing irradiated fuel.

One inactive treatment, storage, and disposal (TSD) facility regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA) is located in the 300 Area. The former 300 Area Process Trenches were used between 1975 and 1994 for disposal of hazardous liquid waste. The trenches were initially remediated under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) in 1991, followed by additional remediation during July 1997 through February 1998, with final backfilling early in 2004. The site continues to be monitored under CERCLA, as well as post-corrective action monitoring under RCRA. Figure 13-2 shows the principal waste sites responsible for contamination in the subsurface environment; outlines for facilities still in use at the 300 Area are also shown on the map.

At the two outlying subregions of the 300-FF-5 OU, groundwater is monitored near two solid waste burial grounds and a former liquid waste disposal crib. The quantity of tritium released from material buried at the 618-11 Burial Ground created a plume in groundwater, with concentrations greatly exceeding the federal drinking water standard (DWS). The plume extends eastward beneath the northern portion of the Energy Northwest generating station complex. The key issues for this subregion are as follows:

- The potential for additional release of radiological contamination from the burial ground in sufficient quantities to impact groundwater is not fully understood. The existing groundwater plume appears to have developed as a consequence of a single event, although the exact processes are largely unknown and uncertainty remains.
- Migration of the tritium plume to locations where groundwater may be withdrawn for beneficial use.

Release of tritium from materials in the 618-11 Burial Ground has resulted in a groundwater plume with very high tritium concentrations that migrates to the east.

A similar impact to groundwater has not been observed at the older 618-10 Burial Ground, where historical disposal activities also included radiological material but apparently not material that releases tritium. Remedial action at this waste site began in 2010, and the use of dust-control water and soil fixatives increases the potential for any uncontained, mobile contaminants to be transported downward to the groundwater. The same is true for residual contamination remaining in the soil beneath the former 316-4 Cribs, which were adjacent to the 618-10 Burial Ground. The key issue for this subregion is as follows:

- Mobilization of contamination that may be present in the vadose zone underlying these two waste disposal sites. The frequency of groundwater monitoring has been increased during the period of remedial actions at the burial ground.

Figures 13-3 and 13-4 provide index maps showing the locations of the waste sites and monitoring wells for the 618-11 and 618-10/316-4 subregions, respectively.

Significant impact to groundwater has not been observed near the 618-10 Burial Ground, where remediation work started in 2010.

Groundwater in the uppermost aquifer beneath the southeastern portion of the Hanford Site generally flows in an easterly direction toward the Columbia River, as indicated by the water table elevation contours shown in Figure 13-5. (Note that flow direction is inferred as being perpendicular to contours.) Beneath the 300 Area, flow tends to converge, with groundwater migrating in from the northwest, west, and southwest. Flow patterns throughout the region are complicated by the variable permeability of sediment in the upper portion of the unconfined aquifer and, near the Columbia River, by the influence river-stage fluctuations, which are related to the operation of dams upstream and downstream from the Hanford Reach. River-stage fluctuations produce significant seasonal variations in groundwater conditions beneath the 300 Area.

Cross sections shown in Figure 13-7 depict the geologic and hydrologic units that are relevant to CERCLA information needs (an index map to the cross sections is provided in Figure 13-6). Although this figure is based on conditions beneath the 300 Area, similar hydrogeologic features are present at the outlying subregions. Contamination is generally contained within the upper portion of the unconfined aquifer (i.e., the interval of Hanford formation gravelly sediment that lies below the water table). The thickness of the contaminated portion of the unconfined aquifer is variable because of the undulating contact surface between stratigraphic units and, at the 300 Area, significant seasonal fluctuations in water table elevation (PNNL-17034, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington*).

Beneath the 300 Area, the undulating contact between the bottom of the saturated Hanford formation interval and the underlying Ringold unit E sediment reveals paleochannels that act as preferential pathways for groundwater flow. Saturated Hanford formation sediment is much more permeable than the underlying sediment intervals, with tracer tests and tracking of unplanned releases suggesting plume movement velocities as high as 15 meters per day in the Hanford formation (PNNL-18529, *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report*; PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*). The high velocities suggest that contamination introduced to groundwater may be transported to the river environment as quickly as several weeks to months, depending on the input location and the mobility characteristics of the contaminant.

Contaminants in groundwater beneath the 300 Area are mainly contained within Hanford formation gravel, through which groundwater flows rapidly.

Near the Columbia River, the contaminant discharge rate to the river is influenced by daily and seasonal river-stage fluctuations (PNNL-17708, *Three-Dimensional Groundwater Models of the 300 Area, Hanford Site, Washington State*). Effects include temporary reversal of flow direction, dilution of contamination by the intrusion of clean river water, and possible influences on contaminant mobility because of changes in the geochemical environment. Contaminant discharge to the river occurs via riverbank springs that flow across the beach region (riparian zone) during periods of low river stage, as well as by upward movement through the riverbed.

Beneath the river shoreline region, a complex hydrologic and geochemical environment is formed as the result of river water interacting with Hanford Site groundwater. An understanding of this dynamic environment is necessary to (1) evaluate potential impact to ecological receptors caused by discharge of contaminated groundwater, and (2) conduct a feasibility study (FS) for selecting

a remedial action alternative. Simulating groundwater flow patterns and contaminant transport through the zone of interaction is challenging because of rapidly changing hydraulic gradients and variable geochemistry ("Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System" [Yabusaki et al., 2008]). Results from a recent research project involving computer simulation of uranium transport through the saturated zone provide additional insight into the migration of uranium via the groundwater pathway beneath the 300 Area ("Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area Using High Performance Computing" [Hammond and Lichtner, 2010]; "Stochastic Simulation of Uranium Migration at the Hanford 300 Area" [Hammond et al., 2010]).

The rise and fall of the Columbia River results in a dynamic zone of interaction between groundwater and river water, causing distinct changes in contaminant plume characteristics.

The conceptual model describing the features, processes, and events associated with groundwater contamination of Hanford Site origin provides a technical basis for future remediation decisions. If a remedial action technology is warranted, additional site-specific details for the conceptual model may be required to design and implement the remedy. The *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units* (DOE/RL-2009-30) describes the activities necessary to complete the remedial investigation (RI) process and to conduct a FS that evaluates alternatives for final remedial actions. A report describing the results of the RI and FS activities will be prepared during 2011 for public release by December 31, 2011, in accordance with *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Milestone M-015-72-T01.

13.1 Groundwater Contaminants

Plume Areas (square kilometers) in the 300-FF-5 Operable Unit:
Tritium*, 20,000 pCi/L — 0.064
Uranium, 30 µg/L — 0.55
**** Excludes tritium from 200-PO-1 Operable Unit.***

Contaminants of potential concern (COPCs) in 300 Area groundwater were identified during the initial evaluation of risk posed by contamination remaining in the vadose zone and unconfined aquifer in the early phase of the RI for the 300-FF-5 OU (DOE/RL-94-85, *Remedial Investigation/ Feasibility Study Report for the 300-FF-5 Operable Unit*). Based on the initial evaluation, uranium, cis-1,2-dichloroethene, and trichloroethene were identified in 1996 by the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology (Ecology), and the U.S. Department of Energy (DOE) as contaminants of concern (COCs) for interim action (EPA/ROD/R10-96/143, *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington*). In 2000, groundwater affected by releases from the 618-11 Burial Ground and the 618-10 Burial Ground/316-4 Cribs was added to the 300-FF-5 OU (EPA/ESD/R10-00/524, *EPA Superfund Explanation of Significant Differences: Hanford 300-Area [USDOE]*). A risk assessment at those sites was not conducted, so the COPCs were not formally identified. However, waste indicators were identified for those sites, which included tritium near the 618-11 Burial Ground, as well as uranium and tributyl phosphate near the 618-10 Burial Ground and 316-4 Cribs.

In 2004, an updated, comprehensive description of groundwater contamination in the 300-FF-5 OU was prepared to show the changes in COC trends since the initial RI in the early 1990s. No major changes were recommended for the list of waste indicator constituents to be monitored (PNNL-15127, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004*). Following that effort, an update to the initial qualitative risk

assessment for the 300-FF-5 OU was completed in 2007 (PNNL-16454, *Current Conditions Risk Assessment for the 300-FF-5 Groundwater Operable Unit)*. The assessment concluded that conditions with regard to risk remained consistent with the earlier conclusions from 1994. Other constituents in groundwater may exceed the federal DWS but have not been explicitly identified in regulatory decision documents as COCs or COPCs for the purpose of evaluating human health and ecological risk.

The list of groundwater constituents identified as COPCs has evolved during the interim action, with an updated list being developed in 2010 as part of the renewed RI.

The work plan for renewed RI activities for 300 Area OUs presents an updated list of groundwater COPCs (DOE/RL-2009-30, Section 4.5). The list is more comprehensive than previously identified in earlier regulatory decision documents and is being used to guide new risk assessment activities. Also, new information from the ongoing River Corridor Baseline Risk Assessment (DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA)* and investigation of contaminant releases to the Columbia River (DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*) may result in the identification of new COPCs or possibly delisting some previously identified COPCs.

The following subsections discuss various constituents in groundwater that are either formally listed as COPCs in regulatory decision documents or are monitored under the 300-FF-5 OU operation and maintenance plan (DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*) and its sampling and analysis plan (DOE/RL-2002-11, *300-FF-5 Operable Unit Sampling and Analysis Plan*) as indicators of hazardous waste in the environment. The constituents of greatest interest for monitoring are uranium, VOCs, tritium, and nitrate. Descriptions include the origins, geographic extent, concentration trends, and other aspects of the particular constituent that are relevant to the ongoing RI.

For monitoring 300-FF-5 OU groundwater quality, the focus is on uranium, VOCs, tritium, and nitrate.

13.1.1 Uranium

Uranium is a contaminant found in subsurface environmental pathways beneath the 300 Area and, to a much lesser degree, beneath the 618-10 Burial Ground/316-4 Cribs subregion. In the 300 Area, a groundwater plume has persisted far longer than predicted by the early phase of the RI. The persistence of the uranium plume is related to geochemistry and environmental conditions. The complex exchange processes involving uranium dissolved in groundwater, and various geochemical complexes associated with solids in the lower vadose zone and aquifer, provide a significant challenge for simulating behavior of the plume, as well as for developing a remediation technology that would lower concentrations in groundwater. Uncertainties in the conceptual model involve contamination remaining in (1) the vadose zone, (2) the periodically rewetted zone (i.e., water table zone), and (3) the unconfined aquifer. The most vexing uncertainties relate to the mobility characteristics of the various forms of uranium in those subsurface pathways, and also to the availability of a medium (e.g., infiltrating moisture) to transport any uranium that becomes remobilized.

The potential for uranium remaining at unremediated waste sites, the underlying vadose zone, and the aquifer to be mobilized is highly variable. Mobility is influenced by sediment texture and mineralogy; chemical makeup of the original waste effluent; and the subsurface geochemical environment, especially the bicarbonate content, pH, and surface properties of minerals. Additional information on mobility characteristics is provided in the following reports, which describe the results of numerous investigations involving uranium in subsurface pathways beneath the 300 Area:

- PNNL-14022, *300 Area Uranium Leach and Adsorption Project*

- PNNL-15121, *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume*
- PNNL-17031, *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site*
- PNNL-17034, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington*
- PNNL-17793, *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model*
- "Geochemical Controls on Contaminant Uranium in Vadose Hanford Formation Sediments at the 200 Area and 300 Area, Hanford Site, Washington" (McKinley et al., 2007)
- "Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System" (Yabusaki et al., 2008).

Numerous investigations have been conducted at the 300 Area to better understand uranium contamination in the subsurface and the potential for the uranium to migrate via environmental pathways.

Uranium contamination in groundwater is typically monitored by measuring total uranium in an unfiltered water sample. The DWS for uranium is 30 µg/L, and the standard is based primarily on uranium's chemical toxicity to humans, which is associated with damage to internal organs. Radiological dose rates are also monitored by measuring the activity concentrations of various isotopes, although for human health, the risk from chemical toxicity occurs at lower mass concentrations than the risk associated with radioactivity. As of 2010, protection standards for freshwater aquatic organisms had not been established by the EPA or Washington State. For the Hanford Site, natural background for uranium in groundwater in the unconfined aquifer is estimated to range between 0.5 and 12.8 µg/L (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*).

13.1.1.1 300 Area

Disposal of uranium-bearing effluent to the last operational infiltration site, the 300 Area Process Trenches, ended in 1986; however, discharge of uncontaminated effluent continued until December 1994 (PNNL-13645, *300 Area Process Trenches Groundwater Monitoring Plan*). Contaminated soil was removed from the site in 1991, with additional excavation of contaminated soil at this site and other major liquid waste disposal sites in the 300 Area occurring primarily from 1997 through 2000. These excavations remained open until backfilling was completed at all excavated sites during early 2004. Figure 13-8 illustrates the historical trend of uranium impact to groundwater near the former 300 Area Process Trenches. The figure includes the chronology for various remedial action activities and more recent treatability testing. The positive correlation between water table elevation and uranium concentrations at this location is also illustrated, where uranium is likely to remain in the lower portion of the vadose zone and to be remobilized during periods of high water table conditions.

The uranium plume has persisted well beyond the 3- to 10-year period after late 1993 that was predicted by the initial phase of the RI (DOE/RL-94-85). Concentration patterns reveal distinct seasonal variability correlated to the elevation of the water table, which is in turn related to Columbia River flow. Incomplete information is available on the contaminant source(s) that continue to supply uranium to the plume (DOE/RL-2009-30). Residual amounts of uranium are known to remain in (1) the vadose zone beneath or immediately adjacent to remediated waste disposal sites, (2) the widespread zone through which the water table fluctuates, and (3) the upper portion of the unconfined aquifer (PNNL-16435, *Limited Field Investigation Report*

for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington; PNNL-17793).

Uranium contamination in groundwater beneath the 300 Area has persisted far longer than initially predicted.

The uranium plume in groundwater beneath the 300 Area is defined by concentrations exceeding 10 µg/L, with natural background concentrations in the contaminated hydrologic unit estimated between 3 and 8 µg/L based on data from 300 Area wells where groundwater was unlikely to have been influenced by waste disposal (PNNL-17034, Section 3.1). Figure 13-9 shows the groundwater plume during June 2010. Maps prepared using the June monitoring results illustrate the conditions that develop during the period when the water table is elevated due to high river stage.

Typical characteristics of the plume during seasonal high water table conditions include (1) lowered concentrations along some portions of the Columbia River shoreline, and (2) increased concentrations at some locations farther inland, near former waste disposal facilities and potential sites of unplanned releases. Figure 13-10 shows the uranium concentration trends at locations representative of near-river and inland conditions. Beneath the shoreline, river water intrudes into the aquifer during high river-stage conditions and lowers contaminant concentrations by dilution. Further inland, increased concentrations are apparently the consequence of contamination in the lower vadose zone being mobilized by temporarily saturated conditions while the water table is elevated, which facilitates downward transport of contamination to groundwater.

Concentration patterns in the uranium plume vary seasonally as a consequence of changes in water table elevation and infiltrating river water.

During other months of the seasonal cycle, the highest concentrations in the plume are often observed near the river. Uranium introduced during the preceding period of high water table conditions has migrated downgradient to the shoreline, and dilution by river water in the zone beneath the shoreline is lessened due to lower river-stage conditions. A more comprehensive description of features and processes associated with uranium in environmental pathways beneath the 300 Area is available in PNNL-17034.

A relatively new area of uranium contamination in groundwater developed in early 2008 immediately downgradient from the former 618-7 Burial Ground. The contaminant plume is related to remediation activities conducted during 2007 and 2008 at the burial ground. Higher-than-expected uranium concentrations were first observed in January 2008, along with increased concentrations of chromium and constituents associated with soil fixative material (calcium and chloride). The impact to groundwater is likely the result of infiltration of dust-control water and soil fixatives during remedial action at the burial ground. By the end of 2010, concentrations at nearby downgradient wells continued to decrease, indicating passage of the contaminant plume (Figure 13-11). New monitoring wells 399-6-3 and 399-6-5, which were installed during late 2010, will provide increased coverage of the downgradient migration of this plume.

Remediation activities at the former 618-7 Burial Ground apparently mobilized uranium, impacting the groundwater.

The uranium plume map in Figure 13-9 represents conditions in the upper portion of the unconfined aquifer, where uranium contamination is contained within saturated Hanford formation gravel sediment. Several wells in the 300 Area have open intervals for sampling that are in the lower portion of the unconfined aquifer. These include wells with a "B" suffix, well 399-1-8, and recently installed wells 399-3-21 and 399-3-22. Screens for these wells are positioned in Ringold unit E gravelly sediment. Uranium concentrations in samples from these wells are typical of natural background levels, suggesting little or no downward migration of contaminant uranium beyond the extent of saturated Hanford formation sediment. Hydrographs for wells screened

in either saturated Hanford formation sediment or Ringold Formation unit E sediment are virtually identical, indicating no significant vertical gradients. Contamination has not been detected in the few wells that monitor the uppermost confined aquifer, which is a somewhat permeable interval within the Ringold lower mud unit (e.g., wells with a "C" suffix and well 399-1-9). Hydrographs for these wells show a distinct upward hydraulic gradient, with a head difference of approximately 9 meters.

As suggested by the rapid changes in groundwater concentrations that likely result from changes in water table elevation and river stage, it is apparent that the timing of groundwater sample collection plays a significant role in determining the uranium concentration for the sample. Thus, concentration patterns shown in groundwater plume maps contain bias in regard to representing aquifer conditions. Bias is also introduced by the different construction features of the various monitoring wells and aquifer tubes that make up the groundwater monitoring network. This bias was evident in recent monitoring results at the polyphosphate treatability test site, which is located at the southern end of the former 300 Area Process Trenches. Significantly higher concentrations of uranium were measured in samples from wells with 0.6-meter screens located in the uppermost portion of the aquifer than in samples from wells with typical 5-meter screens ("River-Induced Wellbore Flow Dynamics in Long-Screen Wells and Their Impact on Aqueous Sampling Results" [Vermeul et al., 2010]). An understanding of bias in monitoring data is important when (1) describing uncertainties associated with the conceptual site model, and (2) establishing criteria for remedial action performance evaluation and subsequent compliance monitoring.

The previous description focuses on the concentration of uranium dissolved in groundwater, which is information used to determine compliance with various regulatory standards and applicable or relevant and appropriate requirements. For screening, design, and implementation of remedial action technologies, additional parameters are needed, such as the spatial distribution and the mass of contaminant (DOE/RL-2008-36, *Remediation Strategy for Uranium in Groundwater at the Hanford Site 300 Area 300-FF-5 Operable Unit*). An analysis of some of those additional parameters for the 300 Area uranium plume is presented in PNNL-17034, from which the following estimates are extracted.

The areal extent of uranium-contaminated groundwater that exceeds the DWS is ~0.5 square kilometers. The length of Columbia River shoreline impacted by the plume is ~1,900 meters. Various estimates for the mass of uranium dissolved in the plume during recent years suggest approximate values between 40 and 80 kilograms. One method for estimating the areal extent and mass of dissolved uranium in the plume since 2002 indicates fairly constant values, although concentration patterns vary significantly with the seasons. An analysis of the inventory of contaminant uranium stored in various subsurface "compartments" indicated that ~4,000 kilograms of uranium may remain in sediment and moisture associated with the vadose zone, as well as an additional 180 kilograms associated with aquifer sediment and groundwater. Under current conditions, the flux of uranium to the Columbia River via groundwater discharge may be several tens of kilograms per year, with an additional 10 kilograms removed from the aquifer via a well providing water for the aquariums in PNNL's 331 Life Sciences Building (well 399-4-12).

Several thousand kilograms of contaminant uranium may remain in the vadose zone and aquifer beneath the 300 Area.

Uranium contamination in groundwater near the Columbia River is monitored by sampling near-river wells, aquifer tubes at twelve sites along the shoreline, and, to a lesser extent, riverbank springs. At locations near the river, uranium concentrations are frequently lowered by the intrusion of river water into the aquifer. Intrusion is

especially pronounced during high river-stage conditions and may occur as layering of river water over groundwater and/or mixing with groundwater. An analysis of samples from aquifer tubes, using specific conductance values as an indicator of river water, suggested approximate proportions of 60% groundwater and 40% river water in samples from the Hanford formation gravels hydrologic unit beneath the shoreline (PNNL-17034). A lowering of concentrations may also occur due to changes in geochemical conditions caused by the intrusion of river water, which could promote adsorption of dissolved uranium onto sediment near the river. The lower bicarbonate content of river water compared to groundwater enhances the tendency for adsorption, although the significance of this process has not yet been quantified (PNNL-17031; Yabusaki et al., 2008).

The mass of uranium in the groundwater plume is roughly the same amount as the mass that leaves the plume each year via groundwater discharge to the Columbia River and withdrawal at a water supply well, suggesting continued resupply of the plume from the vadose zone.

Figure 13-12 shows the uranium concentrations observed in samples from aquifer tubes collected from March 10-17, 2010. Concentrations in tube samples represent more discrete intervals in the aquifer than the concentrations determined for samples from traditional monitoring wells because of different lengths for screened openings (15-centimeter screen length for tubes and typically 5 meters for a monitoring well). Contamination may become more evenly distributed vertically in the aquifer near the river because of mixing during transport from source areas to the river, and the values from tubes at multiple depths at a site support this idea. The cross section shown in Figure 13-12 also includes information on near-river wells with their screen positions projected onto the section, as well as the stratigraphic contacts that are relevant to groundwater movement. The cross section supports the conclusion that most uranium contamination is contained within the saturated Hanford formation gravelly sediment. The only aquifer tube that is clearly installed in the underlying Ringold unit E is tube AT-3-3-D, and concentrations are consistent with natural background uranium levels.

13.1.1.2 618-10 Burial Ground and 316-4 Cribs

From 1948 to 1956, uranium was included in liquid waste disposed to the former 316-4 Cribs, which are adjacent to the easternmost corner of the 618-10 Burial Ground (BHI-00012, *300-FF-2 Operable Unit Technical Baseline Report*). The cribs were vertical culverts, open at their bottoms, into which VOCs contaminated by uranium were discharged. The liquid effluent included compounds such as methyl isobutyl ketone (hexone) and tributyl phosphate. The cribs and some of the contaminated adjacent soil were removed in 2004 and the site was partially backfilled. However, some uranium and tributyl phosphate contamination was known to remain in the soil beneath the excavated site (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*). Uranium concentrations in groundwater have remained below the DWS since 2008.

Uranium was included in waste disposed to the 316-4 Cribs and 618-10 Burial Ground, but the impact to groundwater has been minimal.

Uranium concentrations in groundwater were previously elevated above the DWS at several wells near the southeastern fence line of the 618-10 Burial Ground and within the footprint of the former 316-4 Cribs, although concentrations in that area have remained below the DWS since approximately 2007 (Figure 13-13). The cause for the earlier variability in uranium concentrations at wells 699-S6-E4A and 699-S6-E4L was likely related to the 316-4 Cribs excavation and backfilling activities in 2004. All wells in the vicinity monitor the upper portion of the unconfined aquifer, and the water table elevation at this subregion remains fairly constant. In August 2010, the first intrusive work at the burial ground began as part of preparing for more extensive removal actions, which include removing additional contaminated soil from beneath the 316-4 Cribs site. These removal actions are scheduled to begin in March 2011.

13.1.2 Volatile Organic Compounds

The VOCs trichloroethene and tetrachloroethene were used in substantial quantities in the 300 Area during the fuels fabrication process (BHI-00012; EMO-1026, *Addendum to Data Compilation Task Report for the Source Investigation of the 300-FF-1 Operable Unit Phase I Remedial Investigations*; WHC-MR-0388, *Past Practices Technical Characterization Study – 300 Area – Hanford Site*). Trichloroethene was the primary degreaser used until the 1970s, followed by tetrachloroethene in the 1970s and 1980s. Carbon tetrachloride was also used in small quantities for testing fuel element integrity and is occasionally detected, but at levels below the DWS.

Volatile organic compounds were used extensively as degreasers during fuels manufacturing in the 300 Area.

Cis-1,2-dichloroethene is present in the aquifer beneath the 300 Area, apparently as a degradation product of trichloroethene and tetrachloroethene. Vinyl chloride, a potential degradation product, is not detected in 300 Area groundwater. At the outlying subregions of the 300-FF-5 OU, volatile and semivolatile organic compounds (SVOCs) associated with fuels fabrication were included in waste disposed to burial grounds and cribs, but these compounds are only occasionally detected today in the groundwater.

13.1.2.1 300 Area

Trichloroethene and tetrachloroethene continue to be detected in the upper portion of the unconfined aquifer at 300 Area wells but at concentrations below the 5 µg/L DWS. The detection limit for these compounds increased from 0.2 to 1.0 µg/L in late 2007, so the results for recent samples from many wells where the compounds were previously listed as detected are now listed as nondetected. Trichloroethene and/or tetrachloroethene are occasionally detected at wells screened in the lower portion of the unconfined aquifer (e.g., 399-1-8 and 399-1-16B), but detections have been below the DWS in recent years. Historically, tetrachloroethene has been observed occasionally at higher concentrations near and downgradient of the southern end of the former 300 Area Process Trenches and North Process Pond, which are both waste disposal sites where releases of tetrachloroethene have occurred (a summary of the historical releases is presented in PNNL-17666). Some trichloroethene continues to migrate into the 300 Area from sources to the southwest (see Chapter 14.0).

Concentrations of trichloroethene and tetrachloroethene near the water table are below the DWS.

Trichloroethene was detected in March 2010 samples from some aquifer tubes positioned in Hanford formation gravels sediment along the river, however the concentrations were lower than the DWS (Figure 13-14). One explanation for this occurrence is the release of trichloroethene from a contaminated, finer grained interval of Ringold Formation sediment located just below the Hanford formation gravels. Uncertainty exists regarding this explanation because of a lack of information relating to potential source(s) and transport processes leading to contamination of this interval of sediment. Only one aquifer tube (AT-3-3-D) is clearly positioned within this interval, with a concentration of 430 µg/L for a sample collected in March 2010. This level of contamination is consistent with concentrations observed during characterization drilling through the finer grained interval in 2006 and 2007 (PNNL-17666).

In the lower portion of the unconfined aquifer, cis-1,2-dichloroethene concentrations continue to exceed the DWS at one well located near the former North Process Pond. Concentrations at well 399-1-16B remain above the 70 µg/L DWS, with a maximum concentration of 170 µg/L during 2010 (Figure 13-15). Well 399-1-16B is located along the downgradient flow path from the former 300 Area Process Trenches and

North Process Pond; it is screened in Ringold Formation gravelly sediment in the lower portion of the unconfined aquifer. The origin for cis-1,2-dichloroethene is likely degradation of trichloroethene and/or tetrachloroethene disposed to the former 300 Area Process Trenches and/or North Process Pond (PNNL-17666). This degradation product is also detected at well 399-1-17B, which is also near the two disposal sites but at concentrations much lower than the DWS.

Cis-1,2-dichloroethene, a degradation product of tetrachloroethene and trichloroethene, is detected at one well that monitors the lower portion of the unconfined aquifer.

During a limited field investigation for uranium (PNNL-16435), VOC contamination was encountered in groundwater associated with a finer grained interval of sediment within Ringold unit E. The interval is a subunit within the unconfined aquifer system and is not laterally continuous beneath the 300 Area. The primary contaminant discovered was trichloroethene, with the maximum concentration encountered during drilling at 630 µg/L. Additional drilling was conducted during 2007 to further characterize this occurrence. The results of this investigation, as well as a review of historical operations and potential source locations for VOCs, are presented in PNNL-17666.

The contamination initially appeared to be limited to the area immediately east of the former 307 Process Trenches and South Process Pond. However, 300 Area RI/FS drilling in 2010 indicated that the contamination extends further north and includes the area east of the former sanitary leach trenches. Figure 13-16 provides an updated cross section that shows the results from groundwater samples collected during the various drilling campaigns, including those available in 2010 from the most recent drilling activities. The finer grained interval of sediment is not intercepted by existing well screens, so current knowledge of conditions in the interval is based on samples collected during drilling. The finer grained interval has a very low permeability and does not readily yield groundwater. Groundwater moves very slowly through this hydrologic unit; however, the unit is incised by the river channel, so at least some potential exists for exposure at the riverbed.

Elevated concentrations of trichloroethene are present in a layer of finer grained sediment below the water table, but only in a limited area.

13.1.2.2 Outlying 300-FF-5 Operable Unit Subregions

Tributyl phosphate has been detected in groundwater beneath the former 316-4 Cribs, although at low levels, and recent sampling has indicated nondetects. The cribs received liquid waste associated with research conducted at the 321 Separations Laboratory in the 300 Area from 1948 to 1954 (BHI-00012), which included tributyl phosphate and uranium. Tributyl phosphate concentrations, along with uranium, were elevated in early 2004 at well 699-S6-E4A (located within the footprint of the remedial action excavation) during crib removal activities. Tributyl phosphate, an SVOC, tends to bind to soil in the vadose zone, where it slowly degrades over time; it is not particularly soluble in water and, therefore, not widely dispersed via water transport mechanisms. A DWS for tributyl phosphate has not been established.

13.1.3 Tritium

Tritium released from the 618-11 Burial Ground, which is a 300-FF-2 OU waste site, has contaminated groundwater in the vicinity of the Energy Northwest complex. High concentrations of tritium in groundwater were detected in early 1999 at well 699-13-3A, located next to the eastern fence line of the burial ground. The contamination was unexpected, and concentrations greatly exceeded the 20,000 pCi/L DWS, with peak concentrations reaching 8 million pCi/L. Subsequent investigations revealed a narrow plume that extends downgradient (east) of the burial ground, with concentrations that are much higher than the surrounding site-wide plume from the 200 East Area (PNNL-13675, *Measurement of Helium-3/Helium-4*

Tritium released from materials in the 618-11 Burial Ground has resulted in a groundwater plume with concentrations well above the drinking water standard.

Ratios in Soil Gas at the 618-11 Burial Ground). Concentrations in the plume during 2010 are shown in Figure 13-17.

Concentrations near the burial ground have declined since peak values in 1999 and 2000. The trend in groundwater at well 699-13-3A (Figure 13-18) suggests that a possible episodic event of unknown nature caused tritium released from buried materials to contaminate groundwater. At wells farther away from the burial ground, concentration trends reflect migration of the plume. The conceptual model for the plume, including a simulation of plume evolution over time, suggests that concentrations will be below the DWS when the plume reaches the Columbia River (PNNL-15293, *Evaluation of the Fate and Transport of Tritium-Contaminated Groundwater from the 618-11 Burial Ground*). Groundwater monitoring wells in use by Energy Northwest do not show evidence of this plume, nor is tritium detected in Energy Northwest water supply wells, which tap deep aquifers.

13.1.4 Nitrate

Nitrate exceeds the DWS in groundwater, with sources including past disposal to 300 Area waste sites, 200 East Area waste sites, and non-Hanford Site activities.

Some groundwater contamination by nitrate occurred because of disposal at 300-FF-1 and 300-FF-2 OU waste sites during the active years of fuels production and research, and also while a sanitary sewer system was in use at the 300 Area. Throughout the 1970s and 1980s, nitrate concentrations in groundwater were somewhat higher than today but never greatly exceeded the DWS. Evaluation of concentration trends from 1992 through 2004 revealed a relatively constant level of contamination, but with some variability (PNNL-15127). Trends since 2004 are similar, although concentrations exceeding the DWS continue in the southern portion of the 300 Area and near the 618-11 Burial Ground subregion. Nitrate contamination is also associated with the widespread site-wide contaminant plume.

13.1.4.1 300 Area

Nitrate concentrations in groundwater beneath the 300 Area are lower than the 45 mg/L DWS (i.e., 10 mg/L measured as nitrogen in nitrate), except for the southern portion of the 300 Area where groundwater has been impacted by agricultural and industrial activities not associated with the Hanford Site (see Chapter 14.0 for discussion of sources). The relatively higher concentrations in the southern portion currently reflect the migration of nitrate-contaminated groundwater into the 300 Area from sources to the southwest. Gradually increasing concentrations are observed in wells and at shoreline sites as the nitrate-laden groundwater migrates into the 300 Area. For example, the concentration at well 699-S28-E12 (located near the southwestern corner of the 300 Area boundary) was 157 mg/L in June 2010, and the concentration was 84 mg/L at nearby well 699-S27-E14 in May 2010. Nitrate also migrates into the 300 Area from the northwest as part of the site-wide plume that originates in the 200 East Area, with concentrations typically ranging from 25 to 30 mg/L (Chapter 10.0 includes further discussion of the site-wide plume).

13.1.4.2 618-11 Burial Ground Subregion

Nitrate concentrations near of the 618-11 Burial Ground have remained elevated above the DWS for many years. Concentrations at well 699-13-3A, which is adjacent to the burial ground, have been gradually increasing and reached 136 mg/L during 2010. The origin for nitrate observed in this area is enigmatic; waste acids, such as nitric acid, are not known to have been placed in the burial ground. Septic systems associated with Energy Northwest are not located in the vicinity of this contamination. One explanation suggests that waste disposal at the 200 East Area sites may be implicated (i.e., the contamination is part of the site-wide groundwater plume assigned to the 200-PO-1 OU). The relatively higher concentrations currently observed near

the burial ground may be explained by the local occurrence of lower permeability aquifer sediment that has sequestered higher levels of contamination from earlier periods, and those sediments are continuing to slowly release the contamination (PNNL-13228, *Evaluation of Elevated Tritium Levels in Groundwater Downgradient from the 618-11 Burial Ground Phase I Investigations*).

13.1.4.3 618-10 Burial Ground Subregion

Nitrate in groundwater near the 618-10 Burial Ground primarily reflects the site-wide groundwater plume (200-PO-1 OU), with concentrations in the range of 25 to 30 mg/L. For a brief period that included 2005, concentrations at well 699-S6-E4L, adjacent to the burial ground, were elevated just above the 45 mg/L DWS. Concentrations at the well have subsequently followed a gradual decrease but with occasional, sporadic, higher values. The cause for the temporarily elevated concentrations at the well is not known.

13.1.5 Other Constituents

In addition to the COCs or COPCs that are formally recognized in regulatory decision documents, other constituents of interest are being monitored at various locations in the 300-FF-5 OU because the constituents either exceed their respective DWS or are helpful in characterizing contamination in the aquifer. These include the radiological constituents gross alpha, gross beta, strontium-90, and technetium-99. Chromium has been added to the discussion list because of an occurrence near the 618-7 Burial Ground remedial action site.

Other waste indicators monitored in groundwater include radiological constituents gross alpha, gross beta, strontium-90, and technetium-99, and various chemical constituents included in analyses for major anions and cations (i.e., metals).

13.1.5.1 300 Area

During 2010, radiological contamination in the 300 Area (other than uranium) continued to be at low levels. Gross alpha, which is associated with uranium, exceeds the 15 pCi/L DWS at numerous 300 Area wells. Gross beta periodically exceeds the 50 pCi/L DWS at several 300 Area wells and is elevated above background at many other wells. Sources for the gross beta activity include daughter isotopes from radiological decay of uranium. Other potential contributors to gross beta include low levels of technetium-99 and strontium-90 at isolated locations, including the area near the former 340/307 complex retention basins, trenches, and associated underground piping. While groundwater impacts have not yet been identified, recent discoveries at the 324 Building warranted an increase in radiological monitoring at downgradient wells during 2010. Background radiation from natural sources (e.g., potassium-40 and uranium) also contributes to gross beta levels.

Chromium appeared as part of the plume associated with remedial action at the 618-7 Burial Ground. At well 399-8-5A, which is adjacent to the eastern fence line of the former burial ground, concentrations measured as total chromium in filtered and unfiltered samples during late 2008 and 2009 had a high value of 105 µg/L in July 2009. Since then, concentrations have continued to decline (Figure 13-11). The source for the chromium is unknown but may be related to release of material from the burial ground during remedial action excavation activities or to corrosion of the stainless-steel well screen in well 399-8-5A, which may have occurred due to the elevated chloride level. Other constituents showing a concurrent increase at this well include calcium, chloride, gross alpha, gross beta, nitrate, and sodium. Remediation activities were underway during 2007 and completed late in 2008 at this burial ground.

13.1.5.2 618-11 and 618-10 Burial Grounds Subregions

These subregions lie within the large groundwater plume that originates in the 200 East Area, which contains the mobile radiological contaminants tritium, technetium-99, and iodine-129, as well as the chemical contaminant nitrate (see Chapter 10.0). The concentrations of contaminants from 200 East Area sources at the two subregions are typically below their respective DWS.

Near the 618-11 Burial Ground, technetium-99 is detected at ~200 pCi/L, which is well below the 900 pCi/L DWS but is higher than expected. Technetium-99 may be the likely cause for elevated gross beta activity in the area, with well 699-12-2C showing the highest values. A recent change in laboratory calibration for gross beta analysis appears to be the cause for significant trend changes that began abruptly in August 2008 at wells 699-12-2C and 699-13-2D. At least some of the technetium-99 contamination observed near this burial ground is associated with the site-wide plume, with sources in the 200 East Area. However, historical concentration trends for technetium-99 and tritium at well 699-13-3A (adjacent to the burial ground) are similar, indicating that small amounts of technetium-99 may have been associated with the release that created the local tritium plume in 1999.

At the 618-10 Burial Ground, gross alpha measurements have exceeded the DWS at two wells in the past, which is likely a consequence of uranium contamination. During late 2008 and 2009, a slightly increasing trend in both parameters at this site is suggested, although neither gross alpha nor gross beta exceeded their respective regulatory standards in groundwater. Site preparation activities are underway at this subregion, so increased disturbance of the ground surface and application of water for dust control are anticipated in the coming year, which may impact groundwater.

13.2 CERCLA Groundwater Activities

This section discusses the RI/FS process under CERCLA for the 300-FF-5 OU. The process began in the late 1980s with work planning (DOE/RL-89-14, *Remedial Investigation/Feasibility Study Work Plan for 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*). Several RI and/or FS reports were issued as a result of phasing the process:

- A Phase I RI report was published in July 1993 (Vol. 1) and January 1994 (Vol. 2) (DOE/RL-93-21, *Phase I Remedial Investigation Report for the 300-FF-5 Operable Unit*).
- A Phase I and II FS report published in January 1994 (DOE/RL-93-22, *Phase I and II Feasibility Study Report for the 300-FF-5 Operable Unit*)
- A combined RI/FS report for the OU was published in May 1995 (DOE/RL-94-85) and provided the basis for a Record of Decision (ROD) for interim remedial action. Part of the rationale for an interim action rather than final action was the continuing nature of remedial actions for waste sites and facilities in the 300-FF-1 and 300-FF-2 OUs, which contain waste sites that could potentially impact groundwater.

Interim action for the 300-FF-5 OU is appropriate while extensive remediation of waste disposal sites and removal of decommissioned facilities continues.

Interim remedial action under CERCLA initially targeted groundwater beneath waste sites in the 300 Area portion of the 300-FF-5 OU (EPA/ROD/R10-96/143). The geographic extent of the OU was subsequently expanded in June 2000 to include groundwater potentially impacted by waste sites in two outlying areas north of the 300 Area (EPA/ESD/R10-00/524). The interim remedy, as stated in EPA/ROD/R10-96/143, is as follows:

- Continued monitoring of groundwater contaminated above health-based levels to ensure that concentrations continue to decrease
- Institutional controls to ensure that groundwater use is restricted to prevent unacceptable exposures to groundwater contamination.

Because an engineered remedial action was not part of the interim action ROD, an operation and maintenance plan for the 300-FF-5 OU was prepared in 1996 (DOE/RL-95-73, Rev. 0). The purpose of the plan was to identify monitoring tasks and administrative requirements. The EPA's data quality objectives process was followed in defining monitoring requirements, which led to preparation of a sampling and analysis plan (DOE/RL-2002-11, Rev. 0). The operation and maintenance plan and the sampling and analysis plan have been subsequently revised based on interpretation of the monitoring results and new information obtained from remedial actions at the waste sites and facilities.

As of 2010, two 5-year reviews of the 1996 ROD have been conducted, and a third review is in progress. The first review was performed in 2000 and concluded that the selected remedy and remedial action objectives for the period of interim action were still appropriate (*USDOE Hanford Site First Five-Year Review Report* [EPA, 2001]). However, an action item required the update and expansion of the initial operation and maintenance plan. The second review was completed in 2006 and also concluded that continuation of the interim action remained appropriate, until completion of activities related to the River Corridor Baseline Risk Assessment; waste site remediation; the facility's deactivation, decontamination, decommissioning, and demolition activities; treatability testing for uranium contamination; and FS activities (DOE/RL-2006-20). Action 19-1 specified the completion of a focused FS for uranium and concurrent field testing of polyphosphate injections to immobilize uranium (see Section 13.2.1).

Several 5-year reviews of the 1996 Record of Decision for interim action at the 300-FF-5 OU concluded that continued monitoring of groundwater and restrictions on groundwater use remained appropriate.

During 2009, new milestones and target completion dates were developed under the Tri-Party Agreement (Ecology et al., 1989). Those that apply to the 300-FF-5 OU are as follows:

- Milestone M-015-00D: The DOE shall complete the RI/FS process through the submittal of a proposed plan for all 100 and 300 Area OUs (December 31, 2012).
- Milestone M-015-71: Submit CERCLA RI/FS work plan for the 300-FF-2 and 300-FF-5 OUs for groundwater and soil (October 31, 2009; completed).
- Milestone M-015-72-T01: Submit CERCLA RI/FS report and proposed plan for the 300-FF-2 and 300-FF-5 OUs for groundwater and soil (target date December 31, 2011).
- Milestone M-016-110-T05: The DOE will have a remedy in place designed to meet federal DWSs for uranium throughout the groundwater plume in the 300-FF-5 OU unless otherwise specified in a CERCLA decision document (target date December 31, 2015).

A proposed plan for final remedial action at waste sites and environmental pathways in the 300 Area and outlying subregions is due by December 31, 2012.

13.2.1 Remedial Investigation/Feasibility Study

In 2004, activities were renewed for a FS focused on uranium at the 300 Area. Additional efforts included updating computer simulations of groundwater flow and uranium transport; conducting a limited field investigation for uranium, which involved drilling four characterization boreholes; updating the initial qualitative human health and ecological risk assessment; and assessing potential remedial action technologies for the 300 Area uranium plume. The limited field investigation revealed previously undetected contamination by VOCs in one area, and four additional characterization boreholes were drilled that expanded the uranium investigation.

Tri-Party Agreement Milestone M-016-68 was developed in early 2005 for some of this work and required the completion of two reports by March 31, 2005:

- DOE/RL-2005-41, *Work Plan for Phase III Feasibility Study, 300-FF-5 Operable Unit*
- PNNL-15127, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004.*

Many of the other renewed RI/FS activities were essentially complete by 2008 and are described in the following documents (listed in chronological order):

- PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington*
- PNNL-16454, *Current Conditions Risk Assessment for the 300-FF-5 Groundwater Operable Unit*
- PNNL-16761, *Evaluation and Screening of Remedial Technologies for Uranium at the 300-FF-5 Operable Unit, Hanford Site, Washington*
- DOE/RL-2008-36, *Remediation Strategy for Uranium in Groundwater at the Hanford Site 300 Area, 300-FF-5 Operable Unit*
- PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*
- PNNL-17708, *Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington*
- PNNL-17793, *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model.*

In September 2008, a new Hanford Site planning effort was launched for RI/FS activities that would lead to a proposed plan for final remedial actions for the remaining 300 Area National Priorities List OUs (i.e., 300-FF-2, and 300-FF-5 OUs; remedial actions are considered complete for the 300-FF-1 OU). A work plan was prepared (DOE/RL-2009-30, Rev. 0) for activities that complement those already underway or planned under existing source OU work plans and the groundwater OU operation and maintenance plan. The new work plan activities will fill the data needs deemed necessary to support selection of alternatives for final remedial actions throughout the 300 Area RI/FS interest area.

The RI for 300 Area OUs during 2010 focused on activities to support decisions involving final remedial actions.

For the 300-FF-5 OU, a primary work plan activity during 2010 and 2011 is drilling at eleven locations in the 300 Area, each chosen to represent a different combination of subsurface conditions. Figure 13-19 shows the locations of earlier limited field investigation/VOC investigation characterization drilling and the current drilling campaign. The drilling strategy includes comprehensive characterization of subsurface conditions as drilling proceeds, with extensive collection of sediment and water samples. Analysis of sediment samples is focused on identifying the amounts and the mobility characteristics of contaminants that have the potential to degrade groundwater quality. New stratigraphic data are being used to update the three-dimensional model of subsurface pathways for contamination, which will improve computer simulations of groundwater flow and contaminant transport. Each drilling location is subsequently completed as a groundwater monitoring well.

Other key activities that began in 2010 included (1) more widespread hourly monitoring of the elevation of the water table, which provides data for improving the simulation of groundwater movement; and (2) efforts to simulate transport of uranium through the vadose zone and aquifer. The latter effort is difficult because

of the dynamic nature of groundwater flow beneath the 300 Area, particularly near the Columbia River, and also because of the complex geochemical interactions of uranium between dissolved forms and forms associated with sediment (Yabusaki et al., 2008; Hammond and Lichtner, 2010). However, some insight on future conditions is possible based on modeling efforts, which will be helpful during the remedial action alternative evaluation process.

13.2.2 Interim Remedial Action Monitoring

Groundwater monitoring required under the 1996 ROD is implemented via a sampling and analysis plan (DOE/RL-2002-11), which has been modified several times. Samples are collected from wells, and in the 300 Area, samples are collected from aquifer tubes beneath the shoreline. Comprehensive sampling events occur semiannually, with more frequent sampling occurring when conditions change rapidly and/or major excavation activities are underway. Most monitoring wells have screens positioned to include the zone occupied by the water table. Several wells are screened in the lower portion of the unconfined aquifer, and a few wells are screened in the uppermost confined aquifer.

Groundwater monitoring includes use of wells screened at various depths in the contaminated aquifer and aquifer tubes along the 300 Area shoreline.

During the latter part of 2010, wells and aquifer tubes were not sampled as planned between late September and the end of the year due to a work shutdown related to safety issues. Additional minor exceptions to planned monitoring occurred due to maintenance issues and scheduling compromises. Lists of wells and aquifer tubes used for monitoring and the laboratory analyses conducted on groundwater samples are presented in Appendix A.

Additional environmental monitoring along the 300 Area shoreline, as described in the 300-FF-5 OU operation and maintenance plan, is conducted under the Surface Environmental Surveillance Project (SESP), which is part of DOE's Public Safety and Resource Protection Program (DOE/RL-91-50, *Environmental Monitoring Plan*). The SESP monitors potential contamination in riverbank springs (water and sediment), near-shore river water, and the free-flowing stream of the Columbia River; the project also performs limited biota sampling. The schedule and locations for SESP monitoring for calendar year 2011 will be described in an upcoming PNNL environmental monitoring report.

13.2.3 Treatability Tests for Uranium Contamination in the Subsurface

The DOE's remedial action objective for 300 Area groundwater is to reduce the concentration of dissolved uranium to less than the DWS. One strategy is to transform dissolved uranium to a less mobile form that is sequestered in aquifer sediment. A second strategy involves transforming contaminant uranium remaining in the vadose zone to even less mobile forms, thus reducing the downward flux to groundwater.

Bench-scale testing using polyphosphate solutions to immobilize uranium in the subsurface began in 2006 under DOE's Environmental Management program. The process involves introducing polyphosphate and calcium chloride to groundwater contaminated by uranium. Minerals are formed that cause the dissolved uranium to be sequestered in solid form as part of the new minerals crystal structure, thus reducing the potential for further migration along environmental pathways. Following successful bench-scale testing, field testing involving the injection of polyphosphate into the aquifer at a site near the south end of the former 300 Area Process Trenches was performed in 2007 (see Figure 13-19 for the location of testing). While the chemical reactions worked well in the laboratory, application in the field proved more challenging because of heterogeneous sediment and geochemical conditions

(PNNL-17480, *Challenges Associated with Apatite Remediation of Uranium in the 300 Area Aquifer*). A final report on the aquifer injection test conducted in 2007 is presented in *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report* (PNNL-18529). Additional treatability testing using polyphosphate solutions began in 2009 and continued into 2010 at a second test site, focusing on immobilizing uranium in the vadose zone (DOE/RL-2009-16, *300-FF-5 Groundwater Operable Unit Infiltration Test Sampling and Analysis Plan*).

Application of polyphosphate solutions is being tested for reducing concentrations of uranium dissolved in groundwater.

13.2.4 Research Activities

The DOE's Office of Science, Biological and Environmental Research, is supporting field research involving the mobility of uranium in the environment under a program referred to as the Integrated Field-Scale Research Challenge (IFRC). The focus of the research is multi-scale, mass-transfer processes that control the sequestration and mobility of uranium contamination in the subsurface, including the vadose zone and groundwater. The Hanford Site 300 Area is one of three DOE sites where field and laboratory research activities are being performed. The activities at the Hanford Site are described in the *300 Area Integrated Field-Scale Subsurface Research Challenge (IFRC) Field Site Management Plan* (PNNL-17067). A detailed description of the 300 Area IFRC site's network of boreholes for experiments and the hydrogeologic setting is presented in *Borehole Completion and Conceptual Hydrogeologic Model for the IFRC Well Field, 300 Area, Hanford Site* (PNNL-18340). The location of the IFRC is shown in Figure 13-19.

The DOE supports several basic and applied research activities that focus on uranium contamination beneath the 300 Area, including the IFRC test site.

Other DOE Office of Science projects include geophysical investigations of the aquifer beneath the 300 Area and the connection of the aquifer to the river channel. This investigation uses a variety of near-surface geophysical methods to characterize preferential pathways for groundwater movement and discharge to the river channel. One of the methods uses fiber optic cables on the riverbed, which record temperature at 1-meter increments along the length of the approximately 1-kilometer-long cable. The results and interpretations are presented in "Use of Electrical Imaging and Distributed Temperature Sensing Methods to Characterize Surface-Water/Groundwater Exchange Regulating Uranium Transport at the Hanford 300 Area, Washington" (Slater et al., 2010).

The DOE has also funded a groundwater flow and uranium transport modeling project for the 300 Area via the Scientific Discovery Through Advanced Computing Program. This project involves massively parallel, high-speed computing and conducts calculations that would otherwise require exceedingly long computing times with conventional computer equipment. Initial project results are presented in "Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area Using High Performance Computing" (Hammond and Lichtner, 2010) and "Stochastic Simulation of Uranium Migration at the Hanford 300 Area" (Hammond et al., 2010).

13.3 Facility Monitoring: 300 Area Process Trenches

D.C. Weekes

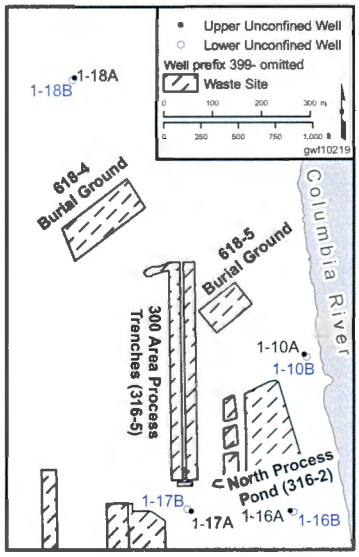
The former 300 Area Process Trenches (waste site 316-5) received effluent discharges of mixed waste from fuel fabrication and nuclear research laboratories in the 300 Area from 1975 through 1985, followed by continued discharge of clean effluent until December 1994. During this period of operation the trenches were used as a TSD facility, therefore the trenches are regulated under RCRA. A comprehensive

description of the facility and its history of operations is provided in *300 Area Process Trenches Groundwater Monitoring Plan* (PNNL-13645). The trenches were remediated in 1991 under a CERCLA expedited response action by scraping contaminated soil to the north end of the facility (DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches*). Additional removal actions were performed in 1997 and 1998, followed by backfilling and surface restoration in 2004 (DOE/RL-2004-74).

The former 300 Area Process Trenches have been remediated. Groundwater impacted by past disposal to the trenches continues to be monitored under RCRA and CERCLA requirements.

13.3.1 Network Evaluation and Compliance Status

Groundwater is monitored under the requirements of the RCRA for hazardous waste constituents and under the *Atomic Energy Act of 1954* for uranium. Groundwater monitoring required by RCRA is conducted in accordance with WAC 173-303-645(11) ("Dangerous Waste Regulations," "Releases from Regulated Units") and the *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*, Part VI, Chapter 1 (WA7890008967). The modified closure plan (DOE/RL-93-73, *300 Area Process Trenches Modified Closure/Postclosure Plan*), which is incorporated into the Hanford Facility RCRA Permit, states that groundwater remediation is deferred to the 300-FF-5 OU under CERCLA.



Post-corrective action monitoring under RCRA uses wells at four locations: one upgradient (north of the former facility) and three downgradient (east, southeast, and south of the facility). The most distant downgradient location is approximately 200 meters to the southeast, along the dominant groundwater flow path from the facility. Groundwater flows generally toward the south-southeast beneath the former trenches. Estimates for flow rates in March 2009 ranged from 0.20 to 20 meters per day (Appendix B, Table B-1).

Two wells are present at each of the four locations, with one well screened near the water table and the second well screened in the lower portion of the unconfined aquifer. The sampling schedule for the eight wells is designed to accommodate two semiannual sampling events, with four time-independent samples collected during each period to provide data amenable to statistical analysis. The schedule results in sampling during 8 months of the year: the first sampling event covers December, January, February, and March, and the second sampling event covers June, July, August, and September. The intervening months at the water table wells are sampled under the CERCLA program, thus obtaining a continuous record of monthly measurements.

During 2010, sampling was performed as planned, except as noted in wells 399-1-10B, 399-1-16B, and 399-1-17A (Appendix B, Table B-16). Reports on the effectiveness of the corrective action monitoring program were prepared semiannually in accordance with WAC 173-303-645(11)(g). The results for 2010 are provided in *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches, January –June 2010* (SGW-47971) and *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches, July – December 2010* (SGW-49268).

13.3.2 Groundwater Contaminants

Groundwater monitoring to meet RCRA requirements is conducted based on the *Groundwater Monitoring Plan for the 300 Area Process Trenches* (WHC-SD-EN-AP-185), which has been in effect since 1997. The dangerous waste constituents monitored under this plan include trichloroethene and tetrachloroethene, as well as their potential environmental degradation products cis-1,2-dichloroethene

and vinyl chloride. Uranium is regulated under the *Atomic Energy Act of 1954*; it is also monitored in samples collected under RCRA and is measured as the total amount in an unfiltered sample. Uranium contamination beneath the 300 Area is also monitored under an extensive CERCLA program (total and periodic isotopic measurements) and in the adjacent river environment under the DOE Public Safety and Resource Protection program (isotopic uranium). Table 13-1 presents a summary of the maximum values observed at each of the eight wells for the four dangerous waste constituents monitored under the RCRA program and uranium monitored under the AEA for the period from 2008 through 2010.

Analytical results for trichloroethene were all below the detection limit of 1 µg/L during 2010, with the exception of two detections in samples from well 399-1-16B (1.4 and 1.1 µg/L) and one detection at well 399-1-17A (0.31 µg/L). Analytical results for tetrachloroethene were all below the 1 µg/L detection limit (the DWS for trichloroethene and tetrachloroethene is 5 µg/L). At well 399-1-16B, which monitors conditions in the lower portion of the unconfined aquifer, cis-1,2-dichloroethene remains at concentrations approximately twice the 70 µg/L DWS, with values ranging from 130 to 170 µg/L during 2010. Concentrations of this compound in other RCRA network monitoring wells ranged from nondetect to 4.8 µg/L. Additional information on the characteristics of VOCs in groundwater beneath the 300 Area is provided in Section 13.1.2.1.

Cis-1,2-dichloroethene and uranium continue to exceed their respective DWSs at RCRA network wells.

Uranium concentrations in groundwater during 2010 remained above the 30 µg/L DWS at each of the three downgradient wells screened in the upper portion of the unconfined aquifer, with values ranging from 19.9 to 89 µg/L. Concentrations at wells 399-1-10A and 399-1-16A, which are near the Columbia River, declined in spring and early summer when the river stage was high as a consequence of dilution by river water intruding into the aquifer. Concentrations at upgradient well 399-1-18A are consistent with background levels for saturated Hanford formation sediment and were in the range of 5 to 7 µg/L during 2010. Concentrations in the lower portion of the unconfined aquifer are typically below detection levels, with the exception of detections at well 399-1-16B that were less than 15 µg/L. Additional information on the characteristics of uranium in groundwater beneath the 300 Area is provided in Section 13.1.1.1.

13.4 Conclusions and Recommendations

13.4.1 Conclusions

Uranium in the subsurface at the 300 Area remains the principal COC for the 300-FF-5 OU because concentrations in groundwater exceed the 30 µg/L DWS and the plume has persisted longer than predicted in the early 1990s by the initial RI. Uranium contamination in the vadose zone and unconfined aquifer beneath the 300 Area is the focus of numerous activities described in the work plan for continuing the RI/FS process (DOE/RL-2009-30). Testing of technologies to reduce concentrations in groundwater, as well as research activities to better understand the mobility potential for uranium in the subsurface, continued during 2010.

The primary groundwater issue for the 300-FF-5 OU RI/FS involves uranium in groundwater beneath the 300 Area.

Tritium in groundwater near the 618-11 Burial Ground is of concern because the concentrations greatly exceed the 20,000 pCi/L DWS and the proximity of the plume to areas of potential withdrawal of groundwater for beneficial use. The processes by which tritium released from materials contained within the 618-11 Burial Ground resulted in a groundwater plume remain uncertain, as does the potential for additional future impacts to groundwater. Computer simulation of this plume indicates that

concentrations will be below the DWS when the affected groundwater reaches the Columbia River, because of natural attenuation by radioactive decay and dispersion.

Other groundwater contaminants identified during the initial qualitative risk assessment (e.g., nitrate, tritium, and VOCs) for the 300-FF-5 OU have shown relatively constant or decreasing concentration trends or are not associated with waste sites in the 300-FF-1 and 300-FF-2 OUs. Characterization of these contaminants through monitoring and computer simulation will continue to provide information to assist in the selection of final remedial action alternatives.

Other COPCs in the 300-FF-5 OU are monitored to establish long-term trends and potential risk to natural resources.

Contaminant characterization activities in the Columbia River environment adjacent to the 300 Area may provide new information on COPCs with regard to human health and ecological risk. The new information will be factored into conclusions and recommendations presented in the RI/FS report for 300 Area National Priorities List OUs, which has a Tri-Party Agreement target date of December 31, 2011 (Milestone M-015-72-T01).

Groundwater monitoring in the 300-FF-5 OU during 2010 included sampling at monitoring wells (Appendix A, Tables A-17, A-18, and A-19) and aquifer tubes (Appendix C, Table C-9) under CERCLA and RCRA programs, and at several research sites where activities involve groundwater:

- Fifty monitoring wells in use at monthly to annual frequencies in the 300 Area
- Twenty-nine aquifer tubes at multiple depths beneath the shoreline (Appendix C)
- Corrective action monitoring under RCRA at eight wells near the former 300 Area Process Trenches (Appendix B, Table B-16)
- Two research test sites that include groundwater monitoring: (1) the polyphosphate treatability test site near the southern end of the former 300 Area Process Trenches, and (2) the IFRC site at the southwest corner of the former South Process Pond.

13.4.2 Recommendations

The path forward for groundwater monitoring in the 300-FF-5 OU will continue to follow the strategies presented in the operation and maintenance plan (DOE/RL-95-73) and its sampling and analysis plan (DOE/RL-2002-11). These plans will be revised based on monitoring results, new insight from research activities and treatability testing, and remedial investigation activities associated with satisfying data needs as presented in the RI/FS work plan (DOE/RL-2009-30).

The third 5-year review of the 1996 ROD for the 300-FF-5 OU will be conducted during 2010 and 2011. The review will be supported by monitoring data gathered during nearly 22 years of sampling since the CERCLA process began. The data will be used to illustrate COPC trends as established under the influence of natural attenuation processes and in response to the remediation of contaminated waste disposal sites, unplanned release locations, and now defunct facilities. Conclusions from the review will complement interpretations being developed as part of the RI/FS and will focus the path forward, which will be presented in a proposed plan (Tri-Party Agreement Milestone M-015-00D), with a due date of December 31, 2012.

The third 5-year review of the 1996 ROD will be conducted during 2010 and 2011 and will be available in 2011.

The plan for RCRA-regulated, post-corrective action groundwater monitoring near the former 300 Area Process Trenches is out of date. New monitoring wells have been installed in the area under the CERCLA program that may be better located to provide information on conditions near the remediated waste disposal trenches. Extensive historical data indicate that trends are well established, suggesting that a decrease in sampling frequency may be appropriate. With the exception of cis-1,2-dichloroethene at well 399-1-16B, little evidence exists of contaminants potentially associated

The need for post-corrective action monitoring under RCRA near the former 300 Area Process Trenches should be re-evaluated to avoid duplication with similar activities being conducted under CERCLA.

with the former trenches having migrated downward to the lower portion of the unconfined aquifer. Also, the origin for the cis-1,2-dichloroethene is not clearly known, with trichloroethene (and later tetrachloroethene) used extensively in the fuels manufacturing process. However, large volumes of waste effluent associated with fuels manufacturing were routinely disposed to the North and South Process Ponds, with the volume decreasing following shutdown of the last production reactors in 1971. Reducing uncertainties regarding the origin and extent of the contamination observed at well 399-1-16B is included as part of the renewed RI under CERCLA.

Table 13-1. Maximum Observed Concentrations for 300 Area Process Trenches Waste Indicators in Groundwater, 2008 Through 2010

Well Names (RCRA Network)	Tetrachloroethene (µg/L)	Trichloroethene (µg/L)	cis-1,2-Dichloro-ethene (µg/L)	Vinyl Chloride	Uranium, Total (µg/L)
Upper Confined Aquifer (water table, saturated Hanford gravels)					
399-1-10A	U	U	U	U	54*
399-1-16A	U	U	U	U	85*
399-1-17A	U	0.3	0.2	U	116*
399-1-18A	U	U	U	U	7
Lower Portion of Unconfined Aquifer (Ringold unit E gravelly sediment)					
399-1-10B	U	U	4.5	U	0
399-1-16B	U	1.4	190.0*	U	16
399-1-17B	U	U	5.7	U	U
399-1-18B	U	U	U	U	0

Notes: Data in this table were obtained via query of the Hanford Environmental Information System database for the period January 1, 2008, through December 31, 2010, using the Data View and Evaluator (DaVE) interface. Maximum values are shown, when detected.

* Exceeds the EPA drinking water standard.

U = not detected in sample

Figure 13-1. Index Map Showing 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units

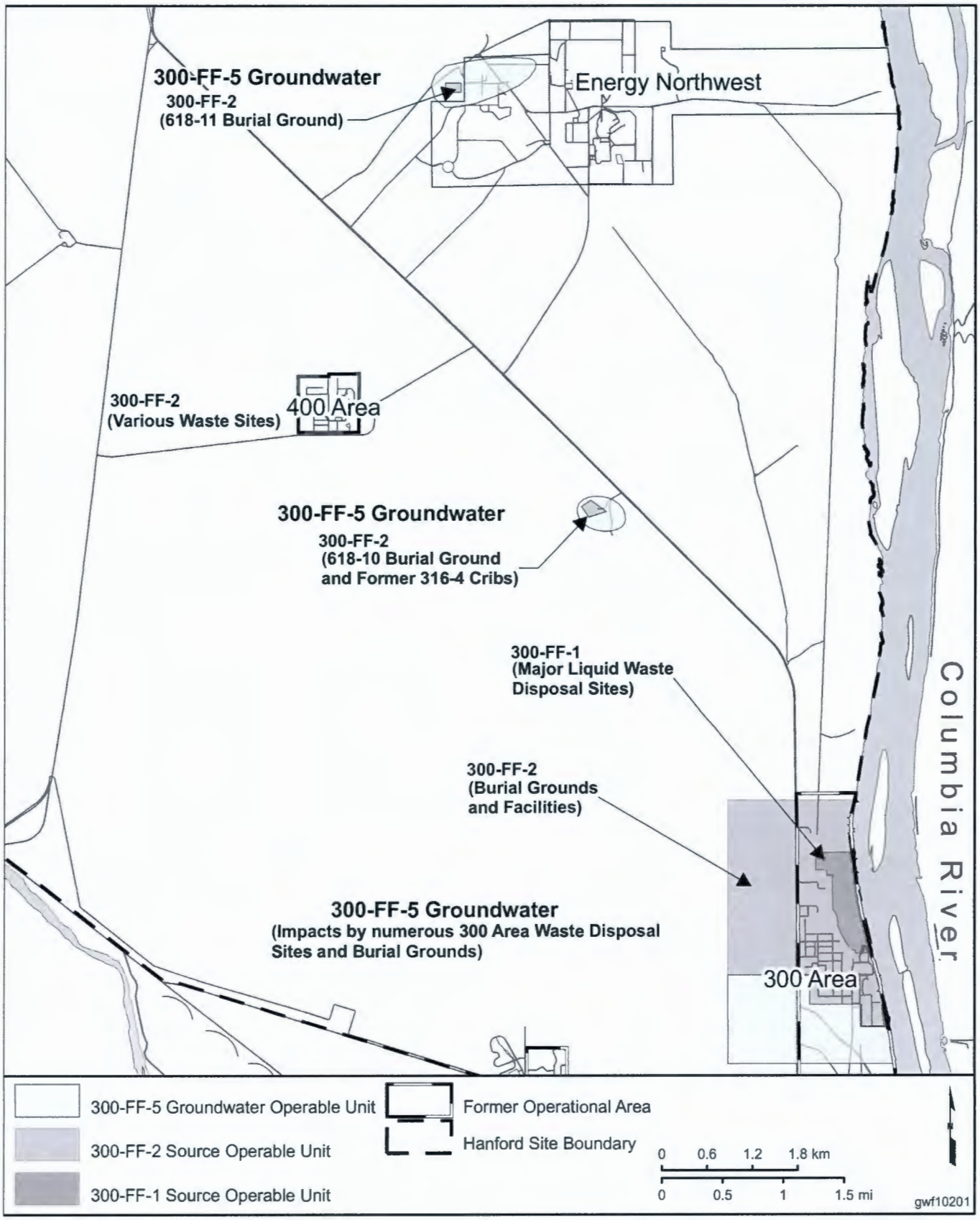


Figure 13-2. 300 Area Monitoring Wells, Waste Sites, Buildings, and Shoreline Monitoring Sites

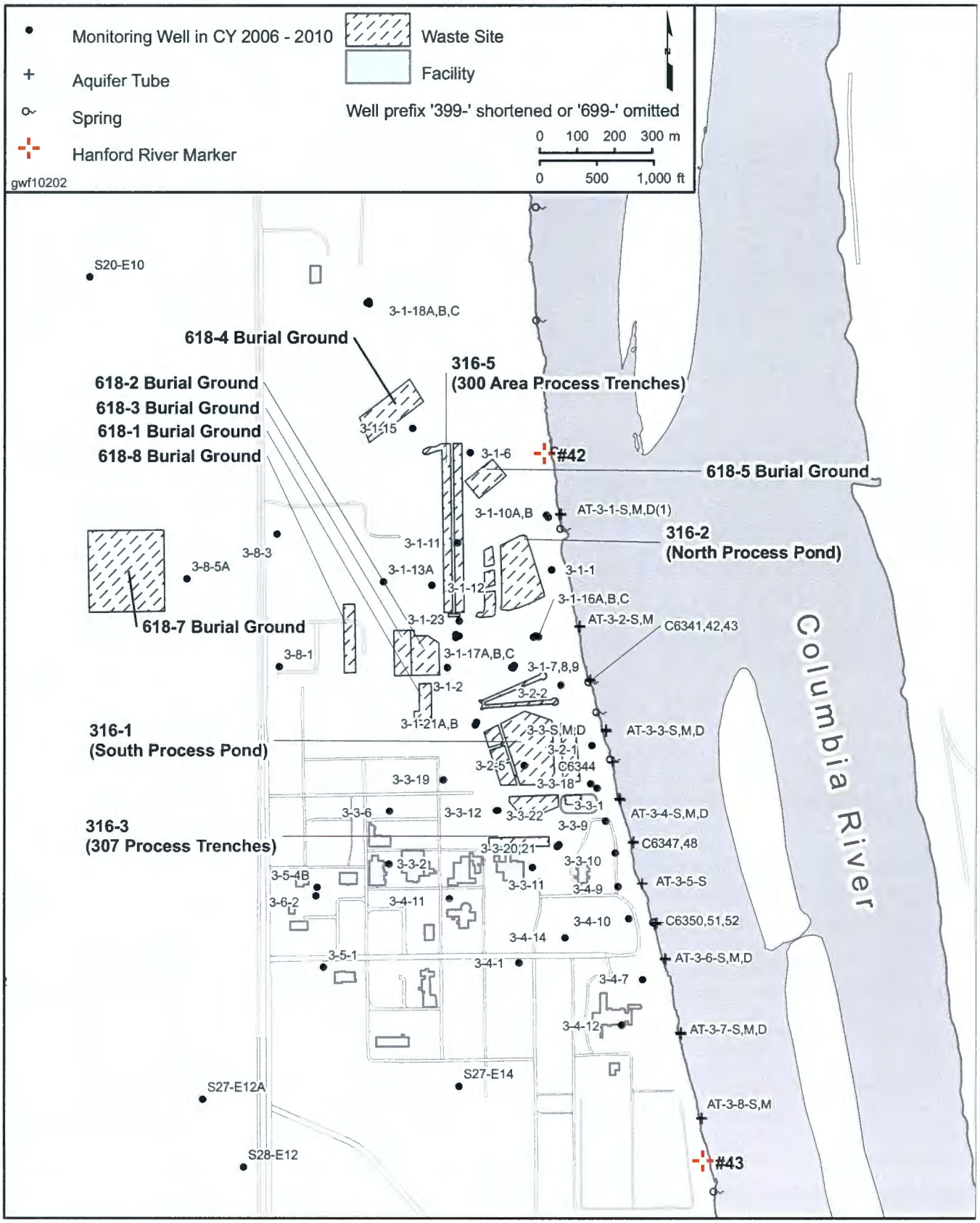


Figure 13-3. Monitoring Wells Near 618-11 Burial Ground

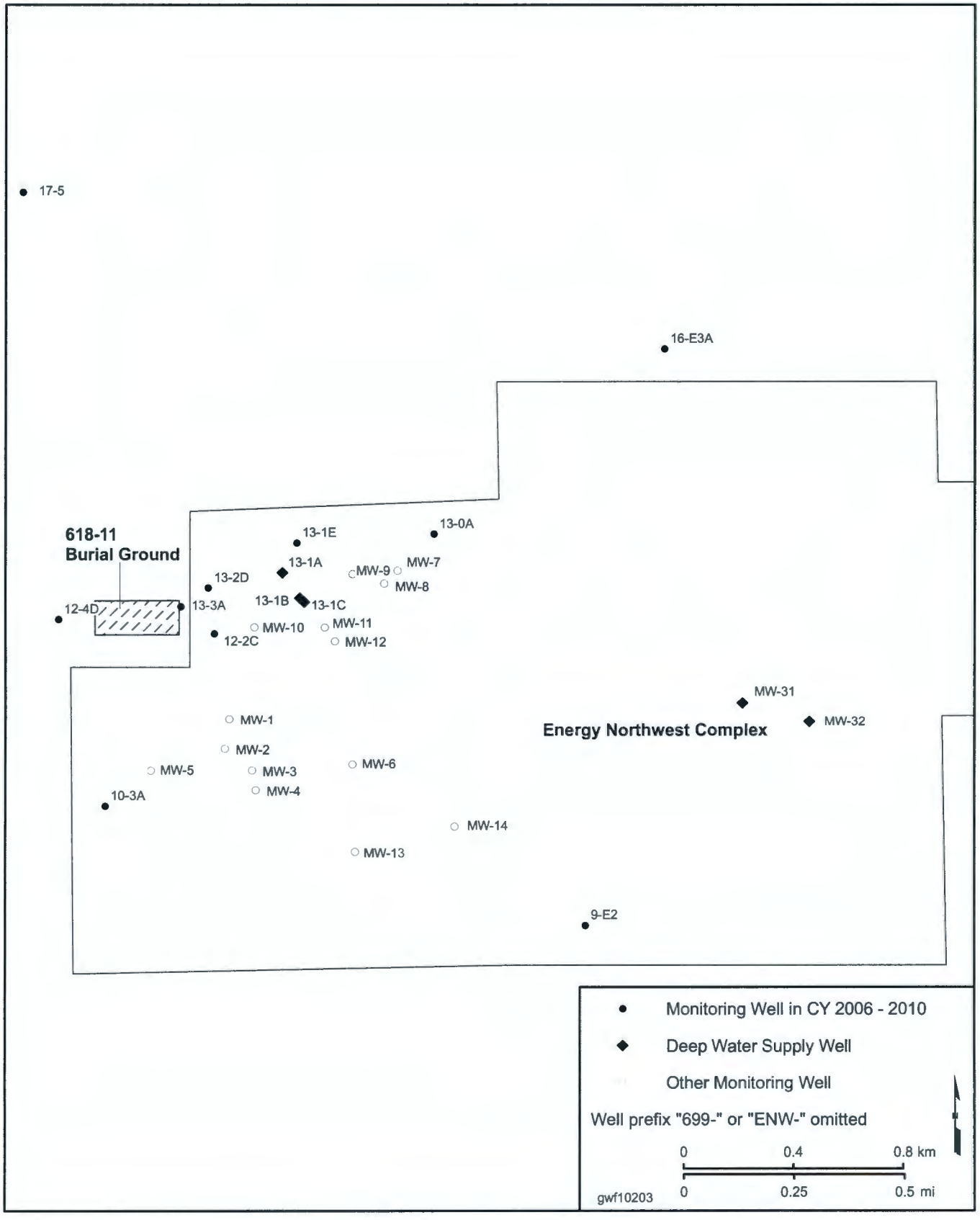


Figure 13-4. Monitoring Wells Near 618-10 Burial Ground

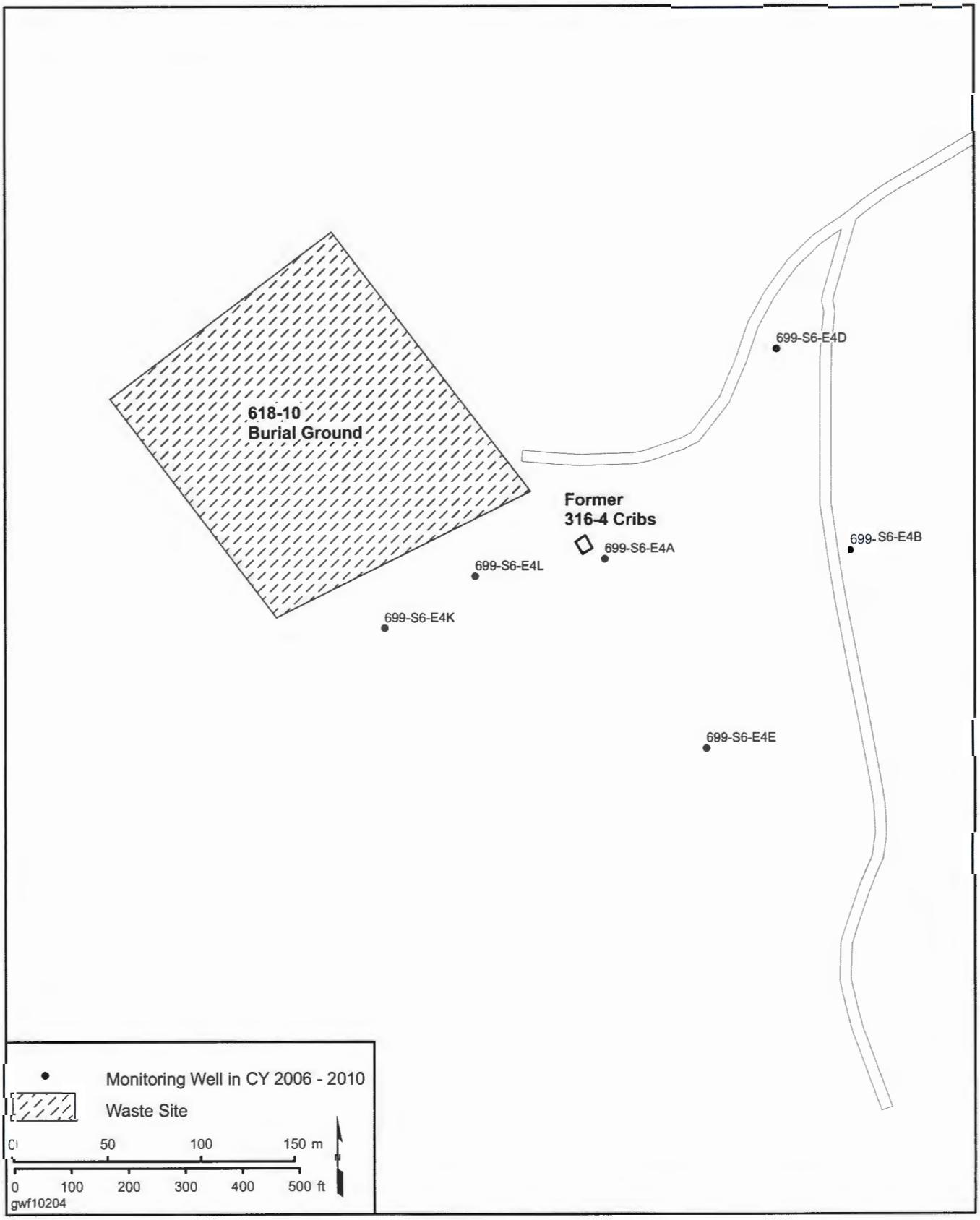


Figure 13-5. Water Table Elevation Map for Region Containing the 300-FF-5 Operable Unit

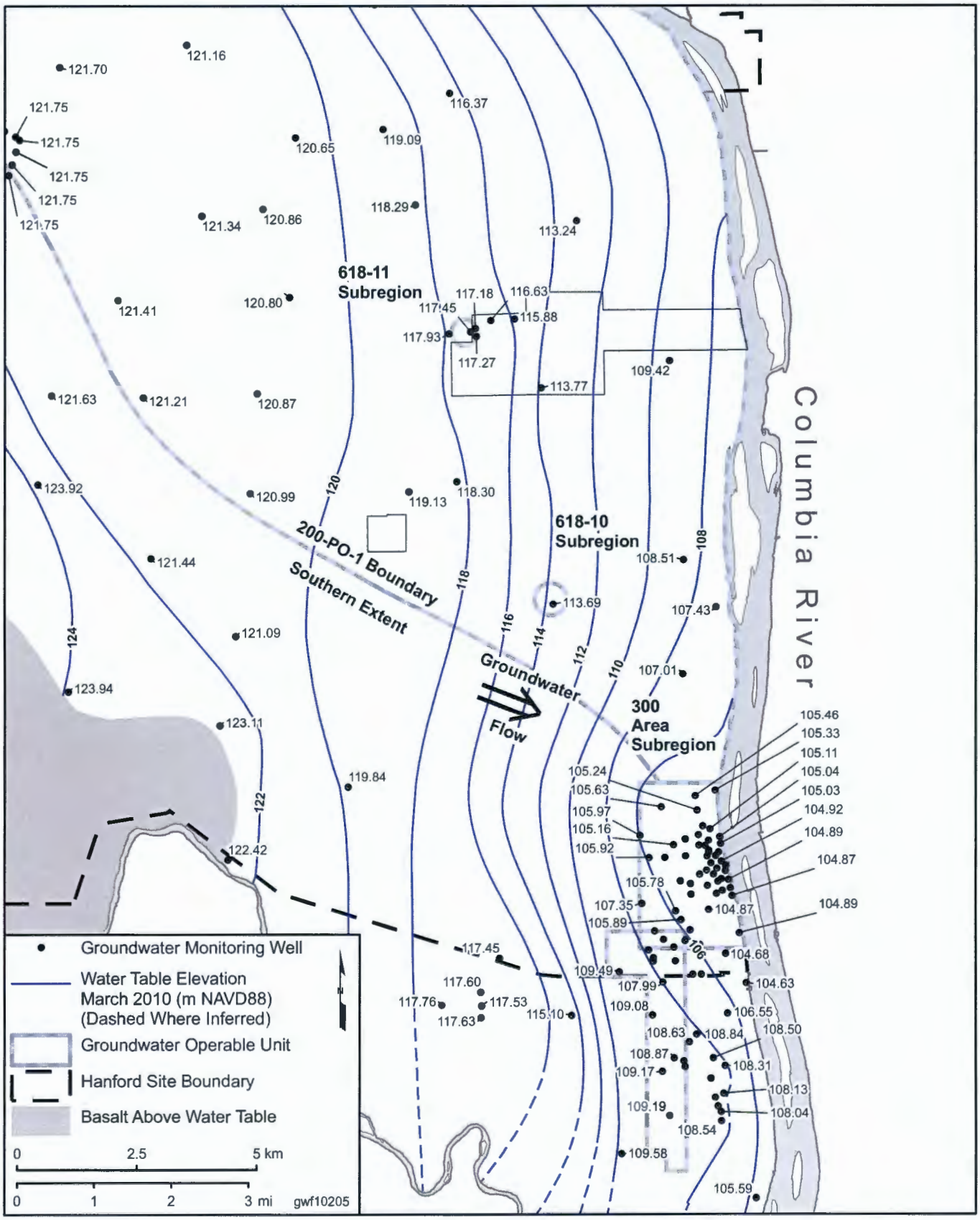


Figure 13-6. Index Map to the Hydrogeologic Cross Sections Illustrating Aquifer Beneath the 300 Area

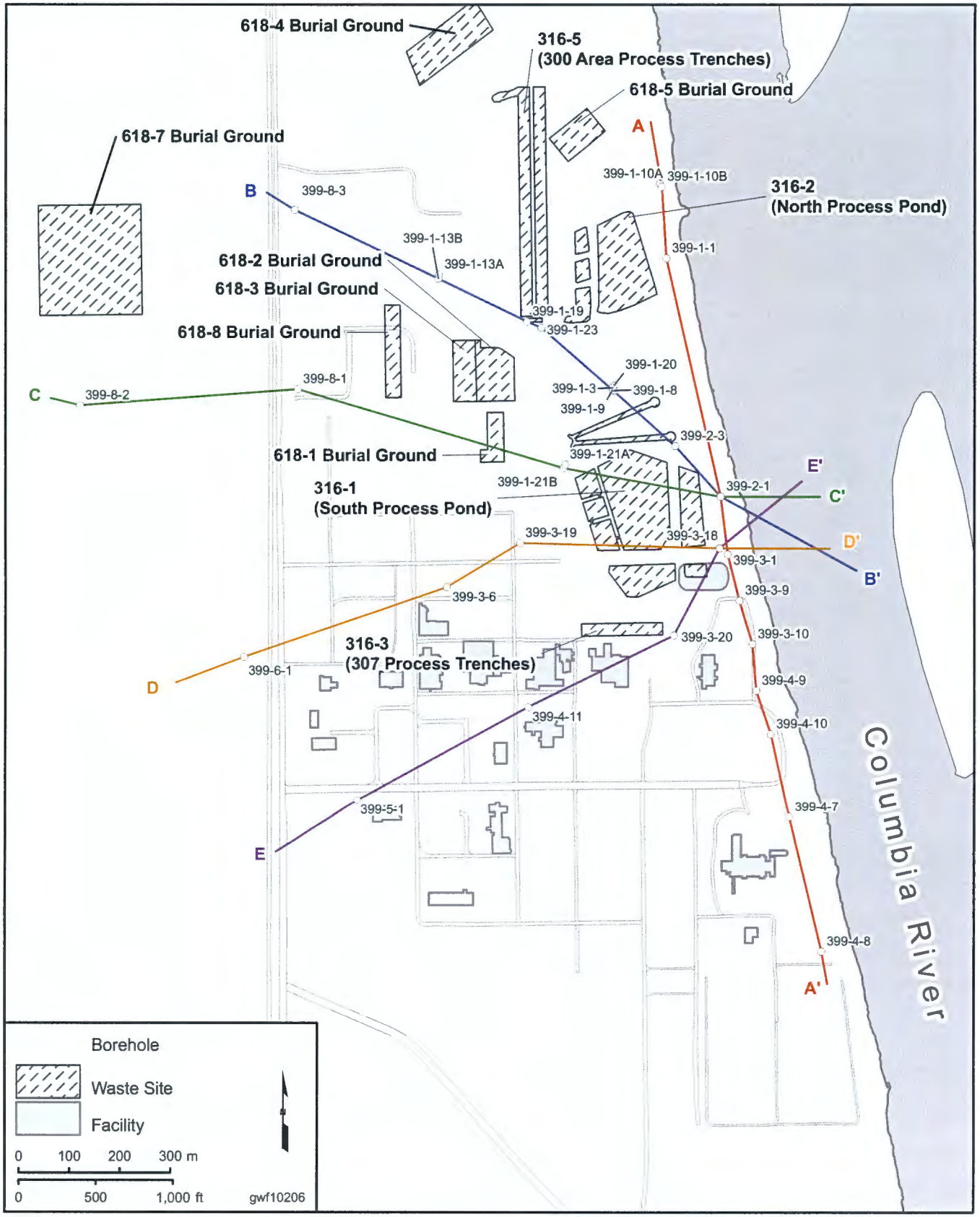
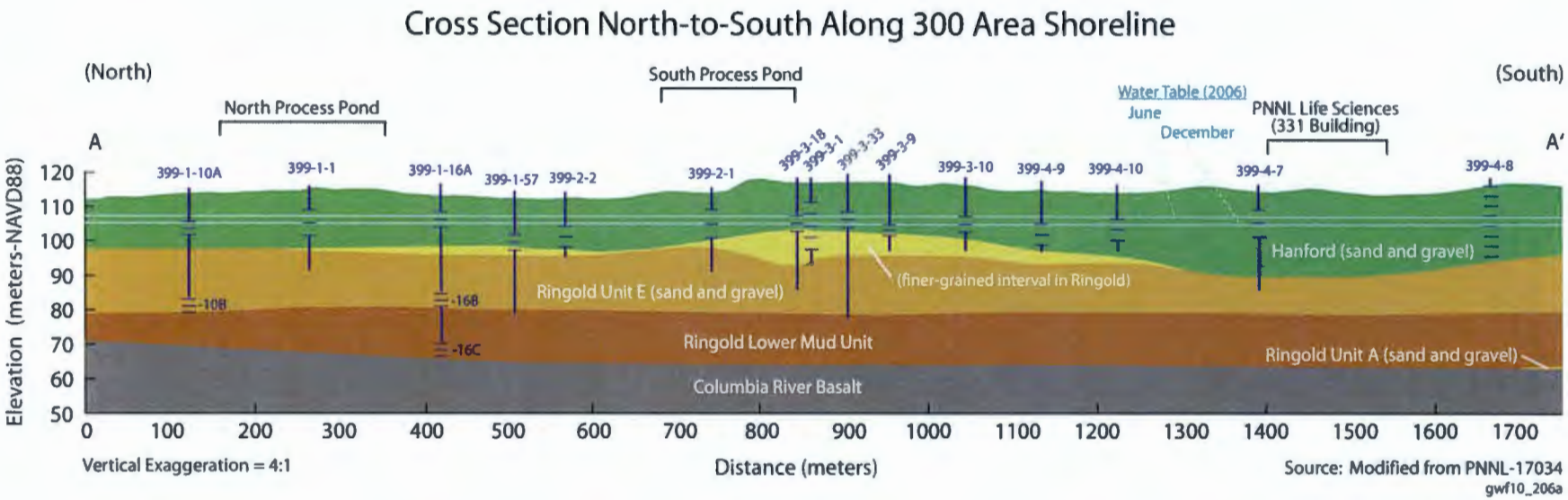


Figure 13-7a and b. Hydrogeologic Cross Sections Illustrating Aquifer Beneath the 300 Area



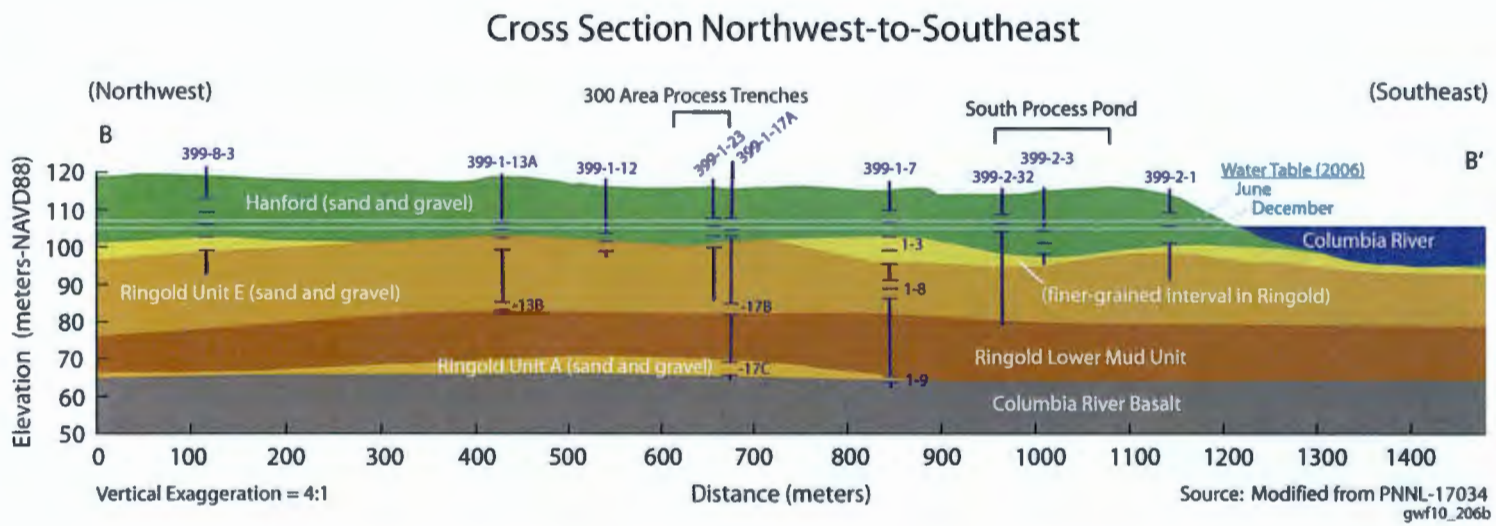


Figure 13-8. Uranium Concentrations in Groundwater Near Former 300 Area Process Trenches

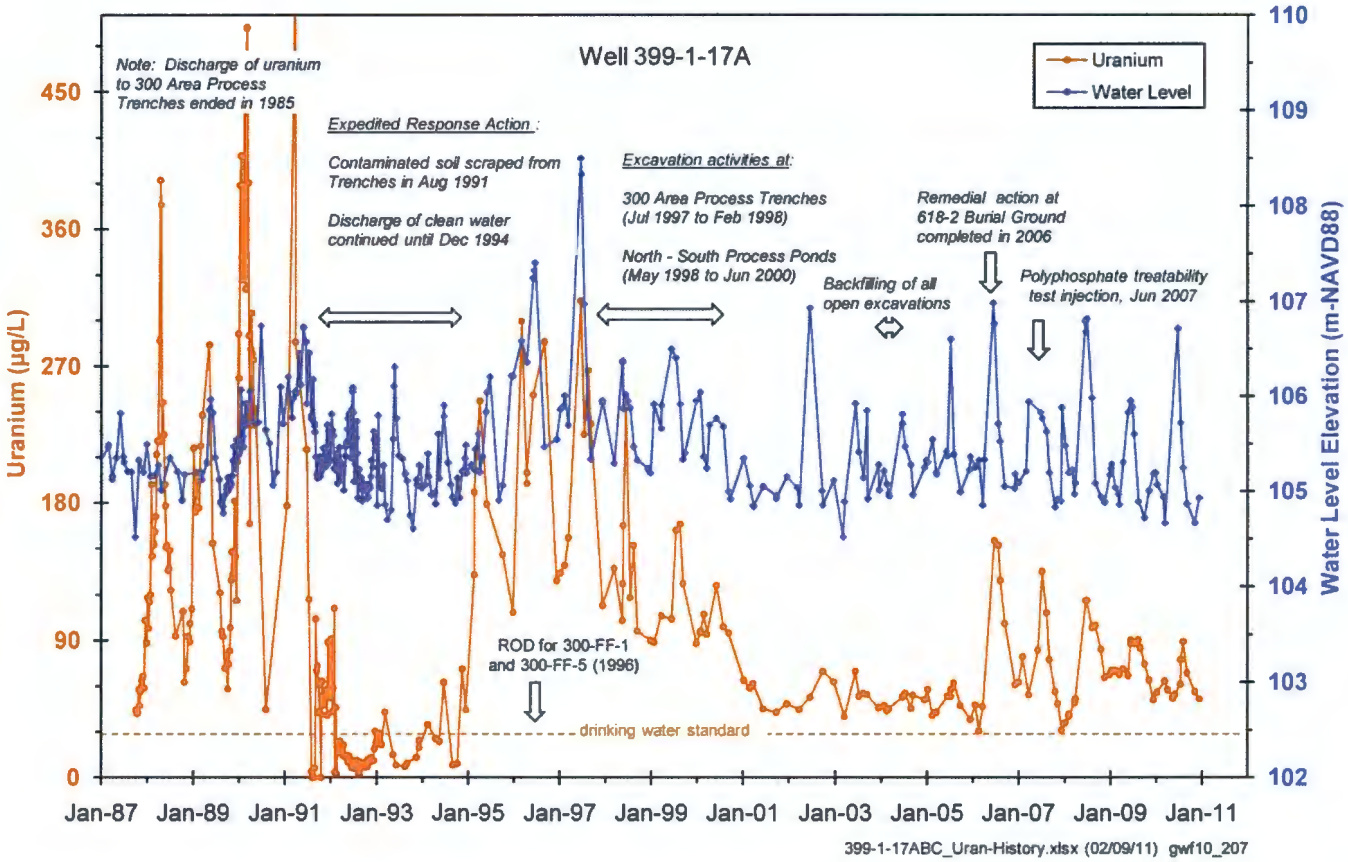


Figure 13-9. Uranium Plume in Groundwater Beneath 300 Area, June 2010

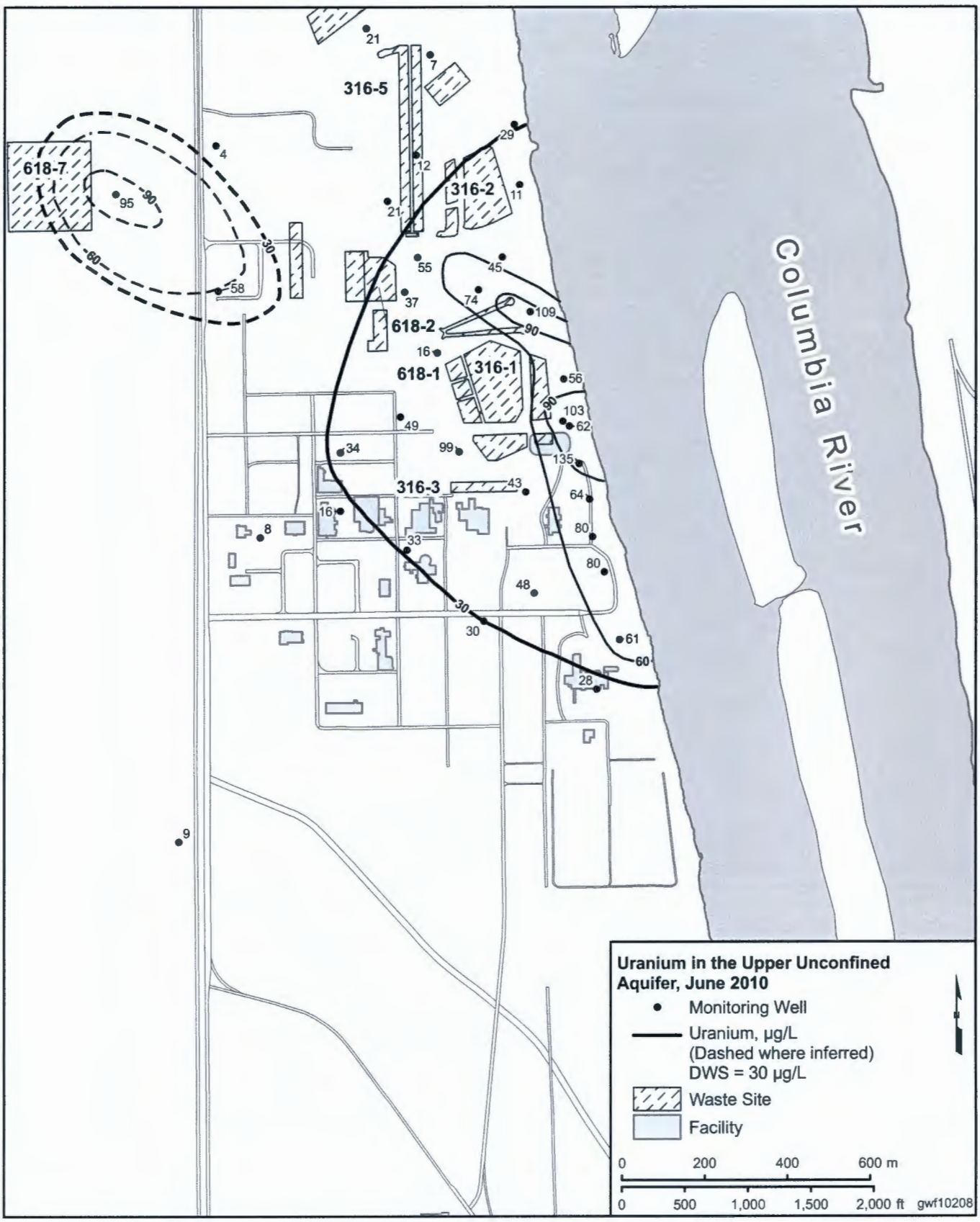


Figure 13-10. Uranium Concentration Trends and Water Levels at (A) Near-River Wells and (B) Inland Wells, 300 Area Groundwater

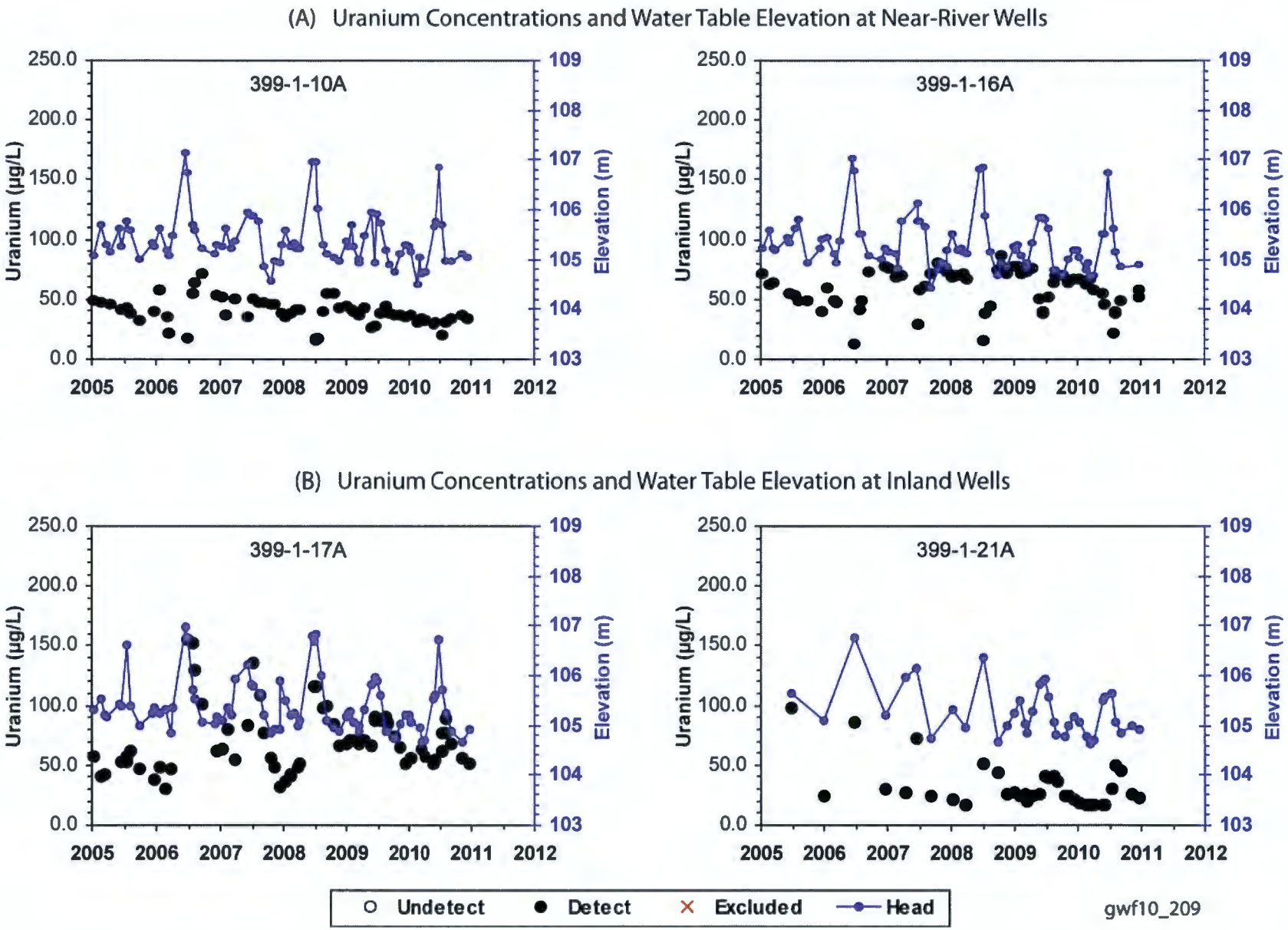


Figure 13-11. Uranium and Chromium Concentration Trends in Groundwater Downgradient from Former 618-7 Burial Ground

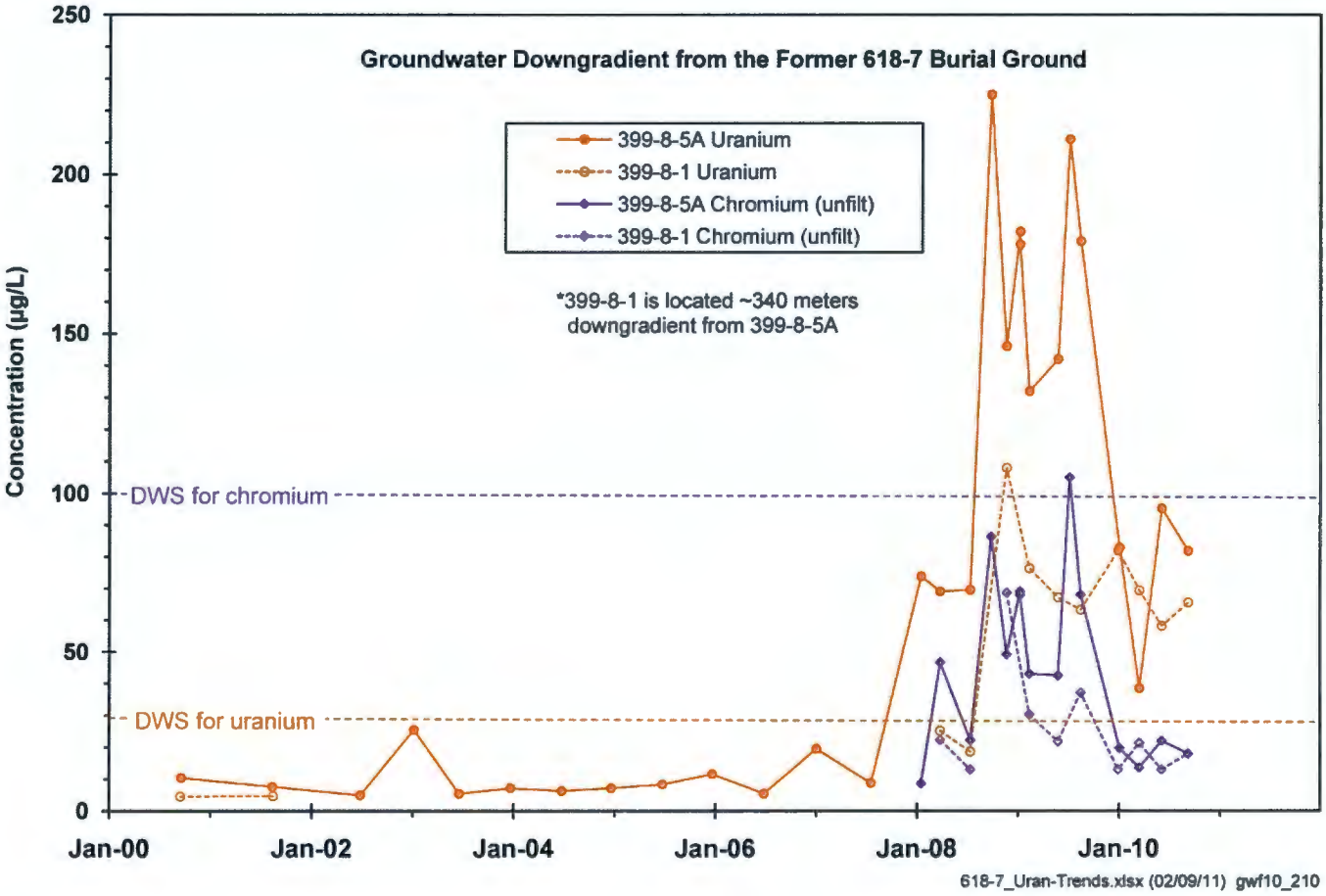


Figure 13-12. Uranium Distribution in Groundwater Beneath 300 Area Shoreline

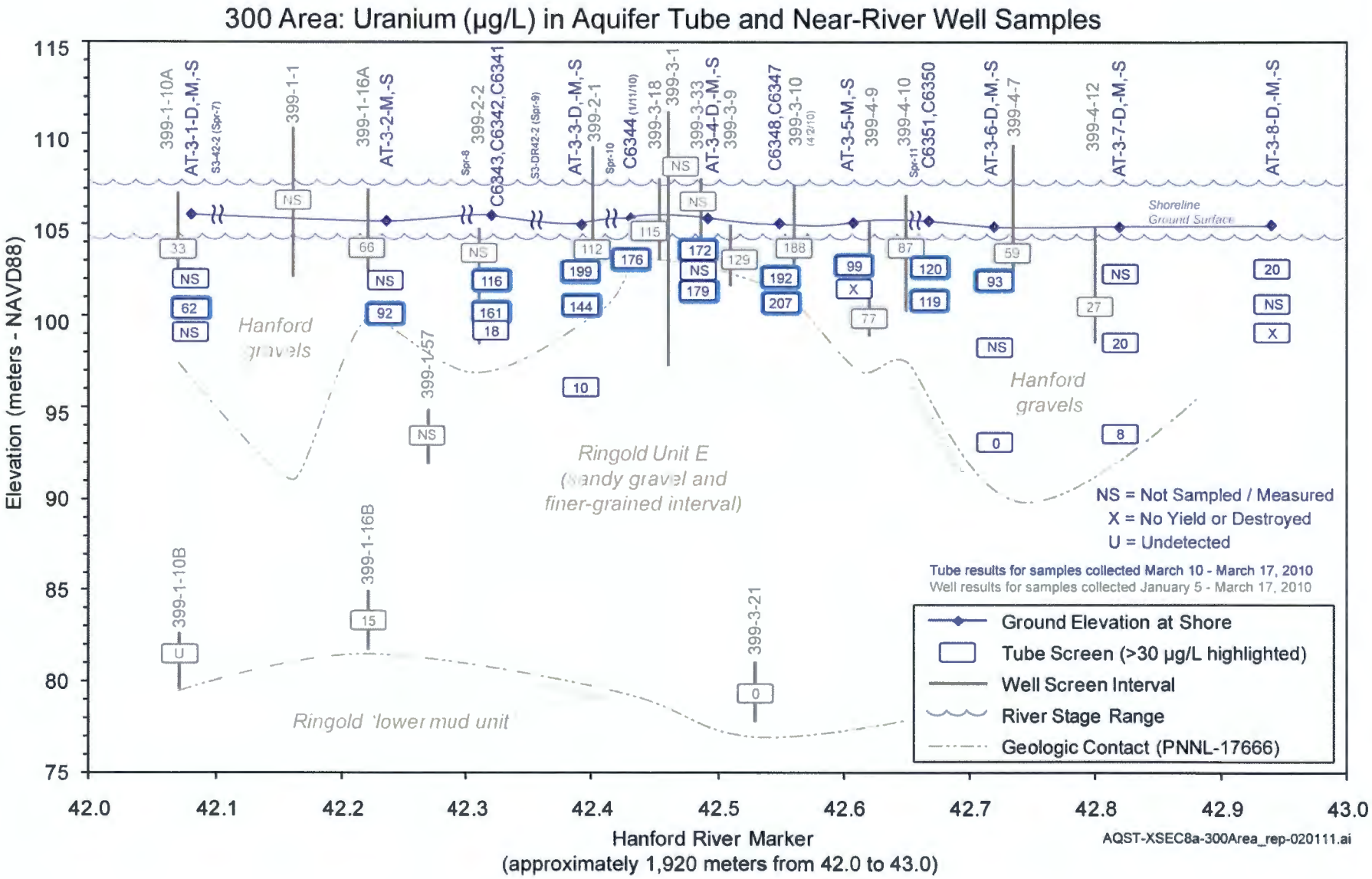


Figure 13-13. Uranium Concentration Trends at Wells Adjacent to 618-10 Burial Ground

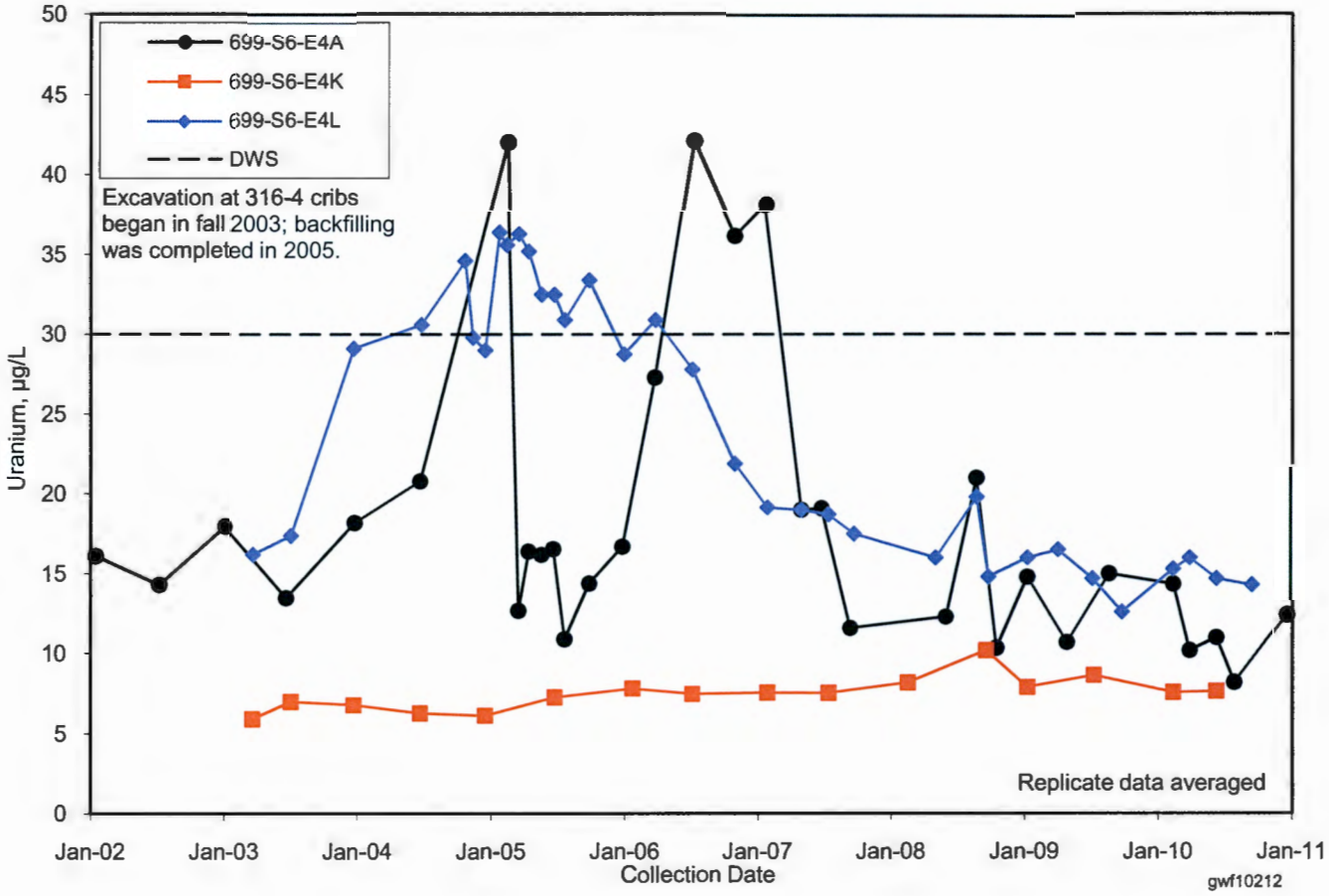


Figure 13-14. Trichloroethene Concentrations in Groundwater Beneath 300 Area Shoreline

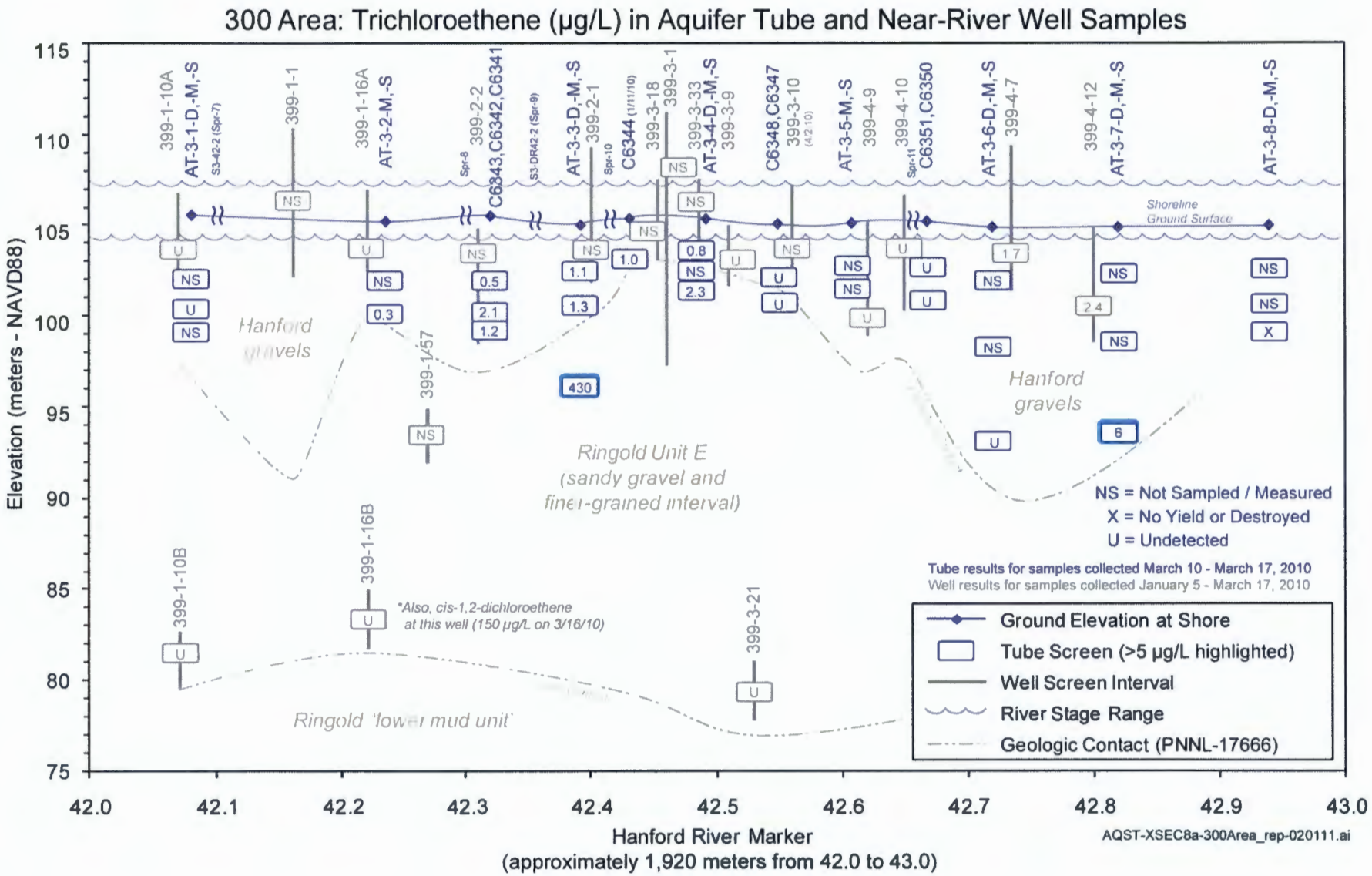


Figure 13-15. Volatile Organic Compound Concentrations in Lower Portion of Unconfined Aquifer at Well 399-1-16B, 300 Area

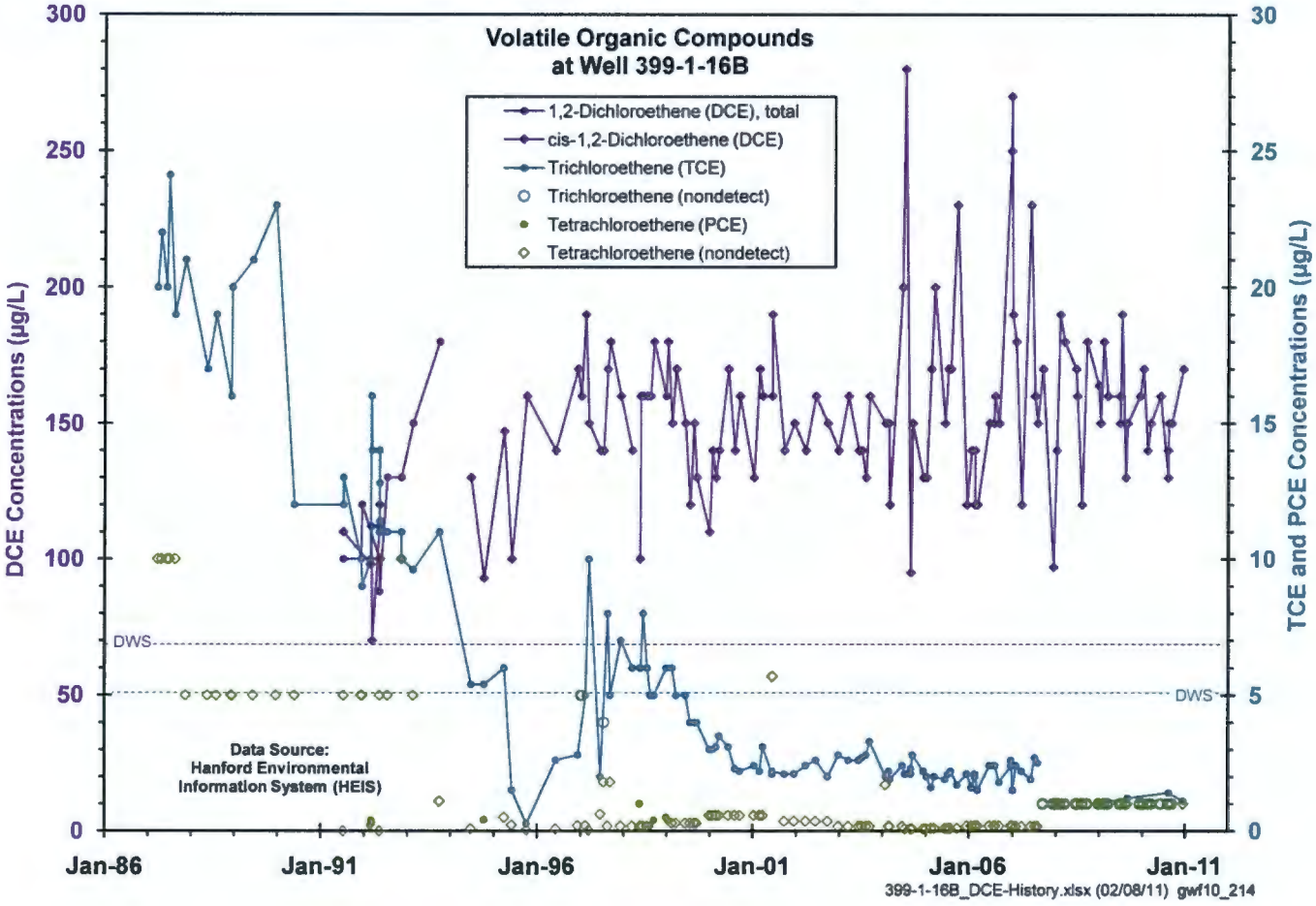
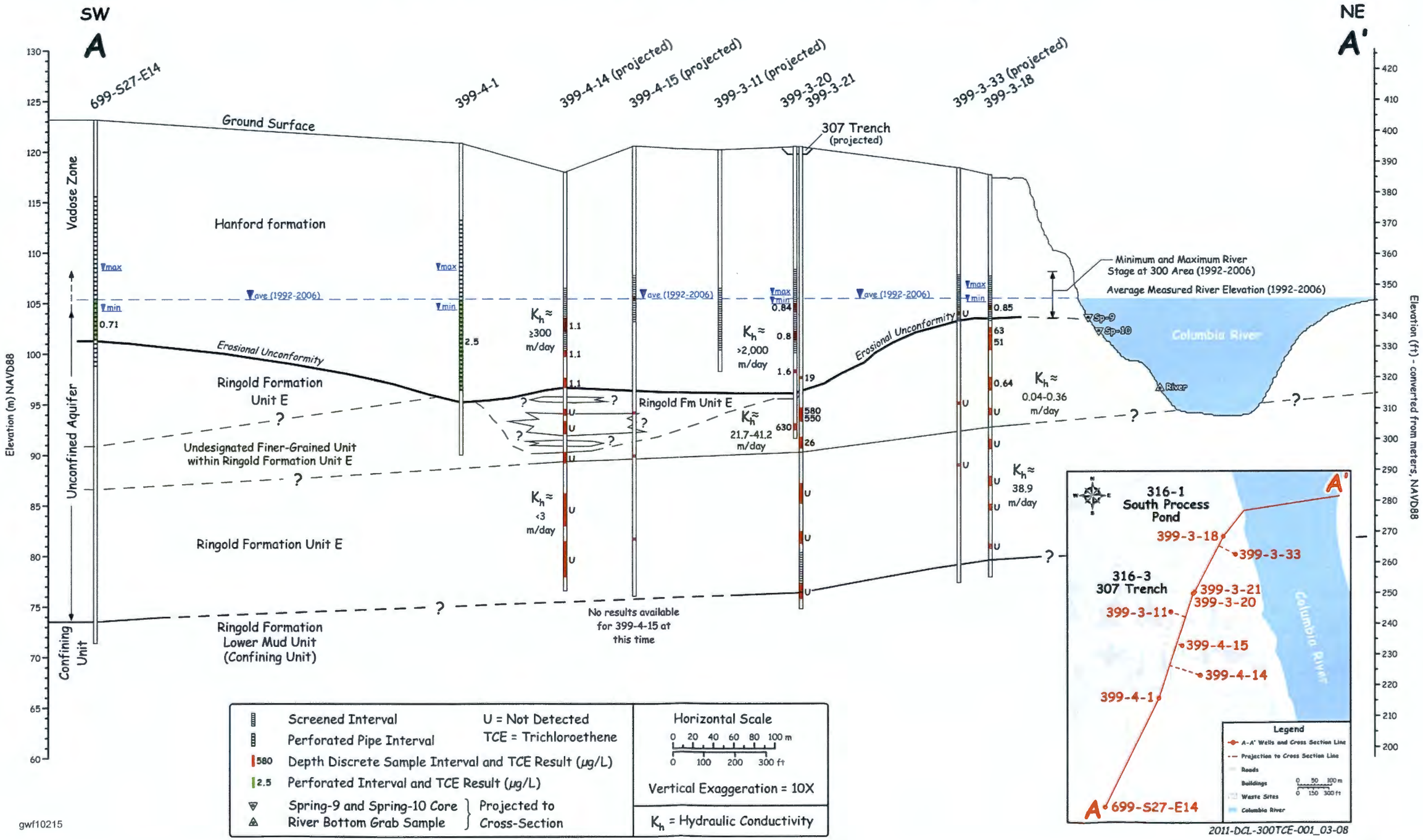


Figure 13-16. Cross Section Showing Volatile Organic Compounds Encountered During Drilling, 300 Area



This page intentionally left blank.

Figure 13-17. Tritium Plume in Groundwater Near 618-11 Burial Ground

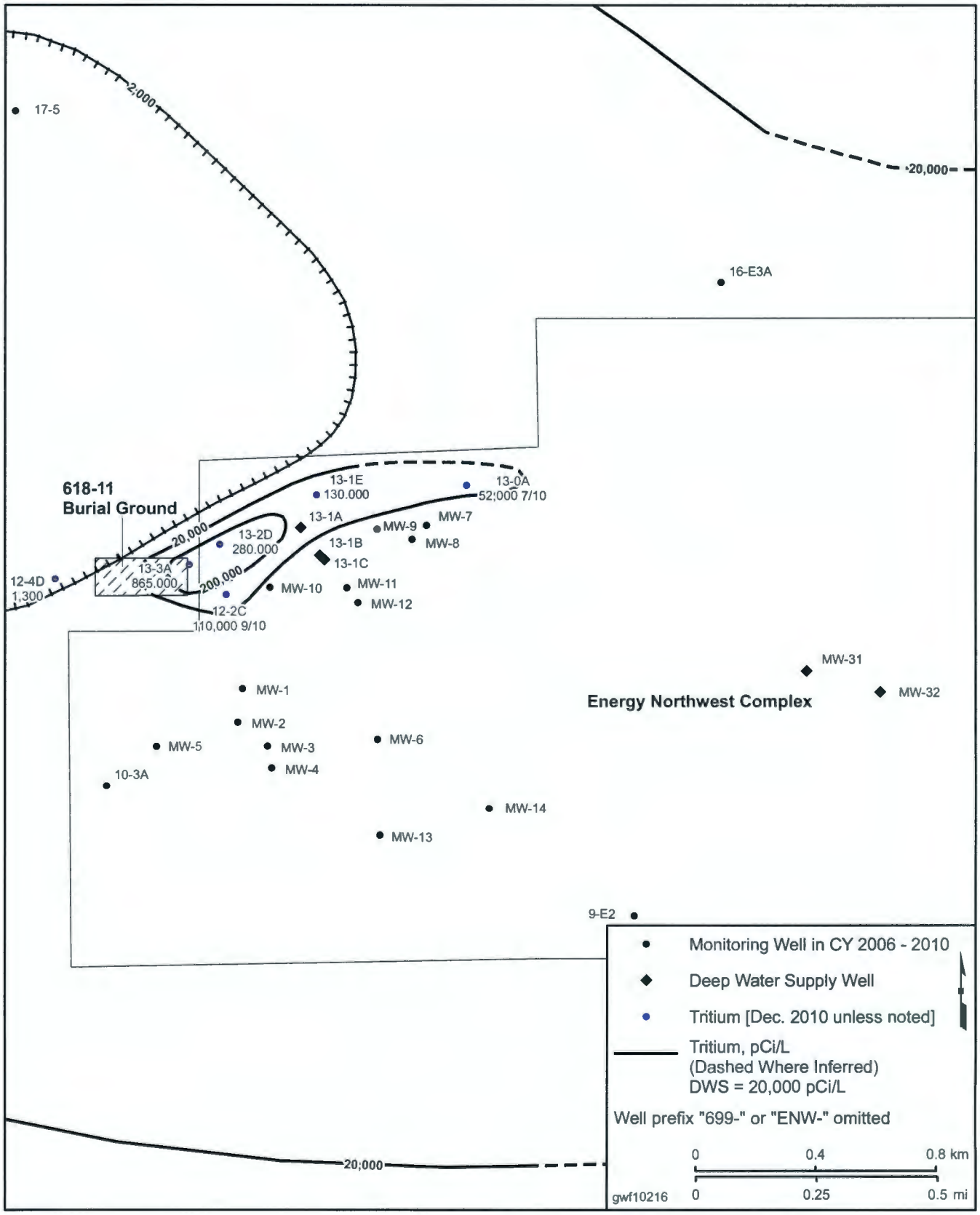


Figure 13-18. Tritium Concentration Trends at Wells Near 618-11 Burial Ground

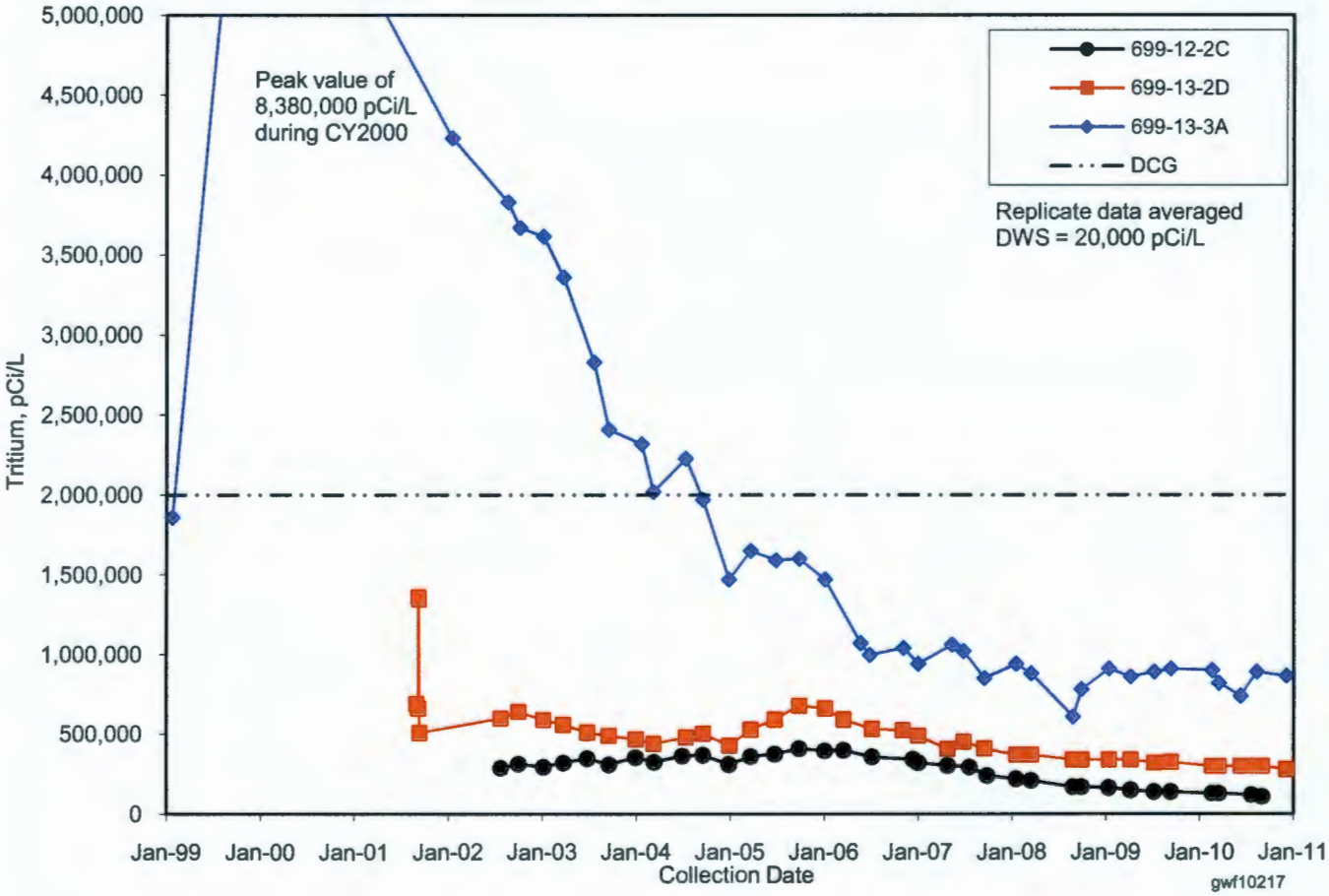
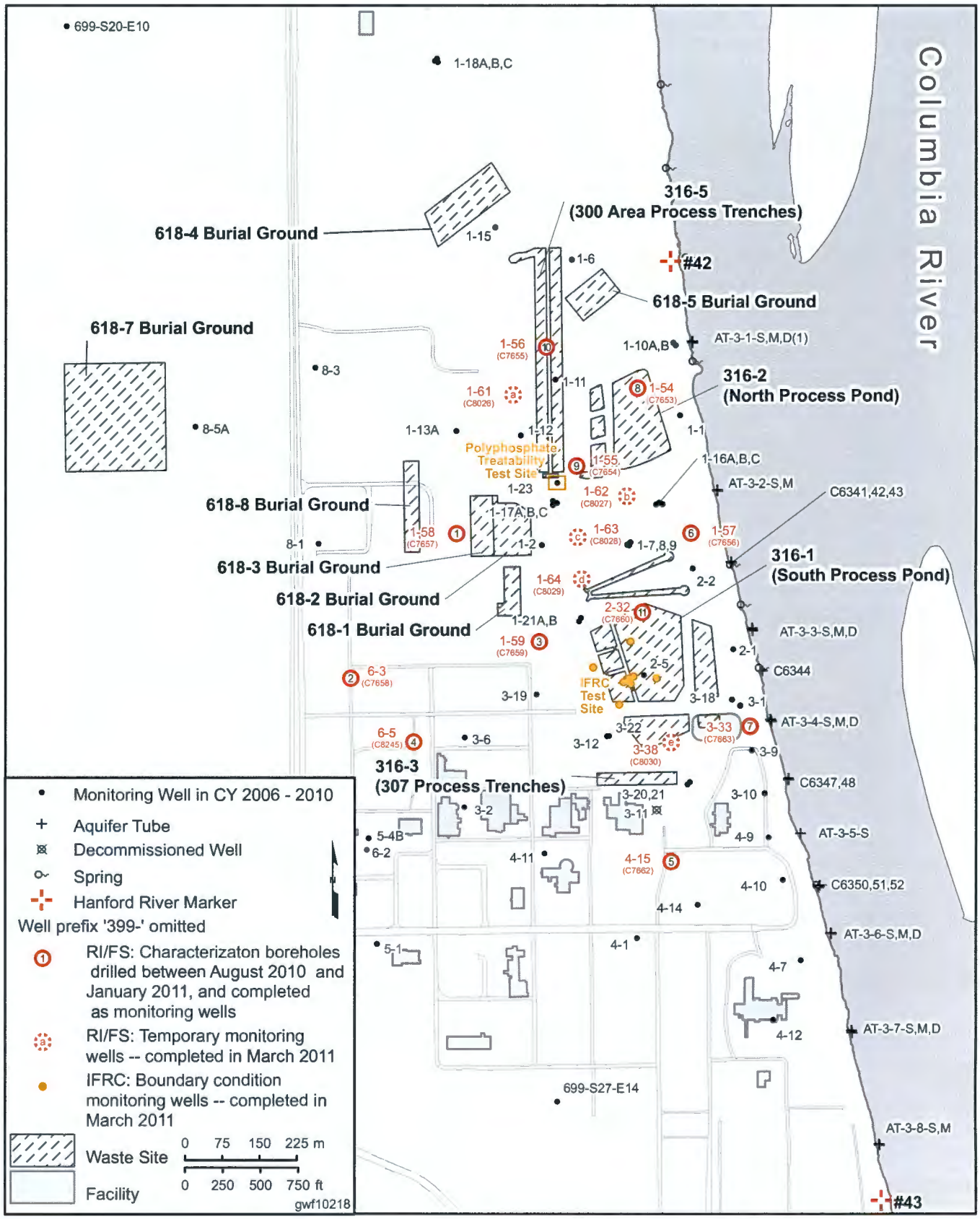


Figure 13-19. 300 Area Index Map Showing Remedial Investigation Drilling Locations, Treatability Test Site, and IFRC Site

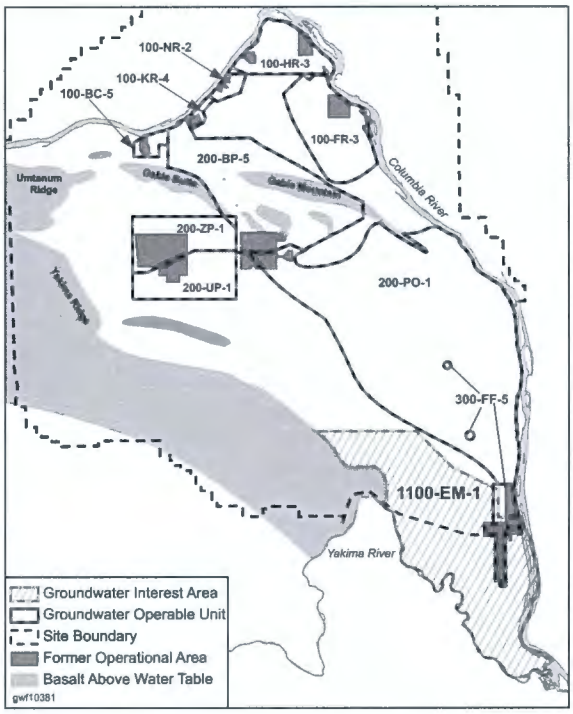


This page intentionally left blank.

14.0 1100-EM-1 Groundwater Interest Area

C.J. Martin

This chapter describes groundwater flow and contaminant distributions in the 1100-EM-1 groundwater interest area, which includes the former 1100-EM-1 Operable Unit (OU) and an area south of the Hanford Site designated as the Richland North Area. The latter includes the areas formerly designated as the 1100 and 3000 Areas. Figure 14-1 shows the facilities and monitoring wells in this region. A brief history of the 1100-EM-1 interest area is presented, including a description of contaminant plumes and concentration trends for the contaminants of potential concern (Section 14.1), along with a discussion of activities associated with the 1100-EM-1 groundwater interest area (Section 14.2). The information in this chapter covers the period from January 1, 2010, through December 31, 2010.



Trichloroethene and nitrate are contaminants of potential concern in groundwater, while uranium has been increasing in wells downgradient of an offsite facility. Groundwater beneath the northern part of the 1100-EM-1 OU portion of the 1100-EM-1 groundwater interest area is monitored to assess the performance of natural attenuation in breaking down volatile organic compounds (VOCs). Groundwater samples are analyzed for trichloroethene and its degradation products, which include 1,2-dichloroethene and vinyl chloride; nitrate and radiological contamination indicators are also monitored. Groundwater monitoring for the *Atomic Energy Act of 1954* is integrated fully with *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring. No active waste disposal facilities or *Resource Conservation and Recovery Act of 1976* (RCRA) sites are located in this area.

The primary site of concern in the 1100-EM-1 groundwater interest area is the former Horn Rapids Landfill (HRL) (Figure 14-1). Located north of Horn Rapids Road near its intersection with Stevens Drive, along the southern boundary of the Hanford Site, the HRL operated from the late 1940s to the 1970s as an uncontrolled landfill. The landfill extends over 0.2 square kilometers of generally flat terrain. Originally a borrow pit for sand and gravel, the HRL was used primarily for disposal of office and construction waste, asbestos, sewage sludge, fly ash, and reportedly numerous drums of unidentified organic liquids (DOE/RL-90-18, *Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*; DOE/RL-92-67, *Final Remedial Investigation/Feasibility Study for the 1100-EM-1 Operable Unit, Hanford*).

Groundwater beneath the 1100-EM-1 groundwater interest area flows primarily west to east and discharges to the Columbia River (Figure 14-2). In the northeastern portion of the groundwater interest area, groundwater flows northeast and converges with groundwater beneath the 300 Area. In the east-central portion of the interest area (Richland North Area), groundwater flow from the west is diverted to the northeast and southeast around a recharge mound near the Richland North Well Field, which developed because of Richland's recharge ponds. The unconfined aquifer beneath the groundwater interest area is recharged by water from the Yakima River, by infiltration of agricultural irrigation in the area between the Yakima and Columbia Rivers, and

Plume areas (square kilometers) above the drinking water standard at the 1100-EM-1 Operable Unit:

Nitrate, 45 mg/L — 4.549

Primarily from offsite sources.

possibly by natural precipitation. Water for agricultural irrigation is mainly extracted from the Columbia River.

Local stratigraphy is consistent with other areas where the Ringold Formation lower mud unit (unit 8) is in direct contact with the basalt. The remainder of the Ringold Formation consists of the fine-grained unit sediments and the mixed coarse and fine layers of units 6 and 7, and the lowermost material of unit 5 (see Chapter 2.0). The gravel- and sand-dominated facies of the Hanford formation unconformably overlie the Ringold Formation units.

None of the wells in the 1100-EM-1 OU penetrate the full thickness of the aquifer; however, wells in the nearby 300 Area suggest that the sediments above the basalt are up to 53 meters thick. The silt and clay-dominated facies of unit 6 form a local, laterally extensive upper aquitard that is up to 10 meters thick. The thickness of the unconfined aquifer in this area is ~5.6 to 9 meters, with all but the upper few meters residing in the Ringold Formation. Because of the significant difference in hydraulic properties between the open-matrixed Hanford formation and the more indurated Ringold sediments, most of the wells used to monitor trichloroethene have screen intervals that penetrate the upper ~4.5 to 7.5 meters of the unconfined aquifer and cross the water table.

Trichloroethene-contaminated groundwater was found both upgradient and downgradient of the HRL. A review of available information indicated that trichloroethene contamination moved into the Hanford Site's 1100 Area via groundwater. AREVA, a facility adjacent to the HRL, has investigated soil and groundwater contamination as an independent action in accordance with WAC 173-340, "Model Toxics Control Act – Cleanup," which is discussed in the *2006 Annual RCRA Report – Groundwater Quality Assessment Program* (E06-02-2006). The past use of organic solvents at the AREVA lagoon area was the only documented record of trichloroethene occurrence or use near the contaminant plume identified during the 1100-EM-1 OU remedial investigation (RI)/feasibility study (FS) (DOE/RL-92-67). Trichloroethene was used during the installation, repair, and cleaning of lagoon liners at various times from 1978 through 1988 (i.e., for bonding overlapping liner sections together). While the HRL was alleged to have received drummed waste solvents (DOE/RL-90-18), soil vapor surveys, geophysical investigations, and trenching activities during the RI/FS did not reveal evidence of a trichloroethene source at the HRL (DOE/RL-92-67).

The *Declaration of the Record of Decision for the 1100 Area* (EPA/ROD/R10-93/063) established natural attenuation as the remedial action alternative for the trichloroethene plume. Site characterization was conducted to evaluate natural attenuation as a remedial action alternative at the HRL site during the RI/FS in the late 1980s and early 1990s (DOE/RL-90-18; DOE/RL-92-67). The degradation of trichloroethene by microbial action may result in the formation of organic compounds such as cis-1,2-dichloroethene and vinyl chloride. These degradation products also pose a risk to human health and the environment and are therefore monitored in groundwater at the site. Since implementation of the selected remedy, concentrations of trichloroethene have declined dramatically and have been below the detection limit from 2008 to 2010. To date, degradation products have not been detected.

14.1 Groundwater Contaminants

Wells in the 1100-EM-1 groundwater interest area are monitored either semiannually, annually, or triennially, and samples are analyzed for chlorinated hydrocarbons (especially trichloroethene), and the co-contaminants nitrate, tritium, gross alpha, uranium, ammonia, and gross beta, under CERCLA and the *Atomic Energy Act of 1954*.

14.1.1 Trichloroethene

Trichloroethene contamination occurs at levels below the 5 µg/L drinking water standard (DWS) in the 1100-EM-1 groundwater interest area beneath the inactive HRL and offsite in wells monitored by AREVA. The distribution of trichloroethene in the upper portion of the unconfined aquifer follows the northeast flow direction, toward the 300 Area.

The past use of solvents to install and maintain process lagoon liners at AREVA is the only potential source of trichloroethene identified in the northern portion of the 1100-EM-1 OU (DOE/RL-92-67). Evidence does not exist for volatile organics having migrated from the HRL or the nearby Richland sanitary landfill. Information reported for the AREVA facility was obtained from AREVA's calendar year (CY) 2010 report (E06-09-003, *EHS&L 2010 Annual Groundwater Report*).

Trichloroethene concentrations continued to be below detection limits during the reporting period.

Trichloroethene concentrations have decreased in all areas near the HRL (Figure 14-3). During CY 2010, trichloroethene concentrations downgradient of the landfill were less than the detection limit of 1.0 µg/L. Potential breakdown products of trichloroethene also remained undetected at a detection limit of 1.0 µg/L during CY 2010. Monitoring results from wells screened at the base of the unconfined aquifer have been below the DWS since monitoring began. These wells remain below the detection limit. For additional information on volatile organic compounds in groundwater beneath the 300 Area, see Chapter 13.0.

The city of Richland monitors groundwater quarterly in the upper portion of the unconfined aquifer for chemical constituents at their Horn Rapids Sanitary Landfill (formerly the Richland Landfill), located ~1 kilometer south of the Hanford Site boundary on Highway 240. Various chlorinated hydrocarbons (e.g., tetrachloroethene, trichloroethene, and vinyl chloride), while exceeding DWSs in several of the city's monitoring wells, show signs of natural attenuation occurring (*Horn Rapids Landfill Environmental Monitoring Report Calendar Year 2009* [City of Richland, 2010]). During CY 2010, chlorinated hydrocarbons were below their respective minimum detection limits at Hanford Site well 699-S31-1, which is northeast of the city's sanitary landfill.

A confined aquifer near the base of the Ringold Formation is also monitored for trichloroethene at locations near the HRL. Two wells, one upgradient and one downgradient of the landfill, monitor this confined aquifer, which lies between a clay-silt aquitard and the underlying basalt surface, at a depth of ~18 to 21 meters below the water table. Trichloroethene has not been detected in this confined aquifer since monitoring began in 1991, suggesting that the trichloroethene plume in the unconfined aquifer did not migrate downward into the underlying confined aquifer.

14.1.2 Nitrate

Nitrate concentrations above the DWS of 45 mg/L are found throughout much of the 1100-EM-1 groundwater interest area (Figure 14-4) and continued to increase in a number of wells during CY 2010. Some of the highest nitrate levels occur near the offsite AREVA facility and the inactive HRL. The highest nitrate concentration in this area was 370 mg/L, downgradient of the AREVA facility. Nitrate data for the AREVA wells are reported in E06-09-003. Nitrate contamination in this area has likely resulted from industrial and agricultural uses off the Hanford Site. Agricultural uses include fertilizer applications to the irrigated fields located west of the 1100-EM-1 groundwater interest area (Figure 14-4).

Elevated nitrate concentrations continued to be measured but are related to offsite industrial and agricultural activities.

The distribution of nitrate and the shape of the nitrate plume near the AREVA facility and the HRL indicate that nitrate in these areas continues to migrate in a northeastern direction, toward the 300 Area (Figure 14-4). Groundwater and aquifer tube sampling data indicate that groundwater with nitrate levels above the DWS has reached the Columbia River immediately south of the 300 Area. Nitrate concentrations in springs near the 1100-EM-1 groundwater interest area came from the 300 Area and ranged from 1.7 to 6.2 mg/L, while the Columbia River had nitrate concentrations of ranging from 0.08 to 0.2 mg/L near the city of Richland's Columbia River pump station (PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*).

14.1.3 Tritium

The site-wide tritium plume that originates in the 200 Area extends southeast through the 600 Area and into the 300 Area and 1100-EM-1 interest area continuing during CY 2010, with tritium concentrations below the DWS of 20,000 pCi/L (Figure 14-5). The leading edge of the sitewide tritium plume is closely monitored because of its proximity to the city of Richland's North Well Field. The background geometric mean tritium concentration in the upper portion of the unconfined aquifer was 63.9 pCi/L (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*). Although tritium levels were above background in several wells near the Richland North Well Field during CY 2010 (maximum concentration of 315 pCi/L), these levels are far below the DWS. Tritium concentration trends in wells located west and north of the Richland North Well Field continue to fluctuate.

Due to the random occurrence of tritium detections and the concentrations measured, it is believed that the tritium plume from the 200 Area is not migrating via groundwater to the Richland North Well Field. The following factors limit migration of the tritium plume into the eastern portion of the 1100-EM-1 groundwater interest area:

- Groundwater generally flows from west to east between the Yakima River, a recharge source, and the Columbia River.
- Artificial recharge from agricultural irrigation in the west and central portions of the 1100-EM-1 groundwater interest area south of the Hanford Site further contribute to the eastward and northeastward flow.
- Groundwater flow is directed radially outward from the elevated groundwater levels at the Richland North Well Field because of the ponds used to recharge the well field.

These factors produce converging groundwater flow lines in the 300 Area where groundwater discharges to the Columbia River (Figure 14-2). Chapter 13.0 discusses tritium in groundwater in the 300 Area.

14.1.4 Gross Alpha and Uranium

Elevated levels of radiological contamination indicators gross alpha and uranium occur downgradient of the AREVA facility, near the HRL. Gross alpha data for the AREVA wells are reported in E06-09-003. During CY 2010, several wells downgradient of the AREVA facility showed gross alpha levels higher than the 15 pCi/L DWS, with the maximum observed concentration of 116 pCi/L immediately downgradient of the AREVA facility (south of Horn Rapids Road). Gross alpha is largely attributed to uranium from fuels manufacturing activities at the facility. The maximum uranium concentration observed was 55.8 µg/L in June 2010 (E06-09-003).

The fiscal year 2006 annual groundwater report (PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*) discussed the distribution of uranium near the HRL. The CY 2010 uranium concentrations in wells downgradient of the HRL increased slightly (maximum of 25.3 µg/L) compared to CY 2009 (maximum of 23.5 µg/L). The presence of uranium at these locations is likely associated with the plume moving northeast from the AREVA facility.

14.2 CERCLA Activities

The 1100-EM-1 OU, including the inactive HRL, was placed on the National Priorities List in 1989 and was delisted from the National Priorities List in 1996. The results of the CERCLA investigation for the 1100-EM-1 OU are presented in the final RI study (DOE/RL-92-67) and the Record of Decision (EPA/ROD/R10-93/063). The selected remedy for groundwater is monitored natural attenuation of VOCs, with institutional controls on drilling of new water supply wells. Monitoring focuses on trichloroethene, its potential degradation products, and nitrate in wells downgradient of the HRL, as recommended in the sampling and analysis plan (PNNL-12220, *Sampling and Analysis Plan Update for Groundwater Monitoring -- 1100-EM-1 Operable Unit*).

The Second CERCLA Five-Year Review Report for the Hanford Site (DOE/RL-2006-20), published in November 2006, stated that the plume mass and concentration have been adequately reduced to be protective of human health and the environment. The review also stated that groundwater monitoring for the 1100-EM-1 OU is no longer necessary but continues following an extended period of monitoring, indicating that contaminant levels are below the DWS and continue to show a downward trend.

In June 2007, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) change notice TPA-CN-163 was approved, which reduced the groundwater monitoring requirements to annual monitoring and analysis of trichloroethene at three of the original network wells (699-S28-12, 699-S31-E10A, and 699-S31-E10C). All three of the wells were sampled for VOCs in CY 2010 (Appendix A, Table A-19).

14.3 Conclusions and Recommendations

Natural attenuation appears to be successful as a remedy for contamination by chlorinated organic compounds in groundwater. During CY 2010, trichloroethene concentrations downgradient of the HRL were less than the detection limit of 1.0 µg/L. Potential degradation products of trichloroethene (e.g., cis-1,2-dichloroethene and

vinyl chloride) also remained undetected, at a detection limit of 1.0 µg/L during CY 2010. Concentrations of nitrate and uranium were elevated during CY 2010; however, these contaminants are associated with non-Hanford Site sources.

Various chlorinated hydrocarbons continue to exceed their respective DWSs in several monitoring wells at the city of Richland sanitary landfill. During CY 2010, chlorinated hydrocarbons were below their respective minimum detection limits at Hanford Site well 699-S31-1, which is northeast of the city's sanitary landfill.

Groundwater monitoring for CY 2011 will continue annually at the three wells downgradient of the HRL in accordance with the sampling and analysis plan. Wells in the area between the Hanford Site boundary and the Richland North Well Field will be sampled semiannually to verify that contaminants from the Hanford Site are not migrating toward the well field.

Figure 14-1. Facilities and Groundwater Monitoring Wells in the 1100-EM-1 Operable Unit

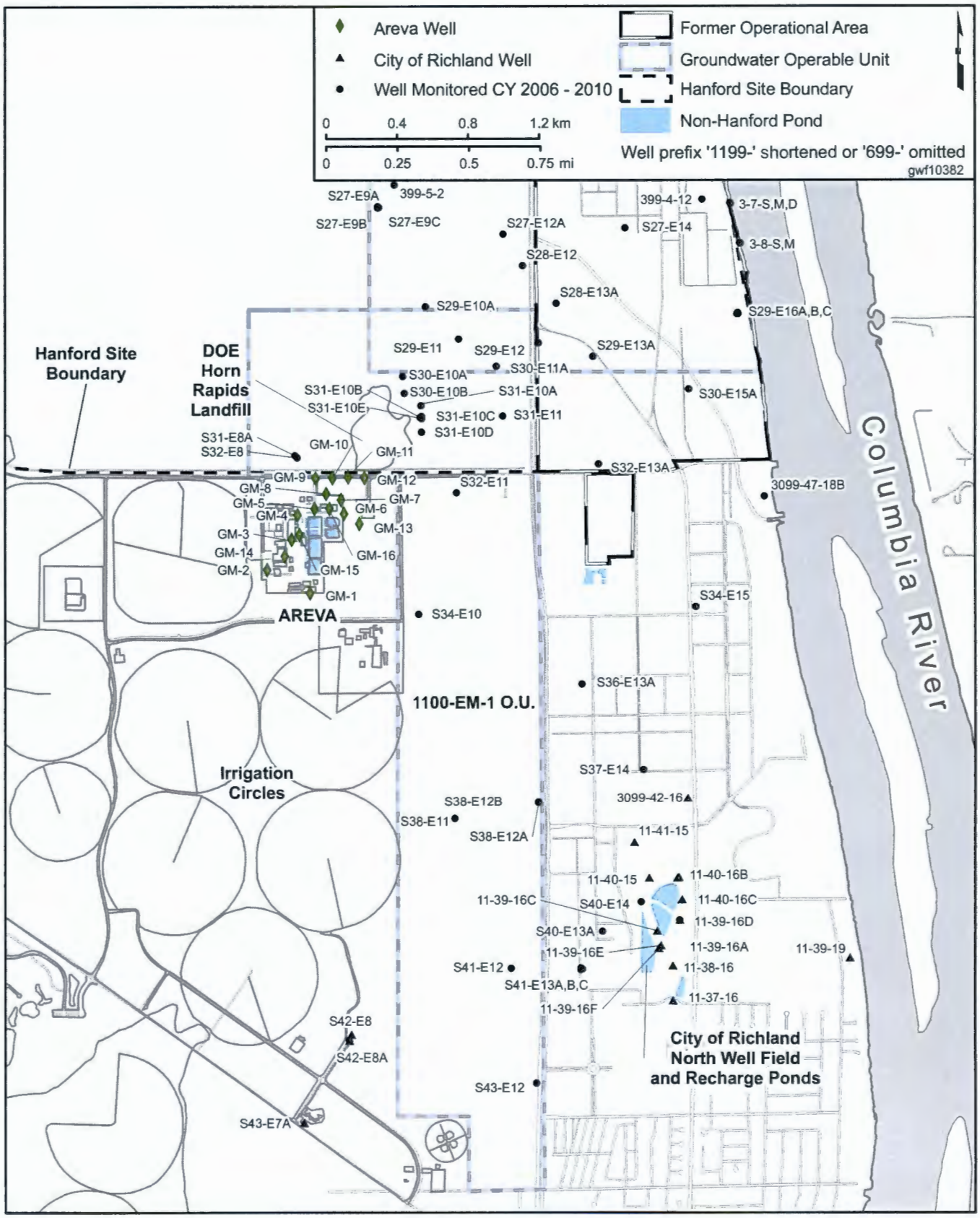


Figure 14-2. 1100-EM-1 Operable Unit and Adjacent 300 Area Water Table Map, March 2010

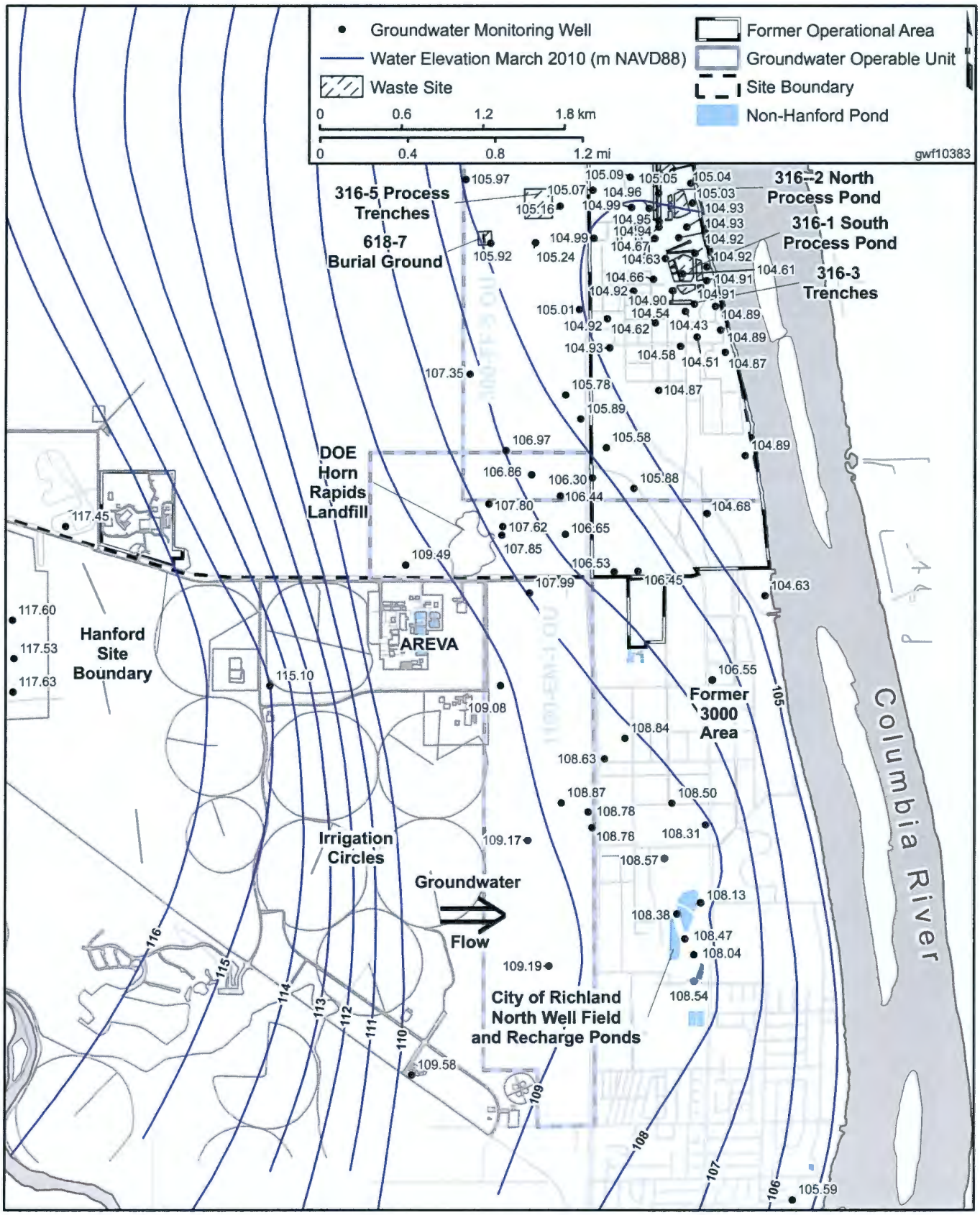


Figure 14-3. Trichloroethene Concentrations in 1100-EM-1 Operable Unit and Adjacent Richland North Area, Upper Portion of Unconfined Aquifer

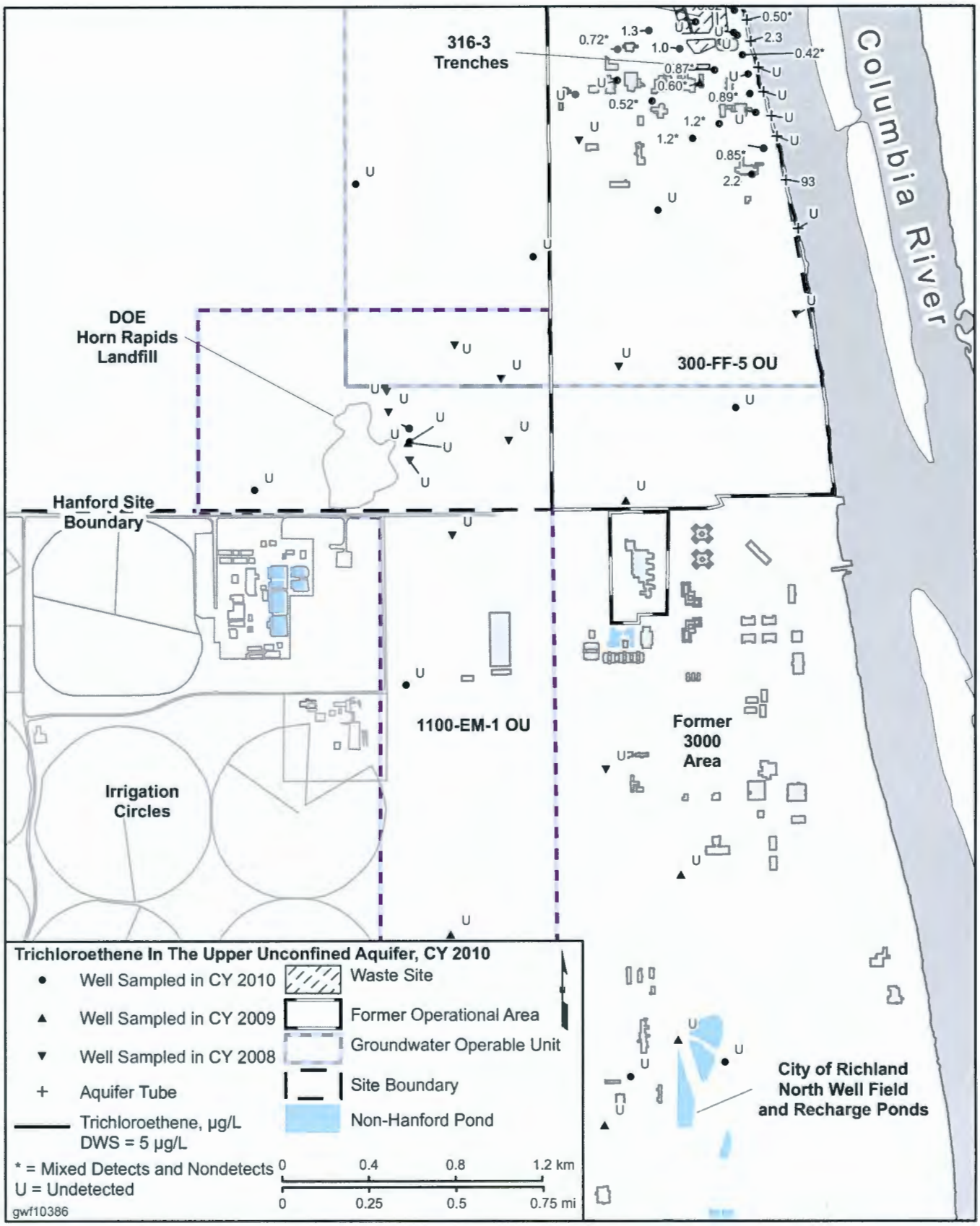


Figure 14-4. Average Nitrate Concentrations in the 1100-EM-1 Operable Unit and Adjacent 300 Area, Upper Portion of Unconfined Aquifer

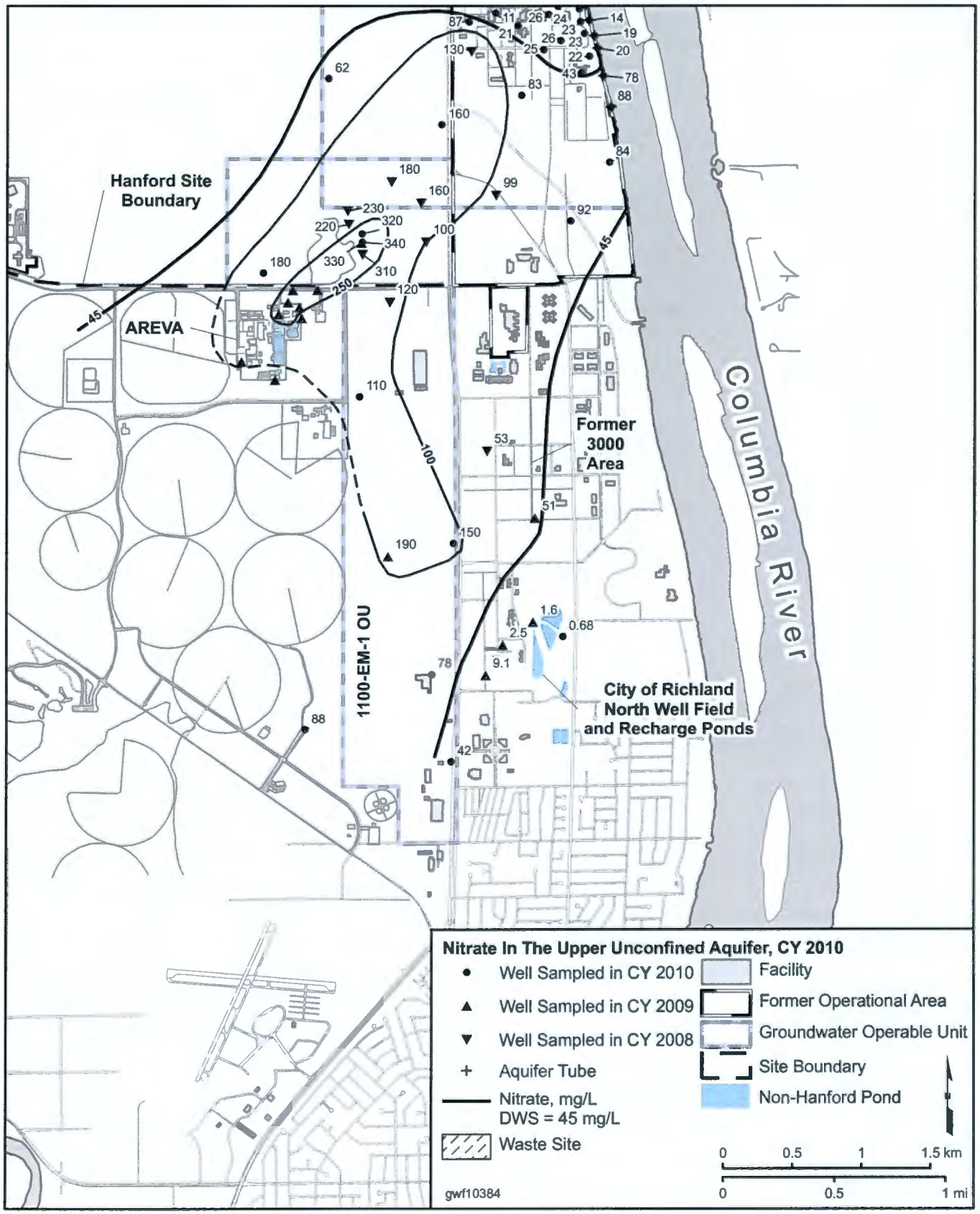
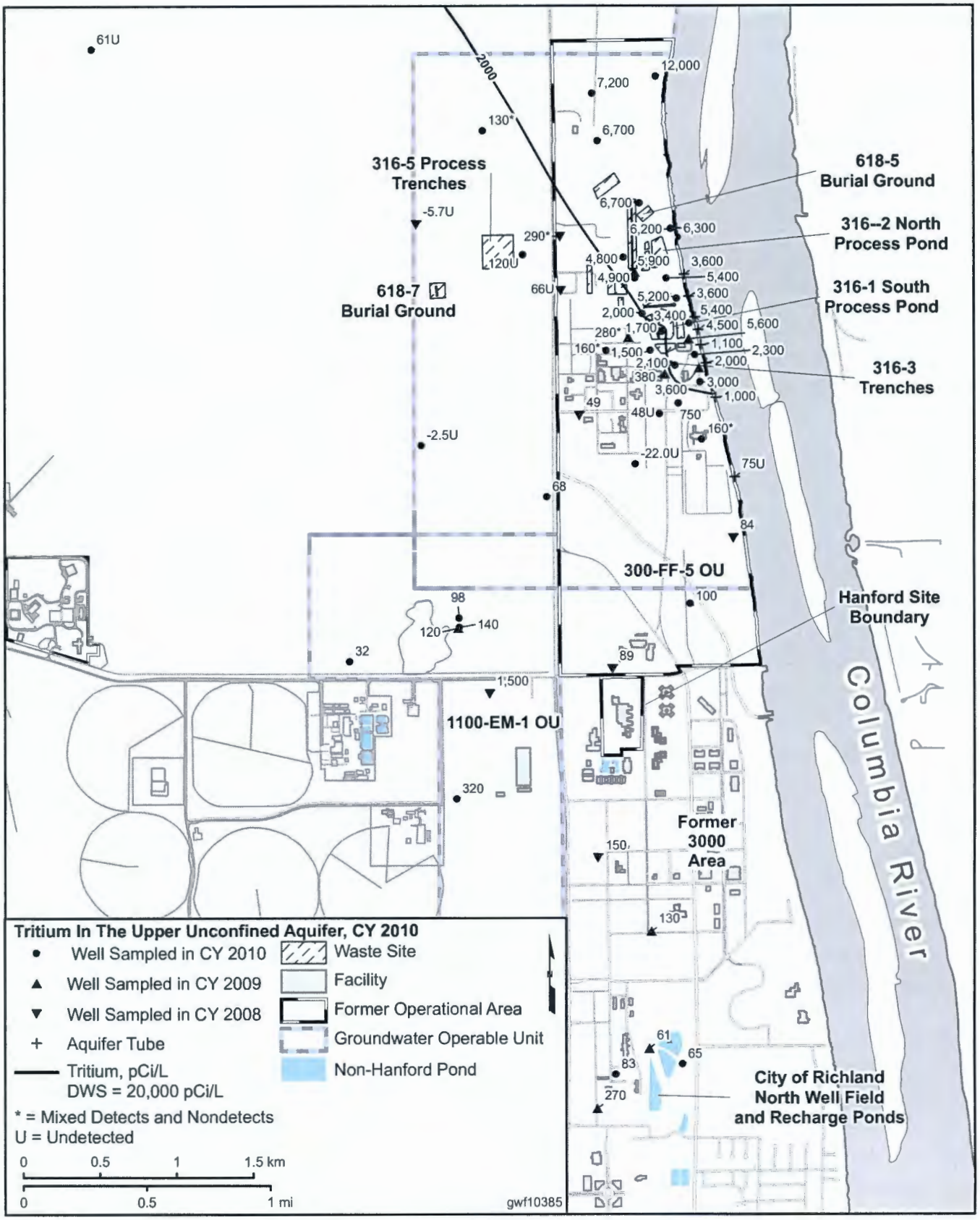


Figure 14-5. Average Tritium Concentrations in the 1100-EM-1 Operable Unit and Adjacent 300 Area, Upper Portion of Unconfined Aquifer



This page intentionally left blank.

15.0 Confined Aquifers

C.J. Martin

This chapter describes groundwater flow and groundwater quality in confined aquifers within the Ringold Formation and in confined aquifers present in the upper portion of the Columbia River Basalt Group. The information provided in this chapter covers the period from January 1, 2010, through December 31, 2010.

A confined aquifer in the Ringold Formation exists beneath much of the Hanford Site, including the 100 and 300 Areas, but it has been described only for the 200 Area of the Central Plateau because only a few wells are completed in this aquifer outside of the Central Plateau. The upper basalt-confined aquifer system has also been identified beneath much of the Hanford Site, but it is monitored only in the area where intercommunication with the unconfined aquifer has been shown to occur, primarily south of Gable Butte and Gable Mountain. Figure 2-2 in Chapter 2.0 depicts the stratigraphy associated with the various aquifers beneath the Hanford Site.

Intercommunication between the unconfined aquifer and the underlying confined aquifers is an important consideration for environmental cleanup activities at the Hanford Site. To develop Records of Decision for final action in the various groundwater operable units (OUs), the nature and extent of groundwater contamination in all aquifers potentially impacted must be characterized sufficiently (1) to evaluate risk to human health and the environment; and (2) to identify, evaluate, and select a remedial action alternative. This necessarily includes assessing the degree to which the upper basalt-confined aquifer system may have been affected by groundwater plumes in the unconfined aquifer. Several studies have been conducted regarding communication between these aquifers, and the following discussion briefly summarizes the current conceptual model. *Hanford Site Groundwater Monitoring for Fiscal Year 2007* (DOE/RL-2008-01) discusses this topic in detail and provides an analysis of the potential for aquifer intercommunication on the Hanford Site.

Intercommunication between the upper basalt-confined aquifer and the overlying unconfined aquifer systems may occur where a pathway exists for movement of water, as well as a difference in hydraulic head between the two systems. An area of intercommunication between the unconfined and upper basalt-confined aquifer systems was first identified in the northern portion of the 200 East Area (RHO-BWI-ST-5, *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*). Intercommunication between the unconfined and confined aquifers in this region is attributed to erosion of the upper Saddle Mountains Basalt and a downward hydraulic gradient resulting from groundwater mounding associated with past wastewater disposal to receiver ponds in the area (e.g., 216-B-3 Pond and Gable Mountain Pond). However, since 1984, the groundwater mound beneath Gable Mountain Pond has dissipated completely, and the mound beneath the 216-B-3 Pond has diminished significantly, decreasing more than 3 meters since discharges ceased.

Additional studies (including PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*; PNL-10817, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System*; RHO-ST-38, *Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond Area*; and RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*) delineated areas of erosion in the basalt extending from Gable Gap across the northern portion of the

200 East Area to B Pond. The extent of this area of erosion does not encompass Gable Mountain Pond, but the western lobe of B Pond does overlie the area where the Elephant Mountain Basalt has been partially removed by erosion (Figure 15-1).

Another location where intercommunication between aquifers is known to have occurred is centered on well 299-E33-12 in the northwestern portion of the 200 East Area. This well was drilled in 1953 into the Pomona Basalt underlying the Rattlesnake Ridge interbed and was uncased from just above the bottom of the unconfined aquifer through the Rattlesnake Ridge interbed. Contamination is believed to have migrated from the unconfined aquifer, down the open borehole, to the Rattlesnake Ridge interbed (DOE/RL-2008-1). The well was sealed from the unconfined aquifer in the early 1980s, with an additional seal placed in the well in 1990 to shorten the open interval. Concentrations of waste indicators cyanide, nitrate, technetium-99, and tritium continue to be elevated in samples from this well (see Section 15.2.2).

15.1 Ringold Formation Confined Aquifer

Confined water-bearing units are present in the Ringold Formation at various locations beneath the Hanford Site. The most widespread Ringold confined aquifer is where the lowermost sediments of Ringold Formation hydrologic unit 9 are overlain by the Ringold lower mud unit (see Figure 2-8 in Chapter 2.0). In the 100-HR-3 OU, a locally confined aquifer that occurs beneath the Ringold upper mud unit is being studied (see Chapter 7.0). In the 300 Area, several wells are completed in a confined transmissive unit within the Ringold lower mud unit (see Chapter 13.0).

In the 200 East Area, another locally confined aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of Ringold Formation hydrologic unit 9. This aquifer is confined between the bottom of the lower mud unit and the top of the uppermost basalt. Where hydrologic unit 9 is overlain by fine-grained units, confined conditions generally exist. Where hydrologic unit 9 is absent beneath the lower mud unit, limited vertical groundwater flow may occur. This confined aquifer is of concern because of its location relative to contamination sources in the 200 East Area. Wells completed in the lower portion of the unconfined aquifer above the lower mud unit in regions where hydrologic unit 9 is absent provide information on the distribution of contaminants in the lowermost portion of the unconfined aquifer system.

Approximately 36 wells/piezometers are currently available to monitor the Ringold confined aquifer on the Hanford Site. Of these wells/piezometers, 13 are used for water-level monitoring and have either one or no chemical analysis results; the remaining 23 have regular analytical results. Seven of the 23 wells/piezometers were sampled in calendar year (CY) 2010. Of these seven, four were also sampled in CY 2009.

15.1.1 Groundwater Flow in the Ringold Confined Aquifer

J.P. McDonald

Figure 15-2 presents the interpreted potentiometric surface for a portion of the Ringold confined aquifer for March 2010. This map is subject to uncertainty because only a few wells monitor this aquifer. However, generalized flow patterns can be inferred from available data when the hydrogeologic framework (i.e., extent of the confined unit, presence of basalt subcrops, and influence of the May Junction Fault) is considered.

Groundwater flow in the Ringold confined aquifer is generally west to east near the 200 West Area and along the southern boundary of the aquifer near the Rattlesnake Hills. This flow pattern indicates that recharge occurs west of the 200 West Area in upgradient areas within the Cold Creek Valley, as well as in the Dry Creek Valley and possibly the Rattlesnake Hills. Near the 200 East Area, flow in the Ringold confined aquifer converges from the west, south, and east before discharging to the unconfined aquifer where the lower mud unit is absent (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, Section 4.2.3). This water is thought to flow southeast over the top of the confining unit (PNNL-15479, *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility*, Section 2.3). Near the 200 East Area, water-level elevation data from piezometers 299-E25-32P and 299-E25-32Q (used to monitor different depths in the unconfined aquifer) indicate a slight upward gradient along the confined unit boundary. This upward gradient is consistent with discharge of groundwater from the confined aquifer to the overlying unconfined aquifer.

As a remnant of past wastewater discharges to the 216-B-3 Pond (B Pond), artificially elevated water levels are present in the Ringold confined aquifer to the northeast of this facility, which causes a southwest flow beneath B Pond to the 200 East Area. Eastward flow away from the region of elevated water levels does not occur; the May Junction Fault, located east of the B Pond area, is thought to be a hydrologic barrier preventing flow to the east (PNNL-15479, Section 3.1). South of the B Pond area, the flow of water divides, with some flow moving northwest toward the 200 East Area and some moving east or southeast. The exact location of the flow divide is not known due to a lack of water-level data in this area and a need to define the southward extent of the May Junction Fault.

The potentiometric contours for the Ringold confined aquifer (Figure 15-2) are similar to the potentiometric surface contours for the upper basalt-confined aquifer system, indicating that flow patterns in the central portion of the Hanford Site are similar in both aquifers. Basalt bedrock from the topographic low at Gable Gap near the 200 East Area was eroded significantly by late Pleistocene catastrophic flooding (PNNL-19702, Section 7.0), which facilitates intercommunication between the unconfined and confined aquifers. The 200 East Area is a discharge area for both of the confined aquifers, which explains the similar flow patterns.

Water levels declined throughout much of the Ringold confined aquifer from March 2009 to March 2010. The decline in individual wells ranged from 0.04 to 0.23 meters. The potentiometric surface is responding to the reduction of liquid effluent discharges to the ground since discharge volumes peaked in the mid-1980s.

15.1.2 Groundwater Quality in the Ringold Confined Aquifer

The 200 Area of the Central Plateau and the area near the inactive B Pond system are two known areas where conditions may allow contamination to migrate from the unconfined aquifer into the Ringold confined aquifer. Groundwater chemistry data for the Ringold confined aquifer are limited to wells north of the 200 Area and near B Pond, and in the 300 Area. During CY 2010, seven wells completed in the Ringold confined aquifer were sampled (Figure 15-3). Table 15-1 provides data for selected contaminants of interest from the sampled wells.

Tritium is the only constituent to exceed DWSs in the Ringold confined aquifer.

During CY 2010, only one waste indicator constituent, tritium, exceeded the drinking water standard (DWS) of 20,000 pCi/L for wells completed in the Ringold confined aquifer. Well 699-41-40 (located near the B-3 Pond) had a tritium concentration of 36,000 pCi/L. This well is sampled every 3 years and has shown a steadily declining trend since 1990.

Other detected contaminants potentially associated with Hanford Site operations include tritium in wells 699-28-40 and 699-31-31 downgradient of the 200 East Area; wells 699-41-40, 699-42-39B, and 699-42-42B near the B-3 Pond; and tritium and uranium in well 699-S28-E0 near the 300 Area. Concentrations measured during the reporting period were consistent with historical results. Tritium shows a long-term declining trend, while uranium concentrations increased in both wells. With the exception of tritium, which shows a decreasing trend in wells where it is detected, all other constituents show stable long-term trends, with only minor variations.

15.2 Upper Basalt-Confined Aquifer System

C.J. Martin

Groundwater quality in the upper basalt-confined aquifer system is monitored due to the potential for downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer system may have the potential to migrate through the aquifer to areas of exposure off the Hanford Site, such as the Columbia River downstream of the Tri-Cities (i.e., Richland, Kennewick, and Pasco). The upper basalt-confined aquifer system is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources. PNL-10817 and *Groundwater Chemistry and Hydrogeology of the Upper Saddle Mountains Basalt-Confined Aquifer South and Southeast of the Hanford Site* (PNNL-14107) provide additional information on the potential for contaminants to migrate off the Hanford Site. A large source of additional information is available through the reports of the Basalt Waste Isolation Project that was performed on the Hanford Site in the 1980s.

Within the upper basalt-confined aquifer system, groundwater occurs primarily within sedimentary interbeds and at interflow contacts but is also present in basalt fractures and joints (see Figure 2-2 in Chapter 2.0). The thickest and most widespread upper sedimentary unit in this system is the Rattlesnake Ridge interbed, which is present beneath a large portion of the Hanford Site. Groundwater also occurs within the Levey interbed, which is present only in the southern portion of the Hanford Site. An interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt and may be significant to the lateral transmission of water where it occurs. Overall, this system is confined by the dense, low-permeability, interior portions of basalt flows and, in some places, by Ringold Formation silts and clays (lower mud unit) overlying the basalt.

Approximately seventy wells have been completed in the Columbia River Basalt Group. Of this total, 32 wells are completed in deeper interbeds/basalts or are screened across multiple intervals, 16 wells are completed in the Rattlesnake Ridge interbed, 9 wells are completed in the Elephant Mountain Basalt, and 7 wells have completion intervals that include both the Elephant Mountain Basalt and the Rattlesnake Ridge interbed. During CY 2010, fifteen wells were sampled, with analyses for at least one constituent. Figure 15-3 shows the location of the upper basalt-confined aquifer system monitoring wells on the Hanford Site. Of the fifteen wells sampled, seven wells are in the Rattlesnake Ridge interbed, three wells are across the Elephant Mountain Basalt/Rattlesnake Ridge interbed, two wells are in the Elephant Mountain Basalt, and one well is open across multiple deep intervals. The exact unit monitored by the two remaining wells is unclear, but these two wells are likely completed in the Rattlesnake Ridge interbed based on well depth.

15.2.1 Groundwater Flow in the Upper Basalt-Confined Aquifer System

J.P. McDonald

Figure 15-4 presents the interpreted March 2010 potentiometric surface for the upper basalt-confined aquifer system south of Gable Butte and Gable Mountain. The region to the north of Gable Butte and Gable Mountain was not contoured due to insufficient well control. *Preliminary Potentiometric Map and Flow Dynamic Characteristics for the Upper-Basalt Confined Aquifer System* (PNL-8869, Plate 1) provides a generalized potentiometric surface map of this area. The upper basalt-confined aquifer system does not exist in the Cold Creek Valley and along the west portion of the Gable Mountain/Gable Butte structural area due to the absence of the Rattlesnake Ridge interbed.

Recharge to the upper basalt-confined aquifer system likely occurs from upland areas along the margins of the Pasco Basin and results from the infiltration of precipitation and surface water where the basalt and interbeds are exposed at or near ground surface. Recharge may also occur from the overlying aquifers (i.e., the unconfined aquifer or Ringold confined aquifer) in areas where the hydraulic gradient is downward and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge to this aquifer system. The Columbia River represents a discharge area for this aquifer system in the southeastern portion of the Hanford Site where the river has a lower head than the upper basalt-confined aquifer, but not for the northern portion of the site where the river head is higher (PNL-8869, Section 3.2). Discharge also occurs to the overlying aquifers in areas where the hydraulic gradient is upward. Discharge to the overlying unconfined aquifer near the Gable Butte/Gable Mountain structural area is believed to occur through erosional windows in the basalt.

South of Gable Butte and Gable Mountain, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site, toward the Columbia River. The north-south trending May Junction Fault, located east of B Pond, acts as a barrier to groundwater flow in the unconfined aquifer and the Ringold confined aquifer (PNNL-15479, Section 3.1). It may also impede the movement of water in the upper basalt-confined aquifer system by juxtaposing permeable units opposite impermeable units. As with the Ringold confined aquifer, a flow divide is interpreted to exist southeast of the 200 East Area and B Pond in the upper basalt-confined aquifer system, but the exact location of this divide is uncertain due to a lack of wells in the area.

Groundwater flow rates within the Rattlesnake Ridge interbed have been estimated between 0.7 and 2.9 meters per year (PNL-10817, Section 4.2), which is a considerably lower flow rate than most estimates for the overlying unconfined aquifer system. The sediment comprising the interbed consists mostly of sandstone, with some silts and clays, and is much less permeable than the sediments in the unconfined aquifer. Also, the magnitude of the hydraulic gradient is generally lower than in the unconfined aquifer.

The vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer varies spatially, as shown by comparison of observed heads (Figure 15-5). A downward gradient exists in the central portion of the Hanford Site, near the B Pond recharge mound, as well as in regions north and east of the Columbia River. Near the B Pond, the vertical head gradient between the unconfined aquifer

system and the upper basalt-confined aquifer system has diminished in recent years but remains downward. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer system to the overlying aquifer system.

In the 200 East Area, the potentiometric surface (Figure 15-4) is similar to the potentiometric surface for the Ringold confined aquifer (Figure 15-2). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication (PNNL-19702, Section 7.0). In the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer is upward. It is likely that the upper basalt-confined aquifer system currently discharges to the overlying aquifer in this region.

Water levels in the upper basalt-confined aquifer system declined throughout the Hanford Site from March 2009 to March 2010. In the 200 East Area and to the immediate north and east (near B Pond), water-level declines in wells were up to 0.15 meters, and water levels declined up to 0.14 meters in wells near the 200 West Area. These declines are in response to reduced effluent disposal activities in the 200 Area and are consistent with water-level declines in the overlying unconfined aquifer and Ringold confined aquifer. The largest decline occurred in well 699-S24-19P (0.39 meters) near the Yakima River.

15.2.2 Groundwater Quality in the Upper Basalt-Confined Aquifer System

The upper basalt-confined aquifer system is not affected by contamination as much as the overlying unconfined aquifer system. Contamination found in the upper basalt-confined aquifer system is most likely to occur in areas where the basalt-confined units have been eroded away or were never deposited, and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. Although areas of intercommunication between the contaminated unconfined aquifer and the upper basalt-confined aquifer are well documented to date, groundwater monitoring data do not indicate that substantial contamination has migrated from the unconfined aquifer into the upper basalt-confined aquifer. In some areas, wells constructed prior to implementation of WAC 173-160 ("Minimum Standards for Construction and Maintenance of Wells") and penetrating the upper basalt-confined aquifer system lacked an impermeable seal between the well casing and the borehole wall. This provided a direct conduit between the upper unconfined and deeper confined aquifers. When this is discovered, the wells are either modified by installing an impermeable seal or are decommissioned using a method to isolate the aquifer. As a result of poor well seals, intercommunication between the aquifers permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer, increasing the potential to spread contamination. Section 2.14.2.3 of DOE/RL-2008-01 discusses the communication between the upper basalt-confined aquifer system and the overlying aquifers.

Wells completed in the upper basalt-confined aquifer system are routinely sampled on the Hanford Site. Most of these wells are sampled every 3 years, but a few wells are sampled annually. During CY 2010, twenty wells were sampled and 348 analyses were performed for chemical and radiological constituents. Many of the samples were analyzed for tritium, iodine-129, and nitrate, which are the most widespread constituents in the overlying unconfined aquifer and are some of the most mobile constituents in groundwater. Detection of tritium, iodine-129, and nitrate provides an early warning for potential contamination in the upper basalt-confined aquifer

system. Groundwater samples from the upper basalt-confined aquifer system were also analyzed for anions (other than nitrate), major cations, cyanide, gross alpha, gross beta, gamma emitters, strontium-90, technetium-99, and uranium isotopes. Data for selected contaminants of interest are provided in Table 15-2. A full data set is included in the data files accompanying this report.

Initially, high concentrations of contaminants (above DWSs) in new well 299-E33-340 declined significantly during the reporting period.

Well 299-E33-340 was installed as part of the 200-BP-5 OU remedial investigation in fiscal year 2008 within the upper basalt-confined aquifer system. The data reported in *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (DOE/RL-2008-66) were collected shortly after the well was completed and, more importantly, prior to well development. The concentrations of cyanide, nitrate, nitrite, and technetium-99 were all well above their respective DWSs at that time. This well was developed on October 13, 2008, with the next samples collected January 12, 2009. Concentrations of cyanide, nitrate, nitrite, and technetium-99 (as well as elevated concentrations of chloride, sulfate, tritium, and uranium) all showed a significant decline (over 90% for cyanide, nitrate, nitrite, technetium-99, and tritium). For the remainder of the reporting period, this well showed constituent concentrations consistent with the nearby upper basalt-confined aquifer well 299-E33-50. Therefore, it is believed that the initial high values were not representative of true aquifer conditions.

15.2.2.1 Anions

Nitrate and cyanide remain elevated in the 200 East Area during the reporting period, but neither constituent exceeded the respective DWS.

Because of their negative charge, anions are more mobile than most other contaminants. The anions most related to contamination from Hanford Site operations are nitrate and cyanide. During the reporting period, neither of these constituents exceeded their respective DWS. Concentrations of cyanide and nitrate in well 299-E33-340 declined to levels consistent with other upper basalt-confined wells in CY 2009 and remained at those levels throughout CY 2010, further supporting the belief that the initial high concentrations were the result of contamination drawn down during the drilling process. Well 299-E33-12 was the only other well with elevated levels of cyanide and nitrate, which is consistent with previous years and is attributed to migration of contaminated groundwater from the unconfined aquifer moving down the borehole during well construction when it was open to both the unconfined and confined aquifers, as discussed in the intercommunication assessment report (RHO-RE-ST-12P).

As in previous years, the only anion to exceed a DWS was fluoride in well 699-S2-34B, which is located in the south-central portion of the Hanford Site. The concentration of fluoride in this well has always been reported above the DWS. Because this well is removed from any potential contamination source, the fluoride levels are likely naturally occurring in that portion of the aquifer. This is further supported based on its location near an area of known confined aquifer high fluoride water (e.g., near the Laser Interferometer Gravitational-Wave Observatory facility).

15.2.2.2 Metals

Iron and manganese are the only metals to exceed DWSs.

Contamination associated with metals from Hanford Site operations tends to be rapidly sorbed before reaching the unconfined aquifer. The major metal of concern is chromium, which is more prevalent along the River Corridor than in the Central Plateau area. Chromium concentrations in the upper basalt-confined aquifer wells were all below the detection limit during the reporting period, with the exception of well 699-50-53B. The chromium concentration in this well was 17 μg/L, just above the reporting limit of 14 μg/L. This well is located north of the 200 East Area and has previously had positive detections.

The concentrations of the major soil elements (i.e., calcium, magnesium, potassium, and sodium) and most trace elements (e.g., barium, strontium, vanadium, and zinc) remained at levels similar to those of previous years.

Two metals, iron and manganese, exceeded their secondary DWS concentrations in filtered samples from several wells in the upper basalt-confined aquifer. Iron was above the secondary DWS of 300 µg/L in well 699-54-34 at 965 µg/L (adjacent to Gable Mountain). The concentration of 1,650 µg/L in well 699-49-55B is out of trend and likely an artifact of contamination in the sample. This is supported by the fact that the August 2010 sample was back in trend and an order of magnitude lower at only 133 µg/L.

The manganese secondary DWS of 50 µg/L was exceeded in four wells: 299-E33-50, 299-E33-340, 699-49-55B, and 699-54-34. The maximum concentration measured during CY 2010 (in March sampling) was 128 µg/L in well 699-49-55B. As stated above for the iron result, this value is likely nonrepresentative, as the August value had decreased to 16 µg/L. Concentrations in the other three wells are consistent with previous results.

Two possible reasons for the elevated levels of manganese and iron in upper-basalt-confined aquifer wells are (1) natural variation related to the breakdown of basalt minerals high in manganese and iron, or (2) degradation of the well casing releasing these metals to the groundwater. The latter reason seems unlikely at two locations, however, because wells 299-E33-340 and 299-E33-50 were installed less than 4 years ago.

15.2.2.3 Radionuclides

No radionuclides exceeded DWSs during the reporting period.

Radionuclide contamination is a concern in the upper basalt-confined aquifer system due to the large amounts released to the subsurface during Hanford Site operations. Radionuclides are also of concern due to their mobility (e.g., tritium and technetium-99) and/or their long half-lives (e.g., iodine-129 at 15.7 million years).

None of the wells exceeded the DWS for tritium (20,000 pCi/L) during CY 2010. The maximum concentration measured during the reporting period was 3,500 pCi/L in well 699-42-40C, which is located near the 216-B-3 Pond east of the 200 East Area. Low levels of tritium (less than 1,000 pCi/L) were measured in the basalt-confined aquifer near the center of the Hanford Site in CY 2010. Most of the positive tritium results are in the 200 East Area/Gable Mountain region, which is in an area of intercommunication with the overlying contaminated unconfined aquifer. Nearby wells completed in the unconfined aquifer in the Ringold Formation (e.g., well 699-43-41G) show elevated but declining trends. A slight downward hydraulic gradient continues to exist at this location.

In the northern portion of the 200 East Area, technetium-99 continued to be elevated in the upper basalt-confined aquifer system in wells 299-E33-12, 299-E33-50, and 299-E33-340. These wells are located within the technetium-99 plume in the overlying unconfined aquifer (see discussion in Chapter 9.0). The maximum technetium-99 concentration during the reporting period was 1,300 pCi/L in well 299-E33-12. This well is known to have contamination that resulted from flow down along the unsealed borehole. Concentrations in well 299-E33-340 continued to decline significantly, from a concentration of 26.6 pCi/L in January 2010 to 12.9 pCi/L in August 2010. These concentrations are more representative of the basalt-confined aquifer and are consistent with the technetium-99 concentration in well 299-E33-50.

Samples collected from upper basalt-confined aquifer system wells were also analyzed for iodine-129. Iodine-129 was detected in wells 699-42-40C and 699-49-55B in the upper basalt-confined aquifer system during CY 2010 (Table 15-2). The maximum concentration reported was 0.32 pCi/L in well 699-49-55B. Concentrations in well 299-E33-340 decreased to below the DWS of 1 pCi/L in June 2009 and remained below the detection limit throughout CY 2010.

Groundwater samples from upper basalt-confined aquifer system wells were also analyzed for gamma-emitting radionuclides and uranium isotopes. During CY 2009, gamma-emitting radionuclides were not detected in the upper basalt-confined aquifer system on the Hanford Site, including the Gable Mountain/200 East Area.

No uranium isotopes (uranium-234, uranium-235, or uranium-238) were observed in the upper basalt-confined aquifer in CY 2010. The only other radionuclides detected were naturally occurring carbon-14, at 34.7 pCi/L in well 299-E33-50 in January 2010, and potassium-40 in August in wells 699-42-40C and 699-42-E9B at concentrations of 30.4 pCi/L and 36 pCi/L, respectively

15.2.2.4 Field Parameters

A series of general water quality parameter measurements were obtained in CY 2010. The parameters for dissolved oxygen, oxygen-reduction potential, pH, specific conductance, temperature, and turbidity are collected in the field at the time of sampling, while other parameters (e.g., alkalinity) are measured in the laboratory. These parameters provide information on the overall character of the upper basalt-confined aquifer system. There are no regulatory guidelines for the values of these parameters, and the value ranges tend to be very narrow. The ranges, as well as minimum and maximum values, are presented in Table 15-3.

15.3 Conclusions and Recommendations

No significant changes occurred in contaminant concentrations in the confined aquifers. The naturally occurring trace metals iron and manganese continue to exceed their respective DWSs in some wells near and northwest of the 200 East Area. Radionuclides are also found in measurable concentrations in this area. Since the reduction of wastewater discharges to the ground surface, the hydraulic gradient in the confined aquifers has returned to its pre-Hanford condition of flowing from the confined aquifers into the unconfined aquifer over much of the site. A localized area with a downward hydraulic gradient still exists near the 216-B-3 Pond and 200 East Area. The zone of downward flow in the western portion of the site is likely natural and related to recharge of the upper basalt-confined aquifer.

The single largest recommendation for these aquifers is to continue monitoring on a regular basis. A revised groundwater monitoring plan covering monitoring of the confined aquifers throughout the Hanford Site was issued for review in late 2010 and is planned for issuance by late 2011.

Table 15-1. Potential Contaminants of Interest in Ringold Confined Aquifer, 2008 Through 2010

Well	Sample Date	Specific Conductance (µS/cm)	Nitrate (mg/L)		Uranium (µg/L)		Tritium (pCi/L)		Chromium (Filtered) (µg/L)		Iron (Filtered) (µg/L)		Manganese (Filtered) (µg/L)	
199-H4-15CQ	11/24/08	244	--		--		--		--		--		--	
199-H4-15CQ	6/9/09	281	--		--		--		--		--		--	
199-H4-15CQ	11/9/09	306	--		--		--		--		--		--	
199-H4-15CQ	5/16/10	279	--		--		--		--		--		--	
199-H4-15CR	1/3/08	249	2.7	D	--		--		49.9		17.6	C	4	U
199-H4-15CR	11/24/08	342	--		--		--		--		--		--	
199-H4-15CR	6/9/09	270	--		--		--		--		--		--	
199-H4-15CR	11/9/09	345	--		--		--		--		--		--	
199-H4-15CR	5/16/10	271	--		--		--		--		--		--	
199-H4-15CS	1/3/08	253	5.18	D	120	U	2.51		100		9	U	4	U
199-H4-15CS	5/29/08	249	--		--		--		--		--		--	
199-H4-15CS	11/24/08	252	--		--		--		--		--		--	
199-H4-15CS	6/10/09	252	--		--		--		--		--		--	
199-H4-15CS	11/9/09	268	--		--		--		--		--		--	
199-H4-15CS	5/16/10	257	--		--		--		--		--		--	
399-1-9	1/18/08	370	0.44	UD	0.05	U	--		4	U	173		**65.6**	
399-1-9	1/6/09	361	0.089	UD	0.05	U	--		13	U	164		**60.9**	
399-1-9	12/28/09	371	0.274		1.41	D	--		13	U	116	C	**62.2**	
399-1-16C	1/31/08	367	0.25	U	0.05	U	--		4	U	77.6		**50.4**	
399-1-16C	12/31/08	380	0.106	UD	0.05	U	--		13	U	80.9	B	49.6	
399-1-16C	12/14/09	377	0.274		0.1	UD	--		13	U	85.7	B	49.5	
399-1-17C	1/17/08	381	0.047	BDX	0.05	U	--		4	U	52.7		17.7	
399-1-17C	12/30/08	384	0.173	BD	0.0885	B	--		10	U	46.2	B	17.9	
399-1-17C	12/28/09	392	0.274		0.698	D	--		13	U	60.5	BC	23.1	
699-43-69	3/12/08	499	38.0		1.13		33.7	U	--		--		--	
699-43-69	3/14/08	1,195	39.0		0.94		25.6	U	--		--		--	
699-43-69	3/18/08	490	42.0		1.05		-35.6	U	--		--		--	
699-43-69	3/26/08	486	31.0		1.48		113	U	--		--		--	
699-43-69	4/1/08	499	30.0		1.24		9.36	U	--		--		32.1	
699-43-69	4/2/08	449	35.0		1.08		0	U	--		--		--	
699-43-69	4/4/08	498	26.0		0.6		-94.6	U	--		--		--	
699-43-69	4/9/08	415	23.0		1.12		-85.5	U	--		--		--	
699-43-69	6/10/08	515	32.4	D	--		--		--		--		--	
699-43-69	9/28/08	506	31.5	D	--		--		--		--		--	
699-43-69	11/23/08	497	32.0	D	--		--		--		--		--	
699-43-69	3/4/09	517	30.6	D	--		--		--		--		--	
699-43-69	11/23/09	517	31.9	D	--		--		--		--		--	
699-43-69	6/02/10	519	30.4	D	--		--		--		--		--	
699-45-42	10/26/09	281	4.47	D	--		7,000		--		--		--	
699-45-42	12/20/10	284	4.78	D	--		6,500		--		--		--	
699-S22-E9C	2/28/08	367	0.044	UD	--		18.8	U	4	U	204	C	**65.1**	
699-S27-E9C	2/11/08	381	0.044	UD	0.05	U	13.1	U	95.1		202	C	**95**	
699-S28-E0	6/10/10	371	16.4	D	4.16	D	10	U	1.76	BD	18	U	4	U
699-S28-E0	6/10/10	--	--		--		--		13	U	--		--	
699-S28-E0	8/02/10	371	17.2	D	1.32	D	-39	U	1	UD	18		4	U
699-S28-E0	8/02/10	--	--		--		--		13	U	--		--	
699-S28-E0	12/14/10	395	17.4	D	4.05	D	84	U	1.76	BD	51		12	B

Table 15-1. (Cont.)

Well	Sample Date	Specific Conductance (µS/cm)	Nitrate (mg/L)	Uranium (µg/L)	Tritium (pCi/L)	Chromium (Filtered) (µg/L)	Iron (Filtered) (µg/L)	Manganese (Filtered) (µg/L)
699-S28-E0	12/14/10	--	--	--	--	14 U	--	--
699-S29-E16C	8/19/08	381	0.107 UD	0.05 U	-23.1 U	13 U	**3,290**	**139**
699-S29-E16C	4/16/09	383	--	--	--	--	--	--

Notes:

1. Cells with "--" notation indicate not analyzed during the reporting period.
2. Shaded cells with **bold type** indicate values above secondary DWS (iron = 300 µg/L, manganese = 50 µg/L).
3. Laboratory qualifiers are as follows:

   B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit

   C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration

   D = analyte reported at a secondary dilution factor

   U = not detected in sample; value shown is the detection limit

   X = additional result-specific information is available

Table 15-2. Potential Contaminants of Interest in the Upper Basalt-Confined Aquifer, Calendar Year 2008 Through Calendar Year 2010

Well Name	Date	Specific Conductance (µS/cm)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tc-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Cesium-137 (pCi/L)	Cobalt-60 (pCi/L)	Iodine-129 (pCi/L)	Sr-90 (pCi/L)	Nitrate (mg/L)	Cyanide (µg/L)
199-H4-2	8/25/09	262	0.78 U	9.6	--	-25.6 U	--	--	--	--	--	1.27 D	--
199-H4-15CP	5/16/10	369	--	--	--	--	--	--	--	--	--	--	--
299-E16-1	6/24/09	293	0.63 U	22	--	-5.4 U	--	--	--	0.04 U	--	0.27 UD	--
	3/28/10	301	-0.66 U	9.2	-10 U	29 U	0.121 BD	-0.695 U	0.314 U	--	--	0.27 UD	--
	6/09/10	296	--	12.9	--	--	--	--	--	--	--	--	--
	6/09/10	--	--	11	--	--	--	--	--	--	--	--	--
	8/03/10	320	-0.15 U	11	2.8 U	-120 U	0.182 BD	-0.967 U	1.56 U	-0.03 U	-1.8 U	0.27 UD	--
299-E26-8	7/9/09	292	1.8	9.8	--	-1.73 U	--	--	--	0.35	--	2.13 D	--
299-E33-12	6/25/08	351	1.0 U	**690**	**1,300**	140 U	3.2	-3.18 U	4.27 U	0.09 U	--	40.20 D	31.3
	3/28/10	315	0.12 U	**800**	**1,180**	189	3.15 D	0.483 U	3.55 U	-0.05 U	-5.8 U	41.3 D	26.9
	7/06/10	346	0.84 U	**790**	**1,200**	--	--	--	--	--	--	--	--
299-E33-50	1/12/09	260	0.187 U	17.8	43	50 U	2.29	-0.27 U	-1.49 U	0.11 U	-2.8 U	1.36 D	4 U
	6/25/09	263	0.006 U	**52**	250 Y	-100 U	2.35	-0.65 U	-0.481 U	0.18	-1.6 U	1.93 D	4 UX
	1/06/10	265	1.5 U	36	46.1	-6.3 U	2.25 DC	0.407 U	2.47 U	0.08 U	-5.3 U	2.31 D	4 U
	6/29/10	261	1.8	38	--	-94 U	2.29 D	0.446 U	1.66 U	0.01 U	-2.8 U	2.03 D	4 U
299-E33-340	4/2/09	319	2.20	31	23	52 UJ	3.05	0.739 U	-0.51 U	0.24	-3.4 U	3.46 D	4.40 J
	6/26/09	310	0.48 U	30	28	86 U	3.27	-1.42 U	1.53 U	0.07 U	0.48 U	3.05 D	4 UX
	9/3/09	318	2.3	28 Q	20	120 U	3.05	-0.203 U	-1.04 U	0.07 U	-1.2 U	2.92 D	5.04 B
	1/15/10	304	1.8 U	28	26.6	-23 U	3.02 D	-0.516 U	0.782 U	0.03 U	-2.8 U	2.71 D	4 U
	1/15/10		0.97 U	30	22.9	-19 U	2.99 D	-1.09 U	0.0414 U	-0.1 U	-3.9 U	2.86 D	4 U
	3/28/10	280	2.1 U	18	15.8	70 U	2.97 D	--	--	--	--	2.09 D	4 U
	6/29/10	303	2.5	25	19.2	-33 U	2.93 D	-1.42 U	1.88 U	0.11 U	-3 U	2.82 D	4 U
	8/26/10	297	0.91 U	7.3	12.9	-51 U	2.83 D	--	--	--	--	1.29 D	4 U
	12/28/10	306	0.37 U	8.5	10.9	100 U	2.8 D	-9.3 U	1.3 U	--	--	1.95 D	4 U
	12/28/10	305	0.98 U	8.8	12	71 U	2.86 D	-0.16 U	0.0019 U	--	--	2.02 D	4 U
399-5-2	6/29/07	349	0.28 U	11	--	5.74 U	--	--	--	--	--	0.02 U	--
	6/06/10	348	0.48 U	7.9	-10 U	-6.8 U	0.1 UD	-1.34 U	-0.813 U	0.01 U	-0.73 U	0.27 UD	--
699-2-E14	8/25/09	427	0.73 U	6.8	-3.9 U	-110 U	0.05 U	--	0.23 U	-0.07 U	-0.61 U	0.27 UD	--
	10/26/09	435	4.0	8.9	-6.7 U	-50.3 U	0.1 UD	-0.14 U	--	--	--	0.27 UD	--
699-13-1C	7/24/09	375	0.4 U	8.7	--	120 U	--	--	--	--	--	0.27 UD	--
699-32-22B	9/24/09	380	0.009 U	5.5 U	--	220 U	--	--	--	0.06 U	--	0.27 UD	--
	12/19/10	376	0.72 U	9.7	-4.5 U	25.1 U	0.17 BD	--	--	--	--	0.841 UD	--

Table 15-2. (Cont.)

Well Name	Date	Specific Conductance (µS/cm)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tc-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Cesium-137 (pCi/L)	Cobalt-60 (pCi/L)	Iodine-129 (pCi/L)	Sr-90 (pCi/L)	Nitrate (mg/L)	Cyanide (µg/L)
699-42-40C	7/8/09	341	2.2	14	--	3,900	--	--	--	0.25	--	6.24 D	--
	8/18/10	342	0.006 U	12	-0.5 U	3,500	2.49 D	-0.165 U	0.826 U	0.29	-- U	6.15 D	4 U
699-42-E9B	9/27/09	392	-0.19 U	13	--	78 U	--	0.575 U	-0.132 U	0.04 U	--	0.27 UD	--
	8/23/10	420	6.6 Y	6.4	-0.5 U	-6.3 U	0.1 UD	-0.416 U	0.057 U	0.04 U	--	0.08 UD	--
699-49-55B	2/6/08	278	2.96	7.97	1.23 U	-170 U	3.32	-0.278 U	0.96 U	-0.26 U	--	0.66 BD	4 U
	3/21/10	281	1 U	7.2	-6.5 U	-6.75 U	0.995 DC	0.514 U	0.321 U	0.32	-0.31 U	0.28 BDX	--
	8/17/10	286	2 U	7.4	-2.1 U	-0.004 U	4.09 D	-0.535 U	-1.46 U	--	--	0.69 BD	--
699-49-57B	4/1/09	305	--	--	-7.1 U	-9.0 U	--	1.61 U	-1.04 U	-0.02 U	--	1.23 D	2 UDN
	3/21/10	311	--	--	-10 U	-39 U	--	-1.89 U	0.49 U	0.01 U	--	1.11 DX	4 U
699-50-53B	9/20/09	372	--	--	-5.7 U	-0.83 U	--	--	--	-0.09 U	--	11.82 D	--
	4/06/10	370	1.8 U	7.4	-8.7 U	-37.3 U	2.18 D	--	--	--	--	12.3 D	--
	8/18/10	386	1.3 U	6.3	-2.5 U	-11.1 U	1.94 D	--	--	--	--	11.9 D	--
699-52-46A	6/30/07	326	3.6	7.6	--	7.92	--	--	--	--	0.22 U	1.84	--
	9/22/10	339	2.7	9.8	-5.4 U	10.7 U	5.76 D	0.207 U	0.369 U	0.02 U	-1.3 U	2.13 D	--
699-52-55B	01/13/09	339	0.823 U	8.55	-8 U	31 U	2.21	-1.33 U	1.01 U	0.0719 U	-0.42 U	0.39 BD	4 U
	04/01/09	383	0.51 U	11	-12 U	-60 U	3.11	-0.476 U	-0.648 U	-0.0141 U	1.2 U	1.45 D	2 UDN
	08/27/09	315	1.6 U	10	-3.5 U	31 U	3.02	0.578 U	0.533 U	-0.0287 U	-3.2 U	1.9 D	4 U
	09/20/09	339	3.6	7.6	-6.5 U	-18 U	3	0.664 U	-0.69 U	-0.0539 U	-5 U	2.14 D	4 U
	02/19/10	324	1 U	12	7.4	-78.2 U	2.92 D	0.113 U	-0.917 U	0.0146 U	-2 U	1.89 D	4 U
	09/22/10	326	5.2	13	-6 U	81 U	3.57 D	-0.248 U	0.803 U	0.0335 U	-4.7 U	2.41 D	4 U
699-54-34	7/18/10	335	1.5	5.7	6.7	-13.4 U	1.97	0.302 U	0.538 U	-0.039 U	-5.4 U	18.5 DN	--
699-54-57	11/117/10	306	2.2 U	3.4	-2.8 U	110 U	2.39 D	1.3 U	-3.3 U	-0.09 U	-1.4 U	1.37 D	4 U
699-56-43	9/24/09	322	2.0 U	6.9		-18.1 U	--	--	--	--	--	5.05 D	--
699-66-91	9/21/10	324	-2.3 U	1.3 U	-2.9 U	12.2 U	1.87 D	-1.42 U	2.71 U	-0.067 U	-2 U	4.21 D	--
699-S2-34B	2/4/09	624	2.7 U	10	--	-110 U	--	--	--	--	--	0.11 UD	--
	2/21/10	596	-0.23 U	13	-1.4 U	41.1	0.1 UD	0.57 U	-0.31 U	0.15 U	--	0.27 UD	--
699-S11-E12AP	8/25/09	356	0.87 U	8.8	--	-54 U	--	--	--	--	--	0.27 UD	--
	2/21/10	356	-0.62 U	8.4	-6.2 U	33.8	0.1 UD	-0.972 U	0.025 U	0.032 U	-2.9 U	0.27 UD	--
699-S24-19P	2/28/08	201	--	--	--	19.9 U	--	--	--	--	--	2.05 D	--
	7/23/10	267	-0.76 U	2 U	-2.6 U	0.53 U	0.788 D	-0.298 U	-0.574 U	0.03 U	-2.9 U	3.3 D	--

Table 15-2. (Cont.)

Well Name	Date	Specific Conduc-tance (µS/cm)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tc-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Cesium-137 (pCi/L)	Cobalt-60 (pCi/L)	Iodine-129 (pCi/L)	Sr-90 (pCi/L)	Nitrate (mg/L)	Cyanide (µg/L)

Notes:

1. Cells with "--" notation indicate not analyzed between October 1, 2007, and December 31, 2010.
2. Shaded cells with **bold type** indicate values greater than drinking water standards (technetium-99 = 900 pCi/L, cobalt-60 = 100 pCi/L, iodine-129 = 1 pCi/L, nitrate = 45,000 µg/L, and cyanide = 200 µg/L).
3. Laboratory qualifiers are as follows:

B = analyte detected at a value less than contract required detection limit but greater than or equal to the instrument or method detection limit

C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration

D = analyte reported at a secondary dilution factor

H = laboratory holding time exceeded before sample was analyzed

J = estimated value; constituent detected at a level less than the contract required detection limit and greater than or equal to the method detection limit

N = spike and/or spike duplicate sample recovery is outside control limits

Q = associated quality control sample is out of limits

U = not detected in sample; value shown is the detection limit

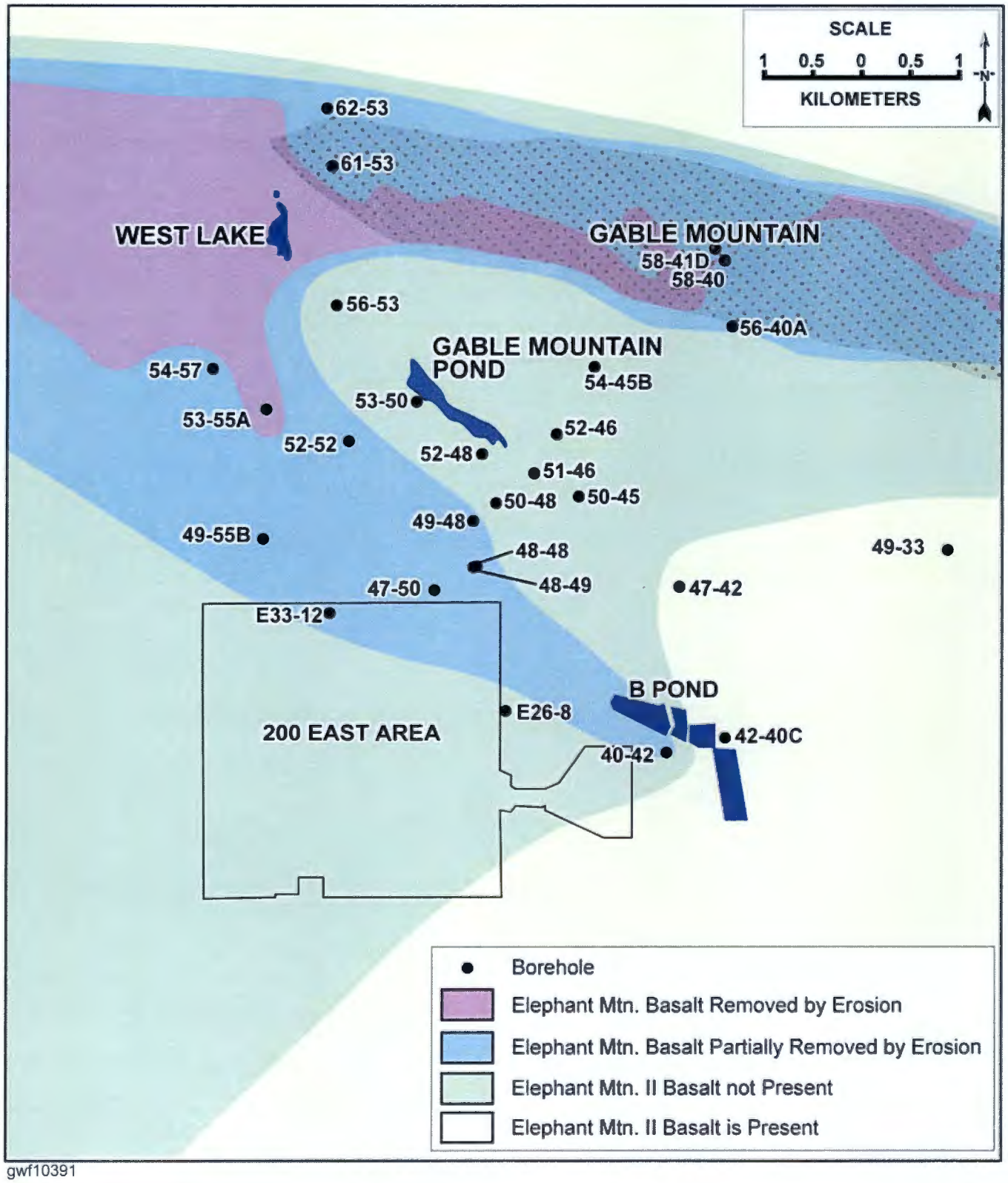
X = additional result-specific information is available

Y = result is suspect; review had insufficient data to show result valid or invalid

Table 15-3. Upper Basalt-Confined Aquifer Field Parameters for Calendar Year 2010

Parameter	Unit	Range	Minimum	Well	Maximum	Well
Dissolved oxygen	mg/L	8.83	0.04	699-S11-E12AP	8.87	699-S24-19P
Oxidation-reduction potential	mV	68	230	299-E33-340	298	699-49-57B
pH	Standard units	2.24	7.36	699-S24-19P	9.6	699-42-E9B
Specific conductivity	µS/cm	335	261	299-E33-50	596	699-S2-34B
Temperature	°C	6.4	16.4	699-S24-19P	22.8	299-E16-1
Turbidity	NTU	40.94	0.16	199-H4-15CP	41.1	699-49-55B

Figure 15-1. Extent of Partial or Complete Erosion of the Elephant Mountain Basalt in the 200 East Area/Gable Mountain Region (from DOE/RL-2008-01)



gwf10391

Figure 15-2. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 2010

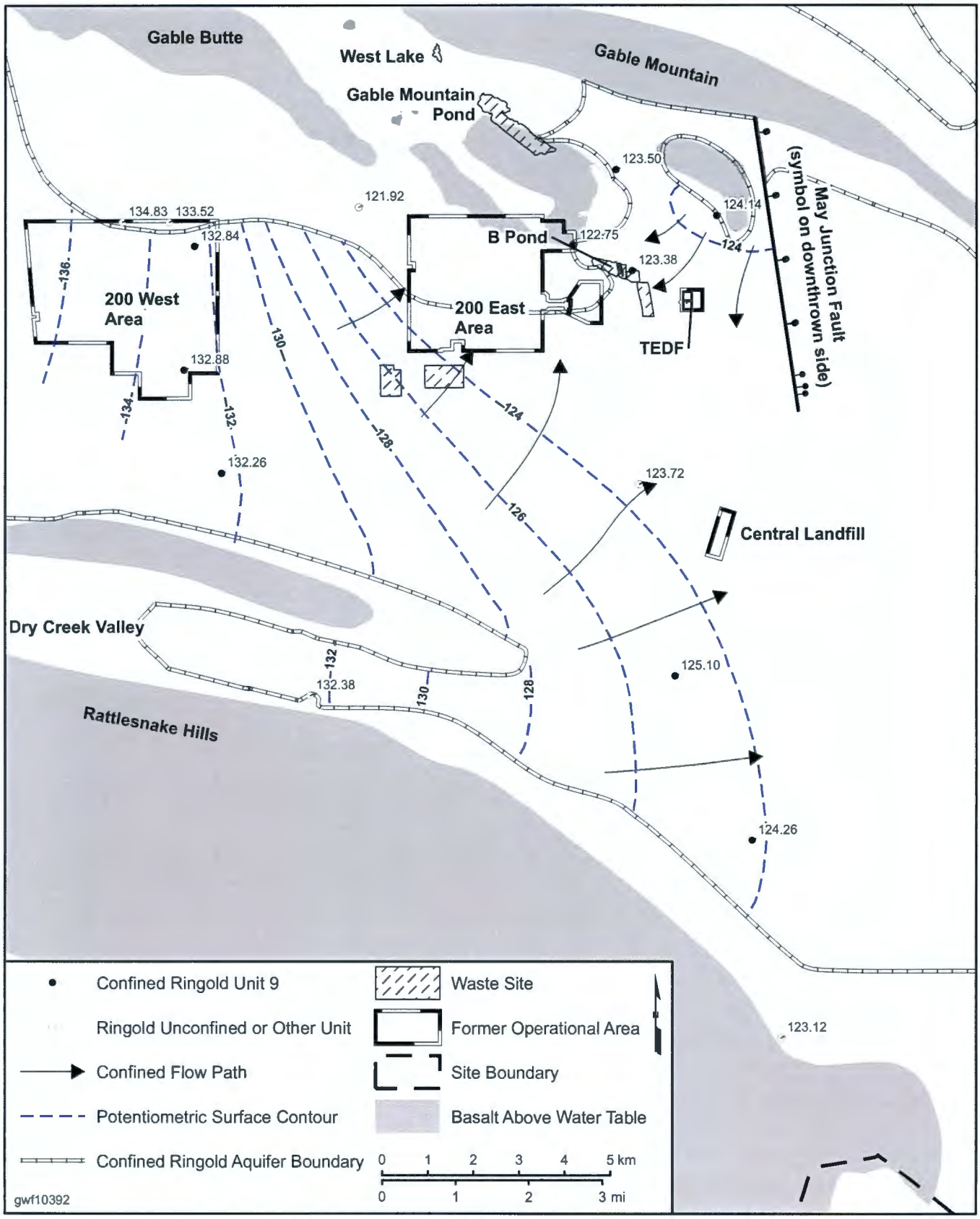


Figure 15-3. Groundwater Monitoring Wells Sampled in Ringold Formation Confined and Upper Basalt-Confined Aquifers, Fiscal Year 2007 Through Calendar Year 2010

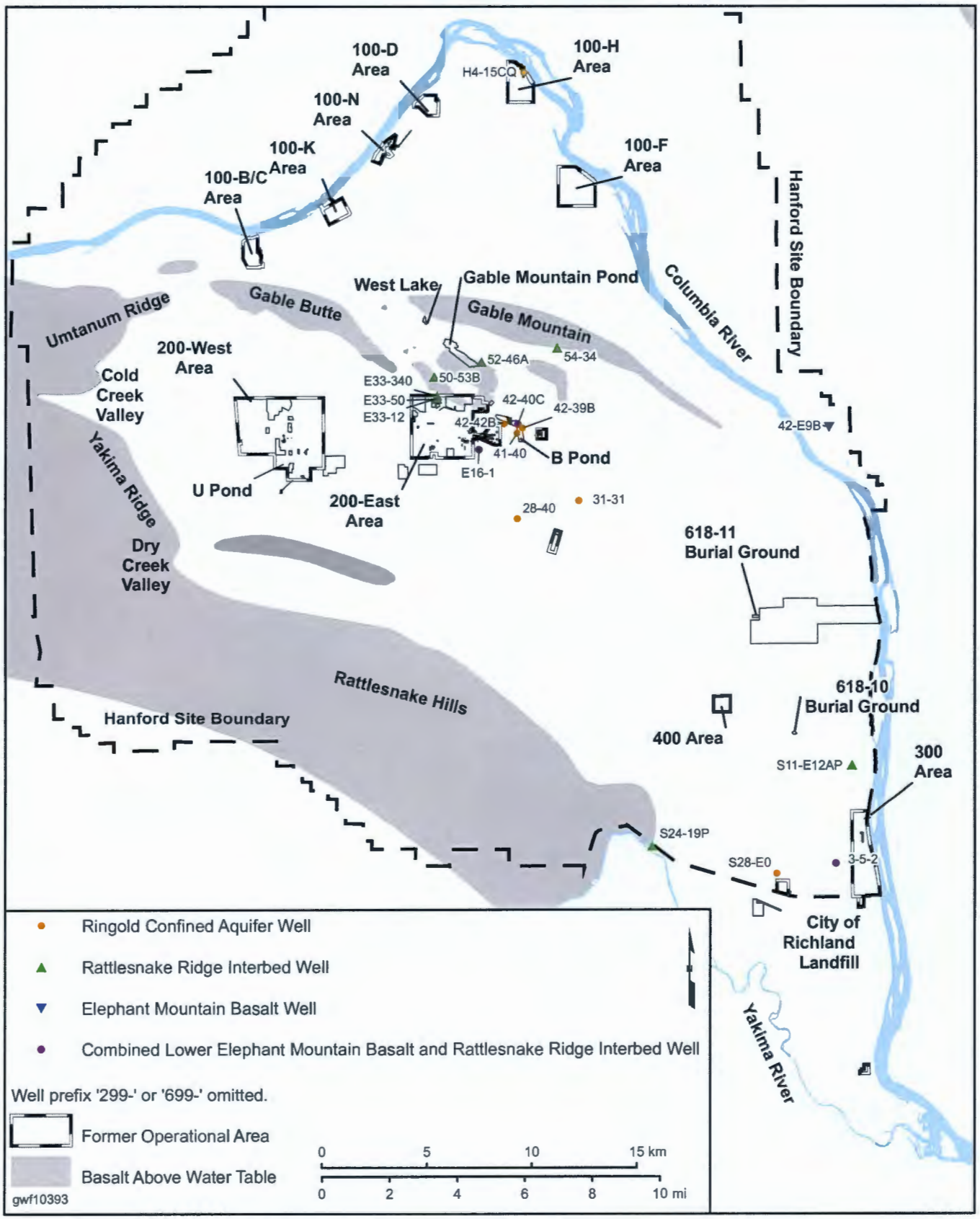


Figure 15-4. Potentiometric Surface Map of Upper Basalt-Confined Aquifer System, March 2010

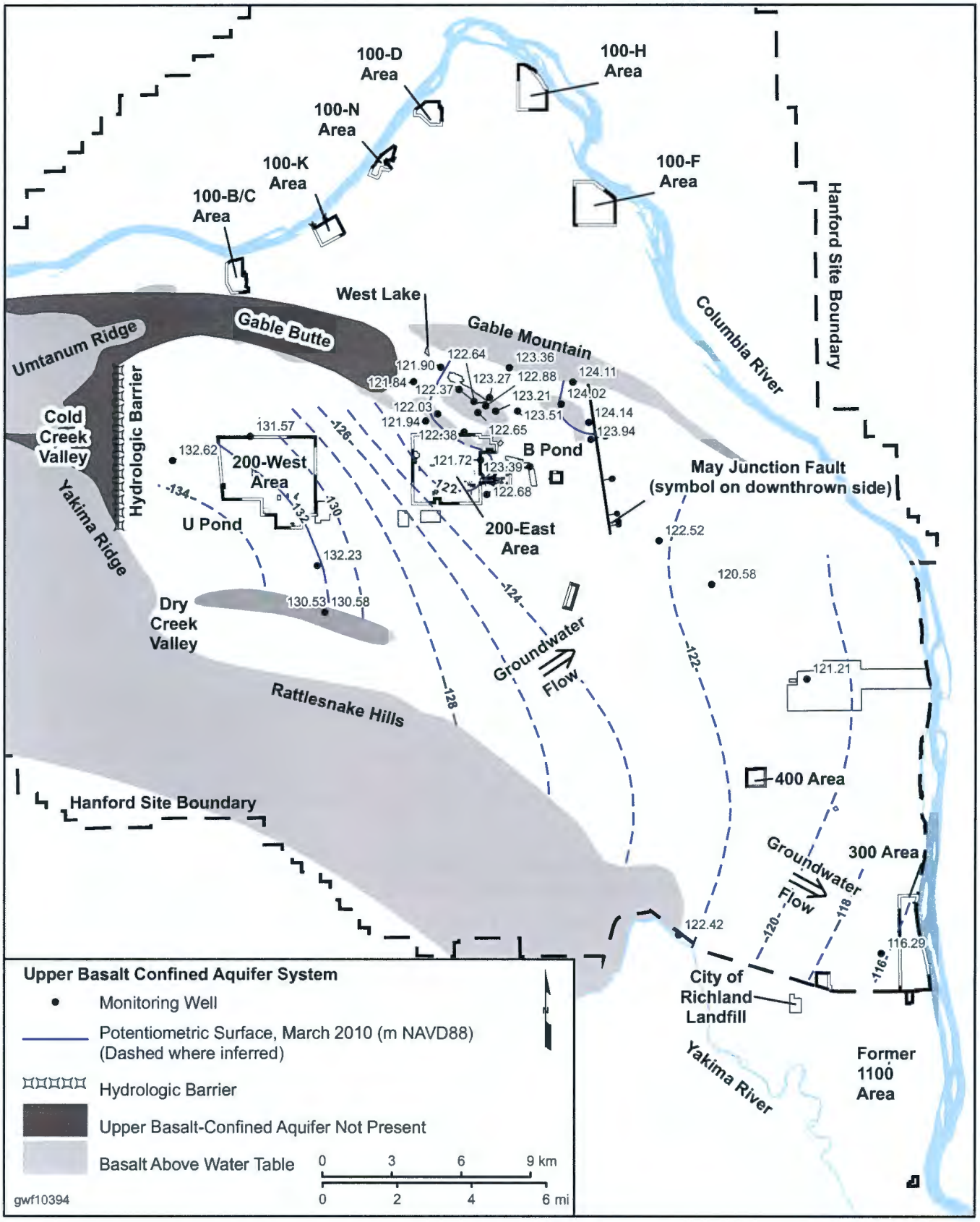
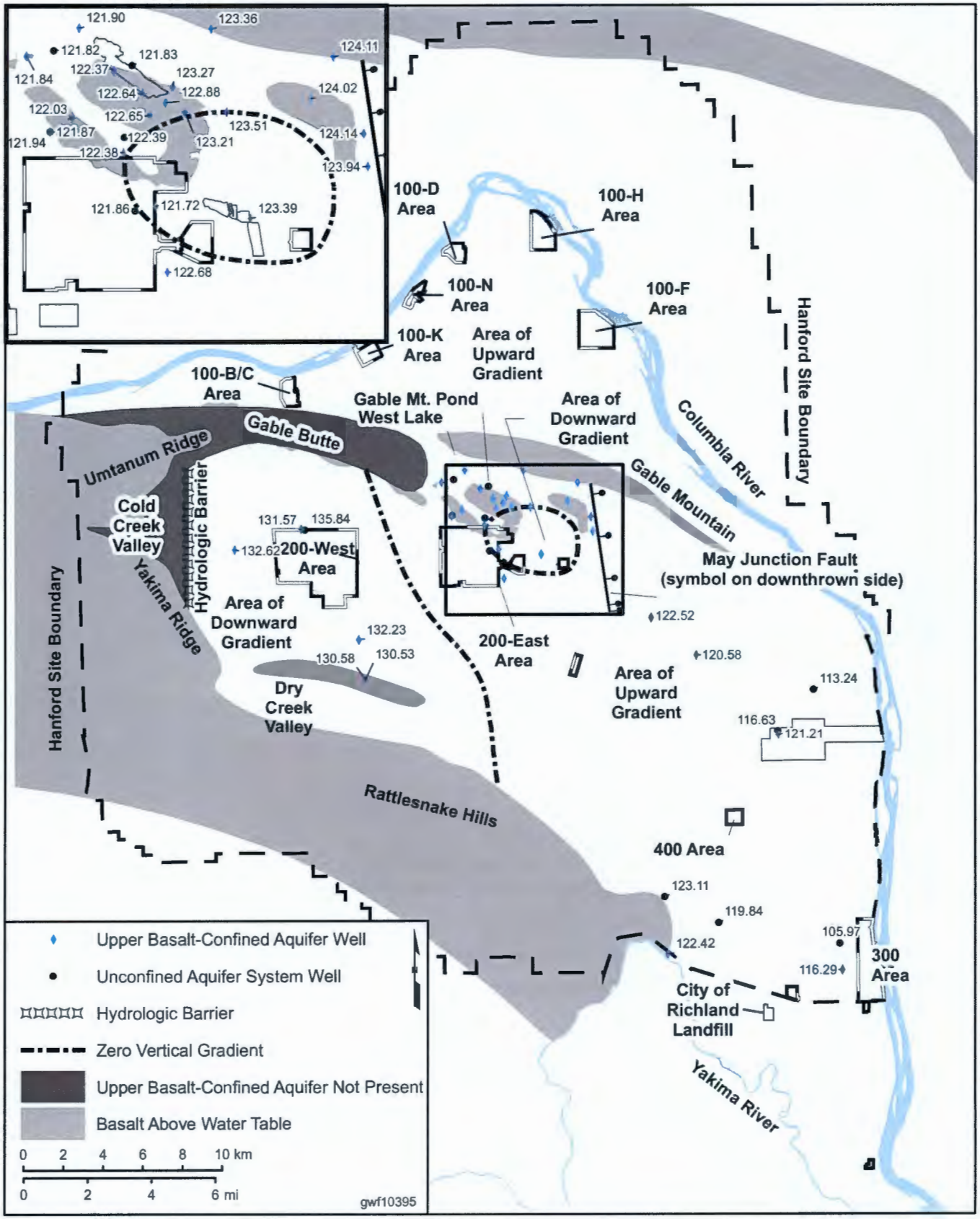


Figure 15-5. Comparison of Observed Heads for Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer



16.0 Well Installation, Maintenance, and Decommissioning

B.J. Howard and L.C. Hall

This chapter describes new groundwater well and characterization borehole installations, well decommissioning, and maintenance activities conducted on the Hanford Site during the calendar year (CY) 2010.

Approximately 10,979 unique well identification numbers have been assigned at the Hanford Site. All wells, characterization boreholes, aquifer tubes, soil tubes, piezometers, and other subsurface excavations are required to receive a unique Hanford well identification number. All wells are also required to have a state well identification number, which is currently tracked by the Washington State Department of Ecology (Ecology). Figure 16-1 presents the categorization of unique well numbers from the Well Information and Document Lookup (WIDL) database and their approximate geographic designations. Figure 16-2 identifies the geographic designations for the Hanford Site.

During CY 2010, a total of 3,762 unique well identification numbers were documented as in use, which includes 2,846 wells; 71 piezometers within host wells; 7 lysimeters within host lysimeters; 522 aquifer tubes; and 316 soil tubes. Section 16.1 discusses the well installations and provides information on 282 new wells. Section 16.2 describes the 96 characterization boreholes and direct-push installations. Well maintenance completed tasks for 930 wells and is discussed in Section 16.3. Section 16.4 discusses the wells that were decommissioned.

16.1 Well Installation

The Soil and Groundwater Remediation Project, working with the U.S. Department of Energy (DOE) and the appropriate regulatory agencies, defines the need for new wells at the Hanford Site. Each year, the groundwater project identifies new wells to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA) detection and assessment groundwater monitoring requirements; characterization, remediation, and monitoring for the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); and long-term monitoring of regional groundwater plumes in accordance with DOE orders, based on requirements of the *Atomic Energy Act of 1954* (AEA). These efforts include ongoing RCRA assessment of groundwater contamination, replacing monitoring wells that go dry due to the declining regional water table, replacing wells that need to be decommissioned, improving spatial coverage for the detection monitoring networks or for plume monitoring, and characterizing subsurface contamination.

New RCRA, CERCLA, and AEA well proposals are reviewed, prioritized, and approved annually as required by the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Milestone M-024. All new wells are resource protection wells and are constructed or decommissioned in accordance with the provisions of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." Well requirements are integrated and documented through development of the Groundwater Project's budget, discussions with the regulators, and monitoring requirements. Funding from the *American Recovery and Reinvestment Act of 2009* supplemented baseline funding in CY 2010 to plan and install new groundwater and deep vadose zone monitoring wells, borehole

sampling treatability tests, and remediation systems in order to achieve the Tri-Party Agreement milestones.

During CY 2010, a total of 282 wells were installed at the Hanford Site (Table 16-1). These wells were constructed to support activities funded under Tri-Party Agreement Milestone M-024 or other project-specific requirements. The approximate locations of the new wells are shown in Figure 16-3. Information for the 282 wells installed is provided below:

- A total of 171 apatite/barrier injection wells at the 100-NR-2 Operable Unit (OU) (Figure 16-4)
- Six wells at the 100-BC-5 OU to support the 100-BC-5 remedial investigation/ feasibility study (RI/FS) (Figure 16-4)
- Three wells at the 100-FR-3 OU to support the 100-FR-3 RI/FS (Figure 16-3)
- Thirty-four pump-and-treat wells to support the 100-D Area pump-and-treat facility (Figure 16-5)
- Thirty-three pump-and-treat wells to support the 100-H Area pump-and-treat facility (Figure 16-5)
- Five wells to support the RI/FS at the 100-KR-4 OU(Figure 16-4)
- Eight wells in the 200-BP-5 OU to support Tri-Party Agreement Milestone M-024 and the 200-BP-5 OU RI/FS (Figure 16-6)
- Two wells in the 200-UP-1 OU to support Tri-Party Agreement Milestone M-024 and the 200 West Area pump-and-treat system expansion (Figure 16-6)
- Fifteen wells in the 200-ZP-1 OU to support the 200 West Area pump-and-treat system expansion (Figure 16-6)
- Five wells in the 300-FF-5 OU (two wells for 618-10 Burial Ground dust control and three wells to support the Integrated Field-Scale Research Challenge [IFRC]) (Figure 16-3).

Water well reports for all newly constructed wells, as required by WAC 173-160, were submitted to Ecology and added to the Ecology well log database. Detailed well information such as geologic and geophysical descriptions, a list of characterization activities (i.e., sediment and groundwater sampling, aquifer testing, and geophysical logging), and construction records for the new wells is stored in the Integrated Data Management System (IDMS) database. Select drilling and well construction information (e.g., drill depth and screen interval) is entered into the Well Maintenance Application database, which is accessible to the WIDL database (contained within the Hanford Environmental Information System [HEIS] database), and this information is accessible through the Environmental Dashboard Application.

16.2 Characterization Boreholes and Direct-Push Technology Installation

During CY 2010, 96 direct-push and characterization boreholes were completed. The boreholes were installed for subsurface characterization of radiological constituents, volatile organics (e.g., carbon tetrachloride), or hydrologic property determination (e.g., moisture or grain-size distribution). While typically installed to characterize the vadose zone, borings can be drilled to groundwater to obtain a one-time sample at the general location of these boreholes. Table 16-2 provides a summary of the number and general location of the direct-push and characterization

boreholes. The approximate locations of the new borings are shown in Figure 16-3, and the area locations are shown in Figures 16-4 through 16-6. The characterization and direct-push boreholes are summarized below:

- Two characterization boreholes for Washington Closure Hanford at the 100-C-7 dump site to support confirmatory sampling
- Six characterization boreholes at the HR-3 pump-and-treat system (100-D and 100-H Areas) to support supplemental 100-HR-3 OU RI/FS sampling
- Twelve direct-push boreholes at the 216-E-127 pipeline to support confirmatory sampling
- Forty-two direct-push boreholes in the 600 Area waste site for confirmatory sampling
- Nine direct-push boreholes for confirmatory sampling in UPR-600-12
- Two direct-push boreholes for confirmatory sampling of the 216-A-25 Pond
- One direct-push borehole for confirmatory sampling of the 216-B-3 Pond
- Twelve direct-push boreholes for confirmatory sampling of the 216-U-10 Pond
- Three direct-push borehole for confirmatory sampling of the 216-T-4B Pond
- One direct-push borehole for confirmatory sampling of the 216-S-16 Pond
- Two direct-push borehole for confirmatory sampling of the 216-S-17 Pond
- Four direct-push borehole for confirmatory sampling in the 216-S-26 Crib.

16.3 Well Maintenance

During CY 2010, well maintenance tasks were completed on 930 wells on the Hanford Site (Table 16-3). The maintenance tasks, which include surface and subsurface aspects, are varied and depend on the specific problems or issues encountered at each well. Several wells required multiple visits to correct new or recurring problems. Other maintenance issues included replacement of locking well caps, casing repairs, diagnosis and repair of surface electrical wiring, and pump-discharge fittings. Subsurface tasks typically include repairing and replacing sampling pumps, performing camera surveys, pump and equipment retrieval, and replacing discharge tubing. Well maintenance actions are entered in the Well Maintenance Application database, which is accessible to the WIDL database (contained within the HEIS database), and this information is accessible through the Environmental Dashboard Application.

For CY 2010, well maintenance activities also included surging, swabbing, screen brushing, chemical treatment, and over-pumping to improve well performance. Two projects tested an advanced airburst technology that is new to the Hanford Site, and it was used in addition to the above methods to increase the specific capacity of extraction or injection wells. Airburst technology applies repeated high-energy pulses or bursts of gas (air) to break up scale, incrustation, and biological fouling, and it dislodges fine-grained sediments in the near-well pore space. The objective of the treatment is to increase the specific capacity of the extraction or injection wells. Airburst technology was applied at extraction/injection wells 199-D5-20, 199-D5-42, 299-W15-35, 299-W15-47, 299-W19-36, and 299-W19-43. The specific capacity in these wells was not significantly improved.

16.4 Well Decommissioning

A well becomes a candidate for decommissioning under one of the following conditions:

- The well use has been permanently discontinued (i.e., the well has gone dry).
- The well condition is so poor that its continued use is impractical.
- The well is in the path of intended remediation, excavation, and/or construction activities.
- The well poses an environmental, safety, or public health hazard (e.g., casing corroded).

Well decommissioning is driven by the *Hanford Site Well Decommissioning Plan* (DOE/RL-2005-70), available funding for the fiscal year, and the requirements and provisions of WAC 173-160. A well is identified in the WIDL as a candidate for decommissioning when the well has no further use. All candidate wells for decommissioning must be reviewed and approved by the contractors, DOE, Ecology, U.S. Environmental Protection Agency, and other potential well users (e.g., Pacific Northwest National Laboratory) prior to actual decommissioning. During review of wells available as candidates for decommissioning, a thorough records review and physical inspection of each well is conducted to confirm the well's location and its attributes.

A very limited number of unknown wells are also discovered during the conduct of field activities. These wells are assigned a unique well identification number, assigned an appropriate well status, and added to the Hanford Site well database. A total of 186 wells were physically decommissioned in CY 2010 (Table 16-4). Decommissioning typically involves backfilling a well with impermeable material to prevent vertical movement of water and/or contaminants both in the well and along the annular space. For wells that are *Washington Administrative Code* compliant, decommissioning is typically performed by placing sand across the screen interval and filling the casing with an impermeable material (e.g., bentonite or cement grout). For older, noncompliant wells, the casing is perforated and pressure grouted to create an external seal or the casing is removed. A brass survey marker identifying the well is typically set in grout at the surface and over the well location. Decommissioning activities result in the permanent removal of a well, borehole, or piezometer from service and from the Hanford Site active well inventory. Decommissioning is performed in accordance with WAC 173-160-460, applicable well variances, and conditions defined in the Hanford Facility RCRA Permit (WA78900008967).

A completed water well report form is required to be transmitted (by the driller) to Ecology when a well is decommissioned. The report provides the details on the well's construction and the steps taken to decommission (plug) the well. During CY 2010, three 200-ZP-1 OU soil tubes were administratively decommissioned by the Well Management Program, as field walkdowns confirmed that the soil tubes did not exist.

Table 16-1. Well Installations for the Reporting Period

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-BC-5	199-B5-5	C7505	Support RI/FS	189.15	214.8	2/25/10
100-BC-5	199-B3-50	C7506	Support RI/FS	91.25	183.3	2/25/10
100-BC-5	199-B5-6	C7507	Support RI/FS	195.2	195.5	2/25/10
100-BC-5	199-B8-9	C7508	Support RI/FS	112.09	219.5	12/30/10
100-BC-5	199-B2-14	C7665	Support RI/FS	71.91	152.3	2/25/10
100-BC-5	199-B4-14	C7786	Support RI/FS	94.67	95.8	12/30/10
100-FR-3	199-F5-52	C7790	Support RI/FS	62.92	73.8	12/28/10
100-FR-3	199-F5-53	C7791	Support RI/FS	110.06	116	12/30/10
100-FR-3	199-F5-54	C7792	Support RI/FS	61.13	77.4	12/30/10
100-HR-3-D	199-D4-95	C7083	100-D Area pump-and-treat	117.22	121.4	2/23/10
100-HR-3-D	199-D4-96	C7084	100-D Area pump-and-treat	101	106.5	2/23/10
100-HR-3-D	199-D4-97	C7085	100-D Area pump-and-treat	106.1	111	2/23/10
100-HR-3-D	199-D4-98	C7086	100-D Area pump-and-treat	103.2	111	2/23/10
100-HR-3-D	199-D4-99	C7087	100-D Area pump-and-treat	110.87	116.2	2/23/10
100-HR-3-D	199-D2-10	C7089	100-D Area pump-and-treat	27.87	31	2/23/10
100-HR-3-D	199-D2-12	C7090	100-D Area pump-and-treat	29.84	34	2/23/10
100-HR-3-D	199-D8-89	C7091	100-D Area pump-and-treat	80.07	84.8	2/23/10
100-HR-3-D	199-D8-90	C7092	100-D Area pump-and-treat	52.45	56.4	2/23/10
100-HR-3-D	199-D8-91	C7093	100-D Area pump-and-treat	43.44	46.5	2/23/10
100-HR-3-D	199-D8-93	C7095	100-D Area pump-and-treat	18.06	21	2/23/10
100-HR-3-D	199-D8-94	C7096	100-D Area pump-and-treat	28.01	31.3	2/23/10
100-HR-3-D	199-D4-101	C7580	100-D Area pump-and-treat	106.23	109.9	5/4/10
100-HR-3-D	199-D8-97	C7582	100-D Area pump-and-treat	100.91	104.3	5/4/10
100-HR-3-D	199-D5-101	C7583	100-D Area pump-and-treat	111.24	114.3	5/4/10
100-HR-3-D	199-D8-95	C7589	100-D Area pump-and-treat	99.96	104.4	5/4/10
100-HR-3-D	199-D5-130	C7590	100-D Area pump-and-treat	99.05	101.4	5/4/10
100-HR-3-D	199-D5-127	C7591	100-D Area pump-and-treat	104.39	109	5/4/10
100-HR-3-D	199-D6-1	C7592	100-D Area pump-and-treat	105	107	5/4/10
100-HR-3-D	199-D8-99	C7593	100-D Area pump-and-treat	84.96	88.9	5/4/10
100-HR-3-D	199-D7-4	C7594	100-D Area pump-and-treat	75	77.5	5/4/10
100-HR-3-D	199-D7-3	C7599	100-D Area pump-and-treat	87.29	89.3	5/4/10
100-HR-3-D	199-D5-129	C7600	100-D Area pump-and-treat	108.03	113.5	5/4/10
100-HR-3-D	199-D5-131	C7601	100-D Area pump-and-treat	111.18	116.4	5/4/10
100-HR-3-D	199-D8-98	C7602	100-D Area pump-and-treat	87.95	91.4	5/4/10
100-HR-3-D	199-D8-96	C7603	100-D Area pump-and-treat	95.07	101.5	5/4/10
100-HR-3-D	199-D6-2	C7607	100-D Area pump-and-treat	77.04	80.4	5/4/10
100-HR-3-D	199-D7-5	C7608	100-D Area pump-and-treat	58.51	63.5	6/29/10
100-HR-3-D	199-D7-6	C7611	100-D Area pump-and-treat	40.5	43.8	6/29/10
100-HR-3-D	199-D5-128	C7612	100-D Area pump-and-treat	102.92	106.6	2/23/10
100-HR-3-D	199-H4-80	C7595	100-D Area pump-and-treat	69.2	74.3	6/29/10
100-HR-3-D	199-H4-81	C7596	100-D Area pump-and-treat	41.5	44.4	6/29/10
100-HR-3-D	199-H4-82	C7609	100-D Area pump-and-treat	55.68	59.1	6/29/10
100-HR-3-D	199-H1-5	C7610	100-D Area pump-and-treat	44.1	46.5	6/29/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-HR-3-H	199-H1-38	C7098	100-H Area pump-and-treat	44.53	47.5	2/23/10
100-HR-3-H	199-H1-37	C7099	100-H Area pump-and-treat	43.52	46.4	7/1/10
100-HR-3-H	199-H1-32	C7100	100-H Area pump-and-treat	45.5	51.4	7/1/10
100-HR-3-H	199-H1-36	C7102	100-H Area pump-and-treat	41	46.5	7/1/10
100-HR-3-H	199-H1-40	C7104	100-H Area pump-and-treat	41	44.4	7/1/10
100-HR-3-H	199-H1-33	C7105	100-H Area pump-and-treat	41	45	7/1/10
100-HR-3-H	199-H1-35	C7106	100-H Area pump-and-treat	43.5	48	7/1/10
100-HR-3-H	199-H1-42	C7107	100-H Area pump-and-treat	40.89	44	11/5/09
100-HR-3-H	199-H1-34	C7108	100-H Area pump-and-treat	42.6	44.9	7/1/10
100-HR-3-H	199-H1-39	C7109	100-H Area pump-and-treat	41	44	7/1/10
100-HR-3-H	199-H3-25	C7110	100-H Area pump-and-treat	56.72	61.3	11/5/09
100-HR-3-H	199-H1-21	C7111	100-H Area pump-and-treat	35.11	39.8	7/1/10
100-HR-3-H	199-H1-20	C7113	100-H Area pump-and-treat	34.44	57.7	7/1/10
100-HR-3-H	199-H3-27	C7114	100-H Area pump-and-treat	58.79	61.9	11/5/09
100-HR-3-H	199-H3-26	C7115	100-H Area pump-and-treat	52.99	56.3	11/5/09
100-HR-3-H	199-H1-45	C7477	100-H Area pump-and-treat	56.88	61.08	11/5/09
100-HR-3-H	199-H1-25	C7478	100-H Area pump-and-treat	34.55	39.5	7/1/10
100-HR-3-H	199-H1-27	C7480	100-H Area pump-and-treat	37.2	41.2	7/1/10
100-HR-3-H	199-H4-70	C7483	100-H Area pump-and-treat	58	61.4	11/5/09
100-HR-3-H	199-H4-73	C7484	100-H Area pump-and-treat	66.29	71	11/5/09
100-HR-3-H	199-H4-69	C7485	100-H Area pump-and-treat	58.77	63.83	11/5/09
100-HR-3-H	199-H4-71	C7487	100-H Area pump-and-treat	63.09	71	11/5/09
100-HR-3-H	199-H4-72	C7488	100-H Area pump-and-treat	58.01	61.25	11/5/09
100-HR-3-H	199-H6-2	C7489	100-H Area pump-and-treat	52.83	60.7	11/5/09
100-HR-3-H	199-H1-43	C7492	100-H Area pump-and-treat	45	49	11/5/09
100-HR-3-H	199-H1-2	C7584	100-H Area pump-and-treat	50.4	54.5	10/6/10
100-HR-3-H	199-H1-1	C7585	100-H Area pump-and-treat	38	41.1	10/6/10
100-HR-3-H	199-H4-79	C7586	100-H Area pump-and-treat	64.05	65	10/6/10
100-HR-3-H	199-H4-76	C7587	100-H Area pump-and-treat	52	56.5	10/6/10
100-HR-3-H	199-H4-78	C7588	100-H Area pump-and-treat	61	64.1	10/6/10
100-HR-3-H	199-H4-75	C7597	100-H Area pump-and-treat	54.5	59.2	10/6/10
100-HR-3-H	199-H4-74	C7598	100-H Area pump-and-treat	43	46	10/6/10
100-HR-3-H	199-H4-77	C7605	100-H Area pump-and-treat	47.58	51	10/6/10
100-KR-4	199-K-187	C7687	Support RI/FS	202.2	202.4	11/18/10
100-KR-4	199-K-190	C7690	Support RI/FS	138.47	152	11/18/10
100-KR-4	199-K-191	C7691	Support RI/FS	105.31	158	11/18/10
100-KR-4	199-K-200	C7831	Support RI/FS	59.39	59.39	11/5/10
100-KR-4	199-K-201	C7832	Support RI/FS	58.8	60.4	11/5/10
100-NR-2	199-N-234	C7293	Apatite barrier injection/monitoring	14.82	16.8	5/21/10
100-NR-2	199-N-233	C7294	Apatite barrier injection/monitoring	25.04	27.3	12/14/09
100-NR-2	199-N-232	C7295	Apatite barrier injection/monitoring	14.61	16.3	5/21/10
100-NR-2	199-N-231	C7296	Apatite barrier injection/monitoring	25.08	26.2	12/14/09
100-NR-2	199-N-230	C7297	Apatite barrier injection/monitoring	15.42	15.8	5/21/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-NR-2	199-N-229	C7298	Apatite barrier injection/monitoring	24.92	26.5	12/15/09
100-NR-2	199-N-228	C7299	Apatite barrier injection/monitoring	14.61	16.1	5/21/10
100-NR-2	199-N-227	C7300	Apatite barrier injection/monitoring	25.29	27.5	12/15/09
100-NR-2	199-N-226	C7301	Apatite barrier injection/monitoring	14.88	16	5/21/10
100-NR-2	199-N-225	C7302	Apatite barrier injection/monitoring	24.73	26.8	2/26/10
100-NR-2	199-N-224	C7303	Apatite barrier injection/monitoring	15.3	17.5	5/21/10
100-NR-2	199-N-223	C7304	Apatite barrier injection/monitoring	24.96	26.7	2/26/10
100-NR-2	199-N-222	C7305	Apatite barrier injection/monitoring	17.1	27.1	5/21/10
100-NR-2	199-N-221	C7306	Apatite barrier injection/monitoring	25.47	26.9	2/26/10
100-NR-2	199-N-220	C7307	Apatite barrier injection/monitoring	16.3	26.2	5/21/10
100-NR-2	199-N-219	C7308	Apatite barrier injection/monitoring	25.53	27.5	2/26/10
100-NR-2	199-N-218	C7309	Apatite barrier injection/monitoring	15.29	17.1	5/21/10
100-NR-2	199-N-217	C7310	Apatite barrier injection/monitoring	24.88	26.7	2/26/10
100-NR-2	199-N-216	C7311	Apatite barrier injection/monitoring	14.77	16.3	5/21/10
100-NR-2	199-N-215	C7312	Apatite barrier injection/monitoring	24.31	27.2	11/18/09
100-NR-2	199-N-214	C7313	Apatite barrier injection/monitoring	14.6	16	5/21/10
100-NR-2	199-N-213	C7314	Apatite barrier injection/monitoring	24.53	26.2	11/18/09
100-NR-2	199-N-212	C7315	Apatite barrier injection/monitoring	15.07	16	5/21/10
100-NR-2	199-N-211	C7316	Apatite barrier injection/monitoring	24.63	26.2	11/18/09
100-NR-2	199-N-210	C7317	Apatite barrier injection/monitoring	15.46	16.5	5/21/10
100-NR-2	199-N-209	C7318	Apatite barrier injection/monitoring	25.48	26.3	11/2/09
100-NR-2	199-N-208	C7319	Apatite barrier injection/monitoring	15.19	16.2	5/21/10
100-NR-2	199-N-207	C7320	Apatite barrier injection/monitoring	25.9	27	11/2/09
100-NR-2	199-N-206	C7321	Apatite barrier injection/monitoring	15.16	17.6	5/21/10
100-NR-2	199-N-205	C7322	Apatite barrier injection/monitoring	25.01	26.2	10/30/09
100-NR-2	199-N-204	C7323	Apatite barrier injection/monitoring	15.2	16.05	5/21/10
100-NR-2	199-N-203	C7324	Apatite barrier injection/monitoring	24.4	27.1	10/30/09
100-NR-2	199-N-202	C7325	Apatite barrier injection/monitoring	15.04	17.1	5/21/10
100-NR-2	199-N-201	C7326	Apatite barrier injection/monitoring	25.09	26.4	10/30/09
100-NR-2	199-N-200	C7327	Apatite barrier injection/monitoring	15.52	18	5/21/10
100-NR-2	199-N-235	C7328	Apatite barrier injection/monitoring	15.05	16.2	5/21/10
100-NR-2	199-N-236	C7329	Apatite barrier injection/monitoring	24.82	26.6	12/7/09
100-NR-2	199-N-237	C7330	Apatite barrier injection/monitoring	15.29	16.8	5/21/10
100-NR-2	199-N-238	C7331	Apatite barrier injection/monitoring	25.18	26.7	12/7/09
100-NR-2	199-N-239	C7332	Apatite barrier injection/monitoring	15.48	16.9	5/21/10
100-NR-2	199-N-240	C7333	Apatite barrier injection/monitoring	24.59	26.4	12/7/09
100-NR-2	199-N-241	C7334	Apatite barrier injection/monitoring	15.24	16.4	5/21/10
100-NR-2	199-N-242	C7335	Apatite barrier injection/monitoring	25.26	26.4	12/14/09
100-NR-2	199-N-243	C7336	Apatite barrier injection/monitoring	15.49	16.9	5/21/10
100-NR-2	199-N-244	C7337	Apatite barrier injection/monitoring	24.28	26.2	12/14/09
100-NR-2	199-N-245	C7338	Apatite barrier injection/monitoring	15.48	17.3	5/21/10
100-NR-2	199-N-246	C7339	Apatite barrier injection/monitoring	24.86	27	1/22/10
100-NR-2	199-N-247	C7340	Apatite barrier injection/monitoring	15.49	18	5/21/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-NR-2	199-N-248	C7341	Apatite barrier injection/monitoring	24.79	26.8	1/22/10
100-NR-2	199-N-249	C7342	Apatite barrier injection/monitoring	15.42	17.1	5/21/10
100-NR-2	199-N-250	C7343	Apatite barrier injection/monitoring	25.22	27	1/22/10
100-NR-2	199-N-251	C7344	Apatite barrier injection/monitoring	15.41	17	5/21/10
100-NR-2	199-N-252	C7345	Apatite barrier injection/monitoring	24.7	26.5	1/25/10
100-NR-2	199-N-253	C7346	Apatite barrier injection/monitoring	15.47	17.2	5/21/10
100-NR-2	199-N-254	C7347	Apatite barrier injection/monitoring	24.73	26.5	1/2/10
100-NR-2	199-N-255	C7348	Apatite barrier injection/monitoring	15.39	17.2	5/21/10
100-NR-2	199-N-256	C7349	Apatite barrier injection/monitoring	24.93	27.1	1/26/10
100-NR-2	199-N-257	C7350	Apatite barrier injection/monitoring	15.29	17	5/21/10
100-NR-2	199-N-258	C7351	Apatite barrier injection/monitoring	24.65	26.6	1/26/10
100-NR-2	199-N-259	C7352	Apatite barrier injection/monitoring	15.28	17.2	5/21/10
100-NR-2	199-N-260	C7353	Apatite barrier injection/monitoring	24.94	26.4	1/26/10
100-NR-2	199-N-261	C7354	Apatite barrier injection/monitoring	15.31	17.7	5/21/10
100-NR-2	199-N-262	C7355	Apatite barrier injection/monitoring	25.31	26.3	1/27/10
100-NR-2	199-N-263	C7356	Apatite barrier injection/monitoring	15.28	17.7	5/21/10
100-NR-2	199-N-264	C7357	Apatite barrier injection/monitoring	25.06	26.6	1/27/10
100-NR-2	199-N-265	C7358	Apatite barrier injection/monitoring	15.31	17.3	5/21/10
100-NR-2	199-N-266	C7359	Apatite barrier injection/monitoring	24.77	26.9	1/27/10
100-NR-2	199-N-267	C7360	Apatite barrier injection/monitoring	15.33	17.7	5/21/10
100-NR-2	199-N-268	C7361	Apatite barrier injection/monitoring	24.75	26.9	1/28/10
100-NR-2	199-N-269	C7362	Apatite barrier injection/monitoring	15.31	17.5	5/21/10
100-NR-2	199-N-270	C7363	Apatite barrier injection/monitoring	25.35	26.5	1/28/10
100-NR-2	199-N-271	C7364	Apatite barrier injection/monitoring	15.31	18	5/21/10
100-NR-2	199-N-272	C7365	Apatite barrier injection/monitoring	25.03	26.8	1/28/10
100-NR-2	199-N-273	C7366	Apatite barrier injection/monitoring	15.34	17.7	5/21/10
100-NR-2	199-N-274	C7367	Apatite barrier injection/monitoring	24.71	26	2/16/10
100-NR-2	199-N-275	C7368	Apatite barrier injection/monitoring	15.37	17.5	5/21/10
100-NR-2	199-N-276	C7369	Apatite barrier injection/monitoring	25.19	26.3	2/16/10
100-NR-2	199-N-277	C7370	Apatite barrier injection/monitoring	15.34	17.9	5/21/10
100-NR-2	199-N-278	C7371	Apatite barrier injection/monitoring	24.77	26.4	2/16/10
100-NR-2	199-N-279	C7372	Apatite barrier injection/monitoring	15.31	17.7	5/21/10
100-NR-2	199-N-280	C7373	Apatite barrier injection/monitoring	25.25	27	2/16/10
100-NR-2	199-N-281	C7374	Apatite barrier injection/monitoring	16	18.1	5/21/10
100-NR-2	199-N-282	C7375	Apatite barrier injection/monitoring	24.6	26.8	2/17/10
100-NR-2	199-N-283	C7376	Apatite barrier injection/monitoring	15.88	17.7	5/21/10
100-NR-2	199-N-284	C7377	Apatite barrier injection/monitoring	24.82	25.9	2/17/10
100-NR-2	199-N-285	C7378	Apatite barrier injection/monitoring	15.88	17.7	5/21/10
100-NR-2	199-N-286	C7379	Apatite barrier injection/monitoring	25.03	27.4	2/17/10
100-NR-2	199-N-287	C7380	Apatite barrier injection/monitoring	15.33	17.6	5/21/10
100-NR-2	199-N-288	C7381	Apatite barrier injection/monitoring	24.5	27.1	4/29/10
100-NR-2	199-N-289	C7382	Apatite barrier injection/monitoring	15.3	17	5/21/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-NR-2	199-N-290	C7383	Apatite barrier injection/monitoring	24.81	27.5	4/29/10
100-NR-2	199-N-291	C7384	Apatite barrier injection/monitoring	15.31	17.3	5/21/10
100-NR-2	199-N-292	C7385	Apatite barrier injection/monitoring	24.87	27.5	4/29/10
100-NR-2	199-N-293	C7386	Apatite barrier injection/monitoring	15	17.6	5/21/10
100-NR-2	199-N-294	C7387	Apatite barrier injection/monitoring	24.88	27.1	4/29/10
100-NR-2	199-N-295	C7388	Apatite barrier injection/monitoring	15.84	17.9	5/21/10
100-NR-2	199-N-296	C7389	Apatite barrier injection/monitoring	24.68	27.2	4/29/10
100-NR-2	199-N-297	C7390	Apatite barrier injection/monitoring	15.32	17.9	5/21/10
100-NR-2	199-N-298	C7391	Apatite barrier injection/monitoring	24.55	27.4	4/23/10
100-NR-2	199-N-299	C7392	Apatite barrier injection/monitoring	15.43	18	5/21/10
100-NR-2	199-N-300	C7393	Apatite barrier injection/monitoring	24.67	27.2	4/23/10
100-NR-2	199-N-301	C7394	Apatite barrier injection/monitoring	16.2	17.5	5/21/10
100-NR-2	199-N-302	C7395	Apatite barrier injection/monitoring	25	27.1	4/22/10
100-NR-2	199-N-303	C7396	Apatite barrier injection/monitoring	15.43	16.9	5/21/10
100-NR-2	199-N-304	C7397	Apatite barrier injection/monitoring	25.47	27.9	4/14/10
100-NR-2	199-N-305	C7398	Apatite barrier injection/monitoring	15.53	17.9	5/21/10
100-NR-2	199-N-306	C7399	Apatite barrier injection/monitoring	25.48	27.6	4/14/10
100-NR-2	199-N-307	C7400	Apatite barrier injection/monitoring	15.83	17.1	5/21/10
100-NR-2	199-N-308	C7401	Apatite barrier injection/monitoring	25.74	26.9	4/14/10
100-NR-2	199-N-309	C7402	Apatite barrier injection/monitoring	15.86	17.8	5/21/10
100-NR-2	199-N-310	C7403	Apatite barrier injection/monitoring	25.44	27.5	4/14/10
100-NR-2	199-N-311	C7404	Apatite barrier injection/monitoring	15.43	17.6	5/21/10
100-NR-2	199-N-312	C7405	Apatite barrier injection/monitoring	25.9	28	4/15/10
100-NR-2	199-N-313	C7406	Apatite barrier injection/monitoring	16.29	17.2	5/21/10
100-NR-2	199-N-314	C7407	Apatite barrier injection/monitoring	25.72	26.7	4/15/10
100-NR-2	199-N-315	C7408	Apatite barrier injection/monitoring	15.19	17.5	5/21/10
100-NR-2	199-N-316	C7409	Apatite barrier injection/monitoring	25.43	27.6	4/13/10
100-NR-2	199-N-317	C7410	Apatite barrier injection/monitoring	15.43	17.5	5/21/10
100-NR-2	199-N-318	C7411	Apatite barrier injection/monitoring	25.35	26.8	4/13/10
100-NR-2	199-N-319	C7412	Apatite barrier injection/monitoring	15.31	16.9	5/21/10
100-NR-2	199-N-320	C7413	Apatite barrier injection/monitoring	25.46	27.3	4/13/10
100-NR-2	199-N-321	C7414	Apatite barrier injection/monitoring	15.43	17.9	5/21/10
100-NR-2	199-N-322	C7415	Apatite barrier injection/monitoring	25.15	26.6	4/13/10
100-NR-2	199-N-323	C7416	Apatite barrier injection/monitoring	15.43	17.2	5/21/10
100-NR-2	199-N-324	C7417	Apatite barrier injection/monitoring	25.54	26.8	4/13/10
100-NR-2	199-N-325	C7418	Apatite barrier injection/monitoring	16.32	18.1	5/21/10
100-NR-2	199-N-326	C7419	Apatite barrier injection/monitoring	25.6	26.5	4/15/10
100-NR-2	199-N-327	C7420	Apatite barrier injection/monitoring	15.43	17.9	5/21/10
100-NR-2	199-N-328	C7421	Apatite barrier injection/monitoring	24.61	26	4/15/10
100-NR-2	199-N-329	C7422	Apatite barrier injection/monitoring	15.44	16.8	5/21/10
100-NR-2	199-N-330	C7423	Apatite barrier injection/monitoring	25.26	25.9	3/19/10
100-NR-2	199-N-331	C7424	Apatite barrier injection/monitoring	15.02	18.6	5/21/10
100-NR-2	199-N-332	C7425	Apatite barrier injection/monitoring	24.77	26.3	3/19/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-NR-2	199-N-333	C7426	Apatite barrier injection/monitoring	15.08	17.3	5/21/10
100-NR-2	199-N-334	C7427	Apatite barrier injection/monitoring	24.72	26.3	3/18/10
100-NR-2	199-N-335	C7428	Apatite barrier injection/monitoring	14.88	17.3	5/21/10
100-NR-2	199-N-336	C7429	Apatite barrier injection/monitoring	24.96	26.8	3/18/10
100-NR-2	199-N-337	C7430	Apatite barrier injection/monitoring	15.17	17.4	5/21/10
100-NR-2	199-N-338	C7431	Apatite barrier injection/monitoring	25.11	27	3/18/10
100-NR-2	199-N-339	C7432	Apatite barrier injection/monitoring	15.31	17.4	5/21/10
100-NR-2	199-N-340	C7433	Apatite barrier injection/monitoring	24.57	25.9	3/19/10
100-NR-2	199-N-341	C7434	Apatite barrier injection/monitoring	15.26	17.1	5/21/10
100-NR-2	199-N-342	C7435	Apatite barrier injection/monitoring	24.4	28.4	2/18/10
100-NR-2	199-N-343	C7436	Apatite barrier injection/monitoring	15.3	17.4	5/21/10
100-NR-2	199-N-344	C7437	Apatite barrier injection/monitoring	24.58	27.4	2/18/10
100-NR-2	199-N-345	C7438	Apatite barrier injection/monitoring	15.3	18.1	5/21/10
100-NR-2	199-N-349	C7439	Apatite barrier injection/monitoring	24.83	26.7	3/8/10
100-NR-2	199-N-348	C7440	Apatite barrier injection/monitoring	24.79	26.5	3/8/10
100-NR-2	199-N-347	C7441	Apatite barrier injection/monitoring	24.68	26.8	3/8/10
100-NR-2	199-N-346	C7442	Apatite barrier injection/monitoring	24.72	26.8	3/8/10
100-NR-2	199-N-350	C7443	Apatite barrier injection/monitoring	24.69	26.9	2/9/10
100-NR-2	199-N-351	C7444	Apatite barrier injection/monitoring	24.87	26.9	2/9/10
100-NR-2	199-N-352	C7445	Apatite barrier injection/monitoring	25.22	27	2/9/10
100-NR-2	199-N-353	C7446	Apatite barrier injection/monitoring	25.15	26.4	3/25/10
100-NR-2	199-N-354	C7447	Apatite barrier injection/monitoring	25.3	26.9	3/25/10
100-NR-2	199-N-355	C7448	Apatite barrier injection/monitoring	25.33	26.6	3/25/10
100-NR-2	199-N-356	C7449	Apatite barrier injection/monitoring	24.64	25.6	3/25/10
100-NR-2	199-N-357	C7450	Apatite barrier injection/monitoring	25.34	26.8	3/25/10
100-NR-2	199-N-358	C7451	Apatite barrier injection/monitoring	25.09	26.5	3/25/10
100-NR-2	199-N-359	C7452	Apatite barrier injection/monitoring	24.8	26.9	4/29/10
100-NR-2	199-N-360	C7453	Apatite barrier injection/monitoring	25.06	26.5	4/29/10
100-NR-2	199-N-361	C7454	Apatite barrier injection/monitoring	25.43	27	4/29/10
100-NR-2	199-N-362	C7455	Apatite barrier injection/monitoring	25.21	27.1	4/15/10
100-NR-2	199-N-363	C7456	Apatite barrier injection/monitoring	25.18	26.9	4/15/10
100-NR-2	199-N-364	C7457	Apatite barrier injection/monitoring	25.24	27.4	4/15/10
100-NR-2	199-N-365	C7458	Apatite barrier injection/monitoring	25.18	26.4	4/15/10
100-NR-2	199-N-366	C7459	Apatite barrier injection/monitoring	24.76	25.5	4/15/10
100-NR-2	199-N-368	C7460	Apatite barrier injection/monitoring	25.39	26.2	11/10/09
100-NR-2	199-N-369	C7461	Apatite barrier injection/monitoring	23.8	26.2	11/10/09
100-NR-2	199-N-370	C7462	Apatite barrier injection/monitoring	24.07	26.2	11/10/09
100-NR-2	199-N-367	C7463	Apatite barrier injection/monitoring	24.64	27.1	4/15/10
200-BP-5	299-E29-54	C5860	200-BP-5 OU support RI/FS	322.69	375.2	3/23/10
200-BP-5	299-E24-25	C7514	200-BP-5 OU support RI/FS	309.03	361.9	3/23/10
200-BP-5	299-E28-30	C7515	200-BP-5 OU support RI/FS	323.99	375.6	3/23/10
200-BP-5	299-E33-265	C7564	Support Milestone M-24	282.77	283.6	9/7/10
200-BP-5	299-E33-266	C7565	Support Milestone M-24	286.06	286.06	9/7/10

Table 16-1. (Cont.)

Operable Unit	Well Name	Well ID	Well Purpose	Construction (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
200-BP-5	299-E27-24	C7570	Support Milestone M-24	317.59	317.8	9/7/10
200-BP-5	299-E27-25	C7571	Support Milestone M-24	234.16	248	9/7/10
200-BP-5	199-K-183	C7683	200-BP-5 OU support RI/FS	112	153.2	11/18/10
200-UP-1	299-W17-3	C7577	200 West Area expansion	440.01	492	9/27/10
200-UP-1	299-W22-89	C7664	Support Milestone M-24	269.19	332.6	9/7/10
200-ZP-1	299-W11-49	C7019	200 West Area expansion	430	457	9/27/10
200-ZP-1	299-W11-90	C7022	200 West Area expansion	519.53	525.9	9/27/10
200-ZP-1	299-W14-74	C7024	200 West Area expansion	504.85	508	3/1/10
200-ZP-1	299-W14-74	C7024	200 West Area expansion	504.85	508	3/1/10
200-ZP-1	299-W11-92	C7025	200 West Area expansion	405.25	460	9/27/10
200-ZP-1	299-W12-2	C7027	200 West Area expansion	492.03	505	3/1/10
200-ZP-1	299-W12-3	C7028	200 West Area expansion	494.9	496	3/1/10
200-ZP-1	299-W12-4	C7029	200 West Area expansion	508.7	515.8	3/1/10
200-ZP-1	299-W14-21	C7494	200 West Area expansion	520	525	3/1/10
200-ZP-1	299-W15-226	C7574	200 West Area expansion	448.63	489	9/27/10
200-ZP-1	299-W15-227	C7575	200 West Area expansion	456.2	511.85	9/27/10
200-ZP-1	299-W17-2	C7576	200 West Area expansion	405.22	470	9/27/10
200-ZP-1	699-45-67	C7578	200 West Area expansion	325.08	421	9/27/10
200-ZP-1	699-43-67	C7579	200 West Area expansion	365.1	478	9/27/10
200-ZP-1	299-W11-96	C7754	200 West Area expansion	474.7	480.3	3/1/10
300-FF-5	699-S5-E2	C7829	618-10 dust control	245	246	11/19/10
300-FF-5	699-S5-E2B	C7830	618-10 dust control	254.48	260	11/19/10
300-FF-5	399-3-35	C7874	Support IFRC	37.99	41.6	5/4/10
300-FF-5	399-2-34	C7875	Support IFRC	37.4	41.9	5/4/10
300-FF-5	399-2-37	C7876	Support IFRC	38.4	40.6	5/4/10

Table 16-2. Characterization Boreholes and Direct-Push Technology Installation, Calendar Year 2010

Project/Location	Well Name	Drill Depth (ft bgs)	Type of Borehole
100-C-7:1	C7883	89.7	Characterization
100-C-7:1	C7884	91.1	Characterization
116-D-1B	C7855	91.2	Characterization
116-D-7	C7851	69	Characterization
116-DR-9	C7850	72.3	Characterization
116-H-1	C7864	50.8	Characterization
116-H-4	C7862	52.4	Characterization
116-H-6	199-H4-84	48.6	Characterization
216-A-25 Pond	C6960	4	Direct push
216-A-25 Pond	C6961	4.5	Direct push
216-B-3 Pond	C6962	9.5	Direct push
216-E-127 pipeline	C6723	25	Direct push
216-E-127 pipeline	C6724	25	Direct push
216-E-127 pipeline	C6725	25	Direct push
216-E-127 pipeline	C6726	25	Direct push
216-E-127 pipeline	C7885	25	Direct push
216-E-127 pipeline	C7886	25	Direct push
216-E-127 pipeline	C7887	25	Direct push
216-E-127 pipeline	C7888	25	Direct push
216-E-127 pipeline	C7889	15	Direct push
216-E-127 pipeline	C7890	10	Direct push
216-E-127 pipeline	C7892	15	Direct push
216-E-127 pipeline	C7893	15	Direct push
216-S-16 Pond	C5727	9.7	Direct push
216-S-17 Pond	C5758	9.7	Direct push
216-S-17 Pond	C5759	5.5	Direct push
216-S-26 Crib	C7965	17	Direct push
216-S-26 Crib	C7966	17	Direct push
216-S-26 Crib	C7967	17	Direct push
216-S-26 Crib	C7968	17	Direct push
216-T-4B Pond	C6969	3	Direct push
216-T-4B Pond	C6970	5	Direct push
216-T-4B Pond	C7944	5	Direct push
216-U-10 Pond	C5766	6.8	Direct push
216-U-10 Pond	C5767	6.8	Direct push
216-U-10 Pond	C5768	5.7	Direct push
216-U-10 Pond	C5773	7	Direct push
216-U-10 Pond	C6968	8.5	Direct push
216-U-10 Pond	C7945	6.8	Direct push
216-U-10 Pond	C7946	6.8	Direct push
216-U-10 Pond	C7947	6.8	Direct push
216-U-10 Pond	C7948	10.5	Direct push
216-U-10 Pond	C7949	6.9	Direct push
216-U-10 Pond	C7950	6.2	Direct push
216-U-10 Pond	C7951	6.2	Direct push
600 OCL	C5804	15	Direct push
600 OCL	C7952	21	Direct push
600 OCL	C7953	14	Direct push
600 OCL	C7954	19	Direct push
600 OCL	C7955	16	Direct push
600 OCL	C7956	23	Direct push
600 OCL	C7957	18	Direct push
600 OCL	C7958	18	Direct push
600 OCL	C7959	21	Direct push
600 OCL	C7960	21	Direct push
600 OCL	C7961	21	Direct push
600 OCL	C7962	21	Direct push
600-218	C7834	4	Direct push
600-218	C7835	9.5	Direct push
600-218	C7836	8.5	Direct push
600-218	C7837	9.5	Direct push
600-218	C7838	9.3	Direct push
600-220	C8037	4	Direct push
600-220	C8038	7	Direct push
600-220	C8039	7	Direct push
600-220	C8040	7	Direct push
600-228	C8051	4	Direct push
600-228	C8052	4	Direct push
600-228	C8053	4	Direct push
600-228	C8054	4	Direct push
600-228	C8055	4	Direct push
600-228	C8056	13	Direct push
600-228	C8057	4	Direct push
600-228	C8058	4	Direct push
600-228	C8059	4	Direct push
600-228	C8060	4	Direct push
600-228	C8061	4	Direct push
600-228	C8062	4	Direct push
600-228	C8063	4	Direct push
600-228	C8125	4	Direct push
600-262	C7772	8	Direct push
600-262	C7808	8	Direct push
600-37	C5799	22.6	Direct push
600-37	C5800	22.1	Direct push
600-37	C5801	21.1	Direct push
600-37	C5802	27.2	Direct push
600-37	C5803	27.5	Direct push
UPR 600-12	C5788	16	Direct push
UPR 600-12	C5789	16	Direct push
UPR 600-12	C5790	16	Direct push
UPR 600-12	C5791	16	Direct push
UPR 600-12	C5792	16	Direct push
UPR 600-12	C5793	16	Direct push
UPR 600-12	C5794	16	Direct push
UPR 600-12	C5795	16	Direct push
UPR 600-12	C5796	16	Direct push

Table 16-3. Well Maintenance Summary for the Reporting Period

Well Name	Well ID	Field Order No.
699-38-65	A5148	WMO-NR-2010-3-096
299-W11-18	A7284	WMO-NR-2010-4-081
699-12-4D	A8252	WMO-NR-2010-2-033
199-H4-15CS	A4625	WMO-NR-2009-4-053
199-H4-15CS	A4625	WMO-NR-2009-4-053
199-K-119A	B2806	WMO-NR-2010-2-011
299-E28-1	A6784	WMO-NR-2010-3-103
199-F7-3	A4605	WMO-NR-2010-4-060
299-E33-15	A4842	WMO-NR-2010-2-025
299-W11-12	A4902	WMO-NR-2011-1-017
299-W11-12	A4902	WMO-NR-2011-1-017
299-W19-20	A4949	WMO-NR-2011-1-342
699-53-35	A5238	WMO-NR-2010-3-105
699-53-35	A5238	WMO-NR-2010-3-105
699-54-45A	A5251	WMO-NR-2010-3-048
299-W19-36	B2461	WMO-NR-2010-2-076
299-W10-1	A7136	WMO-NR-2010-3-133
299-W14-6	A7331	WMO-NR-2011-1-322
299-W14-6	A7331	WMO-NR-2010-4-048
199-D4-15	B8073	WMO-NR-2010-3-099
199-D8-69	B2773	WMO-NR-2010-3-041
199-D8-69	B2773	WMO-NR-2010-3-010
199-K-114A	B2801	WMO-NR-2010-4-065
199-K-116A	B2803	WMO-NR-2010-2-064
299-E28-18	A4821	WMO-NR-2010-4-032
199-N-26	A4675	WMO-NR-2010-1-022
199-D8-6	A4585	WMO-NR-2010-3-043
199-K-113A	B2800	WMO-NR-2010-4-063
199-K-113A	B2800	WMO-NR-2010-4-063
299-W10-14	A4891	WMO-NR-2010-3-076
299-W10-24	B8546	WMO-NR-2010-2-053
299-E33-44	B8554	WMO-NR-2010-4-069
299-W14-15	C3114	WMO-NR-2011-1-315
299-W14-15	C3114	WMO-NR-2010-3-164
299-W11-40	C3118	WMO-NR-2010-3-162
299-W14-17	C3121	WMO-NR-2011-1-317
299-W11-42	C3242	WMO-NR-2010-3-102
299-W19-43	C3381	WMO-NR-2010-4-009
299-W19-43	C3381	WMO-NR-2010-1-025
299-W19-45	C3394	WMO-NR-2011-1-352
299-W19-45	C3394	WMO-NR-2010-3-075
299-W14-18	C3396	WMO-NR-2011-1-318
299-W14-18	C3396	WMO-NR-2010-3-082
699-23-34A	A5087	WMO-NR-2011-1-531
199-N-32	A4681	WMO-NR-2010-3-078

Well Name	Well ID	Field Order No.
199-D5-130	C7590	WMO-NR-2010-3-119
199-H1-5	C7610	WMO-NR-2011-1-526
199-H4-80	C7595	WMO-NR-2010-4-037
199-H4-81	C7596	WMO-NR-2011-1-527
199-B5-5	C7505	WMO-NR-2010-4-004
199-N-281	C7374	WMO-NR-2011-1-158
199-N-287	C7380	WMO-NR-2011-1-164
299-E27-24	C7570	WMO-NR-2011-1-238
199-N-297	C7390	WMO-NR-2011-1-174
199-N-299	C7392	WMO-NR-2011-1-175
199-N-306	C7399	WMO-NR-2011-1-182
199-N-315	C7408	WMO-NR-2011-1-191
199-D4-95	C7083	WMO-NR-2010-2-037
199-D4-95	C7083	WMO-NR-2010-2-037
199-D4-96	C7084	WMO-NR-2010-2-039
199-D4-99	C7087	WMO-NR-2010-2-041
299-W15-225	C7017	WMO-NR-2010-2-022
199-D2-12	C7090	WMO-NR-2010-3-146
C7074	C7074	WMO-NR-2010-1-069
199-D8-89	C7091	WMO-NR-2010-2-043
199-D8-90	C7092	WMO-NR-2010-2-042
199-D8-94	C7096	WMO-NR-2010-3-148
199-K-178	C7149	WMO-NR-2011-1-052
199-K-179	C7150	WMO-NR-2010-2-013
199-K-180	C7151	WMO-NR-2010-2-024
299-E28-30	C7515	WMO-NR-2010-3-047
199-N-362	C7455	WMO-NR-2011-1-209
199-N-200	C7327	WMO-NR-2011-1-106
C7756	C7756	WMO-NR-2010-1-070
199-H4-10	A4614	WMO-NR-2010-2-062
299-E27-13	A4811	WMO-NR-2010-3-128
299-E33-31	A4856	WMO-NR-2010-4-068
299-W11-14	A4903	WMO-NR-2011-1-298
699-42-40C	A5169	WMO-NR-2010-3-012
299-W15-2	A5466	WMO-NR-2010-4-083
199-K-115A	B2802	WMO-NR-2010-4-064
199-B3-47	A4554	WMO-NR-2010-4-001
199-N-75	A4718	WMO-NR-2011-1-215
299-E28-1	A6784	WMO-NR-2010-4-077
199-K-18	A4647	WMO-NR-2010-2-061
199-N-18	A4667	WMO-NR-2011-1-104
299-E25-28	A4773	WMO-NR-2010-3-084
299-E25-36	A4784	WMO-NR-2011-1-226
299-W12-1	A4912	WMO-NR-2010-3-094
299-W15-15	A4919	WMO-NR-2010-4-066

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-E17-22	C3826	WMO-NR-2010-4-044
199-D4-92	C4688	WMO-NR-2010-4-125
199-D4-93	C4689	WMO-NR-2010-4-126
299-W11-43	C4694	WMO-NR-2011-1-306
199-K-134	C4735	WMO-NR-2010-4-119
199-K-135	C4736	WMO-NR-2010-4-120
299-W19-101	C4966	WMO-NR-2010-3-141
299-W19-101	C4966	WMO-NR-2010-4-073
299-W22-69	C4969	WMO-NR-2011-1-365
299-W22-72	C4970	WMO-NR-2011-1-366
299-W22-86	C4971	WMO-NR-2011-1-370
699-50-59	C4882	WMO-NR-2010-3-049
199-N-126	C5032	WMO-NR-2011-1-071
299-W14-71	C5102	WMO-NR-2010-3-093
299-W14-72	C5103	WMO-NR-2010-3-069
N116mArray-11A	C5265	WMO-NR-2010-4-021
199-N-152	C5320	WMO-NR-2011-1-092
299-W15-44	C3956	WMO-NR-2011-1-432
299-W15-44	C3956	WMO-NR-2010-3-077
299-W14-19	C3957	WMO-NR-2010-3-080
299-E27-4	C4125	WMO-NR-2010-3-129
299-W15-47	C4184	WMO-NR-2010-4-008
199-D5-32	C4185	WMO-NR-2010-2-019
399-4-9	A5056	WMO-NR-2010-2-029
299-E29-54	C5860	WMO-NR-2010-4-057
699-52-55B	C5862	WMO-NR-2010-3-022
699-52-55B	C5862	WMO-NR-2010-3-022
199-D5-119	C5933	WMO-NR-2010-3-013
C6240	C6240	WMO-NR-2010-4-012
299-E33-49	C4261	WMO-NR-2010-3-169
199-N-159	C6177	WMO-NR-2011-1-097
199-D5-107	C5577	WMO-NR-2010-4-105
199-D5-112	C5582	WMO-NR-2010-4-108
199-N-169	C7034	WMO-NR-2011-1-100
299-E24-25	C7514	WMO-NR-2010-2-023
199-D8-98	C7602	WMO-NR-2010-3-122
199-D8-99	C7593	WMO-NR-2010-3-152
199-D7-5	C7608	WMO-NR-2010-4-075
199-H4-80	C7595	WMO-NR-2011-1-529
199-H4-81	C7596	WMO-NR-2010-4-036
199-D6-1	C7592	WMO-NR-2010-3-153
199-N-250	C7343	WMO-NR-2011-1-135
199-B2-14	C7665	WMO-NR-2010-4-003
199-B2-14	C7665	WMO-NR-2010-3-050
199-B3-50	C7506	WMO-NR-2011-1-022

Well Name	Well ID	Field Order No.
299-W22-26	A4968	WMO-NR-2011-1-356
299-W22-26	A4968	WMO-NR-2011-1-424
699-26-15A	A5100	WMO-NR-2010-3-027
699-35-70	A5140	WMO-NR-2010-4-040
699-40-33A	A5153	WMO-NR-2010-2-006
699-53-35	A5238	WMO-NR-2010-3-105
699-53-55C	A5246	WMO-NR-2010-1-057
699-61-62	A5285	WMO-NR-2010-3-024
699-63-90	A5293	WMO-NR-2010-2-000
699-8-25	A5334	WMO-NR-2010-3-032
299-W11-3	A5473	WMO-NR-2010-4-091
299-W19-36	B2461	WMO-NR-2010-2-076
199-N-103A	A9988	WMO-NR-2011-1-065
299-E28-18	A4821	WMO-NR-2010-4-032
299-E26-8	A4805	WMO-NR-2010-4-061
699-48-71	A5214	WMO-NR-2010-3-111
199-D5-40	B8749	WMO-NR-2010-4-090
299-W22-50	B8814	WMO-NR-2011-1-364
299-W11-39	C3117	WMO-NR-2010-3-165
299-W22-83	C3126	WMO-NR-2010-3-158
299-W11-42	C3242	WMO-NR-2010-3-160
299-W15-763	C3339	WMO-NR-2011-1-331
199-D4-85	C3317	WMO-NR-2010-3-006
199-D4-86	C3318	WMO-NR-2010-3-097
299-W19-43	C3381	WMO-NR-2011-1-350
299-W14-18	C3396	WMO-NR-2010-3-166
299-W14-18	C3396	WMO-NR-2010-3-082
399-8-3	A5061	WMO-NR-2010-2-030
299-W22-10	A7835	WMO-NR-2011-1-355
699-S18-E2B	A9199	WMO-NR-2010-4-038
699-25-33A	A5094	WMO-NR-2010-4-053
299-W22-9	A7834	WMO-NR-2011-1-372
199-N-27	A4676	WMO-NR-2011-1-146
299-W11-31	A5472	WMO-NR-2011-1-300
199-D8-88	C4536	WMO-NR-2010-3-107
299-W11-43	C4694	WMO-NR-2010-3-140
199-N-131	C5037	WMO-NR-2011-1-076
199-N-132	C5038	WMO-NR-2011-1-077
199-N-144	C5050	WMO-NR-2011-1-086
199-N-150	C5318	WMO-NR-2011-1-090
199-N-151	C5319	WMO-NR-2011-1-091
199-K-150	C5366	WMO-NR-2010-2-058
299-W14-19	C3957	WMO-NR-2011-1-319
199-D5-32	C4185	WMO-NR-2010-2-019
299-E27-23	C4190	WMO-NR-2010-1-051

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
199-B5-6	C7507	WMO-NR-2011-1-449
199-B5-6	C7507	WMO-NR-2010-2-071
199-N-257	C7350	WMO-NR-2011-1-138
199-N-258	C7351	WMO-NR-2011-1-139
199-N-282	C7375	WMO-NR-2011-1-159
199-N-284	C7377	WMO-NR-2011-1-161
199-N-292	C7385	WMO-NR-2011-1-169
199-N-303	C7396	WMO-NR-2011-1-180
199-N-350	C7443	WMO-NR-2011-1-199
199-N-355	C7448	WMO-NR-2011-1-202
199-D4-95	C7083	WMO-NR-2010-2-037
199-D4-96	C7084	WMO-NR-2010-2-039
199-D4-97	C7085	WMO-NR-2010-2-038
199-D4-99	C7087	WMO-NR-2010-2-041
199-D8-91	C7093	WMO-NR-2010-2-044
199-D4-94	C7075	WMO-NR-2010-4-127
199-K-178	C7149	WMO-NR-2010-2-054
199-N-226	C7301	WMO-NR-2011-1-113
199-N-225	C7302	WMO-NR-2011-1-112
199-N-249	C7342	WMO-NR-2011-1-134
199-K-183	C7683	WMO-NR-2011-1-054
199-B9-2	A4565	WMO-NR-2010-3-018
299-E27-13	A4811	WMO-NR-2010-3-128
399-1-2	A5035	WMO-NR-2010-2-008
699-35-78A	A5141	WMO-NR-2010-3-092
699-S30-E15A	A5377	WMO-NR-2010-3-062
699-12-4D	A8252	WMO-NR-2010-2-033
199-K-115A	B2802	WMO-NR-2010-4-064
199-B3-47	A4554	WMO-NR-2010-4-001
299-E13-4	A5852	WMO-NR-2011-1-219
299-W27-1	A8062	WMO-NR-2010-2-021
199-N-99A	A9910	WMO-NR-2011-1-218
299-E33-18	A4844	WMO-NR-2010-3-167
299-E33-39	A4864	WMO-NR-2010-1-056
299-W12-1	A4912	WMO-NR-2011-1-312
299-W12-1	A4912	WMO-NR-2010-3-094
299-W15-15	A4919	WMO-NR-2011-1-324
299-W22-26	A4968	WMO-NR-2011-1-424
699-34-42	A5136	WMO-NR-2010-2-036
699-40-1	A5152	WMO-NR-2010-2-005
699-53-35	A5238	WMO-NR-2010-3-105
699-37-E4	A8588	WMO-NR-2010-2-004
299-W19-36	B2461	WMO-NR-2010-1-026
299-W19-36	B2461	WMO-NR-2010-1-026
299-E33-16	A6855	WMO-NR-2010-4-071

Well Name	Well ID	Field Order No.
399-3-11	A8077	WMO-NR-2010-2-068
299-E27-155	C5852	WMO-NR-2011-1-235
C6242	C6242	WMO-NR-2010-4-013
199-K-165	C6451	WMO-NR-2010-2-035
199-K-166	C6452	WMO-NR-2011-1-049
199-N-171	C7036	WMO-NR-2011-1-102
199-D5-101	C7583	WMO-NR-2010-3-091
199-D5-127	C7591	WMO-NR-2010-3-089
199-D8-95	C7589	WMO-NR-2010-3-118
199-D8-97	C7582	WMO-NR-2010-3-120
199-D7-3	C7599	WMO-NR-2010-3-121
199-H4-80	C7595	WMO-NR-2010-4-037
199-H4-81	C7596	WMO-NR-2011-1-527
199-H4-82	C7609	WMO-NR-2011-1-528
199-B2-14	C7665	WMO-NR-2011-1-021
199-N-270	C7363	WMO-NR-2011-1-147
199-N-272	C7365	WMO-NR-2011-1-149
199-N-275	C7368	WMO-NR-2011-1-152
199-N-278	C7371	WMO-NR-2011-1-155
199-N-279	C7372	WMO-NR-2011-1-156
199-N-280	C7373	WMO-NR-2011-1-157
199-N-286	C7379	WMO-NR-2011-1-163
199-N-300	C7393	WMO-NR-2011-1-177
199-N-307	C7400	WMO-NR-2011-1-183
199-N-309	C7402	WMO-NR-2011-1-185
199-N-358	C7451	WMO-NR-2011-1-205
199-D4-97	C7085	WMO-NR-2010-2-038
199-D4-97	C7085	WMO-NR-2010-2-038
199-D2-10	C7089	WMO-NR-2010-3-147
199-D2-12	C7090	WMO-NR-2010-3-146
199-D8-90	C7092	WMO-NR-2010-2-042
199-N-222	C7305	WMO-NR-2011-1-109
199-N-236	C7329	WMO-NR-2011-1-122
199-N-242	C7335	WMO-NR-2011-1-127
199-N-246	C7339	WMO-NR-2011-1-132
199-K-185	C7685	WMO-NR-2011-1-055
299-W22-24Q	A9569	WMO-NR-2010-3-054
199-N-76	A4719	WMO-NR-2011-1-216
299-E24-20	A4756	WMO-NR-2010-2-077
299-E33-31	A4856	WMO-NR-2010-1-055
399-1-2	A5035	WMO-NR-2010-2-008
699-42-37	A5164	WMO-NR-2011-1-532
699-63-58	A5292	WMO-NR-2010-3-025
199-K-115A	B2802	WMO-NR-2010-4-064
299-E28-1	A6784	WMO-NR-2010-4-077

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-W14-6	A7331	WMO-NR-2010-4-048
299-W11-13	A5465	WMO-NR-2010-2-026
299-W11-13	A5465	WMO-NR-2010-2-026
299-E17-21	B8500	WMO-NR-2010-4-043
199-K-114A	B2801	WMO-NR-2010-4-065
199-K-114A	B2801	WMO-NR-2010-4-065
1199-41-15	A9371	WMO-NR-2010-3-067
199-K-125A	B8559	WMO-NR-2010-2-012
699-20-20	A5080	WMO-NR-2010-3-029
299-E26-8	A4805	WMO-NR-2010-4-061
299-W22-46	A4977	WMO-NR-2011-1-360
299-W19-42	B8553	WMO-NR-2011-1-349
199-D5-37	B8745	WMO-NR-2010-3-100
299-W22-49	B8813	WMO-NR-2011-1-363
299-W15-41	B8815	WMO-NR-2011-1-535
299-W15-41	B8815	WMO-NR-2011-1-535
199-D4-25	B8976	WMO-NR-2010-4-123
199-D4-27	B8978	WMO-NR-2010-4-122
199-D4-39	B8990	WMO-NR-2010-3-036
299-W14-15	C3114	WMO-NR-2010-3-164
299-W11-40	C3118	WMO-NR-2010-3-162
299-W11-41	C3119	WMO-NR-2011-1-304
299-W14-17	C3121	WMO-NR-2010-3-083
299-W22-82	C3124	WMO-NR-2010-3-157
299-W10-27	C3125	WMO-NR-2011-1-295
299-W19-43	C3381	WMO-NR-2010-1-025
299-W19-44	C3393	WMO-NR-2011-1-351
299-E33-339	C3392	WMO-NR-2010-1-047
299-W14-18	C3396	WMO-NR-2010-4-082
699-65-83	A5303	WMO-NR-2010-3-051
299-E25-26	A4771	WMO-NR-2010-3-085
199-N-32	A4681	WMO-NR-2010-3-078
299-E27-7	A4816	WMO-NR-2010-1-058
299-W6-10	A5435	WMO-NR-2011-1-376
299-W22-47	C4667	WMO-NR-2010-3-155
299-W11-46	C4950	WMO-NR-2011-1-308
299-W15-224	C4986	WMO-NR-2011-1-323
299-W22-87	C4977	WMO-NR-2010-2-063
699-50-59	C4882	WMO-NR-2010-3-049
399-3-20	C5002	WMO-NR-2010-3-125
199-N-139	C5045	WMO-NR-2011-1-082
299-W11-48	C5243	WMO-NR-2011-1-310
199-K-153	C5369	WMO-NR-2010-3-004
199-K-129	C4117	WMO-NR-2010-4-062
299-E27-21	C4127	WMO-NR-2010-1-059

Well Name	Well ID	Field Order No.
299-W15-35	B2749	WMO-NR-2011-1-327
299-E17-15	A4733	WMO-NR-2011-1-220
299-E25-41	A4790	WMO-NR-2011-1-227
299-W11-12	A4902	WMO-NR-2011-1-017
299-W10-20	A5439	WMO-NR-2010-3-070
199-K-107A	A9843	WMO-NR-2011-1-030
199-K-108A	A9844	WMO-NR-2011-1-031
299-W19-36	B2461	WMO-NR-2010-2-076
299-W10-1	A7136	WMO-NR-2010-3-133
299-W10-1	A7136	WMO-NR-2010-3-086
299-W10-1	A7136	WMO-NR-2010-3-086
199-K-111A	A9830	WMO-NR-2011-1-032
699-38-15	A8594	WMO-NR-2010-3-031
699-84-34B	A9021	WMO-NR-2010-2-001
299-E28-2	A6785	WMO-NR-2011-1-240
299-E28-9	A4828	WMO-NR-2010-4-076
299-W11-13	A5465	WMO-NR-2010-2-026
299-W11-34P	B2403	WMO-NR-2011-1-301
199-D4-15	B8073	WMO-NR-2010-3-099
199-N-105A	B2408	WMO-NR-2011-1-067
299-W15-30	B2410	WMO-NR-2010-4-050
199-N-106A	B2538	WMO-NR-2011-1-066
199-N-16	A4665	WMO-NR-2010-1-007
299-E28-18	A4821	WMO-NR-2010-4-032
299-W18-23	A4935	WMO-NR-2011-1-337
299-W10-4	A7137	WMO-NR-2011-1-207
299-W10-4	A7137	WMO-NR-2010-3-134
199-K-32A	A4657	WMO-NR-2011-1-062
199-K-113A	B2800	WMO-NR-2010-4-063
299-W18-30	A4942	WMO-NR-2011-1-338
699-25-34A	A5095	WMO-NR-2010-2-003
299-W22-24	A7845	WMO-NR-2010-4-029
199-D5-37	B8745	WMO-NR-2010-3-100
199-D5-44	B8754	WMO-NR-2010-3-142
199-D4-22	B8778	WMO-NR-2010-2-055
199-D4-38	B8989	WMO-NR-2010-3-038
199-D4-38	B8989	WMO-NR-2010-3-007
199-D4-38	B8989	WMO-NR-2011-1-046
299-W23-21	C3113	WMO-NR-2010-3-159
299-W11-41	C3119	WMO-NR-2010-3-163
299-W14-17	C3121	WMO-NR-2010-3-083
299-W10-27	C3125	WMO-NR-2010-3-161
199-D4-84	C3316	WMO-NR-2010-3-039
199-D4-84	C3316	WMO-NR-2010-3-008
299-W14-18	C3396	WMO-NR-2010-3-166

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-W15-47	C4184	WMO-NR-2010-4-008
199-D5-106	C5511	WMO-NR-2010-2-020
199-D5-106	C5511	WMO-NR-2010-2-020
299-E33-343	C5858	WMO-NR-2010-1-046
199-B8-8	C5672	WMO-NR-2010-2-066
299-E33-47	C4259	WMO-NR-2010-3-168
299-E33-49	C4261	WMO-NR-2010-3-169
199-N-119	C4471	WMO-NR-2011-1-068
199-D5-109	C5579	WMO-NR-2010-4-104
199-D5-101	C7583	WMO-NR-2010-3-091
199-D5-128	C7612	WMO-NR-2010-3-143
199-D8-95	C7589	WMO-NR-2010-3-118
199-D8-99	C7593	WMO-NR-2010-3-152
199-D7-3	C7599	WMO-NR-2010-3-121
199-D7-4	C7594	WMO-NR-2010-3-151
199-H1-5	C7610	WMO-NR-2011-1-526
199-H4-80	C7595	WMO-NR-2011-1-529
199-H4-82	C7609	WMO-NR-2011-1-528
199-B5-5	C7505	WMO-NR-2011-1-023
199-B5-5	C7505	WMO-NR-2010-4-004
199-B3-50	C7506	WMO-NR-2010-2-070
199-B5-6	C7507	WMO-NR-2011-1-449
199-B5-6	C7507	WMO-NR-2011-1-449
199-N-267	C7360	WMO-NR-2011-1-143
199-N-273	C7366	WMO-NR-2011-1-150
199-N-283	C7376	WMO-NR-2011-1-160
199-N-285	C7378	WMO-NR-2011-1-162
199-N-301	C7394	WMO-NR-2011-1-178
199-N-308	C7401	WMO-NR-2011-1-184
199-N-310	C7403	WMO-NR-2011-1-186
199-N-311	C7404	WMO-NR-2011-1-187
199-D4-95	C7083	WMO-NR-2010-2-037
199-D4-98	C7086	WMO-NR-2010-2-040
199-D4-99	C7087	WMO-NR-2010-2-041
199-D2-10	C7089	WMO-NR-2010-3-147
199-D8-90	C7092	WMO-NR-2010-2-042
199-D8-93	C7095	WMO-NR-2010-3-149
199-K-180	C7151	WMO-NR-2010-2-024
199-N-229	C7298	WMO-NR-2011-1-116
199-N-237	C7330	WMO-NR-2011-1-123
199-N-238	C7331	WMO-NR-2011-1-124
199-N-239	C7332	WMO-NR-2011-1-125
199-N-240	C7333	WMO-NR-2011-1-126
C7755	C7755	WMO-NR-2010-1-071
C7757	C7757	WMO-NR-2010-1-072

Well Name	Well ID	Field Order No.
299-W14-18	C3396	WMO-NR-2010-4-082
299-W22-84	C3398	WMO-NR-2011-1-369
199-K-30	A4655	WMO-NR-2011-1-060
199-N-14	A4664	WMO-NR-2011-1-083
199-N-32	A4681	WMO-NR-2010-3-078
299-W8-1	A5016	WMO-NR-2010-4-092
199-N-2	A4669	WMO-NR-2011-1-105
299-W19-48	C4300	WMO-NR-2011-1-354
199-D8-88	C4536	WMO-NR-2010-3-011
299-W22-47	C4667	WMO-NR-2011-1-361
299-W22-47	C4667	WMO-NR-2010-3-155
199-K-132	C4670	WMO-NR-2010-3-136
299-W11-47	C4990	WMO-NR-2011-1-309
199-N-128	C5034	WMO-NR-2011-1-073
199-N-136	C5042	WMO-NR-2011-1-079
199-N-137	C5043	WMO-NR-2011-1-080
199-K-137	C5112	WMO-NR-2011-1-034
699-50-56	C5197	WMO-NR-2010-1-053
199-N-156	C5324	WMO-NR-2011-1-096
199-K-150	C5366	WMO-NR-2010-3-035
299-W15-44	C3956	WMO-NR-2011-1-329
299-W14-19	C3957	WMO-NR-2010-3-080
199-K-129	C4117	WMO-NR-2010-4-062
199-K-129	C4117	WMO-NR-2010-4-062
299-W22-85	C3399	WMO-NR-2010-4-093
299-E27-4	C4125	WMO-NR-2010-3-129
299-E27-4	C4125	WMO-NR-2010-1-054
299-E27-23	C4190	WMO-NR-2010-3-156
299-E27-23	C4190	WMO-NR-2010-1-051
399-3-11	A8077	WMO-NR-2010-3-005
199-D8-55	A4584	WMO-NR-2010-3-145
199-D5-106	C5511	WMO-NR-2010-3-101
299-E33-345	C6226	WMO-NR-2010-1-052
299-E27-155	C5852	WMO-NR-2010-3-154
299-E33-340	C5853	WMO-NR-2010-3-019
C6241	C6241	WMO-NR-2010-4-011
199-K-165	C6451	WMO-NR-2011-1-048
199-K-165	C6451	WMO-NR-2010-2-035
299-E25-236	C6542	WMO-NR-2011-1-224
199-D8-73	C4474	WMO-NR-2010-3-042
199-D8-73	C4474	WMO-NR-2010-3-042
199-D5-115	C5585	WMO-NR-2010-4-112
199-D5-117	C5587	WMO-NR-2010-4-114
199-N-172	C7037	WMO-NR-2011-1-103
199-D4-101	C7580	WMO-NR-2010-3-090

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-E27-13	A4811	WMO-NR-2011-1-233
699-35-78A	A5141	WMO-NR-2010-3-092
699-55-55	A5258	WMO-NR-2010-4-080
299-E28-5	A6787	WMO-NR-2011-1-244
199-B8-6	A4563	WMO-NR-2010-4-002
199-B8-6	A4563	WMO-NR-2010-4-002
699-98-49A	A5363	WMO-NR-2010-3-002
299-W19-18	A7743	WMO-NR-2011-1-341
699-81-58	A5338	WMO-NR-2009-3-085
199-K-31	A4656	WMO-NR-2011-1-061
199-N-18	A4667	WMO-NR-2010-4-024
299-W15-17	A4921	WMO-NR-2010-2-048
299-W18-21	A4933	WMO-NR-2011-1-336
399-1-16B	A5026	WMO-NR-2010-4-054
699-50-28B	A5222	WMO-NR-2010-3-046
699-53-55C	A5246	WMO-NR-2010-1-057
699-54-45A	A5251	WMO-NR-2010-3-171
299-W11-3	A5473	WMO-NR-2010-2-009
199-K-106A	A9842	WMO-NR-2011-1-029
299-W19-36	B2461	WMO-NR-2010-2-076
299-W19-36	B2461	WMO-NR-2010-2-076
299-W19-36	B2461	WMO-NR-2010-2-076
299-W19-36	B2461	WMO-NR-2010-1-026
299-W19-36	B2461	WMO-NR-2010-1-026
299-W19-36	B2461	WMO-NR-2010-1-026
299-W10-1	A7136	WMO-NR-2010-2-028
299-W10-1	A7136	WMO-NR-2010-3-086
699-21-6	A8438	WMO-NR-2010-2-056
299-E28-23	A6799	WMO-NR-2011-1-241
299-E28-24	A6800	WMO-NR-2011-1-242
299-E28-9	A4828	WMO-NR-2010-4-076
299-E28-9	A4828	WMO-NR-2010-4-076
699-52-19	A5233	WMO-NR-2010-2-031
699-101-48B	A5066	WMO-NR-2010-4-030
199-D8-69	B2773	WMO-NR-2010-3-041
199-K-114A	B2801	WMO-NR-2010-4-065
199-K-114A	B2801	WMO-NR-2010-4-065
199-K-116A	B2803	WMO-NR-2010-2-074
199-N-16	A4665	WMO-NR-2010-1-007
199-N-26	A4675	WMO-NR-2010-3-108
699-35-9	A5142	WMO-NR-2010-3-030
199-H4-9	A4640	WMO-NR-2010-2-078
199-H4-63	B2776	WMO-NR-2010-2-034
199-D8-6	A4585	WMO-NR-2010-3-043
199-K-113A	B2800	WMO-NR-2010-4-063

Well Name	Well ID	Field Order No.
199-D4-101	C7580	WMO-NR-2010-3-090
199-D5-127	C7591	WMO-NR-2010-3-089
199-D5-129	C7600	WMO-NR-2010-3-144
199-D5-130	C7590	WMO-NR-2010-3-119
199-D5-131	C7601	WMO-NR-2010-3-123
199-D5-131	C7601	WMO-NR-2010-3-123
199-D8-96	C7603	WMO-NR-2010-3-124
199-D8-97	C7582	WMO-NR-2010-3-120
199-H1-5	C7610	WMO-NR-2011-1-526
199-H4-80	C7595	WMO-NR-2011-1-529
199-H4-81	C7596	WMO-NR-2011-1-527
199-H4-82	C7609	WMO-NR-2011-1-528
199-N-251	C7344	WMO-NR-2011-1-136
199-N-252	C7345	WMO-NR-2011-1-137
199-B5-5	C7505	WMO-NR-2010-4-004
199-N-277	C7370	WMO-NR-2011-1-154
199-N-369	C7461	WMO-NR-2011-1-211
199-N-289	C7382	WMO-NR-2011-1-166
199-N-290	C7383	WMO-NR-2011-1-167
199-N-293	C7386	WMO-NR-2011-1-170
199-N-316	C7409	WMO-NR-2011-1-192
199-N-323	C7416	WMO-NR-2011-1-195
199-N-348	C7440	WMO-NR-2011-1-197
199-D4-98	C7086	WMO-NR-2010-2-040
299-W14-20	C7018	WMO-NR-2011-1-320
199-D8-90	C7092	WMO-NR-2010-2-042
199-K-180	C7151	WMO-NR-2010-2-024
199-N-230	C7297	WMO-NR-2011-1-117
199-N-228	C7299	WMO-NR-2011-1-115
199-N-224	C7303	WMO-NR-2011-1-111
199-N-247	C7340	WMO-NR-2011-1-130
C7758	C7758	WMO-NR-2010-1-073
C7764	C7764	WMO-NR-2010-1-075
C7765	C7765	WMO-NR-2010-1-076
699-10-E12Q	A9580	WMO-NR-2010-3-056
199-K-36	A4662	WMO-NR-2011-1-064
299-E33-31	A4856	WMO-NR-2010-1-055
699-42-12A	A5163	WMO-NR-2010-3-033
699-42-40C	A5169	WMO-NR-2010-3-139
299-W11-18	A7284	WMO-NR-2011-1-299
299-W11-18	A7284	WMO-NR-2010-4-081
199-B8-6	A4563	WMO-NR-2010-4-002
199-K-115A	B2802	WMO-NR-2010-4-064
199-K-115A	B2802	WMO-NR-2010-4-064
199-K-119A	B2806	WMO-NR-2010-2-011

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
199-B2-12	A4550	WMO-NR-2010-4-000
199-D4-22	B8778	WMO-NR-2010-2-055
199-D4-23	B8779	WMO-NR-2010-3-098
299-W22-48	B8812	WMO-NR-2011-1-362
299-W15-41	B8815	WMO-NR-2010-4-051
199-D4-26	B8977	WMO-NR-2010-4-124
199-D4-38	B8989	WMO-NR-2011-1-026
199-D4-39	B8990	WMO-NR-2010-3-036
299-W14-17	C3121	WMO-NR-2010-3-083
299-W22-82	C3124	WMO-NR-2011-1-367
299-W11-42	C3242	WMO-NR-2011-1-305
199-D4-84	C3316	WMO-NR-2010-3-039
199-D4-85	C3317	WMO-NR-2010-3-040
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-1-025
SPC-P-1	B8106	WMO-NR-2010-3-057
299-W18-33	A5450	WMO-NR-2010-3-074
699-53-47A	A5239	WMO-NR-2010-4-041
699-25-33A	A5094	WMO-NR-2010-4-053
199-N-46	A5833	WMO-NR-2011-1-213
199-K-132	C4670	WMO-NR-2010-3-136
199-N-122	C4954	WMO-NR-2011-1-069
199-N-127	C5033	WMO-NR-2011-1-072
199-N-129	C5035	WMO-NR-2011-1-074
199-N-130	C5036	WMO-NR-2011-1-075
199-N-138	C5044	WMO-NR-2011-1-081
199-N-143	C5049	WMO-NR-2011-1-085
199-K-140	C5115	WMO-NR-2011-1-037
199-N-147	C5116	WMO-NR-2011-1-088
N116mArray-10A	C5264	WMO-NR-2010-4-020
199-N-153	C5321	WMO-NR-2011-1-093
199-K-144	C5360	WMO-NR-2011-1-039
299-W15-46	C3426	WMO-NR-2011-1-330
199-D5-32	C4185	WMO-NR-2010-3-044
299-E27-23	C4190	WMO-NR-2011-1-237
299-W17-1	C4237	WMO-NR-2010-4-084
199-D8-55	A4584	WMO-NR-2010-3-145
199-D5-106	C5511	WMO-NR-2010-3-101
299-E26-77	C6455	WMO-NR-2010-4-103
699-36-66B	C6219	WMO-NR-2011-1-428
299-E33-345	C6226	WMO-NR-2010-4-070
299-E27-155	C5852	WMO-NR-2010-3-001
299-E27-155	C5852	WMO-NR-2010-3-001
299-E33-340	C5853	WMO-NR-2010-3-019
C6239	C6239	WMO-NR-2010-4-010

Well Name	Well ID	Field Order No.
199-B3-47	A4554	WMO-NR-2010-4-001
699-98-49A	A5363	WMO-NR-2010-3-002
299-E28-3	A6786	WMO-NR-2010-4-078
399-1-10B	A8064	WMO-NR-2010-4-055
199-D5-18	A4575	WMO-NR-2011-1-025
199-K-20	A4649	WMO-NR-2011-1-058
199-K-31	A4656	WMO-NR-2010-2-060
299-E17-9	A4742	WMO-NR-2011-1-221
299-E25-28	A4773	WMO-NR-2010-3-084
299-E27-10	A4808	WMO-NR-2010-1-050
299-E27-14	A4812	WMO-NR-2011-1-234
299-E28-7	A4827	WMO-NR-2011-1-245
299-E33-18	A4844	WMO-NR-2010-3-167
299-W11-12	A4902	WMO-NR-2011-1-017
299-W11-12	A4902	WMO-NR-2011-1-017
699-24-33	A5089	WMO-NR-2010-4-049
699-61-62	A5285	WMO-NR-2010-3-024
699-S31-E10C	A5381	WMO-NR-2010-2-059
699-S34-E15	A5389	WMO-NR-2010-3-055
299-W14-5	A5475	WMO-NR-2011-1-321
299-W19-36	B2461	WMO-NR-2010-2-067
299-W10-1	A7136	WMO-NR-2010-3-133
299-W10-1	A7136	WMO-NR-2010-2-028
299-W10-1	A7136	WMO-NR-2010-3-014
699-12-18	A8254	WMO-NR-2010-3-017
699-20-E5A	A8428	WMO-NR-2010-3-034
299-E25-8	A6027	WMO-NR-2011-1-229
299-E33-16	A6855	WMO-NR-2011-1-530
299-E25-29P	A4774	WMO-NR-2010-1-045
299-E28-9	A4828	WMO-NR-2010-4-076
299-W11-13	A5465	WMO-NR-2010-2-026
299-W15-30	B2410	WMO-NR-2010-4-050
299-W15-33	B2643	WMO-NR-2010-2-045
199-K-116A	B2803	WMO-NR-2010-2-074
699-54-45B	A8862	WMO-NR-2010-3-137
199-N-81	A5443	WMO-NR-2011-1-217
199-B2-12	A4550	WMO-NR-2010-4-000
199-B2-12	A4550	WMO-NR-2010-4-000
299-W18-30	A4942	WMO-NR-2010-3-071
299-W23-15	A4984	WMO-NR-2010-3-003
199-D4-23	B8779	WMO-NR-2010-3-098
299-W15-41	B8815	WMO-NR-2011-1-328
299-W15-41	B8815	WMO-NR-2011-1-535
199-D4-38	B8989	WMO-NR-2011-1-026
199-D4-38	B8989	WMO-NR-2010-4-128

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-E24-33	C4257	WMO-NR-2011-1-223
199-N-161	C6179	WMO-NR-2011-1-098
199-D5-108	C5578	WMO-NR-2010-4-110
199-D5-128	C7612	WMO-NR-2010-3-143
199-D5-129	C7600	WMO-NR-2010-3-144
199-D8-96	C7603	WMO-NR-2010-3-124
199-D7-5	C7608	WMO-NR-2010-4-075
199-D7-5	C7608	WMO-NR-2010-4-075
199-D7-6	C7611	WMO-NR-2010-4-033
199-H1-5	C7610	WMO-NR-2010-4-034
199-H4-82	C7609	WMO-NR-2010-4-035
199-B5-6	C7507	WMO-NR-2011-1-449
199-N-259	C7352	WMO-NR-2011-1-140
199-N-268	C7361	WMO-NR-2011-1-144
199-N-271	C7364	WMO-NR-2011-1-148
199-N-276	C7369	WMO-NR-2011-1-153
199-N-368	C7460	WMO-NR-2011-1-210
199-N-296	C7389	WMO-NR-2011-1-173
199-N-302	C7395	WMO-NR-2011-1-179
199-N-305	C7398	WMO-NR-2011-1-181
199-N-319	C7412	WMO-NR-2011-1-193
199-N-321	C7414	WMO-NR-2011-1-194
199-N-349	C7439	WMO-NR-2011-1-198
199-N-352	C7445	WMO-NR-2011-1-201
199-N-359	C7452	WMO-NR-2011-1-206
199-D4-96	C7084	WMO-NR-2010-2-039
199-D4-98	C7086	WMO-NR-2010-2-040
199-D4-99	C7087	WMO-NR-2010-2-041
199-K-181	C7464	WMO-NR-2011-1-053
199-D8-89	C7091	WMO-NR-2010-2-043
199-D8-91	C7093	WMO-NR-2010-2-044
199-D8-94	C7096	WMO-NR-2010-3-148
199-N-231	C7296	WMO-NR-2011-1-118
199-N-218	C7309	WMO-NR-2011-1-108
199-N-235	C7328	WMO-NR-2011-1-121
199-N-245	C7338	WMO-NR-2011-1-131
299-W22-89	C7664	WMO-NR-2011-1-371
299-W22-24Q	A9569	WMO-NR-2010-3-054
699-38-65	A5148	WMO-NR-2010-3-096
199-B9-2	A4565	WMO-NR-2010-3-018
299-W23-4	A4987	WMO-NR-2010-2-017
299-W7-7	A5013	WMO-NR-2010-3-073
399-1-2	A5035	WMO-NR-2010-2-008
699-42-40C	A5169	WMO-NR-2010-4-072
699-55-55	A5258	WMO-NR-2010-4-080

Well Name	Well ID	Field Order No.
299-W11-39	C3117	WMO-NR-2011-1-302
299-W11-39	C3117	WMO-NR-2010-3-165
299-W10-27	C3125	WMO-NR-2010-3-161
199-D4-84	C3316	WMO-NR-2010-3-106
199-D4-85	C3317	WMO-NR-2010-3-040
199-D4-86	C3318	WMO-NR-2010-3-097
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-1-025
299-W19-44	C3393	WMO-NR-2010-2-027
299-W19-44	C3393	WMO-NR-2010-2-027
199-N-3	A4679	WMO-NR-2011-1-176
299-W22-44	A4975	WMO-NR-2011-1-358
299-W11-7	A4910	WMO-NR-2011-1-311
299-E27-7	A4816	WMO-NR-2010-1-058
299-E25-5	A6025	WMO-NR-2011-1-228
299-W18-9	A7526	WMO-NR-2010-3-000
299-W15-42	C3803	WMO-NR-2010-4-089
299-W22-45	A4976	WMO-NR-2011-1-359
299-E24-24	C4647	WMO-NR-2010-4-042
299-W14-11	C4668	WMO-NR-2011-1-313
199-K-132	C4670	WMO-NR-2010-3-136
199-K-132	C4670	WMO-NR-2010-3-136
299-W15-152	C4685	WMO-NR-2011-1-325
199-N-123	C4955	WMO-NR-2011-1-070
299-W19-101	C4966	WMO-NR-2011-1-339
299-W19-101	C4966	WMO-NR-2010-4-073
199-N-141	C5047	WMO-NR-2011-1-084
299-W14-71	C5102	WMO-NR-2010-3-093
199-K-139	C5114	WMO-NR-2011-1-036
699-50-56	C5197	WMO-NR-2010-1-053
199-N-149	C5317	WMO-NR-2011-1-089
199-N-154	C5322	WMO-NR-2011-1-094
299-W15-44	C3956	WMO-NR-2010-3-077
199-K-129	C4117	WMO-NR-2010-4-062
299-W15-765	C3397	WMO-NR-2010-3-079
299-E27-4	C4125	WMO-NR-2011-1-239
199-D8-55	A4584	WMO-NR-2010-3-009
C6132	C6132	WMO-NR-2010-4-022
199-K-165	C6451	WMO-NR-2010-2-035
199-D5-118	C5588	WMO-NR-2010-4-115
N116mArray-15A	C5512	WMO-NR-2010-4-023
199-N-167	C7032	WMO-NR-2011-1-099
199-N-170	C7035	WMO-NR-2011-1-101
199-D8-98	C7602	WMO-NR-2010-3-122

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
699-9-E2	A5349	WMO-NR-2010-4-133
699-12-4D	A8252	WMO-NR-2010-2-033
199-K-124A	B2811	WMO-NR-2010-2-010
199-K-124A	B2811	WMO-NR-2010-2-010
699-14-38	A5068	WMO-NR-2010-3-015
299-E28-3	A6786	WMO-NR-2010-4-078
299-E28-3	A6786	WMO-NR-2010-4-078
699-53-55A	A5244	WMO-NR-2010-4-045
199-D5-16	A4573	WMO-NR-2010-2-073
199-F8-3	A4608	WMO-NR-2011-1-028
199-F8-3	A4608	WMO-NR-2010-4-058
199-K-34	A4660	WMO-NR-2011-1-063
199-N-18	A4667	WMO-NR-2010-4-024
299-E25-28	A4773	WMO-NR-2010-3-084
299-E33-39	A4864	WMO-NR-2010-1-056
299-W11-12	A4902	WMO-NR-2011-1-017
299-W18-21	A4933	WMO-NR-2010-4-031
299-W19-12	A4945	WMO-NR-2011-1-340
299-W19-39	B2460	WMO-NR-2011-1-347
299-W19-36	B2461	WMO-NR-2010-2-076
299-W19-35	A9515	WMO-NR-2011-1-344
299-E25-3	A6024	WMO-NR-2011-1-225
299-E28-25	A6801	WMO-NR-2011-1-243
699-42-40A	A5167	WMO-NR-2010-4-046
699-42-40A	A5167	WMO-NR-2010-4-046
299-W10-22	A9890	WMO-NR-2010-2-018
299-W19-37	B2465	WMO-NR-2010-2-046
199-N-106A	B2538	WMO-NR-2010-4-132
199-K-114A	B2801	WMO-NR-2010-4-065
199-K-116A	B2803	WMO-NR-2010-2-074
199-K-116A	B2803	WMO-NR-2010-2-064
199-N-26	A4675	WMO-NR-2010-3-108
199-N-26	A4675	WMO-NR-2010-1-022
299-E26-8	A4805	WMO-NR-2010-4-061
199-H4-63	B2776	WMO-NR-2010-2-034
199-K-113A	B2800	WMO-NR-2010-4-063
299-E25-10	A4760	WMO-NR-2010-4-088
699-25-34A	A5095	WMO-NR-2010-2-032
299-W10-26	B8548	WMO-NR-2011-1-294
299-W14-13	B8549	WMO-NR-2011-1-314
199-K-126	B8760	WMO-NR-2010-4-117
199-D4-22	B8778	WMO-NR-2010-2-055
199-D4-38	B8989	WMO-NR-2010-3-038
199-D4-38	B8989	WMO-NR-2011-1-046
299-W23-21	C3113	WMO-NR-2010-3-159

Well Name	Well ID	Field Order No.
199-D7-4	C7594	WMO-NR-2010-3-151
199-H4-82	C7609	WMO-NR-2010-4-035
199-D6-2	C7607	WMO-NR-2010-3-150
199-B2-14	C7665	WMO-NR-2010-4-003
199-N-265	C7358	WMO-NR-2011-1-141
199-N-294	C7387	WMO-NR-2011-1-171
199-N-313	C7406	WMO-NR-2011-1-189
199-N-314	C7407	WMO-NR-2011-1-190
199-N-351	C7444	WMO-NR-2011-1-200
199-N-357	C7450	WMO-NR-2011-1-204
199-D4-98	C7086	WMO-NR-2010-2-040
199-D8-89	C7091	WMO-NR-2010-2-043
199-D8-89	C7091	WMO-NR-2010-2-043
199-D8-93	C7095	WMO-NR-2010-3-127
199-N-232	C7295	WMO-NR-2011-1-119
199-N-227	C7300	WMO-NR-2011-1-114
199-N-223	C7304	WMO-NR-2011-1-110
199-N-244	C7337	WMO-NR-2011-1-129
199-K-190	C7690	WMO-NR-2011-1-057
C7766	C7766	WMO-NR-2010-1-077
299-E26-11	A4800	WMO-NR-2011-1-231
299-W23-4	A4987	WMO-NR-2010-2-017
699-35-78A	A5141	WMO-NR-2010-4-052
699-63-58	A5292	WMO-NR-2010-3-025
699-S36-E12B	A5391	WMO-NR-2010-3-059
299-W15-32	B2423	WMO-NR-2010-2-051
299-W11-12	A4902	WMO-NR-2011-1-017
299-W15-15	A4919	WMO-NR-2010-3-072
299-W22-21	A4966	WMO-NR-2011-1-357
699-53-35	A5238	WMO-NR-2010-3-105
699-63-90	A5293	WMO-NR-2010-2-000
299-W11-3	A5473	WMO-NR-2011-1-423
299-W18-1	A5481	WMO-NR-2010-2-050
299-W19-36	B2461	WMO-NR-2011-1-346
699-12-18	A8254	WMO-NR-2010-3-017
299-W19-35	A9515	WMO-NR-2010-3-138
299-E33-16	A6855	WMO-NR-2011-1-530
299-W11-13	A5465	WMO-NR-2011-1-297
699-74-44	A5328	WMO-NR-2010-3-088
299-W19-40	B2464	WMO-NR-2011-1-348
299-W19-37	B2465	WMO-NR-2011-1-345
199-K-125A	B8559	WMO-NR-2010-2-012
699-29-4	A8490	WMO-NR-2010-3-028
199-N-67	A4711	WMO-NR-2011-1-214
699-48-71	A5214	WMO-NR-2010-3-095

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
299-W22-82	C3124	WMO-NR-2010-3-157
299-W22-83	C3126	WMO-NR-2011-1-368
299-W22-83	C3126	WMO-NR-2010-3-158
299-W11-42	C3242	WMO-NR-2010-3-160
299-W15-763	C3339	WMO-NR-2010-2-049
199-D4-83	C3315	WMO-NR-2010-3-037
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-43	C3381	WMO-NR-2010-4-009
299-W19-43	C3381	WMO-NR-2010-1-025
699-65-83	A5303	WMO-NR-2010-3-051
299-E26-5	A6641	WMO-NR-2010-4-087
699-S18-E2B	A9199	WMO-NR-2010-4-038
299-E17-22	C3826	WMO-NR-2010-2-002
AT-3-4-M	C4355	WMO-NR-2010-4-016
AT-3-5-S	C4358	WMO-NR-2010-4-017
199-D8-88	C4536	WMO-NR-2010-3-045
199-D8-88	C4536	WMO-NR-2010-3-045
299-W15-94	C4684	WMO-NR-2011-1-334
199-K-133	C4734	WMO-NR-2010-4-118
199-K-136	C4737	WMO-NR-2010-4-121
299-W22-69	C4969	WMO-NR-2011-1-536
199-N-133	C5039	WMO-NR-2011-1-078
N116mArray-13A	C5267	WMO-NR-2010-4-019
199-N-155	C5323	WMO-NR-2011-1-095
199-K-153	C5369	WMO-NR-2010-3-004
299-W15-44	C3956	WMO-NR-2011-1-432
299-W15-765	C3397	WMO-NR-2010-3-079
299-E27-4	C4125	WMO-NR-2010-1-054
299-E27-21	C4127	WMO-NR-2011-1-236
199-B8-7	C5671	WMO-NR-2010-2-065
299-E27-155	C5852	WMO-NR-2010-3-154
C6243	C6243	WMO-NR-2010-4-014
299-W19-47	C4258	WMO-NR-2011-1-353
199-D5-110	C5580	WMO-NR-2010-4-106
199-D5-111	C5581	WMO-NR-2010-4-107
299-E33-345	C6226	WMO-NR-2010-1-052
199-K-168	C6454	WMO-NR-2011-1-050
299-E33-47	C4259	WMO-NR-2010-3-168
299-E33-49	C4261	WMO-NR-2010-1-048
199-D5-113	C5583	WMO-NR-2010-4-109
199-D5-114	C5584	WMO-NR-2010-4-111
199-D5-116	C5586	WMO-NR-2010-4-113
199-D7-6	C7611	WMO-NR-2010-4-033

Well Name	Well ID	Field Order No.
699-48-71	A5214	WMO-NR-2010-3-095
299-W10-4	A7137	WMO-NR-2011-1-296
299-W10-4	A7137	WMO-NR-2011-1-207
699-S3-25	A5373	WMO-NR-2010-3-016
699-S32-E11	A9223	WMO-NR-2010-3-061
299-W19-34A	A9517	WMO-NR-2011-1-343
299-W11-37	A9889	WMO-NR-2010-2-016
299-W11-37	A9889	WMO-NR-2010-2-016
299-W15-31A	B2471	WMO-NR-2010-2-047
699-S29-E11	A9207	WMO-NR-2010-3-060
199-K-22	A4651	WMO-NR-2010-3-052
299-W14-13	B8549	WMO-NR-2010-3-081
199-D5-44	B8754	WMO-NR-2010-3-142
199-D4-20	B8750	WMO-NR-2010-4-116
DD-41-2	B8483	WMO-NR-2010-4-018
299-W11-40	C3118	WMO-NR-2011-1-303
299-W11-41	C3119	WMO-NR-2010-3-163
299-W14-16	C3120	WMO-NR-2011-1-316
299-W11-42	C3242	WMO-NR-2010-2-052
199-D4-83	C3315	WMO-NR-2010-3-037
299-W19-43	C3381	WMO-NR-2010-2-075
299-W19-44	C3393	WMO-NR-2010-2-027
299-W14-18	C3396	WMO-NR-2010-4-067
699-S37-E11A	A5393	WMO-NR-2010-3-068
699-S36-E13B	A9226	WMO-NR-2010-3-058
299-W15-8	A5468	WMO-NR-2011-1-333
199-F7-1	A4603	WMO-NR-2010-4-059
699-25-33A	A5094	WMO-NR-2010-4-053
199-K-29	A5480	WMO-NR-2011-1-059
AT-3-3-D	C4351	WMO-NR-2010-4-015
199-K-132	C4670	WMO-NR-2011-1-033
299-W11-45	C4948	WMO-NR-2011-1-307
199-N-146	C5052	WMO-NR-2011-1-087
199-K-138	C5113	WMO-NR-2011-1-035
199-K-142	C5304	WMO-NR-2011-1-038
199-K-150	C5366	WMO-NR-2010-3-035
199-K-150	C5366	WMO-NR-2010-2-058
199-K-157	C5373	WMO-NR-2011-1-040
199-K-129	C4117	WMO-NR-2010-4-062
299-W15-765	C3397	WMO-NR-2011-1-332
299-E25-93	C4122	WMO-NR-2011-1-232
299-E27-21	C4127	WMO-NR-2010-1-059
299-E27-23	C4190	WMO-NR-2010-3-156
299-E33-342	C5857	WMO-NR-2010-1-049
299-E28-30	C7515	WMO-NR-2010-3-047

Table 16-3. (Cont.)

Well Name	Well ID	Field Order No.
199-H1-5	C7610	WMO-NR-2010-4-034
199-H4-81	C7596	WMO-NR-2010-4-036
199-D6-1	C7592	WMO-NR-2010-3-153
199-D6-2	C7607	WMO-NR-2010-3-150
199-B2-14	C7665	WMO-NR-2010-4-003
199-B2-14	C7665	WMO-NR-2010-2-072
199-B5-5	C7505	WMO-NR-2010-2-069
199-B5-6	C7507	WMO-NR-2011-1-024
199-N-266	C7359	WMO-NR-2011-1-142
199-N-269	C7362	WMO-NR-2011-1-145
199-N-274	C7367	WMO-NR-2011-1-151
199-N-288	C7381	WMO-NR-2011-1-165
199-N-370	C7462	WMO-NR-2011-1-212
199-N-291	C7384	WMO-NR-2011-1-168
199-N-295	C7388	WMO-NR-2011-1-172

Well Name	Well ID	Field Order No.
199-K-173	C7016	WMO-NR-2011-1-051
199-N-234	C7293	WMO-NR-2011-1-120
199-N-221	C7306	WMO-NR-2011-1-107
199-N-243	C7336	WMO-NR-2011-1-128
199-N-248	C7341	WMO-NR-2011-1-133
199-K-189	C7689	WMO-NR-2011-1-056
199-D4-97	C7085	WMO-NR-2010-2-038
199-D8-91	C7093	WMO-NR-2010-2-044
199-D8-91	C7093	WMO-NR-2010-2-044
199-D8-93	C7095	WMO-NR-2010-3-149
199-N-356	C7449	WMO-NR-2011-1-203
199-D4-96	C7084	WMO-NR-2010-2-039
199-N-325	C7418	WMO-NR-2011-1-196
199-N-312	C7405	WMO-NR-2011-1-188

Table 16-4. Decommissioned Wells for the Reporting Period

Project/ Location	Well Name	Well ID	Out of Service Date
100-BC-5	199-B8-7	C5671	3/30/10
100-BC-5	199-B8-8	C5672	3/30/10
100-FR-3	699-57-25A	A5266	4/20/10
100-FR-3	699-59-24	A8915	4/28/10
100-FR-3	699-65-23	A5298	4/30/10
100-FR-3	699-74-48	A5329	5/10/10
100-FR-3	699-80-43Q	A8994	5/3/10
100-FR-3	699-80-43R	A8995	5/3/10
100-FR-3	699-85-40	A5343	5/12/10
100-FR-3	C3178	C3178	12/11/10
100-FR-3	C3180	C3180	12/11/10
100-FR-3	C3181	C3181	12/11/10
100-FR-3	C3183	C3183	12/11/10
100-FR-3	C3370	C3370	4/30/10
100-KR-4	199-K-35	A4661	5/11/10
200-BP-5	299-E35-2	A4886	5/18/10
200-BP-5	699-49-28	A5216	5/18/10
200-BP-5	699-49-32A	A8791	6/2/10
200-BP-5	699-50-28C	A8811	5/14/10
200-BP-5	699-52-37A	A8837	5/25/10
200-BP-5	699-52-37B	A8838	5/25/10
200-BP-5	699-52-38A	A8839	5/25/10
200-BP-5	699-52-38B	A8840	5/21/10
200-BP-5	699-52-57	A5237	5/19/10
200-BP-5	699-57-41A	A8896	12/13/10
200-BP-5	699-57-41F	A8901	12/13/10
200-BP-5	699-58-40	A8907	12/13/10
200-BP-5	699-58-41B	A8909	12/15/10
200-BP-5	699-59-41	C6470	7/1/10
200-BP-5	699-59-41B	C6471	7/1/10
200-BP-5	699-59-42	C6468	7/1/10
200-BP-5	699-59-42B	C6469	6/30/10
200-BP-5	699-59-43	C6462	6/25/10
200-BP-5	699-59-43B	C6463	6/25/10
200-BP-5	699-59-43C	C6464	6/28/10
200-BP-5	699-59-43D	C6465	6/29/10
200-BP-5	699-59-43E	C6466	6/29/10
200-BP-5	699-59-43F	C6467	6/29/10
200-BP-5	699-59-44	A8917	6/25/10
200-BP-5	699-59-44B	C6460	6/23/10
200-BP-5	699-59-44C	C6461	6/24/10
200-BP-5	C7789	C7789	7/7/10
200-BP-5	C7809	C7809	7/2/10
200-BP-5	C7810	C7810	7/2/10
200-BP-5	C8002	C8002	12/13/10
200-PO-1	299-E17-53	A5887	1/20/10
200-PO-1	299-E17-54	A5888	1/20/10
200-PO-1	699-10-30B	A8180	3/30/10
200-PO-1	699-11-45B	A8216	3/24/10
200-PO-1	699-11-45C	A8217	3/24/10
200-PO-1	699-13-26	A8269	4/2/10
200-PO-1	699-16-51	A8345	3/19/10
200-PO-1	699-17-25B	A8359	4/7/10
200-PO-1	699-17-26F	A8366	4/8/10
200-PO-1	699-18-25C	A8379	4/7/10
200-PO-1	699-19-27	A8409	4/7/10
200-PO-1	699-21-30A	A8439	3/19/10
200-PO-1	699-25-26	A8460	4/13/10
200-PO-1	699-26-29B	A8470	4/14/10
200-PO-1	699-32-18	A8511	3/5/10
200-PO-1	699-35-16	A8549	3/3/10
200-PO-1	699-35-19A	A8550	3/5/10
200-PO-1	699-35-19B	A8551	2/26/10
200-PO-1	699-36-17	A8564	3/3/10
200-PO-1	699-36-21	A8565	2/26/10
200-PO-1	699-37-16	A8576	3/1/10
200-PO-1	699-37-22	A8577	2/26/10
200-PO-1	699-37-25	A8578	3/15/10
200-PO-1	699-38-14	A8593	4/16/10
200-PO-1	699-38-19	A8595	3/1/10
200-PO-1	699-38-34B	A8597	4/16/10
200-PO-1	699-39-23	A8606	3/3/10
200-PO-1	699-40-13	A8636	8/20/10
200-PO-1	699-40-21	A8638	3/15/10
200-PO-1	B2871	B2871	2/8/10
200-PO-1	B2880	B2880	2/3/10
200-PO-1	B2881	B2881	6/7/10
200-PO-1	B8542	B8542	5/13/10
200-PO-1	C3359	C3359	4/27/10
200-PO-1	C3364	C3364	4/20/10
200-PO-1	C3368	C3368	4/16/10
200-PO-1	C3377	C3377	5/17/10

Table 16-4. (Cont.)

Project/ Location	Well Name	Well ID	Out of Service Date
200-PO-1	C3380	C3380	5/17/10
200-PO-1	C3403	C3403	2/3/10
200-PO-1	C3404	C3404	5/17/10
200-PO-1	C3405	C3405	5/17/10
200-PO-1	C3406	C3406	5/17/10
200-PO-1	C3407	C3407	2/3/10
200-PO-1	C3424	C3424	1/20/10
200-PO-1	C3425	C3425	5/17/10
200-PO-1	C3429	C3429	2/2/10
200-PO-1	C3430	C3430	1/20/10
200-PO-1	C3431	C3431	1/20/10
200-PO-1	C3432	C3432	2/2/10
200-PO-1	C3433	C3433	1/20/10
200-PO-1	C3435	C3435	5/17/10
200-PO-1	C3441	C3441	5/12/10
200-PO-1	C3518	C3518	4/16/10
200-PO-1	C3529	C3529	4/16/10
200-PO-1	C3530	C3530	4/16/10
200-PO-1	C7963	C7963	5/12/10
200-PO-1	C7964	C7964	5/27/10
200-UP-1	299-W23-14	A4983	1/25/10
200-UP-1	299-W23-43	A4974	1/25/10
200-UP-1	299-W26-11	A4993	1/25/10
300-FF-5	399-3-11	A8077	6/21/10
300-FF-5	644-S6-E4A	C4074	3/18/10
300-FF-5	644-S6-E4B	C4075	3/18/10
300-FF-5	644-S6-E4C	C4076	3/18/10
300-FF-5	644-S6-E4D	C4077	3/18/10
300-FF-5	644-S6-E4E	C4078	3/18/10
300-FF-5	644-S6-E4F	C4079	3/18/10
300-FF-5	644-S6-E4G	C4080	3/18/10
300-FF-5	644-S6-E4H	C4081	3/18/10
300-FF-5	644-S6-E4I	C4082	3/18/10
300-FF-5	644-S6-E4J	C4083	3/18/10
300-FF-5	644-S6-E4K	C4084	3/18/10
300-FF-5	644-S6-E4L	C4085	3/18/10
300-FF-5	644-S6-E4M	C4086	3/18/10
300-FF-5	644-S6-E4N	C4087	3/18/10
300-FF-5	699-11-E10	A8230	6/21/10
300-FF-5	699-9-E4A	A8126	6/9/10
300-FF-5	699-9-E4B	A8163	6/8/10

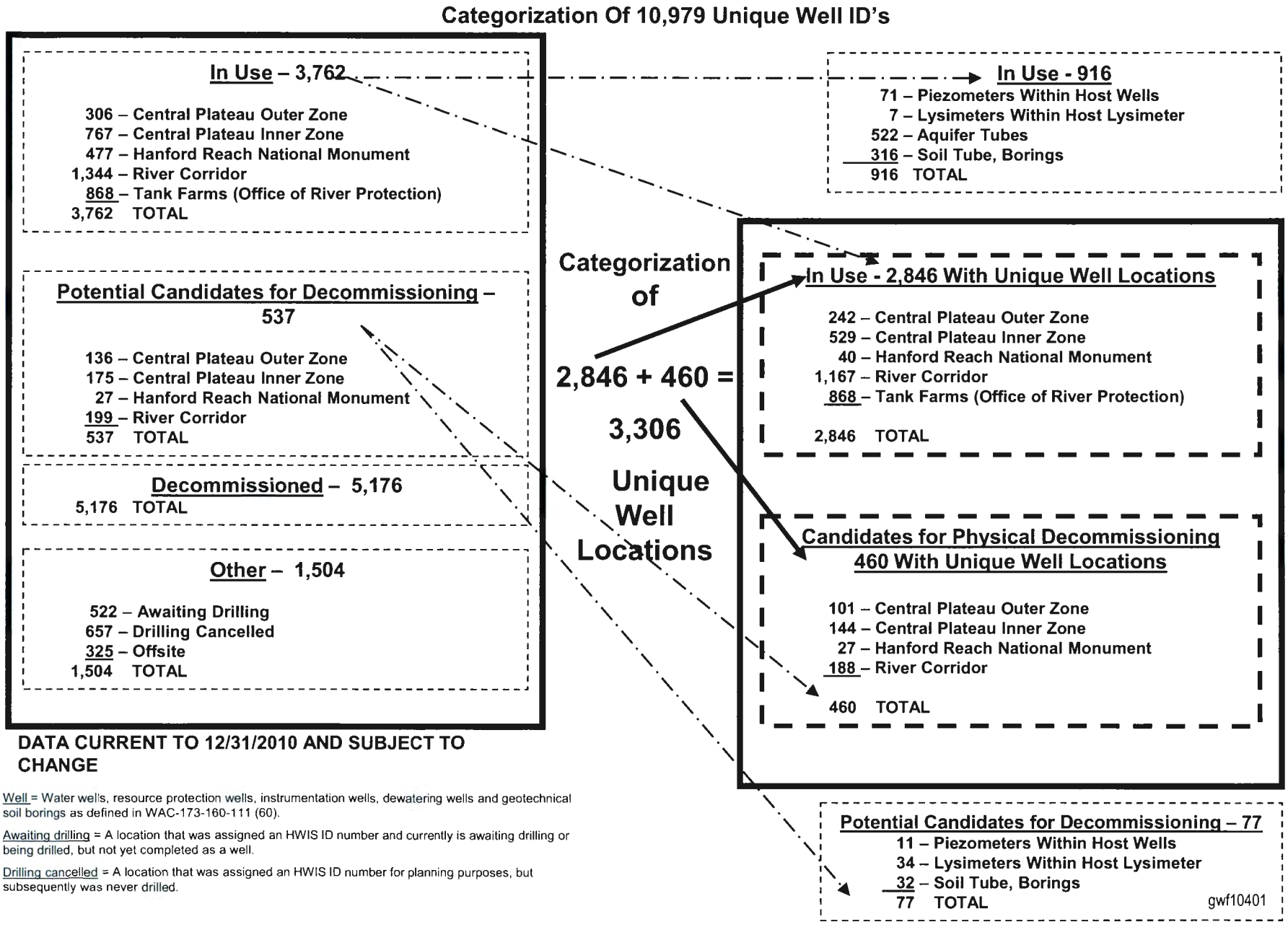
Project/ Location	Well Name	Well ID	Out of Service Date
300-FF-5	699-9-E5B	A8165	6/22/10
300-FF-5	B2874	B2874	4/15/10
300-FF-5	B2875	B2875	4/15/10
300-FF-5	B2883	B2883	5/17/10
300-FF-5	C3186	C3186	4/15/10
300-FF-5	C3187	C3187	4/15/10
300-FF-5	C3319	C3319	4/15/10
300-FF-5	C3348	C3348	6/4/10
300-FF-5	C3365	C3365	4/15/10
300-FF-5	C3371	C3371	5/12/10
300-FF-5	C3372	C3372	5/12/10
300-FF-5	C3373	C3373	6/3/10
300-FF-5	C3374	C3374	5/12/10
300-FF-5	C3375	C3375	5/12/10
300-FF-5	C3376	C3376	5/17/10
300-FF-5	C3408	C3408	5/12/10
300-FF-5	C3409	C3409	5/12/10
300-FF-5	C3410	C3410	5/12/10
300-FF-5	C3411	C3411	5/12/10
300-FF-5	C3412	C3412	5/12/10
300-FF-5	C3413	C3413	6/3/10
300-FF-5	C3414	C3414	6/3/10
300-FF-5	C3415	C3415	4/15/10
300-FF-5	C3416	C3416	4/15/10
300-FF-5	C3417	C3417	4/15/10
300-FF-5	C3418	C3418	4/15/10
300-FF-5	C3419	C3419	4/15/10
300-FF-5	C3420	C3420	4/15/10
300-FF-5	C3421	C3421	4/15/10
300-FF-5	C3422	C3422	4/15/10
300-FF-5	C3423	C3423	4/15/10
300-FF-5	C3434	C3434	5/17/10
300-FF-5	C3436	C3436	5/24/10
300-FF-5	C3437	C3437	5/24/10
300-FF-5	C3438	C3438	5/24/10
300-FF-5	C3439	C3439	5/24/10
300-FF-5	C3442	C3442	5/24/10
300-FF-5	C3443	C3443	5/24/10
300-FF-5	C3444	C3444	5/24/10
300-FF-5	C3445	C3445	5/24/10
300-FF-5	C3446	C3446	5/24/10

Table 16-4. (Cont.)

Project/ Location	Well Name	Well ID	Out of Service Date
300-FF-5	C3447	C3447	5/24/10
300-FF-5	C3453	C3453	5/27/10
300-FF-5	C3520	C3520	5/27/10
300-FF-5	C3521	C3521	5/27/10
300-FF-5	C3522	C3522	5/27/10
300-FF-5	C3523	C3523	5/27/10
300-FF-5	C3524	C3524	5/27/10
300-FF-5	C3525	C3525	5/27/10
300-FF-5	C3526	C3526	6/1/10
300-FF-5	C3527	C3527	6/1/10
300-FF-5	C3533	C3533	4/15/10
300-FF-5	C3534	C3534	4/15/10

Project/ Location	Well Name	Well ID	Out of Service Date
300-FF-5	C3535	C3535	4/15/10
300-FF-5	C3536	C3536	4/15/10
300-FF-5	C3537	C3537	6/1/10
300-FF-5	C8000	C8000	8/17/10
300-FF-5	C8001	C8001	8/17/10
Monument South (ALE, Riverland, McGee Ranch)	699-24-95	A8458	9/30/10
Monument South (ALE, Riverland, McGee Ranch)	699-S25-51	A9203	9/9/10
Monument South (ALE, Riverland, McGee Ranch)	C7762	C7762	8/19/10

Figure 16-1. Categorization of Unique Well Identification Numbers



DATA CURRENT TO 12/31/2010 AND SUBJECT TO CHANGE

Well = Water wells, resource protection wells, instrumentation wells, dewatering wells and geotechnical soil borings as defined in WAC-173-160-111 (60).

Awaiting drilling = A location that was assigned an HWIS ID number and currently is awaiting drilling or being drilled, but not yet completed as a well.

Drilling cancelled = A location that was assigned an HWIS ID number for planning purposes, but subsequently was never drilled.

Figure 16-2. Hanford Site and Surrounding Area Depicting Various Geographic Regions

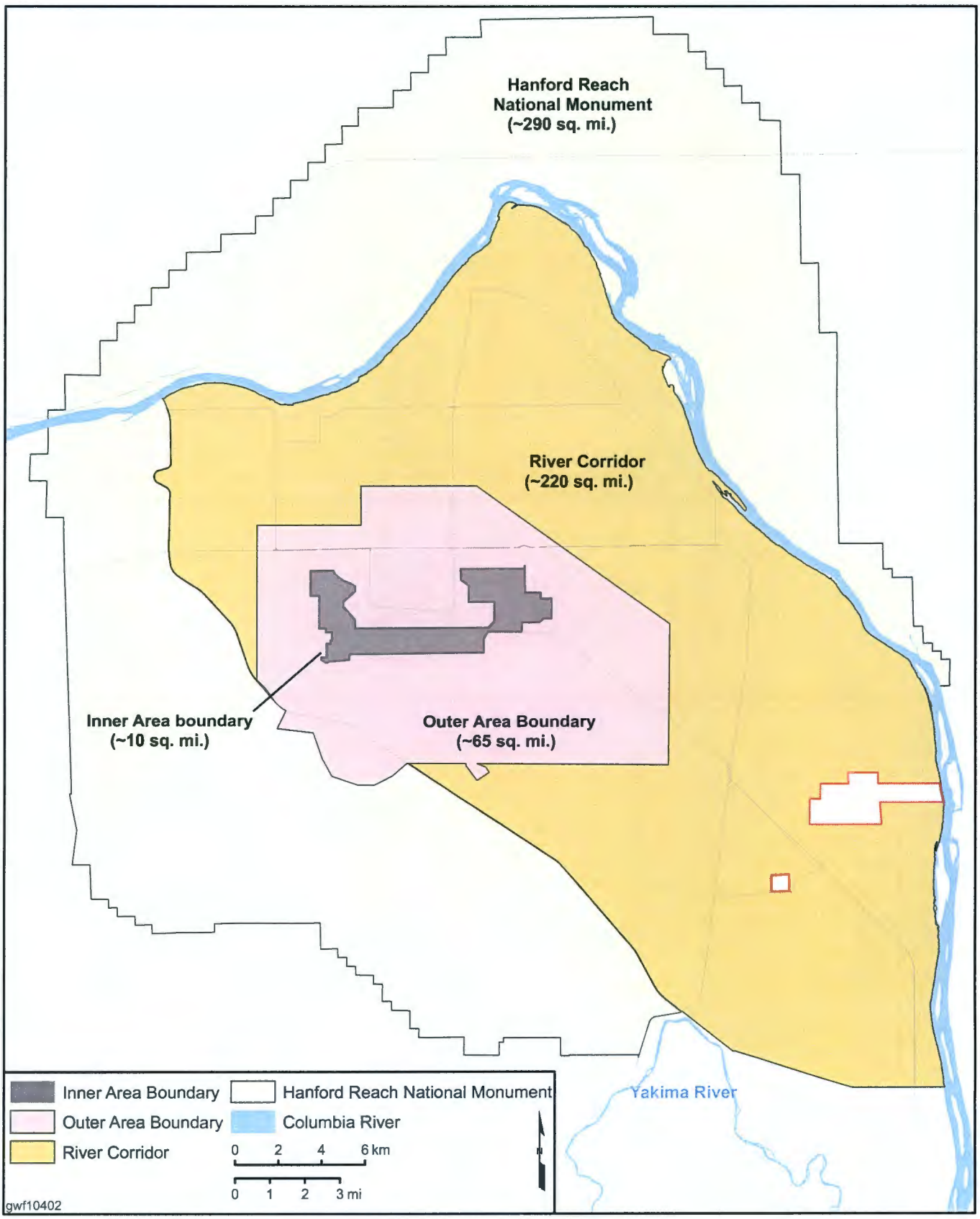


Figure 16-3. Site-Wide Well Installations for the Reporting Period

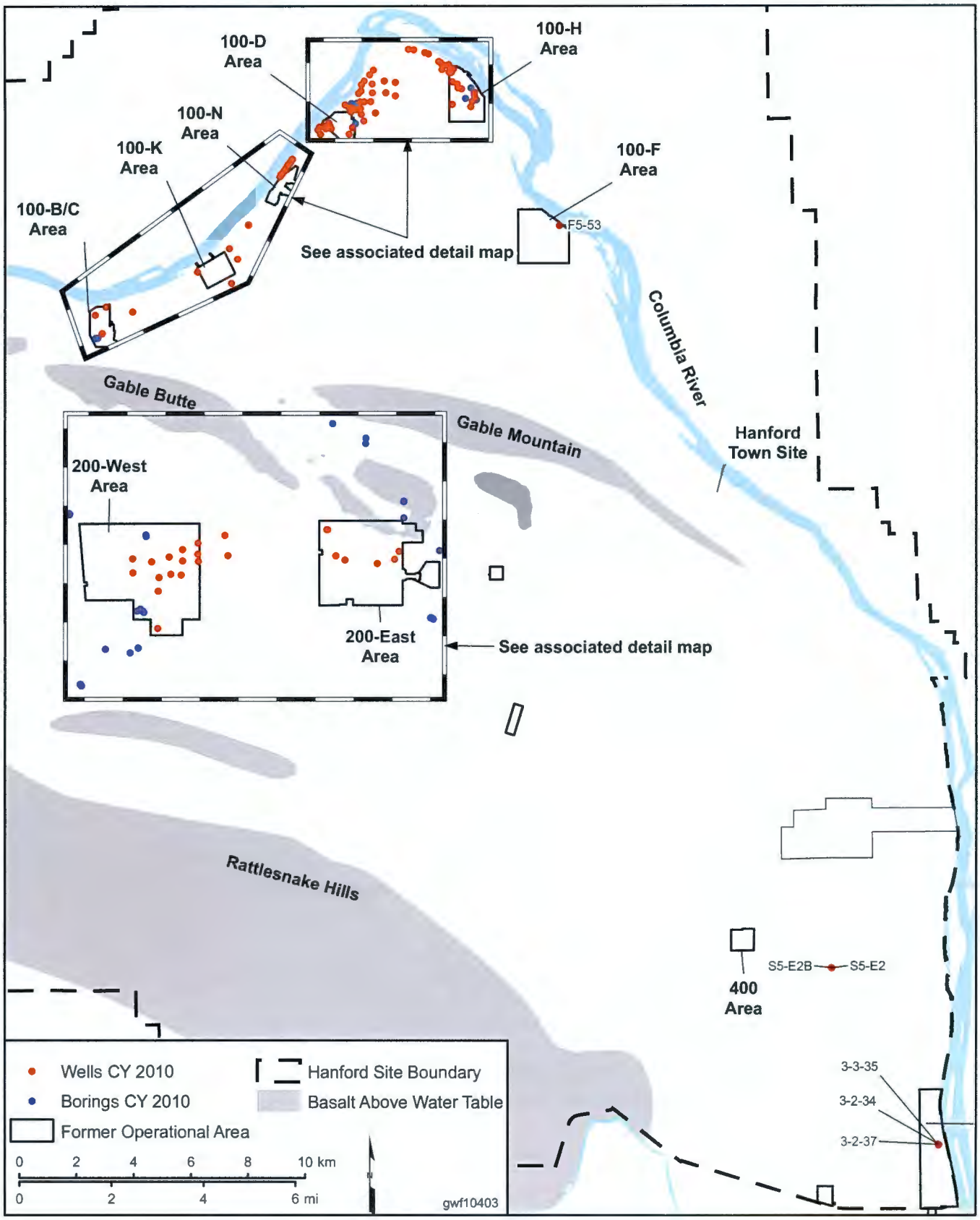


Figure 16-4. 100-B/C, 100-K, and 100-N Area Well Installations for the Reporting Period

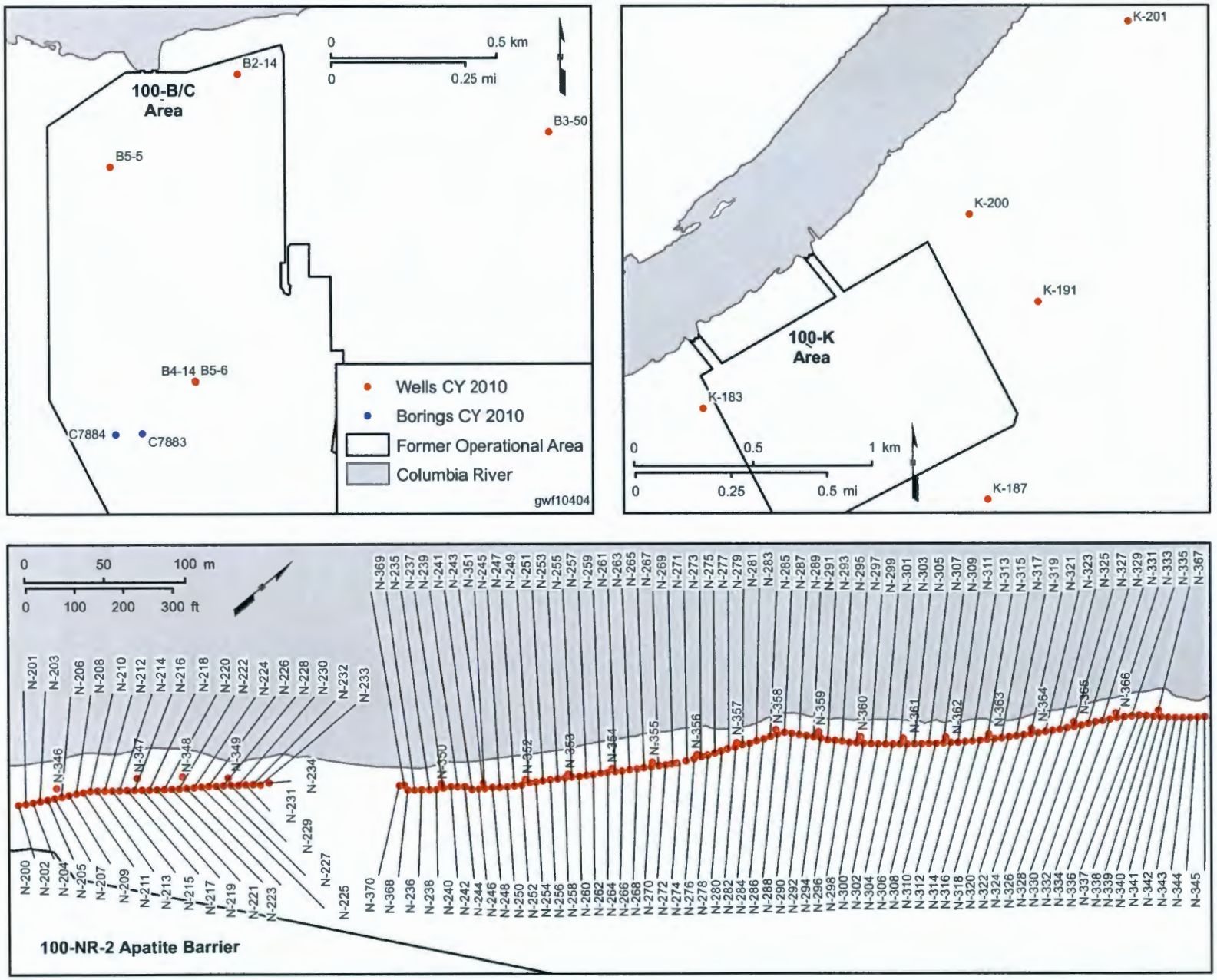


Figure 16-5. 100-D and 100-H Area Well Installations for the Reporting Period

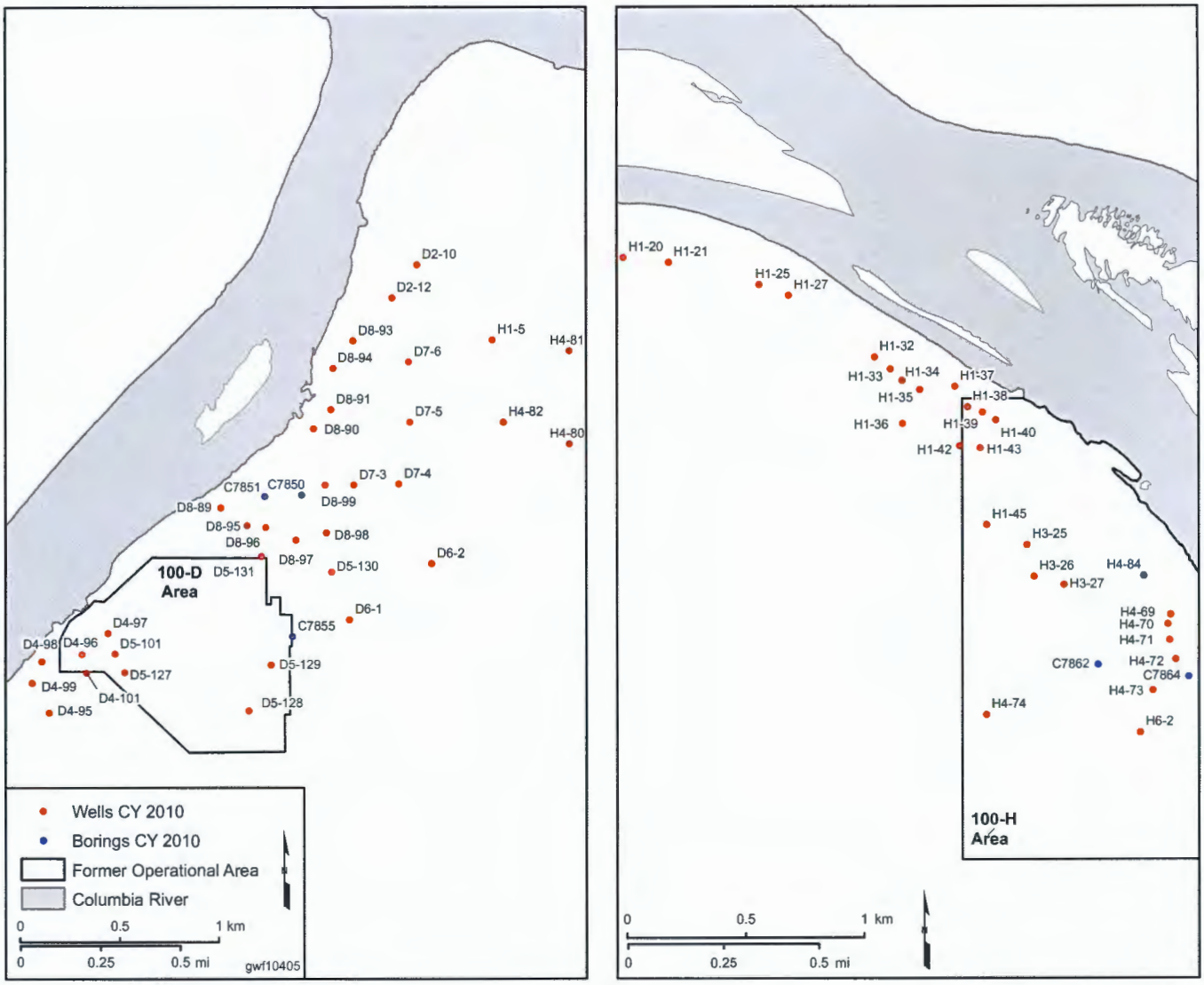
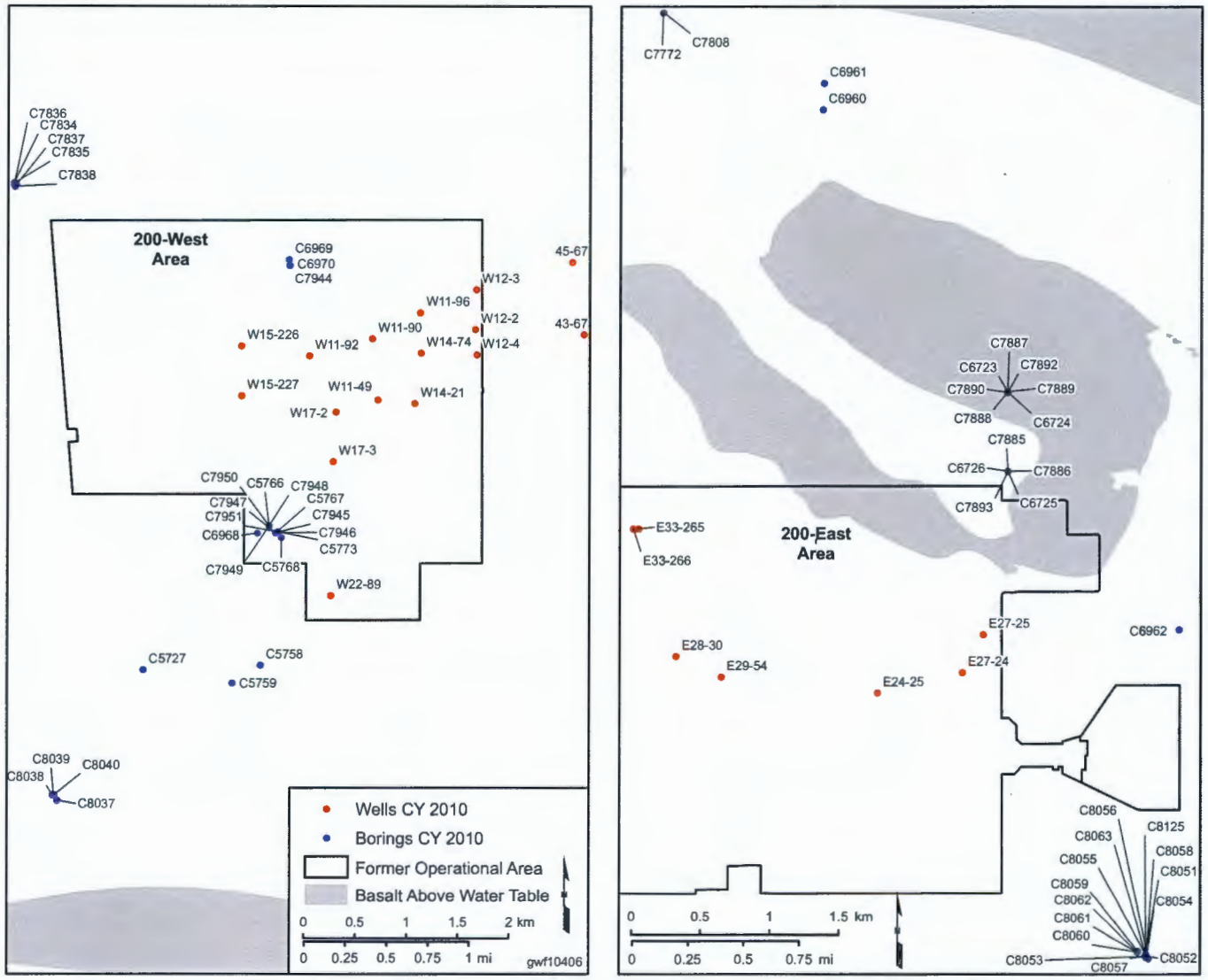


Figure 16-6. 200 East Area and 200 West Area Well Installations for the Reporting Period



17.0 Columbia River

M.J. Hartman

The Hanford Reach of the Columbia River begins upstream of the Hanford Site at Priest Rapids Dam and extends 82 kilometers downstream to the upper end of Lake Wallula, impounded by McNary Dam. Although flow volume and water levels are controlled by upstream dams, the Hanford Reach is essentially the only free-flowing stretch of the Columbia River in the United States.

The DOE is committed to protecting the Columbia River from the Hanford Site's contaminated groundwater.

The U.S. Department of Energy (DOE) is committed to protecting the Columbia River from the Hanford Site's contaminated groundwater. The *Hanford Integrated Groundwater and Vadose Zone Management Plan* (DOE/RL-2007-20) outlines the steps for addressing groundwater and vadose zone contamination. The DOE developed the plan in consultation with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology).

Many actions have already been taken to address principal threats to the Columbia River and groundwater, including the following:

- Ceasing discharge of all unpermitted liquids in the central Hanford Site
- Remediating the former liquid waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination
- Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat.

Near the Columbia River, the rise and fall of the river stage creates a dynamic zone of interaction between groundwater and the river, influencing flow patterns, contaminant concentrations, and, in some instances, contaminant mobility (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*). The zone of interaction is monitored via near-shore groundwater wells and aquifer tubes, riverbank seeps (springs), and near-shore river water. Aquifer tube data and data from monitoring wells are discussed in earlier chapters of this report. Data from seeps and river water are summarized below.

The DOE conducts water quality monitoring in the Columbia River environment as part of its Public Safety and Resource Protection Program, with the purpose of monitoring offsite migration of contaminants of Hanford Site origin via multiple pathways (DOE/RL-91-50, *Environmental Monitoring Plan*). The Surface Environmental Surveillance Project at Pacific Northwest National Laboratory (PNNL) conducts monitoring related to contaminants carried by groundwater to the Columbia River. Hanford Site shoreline monitoring is further discussed in *Water Quality Sampling Locations Along the Shoreline of the Columbia River, Hanford Site, Washington* (PNNL-19052), which also provides detailed location maps for near-river monitoring.

The DOE is conducting a risk assessment and remedial investigation of contaminant releases to the Columbia River, which are also summarized in this chapter.

17.1 Seep and River Monitoring

PNNL collects samples from seepage areas on the banks of the Columbia River in the fall when the river stage is low. Samples are analyzed for a variety of chemicals and radionuclides, and the results are published annually in the Hanford Site environmental report (e.g., Section 8.5 of PNNL-19455, *Hanford Site Environmental*

Report for Calendar Year 2009). Table 17-1 lists concentrations of contaminants of interest for each of the shoreline segments in calendar year (CY) 2010, the most recent year for which results are available.

Concentrations of dissolved chromium exceeded the ambient water quality standard for hexavalent chromium (10 µg/L) in seeps in each of the 100 Areas. The highest concentration was 35.4 µg/L in a 100-D Area seep. Strontium-90 was detected in the 100-BC, 100-D, and 100-H Area seeps, but all concentrations were below the 8 pCi/L drinking water standard (DWS). The only seep in the 100-N Area is located downstream from the strontium-90 groundwater plume. Tritium was detected in a seep at the former Hanford town site at 20,000 pCi/L (which is also the DWS). Uranium was detected at a maximum concentration of 70 µg/L in a 300 Area seep.

PNNL monitors Columbia River water by collecting samples along several cross-river transects and at near-shore river locations adjacent to groundwater plumes, where humans and aquatic biota are potentially exposed to contaminants. The surveillance includes sampling Columbia River water, Columbia River sediment, riverbank springs, and other media (e.g., air, plants, and animals). The surveillance data provide a historical record of radionuclides and chemicals in the environment. The results of water quality monitoring along the shoreline and in the free-flowing river are presented annually in the Hanford Site environmental report (e.g., Section 8.4 of PNNL-19455) and are summarized below.

The Hanford Site environmental report for 2009 is available at http://hanford-site.pnnl.gov/envreport/2009/index.htm.

Statistical analyses indicated that downstream tritium concentrations were higher than upstream concentrations. The average tritium concentration in Columbia River water collected at the city of Richland (41 [±27] pCi/L) was 0.2% of the Washington State ambient surface water quality criterion of 20,000 pCi/L. Average total uranium concentration measured at the city of Richland (0.56 [±0.096] pCi/L) was higher than at Priest Rapids Dam (0.43 [±0.078] pCi/L). The primary source of uranium discharging to the Columbia River at the Hanford Site is the 300 Area, which is a short distance upstream from the city of Richland. Plutonium was not detected in filtered water samples in 2009. Statistical comparisons for strontium-90, gross alpha, and gross beta concentrations at Priest Rapids Dam and the city of Richland were not performed because most of the concentrations were less than detection limits.

All metal and anion concentrations in river water, including dissolved chromium, were less than the ambient water quality standard in 2009.

In 2009, the U.S. Geological Survey sampled Columbia River water at Vernita Bridge (upstream of the Hanford Site) and the city of Richland. These data did not provide any indication of deterioration of water quality along the Hanford Reach of the Columbia River. Median concentrations of dissolved chromium were similar for water samples collected near Vernita Bridge and the city of Richland, and the concentrations were well below the ambient water quality criterion.

17.2 River Corridor Baseline Risk Assessment

A critical step in developing final remedial action decisions for portions of the Hanford Site along the Columbia River is the completion of a quantitative baseline risk assessment. Washington Closure Hanford is responsible for the River Corridor Baseline Risk Assessment (RCBRA). The RCBRA addresses potential risk to human health and the environment from post-remediation, residual contaminant concentrations in the 100 and 300 Areas, as well as the Hanford and White Bluffs town sites. This assessment also investigates risks related to the potential transport of

Hanford Site contaminants to Columbia River riparian and near-shore environments adjacent to the former operational areas.

Draft C of the RCBRA, Volume 1, *Ecological Risk Assessment*, and Volume 2, *Human Health Risk Assessment*, are scheduled to be issued in 2011 for review by EPA, Ecology, and Hanford Site stakeholders.

Additional information about the River Corridor Baseline Risk Assessment and links to supporting documents and reports are available at http://www.washingtonclosure.com/documents/mission_complete/100-300Area/RL2007-21_DraftA.pdf.

17.3 Hanford Site Releases to the Columbia River

The DOE and Washington Closure Hanford are investigating Hanford Site contaminant releases to the Columbia River (DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*). It is important to understand the contaminants that are present, their concentrations, and the locations because these contaminants may have undesirable health effects for humans, animals, and plants that use or live in the Columbia River. The information obtained from this investigation will ultimately be used to help make final cleanup decisions for Hanford Site contaminants that exist in and along the Columbia River.

Recent documents associated with the Columbia River component of the RCBRA include the following:

- WCH-352, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils*
- WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*
- WCH-381, *Data Quality Assessment Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*
- WCH-387, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Fish Tissue Samples*.

Additional information about the remedial investigation is available at http://www.washingtonclosure.com/projects/environmental_protection/mission_completion/project_library/#investigation.

Sampling associated with this work was completed in June 2010. Data collected as part of these field activities are being compiled into a data summary report which will be finalized in 2011. These data are being evaluated as part of the development of a screening level ecological risk assessment and a baseline human health risk assessment for the Columbia River component of the RCBRA. These risk assessments are anticipated to be completed by CY 2012.

17.4 Columbia River Porewater Sampling in the 100-BC and 100-N Areas

Initial results of river porewater sampling in 2009 and early 2010 (Section 17.3) raised questions regarding the persistence and extent of porewater contamination. The remedial investigation work plan for the 100-BC Area (DOE/RL-2008-46-ADD3, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*) and a sampling and analysis plan for the 100-N Area (DOE/RL-2010-69, *Sampling and Analysis Plan for the 100-NR-2 Operable Unit River Pore Water Investigation*) called for additional porewater sampling in those areas. Chapters 4.0 and 6.0 discuss the studies and preliminary results.

Hanford Reach National Monument

The Hanford Reach of the Columbia River, the last free-flowing stretch of this river in the United States, is part of the Hanford Reach National Monument. The monument also includes the Saddle Mountains Wildlife Refuge north of the river, and the Fitzner-Eberhardt Arid Lands Ecology Reserve in the southwestern Hanford Site. The 195,000-acre monument contains a wealth of wildlife and remnants of human history spanning more than 10,000 years.

The monument was established by Presidential decree in 2000 and is administered by the U.S. Fish and Wildlife Service.

For more information, see http://www.fws.gov/hanfordreach/.

Table 17-1. Hanford Site Contaminants in Columbia River Seeps (Springs), Calendar Year 2010

Shoreline Segment	Constituent	Maximum Concentration	Aquatic Water Quality Criteria	Drinking Water Standard
100-B/C	Chromium (dissolved)	18 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	2.2 mg/L	NA[d]	45 mg/L[e]
	Strontium-90	1.8 pCi/L	8 pCi/L	8 pCi/L
	Tritium	1,800 pCi/L	20,000 pCi/L	20,000 pCi/L
100-K	Chromium (dissolved)	72 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	7.1 mg/L	NA[d]	45 mg/L[e]
	Strontium-90	Nondetect	8 pCi/L	8 pCi/L
	Trichloroethene	1.51 µg/L[f]	5 µg/L	5 µg/L
	Tritium	680 pCi/L	20,000 pCi/L	20,000 pCi/L
100-N	Chromium (dissolved)	11 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	4.7 mg/L	NA[d]	45 mg/L[e]
	Strontium-90	Nondetect	8 pCi/L	8 pCi/L
	Tritium	4,000 pCi/L	20,000 pCi/L	20,000 pCi/L
100-D	Chromium (dissolved)	54 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	3.4 mg/L	NA[d]	45 mg/L[e]
	Strontium-90	1.3 pCi/L	8 pCi/L	8 pCi/L
	Tritium	6,200	20,000 pCi/L	20,000 pCi/L
100-H	Chromium (dissolved)	37 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	6.9	NA[d]	45 mg/L[e]
	Strontium-90	3.0 pCi/L	8 pCi/L	8 pCi/L
	Tritium	1,600 pCi/L	20,000 pCi/L	20,000 pCi/L
100-F	Chromium (dissolved)	16 µg/L	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	10 mg/L	NA[d]	45 mg/L[e]
	Strontium-90	Nondetect	8 pCi/L	8 pCi/L
	Tritium	880 pCi/L	20,000 pCi/L	20,000 pCi/L
Hanford town site	Chromium (dissolved)	2.7 µg/L	10 µg/L[a]	100 µg/L[b]
	Iodine-129	Nondetect	1 pCi/L	1 pCi/L
	Nitrate[c]	5.2 mg/L	NA[d]	45 mg/L[e]
	Tritium	20,000 pCi/L	20,000 pCi/L	20,000 pCi/L
300 Area	Chromium (dissolved)	3.5	10 µg/L[a]	100 µg/L[b]
	Nitrate[c]	6.2 mg/L	NA[d]	45 mg/L[e]
	Trichloroethene	1.05 µg/L[f]	5 µg/L	5 µg/L
	Tritium	9,000 pCi/L	20,000 pCi/L	20,000 pCi/L
	Uranium (total)	70 µg/L	30 µg/L	30 µg/L

Source: PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*, Section 8.5, Table C.10 and Appendix 1.

a. As dissolved hexavalent chromium.

b. As total chromium.

c. Nitrate is expressed as NO_3.

d. "NA" indicates none assigned; a concentration for this constituent has not been assigned.

e. 45 mg/L as NO_3^- is equivalent to 10 mg/L of nitrate as nitrogen.

f. Value is less than the laboratory contract-required detection limit.

This page intentionally left blank.

18.0 Vadose Zone Remediation, Monitoring, and Characterization

D.C. Weekes

Vadose zone monitoring using leachate and soil vapor sampling occurred at three areas in the Hanford Site in calendar year (CY) 2010. Leachate and soil vapor monitoring continued at the Environmental Restoration Disposal Facility (ERDF) and the Solid Waste Landfill. Monitoring for the ERDF is discussed in Chapter 11.0, Section 11.3.4 and for the Solid Waste Landfill in Chapter 10.0, Section 10.4.1. Soil vapor monitoring at the carbon tetrachloride expedited response action site also continued during CY 2010.

The Tank Farm Vadose Zone Project installed direct-push boreholes at the C and BY Tank Farms for subsurface characterization of unplanned releases and future geophysical surveys. The Tank Farm Vadose Zone Project also completed surface geophysical exploration at Waste Management Area (WMA) S-SX and UPR-200-E-86 to map subsurface contaminant distribution. The interim surface barrier was placed over WMA TY to reduce water infiltration into the contamination area. These monitoring and characterization efforts are summarized in this chapter.

Further interpretation of data collected at the Sisson and Lu vadose zone field injection test site in the 200 East Area from the year 2000 is presented in this chapter. The spatial and temporal evolution of the observed moisture plume at the injection site was compared with simulated plumes based on three methods: (1) upscaling, (2) cokriging/artificial neural network (ANN), and (3) transition probability (TP)/ Markov chain (MC). Upscaling uses small, core-scale measurements of hydraulic properties to model large, field-scale behavior. In summary, the upscaling method captured the overall movement pattern of the injected water in terms of the first and second moments of the observed plume at the field site, but it was not able to simulate the detailed distribution of the moisture plume. The cokriging/ANN method simulated the observed moisture plume well, but the simulated vertical movement was faster than the observed vertical movement. The TP/MC method best reproduced the media heterogeneity and the contrast existing between the coarse and fine soil horizons at the Sisson and Lu site.

18.1 Carbon Tetrachloride Soil Vapor Monitoring and Remediation

E.J. Freeman

Soil vapor extraction (SVE) is used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency and the Washington State Department of Ecology (Ecology) authorized the U.S. Department of Energy to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) expedited response action. This section summarizes the CY 2010 activities associated with carbon tetrachloride removal. A report containing detailed results from CY 2010 activities will be issued in CY 2011. Historic monitoring and remediation results are documented in several reports, including the following:

- SGW-44694, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2009*
- SGW-40456, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2008*
- SGW-37111, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2007*
- SGW-33746, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2006*
- WMP-30426, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2005*
- WMP-26178, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004*
- WMP-21327, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2003*
- WMP-17869, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2002*
- BHI-00720, *Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2001.*

In CY 2010, two SVE systems were operating to remove carbon tetrachloride from the vadose zone. Each of the systems has an extraction capacity of 14.2 cubic meters per minute. Figure 18-1 shows the locations of the SVE wells.

One SVE system was operated at the 216-Z-1A well field and one system was operated at the 216-Z-9 well field. Each system was operated from March 1 through November 1, 2010. Temporarily suspending SVE operations at each well field during the winter allows carbon tetrachloride concentrations to recharge and be extracted more efficiently and economically when operations resume. Cyclic operation of the SVE system was implemented based on the *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997* (BHI-01105). Section 18.1.1 discusses the results of the CY 2010 SVE in more detail.

Approximately 79,751 kilograms of carbon tetrachloride have been removed since extraction operations started in 1991. The mass of carbon tetrachloride removed in CY 2010 was 194 kilograms.

To track the effectiveness of the remediation effort, soil vapor concentrations of carbon tetrachloride were monitored at the inlets to the SVE systems and at individual online extraction wells during the 8-month operating period. To assess the impact of the SVE system on subsurface concentrations, soil vapor concentrations of carbon tetrachloride were monitored at offline wells and probes during the entire CY (Section 18.1.2). Remediation efforts during CY 2010 also included passive SVE (Section 18.1.3).

18.1.1 Soil Vapor Extraction

During CY 2010, SVE operations continued from March 1, 2010, through November 1, 2010, using two, 14.2 cubic meter per minute SVE systems. One system operated at the 216-Z-1A/216-Z-12/216-Z-18 well field and one system operated at the 216-Z-9 well field.

For the system at the 216-Z-1A well field, initial online wells were selected within the perimeter of the 216-Z-1A Tile Field. For the system at the 216-Z-9

well field, initial online wells were selected near the 216-Z-9 Trench. As extraction continued at both locations, additional wells in the vicinity of these two waste sites were brought online. Extraction wells open near the less-permeable Cold Creek unit (CCU), where the highest carbon tetrachloride concentrations have been detected consistently in the past, were selected at both locations to optimize mass removal of the contaminant. Extraction wells open near the groundwater were also selected for SVE or passive SVE (Section 18.1.3).

As of November 2010, ~79,751 kilograms of carbon tetrachloride had been removed from the vadose zone since extraction operations started with the pilot test in 1991 (Table 18-1). The mass of carbon tetrachloride removed in CY 2010 was 194 kilograms. The most recent performance evaluation report (SGW-44694) provides the amount of carbon tetrachloride removed per year between 1991 and 2009.

18.1.2 Monitoring of Offline Wells and Probes

During CY 2010, soil vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the CCU (~40 meters below ground surface [bgs]), and near groundwater (~66 meters bgs). Soil vapor concentrations were monitored near the ground surface and groundwater to evaluate if nonoperation of the SVE system negatively affects the soil atmosphere or groundwater. The maximum concentration detected near the ground surface (between 2 and 10 meters bgs) was 5.5 parts per million by volume (ppmv). Near the groundwater (between 53 and 66 meters bgs), the maximum concentration was 12 ppmv.

Soil vapor concentrations were also monitored above and within the CCU to provide an indication of concentrations that could be expected during restart of the SVE system. The maximum concentration detected near the CCU (between 25 and 44 meters bgs) was 229 ppmv in soil vapor probe CPT-28 (27 meters bgs), ~90 meters south of the 216-Z-9 Trench. This location may be beyond the zone of influence of the SVE system. Within the 216-Z-9 well field, the maximum carbon tetrachloride concentration detected near the CCU was 6 ppmv at well 299-W15-8U (35 meters bgs). At the 216-Z-1A well field, the maximum carbon tetrachloride concentration detected near the CCU was 70 ppmv at wells 299-W18-165 and 299-W18-167 (both about 32 meters bgs).

The maximum carbon tetrachloride concentration detected in the vadose zone overlying the CCU (between 11 and 23 meters bgs) was 68 ppmv at well CPT-21A (20 meters bgs) near the 216-Z-9 Trench.

18.1.3 Passive Soil Vapor Extraction

Passive SVE is a remediation technology that uses naturally induced pressure gradients between the subsurface and the ground surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, whereas rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive SVE systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive SVE systems were installed at the end of FY 1999 at eight wells open near the vadose/groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field. The passive systems have check valves that allow only soil vapor flow out of the borehole (i.e., one-way movement) and canisters holding granular activated carbon that adsorbs carbon tetrachloride upstream of the check valves before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which tends to dilute and spread carbon tetrachloride vapors in the subsurface.

The wells are sampled periodically upstream of the granular activated carbon canisters. During CY 2010, the maximum carbon tetrachloride concentrations ranged from 12 to 15 ppmv at the three wells (299-W18-6, 299-W18-7, and 299-W18-246) near the 216-Z-1A Tile Field. The maximum carbon tetrachloride concentrations ranged from 9 to 11 ppmv at the four wells (299-W18-10, 299-W18-11, 299-W18-12, and 299-W18-247) near the 216-Z-18 Crib.

18.2 Tank Farm Vadose Zone Activities

D.A. Myers, C.L. Tabor, H.A. Sydnor, J.G. Field, and D.L. Parker

The Vadose Zone Integration Program is responsible for implementing the Tank Farm *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action program through field characterization, laboratory analyses, technical analyses, risk assessment for past tank leaks, and installation of interim measures to reduce the threat from contaminants until permanent solutions can be found. In CY 2010, several direct-push boreholes were installed for soil sampling and geophysical logging in the C and BY Tank Farms (Section 18.2.1). Section 18.2.2 discusses three-dimensional applications of surface geophysical exploration of the northeast corner of the SX Tank Farm and southeast corner of the S Tank Farm (RPP-RPT-47851, *Three-Dimensional Surface Geophysical Exploration of S/SX Tank Farm*) and at UPR-200-E-86 adjacent to the C Tank Farm, and a well-to-well resistivity survey of WMA A-AX. Section 18.2.3 briefly describes geophysical logging. Section 18.2.4 describes the interim surface barrier work associated with the TY, BY and SX Tank Farms to reduce the infiltration of precipitation.

18.2.1 Direct-Push Boreholes and Sampling

The hydraulic hammer unit was deployed in three tank farms during the report period to evaluate subsurface contamination in the vadose zone. The hydraulic hammer unit was deployed in the C Tank Farm to support Phase 2 of the facility investigation. The hydraulic hammer unit was deployed in the S Tank Farm to assess the extent of contamination to support a proposed interim barrier. The sites were identified from previous investigations of subsurface resistivity (RPP-RPT-42513, *Surface Geophysical Exploration of the SX Tank Farm at the Hanford Site*). The hydraulic hammer unit was deployed at the BY Tank Farm to support a proposed interim barrier over that facility. The BY Tank Farm sites investigated were previously identified using historical release information and electrical resistivity (RPP-34690, *Surface Geophysical Exploration of B, BX, and BY Tank Farms at the Hanford Site).*

Sample horizons were selected and agreed upon using borehole logs of gamma and moisture content. A multi-level sampler was then used at the sites to collect samples at the selected horizons for laboratory analysis. During CY 2010, installation of multiple-depth electrode strings was performed at the S, C, and BY Tank Farms. Electrodes were placed in every direct-push logging hole as the holes were decommissioned. These electrodes will be used during a future deployment of surface geophysical exploration in the tank farms. The analytical results will be used to support placement of proposed interim barriers for the BY and S Tank Farms, as necessary, and for the Phase 2 (tank farm closure) investigation of C Tank Farm. A total of 24 samples from seven boreholes were collected in the BY Tank Farm, 65 samples from seven boreholes in the C Tank Farm, and 16 samples from five boreholes in the S Tank Farm.

18.2.2 Surface Geophysical Exploration

A fully three-dimensional application of surface geophysical exploration, which is a combination of surface deployed geophysical techniques, was applied over a portion of the northeast corner of the SX Tank Farm and the southeast corner of the S Tank Farm (RPP-RPT-47851) during the report period. The primary tool applied through surface geophysical exploration is pole-pole electrical resistivity; other tools applied during CY 2010 included ground-penetrating radar. Ground-penetrating radar was used to help define locations where the direct-push sampling holes could be safely advanced. The depth to which the resistivity measurements interrogate the subsurface is determined by the distance between electrode pairs (i.e., the further apart, the deeper the interrogation). Because resistivity is an indirect measure of several subsurface phenomena (e.g., moisture distribution, saline contaminants, and soil texture), the more separated the electrode pairs, the lower the resolution of the analysis. The resistivity data are mathematically analyzed through a process known as inversion to provide a best estimate of the distribution of resistivity anomalies. Surface geophysical exploration provides a means of extrapolating direct measurements taken by sampling, logging, or other means to provide a cost-effective overview of large areas that may have been impacted by a variety of waste management practices.

Work during CY 2010 in the S and SX Tank Farms was performed to further define anomalous features reported last year in RPP-RPT-42513. In addition, this year's survey was used to assess a variety of installation configurations for deep electrodes. The lessons learned from this assessment are being applied to ongoing surface geophysical exploration applications. Sampling of the anomalous regions showed that the anomaly was likely due to increased soil moisture; no increased levels of contamination were discovered during the sampling effort.

A fully three-dimensional surface geophysical exploration survey, including buried electrodes, was completed over UPR-200-E-86 during the reporting period. The survey covered an unplanned release site associated with a pipeline leak (RPP-RPT-41236, *Surface Geophysical Exploration of UPR 200-E-86 Near the C Tank Farm*). During this survey, 301 surface electrodes were placed over the area of the known release, including 5 electrodes placed in five direct-push holes; the entire array was then interrogated both forward and reciprocally. The results of this survey are depicted in Figure 18-2, which is an isometric view of the interpreted results. No large regions of anomalous resistivity signatures were identified; neither had significant contamination been found in the direct push derived samples from this region. This leads to a possible conclusion that the known release at this site had a much smaller volume than originally estimated.

A well-to-well resistivity survey was completed in the A and AX Tank Farms (RPP-RPT-46613, *Surface Geophysical Exploration of the A and AX Tank Farms*). The results of this application of surface geophysical exploration (Figure 18-3) generally conform to regions of previously identified releases. However, an additional anomaly to the north and east of the AX Tank Farm is indicated (this region extends beyond the bounds of the AX Tank Farm well-to-well survey). A possible reason for this anomaly is the 216-A-39 Crib.

18.2.3 Geophysical Logging

Geophysical neutron moisture logging was completed for twenty drywells in the TY Tank Farm to support interim surface barrier monitoring. Spectral gamma logging of these wells is planned for CY 2011. Spectral gamma logging was completed for 26 drywells, and neutron logging began in support of RCRA facility investigation/

corrective measures study characterization in the C Tank Farm. Additionally, in response to Ecology's concerns regarding gamma logging data, eight drywells (20-07-02 in the B Tank Farm; 21-01-01 and 21-06-05 in BX Tank Farm; 22-07-09 and 22-09-08 in the BY Tank Farm; 30-01-09 and 30-08-02 in the C Tank Farm; and 41-07-08 in the SX Tank Farm) were logged using the high-rate logging system. The CY 2010 high-rate logging system determined that cesium-137 concentrations were within a factor of three compared to previous logging results, which is well within the margin of error for the previous results and indicates little or no change in the cesium-137 distribution.

18.2.4 Interim Barriers

The *T Farm Interim Surface Barrier Demonstration: Vadose Zone FY 09 Monitoring Report* (PNNL-19123), issued January 2010, concluded that results of neutron probe, capacitance probe, and heat dissipation unit monitoring showed that the T Tank Farm interim surface barrier performed as expected. The barrier prevented meteoric water from infiltrating into the soil, resulting in the soil becoming gradually drier. The barrier also affected the soil below the barrier edge but at a reduced magnitude. Based on T Tank Farm interim surface barrier monitoring and modeling results to date, additional interim surface barriers were recommended as interim measures to slow water flux in other locations and to reduce the rate of contaminant movement toward the groundwater prior to a final remedy (RPP-RPT-47123, *Interim Surface Barrier Evaluation Report*).

During CY 2010, an interim surface barrier was constructed over the TY Tank Farm (Figure 18-4). This project altered the surface of the farm to direct runoff and placed a modified asphalt cover over all six tanks. Runoff is directed to a lined evapotranspiration basin west of the tank farm, where the water then re-enters the atmosphere. This barrier covers approximately 7,500 square meters and consists of engineered fill to create a 0.8% slope, covered by approximately 0.1 meter of modified asphalt. Monitoring of this configuration is underway to assess its performance. The evapotranspiration basin is approximately 2 meters deep and was backfilled to a depth of ~1 meter; the area of the basin is ~6,650 square meters.

The first of two interim surface barriers and an evapotranspiration basin are being designed for the SX Tank Farm to meet *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Milestone M-045-92. The first interim barrier at the SX Tank Farm, referred to as the SX south barrier, will cover the southernmost six tanks in the tank farm. The evapotranspiration basin will be located to the south of the tank farm in an existing excavation. The design for the SX Tank Farm barriers is based, in large part, on lessons learned from construction of T and TY Tank Farm barriers and will be very similar to the barrier system installed at the TY Tank Farm.

Site characterization activities are underway at the BY Tank Farm to evaluate the appropriateness of interim surface barriers over this facility. The western portion of the tank farm has been sampled as noted above and a resistivity survey has been conducted. Drilling and sampling is continuing, and a resistivity survey is planned for mid-CY 2011.

18.3 Comparison of Three Methods for Characterizing Heterogeneous Hanford Sediments

R. Khaleel

Hanford sediments are inherently heterogeneous at a variety of scales. An accurate simulation of flow and contaminant transport in heterogeneous media is often hampered by the difficulty in characterizing media heterogeneity and the variability of sediment layering structure. The difficulty partly arises due to a lack of site characterization data. In situations where data are available, the data are typically obtained from widely spaced boreholes. While the borehole data can often provide relatively adequate information of heterogeneity in the vertical direction, the data cannot provide sufficient information of heterogeneity in the lateral direction. Thus, interpolating information between boreholes is needed to characterize the lateral heterogeneity.

In order to resolve the problem of sparse characterization data, the use of multiple types of "hard" and "soft" data has often been suggested ("Heterogeneity in Sedimentary Deposits, a Review of Structure-Imitating, Process-Imitating, and Descriptive Approaches" [Koltermann and Gorelick, 1996]). Hard and soft data are, respectively, direct and indirect measurements of sediment properties. For vadose zone modeling, hard data include, for example, soil hydraulic properties and, in particular, soil moisture retention and unsaturated hydraulic conductivity measurements. Due to limits in measurement techniques, time, and/or budget, moisture retention and unsaturated hydraulic conductivity measurements are usually sparse. By contrast, it is generally easier to obtain data that contain indirect information about spatial structure and heterogeneity of the parameters. Such data may include soil moisture content, bulk density, sediment textural data, geophysical data, and other quantitative or qualitative information about a site of interest. Various inverse and forward methods have been developed to combine data of multiple types and thereby improve predictions of moisture flow in heterogeneous unsaturated media.

During CY 2010, work was completed on comparing three different methods for modeling moisture flow for the heterogeneous Hanford formation. The following discussion provides a summary of the results for application of the three methods. The methods are evaluated by comparing the simulated and observed moisture content profiles for a vadose zone field injection experiment at the Sisson and Lu site, located in the 200 East Area south of the Plutonium-Uranium Extraction Plant. This is the same field injection experiment site considered in the *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* (DOE/RL-2010-11).

18.3.1 Field Injection Experiment

The field injection site was specifically designed by Sisson and Lu (RHO-ST-46P, *Field Calibration of Computer Models for Application to Buried Liquid Discharges: A Status Report*) to understand moisture movement underneath buried discharges such as tank leaks. The Sisson and Lu site was used for a field infiltration experiment from June to July 2000 (PNNL-13679, *Vadose Zone Transport Field Study: Status Report*; PNNL-13795, *Vadose Zone Transport Field Study: Soil Water Content Distributions by Neutron Moderation*). Initial moisture content distribution was measured on May 5, 2000, at the 32 radially and symmetrically arranged cased boreholes (Figure 18-5). Injections began on June 1 (the 153rd day of the year), and

4,000 liters of water were metered into an injection point 5 meters below the land surface over a period of 6 hours. Similarly, 4,000 liters of water were injected in each subsequent injection on June 8, June 15, June 22, and June 28. During the injection period, neutron logging in 32 wells took place within a day (i.e., June 2, June 9, June 16, and June 23) following each of the first four injections. A wildfire near the field site prevented immediate logging of the moisture content (θ) distribution for the fifth injection on June 28. Three additional readings of the 32 wells were subsequently completed on July 7, July 17, and July 31. During each neutron-logging event, moisture content was recorded in each well at a depth interval of 0.3048 meters, starting from a depth of 3.9625 meters and continuing to a depth of 16.764 meters, resulting in a total of 1,376 measurements in each of the eight observation days over a 2-month period.

18.3.1.1 Upscaling Method

The upscaling method uses snapshots of the observed moisture content plume under transient flow conditions to derive a three-dimensional effective unsaturated hydraulic conductivity (K) tensor. The methodology uses the temporal evolution of spatial moments of observed moisture content (θ) plumes. Thus, unlike stochastic methods which rely on the spatial statistics of small-scale hydraulic properties, this method derives directly the effective properties using observed responses, specifically, the spatial and temporal changes in θ within the vadose zone. Additional details are provided in "Estimation of Effective Unsaturated Hydraulic Conductivity Tensor Using Spatial Moments of Observed Moisture Plume" (Yeh et al., 2005), which are briefly outlined below:

- The method estimates the upscaled unsaturated hydraulic conductivity based on spatial moments of the initial moisture content measurements.
- Unsaturated hydraulic conductivity in the vertical direction (K_z) is first estimated using the first-order moment in the z direction.
- The lateral to vertical unsaturated hydraulic conductivity ratios (K_x/K_z and K_y/K_z) are estimated next using the second-order moments in the respective x and y directions.

Numerical results based on the upscaling method are compared with laboratory-measured unsaturated media properties at the site (WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*; "Evaluation of van Genuchten-Mualem Relationships to Estimate Unsaturated Conductivity at Low Water Contents" [Khaleel et al., 1995]); PNNL-14284, *Laboratory Measurements of the Unsaturated Hydraulic Properties at the Vadose Zone Transport Field Study Site*). Subsequently, using the derived effective hydraulic properties, the evolution of the three-dimensional moisture plume is simulated during to the injection experiment. The results are then compared with the observed moisture plume.

18.3.1.2 Cokriging/Artificial Neural Network Method

This methodology integrates data that can be easily obtained (e.g., initial moisture content, θ_i, bulk density, and soil texture) with data on soil hydraulic properties via cokriging and ANN-based pedotransfer functions. Details on the technique are presented in "Simulation of Field Injection Experiments in Heterogeneous Unsaturated Media using Cokriging and Artificial Neural Network" (Ye et al., 2007). Briefly, the cokriging/ANN method directly estimates the heterogeneous soil hydraulic properties in two steps:

1. Cokriging is first used to estimate heterogeneous fields of pedotransfer variables (the primary variables) using the database on initial moisture content (θ_i) as the secondary variable.
2. Heterogeneous soil hydraulic parameters are estimated next using ANN, which uses the heterogeneous pedotransfer variables as inputs.

Using the cokriging/ANN-based parameter estimates, the evolution of the three-dimensional moisture plume is simulated for the Sisson and Lu site. The results are then compared with the observed moisture plume.

18.3.1.3. Transition Probability/Markov Chain Method

By applying the TP-based MC model to sediment textural classes, the TP/MC method leverages use of "soft" data for characterizing the media heterogeneity and sediment layering structure. The TP/MC method is used for characterizing media heterogeneity by describing spatial variability of the geometry of soil textural classes. Details of the TP/MC method are presented in "A Markov Chain Model for Characterizing Medium Heterogeneity and Sediment Layering Structure" (Ye and Khaleel, 2008), which can be briefly summarized as follows:

- The TP/MC method characterizes the heterogeneity of soil classes, each of which is associated with a set of soil hydraulic parameters.
- The observed initial moisture contents are transferred into soil classes using a log score type of transform method.
- The transferred soil classes are used to estimate the Markov chain model and conditioning data for generating heterogeneous soil classes.

The TP/MC method is evaluated by simulating the moisture movement at the Sisson and Lu site, where the stratigraphy consists of imperfectly stratified layers.

18.3.2 Comparison of Observed and Simulated Moisture Plume

The spatial and temporal evolution of the observed moisture plume at the Sisson and Lu injection site was compared with simulated plumes based on the three methods: (1) upscaling, (2) cokriging/ANN, and (3) TP/MC. The comparison results are presented only for July 31, 2000 (Figure 18-6, panels [a] through [d]).

As is typically the case, soil hydraulic parameter measurements are sparse at the site; sixty measurements are from boreholes S-1, S-2, and S-3 (see Figure 18-5 for borehole locations) (PNNL-14284) and seventeen measurements are from boreholes A-7, E-1, and E-7 (WHC-EP-0883). An extensive data set exists, however, for initial water content, θ_i, which carry signature about site heterogeneity, particularly, the sediment layering structure. The θ_i observations are distributed uniformly over the site and are used as a surrogate for describing the site heterogeneity. All three methods use the observed initial moisture content as secondary information for characterizing heterogeneity of soil hydraulic parameters.

The effective hydraulic conductivities, based on the upscaling approach, compared well (not shown here) with the laboratory-measured conductivities for core samples (Yeh et al., 2005). Furthermore, spatial moments of the simulated plume based on the effective hydraulic conductivities were in good agreement with those for the observed plume. The upscaling method not only provided a new way to estimate effective K but also allowed the previously developed moisture-dependent anisotropy concept to be quantitatively evaluated (Yeh et al., 2005). The overall good agreement of conductivities derived from laboratory measurements and the good comparison

between the numerically simulated plume and the observed plume demonstrate that moisture-dependent anisotropy is a valid, reproducible phenomenon in the field. The macroscopic anisotropy does indeed vary with decreasing moisture content of the unsaturated medium. For the Sisson and Lu field site, the effective hydraulic properties of an equivalent homogeneous medium can yield a similar temporal evolution of spatial moment of the observed moisture plume. The simulated moisture plume, based on the effective hydraulic conductivities of an equivalent homogeneous medium, however, does not necessarily resemble the observed distribution (Figure 18-6[b]). Nonetheless, in spite of the inherent limitation of the effective property approach, the upscaling method is a useful, practical tool for estimating effective unsaturated hydraulic conductivities based on snapshots of moisture movement in a large-scale vadose zone.

For the cokriging/ANN method, the overall shape and local variation of the observed moisture plumes were simulated well (Figure 18-6[c]) when compared to the upscaling method. In particular, the effects of imperfectly stratified layering structure on moisture movement were captured well. At the Sisson and Lu site, the injected water spreads in the top layer of fine material at an elevation of ~9 meters; the vertical movement of the injected water is retarded by the bottom layer of fine material at an elevation of ~5 meters. Between these two layers of fine materials is a layer of coarse material where the plume splits. Such a separation of the plume beneath the top layer of fine material, as well as the observed eastward movement of the injected water above the bottom layer of fine material, was well represented in the simulation (Figure 18-6[c]). Unlike in cokriging/ANN, the upscaling method conceptualized the heterogeneous medium at the Sisson and Lu site as an equivalent homogeneous medium. Thus, the upscaling numerical simulations essentially captured the ensemble mean behavior and did not capture the highly variable, single realization behavior of the observed moisture plume and its splitting within the coarse-textured layer that is between two fine-textured layers. Nonetheless, while the cokriging/ANN method simulated the split in the moisture plume well, the simulated vertical movement was faster than the observed vertical movement (Ye et al., 2007).

Among the three methods, the TP/MC method provided a superior match of the observed plume behavior (Figure 18-6[d]). An evaluation of the root-mean-squared error and correlation coefficient suggested that the overall pattern of the moisture movement and the spatial variability of observed moisture content are captured better by the TP/MC method (Ye and Khaleel, 2008). The heterogeneous geometry of soil classes generated by the TP/MC method is the cornerstone of successful simulation of the injection experiments at the Sisson and Lu site. The θ_i measurements, when transitioned into soil classes, were indispensable for depicting the sediment layering structure prevalent at the site. Multiple conditional realizations of the soil classes were generated to represent uncertainty in characterizing geometry of the soil classes (Ye and Khaleel, 2008). A Monte Carlo simulation showed that the simulated mean moisture contents were in agreement with corresponding field observations, whose spatial variability was sufficiently captured by the 95% confidence intervals calculated from the Monte Carlo simulations. This was achieved by treating soil hydraulic parameters of each soil class deterministically and estimating them from core samples. The TP/MC method adequately simulated the observed flow patterns, including the splitting of the moisture plume in the coarse layer which is between the two fine layers, the southeastward movement of the plume, and the near-zero fluid flux below the bottom fine layer (Ye and Khaleel, 2008).

In summary, the upscaling method captured the overall movement pattern of the injected water in terms of the first and second moments of the observed plume at the Sisson and Lu site but was not able to simulate the detailed distribution of the moisture plume. The cokriging/ANN method simulated well the observed moisture plume, but the simulated vertical movement was faster than the observed vertical movement. The TP/MC method reproduced best the media heterogeneity and the contrast existing between the coarse and fine soil horizons at the Sisson and Lu site. The TP/MC method used the soft data in the most direct way and yielded a superior comparison of observed and simulated moisture movement. Spatial variability of the observed moisture contents was well simulated by considering uncertainty in the soil class geometry. This suggests that uncertainty in geometry of soil classes is more important than uncertainty of the soil hydraulic parameters. In other words, if soil types and their textural distribution are important aspects for an accurate simulation of unsaturated flow, additional focus should be placed on collecting such data.

Table 18-1. Carbon Tetrachloride Inventory Removed by Vapor Extraction from Primary Disposal Sites

Well Field	Mass Removed Using SVE, March 2010 to November 2010 (kg)	Mass Removed Using SVE, 1991 to November 2010 (kg)
216-Z-1A	93*	24,938*
216-Z-18		
216-Z-9	101	54,812
Totals	**194***	**79,751***

* Total due to rounding.

Figure 18-1. Locations of Carbon Tetrachloride Soil Vapor Extraction Wells at 216-Z-1A/216-Z-12/216-Z-18 and 216-Z-9 Well Fields

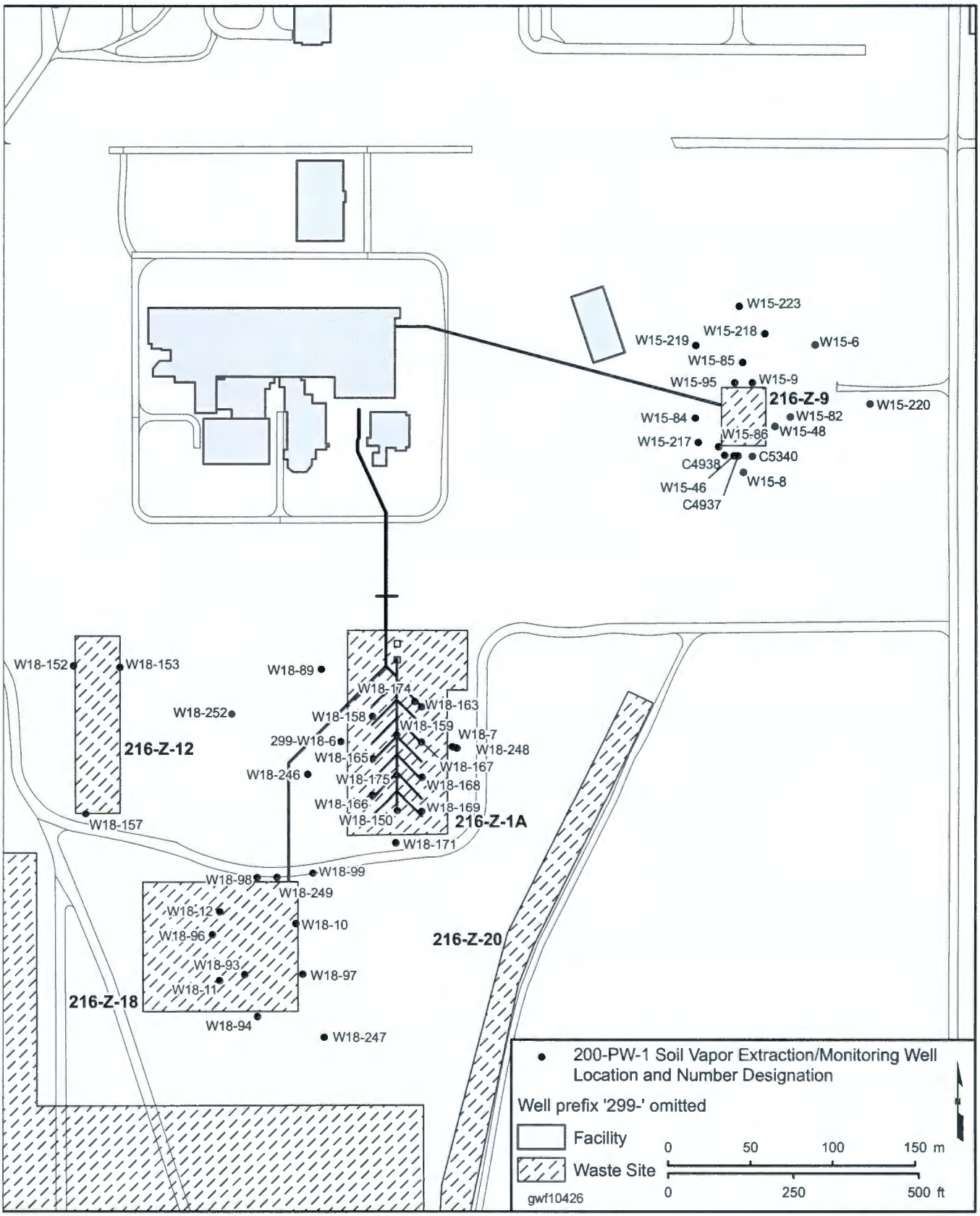


Figure 18-2. Results of Three-Dimensional Resistivity Survey of UPR-200-E-86

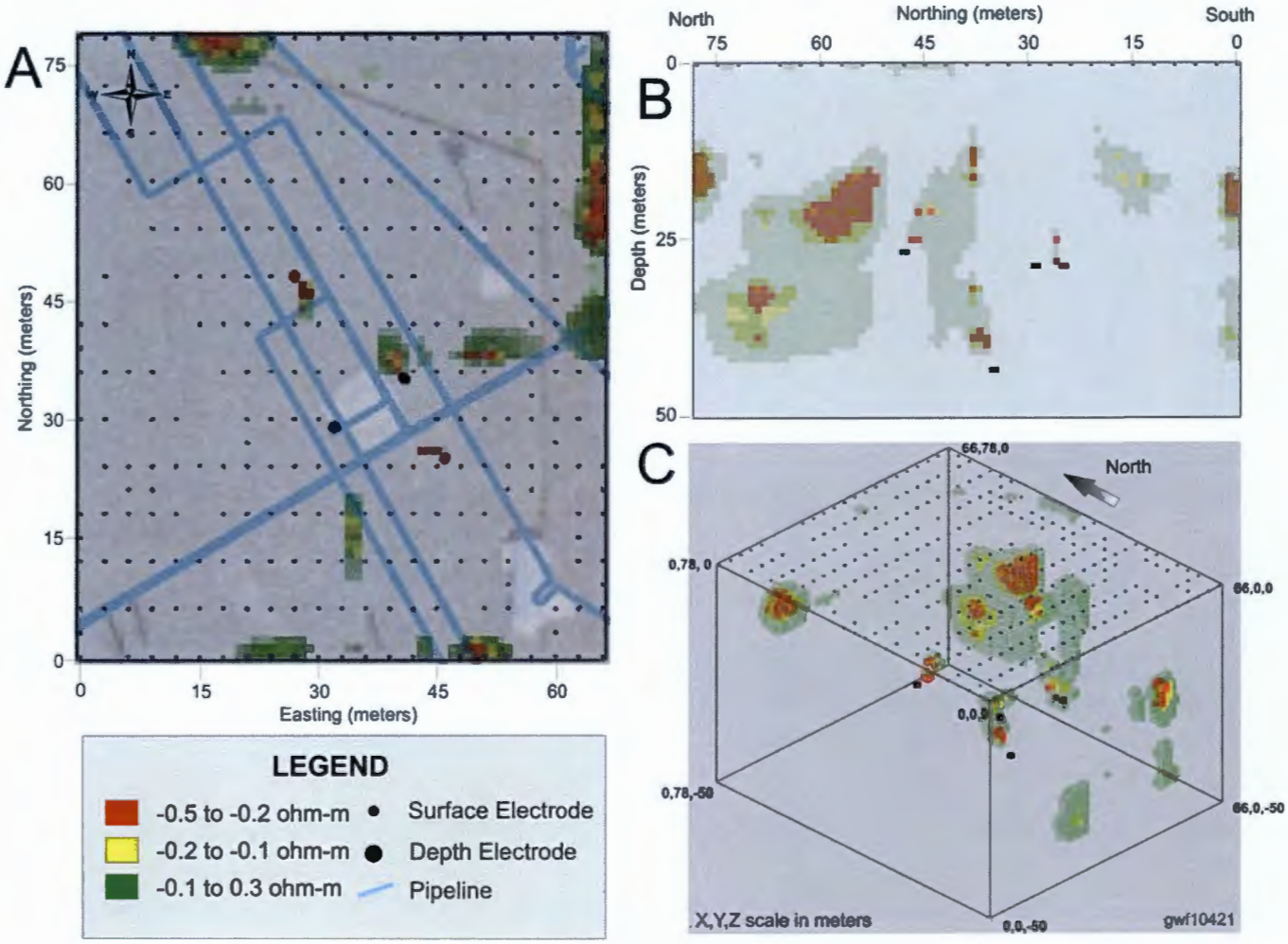
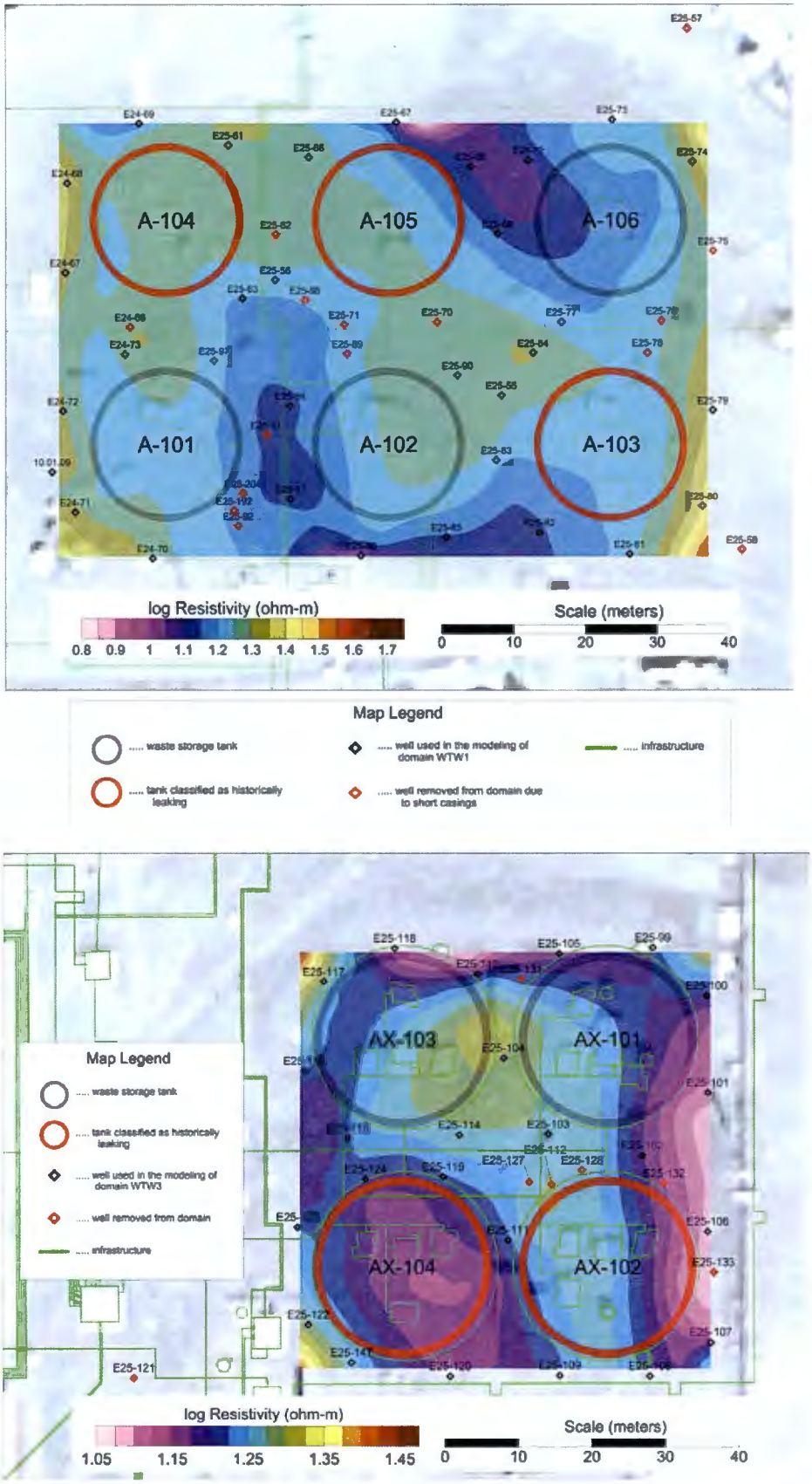


Figure 18-3. Results of Well-to-Well Resistivity Survey of Waste Management Area A-AX



gwf10422

Figure 18-4. Aerial Photograph of Interim Surface Barrier and Evapotranspiration Basin, TY Tank Farm

Figure 18-5. Plan View of the Sisson and Lu Injection Site and the Well Numbering Scheme

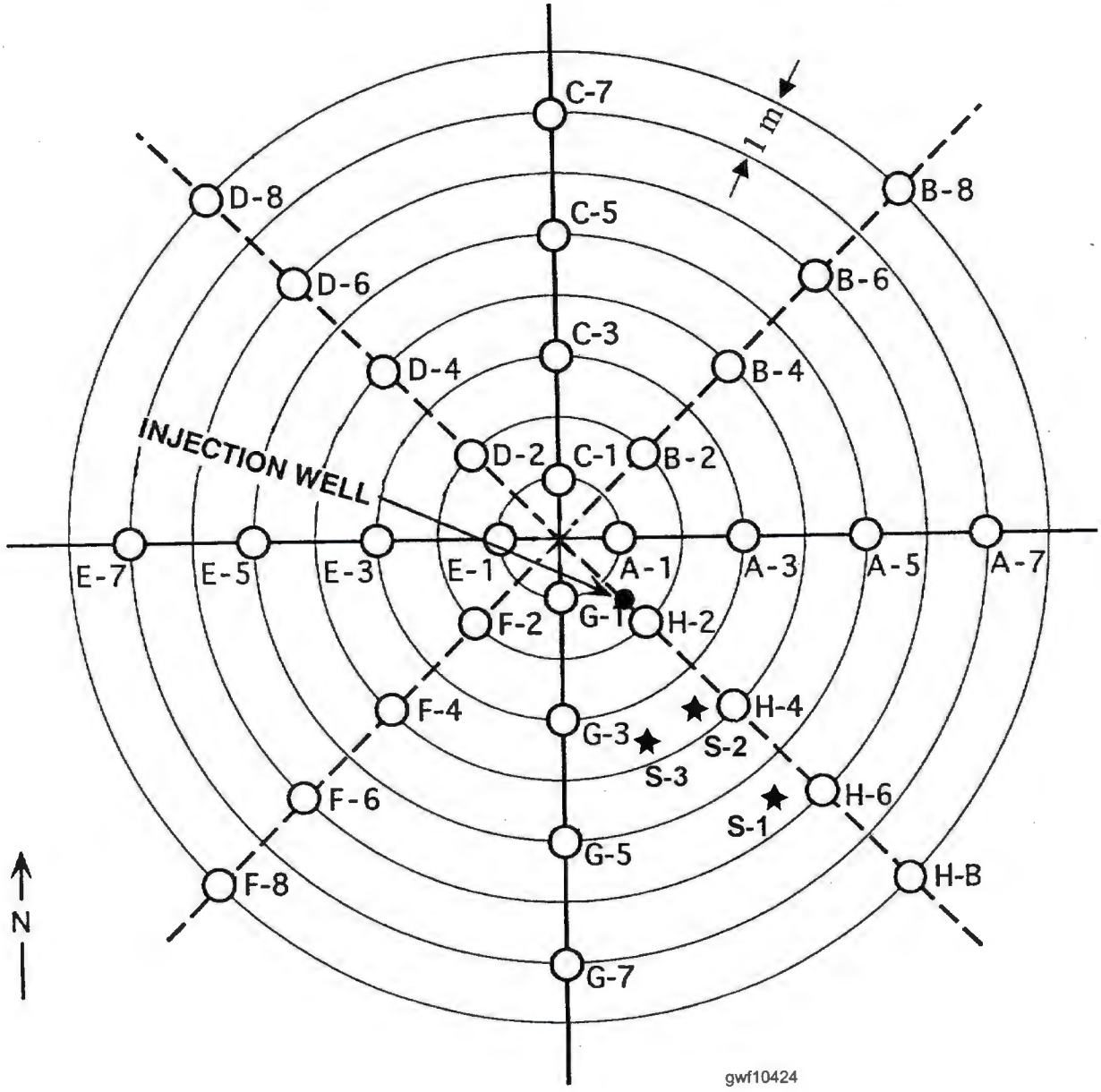
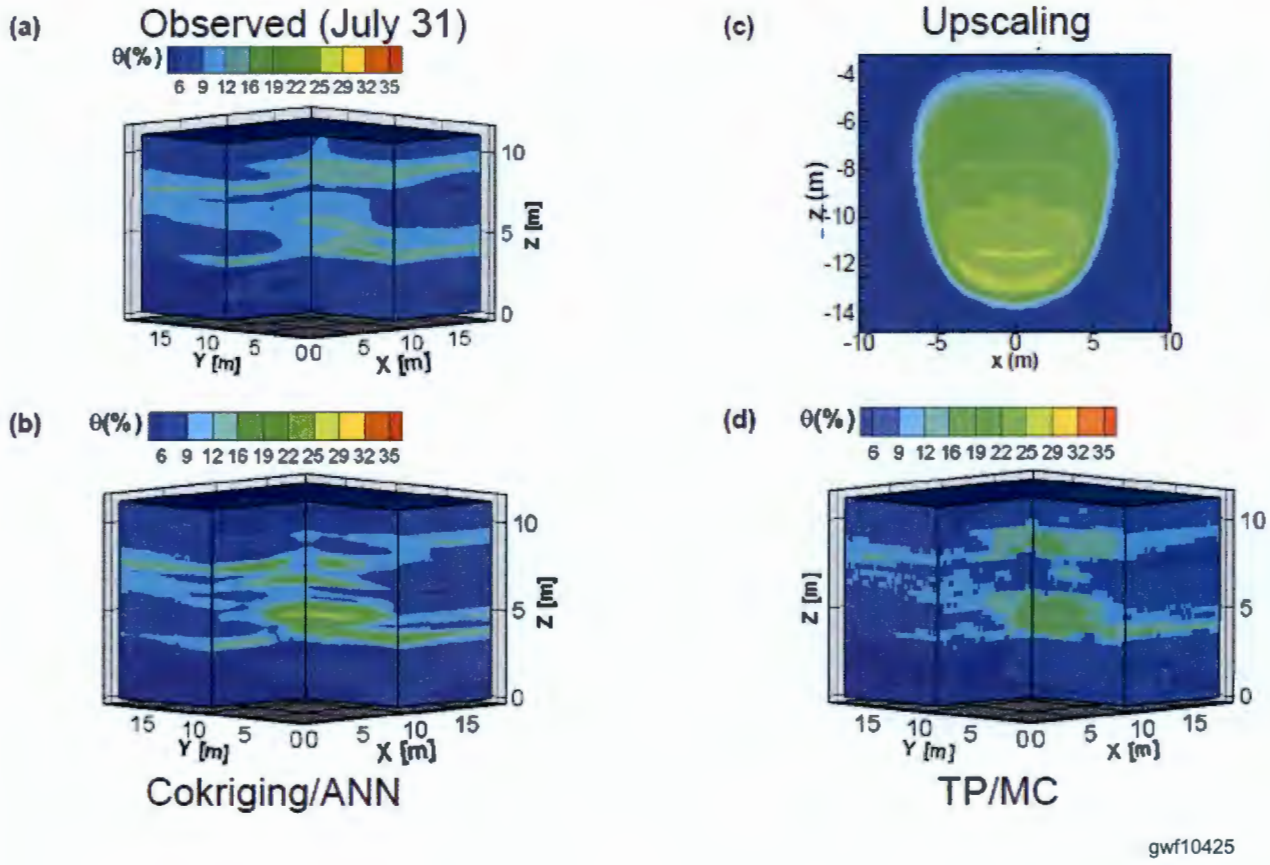


Figure 18-6. (a) Observed Moisture Plume at the Sisson and Lu Injection Site on July 31, 2000; (b) Upscaling Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000; (c) Cokriging/Artificial Neural Network (ANN) Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000; and (d) Transition Probability (TP)/Markov Chain (MC) Method Based Simulated Moisture Plume at the Sisson and Lu Field Injection Site on July 31, 2000



19.0 References

Public Laws

American Recovery and Reinvestment Act of 2009, Public Law 1115, et seq.

Atomic Energy Act of 1954, 42 U.S.C. 2011, et seq.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

Freedom of Information Act of 1966, Public Law 89-554, 80 Stat. 383, et seq.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq.

Code of Federal Regulations

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*.

40 CFR 143, "National Secondary Drinking Water Regulations," *Code of Federal Regulations*.

40 CFR 261, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*.

40 CFR 264, Appendix IX, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring List," *Code of Federal Regulations*.

40 CFR 264, Subpart F, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Releases from Solid Waste Management Units," *Code of Federal Regulations*.

40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*.

40 CFR 265.91, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring System," *Code of Federal Regulations*.

40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis," *Code of Federal Regulations*.

40 CFR 265.93, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response," *Code of Federal Regulations*.

40 CFR 265, Subpart F, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring," *Code of Federal Regulations*.

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*.

Washington Administrative Code

WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," *Washington Administrative Code*.

WAC 173-160-111, "Minimum Standards for Construction and Maintenance of Wells," "What are the definitions of specific words as used in this chapter?," *Washington Administrative Code*.

WAC 173-160-410, "Minimum Standards for Construction and Maintenance of Wells," "What are the specific definitions for words in this chapter?," *Washington Administrative Code*.

WAC 173-160-460, "Minimum Standards for Construction and Maintenance of Wells," "What is the decommissioning process for resource protection wells?," *Washington Administrative Code*.

WAC 173-200-040, "Water Quality Standards for Ground Waters of the State of Washington," "Criteria," *Washington Administrative Code.*

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," *Washington Administrative Code.*

WAC 173-216, "State Waste Discharge Permit Program," *Washington Administrative Code.*

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code.*

WAC 173-303-040, "Dangerous Waste Regulations," "Definitions," *Washington Administrative Code.*

WAC 173-303-080, "Dangerous Waste Regulations," "Dangerous Waste Lists," *Washington Administrative Code.*

WAC 173-303-100, "Dangerous Waste Regulations," "Dangerous Waste Criteria," *Washington Administrative Code.*

WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards," *Washington Administrative Code.*

WAC 173-303-645, "Dangerous Waste Regulations; Releases from Regulated Units," *Washington Administrative Code.*

WAC 173-304, "Minimum Functional Standards for Solid Waste Handling," *Washington Administrative Code.*

WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code.*

WAC 173-340-720, "Model Toxics Control Act – Cleanup," "Ground Water Cleanup Standards," *Washington Administrative Code.*

WAC 173-350, "Solid Waste Handling Standards," *Washington Administrative Code.*

WAC 173-350-500, "Solid Waste Handling Standards," "Ground Water Monitoring," *Washington Administrative Code.*

WAC 173-350, "Solid Waste Handling Standards," "Permit Application and Issuance," *Washington Administrative Code.*

WAC 246-290, "Group A Public Water Supplies," *Washington Administrative Code.*

WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)," *Washington Administrative Code.*

Revised Code of Washington

RCW 70.105, "Hazardous Waste Management," *Revised Code of Washington.*

Other References

00-GWVZ-054, 2000, *Results of Assessment at the 1325-N Facility*, letter to J. Hedges (Washington State Department of Ecology), from K. M. Thompson, U.S. Department of Energy, Richland Operations Office, Richland, Washington, dated July 11, 2000.

Ababou, R., 1996, "Random Porous Media Flow on Large 3-D Grids: Numerics, Performance, and Application to Homogenization," M. F. Wheeler (ed.), in *Environmental Studies-Mathematical, Computational, and Statistical Analysis*, Springer-Verlag, New York.

Bair, E. S. and T. D. Lahm, 1996, "Variations in Capture-Zone Geometry of a Partially Penetrating Pumping Well in an Unconfined Aquifer," *Ground Water*, 34(5):842-852.

Baker, V. R., B. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moddy, J. G. Rigby, O. F. Stradling, and A. M. Tallman, 1991, "Quaternary Geology of the Columbia Plateau," *Quaternary Nonglacial Geology; Conterminous United States: The Geology of North America*, Vol. K-2, R. B. Morrison (ed.), Geological Society of America, Boulder, Colorado.

Bauer, H. H., J. J. Vaccaro, and R. C. Lane, 1985, *Maps Showing Ground-Water Levels in the Columbia River Basalt and Overlying Materials, Spring 1983, Southeastern Washington*, Water Resources Investigation Report 84-4360, U.S. Geological Survey, Tacoma, Washington.

BHI-00012, 1994, *300-FF-2 Operable Unit Technical Baseline Report*, Rev. 00, D. H. DeFord, R. W. Carpenter, and M. W. Einan, Bechtel Hanford, Inc., Richland, Washington.

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

BHI-00368, 1996, *Data Quality Objectives Workshop Results for 1301-N and 1325-N Characterization*, Rev. 0, Bechtel Hanford Inc., Richland, Washington.

BHI-00720, 2002, *Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2001*, Rev. 6, V. J. Rohay, Bechtel Hanford, Inc., Richland, Washington.

BHI-00725, 1996, *100-N Pilot Project: Proposed Consolidated Groundwater Monitoring Program*, Rev. 0, J. V. Borghese, M. J. Hartman, S. P. Luttrell, C. J. Perkins, J. P. Zoric, and S. C. Tindall, Bechtel Hanford, Inc., Richland, Washington.

BHI-00917, 1996, *Conceptual Site Models for Groundwater Contamination at the 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units*, Rev. 0, R. E. Peterson, R. F. Raidl, and C. W. Denslow, Bechtel Hanford, Inc., Richland, Washington.

BHI-01103, 1999, *Clastic Injection Dikes of the Pasco Basin and Vicinity: Geologic Atlas Series*, Rev. 0, K. R. Fecht, B. N. Bjornstad, D. G. Horton, G. V. Last, S. P. Reidel, and K. A. Lindsey, Bechtel Hanford, Inc., Richland, Washington.

BHI-01105, 1997, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*, Rev. 0, V. J. Rohay, Bechtel Hanford, Inc., Richland, Washington.

BHI-01177, 1998, *Borehole Summary Report for the 216-B-2-2 Ditch*, Rev. 0, V. J. Rohay and D. C. Weekes, Bechtel Hanford, Inc., Richland, Washington.

Bjornstad, B. N., 1985, "Late-Cenozoic Stratigraphy and Tectonic Evolution Within a Subsiding Basin, South-Central Washington," *Geological Society of America Abstracts with Programs*, 17(7):524.

Bjornstad, B. N., and K. R. Fecht, 1989, "Pre-Wisconsin Glacial Outburst Floods: Pedogenic and Paleomagnetic Evidence from the Pasco Basin and Adjacent Channeled Scabland," *Geological Society of America Abstracts with Programs*, 21(5):58.

BNWL-B-360, 1974, *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation*, 1944-1973, K. L. Kipp and R. D. Mudd, Pacific Northwest Laboratory, Richland, Washington.

Brochu, Y., and D. Marcotte, 2003, "A Simple Approach to Account for Radial Flow and Boundary Conditions When Kriging Hydraulic Head Fields for Confined Aquifers," *Mathematical Geology*, 35(2):111-139.

Chiles, J., and P. Delfiner, 1999, *Geostatistics: Modeling Spatial Uncertainty*, John Wiley & Sons, New York.

City of Richland, 2010, *Horn Rapids Landfill Environmental Monitoring Report Calendar Year 2009*, dated March 2010, prepared by Paramatrix (Bellevue, Washington), City of Richland, Richland, Washington.

Deng, H., M. Ye, M. G. Schaap, and R. Khaleel, 2009, "Quantification of Uncertainty in Pedotransfer Function-Based Parameter Estimation for Unsaturated Flow Modeling," *Water Resources Research*, 45:W04409, doi:10.1029/2008WR007477.

DOE O 450.1A, *Environmental Protection Program*, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, U.S. Department of Energy, Washington, D.C.

DOE/RL-89-14, 1990, *Remedial Investigation/Feasibility Study Work Plan for 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-89-28, 1993, *216-B-3 Expansion Ponds Closure Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-90-18, 1990, *Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-90-21, 1992, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-91-50, 2008, *Environmental Monitoring Plan*, Rev. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-91-60, 1992, *S Plant Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-92-05, 1993, *B Plant Source Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-92-32, 1992, *Expedited Response Action Assessment for 316-5 Process Trenches*, Vols. 1 and 2, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-92-67, 1993, *Draft Remedial Investigation/Feasibility Study for the 1100-EM-1 Operable Unit, Hanford*, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-92-76, 2004, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*, Rev. 1 Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-21, 1994, *Phase I Remedial Investigation Report for the 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-22, 1993, *Phase I and II Feasibility Study Report for the 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-73, 1995, *300 Area Process Trenches Modified Closure Postclosure Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-88, 1994, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-94-48, 1995, *100-KR-4 Operable Unit Focused Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-94-85, 1995, *Remedial Investigation/Feasibility Study Report for the 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland, Washington.

DOE/RL-95-59, 1996, *200-BP-5 Operable Unit Treatability Test Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-95-73, 1996, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-95-73, 2002, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-95-99, 1996, *100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-95-111, 1997, *Corrective Measures Study for 100-NR-1 and 100-NR-2 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-07, 2008, *200-ZP-1 Interim Remedial Measure Remedial Design Report*, Rev. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-39, 1998, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-61, 1997, *Hanford Site Background: Part 3, Groundwater Background*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-84, 1996, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-84, 2003, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, Rev. 0-A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-90, 1997, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-105, 1997, *Richland Environmental Restoration Project Baseline*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-97-36, 2010, *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-99-51, 2000, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-99-59, 2000, *Proposed Plan for the 100 Area Burial Grounds Interim Remedial Action*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2000-35, 2001, *200-CW-1 Operable Unit Remedial Investigation Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2000-59, 2000, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2000-60, 2004, *Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan Includes: 200-PW-2 and 200-PW-4 Operable Units*, Rev. 1, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2000-72, 2006, *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2001-21, 2011, *Remedial Design Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Rev. 1, Draft A, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

DOE/RL-2001-27, 2002, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2001-49, 2004, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-10, 2002, *Sampling and Analysis Plan for the 200-UP-1 Groundwater Monitoring Well Network*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-11, 2008, *300-FF-5 Operable Unit Sampling and Analysis Plan*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-17, 2002, *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-39, 2002, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments Within the Central Pasco Basin*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-68, 2003, *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-04, 2005, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-12, *Hanford Facility Dangerous Waste Permit Application Integrated Disposal Facility*, 4 vols., U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-38, 2004, *100-BC-5 Operable Unit Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-49, 2003, *100-FR-3 Operable Unit Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-49, 2004, *100-FR-3 Operable Unit Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-55, 2004, *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2004-37, 2005, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment (RCBRA)*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2004-56, 2004, *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2004-74, 2005, *300-FF-1 Operable Unit Remedial Action Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-40, 2005, *100-B/C Pilot Project Risk Assessment Report*, Vol. 1, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-41, 2005, *Work Plan for Phase III Feasibility Study 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-42, 2006, *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-70, 2008, *Hanford Site Well Decommissioning Plan*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-96, 2006, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-17, 2006, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-20, 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-24, 2006, *Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-52, 2006, *The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-52, 2009, *The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-58, 2006, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Interim Characterization Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-75, 2008, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System*, Rev. 1, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-76, 2007, *Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-18, 2008, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-20, 2007, *Hanford Integrated Groundwater and Vadose Zone Management Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-21, 2008, *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment*, Draft B, U.S. Department of Energy, Richland Operations, Richland, Washington.

DOE/RL-2007-21, 2011, *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment*, Draft C, pending issuance, U.S. Department of Energy, Richland Operations, Richland, Washington.

DOE/RL-2007-22, 2007, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report Addendum*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-23, 2007, *Technetium-99 Pump-and-Treat System to Support the 200-ZP-1 CERCLA Remedial Investigation/Feasibility Study Process*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-28, 2008, *Feasibility Study Report for 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-31, 2008, *Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-33, 2008, *Proposed Plan for Remediation of 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-01, 2008, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-11, 2008, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-36, 2008, *Remediation Strategy for Uranium in Groundwater at the Hanford Site 300 Area 300-FF-5 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-42, 2009, *Hydrogeological Summary Report for the 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46-ADD1, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46-ADD2, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46-ADD3, 2010, *Integrated 100 Area Remedial Investigation Study/Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46-ADD4, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-46-ADD5, 2010, *Integrated 100 Area Remedial Investigation Study/Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-56, 2010, *200-West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses, Proposed Plan for Remediation of the 200-ZP-1 Groundwater Operable Unit*, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-57, 2008, *Sampling and Analysis Plan for the First Set of Remedial Action Wells in the 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-58, 2010, *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-59, 2010, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-60, 2010, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-61, 2010, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-66, 2009, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-77, 2009, *200-UP-1 and 200-ZP-1 Operable Units Pump-and-Treat System Annual Report for Fiscal Year 2008*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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.

DOE/RL-2009-01, 2009, *Fiscal Year 2008 Annual Summary Report for the In Situ Redox Manipulation Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington

DOE/RL-2009-09, 2009, *Sampling and Analysis Plan for Installation of 100-HR-3 Groundwater Operable Unit Remedial Process Optimization Wells*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-15, 2009, *Calendar Year 2008 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-16, 2009, *300-FF-5 Groundwater Operable Unit Infiltration Test Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-30, 2010, *300 Area Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-32, 2009, *100-NR-2 Groundwater Operable Unit Sr-90 Plume Rivershore Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-35, 2009, *Treatability Test Report on Mending the In Situ Redox Manipulation Barrier Using Nano-Size Zero Valent Iron*, Rev. 0, Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-38, 2009, *Description of Modeling Analysis in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-40, 2010, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-41, 2009, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-42, 2009, *Sampling and Analysis Plan for the 100N Decision Unit Remedial Investigation Feasibility Study*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-43, 2010, *Sampling and Analysis Plan for the 100-F/IU-2/IU-6 Decision Unit Remedial Investigation/ Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-44, 2010, *Sampling and Analysis Plan for the 100-BC Decision Unit Remedial Investigation/ Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-54, 2009, *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-57, 2010, *100-HR-3 Integrated Groundwater Sampling and Analysis Plan*, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-58, 2010, *100-N Area Integrated Groundwater Sampling and Analysis Plan*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-61, 2009, *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-66, 2011, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-67, 2011, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-68, 2011, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-69, 2010, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-70, 2010, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-73, 2011, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-74, 2011, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-75, 2010, *Interim Status Groundwater Monitoring Plan for LLBG WMA-1*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-76, 2010, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-77, 2010, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-85, 2010, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-92, 2010, *Report on Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*, Rev. 1, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-115, 2010, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-122, 2010, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-124, 2010, *200 West Area Pump-and-Treat Facility Operations and Maintenance Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-127, 2011, *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit*, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-05, 2010, *Proposed Plan to Amend the 200-ZP-1 Groundwater Operable Unit Record of Decision to Include the Remedial Actions for the 200-UP-1 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-11, 2010, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-13, 2010, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-28, 2010, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-29, 2010, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-40, 2010, *Report on Investigation of Hexavalent Chromium Source in the Northern 100-D Area*, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-68, 2010, *Jet Injection Design Optimization Study for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-69, 2010, *Sampling and Analysis Plan for the 100-NR-2 Operable Unit River Pore Water Investigation*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-72, 2010, *Sampling and Analysis Plan for Eight Remediation Wells in the 200-ZP-1 Operable Unit in Fiscal Year 2011*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-74, 2010, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-78, 2010, *200 West Area Groundwater Pump-and-Treat Facility Extraction and Injection Well Maintenance Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-92, 2010, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-93, 2010, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2011-25, 2011, *Calendar Year 2010 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2011-26, 2011, *Calendar Year 2010 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RW-0164, 1988, *Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*, Vols. 1 and 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DUN-7238, 1970, *Liquid Waste Disposal Review 100-K Plant*, G. W. Wells, Douglas United Nuclear, Inc., Richland, Washington.

E06-09-003, 2011, *EHS&L 2010 Annual Groundwater Report*, AREVA, Richland, Washington.

Ecology, 2000a, *State Waste Discharge Permit ST 4500*, Washington State Department of Ecology, Kennewick, Washington.

Ecology, 2000b, *State Waste Discharge Permit ST 4502*, Washington State Department of Ecology, Kennewick, Washington.

Ecology Publication 94-06, 2007, *Model Toxics Control Act Cleanup Regulation 173-340 WAC*, as revised, Washington State Department of Ecology, Olympia, Washington.

Ecology Publication 97-407, 2009, *Chemical Testing Methods for Designating Dangerous Waste: WAC 173-303-090 & -100*, Appendix 5, "Appendix IX of 40 CFR 264," Washington State Department of Ecology, Olympia, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EMO-1026, 1991, *Addendum to Data Compilation Task Report for the Source Investigation of the 300-FF-1 Operable Unit Phase I Remedial Investigations*, J. S. Young and J. S. Fruchter, Pacific Northwest Laboratory, Environmental Management Operations, Richland, Washington.

EPA/402/R-99-001, 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13, U.S. Environmental Protection Agency, Washington, D.C.

EPA 402-R-99-004B, 1999, "Understanding Variation In Partition Coefficient, Kd, Values," in *Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium*, U.S. Environmental Protection Agency, Washington, D.C.

EPA 822/R-96/001, 1996, *Drinking Water Regulations and Health Advisories*, Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 2001, *USDOE Hanford Site First Five-Year Review Report*, dated April 2001, U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

EPA, Ecology, and DOE, 2008, *Declaration of the Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA, Ecology, and DOE, 2009a, *Explanation of Significant Differences for the Interim Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA, Ecology, and DOE, 2009b, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/541/R-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/600/R-08/003, 2008, *A Systematic Approach for Evaluation of Capture Zones at Pump-and-Treat Systems, Final Project Report*, U.S. Environmental Protection Agency, Washington, D.C.

EPA/AMD/R10-00/122, 2000, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington, D.C.

EPA/ESD/R10-00/524, 2000, *EPA Superfund Explanation of Significant Differences: Hanford 300-Area (USDOE)*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-93/063, 1993, *Declaration of the Record of Decision for the 1100 Area*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-95/110, 1995, *Record of Decision: U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-95/114, 1995, *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-96/134, 1996, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-96/143, 1996, *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-97/048, 1997, *Declaration of the Record of Decision for the 200-UP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-99/039, 1999, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-99/112, 1999, *Interim Action Record of Decision for the U.S. Department of Energy Hanford 100-NR-1 and 100-NR-2 Operable Units Interim Remedial Actions*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

Fecht, K. R., S. P. Reidel, and A. M. Tallman, 1987, "Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State – A Summary," *Washington Division of Geology and Earth Resources Bulletin 77*, Basalt Waste Isolation Project, Westinghouse Hanford Company, Richland, Washington.

Hammond, G. E, and P. C. Lichtner, 2010, "Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area Using High Performance Computing," *Water Resources Research*, doi:10.1029/2009WR008819.

Hammond, G. E., P. C. Lichtner, and M. L. Rockhold, 2010, "Stochastic Simulation of Uranium Migration at the Hanford 300 Area," *Journal of Contaminant Hydrology*, doi:10.1016/j.jconhyd.2010.04.005.

HNF-4936, 1999, *Subsurface Conditions Description Report for the S-SX Waste Management Area*, Rev. 0, M. I. Wood, V. G. Johnson, S. P. Reidel, and T. E. Jones, Lockheed Martin Hanford Company, Richland, Washington.
HW-10475, 1944, Hanford Technical Manual, General Electric Company, Hanford Atomic Products Operation, Richland, Washington.

Holten, R. A., 2010, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington, July 2010, Memo to File Regarding: Supplemental Actions for the In-Situ Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy," CCN 0092078, letter to J. A. Hedges (Washington State Department of Ecology) and D. A. Faulk (U.S. Environmental Protection Agency), U.S. Department of Energy, Richland Operations Office, Richland, Washington, October 26.

HW-17088, 1950, *Underground Disposal of Liquid Wastes at the Hanford Works*, R. E. Brown and H. G. Ruppert, General Electric Company, Hanford Atomic Products Operation, Richland, Washington.

HW-23043,1951, *Flow Sheets and Flow Diagrams of Precipitation Separations Process*, General Electric Company, Hanford Atomic Products Operation, Richland, Washington.

HW-48916, 1957, *Hydraulic Characteristics of Hanford Aquifers*, AEC R&D Report, W. H. Bierschenk, General Electric Company, Richland, Washington.

HW-61780, 1959, *Subsurface Geology of the Hanford Separations Areas*, D. J. Brown, General Electric Company, Hanford Atomic Products Operation, Richland, Washington.

INEEL/EXT-04-01793, 2004, *Multiphase Carbon-14 Transport in a Near-Field-Scale Unsaturated Column of Natural Sediments, Idaho National Engineering and Environmental Laboratory*, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Karanovic, M., M. Tonkin, and D. Wilson, 2009, "KT3D_H2O: A Program for Kriging Water Level Data Using Hydrologic Drift Terms," *Ground Water*, 45(4):580-586.

Khaleel, R., J. F. Relyea, and J. L. Conca, 1995, "Evaluation of van Genuchten-Mualem Relationships to Estimate Unsaturated Conductivity at Low Water Contents," *Water Resources Research*, 31(11):2659-2668.

Koch, M., and Zhang, G., 2005, "Numerical Simulation of the Effects of Variable Density in a Contaminant Plume," *Ground Water*, 30(5):731-742.

Koltermann, C. E., and S. M. Gorelick, 1996, "Heterogeneity in Sedimentary Deposits, a Review of Structure-Imitating, Process-Imitating, and Descriptive Approaches," *Water Resources Research*, 32(9):2617-2658.

Lindsey, K. A., S. P. Reidel, K. R. Fecht, J. L. Slate, A. G. Law, and A. M. Tallman, 1994, "Geohydrologic Setting of the Hanford Site, South-Central Washington," *Geologic Field Trips of the Pacific Northwest*, pp. K-1 to K-16, 1994 Geological Society of America Annual Meeting, Department of Geological Sciences, University of Washington, Seattle, Washington.

McKinley, J. P., J. M. Zachara, J. Wan, D. E. McCready, and S. M. Heald, 2007, "Geochemical Controls on Contaminant Uranium in Vadose Hanford Formation Sediments at the 200 Area and 300 Area, Hanford Site, Washington," *Vadose Zone Journal*; 6(4):1004-1017; DOI:10.2136/vzj2006.0184.

Mualem, Y., 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research*, 12:513-522.

NBS, 1959, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," as amended 1963, in *National Bureau of Standards Handbook 69*, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C.

PNL-5428, 1985, *Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography*, G. W. Gee and P. R. Heller, Pacific Northwest Laboratory, Richland, Washington.

PNL-5506, 1986, *Hanford Site Water-Table Changes, 1950 Through 1980 - Data Observations and Evaluation*, D. A. Zimmerman, A. E. Reisenauer, G. D. Black, and M. A. Young, Pacific Northwest Laboratory, Richland, Washington.

PNL-6313, 1987, *An Evaluation of Aquifer Intercommunication Between the Unconfined and Rattlesnake Ridge Aquifers on the Hanford Site*, E. J. Jensen, Pacific Northwest Laboratory, Richland, Washington.

PNL-6820, 1989, *Hydrogeology of the 200 Areas Low-Level Burial Grounds – An Interim Report*, Vol. 2, G. V. Last, B. N. Bjornstad, M. P. Bergeron, D. W. Wallace, D. R. Newcomer, J. A. Schramke, M. A. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilbur, Pacific Northwest Laboratory, Richland, Washington.

PNL-7147, 1989, *Final Report: Soil Gas Survey at the Solid Waste Landfill*, J. C. Evans, R. M. Freeland, D. W. Glover, and C. Veverka, Pacific Northwest Laboratory, Richland, Washington.

PNL-7498, 1990, *Evaluation of Hanford Site Water-Table Changes – 1980 to 1990*, D. R. Newcomer, Pacific Northwest Laboratory, Richland, Washington.

PNL-8869, 1993, *Preliminary Potentiometric Map and Flow Dynamic Characteristics for the Upper-Basalt Confined Aquifer System*, F. A. Spane and R. G. Raymond, Pacific Northwest Laboratory, Richland, Washington.

PNL-8971, 1993, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 93 Status Report*, P. D. Thorne, M. A. Chamness, F. A. Spane, V. R. Vermeul, and W. D. Webber, Pacific Northwest Laboratory, Richland, Washington.

PNL-10698, 1995, *Hanford Site Ground-Water Monitoring for 1994*, P. E. Dresel, P. D. Thorne, S. P. Lutrrell, B. M. Gillespie, and W. D. Webber (eds.), Pacific Northwest Laboratory, Richland, Washington.

PNL-10817, 1995, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System*, F. A. Spane and W. D. Webber, Pacific Northwest Laboratory, Richland, Washington.

PNL-10886, 1995, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*, S. K. Wurstner, P. D. Thorne, M. A. Chamness, M. D. Freshley, and M. D. Williams, Pacific Northwest Laboratory, Richland, Washington.

PNNL-11141, 1996, *Hanford Site Ground-Water Monitoring for 1995*, P. E. Dresel, J. T. Rieger, W. D. Webber, P. D. Thorne, B. M. Gillespie, S. P. Luttrell, S. K. Wurstner, and T. L. Liikala (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11523, 2007, *Interim-Status RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs*, Rev. 1, J. W. Lindberg and R. P. Elmore, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11573, 1997, *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11620, 1997, *Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan*, M. D. Sweeney, C. J. Chou, and B. N. Bjornstad, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11800, 1998, *Composite Analysis of Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, C. T. Kincaid, M. P. Bergeron, C. R. Cole, M. D. Freshley, and N. L. Hassig, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11809, 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site*, F. N. Hodges, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11810, 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX- at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11826, 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site*, S. M. Narbutovskih, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12086, 1999, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*, M. J. Hartman (ed.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12114, 2006, *RCRA Assessment Plan for Single-Shell Task Waste Management Area S-SX at the Hanford Site*, Interim Change Notice 4, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12220, 1999, *Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit*, D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12227, 1999, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, J. W. Lindberg and M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12261, 2000, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity*, Hanford Site, Washington, B. A. Williams, B. N. Bjornstad, R. Schalla, and W. D. Webber, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13014, 2000, *Groundwater Monitoring Plan for the Solid Waste Landfill*, J. W. Lindberg and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13022, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site*, Rev. 1, S. M. Narbutovskih, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13024, 2001, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13032, 2000, *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility*, D. B. Barnett, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13047, 1999, *Groundwater Monitoring Plan for the 216-A-29 Ditch, M. D. Sweeney*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13080, 2000, *Hanford Site Groundwater: Settings, Sources, and Methods*, M. J. Hartman (ed.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13116, 2000, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*, M. J. Hartman, L. F. Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13121, 2000, *Groundwater Monitoring and Tritium Tracking Plan for the 200 Area State- Approved Land Disposal Site*, D. B. Barnett, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13185, 2000, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*, F. N. Hodges and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13228, 2000, *Evaluation of Elevated Tritium Levels in Groundwater Downgradient from the 618-11 Burial Ground Phase I Investigations*, P. E. Dresel, B. A. Williams, J. C. Evans, R. M. Smith, and C. J. Thompson, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13282, 2000, *Groundwater Quality Assessment for Waste Management Area U: First Determination*, F. N. Hodges and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13378, 2001, *Results of Detailed Hydrologic Characterization Tests: Fiscal Year 1999*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13441, 2001, *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX (November 1997 through April 2000)*, V. G. Johnson and C. J. Chou, Pacific Northwest Laboratory, Richland, Washington.

PNNL-13447, 2001, *Transient Inverse Calibration of Hanford Site-Wide Groundwater Model to Hanford Operational Impacts – 1943 to 1996*, C. R. Cole, M. P. Bergeron, S. K. Wurstner, P. D. Thorne, and S. Orr, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13514, 2001, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13612, 2006, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U, Interim Change Notice 2*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13631, 2001, *Sampling of Boreholes WL-3A through -12 in Support of the Vadose Zone Transport Field Study*, G. V. Last, T. G. Caldwell, and A. T. Owen, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13645, 2001, *300 Area Process Trenches Groundwater Monitoring Plan*, J. W. Lindberg and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13674, 2001, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River, Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project*, R. E. Peterson and M.P. Connelly, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13675, 2001, *Measurement of Helium-3/Helium-4 Ratios in Soil Gas at the 618-11 Burial Ground*, K. B. Olsen, P. E. Dresel, and J. C. Evans, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13679, 2001, *Vadose Zone Transport Field Study: Status Report*, G. W. Gee and A. L. Ward, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13788, 2002, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*, M. J. Hartman, L. F. Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13795, 2000, *Vadose Zone Transport Field Study: Soil Water Content Distributions by Neutron Moderation*, A. L. Ward, T. G. Caldwell, and G. W. Gee, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13858, 2002, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity*, Hanford Site, Washington, B. A. Williams, B. N. Bjornstad, R. Schalla, and W. D. Webber, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13914, 2002, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13962, 2002, *Natural Gas Storage in Basalt Aquifers of the Columbia Basin, Pacific Northwest USA: A Guide to Site Characterization*, S. P. Reidel, V. G. Johnson, and F. A. Spane, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14004, 2002, *RCRA Groundwater Quality Assessment Report for Single-Shell Tank Waste Management Area TX-TY (January 1998 through December 2001)*, D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14022, 2002, *300 Area Uranium Leach and Adsorption Project*, R. J. Serne, C. F. Brown, H. T. Schaef, E. M. Price, M. J. Lindberg, Z. Wang, P. L. Gassman, and J. G. Catalano, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14033, 2002, *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*, R. E. Peterson, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14058, 2002, *Prototype Database and User's Guide of Saturated Hydraulic Properties for the Hanford Site*, P.D. Thorne and D.R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14070, 2002, *Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*, B. A. Williams and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14098, 2002, *Results of Groundwater Monitoring at the Hanford Site 200 Area Treated Effluent Disposal Site – 1999 through FY 2002*, J. T. Rieger, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14107, 2002, *Groundwater Chemistry and Hydrogeology of the Upper Saddle Mountains Basalt-Confined Aquifer South and Southeast of the Hanford Site*, D. R. Newcomer, E. C. Thornton, and T. L. Liikala, Pacific Northwest Laboratory, Richland, Washington.

PNNL-14112, 2002, *Groundwater Monitoring Plan for the 216-B-63 Trench on the Hanford Site*, M. D. Sweeney, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14113, 2002, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14186, 2003, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14187, 2003, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*, M. J. Hartman, L. F. Morasch, and W. D. Webber, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14284, 2003, *Laboratory Measurements of the Unsaturated Hydraulic Properties at the Vadose Zone Transport Field Study Site*, M. G. Schaap, P. J. Shouse, and P. D. Meyer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14287, 2003, *Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units*, M. D. Sweeney and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14548, 2004, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*, M. J. Hartman, L. F. Morasch, and W. D. Webber, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14702, 2004, *Vadose Zone Hydrogeology Data Package for the 2004 Composite Analysis*, Rev. 0, G. V. Last, E. J. Freeman, K. J. Cantrell, M. J. Fayer, and G. W. Gee, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14702, 2006, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, Rev. 1, G. V. Last, G. W. Gee, E. J. Freeman W. E. Nichols, K. J. Cantrell B. N. Bjornstad, M. J. Fayer, and D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14753, 2006, *Groundwater Data Package for Hanford Assessments*, Rev. 1, P. D. Thorne, M. P. Bergeron, M. D. Williams, and V. L. Freedman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14859, 2004, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*, P. E. Dresel, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15070, 2005, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*, M. J. Hartman, L. F. Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15121, 2005, *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume*, J. M. Zachara (ed.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15127, 2005, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004*, R. E. Peterson, E. J. Freeman, M. J. Truex, S. B. Yabusaki, and J. P. McDonald, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15141, 2008, *Investigation of Accelerated Casing Corrosion in Two Wells at Waste Management Area A-AX*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15293, 2005, *Evaluation of the Fate and Transport of Tritium-Contaminated Groundwater from the 618-11 Burial Ground*, V. R. Vermeul, M. P. Bergeron, P. E. Dresel, E. J. Freeman, R. E. Peterson, and P. D. Thorne, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15301, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area*, T. D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15315, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*, S. M. Narbutovskih and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15479, 2005, *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility*, D. B. Barnett, R. M. Smith, C. J. Chou, and J. P. McDonald, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15670, 2006, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, M. J. Hartman, L. F. Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15731, 2006, *Post-Closure RCRA Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*, B. A. Williams, D. B. Barnett, C. J. Chou, and M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15782, 2006, *STOMP Subsurface Transport Over Multiple Phases Version 4.0 User's Guide*, M. D. White and M. Oostrom, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15798, 2006, *100-N Shoreline Groundwater Monitoring Plan*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15837, 2007, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*, D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16069, 2006, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site (1950-1970)*, T.M. Kinney and J.P. McDonald, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16100, 2007, *Carbon Tetrachloride Partition Coefficients Measured by Aqueous Sorption to Hanford Sediments from Operable Units 200-UP-1 and 200-ZP-1*, D. M. Wellman, R. G. Riley, E. A. Rodriguez, A. V. Mitroshkov, and K. E. Parker, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16346, 2007, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, M. J. Hartman, L. F. Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16435, 2007, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington*, B. A. Williams, C. F. Brown, W. Um, M. J. Nimmons, and R. E. Peterson, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16436, 2007, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, M. J. Hartman, L. F, Morasch, and W. D. Webber (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16454, 2007, *Current Conditions Risk Assessment for the 300-FF-5 Groundwater Operable Unit*, T. B. Miley, A. L. Bunn, B. A. Napier, R. E. Peterson, and J. M. Becker, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16538, 2007, *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring*, Z. F. Zhang, J. M. Keller, and C. E. Strickland, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16761, 2007, *Evaluation and Screening of Remedial Technologies for Uranium at the 300-FF-5 Operable Unit, Hanford Site, Washington*, M. J. Nimmons, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16891, 2007, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*, J. E. Szecsody, C. A. Burns, R. C. Moore, J. S. Fruchter, and V. R. Vermeul, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16894, 2007, *Investigation of the Strontium-90 Contaminant Plume Along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*, D. P. Mendoza, G. W. Patton, M. J. Hartman, and M. D. Sweeney, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17031, 2007, *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site*, J. M. Zachara, C. F. Brown, J. N. Christensen, J. A. Davis, and P. E. Dresel, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17034, 2008, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington*, R. E. Peterson, M. L. Rockhold, R. J. Serne, P. D. Thorne, and M. D. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17067, 2008, *300 Area Integrated Field-Scale Subsurface Research Challenge (IFRC) Field Site Management Plan*, Rev. 2, M. D. Freshley, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17154, 2008, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank*

Waste Management Areas at the Hanford Site, K. J. Cantrell, C. F. Brown, R. J. Serne, and K. M. Krupka, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17306, 2008, *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring FY07 Report*, Z. F. Zhang, C. E. Strickland, and J. M. Keller, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17429, 2008, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injections for In Situ Strontium-90 Immobilization*, M. D. Williams, B. G. Fritz, D. P. Mendoza, M. L. Rockhold, and P. D. Thorne, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17480, 2008, *Challenges Associated with Apatite Remediation of Uranium in the 300 Area Aquifer*, D. M. Wellman, J. S. Fruchter, V. R. Vermeul, and M. D. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17603, 2008, *Hanford Site Environmental Report for Calendar Year 2007*, T. M. Poston, J. P. Duncan, R. L. Dirkes, L. E. Bisping, and C. J. Perkins (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17666, 2008, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*, R. E. Peterson, B. A. Williams, and R. M. Smith, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17674, 2008, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*, P. E. Dresel, N. P. Qafoku, J. P. McKinley, J. S. Fruchter, and C. C. Ainsworth, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17708, 2008, *Three-Dimensional Groundwater Models of the 300 Area, Hanford Site, Washington State*, M. D. Williams, M. L. Rockhold, P. D. Thorne, and Y. Chen, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17793, 2008, *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model*, Rev. 0, C. F. Brown, W. Um, and R. J. Serne, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17913, 2009, *Hydrogeology of the Hanford Site Central Plateau – A Status Report for the 200 West Area*, Rev. 1, G. V. Last, P. D. Thorne, J. A. Horner, K. R. Parker, B. N. Bjornstad, R. D. Mackley, D. C. Lanigan, and B. A. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18100, 2008, *Spatial Analysis of Contaminants in 200 West Area Groundwater in Support of the 200-ZP-1 Operable Unit Pre-Construction Remedy Design*, C. J. Murray and Y. J. Bott, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18118, 2008, *Revised Geostatistical Analysis of the Inventory of Carbon Tetrachloride in the Unconfined Aquifer in the 200 West Area of the Hanford Site*, C. J. Murray and Y. J. Bott, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18279, 2009, *Aquifer Testing Recommendations for Well 299-W15-225: Supporting Phase I of the 200-ZP-1 Groundwater Operable Unit Remedial Design*, F. A. Spane and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18303, 2009, *Sequestration of Sr-90 Subsurface Contamination in the Hanford 100N Area by Surface Infiltration of a Ca-Citrate- PO4 Solution*, J. E. Szecsody M. L. Rockhold, M. Oostrom, R. C. Moore, C. A. Burns, M. D. Williams, L. Zhong, J. S. Fruchter, J. P. McKinley, V. R. Vermeul, M. A. Covert, T. W. Wietsma, A. T. Breshears, and B. J. Garcia, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18340, 2009, *Borehole Completion and Conceptual Hydrogeologic Model for the IFRC Well Field, 300 Area, Hanford Site*, B. N. Bjornstad, J. A. Horner, D. C. Lanigan, and P. D. Thorne, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18427, 2009, *Hanford Site Environmental Report for Calendar Year 2008*, T. M. Poston, J. P. Duncan, R. L. Dirkes, L. E. Bisping, C. J. Perkins, M. C. Dorsey, S. M. McKinney, and J. W. Wilde (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18529, 2009, *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report*, V. R. Vermeul, B. N. Bjornstad, B. G. Fritz, J. S. Fruchter, R. D. Mackley, D. R. Newcomer, D. P. Mendoza, M. L. Rockhold, D. M. Wellman, and M. D. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18564, 2009, *Selection and Traceability of Parameters To Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*, G. V. Last, M. L. Rockhold, C. J. Murray, and K. J. Cantrell, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18645, 2010, *Summary of TPH Monitoring Conducted at 100-NR-2 2008 Through 2010*, B. G. Fritz, D. P. Mendoza, D. R. Yonge, J. A. Stegen, A. L. Bunn, and R. J. Cameron, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18732, 2009, *Field Test Report: Preliminary Aquifer Test Characterization Results for Well 299-W15-225: Supporting Phase I of the 200-ZP-1 Groundwater Operable Unit Design*, F. A. Spane and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18784, 2009, *Hanford 100-D Area Biostimulation Treatability Test Results*, M. J. Truex, V. R. Vermeul, B. G. Fritz, R. D. Mackley, and D. P. Mendoza, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18807, 2010, *Soil Water Balance and Recharge Monitoring at the Hanford Site – FY09 Status Report*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19052, 2009, *Water Quality Sampling Locations Along the Shoreline of the Columbia River, Hanford Site, Washington*, R. E. Peterson and G. W. Patton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19120, 2010, *100-N Area Strontium-90 Treatability Demonstration Project: Phytoextraction Along the Riparian Zone – Field Treatability Study*, R. J. Fellows, J. S. Fruchter, C. J. Driver, and C. C. Ainsworth, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19123, 2010, *T Tank Farm Interim Surface Barrier Demonstration: Vadose Zone Monitoring FY09 Report*, F. Zhang, C. E. Strickland, J. G. Field, and D. L. Parker, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19277, 2010, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and into the Upper Unconfined Aquifer Below the B-Complex*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19455, 2010, *Hanford Site Environmental Report for Calendar Year 2009*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19572, 2010, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19681, *Tc-99 Ion Exchange Resin Testing*, M. M. Valenta, K. E. Parker, and E. M. Pierce, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19702, 2010, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*, B. N. Bjornstad, P. D. Thorne, B. A. Williams, G. V. Last, G. S. Thomas, M. D. Thompson, J. L. Ludwig, and D. C. Lanigan, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20252, 2011, *100-NR-2 Apatite Treatability Test: An Update on Barrier Performance*, B. G. Fritz, V. R. Vermeul, J. S. Fruchter, J. E. Szecsody, and M. D. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20548, 2011, *Hanford Site Environmental Report for Calendar Year 2010*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-18197, 2009, *Analytical Data Report for Sediment Samples Collected from Well 299-E25-236 in the 200-PO-1 Operable Unit*, M. Lindberg, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-18578, 2009, *Analytical Data Report for Water Samples Collected from Operable Unit BP-5 B Well*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-50369, 2006, *Project Work Plan Hanford 100-D Area Treatability Demonstration: Accelerated Bioremediation Through Polylactate Injection*, J. S. Fruchter, V. R. Vermeul, M. J. Truex, and P. E. Long, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-56038, 2007, *Hanford Site Groundwater and the Columbia River, South-Central Washington, presented at the 6th Washington Hydrogeology Symposium in Tacoma, Washington*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-62124, 2009, *Analytical Data Report for Sediment Samples Collected from BP-5 Operable Unit C Well*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-62141, 2009, *Analytical Data Report for Grab Samples Collected from BP-5 Operable Unit N Well*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-62656, 2009, *Analytical Data Report for Grab Samples Collected from Operable Unit BP-5 B Well*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-SA-70033, 2009, *100-NR-2 Apatite Treatability Test FY09 Status: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization: Interim Report*, V. R. Vermeul, J. E. Szecsody, B. G. Fritz, M. D. Williams, and J. S. Fruchter, Pacific Northwest National Laboratory, Richland, Washington.

PNWD-2161 HEDR, 1993, *Fuel Element Failures in Hanford Single-Pass Reactors 1944-1971*, S. P. Gydesen, Battelle Pacific Northwest Laboratories, Richland Washington.

Pollock, D. W., 1994, *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model*, Open File Report 94-464, U.S. Geological Survey, Reston, Virginia.

PSPL, 1982, *Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report*, App. 20, Amendment 23, Puget Sound Power and Light Company, Bellevue, Washington.

Qafoku, N. P., C. C. Ainsworth, J. E. Szecsody, O. S. Qafoku, and S. M. Heald, 2003, "Effect of Coupled Dissolution and Redox Reactions on Cr(VI)aq Attenuation during Transport in the Sediments Under Hyperalkaline Conditions," *Environmental Science & Technology*, 37(16):3640-3646.

Rai, D., L. E. Eary, and J. M. Zachara, 1989, "Environmental Chemistry of Chromium," *Sci. Total Environ.* 86(1-2):15-23.

Reilly, E. T., and D. W. Pollock, 1996, "Sources of Water to Wells for Transient Cyclic Systems," *Ground Water*, 34(6):979-988.

Remoudaki, E., A. Hatzikioseyian, F. Kaltsa, and M. Tsezos, 2003, "The Role of Metal-Organic Complexes in the Treatment of Chromium Containing Effluents in Biological Reactors," *15th International Biohydrometallurgy Symposium, Biohydrometallurgy: a Sustainable Technology in Evolution*," September 14-19, Athens, Hellas.

RHO-BWI-LD-5, 1978, *Geology of Gable Mountain - Gable Butte Area*, K. R. Fecht, Rockwell Hanford Operations, Richland, Washington.

RHO-BWI-ST-14, 1981, *Subsurface Geology of the Cold Creek Syncline*, C. W. Meyers and S. M. Price (eds.), Rockwell Hanford Operations, Richland, Washington.

RHO-BWI-ST-4, 1979, *Geological Studies of the Columbia Plateau – A Status Report*, C. W. Myers and S. M. Price (eds.), Rockwell Hanford Operations, Richland, Washington.

RHO-BWI-ST-5, 1979, *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*, R. E. Gephart, R. C. Arnett, R. G. Baca, L. S. Leonhart, and F. A. Spane, Rockwell Hanford Operations, Richland, Washington.

RHO-RE-ST-12P, 1984, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-23, 1979, *Geology of the Separations Areas, Hanford Site, South-Central Washington*, A. M. Tallman, K. R. Fecht, M. C. Marratt, and G. V. Last, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-38, 1982, *Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond Area*, S. R. Strait and B. A. Moore, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-42, 1981, *Hydrology of the Separations Area*, M. J. Graham, M. D. Hall, S. R. Strait, and W. R. Brown, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-46P, 1984, *Field Calibration of Computer Models for Application to Buried Liquid Discharges: A Status Report*, J. B. Sisson and A. Lu, Rockwell Hanford Operations, Richland, Washington.

RPP-10757, 2002, *Technetium-99 in Groundwater at Hanford Well 299-W23-19: Options Analysis and Recommended Action Report*, Rev. 0, S. E. Parnell and W. J. McMahon, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-23403, 2006, *Single-Shell Tank Component Closure Data Quality Objectives*, Rev. 3, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-23748, 2006, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-23752, 2005, *Field Investigation Report for Waste Management Areas T and TX-TY*, Rev. 0-A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-26744, 2005, *Hanford Soil Inventory Model, Rev. 1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-34690, 2007, *Surface Geophysical Exploration of the B, BX, and BY Tank Farm at the Hanford Site*, Rev. 0, CH2M HILL Hanford Group Inc., Richland, Washington.

RPP-35485, 2007, *Field Investigation Report of Waste Management Area U*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7884, 2002, *Field Investigation Report for Waste Management Area S-SX*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-ENV-33430, 2007, *RPP NEPA Screening Form and Categorical Exclusion for the 241-T-106 Interim Infiltration Barrier*, J. G. Field, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-26534, 2008, *Integrated Disposal Facility Operational Monitoring Plan to Meet DOE Order 435.1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-30976, 2006, *Surface Geophysical Exploration of S Tank Farm at the Hanford Site*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-38320, 2008, *Surface Geophysical Exploration of the TX and TY Tank Farms at the Hanford Site*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-35222, 2007, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*, R. Khaleel, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-41236, 2009, *Surface Geophysical Exploration of UPR 200-E-81 Near the C Tank Farm*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-42296, 2010, *Hanford TY-Farm Leak Assessments Report, Rev. 0, Washington River Protection Solutions*, Richland, Washington.

RPP-RPT-42513, 2009, *Surface Geophysical Exploration of the SX Tank Farm at the Hanford Site*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-46613, 2010, *Surface Geophysical Exploration of the A and AX Tank Farms, Washington River Protection Solutions*, Richland, Washington.

RPP-RPT-47851, 2010, *Three-Dimensional Surface Geophysical Exploration of S/SX Tank Farm*, Washington River Protection Solutions, Richland, Washington.

RPP-RPT-44123, 2010, *Interim Surface Barrier Evaluation Report*, Rev. 0, J. G. Field, D. L. Parker, and Z. F. Zhang, Washington River Protection Solutions, Richland, Washington.

Ryan, M. P., D. E. Williams, R. J. Chater, B. M. Hutton, and D. S. McPhail, 2002, "Why Stainless Steel Corrodes," *Nature*, 415:770-774.

SD-BWI-DP-039, 1984, *Suprabasalt Stratigraphy Within and Adjacent to the Reference Repository Location*, B. N. Bjornstad, Rockwell Hanford Operations, Richland, Washington.

SD-BWI-TI-335, 1987, *Fresh-Water Potentiometric Map and Inferred Flow Direction of Ground Water Within the Mabton Interbed, Hanford Site, Washington State – January 1987*, F. A. Spane, Rockwell Hanford Operations, Richland, Washington.

SGW-33746, 2007, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site*, Fiscal Year 2006, Rev. 0, V. J. Rohay, Fluor Hanford, Inc., Richland, Washington.

SGW-37111, 2008, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site*, Fiscal Year 2007, Rev. 0, V. J. Rohay, Fluor Hanford, Inc., Richland, Washington.

SGW-38338, 2008, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

SGW-38757, 2008, *Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*, Draft A, Fluor Hanford, Inc., Richland, Washington.

SGW-38815, 2009, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project, Hanford Site*, Rev. 0, J. P. McDonald, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-39305, 2008, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the U.S. Department of Energy Hanford Site, 100-D Area*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

SGW-39496, 2008, *Borehole Summary Report for the Installation of One Groundwater Monitoring Well at the 200-BP-5 Operable Unit*, Rev. 0, B. Mayhew, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-39626, 2008, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit*, CY 2008, Rev. 0, L. Stratton, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40037, 2009, *Groundwater Monitoring Needs Assessment for Low-Level Burial Grounds Waste Management Areas*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40044, 2009, *100-HR-3 Remedial Process Optimization Modeling Technical Memorandum*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40211, 2009, *First Determination RCRA Groundwater Quality Assessment Plan for the Low-Level Burial Grounds Low-Level Waste Management Area 4*, Rev. 0, S. P. Luttrell, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40274, 2009, *Groundwater Quality Assessment Plan for the Non-Radioactive Dangerous Waste Landfill*, Rev. 0, S. P. Luttrell, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40456, 2009, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site*, Fiscal Year 2008, Rev. 0, V. J. Rohay, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40852, 2009, *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches – July-December 2008*, Rev. 0, M. J. Hartman, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-41213, 2009, *100-KR-4 Remedial Process Optimization Modeling Data Package*, Rev. 0, R. Khaleel, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-41903, 2009, *Groundwater Quality Assessment Plan for Low-Level Waste Management Area 4*, Rev. 0, Reissue, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-41904, 2009, *Groundwater Quality Assessment Report for the Nonradioactive Dangerous Waste Landfill*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-42305, 2009, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, Rev. 0, M. J. Tonkin, S. Dadi, and R. Shannon, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-42604, 2010, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State-Approved Land Disposal Site Fiscal Year 2009*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-42736, 2009, *Geohydrologic Data Package in Support of 200-ZP-1 Modeling*, Rev. 0, R. Khaleel and B. A. Williams, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-42788, 2009, *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches – January-June 2009*, Rev. 0, M. J. Hartman, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-43746, 2009, *Landstreamer/Gimbaled Geophone Acquisition of High Resolution Seismic Reflection Data North of the 200 Areas – Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-44071, 2011, *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit: November 2004 through November 2009 Groundwater Data*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-44329, 2010, *200-BP-5 OU Data Quality Objectives Summary Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-44694, 2010, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site*, Fiscal Year 2009, Rev. 0, CH2M HILL Plateau Remediation, Richland, Washington.

SGW-46279, 2010, *Conceptual Framework and Numerical Implementation of 100 Area Groundwater Flow and Transport Model*, Rev. 0, R. Khaleel, B. A. Williams, A. S. Spiliotopoulos, and M. J. Tonkin, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-46453, 2010, *Testing Guidelines for Technetium-99 Adsorption on Activated Carbon*, Rev. 0, M. E. Byrnes, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47040, 2010, *Geohydrologic Data Package in Support of 100-FR-3 Modeling*, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington.

SGW-47535, 2010, *Measurement of Compressional-Wave Seismic Velocities in 29 Wells at the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47538, 2010, *Groundwater Quality Assessment Report for Waste Management Area A-AX: First Determination*, Rev. 0, J. W. Lindberg, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47602, 2010, *Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100-NR-2 Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47662, 2010, *Test Plan for Technetium-99 Adsorption on Selected Resins from Hanford Site 200 West Area Groundwater*, Rev. 0, M. E. Byrnes and R. M. Smith, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47776, 2010, *Aquifer Testing and Rebound Study in Support of the 100-H Deep Chromium Investigation*, Rev. 0, J. L. Smoot, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47791, 2011, *Borehole Summary for the Installation of One Hundred and Seventy One Wells at 100-NR-2 Operable Unit*, FY 2009-2010, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47923, 2010, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site*, Fiscal Year 2010, Rev. 0, E. J. Freeman, M. E. Caron, and M. J. Tonkin, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47971, 2010, *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches, January –June 2010*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-47996, 2010, *Testing Ground Based Geophysical Techniques to Refine Electromagnetic Surveys North of the 300 Area, Hanford, Washington*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-49268, 2011, *Results of Groundwater Monitoring for the 183-H Solar Evaporation Basins and 300 Area Process Trenches, July—December 2010*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-49368, 2011, *Columbia River Pore Water Sampling in 100-BC Area, November 2010*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Slater, L. D., D. Ntarlagiannis, F. D. Day-Lewis, K. Mwakanyamale, R. J. Versteeg, A. Ward, C. Strickland, C. D. Johnson, and J. W. Lane Jr., 2010, "Use of Electrical Imaging and Distributed Temperature Sensing Methods to Characterize Surface-Water/Groundwater Exchange Regulating Uranium Transport at the Hanford 300 Area, Washington," *Water Resources Research*, doi:10.1029/2010WR009110.

Tonkin, M. J., and S. P. Larson, 2002, "Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift," *Ground Water*, 40(2):185-193.

TPA-CN-163, 2007, *Change Notice for Modifying Approved Documents Work Plans in Accordance with TPA Action Plan Section 9.0 Documentation and Records PNNL-12220 Sampling and Analysis Plan Update for Groundwater Monitoring 100-EM-1 OU*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-228, 2008, *Change Notice for Modifying Approved Documents/Workplans in Accordance with Tri-Party Agreement Action Plan Section 9.0 Documentation and Records, 100-FR-3 OU Sampling and Analysis Plan DOE/RL-2003-49 Rev. 1, and Waste Control Plan for 100-FR-3 OU DOE/RL-2004-31*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland, Operations Office, Richland, Washington.

TPA-CN-240, 2008, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev 1 and TPA-CN-182 (September 6, 2007)*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-241, 2008, *Change Notice for Modifying 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-252, 2009, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, DOE/RL-92-76 Revision 1, Remedial Investigation Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-256, 2009, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2001-27, Rev 0, Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*, Washington State Department of Ecology and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-271, 2009, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit, DOE/RL-2005-96 Addendum*, Washington State Department of Ecology and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-273, 2009, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, DOE/RL-2006-75 Revision 1 Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and treat System*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-293, 2009, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev 1 (as modified by TPA-CN-240 (12/08/08)*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-353, 2010, *Change Notice for Sampling and Analysis Plan for Aquifer Sampling Test Tubes, DOE/RL-2009-59, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-357, 2010, *Change Notice for Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0*, U.S. Department of Energy, Richland Operations Office, and U.S. Environmental Protection Agency, Richland, Washington.

Um, W., R. J. Serne, and K. M. Krupka, 2004, "Linearity and Reversibility of Iodide Adsorption on Sediments from Hanford, Washington Under Water Saturated Conditions," *Water Research*, 38(8):2009-2016.

Vermeul, V. R., J. P. McKinley, D. R. Newcomer, R. D. Mackley, and J. M. Zachara, 2010, "River-Induced Wellbore Flow Dynamics in Long-Screen Wells and Their Impact on Aqueous Sampling Results," *Groundwater* (in press).

Volpi, G., and G. Gambolati, 1978, "On the Use of a Main Trend for the Kriging Technique in Hydrology," *Advances in Water Resources*, 1:345-349.

WA7890008967, 2006, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*, as amended, Washington State Department of Ecology, Richland, Washington.

Wanek, D. M., 1998, "Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units," CCN 062039, letter to S. M. Alexander (Washington State Department of Ecology) and D. R. Sherwood (U.S. Environmental Protection Agency), from D. M. Wanek, U.S. Department of Energy, Richland Operations Office, Richland, Washington, September 16.

Ward, A. L., Z. F. Zhang, and G. W. Gee, 2006, "Upscaling Unsaturated Hydraulic Parameters for Flow Through Heterogeneous Anisotropic Sediments," *Advances in Water Resources*, 29:268-280.

WCH-198, 2008, *Groundwater Protection Plan for the Environmental Restoration Disposal Facility*, Rev. 0, R. L. Weiss, Washington Closure Hanford, Richland, Washington.

WCH-274, 2008, *Inter-Areas Component of the River Corridor Baseline Risk Assessment Sampling Summary*, Rev. 0, J. M. Queen, Washington Closure Hanford, Richland, Washington.

WCH-323, 2008, *Sampling and Analysis Instruction for installation of UPR-100-N-17 Bioremediation Wells and Performance of Bioventing Pilot Tests*, Rev. 0, W. S. Thompson, Washington Closure Hanford, Richland, Washington.

WCH-380, 2010, *Field Summary Report for Remedial Investigation of Hanford Site Release to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*, Rev. 1, Washington Closure Hanford, Richland, Washington.

WCH-381, 2010, *Data Quality Assessment Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*, Rev. 1, L. C. Hulstrom, Washington Closure Hanford, Richland, Washington.

WCH-352, 2009, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils*, Rev. 0, L. C. Hulstrom, Washington Closure Hanford, Richland, Washington.

WCH-370, 2009, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*, Rev. 0, D. A. Gamon, Washington Closure Hanford, Richland, Washington.

WCH-380, 2010, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*, Rev. 1, Washington Closure Hanford, Richland, Washington.

WCH-381, 2010, *Data Quality Assessment Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*, Rev. 1, L. C. Hulstrom, Washington Closure Hanford, Richland, Washington.

WCH-387, 2010 , *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Fish Tissue Samples*, Rev. 0, L. C. Hulstrom, Washington Closure Hanford, Richland, Washington.

WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*, Rev. 0, Washington Closure Hanford, Richland, Washington.

WCH-455, 2011, *Groundwater and Leachate Monitoring and Sampling at ERDF, CY 2010*, Rev. 0, R. L. Weiss and B. L. Lawrence, Washington Closure Hanford, Richland, Washington.

WCH-490, 2011, *UPR-100-N-17: Bioventing Pilot Plant Performance Report, Washington Closure Hanford*, Richland, Washington.

WHC-EP-0500, 1991, *Geology and Hydrology of 300 Area and Vicinity, South Central Washington*, D. R. Gaylord and E. P. Poeter, Washington Closure Hanford, Richland, Washington.

WHC-EP-0587, 1992, *Groundwater Impact Assessment Report for the 400 Area Ponds*, Rev. 0, D. K. Tyler, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0595, 1993, *Westinghouse Hanford Company Operational Groundwater Status Report, 1990-1992*, Rev. 0, V. G. Johnson, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0813, 1995, *Groundwater Impact Assessment Report for the 216-B-3 Pond System*, Rev. 0, V. G. Johnson, A. G. Law, S. P. Reidel, S. D. Evelo, and D. B. Barnett, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0883, 1995, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*, Rev. 0, R. Khaleel and E. J. Freeman, Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0132, 1990, *History of 200 Area Tank Farms*, Rev. 0, J. D. Anderson, Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0388, 1992, *Past Practices Technical Characterization Study – 300 Area – Hanford Site*, Rev. 0, M. S. Gerber, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-012, 1989, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-031, 1990, *Interim-Status Groundwater Quality Assessment Plan for the 216-A-29 Ditch*, Rev. 0, C. J. Chou, G. L. Kasza, and R. B. Mercer, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-045, 1991, *Groundwater Monitoring Plan for the 216-A-29 Ditch*, Rev. 0, G. L. Kasza and S. M. Goodwin, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-132, 1993, *Interim-Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Areas T and TX-TY*, Rev. 0, J. A. Caggiano and C. J. Chou, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-185, 1995, *Groundwater Monitoring Plan for the 300 Area Process Trenches*, Rev. 0, J. W. Lindberg, C. J. Chou, and V. G. Johnson, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-DP-052, 1993, *Borehole Completion Data Package for the 216-S-10 Facility*, CY-1992, Rev. 0, B. A. Williams and D. B. Barnett, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EE-004, 1991, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington*, Rev. 0, K. A. Lindsey, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EV-003, 1992, *Results of Groundwater Quality Assessment Monitoring at the 1301-N and 1324-N/NA Facilities*, Rev. 1, M. J. Hartman, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EV-025, 1994, *Results of Groundwater Quality Assessment Program at Low-Level Waste Management Area 1 of the Low-Level Burial Grounds*, Rev. 0, R. B. Mercer, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EV-027, 1993, *Hydrogeology of the 100-N Area, Hanford Site, Washington*, Rev. 0, M. J. Hartman and K. A. Lindsey, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EV-032, 1995, *Results of Groundwater Quality Assessment Program at the 216-A-29 Ditch RCRA Facility*, Rev. 0, J. M. Votava, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TA-003, 1993, *Potential for Groundwater Contamination from High Density Wastes Disposed at the BY Cribs, 200-BP-1 CERCLA Operable Unit*, Rev. 0, G. L. Kasza, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-012, 1992, *Geologic Setting of the 200-East Area: An Update*, Rev. 0, K. A. Lindsey, B. N. Bjornstad, J. W. Lindberg, and K. M. Hoffman, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-023, 1992, *Hydrologic Information Summary for the Northern Hanford Site*, Rev. 0, M. J. Hartman and R. E. Peterson, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-132, 1993, *Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington*, Rev. 0, K. A. Lindsey, and G. K. Jaeger, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-133, 1993, *Geology of the 100-B/C Area, Hanford Site, South-Central Washington*, Rev. 0, J. W. Lindberg, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-155, 1993, *Geology of the 100-B/C Area, Hanford Site, South-Central Washington*, Rev. 0, J. W. Lindberg, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-199, 1993, *Nonradioactive Dangerous Waste Landfill Soil Gas Survey: Final Data Report*, Rev. 0, I. D. Jacques and R. B. Kerkow, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-221, 1994, *Geology of the 100-FR-3 Operable Unit, Hanford Site, South-Central Washington*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-290, 1994, *Geologic Setting of the Low-Level Burial Grounds*, Rev. 0, K. A. Lindsey, G. K. Jaeger, J. L. Slate, K. J. Swett, and R. B. Mercer, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-294, 1994, *Hydrogeology of the 100-K Area, Hanford Site, South-Central Washington*, Rev. 0, J. W. Lindberg, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-302, 1995, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*, Rev. 0, E. C. Thornton, J. E. Amonette, J. A. Olivier, and D. L. Huang, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-ER-TI-003, 1991, *Geology and Hydrology of Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*, Rev. 0, C. D. Delaney, K. A. Lindsey, and S. P. Reidel, Westinghouse Hanford Company, Richland, Washington.

WMP-17869, 2003, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2002*, Rev. 0, P. M. Gent, Fluor Hanford, Inc., Richland, Washington.

WMP-21327, 2004, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2003*, Rev. 0, P. M. Gent, Fluor Hanford, Inc., Richland, Washington.

WMP-26178, 2005, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004*, Rev. 0, V. J. Rohay, Fluor Hanford, Inc., Richland, Washington.

WMP-28389, 2007, *T-Area Technetium-99 Data Quality Objectives Summary Report*, Rev. 1, V. J. Rohay, Fluor Hanford, Inc., Richland, Washington.

WMP-28945, 2008, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process*, Rev. 1, G. S. Thomas, Fluor Hanford, Inc., Richland, Washington.

WMP-30426, 2006, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site*, Fiscal Year 2005, Rev. 0, V. J. Rohay, Fluor Hanford, Inc., Richland, Washington.

Yabusaki, S. B., Y. Fang, and S. R. Waichler, 2008, "Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System," *Water Resources Research*, Vol. 44, W12403, doi:10.1029/2007WR006617.

Ye, M., and R. Khaleel, 2008, "A Markov Chain Model for Characterizing Medium Heterogeneity and Sediment Layering Structure," *Water Resources Research*, 44(9):W09427.1-W09427.15.

Ye, M., R. Khaleel, and T. C. J. Yeh, 2005, "Stochastic Analysis of Moisture Plume Dynamics of a Field Injection Experiment," *Water Resources Research*, 41(3):W03013.1-W03013.13.

Ye, M., R. Khaleel, M. G. Schaap, and J. Zhu, 2007, "Simulation of Field Injection Experiments in Heterogeneous Unsaturated Media Using Cokriging and Artificial Neural Network," *Water Resources Research*, 43(7):W07413.1-W07413.16.

Yeh, T. C. J., L.W. Gelhar, and A. L. Gutjahr, 1985, "Stochastic Analysis of Unsaturated Flow in Heterogeneous Soils 2. Statistically Anisotropic Media with Variable a," *Water Resources Research*, 21(4):457-464.

Yeh, T. C. J., M. Ye, and R. Khaleel, 2005, "Estimation of Effective Unsaturated Hydraulic Conductivity Tensor Using Spatial Moments of Observed Moisture Plume," *Water Resources Research*, 41(3):W03014.1-W03014.12.

Zachara, J. M., C. C. Ainsworth, G. E. Brown, Jr., J. G. Catalano, J. P. McKinley, O. Qafoku, S. C. Smith, J. E. Szecsody, S. J. Traina, and J. A. Warner, 2004, "Chromium Speciation and Mobility in a High Level Nuclear Waste Vadose Zone Plume," *Geochimica et Cosmochimica Acta*, 68(1):13-30.

Zhang, Z. F., A. L. Ward, and G. W. Gee, 2003, "Describing the Unsaturated Hydraulic Properties of Anisotropic Soils Using a Tensorial Connectivity-Tortuosity (TCT) Concept," *Vadose Zone Journal*, 2(3):313-321.

Zhang, Z. F., and R. Khaleel, 2010, "Simulating Field-Scale Moisture Flow Using a Combined Power-Averaging and Tensorial Connectivity-Tortuosity Approach," *Water Resources Research*, in press.

This page intentionally left blank.

Appendix A

Supporting Information for CERCLA Groundwater Operable Units

This page intentionally left blank.

Contents

Appendix A — Supporting Information for CERCLA Groundwater Operable Units A-1
References A-1

Tables

Table A-1. Monitoring Wells and Constituents for the 100-BC-5 Operable Unit A-4
Table A-2. Monitoring Wells and Constituents for the 100-KR-4 Pump-and-Treat Systems A-5
Table A-3. Monitoring Wells and Constituents for 100-KR-4 Operable Unit Long-Term Monitoring A-8
Table A-4. Monitoring Wells and Constituents for 100-NR-2 Interim Action A-9
Table A-5. Monitoring Wells and Constituents for 100-NR-2 Shoreline Monitoring A-11
Table A-6. Monitoring Wells and Constituents for the 100-NR-2 Apatite Treatability Test Plan A-12
Table A-7. Monitoring Wells and Constituents for the 100-HR-3 Operable Unit In Situ Redox Manipulation System A-13
Table A-8. Monitoring Wells and Constituents for the 100-HR-3 Pump-and-Treat Systems A-14
Table A-9. Monitoring Wells and Constituents for 100-HR-3 Operable Unit Long-Term Monitoring A-15
Table A-10. Monitoring Wells and Constituents for the 100-FR-3 Operable Unit A-17
Table A-11. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit A-18
Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit A-20
Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit A-22
Table A-14. Monitoring Wells and Constituents for 200-PO-1 Operable Unit Near-Field Wells A-26
Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells A-28
Table A-16. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area A-31
Table A-17. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-11 Subregion A-33
Table A-18. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-10/316-4 Subregion A-34
Table A-19. Monitoring Wells and Constituents for the Former 1100-EM-1 Operable Unit A-35

This page intentionally left blank.

Appendix A—Supporting Information for CERCLA Groundwater Operable Units

C.J. Martin

Under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), the groundwater beneath contaminated portions of the Hanford Site are divided into eleven groundwater operable units. Figure 1-2 in Chapter 1.0 shows the locations of these units and related groundwater interest areas on the Hanford Site. The interest areas are defined informally to aid in planning, scheduling, and data interpretation.

The tables provided in this appendix list the constituents, monitoring wells, and the sampling frequency for each operable unit, as required by their respective sampling and analysis plans or other documentation. The tables also indicate whether the wells were sampled as scheduled during the reporting period (January1, 2010, through December 31, 2010).

In many cases, wells are sampled for additional constituents not strictly required by the plans. Those constituents are not listed in the tables of this appendix, but data files accompanying this report include all of the required and supplemental data.

References

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

DOE/RL-92-72, 1991, *200 Area Effluent Treatment Facility Delisting Petition*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-92-76, 2005, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-84, 2003, *Remedial Design and Remedial Action Work Plan for 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, Rev. 0-A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-90, 1997, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-99-51, 2000, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2000-59, 2009, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, Rev. 1, U. S. Department of Energy, Richland Operations, Richland, Washington.

DOE/RL-2001-27, 2002, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2001-49, 2004, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-11, 2008, *300-FF-5 Operable Unit Sampling and Analysis Plan*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-04, 2006, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-38, 2004, *100-BC-5 Operable Unit Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-49, 2004, *100-FR-3 Operable Unit Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-55, 2004, *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-52, 2006, *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-75, 2008, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System*, Rev. 1 Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

FH, 2008, *100/300 Area Unit Managers Meeting Minutes*, Attachment 2, CCN 0078408, dated May 8, 2008, Fluor Hanford, Inc., Richland, Washington.

NPL Agreement/Change Control Form 108, 1996, *Modifications to the Groundwater Sampling and Analysis Schedules for the 100-KR-4 Groundwater Sampling Project*, dated November 20, 1996.

PNNL-14033, 2002, *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*, R. E. Peterson, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15798, 2006, *100-N Shoreline Groundwater Monitoring Plan*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq.

SGW-39408, 2008, *Aquifer Sampling Tube Results for Fiscal Year 2008*, M. J. Hartman and R. O. Mahood, CH2M HILL Hanford Group, Inc., Richland, Washington.

TPA-CN-163, 2007, *TPA Change Notice Modifying Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit, PNNL-12220*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-182, 2007, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev. 2*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-228, 2008, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-240, 2008, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-241, 2008, *TPA Change Notice for Modifying 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-256, 2008, *TPA Change Notice for Modifying Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit, DOE/RL-2001-27 and Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*, Washington State Department of Ecology and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-271, 2009, *TPA Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit DOE/RL-2005-96 Addendum*, Washington State Department of Ecology and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-293, 2009, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev. 1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

TPA-CN-298, 2009, *TPA Change Notice for Modifying the Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units, DOE/RL-96-90, Rev. 0*, Washington State Department of Ecology and U.S. Department Of Energy, Richland Operations Office, Richland, Washington.

Waneck, D. M., 1998, *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units*, CCN 062039, letter to S. M. Alexander (Washington State Department of Ecology) and D. R. Sherwood (U.S. Environmental Protection Agency), dated September 16, 1998, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Table A-1. Monitoring Wells and Constituents for the 100-BC-5 Operable Unit

Well	Hydrologic Unit Monitored	Alkalinity	Alpha/Beta	Anions	Hexavalent Chromium	Metals	Sr-90	Tritium	Tc-99	Sampled as Scheduled in Reporting Period
199-B2-12	Ringold aquitard	BO	--	BO	BO	BO	BO	BO	--	Not scheduled
199-B2-13[a]	Top of unconfined	BE	--	BE	BE	BE	BE	BE	--	Yes
199-B2-14[b]	Top of unconfined	Q	Q	Q	Q	Q	Q	Q	--	Yes
199-B3-1[a]	Top of unconfined	BE	--	BE	A	BE	A	A	--	Yes
199-B3-46[a]	Top of unconfined	BO	--	BO	A	BO	A	A	--	Yes
199-B3-47[a]	Top of unconfined	BE	--	BE	A	BE	A	A	--	Yes
199-B3-50[b]	Top of unconfined	Q	Q	Q	Q	Q	Q	Q	--	Yes
199-B4-1	Top of unconfined	BE	--	BE	A	BE	BE	A	--	Yes
199-B4-4[a]	Top of unconfined	--	--	--	--	--	BE	BE	--	Yes
199-B4-7	Top of unconfined	BO	--	BO	BO	BO	BO	BO	--	Not scheduled
199-B4-8[a]	Top of unconfined	BE	--	BE	BE	BE	BE	BE	--	Yes
199-B5-1[a]	Top of unconfined	BE	--	BE	A	BE	BE	A	--	Yes
199-B5-2[a]	Top of unconfined	--	--	--	A	--	BO	A	--	Yes
199-B5-5[b]	Bottom of unconfined	Q	Q	Q	Q	Q	Q	Q	--	Yes
199-B5-6[b]	Bottom of unconfined	Q	Q	Q	Q	Q	Q	Q	--	Yes
199-B8-6[a]	Top of unconfined	BO	BO	BO	A	BO	BO	A	--	Yes
199-B8-7	Top of unconfined	Q	Q	Q	Q	Q	--	Q	--	No[c]
199-B8-8	Top of unconfined	Q	Q	Q	M/Q	Q	--	Q	--	No[c]
199-B9-2	Top of unconfined	--	BE	--	BE	--	--	BE	--	Yes
199-B9-3[a]	Top of unconfined	BO	BO	BO	BO	BO	--	BO	--	Not scheduled
699-63-90	Unconfined	BE	BE	BE	--	BE	--	BE	--	Yes
699-65-83[a]	Unconfined	--	--	--	--	--	--	BE	--	Yes
699-67-86[a]	Unconfined	--	--	--	--	--	--	BO	--	Not scheduled
699-68-105	Unconfined	BO	--	BO	--	BO	--	BO	--	Not scheduled
699-71-77[a]	Unconfined	BO	--	BO	--	BO	--	BO	BO	Not scheduled
699-72-73	Unconfined	BE	--	BE	--	BE	--	BE	BE	Yes
699-72-92	Unconfined	BO	--	BO	--	BO	--	BO	--	Not scheduled
199-B2-15	Ringold aquitard	Q	--	Q	Q	Q	Q	Q	--	New wells to be sampled 2011
199-B2-16	Bottom of unconfined	Q	--	Q	Q	Q	Q	Q	--	
199-B3-51	Bottom of unconfined	--	--	--	Q		Q	Q	--	
199-B4-14	Top of unconfined	Q	--	Q	Q	Q	Q	Q	--	
199-B5-8	Top of unconfined	Q	Q	Q	Q	Q	Q	Q	Q	
199-B8-9	Top of unconfined	Q	Q	Q	Q	Q	Q	Q	--	

Notes: Requirements are from the following:

- DOE/RL-2003-38, *100-BC-5 Operable Unit Sampling and Analysis Plan*, Rev. 1
- TPA-CN-240, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev. 1* (dated December 8, 2008)
- TPA-CN-293, *TPA Change Notice for Modifying 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev. 1* (dated October 6, 2009).

a. Wells sampled three times in 2010 for RI/FS to evaluate spatial and temporal uncertainty. Analyzed for RI/FS COPCs.

b. New wells added to sampling schedule beginning in April 2010; not in DOE/RL-2003-38, TPA-CN-240, or TPA-CN-293.

c. Wells 199-B8-7 and 199-B8-8 were sampled in January 2010 and then decommissioned to allow for remediation of the 100-C-7 waste site.

A = to be sampled annually

BE = to be sampled biennially, even fiscal years

BO = to be sampled biennially, odd fiscal years

Table A-2. Monitoring Wells and Constituents for the 100-KR-4 Pump-and-Treat Systems

Well	Monitoring Purpose	Hexavalent Chromium	Sr-90	Tritium	C-14	Sampled as Scheduled in 2010 (12 months)	Comment
116-K-2 Trench Wells							
199-K-18	Monitoring	Q	S	S	S	No; Sr-90 and C-14 only analyzed in December 2010 sample	Sampled in April, June, August, and December 2010.
199-K-19	Monitoring	S	A	A	A	Yes	Sampled in July and December 2010.
199-K-20	Compliance	Q	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in March, June, and August 2010.
199-K-21	Monitoring	S	A	A	A	Yes	Sampled in July and December 2010.
199-K-22	Monitoring	S	A	A	A	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-37	Monitoring	S	A	A	A	Yes	Sampled in June and December 2010.
199-K-113A	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-114A	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-115A	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010. Well offline October 2010 to January 2011 for system upgrades.
119-K-116A	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-117A	Monitoring	Q	S	S	S	No; Sr-90 and tritium only analyzed in December 2010 sample	Sampled in March, June, August, and December 2010.
199-K-119A	Monitoring	Q	S	S	S	No; Sr-90 and C-14 only analyzed in December 2010 sample	Sampled in July and December 2010.
199-K-120A	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium (1 sample), and C-14 missed in 2010	Sampled in July 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-124A	Monitoring	S	A	A	A	Yes	Sampled in July and December 2010.
199-K-125A	Compliance	Q	S	S	S	No; Sr-90, tritium (1 sample), and C-14 missed in 2010	Replaces well 199-K-118. Sampled in March, July, and August 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-127	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium (1 sample), and C-14 missed in 2010	Sampled in July 2010.
199-K-129	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium (1 sample), and C-14 missed in 2010	Sampled in June 2010. Well offline October 2010 to January 2011 for system upgrades.
199-K-130	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 not analyzed in June 2010 sample	Sampled in June and November 2010.
199-K-131	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-141	Extraction	S	S	S	S	Yes	Sampled in February and July 2010.
199-K-142	Performance	S	S	S	S	Yes	Sampled in March, June, September, and December 2010.
199-K-144	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-145	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium (1 sample), and C-14 missed in 2010	Sampled in June 2010.
199-K-146	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-147	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 not analyzed in June 2010 sample	Sampled in June and November 2010.
199-K-148	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 not analyzed in June 2010 sample	Sampled in June and November 2010.

Table A-2. (Cont.)

Well	Monitoring Purpose	Hexavalent Chromium	Sr-90	Tritium	C-14	Sampled as Scheduled in 2010 (12 months)	Comment
199-K-149	Extraction/ compliance	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010. Well disconnected in December 2010.
199-K-150	Extraction/ compliance	S	S	S	S	No; well not sampled in 2010	Well disconnected in December 2010.
199-K-151	Performance	S	A	A	A	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-152	Performance	S	A	A	A	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in June 2010.
199-K-153	Extraction	S	S	S	S	No; Sr-90, tritium, and C-14 not analyzed in August 2010 sample	Well activated on 3/25/2010. Sampled in August and November 2010.
199-K-157	Performance	S	S	S	S	No; Sr-90 and C-14 only analyzed in December 2010 sample	Sampled in February, March, April, June, July, September, and December 2010.
199-K-161	Extraction/ compliance	S	S	S	S	No; tritium and C-14 not analyzed in June 2010 sample	Sampled in June and November 2010.
199-K-162	Extraction	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in July 2010.
199-K-163	Extraction	S	S	S	S	No; Sr-90, tritium, and C-14 not analyzed in June 2010 sample	Sampled in June and November 2010.
199-K-178	Extraction	S	S	S	S	Yes	Sampled in April, June, July, August, and November 2010. Well offline due to sand plugging; redeveloped in June 2011.
199-K-181	Performance	S	S	S	S	No; Sr-90, tritium, and C-14 only analyzed in August 2010 sample	Sampled in January, February, March, April, May, and August 2010.
199-K-182	Monitoring	S	S	S	S	No; Sr-90 only analyzed in June 2010 sample	Sampled in June and August 2010.
KW Wells							
199-K-34	Performance	Q	A	A	A	Yes	Sampled in April, June, September, and December 2010.
199-K-106A	Performance	Q	A	A	A	No; fourth sampling event missed in 2010	Sampled in March, June, and September 2010.
199-K-107A	Performance	Q	A	A	A	No; hexavalent chromium not analyzed in January and July 2010 samples	Sampled in January, April, July, and December 2010.
199-K-132	Extraction/ compliance	Q	S	S	S	No; Sr-90, tritium, and C-14 only analyzed in November 2010 sample	Sampled in February, June, August, and November 2010.
199-K-138	Extraction/ compliance	Q	S	S	S	No; Sr-90, tritum, and C-14 only analyzed in November 2010 sample	Sampled in February, June, August, and November 2010.
199-K-139	Extraction/ compliance	Q	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in February, June, and August 2010.
199-K-140	Monitoring	S	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in February 2010. Converted to monitoring well after April 15, 2010.
199-K-137	Extraction	Q	S	S	S	No; Sr-90, tritium, and C-14 (1 sample) missed in 2010	Sampled in February, June, and August 2010.
199-K-165	Extraction	Q	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in February, June, and August 2010.
199-K-166	Extraction	Q	S	S	S	No; Sr-90, tritium, and C-14 only analyzed in November 2010 sample	Sampled in April, June, August, and November 2010.

Table A-2. (Cont.)

Well	Monitoring Purpose	Hexavalent Chromium	Sr-90	Tritium	C-14	Sampled as Scheduled in 2010 (12 months)	Comment
199-K-168	Extraction	Q	S	S	S	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in February, June, and August 2010.
199-K-173	Monitoring	Q	A	A	A	No; Sr-90, tritium, and C-14 missed in 2010	Sampled in March, April, June, August, and September 2010.

Notes:

1. Requirements from *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action* (DOE/RL-2006-52) and the *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System* (DOE/RL-2006-75). Wells 199-K-130 through 199-K-162 (116-K-2 Trench) monitored under "pre-startup" phase.

2. TPA-CN-273,dated May 21, 2009, revised DOE/RL-2006-75 by specifying semi-annual sampling at KR4 and KX pump-and-treat wells for hexavalent chromium, tritium, strontium-90, carbon-14, technetium-99, and nitrate.

A = to be sampled annually

Q = to be sampled quarterly

S = to be sampled semiannually

W = to be sampled weekly (field analysis)

M = to be sampled monthly (field analysis)

Table A-3. Monitoring Wells and Constituents for 100-KR-4 Operable Unit Long-Term Monitoring

Well or Seep	Alpha	Anions	Beta	C-14	Gamma	Hexavalent Chromium	Mercury	Metals	Sr-90	Tc-99	Tritium	Sampled as Scheduled in 2010
199-K-11	--	A	A	A	--	A	--	A	--	--	A	Yes; sampled in December 2010
199-K-18	--	A	--	--	--	Q	--	A	A	A	A	Yes; sampled in April, June, August, and December 2010
199-K-19	A	A	A	A	A	S	--	A	A	A	A	Yes; sampled in July and December 2010.
199-K-20	A	A	A	A	A	Q	--	A	A	A	A	No; sampled in March, June, and August 2010
199-K-21	A	A	A	A	A	S	--	A	A	A	A	Yes; sampled in July and December 2010
199-K-22	A	A	A	A	A	A	--	A	A	A	A	No; sampled in June 2010, only analyzed for hexavalent chromium
199-K-23	--	BO	BO	--	--	A	--	BO	--	--	BO	No; not sampled in 2010
199-K-30	Q	Q	Q	S	--	Q	--	Q	Q	S	Q	No; sampled in January, April, and December 2010. Decommissioned in December 2010
199-K-31	S	A	S	A	--	A	--	A	A	A	S	Yes; sampled in March and June 2010
199-K-32A	--	A		A	--	Q	--	A	A	A	A	Yes; sampled in March, June, September, and December 2010
199-K-32B	--	A		A	--	A	--	A	A	A	A	Yes; sampled in December 2010
199-K-34	--	Q		A	--	Q	--	Q	A	A	Q	Yes; sampled in April, June, September, and December 2010
199-K-35	--	--	--	W	--	--	W	W	--	--	--	Yes; sampled weekly until decommissioned in April 2010
199-K-36	A	S	A	A	A	Q	Q	Q	A	A	S	No; sampled in March, June, and December 2010
199-K-37	--	A		A	--	S	--	A	A	A	A	Yes; sampled in March, June, September, and December 2010
199-K-106A	Q	Q	Q	A	--	Q	--	Q	A	A	Q	No; sampled in March and June 2010
199-K-107A	Q	Q	Q	A	--	Q	--	Q	A	A	Q	Yes; sampled in January, April, July, and December 2010
199-K-108A	S	S	S	Q	--	Q	--	S	Q	A	Q	Yes; sampled in January, March, June, August, September, and December 2010
199-K-110A	S	S	S	A	--	A	--	S	A	A	S	Yes; sampled in April and December 2010
199-K-111A	Q	Q	Q	Q	--	A	--	Q	A	A	Q	Yes; sampled in February, March, April, June, July, September, and December 2010
699-70-68	--	A	--	--	--	--	--	A		A	A	Yes; sampled in April, July, and November 2010
699-72-73	BO	BO	--	BO	--	BO	--	BO	BO	BO	BO	Yes; sampled in March and June 2010
699-73-61	--	BO	--	--	--	BO	--	BO	--	--	BO	Yes; sampled in May, June, and September 2010
699-78-62	--	--	--	--	--	--	--	--	--	--	--	Not sampled in 2010; adjacent to active injection well 199-K-172; no useful data
Aquifer tubes (21 tubes sampled)												
SK-057-3	A	A	A	--	A	--	--	A	--	--	A	No
SK-077-1	A	A	A	--	A	--	--	A	--	--	A	No
SK-082-2	A	A	A	--	A	--	--	A	--	--	A	No

Note: Requirements from NPL Agreement/Change Control Form 108, *Modifications to the Groundwater Sampling and Analysis Schedules for the 100-KR-4 Groundwater Sampling Project* (dated November 20, 1996), as modified by *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units* (Wanek, 1998); further modified in subsequent years.

A = to be sampled annually

BE = to be sampled biennially, in even fiscal years

BO = to be sampled biennially, in odd fiscal years

M = to be sampled monthly

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-4. Monitoring Wells and Constituents for 100-NR-2 Interim Action

Well Name	Field Parameters	Alkalinity	Alpha	Anions	Beta	Gamma	Metals	Oil and Grease	Sr-90	Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2009
199-N-2	A	A	--	A	A	--	A	--	A	--	A	No
199-N-3	A	A	--	A	A	--	A	--	A	A	A	Yes
199-N-14	A	A	--	A	A	--	A	--	A	--	A	Yes
199-N-16	A	A	--	A	A	--	A	A	A	A	--	Yes
199-N-18	A	A	--	A	A	--	A	A	A	A	A	Yes
199-N-19	A	--	--	A	--	--	A	--	A	A	A	Yes
199-N-21	A	--	--	A	--	--	A	--	--	A	--	Yes
199-N-26	A	A	--	A	--	--	A	--	--	A	--	Yes
199-N-27	A	--	--	A	--	A	A	--	A	--	A	Yes
199-N-28	A	A	--	A	--	--	A	--	A	--	--	Yes
199-N-32	S	--	--	S	S	S	S	--	S	--	S	Yes
199-N-34	A	A	--	A	--	--	A	--	A	--	A	Yes
199-N-41	A	A	--	A	--	--	A	--	A	--	A	Yes
199-N-46	S	S	S	S	S	S	S	--	S	--	S	Yes
199-N-50	A	--	--	--	A	--	--	--	A	--	A	Yes
199-N-51	A	--	--	--	A	--	--	--	A	--	A	Yes
199-N-56	A	A	A	A	A	A	A	--	A	A	A	Yes
199-N-57	A	A	A	A	A	A	A	--	A	A	A	Yes
199-N-64	A	A	A	A	A	--	A	--	A	--	A	Yes
199-N-67	A	A	A	A	A	--	A	--	A	--	A	Yes
199-N-69	A	A	A	A	A	A	A	--	A	--	A	Yes
199-N-70	A		A	A	A	A	A	--	A	--	A	Yes
199-N-73	A	A	--	A	--	--	A	--	--	--	--	Yes
199-N-74	A	--	A	--	A	A	A	--	--	--	--	Yes
199-N-75	A	A	--	A	A		A	--	A	--	A	Yes
199-N-76	S	S	--	S	S	S	S	--	S	--	S	Yes
199-N-80	A	--	A	A	A	A	A	--	A	--	A	Yes
199-N-81	A	A	--	A	A	A	A	--	A	--	A	Yes
199-N-92A	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-96A	A	--	--	A	A	--	A	A	A	A	A	Yes
199-N-99A	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-103A	A	A	A	A	A	A	A	--	A	--	A	Yes
199-N-105A	A	A	A	A	A	A	A	--	A	--	A	Yes
199-N-106A	A	A	A	A	A	A	A	--	A	--	A	No
199-N-119	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-120	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-121	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-122	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-123	A	--	--	A	A	--	A	--	A	--	A	Yes

Table A-4. (Cont.)

Well Name	Field Parameters	Alkalinity	Alpha	Anions	Beta	Gamma	Metals	Oil and Grease	Sr-90	Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2009
199-N-146	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-147	A	--	--	A	A	--	A	--	A	--	A	Yes
199-N-173	A	A	A	A	A	--	A	--	A	A	A	Yes

Notes:

1. Monitoring requirements have been modified (expanded) from *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27).

2. TPA-CN-256 (*TPA Change Notice for Modifying Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit, DOE/RL-2001-27 and Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*) modified the monitoring requirements, including updating analyses and removing decommissioned wells.

3. Field parameters include pH, temperature, conductivity, and turbidity; with dissolved oxygen and oxidation-reduction potential on some wells.

A = to be sampled annually

S = to be sampled semiannually

Table A-5. Monitoring Wells and Constituents for 100-NR-2 Shoreline Monitoring

Well or Tube Name	Alkalinity	Anions	Beta	Dissolved Oxygen	Gamma	Metals	Sr-90	Total Organic Carbons, Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2010
NVP1-1	--	--	Q	Q	--	--	--	--	--	May and June
NVP1-2	--	--	Q	Q	--	--	--	--	--	January, May, and June
NVP1-3	--	--	Q	Q	--	--	--	--	--	May and June
NVP1-4	--	--	Q	Q	--	--	--	--	--	March and June
NVP1-5	--	--	Q	Q	--	--	--	--	--	March, June, and September
NVP2-116.3	--	--	Q	Q	--	--	--	--	--	March and June
NVP2-116.0	Q	Q	M	M	Q	Q	Q	--	Q	February, March, April, May, June, July, December (2)
NVP2-115.7	--	--	Q	Q	--	--	--	--	--	March, June, and September
NVP2-115.4	--	--	Q	Q	--	--	--	--	--	March, June, and September
NVP2-115.1	--	--	Q	Q	--	--	--	--	--	March, June, and September
Array-0A	A	A	Q	Q	A	A	Q	Q	A	March, June, and September
Array-1A	A	A	Q	Q	A	A	Q	Q	A	January, March, June, and September
Array-2A	A	A	Q	Q	A	A	Q	Q	A	January, March, June, and September
Array-3A	Q	Q	M	M	Q	Q	Q	--	Q	February, March, April. May, June, August, September, December (2)
Array-4A	Q	Q	M	M	Q	Q	Q	--	Q	February, March, April. May, June, July, August, September, December (2)
Array-6A	Q	Q	M	M	Q	Q	Q	--	Q	February, March, April, May, June, August, September, December (2)
Array-7A	A	A	Q	Q	A	A	A	--	A	Unable to sample tube, putting in replacement
Array-8A	A	A	Q	Q	A	A	A	--	A	March, June, and September
Array-8.5A	A	A	Q	Q	A	A	A	--	A	March, June, and September
Array-9A	A	A	Q	Q	A	A	A	--	A	March and June
Array-10A	A	A	Q	Q	A	A	A	--	A	March, June, and September
Array-11A	A	A	Q	Q	A	A	A	--	A	March, June, and September
Array-12A	A	A	Q	Q	A	A	A	--	A	March and June
Array-13A	A	A	Q	Q	A	A	A	--	A	March
Array-14A	A	A	Q	Q	A	A	A	--	A	March and June
Array-15A	A	A	Q	Q	A	A	A	--	A	March, June, and September
Array-16A	A	A	Q	Q	A	A	A	--	A	No
C6132	A	A	Q	Q	A	A	Q	Q	A	March and September
C6135	A	A	Q	Q	A	A	Q	Q	A	March and September

Note: Requirements from DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, Rev. 1.

A = to be sampled annually

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-6. Monitoring Wells and Constituents for the 100-NR-2 Apatite Treatability Test Plan

Well Name	Well Type	Anions	Beta	Metals	Sr-90	Sampled as Scheduled in 2010
199-N-122	Compliance	Q	Q	Q	P	Yes; February, May, and August
199-N-123	Compliance	BM/Q	BM/Q	BM/Q	P	Yes; February, May, and August
199-N-126	Monitoring	FQ	FQ	FQ	P	August only
199-N-127	Monitoring	FQ	FQ	FQ	P	Unable to sample in August
199-N-128	Monitoring	Q	Q	Q	P	Yes; February, May, and August
199-N-129	Monitoring	FQ	FQ	FQ	P	May only
199-N-130	Monitoring	FQ	FQ	FQ	P	August only
199-N-131	Monitoring	FQ	FQ	FQ	P	Unable to sample in August
199-N-132	Monitoring	Q	Q	Q	P	February (early March), May, and August
199-N-133	Monitoring	FQ	FQ	FQ	P	May only
199-N-136	Barrier	FQ	FQ	FQ	P	August only
199-N-137	Barrier	FQ	FQ	FQ	P	August only
199-N-138	Barrier	FQ	FQ	FQ	P	August only
199-N-139	Barrier	FQ	FQ	FQ	P	August only
199-N-140	Barrier	FQ	FQ	FQ	P	August only
199-N-141	Barrier	FQ	FQ	FQ	P	August only
199-N-142	Barrier	Q	Q	Q	P	Yes; February, May, and August
199-N-143	Barrier	FQ	FQ	FQ	P	August only
199-N-144	Barrier	FQ	FQ	FQ	P	August only
199-N-145	Barrier	Q	Q	Q	P	Yes; February, May, and August
199-N-146	Compliance	Q	Q	Q	P	Yes; February, May, and August
199-N-147	Compliance	Q	Q	Q	P	Yes; February, May, and August
199-N-148	Monitoring	Q	Q	Q	P	Yes; February, May, and August
199-N-149	Monitoring	Q	Q	Q	P	February and May; unable to sample in August
199-N-150	Monitoring	Q	Q	Q	P	February and May; unable to sample in August
199-N-151	Monitoring	BM/Q	BM/Q	BM/Q	P	Yes; February, May, and August
199-N-152	Monitoring	FQ	FQ	FQ	P	August only
199-N-153	Monitoring	FQ	FQ	FQ	P	August only
199-N-154	Monitoring	FQ	FQ	FQ	P	August only
199-N-155	Monitoring	Q	Q	Q	P	February and May; unable to sample in August
199-N-156	Monitoring	Q	Q	Q	P	Yes; February, May, and August
199-N-159	Barrier	FQ	FQ	FQ	P	August only
199-N-160	Barrier	Q	Q	Q	P	Yes; February, May, and August
199-N-161	Barrier	FQ	FQ	FQ	P	August only
199-N-162	Barrier	FQ	FQ	FQ	P	August only
199-N-163	Barrier	FQ	FQ	FQ	P	August only
199-N-164	Barrier	Q	Q	Q	P	Yes; February, May, and August

Notes: Requirements from *100/300 Area Unit Managers Meeting Minutes*, Attachment 2 (FH, 2008). Additional requirements are applied during injection.

P = periodic splits for strontium-90 during performance monitoring period; full set at least once a year

Q = schedule changed to February, May, August, and November quarterly monitoring in accordance with TPA-CN-271 (*TPA Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit DOE/RL-2005-96 Addendum*)

FQ = final quarterly performed under TPA-CN-27; future performance monitoring will be twice each year (at high and low river stages)

Table A-7. Monitoring Wells and Constituents for the 100-HR-3 Operable Unit In Situ Redox Manipulation System

Well	Purpose	Anions	Cations	Arsenic	Hexavalent Chromium	Metals	Sulfate	Uranium	Tritium	Sampled as Scheduled in Reporting Period
199-D2-6	Monitoring	A	--	A	A	A	A	A	A	Yes
199-D2-8	Monitoring	--	--	--	M	--	--	--	--	Yes
199-D3-2	Monitoring	Q	--	A	Q	A	Q	--	A	No
199-D4-1	Monitoring	Q	--	A	Q	A	Q	A	--	No
199-D4-13	Barrier performance	Q	--	A	Q	A	Q	--	A	No
199-D4-14	Barrier performance	Q	--	A	Q	A	Q	--	A	No
199-D4-15	Monitoring	A	--	A	Q	A	A	A	A	No
199-D4-19	Barrier performance	Q	--	A	Q	A	A	A	A	No
199-D4-20	Monitoring	Q	--	A	Q	A	Q	A	A	No
199-D4-22	Monitoring	Q	--	A	Q	A	Q	--	A	No
199-D4-23	Compliance	Q	--	A	Q	A	Q	A	A	No
199-D4-26	Monitoring	Q	--	A	Q	A	Q	A	--	No
199-D4-31	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-32	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-38	Compliance	A	Q	A	Q	Q	Q	A	--	No
199-D4-39	Compliance	Q	--	A	Q	A	Q	A	--	No
199-D4-4	Monitoring	Q	--	A	Q	A	Q	A	--	No
199-D4-48	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-5	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-6	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-62	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-7	Barrier performance	Q	--	A	Q	A	Q	A	--	No
199-D4-78	Barrier performance	--	--	--	--	--	--	--	A	Yes
199-D4-83	Compliance	Q	--	A	Q	A	Q	A	--	No
199-D4-84	Compliance	--	--	--	--	--	--	--	A	Yes
199-D4-85	Compliance	--	--	--	--	--	--	--	A	Yes
199-D4-86	Compliance	--	--	--	--	--	--	--	A	Yes
199-D5-36	Monitoring	Q	--	A	Q	A	Q	A	A	No
199-D5-38	Monitoring	Q	--	A	Q	A	Q	A	A	No
199-D5-39	Monitoring	Q	--	A	Q	A	Q	A	A	No
199-D5-43	Monitoring	Q	--	A	Q	A	Q	A	A	No
DD-39	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
199-D4-25	Barrier performance	Q	Q	Q	Q	Q	Q	Q	--	No
199-D4-27	Barrier performance	Q	Q	Q	Q	Q	Q	Q	--	No
199-D4-92	Barrier performance	Q	Q	Q	Q	Q	Q	Q	--	No
199-D4-93	Barrier performance	Q	Q	Q	Q	Q	Q	Q	--	No
DD-41	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
DD-42	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
DD-43	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
DD-44	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
Redox-1	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
Redox-2	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
Redox-3	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
Redox-4	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No
TD-39	Aquifer tube	Q	Q	Q	Q	Q	Q	Q	--	No longer in use

Notes: Requirements from *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation* (DOE/RL-99-51).

A = to be sampled annually

M = to be sampled monthly

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-8. Monitoring Wells and Constituents for the 100-HR-3 Pump-and-Treat Systems

Well	Monitoring Purpose	Hexavalent Chromium	Nitrate	Sr-90	Tc-99	Tritium	Uranium	Sampled as Scheduled in CY 2010
199-D8-53	Extraction	Q	--	S	--	S	--	Yes
199-D8-54A	Extraction	Q	--	S	--	S	--	Yes
199-D8-54B	Performance	S	--		--	--	--	Not sampled
199-D8-68	Extraction	Q	--	S	--	S	--	Yes
199-D8-69	Compliance	Q	--	A	--	A	--	Hexavalent chromium missed last three quarters, no strontium-90 or tritium
199-D8-70	Compliance	Q	--	A	--	A	--	Hexavalent chromium missed last two quarters
199-D8-71	Performance	S	--	--	--	--	--	Yes
199-D8-72	Extraction	Q	--	S	--	S	--	Hexavalent chromium missed last quarter*
199-H3-2A	Former extraction well	S	S	S	S	S	S	Yes
199-H3-2C	New extraction well	A	A	A	A	A	A	Sampled only for hexavalent chromium
199-H3-3	Former injection well	S	A	S	--	S	--	Yes
199-H3-4	Former injection well	S	A	S	--	S	--	Yes
199-H3-5	Former injection well	S	A	S	--	S	--	Yes
199-H4-3	Extraction/performance	Q	S	S	S	S	S	Yes
199-H4-4	Extraction/compliance	Q	S	S	S	S	S	Hexavalent chromium missed first quarter, not sampled second half of year
199-H4-5	Compliance	M	A	A	A	A	A	Hexavalent chromium missed February and October through December*
199-H4-6	Performance	S	--	--	--	--	--	Yes
199-H4-8	Performance	S	--	--	--	--	--	Yes
199-H4-10	Performance	S	--	--	--	--	--	Yes
199-H4-11	Performance/former extraction well	Q	S	S	S	S	S	Hexavalent chromium missed third quarter
199-H4-12A	Extraction	Q	S	S	S	S	S	Hexavalent chromium missed third quarter
199-H4-12B	Performance	S	--	--	--	--	--	Yes
199-H4-12C	Extraction/performance	S	S	S	S	S	S	Not sampled first half of year, no strontium-90
199-H4-13	Performance	S	--	--	--	--	--	Yes
199-H4-15A	Extraction	Q	S	S	S	S	S	Yes
199-H4-15B	Performance	S	--	--	--	--	--	Yes
199-H4-15CS	Performance	S	--	--	--	--	--	Not sampled second half of year*
199-H4-16	Performance	S	--	--	--	--	--	Yes
199-H4-45	Performance	S	--	--	--	--	--	Yes
199-H4-46	Performance	S	--	--	--	--	--	Yes
199-H4-48	Performance	S	--	--	--	--	--	Yes
199-H4-49	Performance	S	--	--	--	--	--	Not sampled first half of year
199-H4-63	Extraction/compliance	M	A	A	A	A	A	Hexavalent chromium missed March, July, August, November, and Deember
199-H4-64	Extraction/compliance	M	A	A	A	A	A	Hexavalent chromium missed January, February, and August through December No co-contaminants sampled*
199-H4-65	Former extraction well	S	--	--	--	--	--	Yes
199-H5-1A	Performance	S	--	--	--	--	--	Yes

Note: Requirements from *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90), as modified by the *Remedial Design and Remedial Action Work Plan for 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action* (DOE/RL-96-84), further modified in subsequent years.

* Some monthly, quarterly, and annual samples missed in fall 2010 because of inclement weather and process-related issues.

A = to be sampled annually

M = to be sampled monthly

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-9. Monitoring Wells and Constituents for 100-HR-3 Operable Unit Long-Term Monitoring

Well	Alpha	Anions	Beta	Hexavalent Chromium	Metals	Sulfate	Tritium	Sampled as Scheduled in CY 2010
199-D2-11	--	A	--	M	--	--	--	Hexavalent chromium missed October through December*
199-D4-1	--		--		--	--	--	Not scheduled
199-D5-102	--	A	--	M	--	--	--	No anions; hexavalent chromium missed October through December*
199-D5-103	--	A	--	M	A	A	--	Hexavalent chromium missed October through December*
199-D5-104	--	--	--	M	--	--	--	Hexavalent chromium missed January, June, and December
199-D5-119	--	A	--	M	A	A	--	Hexavalent chromium missed October through December*
199-D5-120	--	--	--	M	--	--	--	Hexavalent chromium missed October and November*
199-D5-121	--	--	--	M	--	--	--	Hexavalent chromium missed October through December*
199-D5-122	--	--	--	M	--	--	--	Hexavalent chromium missed October through December*
199-D5-123	--	--	--	M	--	--	--	Hexavalent chromium missed October through December*
199-D5-125	--	--	--	M	--	--	--	Hexavalent chromium missed August through November
199-D5-126	--	--	--	M	--	--	--	Hexavalent chromium missed October and November*
199-D5-13	A	A	A	S	A	A	A	Hexavalent chromium missed second half of year*
199-D5-14	A	A	A	S	A	A	A	Hexavalent chromium missed second half of year*
199-D5-15	A	A	A	S	A	A	A	Yes
199-D5-16	A	A	A	S	A	A	A	Yes
199-D5-17	A	A	A	A	A	A	A	Yes
199-D5-18	--	--	--	A	--	--	--	Yes
199-D5-19	--	--	--	A	--	--	--	Yes
199-D5-20	--	--	--	A	A	--	A	Not sampled
199-D5-32	--	A	--	A	--	A	S	Only hexavalent chromium sampled
199-D5-33	--	--	--	Q	--	--	--	Hexavalent chromium missed last quarter *
199-D5-34	--	A	--	Q	A	A	--	Hexavalent chromium missed last quarter *
199-D5-36	A	Q	A	Q	A	A	A	No alpha/beta or tritium, no hexavalent chromium or anions last two quarters
199-D5-37	--	S	--	S	--	S	--	No samples taken last half of year*
199-D5-38	A	Q	A	Q	A	Q	A	Hexavalent chromium and anions missed last quarter*
199-D5-39	A	A	A	A	A	A	S	Only hexavalent chromium sampled*
199-D5-40	A	Q	A	Q	A	Q	A	Yes
199-D5-41	--	A	--	A	--	--	--	Not sampled
199-D5-43	A	Q	A	Q	A	Q	A	Last quarter not sampled*
199-D5-44	--	A	--	A	--	--	--	Yes
199-D5-92	--	A	--	A	--	A	A	No anions or sulfate
199-D5-93	--	A	--	A	A	--	--	Yes
199-D5-97	--	A	--	Q	--	--	--	Hexavalent chromium missed last quarter*
199-D5-98	--	A	--	Q	--	--	--	No anions, hexavalent chromium missed last quarter*
199-D5-99	--	A	--	M	--	--	--	Hexavalent chromium missed October through December*
199-D8-4	A	A	A	S	A	A	A	Only hexavalent chromium sampled first half of year*
199-D8-5	A	A	A	Q	A	A	A	Yes
199-D8-54B	A	A	A	A	A	A	A	Not sampled*
199-D8-55	--	--	--	A	--	--	--	Yes
199-D8-6	A	A	A	A	A	A	A	Not sampled*
199-H4-10	A	A	A	S	A	A	A	Yes
199-H4-13	A	A	A	S	A	A	A	Yes
199-H4-15CP	--	--	--	S	--	--	--	Missed second half of year*
199-H4-15CQ	--	--	--	S	--	--	--	Missed second half of year*
199-H4-15CR	--	--	--	S	--	--	--	Missed second half of year*
199-H4-45	A	A	A	S	A	A	A	Yes
199-H4-46	A	A	A	S	A	A	A	Hexavalent chromium missed second half of year*
199-H4-47	--	--	--	--	--	--	--	Not scheduled
199-H4-48	--	--	--	S	--	--	--	Hexavalent chromium missed second half of year*

Table A-9. (Cont.)

Well	Alpha	Anions	Beta	Hexavalent Chromium	Metals	Sulfate	Tritium	Sampled as Scheduled in CY 2010
199-H4-49	--	--	--	S	--	--	--	Hexavalent chromium missed first half of year
199-H4-5	A	A	A	M	A	A	A	Hexavalent chromium missed last quarter*
199-H4-6	A	A	A	S	A	A	A	Yes
199-H4-9	A	A	A	A	A	A	A	Yes
199-H5-1A	--	--	--	S	--	--	--	Yes
199-H6-1	A	A	A	--	A	A	A	Yes
699-86-42	--	--	--	A	--	--	--	Not sampled*
699-87-42A	--	--	--	A	--	--	--	Not sampled*
699-88-41	--	--	--	A	--	--	--	Not sampled*
699-90-45	--	--	--	A	--	--	--	Yes
699-91-46A	--	--	--	A	--	--	--	Not sampled*
699-93-48A	--	--	--	A	--	--	--	Yes
699-94-41	Q	A	Q	A	A	A	A	Yes
699-94-43	Q	A	Q	A	A	A	A	Yes
699-95-45	Q	A	Q	A	A	A	A	Yes
699-95-48	Q	A	Q	A	A	A	A	Yes
699-95-51	Q	A	Q	A	A	A	A	Yes
699-96-43	A	A	A	A	A	A	A	Not sampled*
699-96-49	A	A	A	A	A	A	A	Not sampled*
699-96-52B	Q	A	Q	A	A	A	A	Alpha/beta missed last quarter*
699-97-41	Q	A	Q	A	A	A	A	Not sampled
699-97-43	--	--	--	--	--	--	--	Not scheduled
699-97-43B	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-97-43C	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-97-45	Q	A	Q	A	A	A	A	Yes
699-97-45B	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-97-48B	Q	A	Q	A	A	A	A	Alpha/beta missed last quarter*
699-97-48C	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-97-51A	A	A	A	A	A	A	A	Yes
699-98-43	Q	A	Q	A	A	A	A	Yes
699-98-46	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-98-49A	--	--	--	A	--	--	--	Yes
699-98-51	Q	A	Q	A	A	A	A	Yes
699-99-41	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-99-42B	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
699-99-44	Q	A	Q	A	A	A	A	Only alpha, beta, and hexavalent chromium sampled*
Seep SD-102-1	--	--	--	A	--	--	--	Not sampled*
Seep SD-110-1	--	--	--	A	--	--	--	Not sampled*
Seep SD-110-2	--	--	--	A	--	--	--	Not sampled*
Seep SD-098-1	--	--	--	A	--	--	--	Not sampled*
Seep SH-144-1	--	--	--	A	--	--	--	Not sampled*
Seep SH-145-1	--	--	--	A	--	--	--	Not sampled*
Seep SH-150-1	--	--	--	A	--	--	--	Not sampled*
Seep SH-152-2	--	--	--	A	--	--	--	Not sampled*
Seep SH-153-1	--	--	--	A	--	--	--	Not sampled*

Notes: Monitoring requirements have been modified (expanded) from *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units* (CCN 062039).

* Some monthly, quarterly, and annual samples missed in fall 2010 due to inclement weather and process-related issues.

A = to be sampled annually

M = to be sampled monthly

S = to be sampled semi-annually

Q = to be sampled quarterly

Table A-10. Monitoring Wells and Constituents for the 100-FR-3 Operable Unit

Well	Alkalinity	Alpha	Anions	Hexavalent Chromium	Metals	Sr-90	Tritium	TCE (VOA)	Uranium	Sampled as Scheduled in Reporting Period
199-F1-2[a]	BO	--	BO	--	BO	--	--	--	--	Yes
199-F5-1[a]	A	BE	A	--	A	BE	BE	--	--	Yes
199-F5-4[a]	BO	BO	BO	--	BO	--	BO	BO	--	Yes
199-F5-6[a]	A	BE	A	--	A	BE	BE	--	--	Yes
199-F5-42[a]	BO	BO	BO	--	BO	BO	BO	--	--	Yes
199-F5-43A[a]	BE	BE	BE	--	BE	BE	BE	--	--	Not scheduled
199-F5-43B	BE	BE	BE	--	BE	BE	--	--	--	Not scheduled
199-F5-44[a]	BE	BE	BE	--	BE	BE	BE	--	--	Not scheduled
199-F5-45[a]	BO	BO	BO	--	BO	BO	BO	BO	BO	Yes
199-F5-46[a]	BE	A	BE	--	BE	BE	A	BE	A	Yes
199-F5-47	BE	BE	BE	--	BE	--	BE	--	BE	Not scheduled
199-F5-48[a]	BO	BO	BO	--	BO	--	BO	--	BO	Yes
199-F6-1[a]	BO	BO	BO	--	BO	BO	BO	--	--	Yes
199-F7-1[a]	BE	--	BE	--	BE	--	--	BE	--	Yes[b]
199-F7-2[a]	BE	BE	BE	--	BE	--	BE	BE	--	Not scheduled
199-F7-3[a]	BE	BE	BE	--	BE	--	BE	BE	--	Yes[b]
199-F8-2[a]	BO	BO	BO	--	BO	--	BO	--	BO	Yes
199-F8-3[a]	BE	BE	BE	--	BE	BE	BE	BE	BE	Not scheduled
199-F8-4[a]	BE	BE	BE	--	BE	--	BE	--	BE	Not scheduled
199-F8-7[a]	A	--	A	A	A	A	A	A	A	Yes
699-58-24	BE	--	BE	--	BE	--	--	--	--	Not scheduled
699-60-32	BO	--	BO	--	BO	--	--	--	--	Yes
699-62-31	BO	--	BO	--	BO	--	--	--	--	Yes
699-62-43F	BE	--	BE	--	BE	--	BE	--	--	Not scheduled
699-63-25A	BO	--	BO	--	BO	--	BO	--	--	Yes
699-63-55	BO	--	BO	--	BO	--	BO	--	--	Yes
699-64-27	BE	--	BE	--	BE	--	--	--	--	Not scheduled
699-66-23	BE	--	BE	--	BE	--	BE	--	--	Not scheduled
699-67-51	BO	--	BO	--	BO	--	BO	--	--	Yes
699-71-30	BO	BO	BO	--	BO	--	BO	--	--	Yes
699-74-44	BO	--	BO	--	BO	--	--	BO	--	Yes
699-77-36[a]	BE	--	BE	--	BE	--	--	BE	--	Not scheduled
699-77-54[a]	BO	--	BO	--	BO	--	--	--	--	Yes
699-81-38	BE	--	BE	--	BE	--	--	--	--	Not scheduled
699-83-47	BE	--	BE	--	BE	--	--	BE	--	Not scheduled
199-F5-52	Q	Q	Q	Q	Q	Q	Q	Q	Q	New wells to be sampled 2011
199-F5-53	Q	Q	Q	Q	Q	Q	Q	Q	Q	
199-F5-54	Q	Q	Q	Q	Q	Q	Q	Q	Q	

Notes:

1. Requirements from *100-FR-3 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-49, Rev. 1), as modified by TPA-CN-241 (*TPA Change Notice for Modifying 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1*).

2. All wells are screened in the unconfined aquifer, except wells 199-F5-43B and 199-F5-53, which are screened in the Ringold Formation aquitard.

a. Wells sampled three times in 2010 for RI/FS to evaluate spatial and temporal uncertainty. Analyzed for RI/FS COPCs.

b. Sampling not required for these wells in odd fiscal year, but sampled to check rising TCE concentrations from previous year.

A = to be sampled annually

BE = to be sampled biennially, even fiscal years

BO = to be sampled biennially, odd fiscal years (note that fiscal year 2011 sampling was scheduled for October 2010; sampling occurred between late September and November 2010)

Q = new well; sampled quarterly first year after installation

VOA = volatile organic analyte

Table A-11. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit

Well	Anions	Arsenic	I-129	Metals	Sr-90	Tc-99	Tritium	Uranium	VOA	Sampled as Scheduled in CY 2010
299-W6-10	--	--	--	--	--	--	--	--	--	Dry
299-W7-4	--	--	--	--	--	--	--	--	--	Not sampled
299-W8-1	--	--	--	--	--	--	--	--	--	Dry
299-W10-1	A	--	--	A	--	--	A	--	A	Yes
299-W10-4	S	S	S	--	--	S	S	--	S	Yes
299-W10-5	A	--	--	A	--	A	A	--	A	Missed (November)
299-W10-22	S	--	--	S	--	S	S	--	S	Yes
299-W10-23	S	--	--	S	--	S	S	--	S	Yes
299-W10-24	Q	--	Q	Q	--	Q	Q	--	Q	Yes
299-W10-33	S	--	S	--	--	S	S	--	S	Yes
299-W11-3	S	--	S	S	--	--	S	--	S	Missed (November)
299-W11-6	S	--	S	--	--	S	--	--	S	Missed (November)
299-W11-7	A	--	A	A	--	A	A	--	A	Yes
299-W11-10	S	--	--	--	--	--	--	--	S	Yes
299-W11-13	S	--	S	--	--	S	S	--	S	Yes
299-W11-18	A	--	A	--	--	A	A	--	A	Yes
299-W11-34P	S	--	S	S	--	S	S	--	S	Missed (December)
299-W11-37	S	--	S	--	--	--	S	S	S	Yes
299-W11-39	Q	--	Q	Q	--	Q	Q	--	Q	Yes
299-W11-40	Q	--	--	Q	--	Q	Q	--	Q	Yes
299-W11-42	Q	--	Q	Q	--	Q	Q	--	Q	Yes
299-W11-43	S	--	S	S	--	--	S	S	S	Missed (November)
299-W11-45	Q	--	Q	Q	--	Q	Q	--	Q	Missed (October)
299-W11-46	Q	--	Q	Q	--	Q	Q	--	Q	Yes
299-W11-47		--	--	--	--	--	--	--	--	Not sampled
299-W11-48	S	--	S	S	--	S	S	--	S	Missed (November)
299-W11-87	A	--	A	A	--	A	A	--	A	Missed (November)
299-W11-88	S	--	--	S	--	--	S	--	S	Missed (November)
299-W12-1	A	--	A	A	--	--	A	--	A	
299-W13-1	S	--	--	S	--	S	S	--	S	Missed (November)
299-W14-14	A	--	A	A	--	A	A	--	A	Yes
299-W14-16	A	--	A	A	--	A	A	--	A	Yes
299-W14-71	A	--	--	A	--	--	A	--	A	Yes
299-W14-72	A	--	--	A	--	--	A	--	A	Yes
299-W15-1	S	--	--	--	--	--	--	--	S	Yes
299-W15-2	A	--	--	A	--	--	A	--	A	Yes
299-W15-7	S	--	--	--	--	S	--	--	S	Missed (November)
299-W15-11	S	--	--	--	--	S	S	--	S	Missed (November)
299-W15-15	--	--	--	--	--	--	--	--	--	dry
299-W15-17	S	--	--	S	--	S	--	--	S	Yes
299-W15-30	S	--	--	S	--	S	--	--	S	Yes
299-W15-31A	S	--	--	--	--	S	--	--	S	Yes
299-W15-34	A	--	--	--	--	A	--	--	A	Yes
299-W15-35	A	A	A	--	A	A	--	A	A	Yes

Table A-11. (Cont.)

Well	Anions	Arsenic	I-129	Metals	Sr-90	Tc-99	Tritium	Uranium	VOA	Sampled as Scheduled in CY 2010
299-W15-36	A	--	--	--	--	--	--	--	A	Missed (May)
299-W15-38	--	--	--	--	--	--	--	--	--	Dry
299-W15-39	--	--	--	--	--	--	--	--	--	Dry
299-W15-40	A	--	A	A	--	A	A	--	A	Yes
299-W15-41	S	--	--	S	--	S	S	--	S	Yes
299-W15-42	S	--	--	S	--	S	--	--	S	Yes
299-W15-43	S	--	--	S	--	S	S	--	S	Yes
299-W15-44	S	--	S	S	--	S	S	--	S	Yes
299-W15-45	A	--	--	--	--	A	--	--	A	Missed (November)
299-W15-46	Q	--	--	--	--	Q	--	--	Q	Missed (November)
299-W15-47	S	S	S	--	S	S	S	S	S	Missed (November)
299-W15-49	S	--	--	--	--	S	--	--	S	Missed (November)
299-W15-50	S	--	--	S	--	S	--	--	S	Missed (November)
299-W15-152	A	--	--	--	--	--	--	--	A	Missed (January)
299-W15-763	--	--	Q	--	--	Q	--	--	Q	Yes
299-W15-765	Q	--	Q	Q	--	Q	Q	--	Q	Yes
299-W17-1	S	--	--	S	--	S	S	--	S	Yes
299-W18-1	Q	--	--	Q	--	--	Q	--	Q	Missed (September)
299-W18-16	S	--	--	--	--	--	--	--	S	Missed (November)
299-W18-23	--	--	--	--	--	--	--	--	--	Dry
699-43-69	S	--	--	--	--	--	--	--	S	Yes
699-43-89	A	A	A	A	A	A	A	A	A	Yes
699-44-64	A	--	A	--	--	A	--	A	A	Yes
699-45-69A	A	--	A	--	--	--	--	--	A	Yes
699-45-69C	A	--	--	--	--	--	A	--	A	Yes
699-48-71	S	S	S	S	--	S	S	--	S	Yes
699-48-77A	A	A	A	--	A	A	A	A	A	Yes
699-50-74	S	--	S	S		S	S	S	S	Yes
699-55-60A	A	A	A	--	A	A	A	A	A	Yes

Notes:

1. Requirement have been modified (expanded) from DOE/RL-2003-55.
2. The following wells (from DOE/RL-2003-55) have gone dry: 299-W7-12, 299-W10-13, 299-W10-20, 299-W10-21, 299-W11-14, and 299-W18-27.
3. Samples were not collected during September, October, and November 2010 due to a stop work.

A = to be sampled on an annually

BE = to be sampled biennially, even years

BO = to be sampled biennially, odd years

S = to be sampled semiannually

Q = to be sampled quarterly

VOA = volatile organic analyte

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	C-14	Chromium	I-129	Iron	Manganese	Nitrate and Fluoride	Se-79	Sr-90	Tc-99	Tritium	Uranium	VOA	Sampled as Scheduled in 2010
299-W15-37[a]	A	A	--	--	--	--	--	A	--	--	--	--	A	S	Yes
299-W18-15	S	--	--	--	--	--	--	S	--	--	--	--	S	S	Yes
299-W18-21[a]	A	--	--	--	--	--	--	A	--	--	A	--	A	S	Second sampling not successful; well is dry
299-W18-22[a]	A	--	--	--	--	--	--	A	--	--	A	--	A	S	Yes
299-W18-30	A	--	--	--	A	--	--	A	--	--	--	--	A	A	Yes
299-W19-4	--	--	--	--	BO	--	--	BO	--	--	BO	--	BO	BO	Not scheduled
299-W19-18[b]	--	--	--	--	A	--	--	A	--	--	A	--	A	A	Yes
299-W19-101[c]	--	--	--	--	Q	--	--	Q	--	--	Q	Q	Q	Q	No; three samples missed due to maintenance issues
299-W19-105[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
299-W19-107[g]	--	--	--	--	S	--	--	S	--	--	S	--	S	S	Yes
299-W19-34A	A	--	--	--	A	--	--	A	--	--	A	--	A	A	Yes
299-W19-34B	BE	--	--	--	BE	--	--	BE	--	--	BE	--	BE	BE	Yes
299-W19-35	--	S	--	--	S	--	--	S	--	--	S	--	S	S	No; second sampled delayed until 2011
299-W19-36[d]	--	--	--	--	A	--	--	Q	--	--	Q	--	Q	Q	No; three samples missed due to system outages and stop work
299-W19-43[e]	--	--	--	--	S	--	--	Q	--	--	Q	--	Q	Q	No; three samples missed due to system outages and stop work
299-W19-46	--	S	--	--	S	--	S	S	--	--	S	S	S	S	Yes
299-W19-48	--	--	--	--	Q	--	--	Q	--	--	Q	Q	Q	Q	No; one sample missed due to stop work
299-W19-49[f,g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
299-W21-2[g]	--	--	--	--	S	--	--	S		S	S	S	S	S	No; one sample missed due to stop work
299-W22-26	--	A	--	--	A	--	--	A	A	--	A	A	A	A	Yes
299-W22-45	--	A	--	--	A	--	--	A	--	A	--	A	A	A	Yes
299-W22-48	S	S	--	--	S	--	S	S	--	S	--	S	S	S	Yes
299-W22-49	--	S	--	--	S	S	S	S	--	S	S	S	S	S	Yes
299-W22-69[g]	--	--	--	--	A	--	--	A	--	--	A	A	--	A	Yes
299-W22-72[g]	--	--	S	--	S	--	--	S	--	S	S	S	S	S	Yes
299-W22-83	--	Q	--	--	Q	--	--	Q	Q	Q	Q	Q	Q	Q	Yes
299-W22-86[g]	--	--	--	S	S	--	--	S	S	--	--	S	--	S	Yes
299-W22-87[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
299-W22-88[g]	--	--	--	--	S	--	--	S	--	--	S	S	S		Yes
299-W23-4	S	--	--	--	--	--	--	S	--	--	--	S	S	S	Yes
299-W23-15	--	--	--	--	--	S	--	S	--	--	S	S	S	S	Yes
299-W23-21	--	--	--	--	--	--	--	Q	--	--	Q	Q	Q	Q	Yes
299-W26-13	--	--	--	--	BO	--	--	BO	--	--	--	BO	BO	BO	Not scheduled
299-W26-14	--	--	--	--	BE	--	BE	BE	--	--	BE	BE	BE	BE	Yes
699-30-66[g]	--	--	--	S	S	--	--	S	--	--	--	S	S	S	No; second sample delayed until 2011 due to stop work
699-32-62	--	--	--	BO	BO	--	--	BO	--	--	--	BO	--	--	Not scheduled
699-32-72A	--	--	--	--	BO	--	--	BO	--	--	--	BO	--	BO	Not scheduled
699-32-76[g]	--	--	--	BO	BO	--	--	BO	--	--	--	--	--	BO	Not scheduled

Table A-12. (Cont.)

Well	Arsenic	Cadmium	C-14	Chromium	I-129	Iron	Manganese	Nitrate and Fluoride	Se-79	Sr-90	Tc-99	Tritium	Uranium	VOA	Sampled as Scheduled in 2010
699-33-74[g]	--	--	--	A	A	--	--	A	--	--	A	A	A	A	Yes
699-33-75[g]	--	--	--	S	S	--	--	S	--	--	--	S	S	S	Yes
699-33-76[g]	--	--	--	A	A	--	--	A	--	--	--	--	--	A	No; delayed until 2011 due to stop work
699-34-72[g]	--	--	S	--	S	--	--	S	--	S	S	S	S	S	No; second sample missed due to stop work
699-35-66A	--	--		BO	BO	--	--	BO	--	--	--	BO	--	BO	Not scheduled
699-35-70	--	--	BE		BE	--	--	BE	--	--	--	BE	--	BE	Missed; well is dry
699-35-78A	A	--	--	--	--	--	--	A	--	--	--	--	A	A	Yes
699-36-61A	--	--	--	BE	BE	--	--	BE	--	--	--	BE	--	--	Yes
699-36-70A	--	--	--	--	A	--	--	A	--	--	A	A	A	A	Yes
699-36-70B[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	No; second sample missed due to stop work
699-38-65	--	--	--	--	A	--	--	A	--	--	--	A	--	--	Yes
699-38-68A	--	--	--	--	BO	--	--	BO	--	--	BO	BO	BO	BO	Not scheduled
699-38-70B	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
699-38-70C	--	--	--	--	S	--	--	S	--	--	S	S	S	S	No; second sample delayed until 2011 due to stop work
699-40-62	--	--	--	--	BO	--	--	BO	--	--	BO	BO	BO	BO	Not scheduled
699-40-65[g]	--	--	--	--	S	--	--	S	--	--	--	S	--	S	No; second sample delayed until 2011 due to stop work

Notes:

1. Requirements modified from *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-92-76, Rev. 1).

2. Wells listed DOE/RL-92-76 that are now dry include the following: 299-W18-21, 299-W18-33, 299-W19-37, 299-W19-40, 299-W22-9, 299-W22-20, 299-W23-9, 299-W23-10, 299-W23-14 (replaced with well 299-W23-21), 699-35-70, and 699-38-70.

3. Well 299-W19-39 is included in the DOE/RL-92-76 but is no longer sampled; the well is configured as an extraction well but is not operating and cannot be sampled.

a. The VOAs listed as annual in DOE/RL-92-76; sampled semiannually to support the 200-ZP-1 pump-and-treat system.

b. Not listed in DOE/RL-92-76 but sampled annually to support the 200-UP-1 pump-and-treat system.

c. Listed as "299-W19-50 (new well 'L')" in DOE/RL-92-76; was abandoned during drilling and replaced by 299-W19-101.

d. Frequency specified as annual in DOE/RL-92-76; now a pump-and-treat system extraction well sampled quarterly.

e. Frequency specified as semiannual in DOE/RL-92-76; now a pump-and-treat system extraction well sampled quarterly.

f. Listed as "299-W19-47 (new well 'M')" in DOE/RL-92-76; assumed to be a typographical error. New well "M" is 299-W19-49.

g. Frequency reduced from quarterly after first year of sampling.

A = to be sampled annually

BE = to be sampled biennially, even fiscal years

BO = to be sampled biennially, odd fiscal years

CY = calendar year

Q = to be sampled quarterly

S = to be sampled semiannually

VOA = volatile organic analyte

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2010
	Cs-137	Co-60	Cyanide	I-129	Nitrate	Pu-239/240	Sr-90	Tc-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Am-241	Arsenic	Metals (Filtered)	Np-237	TOC/TOX	
299-E24-8	3-10	3-10		3-10	3-10	--	--	--	3-10	--	--	3-10		3-10	--	--	--	Yes
299-E26-10	--	--	--	A	A	--	--	--	A	--	--	--	--	--	--	--	--	Yes
299-E26-11	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Yes
299-E27-10	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Yes
299-E27-14	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
299-E27-15	--	--	--	--	A	--	--	A	--	--	A	--	--	--	A	--	--	Yes
299-E27-17	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Yes
299-E27-18	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Yes
299-E27-7	--	--	--	A	A	--	--	A	A	--	--	--	--	A	--	--	--	Yes
299-E27-155*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	No; Am-241, Np-237, Pu-239/240, Sr-90
299-E28-13	--	--	--	3-10	3-10	--	3-10	--	3-10	3-10		3-10	--	--	--	--	--	Yes
299-E28-17	A	--	--	--	A	A	A	--	--	A	--	--	--	--	--	--	--	Yes
299-E28-18	--	--	--	A	A	--	--	--	A	A	--	A	--	A	--	--	--	Not sampled
299-E28-2	A	--	--	A	A	A	A	A	A	--	A	A	--	--	A		--	Yes
299-E28-21	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	Yes
299-E28-23	A	--	--	--	--	A	A	--	--	A	--	A	A	--	--	A	--	Yes
299-E28-24	A	--	--	--	--	A	A	--	A	A	--	A	A	--	--	A	--	Yes
299-E28-25	A	--	--	A	A	A	A	--	A	A	--	A	A	A	--	A	--	Yes
299-E28-26	--	--	--	3-10	A	--	--	A	3-10	A	--	--	--	3-10	--	--	--	Yes
299-E28-27	A	--	--	A	A	A	A	A	3-10	A	--	--	--	--	--	--	--	Yes
299-E28-28	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E28-5	A	--	--	3-10	3-10	A	A	--	3-10	A	--	3-10	--	3-10	--	--	--	No; delayed to January 2011
299-E28-6	A	A	--	3-10	3-10	A	A	--	3-10	A	--	3-10	--	3-10	--	--	--	No; delayed to January 2011
299-E28-8	A	--	--	--	--	A	A	A		A	--	--	--	--	--	--	--	Yes
299-E32-10	--	A	A	3-10	3-10	--	--	A	3-10	A	--	--	--	3-10	--	--	--	Yes
299-E32-2	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E32-4	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
299-E32-5	--	--	--	3-10	3-10	--	--	--	3-10	3-10	--	--	--	--	--	--	--	Yes

Table A-13. (Cont.)

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2010
	Cs-137	Co-60	Cyanide	I-129	Nitrate	Pu-239/240	Sr-90	Tc-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Am-241	Arsenic	Metals (Filtered)	Np-237	TOC/TOX	
299-E32-6	--	--	--	3-10	A	--	--	A	3-10	3-10	--	--	--	--	--	--	--	Yes
299-E32-7	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E32-8	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E32-9	--	--	3-10	A	A	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E33-12	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	--	Yes
299-E33-13	--	--	A	--	--	--	--	--	--	A	--	--	--	--	--	--	--	Yes
299-E33-15	--	--	--	--	A	--	--	A	--		--	--	--	--	--	--	--	Yes
299-E33-16	--	--	--	A	A	--	--	A	--	A	--	--	--	--	--	--	--	No I-129
299-E33-18	--	--	--	A	A	--	--	A	--	A	--	--	--	--	--	--	--	No I-129
299-E33-205*	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	--	Only first quarter due to access issues
299-E33-26	--	A	A	3-10	3-10	--	--	A	3-10	A	--	3-10	--	--	--	--	--	No; I-129
299-E33-28	--	--	--	--	A	--	--	A	--	--	--	--	--	--	--	--	--	Yes
299-E33-29	--	--	--	3-10	3-10	--	--	3-10	3-10		--	--	--	--	--	--	--	Yes
299-E33-30	--	--	--	--	A	--	--	A	--	--	--	--	--	--	--	--	--	Yes
299-E33-32	--	--	--	3-10	3-10	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Yes
299-E33-33	--	--	--	3-10	3-10	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	Yes
299-E33-334	--	--	--	--	A	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-335	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	--	--	Yes
299-E33-338	--	--	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-34	--	A	A	A	A	--	--	A	A	A	--	--	--	--	--	--	--	Yes
299-E33-340*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-341*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-342*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-343*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-344*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-345*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	Yes
299-E33-35	3-10	3-10	A	3-10	A	--	--	A	3-10	A	--	--	--	--	--	--	--	Yes
299-E33-37	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes

Table A-13. (Cont.)

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2010
	Cs-137	Co-60	Cyanide	I-129	Nitrate	Pu-239/240	Sr-90	Tc-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Am-241	Arsenic	Metals (Filtered)	Np-237	TOC/TOX	
299-E33-38	--	A	A	A	A	A	A	A	A	A	--	A	--	A	--	--	--	Yes
299-E33-39	--	--	A	A	A	--	--	A	A	A	--	--	--	--	--	--	--	Yes
299-E33-41	3-10	3-10	3-10	3-10	3-10	--	--	A	3-10	A	--	--	--	--	--	--	--	Yes
299-E33-42	--	--	--	A	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-43	--	--	--	A	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-44	--	A	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-50*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA		Yes
299-E33-7	A	A	A	A	A	--	--	A	A	A	--	A	--	--	--	--	--	Yes
299-E34-2	--	--	--	A	A	--	--	--	A	--	--	--	--	--	--	--	--	Yes
299-E34-9	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
699-44-39B	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
699-45-42	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
699-47-60	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-48-50B*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	Yes
699-49-55A	A	A	A	A	A	A	A	A	A	A	--	A	--	--	--	--	--	Yes
699-49-57A	A	A	A	A	A	--	--	A	A	A	--	--	--	A	--	--	--	Yes
699-49-57B	A	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-50-56*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	Yes
699-50-59*	--	--	A	A	A	--	--	A	A	A	A	A	--	--	A	--	--	Yes
699-52-55*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	Yes
699-52-55B*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	Yes
699-53-47A	--	--	--	--	A	--	A	--	A	--	--	A	--	--	--	--	--	Yes
699-53-47B	--	--	--	--	3-09	--	3-09	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-53-48A	--	--	--	A	A	--	A	--	A	--	--	A	--	--	A	--	--	Yes
699-53-55A	--	A	A	--	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-53-55B	--	A	A	--	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-53-55C	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-54-45A	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	--	--	Yes
699-54-45B	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	--	--	Not scheduled

Table A-13. (Cont.)

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2010
	Cs-137	Co-60	Cyanide	I-129	Nitrate	Pu-239/240	Sr-90	Tc-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Am-241	Arsenic	Metals (Filtered)	Np-237	TOC/TOX	
699-54-48	--	--	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-54-49	--	--	--	--	A	--	A	--	A	--	--	A	--	--	--	--	--	Yes
699-55-50C	--	--	--	A	A	--	A	A	A	--	--	--	--	--	--	--	--	Yes
699-55-57	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-55-60A	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-57-59	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-59-58	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-60-60	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-61-62	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-61-66	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-64-62	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
699-65-50	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	--	Yes
699-65-72	--	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
699-66-58	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Yes
699-66-64	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Yes
699-70-68	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Yes
699-72-73	--	--	--	--	3-10	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Yes
699-73-61	--	--	--	--	--	--	--		3-10	--	--	--	--	--	--	--	--	Yes

Notes: Requirements from *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49).

* Well not listed in DOE/RL-2001-49 but added to sampling schedule per the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18, Rev. 1). Note that wells were also sampled and analyzed for volatile organic analytes and semivolatile organic analytes.

3-xx = to be sampled triennially (every 3 years); xx indicates the fiscal year of sampling for specified analyte

A = to be sampled annually

Q = to be sampled quarterly

SA = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table A-14. Monitoring Wells and Constituents for 200-PO-1 Operable Unit Near-Field Wells

Well Number[a]	Contaminants of Concern							Supporting Constituents					Sampled as Scheduled in 2010
	Arsenic	Chromium, Manganese,, and Vanadium (Filtered)	I-129	Nitrate	Sr-90	Tc-99	Tritium	Alpha	Anions[b]	Beta	Metals[c]	Uranium	
299-E16-2	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-1	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-12	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-13	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-14	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-16	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-18	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-19	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-23[d]	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E17-25[d]	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E18-1[d]	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E23-1	A	A	A	A	--	--	A	A	A	A	A	--	No
299-E24-16	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-18	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-20	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-22	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-23	A	A	A	A	A	A	A	A	A	A	A	A	No
299-E24-33	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-5	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-17	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-18	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-19	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-2	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-20	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-22	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-28	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-29P	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-29Q	A	A	A	A	--	--	A	--	--	A	A	--	Yes
299-E25-236	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-3	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-32P	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-32Q	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-34	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-35	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-36	A	A	A	A	A	--	A	A	A	A	A	A	Yes
299-E25-37	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-40	A	A	A	A	A	A	A	A	A	A	A	--	Yes

Table A-14. (Cont.)

Well Number[a]	Contaminants of Concern							Supporting Constituents					Sampled as Scheduled in 2010
	Arsenic	Chromium, Manganese,, and Vanadium (Filtered)	I-129	Nitrate	Sr-90	Tc-99	Tritium	Alpha	Anions[b]	Beta	Metals[c]	Uranium	
299-E25-41	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-42	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-43	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-44	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-47	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-6	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-93	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-94	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E26-4	A	A	A	A	A	--	A	A	A	A	A	--	Yes
699-37-47A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
699-39-39	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-41-42	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-42-40A	A	A	A	A	--	--	A	A	A	A	A	--	No
699-42-42B	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-43-45[d]	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-44-39B	A	A	A	A	--	--	A	A	A	A	A	--	Yes

Notes: Requirements from *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04).

a. Some wells added in anticipation of revision of DOE/RL-2003-04. Well scheduled and sampled during first quarter of FY 2010.

b. Anions; analytes include, but are not limited to, nitrate.

c. Metals; analytes include, but are not limited to, chromium, manganese, and vanadium.

d. Well sampled in first quarter of FY 2010 and not during CY 2010.

A = to be sampled annually

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2010
	I-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Sr-90	Tc-99	Uranium	VOAs	
BC Cribs														
299-E13-14	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E13-5	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E13-11	--	A	A	A	A	A	A	A	A	A	A	A	--	No
299-E13-19	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
Southeast Transect														
699-10-54A	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-24-46	A	A	A	A	A	A	--	A	A	A	--	--	A	No
699-26-33	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-31-31	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-32-22A	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-32-43	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-41-23	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-46-21B	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
River Transect														
699-10-E12	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-20-E12O	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-41-1A	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-46-4	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-S3-E12	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-S19-E13	--	A	A	A	A	A	--	A	A	A	--	--	A	No
Basalt-Confined Aquifer														
299-E16-1	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-13-1C	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-24-1P	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-32-22B	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-42-40C	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-S2-34B	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
699-S11-E12AP	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not Scheduled
Far-Field General														
499-S0-7	A	A	A	A	A	A	--	A	A	A	A	A	A	Yes
499-S0-8 a	A	A	A	A	A	A	--	A	A	A	A	A	A	Yes
499-S1-8J a	A	A	A	A	A	A	--	A	A	A	A	A	A	Yes
699-12-4D	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-13-1A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-13-3A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-14-38	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-17-5	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-19-43	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-20-20	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-20-E12S	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-20-E5A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes

Table A-15. (Cont.)

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2010
	I-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Sr-90	Tc-99	Uranium	VOAs	
699-21-6	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-2-3	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-22-35	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes[d]
699-24-34C	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes[d]
699-26-15A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-26-35A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes[d]
699-2-6A a	--	A	A	--	A	--	--	--	--	--	--	--	--	Yes
699-2-7 a	--	A	A	--	A	--	--	--	--	--	--	--	--	Yes
699-28-40	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-29-4	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-31-11	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-33-56	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-34-41B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-34-42	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	No
699-35-9	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-37-43	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-37-E4	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-38-15	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-40-1	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-40-33A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-40-36	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-41-40	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-41-42 a	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-42-12A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-42-39A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-42-39B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-42-40A a	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	No
699-43-3	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-45-42	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes[d]
699-47-5	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-48-7A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-49-13E	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-50-28B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-52-19	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-8-17	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes[d]
699-8-25	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-9-E2	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	No
699-S12-3	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	No
699-S19-E14	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-S3-25	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-S6-E14A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-S6-E4A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes

Table A-15. (Cont.)

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2010
	I-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Sr-90	Tc-99	Uranium	VOAs	
699-S6-E4B	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-S8-19	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes

Notes: Requirements from *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04).

a. Some wells added in anticipation of revision of DOE/RL-2003-04.

b. Anions; analytes include, but are not limited to, nitrate.

c. Metals; analytes include, but are not limited to, chromium, manganese, and vanadium.

d. Well sampled in first quarter of fiscal year 2010 and not sampled during CY 2010.

3-xx = to be sampled triennially (every three years); xx indicates the fiscal year of sampling for specified analyte

A = to be sampled annually

VOA = volatile organic analyte

Table A-16. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2010
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Sr-90	Tritium	Nitrate	Anions	Alkalinity	Metals	VOCs	Alpha/Beta	Uranium, Isotopic	
Near-River Well Group															
399-1-1	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-10A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	No; missed June
399-1-10B	LU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-1-16A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	Yes
399-1-16B	LU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-1-16C	C	A	A	A	A	--	--	A	A	A	A	A	--	--	No; not sampled
399-2-1	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Yes
399-2-2	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-3-1	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-3-9	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-3-10	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Yes
399-3-18[b]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	No; missed October, November, December
399-4-7	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-4-9	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-4-10	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
Central Region — Uranium Plume Transport Corridor Well Group															
399-1-2[c]	TU	S	S	S/M	S	--	--	S	S/M	S/M	S	S	S/M	--	No; missed January
399-1-6	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-7	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-8	LU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-9	C	A	A	A	A	--	--	A	A	A	A	A		--	Yes
399-1-11	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-12	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-17A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	No; missed June, August, September
399-1-17B	LU	S	S	S	S	--	--	S	S	S	S	S	S	--	No; missed June
399-1-17C	C	A	A	A	A	--	--	A	A	A	A	A	--	--	Yes
399-1-21A[c]	TU	S	S	Q/M	S		A	Q	Q/M	Q/M	S	S	S/M	A	Yes
399-1-21B	LU	S	S	S	S	--		S	S	S	S	S	S	--	Yes
399-1-23	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	No; missed June and December
399-2-5	TU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	A	No; missed December
399-3-11	TU	S	S	Q	S	A	A	Q	Q	Q	S	S	S	A	Yes; decommissioned in March
399-3-12	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes

Table A-16. (Cont.)

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2010
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Sr-90	Tritium	Nitrate	Anions	Alkalinity	Metals	VOCs	Alpha/Beta	Uranium, Isotopic	
399-3-20	TU	S	S	Q	S	A	A	Q	Q	Q	S	S	S	A	Yes
399-3-21	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	No; missed December
399-3-22	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	No; missed December
Northwest Region — Upgradient Conditions Well Group															
399-1-15	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-18A	TU	--	--	S	--	--	S	S	S	S	S	--	--	--	Yes
399-1-18B	LU	--	--	S	--	--	S	S	S	S	S	--	--	--	Yes
399-1-18C	C	--	--	A	--	--	--	A	A	A	A	--	--	--	Yes
399-8-1[d]	TU	Q	Q	Q	Q	--	--	Q	Q	Q	Q	Q	Q	--	Yes
399-8-3[d]	TU	Q	Q	Q	Q	--	--	Q	Q	Q	Q	Q	Q	--	Yes
399-8-5A[d]	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
699-S20-E10	TU	--	--	S	--	--	S	S	S	S	S	--	--	--	No; missed December
Southwest Region — Upgradient Conditions Well Group															
399-3-2	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	No; missed December
399-3-6	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	No; missed December
399-3-19	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	No; missed December
399-4-1	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-4-12	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-4-14	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	Yes
399-5-4B	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
699-S27-E14	TU	A	A	A	A	--	--	A	A	A	A	A	--	--	Yes

Notes: Requirements from *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11, Rev. 2).

a. CERCLA supplements RCRA sampling to provide a full year of monthly monitoring for uranium.

b. Special sampling frequency at near-river well to provide more detailed record of seasonal fluctuations in uranium.

c. Frequency increased to monthly during and following remedial action at former 618-1 Burial Ground.

d. Additional well coverage and sampling frequency to monitor plume that developed downgradient of former 618-7 Burial Ground.

A = to be sampled annually

C = uppermost confined aquifer

LU = lower portion of unconfined aquifer

Q = to be sampled quarterly

S = to be sampled semiannually during seasonal high water table and seasonal low water table

TU = upper portion of unconfined aquifer, including water table

Table A-17. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-11 Subregion

Well	Contaminants of Potential Concern						Supporting Measurements			Sampled as Scheduled in 2010
	Tritium	Gross Beta	Uranium, Total (Unfiltered)	Tc-99	Gross Alpha	Nitrate	Anions	Alkalinity	Metals	
Downgradient of 618-11 Burial Ground (Near-Field)										
699-12-2C	Q	Q	S	S	Q	S	S	S	S	Yes
699-13-2D	Q	Q	S	S	Q	S	S	S	S	Yes
699-13-3A	Q	Q	S	S	Q	S	S	S	S	Yes
Upgradient Conditions (Near-Field)										
699-12-4D	A	A	A	A	A	A	A	A	A	Yes
Downgradient of 618-11 Burial Ground (Far-Field)										
699-13-0A	S	S	--	--	S	S	S	S	S	Yes
699-13-1E	S	S	--	--	S	S	S	S	S	Yes

Notes: Requirements from the *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11, Rev. 2).

A = to be sampled annually

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-18. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-10/316-4 Subregion

Well	Contaminants of Potential Concern					Supporting Measurements						Sampled as Scheduled in 2010
	Uranium, Total (Unfiltered)	Tributyl Phosphate	Gross Alpha	Gross Beta	Nitrate	Alkalinity	Metals	VOC and SVOC	Tritium	Tc-99	Uranium, Isotopic	
Downgradient of 618-10 Burial Ground (Near-Field)												
699-S6-E4K	S	S	S	S	S	S	S	S	S	S	A	Yes
699-S6-E4L	Q	S	Q	Q	Q	S	S	S	S	S	A	Yes
Downgradient of 618-10 Burial Ground, Within 316-4 Crib Footprint (Near-Field)												
699-S6-E4A	Q	S	Q	Q	Q	S	S	S	S	S	A	Yes
Background, 618-10 Burial Ground/316-4 Cribs												
699-S6-E4D	A		A	A	A	A	A	--	A	A	--	No; not sampled
Downgradient of 618-10 Burial Ground/316-4 Crib												
699-S6-E4B	S	--	S	S	S	S	S	--	S	--	--	No; missed December sample
699-S6-E4E	S	--	S	S	S	S	S	--	S	--	--	Yes

Notes:

1. Requirements from *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11, Rev. 2).
2. Wells completed at the top of the unconfined aquifer.

A = to be sampled annually

Q = to be sampled quarterly

S = to be sampled semiannually

Table A-19. Monitoring Wells and Constituents for the Former 1100-EM-1 Operable Unit

Well	1,1-Dichloroethene	Trichloroethane	Vinyl Chloride	Anions[a]	Sampled as Scheduled in 2010
699-S28-E12	A	A	A	A	No[b]
699-S31-E10A	A	A	A	A	No[b]
699-S31-E10C	A	A	A	A	No[b]

Notes: Requirements from TPA-CN-163, *Change Notice for Modifying Approved Documents/Work Plans in Accordance with TPA Action Plan Section 9.0, Documentation and Records, PNNL-12220, Sampling and Analysis Plan Update for Groundwater Monitoring 1100-EM-1 OU.*

a. Supplemental analyses.

b. The final semiannual sampling event was canceled due to the site-wide stop work.

A = to be sampled annually

This page intentionally left blank.

Appendix B

Supporting Information for Monitored Facilities

This page intentionally left blank.

Contents

Appendix B — Supporting Information for Monitored Facilities B-1
References B-1

Tables

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities B-7
Table B-2. Upgradient/Downgradient Comparison Values Used for Statistical Comparisons at RCRA Sites, CY 2010 ..... B-9
Table B-3. Monitoring Wells and Constituents for 100-N Area Units B-10
Table B-4. Critical Means for 1301-N (116-N-1) Liquid Waste Disposal Facility for CY 2011 Comparisons B-11
Table B-5. Critical Means for 1324-NA (120-N-1) Percolation Pond and 1324-N (120-N-2) Surface Impoundment for CY 2011 Comparisons B-11
Table B-6. Critical Means for 1325-N (116-N-3) Liquid Waste Disposal Facility for CY 2011 Comparisons B-12
Table B-7. Monitoring Wells and Constituents for 116-H-6 Evaporation Basins B-12
Table B-8. Monitoring Wells and Constituents for 216-A-29 Ditch B-13
Table B-9. Critical Means for 216-A-29 Ditch for CY 2011 Comparisons B-13
Table B-10. Monitoring Wells and Constituents for 216-B-3 Pond B-14
Table B-11. Critical Means for 216-B-3 Pond for CY 2011 Comparisons B-14
Table B-12. Monitoring Wells and Constituents for 216-B-63 Trench B-15
Table B-13. Critical Means for 216-B-63 Trench for CY 2011 Comparisons B-16
Table B-14. Monitoring Wells and Constituents for 216-S-10 Pond and Ditch B-16
Table B-15. Critical Means for 216-S-10 Pond and Ditch for CY 2011 Comparisons B-17
Table B-16. Monitoring Wells and Constituents for 316-5 Process Trenches B-17
Table B-17. Monitoring Wells and Constituents for the Integrated Disposal Facility B-18
Table B-18. Monitoring Wells and Constituents for Liquid Effluent Retention Facility B-18
Table B-19. Monitoring Wells and Constituents for Low-Level Waste Management Area 1 ..... B-19
Table B-20. Critical Means for Low-Level Waste Management Area 1 for CY 2011 Comparisons B-20
Table B-21. Monitoring Wells and Constituents for Low-Level Waste Management Area 2 ..... B-21
Table B-22. Critical Means for Low-Level Waste Management Area 2 for CY 2011 Comparisons B-22
Table B-23. Monitoring Wells and Constituents for Low-Level Waste Management Area 3 ..... B-22
Table B-24. Monitoring Wells and Constituents for Low-Level Waste Management Area 4 ..... B-23
Table B-25. Critical Means for Low-Level Waste Management Area 4 for CY 2011 Comparisons B-24
Table B-26. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill B-25
Table B-27. Critical Means for Nonradioactive Dangerous Waste Landfill for CY 2011 Comparisons B-26
Table B-28. Monitoring Wells and Constituents for RCRA PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1 ..... B-26
Table B-29. Monitoring Wells and Constituents for Waste Management Area A-AX B-27
Table B-30. Monitoring Wells and Constituents for Waste Management Area B-BX-BY B-28
Table B-31. Monitoring Wells and Constituents for Waste Management Area C B-29
Table B-32. Groundwater Assessment Volatile Organic Compound Monitoring at Waste Management Area C B-30
Table B-33. Groundwater Assessment Semivolatile Organic Compound Monitoring at Waste Management Area C B-31
Table B-34. Groundwater Assessment Inorganic Constituent Monitoring at Waste Management Area C B-32
Table B-35. Monitoring Wells and Constituents for Waste Management Area S-SX B-33
Table B-36. Monitoring Wells and Constituents for Waste Management Area T B-34
Table B-37. Monitoring Wells and Constituents for Waste Management Area TX-TY B-35
Table B-38. Monitoring Wells and Constituents for Waste Management Area U B-36
Table B-39. Monitoring Wells and Constituents for the KE and KW Basins B-37
Table B-40. Monitoring Wells, Constituents, and Enforcement Limits for 200 Area Treated Effluent Disposal Facility B-38
Table B-41. Monitoring Wells and Constituents for Environmental Restoration Disposal Facility B-38
Table B-42. Monitoring Wells and Constituents for Solid Waste Landfill B-39
Table B-43. Monitoring Wells, Constituents, and Enforcement Limits for State-Approved Land Disposal Site B-40
Table B-44. Analytical Results for Required Constituents at the Solid Waste Landfill B-41
Table B-45. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill B-43

Figures

Figure B-1. RCRA Units on the Hanford Site Requiring Groundwater Monitoring B-44
Figure B-2. Groundwater Monitoring Wells for 100-N Area RCRA Sites B-45
Figure B-3. Groundwater Monitoring Wells at 116-H-6 Evaporation Basins B-46
Figure B-4. Groundwater Monitoring Wells at 216-A-29 Ditch, PUREX Cribs, and Waste Management Areas A-AX and C B-47
Figure B-5. Groundwater Monitoring Wells at 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility B-48
Figure B-6. Groundwater Monitoring Wells at 216-S-10 Pond and Ditch B-49
Figure B-7. Groundwater Monitoring Wells at 316-5 Process Trenches B-50
Figure B-8. Groundwater Monitoring Wells at Integrated Disposal Facility B-51
Figure B-9. Groundwater Monitoring Wells at Liquid Effluent Retention Facility B-52
Figure B-10. Groundwater Monitoring Wells at Low-Level Waste Management Area 1 ..... B-53
Figure B-11. Groundwater Monitoring Wells at 216-B-63 Trench and Low-Level Waste Management Area 2 ..... B-54
Figure B-12. Groundwater Monitoring Wells at Low-Level Waste Management Area 3 ..... B-55
Figure B-13. Groundwater Monitoring Wells at Low-Level Waste Management Area 4 ..... B-56
Figure B-14. Groundwater Monitoring Wells at Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill B-57
Figure B-15. Groundwater Monitoring Wells at Waste Management Area B-BX-BY B-58
Figure B-16. Groundwater Monitoring Wells at Waste Management Areas S-SX and U B-59
Figure B-17. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY B-60
Figure B-18. Non-RCRA Regulated Units on the Hanford Site Requiring Groundwater Monitoring B-61
Figure B-19. Groundwater Monitoring Wells at 100-K Basins B-62
Figure B-20. Groundwater Monitoring Wells at State-Approved Land Disposal Site B-63
Figure B-21. Groundwater Monitoring Wells at the Environmental Restoration Disposal Facility B-64

Appendix B — Supporting Information for Monitored Facilities

C.J. Martin

This appendix provides supplemental information for *Resource Conservation and Recovery Act of 1976* (RCRA) and other regulated units on the Hanford Site that require groundwater monitoring, excluding *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* units (which are discussed in Appendix A). Site-specific discussions for each facility included in this appendix are included in the main text of this document under the respective operable unit in which the facility is located.

Groundwater monitoring under RCRA continued during the reporting period (January 1, 2010, through December 31, 2010) at 24 waste management areas (Figure B-1). Estimates of groundwater velocity, hydrologic properties, and associated references are shown in Table B-1 for the RCRA sites. To determine if a waste site has adversely affected groundwater quality under RCRA interim status regulations (WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards," and by reference, 40 CFR 265.93, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), concentrations of indicator parameters in downgradient wells are compared to statistically derived critical mean values. The indicator parameters under interim status are specific conductance, pH, total organic carbon, and total organic halides. The critical values to which the indicator parameters are compared represent 99% prediction limits, which are calculated for each facility based on samples from upgradient wells. The upper prediction limits (and lower limit in the case of pH) also are known as critical mean values.

Critical mean values are recalculated annually or if the number of analyses changes. Annual recalculation accounts for changing background conditions. Changes in the number of analyses are usually the result of changes in monitoring well networks (e.g., wells are added or deleted). If changes occur in a monitoring well network, critical mean values for that facility are recalculated for subsequent semiannual sampling events using the new well network.

To reliably indicate potential groundwater effects from a facility, the sample results must be reasonably precise or quantifiable. Specific conductance and pH are field-measured indicator parameters that are reasonably detectable and quantifiable. The parameters of total organic carbon and total organic halides, however, are much more variable and are often below detection levels. Significant imprecision and variability occur when measuring these parameters near detection limits. The variability in laboratory measurements of field blanks are used to estimate laboratory limits of quantitation during the sampling period. The limit of quantitation is defined as ten times the standard deviation of the field blank analyses (see discussion in Appendix D). For detection monitoring, the statistical comparison values for total organic carbon and total organic halides are the larger of either the critical mean or the limit of quantitation.

Table B-2 lists the comparison values (critical mean values and limits of quantitation) used during the reporting period. Additional tables list updated critical mean values for use in calendar year 2011 for each RCRA unit where these statistics apply. Tables B-3 through B-43 provide supporting information for the RCRA sites, and Figures B-2 through B-17 show the locations of monitoring wells at RCRA regulated units.

This appendix also provides constituent lists, well network configurations, and other ancillary information for regulated facilities that fall outside of the RCRA program. Some network wells in these facilities are shared with RCRA facilities, and Figure B-18 shows the general locations of these facilities. Locations of monitoring wells for these facilities are shown in Figures B-14, B-15, B-19, B-20, B-21, B-22, B-23, B-24, and B-25. Tables B-39 through B-44 list the constituents and/or the results summaries for these facilities.

References

40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*.

Atomic Energy Act of 1954, 42 U.S.C. 2011, et seq.

BNWL-1709, 1973, *Collection and Analysis of Pump Test Data for Transmissivity Values*, K. L. Kipp and R. D. Mudd, Battelle Northwest Laboratories, Richland, Washington.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

DOE O 435.1, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE/RL-2000-72, 2006, *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds*, Rev. 1, U. S. Department of Energy, Richland Operations, Richland, Washington.

DOE/RL-2003-12, 2003, *Hanford Facility Dangerous Waste Permit Application, Integrated Disposal Facility*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-58, 2010, *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-59, 2010, *Interim Status Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-60, 2010, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-61, 2010, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2008-66, 2009, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-38, 2009, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial DesignlRemedial Action Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-68, 2011, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-69, 2010, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-73, 2011, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-75, 2009, *Interim Status Groundwater Monitoring Plan for LLBG WMA 1*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-76, 2010, *Interim Status Groundwater Monitoring Plan for LLBG WMA 2*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-77, 2010, *Interim Status Groundwater Quality Assessment Plan for the Single Shell Tank Waste Management Area – C*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-11, 2010, *Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 And 2*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, 2009, *Chemical Test Methods for Designating Dangerous Waste, Appendix 5*, Washington State Department of Ecology, Olympia, Washington.

PNL-6716, 1988, *Interim Characterization Report for the 300 Area Process Trenches*, R. Schalla, R. W. Wallace, R. L. Aaberg, S. P. Airhart, and D. J. Bates, Pacific Northwest Laboratory, Richland, Washington.

PNL-6728, 1988, *Geohydrologic Characterization of the Area Surrounding the 183-H Solar Evaporation Basins*, T. L. Liikala, R. L. Aaberg, N. J. Aimo, D. J. Bates, T. J. Gilmore, E. J. Jensen, G. V. Last, P. L. Oberlander, K. B. Olsen, K. R. Oster, L. R. Roome, J. C. Simpson, S. S. Teel, and E. J. Westergard, Pacific Northwest Laboratory, Richland, Washington.

PNL-6820, 1989, *Hydrogeology of the 200 Areas Low-Level Burial Grounds — An Interim Report*, Pacific Northwest Laboratory, Richland, Washington.

PNL-8335, 1992, *Applications of Three Aquifer Test Methods for Estimating Hydraulic Properties Within the 100-N Area*, T. J. Gilmore, F. A. Spane, D. R. Newcomer, and C. R. Sherwood, Pacific Northwest Laboratory, Richland, Washington.

PNL-8337, 1992, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System*, P. D. Thorne and D. R. Newcomer, Pacific Northwest Laboratory, Richland, Washington.

PNL-10195, 1994, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System: FY 1994 Status Report*, P. D. Thorne, M. A. Chamness, V. R. Vermeul, Q. C. MacDonald, and S. E. Schubert, Pacific Northwest Laboratory, Richland, Washington.

PNNL-11523, 1997, *Combination RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs*, J. W. Lindberg, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11573, 1997, *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11957, 1998, *Immobilized Low-Activity Waste Site Borehole 299-E17-21*, S. P. Reidel, K. D. Reynolds, and D. G. Horton, Pacific Northwest Laboratory, Richland, Washington.

PNNL-12114-ICN-3, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, Interim Change Notice 3, V. G. Johnson and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12114-ICN-4, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, Interim Change Notice 4, V. G. Johnson and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12227, 1999,*Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, J. W. Lindberg and M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12227-ICN-1, 2001, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill,* Interim Change Notice 1, Rev. 1, J. W. Lindberg and M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13014, 2000, *Groundwater Monitoring Plan for the Solid Waste Landfill*, J. W. Lindbert and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13022-ICN-3, 2006, *Groundwater Quality Assessment Plan for Single-Shell Waste Management Area B-BX-BY at the Hanford Site*, Interim Change Notice 3, S. M. Narbutovskih, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13024-ICN-4, 2004, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*, Interim Change Notice 4, S. M. Narbutovskih, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13024-ICN-5, 2007, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*, Interim Change Notice 5, S. M. Narbutovskih, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13032, 2000, *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility*, D. B. Barnett, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13121, 2000, *Groundwater Monitoring and Tritium Tracking Plan for the 200 Area State-Approved Land Disposal Site*, D. B. Barnett, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13378, 2001, *Results of Detailed Hydrologic Characterization Tests – FY 1999*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13514, 2001, *Results of Detailed Hydrologic Characterization Tests – FY 2000*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13612-ICN-2, 2006, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U*, Interim Change Notice 2, R. M. Smith, F. N. Hodges, and B. A. Williams, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13914, 2002, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*, M. J. Hartman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14033, 2002, *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*, R. E. Peterson, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14113, 2002, *Results of Detailed Hydrologic Characterization Tests – FY 2001*, F. A. Spane, P. D. Thorne, and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14656, 2004, *Borehole Data Package for Four CY 2003 RCRA Wells 299-E27-4, 299-E27-21, 299-E27-22, and 299-E27-23 at Single-Shell Tank, Waste Management Area C, Hanford Site, Washington*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-14753, 2006, *Groundwater Data Package for Hanford Assessments*, Rev. 1, P. D. Thorne, M. P. Bergeron, M. D. Williams, and V. L. Freedman, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14804, 2004, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2003*, F. A. Spane and D. R. Newcomer, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15301, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15315, 2006, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*, S. M. Narbutovskih and C. J. Chou, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16005, 2007, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area TX-TY*, D. G. Horton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17732, 2008, *Analysis of the Hydrologic Response Associated With Shutdown and Restart of the 200-ZP-1 WMA T Tank Farm Pump-and-Treat System*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-18279, 2009, *Aquifer Testing Recommendations for Well 299-W15-225: Supporting Phase I of the 200-ZP-1 Groundwater Operable Unit Remedial Design*, Pacific Northwest Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq.

RPP-21895, 2006, *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan*, Rev. 3, J. S. Schofield, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-26534, *Integrated Disposal facility Operational Monitoring Plan to Meet DOE Order 435.1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Shapiro, S. S, 1980, "How to Test Normality and Other Distributional Assumptions," in *ASQC Basic References in Quality Control: Statistical Techniques*, Vol. 3, E. J. Dudewicz (ed.), American Society of Quality Control, Milwaukee, Wisconsin.

Shapiro, S. S., and R. S. Francia, 1972, "Approximate Analysis of Variance Test for Normality," in *Journal of the American Statistical Association*, 67:215-216.

WA7890008967, 2006, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*, as amended, Washington State Department of Ecology, Richland, Washington.

WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," *Washington Administrative Code*.

WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards," *Washington Administrative Code*.

WAC 173 303 645, "Dangerous Waste Regulations," "Releases from Regulated Units," *Washington Administrative Code*.

WAC 173-350, "Solid Waste Handling Standards," *Washington Administrative Code*, Olympia, Washington.

WAC 173-304-500, "Minimum Functional Standards for Solid Waste Handling," *Washington Administrative Code*, Olympia, Washington.

WCH-198, 2008, *Groundwater Protection Plan for the Environmental Restoration Disposal Facility*, Rev. 0, R. L. Weiss, Washington Closure Hanford, Richland, Washington.

WHC-EP-0021, 1987, *Interim Hydrogeologic Characterization Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site*, Rev. 0, D. C. Weekes, S. P. Luttrell, and M. R. Fuchs, Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0207, 1990, *Borehole Completion Data Package for the 216-B-63 Trench – 1990*, Rev. 0, S. M. Goodwin, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-024, 1991, *Interim Status Groundwater Monitoring Plan for the 200 East Area Liquid Effluent Retention Facility*, Rev. 1, J. S. Schmid, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-AP-185, 1995, *Groundwater Monitoring Plan for the 300 Area Process Trenches*, Rev. 0, J. W. Lindberg, C. J. Chou, and V. G. Johnson, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-DP-047, 1992, *Borehole Completion Data Package for 216-A-29 RCRA Facility Monitoring Wells 299-E25-42, 299-E25-43, 299-E26-12, and 299-E26-13*, Rev. 0, G. L. Kasza, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-DP-052, 1993, *Borehole Completion Data Package for the 216-S-10 Facility, CY-1992*, Rev. 0, B. A. Williams and D. B. Barnett, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-EV-002, 1990, *Interim Hydrogeologic Characterization Report for the 216-B-3 Pond*, Rev. 0, M. J. Hartman, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-019, 1992, *Hydrogeologic Model for the 200-East Groundwater Aggregate Area*, Rev. 0, M. P. Connelly, J. V. Borghese, C. D. Delaney, B. H. Ford, J. W. Lindberg, and S. J. Trent, Westinghouse Hanford Company, Richland, Washington.

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
116-N-1 LWDF	Northwest	0.05 to 0. 90	Darcy	6.1 to 37 (PNL-8335)	--	0.0024	Gradient calculated between wells 199-N-34 and 199-N-2.
120-N-1 and 120-N-2	Northwest	0.07 to 1.3	Darcy	6.1 to 37 (PNL-8335)	--	0.0034	Gradient calculated between wells 199-N-72 and 199-N-26.
116-N-3 LWDF	North	0.02 to 0.37	Darcy	6.1 to 37 (PNL-8335)	--	0.0010	Gradient calculated between wells 199-N-28 and 199-N-81.
116-H-6 Evaporation Basins	East	0.32 to 8.9	Darcy	15 to 140 (PNL-6728)	--	0.0064	Gradient calculated between wells 199-H4-9 and 199-H4-12B.
216-A-29 Ditch	Southeast[c]	Indeterminate	Darcy	18 (WHC-SD-EN-DP-047)	0.25	Indeterminate	Uncertainty with gradient and rate of flow (see Section 10.3.4).
216-B-3 Pond	West	0.0048	Darcy	1.0 (WHC-SD-EN-EV-002; PNL-10195)	0.25	0.0014	Average gradient calculated using well 299-E25-32P as downgradient well and wells 699-44-39B, 699-41-40, 699-41-42, 699-42-42B, 699-43-44, and 699-43-45.
216-B-63 Trench	Indeterminate	Indeterminate	Darcy	182 (WHC-MR-0207)	0.2	Indeterminate	Uncertainty with gradient and rate of flow (see Section 9.3.6).
216-S-10 Pond and Ditch	Southeast	0.15	Darcy	10.4 (WHC-SD-EN-DP-052)	0.1 to 0.2	0.0022	Average gradient calculated using wells 299-W26-13, 299-W26-14, 699-32-76, 699-32-77, 699-33-75, and 699-33-76.
316-5 Process Trenches	South-southeast	0.20 to 20	Darcy	150 to 15,000 (PNL-6716)	0.25	0.00033	Gradient calculated between wells 399-1-18A and 399-1-17A.
IDF	East	0.002 to 0.008	Darcy	68 to 75 (PNNL-13652; PNNL-11957)	--	0.00002	Flow direction and gradient determined from trend surface analysis (see Section 10.3.1).
LERF	Southwest	0.0184	Darcy	39.8 (PNNL-14804)	0.373	0.0002	Gradient calculated from PNNL-14804.
LLWMA-1	North-northwest	0.1875 to 0.8	Darcy & Trend Matching	2,500 to 7,500 (PNNL-14753)	0.2	0.000015 – 0.000021	Gradient calculated from two areas: (1) between wells 299-E33-26 and 299-E33-38 and (2) from the regional low gradient water levels for LLWMA-1.
LLWMA-2	Indeterminate	Indeterminate	--	2,500 to 7,500 (PNNL-14753)	0.2	--	Uncertain of flow direction. Gradient too low to determine flow rate.
LLWMA-3	East-northeast	0.04 to 0.16	Darcy	2.5 to 10 (PNNL-14753)	0.1 (PNNL-14753)	0.0016	Flow direction and gradient from water table map.
LLWMA-4	East	0.1 to 0.4	Darcy	2.5 to 10 (PNNL-14753)	0.1 (PNNL-14753)	0.004	Flow direction and gradient are variable due to effects of the pump-and-treat system.
NRDWL	Southeast	0.026 to 0.23	Darcy	518 to 1,524 (WHC-EP-0021)	--	0.000015	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.

Table B-1. (Cont.)

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
PUREX Cribs	East	0.001 to 0.60	Darcy	18 to 3,000 (PNNL-11523)	--	0.00002	Flow direction and gradient determined from trend surface analysis (see Section 10.3.2).
WMA A-AX	Southeast	0.13 to 0.40	Darcy	1,981 (PNL-8337; WHC-SD-EN-TI-019)	--	0.00002	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
WMA B-BX-BY	North-northwest	Indeterminate	--	73 to 2,520 (PNNL-6820)	0.3	Indeterminate	Uncertainty with gradient and rate of flow (see Section 9.3.3). Maximum hydraulic conductivity based on aquifer test data.[d]
WMA C	Southerly	Indeterminate	--	1890 to 6,888 (PNNL-14656)	0.3	Indeterminate	The Tc-99 plume configuration, ion chemistry comparison, and Tc-99 trend comparisons provide consistent indication of southwest flow; Tc-99 trend markers between wells 299-E27-23 and 299-E27-21 indicate average flow rate.
WMA S-SX	East to east-southeast	0.07 to 0.14	Contaminant travel time (PNNL-13441)	NA	NA	NA	Based on inferred contaminant travel time between 216-S-25 Crib and downgradient wells 299-W23-15 and 299-W22-46, and between wells 299-W22-46 and 299-W22-83.
	East	0.011 to 0.27 (Best value: 0.088)	Darcy	1.33 to 14.4 (Best value: 6.1) (PNNL-13514; PNNL-14113)	0.09 to 0.20 (Best value: 0.12)	0.0017	Gradient determined by trend surface analysis.
WMA T	East	0.12 to 0.19 (PNNL-17732)	Darcy	6.11 to 9.69 (PNNL-17732)	0.1	0.002	Flow direction based on trend surface analysis. Flow direction and gradient influenced by pump-and-treat.
WMA TX-TY	Variable (see text discussion)	NA	NA	0.07 to 19.9 (PNNL 18279)	0.18 (DOE/RL-2009-38)	NA	Flow direction and rate influenced by 200-ZP-1 pump-and-treat system.
WMA U	East to east-northeast	0.018 to 0.20 (Best value: 0.077)	Darcy	1.69 to 9.5 (Best value: 6.12) (PNNL-13378)	0.10 to 0.20 (Best value: 0.17)	0.0022	Gradient determined by trend surface analysis.

a. Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system, unless otherwise noted.

b. March 2010, unless noted otherwise.

c. Flow direction is based on those determined on a regional basis.

d. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of WMA B-BX-BY Well 299-E33-49 (C4261)*, letter report, F. A. Spane and D. R. Newcomer, Pacific Northwest National Laboratory, dated October 8, 2004.

NA = not applicable

Table B-2. Upgradient/Downgradient Comparison Values Used for Statistical Comparisons at RCRA Sites, CY 2010

Quarter	Specific Conductance Critical Mean (µS/cm)	pH Critical Range	TOC Critical Mean[a,b]/ LOQ (µg/L)	TOX Critical Mean[a]/ LOQ (µg/L)
116-N-1 (1301-N) Facility				
Jan. to Mar. 2010	1,600	5.97 – 9.33	**3,760**/1,130	**26.3**/11.4
July to Sept. 2010	1,600	5.97 – 9.33	**3,760**/990	**26.3**/12.0
120-N-1 and 120-N-2 (1324-N/NA) Facilities				
Apr. to June 2010	750	7.11 – 8.79	870/**1,040**	**13.9**/12.0
Oct. to Dec. 2010	750	7.11 – 8.79	**870**/210	**13.9**/11.8
116-N-3 (1325-N) Facility				
Jan. to Mar. 2010	510	7.17 – 8.76	**1,250**/1,040	**24.2**/11.4
July to Sept. 2010	510	7.17 – 8.76	**1,250**/210	**24.2**/12.0
216-A-29 Ditch				
Apr. to June 2010	260	6.96 – 9.62	**1,280**/1,040	**20.7**12.0
Oct. to Dec. 2010	260	6.96 – 9.62	**1,280**/210	**20.7**/11.8
216-B-3 Pond				
Jan. to Mar. 2010	390	6.29 – 9.92	1,010/**1,130**	10.6/**11.4**
July to Sept. 2010	390	6.29 – 9.92	**1,010**/990	10.6/**12.0**
216-B-63 Trench				
Apr. to June 2010	980	7.25 to 8.62	930/**1,040**	**19.9**/12.0
Oct. to Dec. 2010	980	7.25 to 8.62	**930**/210	**19.9**/11.8
216-S-10 Pond and Ditch				
Apr. to June 2010	360	7.27 to 8.18	**23,950**/1,040	20.8/12.0
Oct. to Dec. 2010	360	7.27 to 8.18	**23,950**/210	20.8/11.8
LLWMA-1				
Apr. to June 2010	910	7.48 to 8.43	590/**1,040**	**17.5**/12.0
Oct. to Dec. 2010	910	7.48 to 8.43	**590**/210	**17.5**/11.8
LLWMA-2				
Apr. to June 2010	1,280	6.85 to 8.56	**3,036**/1,040	**91.0**/12.0
Oct. to Dec. 2010	1,280	6.85 to 8.56	**3,036**/210	**91.0**/11.8
LLWMA-3				
No statistical comparisons until new baseline is established.				
LLWMA-4				
Jan. to Mar. 2010	770	6.94 to 8.91	900/**1,130**	**25.9**/11.4
July to Sept. 2010	770	6.94 to 8.91	900/**990**	**25.9**/12.0
NRDWL				
Jan. to Mar. 2010	590	6.79 to 7.72	925/**1,130**	**22.5**/11.4
July to Sept. 2010	590	6.79 to 7.72	925/**990**	**22.5**/12.0

a. Upgradient/downgradient comparison values (in **bold**) for TOC and TOX are the larger of calculated critical mean value and limit of quantitation for the respective quarter.

b. Reported values rounded to the nearest 10 µg/L.

c. Critical mean value could not be calculated because essentially all measurements were below vendor specified method detection limit.

LOQ = limit of quantitation; based on field blanks collected and analyzed in the previous four quarters

NC = not calculated

TOC = total organic carbon

TOX = total organic halides

Table B-3. Monitoring Wells and Constituents for 100-N Area Units

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters				Sampled as Scheduled in Reporting Period
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha[b]	Anions	Metals (Filtered)	
116-N-1 (1301-N) Liquid Waste Disposal Facility											
199-N-105A	--	C	S	S	S	S	A	--	A	A	Yes
199-N-2	--	P	S	S	S	S	A	--	A	A	Yes
199-N-3	--	P	S	S	S	S	A	--	A	A	Yes
199-N-34	--	P	S	S	S	S	A	--	A	A	Yes
199-N-57	--	C	S	S	S	S	A	--	A	A	Yes
120-N-1 and 120-N-2 (1324-N/NA) Facilities											
199-N-71	--	C	S	S	S	S	A	--	A	A	Yes
199-N-72	--	C	S	S	S	S	A	--	A	A	Yes
199-N-73	--	C	S	S	S	S	A	--	A	A	Yes
199-N-77	Bottom of aquifer; no statistics	C	S	S	S	S	A	S	A	A	Yes
199-N-165	--	C	S	S	S	S	A	A	A	A	Yes
116-N-3 (1325-N) Liquid Waste Disposal Facility											
199-N-28	Information only; no statistics	P	S	S	S	S	A	--	A	A	Yes
199-N-32	--	P	S	S	S	S	S	--	S	S	Yes
199-N-41	--	P	S	S	S	S	A	--	A	A	Yes
199-N-74	--	C	S	S	S	S	A	--	A	A	Yes
199-N-81	--	C	S	S	S	S	A	--	A	A	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities* (PNNL-13914).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Monitored for *Atomic Energy Act of 1954.*

A = to be sampled annually

C = well is constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

F = fiscal year

P = constructed prior to WAC requirements

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-4. Critical Means for 1301-N (116-N-1) Liquid Waste Disposal Facility for CY 2011 Comparisons

Constituent (units)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	8	7	7.771	0.3689	4.7	6.0818	5.39 – 10.15
Specific conductance (µS/cm)	8	7	662.1	224.1	33.8	5.4079	1,950
TOC* (µg/L)	8	7	599.7	304.5	50.8	5.4079	2,350
TOX* (µg/L)	7	6	6.090	4.281	70.3	5.9588	33.4

Note: Based on semiannual sampling events from March 2009 through September 2010 for upgradient wells 199-N-34 and 199-N-57.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 20 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-5. Critical Means for 1324-NA (120-N-1) Percolation Pond and 1324-N (120-N-2) Surface Impoundment for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	5	4	7.97	0.0589	0.74	9.7291	7.34 – 8.59
Specific conductance (µS/cm)	5	4	480.6	34.2703	7.13	8.1216	785
TOC* (µg/L)	5	4	382.7	53.352	13.9	8.1216	860
TOX* (µg/L)	6	5	4.52	1.6176	35.8	6.5414	15.9

Note: Based on semiannual sampling events from upgradient well 199-N-71, June 2008 through August 2010.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and sixteen comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-6. Critical Means for 1325-N (116-N-3) Liquid Waste Disposal Facility for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	5	4	8.016	0.0840	1.05	9.729074	7.12 - 8.91
Specific conductance (µS/cm)	5	4	404.0	12.93	3.2	8.121637	520
TOC* (µg/L)	5	4	200.9	94.76	47.2	8.121637	1,040
TOC* (µg/L)	6	5	5.205	2.303	44.3	6.541442	21.5

Note: Based on semiannual sampling events from September 2008 through September 2010 for upgradient well 199-N-74.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and sixteen comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-7. Monitoring Wells and Constituents for 116-H-6 Evaporation Basins

Well Number	Comment	WAC-Compliant	Permit-Specified					Other Parameters			Sampled as Scheduled in Reporting Period[b]
			Chromium (Filtered)	Nitrate	Tc-99[a]	Fluoride	Uranium[a]	Alkalinity	Anions	Metals (Filtered)	
199-H4-12A	Extraction well	C	A	A	A	A	A	A	A	A	Yes
199-H4-12C	Extraction well; mid-depth unconfined	C	A	A	A	A	A	A	A	A	Yes
199-H4-3	Extraction well	P	A	A	A	A	A	A	A	A	Yes
199-H4-8	--	C	A	A	A	A	A	A	A	A	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins* (PNNL-11573) and 2008 Permit modification (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. Radionuclides not typically subject to RCRA monitoring but included in the current Hanford Facility RCRA Permit (WA7890008967) for this facility.

b. 183-H wells are typically sampled in November (sampled in December 2010).

c. Well 199-H4-12C begin extraction operations in August 2010.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Table B-8. Monitoring Wells and Constituents for 216-A-29 Ditch

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters				Sampled as Scheduled in 2010
			Specific. Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-E25-26	Upper unconfined	C	S	S	S	S	S	S	A	A	No[b]
299-E25-28	Deep unconfined; no statistics	C	A	A	A	A	A	A	A	A	Yes
299-E25-32P	--	C	S	S	S	S	S	S	A	A	Yes
299-E25-34	--	C	A	A	A	A	A	A	A	A	Yes
299-E25-35	--	C	S	S	S	S	S	S	A	A	Yes
299-E25-48	--	C	S	S	S	S	S	S	A	A	Yes
299-E26-12	--	C	A	A	A	A	A	A	A	A	Yes
299-E26-13	--	C	S	S	S	S	S	S	A	A	Yes
699-43-45	--	C	S	S	S	S	S	S	A	A	No[c]

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch* (DOE/RL-2008-58).
2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. Upgradient well(s) are noted in ***bold italic***.

b. Well was not sampled for the year due to maintenance and pump issues.

c. The first 6-month sample from this well was missed due to access restrictions.

A = to be sampled annually

C = well is constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-9. Critical Means for 216-A-29 Ditch for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	8	7	8.125	0.0947	1.2	6.5715	7.46 – 8.79
Specific conductance (µS/cm)	8	7	287.72	7.733	2.7	5.8588	336
TOC* (µg/L)	8	7	428.44	248.06	57.9	5.8588	1970
TOX* (µg/L)	8	7	3.630	1.097	30.2	5.8588	10.4

Note: Based on semiannual sampling events from October 2007 through November 2010 for upgradient well 699-43-45.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and 32 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-10. Monitoring Wells and Constituents for 216-B-3 Pond

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters						Sampled as Scheduled in 2010
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha[b]	Anions	Beta[b]	Metals	Phenols	
699-42-42B	Bottom of aquifer	C	S	S	S	S	A	A	A	A	A	A	Yes
699-43-44	--	C	S	S	S	S	A	A	A	A	A	A	Yes
699-43-45	--	C	S	S	S	S	A	A	A	A	A	A	No[c]
699-44-39B	--	C	S	S	S	S	A	A	A	A	A	A	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond* (DOE/RL-2008-59).
2. Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Upgradient well noted by ***bold italic***.

b. Monitored for *Atomic Energy Act of 1954*.

c. Annual metals and phenol samples were missed due to lapse in sample scheduling.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standard for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-11. Critical Means for 216-B-3 Pond for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	6	5	8.034	0.138	1.7	7.6037	6.90 - 9.17
Specific conductance (µS/cm)	6	5	276	9.05	3.3	6.5414	340
TOC* (µg/L)	6	5	221.1	98.3	44.5	6.5414	920
TOX* (µg/L)	6	5	3.375	1.38	40.8	6.5414	13.1

Note: Based on semiannual sampling events from January 2008 through July 2010 for upgradient well 699-44-39B.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and sixteen comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-12. Monitoring Wells and Constituents for 216-B-63 Trench

Well Number	WAC-Compliant	Contamination Indicator Parameters				Other Parameters						Sampled as Scheduled in 2010
		Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha[a]	Anions	Beta[a]	Metals	Phenols	
299-E27-8	C	S	S	S	S	A	S	A	S	A	A	All sampled once[b]
299-E27-9	C	S	S	S	S	A	S	A	S	A	A	All sampled once[b]
299-E27-11	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-16	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-17	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-18	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-19	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E33-33	C	S	S	S	S	A	A	A	A	A	A	All sampled once[b]
299-E33-36	C	S	S	S	S	A	A	A	A	A	A	All sampled once[b]
299-E33-37	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E34-8	C	S	S	S	S	A	A	A	A	A	A	All sampled once[b]
299-E34-10	C	S	S	S	S	A	A	A	A	A	A	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench* (DOE/RL-2008-60).

2. Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Monitored for *Atomic Energy Act of 1954*.

b. Sampled first half of calendar year 2010, well was dropped from the network with issuance of the revised groundwater monitoring plan in June 2010.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-13. Critical Means for 216-B-63 Trench for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	20	19	8.044	0.1337	1.7	4.5718	7.42 - 8.67
Specific conductance (µS/cm)	20	19	506.7	119.6	23.6	4.2669	1,030
TOC* (µg/L)	21	20	321.8	157.5	48.9	4.224	1,000
TOX* (µg/L)	21	20	4.133	1.557	37.7	4.224	10.9

Note: Based on semiannual sampling events from April 2009 through December 2010 for upgradient wells 299-E27-8, 299-E27-9, 299-E27-11, 299-E27-17, and 299-E34-10.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and 48 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-14. Monitoring Wells and Constituents for 216-S-10 Pond and Ditch

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters								Sampled as Scheduled During 2010
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Anions	Carbon Tetrachloride	Chloroform	Hexavalent Chromium	Metals	Phenols	Mercury	
299-W26-13	--	C	S	S	S	S	S	A	A	A	S	A	A	S	Yes
299-W26-14	--	C	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-W27-2	Bottom of aquifer; no statistics	C	A	A	A	A	A	A	A	A	A	A	A	A	Yes
699-32-76	Quarterly samples[b]	C	S	S	S	S	S	A	A	A	S	A	A	S	Yes
699-33-75	Quarterly samples[b]	C	S	S	S	S	S	A	A	A	S	A	A	S	No[c]
699-33-76	Quarterly samples[b]	C	S	S	S	S	S	A	A	A	S	A	A	S	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch* (DOE/RL-2008-61).
2. Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Upgradient well noted by ***bold italic***.

b. Second year of quarterly RCRA-specific sampling for obtaining baseline conditions. Routine monitoring frequency will be semiannual as shown.

c. The sample for the last quarter of 2010 was not collected due to the stop-work that ran from September to November.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-15. Critical Means for 216-S-10 Pond and Ditch for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	4	3	7.78	0.0584	0.75	16.3263	6.72 – 8.85
Specific conductance (µS/cm)	4	3	289.7	3.9863	1.38	12.9240	350
TOC* (µg/L)	4	3	226.7	88.594	39.1	12.9240	1,510
TOX* (µg/L)	4	3	5.71	0.8236	14.4	12.9240	17.6

Note: Based on sampling events from August 2009 through August 2010 for new upgradient well 699-33-76.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and twenty comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-16. Monitoring Wells and Constituents for 316-5 Process Trenches

Well Number	Comment	WAC-Compliant	cis-1,2-Dichloroethene	Tetrachloroethene	Trichloroethene	Uranium[a]	Sampled as Scheduled in 2010[b]
399-1-10A	--	C	S	S	S	S	Yes
399-1-10B	Lower unconfined	C	S	S	S	S	Missed July; resampled in August
399-1-16A	--	C	S	S	S	S	Yes
399-1-16B	Lower unconfined	C	S	S	S	S	Missed July; resampled in August
399-1-17A	--	C	S	S	S	S	Missed February; paperwork not prepared
399-1-17B	Lower unconfined	C	S	S	S	S	Yes
399-1-18A	--	C	S	S	S	S	Yes
399-1-18B	Lower unconfined	C	S	S	S	S	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the 300 Area Process Trenches* (WHC-SD-EN-AP-185).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. Radionuclides not typically subject to RCRA monitoring, but included in the current Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*) for this facility.

b. During the reporting period (January through December 2010), the 316-5 Process Trenches wells were sampled in January, February, March, June, July, August, September, and December.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled four times semiannually (8 months)

Table B-17. Monitoring Wells and Constituents for the Integrated Disposal Facility

Well Number[a]	WAC-Compliant	Indicator Parameters					Other Parameters								Sampled as Scheduled in 2010
		Chromium (Filtered)	Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Turbidity (Field)	Anions	Metals	Alpha[b]	Beta[b]	I-129[b]	Tc-99[b]	
299-E17-22	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E17-23	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E17-25	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E17-26	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E18-1	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E24-21	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes
299-E24-24	C	S[c]	S[c]	S[c]	S[c]	S[c]	S	S	S	S	S	S	S	S	Yes

Notes:

1. Requirements from *Hanford Facility Dangerous Waste Permit Application, Integrated Disposal Facility* (DOE/RL-2003-12) and *Integrated Disposal facility Operational Monitoring Plan to Meet DOE Order 435.1* (RPP-PLAN-26534).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Operational parameters monitored for DOE O 435.1, *Radioactive Waste Management*.

c. To be sampled four times semiannually (total of eight times per well each year).

d. The sample frequency on all samples was changed to annually with the approval of Ecology after the April 2010 sampling event. Annual sampling will begin in CY 2011 to maintain baseline monitoring.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-18. Monitoring Wells and Constituents for Liquid Effluent Retention Facility

Well Number[a]	WAC-Compliant	Alkalinity	Alpha[b]	Ammonium	Anions	Beta[b]	Metals	Phenols	VOA	Sampled as Scheduled in 2010
299-E26-10	C	A	S	S	A	S	A	A	S	Yes
299-E26-11	C	A	S	S	A	S	A	A	S	Yes
299-E26-77	C	A	S	S	A	S	A	A	S	Yes, resampled in December due to unsuccessful attempt in July
299-E26-79	C	A	S	S	A	S	A	A	S	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the 200 East Area Liquid Effluent Retention Facility* (WHC-SD-EN-AP-024).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Monitored for *Atomic Energy Act of 1954*.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

VOA = volatile organic analysis

Table B-19. Monitoring Wells and Constituents for Low-Level Waste Management Area 1

Well Name[a]	Purpose	WAC Compliant	Water Level[b]	RCRA Required Constituents[c]										Supporting Constituents[e]				Sampled as Scheduled in 2010
				Contaminant Indicator Parameters				Groundwater Quality Parameters										
								Anions[d]			Metals, Unfiltered, Filtered[d]							
				pH[b]	Specific Conductance[b]	TOC	TOX	Chloride	Sulfate	Phenols[d]	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[b]	Temperature[b]	Turbidity[b]	
299-E28-26	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E28-27	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E28-28	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-2	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-3	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-4	Cross-gradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-5	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-6	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-7	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-8	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-10	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-28	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-29	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-34	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-35	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-265	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Sampled once
299-E33-266	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Sampled once

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for LLBG WMA 1* (DOE/RL 2009 75).

a. Upgradient wells are noted in ***bold italic***.

b. Field measurement.

c. Constituents and parameters required by 40 CFR 265.92, "Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis."

d. For anions, analytes include chloride, fluoride, nitrate, nitrite, and sulfate. For metals, analytes include (but are not limited to) calcium, chromium, iron, manganese, potassium, and sodium.

e. Constituents not required by RCRA but needed to support interpretation.

A = to be sampled annually

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Y = well is constructed in accordance with WAC 173-160 requirements

Table B-20. Critical Means for Low-Level Waste Management Area 1 for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	28	27	8.000	0.1276	1.6	4.4137	7.43 – 8.57
Specific conductance (µS/cm)	28	27	562.94	128.11	22.8	4.1540	1,100
TOC[a,b] (µg/L)	27	26	268.31	249.56	93.0	4.1772	1,330
TOX[a] (µg/L)	28	27	3.880	1.703	43.9	4.1540	11.1

Note: Based on semiannual sampling events from upgradient wells 299-E28-26 and 299-E28-27: June 2009 through December 2010 for all indicators; upgradient wells 299-E28-28 and 299-E32-4: December 2008 through June 2010 for pH and specific conductance, June 2009 through January 2011 (December 2010 delayed sample) for TOC and TOX; from upgradient wells 299-E33-28, 299-E33-29; and 299-E33-35: December 2008 through July 2010 for pH and specific conductance, June 2009 through January 2011 for TOC and TOX.

a. For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

b. Excluding erroneous data from June 2010.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and 68 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-21. Monitoring Wells and Constituents for Low-Level Waste Management Area 2

Well Name	Purpose	WAC Compliant	Water Level[c]	RCRA Required Constituents[a]														Sampled as Scheduled in 2010
				Contaminant Indicator Parameters				Groundwater Quality Parameters						Supporting Constituents[b]				
								Anions[d]			Metals, Unfiltered, Filtered[d]							
				pH[c]	Specific Conductance[c]	TOC	TOX	Chloride	Sulfate	Phenols[d]	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[c]	Temperature[c]	Turbidity[c]	
299-E27-8	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-10	Cross-gradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-11	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-17	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-2	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-10	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-12	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for LLBG WMA 2* (DOE/RL 2009 76).

a. Constituents and parameters required by 40 CFR 265.92, "Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis."

b. Constituents not required by RCRA but needed to support interpretation.

c. Field measurement.

d. For anions, analytes include chloride, fluoride, nitrate, nitrite, and sulfate. For metals, analytes include (but are not limited to) calcium, chromium, iron, manganese, potassium, and sodium.

A = to be sampled annually

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Y = well is constructed in accordance with requirements of WAC 173-160

Table B-22. Critical Means for Low-Level Waste Management Area 2 for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	6	5	7.80	0.111	1.4	9.0332	6.72 – 8.89
Specific conductance (µS/cm)	6	5	1,046.4	49.27	4.7	7.7981	1,460
TOC* (µg/L)	6	5	689.1	181.3	26.3	7.7981	2,220
TOX* (µg/L)	7	6	6.90	4.24	61.5	6.6568	37.1

Note: Based on semiannual sampling events from April 2008 through December 2010 for upgradient well 299-E27-10.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 36 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-23. Monitoring Wells and Constituents for Low-Level Waste Management Area 3

Well Number	WAC-Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2010
		pH (Field)	Specific Conductance (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-W7-4	C	S	S	S	S	A	A	A	A	No*
299-W10-29	C	S	S	S	S	A	A	A	A	Yes
299-W10-30	C	S	S	S	S	A	A	A	A	Yes
299-W10-31	C	S	S	S	S	A	A	A	A	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3* (DOE/RL-2009-68).
2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

* Well 299-W7-4 added back to network as required in DOE/RL-2009-68.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-24. Monitoring Wells and Constituents for Low-Level Waste Management Area 4

Well Number[a]	Comment	WAC Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2010
			pH (Field)	Specific Conductance (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-W15-17	Deep unconfined; no statistics	C	S	S	S	S	S	A	A	A	Yes
299-W15-30	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-83	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-94	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-152	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-224	--	C	S	S	S	S	S	A	A	A	Yes
299-W18-21	Went dry in mid-2010	C	S	S	S	S	S	A	A	A	No[b]
299-W18-22	Deep unconfined; no statistics	C	S	S	S	S	S	A	A	A	Yes

Notes:

1. Requirements from *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4* (DOE/RL-2009-69).
2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Well 299-W18-21 was not sampled during the second half of the year as it went dry in July.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-25. Critical Means for Low-Level Waste Management Area 4 for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	14	13	7.920	0.1892	2.4	4.6981	7.00 – 8.84
Specific conductance (µS/cm)	13	12	497.5	54.79	11.0	4.4215	750
TOC[a,b] (µg/L)	14	13	304.6	126.4	41.5	4.3191	870
TOX[a] (µg/L)	12.0	11	5.983	3.866	64.6	4.5477	24.3

Note: Based on semiannual sampling events from January 2007 through July 2007 for upgradient well 299-W15-15, from January 2007 through February 2010 for upgradient well 299-W18-21, and from February 2007 through May 2008 for upgradient well 299-W18-23.

a. For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

b. Excluding "R" flagged data, February 2008.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 24 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-26. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2010
			pH (field)	Specific Conductance (Field)	TOC	TOX	Anions	Metals	Phenols	VOA	
699-25-33A	Top of LPU; no statistics	C	S	S	S	S	S	A	A	S	Yes
699-25-34A	--	C	S	S	S	S	S	A	A	S	No[b]
699-25-34B	--	C	S	S	S	S	S	A	A	S	Yes
699-25-34D	--	C	S	S	S	S	S	A	A	S	Yes
699-26-33	--	C	S	S	S	S	S	A	A	S	Yes
699-26-34A	--	C	S	S	S	S	S	A	A	S	Yes
699-26-34B	--	C	S	S	S	S	S	A	A	S	Yes
699-26-35A	--	C	S	S	S	S	S	A	A	S	Yes
699-26-35C	Top of LPU; no statistics	C	S	S	S	S	S	A	A	S	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill* and Interim Change Notice 1 (PNNL-12227 and PNNL-12227-ICN-1).

2. Wells completed at the top of the unconfined aquifer unless otherwise specified.

a. ***Bold italic*** indicates upgradient well.

b. The first semiannual sample for the January through April 2010 time period was not collected for well 699-25-34A because of limited resources by the sampling teams in the January through July 2010 time period.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

LPU = low-permeability unit in upper portion of Ringold Formation (within HSU-5)

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

VOA = volatile organic analysis

Table B-27. Critical Means for Nonradioactive Dangerous Waste Landfill for CY 2011 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean
pH	8	7	7.306	0.0521	0.7	6.4295	6.95 – 7.66
Specific conductance (µS/cm)	8	7	529.6	6.027	1.1	5.7282	570
TOC* (µg/L)	8	7	251.3	124.4	49.5	5.7282	1,010
TOX* (µg/L)	8	7	3.722	1.671	44.9	5.7282	13.9

Note: Based on semiannual sampling events from January 2009 through July 2010 for upgradient wells 699-26-34A and 699-26-35A.

* For values reported below laboratory's specified method detection limit, one-half of the method detection limit is used in the critical mean calculation.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons

TOC = total organic carbon

TOX = total organic halides

Table B-28. Monitoring Wells and Constituents for RCRA PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1

Well Number[a]	Comment	WAC-Compliant	Primary RCRA Constituent	Supporting Parameters			Sampled as Scheduled in 2010
			Nitrate	Anions	Metals	Phenols	
299-E17-1	216-A-10	P	S	S	S	A	Yes
299-E17-14	216-A-36B	C	Q	Q	Q	A	Yes
299-E17-16	216-A-36B	C	S	S	S	A	Yes
299-E17-18	216-A-36B	C	S	S	S	A	Yes
299-E17-19	216-A-10	C	S	S	S	A	Yes
299-E24-16	216-A-10	C	Q	Q	Q	A	Yes
299-E24-18	Upgradient	C	S	S	S	A	Yes
299-E25-17	216-A-37-1	P	S	S	S	A	Yes
299-E25-19	216-A-37-1	P	Q	Q	Q	A	Yes
299-E25-31	Upgradient	C	S	S	S	A	Yes
699-37-47A	Downgradient	C	S	S	S	A	Yes
Additional wells	Far-field	--	[b]	[b]	--	--	See Appendix A for 200-PO-1

Notes:

1. Requirements from *Combination RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs* (PNNL-11523).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Far-field wells sampled annually to triennially in conjunction with the 200-PO-1 OU.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-29. Monitoring Wells and Constituents for Waste Management Area A-AX

Well Number[a]	WAC-Compliant	Site-Specific Constituents										Sampled as Scheduled in 2010
		Nitrate	Sodium	Sulfate	TOC	Chromium	Lead	Alkalinity	Anions	Metals	Tc-99[b]	
299-E24-20	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E24-22	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E24-33	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[c]
299-E25-2	P	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[c]
299-E25-40	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-41	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-93	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-94	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-236	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes

Notes:

1. Requirements from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site* (PNNL-15315).
2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. *Atomic Energy Act of 1954* parameter.

c. Samples not collected during fourth quarter as a result of the site-wide stop work.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells

P = constructed prior to WAC requirements

Q = to be sampled quarterly

TOC = total organic carbon

Table B-30. Monitoring Wells and Constituents for Waste Management Area B-BX-BY

Well Number*	WAC-Compliant	RCRA Parameters				AEA Parameters				Sampled as Scheduled in 2010
		Alkalinity	Anions	Cyanide	Metals	Gamma	Tc-99	Tritium	Uranium	
299-E28-8	P	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-7	P	S	S	S	S	S	S	S	S	Missed second half of CY 2010 sample due to water below the pump inlet. Maintenance to lower pump.
299-E33-9	P	S	S	S	S	S	S	S	S	Missed second half of CY 2010 sample due to work stoppage.
299-E33-15	P	S	S	S	S	S	S	S	S	Due to the work stoppage the second semiannual sample was not collected until 1/4/11.
299-E33-16	P	Q	Q	Q	Q	S	Q	Q	Q	Third quarter sample missed due to maintenance issues.
299-E33-17	P	A	A	A	A	--	A	A	A	Yes
299-E33-18	P	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-20	P	A	A	A	A	--	A	A	A	Yes
299-E33-21	P	A	A	A	A	--	A	A	A	Yes
299-E33-26	C	Q	Q	Q	Q	S	Q	Q	Q	Fourth quarter sample missed due to maintenance issues.
299-E33-31	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-32	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-38	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-39	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-41	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-42	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-43	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-44	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-47	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-48	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-49	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-334	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-335	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-337	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-338	C	Q	Q	Q	Q	--	Q	Q	Q	Due to the work stoppage the fourth quarter sample was not collected until 1/5/11.
299-E33-339	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-205	C	S	S	S	S	S	S	S	S	Missed second half of CY 2010 due to work stoppage.
299-E33-341	C	Q	Q	Q	Q	Q	Q	Q	Q	Missed first quarter sample due to sample schedule lapse.
299-E33-342	C	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E33-343	C	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E33-344	C	S	S	S	S	Q	S	S	S	Well was scheduled for annual sampling only during CY 2010. Perched well that has not been formally accepted into the network.
299-E33-345	C	Q	Q	Q	Q	Q	Q	Q	Q	Yes

Table B-30. (Cont.)

Well Number*	WAC-Compliant	RCRA Parameters				AEA Parameters				Sampled as Scheduled in 2010
		Alkalinity	Anions	Cyanide	Metals	Gamma	Tc-99	Tritium	Uranium	

Notes:

1. Requirements from *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site* (PNNL-13022-ICN-3).

2. Wells completed at the top of the unconfined aquifer.

* Gradient nearly flat; indeterminate flow direction; no upgradient wells defined.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-31. Monitoring Wells and Constituents for Waste Management Area C

Well Name[a]	Purpose	Well Construction Standard	pH	Specific Conductance	Alkalinity	Anions	Cyanide	Metals[b], Unfiltered, Filtered	Water Level	Sampled as Scheduled in 2010
299-E27-4	Downgradient	C	Q	Q	Q	Q	Q	Q	Q-	Yes
299-E27-7	Upgradient	N	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-12	Upgradient	C	Q	Q	Q	Q	Q	Q	Q	Sampled in three of four quarters
299-E27-13	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-14	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-15	Upgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-21	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-22	Upgradient	C	Q	Q	Q	Q	Q	Q	Q-	Yes
299-E27-23	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-155	Cross- to downgradient	C	SA	SA	SA	SA	SA	SA	SA	Yes
299-E27-24	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-25	Cross-gradient	C	Q	Q	Q	Q	Q	Q	Q	Yes

Notes:

1. Requirements from *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Waste Management Area C* (DOE/RL-2009-77).

2. Water levels are measured in all wells before sampling. T he measurement frequency is provided.

3. WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

a. ***Bold italic*** indicates upgradient well.

b. Metals for groundwater quality include iron, manganese, and sodium.

C = well constructed as a WAC 173-160 resource protection wells

N = well constructed before requirements of WAC 173-160 were applicable at the Hanford Site

Q = quarterly

SA = semiannually

Table B-32. Groundwater Assessment Volatile Organic Compound Monitoring at Waste Management Area C

Dangerous Waste Constituent Name[a]	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	Proposed Upgradient Well[b]	Proposed Downgradient Well[b]
1,1-Dichloroethane	75-34-3	X	X	X	X	X	X	X	X	X	X	X	X
1,1-Dichloroethylene	75-35-4	X	X	X	X	X	X	X	X	X	X	X	X
1,1,1-Trichloroethane	71-55-6	X	X	X	X	X	X	X	X	X	X	X	X
1,1,2,2-Tetrachloroethane	79034-5	X	X	X	X	X	X	X	X	X	X	X	X
1,1,2-Trichloroethane	79-00-5	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dibromoethane	106-93-4	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dichloroethane	107-06-2	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dichloropropane	78-87-5	X	X	X	X	X	X	X	X	X	X	X	X
1,2,4-Trichlorobenzene	120-82-1	X	X	X	X	X	X	X	X	X	X	X	X
1,4-Dichlorobenzene	106-46-7	X	X	X	X	X	X	X	X	X	X	X	X
1,4-Dioxane	123-91-1	X	X	X	X	X	X	X	X	X	X	X	X
2-Butanone (MEK)	78-93-3	X	X	X	X	X	X	X	X	X	X	X	X
2-Hexanone	591-78-6	X	X	X	X	X	X	X	X	X	X	X	X
2-Propanone (Acetone)	67-64-1	X	X	X	X	X	X	X	X	X	X	X	X
3-Chloropropene	107-05-1	X	X	X	X	X	X	X	X	X	X	X	X
4-Methyl-2-petanone	108-10-1	X	X	X	X	X	X	X	X	X	X	X	X
Acetonitrile	75-05-8	X	X	X	X	X	X	X	X	X	X	X	X
Acrolein	107-02-8	X	X	X	X	X	X	X	X	X	X	X	X
Acrylonitrile	107-13-1	X	X	X	X	X	X	X	X	X	X	X	X
Benzene	71-43-2	X	X	X	X	X	X	X	X	X	X	X	X
Bromomethane	74-83-9	X	X	X	X	X	X	X	X	X	X	X	X
Carbon disulfide	75-15-0	X	X	X	X	X	X	X	X	X	X	X	X
Carbon tetrachloride	56-23-5	X	X	X	X	X	X	X	X	X	X	X	X
Chlorobenzene	108-90-7	X	X	X	X	X	X	X	X	X	X	X	X
Chloroethene	75-01-4	X	X	X	X	X	X	X	X	X	X	X	X
Chloroform	67-66-3	X	X	X	X	X	X	X	X	X	X	X	X
Chloromethane	74-87-3	X	X	X	X	X	X	X	X	X	X	X	X
Cis-1,3-dichloropropene	10061-01-5	X	X	X	X	X	X	X	X	X	X	X	X
Dichlorodifluoro-methane	75-71-8	X	X	X	X	X	X	X	X	X	X	X	X
Dichloromethane	75-09-2	X	X	X	X	X	X	X	X	X	X	X	X
Ethylbenzene	100-41-4	X	X	X	X	X	X	X	X	X	X	X	X
Ethyl cyanide	107-12-0	X	X	X	X	X	X	X	X	X	X	X	X
Methacrylonitrile	126-98-7	X	X	X	X	X	X	X	X	X	X	X	X
Styrene	100-42-5	X	X	X	X	X	X	X	X	X	X	X	X
Tetrachloroethene	127-18-4	X	X	X	X	X	X	X	X	X	X	X	X
Toluene	108-88-3	X	X	X	X	X	X	X	X	X	X	X	X
Trans-1,3-dichloropropene	10061-02-6	X	X	X	X	X	X	X	X	X	X	X	X
Trichloroethylene	79-01-06	X	X	X	X	X	X	X	X	X	X	X	X
Trichlorofluoro-methane	75-69-4	X	X	X	X	X	X	X	X	X	X	X	X
Xylenes	1330-20-7	X	X	X	X	X	X	X	X	X	X	X	X

a. Constituents collected and analyzed during the December sampling event. Constituents considered dangerous constituents, as defined in WAC 173-303-645(4) and based on the logic discussed in Section 9.2, will be retained for quarterly sampling for the first year, semiannual sampling in the second year, and annually thereafter, or until no longer required.

b. Wells will be sampled for constituents in the December sampling event if sample-ready; otherwise, the wells are sampled in March.

CAS = Chemical Abstract Services

Table B-33. Groundwater Assessment Semivolatile Organic Compound Monitoring at Waste Management Area C

Dangerous Waste Constituent Name[a]	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	Proposed Upgradient Well[b]	Proposed Downgradient Well[b]
1,2-Dichlorobenzene	95-50-1	X	X	X	X	X	X	X	X	X	X	X	X
1,3-Dichlorobenzene	541-73-1	X	X	X	X	X	X	X	X	X	X	X	X
2-Chlorophenol	95-57-8	X	X	X	X	X	X	X	X	X	X	X	X
2-Methylphenol	95-48-7	X	X	X	X	X	X	X	X	X	X	X	X
2-Nitrophenol	88-75-5	X	X	X	X	X	X	X	X	X	X	X	X
2-sec-Butyl-4,6-dinitrophenol	88-85-7	X	X	X	X	X	X	X	X	X	X	X	X
2,4-Dinitrotoluene	121-14-2	X	X	X	X	X	X	X	X	X	X	X	X
2,4,5-Trichlorophenol	95-95-4	X	X	X	X	X	X	X	X	X	X	X	X
2,4,6-Trichlorophenol	88-06-2	X	X	X	X	X	X	X	X	X	X	X	X
3-Methylphenol	108-39-4	X	X	X	X	X	X	X	X	X	X	X	X
4-Methylphenol	106-44-5	X	X	X	X	X	X	X	X	X	X	X	X
Acenaphthene	83-32-9	X	X	X	X	X	X	X	X	X	X	X	X
Acetophenone	98-86-2	X	X	X	X	X	X	X	X	X	X	X	X
Aldrin	309-00-2	X	X	X	X	X	X	X	X	X	X	X	X
Alpha-BHC	319-84-6	X	X	X	X	X	X	X	X	X	X	X	X
Benzo[a]pyrene	50-32-8	X	X	X	X	X	X	X	X	X	X	X	X
Beta-BHC	319-85-7	X	X	X	X	X	X	X	X	X	X	X	X
Butylbenzylphthalate	85-68-7	X	X	X	X	X	X	X	X	X	X	X	X
Dibenzene[a,h]anthracene	53-70-3	X	X	X	X	X	X	X	X	X	X	X	X
Dieldrin	60-57-1	X	X	X	X	X	X	X	X	X	X	X	X
Di-n-butylphthalate	84-74-2	X	X	X	X	X	X	X	X	X	X	X	X
Diphenylamine	122-39-4	X	X	X	X	X	X	X	X	X	X	X	X
Endrin	72-20-8	X	X	X	X	X	X	X	X	X	X	X	X
Fluoranthene	206-44-0	X	X	X	X	X	X	X	X	X	X	X	X
Gamma-BHC	58-89-9	X	X	X	X	X	X	X	X	X	X	X	X
Heptachlor	76-44-8	X	X	X	X	X	X	X	X	X	X	X	X
Hexachlorobenzene	118-74-1	X	X	X	X	X	X	X	X	X	X	X	X
Hexachlorobutadiene	87-68-3	X	X	X	X	X	X	X	X	X	X	X	X
Hexachloroethane	67-72-1	X	X	X	X	X	X	X	X	X	X	X	X
Isodrin	465-73-6	X	X	X	X	X	X	X	X	X	X	X	X
Naphthalene	91-20-3	X	X	X	X	X	X	X	X	X	X	X	X
Nitrobenzene	98-95-3	X	X	X	X	X	X	X	X	X	X	X	X
N-Nitrosodi-methylamine	62-75-9	X	X	X	X	X	X	X	X	X	X	X	X
N-Nitrosodi-propylamine	62164-7	X	X	X	X	X	X	X	X	X	X	X	X
n-Nitrosomorpholine	59-89-2	X	X	X	X	X	X	X	X	X	X	X	X
p-Chorol-m-cresol	59-50-7	X	X	X	X	X	X	X	X	X	X	X	X
Pentachloronitro-benzene	82-68-8	X	X	X	X	X	X	X	X	X	X	X	X
Pentachlorophenol	87-86-5	X	X	X	X	X	X	X	X	X	X	X	X
Phenol	108-95-2	X	X	X	X	X	X	X	X	X	X	X	X
Pyrene	129-00-0	X	X	X	X	X	X	X	X	X	X	X	X
Pyridine	110-86-1	X	X	X	X	X	X	X	X	X	X	X	X
Toxaphene	8001-35-2	X	X	X	X	X	X	X	X	X	X	X	X

Table B-33. (Cont.)

Dangerous Waste Constituent Name[a]	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	Proposed Upgradient Well[b]	Proposed Downgradient Well[b]

a. Constituents collected and analyzed during December sampling event. Constituents considered dangerous constituents, as defined in WAC 173-303-645(4) and per the logic discussed in Section 9.2, will be retained for quarterly sampling for the first year, semiannual sampling in the second year, and annually thereafter, or until no longer required.

b. Wells will be sampled for constituents in the December sampling event if sample-ready; otherwise, the wells are sampled in March.

CAS = Chemical Abstract Services

Table B-34. Groundwater Assessment Inorganic Constituent Monitoring at Waste Management Area C

Dangerous Waste Constituent Name[a]	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	Proposed Upgradient Well[b]	Proposed Downgradient Well[b]
Antimony	7440-36-0	X	X	X	X	X	X	X	X	X	X	X	X
Arsenic	7440-38-2	X	X	X	X	X	X	X	X	X	X	X	X
Barium	7440-39-3	X	X	X	X	X	X	X	X	X	X	X	X
Beryllium	7440-41-7	X	X	X	X	X	X	X	X	X	X	X	X
Cadmium	7440-43-9	X	X	X	X	X	X	X	X	X	X	X	X
Chromium	7440-47-3	X	X	X	X	X	X	X	X	X	X	X	X
Cobalt	7440-48-4	X	X	X	X	X	X	X	X	X	X	X	X
Copper	7440-50-8	X	X	X	X	X	X	X	X	X	X	X	X
Cyanide	57-12-5	X	X	X	X	X	X	X	X	X	X	X	X
Lead	7439-92-1	X	X	X	X	X	X	X	X	X	X	X	X
Mercury	7439-97-6	X	X	X	X	X	X	X	X	X	X	X	X
Nickel	7440-02-0	X	X	X	X	X	X	X	X	X	X	X	X
Selenium	7782-49-2	X	X	X	X	X	X	X	X	X	X	X	X
Silver	7440-22-4	X	X	X	X	X	X	X	X	X	X	X	X
Sulfide	18496-25-8	X	X	X	X	X	X	X	X	X	X	X	X
Thallium	7440-28-0	X	X	X	X	X	X	X	X	X	X	X	X
Tin	7440-31-5	X	X	X	X	X	X	X	X	X	X	X	X
Vanadium	7440-62-2	X	X	X	X	X	X	X	X	X	X	X	X
Zinc	7440-66-6	X	X	X	X	X	X	X	X	X	X	X	X

a. Constituents will be collected and analyzed during December sampling event. Constituents considered dangerous constituents, as defined in WAC 173-303-645(4) and according to the logic discussed in Section 9.2, will be retained for quarterly sampling for the first year, semiannual sampling in the second year, and annually thereafter, or until no longer required.

b. Wells will be sampled for constituents in the December sampling event if sample-ready; otherwise, the wells are sampled in March.

CAS = Chemical Abstract Services

Table B-35. Monitoring Wells and Constituents for Waste Management Area S-SX

Well Number[a]	WAC-Compliant	RCRA	Supporting Constituents									Sampled as Scheduled in 2010
		Chromium	Nitrate	Alkalinity	Anions	Metals	Se-79	Tc-99	Tritium	Uranium	Gamma	
299-W22-26[b]	P	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-44	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes
299-W22-45	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-47	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes
299-W22-48	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-49	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-50	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes
299-W22-69	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-72	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-80	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-81	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-82	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-83	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-84	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-85	C	Q	Q	Q	Q	Q	--	Q	A	A	--	No; third quarter missed due to maintenance issue and stop work
299-W22-86	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W22-89[c]	C	2	2	2	2	2	--	2	1	1	--	Yes
299-W23-15	C	Q	Q	Q	Q	Q	--	Q	A	A	--	Yes
299-W23-19	C	Q	Q	Q	Q	Q	A	Q	A	A	A	Yes
299-W23-20	C	Q	Q	Q	Q	Q	A	Q	A	A	--	No; fourth quarter missed due to stop work
299-W23-21	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes

Notes:

1. Requirements from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, Interim Change Notice 4 (PNNL-12114-ICN-4).

2. Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

b. Sampled during the reporting period; was added to the revised monitoring plan (DOE/RL-2009-73) for sampling in 2011.

c. New well installed in June 2010; sampled the indicated number of times; was added to the revised monitoring plan (DOE/RL-2009-73) for sampling in 2011.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

Table B-36. Monitoring Wells and Constituents for Waste Management Area T

Well Number*	Comment	WAC-Compliant	Constituents of Concern		Supporting Groundwater Quality Constituents and AEA Parameters									Sampled as Scheduled in 2010
			Chromium (Total, Filtered)	Nitrate	Alkalinity	Anions	Gamma	Alpha	Beta	I-129	Metals	Tc-99	Tritium	
299-W10-1	--	P	Q	Q	Q	Q		A	A	--	Q	Q	Q	Yes
299-W10-4	Not sampled second quarter	P	Q	Q	Q	Q	A	A	A	--	Q	Q	Q	No
299-W10-8	Not sampled fourth quarter	P	Q	Q	Q	Q	--	A	A	--	Q	Q	Q	No
299-W10-22	Removed from network in the revised monitoring plan	C	S	S	S	S	--	--	--	--	S	S	S	No
299-W10-23	--	C	Q	Q	Q	Q	--	A	A	--	Q	Q	Q	Yes
299-W10-24	--	C	Q	Q	Q	Q	S	S	S	--	Q	Q	Q	Yes
299-W10-28	--	C	Q	Q	Q	Q	--	A	A	--	Q	Q	Q	Yes
299-W11-7	Removed from network in the revised monitoring plan	P	S	S	S	S	--	--	--	--	S	S	S	No
299-W11-12	Not sampled first and fourth quarters	P	Q	Q	Q	Q	--	A	A	--	Q	Q	Q	No
299-W11-39	--	C	Q	Q	Q	Q	S	S	S	--	Q	Q	Q	Yes
299-W11-40	--	C	Q	Q	Q	Q	--	A	A	--	Q	Q	Q	Yes
299-W11-41	--	C	Q	Q	Q	Q	S	S	S	A	Q	Q	Q	Yes
299-W11-42	--	C	Q	Q	Q	Q	S	S	S	--	Q	Q	Q	Yes
299-W11-45	Extraction well; screened 8.5 to13 meters below water table Not sampled third and fourth quarters	C	Q	Q	Q	Q	A	A	A	--	Q	Q	Q	No
299-W11-46	Extraction well; screened 6 to 12 meters below water table	C	Q	Q	Q	Q	S	S	S	--	Q	Q	Q	Yes
299-W11-47	Screened 9 to 18 meters below water table	C	Q	Q	Q	Q	S	S	S	A	Q	Q	Q	Yes

Notes:

1. Requirements from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T* (PNNL-15301).
2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

* ***Bold italic*** indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-37. Monitoring Wells and Constituents for Waste Management Area TX-TY

Well Number[a]	Comment	WAC-Compliant	RCRA Parameters		Supporting Groundwater Quality Constituents and AEA Parameters										Sampled as Scheduled in 2010
			Chromium (Total, Filtered)	Nitrate	Alkalinity	Anions	Alpha	Beta	Gamma	I-129	Metals	Sr-90	Tc-99	Tritium	
299-W10-26	--	C	Q	Q	Q	Q	A	A	A	--	Q		Q	Q	Yes
299-W10-27	--	C	Q	Q	Q	Q	A	A	A	--	Q		Q	Q	Yes
299-W14-6	Well went dry in fourth quarter	P	Q	Q	Q	Q	--	--	--	--	Q		Q	Q	No
299-W14-11	Screened 11 to 14.6 m below water table	C	Q	Q	Q	Q	A	A	S	Q	Q	A	Q	Q	Yes
299-W14-13	Not sampled in second, third, and fourth quarters	C	Q	Q	Q	Q	A	A	S	Q	Q	A	Q	Q	No
299-W14-14	--	C	Q	Q	Q	Q	A	A	A	--	Q	--	Q	Q	Yes
299-W14-15	--	C	Q	Q	Q	Q	S	S	A	Q	Q	--	Q	Q	Yes
299-W14-16	--	C	Q	Q	Q	Q	S	S	--	Q	Q	--	Q	Q	Yes
299-W14-17	Not sampled in second and fourth quarters	C	Q	Q	Q	Q	A	A	--	Q	Q	--	Q	Q	No
299-W14-18	Not sampled in second quarter	C	Q	Q	Q	Q	A	A	A	Q	Q	--	Q	Q	No
299-W14-19	Not sampled in second quarter	C	Q	Q	Q	Q	--	--	A	--	Q	--	Q	Q	No
299-W15-40	Extraction well	C	Q	Q	Q	Q	--	--	--	--	Q	--	Q	Q	Yes
299-W15-41	--	C	Q	Q	Q	Q	A	A	A	S	Q	--	Q	Q	Yes
299-W15-44[b]	Extraction well; not sampled in first and second quarters	C	Q	Q	Q	Q	A	A	A	S	Q	--	Q	Q	No
299-W15-763	--	C	Q	Q	Q	Q	A	A	A	--	Q	--	Q	Q	Yes
299-W15-765	Extraction well; not sampled in second quarter	C	Q	Q	Q	Q	A	A	A	S	Q	--	Q	Q	No

Notes:

1. Requirements from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area TX-TY* (PNNL-16005).
2. Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Well 299-W15-44 was taken out of service as an extraction well and converted to a monitoring well by third quarter CY 2010.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-38. Monitoring Wells and Constituents for Waste Management Area U

Well Number[a]	WAC-Compliant	RCRA	Supporting Parameters							Sampled as Scheduled in 2010[b]
		Chromium	Nitrate	Alkalinity	Anions	Metals	Tc-99	Gross Alpha/ Beta	Gamma	
299-W18-30	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W18-31	C	Q	Q	Q	Q	Q	Q	A	A	Dry in fiscal year 2008
299-W18-40	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W19-12	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W19-41	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W19-42	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W19-44	C	Q	Q	Q	Q	Q	Q	A	A	No; first quarter missed due to maintenance issue
299-W19-45	C	Q	Q	Q	Q	Q	Q	A	A	Yes
299-W19-47	C	Q	Q	Q	Q	Q	Q	A	A	Yes

Notes:

1. Requirement from *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U*, Interim Change Notice 2 (PNNL-13612-ICN-2).

2. Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

b. Fourth quarter sampling delayed from October to November/December for all wells due to stop work.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

Q = to be sampled quarterly

Table B-39. Monitoring Wells and Constituents for the KE and KW Basins

Well	Comment	WAC-Compliant	Contaminants of Concern											Sampled as Scheduled in 2010
			Gross Alpha	Anions	Gross Beta	C-14	Metals	Sr-90	Tc-99	Tritium	Alkalinity	Uranium (Total)	VOA	
KE Basin														
199-K-29	--	P	Q/M	Q	Q/M	A/S	A/S	0/S	0/Q	M	0/S	--	--	No; sampled in December 2010. Decommissioned in December 2010
199-K-30	--	P	Q	Q	Q	A/S	S	--	0/S	Q	0/S	--	--	No; sampled in January, April, and December 2010. Decommissioned in December 2010
199-K-32A	--	C	Q	Q	Q	A/S	A/S	--	A/S	Q	0/S	--	--	Yes; sampled in March, June, September, and December 2010
199-K-110A	--	C	S	S	S	--	A/S	--	--	S	0/S	--	--	Yes; sampled in April and December 2010
199-K-111A	--	C	Q/Q	Q	Q/Q	A	A/S	--	A/S	Q/Q	0/S	--	--	Yes; sampled in February, March, April, June, July, September, and December 2010
199-K-141	--	C	0/S	0/S	0/S	0/S	0/S	0/S	0/S	0/S	0/S	--	--	Yes; sampled in February and July 2010
199-K-142	--	C	0/S	0/S	0/S	0/S	0/S	0/S	0/S	0/S	0/S	0/S	--	Yes; sampled in March, June, September, and December 2010
KW Basin														
199-K-31	Not included in monitoring plan	P	0/S	0/S	0/S	--	0/S	--	0/A	0/S	0/A	--	--	Yes; sampled in March and June 2010
199-K-34	--	C	Q	Q	Q	A	S/Q	A	A	Q	0/A	0/A	--	Yes; sampled in April, June, September, and December 2010
199-K-106A	--	C	Q	Q	Q	A/S	S/Q	--	0/Q	Q	0/S	--	0/S	No; sampled in March and June 2010
199-K-107A	--	C	Q	Q	Q	A	S/Q	A	A	Q	0/A	0/A	--	Yes; sampled in January, April, July, and December 2010
199-K-108A	--	C	S	S	S	0/S	S	--	--	S	0/S	--	--	Yes; sampled in January, March, June, August, September, and December 2010
199-K-132	--	C	S/Q	S/Q	S/Q	A/S	S/Q	--	0/S	S/Q	0/S	--	0/S	Yes; sampled in February, June, August, and November 2010

Notes:

1. Requirements from *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins* (PNNL-14033).
2. Frequency required under monitoring plan is listed first. Some constituents are sampled more frequently during basin cleanout; those frequencies are listed after the slash. For example, "0/Q" means not required under monitoring plan but currently sampled quarterly.
3. Wells are completed at the top of the unconfined aquifer.
4. Sampling abbreviations used in this table are as follows:

A = to be sampled annually
C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standard for Construction and Maintenance of Wells"
M = to be sampled monthly
P = constructed prior to WAC requirements
Q = to be sampled quarterly
S = to be sampled semiannually

Table B-40. Monitoring Wells, Constituents, and Enforcement Limits for 200 Area Treated Effluent Disposal Facility

Well Number*	WAC-Compliant	Constituents with Enforcement Limits			Other Constituents								Sampled as Scheduled in 2010
		pH (6.5 to 8.5)	Cadmium (5 µg/L)	Lead (10 µg/L)	Specific Conductance	Alpha	Anions	Beta	Metals	Total Dissolved Solids	Trace Metals	Tritium	
699-40-36	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes
699-41-35	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes
699-42-37	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility* (PNNL-13032).
2. All wells completed at the top of the Ringold Formation confined aquifer.

* ***Bold italic*** indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

Q = to be sampled quarterly

Table B-41. Monitoring Wells and Constituents for Environmental Restoration Disposal Facility

Well Number[a]	WAC-Compliant	Alkalinity	Alpha	Anions	Beta	C-14	I-29	Metals	Radium[b]	Total Dissolved Solids	Tc-99	TOX	Uranium	VOA	Sampled as Scheduled in 2010
699-35-66A	P	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-36-66B	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-36-70A	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-37-66	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes

Notes:

1. Requirements from *Groundwater Protection Plan for the Environmental Restoration Disposal Facility* (WCH-198).
2. Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

b. Total alpha energy emitted from radium.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

S = to be sampled semiannually

TOX = total organic halides

VOA = volatile organic analyte

Table B-42. Monitoring Wells and Constituents for Solid Waste Landfill

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters														Other Parameters				Sampled as Scheduled in 2010
			Ammonia	Chemical Oxygen Demand	Chloride	Iron (Filtered)	Manganese (Filtered)	Zinc (Filtered)	Nitrate	Nitrite	pH (Field)	Specific Conductance (Field)	Sulfate	Temperature (Field)	Coliform Bacteria	TOC	Anions	Metals (Filtered)	Arsenic (Filtered)	VOA	
699-22-35	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]
699-23-34A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-23-34B	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-33	Information only; no statistics	P	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-34A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-34B	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]
699-24-34C	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-35	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]
699-26-35A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes

Notes:

1. Requirements from *Groundwater Monitoring Plan for the Solid Waste Landfill* (PNNL-13014).
2. Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

b. Well not sampled as scheduled in December 2010 due to large sampling load after work stoppage in October 2010.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

TOC = total organic carbon

VOA = volatile organic analysis

Table B-43. Monitoring Wells, Constituents, and Enforcement Limits for State-Approved Land Disposal Site

Well	Comment	Constituents with Enforcement Limits												Other Constituents					Sampled as Scheduled for CY 2010
		WAC Compliant	pH	Acetone	Benzene	Cadmium *	Chloroform	Copper *	Lead *	Mercury *	Sulfate	Tetrahydrofuran	Total Dissolved Solids	Specific Conductance	Alpha	Beta	Sr-90	Tritium	
299-W6-6	Bottom of unconfined	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W6-11	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W6-12	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W7-3	Bottom of unconfined	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	Yes
299-W8-1	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
699-48-71	Unconfined	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
699-48-77A	Ringold Formation unit E, upper	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-48-77C	Ringold Formation unit E, middle to lower	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-48-77D	Ringold Formation unit E, upper	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-49-79	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
699-51-75	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	Yes
699-51-75P	Lower unconfined	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes

Notes:

1. Requirements are from *Groundwater Monitoring and Tritium Tracking Plan for the 200 Area State-Approved Land Disposal Site* (PNNL-13121).

2. Wells are completed at the top of the aquifer unless specified otherwise

* Filtered and unfiltered samples.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC-173-160

P = constructed prior to WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-44. Analytical Results for Required Constituents at the Solid Waste Landfill

Constituent[a]	Date	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
Ammonium ion (µg/L) BTV = 90 µg/L[b]	1/19/10	5.54	<4.38	5.54	5.80	4.89	7.47	4.77	16.7	<4.38
	4/20-21/10	<4.38	<4.38	<4.38	<4.38	14.0	<4.38	12.9	23.7	<4.38
	7/19/10	14.6	10.6	39.3	51.3	26.5	21.6	34.3	15.6	11.2
	12/6/10	SNC	<3.09	<3.09	12.6	<3.09	SNC	<3.09	SNC	<3.09
Chemical oxygen demand (mg/L) BTV = 10 mg/L	1/19/10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	4/20-21/10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	7/19/10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	12/6/10	SNC	<10	<10	<10	<10	SNC	<10	SNC	<10
Chloride (mg/L) BTV = 7.82 mg/L	1/19/10	6.18	6.22	5.86	6.52	6.83	6.40	6.47	5.95	7.10
	4/20-21/10	6.37	6.27	5.85	6.53	6.84	6.43	6.60	6.00	7.11
	7/19/10	7.28	7.14	6.62	7.16	7.42	7.1	7.19	6.44	7.41
	12/6/10	SNC	NAR	NAR	7.03	7.37	SNC	7.12	SNC	7.53
Coliform bacteria (colonies/100mL) BTV = 1 col./100 ml	1/19/10	≤1	≤1	≤1	≤1	**3.1**	≤1	≤1	≤1	≤1
	4/20-21/10	0	0	0	0	0	0	0	0	0
	7/19/10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
	12/6/10	SNC	NAR	NAR	NAR	NAR	SNC	NAR	SNC	NAR
Iron (filtered) (µg/L) BTV = 160 µg/L	1/19/10	<18	38.7	25.9	<18	42.7	77.6	54.2	34.3	20.5
	4/20-21/10	21.1	23.0	<18	<18	66.8	149	43.9	19.6	<18
	7/19/10	29.5	41.0	38.0	<18	36.0	73.0	20.0	<18	<18
	12/6/10	SNC	<38	<38	<38	<38	SNC	<38	SNC	<38
Manganese (filtered) (µg/L) BTV = 18 µg/L	1/19/10	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
	4/20-21/10	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
	7/19/10	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
	12/6/10	SNC	<4.0	<4.0	<4.0	<4.0	SNC	<4.0	SNC	<4.0
Nitrate (mg/L) BTV = 29 mg/L	1/19/10	17.8	19.4	17.4	14.9	13.9	15.2	14.7	12.8	17.9
	4/20-21/10	18.2	20.1	17.8	15.1	14.4	16.1	15.2	13.2	18.1
	7/19/10	18.1	19.5	17.8	15.1	14.3	16.0	14.6	12.5	17.9
	12/6/10	SNC	NAR	NAR	15.1	14.2	SNC	14.4	SNC	18.2
Nitrite (µg/L) BTV = 266 µg/L	1/19/10	<118	<118	<118	<118	<118	<118	<118	<118	<118
	4/20/10 to 4/21/10	<118	<118	<118	<118	<118	<118	<118	<118	<118
	7/19/10	<118	<118	<118	<118	<118	<118	<118	<118	<118
	12/6/10	SNC	NAR	NAR	<118	<118	SNC	<118	SNC	<118

Table B-44. (Cont.)

Constituent[a]	Date	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
pH measurement BTR = 6.68-7.84	1/19/10	6.95	**6.65**	**6.67**	6.86	6.7	6.71	6.96	6.87	7.27
	4/20/10 to 4/21/10	6.91	**6.63**	**6.64**	6.86	6.81	6.85	7.60	6.83	7.26
	7/19/10	6.93	**6.67**	**6.66**	6.95	6.74	6.70	6.85	6.85	7.33
	12/6/10	SNC	**6.67**	**6.66**	6.98	6.96	SNC	7.21	SNC	7.29
Specific conductance (µS/cm) BTV = 583 µS/cm	1/19/10	**788**	**741**	**738**	**753**	**668**	**682**	**712**	573	534
	4/20/10 to 4/21/10	**806**	**758**	**750**	**750**	**652**	**676**	**725**	565	532
	7/19/10	**812**	**758**	**757**	**732**	**662**	**689**	**725**	566	522
	12/6/10	SNC	**758**	**747**	**742**	**650**	SNC	**720**	SNC	534
Sulfate (mg/L) BTV = 47.2 mg/L	1/19/10	43.3	**48.4**	45.3	44.3	45.7	46.0	42.5	44.9	40.0
	4/20/10 to 4/21/10	44.3	**49.2**	45.3	45.4	47.0	47.3	43.9	46.1	40.9
	7/19/10	43.9	**48.8**	44.8	44.5	46.3	46.7	43.6	44.7	40.5
	12/6/10	SNC	NAR	NAR	44.3	46.8	SNC	43.4	SNC	40.7
Temperature (°C) BTV = 20.7°C	1/19/10	16.7	18.6	18.0	19.2	17.2	18.5	18.2	17.0	19.0
	4/20/10 to 4/21/10	19.4	18.1	17.9	19.6	18.1	18.5	18.4	17.8	19.7
	7/19/10	19.4	20.3	20.0	19.9	20.6	**22.6**	**20.8**	18.5	19.6
	12/6/10	SNC	17.9	17.7	19.2	15.7	SNC	16.5	SNC	18.8
TOC (µg/L) BTV = 1,200 µg/L	1/19/10	434	430	461	319	350	300	364	300	300
	4/20/10 to 4/21/10	783	872	864	760	564	559	544	498	417
	7/19/10	435	487	541	435	332	328	398	305	300
	12/6/10	SNC	886	1,000	881	699	SNC	837	SNC	536
Zinc (filtered) (µg/L) BTV = 42.3 µg/L	1/19/10	<6	<6	<6	7.5	<6	<6	6.5	<6	7.1
	4/20/10 to 4/21/10	<6	<6	<6	9.2	<6	<6	7.6	6.3	<6
	7/19/10	6.5	<6	<6	<6	<6	<6	8.0	6.0	<6
	12/6/10	SNC	<4	<4	6.0	<4	SNC	12.0	SNC	5.0

Note: Results in **bold** exceed background threshold values.

a. WAC 173-304, "Minimum Functional Standards for Solid Waste Handling."

b. 2010 Background threshold values obtained from Table C-41 of *Hanford Site Groundwater Monitoring for Calendar Year 2009* (DOE/RL-2010-11).

BTV = background threshold value

NAR = no analysis result

SNC = sample not collected

TOC = total organic carbon

Table B-45. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill

Constituent[a] (unit)	W-test Statistic[b] (Log Value)	W-test Statistic[b] (Raw Data)	W-test[b] Critical Value, Wα[c]	Upper Tolerance Limit	Background Threshold Value
Ammonium (as NH_3^-) (µg/L)	NC	NC	NC	90[d] 19.7[e] WSCF 27.5[e] STL	90
Chemical oxygen demand (µg/L)	NC	NC	NC	10,000[f]	10,000
Chloride (µg/L)	0.954 s	0.962 s	0.963	7,820[d]	7,820
Coliform bacteria (colonies/100 mL)	NC	NC	NC	1[f]	1
Field pH	0.988 ns	NA	0.963	[6.68, 7.84][g]	[6.68, 7.84]
Iron, dissolved (µg/L)	0.960 s	0.802 s	0.962	160[d] 174[e] WSCF 129[e] STL	174
Manganese, dissolved (µg/L)	NC	NC	NC	10[d] 27.5[e] WSCF 15.1[e] STL	27.5
Nitrate (as NO_3^-) (µg/L)	0.833 s	0.844 s	0.963	29,000[d]	29,000
Nitrite (as NO_2^-) (µg/L)	NC	NC	NC	165[e] WSCF 14[e] STL	165
Specific conductance (µS/cm)	0.978 ns	NA	0.960	583[g]	583
Sulfate (µg/L)	0.983 ns	NA	0.963	47,200[g]	47,200
Temperature (degrees C)	0.953 s	0.961 s	0.963	20.7[d]	20.7
Total organic carbon (µg/L)	NC	NC	NC	842[d] 210[e]	842
Zinc, dissolved (µg/L)	NC	NC	NC	42.3[d] 18.3[e] WSCF 32.1[e] STL	42.3

a. Constituents are specified in WAC 173-304-490(2)(d). Data collected from March 1993 to May 2000 from upgradient wells 699-24-35 and 699-26-35A.

b. From "Approximate Analysis of Variance Test for Normality," in *Journal of the American Statistical Association* (Shapiro and Francia, 1972).

c. Obtained from Table A-9 in "How to Test Normality and Other Distributional Assumptions," in *ASQC Basic References in Quality Control: Statistical Techniques* (Shapiro, 1980) for $\alpha = 5\%$.

d. Maximum value reported.

e. Based on limit of quantitation determined from field blanks (for total organic carbon) or laboratory blanks.

f. Based on laboratory lowest detected result.

g. Based on log-normal distribution.

NA = not applicable

NC = not calculated; insufficient measured values

ns = not significant at 0.05 level of significance

s = significant at 0.05 level of significance

STL = Severn Trent Laboratories (St. Louis)

WSCF = Waste Sampling and Characterization Facility

Figure B-1. RCRA Units on the Hanford Site Requiring Groundwater Monitoring

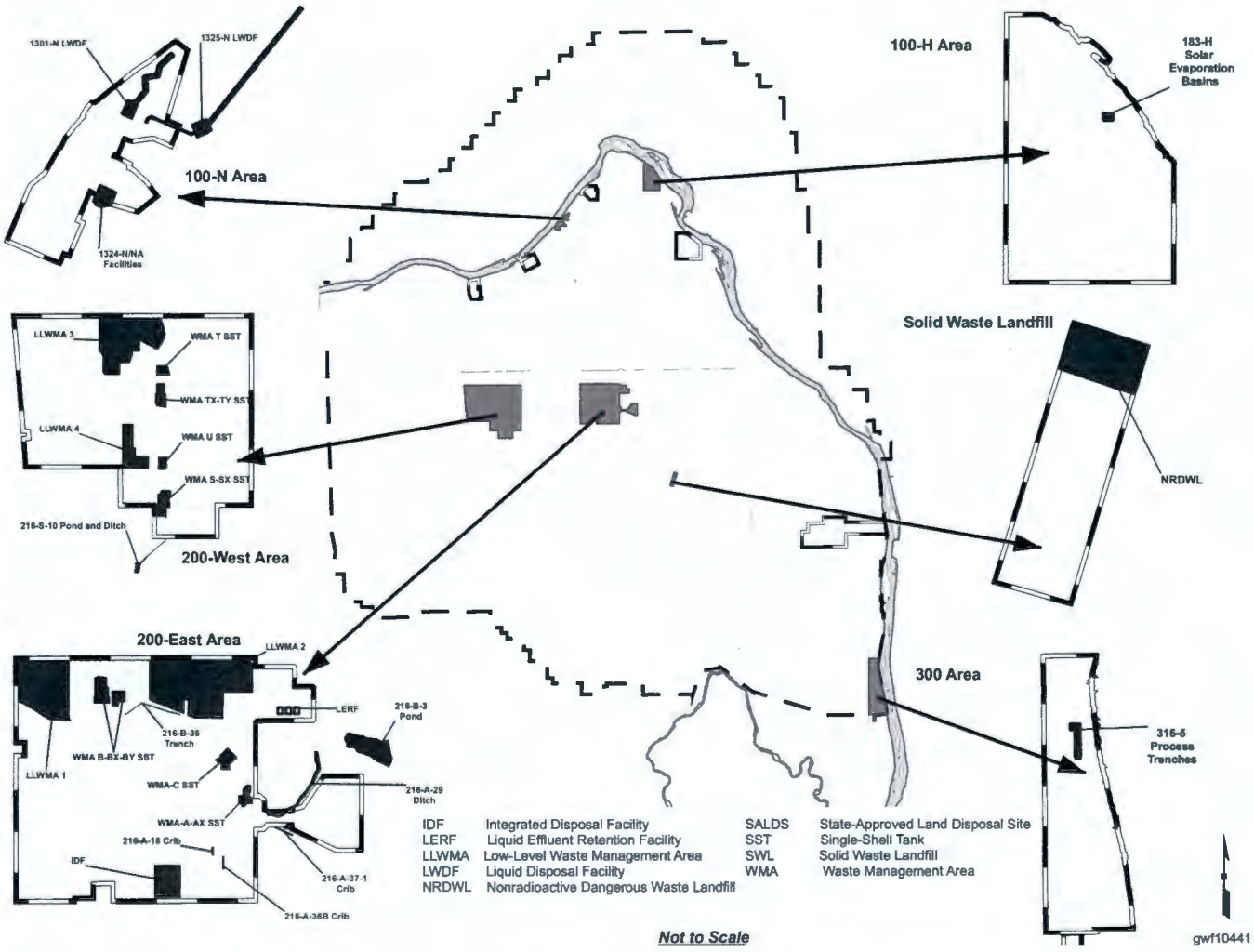


Figure B-2. Groundwater Monitoring Wells for 100-N Area RCRA Sites

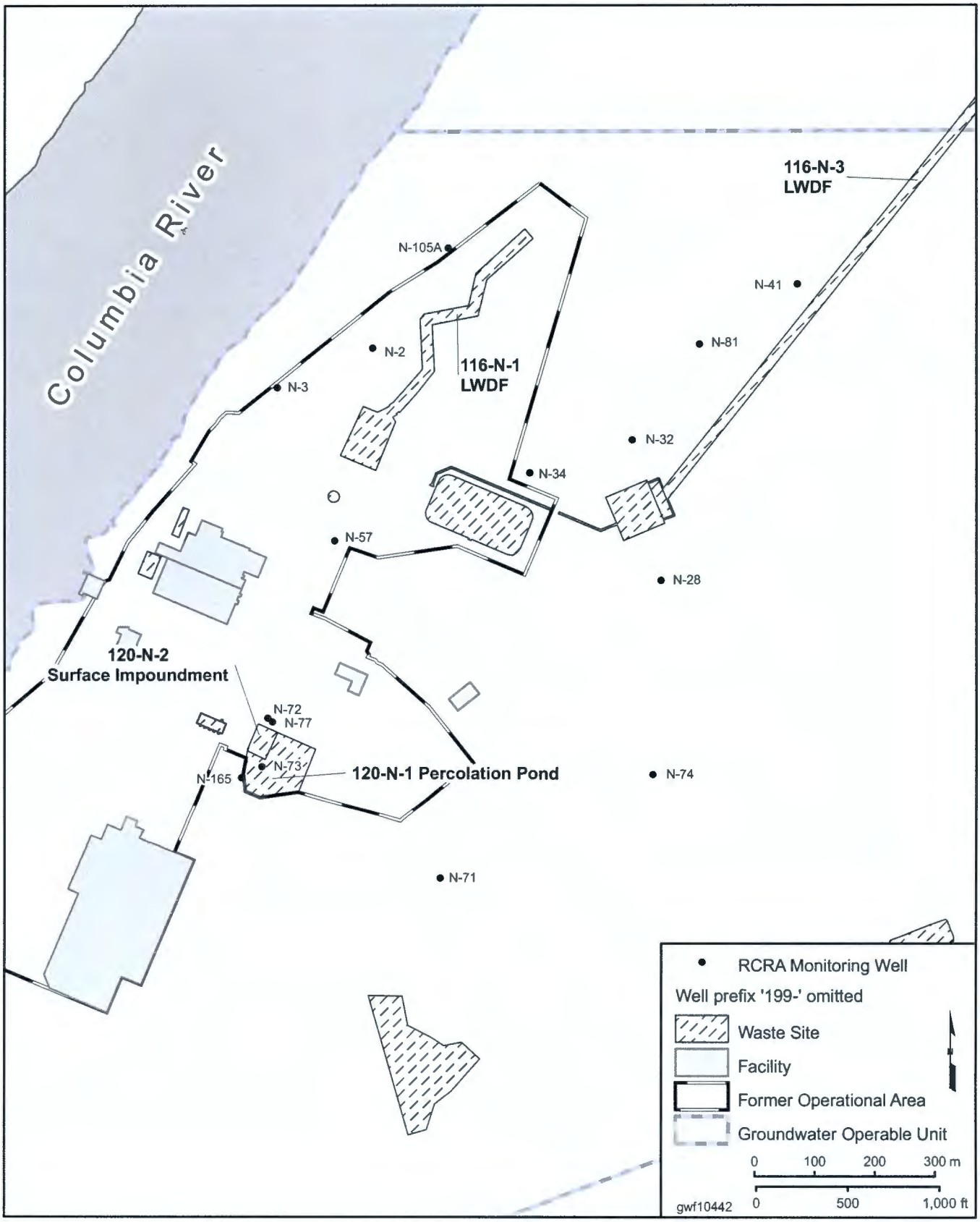


Figure B-3. Groundwater Monitoring Wells at 116-H-6 Evaporation Basins

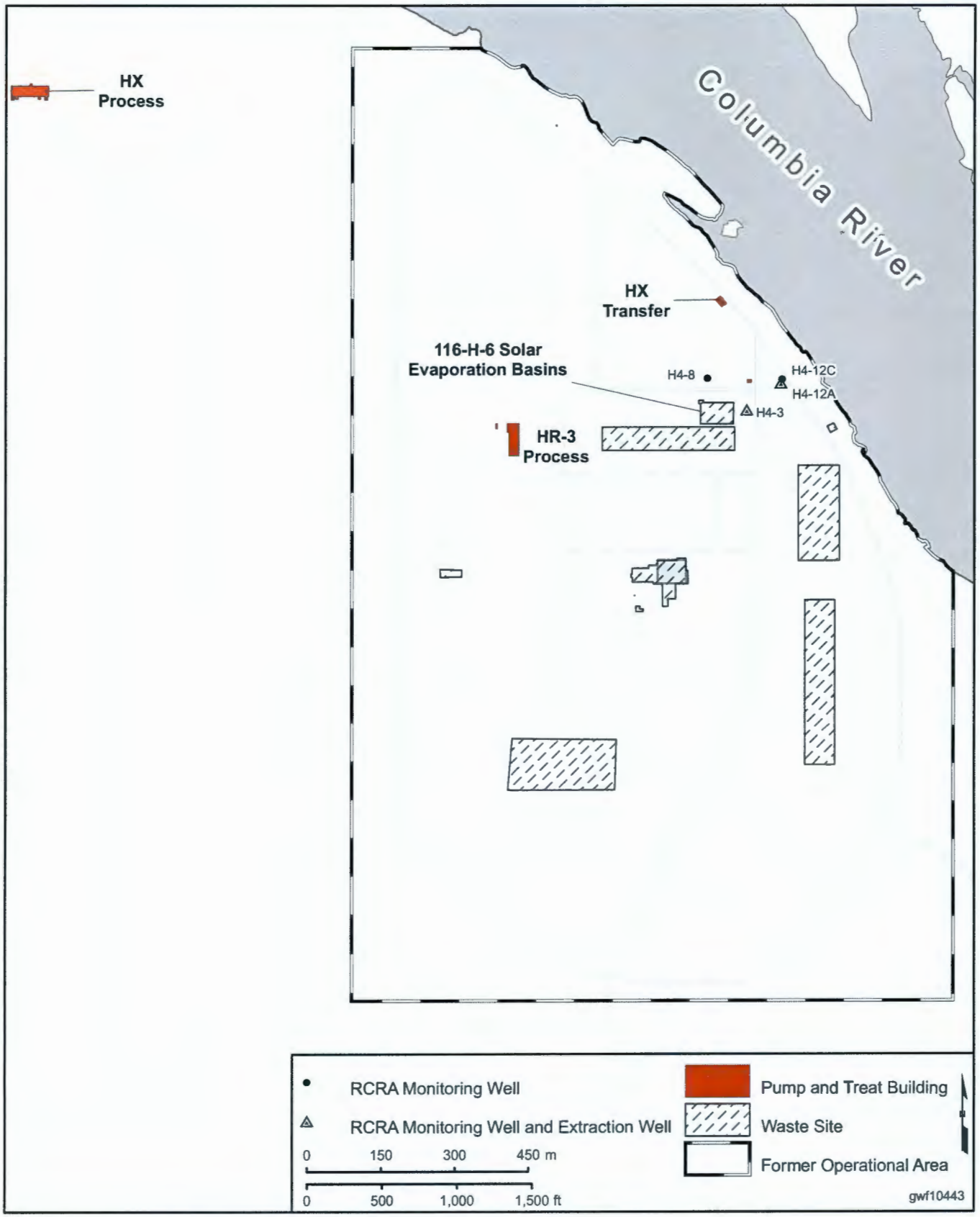


Figure B-4. Groundwater Monitoring Wells at 216-A-29 Ditch, PUREX Cribs, and Waste Management Areas A-AX and C

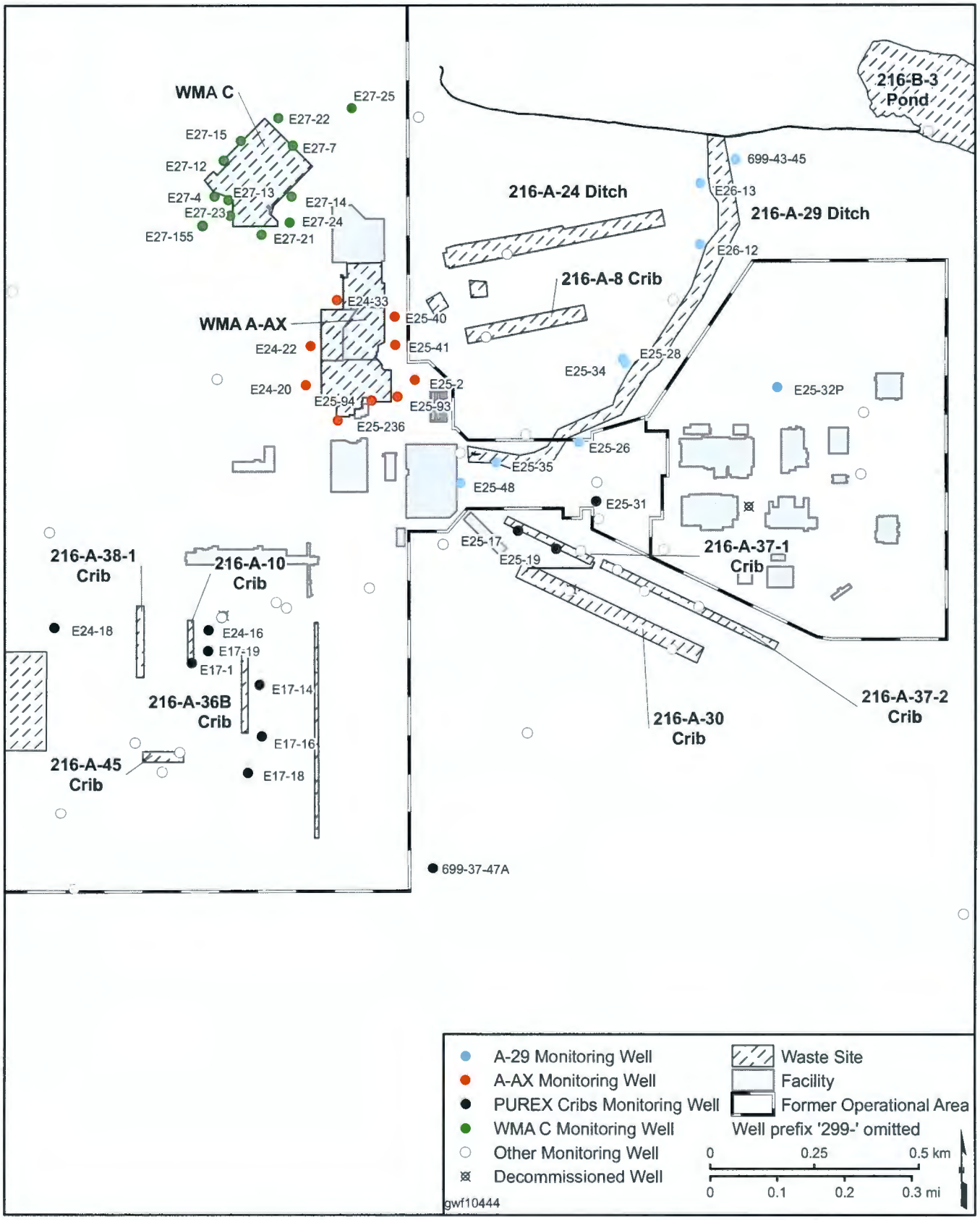


Figure B-5. Groundwater Monitoring Wells at 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility

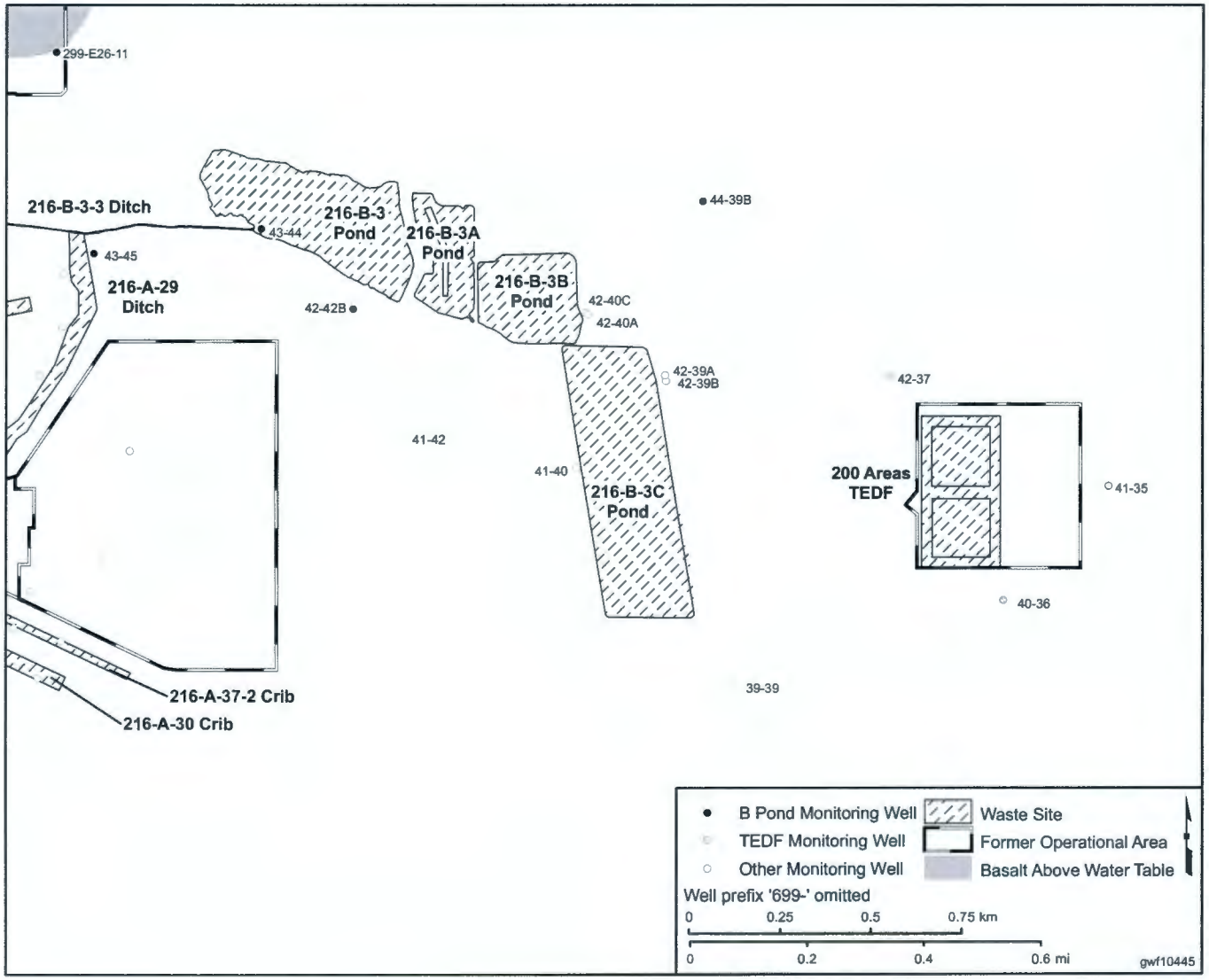


Figure B-6. Groundwater Monitoring Wells at 216-S-10 Pond and Ditch

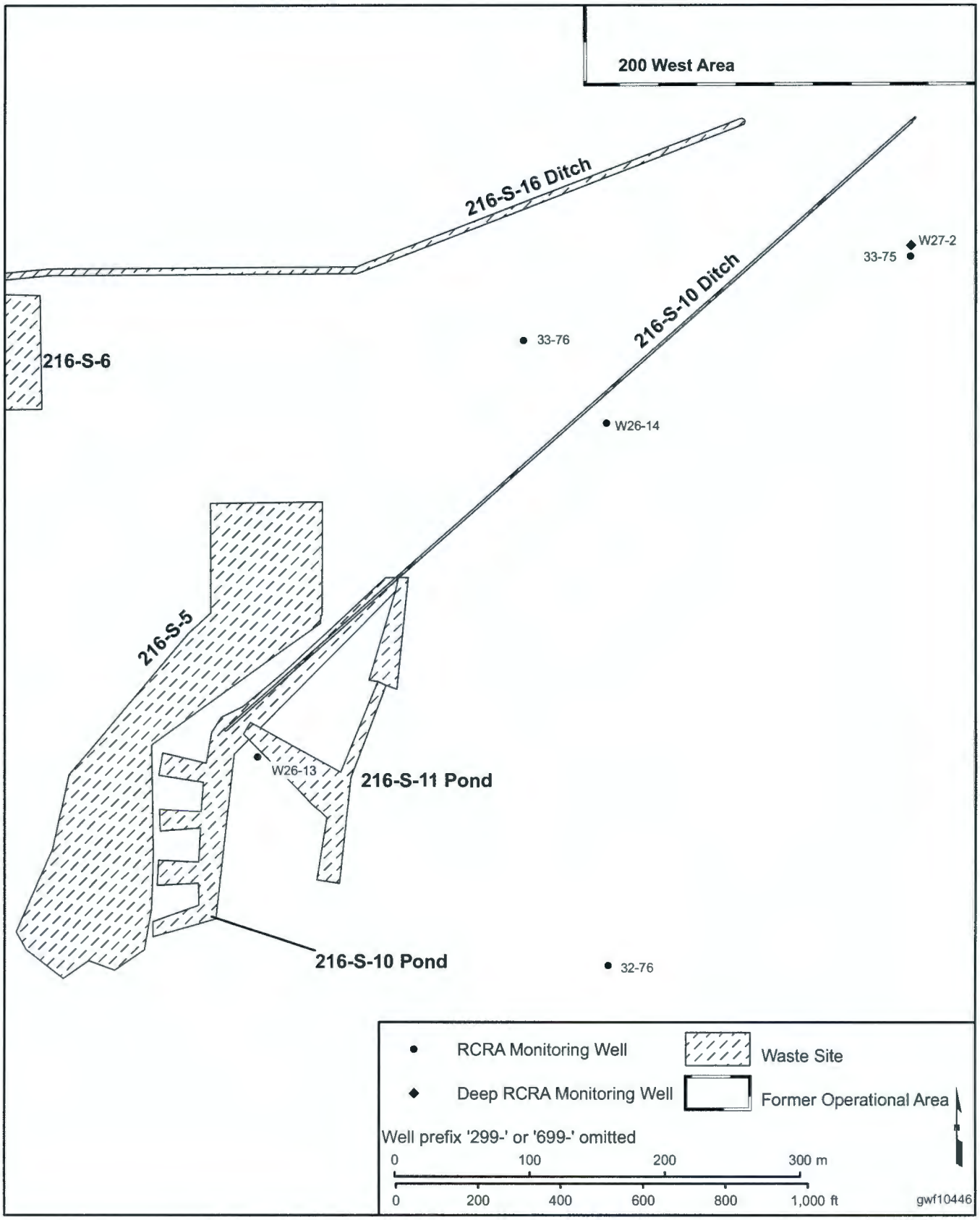


Figure B-7. Groundwater Monitoring Wells at 316-5 Process Trenches

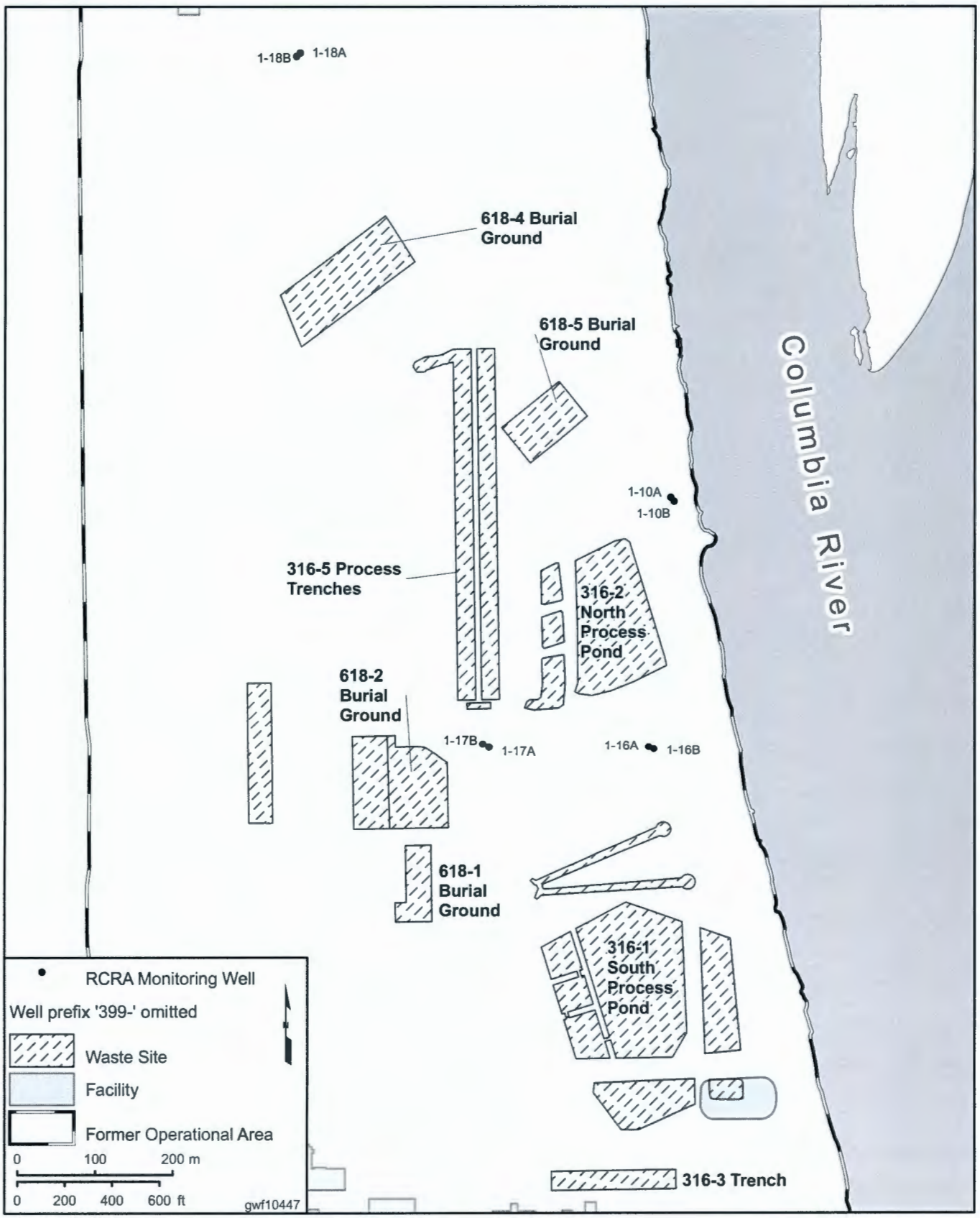


Figure B-8. Groundwater Monitoring Wells at Integrated Disposal Facility

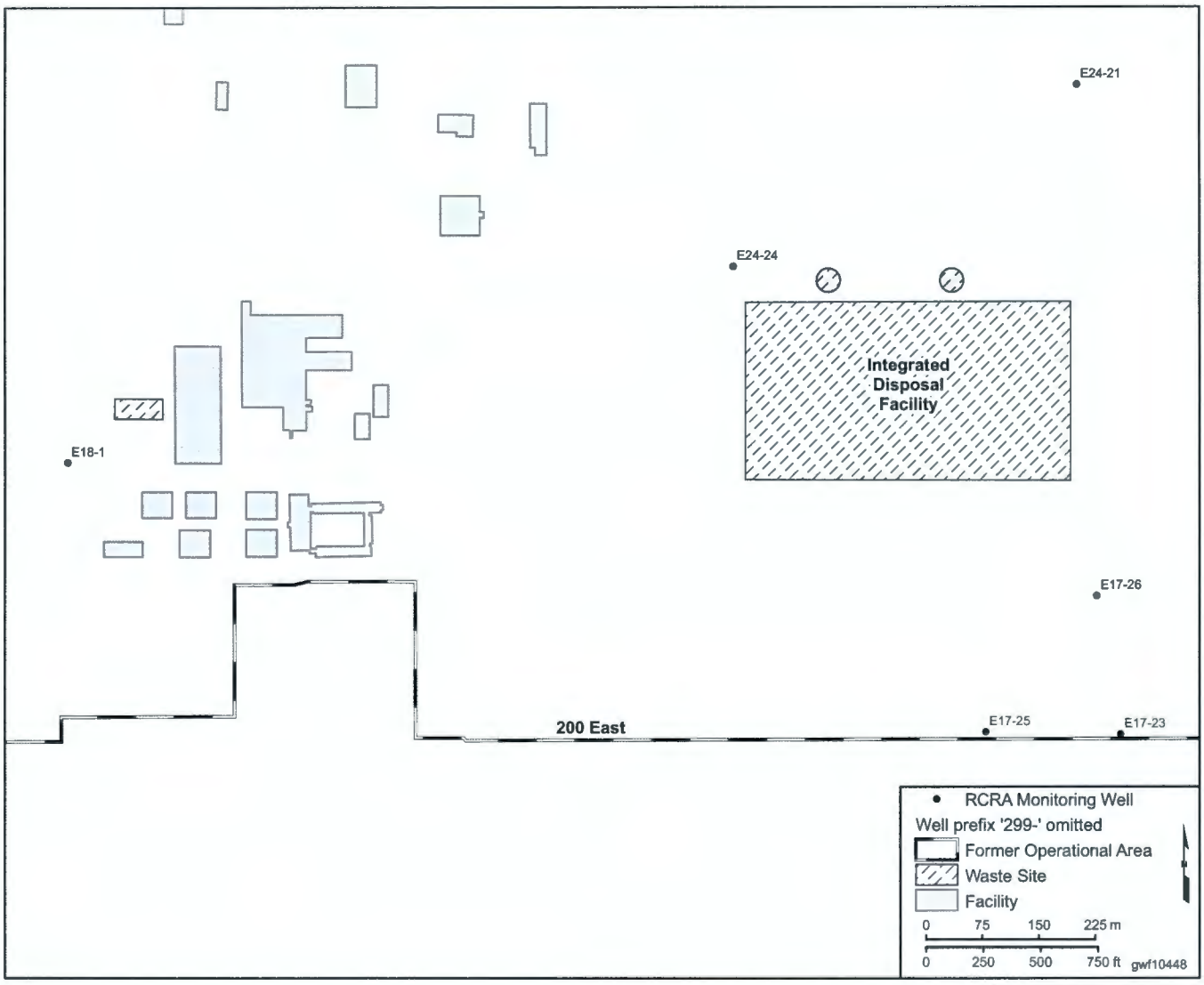


Figure B-9. Groundwater Monitoring Wells at Liquid Effluent Retention Facility

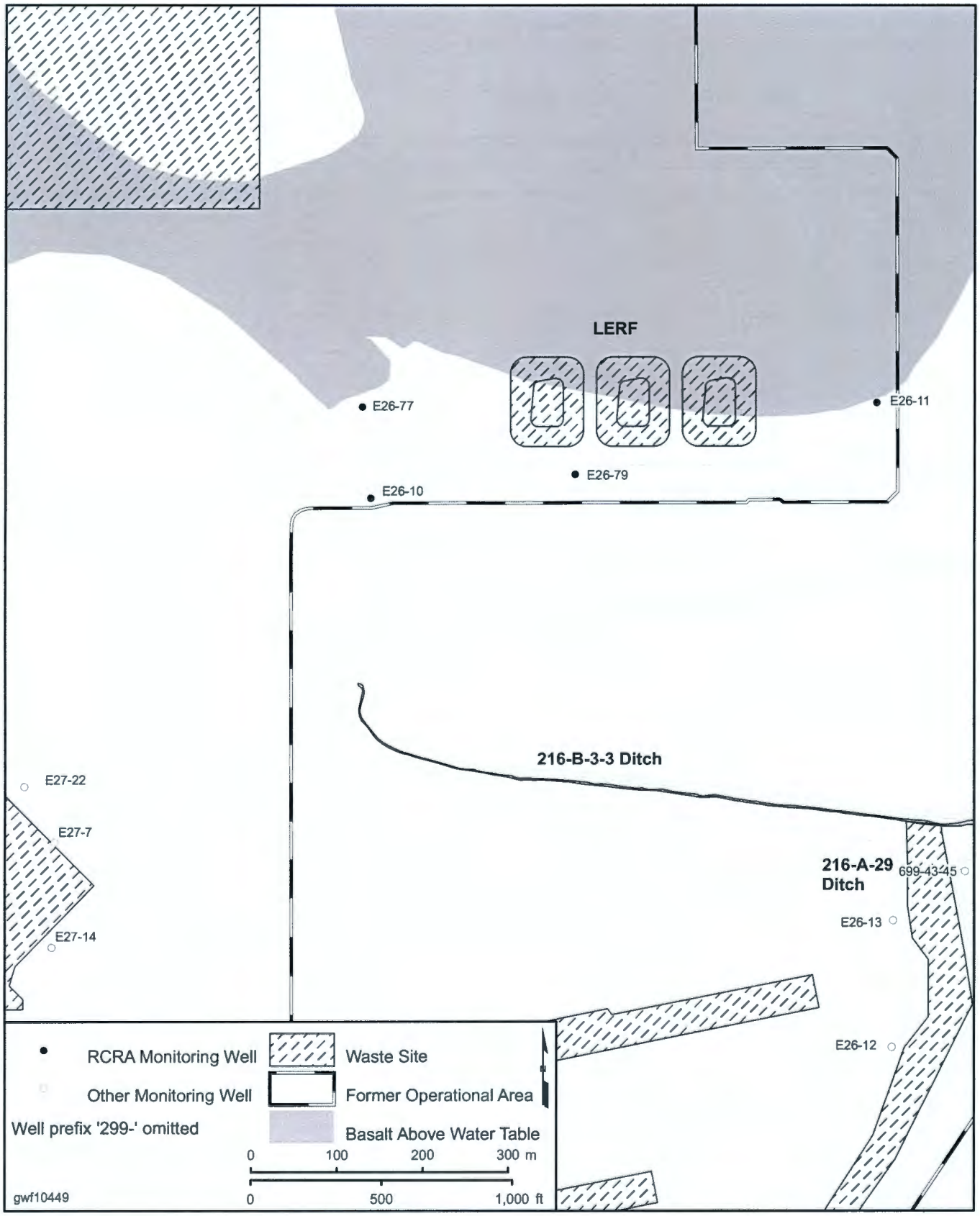


Figure B-10. Groundwater Monitoring Wells at Low-Level Waste Management Area 1

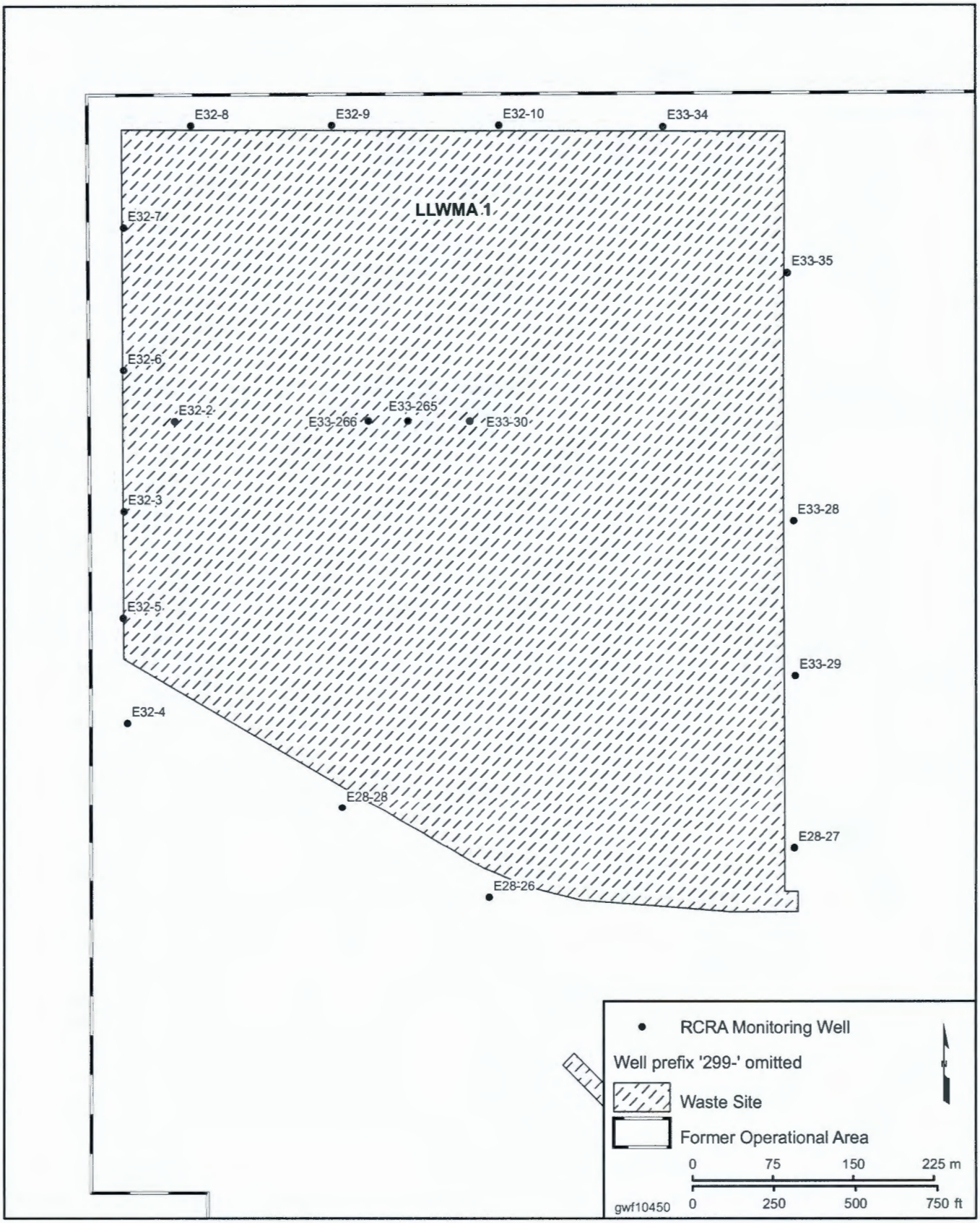


Figure B-11. Groundwater Monitoring Wells at 216-B-63 Trench and Low-Level Waste Management Area 2

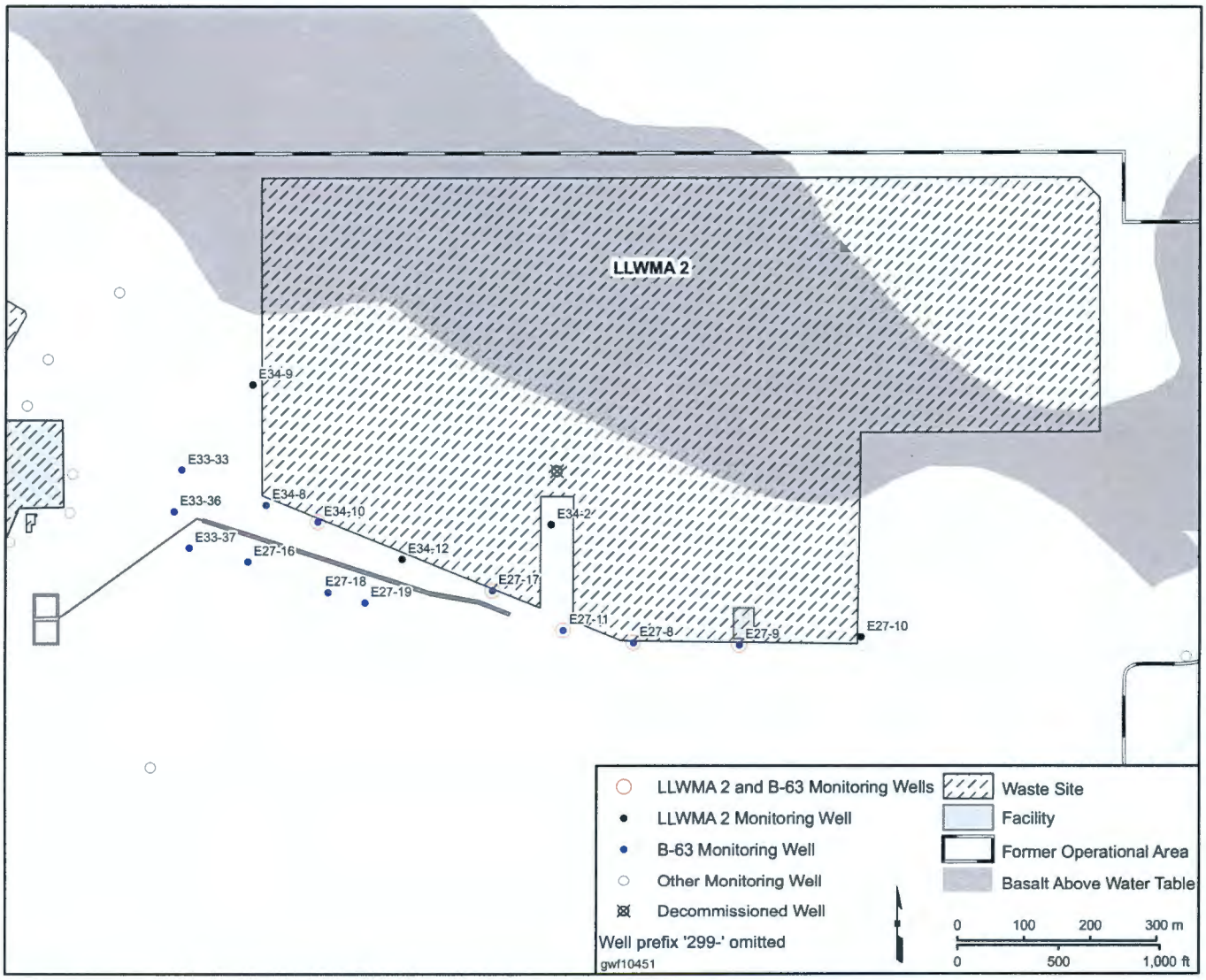


Figure B-12. Groundwater Monitoring Wells at Low-Level Waste Management Area 3

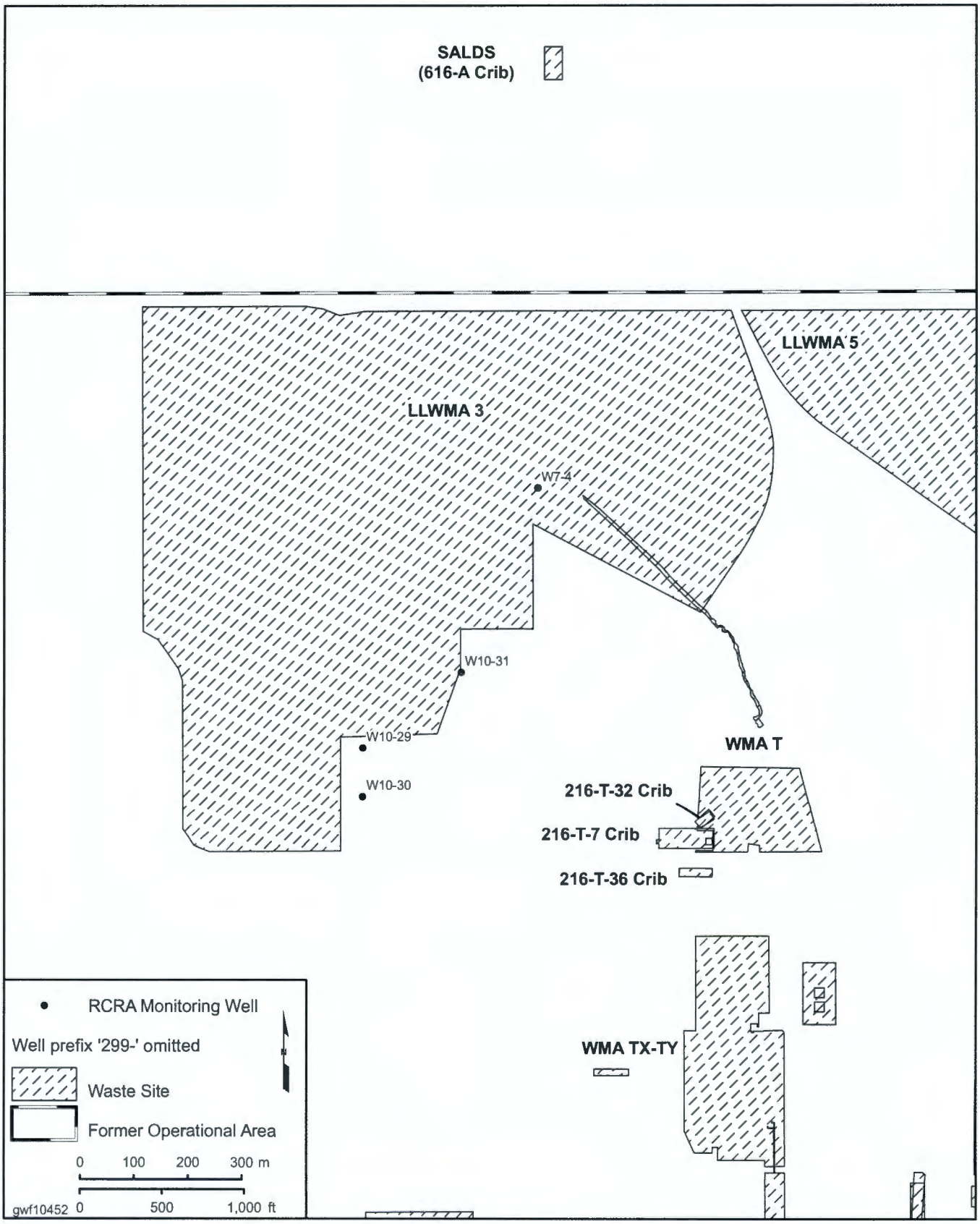


Figure B-13. Groundwater Monitoring Wells at Low-Level Waste Management Area 4

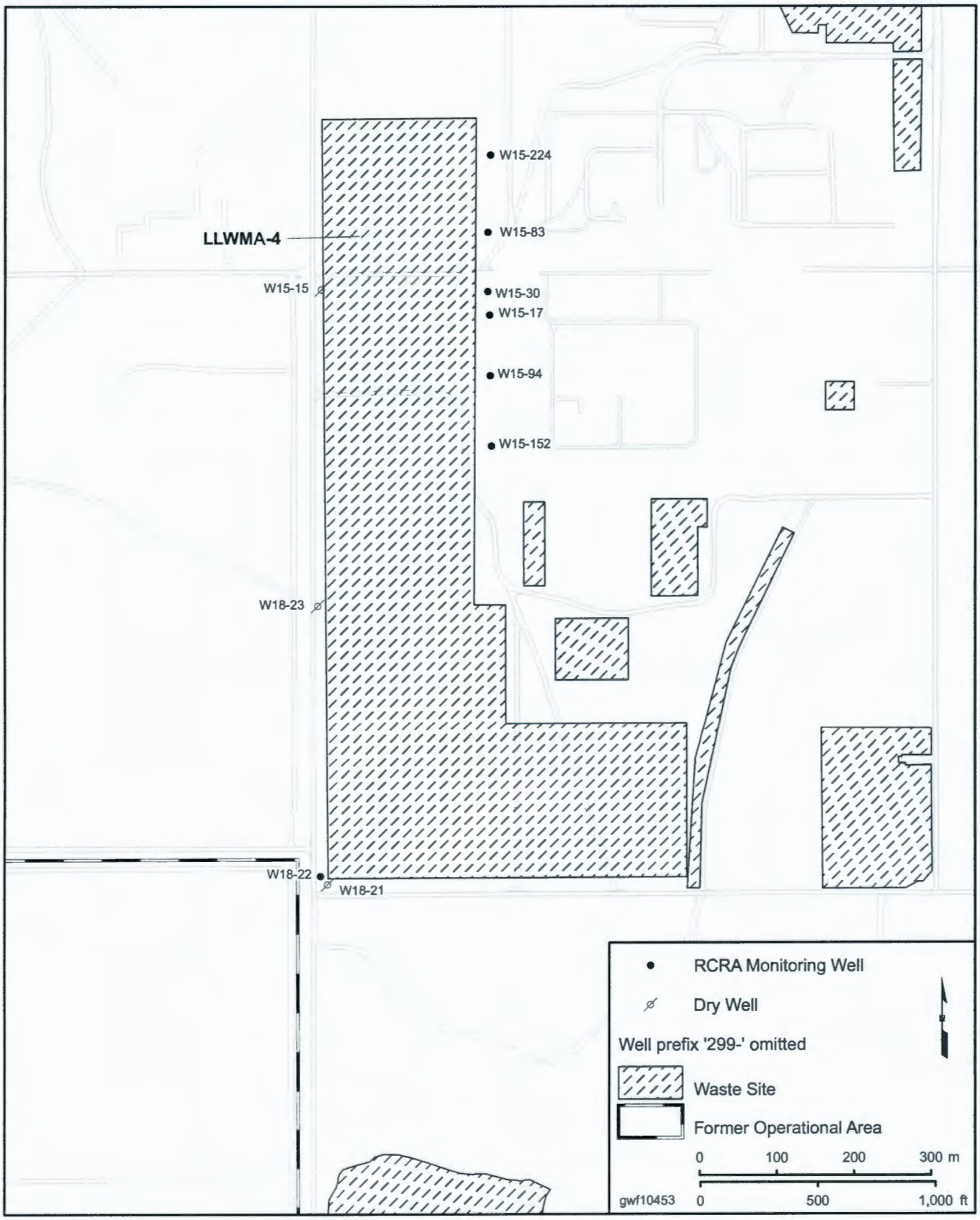


Figure B-14. Groundwater Monitoring Wells at Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill

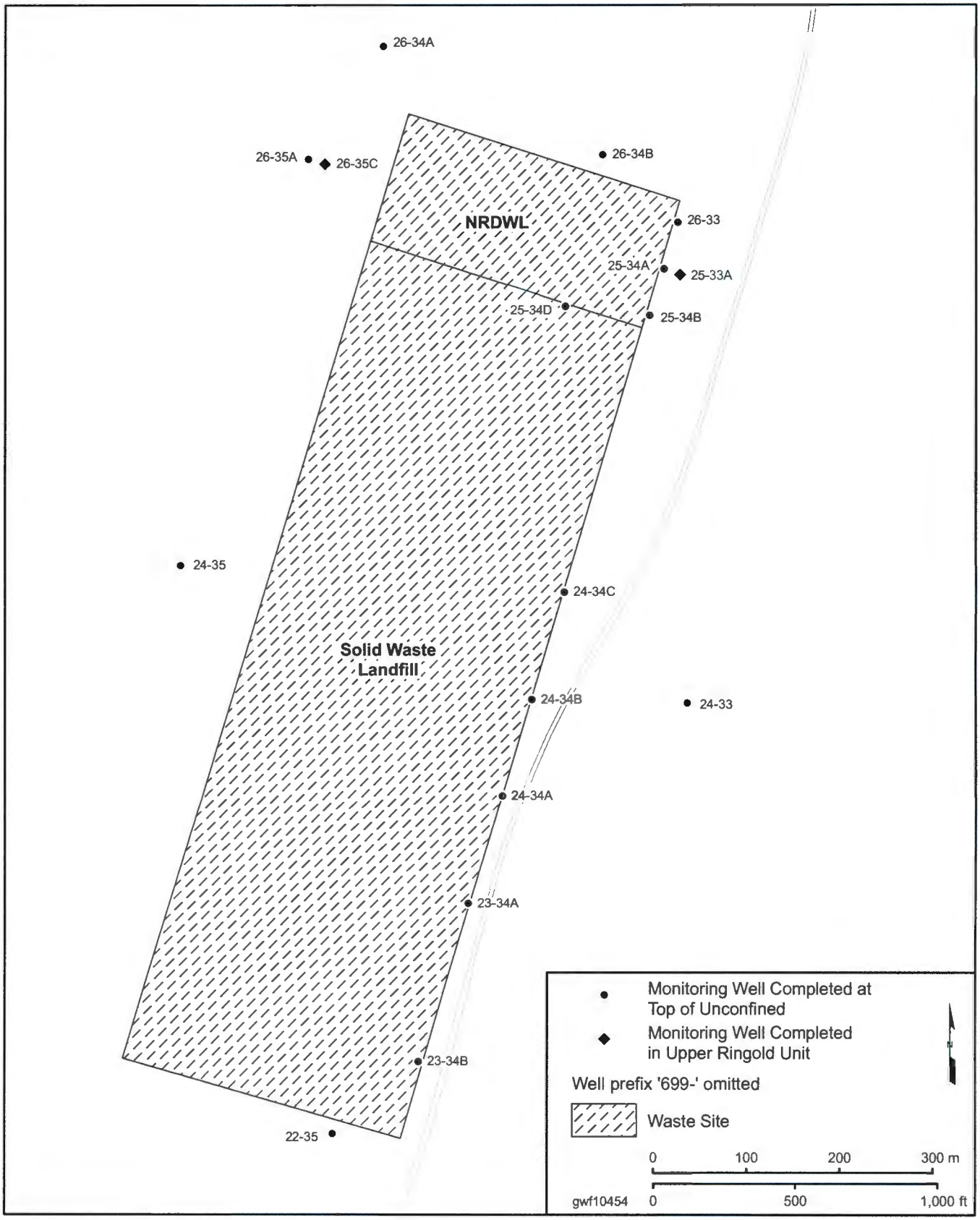


Figure B-15. Groundwater Monitoring Wells at Waste Management Area B-BX-BY

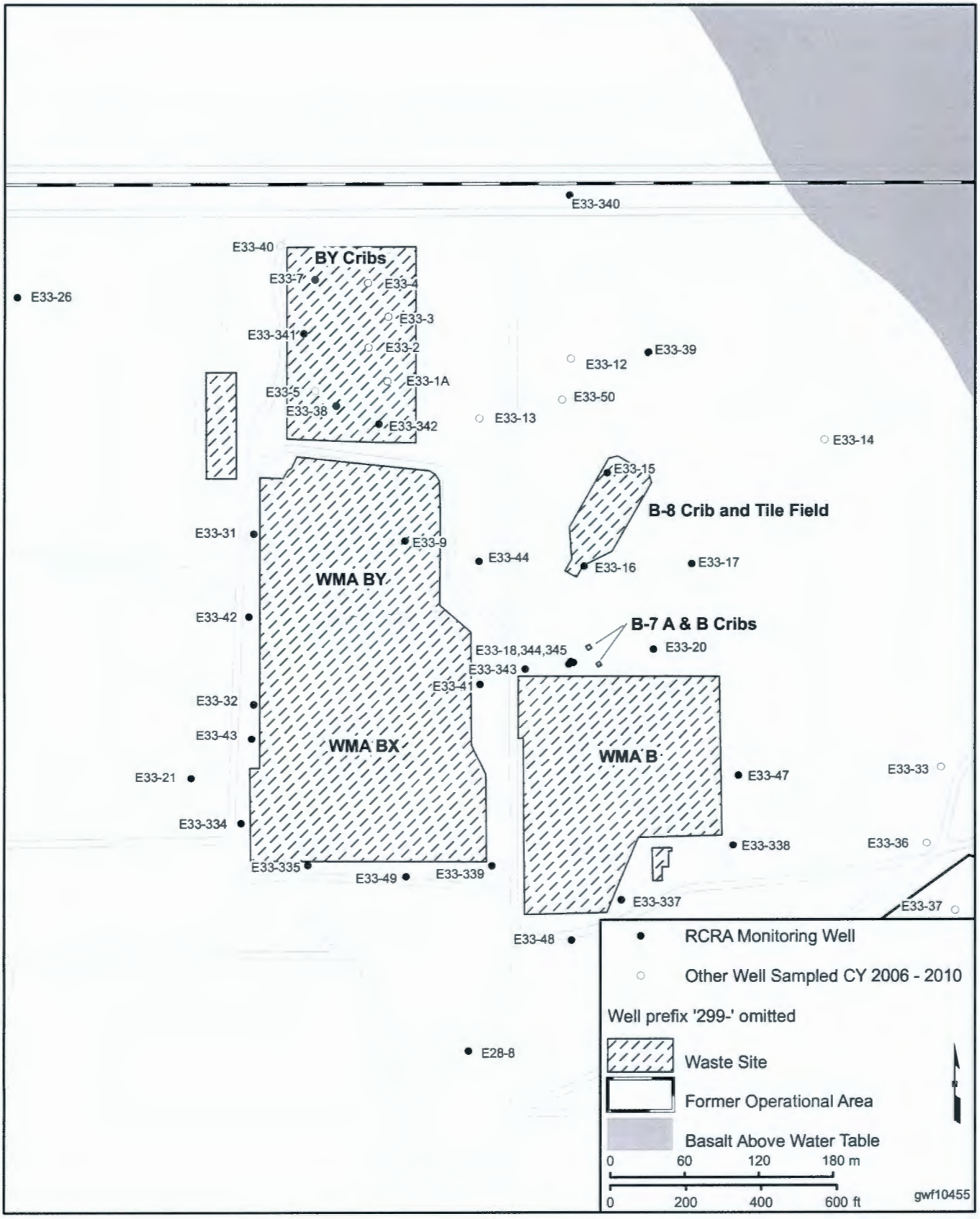


Figure B-16. Groundwater Monitoring Wells at Waste Management Areas S-SX and U

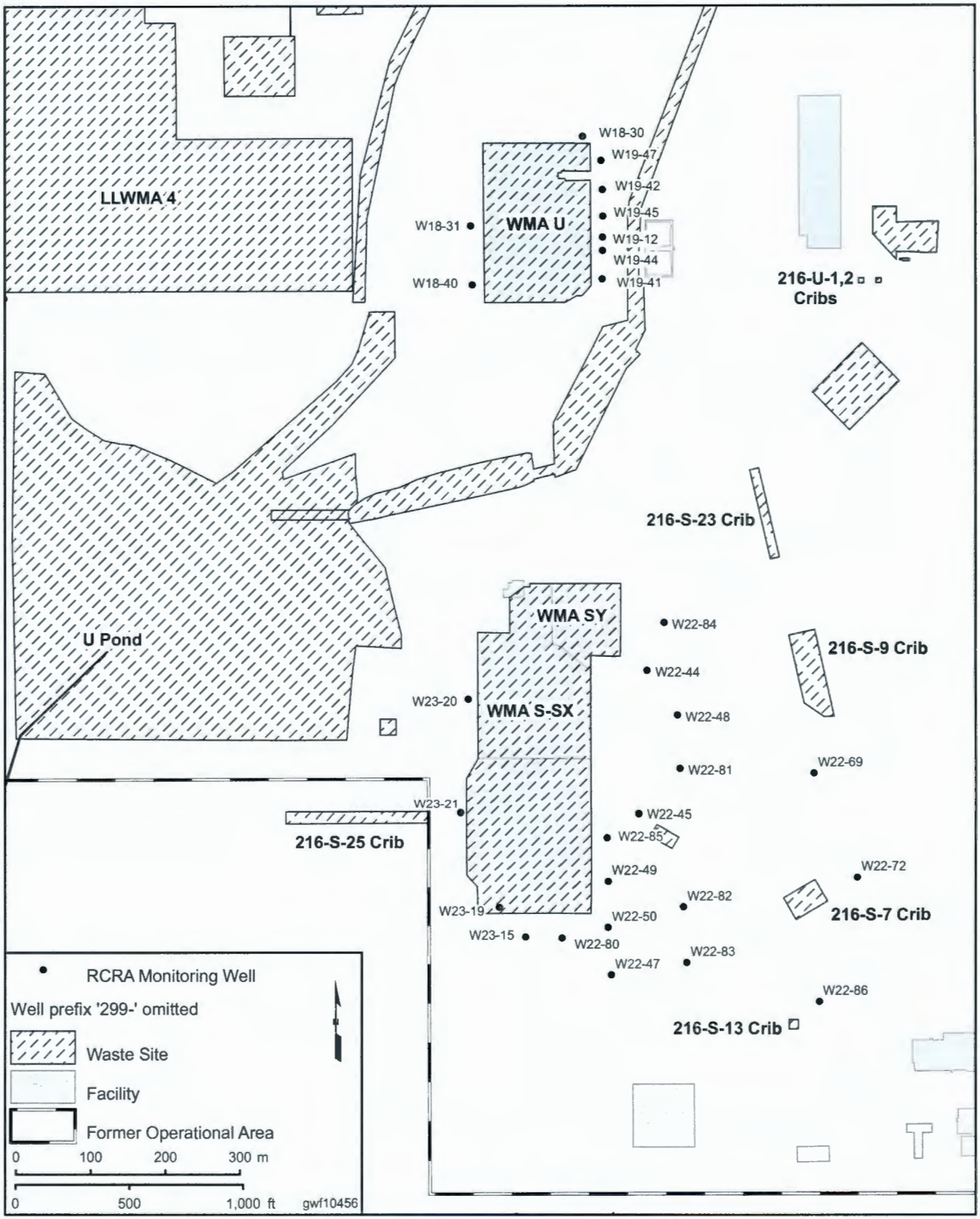


Figure B-17. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY

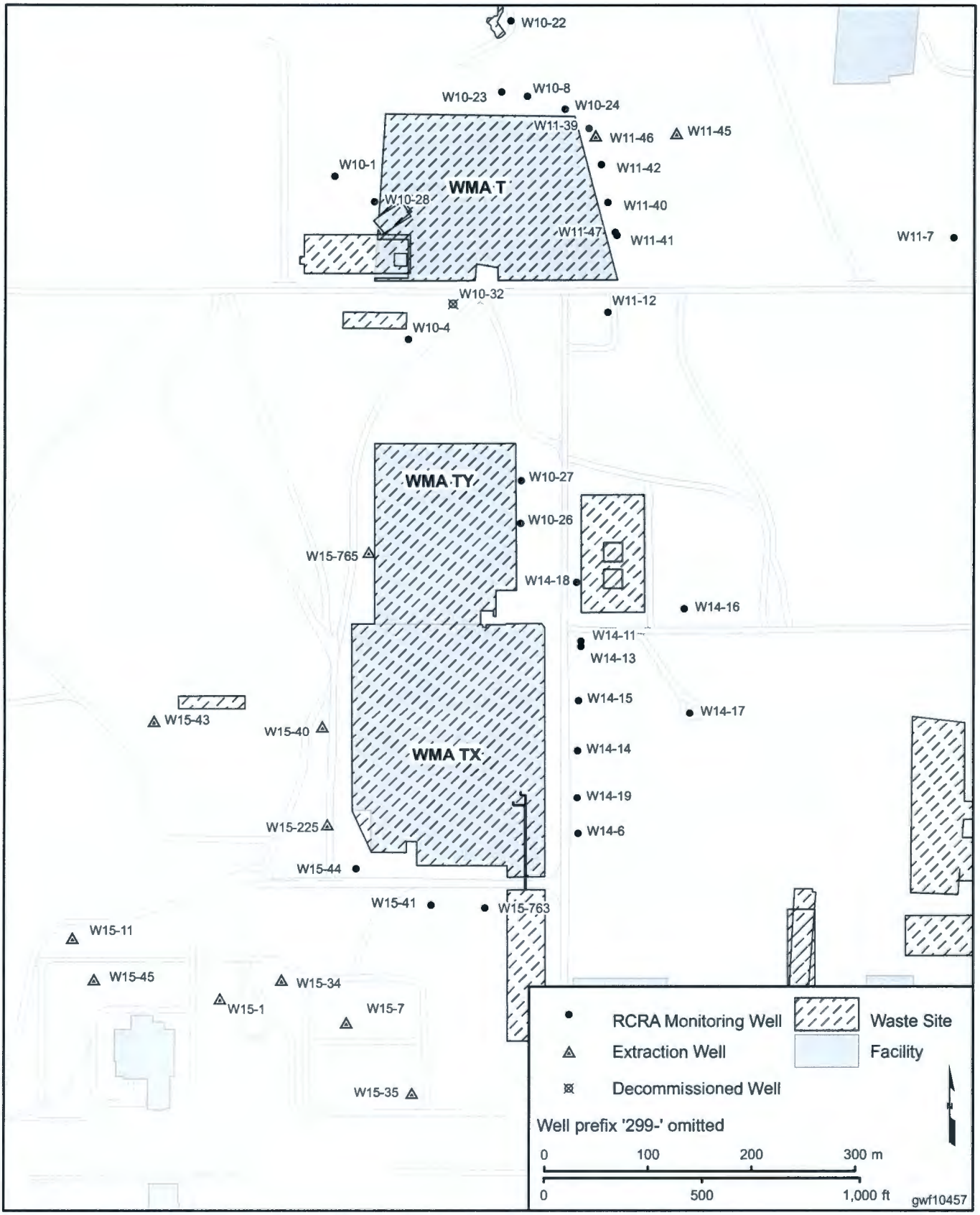


Figure B-18. Non-RCRA Regulated Units on the Hanford Site Requiring Groundwater Monitoring

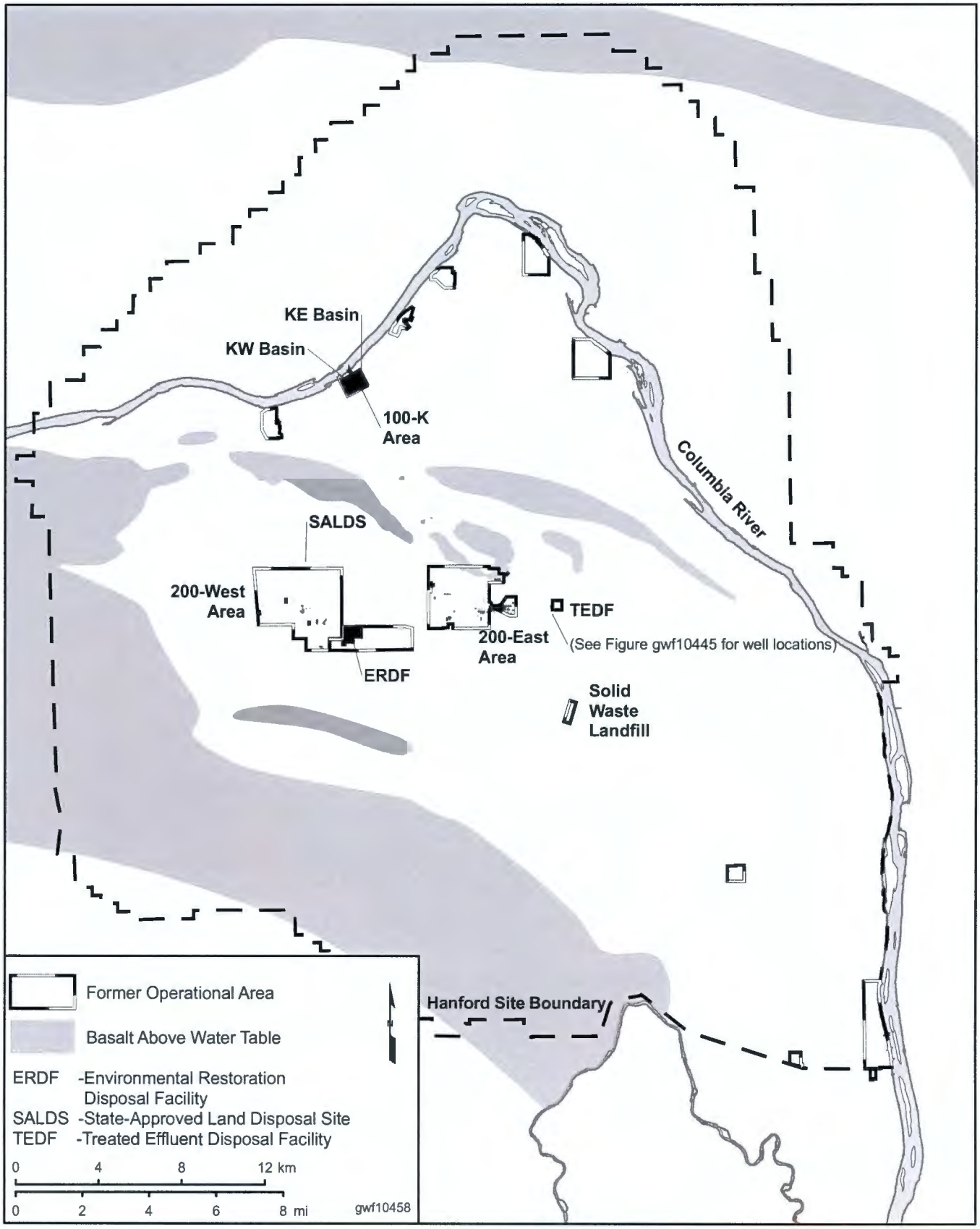


Figure B-19. Groundwater Monitoring Wells at 100-K Basins

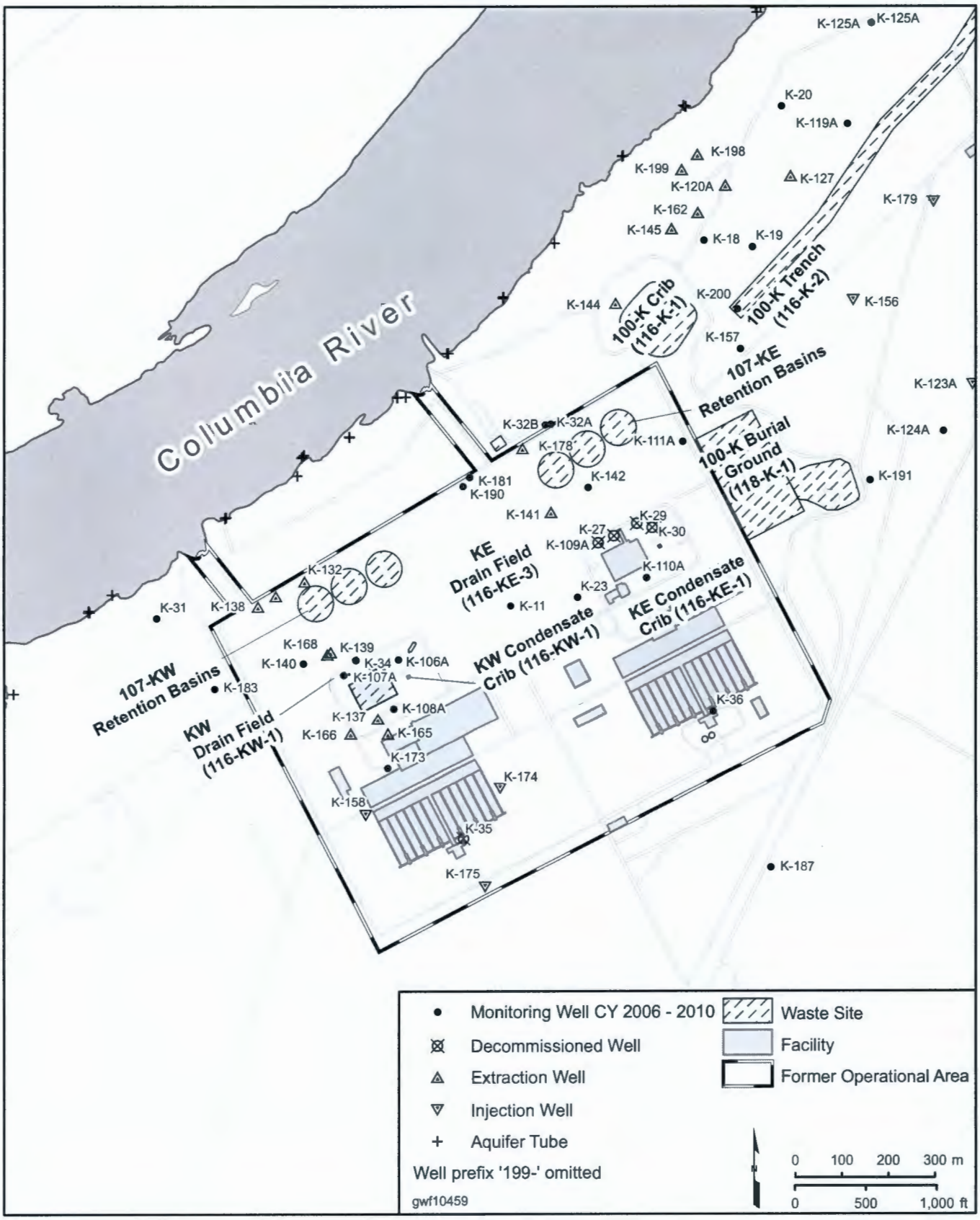


Figure B-20. Groundwater Monitoring Wells at State-Approved Land Disposal Site

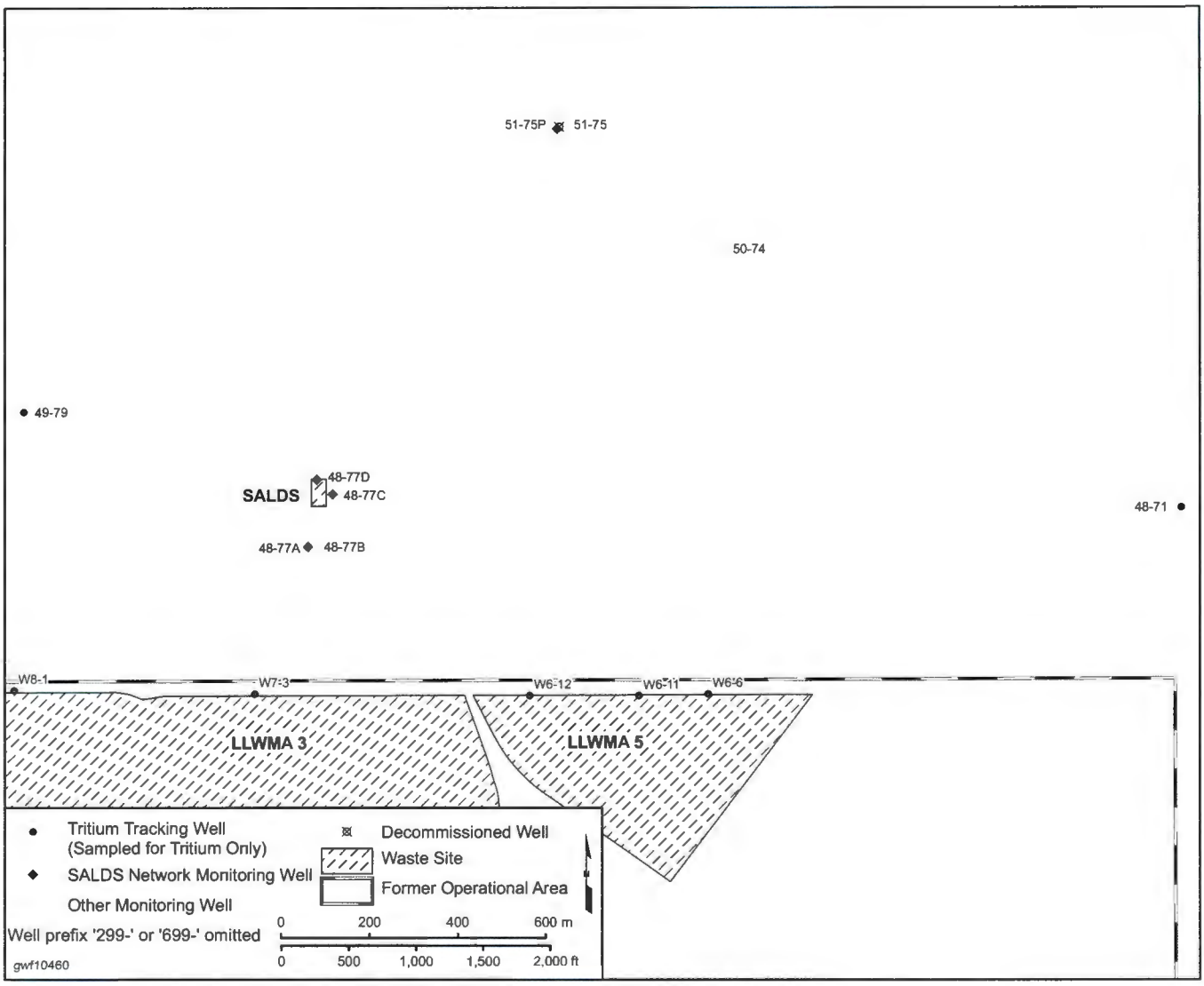
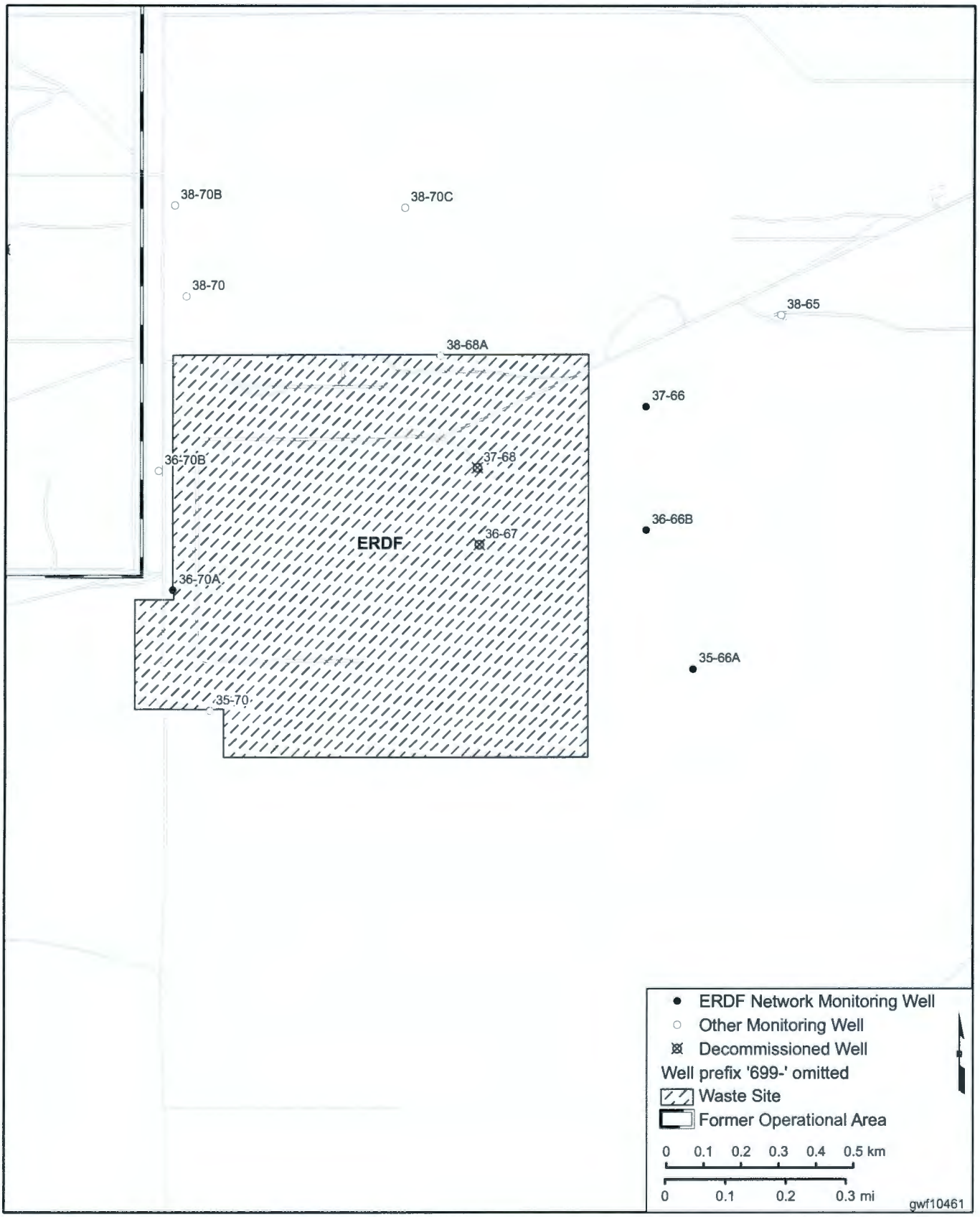


Figure B-21. Groundwater Monitoring Wells at the Environmental Restoration Disposal Facility



Appendix C

Supporting Information for Aquifer Sampling Tubes

Contents

Appendix C — Supporting Information for Aquifer Sampling Tubes C-1
C.1 Sampling Metrics for 2010 ..... C-1
C.2 Sampling Dates and River Stage C-1
C.3 Evaluation of Changes in Specific Conductance During Aquifer Tube Sampling C-2
C.3.1 Approach C-2
C.3.2 Discussion C-2
C.3.3 Results of Statistical Tests C-2
C.4 Reference C-4

Tables

Table C-1. Inventory of Hanford Site Aquifer Tubes as of December 31, 2010 ..... C-5
Table C-2. Aquifer Tube Sampling Dates, Calendar Year 2010 ..... C-6
Table C-3. Summary Statistics for Percent Change in Specific Conductance C-15
Table C-4. Results of t-Test on Percentage Change C-15
Table C-5. Shapiro-Wilk Test of Normality for Percent Change Conductivity C-15
Table C-6. Results of the Sign Test C-15
Table C-7. Results of the Signed-Rank Test C-15

Figures

Figure C-1. Driving the Temporary Casing for Aquifer Tube Installation C-16
Figure C-2. Installation of Aquifer Tube and Screen C-17
Figure C-3. Typical Aquifer Tube Completion C-18
Figure C-4. Aquifer Tube Sampling Trips by Month, 2010 ..... C-19
Figure C-5. 100-B/C Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-19
Figure C-6. 100-K Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-20
Figure C-7. 100-N Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-20
Figure C-8. 100-D Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-21
Figure C-9. 100-H Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-21
Figure C-10. 300 Area River Stage and Aquifer Tube Sampling Dates, 2010 ..... C-22
Figure C-11. Percent Change in Specific Conductance versus Elapsed Time Between Measurements C-22
Figure C-12. Change in Specific Conductance in Aquifer Tubes C-23

Appendix C — Supporting Information for Aquifer Sampling Tubes

M.J. Hartman and C.A. Newbill

Aquifer tubes are small-diameter, flexible tubes that have a screen on one end. The tubes are installed in the aquifer along the Columbia River shoreline by driving a temporary steel casing into the ground adjacent to the river. The temporary casing is filled with water to keep sediments from coming up into the casing, then the drive-tip on the casing end is knocked out and the screened end of a tube is inserted into the casing (Figures C-1 and C-2). The steel casing is then pulled out, leaving the tube in place (Figure C-3). Water is withdrawn from the tube using a peristaltic pump. Most aquifer tube sites include two or three individual tubes monitoring different depths, from ~1 to 8 meters. The tube sites cover the Hanford Site shoreline, from just upstream of the 100-B/C Area to downstream at the 300 Area. Sites are more closely spaced along some segments where higher density spatial resolution of contaminant plumes is needed.

C.1 Sampling Metrics for 2010

A total of 562 aquifer tubes were installed on the Hanford Site between 1997 and 2010. A subset of tubes is selected for sampling. The Sampling and Analysis Plan for Aquifer Sampling Tubes (DOE/RL-2000-59) contains a list of tubes and constituents scheduled to be sampled in fiscal year (FY) 2009. The same list of tubes and constituents were scheduled for sampling in FY 2010 and FY 2011. The sampling and analysis plan also summarizes the history of Hanford Site aquifer tube installation and describes tube site nomenclature.

At most aquifer tube sites, if specific conductance of the water is less than 160 µS/cm, the conductance is recorded and water is not collected for laboratory analyses because the samples contain more river water than groundwater. These sampling trips are considered successful because they reflect representative conditions at the time. In some locations, notably the 100-N Area, samples are collected for laboratory analyses even when specific conductance is low.

Most of the tubes are sampled once per year, generally in the fall. For FY 2011, sampling was scheduled for October through December 2010, but sampling was delayed into calendar year (CY) 2011. As a result, fewer aquifer tubes were sampled in CY 2010 than usual. Most of the sampling for CY 2010 was for tubes that are on a semiannual, quarterly, or monthly sampling schedule.

Twenty-six new aquifer tubes were installed in CY 2010 to support remedial investigation studies in the River Corridor operable units. A total of 145 aquifer tubes were sampled in CY 2010 (Figure C-4). Many of the tubes were sampled more than once, for a total of 335 sampling trips. Table C-1 summarizes the total number of tubes and clusters in each segment of shoreline, the tubes installed in 2010, the number of tubes sampled, and the number of sampling trips in 2010. Table C-2 provides information on 2010 sampling dates and other supporting information (the aquifer tubes are listed in the table in order from upstream to downstream).

C.2 Sampling Dates and River Stage

The water in the Hanford Site's unconfined aquifer near the Columbia River represents a mixture of river water and groundwater. When the river stage is low in the fall of each year, aquifer tube samples typically contain the least amount of river water and contaminant concentrations are the highest.

The daily average river stage in 2010 (measured in each of the reactor areas and the 300 Area) and aquifer tube sample dates for 2010 are depicted in the following figures:

- 100-BArea (Figure C-5)
- 100-K Area (Figure C-6)
- 100-N Area (Figure C-7)
- 100-D Area (Figure C-8)

- 100-H Area (Figure C-9)
- 300 Area (Figure C-10).

The gauge in 100-F Area was not operating for the entire year, and a river stage gauge is not located in the 200-PO-1 Operable Unit shoreline segment; therefore, hydrographs are not provided for those segments.

C.3 Evaluation of Changes in Specific Conductance During Aquifer Tube Sampling

The question has been raised whether sampling aquifer tubes results in "short circuiting" (i.e., whether river water is being sucked through the sediment around the tube and into the screen). This problem would be more likely to occur during periods of high river stage when the entry point of the tube into the sediment is submerged. Evaluation of data collected before and after sampling indicates that river water is not pulled into the screen during routine sampling. Details are provided in the following discussion.

The maximum pumping rate for aquifer tube sampling is 650 milliliters per minute. Actual pumping rates are less and depend on factors such as depth to water, aquifer material surrounding the screen, and the voltage of the battery in the sampling pump. Typical screen depths are between 2.4 and 6 meters.

C.3.1 Approach

To determine if river water was being drawn into aquifer tubes during sampling, 333 pairs of specific conductance data (sampling dates January 4, 2009, through April 19, 2010) were analyzed to determine if there is a statistically significant difference between the first and second measurements. The first measurement is the specific conductance after the aquifer tube has been purged and specific conductance has stabilized (three consecutive measurements that differ by less than 10%). Once specific conductance is stable, the other field parameters are measured and sample bottles are filled. After all the sample bottles have been filled with water, specific conductance is measured again. The elapsed time (i.e., time pumping) between measurements ranged from 0 to 73 minutes. Because river water has a lower specific conductance than groundwater, successive aquifer tube samples would have decreasing conductance if river water were drawn in by the sampling process.

Three statistical tests were used to analyze the data: t-test, sign test, and signed-rank test. For each of the three tests, the percentage change from the first measurement to the second was analyzed. This avoided weighting large changes from high measurements more than small changes from low measurements.

C.3.2 Discussion

Changes in conductance ranged from a decrease of 299 µS/cm to an increase of 102 µS/cm (-50% to +37% change); however, such large changes were uncommon. The median change was 0% and the mean was -0.5% (Figures C-11 and C-12).

The largest percent decline in conductance was -50% in tube N116mArray-1A (conductance declined from 253 to 127 µS/cm). The lower conductance is more in line with previous trends in this tube. The sample was collected after nearby injections of apatite-forming chemicals into the aquifer, which likely temporarily increased the conductance.

The largest increase was 37% (from 276 to 378 µS/cm) in tube C5638, but this appears to be an anomaly as the elapsed time recorded was 0 minutes. The lower value is more in line with the trend in this tube.

The average relative percent difference in the 333 pairs of specific conductance measurements was 2.2%. The laboratory control limits for field duplicates is 20%. Only four pairs of samples (1.2%) exceeded 20%. Therefore, differences between samples were not significant relative to laboratory precision, which indicates insignificant evidence of river water intrusion.

C.3.3 Results of Statistical Tests

This section presents results of the t test and sign and sign ranked tests.

C.3.3.1 Results of t-Test

The hypothesis for the t-test in this application is that if there is no difference between the first and second measurements (i.e., insignificant river water influence), the average change in measurements should be close to zero, relative to the variability in the average changes. Table C-3 shows the average change and standard deviation in changes, as well as other pertinent values.

The average change from the first measurement to the second is a decrease of 0.50% (-0.0050). The standard deviation of the changes is 0.055. The t-test statistic is the departure of the average change from zero relative to the expected variability in the average change. The expected variability in the average change (standard error of the mean) is estimated by dividing the standard deviation of the changes by the square root of the number of sample pairs. Table C-4 shows the results of the t-test.

The computed t-statistic indicates that the average change from the first measurement to the second is 1.655 standard deviations of the mean from the expected value of zero. If these were drawn from a normal population with mean zero and standard deviation one, a larger difference from zero 9.88% of the time (P-value) would be expected. Therefore, the t-test on the 333 pairs of specific conductance measurements does not show significant river water influence at the 5% level but it does at the 10% level.

However, the t-test assumes the data set is drawn from a normal population. The large coefficient of variation (1,102%), large magnitudes in the skewness (-28) and kurtosis (163), and results of the Shapiro Wilk test (Table C-5) indicate that the changes in specific conductance are not normally distributed. The coefficient of variation should be less than 100%, skewness and kurtosis should be in the range of -2 to +2, and the P-value on the Shapiro-Wilk test should exceed 5%. This non normality indicates that the t test result for this data may be questionable.

C.3.3.2 Results of Sign and Signed-Rank Tests

Using the nonparametric (not based on an assumption of data normality) sign and signed-rank tests, the differences in measurements are not significant at the 5% level (Tables C-6 and C-7).

The sign test simply counts the number of times the first measurement exceeds the second. Assuming no difference between the measurements (equal probability of either being larger; a simple coin toss), this number should be about one-half the number of sample pairs (e.g., equal numbers of heads and tails in a coin toss). The amount by which this differs from the expected number is an indication of the likelihood that the two measurements really are different. In the specific conductance measurements, 54 of the 333 pairs had equal measurements, leaving 279 pairs for comparison. The first measurement exceeded the second 131 out of 279 times (e.g., equivalent to getting 131 heads and 148 tails in 279 tosses of a fair coin). Assuming equal probability of one exceeding the other, this amount of departure from an idealized split of 139/140 would occur 33.8% of the time. This indicates no statistically significant difference in the frequency at which the first measurement exceeds the second, or vice versa. Therefore, according to the sign test, there is no indication of river water intrusion.

Another test of significant differences between the measurements is the signed-rank test. In this test, the absolute values of the differences are ranked, with the smallest difference being ranked as 1, the next smallest difference ranked as 2, etc. Ties are assigned the average rank for the set of ties. After the measurements are ranked, the signs are restored to the rankings. The sum of the ranks for the negative (or positive) ranks is compared to the expected value of $n(n+1)/4$. Equivalently, the average negative or positive rank is compared to the expected average rank of $(n+1)/2$. The amount of departure from this expected value is an indication of the likelihood that the measurements really are different. The results of the signed-rank test are shown in Table C-7.

When the number of pairs exceeds 16, the test statistic is an approximate normal deviate. In this case, the sum of the signed ranks only differs by 0.094 standard deviations from the expected value. This is expected to be exceeded 92% of the time if there is no difference between the first and second measurements. Therefore, the signed-rank test also indicates no statistically significant difference between specific conductance measurements at the 5% level.

C.3.3.3 Conclusion

The t-test, sign test, and signed-rank tests performed on the percentage change from the first to the second measurements of 333 pairs of specific conductance measurements do not indicate statistically significant differences. In addition, the average relative percent difference among the pairs is well within laboratory control limits. Therefore, there is no statistical indication of river water effects on the measurements of specific conductance in aquifer tubes. This shows that there is no "short circuiting" of the system occurring during sample collection.

C.4 Reference

DOE/RL-2000-59, 2009, *Sampling and Analysis Plan for Aquifer Sampling Tubes,* Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Table C-1. Inventory of Hanford Site Aquifer Tubes as of December 31, 2010

Segment	Total Tubes/ Sites*	Tubes Not in Service	New Tubes CY 2010	Tubes Sampled, CY 2010	Sites Sampled, CY 2010	Tube Trips, CY 2010
100-B/C	53/21	1	9	9	3	9
100-K	70/28	0	3	19	10	44
100-N	84/40	10	8	42	23	141
100-D	97/37	10	4	27	11	84
100-H	97/41	11	2	23	12	30
100-F	81/29	16	0	1	1	1
200-PO-1	28/17	4	0	1	1	1
300 Area	52/25	3	0	23	12	25
Totals	**562/238**	**55**	**26**	**145**	**73**	**335**

* A tube site (cluster) contains one or more tube; multiple tubes monitor different depths.

Table C-2. Aquifer Tube Sampling Dates, Calendar Year 2010

Tube Name	Frequency	CY 2010 Sample Dates	Comments
100-BC Area Segment			
C7718	A	9/15/10	Installed 2010
C7719	A	9/15/10	Installed 2010
C7720	A	9/15/10	Installed 2010
C7724	A	9/15/10	Installed 2010
C7725	A	9/15/10	Installed 2010
C7726	A	9/15/10	Installed 2010
C7780	A	9/15/10	Installed 2010
C7781	A	9/15/10	Installed 2010
C7782	A	9/15/10	Installed 2010
100-K Area Segment			
AT-K-1-D	A	12/16/10	
C7641	Q	8/15/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	11/22/10	Installed 2010
	Q	12/19/10	Installed 2010
C7642	Q	8/15/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	11/22/10	Installed 2010
	Q	12/19/10	Installed 2010
C7643	Q	8/15/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	11/22/10	Installed 2010
	Q	12/19/10	Installed 2010
C6241	Q	2/1/10	
	Q	5/12/10	
	Q	8/15/10	
AT-K-2-D	A	12/16/10	
AT-K-3-D	A	12/16/10	
AT-K-3-S	A	1/12/10	
AT-K-3-M	A	1/12/10	
C6250	Q	2/1/10	
	Q	5/11/10	
	Q	8/15/10	
C6252	A	1/14/10	
C6253	A	1/12/10	
C6256*	A	1/14/10	Submerged 1/12/10
26-S	Q	2/1/10	Field readings only; SC low
	Q	5/11/10	Field readings only; SC low
	Q	8/15/10	
26-M	Q	2/1/10	Field readings only; SC low

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	Q	5/11/10	Field readings only; SC low
	Q	8/15/10	Field readings only; SC low
26-D	Q	2/1/10	Field readings only; SC low
	Q	5/11/10	
	Q	8/15/10	
C6263	A	12/28/10	
	3	8/17/10	
	3	9/13/10	
C6264	A	12/28/10	
	3	8/17/10	
	3	9/13/10	
C6265	A	12/28/10	
	3	8/17/10	
	3	9/13/10	
100-N Area Segment			
C6317	Q	1/13/10	Field readings only
	Q	8/12/10	
	Q	9/13/10	
C6318	Q	1/13/10	Field readings only
	Q	8/12/10	
	Q	9/13/10	
C6319	Q	1/13/10	
	Q	8/12/10	
	Q	9/13/10	
C7934	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010
	Q	12/28/10	Installed 2010
C7935	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010
	Q	12/28/10	Installed 2010
C7936	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010
	Q	12/28/10	Installed 2010
C7937	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010
	Q	12/27/10	Installed 2010
C7938	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010
	Q	12/27/10	Installed 2010
C7939	Q	7/15/10	Installed 2010; under water 6/29/10
	Q	9/12/10	Installed 2010

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	Q	12/27/10	Installed 2010
C6320	Q	8/11/10	
	Q	9/9/10	
	Q	12/27/10	
C6321	Q	8/11/10	
	Q	9/9/10	
	Q	12/27/10	
C6322	Q	8/12/10	
	Q	9/9/10	
	Q	12/27/10	
C6352	A	1/14/10	Field readings only
C6132	Q	3/8/10	
	Q	9/16/10	
N116mArray-0A	Q/A	3/8/10	
	Q/A	6/28/10	Tube broken but sampleable
	Q/A	9/16/10	
C6135	Q	3/8/10	
	Q	6/29/10	
	Q	9/16/10	
N116mArray-1A	Q/A	3/8/10	
	Q/A	6/28/10	
	Q/A	9/16/10	
N116mArray-2A	Q/A	3/8/10	
	Q/A	6/28/10	
	Q/A	9/16/10	
N116mArray-3A	M/Q	2/1/10	
	M/Q	2/25/10	
	M/Q	3/8/10	
	M/Q	4/19/10	
	M/Q	5/11/10	
	M/Q	6/28/10	
	M/Q	7/12/10	
	M/Q	8/15/10	
	M/Q	9/16/10	
	M/Q	12/9/10	
N116mArray-4A	M/Q	2/1/10	
	M/Q	2/25/10	
	M/Q	3/8/10	
	M/Q	4/19/10	
	M/Q	5/11/10	
	M/Q	6/28/10	

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	M/Q	7/12/10	
	M/Q	8/15/10	
	M/Q	9/16/10	
	M/Q	12/9/10	
NVP1-1	Q	5/12/10	No yield 3/5/10, 3/16/10
	Q	6/29/10	
NVP1-2	Q	1/13/10	No yield 12/19/09 or 12/29/09
	Q	5/12/10	No yield 3/5/10 or 3/16/10
	Q	6/29/10	
NVP1-3	Q	5/12/10	No yield 3/5/10 or 3/16/10
	Q	6/29/10	
NVP1-4	Q	3/5/10	
	Q	6/29/10	
NVP1-5	Q	3/5/10	
	Q	6/29/10	
	Q	9/16/10	
NVP2-116.3	Q	3/5/10	
	Q	6/29/10	
NVP2-116.0	M/Q	2/1/10	
	M/Q	2/25/10	
	M/Q	3/9/10	
	M/Q	4/19/10	
	M/Q	5/11/10	
	M/Q	6/29/10	
	M/Q	7/12/10	
	M/Q	8/15/10	
	M/Q	9/19/10	
	M/Q	12/9/10	
NVP2-115.7	Q	3/5/10	
	Q	6/29/10	
	Q	9/19/10	
NVP2-115.4	Q	3/5/10	
	Q	6/29/10	
	Q	9/19/10	
NVP2-115.1	Q	3/5/10	
	Q	6/29/10	
	Q	9/19/10	
N116mArray-6A	M	2/1/10	
	M	3/9/10	
	M	4/19/10	
	M	5/11/10	

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	M	6/28/10	
	M	7/12/10	
	M	8/15/10	
	M	9/19/10	
	M	12/9/10	
N116mArray-8A	Q/A	3/8/10	
	Q/A	6/28/10	
	Q/A	9/19/10	
N116mArray-8.5A	Q/A	3/9/10	
	Q/A	6/28/10	
	Q/A	9/19/10	
N116mArray-9A	Q/A	3/9/10	
	Q/A	6/28/10	
N116mArray-10A	Q/A	3/16/10	No yield 3/9/10
	Q/A	6/28/10	
	Q/A	9/19/10	
N116mArray-11A	Q/A	3/16/10	No yield 3/9/10
	Q/A	6/28/10	
	Q/A	9/19/10	
N116mArray-12A	Q/A	3/9/10	
	Q/A	6/28/10	
N116mArray-13A	Q/A	3/9/10	
C6323	A	1/14/10	Field readings only
C6324	A	1/14/10	Field readings only
C6325	A	1/13/10	
N116mArray-14A	Q	3/9/10	
	Q	6/28/10	
N116mArray-15A	Q	3/16/10	No yield 3/9/10
	Q	6/28/10	
	Q	9/19/10	
100-D Area Segment			
C7645	Q	7/23/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	12/14/10	Installed 2010
C7646	Q	7/23/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	12/14/10	Installed 2010
C7647	Q	7/23/10	Installed 2010
	Q	8/29/10	Installed 2010
	Q	12/14/10	Installed 2010
C7648	Q	7/23/10	Installed 2010

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	Q	8/29/10	Installed 2010
	Q	12/14/10	Installed 2010
C6266	Q	4/13/10	
	Q	8/19/10	
C6267	Q	4/13/10	
	Q	8/19/10	
C6268	Q/A	4/13/10	
	Q/A	8/19/10	
C6269	Q	4/13/10	
	Q	8/19/10	
C6270	Q	4/13/10	
	Q	8/19/10	
C6271	Q/A	4/13/10	
	Q/A	8/19/10	
DD-44-3	Q/A	2/2/10	
	Q/A	4/15/10	
	Q/A	9/20/10	
DD-44-4	Q/A	2/2/10	
	Q/A	4/15/10	
	Q/A	9/20/10	
DD-43-2	Q	2/2/10	
	Q	4/15/10	
	Q	9/20/10	
DD-43-3	Q/A	2/2/10	
	Q/A	4/15/10	
	Q/A	9/20/10	
DD-42-2	Q	1/21/10	Field readings only; low SC
	Q	4/15/10	
	Q	8/19/10	
DD-42-3	Q	1/21/10	
	Q	4/15/10	
	Q	8/19/10	
DD-42-4	Q/A	1/21/10	
	Q/A	4/15/10	
	Q/A	8/19/10	
DD-41-1	Q	1/21/10	Field readings only; low SC
	Q	4/13/10	Field readings only; low SC
	Q	8/19/10	Field readings only; low SC
DD-41-2	Q/A	8/19/10	
DD-41-3	Q	1/21/10	
	Q	4/13/10	

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
	Q	8/19/10	
REDOX-4-3.0	Q	1/21/10	
	Q	4/15/10	
REDOX-4-6.0	Q/A	1/21/10	
	Q/A	4/9/10	
REDOX-3-3.3	Q	1/21/10	
	Q	4/9/10	
	Q	9/19/10	
REDOX-3-4.6	Q/A	1/21/10	
	Q/A	4/9/10	
DD-39-1	Q	4/9/10	
	Q	8/17/10	
DD-39-2	Q	1/18/10	
	Q	4/9/10	
	Q	8/17/10	
DD-39-3	Q/A	1/18/10	
	Q/A	4/9/10	
	Q/A	8/17/10	
REDOX-2-3.0	Q	1/18/10	
	Q	4/9/10	
REDOX-2-6.0	Q/A	1/18/10	
	Q/A	4/9/10	
	Q/A	9/19/10	
REDOX-1-3.3	Q	2/2/10	Field readings only; low SC
	Q	4/19/10	
	Q	9/19/10	
REDOX-1-6.0	Q/A	2/2/10	Field readings only; low SC
	Q/A	4/19/10	
	Q/A	9/19/10	
36-S	A	11/10/10	
36-M	A	11/10/10	
38-M	A	11/10/10	
38-D	A	11/10/10	Scheduled for field readings only
100-H Area Segment			
C5632	A	1/4/10	Field readings only; low SC
C5633	A	1/4/10	
C5634	A	1/4/10	
C5635	A	1/4/10	Field readings only; low SC
C5636	A	1/4/10	
C5637	A	1/4/10	
C5638	A	1/6/10	

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
C5641	A	1/6/10	
C5673	A	1/6/10	Field readings only; low SC
C5674	A	1/6/10	
C5676	A	1/8/10	
C5677	A	1/8/10	
C5678	A	1/8/10	
C5679	A	1/4/10	
C5680	A	1/4/10	
C5681	A	1/4/10	
44-M	A	11/10/10	
45-S	A	1/8/10	
	A	11/10/10	
45-M	A	1/8/10	
	A	11/10/10	
45-D	A	1/8/10	
	A	11/10/10	
C7649	Q	8/10/10	Installed 2010
	Q	9/15/10	Installed 2010
	Q	12/16/10	Installed 2010
C7650	Q	8/10/10	Installed 2010
	Q	9/15/10	Installed 2010
	Q	12/16/10	Installed 2010
100-F Area Segment			
AT-F-2-M	A	1/29/10	
200-PO-1 Operable UnitSegment			
C6378	A	1/29/10	
300 Area Segment			
AT-3-1-S	A	1/11/10	
AT-3-1-M	SA	1/11/10	
	SA	3/10/10	
AT-3-1-D(1)	A	1/11/10	
AT-3-2-M	SA	3/10/10	
C6341	SA	3/10/10	
C6342	SA	3/10/10	
C6343	SA	3/10/10	
AT-3-3-S	SA	3/10/10	
AT-3-3-M	SA	3/10/10	
AT-3-3-D	SA	3/17/10	No yield 3/10/10
C6344	SA	1/11/10	
	SA	3/10/10	
AT-3-4-S	SA	3/10/10	

Table C-2. (Cont.)

Tube Name	Frequency	CY 2010 Sample Dates	Comments
AT-3-4-D	SA	3/10/10	
C6347	SA	3/11/10	
C6348	SA	3/11/10	
AT-3-5-S	SA	3/11/10	Stopped producing water; partial sample
C6350	SA	3/11/10	
C6351	SA	3/11/10	
AT-3-6-S	SA	3/11/10	
AT-3-6-D	SA	3/11/10	
AT-3-7-M	SA	3/11/10	
AT-3-7-D	SA	3/11/10	
AT-3-8-S	SA	3/11/10	

Notes: Aquifer tubes are listed in order, upstream to downstream. Alternating shaded and unshaded bands indicate tubes in clusters.

A = annually

M = monthly

Q = quarterly

SA = semiannually

SC = specific conductance

Table C-3. Summary Statistics for Percent Change in Specific Conductance

Count	333
Average	-0.00503
Standard deviation	0.055478
Coefficient of variation	-1102.47%
Minimum	-0.49802
Maximum	0.36957
Range	0.86759
Standard skewness	-27.9229
Standard kurtosis	162.846

Table C-4. Results of t-Test on Percentage Change

Null hypothesis	Mean = 0.0
Alternative	Not equal
Computed t statistic	-1.65522
P-value	0.0988239
Do not reject the null hypothesis for alpha = 0.05	

Table C-5. Shapiro-Wilk Test of Normality for Percent Change Conductivity

Test	Statistic	P-Value
Shapiro-Wilk	0.559484	0.0

Table C-6. Results of the Sign Test

Null hypothesis	Median = 0.0
Alternative	Not equal
Number of values below hypothesized median	131
Number of values above hypothesized median	148
Large sample test statistic (continuity correction applied)	0.957895
P-Value	0.338114
Do not reject the null hypothesis for alpha = 0.05	

Table C-7. Results of the Signed-Rank Test

Null hypothesis	Median = 0.0
Alternative	Not equal
Average rank of values below hypothesized median	150.057
Average rank of values above hypothesized median	131.098
Large sample test statistic (continuity correction applied)	0.0941505
P-Value	0.924984
Do not reject the null hypothesis for alpha = 0.05	

Figure C-1. Driving the Temporary Casing for Aquifer Tube Installation

gwf10026

Figure C-2. Installation of Aquifer Tube and Screen

gwf10027

Figure C-3. Typical Aquifer Tube Completion

gwf10029

Figure C-4. Aquifer Tube Sampling Trips by Month, 2010

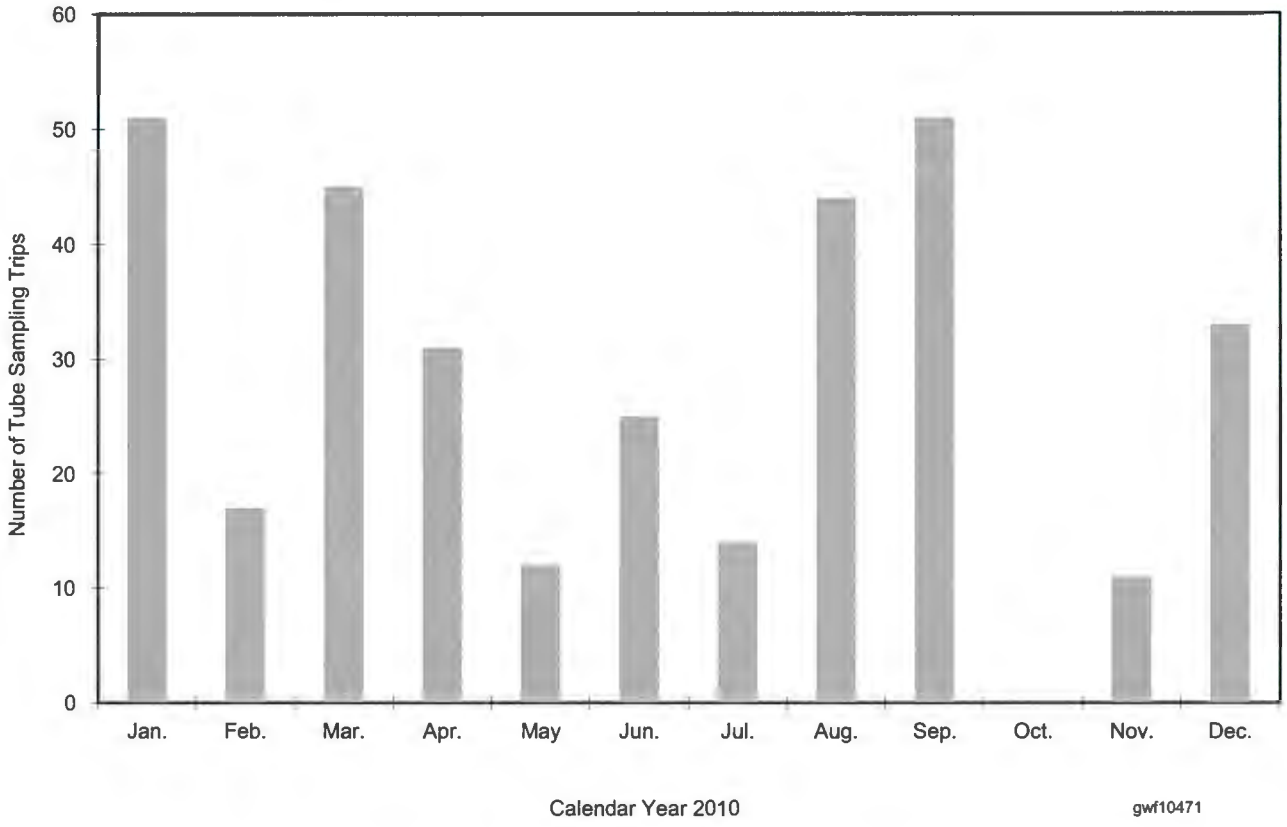


Figure C-5. 100-B/C Area River Stage and Aquifer Tube Sampling Dates, 2010

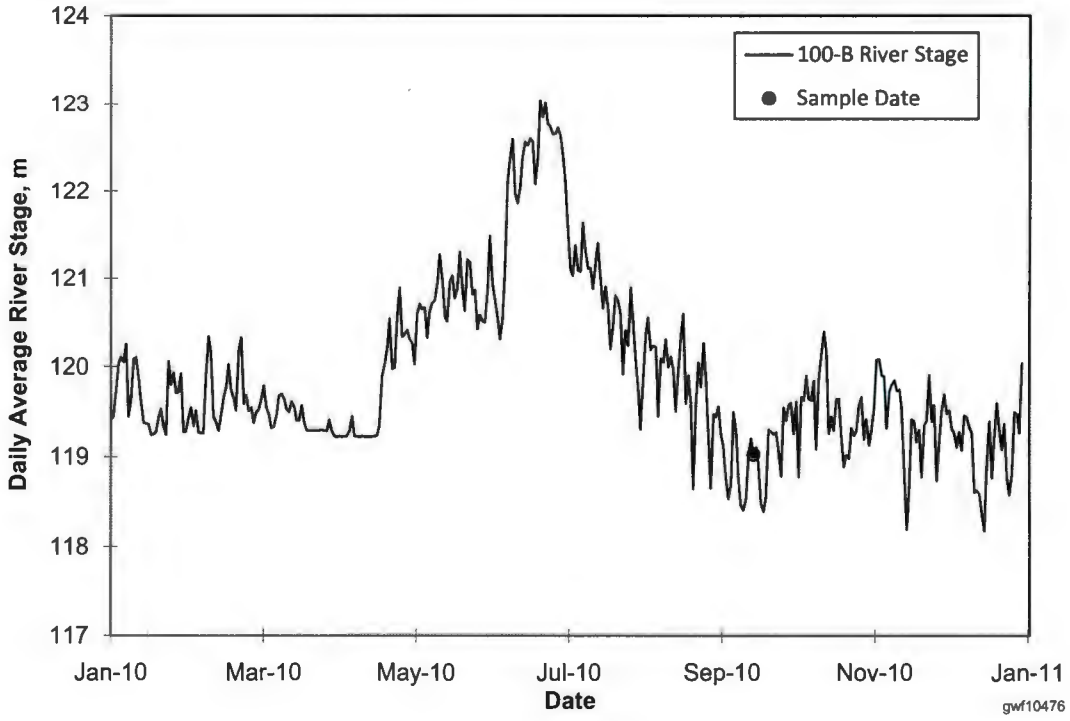


Figure C-6. 100-K Area River Stage and Aquifer Tube Sampling Dates, 2010

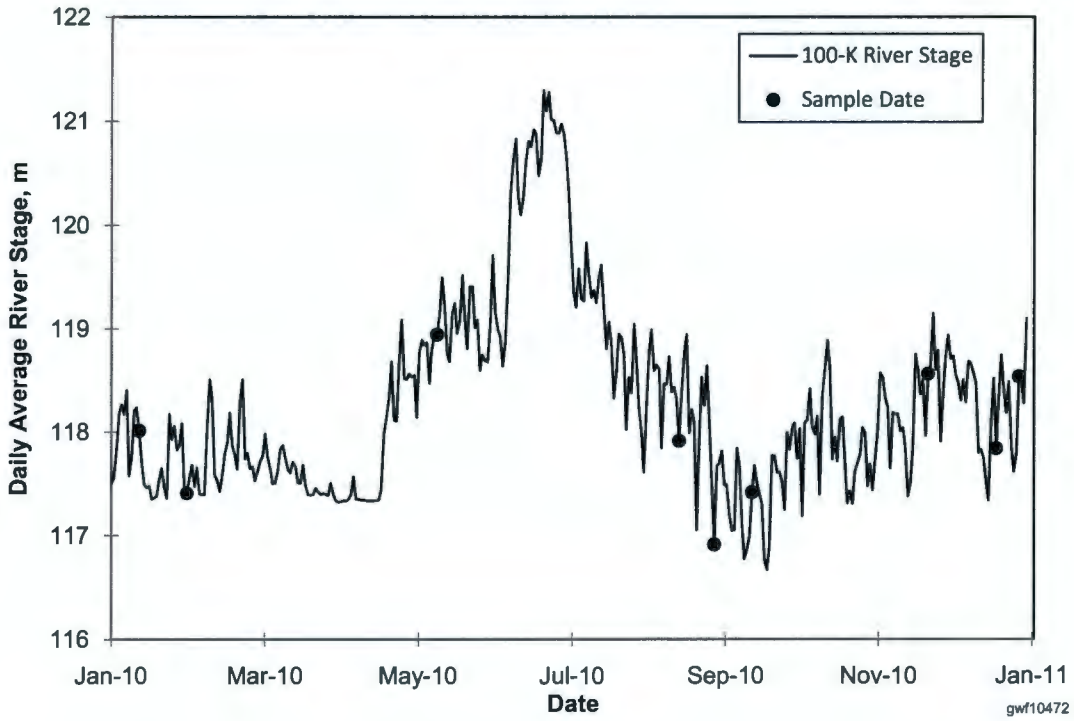


Figure C-7. 100-N Area River Stage and Aquifer Tube Sampling Dates, 2010

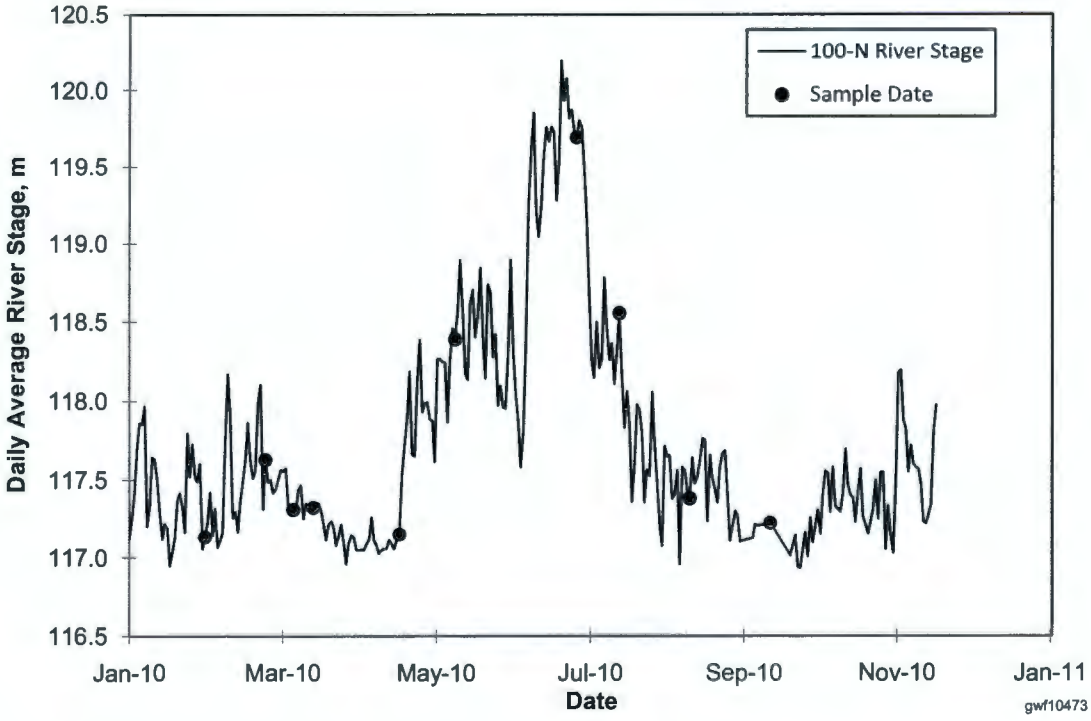


Figure C-8. 100-D Area River Stage and Aquifer Tube Sampling Dates, 2010

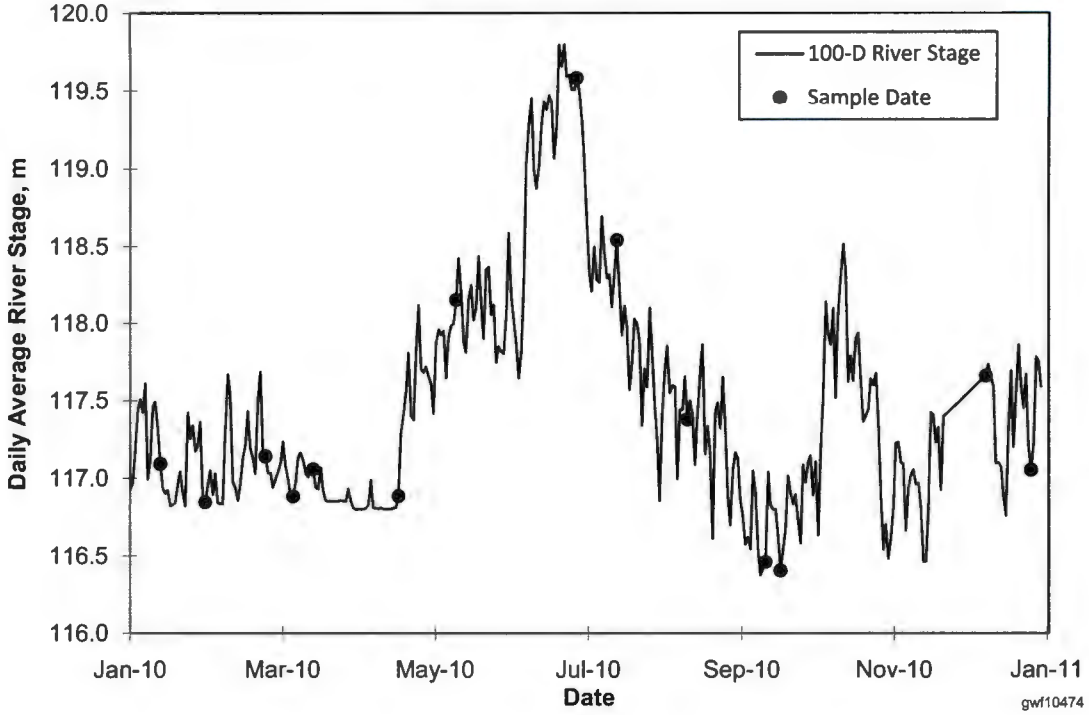


Figure C-9. 100-H Area River Stage and Aquifer Tube Sampling Dates, 2010

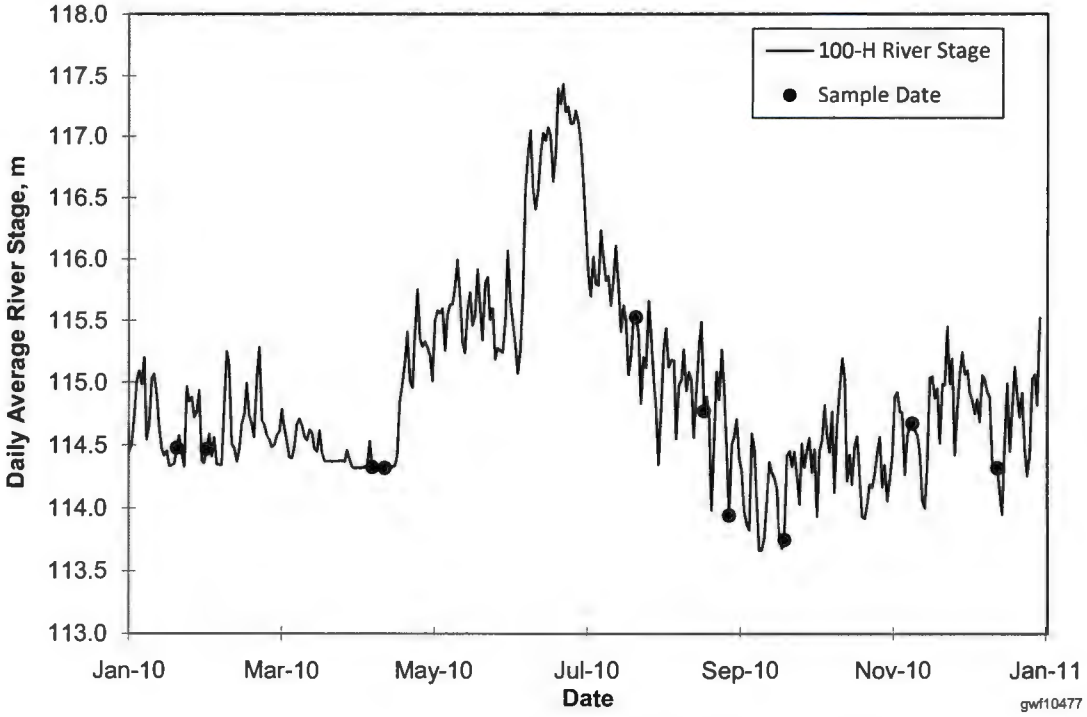


Figure C-10. 300 Area River Stage and Aquifer Tube Sampling Dates, 2010

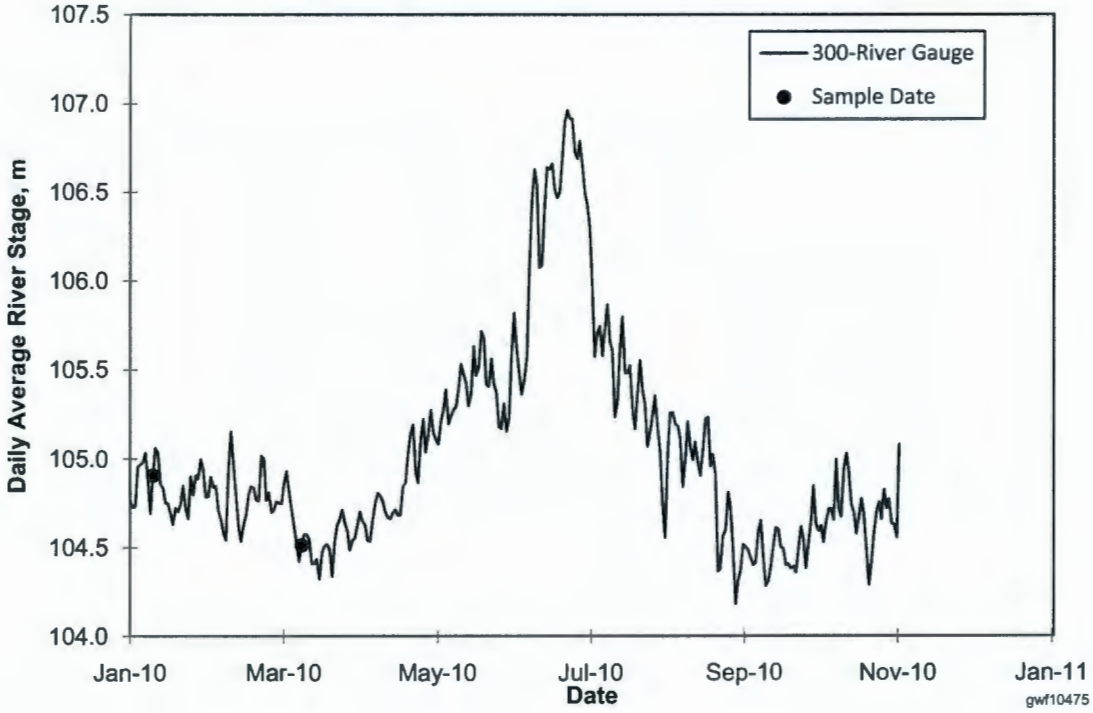


Figure C-11. Percent Change in Specific Conductance versus Elapsed Time Between Measurements

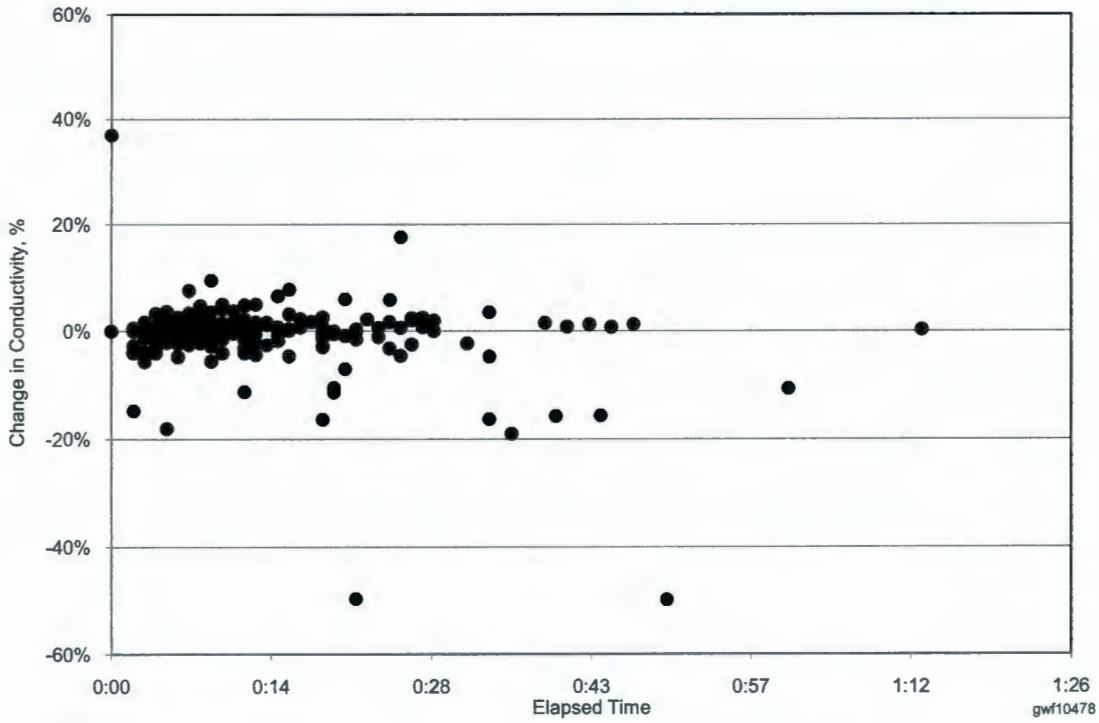
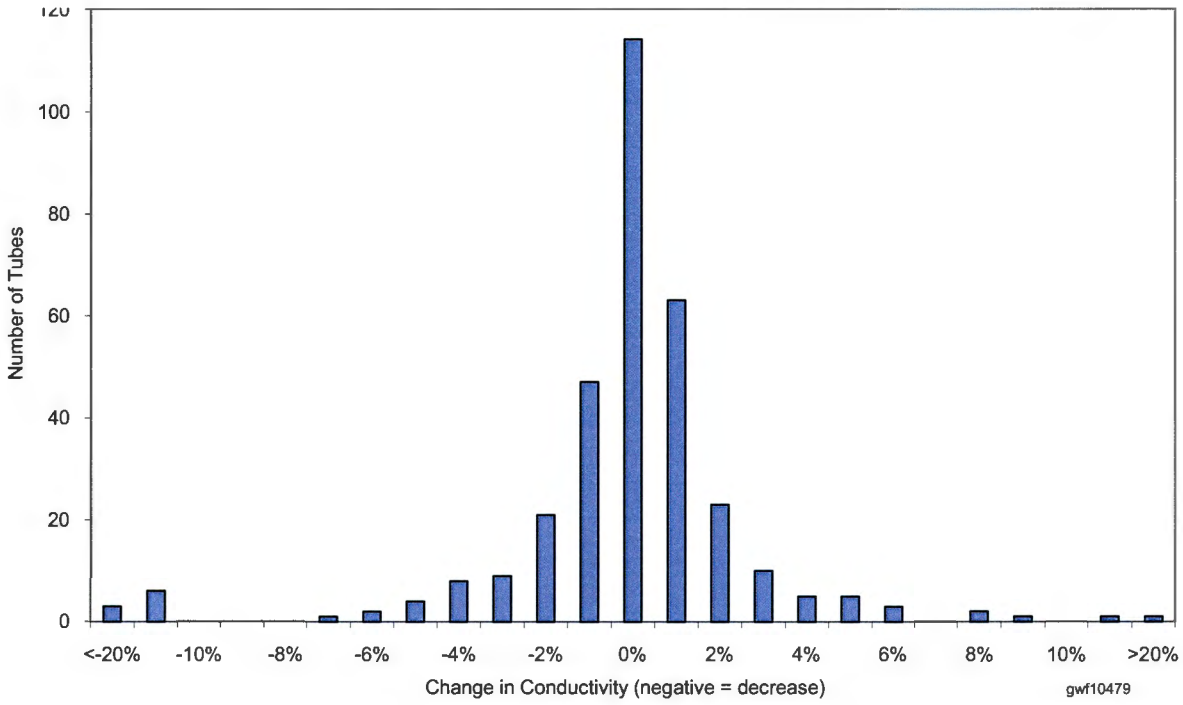


Figure C-12. Change in Specific Conductance in Aquifer Tubes



This page intentionally left blank.

Appendix D

Quality Assurance and Quality Control

This page intentionally left blank.

Contents

Appendix D – Quality Assurance and Quality Control D-1
D.1 Sample Collection and Analysis D-2
D.2 Data Review and Validation D-2
D.2.1 Review of Sampling Documents and Data Verification D-2
D.2.2 Quality Control Evaluation D-2
D.2.3 Project Scientists' Evaluation D-2
D.2.4 Resolution of Data Issues D-3
D.3 Data Completeness D-4
D.4 Field Quality Control Samples D-4
D.4.1 Field Blanks D-4
D.4.2 Field Duplicate Samples D-5
D.4.3 Field Split Samples D-5
D.5 Holding Times D-6
D.6 Laboratory Performance D-6
D.6.1 National Performance Evaluation Studies D-6
D.6.1.1 Water Pollution/Supply Performance Evaluation Studies D-7
D.6.1.2 InterLaB RadCheM Proficiency Testing Program Studies D-7
D.6.1.3 DOE Mixed Analyte Performance Evaluation Program D-7
D.6.2 Double-Blind Standard Evaluation D-8
D.6.3 Laboratory Internal Quality Assurance/Quality Control Programs D-10
D.6.3.1 Issue Resolution D-12
D.6.3.2 Laboratory/Field Audits, Assessments, and Surveillances D-12
D.6.4 Analytical Method Issues D-14
D.6.4.1 Nickel Inter-Element Correction Factor D-14
D.6.4.2 Low-Level Iodine-129 Method D-14
D.6.4.3 Hexavalent Chromium Method D-14
D.7 Limit of Detection, Limit of Quantitation, and Method Detection Limit D-14
D.8 Conclusions D-16
D.9 Glossary D-16
References D-19

Tables

Table D-1. Data Review Flags D-21
Table D-2. Requests for Data Review, Current Reporting Period Data D-21
Table D-3. Summary of Data Completeness D-21
Table D-4. Full Trip Blanks Exceeding Quality Control Limits D-22
Table D-5. Field Transfer Blanks Exceeding Quality Control Limits D-23
Table D-6. Equipment Blanks Exceeding Quality Control Limits D-24
Table D-7. Field Duplicates Exceeding Quality Control Limits D-25
Table D-8. Field Splits Exceeding Quality Control Limits D-27
Table D-9. Summary of Analytical Method Categories D-28
Table D-10. Hanford Site Groundwater Remediation Project Maximum Recommended Holding Times D-30
Table D-11. Summary of WSCF and 222-S Performance Evaluation Studies D-31
Table D-12. Summary of TestAmerica Performance Evaluation Studies D-32
Table D-13. Summary of Eberline Services and Lionville Laboratory Performance Evaluation Studies D-33
Table D-14. Summary of WSCF Double-Blind Spike Determinations D-34
Table D-15. Summary of TestAmerica Laboratories Double-Blind Spike Determinations D-35
Table D-17. Percentage of Out-of-Limit Quality Control Results by Category, WSCF D-36

Table D-16. Summary of Lionville Laboratory and Eberline Services Double-Blind Spike Determinations D-36
Table D-18. Percentage of Out-of-Limit Quality Control Results by Category, TestAmerica Laboratories (Knoxville, Richland, and St. Louis) D-37
Table D-19. Method Blank Results, WSCF D-38
Table D-20. Method Blank Results, TestAmerica Laboratories (Knoxville, Richland, and St. Louis) D-39
Table D-21. Laboratory Control Samples, WSCF D-41
Table D-22. Laboratory Control Samples, TestAmerica Laboratories (Knoxville, Richland, and St. Louis) D-42
Table D-23. Matrix Spikes and Matrix Spike Duplicates, WSCF D-45
Table D-24. Matrix Spikes and Matrix Spike Duplicates, TestAmerica Laboratories (Richland and St. Louis) D-47
Table D-25. Matrix Duplicates, WSCF D-51
Table D-26. Matrix Duplicates, TestAmerica Laboratories (Richland and St. Louis) D-51
Table D-27. Summary of Issue Resolution Forms, Current Reporting Period D-52
Table D-28. Summary of Analytical Laboratory Detection/Quantitation Limits Determined from Field Blanks Data, TestAmerica Laboratories (Richland and St. Louis) and WSCF D-53
Table D-29. Summary of Detection and Quantitation Limits, WSCF D-55
Table D-30. Summary of Detection and Quantitation Units, TestAmerica Laboratories D-59

Appendix D — Quality Assurance and Quality Control

C.J. Thompson

This appendix presents calendar year (CY) 2010 quality assurance (QA)/quality control (QC) information for groundwater monitoring at the Hanford Site. Groundwater monitoring activities were managed by CH2M HILL Plateau Remediation Company (CHPRC) via the Soil and Groundwater Remediation Project (Groundwater Project). This includes monitoring performed to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA); the *Atomic Energy Act of 1954* (AEA); and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). The QA/QC practices used by the Groundwater Project assess and enhance the reliability and validity of field and laboratory measurements conducted to support these programs. Accuracy, precision, and detection are the primary parameters used to assess data quality ("Determination of Measurement Data Quality and Establishment of Achievable Goals for Environmental Measurements" [Mitchell et al., 1985]). Representativeness, completeness, and comparability can also be evaluated for overall quality; however, representativeness and comparability are considered qualitative and do not have specific evaluation criteria in this report. These six parameters are evaluated through laboratory QC checks (e.g., matrix spikes and laboratory blanks), replicate sampling and analysis, analysis of blind standards and field blanks, and inter-laboratory comparisons. Acceptance criteria have been established for each of these QC checks. When QC results are outside the criteria, groundwater analytical support staff review the data and ensure that appropriate data qualifying flags are entered in the Hanford Environmental Information System (HEIS) database. When a recurring problem is identified, corrective actions are taken.

This appendix summarizes the overall QA/QC program for the Groundwater Project. Through a comprehensive review of performance indicators, the Groundwater Project identifies and resolves issues with data quality and initiates process improvements. The annual QA/QC appendix is a tool for data users in determining usability of specific data sets for decision-making purposes.

Several comparisons to 2009 performance are made throughout this appendix. Due to a change in reporting period from a fiscal year (FY) to a calendar year (CY), the 2009 reporting period covered 15 months (October 1, 2008, through December 31, 2009). Although the current, CY reporting period is shorter, comparisons between the two timeframes are provided because they help indicate relative quality trends in the data.

The QA/QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (EPA) in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*. The U.S. Department of Energy (DOE) orders and internal requirements provide the guidance for the collection and analysis of samples for other long-term monitoring. The QA/QC practices for the Groundwater Project are described in the CHPRC QA plan (CHPRC-00189, *CH2M HILL Plateau Remediation Company Quality Assurance Program Plan*). A glossary of QA/QC terms is provided in Section D.9. Additional information about the QA/QC program and data from this year (e.g., results of individual QC samples and/or associated groundwater samples) are available upon request. Referenced data from the previous reporting period can be found in *Hanford Site Groundwater Monitoring and Performance for 2009* (DOE/RL-2010-11).

D.1 Sample Collection and Analysis

C.J. Thompson

Groundwater Project staff collected groundwater samples during the reporting period. Tasks related to sampling included bottle preparation, sample set coordination, measurement of field parameters, sample collection, sample shipping, well pumping, and coordination of purge water containment and disposal.

The Waste Sampling and Characterization Facility (WSCF) is an onsite laboratory managed by Mission Support Alliance. The WSCF was the primary analytical laboratory supporting the Groundwater Project during 2010.

Excluding field measurements, WSCF performed 83% of the sample analyses for groundwater monitoring during the reporting period; the percentage performed by WSCF is 55% when field measurements are included.

WSCF and Test America St. Louis (St. Louis, Missouri) (TA St. Louis) performed most of the routine analyses of Hanford Site groundwater samples for hazardous and nonhazardous chemicals. Lionville Laboratory, Inc. (Lionville, Pennsylvania) (Lionville Laboratory) performed less than 1% of the chemical analyses. Test America Knoxville (Knoxville, Tennessee) (TA Knoxville) performed polychlorinated biphenyl congener and dioxin analysis. Finally, the onsite 222-S Laboratory, which is managed by Advanced Technologies and Laboratories International, Inc., analyzed approximately 100 samples (~0.2%) for anions and hexavalent chromium between February and April.

The majority of radiological analyses on groundwater samples were performed by WSCF and Test America Richland (Richland, Washington) (TA Richland). Eberline Services (Richmond, California) (Eberline) analyzed approximately 4% of the samples for radiological constituents.

Standard methods from EPA, the American Society for Testing and Materials (ASTM), and the *Standard Methods for the Examination of Water and Wastewater* (APHA et al., 1998) were used for the analysis of chemical constituents. Methods employed for radiological constituents were developed by the analyzing laboratories and are recognized as acceptable within the radiochemical industry. Descriptions of the analytical methods used are available upon request.

D.2 Data Review and Validation

S. Champoux

Groundwater staff review and validate groundwater data according to an established process. Validation produces an electronic data set, with suspect or erroneous data corrected or flagged. The validation process includes the following activities:

- Review of sampling documents and analytical data verification
- QC evaluation
- Project scientists' evaluations
- Resolution of data issues identified during the evaluation.

D.2.1 Review of Sampling Documents and Data Verification

Sampling documents include the groundwater sampling record, chain-of-custody forms, field logbook pages, and other paperwork associated with sampling and shipping. Groundwater staff review these forms to determine if the documents are filled out completely, signed appropriately, and legible, as well as to determine if problems arose during sampling that may impact the data. Staff also verify that analytical data from the laboratories are complete and reported correctly. Moreover, staff review laboratory documents to check the condition of the samples upon receipt at the laboratory and determine if problems arose during analysis that may have affected the data. Identified issues are documented, investigated, and resolved (Section D.2.4 and D.6.3.1).

D.2.2 Quality Control Evaluation

A quarterly evaluation of field and laboratory QC data is conducted as part of the validation process. Groundwater analytical support staff assess the laboratories' internal QC practices and submit field QC samples and blind standards to the laboratories on a regular basis.

D.2.3 Project Scientists' Evaluation

Data management staff generate routine data reports for project scientists' review. These reports include biweekly data reports and include analytical data loaded into the HEIS database since the previous reporting period. The tables are organized by groundwater interest area, RCRA site, or special project (e.g., confined aquifer data). As soon as practical after receiving a report, the project scientists review the data, typically by viewing trend plots, to determine the following:

- Whether there are any significant changes in contaminant concentrations or distribution
- If there are data points that appear erroneous (e.g., significantly out of trend).

Project scientists also review quarterly compilations of the data. The quarterly review provides a method for groundwater staff to check whether there were problems with sampling, all requested analyses were received, and that the data seem to represent actual groundwater quality. Unlike biweekly reports, the quarterly reports usually include a full data set (i.e., all data from the wells sampled during the previous quarter that have been received and loaded into the HEIS database). This review also includes water-level data, preliminary maps of selected constituent distribution (plume maps), and a partial listing of sampling comments. When specific questions arise regarding field measurements, analytical results, dates of analysis or sampling, or sample or well numbers, the project scientist requests a formal data review. Section D.2.4 describes the process for data reviews.

D.2.4 Resolution of Data Issues

Requests for data reviews are the formal mechanism used by the Groundwater Project to resolve specific issues with data. When potential anomalies are encountered during a review of analytical data or water-level measurements, the Groundwater Project Support staff or the project scientist reviewing the data will initiate a request for data review. Depending on the type of data issue identified, groundwater analytical support staff resolve the request for data review through some or all of the following actions:

- Request a laboratory recheck, recount, or re-analysis
- Review laboratory hardcopy data
- Review sampling documents for data entry errors or other problems.
- Flag the affected data with one of the flags described in Table D-1.

A review of the sampling documents and/or hardcopy data from the laboratory can sometimes provide an explanation for unusual results (e.g., data-entry errors or samples swapped in the field). Laboratory rechecks involve an internal laboratory review of the data. When discrepancies are discovered by the laboratory, the data are re-reported. The original data are removed from the HEIS database, the corrected data are loaded into HEIS, and the data are flagged appropriately. However, when a laboratory reanalysis or recount is requested, the laboratory reanalyzes or recounts the original sample and reports the new results. If a discrepancy occurs between the original and new results, groundwater staff determine which results appear to be more representative and assign an appropriate review code to the results loaded into the HEIS database.

Requests for data reviews are most commonly resolved by assigning "Y," "G," or "R" flags to the HEIS data. If a review determines that the result is valid, the result is flagged with a "G." If clear, documented evidence exists that a result is erroneous, the result is flagged with an "R." If a review was unable to determine the validity of the result, the result is considered suspect and flagged as "Y." Data flagged with a "Y" or "R" are typically excluded from statistical evaluations, maps, and other interpretations, but the data are not deleted from the HEIS database. Occasionally, a request for data review is submitted on data that are not managed by the Groundwater Project. In those cases, the data owner is notified, but no further action is taken by the Groundwater Project.

Table D-2 lists the number of analytical and water-level results that were flagged during the reporting period as a result of the request for data review process. As of February 8, 2011, requests for data reviews have been filed on 2,613 of 245,705 analytical results (~ 1%). Requests for data reviews of water-level measurements have been filed on 70 of 3,718 measurements (<2%). The resolution of 339 analytical requests for review is pending, and additional requests may yet be filed on data from the reporting period. There are no pending water-level measurement requests for data review. During the reporting period, WSCF analyses generated ~55% of the analytical (laboratory and field) results for groundwater monitoring, and WSCF data had 87% of the requests for data review. The bulk of the requests for data review (46%) were filed on metals results. Requests for data review also were filed on WSCF results from wet chemistry methods (6%), organic methods (20%), and radiological methods (28%). Requests for data review to the field and other laboratories were scattered among a varied group of methods and issues. No other trends in data review requests from the field or other laboratories were identified.

D.3 Data Completeness

C.J. Thompson

Data judged to be complete are data that are not suspect, rejected, associated with a missed holding time, out-of-limit field duplicate, or qualified to indicate laboratory blank contamination. Table D-3 provides a summary of data completeness. During the reporting period, 90% of the groundwater data were considered complete. The percentages of potentially invalid data were 2.4% for field QC problems, 0.5% for exceeding holding times, 0.2% for suspect values, and 7.4% for laboratory blank contamination. These values are similar to the percentages observed in 2009 for field QC problems, suspect data, and rejected data. However, significant increases occurred in the number of flagged results for missed holding times and method blank contamination. Most of the missed holding times were for volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) at Lionville Laboratory, TA St. Louis, and WSCF. The percentage of results that were qualified for method blank detection increased from 0.5% in to 2009 to 7.4% this year. This large increase is mainly associated with metals analyses conducted by WSCF. Analytical support staff are working with the laboratory to implement process improvements to reduce metal blank-detection frequencies in the future.

D.4 Field Quality Control Samples

J. Douglas

Field QC samples include three types of field blanks (full trip, field transfer, and equipment blanks), field duplicate samples, and field split samples. Section D.9 provides definitions for these QC samples. Field QC samples are used to assess precision, repeatability, and potential contamination related to both sampling and laboratory activities. Tables D-4 through D-8 summarize the field QC results that exceeded QC limits. Constituents not listed in the tables had 100% acceptable field QC. The tables are divided into the following categories, where applicable: general chemistry parameters, ammonia and anions, metals, VOCs, SVOCs, and radiological parameters. Table D-9 provides additional information on the method categories.

D.4.1 Field Blanks

Field blanks are used to assess potential contamination associated with sampling and laboratory activities. The percentage of acceptable field blank results evaluated during the reporting period was 97%, indicating little problem with contamination.

Field blank results above two times the method detection limit are identified as suspected contamination; however, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the method detection limit. For radiological data, blank results are identified as potentially contaminated if they are greater than two times the minimum detectable activity. Results associated with field blanks that are above these criteria are flagged with a "Q" in the HEIS database to indicate potential contamination issues. For full trip and field transfer blanks, an associated sample is one that was collected on the same day and analyzed by the same method as a full trip or field transfer blank. For equipment blanks, an associated sample is one that has the same collection date, collection method/sampling equipment, and analysis method as the equipment blank. Data users must evaluate the usability of data associated with quality issues based on the data quality objective requirements established for the specific monitoring campaign.

The acceptable field blank percentage of 97% for CY 2010 is the same as that for the 2009 reporting period. As with the 2009 reporting period, the largest percentage of out-of-limit results were associated with metals analysis at 4.9%; this represents an increase from the 1.8% out-of-limit results for metals blank values in the 2009 reporting period and the 2.7% out-of-limit results in FY 2008. The WSCF laboratory generated all the blank failures for metals during CY 2010. However for CY 2010, WSCF also generated all 7,500 blank results for metals except for two hexavalent chromium values generated at TA Richland. While field blank concentrations of calcium, magnesium, potassium, and sodium were frequently above QC limits, the levels detected in the majority of the blanks were 10 to 100 times lower than the average concentration of these constituents in Hanford Site groundwater. One equipment

blank associated with well 299-W19-44 had four of the highest out-of-limit metal results. This failure is most likely from a groundwater sample swapped with the field blank, but whether a swap occurred in the field or the laboratory was not determined.

Of the 6,262 VOCs results for all field blanks, 229 (3.7%) exceeded the QC limits. This represents an increase over the percentages in the 2009 reporting period (1%) and FY 2008 (1.7%). Methylene chloride continues to be the predominant volatile organic contaminant, accounting for 69% of the VOC out-of-limit results. Similar concentrations of methylene chloride were measured in method blanks; therefore, laboratory contamination is suspected. In addition, 82 field blanks had concentrations of methylene chloride greater than the drinking water standard (DWS) of 5 µg/L. This limits the usability of data with low-level detections for methylene chloride in groundwater monitoring samples. Affected results were flagged as "Q" (quality failures) and/or "Y" (data are suspect) in the HEIS database. Groundwater analytical support staff continue to work with the laboratories to decrease both the frequency and magnitude of methylene chloride contamination.

For carbon tetrachloride, 13 of 235 field blank results, or 5.5%, exceeded the QC limits. This is less than the 2009 reporting period out-of-limits percentage of 12% (41 of 342) and the FY 2008 out-of-limits percentage of 8% (19 of 235). Eight of the thirteen failures were greater than the DWS of 5 µg/L. Trace levels of several other VOCs were also measured in field blanks (Tables D-4 through D-6). The frequencies of detection for these other compounds were low (1%) and the impact on the data is minor.

A small number of other non-metal, non-VOC chemical and radiological constituents were detected at levels that exceeded blank QC limits (Tables D-4 and D-6). However, the out-of-limits percentage (2%) for these compounds was low, and no trends were identified.

D.4.2 Field Duplicate Samples

Field duplicate samples ("field duplicates") are used to assess field sampling and measurement precision. Results of field duplicates must have precision within ±20%, as measured by the relative percent difference. Only field duplicates with at least one result greater than five times the method detection limit or minimum detectable activity are evaluated. Results associated with field duplicates that have greater than ±20% relative percent difference are flagged as "Q" in the HEIS database to indicate potential precision issues.

Of the 2,490 duplicate results evaluated, a total of 2,318, or 93%, were acceptable, indicating reasonable precision overall. However, this represents a decrease from the acceptable results percentage of 99% for the 2009 reporting period. Table D-7 presents the duplicate results that exceeded quality control limits.

Most of out-of-limit duplicates (67%) were associated with metal results from WSCF. Seventy-five of the duplicates that exceeded QC limits were from unfiltered samples. Suspended solids in heterogeneous sample fractions may have caused some of the discrepancies in the results. Likewise, all of the associated samples in the radiological parameters category were unfiltered, which may explain some of the out-of-limit results.

The majority of the out-of-limit duplicate results appear to be anomalous instances of poor precision based on other QC indicators, such as the results from the laboratory duplicates. In several cases, the laboratory was asked to reanalyze or investigate duplicate results with a very high relative percent difference, but the source of the problem was not discovered.

D.4.3 Field Split Samples

Field split samples ("split samples") are used to confirm out-of-trend results and for inter-laboratory comparisons. Results must have a relative percent difference less than or equal to 20%. Only those results that are greater than five times the method detection limit or minimum detectable activity at both laboratories were evaluated. For total organic carbon (TOC) and total organic halides (TOX), sample splits most often consisted of two groups of quadruplicate samples (i.e., four matching samples were submitted to each laboratory). The two sets of quadruplicate samples were evaluated by comparing the average concentration from each laboratory.

During CY 2010, 370 split samples were analyzed for 264 different analytes generating 2,331 split pairs of data. The split sample data were used to evaluate the performance of the laboratories and to determine the extent of any analytical problems. The results for field splits that exceeded QC limits are summarized in Table D-8. For CY 2010,

the percentage of out-of-limit results for evaluated duplicates was 22%. This represents a slight decrease from the 23% out-of-limits percentage in the 2009 reporting period and 25% in FY 2008.

The metals splits constituted 65% of the split failures. Of all the hexavalent chromium splits results evaluated, the TA Richland laboratory showed a distinct low bias compared to the WSCF values. The Method 6010 ICP metals showed no strong bias between the TA St. Louis and WSCF laboratories.

After the metals, the anions contributed next most frequently to the split failures with 22% of the failures. Fluoride results generated by ion chromatography continue to demonstrate poor precision. Of the fluoride splits evaluated, the TA St. Louis results showed a very distinct high bias with respect to the WSCF results. Based on past review of raw chromatographic data, it is possible that one or more of the laboratories may be experiencing interferences from poorly integrated fluoride peaks that elute immediately after the water peak or from the presence of small organic acids that elute near the fluoride peak.

D.5 Holding Times

J. Douglas

Holding time is the elapsed time period between sample collection and analysis. Samples are required to be analyzed within recommended holding times to minimize the possibility of changes in constituent concentrations caused by volatilization, decomposition, or other chemical processes. Samples are also refrigerated to slow potential chemical reactions within the sample matrix. Maximum recommended holding times for constituents frequently analyzed for the Groundwater Project are listed in Table D-10. Results for samples with missed holding times are flagged as "H" in the HEIS database.

Radiological constituents do not have recommended maximum holding times because these constituents are not typically lost under ambient temperatures when appropriate preservatives are used. The results of radionuclide analysis are decay-corrected from the sampling date to analysis date.

During the reporting period, recommended holding times were met for over 99% of nonradiological results (Table D-3). Holding times were exceeded for 1,155 nonradiological results. Missed holding times for volatile organic analyses contributed the single largest fraction to the missed holding times total at 25%. Missed holding times were attributed to late delivery to the laboratory, high sample load at the laboratory, or other laboratory issues.

D.6 Laboratory Performance

D.S. Sklarew, S.J. Champoux, J.G. Douglas, and C.J. Thompson

Laboratory performance is measured by several indicators, including national performance evaluation studies, double-blind standard analyses, laboratory audits, and internal laboratory QA/QC programs. This section provides a detailed discussion of the performance indicators for WSCF, TA St. Louis, and TA Richland. Brief summaries of performance measures for Lionville, Eberline, and 222-S Laboratory are also presented throughout this section.

D.6.1 National Performance Evaluation Studies

During the reporting period, Environmental Resources Associates (ERA) and DOE conducted national studies to evaluate laboratory performance for chemical and radiological constituents. TA St. Louis, TA Richland, and WSCF participated in the EPA sanctioned Water Pollution/Supply Performance Evaluation (WP/WS) studies conducted by Environmental Resources Associates. TA Richland, TA St. Louis, WSCF, and Eberline participated in the Environmental Resources Associates' InterLaB RadCheM Proficiency Testing Program (RAD). All six laboratories supporting the groundwater project (WSCF, TA St. Louis, TA Richland, Lionville, Eberline, and 222-S) took part in DOE's Mixed Analyte Performance Evaluation Program (MAPEP). The results of those studies related to groundwater monitoring at the Hanford Site are described in this section.

D.6.1.1 Water Pollution/Supply Performance Evaluation Studies

The purpose of water pollution/supply performance evaluation studies is to evaluate the performance of laboratories in analyzing selected organic and inorganic compounds in water matrices. An accredited agency (e.g., Environmental Resource Associates) distributes standard water samples to participating laboratories. These samples contain specific organic and inorganic analytes at concentrations unknown to the participating laboratories. After analysis, the laboratories submit results to the accredited agency, which uses regression equations to determine acceptance and warning limits for the study participants. The results of these studies are expressed in the following section as a percentage of the results that the accredited agency found acceptable and independently verify the level of laboratory performance. In the event of an unacceptable result, the laboratories may order an ERA QuiK™Response sample to verify successful corrective action. QuiK™Response samples are similar to water pollution/water supply samples, and results are reported in a comparable fashion.

For the two water pollution and one QuiK™Response performance evaluation studies (ERA WP-180 and WP-186) in which WSCF participated during the reporting period, the percentage of results within the acceptance limits was 98% (160 results) (Table D-11). Three different constituents had unacceptable results.

For the five water pollution/supply performance evaluation studies in which TA St. Louis participated during the reporting period (ERA WP-180, WP-186, WP-188, WS-165, and WS-171), the percentage of results within the acceptance limits was 98% (1,659 results) (Table D-12). Thirty-one different constituents had unacceptable results, only three of which (volatile solids and manganese) were repeated across studies or in more than one WP/WS study this year. As noted, the number of constituents reported by TA St. Louis in the water pollution studies was considerably greater than those reported by WSCF, so the percentages from the two laboratories are not directly comparable.

For the two water pollution performance evaluation studies (ERA WP-180 and WP-186) in which TA Richland participated during the reporting period, the percentage of results within the acceptance limits was 100% (two results). As noted, the number of constituents was very limited, so the percentage of results is not comparable to that of the other two laboratories.

D.6.1.2 InterLaB RadCheM Proficiency Testing Program Studies

The purpose of the InterLaB RadCheM Proficiency Testing Program (also conducted by Environmental Resources Associates) is to evaluate the performance of laboratories in the analysis of selected radionuclides. This program provides blind standards that contain specific amounts of one or more radionuclides in a water matrix to participating laboratories. After sample analysis, the results are forwarded to Environmental Resources Associates for comparison with the known values and with results from other laboratories. Environmental Resources Associates bases its control limits on the EPA's *National Standards for Water Proficiency Testing Studies Criteria Document* (NERL-Ci-0045).

During the reporting period, WSCF participated in one study, RAD-80 (Table D-11), acceptably quantifying all four constituents.

TA Richland participated in three studies, RAD-80, RAD-81, and RAD-82 (Table D-12). All 47 constituents had acceptable results.

TA St. Louis participated in one study, RAD-81 (Table D-12), and analyzed a total of twenty-three constituents. Three results were unacceptable, barium-133 (2) and uranium (nat) mass, all with a high bias.

Eberline Services participated in three studies (RAD-80, RAD-81, and RAD-82), and analyzed a total of 31 constituents. Only one result was unacceptable, radium-228 with a high bias (Table D-13).

D.6.1.3 DOE Mixed Analyte Performance Evaluation Program

The DOE's Mixed Analyte Performance Evaluation Program examines laboratory performance in the analysis of soil and water samples containing metals, SVOCs, and radionuclides. This report considers only water samples. The program is conducted at the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho. The DOE evaluates the accuracy of the Mixed Analyte Performance Evaluation Program results for radiological, inorganic, and organic analytes by determining if they fall within ±30% of the reference value. Two studies were available for all laboratories during the reporting period (MAPEP-09-21 and MAPEP-09-22). The results for MAPEP-09-21 for WSCF and Eberline were reported in last year's annual report.

For the MAPEP-09-22 study, WSCF analyzed radionuclides, including gross alpha/beta, inorganics, and semivolatile organics (Table D-11). Out of 89 analytes, one had an unacceptable result and one received a warning, resulting in 99% acceptable results. The missed analyte was technetium-99 and the warning was for mercury. Both of these constituents were acceptable in the previous study.

For the MAPEP-09-21 and 09-22 studies, 222-S analyzed radionuclides, including gross alpha/beta, and inorganics (Table D-11). Out of 60 analytes, five had unacceptable results, resulting in 92% acceptable results. The missed constituents included uranium-total, manganese-54, plutonium-238, gross beta, and arsenic. None of these unacceptable results were repeated across studies.

For the MAPEP-09-21 and 09-22 studies, TA St. Louis analyzed radionuclides, including gross alpha/beta, inorganics, and semivolatile organics (Table D-11). Out of 222 analytes, three had unacceptable results and one received a warning, resulting in 99% acceptable results. The missed analytes were arsenic, 4,4'-DDE, and 4,4'-DDT, and the warning was for beta-BHC. All of these constituents were within limits in the preceding study.

TA Richland reported results for radionuclides, including gross alpha/beta, for the MAPEP-09-21 and 09-22 studies (Table D-12). Out of 38 constituents, two had unacceptable results and one received a warning, resulting in 95% acceptable results. The missed analytes were iron-55 and plutonium-239/240; the warning was for tritium. These constituents were acceptable in the preceding study.

For the MAPEP-09-21 and 09-22 studies, Lionville Laboratory analyzed inorganics and semivolatile organics (Table D-13). Out of 144 constituents, three had unacceptable results, resulting in 98% acceptable results. The missed constituents included mercury, vanadium, and hexachlorobutadiene. All of these constituents were within limits in the previous study.

For the MAPEP-09-22 study, Eberline Services analyzed radionuclides, including gross alpha/beta (Table D-13). Out of eighteen analytes, 100% had acceptable results.

D.6.2 Double-Blind Standard Evaluation

Double-blind standards are issued quarterly during the calendar year to provide a measure of both inter- and intra-laboratory precision and accuracy. These studies also help groundwater staff troubleshoot analytical problems identified through data reviews and QC evaluations. The double-blind standards also may be used to confirm the adequacy of corrective actions to resolve analytical problems. During the first three quarters of the reporting period, the groundwater project sent double-blind QC standards to Eberline Services, Lionville Laboratory, TA Richland, TA St. Louis, and WSCF. Blind standards for the fourth quarter of CY 2010 were not prepared and submitted to the laboratories in time for the results to be included in this report. Blind standards were generally prepared in triplicate and submitted to the laboratories to check the accuracy and precision of analyses. For most constituents, the standards were matrix-matched double-blind standards prepared in a groundwater matrix from an appropriate background well. Standards for specific conductance were commercially prepared in deionized water. In all cases, the double-blind standards were submitted to the laboratories as regular groundwater samples. After analysis, the laboratories' results were compared with the spiked concentrations, and a set of control limits were used to determine if the data were acceptable. Out-of-limit results were reviewed for errors. In situations where several results for the same method were unacceptable, the results were discussed with the laboratory, potential problems were investigated, and corrective actions were taken when appropriate.

In summary, the evaluation of the double-blind standards indicates that the current laboratories, except Eberline, meet acceptable results requirements for the groundwater monitoring project. Eberline's percentage of acceptable results was only 67%. In general, the performance of the laboratories as measured with the double-blind standards decreased during CY 2010 compared to the 2009 reporting period. Specific analytical areas at each laboratory continue to be identified for process improvements.

Tables D-14 through D-16 summarize the number and types of double-blind standards generated and analyzed in the reporting period, along with the number of unacceptable results and control limits for each constituent. Totaled over all laboratories for CY 2010, 84% of the blind sample determinations were acceptable; this was lower than the 87% for the 2009 reporting period. WSCF and TA (both Richland and St. Louis laboratories) were provided approximately the same number of test samples (198 and 225, respectively), allowing for direct comparison between

their results. For CY 2010, WSCF had 86% of their blind results within control limits compared to 87% in the 2009 reporting period and 91% in FY 2008. For CY 2010, TA (Richland and St. Louis) reported acceptable results for 87% of the blind constituents compared to 88% in the 2009 reporting period. Lionville and Eberline received fewer blinds, both in number and type. The Lionville Laboratory performance remained nearly unchanged, reporting 81% of the blinds correctly compared to 80% in the 2009 reporting period. Eberline's overall performance for CY 2010 radiochemistry blind standards was 67%, which is lower than CY 2009.

The TOC blind sample results for both WSCF (83%) and TA St. Louis (83%) were acceptable, and these laboratories will continue to provide the primary analytical service for this analysis. The Lionville Laboratory's acceptable results percentage for TOC analysis was 56%. All the Lionville Laboratory out-of-limit TOC results were biased about 50% high. Corrective action is needed prior to Lionville performing this work scope.

Blind standards for TOX were prepared using two different spiking solutions: 2,4,5-trichlorophenol and a mixture of carbon tetrachloride, chloroform, and trichloroethene. During this reporting period, TA St. Louis correctly reported 100% of the TOX blinds, while WSCF correctly reported only 62%. For the 2009 reporting period, TA St. Louis reported 92% correctly, and WSCF correctly reported 97%. For the CY 2010 reporting period, the WSCF failures were split between the 2,4,5-trichlorophenol and volatile organic halide standards. The phenol standard failures were all biased high, and the volatile organic halide standard failures were all biased low. The low bias for the volatile organic halide is probably explained by the method WSCF uses to prepare aqueous samples for TOX determination versus the method TA St. Louis uses. The WSCF laboratory uses gas pressure to force aqueous samples through activated charcoal adsorption filters while the TA St. Louis laboratory uses a syringe method. The gas pressure method generates a headspace into which volatile organic halides may be lost from the sample prior to adsorption onto the activated charcoal.

The WSCF and TA St. Louis laboratories are currently performing anion analysis routinely for the groundwater project. The WSCF laboratory reported the anions correctly at 81%; the TA St. Louis laboratory reported the anions correctly at 75%. The laboratories had some difficulty with the analysis of ion-chromatography anions in blind standards, especially with chloride, fluoride, and nitrate. Poor performance for fluoride was noted in the 2009 annual report and warrants continued investigation. Lionville Laboratory's CY 2010 blind sample performance for anions was 89% with all the failures due to nitrate.

The WSCF and TA Richland laboratories perform hexavalent chromium determinations for the groundwater project. The WSCF laboratory reported hexavalent chromium correctly at 100% while the TA Richland laboratory reported correctly at 71%. All of the TA Richland failures were on blind standards with hexavalent chromium values greater than 10,000 µg/L. This issue was identified to TA Richland laboratory management, and corrective actions have been initiated at that facility to mitigate this analytical problem. Until the TA Richland laboratory demonstrates adequate recoveries for samples with high hexavalent chromium content, WSCF will remain the primary laboratory for these determinations.

The TA St. Louis and WSCF laboratories continue to perform the analysis of VOCs for the groundwater project. The acceptance rates for the VOC blind standards were 78% for TA St. Louis and 78% for WSCF. The principal failures at both laboratories were poor recovery of trichloroethene on the same VOC samples. The results reported by the two laboratories for trichloroethene on these samples were nearly identical; this may indicate a possible issue with the standard value itself and is not necessarily attributable solely to poor analytical recovery at the laboratories. The CY 2010 results are an improvement over the 2009 reporting period acceptable result rates: 75% for TA St. Louis and 61% for WSCF. Historically, failures have been associated with carbon tetrachloride and trichloroethene. Because the water solubility of chloroform is much higher than that of carbon tetrachloride and trichloroethene, the low recoveries may be caused by volatilization of the less-soluble compounds prior to analysis.

For the radiochemical blind standards, the percentage of acceptable results was 94% for WSCF, 93% for TA Richland, and 67% for Eberline. By comparison with the 2009 reporting period, the percentage of acceptable results for radiochemical blind standards were WSCF at 84%, TA Richland at 92%, and Eberline at 86%. The failures during CY 2010 were mostly in the determinations for gross alpha and neptunium-237. The Eberline laboratory experienced low percentages of acceptable results in the determination of carbon-14 (67%), low-level iodine-129 (0%) plutonium-239 (67%), technetium-99 (50%), and uranium-238 (67%). For the 2009 reporting period, low-level

iodine-129 was identified as a problem analyte. The TA Richland laboratory returned 100% acceptable results for iodine-129, including six samples at 1.37 pCi/L. Eberline reported all six of its 1.22 pCi/L iodine-129 blind standards as less than detectable. Eberline is currently troubleshooting their ability to quantitate iodine-129 near the 1 pCi/L level.

D.6.3 Laboratory Internal Quality Assurance/Quality Control Programs

WSCF, TA Knoxville, TA Richland, TA St. Louis, Eberline, 222-S, and Lionville maintain internal QA/QC programs that generate data on analytical performance by analyzing method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, matrix duplicates, and surrogates (see Section D.9 for definitions of these terms). This information provides a means to assess laboratory performance and the suitability of a method for a particular sample matrix. Laboratory QC data are not currently used for Groundwater Project validation of individual sample results unless the laboratory is experiencing unusual performance problems with an analytical method. A brief assessment of the laboratory QC data for the January 1, 2010, through December 31, 2010, reporting period is provided in this section. Tables D-17 and D-18 provide a summary of the WSCF and TA (Knoxville, Richland, and St. Louis) internal QC data, respectively, by listing the percentage of QC results that were out of limits for each analyte category and QC parameter. Additional details are presented in Tables D-19 through D-26. Constituents not listed in these tables did not exceed the QC limits for WSCF or any of the TA laboratories. An overview of the data from Lionville and Eberline is presented at the end of the section.

Approximately 98% of the laboratory QC results for the reporting period were within the acceptance limits, which is approximately the same as last year. This percentage indicates that the analyses were in control and reliable data were generated. Method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, matrix duplicates, and surrogates QC results were evaluated against the acceptance limits.

Evaluation of results for method blanks was based on the frequency of detection above the blank QC limits. Except as noted, these limits are two times the method detection limit for chemical constituents and two times the sample-specific minimum detectable activity for radiochemistry parameters. Because minimum detectable activities were not electronically reported for radiochemistry analytes from WSCF, two times the practical quantitation limit (PQL) was used as the radiochemistry QC limit for WSCF. For common laboratory contaminants such as 2-butanone, acetone, methylene chloride, phthalate esters, and toluene, the QC limit is five times the method detection limit.

Table D-19 summarizes method blank results from WSCF. Overall, 99.2% of the results were acceptable. Metals had the greatest percentage of method blank results outside the QC limits (~1.4%), accounting for 96% of the out-of-limit blank results. In most cases, the metal concentrations were greater than a factor of four times the method detection limit, though in most cases, for a given metal, less than 5% of the method blanks were out of limits. Compared to last year, many more metals had out of limit method blanks. The failed blanks are indicative of process improvements needed for metals analysis at the laboratory. Results associated with out-of-limit metal blank results are flagged with a "C" in the HEIS database. Two VOCs, acetone and methylene chloride, had method blank results that exceeded the QC limits. Both compounds are common laboratory contaminants, and low-level detections in Hanford Site groundwater samples should be considered suspect. Results associated with out-of-limit volatile blank results are flagged with a "B" by the laboratory. One radiochemistry parameter, total beta radiostrontium, had method blank results that exceeded the QC limits. As noted above, these out of limit results are based on PQLs and not minimum detectable activities and are, therefore, not directly comparable to those of the other laboratories.

Table D-20 summarizes method blank results from TestAmerica (Knoxville, Richland, and St. Louis). The general chemistry parameters had the greatest percentage of method blank results outside the QC limits (~5%). The percentage and number of different metals, VOCs, and SVOCs that were out of limits increased this year compared to last year; however, for 60% of the analytes, only one method blank was out of limits. Of the blanks that were out of limits, 45% exceeded the method detection limit by more than a factor of four. Most of the VOCs and SVOCs that had results that exceeded the QC limits were found at trace levels (less than 1 μg/L). Blank concentrations for three of the constituents (chloride, silicon, and specific conductance) were relatively insignificant compared to typical levels of these constituents in Hanford Site groundwater. As noted above, results associated with out-of-limit inorganic blank results are flagged with a "C" by the laboratory in both the hard copy and electronic data. Results associated with out-of-limit organic blank results are flagged with a "B" by the laboratory in both the hardcopy and electronic data. In summary, the method blank results for WSCF and TA indicate acceptable laboratory performance.

Table D-21 summarizes results for the laboratory control samples from WSCF. WSCF had a relatively low number of failures; 99.6% of the results were within the control limits. Most of the unacceptable results were associated with low recoveries (10% to 79%), which suggest that some of the associated groundwater results may be biased low. Eighteen of the failed laboratory control sample results were for SVOCs, an increase from last year. Table D-22 summarizes results for the laboratory control samples from TA Knoxville, Richland, and St. Louis. Several VOCs had five or more unacceptable results, mainly biased high; these included acetone, acrolein, bromomethane, carbon disulfide, chloromethane, iodomethane, and tetrahydrofuran. Some bias is likely in the associated groundwater sample results for these compounds.

Table D-23 summarizes results for the matrix spikes and matrix spike duplicates from WSCF. Only those samples that were spiked at a level at least one-fourth of the original sample concentration were included in the evaluation. Approximately 99% of the results were acceptable, similar to last year. The semivolatile organics had the largest percentage of matrix spikes out of limits, 20.1%, a large increase from last year. Most of the individual SVOCs and VOCs had >10% of their analyses out of limits. For these two categories, many of the failures appeared to be caused by poor analytical precision (i.e., lack of agreement between the matrix spike and matrix spike duplicate) rather than sample-matrix issues. The metals had 57 results out of limits. For the metals, both low and high recoveries were observed with the cause of failure possibly due to actual sample matrix issues rather than analytical precision. Table D-24 summarizes the results for the matrix spikes and matrix spike duplicates from TA Knoxville, Richland, and St. Louis. Approximately 92% of the results were acceptable, similar to last year. The categories of ammonia-anions and VOCs had approximately 9% of their results outside the QC limits, and SVOCs had over 6% out of limits.

For matrix duplicates, only those sample results with values five times greater than the method detection limit, the minimum detectable activity, or practical quantitation limit for WSCF are considered. Quantifiable matrix duplicates are evaluated by comparing the relative percent difference with an acceptable relative percent difference maximum for each constituent. Tables D-25 and D-26 list the constituents from WSCF and the TestAmerica laboratories (Knoxville, Richland, and St. Louis), respectively, that exceeded the relative percent difference limits. Overall, the percentage of duplicates having poor precision was less than 1% for all the laboratories, demonstrating good analytical reproducibility. WSCF had minor issues with gross alpha, gross beta, and total beta radiostrontium; eight, eleven and five of the respective matrix duplicates had relative percent differences between 21% and 203%. Bromide, chloride, and nitrogen in nitrite had relative percent differences of 53 to 200% for three, one, and two of the respective matrix duplicates. For the TestAmerica laboratories, no constituent had more than one matrix duplicate that failed to meet the acceptance.

Surrogate data from WSCF that were out of limits included 59 compounds for VOCs and 443 for SVOCs, an increase from last year. Approximately 97% of WSCF's surrogate results were acceptable. Surrogate data from TestAmerica laboratories that were out of limits included 108 compounds for volatile organics and 38 compounds for semivolatile organics. Approximately 98% of TestAmerica's surrogate results were within the acceptance limits.

The QC data for Eberline, 222-S, and Lionville were limited for the reporting period because they did not analyze many samples for routine groundwater monitoring. Lionville reported results for five different wet chemistry and organic methods. The total number of QC results was 2,456. Six QC results (0.2%) were considered to have failed: orthophosphate had 2 elevated matrix spike recoveries, dichlorodifluorobenzene had low recoveries for a laboratory control standard and a matrix spike duplicate, and 4-bromofluorobenzene had 2 elevated surrogate recoveries. No major trends were noted. Eberline's QC data were limited to 14 radiological methods for a total of 649 QC results. Nine laboratory control samples were out of limits; seven of those were low for total alpha energy emitted from radium. One carbon-14 laboratory control sample was slightly low and one radium-228 was slightly high. The remainder of the Eberline QC data were acceptable. The 222-S Laboratory analyzed a limited number of method blanks, laboratory control samples, matrix spikes, and matrix duplicate for anions by ion chromatography and for hexavalent chromium. Four anion blanks (three chloride and one nitrate) were out of limits (1.8%). Only one laboratory control sample was out of limits for nitrite; the recovery was very slightly low at 89.9%. All other 222-S QC data were within the acceptance criteria.

D.6.3.1 Issue Resolution

Issue resolution forms are documents used to record and resolve problems encountered with sample receipt, sample analysis, missed holding times, and data reporting (e.g., broken bottles or QC problems). The laboratories generate these forms and submit them to the Groundwater Project as soon as possible after a potential problem is identified. The forms provide a way for the Groundwater Project to direct the laboratory to resolve problems. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse impact on data integrity. During the reporting period, 296 issue resolution forms addressing analytical requests for groundwater monitoring samples were submitted by the WSCF, TA St. Louis, TA Richland, Eberline, and Lionville laboratories.

Table D-27 indicates the specific issues identified during the reporting period and the number of analytical requests that were impacted. An analytical request is a request for a laboratory to analyze a sample by a particular method. Generally, several analytical requests are made per sample number, and multiple results will be produced for each analytical request. Issues are categorized based on whether they occurred prior to or after receipt at the laboratory. Approximately 1% of the analytical requests were documented as having a problem on an issue resolution form. Roughly one-third of the issues occurred prior to receipt at the laboratories. During the last reporting period, the frequency was approximately the same. The issues that occurred prior to receipt at the laboratory were missed holding times, broken bottles, samples received outside of temperature specifications, insufficient sample volume collected, chain-of-custody issues, requests for discontinued methods, and incorrect preservation of samples. These issues are tracked and, when adverse trends are identified, corrective actions are initiated.

The number of issue resolution forms varies from year to year based on laboratory reporting. Issue resolution forms submitted by WSCF for analyses impacted after receipt at the laboratory were associated with missed holding times (55%), broken bottles (<1%), temperature deviations (<1%), QC issues (31%), and analytical/method deviations (5%).

D.6.3.2 Laboratory/Field Audits, Assessments, and Surveillances

Laboratory and field activities were regularly evaluated by audits, assessments, and surveillances to ensure that quality problems are identified and corrected. Evaluation of laboratory and analytical activities is performed by various oversight organizations, with each using slightly differing criteria and terminology.

During FY 2010, a total of five formal reviews (audits and/or assessments) were conducted on laboratories that routinely analyzed Hanford Site groundwater samples. These formal reviews were audits performed on commercial laboratories by the DOE Consolidated Audit Program. In addition to the formal reviews, a total of thirteen surveillances were performed on sampling, well construction, and analytical data verification activities. Corrective actions were initiated for all findings associated with surveillances, and process improvements were evaluated.

DOE Consolidated Audit Program audits. The goal of the DOE Consolidated Audit Program is to design and implement a program to consolidate site audits of commercial and DOE environmental laboratories providing services to DOE Environmental Management. To support this goal, audits were performed on five commercial laboratories. Audit objectives of the DOE Consolidated Audit Program were to assess the ability of the laboratories to produce data of acceptable and documented quality through analytical operations that follow approved and technically sound methods, and the handling of DOE samples and associated waste in a manner that protects human health and the environment. The DOE Consolidated Audit Program audits were performed at the following laboratories:

- Test America (TA St. Louis), Earth City, Missouri, May 11 to 13, 2010 (100513-TAS)
- Eberline Services, Richmond, California, February 2 to 4, 2010 (100204-ESR)
- Lionville Laboratory, Inc, Lionville, Pennsylvania, February 23 to 25, 2010 (100225-LLI)
- Test America (TA Richland), Richland, Washington, June 21 to 23, 2010 (100623-TAR)
- Test America (TA Knoxville), Knoxville, Tennessee, November 9 to 5, 2010 (101111-TAK).

The scope of the DOE Consolidated Audit Program assessment included the following specific functional areas:

- QA management systems and general laboratory practices
- Data quality for organic analyses
- Data quality for inorganic and wet chemistry analyses

- Data quality for radiochemistry analysis
- Laboratory information management systems/electronic data management
- Hazardous and radioactive materials management
- Verification of corrective action implementation from previous audit findings.

A total of 38 findings and 40 observations were noted for the five DOE audits. All corrective actions have been accepted, and verification of the corrective actions will be performed in future audits. All of the laboratories have been recommended by the DOE Consolidated Audit Program for continuation to provide analytical services for samples generated at DOE sites.

Groundwater Project surveillance. Thirteen surveillances were performed by Groundwater Project QA personnel on various field sampling, well construction, and data management verification activities during FY 2010. Surveillances identified a total of fifteen findings and twelve opportunities for improvement. A list of the surveillances performed is provided below:

- Groundwater Project surveillances on field sampling activities:
  - *Chromium Analysis of Water Samples at the Pump and Treat Facilities*: March 22 to March 24, 2010 (QA-SGRP-SURV-10-012)
  - *Surveillance of CHPRC Sample Hold Time Limit*: May 1 to September 30, 2010 (QA-EQA-SURV-10-012)
  - *Field Surveillance of Groundwater Sample Collection*: May 11 to June 1, 2010 (QA-SGRP-SURV-10-067)
  - *Field Surveillance to Assess Meeting QA Requirements for Sample Bottles*: August 11 to August 23, 2010 (QA-SGRP-SURV-10-032)
  - *Field Surveillance of Groundwater Sample Preservation*: December 1 to December 9, 2010 (QA-SGRP-SURV-11-007)
  - *Control of Field Measurement Equipment used by Soil and Groundwater Sample Personnel*: November through December 2010 (QA-SGRP-SURV-11-008)
  - *Document Control (QA review and approval of Environmental Documents)*: November through December 2010 (QA-SGRP-SURV-11-010)
- Groundwater Project surveillance on well construction activity:
  - *Field surveillance of decontamination/cleaning of down-hole well drilling equipment*: April 6 to May 4, 2010 (QA-SGRP-SURV-10-018)
  - *Field surveillance of well construction materials at 2 well drilling/material lay down yards*: June10, June 22, June 28, 2010 (QA-SGRP-SURV-10-025)
  - *QA oversight of construction activities of the DX Pump and Treat*: October 2009 to September 2010 (QA-SGRP-SURV-10-036)
- Groundwater Project surveillances on data management and verification activities:
  - *Data Verification – Sample Management and Reporting*: June1 to June 24, 2010 (QA-SGRP-SURV-10-026)
  - *Field surveillance of pump and treat facilities logbooks, control and use*: July 12 to August 5, 2010 (QA-SGRP-SURV-10-030)
  - *Data Quality Assessment*: September 1 to September 30, 2010 (QA-SGRP-SURV-10-037).

D.6.4 Analytical Method Issues

This section outlines significant analytical issues that were identified during the CY 2010 reporting period. Three issues were identified: (1) the nickel inter-element correction factor at WSCF, (2) difficulty determining low-level iodine-129 activities near the 1 pCi/L method detection limit at the Eberline laboratory, and (3) low-biased hexavalent chromium results for samples containing more than 2,500 µg/L hexavalent chromium at the TA Richland laboratory.

D.6.4.1 Nickel Inter-Element Correction Factor

In June 2010, a high bias in nickel results was identified in data reported by WSCF. The nickel results were determined using EPA Method 6010 (inductively coupled plasma– atomic emission spectroscopy). The high bias was caused by omission of an inter-element correction (IEC) factor that accounts for a silicon spectral interference with nickel. The omission apparently occurred when the IEC table was reinstalled after maintenance on the instrument. The date range of the affected nickel data was April 14 to June 2, 2010, when the nickel IEC factor was entered into the IEC table for the instrument. The affected nickel data were recalculated with the IEC factor and re-reported to the project. In addition to adding the nickel IEC, WSCF personnel reviewed and confirmed the rest of the IEC factors were correctly entered in the IEC table for the instrument. All corrected nickel results were submitted to the program by October 4, 2010.

Analytical Support Group personnel are currently following this issue with a work site assessment to determine if WSCF has sufficient controls in place to ensure that analytical methods continue to perform correctly after instrument maintenance.

D.6.4.2 Low-Level Iodine-129 Method

During the 2009 reporting period, groundwater Analytical Support staff worked with the laboratories to improve the low-level iodine-129 method to ensure that minimum detection levels were at or below the 1 pCi/L DWS. Monitoring of the low-level iodine-129 method continued during CY 2010. Six iodine-129 double-blind standards near 1 pCi/L were sent each to TA Richland and Eberline Services laboratories. The TA Richland laboratory reported detected values within ±30% for all six samples. Eberline reported less-than-detectable results for all six of their samples; the highest nondetect value reported was 1.56 pCi/L. TA Richland will continue to be the primary laboratory for low-level iodine-129. Analytical Support personnel will continue to work with Eberline to ensure their low-level method can reliably achieve a method detection limit of 1 pCi/L.

D.6.4.3 Hexavalent Chromium Method

Both the WSCF and TA Richland laboratories perform hexavalent chromium determinations for the groundwater project. While the WSCF laboratory reported 100% correct results for hexavalent chromium double-blind standards, the TA Richland laboratory reported only 71% correct results. All the TA Richland failures were on blind standards with hexavalent chromium values greater than 10,000 µg/L. Samples with hexavalent chromium concentrations between 4,000 and 10,000 µg/L had acceptable but low-biased hexavalent chromium results. The TA Richland laboratory was informed of this issue and has modified its hexavalent chromium procedure to dilute samples that exhibit hexavalent chromium concentrations greater than 1000 µg/L. Analytical Support personnel will continue to monitor the TA Richland laboratory's ability to accurately analyze samples with high hexavalent chromium concentrations.

D.7 Limit of Detection, Limit of Quantitation, and Method Detection Limit

C.A. Newbill, S. Champoux, and C.J. Thompson

Detection and quantitation limits are essential to evaluate data quality and usefulness because they provide the limits of a method's measurement. The detection limit is the lower limit at which a measurement can be differentiated from background. The quantitation limit is the lower limit where a measurement becomes quantifiably meaningful. The limit of detection, limit of quantitation, and method detection limit are all useful for evaluating groundwater data.

The limit of detection is defined as the lowest concentration level statistically different from a blank (*Detection in Analytical Chemistry: Importance, Theory, and Practice* [Currie, 1988]). The concentration at which an analyte can be detected depends on the variability of the blank response. For the purpose of this discussion, the blank is discussed as a method blank.

In general, the limit of detection is calculated as the mean concentration in the blank plus three standard deviations of that concentration (EPA/540/P-87/001, *A Compendium of Superfund Field Operations Methods*). The blank-corrected limit of detection is simply three times the blank standard deviation. At three standard deviations from the blank mean, the false-positive and the false-negative error rates are each ~7% (*Statistics for Analytical Chemistry, Second Edition*

[Miller and Miller, 1988]). A false-positive error is an instance when an analyte is declared present, but is absent; a false-negative error is an instance when an analyte is declared absent, but is present.

The limit of detection for a radionuclide is typically computed from the counting error associated with each reported result (EPA/520/1-80/012, *Upgrading Environmental Radiation Data*) and represents instrumental or background conditions at the time of analysis. In contrast, the limit of detection and limit of quantitation for the radionuclides shown in Table D-28 are based on variabilities that result from both counting errors and uncertainties introduced by sample handling. In the latter case, distilled water (submitted as a sample) is processed as if it were an actual sample. Thus, any random cross-contamination of the blank during sample processing will be included in the overall error. The values shown in Table D-28 are most useful to assess long-term variability in the overall measurement process.

The limit of quantitation is defined as the level above which quantitative results may be obtained with a specified degree of confidence (*Environmental Sampling and Analysis: A Practical Guide* [Keith, 1991]). The limit of quantitation is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87/001). The blank-corrected limit of quantitation is simply ten times the blank standard deviation. The limit of quantitation is most useful for defining the lower limit of the useful range of concentration measurement technology. When the analyte signal is ten times larger than the standard deviation of the blank measurements, a 95% probability exists that the true concentration of the analyte is within ±25% of the measured concentration.

The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero. The method detection limit is determined from analysis of a sample in a given matrix containing the analyte (Currie, 1988). The method detection limit is 3.14 times the standard deviation of the results of seven replicates of a low-level standard. Note that the method detection limit, as defined above, is based on the variability of the response of low-level standards rather than on the variability of the blank response. This is the reporting limit most commonly provided from the analytical laboratories with groundwater data (i.e., the reporting limit in the HEIS database).

For this report, TOC, TOX, and radionuclide field blank data are available for limit of detection and limit of quantitation determinations. The field blanks are QC samples that are introduced into a process to monitor the performance of the system. The use of field blanks to calculate the limit of detection and the limit of quantitation is preferred over the use of laboratory blanks because field blanks include error contributions from sample preparation and handling, in addition to analytical uncertainties. Methods to calculate the limit of detection and the limit of quantitation are described in detail in Appendix A of the *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site for 1990* (DOE/RL-91-03).

Because of the lack of blank data for other constituents of concern, it was necessary to calculate approximate limit of detection and limit of quantitation values by using variability information obtained from low-level standards. The data from the low-level standards are obtained from laboratory method detection limit studies. If low-level standards are used, the variability of the difference between the sample and blank response is increased by a factor of two (Currie, 1988, p. 84). The minimum detection level (MDL), level of detection (LOD), and limit of quantitation (LOQ) calculated as follows:

$$MDL = 3.14 * s$$

$$LOD = 3(* \text{ s}) = 4.24 * s$$

$$LOQ = 10(* \text{ s}) = 14.4 * s$$

where s = standard deviation from the seven replicates of the low-level standard.

The results of limit of detection, limit of quantitation, and method detection limit calculations for most nonradiological constituents of concern (other than TOC and TOX) are listed in Tables D-29 and D-30. The values in Table D-29 apply to WSCF and the values in Table D-30 apply to TA St. Louis. The radiological constituents, TOC, and TOX are provided in Table D-28.

D.8 Conclusions

C.J. Thompson

Overall, assessments of QA/QC information from the reporting period indicate that groundwater monitoring data are reliable and defensible. Little contamination or other sampling-related problems were encountered that affected data integrity. Likewise, laboratory performance was good in most respects, based on the large percentages of acceptable field and laboratory QC results. Laboratory audits and generally acceptable results in nationally based performance evaluation studies also demonstrated acceptable laboratory performance for the Groundwater Project. However, the following areas of concern were identified and should be considered when interpreting groundwater monitoring results from the current reporting period.

A few QC samples were probably swapped in the field or at the laboratory based on a small number of unusually high field-blank results and duplicate results with poor precision. The same problem likely occurred for a small number of groundwater samples. Mismatched results for key constituents are identified during data review and flagged when appropriate.

Several indicator parameters, anions, metals, VOCs, and radiological parameters were detected at low levels in field and/or laboratory method blanks. In particular, trace levels of metals were frequently detected in several of WSCF's method blanks. Results associated with this QC issue are flagged in the HEIS database. Data users must consider data flags when making decisions regarding data usability.

Maximum recommended holding times were exceeded for 0.5% of groundwater monitoring samples that were analyzed by nonradiological methods. This is an increase from 0.2% in 2009. Most of the missed holding times were for VOCs and SVOCs. Affected data are flagged with "H" in the HEIS database. Data users should consider "H" flags when making decisions regarding data usability.

Several analytical areas have been identified for continued evaluation and follow up. These include metals, VOCs, and low-level detection of iodine-129.

D.9 Glossary

Accuracy: Closeness of agreement between an observed value and a true value. Accuracy is assessed by means of reference samples and percent recoveries. Laboratory matrix spikes; laboratory control samples; EPA water pollution, water supply and inter-laboratory comparison programs; and blind standards are all used to assess accuracy.

Blind standard: Sample that contains a concentration of analyte known to the supplier but unknown to the analyzing laboratory. The analyzing laboratory is informed that the sample is a QC sample and not a field sample. Blind, double-blind, and matrix-matched double-blind standards are used to evaluate analytical accuracy and precision as a measure of laboratory performance.

Comparability: Degree to which one set of data can be compared to another. For example, the results from samples analyzed by more than one laboratory may or may not be comparable. Ideally, comparability should be evaluated using identical samples to ensure that valid comparisons can be made.

Completeness: Amount of acceptable data divided by the total number of data points. The Groundwater Project determines completeness by calculating the number of unflagged data resulting from the validation process, dividing by the total number of data evaluated, and multiplying by 100. The calculated percentages used in reporting completeness are conservative because all data flagged with "B," "H," "Q," "R," and "Y" (flags) are used in calculating the percentage complete; however, flagged data may still be valid.

Data management staff: Groundwater Project staff responsible for tracking samples and data from sample planning through data receipt. This title includes staff responsible for management of the databases and electronic tools used to support data management activities.

Double-blind standards: Sample that contains a concentration of analyte known to the supplier but unknown to the analyzing laboratory. The analyzing laboratory is not informed that the sample is a QC sample. All attempts are

made to make sure this sample appears like a field sample. Double-blind standards may or may not include matrix matching. Blind, double-blind, and matrix-matched double-blind standards are used to evaluate analytical accuracy and precision as a measure of laboratory performance.

Equipment blank: Sample that contains reagent water and any required preservative(s). An equipment blank is filled by pumping or washing reagent water through nondedicated sampling equipment. The equipment blank is analyzed for all constituents scheduled for the sampling event. Equipment blanks are used to monitor contamination due to improperly cleaned equipment.

Field duplicate sample: Replicate sample to determine the precision of the sampling and analytical measurement process by comparing results from identical samples collected at the same time and location. Matching field duplicates are stored in separate containers and are analyzed independently by the same laboratory.

Field split sample (split sample): Samples sequentially collected from the same location in the same sampling event and analyzed by different laboratories. Filed split samples are used to evaluate laboratory precision and comparability.

Field transfer blank): Sample that contains reagent water and any required preservative(s). At the time of sample collection, the field transfer blank is filled at the sampling site by pouring reagent water from a cleaned container into sample vials. After collection, the field transfer blank is treated in the same manner as the samples collected during the sampling event. Field transfer blanks are collected only on days when other samples are collected for volatile organic analysis and are analyzed only for volatile organic constituents. Field transfer blanks are used to check for volatile organic contamination associated with sampling activities.

Flags (as qualifiers): Codes that alert data users to limitations on reported data values. Data flags may be assigned by the laboratory or by Groundwater Project analytical support staff. A complete list of review flags is provided in Table D-1. The common flags used include, but are not limited to, the following:

- B: Data associated with contamination in the laboratory method blank (organics).
- B: Result detected was less than the contract-required detection limit but greater than the minimum detection level (inorganics).
- B: Data associated with contamination in the blank greater than two times the minimum detectable activity (radiochemistry).
- C: Data associated with contamination in the laboratory method blank (inorganics).
- F: Suspect data currently under review.
- H: Holding time exceeded.
- G: Reviewed data found to be valid.
- P: Potential problem with the sample or well that may have affected the data.
- Q: Result associated with suspect field QC data.
- R: Reviewed data found to be unusable.
- Y: Reviewed data found to be suspect.

Full trip blank: Sample that contains reagent water and any required preservative(s). A full trip blank is used to check for contamination in sample bottles and sample preparation. A full trip blank is analyzed for all constituents of interest and is collected in all types of sample bottles used during that sampling period. The full trip blank is filled during bottle preparation using the same sample preparation procedures as for regular well samples. The full trip blank is then handled the same as all other samples through delivery to the laboratory but is not opened in the field.

Groundwater Project analytical support staff: Groundwater Project staff responsible for reviewing and assessing the quality of data and analytical services. This group performs quarterly and annual reviews of QC data and ensures appropriate data flags are applied. They monitor the qualification and performance of the laboratories supporting the Groundwater Project.

Groundwater Project: The Hanford Site Groundwater Monitoring Program.

Groundwater staff: Employees of the Groundwater Project, including project scientists, analytical support staff, data management staff, field staff, etc.

Laboratory control sample: Sample of reagent water spiked with a known amount of the target analyte(s). The sample is extracted (if appropriate) and analyzed to monitor the performance of the analytical method.

Matrix duplicate: Replicate analysis (including preparation) of a regular (i.e., groundwater) sample performed as part of a laboratory's analytical batch quality control. Matrix duplicates and matrix spike duplicates are used to evaluate the precision of an analysis method. The maximum limit of precision expected for matrix duplicates is ±20%.

Matrix-matched double-blind standard: Sample prepared that contains a concentration of analyte known to the supplier but unknown to the analyzing laboratory. The sample matrix is selected to closely match that of field samples. Matrix-matched double-blind standards are disguised to appear as regular well samples to help ensure that any analyses performed are representative of those for routine well samples. Most of the blind standards submitted for the Groundwater Project are matrix-matched double-blind standards.

Matrix spikes/matrix spike duplicates: Sample(s) prepared at the analytical laboratory by adding known quantities of one or more target analytes to a sample prior to extraction and analysis. Comparison of the original (i.e., unspiked) sample and matrix spike results provides information about the suitability of an analysis for the sample matrix. For example, unusually high or low recoveries of the spiked compounds may indicate that components in the sample matrix interfere with the analysis. Matrix spike duplicates are replicate matrix spike samples that are used to assess the precision of an analysis. The maximum limit of precision expected for matrix spike duplicates is ±20%.

Method blank: Sample of reagent water prepared in the laboratory, extracted (if appropriate), and analyzed as if it were a regular sample. Method blanks are used to monitor the possible introduction of contaminants during sample preparation and analysis at the laboratory.

Precision: Agreement among individual measurements of the same property, usually under prescribed similar conditions. For a set of duplicate measurements, precision is calculated by the relative percent difference of the duplicate results. For the Groundwater Project, results from laboratory duplicates, matrix spike duplicates, blind standards, split samples, and field duplicates are used to evaluate precision.

Project scientist: Groundwater Project scientist responsible for the technical evaluation of data for a specific well or set of wells.

Reagent water: Distilled or deionized water free of contaminants that may interfere with analytical tests.

Relative percent difference (RPD): Calculated as follows:

$$RPD = \frac{|D1 - D2|}{(D1 + D2) / 2} \times 100$$

where $D1$ = original sample value and $D2$ = duplicate sample value.

Representativeness: Expression of the degree to which samples represent the actual composition of the material tested (e.g., groundwater in the aquifer). Representativeness is addressed qualitatively by the specification of well construction, sampling locations, sampling intervals, and sampling and analysis techniques addressed in monitoring plans.

Split samples: See *Field split samples*.

Surrogates: Organic compounds similar to analytes of interest in chemical composition, extraction, and analytical properties, but which are not normally found in environmental samples. Surrogates are spiked into method blanks, samples, and matrix spikes and are then extracted and analyzed to monitor the effectiveness of sample preparation and analysis on individual samples.

References

100204-ESR, 2010, *Continuing Qualification Audit of Eberline Services - Richmond, CA*, U.S. Department of Energy, Office of Health, Safety and Security, Washington, D.C.

100513-TAS, 2010, *Continuing Qualification Audit of TestAmerica, Inc. - Earth City, MO*, U.S. Department of Energy, Office of Health, Safety and Security, Washington, D.C.

100225-LLI, 2010, *Continuing Qualification Audit of Lionville Laboratory, Inc. - Lionville, PA*, U.S. Department of Energy, Office of Health, Safety and Security, Washington, D.C.

100623-TAR, 2010, *Continuing Qualification Audit of TestAmerica, Inc. – Richland, WA*, U.S. Department of Energy, Office of Health, Safety and Security, Washington, D.C.

101111-TAK, 2010, *Continuing Qualification Audit of TestAmerica, Inc. – Knoxville, TN*, U.S. Department of Energy, Office of Health, Safety and Security, Washington, D.C.

Atomic Energy Act of 1954, 42 U.S.C. 2011, et seq.

APHA, AWWA, and WEF, 1998, *Standard Methods for the Examination of Water and Wastewater*, 20th Edition, American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C.

CHPRC-00189, 2009, *CH2M HILL Plateau Remediation Company Quality Assurance Program Plan*, CH2M HILL Plateau Remediation Company, Richland, Washington.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

Currie, L. A. (ed.), 1988, *Detection in Analytical Chemistry: Importance, Theory, and Practice*, ACS Symposium Series 361, American Chemical Society, Washington, D.C., pp. 17, 79-92.

DOECAP, *DOECAP Quality Systems for Analytical Services*, Rev. 2.4, U.S. Department of Energy, Washington, D.C.

DOE/RL-96-68, 2007, *Hanford Analytical Services Quality Assurance Requirements Documents*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2010-11, 2010, *Hanford Site Groundwater Monitoring and Performance for 2009, Vols. 1 & 2*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-91-03, 1991, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site for 1990*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

EPA, 1986, *Resource Conservation and Recovery Act (RCRA) Groundwater Monitoring Technical Enforcement Guidance Document (TEGD)*, OSWER-9950.1, U.S. Environmental Protection Agency, Washington, D.C.

EPA/520/1-80/012, 1980, *Upgrading Environmental Radiation Data*, Health Physics Report HPSR-1, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

EPA/540/P-87/001, 1987, *A Compendium of Superfund Field Operations Methods*, OSWER 9355.0-14, U.S. Environmental Protection Agency, Washington, D.C.

EPA/600/4-81/004, 1981, *Environmental Radioactivity Laboratory Intercomparison Studies Program: Fiscal Year 1980-81*, U.S. Environmental Protection Agency, Washington, D.C.

Keith, L. H., 1991, *Environmental Sampling and Analysis: A Practical Guide*, Lewis Publishers, CRC Press, Inc., Boca Raton, Florida.

MAPEP-09-MaW21&OrW21&GrW21, 2009, *Water Sample MAP-07-W21 Performance Report*, U.S. Department of Energy, Mixed Analyte Performance Evaluation Program, Washington, D.C.

MAPEP-09-MaW22&OrW22&GrW22, 2010, *Water Sample MAP-09-W22 Performance Report*, U.S. Department of Energy, Mixed Analyte Performance Evaluation Program.

Miller, J. B., and J. N. Miller, 1988, *Statistics for Analytical Chemistry, Second Edition*, Ellis Horwood Limited, Chichester, England.

Mitchell, W. J., R. B. Rhodes, and F. F. McElroy, 1985, "Determination of Measurement Data Quality and Establishment of Achievable Goals for Environmental Measurements," in *Quality Assurance for Environmental Measurements*, ASTMSTP 867, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

NERL-Ci-0045, 1998, *National Standards for Water Proficiency Testing Studies Criteria Document*, U.S. Environmental Protection Agency, Washington, D.C.

RAD-80, 2010, *RadCheM™ Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

RAD-81, 2010, *RadCheM™ Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

RAD-82, 2010, *RadCheM™ Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq.

SW-846, 2008, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, as amended, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

WP-180, 2010, *WatR™ Pollution Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

WP-186, 2010, *WatR™ Pollution Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

WP-188, 2010, *WatR™ Pollution Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

WS-165, 2010, *WatR™ Supply Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

WS-171, 2010, *WatR™ Supply Proficiency Testing*, Environmental Resource Associates, Arvada, Colorado.

Table D-1. Data Review Flags

Flag	Definition
F	Result is being reviewed as part of the RDR process. This flag is assigned when an RDR is initiated.
G	Result is valid according to further review.
H	Holding time exceeded before the sample was analyzed.
P	Potential problem. Collection/analysis circumstances make value questionable.
Q	Associated quality control sample is out of limits.
R	Result is not valid according to further review.
Y	Result is suspect. Review had insufficient evidence to show result valid or invalid.
Z	Miscellaneous circumstance exists. See project file.

RDR = request for data review

Table D-2. Requests for Data Review, Current Reporting Period Data

Flag G	Flag Y	Flag R	Flag P	Other Action	Pending	Number of Results with Assigned RDR
Analytical Results*						
525	1,637	16	0	96	339	2,613
Water-Level Measurements						
18	43	8	1	0	0	70

* The software used to track RDRs underwent a major upgrade during 2010. Some values in this table may be incorrect (i.e., slightly low) due to problems encountered during the upgrade.

G = result was reviewed and determined to be correct or data was corrected

P = potential problem with the well, collection, or analysis that makes the result questionable

R = result was reviewed and found to be unusable

RDR = requests for data review

Y = result is suspect

Table D-3. Summary of Data Completeness

	Suspect Data	Rejected Data	Field QC	Holding Time	Method Blank	Total
Number of results flagged	586	35	5,819	1,155	18,139	24,645
Percent flagged data	0.2%	0.0%	2.4%	0.5%	7.4%	10.0%
Percent acceptable data	--	--	97.6%	99.5%	92.6%	90.0%

Notes: Total number of reported results was 245,705.

Table D-4. Full Trip Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
General Chemistry Parameters					
Total organic halides	80	1	1.3	10 µg/L	27.8 µg/L
Ammonia and Anions					
Chloride	109	4	3.7	40 - 860 µg/L	4,880 - 16,500 µg/L
Fluoride	109	3	2.8	20 - 600 µg/L	189 - 286 µg/L
Nitrogen in ammonium	4	1	25.0	6.18 - 8.76 µg/L	12 µg/L
Nitrogen in nitrate	108	4	3.7	76.2 - 2,740 µg/L	1,620 - 110,000 µg/L
Sulfate	109	3	2.8	100 - 1,320 µg/L	9,370 - 64,000 µg/L
Metals					
Arsenic	170	1	0.6	0.8 - 130 µg/L	6.48 µg/L
Barium	266	9	3.4	0.4 - 8 µg/L	0.81 - 67 µg/L
Beryllium	266	1	0.4	0.1 - 8 µg/L	0.27 µg/L
Boron	64	1	1.6	38 - 82 µg/L	98 µg/L
Calcium	196	65	33.2	54 - 78 µg/L	162 - 46,100 µg/L
Chromium	266	3	1.1	1 - 28 µg/L	32 - 465 µg/L
Cobalt	266	1	0.4	0.1 - 8 µg/L	0.29 µg/L
Copper	266	6	2.3	0.2 - 10 µg/L	0.43 - 10 µg/L
Hexavalent chromium	104	2	1.9	4 - 7.4 µg/L	24.7 - 27.1 µg/L
Iron	196	6	3.1	36 - 76 µg/L	39.5 - 492 µg/L
Lithium	64	2	3.1	8 µg/L	14 - 15 µg/L
Magnesium	196	38	19.4	28 - 32 µg/L	32.2 - 12,300 µg/L
Manganese	196	1	0.5	8 - 12 µg/L	69.1 µg/L
Molybdenum	134	5	3.7	0.1 - 8 µg/L	0.46 - 16 µg/L
Nickel	196	1	0.5	8 µg/L	18 µg/L
Phosphorus	64	1	1.6	110 - 144 µg/L	174 µg/L
Potassium	196	6	3.1	110 - 146 µg/L	3,090 - 5,740 µg/L
Selenium	140	1	0.7	0.6 - 94 µg/L	1.7 µg/L
Silicon	64	2	3.1	50 - 122 µg/L	7,710 - 16,300 µg/L
Sodium	196	50	25.5	22 - 46 µg/L	23 - 21,600 µg/L
Strontium	196	6	3.1	8 µg/L	79.1 - 277 µg/L
Thallium	142	1	0.7	0.1 - 98 µg/L	0.29 µg/L
Tin	136	2	1.5	0.1 - 98 µg/L	0.21 - 0.34 µg/L
Uranium	64	3	4.7	0.1 - 0.2 µg/L	0.20 - 8.11 µg/L
Vanadium	196	1	0.5	24 - 34 µg/L	25.8 µg/L
Zinc	196	4	2.0	8 - 12 µg/L	10 - 590 µg/L
Volatile Organic Compounds					
1,4-Dichlorobenzene	73	1	1.4	0.22 - 400 µg/L	0.32 µg/L
Bromomethane	35	5	14.3	0.17 - 0.5 µg/L	0.46 - 1.1 µg/L
Carbon disulfide	73	3	4.1	0.1 - 400 µg/L	0.19 - 0.36 µg/L

Table D-4. (Cont.)

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
Carbon tetrachloride	73	2	2.7	0.13 - 400 µg/L	6.6 - 6.7 µg/L
Chloroform	73	1	1.4	0.13 - 400 µg/L	2.5 µg/L
Chloromethane	35	8	22.9	0.15 µg/L	0.16 - 0.77 µg/L
Iodomethane	35	2	5.7	0.18 µg/L	0.51 - 0.53 µg/L
Methylene chloride	73	36	49.3	0.5 - 1,000 µg/L	0.78 - 89 µg/L
Styrene	35	1	2.9	0.072 - 0.15 µg/L	0.17 µg/L
Tetrachloroethene	73	1	1.4	0.13 - 400 µg/L	0.22 µg/L
Semivolatile Organic Compounds					
Aldrin	6	1	16.7	0.02 µg/L	0.12 µg/L
Radiological Parameters[b]					
Americium-241	12	1	8.3	0.11 - 0.66 pCi/L	0.31 pCi/L
Gross alpha	68	3	4.4	1.6 - 5.4 pCi/L	3.2 - 11 pCi/L
Gross beta	75	2	2.7	3 - 6.8 pCi/L	6.9 - 24 pCi/L
Technetium-99	64	3	4.7	12.4 - 19.7 pCi/L	16 - 2,900 pCi/L
Total beta radiostrontium	50	1	2.0	2.8 - 22 pCi/L	210 pCi/L
Tritium	89	6	6.7	57.2 - 480 pCi/L	380 - 3,500 pCi/L

a. Because method detection limits are specific to the laboratory and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

b. The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

Table D-5. Field Transfer Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits*	Range of Out-of-Limit Results
Volatile Organic Compounds					
1,4-Dichlorobenzene	240	2	0.83	0.22 - 10 µg/L	0.35 - 0.51 µg/L
Acetone	240	3	1.25	1.7 - 50 µg/L	2.5 - 190 µg/L
Bromomethane	24	3	12.50	0.5 - 20 µg/L	0.54 - 0.6 µg/L
Carbon disulfide	240	6	2.50	0.1 - 10 µg/L	0.12 - 0.37 µg/L
Carbon tetrachloride	240	11	4.58	0.13 - 10 µg/L	0.16 - 10 µg/L
Chloromethane	24	7	29.17	0.15 - 20 µg/L	0.18 - 0.3 µg/L
Iodomethane	24	1	4.17	0.18 - 10 µg/L	0.46 µg/L
Methylene chloride	240	115	47.92	0.5 - 30 µg/L	0.61 - 37 µg/L
Tetrachloroethene	240	1	0.42	0.13 - 10 µg/L	0.31 µg/L

* Because method detection limits are specific to the laboratory and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

Table D-6. Equipment Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits*	Range of Out-of-Limit Results
General Chemistry Parameters					
Alkalinity	26	2	7.7	2,000 µg/L	73,000 - 94,000 µg/L
Ammonia and Anions					
Chloride	34	5	14.7	6.2 - 172 µg/L	11.5 - 1,610 µg/L
Nitrogen in nitrate	33	2	6.1	168 - 548 µg/L	2,430 - 2,510 µg/L
Sulfate	34	1	2.9	43.8 - 340 µg/L	13,000 µg/L
Metals					
Barium	86	9	10.5	0.4 - 8 µg/L	1.35 - 339 µg/L
Beryllium	86	1	1.2	0.1 - 8 µg/L	0.40 µg/L
Cadmium	86	1	1.2	0.2 - 8 µg/L	0.42 µg/L
Calcium	62	24	38.7	54 - 78 µg/L	91.6 - 272,000 µg/L
Chromium	86	4	4.7	1 - 28 µg/L	3.91 - 234 µg/L
Cobalt	86	3	3.5	0.1 - 8 µg/L	0.21 - 0.57 µg/L
Copper	86	17	19.8	0.2 - 10 µg/L	0.89 - 30.8 µg/L
Iron	62	7	11.3	36 - 78 µg/L	40.9 - 856 µg/L
Lead	48	3	6.3	0.2 - 84 µg/L	0.74 - 1.51 µg/L
Magnesium	62	17	27.4	28 - 32 µg/L	36.9 - 85,100 µg/L
Manganese	64	3	4.7	0.4 - 12 µg/L	1.45 - 31 µg/L
Molybdenum	48	4	8.3	0.1 - 8 µg/L	0.29 - 0.90 µg/L
Nickel	64	2	3.1	0.8 - 8 µg/L	4.98 - 16 µg/L
Potassium	62	8	12.9	110 - 146 µg/L	207 - 11,700 µg/L
Silicon	24	2	8.3	50 - 122 µg/L	9,140 - 9,240 µg/L
Sodium	62	27	43.5	22 - 46 µg/L	23 - 209,000 µg/L
Strontium	64	7	10.9	0.4 - 8 µg/L	0.64 - 1,390 µg/L
Thallium	48	1	2.1	0.1 - 98 µg/L	0.81 µg/L
Tin	48	2	4.2	0.1 - 98 µg/L	0.27 - 0.29 µg/L
Zinc	64	3	4.7	3.2 - 12 µg/L	5.42 - 21 µg/L
Volatile Organic Compounds					
Acetone	23	5	21.7	1.7 - 5 µg/L	1.9 - 15 µg/L
Bromomethane	12	4	33.3	0.17 - 0.5 µg/L	0.17 - 0.99 µg/L
Chloroform	23	7	30.4	0.2 - 2 µg/L	0.68 - 9.5 µg/L
Chloromethane	12	2	16.7	0.15 µg/L	0.63 - 0.65 µg/L
Methylene chloride	23	2	8.7	0.55 - 5 µg/L	7.8 - 21 µg/L
Semivolatile Organic Compounds					
Aldrin	1	1	100.0	0.02 µg/L	0.074 µg/L
Radiological Parameters					
Gross alpha	14	1	7.1	1.32 - 4.8 pCi/L	2.5 pCi/L
Gross beta	14	2	14.3	3.8 - 6.6 pCi/L	8.2 - 60 pCi/L
Total beta radiostrontium	15	2	13.3	3.2 - 4.6 pCi/L	5.5 - 21 pCi/L
Tritium	28	2	7.1	320 - 480 pCi/L	610 - 860 pCi/L
Uranium-233/234	1	1	100.0	0.048 pCi/L	0.053 pCi/L

* Because method detection limits are laboratory specific and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

Table D-7. Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Out-of-Limit RPD[b]
Ammonia and Anions					
Bromide	42	3	1	33.3	127
Chloride	120	119	1	0.8	188
Cyanide	15	4	2	50.0	25.0 - 26.4
Fluoride	120	18	2	11.1	32.1 - 56.3
Nitrogen in nitrate	117	112	1	0.9	195
Nitrogen in nitrite	117	4	2	50.0	28.9 -158
Sulfate	120	118	1	0.8	196
Metals					
Aluminum	142	14	9	64.3	20.9 - 164
Arsenic	162	36	1	2.8	65.5
Barium	297	269	8	3.0	21.1 - 162
Cadmium	297	1	1	100.0	38.6
Calcium	223	220	8	3.6	24.7 - 164
Chromium	297	64	4	6.3	20.3 - 144
Cobalt	297	12	6	50.0	24.4 - 171
Copper	297	12	5	41.7	46.2 - 177
Hexavalent chromium	155	73	2	2.7	27.0 - 29.9
Iron	223	38	15	39.5	25.9 - 189
Lead	151	6	4	66.7	90.6 - 199
Magnesium	223	220	6	2.7	23.5 - 163
Manganese	221	24	6	25.0	22.8 - 173
Molybdenum	138	75	7	9.3	26.9 - 136
Nickel	221	18	3	16.7	29.3 - 131
Phosphorus	60	4	1	25.0	23.2
Potassium	223	219	6	2.7	22.0 - 164
Selenium	140	20	5	25.0	24.8 - 56.6
Silicon	60	59	2	3.4	24.1 - 163
Sodium	223	220	4	1.8	22.8 - 162
Strontium	221	218	5	2.3	23.4 - 163
Uranium	61	57	4	7.0	23.1 - 41.8
Zinc	221	16	3	18.8	28.2 - 93.3
Volatile Organic Compounds					
1,2-Dichloroethane	76	1	1	100.0	157
1,4-Dichlorobenzene	76	1	1	100.0	100
Bromomethane	28	3	1	33.3	20.7
Carbon tetrachloride	76	17	5	29.4	28.6 - 186
Chloromethane	28	2	1	50.0	150
Iodomethane	28	2	2	100.0	151 - 152
Methylene chloride	76	5	5	100.0	147 - 191
Styrene	28	1	1	100.0	125
Trichloroethene	76	13	3	23.1	36.7 - 183

Table D-7. (Cont.)

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Out-of-Limit RPD[b]
Semivolatile Organic Compounds					
Aldrin	3	1	1	100.0	194
Diethylphthalate	10	1	1	100.0	194
Radiological Parameters					
Carbon-14	25	9	3	33.3	21.9 - 50.0
Gross alpha	57	6	3	50.0	25.8 - 114
Gross beta	66	39	8	20.5	28.6 - 150
Iodine-129	35	10	2	20.0	37.9 - 51.9
Technetium-99	66	32	1	3.1	94.1
Total beta radiostrontium	49	8	2	25.0	20.2 - 211
Tritium	85	58	4	6.9	22.2 - 208
Uranium-233/234	5	4	1	25.0	20.3
Uranium-235	5	4	1	25.0	75.0

a. Duplicates with both results less than five times the method detection limit or minimum detectable activity were excluded from the evaluation.

b. In cases where a nondetect result was compared with a measured value, the method detection limit or minimum detectable activity was used for the nondetect concentration.

Table D-8. Field Splits Exceeding Quality Control Limits

Constituent	Total Number of Splits	Number of Splits Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Out-of-Limit RPD[b]
General Chemistry Parameters					
Total petroleum hydrocarbons-diesel range	4	1	1	100	76.5
Ammonia and Anions					
Fluoride	33	30	23	76.7	22.2 - 117
Nitrogen in nitrate	32	31	1	3.2	21.1
Nitrogen in nitrite	32	3	1	33.3	30.0 - 94.7
Phosphorus in phosphate	15	1	1	100	114
Metals					
Aluminum	20	2	2	100	56.6 - 59.1
Antimony	54	6	3	50.0	22.7 - 66.3
Arsenic	20	2	2	100	104 - 124
Barium	54	46	1	2.2	93.3
Boron	20	2	1	50.0	37.7
Cadmium	54	2	1	50.0	22.2
Calcium	54	54	2	3.7	24.8 - 137
Chromium	54	25	3	12.0	21.8 - 162
Hexavalent chromium	73	38	4	10.5	20.1 - 180
Iron	54	7	7	100	22.5 - 152
Magnesium	54	54	1	1.9	22.6
Manganese	54	10	4	40.0	24.7 - 36.7
Nickel	54	2	1	50.0	130
Potassium	54	54	34	63.0	20.0 - 154
Silicon	20	20	2	10.0	21.7 - 32.3
Sodium	54	54	2	3.7	22.9 - 37.3
Strontium	54	54	4	7.4	20.2 - 136
Vanadium	54	4	2	50.0	41.4 - 58.2
Volatile Organic Compounds					
Bromomethane	6	1	1	100	167
Carbon tetrachloride	15	3	2	66.7	29.9 - 39.1
Chloroform	15	6	2	33.3	22.2 - 141
Methylene chloride	15	2	2	100	78.8
Trichloroethene	14	2	2	100	47.8 - 140
Semivolatile Organic Compounds					
Acenaphthene	3	1	1	100	72.1
Naphthalene	3	1	1	100	164
Phenanthrene	3	1	1	100	94.9
Pyrene	3	1	1	100	40.0
Radiological Parameters					
Total beta radiostrontium	1	1	1	100	439.0

a. Splits with both results less than five times the method detection limit or minimum detectable activity were excluded from the evaluation.

b. In cases where a nondetect result was compared with a measured value, the method detection limit or minimum detectable activity was used for the nondetect concentration.

Table D-9. Summary of Analytical Method Categories

Category	HEIS Method Name	Description
General chemistry parameters	120.1_CONDUCT	Specific conductivity, conductance bridge
	150.1_PH	pH by electrode
	160.2_TSS	Total suspended solids
	1664A_OILGREASE	Oil and grease, n-hexane extractable material, gravimetric, solid phase extraction
	170.1_TEMP_FLD	Temperature, field measurement
	2320_ALKALINITY	Alkalinity
	310.1_ALKALINITY	Alkalinity, titrametric
	360.1_OXYGEN	Dissolved oxygen
	360.1_OXYGEN_FLD	Dissolved oxygen
	410.4_COD	Chemical oxygen demand, automated; manual
	9020_TOX	Total organic halides
	9060_TOC	Total organic carbon
	9070_OILGREASE	Total recoverable oil and grease, gravimetric
	9223_COLIFORM	Coliform by enzyme substrate test
	CONDUCT_FLD	Field conductivity by instrument manufacturer instructions
	PH_ELECT_FLD	pH analysis by electrode, field measurement
	REDOX_PROBE_FLD	Oxidation-reduction potential by platinum electrode
	TEMP_FLD	Temperature, field measurement
	TURBIDITY_FLD	Nephelometric turbidity, field measurement
	WTPH_DIESEL	Total petroleum hydrocarbons, SE/GC-FID, Ecology
	WTPH_GASOLINE	Total petroleum hydrocarbons, P&T/GC-FID, Ecology
Ammonia and anions	300.0_ANIONS_IC	Anions by ion chromatography
	300.7_CATIONS_IC	Cations by ion chromatography
	335.2_CYANIDE	Total cyanide, titrametric, spectrophotometric
	9012_CYANIDE	Cyanide, automated colorimetric
	9030_SULFIDE	Sulfide by titration
Metals	200.8_METALS_ICPMS	Metals by inductively coupled plasma- mass spectrometry
	6010_METALS_ICP	Metals by inductively coupled plasma
	6020_METALS_ICPMS	Metals by inductively coupled plasma- mass spectrometry
	7196_CR6	Hexavalent chromium, colorimetric
	7470_HG_CVAA	Mercury (Hg) by CVAA
Volatile organic compounds	8015_VOA_GC	Nonhalogenated volatiles by gas chromatography
	8260_VOA_GCMS	Volatile organics by gas chromatography/mass spectrometry capillary column
	RSK175_VOA_HDSPC_GC	Nonhalogenated volatiles (light hydrocarbon) analysis via headspace equilibrium – gas chromatography
Semivolatile organic compounds	1668A_PCB_CONGENER	Polychlorinated biphenyl congeners by high-resolution gas chromatography/high-resolution mass spectrometry
	8040_PHENOLIC_GC	Phenols by gas chromatography
	8081_PEST_GC	Organoclhorine pesticides by gas chromatography
	8082_PCB_GC	Polychlorinated biphenyls by gas chromatography
	8270_SVOA_GCMS	Semivolatiles by gas chromatograpy/mass spectrometry
	8310_SVOA_HPLC	Semivolatile organic analytes by HPLC (PAHs)
	8316_SVOA_HPLC	Semivolatile organic analytes by HPLC (acrylamide, acrylonitrile and acrolein)

Table D-9. (Cont.)

Category	HEIS Method Name	Description
Radiological parameters	900.0_ALPHABETA_GPC	Gross alpha/beta by gas proportional counting
	906.0_H3_LSC	Tritium in drinking water, liquid scintillation
	906.0ML_H3_LSC	Tritium in drinking water, mid-level, liquid scintillation
	9310_ALPHABETA_GPC	Gross alpha and gross beta by gas proportional counting
	ALPHA_GPC	Gross alpha, gas proportional counting
	AMCMISO_EIE_PLT_AEA	Americium/curium isotopic, separated by sequential eichrom ion exchange resin, plated, alpha spectrometry
	AMCMISO_IE_PREC_AEA	Americium/curium isotopic, separated by ion exchange, precipitated, alpha spectrometry
	BETA_GPC	Gross beta gas proportional counting
	C14_CHEM_LSC	Carbon-14, chemical oxidation/liquid scintillation counting
	C14_LSC	Carbon-14 analysis by unknown method
	GAMMA_GS	Gamma spectroscopy, germanium high-energy detectors
	GAMMALL_GS	Gamma spectroscopy, low-level, germanium high-energy detector
	I129_SEP_LEPS_GS	Iodine-129, separation, precipitation, LEPS
	I129LL_SEP_LEPS_GS	Iodine-129, low-level, separation, precipitation, LEPS detection
	NI63_LSC	Nickel-63 by liquid scintillation
	NP237_LLE_PLATE_AEA	Neptunium isotopic, liquid-liquid extraction, electroplated, alpha spectrometry
	PUISO_IE_PRECIP_AEA	Isotopic plutonium, ion-exchange separation, precipitated on disk, alpha spectrometry
	PUISO_PLATE_AEA	Isotopic plutonium, unknown separation, electroplated, alpha spectrometry
	RAISO_SEP_GPC	Radium-226 and radium-228 separated by EDTA, precipitated for alpha scintillation and gas proportional counting
	RATOT_GPC	Total radium, gas proportional counting
	SE79_SEP_DIS_LSC	Selenium-79, separated, distillation, liquid scintillation
	SE79_SEP_IE_LSC	Selenium-79, separated, ion-exchange resin, liquid scintillation
	SRISO_SEP_PRECIP_GPC	Strontium beta isotopic, chemical separation, precipitated, gas proportional counting
	SRTOT_SEP_PRECIP_GPC	Total beta strontium, chemical separation, precipitation, gas proportional counting
	TC99_3MDSK_LSC	Technetium-99, 3M disk separation, liquid scintillation counting
	TC99_ETVDSK_LSC	Technetium-99, eichrome teva disk separation, liquid scintillation counting
	TC99_SEP_LSC	Technetium-99, ppt. and ion-exchange resin separation, liquid scintillation counting
	TC99_TR_SEP_GPC	Technetium-99, separated, tracer yield, gas proportional counting
	THISO_IE_PLATE_AEA	Isotopic thorium, ion exchanges separation with and from lead-210, plated, alpha spectrometry
	THISO_IE_PRECIP_AEA	Isotopic thorium, ion-exchanges separation with and from lead-210, precipitated, alpha spectrometry
	TRITIUM_EIE_LSC	Tritium in water, purification by eichrome ion exchange, liquid scintillation counting
	UISO_IE_PRECIP_AEA	Uranium isotopic, purification by ion exchange, precipitated, alpha spectrometry
	UISO_PLATE_AEA	Uranium isotopic, separation unknown, electroplated, alpha spectrometry
	UTOT_KPA	Total uranium, unknown separation, laser phosphorimetry

Table D-10. Hanford Site Groundwater Remediation Project Maximum Recommended Holding Times

Method	Constituent	Holding Time
120.1 (EPA-600/4-81-004)	Conductivity	28 days
160.1 (EPA-600/4-81-004)	Total dissolved solids	7 days
300.0 (EPA-600/4-81-004)	Bromide	28 days
300.0 (EPA-600/4-81-004)	Chloride	28 days
300.0 (EPA-600/4-81-004)	Fluoride	28 days
300.0 (EPA-600/4-81-004)	Nitrate	48 hours
300.0 (EPA-600/4-81-004)	Nitrite	48 hours
300.0 (EPA-600/4-81-004)	Phosphate	48 hours
300.0 (EPA-600/4-81-004)	Sulfate	28 days
310.1 (EPA-600/4-81-004)	Alkalinity	14 days
350.1 (EPA-600/4-81-004)	Ammonia	28 days
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days
6010 (SW-846)/200.7	Inductively coupled plasma metals	6 months
	Mercury	28 days
6020 (SW-846)/200.8	Inductively coupled plasma-mass spectrometry metals	6 months
	Mercury	28 days
7196 (SW-846)	Hexavalent chromium	24 hours
7470 (SW-846)	Mercury	28 days
8015M (SW-846)	Total petroleum hydrocarbons	14 days
8040 (SW-846)	Phenols	7 days before extraction 40 days after extraction
8081 (SW-846)	Pesticides	7 days before extraction 40 days after extraction
8082 (SW-846)	Polychlorinated biphenyls	1 year before extraction 1 year after extraction
8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction 40 days after extraction
9012 (SW-846)	Cyanide	14 days
9020 (SW-846)	Total organic halides	28 days
9030 (SW-846)	Sulfides	7 days
9060 (SW-846)	Total organic carbon	28 days
9223 (APHA/AWWA/WEF)	Coliform	24 hours

Table D-11. Summary of WSCF and 222-S Performance Evaluation Studies

WatR™ Pollution/WatR™ Supply Performance Evaluation Studies, Environmental Resource Associates		
Study and Date	**WSCF**	**222-S**
WP-180, March 2010	74/76[a]	--
WP-186, September 2010	83/84[b]	--
InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates		
Study and Date	**WSCF**	**222-S**
RAD-80, March 2010	4/4	--
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory		
Study and Date	**WSCF**	**222-S**
MAPEP-09-MaW21, June 2010	--[g]	24/27[d]
MAPEP-09-GrW21, June 2010	--[g]	1/2[e]
MAPEP-09-MaW22, June 2010	29/30[c]	28/29[f]
MAPEP-09-GrW22, June 2010	2/2	2/2

a. Unacceptable results were for nonfilterable residue and strontium.

b. Unacceptable result was for hexane extractable material.

c. Unacceptable result was for technetium-99

d. Unacceptable results were for uranium-total, manganese-54, and plutonium-38.

e. Unacceptable result was for gross beta.

f. Unacceptable result was for arsenic.

g. Reported in 2009.

Table D-12. Summary of TestAmerica Performance Evaluation Studies

WatR™ Pollution/WatR™ Supply Performance Evaluation Studies, Environmental Resource Associates		
Study and Date	**TA St. Louis**	**TA Richland**
WP-180, March 2010	711/737[a]	1/1
WS-165, May 2010	61/62[b]	--
WP-186, September 2010	628/630[c]	1/1
WP-188, October 2010	165/168[d]	--
WS-171, November 2010	61/62[e]	--
InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates		
Study and Date	**TA St. Louis**	**TA Richland**
RAD-80, March 2010	--	15/15
RAD-81, May 2010	20/23[f]	17/17
RAD-82, August 2010	--	15/15
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory		
Study and Date	**TA St. Louis**	**TA Richland**
MAPEP-09-MaW21 June 2010	35/35	17/17
MAPEP-09-GrW21 June 2010	2/2	2/2
MAPEP-09-OrW21 June 2010	72/74[g]	--
MAPEP-09-MaW22 June 2010	33/34[h]	15/17[i]
MAPEP-09-GrW22 June 2010	2/2	2/2
MAPEP-09-OrW22 June 2010	75/75	--

a. Unacceptable results were for volatile solids (2), nitrate and nitrite as N, orthophosphate as P, nitrate as N, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron (2), manganese, nickel, silver, vanadium, zinc, tin, 2,4-D, Dalapon, and endrin ketone (3).

b. Unacceptable result was for 1,2,4-trichlorobenzene.

c. Unacceptable results were for volatile solids and total phosporus as P.

d. Unacceptable results were for manganese (3).

e. Unacceptable result was for n-propylbenzene.

f. Unacceptable results were for barium-133 (2) and uranium (nat) mass.

g. Unacceptable results were for 4,4'-DDE and 4,4'-DDT.

h. Unacceptable result was for arsenic.

i. Unacceptable results were for iron-55 and plutonium-239/240.

Table D-13. Summary of Eberline Services and Lionville Laboratory Performance Evaluation Studies

InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates		
Study and Date	**Eberline**	**Lionville**
RAD-80, March 2010	15/15	--
RAD-81, May 2010	1/1	--
RAD-82, August 2010	14/15[a]	--
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory		
Study and Date	**Eberline**	**Lionville**
MAPEP-09-MaW21, June 2010	--[b]	15/15
MAPEP-09-GrW21, June 2010	--[b]	--
MAPEP-09-OrW21, June 2010	--[b]	56/57[c]
MAPEP-09-MaW22, June 2010	16/16	13/15[d]
MAPEP-09-GrW22, June 2010	2/2	--
MAPEP-09-OrW22, June 2010	--	57/57

a. Unacceptable result was for radium-228.

b. Reported in 2009.

c. Unacceptable result was for hexachlorobutadiene.

d. Unacceptable results were for mercury and vanadium.

Table D-14. Summary of WSCF Double-Blind Spike Determinations

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
General Chemical Parameters					
Specific conductance	Quarterly	9	0	100%	±25
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	12	2	83%	±25
Total organic halides (2,4,5-trichlorophenol spike)	Quarterly	11	3	73%	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	Quarterly	10	5	50%	±25
Ammonia and Anions					
Chloride	Quarterly	12	3	75%	±25
Cyanide	Semiannually	6	0	100%	±25
Fluoride	Quarterly	12	3	75%	±25
Nitrate as nitrogen	Quarterly	12	3	75%	±25
Nitrite as nitrogen	Semiannually	6	0	100%	±25
Metals					
Chromium (total)	Quarterly	18	1	94%	±20
Hexavalent chromium	Quarterly	21	0	100%	±20
Volatile Organic Compounds					
Carbon tetrachloride	Quarterly	6	1	83%	±25
Chloroform	Quarterly	6	0	100%	±25
Trichloroethene	Quarterly	6	3	50%	±25
Radiological Parameters					
Gross alpha (plutonium-239 spike)	Quarterly	6	3	50%	±30
Gross beta (strontium-90 spike)	Quarterly	9	0	100%	±30
Cesium-137	Annually	3	0	100%	±30
Cobalt-60	Annually	3	0	100%	±30
Neptunium-237	Annually	3	0	100%	±30
Plutonium-239	Semiannually	6	0	100%	±30
Technetium-99	Quarterly	9	0	100%	±30
Tritium	Semiannually	3	0	100%	±30
Uranium-238	Quarterly	9	0	100%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. Each result must be within the specified percentage of the known value to be acceptable.

Table D-15. Summary of TestAmerica Laboratories Double-Blind Spike Determinations

Constituent	Laboratory	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
General Chemical Parameters						
Specific conductance	St. Louis	Quarterly	9	0	100%	±25
Total organic carbon (potassium hydrogen phthalate spike)	St. Louis	Quarterly	12	2	83%	±25
Total organic halides (2,4,5-trichlorophenol spike)	St. Louis	Quarterly	11	0	100%	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	St. Louis	Quarterly	10	0	100%	±25
Ammonia and Anions						
Chloride	St. Louis	Quarterly	12	4	67%	±25
Cyanide	St. Louis	Quarterly	9	0	100%	±25
Fluoride	St. Louis	Quarterly	12	5	58%	±25
Nitrate as nitrogen	St. Louis	Quarterly	12	4	67%	±25
Nitrite as nitrogen	St. Louis	Semiannually	6	0	100%	±25
Metals						
Chromium (total)	St. Louis	Quarterly	18	0	100%	±20
Hexavalent chromium	Richland	Quarterly	21	6	71%	±20
Volatile Organic Compounds						
Carbon tetrachloride	St. Louis	Semiannually	6	1	83%	±25
Chloroform	St. Louis	Semiannually	6	0	100%	±25
Trichloroethene	St. Louis	Semiannually	6	3	50%	±25
Radiological Parameters						
Gross alpha (plutonium-239 spike)	Richland	Quarterly	6	0	100%	±30
Gross beta (strontium-90 spike)	Richland	Quarterly	9	0	100%	±30
Carbon-14	Richland	Annually	3	3	0%	±30
Cesium-137	Richland	Annually	3	0	100%	±30
Cobalt-60	Richland	Annually	3	0	100%	±30
Iodine-129	Richland	Semiannually	9	0	100%	±30
Neptunium-237	Richland	Annually	3	1	67%	±30
Nickel-63	Richland	Annually	3	0	100%	±30
Plutonium-239	Richland	Quarterly	9	1	89%	±30
Technetium-99	Richland	Quarterly	9	0	100%	±30
Tritium	Richland	Semiannually	9	0	100%	±30
Uranium-238	Richland	Quarterly	9	0	100%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. Each result must be within the specified percentage of the known value to be acceptable.

Table D-16. Summary of Lionville Laboratory and Eberline Services Double-Blind Spike Determinations

Constituent	Laboratory	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limit[b] (%)
General Chemical Parameters						
Total organic carbon (potassium hydrogen phthalate spike)	Lionville	Quarterly	9	4	56%	±25
Ammonia and Anions						
Chloride	Lionville	Quarterly	9	0	100%	±25
Fluoride	Lionville	Quarterly	9	0	100%	±25
Nitrate as nitrogen	Lionville	Quarterly	6	3	50%	±25
Nitrite as nitrogen	Lionville	Semiannually	3	0	100%	±25
Radiological Parameters						
Gross alpha (plutonium-239 spike)	Eberline	Semiannually	3	1	67%	±30
Gross beta (strontium-90 spike)	Eberline	Quarterly	9	2	78%	±30
Carbon-14	Eberline	Annually	3	1	67%	±30
Cesium-137	Eberline	Annually	3	0	100%	±30
Cobalt-60	Eberline	Annually	3	0	100%	±30
Iodine-129	Eberline	Semiannually	9	6	33%	±30
Neptunium-237	Eberline	Annually	3	2	33%	±30
Nickel-63	Eberline	Annually	3	0	100%	±30
Plutonium-239	Eberline	Semiannually	6	2	67%	±30
Technetium-99	Eberline	Quarterly	6	3	50%	±30
Tritium	Eberline	Annually	3	0	100%	±30
Uranium-238	Eberline	Semiannually	6	2	67%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. Each result must be within the specified percentage of the known value to be acceptable.

Table D-17. Percentage of Out-of-Limit Quality Control Results by Category, WSCF

QC Parameter	General Chemistry Parameters	Ammonia and Anions	Metals	VOC	SVOC	Radiological Parameters	Total
Method blanks	0.0	0.0	1.4	0.1	0.0	0.2	0.8
Laboratory control samples	0.2	0.0	0.2	0.0	7.8	1.8	0.4
Matrix spikes	1.6	0.5	0.5	0.3	20.1	0.5	0.9
Matrix duplicates	0.0	0.3	0.0	0.0	0.0	0.1	0.6
Surrogates	—	—	—	0.6	7.6	—	3.1

Notes: "Total" column indicates the number of QC out-of-limits divided by the total number of QC multiplied by 100.

Table D-18. Percentage of Out-of-Limit Quality Control Results by Category, TestAmerica Laboratories (Knoxville, Richland, and St. Louis)

QC Parameter	General Chemistry Parameters	Ammonia and Anions	Metals	VOC	SVOC	Radiological Parameters	Total
Method blanks	5.3	0.9	2.4	1.1	0.2	0.0	0.7
Laboratory control samples	0.0	0.4	0.4	2.4	2.2	1.2	2.0
Matrix spikes	2.0	9.0	2.2	9.3	6.5	0.0	7.6
Matrix duplicates	0.0	0.0	2.1	0.0	0.0	0.1	0.1
Surrogates	—	—	—	2.6	1.6	—	2.2

Notes: "Total" column indicates the number of QC out-of-limits divided by the total number of QC multiplied by 100.

Table D-19. Method Blank Results, WSCF

Constituent	Percent Out of Limit[a]	Number of Analyses	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total general chemistry parameters	0.0	288	—
Ammonia and Anions			
Total ammonia and anions	0.0	2,714	—
Metals			
Total metals	1.4	9,267	—
Aluminum (ICP)	1.5	134	36.2 – 97.0 µg/L
Calcium (ICP)	2.3	266	61.0 – 185.0 µg/L
Copper (ICP)	0.4	268	131.0 µg/L
Iron (ICP)	0.7	268	48.0 – 73.3 µg/L
Lead (ICP)	1.5	137	51.0 – 55.0 µg/L
Magnesium (ICP)	1.1	266	36.5 – 52.9 µg/L
Phosphorus (ICP)	1.5	135	122.0 – 159.0 µg/L
Potassium (ICP)	0.4	265	152.0 µg/L
Silicon (ICP)	16.1	137	55.0 – 342.0 µg/L
Sodium (ICP)	5.2	268	23.0 – 105.0 µg/L
Thallium (ICP)	0.7	136	75.0 µg/L
Vanadium (ICP)	0.4	267	25.0 µg/L
Zinc (ICP)	1.1	267	24.0 – 89.1 µg/L
Volatile Organic Compounds			
Total volatile organic compounds	0.1	3,482	—
Acetone[b]	0.8	133	400 µg/L
Methylene chloride[b]	0.8	133	54 µg/L
Semivolatile Organic Compounds			
Total semivolatile organic compounds	0.0	379	—
Radiological Parameters			
Total radiochemistry parameters	0.2	1,928	—
Total beta radiostrontium	1.8	226	4.2 – 4.3 pCi/L

a. The QC limits are twice the method detection limit.

b. The QC limits are five times the method detection limit.

Table D-20. Method Blank Results, TestAmerica Laboratories (Knoxville, Richland, and St. Louis)

Constituent	Percent Out of Limit[a]	Number of Analyses	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total general chemistry parameters	5.3	38	—
Specific conductance	100.0	2	0.2 – 0.51 µS/cm
Ammonia and Anions			
Total ammonia and anions	0.9	217	—
Chloride	2.9	35	0.044 mg/L
Phosphorus in phosphate	7.7	13	0.21 mg/L
Metals			
Total metals	2.4	1,154	—
Antimony (ICP)	2.7	37	10.1 µg/L
Arsenic (ICP)	11.8	17	5.8 – 9.3 µg/L
Boron (ICP)	5.9	17	44.4 µg/L
Iron (ICP)	2.7	37	58.1 µg/L
Lithium (ICP)	5.9	17	23.2 µg/L
Phosphorus (ICP)	12.5	8	152 µg/L
Potassium (ICP)	2.7	37	3320 µg/L
Selenium (ICP)	5.9	17	5.8 µg/L
Silicon (ICP)	5.9	17	127 µg/L
Zinc (ICP)	2.7	37	28.7 µg/L
Aluminum (ICP-MS)	7.1	14	70.3 µg/L
Arsenic (ICP-MS)	7.1	14	2.4 µg/L
Boron (ICP-MS)	100.0	1	60.4 µg/L
Copper (ICP-MS)	14.3	14	0.35 – 0.64 µg/L
Molybdenum (ICP-MS)	21.4	14	0.64 – 1.6 µg/L
Selenium (ICP-MS)	7.1	14	2.7 µg/L
Thallium (ICP-MS)	14.3	14	1.3 – 1.4 µg/L
Tin (ICP-MS)	42.9	14	0.62 – 2.5 µg/L
Volatile Organic Compounds			
Total volatile organic compounds	1.1	5,646	—
1,2-Dichloroethane	1.0	103	0.7 µg/L
1,4-Dichlorobenzene	1.9	103	0.35 – 0.64 µg/L
Acetone[b]	1.9	103	2.8 – 3.1 µg/L
Benzene	1.0	104	0.14 µg/L
Bromomethane	22.0	91	0.26 – 2.9 µg/L
Carbon disulfide	1.0	103	0.15 µg/L
Chloromethane	19.6	92	0.17 – 0.82 µg/L
Iodomethane	7.6	92	0.33 – 1.9 µg/L
Methylene chloride[b]	3.9	103	0.63 – 1.5 µg/L
Styrene	4.3	92	0.15 – 0.41 µg/L
Tetrachloroethene	1.0	104	0.21 µg/L
Trichloroethene	1.0	103	0.88 µg/L
Xylenes (total)	1.0	103	0.42 µg/L

Table D-20. (Cont.)

Constituent	Percent Out of Limit[a]	Number of Analyses	Concentration Range of Out-of-Limit Results
Semivolatile Organic Compounds			
Total semivolatile organic compounds	0.2	6,155	—
Aldrin	12.0	25	0.058 – 0.085 µg/L
Dibenz[a,h]anthracene	4.5	22	0.38 µg/L
Fluoranthene	4.5	22	0.13 µg/L
Fluorene	4.5	22	0.093 µg/L
Phenanthrene	9.1	22	0.073 – 0.32 µg/L
Pyrene	9.1	22	0.047 – 0.2 µg/L
Radiological Parameters			
Total radiochemistry parameters	0.0	1,318	—

a. The QC limits are twice the method detection limit.

b. The QC limits are five times the method detection limit.

Table D-21. Laboratory Control Samples, WSCF

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	0.2	513
Total petroleum hydrocarbons-diesel range	2.0	49
Ammonia and Anions		
Total ammonia and anions	0.0	2,731
Metals		
Total metals	0.2	9,221
Iron (ICP)	0.4	269
Phosphorus (ICP)	0.7	135
Potassium (ICP)	1.5	267
Silver (ICP)	0.4	268
Sodium (ICP)	0.4	266
Thallium (ICP)	4.4	137
Mercury (ICP-MS)	0.7	149
Volatile Organic Compounds		
Total volatile organic compounds	0.0	687
Semivolatile Organic Compounds		
Total semivolatile organic compounds	7.8	232
1,2,4-Trichlorobenzene	33.3	12
1,4-Dichlorobenzene	33.3	12
2-Picoline	10.0	10
4-Nitrophenol	10.0	10
Acenaphthene	18.2	11
n-Nitrosodi-n-dipropylamine	18.2	11
Pentachlorophenol	16.7	12
Phenol	20.0	10
Radiological Parameters		
Total radiochemistry parameters	1.8	1,162
Gross alpha	4.5	221
Gross beta	1.3	240
Plutonium-239/240	3.3	30
Total beta radiostrontium	2.1	195
Tritium	1.1	176
Uranium-238	5.9	17

Table D-22. Laboratory Control Samples, TestAmerica Laboratories (Knoxville, Richland, and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemical parameters	0.0	44
Ammonia and Anions		
Total ammonia and anions	0.4	223
Cyanide	8.3	12
Metals		
Total metals	0.4	1,153
Beryllium	2.7	37
Phosphorus	12.5	8
Potassium	8.1	37
Volatile Organic Compounds		
Total volatile organic compounds	2.4	5,357
1,2-Dibromoethane	1.1	92
1,2-Dichloropropane	1.1	92
1,4-Dichlorobenzene	1.0	103
1,4-Dioxane	2.9	103
1-Butanol	2.9	103
Acetone	10.7	103
Acetonitrile	2.2	92
Acrolein	17.4	92
Benzene	1.0	103
Bromodichloromethane	1.1	92
Bromoform	4.3	92
Bromomethane	16.5	92
Carbon disulfide	5.8	103
Chloroethane	2.2	92
Chloromethane	6.5	92
cis-1,2-Dichloroethylene	1.0	103
cis-1,3-Dichloropropene	1.1	92
Dibromochloromethane	2.2	92
Dichlorodifluoromethane	1.1	92
Ethyl cyanide	2.9	103
Ethylbenzene	1.0	103
Iodomethane	12.0	92
Isobutyl alcohol	1.1	92
Methacrylonitrile	2.2	92
Methyl methacrylate	4.3	92
Methylene chloride	2.9	103
Styrene	2.2	92
Tetrachloroethene	3.9	103
Tetrahydrofuran	7.8	103
trans-1,3-Dichloropropene	3.3	92
trans-1,4-Dichloro-2-butene	2.2	92
Trichloroethene	1.0	104

Table D-22. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
Vinyl acetate	2.2	92
Vinyl chloride	1.0	103
Semivolatile Organic Compounds		
Total semivolatile organic compounds	2.2	3,438
2,3,4,6-Tetrachlorophenol	4.2	24
2,4,5-Trichlorophenol	4.2	24
2,4,6-Trichlorophenol	4.2	24
2,4-Dichlorophenol	4.2	24
2,4-Dimethylphenol	4.2	24
2,4-Dinitrophenol	12.5	24
2,6-Dichlorophenol	4.2	24
2-Chlorophenol	8.3	24
2-Methylphenol (cresol, o-)	4.2	24
2-Nitrophenol	4.2	24
3+4 Methylphenol (cresol, m+p)	4.2	24
4,6-Dinitro-2-methylphenol	4.2	24
4-Chloro-3-methylphenol	4.2	24
4-Nitrophenol	4.2	24
Dinoseb(2-secButyl-4,6-dinitrophenol)	4.2	24
Pentachlorophenol	4.2	24
Phenol	4.2	24
beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	4.0	25
Delta-BHC	4.0	25
Heptachlor	4.0	25
1,2-Dichlorobenzene	2.9	34
1,3-Dichlorobenzene	2.9	34
1,4-Dichlorobenzene	2.8	36
2,4-Dichlorophenol	2.8	36
2-Nitrophenol	2.8	36
3+4 Methylphenol (cresol, m+p)	11.1	9
3-Nitroaniline	2.9	34
4-Chloroaniline	5.9	34
Bis(2-chloroethyl) ether	2.9	34
Hexachlorocyclopentadiene	2.9	34
Hexachloroethane	2.9	34
Acenaphthene	13.6	22
Acenaphthylene	18.2	22
Anthracene	9.1	22
Benzo(a)anthracene	4.5	22
Benzo(a)pyrene	4.5	22
Benzo(b)fluoranthene	13.6	22
Benzo(ghi)perylene	13.6	22
Benzo(k)fluoranthene	9.1	22

Table D-22. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
Chrysene	13.6	22
Dibenz[a,h]anthracene	18.2	22
Fluorene	18.2	22
Indeno(1,2,3-cd)pyrene	4.5	22
Naphthalene	18.2	22
Phenanthrene	4.5	22
Pyrene	13.6	22
Radiological Parameters		
Total radiochemistry parameters	1.2	674
Cobalt-60	10.0	10
Thorium-228	100.0	2
Thorium-232	100.0	2
Thorium-228	100.0	2
Thorium-232	100.0	1

Table D-23. Matrix Spikes and Matrix Spike Duplicates, WSCF

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	1.6	619
Total organic halides	0.7	286
Total organic carbon	0.8	241
Total petroleum hydrocarbons-diesel range	10.3	58
Ammonia and Anions		
Total ammonia and anions	0.5	3,531
Bromide	1.1	179
Fluoride	1.5	605
Nitrogen in nitrate	0.3	607
Nitrogen in nitrite	0.3	626
Phosphorus in phosphate	1.0	194
Sulfate	0.2	608
Metals		
Total metals	0.5	11,313
Barium (ICP)	0.5	417
Calcium (ICP)	0.2	458
Chromium (ICP)	0.5	415
Iron (ICP)	1.4	419
Magnesium (ICP)	0.7	461
Phosphorus (ICP)	0.8	124
Potassium (ICP)	2.1	419
Silver (ICP)	2.4	411
Sodium (ICP)	0.7	456
Strontium (ICP)	1.5	411
Thallium (ICP)	0.8	124
Zinc (ICP)	0.5	414
Barium (ICP-MS)	1.8	113
Chromium (ICP-MS)	3.5	114
Mercury (ICP-MS)	3.3	120
Hexavalent chromium	0.4	270
Volatile Organic Compounds		
Total volatile organic compounds	0.3	608
Ethanol	10.0	10
Methanol	16.7	6
Semivolatile Organic Compounds		
Total semivolatile organic compounds	20.1	299
1,2,4-Trichlorobenzene	41.2	17
1,4-Dichlorobenzene	43.8	16
2,4-Dichlorophenol	14.3	14
2,4-Dinitrotoluene	14.3	14

Table D-23. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
2-Chlorophenol	18.8	16
2-Methylphenol (cresol, o-)	14.3	14
2-Nitrophenol	15.4	13
2-Picoline	7.7	13
4-Chloro-3-methylphenol	15.4	13
4-Nitrophenol	57.1	14
Bis(2-ethylhexyl) phthalate	28.6	14
Pentachlorophenol	43.8	16
Phenol	46.2	13
Pyrene	14.3	14
Tributyl phosphate	13.3	15
Tris-2-chloroethyl phosphate	23.1	13
Radiological Parameters		
Total radiochemistry parameters	0.5	208
Tritium	0.9	117

Table D-24. Matrix Spikes and Matrix Spike Duplicates, TestAmerica Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	2.0	51
Total petroleum hydrocarbons-diesel range	8.3	12
Ammonia and Anions		
Total ammonia and anions	9.0	234
Chloride	5.3	38
Fluoride	2.6	39
Nitrogen in nitrate	7.7	39
Nitrogen in nitrite	5.1	39
Phosphorus in phosphate	78.6	14
Sulfate	5.1	39
Metals		
Total metals	2.2	2,412
Beryllium (ICP)	1.3	80
Bismuth (ICP)	6.3	32
Calcium (ICP)	7.5	80
Magnesium (ICP)	1.3	80
Phosphorus (ICP)	7.1	14
Potassium (ICP)	38.5	78
Silver (ICP)	3.8	78
Strontium (ICP)	2.5	80
Hexavalent chromium	4.3	94
Mercury (CVAA)	7.1	28
Volatile Organic Compounds		
Total volatile organic compounds	9.3	11,346
1,1,1,2-Tetrachloroethane	6.8	176
1,1,1-Trichloroethane	5.8	240
1,1,2,2-Tetrachloroethane	19.7	178
1,1,2-Trichloroethane	6.7	240
1,1-Dichloroethane	5.0	240
1,1-Dichloroethene	7.5	240
1,2-Dibromo-3-chloropropane	4.5	176
1,2-Dibromoethane	6.8	176
1,2-Dichloroethane	5.0	240
1,2-Dichloroethene (Total)	6.7	178
1,2-Dichloropropane	6.2	178
1,4-Dichlorobenzene	11.3	240
1,4-Dioxane	27.3	238
1-Butanol	22.9	240
2-Butanone	12.1	240
2-Hexanone	6.7	178

Table D-24. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
4-Methyl-2-pentanone	5.8	240
Acetone	18.3	240
Acetonitrile	17.4	178
Acrolein	40.9	176
Allyl chloride	6.2	178
Benzene	3.8	240
Bromodichloromethane	6.7	178
Bromoform	7.4	176
Bromomethane	28.7	178
Carbon disulfide	6.3	240
Carbon tetrachloride	6.8	236
Chlorobenzene	5.6	178
Chloroethane	7.9	178
Chloroform	5.0	240
Chloromethane	7.4	176
Chloroprene	4.5	178
cis-1,2-Dichloroethylene	5.8	240
cis-1,3-Dichloropropene	8.4	178
Dibromochloromethane	6.7	178
Dichlorodifluoromethane	3.9	178
Ethyl cyanide	9.2	240
Ethyl methacrylate	6.2	178
Ethylbenzene	5.4	240
Iodomethane	31.3	176
Isobutyl alcohol	15.7	178
Methacrylonitrile	5.1	178
Methyl methacrylate	3.9	178
Methylene chloride	4.2	238
Styrene	4.5	178
Tetrachloroethene	2.9	240
Tetrahydrofuran	14.6	240
Toluene	8.3	240
trans-1,2-Dichloroethylene	6.3	240
trans-1,3-Dichloropropene	6.7	178
trans-1,4-Dichloro-2-butene	11.9	176
Trichloroethene	5.0	240
Trichloromonofluoromethane	4.5	178
Vinyl acetate	8.4	178
Vinyl chloride	3.3	240
Semivolatile Organic Compounds		
Total semivolatile organic compounds	6.5	4,996
2,3,4,6-Tetrachlorophenol	8.3	48

Table D-24. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
2,4,5-Trichlorophenol	12.5	48
2,4,6-Trichlorophenol	4.2	48
2,4-Dichlorophenol	2.1	48
2,4-Dimethylphenol	12.5	48
2,4-Dinitrophenol	33.3	48
2,6-Dichlorophenol	12.5	48
2-Chlorophenol	8.3	48
2-Methylphenol (cresol, o-)	8.3	48
2-Nitrophenol	18.8	48
3+4 Methylphenol (cresol, m+p)	8.3	48
4,6-Dinitro-2-methylphenol	18.8	48
4-Chloro-3-methylphenol	12.5	48
4-Nitrophenol	20.8	48
Dinoseb (2-secButyl-4,6-dinitrophenol)	22.9	48
Pentachlorophenol	16.7	48
Phenol	8.3	48
4,4'-DDT (Dichlorodiphenyltrichloroethane)	2.1	48
Delta-BHC	4.2	48
Endosulfan II	4.2	48
Endosulfan sulfate	4.2	48
Endrin aldehyde	8.3	48
Heptachlor	18.8	48
Heptachlor epoxide	4.2	48
Methoxychlor	12.5	48
2,4-Dinitrophenol	6.8	44
3,3'-Dichlorobenzidine	9.1	44
3-Nitroaniline	4.5	44
4-Bromophenylphenyl ether	2.3	44
4-Chloroaniline	18.2	44
4-Nitrophenol	4.5	44
Benzo(a)pyrene	2.3	44
Benzo(ghi)perylene	4.5	44
Dibenz[a,h]anthracene	4.5	44
Hexachlorobenzene	4.5	44
Hexachlorocyclopentadiene	4.5	44
Hexachloroethane	9.1	44
Indeno(1,2,3-cd)pyrene	9.1	44
Pentachlorophenol	3.8	52
Phenol	7.7	52
Acenaphthene	25.0	32
Acenaphthylene	40.6	32

Table D-24. (Cont.)

Constituent	Percent Out of Limit	Number of Analyses
Anthracene	25.0	32
Benzo(a)anthracene	37.5	32
Benzo(a)pyrene	18.8	32
Benzo(b)fluoranthene	28.1	32
Benzo(ghi)perylene	25.0	32
Benzo(k)fluoranthene	18.8	32
Chrysene	37.5	32
Dibenz[a,h]anthracene	28.1	32
Fluoranthene	25.0	32
Fluorene	37.5	32
Indeno(1,2,3-cd)pyrene	21.9	32
Naphthalene	43.8	32
Phenanthrene	28.1	32
Pyrene	12.5	32
Radiological Parameters		
Total radiochemistry parameters	0.0	50

Table D-25. Matrix Duplicates, WSCF

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	0.0	147
Ammonia and Anions		
Total ammonia and anions	0.3	3,042
Bromide	1.5	203
Chloride	0.2	511
Fluoride	0.6	499
Nitrogen in nitrite	0.4	515
Metals		
Total metals	0.0	452
Volatile Organic Compounds		
Total volatile organic compounds	0.0	24
Semivolatile Organic Compounds		
Total semivolatile organic compounds	0.0	0
Radiological Parameters		
Total radiochemistry parameters	0.1	3,289
Gross alpha	3.1	258
Gross beta	3.9	283
Technetium-99	1.8	168
Total beta radiostrontium	2.5	202
Tritium	0.1	228

Table D-26. Matrix Duplicates, TestAmerica Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	0.0	35
Ammonia and Anions		
Total ammonia and anions	0.0	257
Metals		
Total metals	2.1	47
Hexavalent chromium	2.1	47
Volatile Organic Compounds		
Total volatile organic compounds	0.0	0
Semivolatile Organic Compounds		
Total semivolatile organic compounds	0.0	0
Radiological Parameters		
Total radiochemistry parameters	0.1	1,291
Iodine-129	1.5	68

Table D-27. Summary of Issue Resolution Forms, Current Reporting Period

Issue Category	Number of Analyses Impacted				
	Prior to Receipt at Laboratory	After Receipt at WSCF	After Receipt at TA Laboratory[a]	After Receipt at Eberline Laboratory[b]	After Receipt at 222-S Laboratory
Hold time missed	57	156	3	--	31
Broken bottles	30	1	--	--	--
Canceled analysis	--	19	4	2	--
Temperature deviation	21	6	--	--	--
Addition of analysis	--	1	--	1	--
Chain-of-custody form issues	99	--	--	--	--
Laboratory QC out of limits/ incomplete	--	87	30	36	16
Incorrect preservation of the sample	4	--	1	--	--
Analytical preparation deviations/method failures/ discontinued analyses	9	13	12	--	36
Insufficient volume	1	--	1	--	--
Late analysis	--	--	8	--	--
Totals	**221**	**283**	**66**	**39**	**83**

a. Includes data from TA St. Louis and TA Richland Laboratories

b. Includes data from Eberline and Lionville Laboratories

Table D-28. Summary of Analytical Laboratory Detection/Quantitation Limits Determined from Field Blanks Data, TestAmerica Laboratories (Richland and St. Louis) and WSCF

Period[a]	Number of Samples	Mean	Standard Deviation	Limit of Detection[c]	Limit of Quantitation[c]
Total Organic Carbon (µg/L)					
4/8/09 to 3/25/10	70	-35.16	113.0	339	1,130
7/23/09 to 6/13/10	83	-19.54	104.3	313	1,040
10/4/09 to 9/20/10	92	-12.10	98.83	296	988
1/12/10 to 12/16/10	83	-23.77	21.00	63	210
Summary	**83**	**-23.77**	**21.00**	**63**	**210**
Total Organic Halides (µg/L)					
4/10/09 to1/6/10	64	1.38	1.14	3.4	11.4
7/23/09 to 6/13/10	77	1.37	1.20	3.6	12.0
10/4/09 to 9/20/10	86	1.31	1.21	3.6	12.1
1/6/10 to 12/2/10	78	1.37	1.18	3.5	11.8
Summary	**78**	**1.37**	**1.18**	**3.5**	**11.8**
Cesium-137 (pCi/L)					
1/6/10 to 3/31/10	19	0.56	2.75	8.24	27.5
4/9/10 to 6/22/10	17	0.77	2.24	6.73	22.4
7/12/10 to 9/23/10	21	-0.67	2.52	7.55	25.2
11/10/10 to 12/20/10	11	0.81	3.55	10.64	35.5
Summary	**68**	**0.27**	**2.71**	**8.12**	**27.1**
Constituent: Cobalt-60 (pCi/L)					
1/6/10 to 3/31/10	15	0.78	1.93	5.78	19.3
4/9/10 to 6/22/10	17	0.00	0.94	2.83	9.44
7/12/10 to 9/23/10	20	-0.94	2.44	7.31	24.4
11/10/10 to 12/20/10	11	0.33	1.55	4.65	15.5
Summary	**63**	**-0.05**	**1.85**	**5.56**	**18.5**
Europium-152 (pCi/L)					
1/6/10 to 3/31/10	15	2.46	5.73	17.2	57.3
4/9/10 to 6/22/10	17	-1.93	6.44	19.3	64.4
7/12/10 to 9/23/10	20	-0.62	7.60	22.8	76.0
11/10/10 to 12/20/10	11	-2.55	6.49	19.5	64.9
Summary	**63**	**-0.58**	**6.69**	**20.1**	**66.9**
Europium-154 (pCi/L)					
1/6/10 to 3/31/10	19	-0.08	9.43	28.3	94.3
4/9/10 to 6/22/10	17	0.42	3.28	9.8	32.8
7/12/10 to 9/23/10	20	1.99	5.17	15.5	51.7
11/10/10 to 12/20/10	11	-0.61	3.74	11.2	37.4
Summary	**67**	**0.58**	**6.20**	**18.6**	**62.0**
Europium-155 (pCi/L)					
1/6/10 to 3/31/10	15	1.06	6.27	18.8	62.7
4/9/10 to 6/22/10	17	0.48	3.24	9.71	32.4
7/12/10 to 9/23/10	20	1.46	9.18	27.5	91.8
11/10/10 to 12/20/10	11	2.36	3.67	11.0	36.7
Summary	**63**	**1.26**	**6.45**	**19.4**	**64.5**

Table D-28. (Cont.)

Period[a]	Number of Samples	Mean	Standard Deviation	Limit of Detection[c]	Limit of Quantitation[c]
Gross Alpha (pCi/L)					
1/4/10 to 3/31/10	21	0.06	0.80	2.40	7.99
4/9/10 to 6/14/10	24	0.43	1.18	3.54	11.8
7/12/10 to 9/23/10	22	0.16	1.11	3.32	11.1
11/10/10 to 12/27/10	15	0.16	0.90	2.70	9.00
Summary	**82**	**0.21**	**1.02**	**3.07**	**10.2**
Gross Beta (pCi/L)					
1/4/10 to 3/31/10	23[b]	1.23	1.32	3.96	13.2
4/9/10 to 6/28/10	26[b]	0.14	1.05	3.16	10.5
7/12/10 to 9/23/10	24[b]	0.70	1.50	4.51	15.0
11/10/10 to 12/27/10	16	1.34	1.87	5.61	18.7
Summary	**89[b]**	**0.79**	**1.42**	**4.25**	**14.2**
Iodine-129 (pCi/L)					
1/6/10 to 3/28/10	13	0.04	0.06	0.19	0.62
4/6/10 to 6/7/10	12	0.05	0.11	0.32	1.06
7/6/10 to 9/23/10	15[b]	0.01	0.04	0.12	0.38
11/10/10 to 12/20/10	13	-0.03	0.04	0.13	0.42
Summary	**53[b]**	**0.02**	**0.07**	**0.20**	**0.66**
Total Beta Radiostrontium (pCi/L)					
1/6/10 to 3/31/10	16	-2.82	3.63	10.90	36.3
4/9/10 to 6/30/10	16	-2.25	2.89	8.68	28.9
7/8/10 to 9/23/10	21	-3.95	3.59	10.76	35.9
11/3/10 to 12/30/10	20	-5.21	3.15	9.44	31.5
Summary	**73**	**-3.85**	**3.34**	**10.02**	**33.4**
Technetium-99 (pCi/L)					
1/6/10 to 3/31/10	18[b]	-5.28	5.83	17.49	58.3
4/5/10 to 6/14/10	23	-6.98	3.90	11.69	39.0
7/6/10 to 9/23/10	22[b]	-2.95	3.40	10.20	34.0
10/10/10 to 12/27/10	17	-3.34	3.59	10.77	35.9
Summary	**80[b]**	**-4.72**	**4.23**	**12.69**	**42.3**
Tritium (pCi/L)					
1/4/10 to 3/31/10	24[b]	70.2	136	407	1,360
4/5/10 to 6/30/10	32	33.4	93.1	279	931
7/6/10 to 9/23/10	35	22.6	72.0	216	720
11/3/10 to 12/30/10	24	87.2	183	550	1,830
Summary	**115[b]**	**49.0**	**122**	**365**	**1,220**

a. Time period covered for total organic carbon and total organic halides is a moving average of four quarters.

b. Excluded outliers.

c. Limit of detection (blank corrected) equals three times the blank standard deviation; limit of quantitation (blank-corrected) equals ten times the blank standard deviation. Numbers are rounded.

Table D-29. Summary of Detection and Quantitation Limits, WSCF

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
EPA-410.4	Chemical oxygen demand	10	13.50	45.86	--	--	--	--
Anions								
EPA-600/R-93/100, 300.0[b]	Bromide	45	60.76	206.37	8/10/10	54	72.92	247.64
EPA-600/R-93/100, 300.0[b]	Chloride	43	58.06	197.20	12/30/10	84	113.43	385.22
EPA-600/R-93/100, 300.0[b]	Fluoride	30	40.51	137.58	12/30/10	88	118.83	403.57
EPA-600/R-93/100, 300.0[b]	Nitrogen in nitrate	31	41.86	142.17	12/30/10	19	25.66	87.13
EPA-600/R-93/100, 300.0[b]	Nitrogen in nitrite	18	24.31	82.55	12/30/10	36	48.61	165.10
EPA-600/R-93/100, 300.0[b]	Phosphorus in phosphate	70	94.52	321.02	8/10/10	72	97.22	330.19
EPA-600/R-93/100, 300.0[b]	Sulfate	66	89.12	302.68	12/30/10	170	229.55	779.62
EPA-600/R-93/100, 335.2	Cyanide	4	5.40	18.34	--	--	--	--
Metals								
EPA-600/R-94/111, 200.8	Aluminum	5	6.75	22.93	--	--	--	--
EPA-600/R-94/111, 200.8	Antimony	0.3	0.41	1.38	--	--	--	--
EPA-600/R-94/111, 200.8	Arsenic	0.4	0.54	1.83	--	--	--	--
EPA-600/R-94/111, 200.8	Barium	0.2	0.27	0.92	--	--	--	--
EPA-600/R-94/111, 200.8	Beryllium	0.05	0.07	0.23	9/13/10	0.1	0.14	0.46
EPA-600/R-94/111, 200.8	Cadmium	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Chromium	0.5	0.68	2.29	--	--	--	--
EPA-600/R-94/111, 200.8	Cobalt	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Copper	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Lead	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Manganese	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Mercury	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Molybdenum	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Nickel	0.2	0.27	0.92	--	--	--	--
EPA-600/R-94/111, 200.8	Selenium	0.3	0.41	1.38	--	--	--	--
EPA-600/R-94/111, 200.8	Silver	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Strontium	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Thallium	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Thorium	0.1	0.14	0.46	--	--	--	--
EPA-600/R-94/111, 200.8	Tin	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Uranium	0.05	0.07	0.23	--	--	--	--
EPA-600/R-94/111, 200.8	Vanadium	0.2	0.27	0.92	--	--	--	--
EPA-600/R-94/111, 200.8	Zinc	0.8	1.08	3.67	--	--	--	--
SW-846, 6010	Aluminum	17	22.96	77.96	9/1/10	19	25.66	87.13
SW-846, 6010	Antimony	38	51.31	174.27	9/1/10	47	63.46	215.54
SW-846, 6010	Arsenic	65	87.77	298.09	9/1/10	50	67.52	229.30
SW-846, 6010	Barium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Beryllium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Bismuth	23	31.06	105.48	9/1/10	37	49.96	169.68
SW-846, 6010	Boron	19	25.66	87.13	9/1/10	41	55.36	188.03

Table D-29. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Cadmium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Calcium	39	52.66	178.85	9/23/10	28	37.81	128.41
SW-846, 6010	Chromium	13	17.55	59.62	9/1/10	14	18.90	64.20
SW-846, 6010	Cobalt	4	5.40	18.34	--	--	--	--
SW-846, 6010	Copper	4	5.40	18.34	9/1/10	5	6.75	22.93
SW-846, 6010	Iron	18	24.31	82.55	9/1/10	38	51.31	174.27
SW-846, 6010	Lead	23	31.06	105.48	9/1/10	42	56.71	192.61
SW-846, 6010	Lithium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Magnesium	16	21.61	73.38	9/1/10	14	18.90	64.20
SW-846, 6010	Manganese	4	5.40	18.34	9/1/10	6	8.10	27.52
SW-846, 6010	Molybdenum	4	5.40	18.34	--	--	--	--
SW-846, 6010	Nickel	4	5.40	18.34	--	--	--	--
SW-846, 6010	Phosphorus	55	74.27	252.23	9/1/10	72	97.22	330.19
SW-846, 6010	Potassium	55	74.27	252.23	9/1/10	73	98.57	334.78
SW-846, 6010	Selenium	45	60.76	206.37	9/1/10	47	63.46	215.54
SW-846, 6010	Silicon	61	82.37	279.75	9/1/10	25	33.76	114.65
SW-846, 6010	Silver	5	6.75	22.93	9/1/10	7	9.45	32.10
SW-846, 6010	Sodium	23	31.06	105.48	9/1/10	11	14.85	50.45
SW-846, 6010	Strontium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Thallium	35	47.26	160.51	9/1/10	49	66.17	224.71
SW-846, 6010	Tin	39	52.66	178.85	9/1/10	49	66.17	224.71
SW-846, 6010	Titanium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Vanadium	12	16.20	55.03	9/1/10	17	22.96	77.96
SW-846, 6010	Zinc	6	8.10	27.52	9/1/10	4	5.40	18.34
EPA-7196	Hexavalent chromium	2	2.70	9.17	--	--	--	--
Volatile Organic Compounds								
SW-846, 8260	1,1,1-Trichloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8260	1,1,2-Trichloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8260	1,1-Dichloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8260	1,1-Dichloroethene	1	1.35	4.59	--	--	--	--
SW-846, 8260	1,2-Dichloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8260	1,4-Dichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8260	1-Butanol	100	135.03	458.60	--	--	--	--
SW-846, 8260	2-Butanone	1	1.35	4.59	--	--	--	--
SW-846, 8260	4-Methyl-2-pentanone	1	1.35	4.59	--	--	--	--
SW-846, 8260	Acetone	1	1.35	4.59	--	--	--	--
SW-846, 8260	Benzene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Carbon disulfide	1	1.35	4.59	--	--	--	--
SW-846, 8260	Carbon tetrachloride	1	1.35	4.59	--	--	--	--
SW-846, 8260	Chlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Chloroform	1	1.35	4.59	--	--	--	--

Table D-29. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	cis-1,2-Dichloroethylene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Dibromochloromethane	1	1.35	4.59	--	--	--	--
SW-846, 8260	Ethyl cyanide	2	2.70	9.17	--	--	--	--
SW-846, 8260	Ethylbenzene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Methylene chloride	1	1.35	4.59	--	--	--	--
SW-846, 8260	Tetrachloroethene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Tetrahydrofuran	2	2.70	9.17	--	--	--	--
SW-846, 8260	Toluene	1	1.35	4.59	--	--	--	--
SW-846, 8260	trans-1,2-Dichloroethylene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Trichloroethene	1	1.35	4.59	--	--	--	--
SW-846, 8260	Vinyl chloride	1	1.35	4.59	--	--	--	--
SW-846, 8260	Xylenes (total)	1	1.35	4.59	--	--	--	--
SW-846, 8015	1-Propanol	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Diethyl ether	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Ethanol	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Ethyl acetate	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Ethylene glycol	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Methanol	2,000	2,700.64	9,171.97	--	--	--	--
SW-846, 8015	Total petroleum hydrocarbons-gasoline fraction	50	67.52	229.30	--	--	--	--
Semivolatile Organic Compounds								
SW-846, 8015	Total petroleum hydrocarbons-diesel fraction	80	108.03	366.88	--	--	--	--
SW-846, 8015	Total petroleum hydrocarbons-kerosene fraction	80	108.03	366.88	--	--	--	--
EPA-8082	Aroclor-1016	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1221	0.2	0.27	0.92	--	--	--	--
EPA-8082	Aroclor-1232	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1242	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1248	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1254	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1260	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1262	0.1	0.14	0.46	--	--	--	--
EPA-8082	Aroclor-1268	0.1	0.14	0.46	--	--	--	--
SW-846, 8270	1,2,4-Trichlorobenzene	0.7	0.95	3.21	1/20/10	1	1.35	4.59
SW-846, 8270	1,4-Dichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,3,4,6-Tetrachlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4,5-Trichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4,6-Trichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dichlorophenol	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	2,4-Dimethylphenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dinitrophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dinitrotoluene	0.5	0.68	2.29	1/20/10	1	1.35	4.59

Table D-29. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2,6-Dichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Chlorophenol	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	2-Methylphenol (cresol, o-)	0.9	1.22	4.13	1/20/10	1	1.35	4.59
SW-846, 8270	2-Nitrophenol	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	2-Picoline	1	1.35	4.59	--	--	--	--
SW-846, 8270	3+4 Methylphenol (cresol, m+p)	0.7	0.95	3.21	1/20/10	1	1.35	4.59
SW-846, 8270	4,6-Dinitro-2-methylphenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Chloro-3-methylphenol	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	4-Nitrophenol	0.6	0.81	2.75	1/20/10	1	1.35	4.59
SW-846, 8270	Acenaphthene	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	Benzothiazole	0.6	0.81	2.75	1/20/10	1	1.35	4.59
SW-846, 8270	Bis(2-ethylhexyl) phthalate	0.8	1.08	3.67	1/20/10	1	1.35	4.59
SW-846, 8270	Dinoseb(2-secButyl-4,6-dinitrophenol)	1	1.35	4.59	--	--	--	--
SW-846, 8270	Naphthalene	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	n-Nitrosodimethylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosodi-n-dipropylamine	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	Pentachlorophenol	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	Phenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pyrene	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	Total cresols	1	1.35	4.59	--	--	--	--
SW-846, 8270	Tributyl phosphate	0.5	0.68	2.29	1/20/10	1	1.35	4.59
SW-846, 8270	Tris-2-chloroethyl phosphate	0.5	0.68	2.29	1/20/10	1	1.35	4.59

a. The MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

b. Units for this method are mg/L

c. Additional MDLs were used during the year for these compounds.

LOD = limit of detection

LOQ = limit of quantitation

MDL = method detection limit

Table D-30. Summary of Detection and Quantitation Units, TestAmerica Laboratories

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
EPA-600/4-81-004, 120.1	Specific conductance[b]	0.097	0.13	0.44	--	--	--	--
EPA-600/4-81-004, 310.1	Alkalinity	540	729.17	2,476.43	--	--	--	--
EPA-600/4-81-004, 413.1	Oil and grease	2,100	2,835.67	9,630.57	--	--	--	--
Anions								
EPA-600/R-93/100, 300.0[c]	Bromide	25	33.76	114.65	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Chloride	20	27.01	91.72	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Fluoride	10	13.50	45.86	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Nitrogen in nitrate	8.6	11.61	39.44	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Nitrogen in nitrite	3	4.05	13.76	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Phosphorus in phosphate	54	72.92	247.64	--	--	--	--
EPA-600/R-93/100, 300.0[c]	Sulfate	50	67.52	229.30	--	--	--	--
SW-846, 9012	Cyanide	3.6	4.86	16.51	--	--	--	--
SW-846, 9030[c]	Sulfide	83	112.08	380.64	--	--	--	--
Metals								
SW-846, 6010	Aluminum	79.9	107.89	366.42	--	--	--	--
SW-846, 6010	Antimony	4	5.40	18.34	--	--	--	--
SW-846, 6010	Arsenic	2	2.70	9.17	9/27/10	2.7	3.65	12.38
SW-846, 6010	Barium	4	5.40	18.34	--	--	--	--
SW-846, 6010	Beryllium	0.61	0.82	2.80	--	--	--	--
SW-846, 6010	Bismuth	105	141.78	481.53	--	--	--	--
SW-846, 6010	Boron	10.8	14.58	49.53	--	--	--	--
SW-846, 6010	Cadmium	0.91	1.23	4.17	--	--	--	--
SW-846, 6010	Calcium	106	143.13	486.11	--	--	--	--
SW-846, 6010	Chromium	3.1	4.19	14.22	--	--	--	--
SW-846, 6010	Cobalt	4	5.40	18.34	--	--	--	--
SW-846, 6010	Copper	4.6	6.21	21.10	3/19/10	4.6	6.21	21.10
SW-846, 6010	Iron	28.2	38.08	129.32	--	--	--	--
SW-846, 6010	Lead	1.3	1.76	5.96	--	--	--	--
SW-846, 6010	Lithium	9.6	12.96	44.03	--	--	--	--
SW-846, 6010	Magnesium	132	178.24	605.35	--	--	--	--
SW-846, 6010	Manganese	3.3	4.46	15.13	3/19/10	3.3	4.46	15.13
SW-846, 6010	Molybdenum	5	6.75	22.93	--	--	--	--
SW-846, 6010	Nickel	13.3	17.96	60.99	--	--	--	--
SW-846, 6010	Phosphorus	41.6	56.17	190.78	9/28/10	75	101.27	343.95
SW-846, 6010	Potassium	1,650	2,228.03	7,566.88	--	--	--	--
SW-846, 6010	Selenium	2.7	3.65	12.38	9/27/10	5	6.75	22.93
SW-846, 6010	Silicon	40	54.01	183.44	--	--	--	--
SW-846, 6010	Silver	6	8.10	27.52	--	--	--	--
SW-846, 6010	Sodium	324	437.50	1,485.86	--	--	--	--
SW-846, 6010	Strontium	0.54	0.73	2.48	--	--	--	--
SW-846, 6010	Thallium	4	5.40	18.34	--	--	--	--

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Tin	13.5	18.23	61.91	--	--	--	--
SW-846, 6010	Vanadium	4.1	5.54	18.80	--	--	--	--
SW-846, 6010	Zinc	5.2	7.02	23.85	9/27/10	7	9.45	32.10
SW-846, 6020	Aluminum	4.5	6.08	20.64	8/6/10	8.3	11.21	38.06
SW-846, 6020	Antimony	1.1	1.49	5.04	--	--	--	--
SW-846, 6020	Arsenic	0.95	1.28	4.36	--	--	--	--
SW-846, 6020	Barium	0.2	0.27	0.92	--	--	--	--
SW-846, 6020	Beryllium	0.11	0.15	0.50	8/6/10	0.35	0.47	1.61
SW-846, 6020	Boron	7.5	10.13	34.39	--	--	--	--
SW-846, 6020	Cadmium	0.055	0.07	0.25	--	--	--	--
SW-846, 6020	Calcium	68.1	91.96	312.31	--	--	--	--
SW-846, 6020	Chromium	3.3	4.46	15.13	--	--	--	--
SW-846, 6020	Cobalt	0.22	0.30	1.01	--	--	--	--
SW-846, 6020	Copper	0.097	0.13	0.44	8/6/10	0.45	0.61	2.06
SW-846, 6020	Iron	20.4	27.55	93.55	--	--	--	--
SW-846, 6020	Lead	0.17	0.23	0.78	--	--	--	--
SW-846, 6020	Magnesium	1.7	2.30	7.80	--	--	--	--
SW-846, 6020	Manganese	0.24	0.32	1.10	--	--	--	--
SW-846, 6020	Molybdenum	0.22	0.30	1.01	9/28/10	0.41	0.55	1.88
SW-846, 6020	Nickel	0.4	0.54	1.83	--	--	--	--
SW-846, 6020	Phosphorus	8.2	11.07	37.61	--	--	--	--
SW-846, 6020	Potassium	8.3	11.21	38.06	--	--	--	--
SW-846, 6020	Selenium	0.31	0.42	1.42	8/6/10	1.3	1.76	5.96
SW-846, 6020	Silicon	17.8	24.04	81.63	--	--	--	--
SW-846, 6020	Silver	0.04	0.05	0.18	--	--	--	--
SW-846, 6020	Sodium	15	20.25	68.79	--	--	--	--
SW-846, 6020	Strontium	0.15	0.20	0.69	--	--	--	--
SW-846, 6020	Thallium	0.55	0.74	2.52	--	--	--	--
SW-846, 6020	Tin	0.15	0.20	0.69	9/28/10	1	1.35	4.59
SW-846, 6020	Titanium	1	1.35	4.59	--	--	--	--
SW-846, 6020	Vanadium	2.4	3.24	11.01	--	--	--	--
SW-846, 6020	Zinc	8.3	11.21	38.06	--	--	--	--
EPA-7196	Hexavalent chromium	3.7	5.00	16.97	--	--	--	--
EPA-7074	Mercury	0.016	0.02	0.07	--	--	--	--
Volatile Organic Compounds								
SW-846, 8015	Ethanol	670	904.71	3,072.61				
SW-846, 8015	Ethylene glycol	2,100	2,835.67	9,630.57				
SW-846, 8015	Methanol	1,100	1,485.35	5,044.59	--	--	--	--
SW-846, 8260	1,1,1,2-Tetrachloroethane	0.09	0.12	0.41	--	--	--	--
SW-846, 8260	1,1,1-Trichloroethane	0.067	0.09	0.31	5/3/10	0.069	0.09	0.32
SW-846, 8260	1,1,2,2-Tetrachloroethane	0.098	0.13	0.45	--	--	--	--
SW-846, 8260	1,1,2-Trichloroethane	0.063	0.09	0.29	5/3/10	0.15	0.20	0.69

Table D-30. (Cont.)

Method	Constituent	Initial MDL* (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL* (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	1,1-Dichloroethane	0.068	0.09	0.31	--	--	--	--
SW-846, 8260	1,1-Dichloroethene	0.051	0.07	0.23	5/3/10	0.083	0.11	0.38
SW-846, 8260	1,2,3-Trichloropropane	0.15	0.20	0.69	--	--	--	--
SW-846, 8260	1,2-Dibromo-3-chloropropane	0.41	0.55	1.88	--	--	--	--
SW-846, 8260	1,2-Dibromoethane	0.13	0.18	0.60	--	--	--	--
SW-846, 8260	1,2-Dichloroethane	0.1	0.14	0.46	--	--	--	--
SW-846, 8260	1,2-Dichloroethene (Total)	0.13	0.18	0.60	5/3/10	0.15	0.20	0.69
SW-846, 8260	1,2-Dichloropropane	0.097	0.13	0.44	--	--	--	--
SW-846, 8260	1,4-Dichlorobenzene	0.12	0.16	0.55	--	--	--	--
SW-846, 8260	1,4-Dioxane	7.6	10.26	34.85	5/3/10	7.6	10.26	34.85
SW-846, 8260	1-Butanol	12	16.20	55.03	--	--	--	--
SW-846, 8260	2-Butanone	0.52	0.70	2.38	--	--	--	--
SW-846, 8260	2-Hexanone	0.22	0.30	1.01	--	--	--	--
SW-846, 8260	4-Methyl-2-pentanone	0.12	0.16	0.55	--	--	--	--
SW-846, 8260	Acetone	0.34	0.46	1.56	--	--	--	--
SW-846, 8260	Acetonitrile	2	2.70	9.17	--	--	--	--
SW-846, 8260	Acrolein	2.8	3.78	12.84	--	--	--	--
SW-846, 8260	Acrylonitrile	0.58	0.78	2.66	--	--	--	--
SW-846, 8260	Allyl chloride	0.091	0.12	0.42	5/3/10	0.11	0.15	0.50
SW-846, 8260	Benzene	0.045	0.06	0.21	5/3/10	0.06	0.09	0.29
SW-846, 8260	Bromodichloromethane	0.082	0.11	0.38	5/3/10	0.09	0.12	0.40
SW-846, 8260	Bromoform	0.094	0.13	0.43	5/3/10	0.17	0.23	0.78
SW-846, 8260	Bromomethane	0.084	0.11	0.39	7/2110	0.25	0.34	1.15
SW-846, 8260	Carbon disulfide	0.05	0.07	0.23	5/3/10	0.05	0.07	0.23
SW-846, 8260	Carbon tetrachloride	0.063	0.09	0.29	5/3/10	0.12	0.16	0.55
SW-846, 8260	Chlorobenzene	0.15	0.20	0.69	--	--	--	--
SW-846, 8260	Chloroethane	0.085	0.11	0.39	5/3/10	0.10	0.13	0.45
SW-846, 8260	Chloroform	0.1	0.14	0.46	--	--	--	--
SW-846, 8260	Chloromethane	0.077	0.10	0.35	--	--	--	--
SW-846, 8260	Chloroprene	0.086	0.12	0.39	5/3/10	0.10	0.13	0.44
SW-846, 8260	cis-1,2-Dichloroethylene	0.14	0.19	0.64	5/3/10	0.09	0.12	0.40
SW-846, 8260	cis-1,3-Dichloropropene	0.073	0.10	0.33	--	--	--	--
SW-846, 8260	Dibromochloromethane	0.057	0.08	0.26	5/3/10	0.13	0.18	0.60
SW-846, 8260	Dibromomethane	0.21	0.28	0.96	--	--	--	--
SW-846, 8260	Dichlorodifluoromethane	0.07	0.09	0.32	5/3/10	0.08	0.11	0.39
SW-846, 8260	Ethyl cyanide	2.1	2.84	9.63	5/3/10	1.40	1.89	6.42
SW-846, 8260	Ethyl methacrylate	0.11	0.15	0.50	--	--	--	--
SW-846, 8260	Ethylbenzene	0.11	0.15	0.50	3/3/10	0.09	0.12	0.39
SW-846, 8260	Iodomethane	0.092	0.12	0.42	--	--	--	--
SW-846, 8260	Isobutyl alcohol	8.7	11.75	39.90	--	--	--	--
SW-846, 8260	Methacrylonitrile	0.05	0.07	0.23	5/3/10	0.50	0.68	2.29
SW-846, 8260	Methyl methacrylate	0.26	0.35	1.19	--	--	--	--

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	Methylene chloride	0.1	0.14	0.46	3/3/10	0.11	0.15	0.50
SW-846, 8260	Styrene	0.036	0.05	0.17	5/3/10	0.07	0.10	0.34
SW-846, 8260	Tetrachloroethene	0.065	0.09	0.30	5/3/10	0.18	0.24	0.83
SW-846, 8260	Tetrahydrofuran	7.5	10.13	34.39	3/3/10	1.10	1.49	5.04
SW-846, 8260	Toluene	0.07	0.09	0.32	5/3/10	0.07	0.10	0.33
SW-846, 8260	trans-1,2-Dichloroethylene	0.081	0.11	0.37	3/3/10	0.08	0.11	0.38
SW-846, 8260	trans-1,3-Dichloropropene	0.083	0.11	0.38	--	--	--	--
SW-846, 8260	trans-1,4-Dichloro-2-butene	0.29	0.39	1.33	--	--	--	--
SW-846, 8260	Trichloroethene	0.091	0.12	0.42	7/21/10	0.25	0.34	1.15
SW-846, 8260	Trichloromonofluoromethane	0.041	0.06	0.19	5/3/10	0.11	0.15	0.50
SW-846, 8260	Vinyl acetate	0.17	0.23	0.78	5/3/10	0.18	0.24	0.83
SW-846, 8260	Vinyl chloride	0.091	0.12	0.42	5/3/10	0.084	0.11	0.39
SW-846, 8260	Xylenes (total)	0.22	0.30	1.01	5/3/10	0.2	0.27	0.92
EPA-RSK-175	Methane	0.22	0.30	1.01	--	--	--	--
SW-846, 8015	Total petroleum hydrocarbons-gasoline fraction	10	13.50	45.86	--	--	--	--
Semivolatile Organic Compounds								
SW-846, 8015	Total petroleum hydrocarbons-diesel fraction	17	22.96	77.96	--	--	--	--
SW-846, 8015	Total petroleum hydrocarbons-kerosene fraction	10	13.50	45.86	--	--	--	--
SW-846, 8040	2,3,4,6-Tetrachlorophenol	2	2.70	9.17	--	--	--	--
SW-846, 8040	2,4,5-Trichlorophenol	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	2,4,6-Trichlorophenol	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	2,4-Dichlorophenol	2.1	2.84	9.63	--	--	--	--
SW-846, 8040	2,4-Dimethylphenol	2.1	2.84	9.63	--	--	--	--
SW-846, 8040	2,4-Dinitrophenol	2.4	3.24	11.01	--	--	--	--
SW-846, 8040	2,6-Dichlorophenol	2.1	2.84	9.63	--	--	--	--
SW-846, 8040	2-Chlorophenol	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	2-Methylphenol (cresol, o-)	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	2-Nitrophenol	2.3	3.11	10.55	4/26/10	2.3	3.11	10.55
SW-846, 8040	3+4 Methylphenol (cresol, m+p)	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	4,6-Dinitro-2-methylphenol	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	4-Chloro-3-methylphenol	2.4	3.24	11.01	--	--	--	--
SW-846, 8040	4-Nitrophenol	2.2	2.97	10.09	--	--	--	--
SW-846, 8040	Dinoseb(2-secButyl-4,6-dinitro-phenol)	2.4	3.24	11.01	--	--	--	--
SW-846, 8040	Pentachlorophenol	2.4	3.24	11.01	--	--	--	--
SW-846, 8040	Phenol	2.3	3.11	10.55	4/26/10	2.3	3.11	10.55
SW-846, 8081	4,4'-DDD (Dichlorodiphenyldi-chloroethane)	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	4,4'-DDE (Dichlorodiphenyldi-chloroethylene)	0.02	0.03	0.09	8/31/10	0.01	0.01	0.05

Table D-30. (Cont.)

Method	Constituent	Initial MDL* (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL* (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8081	4,4'-DDT (Dichlorodiphenyltri-chloroethane)	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Aldrin	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Alpha-BHC	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	beta-1,2,3,4,5,6-Hexachlorocy-clohexane (beta-BHC)	0.01	0.01	0.05	8/31/10	0.013	0.02	0.06
SW-846, 8081	Chlordane	0.04	0.05	0.18	8/31/10	0.23	0.31	1.05
SW-846, 8081	Delta-BHC	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Dieldrin	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Endosulfan I	0.02	0.03	0.09	8/31/10	0.01	0.01	0.05
SW-846, 8081	Endosulfan II	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Endosulfan sulfate	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Endrin	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Endrin aldehyde	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Gamma-BHC (Lindane)	0.003	0.00	0.01	8/31/10	0.01	0.01	0.05
SW-846, 8081	Heptachlor	0.003	0.00	0.01	8/31/10	0.01	0.01	0.05
SW-846, 8081	Heptachlor epoxide	0.01	0.01	0.05	--	--	--	--
SW-846, 8081	Methoxychlor	0.001	0.00	0.00	8/31/10	0.01	0.01	0.05
SW-846, 8081	Toxaphene	0.66	0.89	3.03	--	--	--	--
SW-846, 8082	Aroclor-1016	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1221	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1232	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1242	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1248	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1254	0.084	0.11	0.39	--	--	--	--
SW-846, 8082	Aroclor-1260	0.084	0.11	0.39	--	--	--	--
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	1,2,4-Trichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	1,2-Dichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	1,3-Dichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	1,4-Dichlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	1,4-Dioxane	5	6.75	22.93	3/21/10	1	1.35	4.59
SW-846, 8270	1,4-Naphthoquinone	1	1.35	4.59	--	--	--	--
SW-846, 8270	1-Naphthylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,3,4,6-Tetrachlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4,5-Trichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4,6-Trichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dimethylphenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,4-Dinitrophenol	2	2.70	9.17	--	--	--	--
SW-846, 8270	2,4-Dinitrotoluene	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,6-Dichlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2,6-Dinitrotoluene	2.2	2.97	10.09	--	--	--	--

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2-Acetylaminofluorene	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Chloronaphthalene	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Chlorophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Methylnaphthalene	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Methylphenol (cresol, o-)	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Naphthylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Nitroaniline	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Nitrophenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	2-Picoline	2	2.70	9.17	--	--	--	--
SW-846, 8270	3,3'-Dichlorobenzidine	1	1.35	4.59	--	--	--	--
SW-846, 8270	3,3'-Dimethylbenzidine	2.6	3.51	11.92	--	--	--	--
SW-846, 8270	3+4 Methylphenol (cresol, m+p)	2	2.70	9.17	--	--	--	--
SW-846, 8270	3-Methylcholanthrene	1	1.35	4.59	--	--	--	--
SW-846, 8270	3-Nitroaniline	1	1.35	4.59	--	--	--	--
SW-846, 8270	4,6-Dinitro-2-methylphenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Aminobiphenyl	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Bromophenylphenyl ether	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Chloro-3-methylphenol	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Chloroaniline	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Chlorophenylphenyl ether	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Methylphenol (cresol, p-)	10	13.50	45.86	--	--	--	--
SW-846, 8270	4-Nitroaniline	1	1.35	4.59	--	--	--	--
SW-846, 8270	4-Nitrophenol	2	2.70	9.17	--	--	--	--
SW-846, 8270	4-Nitroquinoline-1-oxide	5	6.75	22.93	--	--	--	--
SW-846, 8270	5-Nitro-o-toluidine	1	1.35	4.59	--	--	--	--
SW-846, 8270	7,12-Dimethylbenz[a]anthracene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Acenaphthene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Acenaphthylene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Acetophenone	1	1.35	4.59	--	--	--	--
SW-846, 8270	alpha,alpha-Dimethylphenethyl-amine	22	29.71	100.89	--	--	--	--
SW-846, 8270	Aniline	1	1.35	4.59	--	--	--	--
SW-846, 8270	Anthracene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Aramite	20	27.01	91.72	--	--	--	--
SW-846, 8270	Azobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzoaanthracene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzoapyrene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzobfluoranthene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzo(ghi)perylene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzo(k)fluoranthene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzothiazole	1	1.35	4.59	--	--	--	--
SW-846, 8270	Benzyl alcohol	1	1.35	4.59	--	--	--	--
SW-846, 8270	Bis(2-chloro-1-methylethyl)ether	1	1.35	4.59	--	--	--	--

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Bis(2-Chloroethoxy)methane	1	1.35	4.59	--	--	--	--
SW-846, 8270	Bis(2-chloroethyl) ether	1	1.35	4.59	--	--	--	--
SW-846, 8270	Bis(2-ethylhexyl) phthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Butylbenzylphthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Carbazole	1	1.35	4.59	--	--	--	--
SW-846, 8270	Chlorobenzilate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Chrysene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Diallate	2	2.70	9.17	--	--	--	--
SW-846, 8270	Dibenz[a,h]anthracene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Dibenzofuran	1	1.35	4.59	--	--	--	--
SW-846, 8270	Diethylphthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Dimethoate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Dimethyl phthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Di-n-butylphthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Di-n-octylphthalate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Dinoseb(2-secButyl-4,6-dinitro-phenol)	2	2.70	9.17	--	--	--	--
SW-846, 8270	Disulfoton	1	1.35	4.59	--	--	--	--
SW-846, 8270	Ethyl methanesulfonate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Famphur	1.7	2.30	7.80	--	--	--	--
SW-846, 8270	Fluoranthene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Fluorene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Hexachlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Hexachlorobutadiene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Hexachlorocyclopentadiene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Hexachloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8270	Hexachlorophene	10	13.50	45.86	--	--	--	--
SW-846, 8270	Hexachloropropene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Indeno(1,2,3-cd)pyrene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Isodrin	1	1.35	4.59	--	--	--	--
SW-846, 8270	Isophorone	1	1.35	4.59	--	--	--	--
SW-846, 8270	Isosafrole	1.3	1.76	5.96	--	--	--	--
SW-846, 8270	Kepone	20	27.01	91.72	--	--	--	--
SW-846, 8270	m-Dinitrobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Methapyrilene	1.3	1.76	5.96	--	--	--	--
SW-846, 8270	Methyl methanesulfonate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Methyl parathion	1	1.35	4.59	--	--	--	--
SW-846, 8270	Naphthalene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Nitrobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Nitrosopyrrolidine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosodiethylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosodimethylamine	2	2.70	9.17	--	--	--	--
SW-846, 8270	n-Nitrosodi-n-butylamine	1	1.35	4.59	--	--	--	--

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	n-Nitrosodi-n-dipropylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosodiphenylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosomethylethylamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosomorpholine	1	1.35	4.59	--	--	--	--
SW-846, 8270	n-Nitrosopiperidine	1	1.35	4.59	--	--	--	--
SW-846, 8270	O,O,O-Triethyl phosphorothioate	1	1.35	4.59	--	--	--	--
SW-846, 8270	O,O-Diethyl O-2-pyrazinyl phosphorothioate	1	1.35	4.59	--	--	--	--
SW-846, 8270	o-Toluidine	1	1.35	4.59	--	--	--	--
SW-846, 8270	Parathion	1	1.35	4.59	--	--	--	--
SW-846, 8270	p-Dimethylaminoazobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pentachlorobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pentachloroethane	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pentachloronitrobenzene (PCNB)	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pentachlorophenol	1.3	1.76	5.96	--	--	--	--
SW-846, 8270	Phenacetin	1	1.35	4.59	--	--	--	--
SW-846, 8270	Phenanthrene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Phenol	2	2.70	9.17	--	--	--	--
SW-846, 8270	Phorate	1	1.35	4.59	--	--	--	--
SW-846, 8270	p-Phenylenediamine	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pronamide	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pyrene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Pyridine	2	2.70	9.17	--	--	--	--
SW-846, 8270	Safrol	1	1.35	4.59	--	--	--	--
SW-846, 8270	sym-Trinitrobenzene	1	1.35	4.59	--	--	--	--
SW-846, 8270	Tetraethyl dithiopyrophosphate (Sulfotepp)	1	1.35	4.59	--	--	--	--
SW-846, 8270	Total cresols	3	4.05	13.76	--	--	--	--
SW-846, 8270	Tributyl phosphate	1	1.35	4.59	--	--	--	--
SW-846, 8270	Tris-2-chloroethyl phosphate	1	1.35	4.59	--	--	--	--
SW-846, 8310	Acenaphthene	0.3	0.41	1.38	12/5/10	0.65	0.88	2.98
SW-846, 8310	Acenaphthylene	0.28	0.38	1.28	12/5/10	0.4	0.54	1.83
SW-846, 8310	Anthracene	0.014	0.02	0.06	12/5/10	0.02	0.03	0.09
SW-846, 8310	Benzoaanthracene	0.021	0.03	0.10	12/5/10	0.063	0.09	0.29
SW-846, 8310	Benzoapyrene	0.044	0.06	0.20	12/5/10	0.075	0.10	0.34
SW-846, 8310	Benzobfluoranthene	0.022	0.03	0.10	12/5/10	0.051	0.07	0.23
SW-846, 8310	Benzo(ghi)perylene	0.063	0.09	0.29	12/5/10	0.16	0.22	0.73
SW-846, 8310	Benzo(k)fluoranthene	0.026	0.04	0.12	12/5/10	0.074	0.10	0.34
SW-846, 8310	Chrysene	0.015	0.02	0.07	12/5/10	0.035	0.05	0.16
SW-846, 8310	Dibenz[a,h]anthracene	0.053	0.07	0.24	12/5/10	0.15	0.20	0.69
SW-846, 8310	Fluoranthene	0.045	0.06	0.21	12/5/10	0.18	0.24	0.83
SW-846, 8310	Fluorene	0.02	0.03	0.09	12/5/10	0.071	0.10	0.33

Table D-30. (Cont.)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8310	Indeno(1,2,3-cd)pyrene	0.052	0.07	0.24	12/5/10	0.14	0.19	0.64
SW-846, 8310	Naphthalene	0.43	0.58	1.97	12/5/10	0.2	0.27	0.92
SW-846, 8310	Phenanthrene	0.025	0.03	0.11	7/2/10	0.1	0.14	0.46
SW-846, 8310	Pyrene	0.023	0.03	0.11	12/5/10	0.083	0.11	0.38

a. The MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

b. µMhos/cm.

c. Units for this method are mg/L.

d. Additional MDLs were used during the year for these compounds.

LOD = limit of detection

LOQ = limit of quantitation

MDL = method detection limit.

This page intentionally left blank.

Distribution of Printed Full Report

No. of Copies		
1	Washington State Department of Ecology	H0-57
	D. Goswami	
1	DOE Richland Operations Office	A6-38
	N. M. Bland	
1	U.S. Environmental Protection Agency	B1-46
	L. E. Gadbois	
2	CHPRC/FFS/LMSI	
	L. C. Swanson	R3-50
	M. J. Hartman	R3-50

Distribution by Postal Notification/Internet Link

Lynn Albin
Washington State Department of Health
Division of Radiation Protection
P.O. Box 47827
Olympia, WA 98504-7827
ATTN: D. McBaugh
S. VanVerst

Argonne National Laboratory,
EVS-Bldg 900
ATTN: M.M. MacDonell
9700 S. Cass Avenue
Argonne, IL 60439

M. Ault
US Ecology, Inc.
1777 Terminal Drive, Ste. A
Richland, WA 99354

T. D. Bowden
912 N. 48th Street
Seattle, WA 98103

Leo M. Bowman
Benton County Commissioner
620 Market Street
Prosser, WA 99350

Leah Buck
Wanapum People
Grant County P.U.D.
30 "C" Street S.W.
P.O. Box 878
Ephrata, WA 98823

Center for Isotope Geochemistry
Lawrence Berkeley National Laboratory
1 Cyclotron Road, Building 70A44
Berkeley, CA 94720-8 179
ATTN: J.N. Christensen
M. Conrad
J. Chasse

T. Crandell
U.S. Department of Energy
Forrestal Building, EM-22
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Confederated Tribes of the Umatilla Indian Reservation
Environmental Planning/Rights Protection
P.O. Box 638
Pendleton, OR 97801
ATTN: S. Harris
J. H. Richards

D. Crumpler
8208 W. Deschutes Place
Kennewick, WA 99336

Gary Crutchfield, City Manager
525 N. Third Ave.
Pasco, WA 99301

R. A. Danielson
Washington State Department of Health
5508 Englewood Avenue
Yakima, WA 98908

G. De Bruler
Columbia River United
P.O. Box 912
Bingen, WA 98605

J. Fox, Mayor
Richland City Council
P.O. Box 190
Richland, WA 99352

T. Friend
SAIC
3250 Port of Benton Boulevard
Richland, WA 99352

H. Gucinski, Chair
Pacific Northwest Natural Area Committee
3200 Jefferson Way
Corvallis, OR 97331

A. Haymaker
1721 Cottonwood Drive
Pasco, WA 99301

Idaho National Engineering and Environmental Laboratory
P.O. Box 1625, MS-2107
Idaho Falls, ID 83415-2107
ATTN: J.M. Hubbell

R. E. Isaacson
2106 Lee Boulevard
Richland, WA 99352

Russell Jim, Manager
Environmental Restoration/
Waste Management Program
Yakama Nation
2808 Main Street
Union Gap, WA 98903

K. Klaus
Brookhaven National Laboratory
Building 51
Upton, NY 11973

R.J. Leaumont
Lower Columbia Basin Audubon Society
9016 Sunset Terrace
Pasco, WA 99301

L. Maas
Framatome ANP Richland, Inc.
2101 Horn Rapids Rd.
Richland, WA 99352

Marie Mosley, City Manager
Kennewick City Council
P.O. Box 6108
Kennewick, WA 99336

S. McDaniel
South Columbia Basin Irrigation District
402 E Lewis Place
Pasco, WA 99301- 5642

R.G. McCain
S.M. Stoller Corporation
1100 Jadwin Ave., Ste. 300
Richland, WA 99352

Nez Perce Tribe
Environmental Restoration/Waste Management
P.O. Box 365
Lapwai, ID 83540-0365
ATTN: Gabe Bohnee
L. Lilligren
P. Sobotta

NorthWind Environmental
507 Knight Street, Ste. A
Richland, WA 99352
ATTN: Kris Ivarson, H3-21

Oregon Office of Energy
Energy Facility Siting
625 Marion Street N.E.
Salem, OR 97303
ATTN: T. M. Stoops

Oregon Office of Energy
Nuclear Safety Division
625 Marion Street N.E.
Salem, OR 97303
ATTN: Ken Niles
Dale Engstrom
Dirk Dunning

G.M. Pollett
Executive Director
Heart of America, NW
1314 56th Street NE, Ste. 100
Seattle, WA 98105

D. Postma
Bureau of Reclamation
U.S. Department of the Interior
P.O. Box 815
Ephrata, WA 98823

W. Riggsbee
6304 Collins Rd.
West Richland, WA 99353

J. A. Riley
Washington State Department of Health
P.O. Box 453
Post Falls, ID 83877-0453

P. Rogalski
City of Richland
P.O. Box 190
Richland, WA 99352

F. J. Schelling
Sandia National Laboratories
P.O. Box 5800, MS-0779
Albuquerque, NM 87185-0779

L. Seelatsee
Wanapum People
Grant County P.U.D.
30 "C" Street S.W.
P.O. Box 878
Ephrata, WA 98823

D. Sherwood
Rivers Edge Environmental
1616 Riverside Drive
West Richland, WA 99353

J. R. Schinner
11382 Canary Drive
Ijamnsville, MD 21754

M. Sully
Neptune and Company
1505 15th Street, Suite B
Los Alamos, NM 87544

Technical Services
Walla Walla College Library
104 S. College Avenue
College Place, WA 99324-1159

U.S. Department of Energy
Cloverleaf Building
19901 Germantown Road
Germantown, MD 20874-1290
ATTN: K.D. Gerdes, EM-32
D. Rowley
A. Wallo III, HS-20

U.S. Geological Survey
934 Broadway, Ste. 300
Tacoma, WA 98402
ATTN: R. Dinicola

J. VanLeer
Cascadia Community College
18345 Campus Way NE
Bothell, WA 98011

P. H. Wick
ARES Corp.
1100 Jadwin Ave., Suite 400
Richland, WA 99352

Distribution by Electronic Notification/Internet Link

Outside Organizations

H. Heacock	TRIDEC	hheacock@tridec.org
T. A. Marden	Benton County Planning Department	planning.department@co.benton.wa.us
K. Moser	Vista Engineering Technologies	moser@vistaengr.com

U.S. Environmental Protection Agency

L. Buelow	B1-46	BUELOW.LAURA@epa.gov
C.E. Cameron	B1-46	CAMERON.CRAIG@epa.gov
D.A. Faulk	B1-46	FAULK.DENNIS@epa.gov
L.E. Gadbois	B1-46	GADBOIS.LARRY@epa.gov
C. Guzzetti	B1-46	GUZZETTI.CHRISTOPHER@epa.gov
E. Laija	B1-46	LAIJA.EMERALD@epa.gov
R. Lobos	B1-46	LOBOS.ROD@epa.gov

Washington State Department of Ecology

J.M. Ayres	H0-57	jayr461@ecy.wa.gov
A.L. Boyd	H0-57	aboy461@ecy.wa.gov
J.A. Caggiano	H0-57	JCAG461@ecy.wa.gov
D. Goswami	H0-57	dgos461@ecy.wa.gov
A.D. Huckaby	H0-57	ahuc461@ecy.wa.gov
J.J. Lyon	H0-57	jlyo461@ecy.wa.gov
Z. Jackson-Maine	H0-57	zjac461@ecy.wa.gov
N.M. Menard	H0-57	nmen461@ecy.wa.gov
C.F. Pitz		chpi461@ecy.wa.gov
J.B. Price	H0-57	jpri461@ecy.wa.gov
J.A. Seiple	H0-57	jash461@ecy.wa.gov
D.G. Singleton	H0-57	dsin461@ecy.wa.gov

DOE Richland Operations Office

N. M. Bland	A5-11	naomi.bland@rl.doe.gov
B.L. Charbonneau	A6-33	briant.charboneau@rl.doe.gov
M.S. Collins	A6-38	michael.collins@rl.doe.gov
T.W. Ferns	A5-15	thomas.ferns@rl.doe.gov
B.L. Foley	A6-38	bryan.foley@rl.doe.gov
E. Glossbrenner	A3-04	ellwood.glossbrenner@rl.doe.gov
J. P. Hanson	A5-11	james.hanson@rl.doe.gov
R.D. Hildebrand	A6-38	doug.hildebrand@rl.doe.gov
C.S. Louie	A5-11	catherine.louie@rl.doe.gov
K.D. Leary	A6-38	kevin.leary@rl.doe.gov
A.C. McKarns	A5-15	tony.mckarns@rl.doe.gov

DOE Richland Operations Office (continued)

J.G. Morse	A5-11	john.morse@rl.doe.gov
F.M. Roddy	A6-39	francis.roddy@rl.doe.gov
J.P. Sands	A3-04	john.sands@rl.doe.gov
J.M. Silko	A6-38	john.silko@rl.doe.gov
G. L. Sinton	A6-38	gregory.sinton@rl.doe.gov
K.M. Thompson	A6-38	Kenneth.thompson@rl.doe.gov
A. C. Tortoso	A6-38	arlene.tortoso@rl.doe.gov
M. J. Voogd	A6-38	margo.voogd@rl.doe.gov
D.C. Ward	A5-15	

DOE Office of River Protection

R.W. Lober	H6-60	Robert_W_Lober@orp.doe.gov
C.J. Kemp	H6-60	Christopher_J_Kemp@orp.doe.gov

Eberline Federal Services

M. G. Gardner	G2-02	MGGARDNER@energysolutions.com

Freestone Environment Services

E. Garcia	erikagarcia@gofreestone.com
G. Kasza	gregkasza@gofreestone.com
B. Raidl	bobraidl@ gofreestone.com
D.K. Tyler	dantyler@gofreestone.com
M.A. Serkowski	maiserkowski@gofreestone.com

GRAM, Inc.

M.E. Caron	caron@graminc.com

Mission Support Alliance

J.J. Dorian	H7-28	John_J_Dorian@rl.gov
C. J. Perkins	H7-28	Craig_J_Perkins@rl.gov

Pacific Northwest National Laboratory

B.N. Bjornstad	K6-81	Bruce.Bjornstad@pnl.gov
R.W. Bryce	K6-75	rw.bryce@pnl.gov
J.P. Duncan	K4-35	joanne.duncan@pnl.gov
M.J. Fayer	K9-33	mike.fayer@pnl.gov
M.D. Freshley	K9-33	mark.freshley@pnl.gov
J.S. Fruchter	K6-96	john.fruchter@pnl.gov
T.J. Gilmore	K6-96	tyler.gilmore@pnl.gov
G.V. Last	K6-81	george.last@pnl.gov
T.L. Liikala	K6-75	terry.liikala@pnl.gov
G.W. Patton	K6-75	gw.patton@pnl.gov

Pacific Northwest National Laboratory (Continued)

R.E. Peterson	K6-96	Robert.Peterson@pnl.gov
R.M. Smith	K6-96	rmsmith@pnl.gov
F.A. Spane, Jr.	K6-96	frank.spane@pnl.gov
M.D. Sweeney	K6-75	mark.sweeney@pnl.gov
C.J. Thompson	K6-96	chris.thompson@pnl.gov
P.D. Thorne	K6-96	paul.thorne@pnl.gov
V.R. Vermeul	K6-96	vince.vermeul@pnl.gov
M.D. Williams	K6-96	mark.d.williams@pnl.gov
Hanford Technical Library	P8-55	

S.M. Stoller Corp

P. D. Henwood	PHENWOOD@stoller.com

S.S. Papadopulos & Associates, Inc.

M.J. Tonkin	matt@sspa.com

Washington Closure Hanford, LLC

K.A. Hadley	H4-21	kahadley@wch-rcc.com
R.J. Landon	H4-21	rjlandon@wch-rcc.com
D.A. St. John	H4-21	dastjohn@wch-rcc.com
W.S. Thompson	H4-23	wsthomps@wch-rcc.com
R.L. Weiss	H4-21	rlweiss@wch-rcc.com

Washington River Protection Solutions

D.C. Comstock	T6-04	David_C_Comstock@rl.gov
S.J. Eberlein	E6-31	Susan_J_Eberlein@rl.gov
J.G. Field	E6-31	Jim_G_Field@rl.gov
D.A. Myers	E6-31	David_A_Dave_Myers@rl.gov
H.A. Sydnor	E6-31	Harold_A_Sydnor@rl.gov
C.L. Tabor	E6-31	Cynthia_L_Tabor@rl.gov

CHPRC/FFS/LMSI

D.J. Alexander	R3-60	Debra_J_Deb_Alexander@rl.gov
M.A. Baechler	R3-60	Michael_A_Baechler@rl.gov
J.D. Baker	H3-21	Jennifer_D_Baker@rl.gov
W.F. Barrett	R4-23	William_F_Barrett@rl.gov
B.L. Becker-Khaleel	H8-45	Brenda_L_Becker-khaleel@rl.gov
F.H. Biebesheimer	R3-60	Frederick_H_Biebesheimer@rl.gov
R.L. Biggerstaff	R3-50	Richard_L_Biggerstaff@rl.gov
J.G. Blount	R3-50	Jonathan_G_Blount@rl.gov
J.V. Borghese	H3-21	Jane_V_Borghese@rl.gov
N.A. Bowles	R3-60	Nathan_Bowles@rl.gov

CHPRC/FFS/LMSI (continued)

M.E. Byrnes	R3-60	Mark_E_Byrnes@rl.gov
S.J. Champoux	R3-60	Sara_J_Champoux@rl.gov
M.J. Cherry	R3-60	Mark_J_Cherry@rl.gov
H.M. Childers	H6-08	Heather_M_Childers@rl.gov
S.F. Conley	R3-60	Scott_F_Conley@rl.gov
C.W. Connell	H8-51	Carl_W_Connell@rl.gov
A.K. Corbett	H8-75	Angela_Corbett@rl.gov
G.D. Cummins	H8-15	Gloria_D_Cummins@rl.gov
R.A. Daughety	T3-28	Rick_A_Daughety@rl.gov
R.E. Day	H8-15	Roberta_E_Day@rl.gov
D.E. Dooley	R3-60	David_E_Dooley@rl.gov
J.G. Douglas	R3-60	James_G_Jim_Douglas@rl.gov
R.S. Edrington	R3-50	Robert_S_Edrington@rl.gov
J.A. Eluskie	R3-50	James_A_Eluskie@rl.gov
D.B. Erb	R3-60	David_Erb@rl.gov
A.K. Faul	R3-50	Angela_K_Faul@rl.gov
S.L. Fitzgerald	R3-60	Scot_L_Fitzgerald@rl.gov
B.H. Ford	H8-48	Bruce_H_Ford@rl.gov
D.V. Foss	R3-60	Dyan_L_Foss@rl.gov
E.J. Freeman	R3-50	Eugene_J_Freeman@rl.gov
D.A. Gamon	R3-50	Daniel_A_Gamon@rl.gov
M.J. Hartman	R3-50	Mary_J_Hartman@rl.gov
J.G. Hogan	R3-50	James_G_Hogan@rl.gov
B.J. Howard	R3-60	Bonnie_J_Howard@rl.gov
S.L. Huggins	R3-60	Stewart_L_Huggins@rl.gov
R.K. Hulvey	X4-12	Russell_K_Russ_Hulvey@rl.gov
R. Khaleel	R3-50	Raziuddin_Khaleel@rl.gov
G.G. Kelty	R3-50	George_Kelty@rl.gov
M.L. Kemner	R3-60	Mark_L_Kemner@rl.gov
T.J. Larsen	R3-50	Theresa_J_Larsen@rl.gov
G.J. LeBaron	S2-42	Gregory_J_LeBaron@rl.gov
A.K. Lee	R3-60	Art_K_Lee@rl.gov
J.W. Lindberg	R3-50	Jon_W_Lindberg@rl.gov
S.P. Luttrell	R3-50	Stuart_P_Luttrell@rl.gov
R.O. Mahood	R3-50	Richard_O_Mahood@rl.gov
C.J. Martin	R3-50	Christopher_J_Martin@rl.gov
J.P. McDonald	R3-50	John_P_McDonald@rl.gov
W.J. McMahon	H8-51	William_J_Mcmahon@rl.gov
C.W. Miller	H8-51	Charles_W_Miller@rl.gov
A. Miskho	T4-10	Anthony_G_Miskho@rl.gov
D.L. Morgans	H8-51	Donna_L_Morgans@rl.gov
S.M. Narbutovskih	R3-50	Susan_M_Narbutovskih@rl.gov

CHPRC/FFS/LMSI (continued)

M.A. Neely	R3-60	Michael_Neely@rl.gov
C.A. Newbill	R3-50	Chris_A_Newbill@rl.gov
S.W. Petersen	R3-50	Scott_W_Petersen@rl.gov
R. Popielarczyk	R3-60	R_S_Bob_Popielarczyk@rl.gov
J.A. Rediker	H8-15	Julie_A_Rediker@rl.gov
J.T. Rieger	H8-51	JoAnne_T_Rieger@rl.gov
V.J. Rohay	H8-15	Virginia_J_Rohay@rl.gov
R.E. Sage	R3-50	Robert_E_Sage@rl.gov
J.L. Smoot	R3-50	John_L_Smoot@rl.gov
L.C. Swanson	R3-50	L_Craig_Swanson@rl.gov
W.R. Thackaberry	R3-60	W_R_Bill_Thackaberry@rl.gov
G.S. Thomas	R3-50	Greg_S_Thomas@rl.gov
K.R. Thompson	R3-19	Kathleen_R_Thompson@rl.gov
S.J. Trent	R3-50	Stephen_J_Trent@rl.gov
L.D. Walker	R3-60	Leslie_D_Walker@rl.gov
K.S. Waters-Husted	R3-50	Karen_S_Waters-husted@rl.gov
W.D. Webber	H8-51	William_D_Webber@rl.gov
D.C. Weekes	R3-50	David_C_Weekes@rl.gov
C.D. Wittreich	H8-15	Curtis_D_Wittreich@rl.gov
B.A. Williams	H8-51	Bruce_A_Williams@rl.gov
J.D. Williams	H8-43	Janice_D_Williams@rl.gov
W.D. Williams	H8-75	Wallace_D_Williams@rl.gov
J.A. Winterhalder	R3-60	John_A_Winterhalder@rl.gov
S. H. Worley	R3-60	Scott_H_Worley@rl.gov
M. I. Wood	H8-51	Marcus_I_Wood@rl.gov
C. S. Wright	R3-60	Christopher_S_Wright@rl.gov