U.S. Department of Energy
Hanford Site

23-SGD-000511 February 13, 2023

Mr. David Bowen, Program Manager
Nuclear Waste Program
Washington State Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

Mr. Roberto Armijo, Remedial Project Manager
Hanford Project Office
U.S. Environmental Protection Agency, Region 10
825 Jadwin Avenue, Suite 210
Richland, Washington 99352

Dear Addressees:

GROUNDWATER MONITORING PLAN FOR THE 100-D SOUTH SUBAREA REBOUND STUDY (100-HR-3 OPERABLE UNIT), DOE/RL-2021-23-ADD2, DRAFT A

This letter transmits the U.S. Department of Energy's (DOE) Groundwater Monitoring Plan for the 100-D South Subarea Rebound Study (100-HR-3 Operable Unit), DOE/RL-2021-23-ADD2, Draft A, for review. DOE has worked collaboratively with Alicia Boyd of Ecology. Your review and comments are requested within 45 days of receipt of this letter, per the Hanford Federal Facility Agreement and Consent Order.

If you have any questions please contact me, or you may contact Ellwood Glossbrenner, River Corridor Technical Lead, Soil and Groundwater Division, on (509) 376-5828.

Sincerely,

NAOMI JASCHKE Digitally signed by NAOMI JASCHKE
Date: 2023.02.13 06:03:03 -08'00'

Naomi M. Jaschke, Director (Acting)
Soil and Groundwater Division

SGD:ETG

cc: See page 2

cc w/attach:
J. Bell, NPT
A. L. Boyd, Ecology
A. Buck, Wanapum
L. C. Buelow, EPA
A. S. Carlson, Ecology
J. Catrell, HAB
L. Contreras, YN
D. R. Einan, EPA
R. E. Fox, CPCCo
D. Goswani, Ecology
N. M. Menard, Ecology
M. Murphy, CTUIR
S. N. Schleif, Ecology
K. R. Welsch, Ecology
M. Woods, ODOE
Administrative Record (100-HR-3)
Environmental Portal
HAB Facilitation (HAB@slind.net)

cc w/o attach:
S. L. Brasher, HMIS
L. C. Huntoon, CPCCo
M. J. Tuner, HMIS

Attachment
23-SGD-000511

Groundwater Monitoring Plan for the 100-D South Subarea Rebound Study 100-HR-3 Operable Unit
DOE/RL-2021-23 ADD2, Draft A

(41 pages including cover page)

DOE/RL-2021-23-ADD2
Draft A

Groundwater Monitoring Plan for the 100-D South Subarea Rebound Study (100-HR-3 Operable Unit)

Date Published
January 2023

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
By Janis Aardal at 1:13 pm, Jan 19, 2023

Release Approval Date

Printed in the United States of America

Signature Sheet

Title: *Groundwater Monitoring Plan for the 100-D South Subarea Rebound Study (100-HR-3 Operable Unit)*

Print Name U.S. Department of Energy, Richland Operations Office	Signature	Date

Print Name U.S. Environmental Protection Agency	Signature	Date

Print Name Washington State Department of Ecology	Signature	Date

This page intentionally left blank.

Contents

Figures

Tables

Terms

AWLN	Automated Water-Level Network
bgs	below ground surface
DOE-RL	U.S. Department of Energy, Richland Operations Office
Ecology	Washington State Department of Ecology
Hf	Hanford formation
OU	operable unit
P&T	pump and treat
PRZ	periodically rewetted zone
PSQ	principal study question
RD/RA	remedial design/remedial action
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RUM	Ringold Formation upper mud unit
Rwie	Ringold Formation member of Wooded Island – unit E
SAP	sampling and analysis plan

This page intentionally left blank.

1 Introduction

This sampling and analysis plan (SAP) addendum presents the groundwater monitoring plan and test design for an area-specific hexavalent chromium (Cr(VI)) rebound study within the 100-D South Subarea in the 100-HR-3 Operable Unit (OU). As discussed in DOE/RL-2021-23, *Rebound Studies Parent Sampling and Analysis Plan for the 100-HR-3 Operable Unit, Hanford* (hereinafter referred to as the rebound studies parent SAP), the parent document will act as the main body of information, while this SAP addendum provides the area-specific detail associated with implementing a rebound study within the unconfined aquifer. This addendum will implement the guidance of the quality assurance documents that are specifically referenced in Chapter 2 of the rebound studies parent SAP (DOE/RL-2021-23).

A rebound study involves the evaluation of contaminant concentrations as well as hydraulic and hydrochemical changes under ambient aquifer conditions (no active pump and treat [P&T] remediation) for a duration of time. Section 4.2 of DOE/RL-2017-13, *Remedial Design/Remedial Action Work Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2 and 100-HR-3 Operable Units* (hereinafter referred to as the 100-D/H Remedial Design/Remedial Action [RD/RA] Work Plan), identifies rebound testing as part of the Phase 1 final remedial action operations. The rebound testing for the 100-D South Subarea will be focused on gathering data to assess the remedial action identified in EPA et al., 2018, *Record of Decision Hanford 100 Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (hereinafter referred to as the 100-D/H Record of Decision [ROD]), specifically to monitor plume areas with persistent concentrations of Cr(VI) and further investigate continuing secondary sources present in the vadose zone and the periodically rewetted zone (PRZ).

Secondary sources can undermine P&T effectiveness and prolong aquifer cleanup times. Rebound testing provides a mechanism to evaluate concentration trends and can help identify opportunities to enhance operations through remedial process optimization such that the remedial action objectives identified in the 100-D/H ROD will be met. The rebound study at the 100-D South Subarea will occur within the boundary shown in Figure 1. This study boundary has been modified from the original 100-D South Subarea boundary presented in the rebound studies parent SAP. The study area boundary was expanded to ensure that potential plume migration is adequately captured.

Previous evaluations have identified multiple suspect secondary source areas associated with former sodium dichromate handling facilities and releases in this subarea (SGW-58416, *Persistent Source Investigation at 100-D Area*, and SGW-64372, *100-D/H Continuing Hexavalent Chromium Source Evaluation*). Waste sites associated with sodium dichromate in this subarea include the 100-D-30/100-104, 100-D-56:2, and 100-D-100 waste sites.

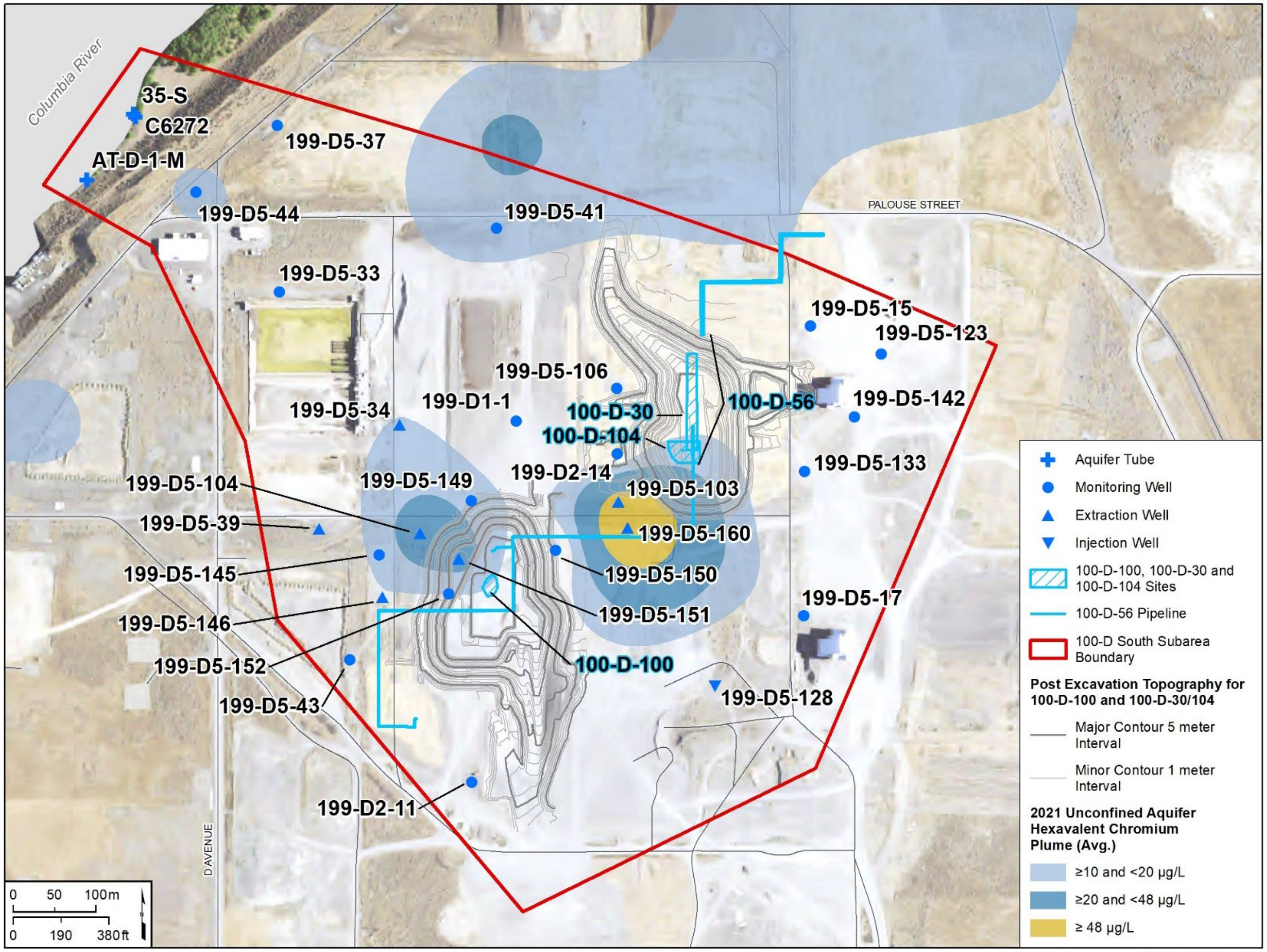


Figure 1. 100-D South Subarea Boundary with Unconfined Aquifer Monitoring Locations

1.1 Project Scope and Objectives

This rebound study SAP addendum uses the principal study questions (PSQs) and the associated data needs developed in the rebound studies parent SAP (DOE/RL-2021-23) as they apply to the 100-D South Subarea. Performance monitoring will continue as described in Addendum 1 of the 100-D/H RD/RA Work Plan (DOE/RL-2017-13-ADD1, *Groundwater Monitoring Sampling and Analysis Plan for the 100-HR-3 Groundwater Operable Unit*). Any performance monitoring samples will be co-sampled with the rebound study samples and would not be duplicative. Performance monitoring will continue as per DOE/RL-2017-13-ADD1 outside of active rebound study areas. The 100-D South Subarea rebound study objectives include the following:

- Provide a mechanism to evaluate concentration trends and enhance P&T operations.
- Determine how the unconfined aquifer changes (hydraulically and hydrochemically) during shutdown of P&T operations.
- Collect additional data to evaluate secondary sources associated with former sodium dichromate facilities in the subarea (SGW-58416 and SGW-64372).
- Evaluate attenuation rates for Cr(VI) under ambient groundwater flow conditions.

The 100-D/H RD/RA Work Plan (DOE/RL-2017-13) identifies that data will be evaluated to quantify how the remedy is affecting the plume dynamics and local conditions at individual wells. Conditions and trends can be interpreted to support remedial process optimization and to assess the potential for continuing sources, as appropriate. Ongoing contaminant releases are associated with elevated chromium in the sediments near the bottom of the vadose zone and within the PRZ left in place after waste site remediation. Water table fluctuations may cause chromium leaching to groundwater, constituting a secondary source. Secondary sources can undermine P&T effectiveness and prolong aquifer cleanup times (DOE/RL-2017-13).

The duration and timing of this subarea rebound study will adhere to the rebound timing regime discussed in Section 1.1, “Project Scope and Objectives,” of the rebound studies parent SAP (DOE/RL-2021-23).

2 Site Background

The 100-HR-3 OU includes the groundwater in the 100-D/H Area. The groundwater was contaminated by releases from facilities and waste sites in the 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 OUs during past operations at the D, DR, and H Reactors. Operations at these reactors resulted in soil and groundwater contamination. Reactor operations and descriptions of contaminant releases are provided in the 100-D/H remedial investigation/feasibility study (RI/FS) report (DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*; hereinafter referred to as the 100-D/H RI/FS).

2.1 100-D-100 Waste Site, 100-D-56 Waste Site, and 100-D-30/104 Waste Site

100-D-100 Waste Site. The 100-D-100 waste site addresses an area of stained soil discovered near a former railcar unloading station. Excavation of the 100-D-100 waste site extended into the groundwater, which was encountered at a depth of 26 m (85 ft) below ground surface (bgs) (WSRF 2014-025, *Remaining Sites Verification Package for the 100-D-100, Stained Soil Near the 183-DR Railroad Track Waste Site*). The post-excavation contours following the remediation of the 100-D-100 waste site are shown in Figure 1.

After excavation was completed, elevated levels of Cr(VI) remained at the interface of the vadose zone with the unconfined aquifer. Therefore, an investigation was initiated to determine the distribution and potential persistence of Cr(VI) within the aquifer and the aquifer sediment. Four temporary boreholes were drilled at the bottom of the 100-D-100 excavation to assess the vertical and horizontal distribution of Cr(VI) remaining in the aquifer and the aquifer sediment. Based upon the results of this investigation, it was decided to remove approximately 3 m (10 ft) of aquifer sediment from below the elevation of the seasonal low water table (DOE/RL-2018-47, *100-D/H Area Interim Remedial Action Report*). The base of the 100-D-100 waste site excavation is located approximately 700 m (2,300 ft) to the southeast of the Columbia River.

Soil samples collected from the northwestern sidewall during the excavation of 100-D-100 had elevated Cr(VI) (SGW-58416). The sidewall area was not excavated due to the depth and size of the excavation. The extent of the contamination is not known but is assumed to be limited based on the small area of elevated groundwater contamination in the area (SGW-64372). The 100-D-100 site is located just upgradient from well 199-D-151 (Figure 2). Elevated Cr(VI) in groundwater at well 199-D5-151 correlates to groundwater fluctuations (SGW-64372).

Additional soil samples were also collected on the northeastern sidewall near the former 100-D-56:2 pipeline. Analytical results at this location had detected levels of Cr(VI), with concentrations collected above the capillary fringe having a maximum value of 6.47 mg/kg Cr(VI) (SGW-58416). Visually stained soil was noted in that area, indicating the concentration may have been higher than indicated by the results. The sidewall area was not excavated. The area of contamination, while not well defined, is likely to be contributing to the western portion of the Cr(VI) plume (and concentrations at well 199-D5-104) based on the groundwater flow direction in that area (SGW-64372). The 100-D-100 site is located upgradient of well 199-D5-104 (Figure 2).

Trend plots for wells 199-D5-104 and 199-D5-151 are presented in Figure 3 and Figure 4, respectively.

100-D-56 Pipeline. The 100-D-56 pipeline included abandoned 7.6 cm (3 in.) diameter underground supply lines that transported sodium silicate and sodium dichromate liquids between the 108-D, 190-D, 185-D, and 189-D facilities; the 100-D-12 Sodium Dichromate Pumping Station; and the 183-DR Building as reported in the Waste Information Data System. Sodium silicate and sodium dichromate were stored, mixed, and used in the D/DR Area water treatment plants. The 100-D-56 sodium dichromate and sodium silicate supply lines exited the 185-D/190-D Building complex running parallel to each other. One set of two pipelines (100-D-56:1) traveled north and east to the 108-D Building, and a second set (100-D-56:2) traveled south and west to the vicinity of the 100-D-12 Sodium Dichromate Pumping Station. The sodium dichromate line continued west from the vicinity of the 100-D-12 Sodium Dichromate Pumping Station and then turned south to the 183-DR Building.

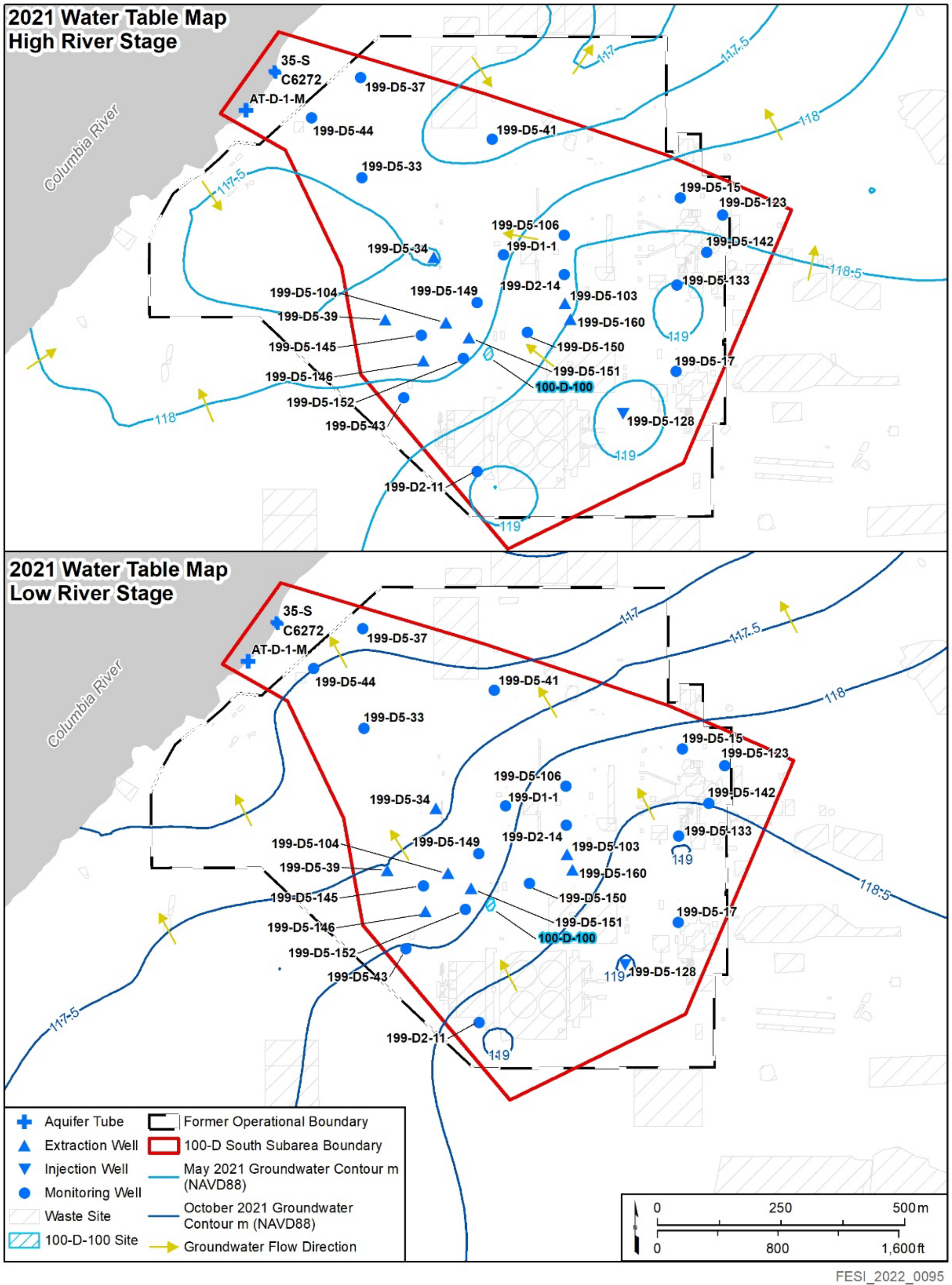
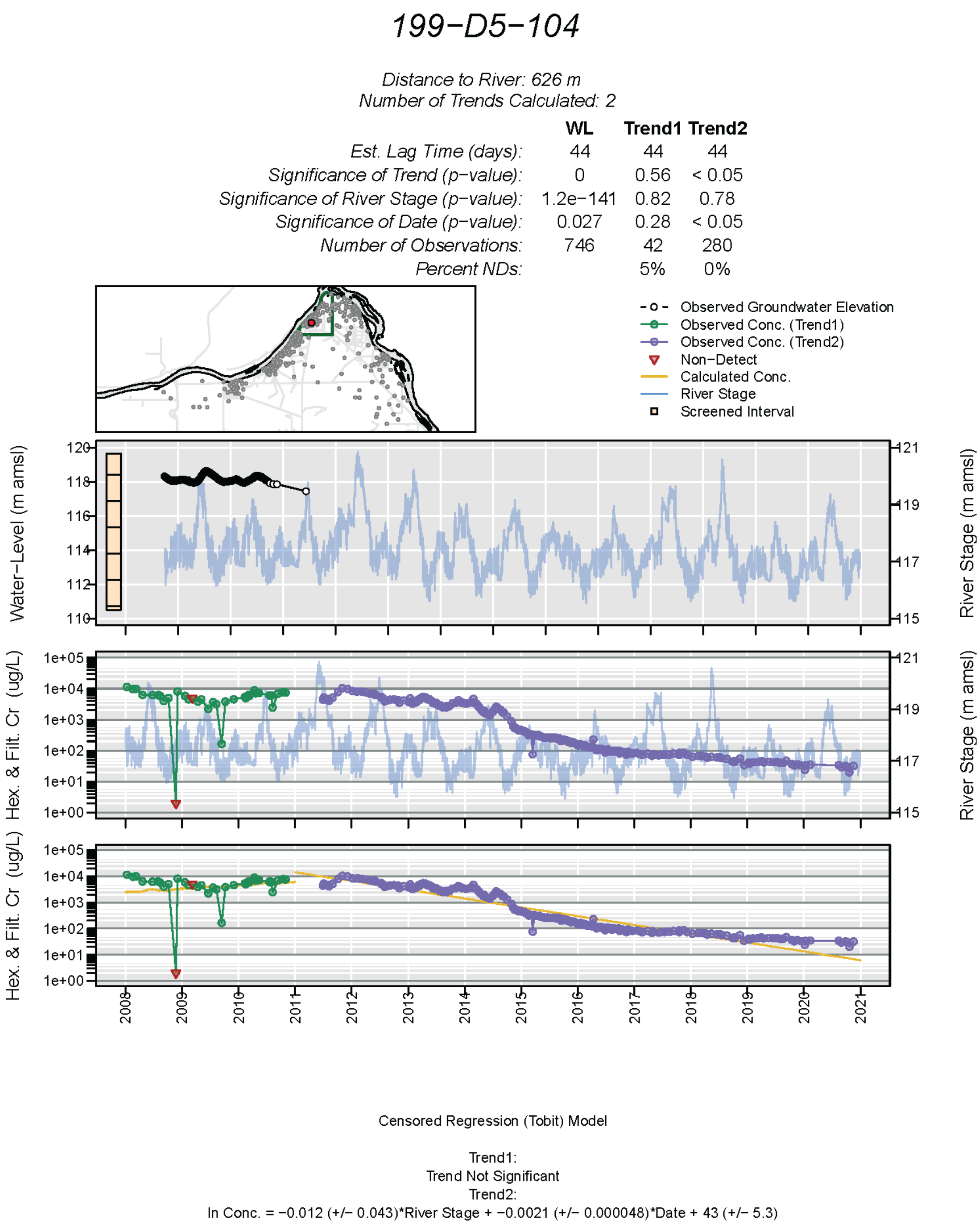
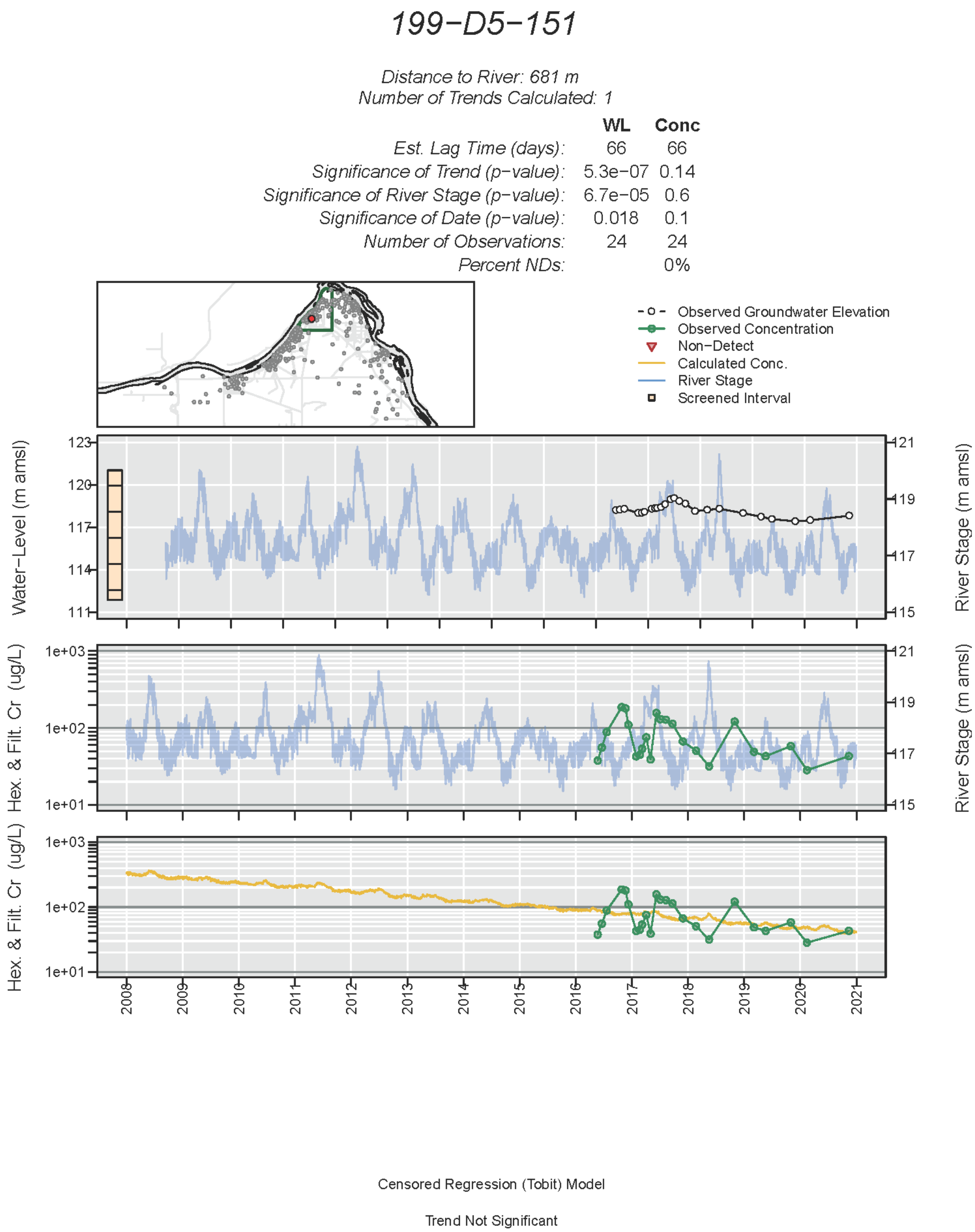


Figure 2. 100-D South Subarea Water Table, High and Low River Stages



Reference: Appendix D of *Description of Groundwater Calculations and Assessments for the Calendar Year 2020 (CY2020) 100 Areas Pump-and Treat Report.*

Figure 3. Trend Plots for Well 199-D5-104



Reference: Appendix D of *Description of Groundwater Calculations and Assessments for the Calendar Year 2020 (CY2020) 100 Areas Pump-and Treat Report.*

Figure 4. Trend Plots for Well 199-D5-151

A continuing Cr(VI) source is known to be present along the former 100-D-56 sodium dichromate supply pipeline that was remediated in 2006, of which 100-D-56:2 is the southern segment. As shown in Figure 1, later remediation of the 100-D-100 waste site extended over a portion of the 100-D-56:2 remediation footprint. The secondary source is likely located east of the 100-D-100 excavation footprint, based on the following lines of evidence:

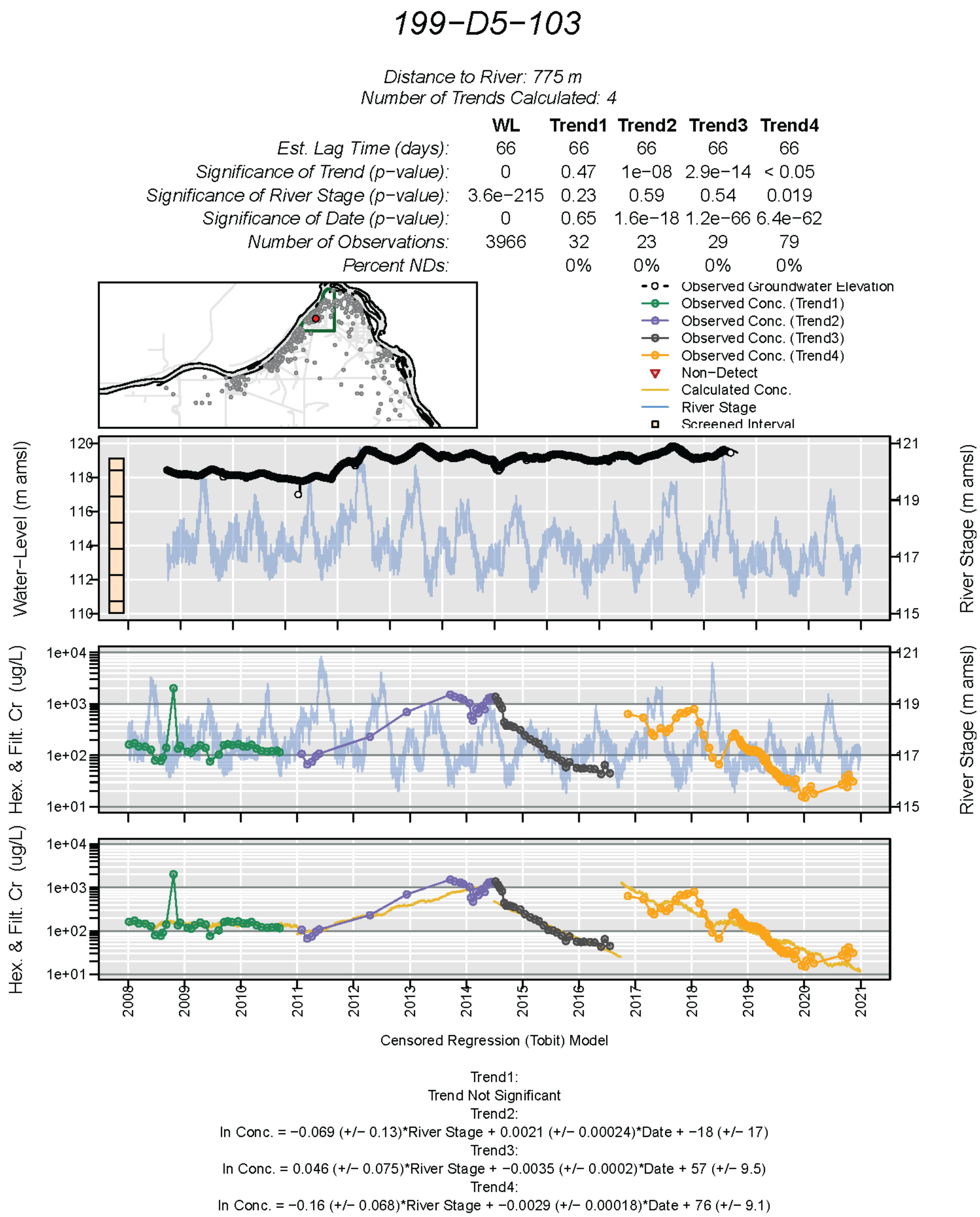
- During remediation activities in 2006, the pipeline was breached twice and Cr(VI)-contaminated liquid was spilled on the ground. Based on the documentation (WSRF 2009-016, *Remaining Sites Verification Package for the 100-D-56:2, South Portion of the 100-D-56 Sodium Dichromate Underground Supply Lines Waste Site*), at least one breach of the pipeline during remediation appears to have been located approximately 80 m (262 ft) east of where well 199-D5-160 now exists (Figure 1).
- Persistent Cr(VI) concentrations are noted in groundwater near the former pipeline at wells 199-D5-103 and 199-D5-160 (Figure 1). Previous contaminant concentrations in well 199-D5-103 also show the influences from changes of the P&T system configuration and river-stage fluctuations.

The exact location of source material is not well defined, and there may be more than one area contributing to the elevated Cr(VI) at well 199-D5-103. The pipeline is a likely candidate for the Cr(VI) detected in samples from well 199-D5-103; however, residual material may be present after the 100-D-104 waste site excavation was completed (SGW-64372).

Trend plots for wells 199-D5-103 and 199-D5-160 are presented in Figure 5 and Figure 6, respectively.

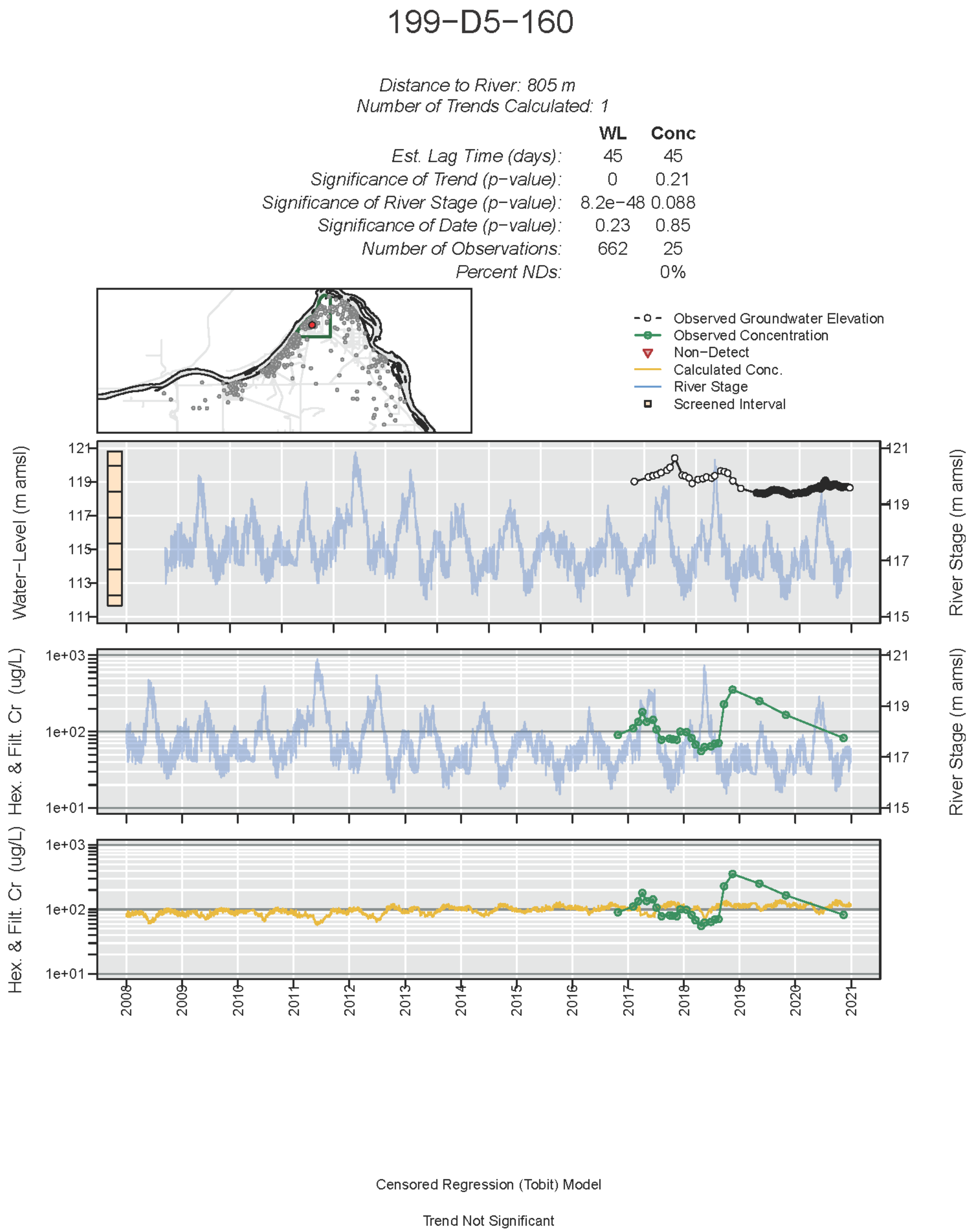
100-D-30 and 100-D-104 Waste Sites. The 100-D-30 waste site consisted of residual sodium dichromate-contaminated soil and concrete rubble that remained after demolition of the 190-D Complex, in particular, the pipe trench and sump that was present in the 185-D Building. During demolition of the 185-D and the 189-D Buildings, sodium dichromate contamination was found in the sub-grade structures. In 1996, shortly after demolition and backfill of the site, yellow soil discoloration was observed at the surface. This residual contamination was found in the soil along the entire length of the 185-D pipe trench.

Initial remediation of the 100-D-30 waste site was performed from June 2006 through May 2007 to a maximum depth of approximately 4.6 m (15 ft) bgs, with sample results indicating remediation was complete. However, investigation boreholes drilled in 2009 identified residual Cr(VI) present in soil below the 185-D sump at a depth of approximately 8 m (26.2 ft) bgs. Therefore, additional remediation was performed from October 2011 through March 2012 to a depth of 15.2 m (50 ft) bgs (WSRF 2009-049/2014-119, *Remaining Sites Verification Package for the 100-D-30, Sodium Dichromate Soil Contamination Waste Site and the 100-D-104, Unplanned Release Near 185-D Sodium Dichromate Storage Tank and Acid Neutralization French Drain Waste Site*).



Reference: Appendix D of *Description of Groundwater Calculations and Assessments for the Calendar Year 2020 (CY2020) 100 Areas Pump-and Treat Report.*

Figure 5. Trend Plots for Well 199-D5-103



Reference: Appendix D of *Description of Groundwater Calculations and Assessments for the Calendar Year 2020 (CY2020) 100 Areas Pump-and Treat Report*.

Figure 6. Trend Plots for Well 199-D5-160

The 100-D-104 waste site, an unplanned release near the 185-D Sodium Dichromate Storage Tank and Acid Neutralization French Drain, consisted of residual sodium dichromate-contaminated soil that was discovered March 4, 2008, at a depth of approximately 4.6 m (15 ft) after the initial remediation of the 100-D-30 waste site. Cr(VI) and sulfate contamination found in stained soil at this depth correlated to the location of a former acid neutralization french drain, acid storage tanks, and a sodium dichromate storage tank. The remediation footprints for 100-D-30 and 100-D-104 are illustrated in Figure 1.

Remediation of the 100-D-104 waste site was initiated on October 2011 and proceeded through March 2012 with the remediation of the 100-D-30 waste site to a depth of 8 m (26.2 ft) bgs. Cr(VI) contamination exceeding cleanup criteria remained present at this depth, identifying the need for remediation to continue. Consequently, soil removal at 100-D-30/104 continued from February 2013 through March 2014 to a depth of approximately 24 m (78.7 ft) bgs with the base of the excavation at an elevation of approximately 119 m (390.4 ft) above mean sea level, the estimated elevation of groundwater (WSRF 2009-049/2014-119).

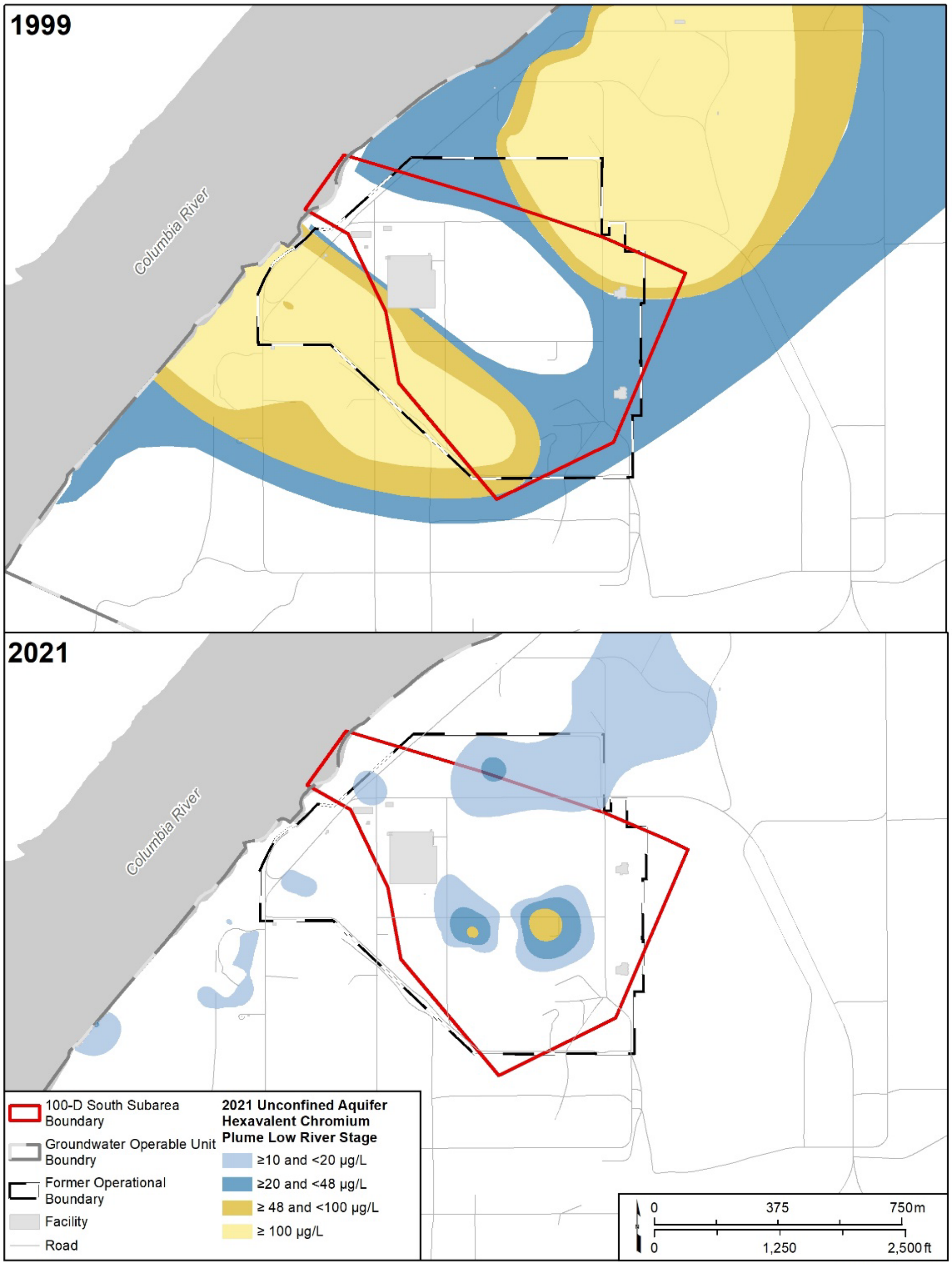
Two soil grab samples from the 100-D-30/104 sidewall, located above the water table, indicated that leachable Cr(VI) was present in the excavation footprint. The conclusion was that leaching of Cr(VI) from the vadose zone soil in this area needs to be considered as a potential long-term source for groundwater contamination (SGW-58416).

2.2 Unconfined Aquifer Cr(VI) Plumes

The Cr(VI) groundwater plumes within the 100-D South Subarea in 1999 (2 years after the first P&T system began operating) and 2021 are shown in Figure 7. The Cr(VI) contamination within the 100-D Area has been reduced to several discontinuous plumes through removal of source material and ongoing P&T groundwater remediation. The spatial extent and concentrations have been reduced in the 100-D South Subarea; however, two plumes continue to exhibit groundwater concentrations near or above 48 µg/L. Figure 1 shows a more detailed view of the 2021 Cr(VI) plumes located within the 100-D South Subarea.

Three Cr(VI) plumes with reported concentrations greater than or equal to 20 µg/L remain in the former 100-D operational boundary: two plumes within the vicinity of the 100-D-100 waste site footprint and the 100-D-56:2 pipeline footprint (within the study area) and a plume in the northern portion of the former 100-D operational boundary, which extends to the north beyond the 100-D South Subarea boundary. There are also small, lower concentration (less than 20 µg/L) plumes to the southwest of the 100-D South Subarea.

Plumes, defined for the purposes of this study, are areas of Cr(VI) concentration exceeding 10 µg/L. The 100-D South Subarea includes the two plumes within the vicinity of the 100-D-100 waste site and the 100-D-56:2 pipeline, a small portion of the northern plume, and one small, lower concentration plume centered on well 199-D5-44 near the shoreline (Figure 1).



Note: Modified from Figure 4-5 of DOE/RL-2021-51, *Hanford Site Groundwater Monitoring Report for 2021*.

Figure 7. Comparison of the Cr(VI) Groundwater Plumes in 1999 (Early in Interim Action Period) and 2021 (During Remedial Action)

The 100-D South Subarea is the subject of this rebound study for the following reasons:

- Cr(VI) concentrations in the unconfined aquifer are persisting at concentrations near or above cleanup levels near areas with potentially persistent and continuing sources.
- Cr(VI) concentrations at wells farther away from the continuing sources have shown generally decreasing trends.
- An extensive network of wells is in place for monitoring the rebound effect.
- An adequate extraction and injection well network is available for contingent protection of the Columbia River.
- Ongoing modeling efforts need additional information to implement a more rigorous representation of continuing sources, which will allow for informed predictions on cleanup timeframes and potential adjustments to the current remedial design

Data from some monitoring wells in the 100-D South Subarea continue to report concentrations near or above the 100-D/H ROD cleanup levels. The cleanup levels established in the 100-D/H ROD reflect the aquatic standards where groundwater discharges to surface water (10 µg/L for Cr(VI)) and WAC 173-340, "Model Toxics Control Act—Cleanup" (MTCA), for Cr(VI) (48 µg/L). The highest Cr(VI) concentrations in the 100-D South Subarea are observed at the 199-D5-103, 199-D5-104, 199-D5-151, and 199-D5-160 groundwater monitoring wells (Figure 8). These four wells are located within the two Cr(VI) plumes located near the 100-D-100 waste site footprint and the 100-D-56:2 pipeline footprint (well locations are shown on Figure 1).

Wells 199-D5-103 and 199-D5-160 are in the center of the highest concentration plume in the 100-D South Subarea (Figure 1) and both wells have exceeded 48 µg/L in the last 5 years. Well 199-D5-103 has most recently operated as an extraction well where Cr(VI) concentrations have trended downward in the past 5 years from a high of 800 µg/L in 2018 to 23.6 µg/L in 2022. Cr(VI) concentrations at well 199-D5-160 have consistently exceeded 48 µg/L in the past 5 years, with a maximum concentration of 360 µg/L reported in 2018. Data from 2021 indicate an increase in concentration from 74.5 µg/L to 117 µg/L. Well 199-D5-160 was converted to an extraction well in November 2022.

Wells 199-D5-104 and 199-D5-151 are in the lower concentration plume just to the west of the highest concentration plume (Figure 1). Well 199-D5-104 has most recently operated as an extraction well where Cr(VI) concentrations have trended downward in the past 5 years from a high of 65 µg/L in 2018 to 24.8 µg/L in 2022. Cr(VI) concentrations at well 199-D5-151 have consistently exceeded 48 µg/L, with a maximum concentration of 110 µg/L reported in 2018 and a concentration of 58 µg/L most recently reported in 2021. Well 199-D5-151 was converted to an extraction well in November 2022.

Well 199-D5-44, which is located just inside the former 100-D operational boundary near the Columbia River (Figure 1), is exhibiting a recent upward trend of Cr(VI). Concentrations have trended upward from a low of 8.1 µg/L in 2020 to 20 µg/L most recently reported in 2021. Higher concentrations recently reported are generally during the low river stage months, which correspond to higher hydraulic gradients and less impact of the river on dilution of the groundwater near the river. Trend plots for well 199-D5-44 are presented in Appendix D of ECF-HANFORD-21-0030.

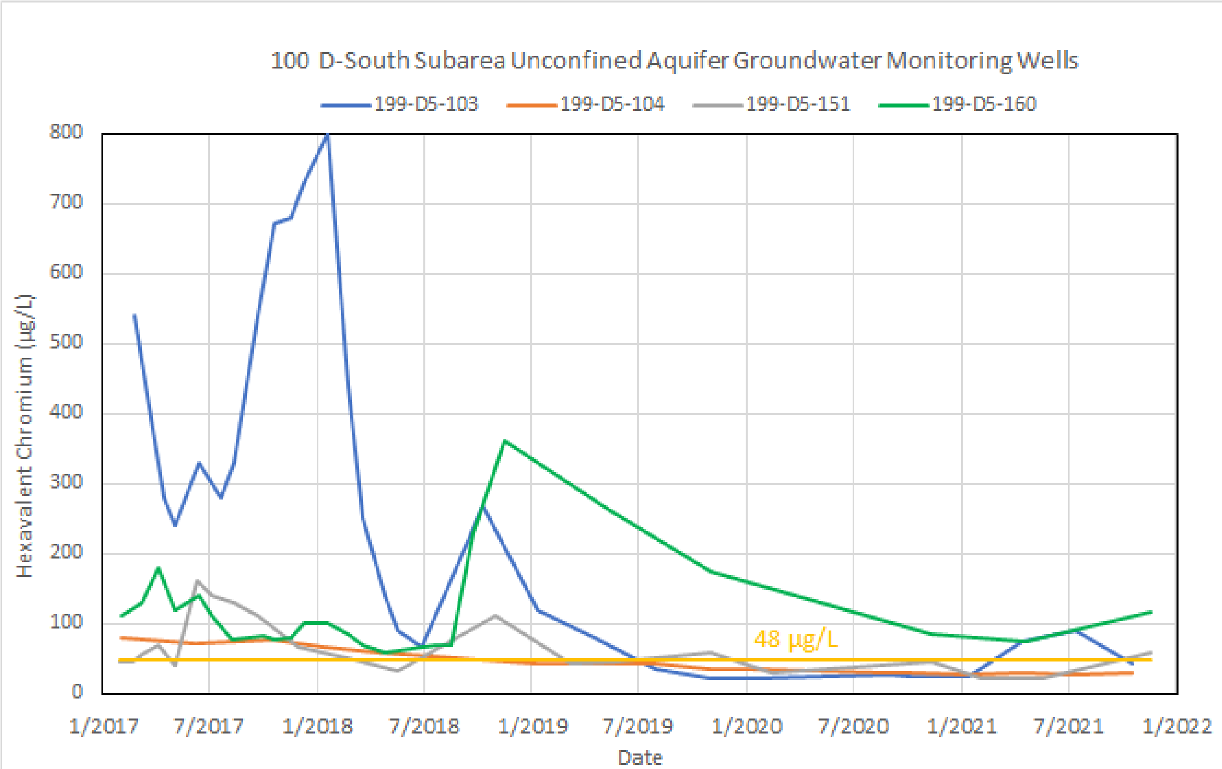


Figure 8. Five-Year Cr(VI) Concentration Trends for Select Monitoring Wells Within the 100-D South Subarea

2.3 Groundwater Pump and Treat Activities

In response to Cr(VI) contamination, groundwater remediation activities were initiated in 1997 with installation of a small P&T system, HR3, under an interim action ROD (EPA/ROD/R10-96/134, *Record of Decision for the USDOE Hanford 100 Area 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington*) and in accordance DOE/RL-96-84, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*. A second P&T system, DR5, was installed in 2004 to address contamination in the southern portion of the 100-HR-3 groundwater OU. The two original systems were replaced with the larger DX and HX P&T systems in 2010 and 2011, respectively. The DX and HX P&T systems have been effective in reducing Cr(VI) concentrations in groundwater and improving hydraulic containment to protect the Columbia River from continuing releases of Cr(VI).

The final remedy in the 100-D/H ROD (EPA et al., 2018) selected continued use, expansion, and optimization of the DX and HX P&T systems for groundwater treatment. The 100-D/H ROD listed cleanup levels of 10 µg/L for Cr(VI) where groundwater discharges to surface water and 48 µg/L inland. Figure 3 identifies the 100-D South Subarea groundwater monitoring wells with Cr(VI) concentrations greater than 48 µg/L in the past 5 years. With the issuance of the 100-D/H ROD, a new 100-D/H RD/RA Work Plan (DOE/RL-2017-13) was prepared. The 100-D/H RD/RA Work Plan was developed to implement the remedial actions requirements in the ROD.

2.4 Site Geology/Hydrogeology

A detailed description of the 100-D/H Area hydrogeologic conditions is included in the 100-D/H RI/FS (DOE/RL-2010-95) and the rebound studies parent SAP (DOE/RL-2021-23). The primary stratigraphic units controlling groundwater flow in the unconfined aquifer in the 100-D South Subarea, from shallowest to deepest, are as follows:

- Hanford formation (Hf)
- Ringold Formation member of Wooded Island – unit E (Rwie)
- Ringold Formation upper mud unit (RUM)

The Hf is the dominant material in the vadose zone (unsaturated zone) in the 100-D Area, where only gravel and sand dominated facies are present (SGW-58416). The Hf in the 100-D South Subarea ranges in thickness from 11.5 to 27.5 m (38 to 90 ft) in the 100-D South Subarea (CP-64995, *Geoframework Model of the Hanford Site 100 Area*, and CP-65222, *Site-Specific Geoframework Model of the 100-HR-3 Intra-RUM Semi-Confined Aquifer System*). The unconfined aquifer in the 100-D Area is primarily within the Rwie, which is overlain by the Hf. The PRZ straddles the Rwie and the Hf contact. The Rwie is a denser, compact, and well-graded formation consisting of fluvial matrix supported by gravels and sands with intercalated fine- to coarse-grained sand and silt layers (DOE/RL-2010-95) and is relatively less transmissive than the overlying Hf. The Rwie in the 100-D South Subarea ranges in thickness from 5.4 to 18.3 m (17.9 to 60 ft) (CP-64995 and CP-65222). The thickness of the unconfined aquifer is determined by the difference between the water table elevation and the surface of the RUM, which forms the base of the unconfined aquifer in the 100-D South Subarea. The unconfined aquifer in the 100-D South Subarea ranges in thickness from 2.4 to 10.2 m (7.9 ft to 33.4 ft) (CP-64995 and CP-65222) and varies at individual locations due to seasonal fluctuations in the Columbia River stage.

The RUM is dominated by a fine-grained paleosol consisting of silt- and clay-rich sediment with a low hydraulic conductivity relative to that of the Hf and the Rwie. Within the RUM, thin sand-to-gravel layers form zones with variable hydraulic conductivities that range from low to high and form confined or semiconfined aquifers. The uppermost confined or semiconfined aquifer is the first water-bearing unit of the RUM, bounded by the silt and clay of the RUM at the top and by either a continuation of the RUM or the Ringold Formation member of Wooded Island – lower mud unit below (DOE/RL-2021-23).

2.4.1 Groundwater Flow and Seasonal Impacts to Cr(VI) Concentrations

Groundwater in the 100-D South Subarea unconfined aquifer typically flows to the north-northwest, towards the Columbia River, with hydraulic gradients shifting to the north-northeast near the shoreline, usually between May and August, reflecting the impact of high river stage conditions (Figure 2). The operation of the P&T wells induces localized changes in flow directions, with converging and diverging flow effects near the extraction and injection wells, respectively, depending on flow rates, well location, and aquifer properties. The Columbia River functions as a discharge boundary for the shallow unconfined aquifer beneath the 100-D South Subarea. Hydraulic gradients are generally lower during the high river stage when compared to low river conditions. The flow directions and gradients experienced during the low and high river stages have a greater effect on contaminant transport than during transitional periods. The high and low river stages, which typically last a few months, affect the groundwater flow near the Columbia River and the effects extend inland, with the distance depending on hydrogeologic characteristics of the aquifer and the height and duration of the river stage. The period of highest river stage is generally from May through June, and lowest river stage is generally observed from September through October.

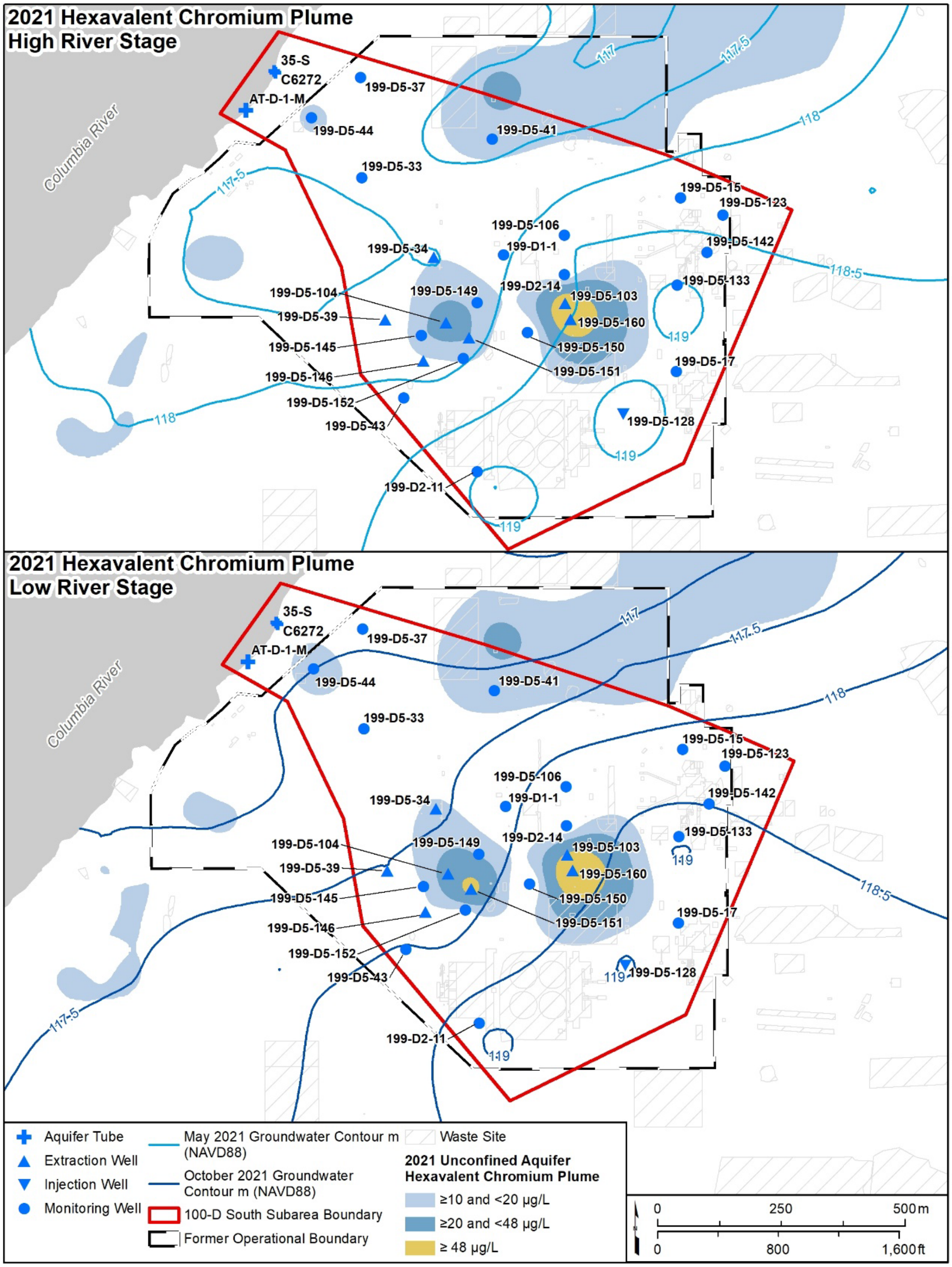
Response of the Cr(VI) plume in the unconfined aquifer within the 100-D South Subarea to the change in river stage has been tracked and is reported as part of the Hanford Site annual groundwater report (e.g., DOE/RL-2021-51 *Hanford Site Groundwater Monitoring Report for 2021*). The dimensions and changes in plume geometry in the unconfined aquifer with changes in river stage are well understood under pumping conditions. The effect of the river stage on plume configuration (e.g., extent) has lessened over time. Plume changes in the unconfined aquifer near the 100-D South Subarea are now primarily controlled by modifications to the P&T system during the year, with the natural gradient dominating in those areas with few or no extraction or injection wells (DOE/RL-2021-51). The plume boundaries are generally farther inland from the Columbia River during high river stage in comparison to low river stage. The greatest flux of contaminants towards the river occurs as the river transitions from seasonal high to seasonal low river levels within the 100-D South Subarea. Cr(VI) plumes and water levels measured in 2021 are shown under high and low river stage conditions (Figure 9). DOE/RL-2021-51 indicates that these trends persisted into 2021.

Additional detail on the seasonal impacts to Cr(VI) concentrations at the 100-D Area is included in the 100-D/H RD/RA Work Plan (DOE/RL-2017-13).

Temporal parameters of the 100-D South Subarea rebound study involve the timing, frequency, and duration of measurements and observations. Timing is affected by Columbia River stage seasonal variation and the associated changes in groundwater flow direction and flow velocity. The rebound study approach focuses on more frequent sampling in areas where there is potential presence of continuing sources and at extraction wells to capture short-term changes in concentrations due to ceased well operation, and regular (monthly) sampling frequency elsewhere (with a few exceptions) to ensure that plume dynamics under ambient groundwater flow conditions are captured. This rebound study is anticipated to last at least a full river stage cycle (i.e., 12 months) to ensure adequate understanding of contaminant migration due to river stage and seasonal transition periods in the absence of P&T. This duration may be extended if additional data are needed to establish concentration trends or support interpretation of unexpected sample results.

2.4.2 Saturated Thickness at the 100-D South Subarea

The monitoring wells within the study area have between 1.9 m to 9.9 m (6.2 ft to 32.4 ft) of screened water column (Table 1). Wells within the 100-D South Subarea are expected to have sufficient groundwater year-round to facilitate sampling using a submersible pump; however, as discussed in Section 3.3 of the rebound studies parent SAP (DOE/RL-2021-23), pumps can be removed and manual bailers or other low-flow sampling techniques may be used, as needed. At the aquifer tubes within the 100-D South Subarea, seasonal fluctuations in water level can make sample collection difficult due to either low or high river stage. The aquifer tubes may be above the water level during the low river stage or submerged and therefore inaccessible during the high river stage.



FESI_2022_0095

Figure 9. 2021 Cr(VI) Concentrations near 100-D South Subarea at High and Low River Stage

Table 1. Monitoring Well Locations in the 100-D South Subarea

Well Name	Well ID	Screened Water Column Length* (m [ft])
199-D1-1	C9935	6.3 (20.6)
199-D2-11	C5394	8.4 (27.7)
199-D2-14	C9718	6.8 (22.2)
199-D5-106	C5511	5.9 (19.4)
199-D5-123	C6387	9.9 (32.4)
199-D5-133	C7621	6.9 (22.8)
199-D5-142	C7857	2.0 (6.6)
199-D5-145	C8725	7.1 (23.3)
199-D5-149	C8729	5.8 (19.0)
199-D5-15	A4572	3.7 (12.0)
199-D5-150	C8730	5.6 (18.3)
199-D5-152	C8732	5.8 (19.1)
199-D5-17	A4574	4.2 (13.9)
199-D5-33	C4186	4.2 (13.7)
199-D5-37	B8745	1.9 (6.2)
199-D5-41	B8751	4.0 (13.0)
199-D5-43	B8753	5.7 (18.6)
199-D5-44	B8754	1.9 (6.3)

Notes: Well screen data are from the Environmental Dashboard Application (https://ehs.hanford.gov/eda/#/eda/Report/Details/64), queried on 11/17/2022.

Water-Level Extraction data are from the Environmental Dashboard Application (https://ehs.hanford.gov/eda/#/eda/Report/Details/4), queried on 11/17/2022.

*Screened Water Column Length = Standard Screen Bottom Depth – Depth to Water.

ID = identification

3 Data Quality Objectives

Groundwater data and water-level measurements are needed to further evaluate continuing sources of Cr(VI) in the 100-D South Subarea to determine whether ongoing remediation of groundwater can be modified to enhance Cr(VI) recovery within the unconfined aquifer and to determine if further soil remediation is needed in addition to the P&T.

Key issues to be addressed include the following:

- Determining progress/status towards 100-D/H Area ROD (EPA et al., 2018) cleanup levels
- Measuring time equivalent water levels for estimating changes in groundwater hydraulic gradient and flow paths

- Evaluating hydraulic and hydrochemical changes in the unconfined aquifer during shutdown
- Evaluating groundwater hydrochemistry data (e.g., specific conductance, pH) to help determine river stage effects on plume migration and Cr(VI) concentrations
- Determining how Cr(VI) concentrations rebound in the absence of P&T
- Considering possible additional actions to address continuing sources in the PRZ and vadose zone

Table 1-1 in the rebound studies parent SAP (DOE/RL-2021-23) identifies the PSQs that were evaluated and used to develop the monitoring data needs for the 100-D South Subarea. All PSQs are applicable to this subarea except for PSQs 2, 3, and 7. PSQs 2 and 7 are not included because the 100-D South Subarea is still in Phase 1 (final remedial action operations) and PSQ 3 is not included because potential continuing sources are spatially distributed and water levels are expected to vary within the screened interval of most wells. It is therefore not practical or beneficial to fit any number of monitoring wells with equipment for depth-discrete sampling. Table 2 identifies the PSQs applicable to the 100-D North Subarea.

Table 2. Principal Study Questions

Principal Study Question		Data Need
PSQ 1	What is the magnitude and spatial extent of Cr(VI) concentration rebound in the absence of P&T?	Increased frequency of Cr(VI) concentration measurements in groundwater in the absence of P&T operations.
PSQ 4	How is the aquifer within the rebound study areas affected hydraulically following shutdown of P&T?	Manual water-level measurements collected during sampling, automated water-level measurements from established AWLN wells, and water-level measurements from existing sensors in P&T extraction and injection wells.
PSQ 5	Has groundwater hydrochemistry reverted to ambient conditions?*	Increased frequency of measurements of major ions (calcium, nitrate, chloride, magnesium, potassium, sodium, and sulfate), alkalinity, specific conductance, and other field parameters in groundwater in the absence of P&T operations. Manual water-level measurements collected during sampling, AWLNs from established AWLN wells, and water-level measurements from existing sensors in P&T extraction and injection wells.
PSQ 6	What are the seasonal effects in groundwater Cr(VI) concentrations within the rebound study area due to river stage?	Increased frequency of Cr(VI) concentration measurements in groundwater, in the absence of P&T operations, and during high-, low-, and intermediate river stages. Increased sampling frequency of major ions (calcium, nitrate, chloride, magnesium, potassium, sodium, and sulfate), alkalinity, specific conductance, and other field parameters in groundwater in the absence of P&T operations. Measured water levels in the unconfined aquifer, in the absence of P&T operations, during high and low river stages.

*Ambient conditions occur when groundwater flows along natural pathways and resumes a stable hydrochemical state in the absence of P&T.

AWLN = Automated Water-Level Network

Cr(VI) = hexavalent chromium

P&T = pump and treat

PSQ = principal study question

All wells identified in Table 1 are applicable to PSQ 1 and PSQs 4 through 6. The alternative outcomes, which will determine actions to be completed based on the information collected, are included in Table A-1 of the rebound studies parent SAP (DOE/RL-2021-23).

Three types of data are required to effectively monitor the progress of the rebound study.

- Water-level measurements: manual, Automated Water-Level Network (AWLN), and other pressure sensor measurements
- Analytical data: Cr(VI), total chromium, and major ion hydrochemistry (calcium, chloride, magnesium, nitrate, potassium, sodium, and sulfate) concentration measurements
- Field parameters: specific conductance, pH, turbidity, dissolved oxygen, and temperature

4 Rebound Study Design

Information to be obtained during the rebound study includes water-level measurements, Cr(VI) and total chromium concentration measurements, major ion hydrochemistry, and field parameters (e.g., turbidity and dissolved oxygen). A 1-year study is planned to be initiated in spring of 2023. Rebound study evaluations will be ongoing during the year to determine if any changes to the rebound study design are required. Such changes will be agreed upon in collaboration between the DOE-RL and Ecology Project Leads. An evaluation will also be made to determine whether sufficient data have been collected to answer the PSQs applicable to the 100-D South Subarea at the end of the 12-month study period. If data gaps or uncertainties are identified at the end of the first year, then the DOE-RL and Ecology Project Leads will make a collaborative decision on whether extending the rebound study would provide data needed to address the data gaps and resolve the applicable PSQs. Concentration data at shoreline monitoring locations will be evaluated to determine whether plume migration and potential discharges to the river are caused due to shutdown of the P&T system. These evaluations will be based on comparing measured concentrations to the aquatic standard. However, associated concentration trends will also be evaluated to assess whether potential exceedances near the shoreline are not significant and should be considered acceptable for the duration of the test. In all cases, sufficient contingency measures (restart of P&T system) are in place to prevent further contaminant discharges to the river.

4.1 Monitoring Well Network

For this rebound study, groundwater monitoring frequency is being increased in areas where there is potential presence of continuing sources and at extraction wells to capture short-term changes in concentrations due to ceased well operation, and regular (monthly) sampling frequency elsewhere (with a few exceptions) to ensure that plume dynamics under ambient groundwater flow conditions are captured. Groundwater wells are identified as “inland” or “near-river” (Table 3) based on proximity to the river and the presence or absence of downgradient wells. The biweekly sampling frequency will continue for 2 months (four sampling events) and then continue with monthly sampling for the remainder of the study. Sampling frequencies may be increased at any time to address any unexpected conditions (e.g., rapidly and continuously changing concentration trends or plume migration to locations of currently proposed lower frequency). The 100-HR-3 OU Lead, in consultation with DOE-RL and Ecology Project Leads, will determine if additional sampling is needed.

Table 3 and Figure 10 provides the sampling locations during the 100-D South Subarea rebound study. The seven extraction wells and three injection wells that will be turned off for the duration of the study are shown in Figure 11.

4.2 Synchronous Water-Level Measurements

Time equivalent water-level measurements are essential for accurate hydraulic gradient and groundwater flow path estimation. Use of the AWLN ensures synchronous measurements. In addition, pressure sensors in the 100-D South Subarea injection and extraction wells will be queried to be synchronized to AWLN water-level measurements. The AWLN wells can be equipped to measure specific conductance in addition to water levels. This data may be collected opportunistically (it is not required by the rebound studies parent SAP [DOE/RL-2021-23]) to observe rapid changes in the hydrochemistry for the duration of the rebound study.

The locations of AWLN wells and P&T wells with pressure sensors are shown in Figure 12and listed in Table 3.

4.3 Groundwater Sampling

Table 3 summarizes the measurements to be collected and the frequencies that will be applied based on the identified PSQs. Quality assurance and quality control standards for sampling and analysis will be followed per the rebound studies parent SAP (DOE/RL-2021-23).

This page intentionally left blank.

Table 3. Summary of Sample Design and Availability of Water-Level Sensors in the 100-D South Subarea

Well Name	Well ID	Well Type	Designation	Status of Water-Level Sensor	Groundwater Constituents and Properties[a]																	
					Hexavalent Chromium (F)	Chloride (UF)	Fluoride (UF)	Nitrate (UF)	Phosphate (UF)	Sulfate (UF)	Calcium (F)	Magnesium (F)	Potassium (F)	Sodium (F)	Total chromium (F)	Alkalinity (UF)	Dissolved Oxygen	pH	Specific Conductance	Temperature	Turbidity	Water Level
AT-D-1-M	C4306	Aquifer Tube	Near-river	N/A	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	DS	DS	DS	DS	DS	DS
C6272	C6273	Aquifer Tube	Near-river	N/A	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	DS	DS	DS	DS	DS	DS
35-S	B8255	Aquifer Tube	Near-river	N/A	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	M[b]	DS	DS	DS	DS	DS	DS
199-D1-1	C9935	Monitoring	Inland	No sensor data[c]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D2-11	C5394	Monitoring	Inland	Currently in AWLN[d]	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	DS	DS	DS	DS	DS	DS
199-D2-14	C9718	Monitoring	Inland	No sensor data[c]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-103	C5399	Extraction	Inland	Sensor data available[e]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-104	C5400	Extraction	Inland	Sensor data available[e]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-106	C5511	Monitoring	Inland	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-123	C6387	Monitoring	Inland	No sensor data[c]	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	DS	DS	DS	DS	DS	DS
199-D5-128	C7612	Injection	Inland	Sensor data available[e]	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	DS	DS	DS	DS	DS	DS
199-D5-133	C7621	Monitoring	Inland	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-142	C7857	Monitoring	Inland	No sensor data[c]	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	DS	DS	DS	DS	DS	DS
199-D5-145	C8725	Monitoring	Inland	No sensor data[c]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-146	C8726	Extraction	Inland	Sensor data available[e]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-149	C8729	Monitoring	Inland	No sensor data[c]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-15	A4572	Monitoring	Inland	No sensor data[c]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-150	C8730	Monitoring	Inland	No sensor data[c]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-151	C8731	Extraction	Inland	Sensor data available[e]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-152	C8732	Monitoring	Inland	No sensor data[c]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-160	C9542	Extraction	Inland	Sensor data available[e]	BW/M	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	BW	DS	DS	DS	DS	DS	DS
199-D5-17	A4574	Monitoring	Inland	Currently in AWLN[d]	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	DS	DS	DS	DS	DS	DS
199-D5-33	C4186	Monitoring	Inland	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-34	C4187	Extraction	Inland	Sensor data available[e]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS

Table 3. Summary of Sample Design and Availability of Water-Level Sensors in the 100-D South Subarea

Well Name	Well ID	Well Type	Designation	Status of Water-Level Sensor	Groundwater Constituents and Properties[a]																	
					Hexavalent Chromium (F)	Chloride (UF)	Fluoride (UF)	Nitrate (UF)	Phosphate (UF)	Sulfate (UF)	Calcium (F)	Magnesium (F)	Potassium (F)	Sodium (F)	Total chromium (F)	Alkalinity (UF)	Dissolved Oxygen	pH	Specific Conductance	Temperature	Turbidity	Water Level
199-D5-37	B8745	Monitoring	Near-river	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-39	B8748	Extraction	Inland	Sensor data available[e]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-41	B8751	Monitoring	Inland	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-43	B8753	Monitoring	Inland	Currently in AWLN[d]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS
199-D5-44	B8754	Monitoring	Near-river	No sensor data[c]	M	M	M	M	M	M	M	M	M	M	M	M	DS	DS	DS	DS	DS	DS

Note: Based on Section A3.2 of the rebound studies parent SAP (DOE/RL-2021-23, *Rebound Studies Parent Sampling and Analysis Plan for the 100-HR-3 Operable Unit, Hanford*), this rebound study is assumed to last up to a full river stage cycle (i.e., 12 months) to ensure adequate understanding of contaminant migration as a result of river stage variation.

a. Identified constituents will be analyzed using the methods specified in Table 2-3 in the rebound studies parent SAP (DOE/RL-2021-23).

b. Water-level data from sensors used to monitor groundwater levels during active P&T operations will be left in place during the rebound study. Water-level data from these sensors can be used to supplement the monitoring network where AWLN stations are not already installed.

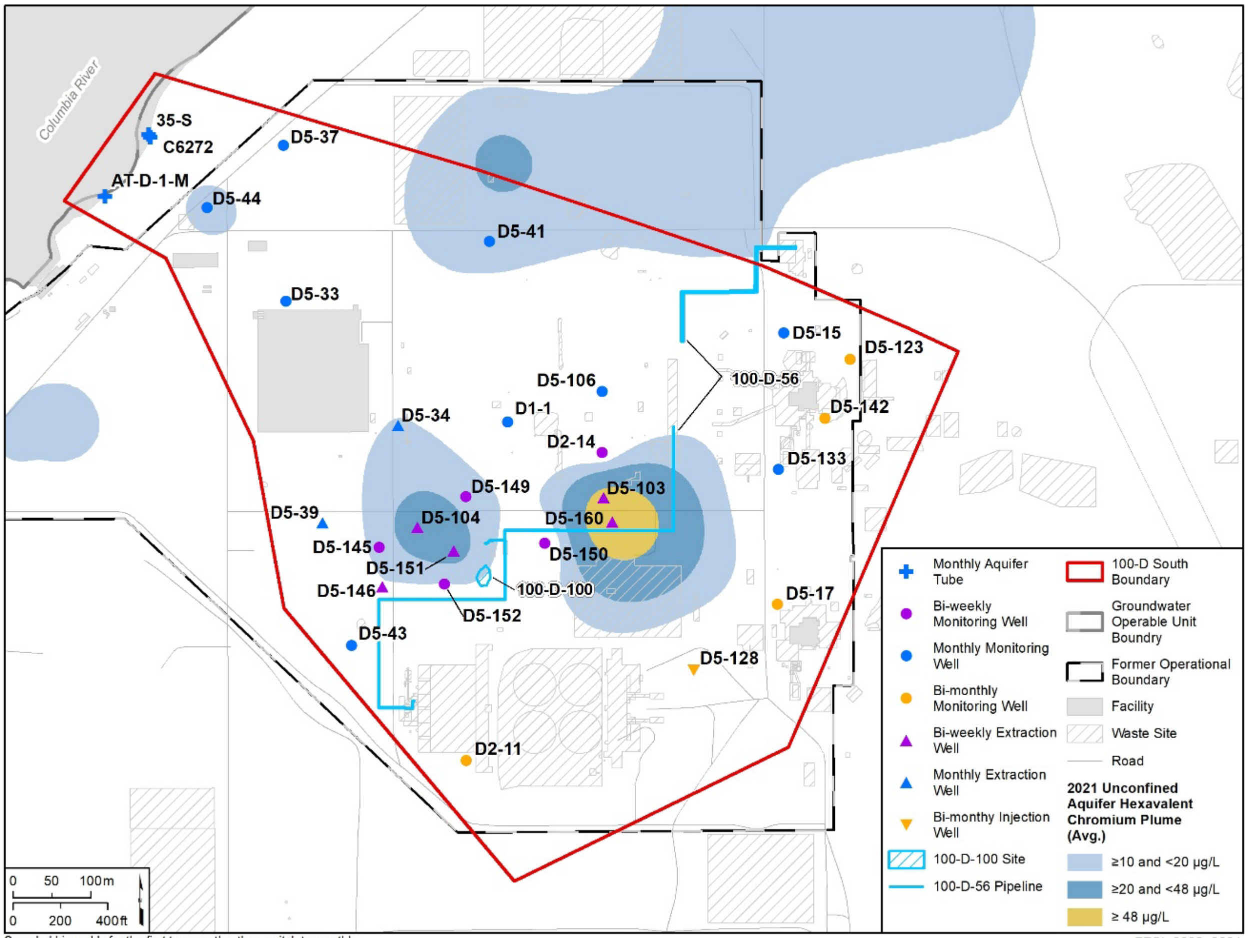
c. The well is not in the AWLN nor does it have a sensor installed. Only manual water-level measurements collected during well sample events will be available at this location.

d. Identified wells are equipped with AWLN transducers that will continue to operate during the rebound study at an hourly frequency.

e. Sampling of aquifer tubes will be done monthly as river levels permit.

AWLN = Automated Water-Level Network
BM = bimonthly, constituent will be sampled every other month
BW/M = biweekly, constituent will be sampled biweekly for the first 2 months then on a monthly basis for the remainder of the study
DS = during sampling
F = filtered
ID = identification
M = monthly; constituent will be sampled monthly
N/A = not applicable
P&T = pump and treat
SAP = sampling and analysis plan
UF = unfiltered

1



Sampled bi-weekly for the first two months, then switch to monthly.

FESI_2022_0091

Figure 10. Near-River and Inland 100-D South Subarea Sampling Locations

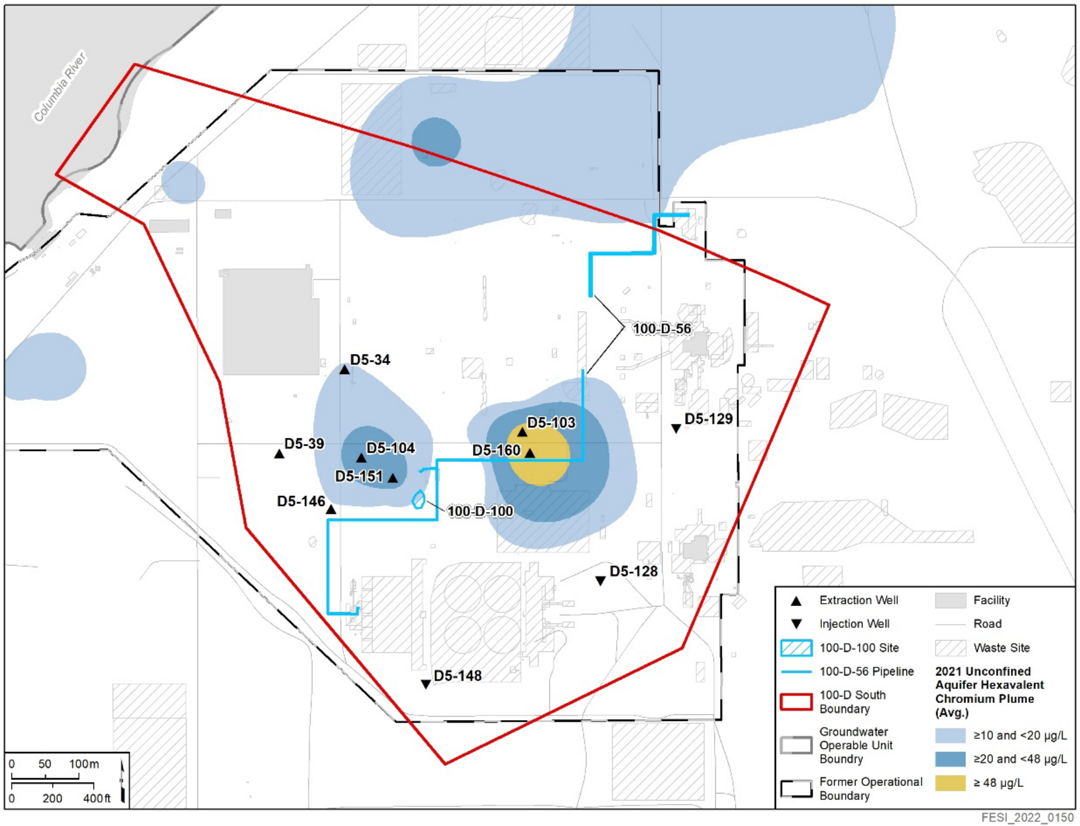


Figure 11. Injection and Extraction Wells in 100-D South Subarea to Be Turned Off for Duration of Study

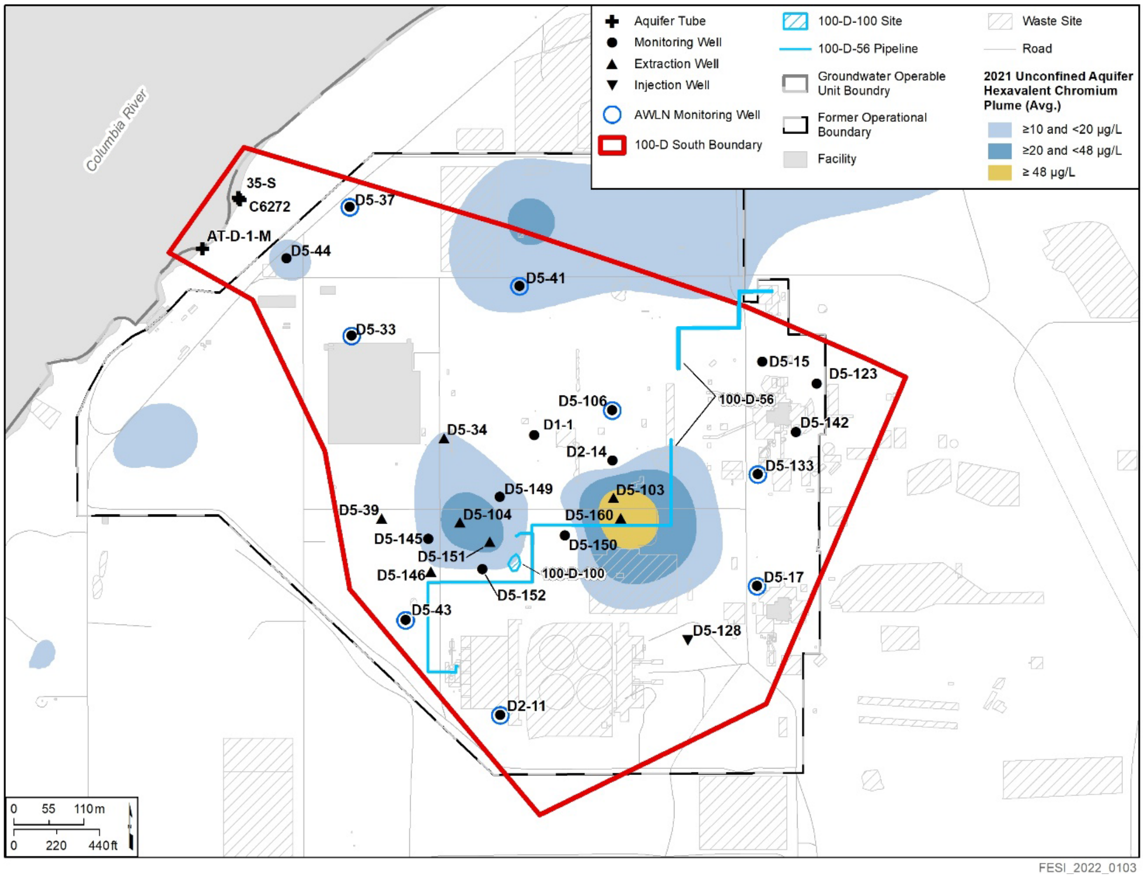


Figure 12. AWLN Wells and P&T Wells with Pressure Sensors

5 Data Evaluation and Reporting

This chapter discusses the evaluation and interpretation of data and reporting the results.

5.1 Data Review

Data review and verification are discussed in Section 2.4.1 of the rebound studies parent SAP (DOE/RL-2021-23). In general, measurement data will be reviewed as they are received and will be verified through assessment against data quality objectives identified in Appendix A of the rebound studies parent SAP. Corrective actions and alternative outcomes will be reviewed and implemented as indicated based on the data review.

5.2 Statistical Evaluation

The primary objective of this 100-D South Subarea-specific rebound study is (1) to detect and quantify changes in Cr(VI) concentrations in unconfined aquifer groundwater that are attributed to the shutdown of P&T systems and (2) to assess remedy performance and potential impacts from continuing sources. Collected Cr(VI) data will be evaluated using appropriate statistical techniques, as discussed below. Measured Cr(VI) concentrations will be compared to the aquifer cleanup standards using the standard and trend tests.

A trend test, as described below, is used to identify sampled locations that exhibit upward, downward, insignificant, or indeterminate changes in concentrations over time. Concentration data will be compared to river stage to determine if concentrations exhibit a relationship to river stage, and if a relationship exists, estimate the lag time between observed changes in river stage and observed concentration changes in the well. The relationship between chemistry and river stage is defined as follows (SGW-58883, *Methodology for the Calculation of Concentration Trends, Means, and Confidence Limits for Performance and Attainment Monitoring*, provides more detail on the basis for this calculation):

$$\ln(C_i) = \alpha - \beta t_i + \beta_1 x_i \qquad \textbf{(Eq. 1)}$$

where:

C	=	a fitted concentration (µg/L)
t	=	the time difference between a particular (daily-average) concentration and the first concentration of the dataset (days)
x	=	the observed river stage (m)
α, β, and β_1	=	fitting parameters corresponding to the equation intercept, date coefficient, and river-stage coefficient, respectively; they are assumed to be constant and are estimated using regression.

Equation 1 reduces to a simple regression over time, shown in Equation 2, if (a) no correlation is determined between water levels in the well and river stage, or (b) the well is a pumping well:

$$\ln(C_i) = \alpha - \beta t_i \qquad \textbf{(Eq. 2)}$$

A censored regression (Tobit) model will be used to estimate the parameters (the basis for use of the Tobit censored regression method is detailed in SGW-58883). The Tobit model estimates linear relationships when there are left- or right-censored data (nondetects are left-censored data) in the dependent variable. When all data are quantified (i.e., no nondetects), the Tobit model yields the same parameter estimates as Ordinary Least Squares regression. The trend test will result in two (or more) slope (trend) estimates and corresponding regression parameter standard errors, with at least one prior to and one (or more) following system shutdown. Trend test calculations aim to determine whether a statistically significant change in concentration trends is observed when the P&T system is shut down.

A regression is calculated if (a) eight or more daily-average datapoints are available and (b) less than 50% of those datapoints are nondetects. The minimum number of datapoints will become available in 6 months or more, depending on sampling frequency. For example, eight datapoints will have been collected after 6 months for wells with a maximum of 2 months of biweekly sampling, followed by monthly sampling. For wells with monthly sampling frequency, the corresponding timeframe will be 8 months. For periods or wells with insufficient data to perform the trend test, qualitative evaluation of the concentration time-series will be performed to determine whether there is evidence for changes in concentration trends at the monitoring location.

This statistical approach has been routinely implemented at the Hanford Site, as part of the annual summary reports for P&T operations in the River Corridor OUs (e.g., DOE/RL-2020-61, *Calendar Year 2020 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*).

In addition to the implementation of the trend test for determining whether there is a statistically significant trend after the P&T system shutdown, a Mann-Whitney U Test should also be performed to evaluate whether concentrations after the P&T system shutdown are statistically different from those prior to shutdown. The Mann-Whitney U Test (also referred to as the Wilcoxon rank-sum test) is a nonparametric test that evaluates whether two independent sets of samples are derived from the same population. The null hypothesis for this test is that the two sets of samples are indeed derived from the same population. As a nonparametric test, the Mann-Whitney U Test addresses the relative magnitude between samples by transforming the sample measurements into ranks. Calculations for this test should use the fitted concentrations calculated using Equation 1 or 2.

5.3 Interpretation

Data from measurements and observations will be used to interpret groundwater conditions in the rebound study area. Interpretive techniques include the following:

- **Hydrographs**: Graph water levels versus time to determine decreases and increases and seasonal or fluctuations in groundwater levels.
- **Hydraulic gradients**: Rose diagrams to evaluate groundwater flow patterns and their impact on plume migration.
- **Water table maps**: Use water table elevations from multiple wells to construct contour maps and estimate flow directions. Groundwater flow is assumed to be perpendicular to the equal potential lines on the maps.
- **Plume maps**: Map distributions of chemical constituent concentrations in the aquifer to determine the extent of contamination. Changes in plume distribution over time assist in determining plume movement and direction of groundwater flow.
- **Trend plots**: Graphs of concentrations of constituents versus time in relation to river stage fluctuations and graphs of regression-based fitted concentrations and associated statistical trend to determine the significance of observed concentrations.
- **Mann-Whitney box plots**: Box plots population quartiles and test statistics (U, p, Z values) to determine whether concentrations before and after shutdown are significantly different.

Trend plots, Mann-Whitney test results, hydrographs, hydraulic gradient rose diagrams, water table maps, and plume maps will be reviewed in tandem to assess if and to what extent observed changes in concentrations relate to changes in water level or groundwater flow directions as a result of the P&T system shutdown.

5.4 Reporting and Notification

Results of the rebound studies will be discussed with DOE-RL and Ecology at least monthly. Monitoring location concentrations will be evaluated during these discussions, and a collaborative decision will be made regarding any potential need to modify the rebound study. Specifically, plume maps, water-level maps, and concentration trend plots will be prepared and presented to DOE-RL and Ecology as the basis for these discussions.

Following the 100-D South Subarea rebound study, a technical report will be prepared that describes the study and test conditions, summarizes data review and evaluations, and includes recommendations for the remedial action.

6 References

CP-64995, 2021, *Geoframework Model of the Hanford Site 100 Area*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-18528.

CP-65222, 2022, *Site-Specific Geoframework Model of the 100-HR-3 Intra-RUM Semi-Confined Aquifer System*, Rev. 0, Central Plateau Cleanup Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-19177.

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. Available at: http://pdw.hanford.gov/arpir/pdf.cfm?accession=D196246917.

DOE/RL-2010-95, 2014, *Remedial Investigation/Feasibility Study for the 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. Available at:
https://pdw.hanford.gov/document/0083383H.
https://pdw.hanford.gov/document/0083382H.
https://pdw.hanford.gov/document/0083381H.
https://pdw.hanford.gov/document/0083380H.

DOE/RL-2017-13, 2021, *Remedial Design/Remedial Action Work Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units,* Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-18373.

DOE/RL-2017-13-ADD1, 2021, *Groundwater Monitoring Sampling and Analysis Plan for the 100-HR-3 Groundwater Operable Unit,* Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-14920.

DOE/RL-2018-47, 2018, *100-D/H Area Interim Remedial Action Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-01144.

DOE/RL-2020-61, 2021, *Calendar Year 2020 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation,* Rev.0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-17526.

DOE/RL-2021-23, 2022, *Rebound Studies Parent Sampling and Analysis Plan for the 100-HR-3 Operable Unit, Hanford*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-20067.

DOE/RL-2021-51, 2022, *Hanford Site Groundwater Monitoring Report for 2021*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://www.hanford.gov/files.cfm/DOE-RL-2021-51_R0_Clean.pdf.

ECF-HANFORD-21-0030, 2021, *Description of Groundwater Calculations and Assessments for the Calendar Year 2020 (CY2020) 100 Areas Pump-and Treat Report*, Rev. 0, Central Plateau Cleanup Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-182356.

EPA/ROD/R10-96/134, 1996, *Record of Decision for the USDOE Hanford 100 Area 100-HR-3 and 100-KR-4 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. Available at: https://pdw.hanford.gov/document/D196097243.

EPA, Ecology, and DOE, 2018, *Record of Decision Hanford 100 Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland, Washington. Available at: https://pdw.hanford.gov/document/0065047H.

SGW-58416, 2015, *Persistent Source Investigation at 100-D Area,* Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0082018H.

SGW-58883, 2015, *Methodology for the Calculation of Concentration Trends, Means, and Confidence Limits for Performance and Attainment Monitoring,* Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0079695H.

SGW-64372, 2020, *100-D/H Continuing Hexavalent Chromium Source Evaluation,* Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03918.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

173-340-410, "Compliance Monitoring Requirements."

WSRF 2009-016, 2011, *Remaining Sites Verification Package for the 100-D-56:2, South Portion of the 100-D-56 Sodium Dichromate Underground Supply Lines Waste Site*, Rev. 0, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0093379.

WSRF 2009-049/2014-119, 2015, *Remaining Sites Verification Package for the 100-D-30, Sodium Dichromate Soil Contamination Waste Site and the 100-D-104, Unplanned Release Near 185-D Sodium Dichromate Storage Tank and Acid Neutralization French Drain Waste Site*, Rev. 0, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0080913H.

WSRF 2014-025, 2015, *Remaining Sites Verification Package for the 100-D-100, Stained Soil Near the 183-DR Railroad Track Waste Site*, Rev. 0, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0080451H.

This page intentionally left blank.