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Revision 0

Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater

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

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Terms

100-AGWM	100 Area Groundwater Model
ARAR	applicable or relevant and appropriate requirement
AWLN	automated water level network
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
Cr(VI)	hexavalent chromium
CSM	conceptual site model
CY	calendar year
DO	dissolved oxygen
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
HASP	health and safety plan
IC	institutional control
LCL	lower confidence limit
MNA	monitored natural attenuation
O&M	operations and maintenance
OU	operable unit
PPE	personal protective equipment
PQL	practical quantitation limit
PSQ	principal study question
QA	quality assurance
QC	quality control
RA	remedial action
RAO	remedial action objective
RAWP	remedial action work plan
RDR	remedial design report
ROD	record of decision
RI/FS	remedial investigation/feasibility study
SAP	sampling and analysis plan
TCE	trichloroethene
UCL	upper confidence limit
UU/UE	unlimited use/unrestricted exposure

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1 Introduction

The 100 Area (*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA] site identification number WA38900900076) includes the River Corridor areas of the Hanford Site, in Benton County, Washington. The 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units (OUs), hereinafter referred to as 100-F/IU, are part of the Hanford Site 100 Area. Within the 100 Areas, 100-F/IU has four source OUs (100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6) and a groundwater OU (100-FR-3) (Figure 1-1).

The remedial design report/remedial action work plan (RDR/RAWP) (DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU*), hereinafter called the Integrated RDR/RAWP, addresses all five OUs and is accompanied by two addenda. The two addenda correspond to the two distinct media (soil and groundwater).

DOE/RL-2014-44-ADD1, *Remedial Design Report/Remedial Action Work Plan Addendum for 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Soils* (referred to as the Soil Addendum), describes the work elements, performance measurements, construction management and oversight, schedule, and costs specific to the removal, treatment (as required), and disposal remedy for waste sites associated with the 100-IU-2 and 100-IU-6 OUs.

This *RDR/RAWP Addendum for 100-FR-3 Groundwater* (referred to as the Groundwater Addendum) describes the design, work elements, construction management and oversight, schedule, and costs specific to the groundwater remedy, which is monitored natural attenuation (MNA) and institutional controls (ICs) to restrict well drilling and groundwater use. Performance monitoring will be implemented to evaluate progress of the MNA remedy and verify attainment of the remedial action objectives (RAOs) for groundwater. The remedial design approach, remedial action (RA) management approach, environmental management and controls, RA completion, and cost/schedule components of the groundwater remedy are presented in Chapters 3 through 7 of this Groundwater Addendum. The performance monitoring component of the MNA remedy is discussed in Chapter 3 of this Groundwater Addendum and presented in the 100-FR-3 Groundwater Sampling and Analysis Plan (SAP) in Appendix A.

1.1 Purpose

This Groundwater Addendum describes how the progress of MNA will be evaluated and final attainment of RAOs will be demonstrated. RAOs were identified in 2014 by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) in *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA and DOE, 2014), hereinafter called the 100-F/IU record of decision (ROD). This addendum is the companion document to the Soil Addendum (DOE/RL-2014-44-ADD1).

1.2 Scope

This Groundwater Addendum includes RAs that will be implemented to meet the requirements of the 100-F/IU ROD (EPA and DOE, 2014). Groundwater components discussed in this addendum for the 100-FR-3 OU are summarized in Table 1-1.

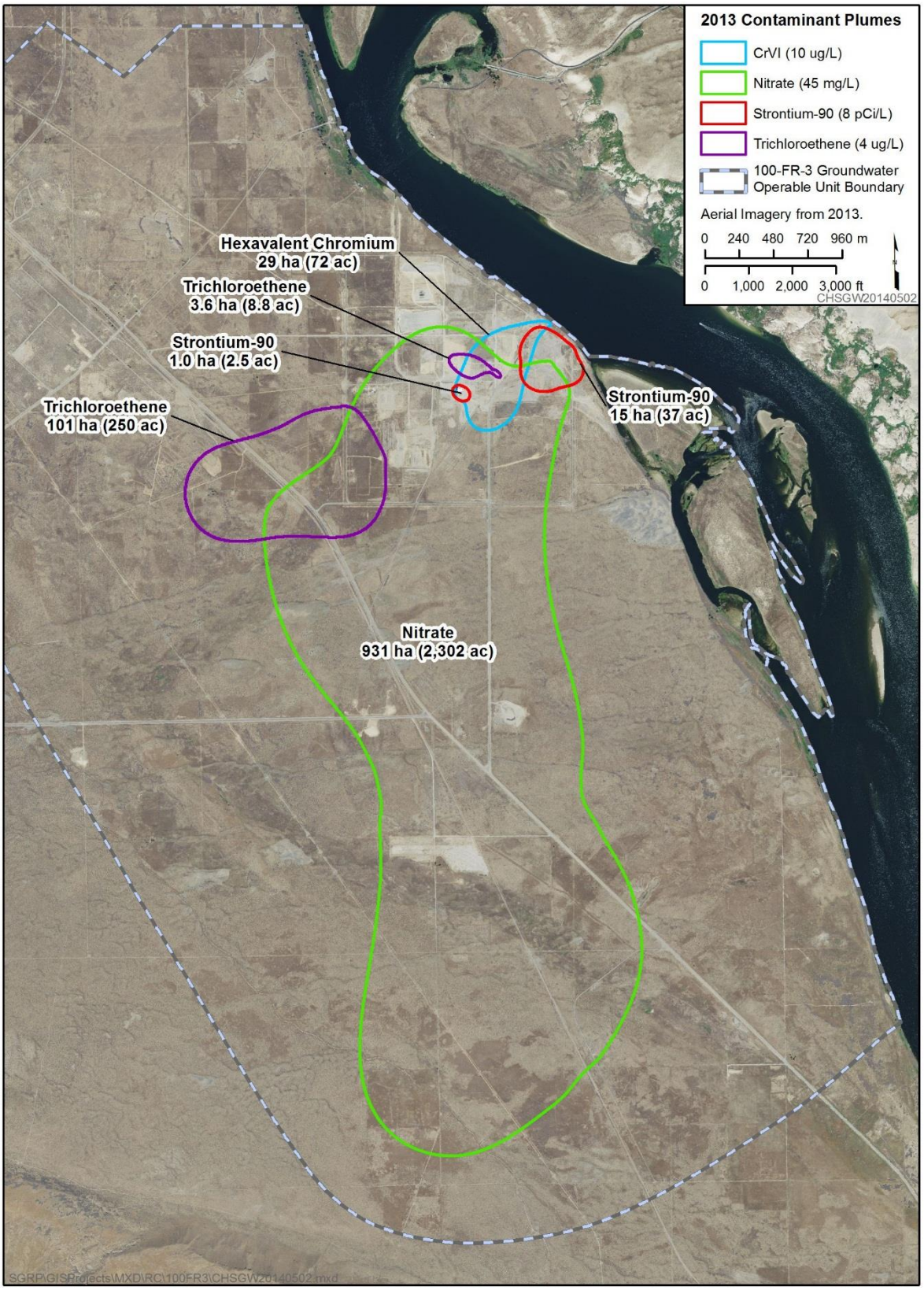

Figure 1-1. 100-FR-3 Operable Unit and 2013 Groundwater Plumes

Table 1-1. Major Components of the Selected Groundwater Remedy

100-FR-3 Operable Unit
Natural attenuation for Cr(VI), nitrate, strontium-90, and TCE in groundwater
Groundwater monitoring for Cr(VI), nitrate, strontium-90, and TCE in groundwater
Institutional controls*

* Institutional controls are implemented by DOE through DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*. Details are described in Section 2.1.2 of DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU*.

Cr(VI) = hexavalent chromium
TCE = trichloroethene

MNA is a remedial strategy that monitors natural attenuation processes until cleanup levels are met. MNA measures and documents contaminant concentration reductions arising from various naturally occurring physical, chemical, and biological processes. The performance monitoring component of the MNA remedy includes installation of new monitoring wells, periodic sampling of new and existing monitoring wells, laboratory analysis, and data evaluation to assess and confirm the natural attenuation processes, rates of attenuation, and overall protectiveness. Well decommissioning will be performed when the RA is complete and may be performed when wells are determined to be no longer needed for any monitoring purpose.

ICs are required to control well drilling through excavation permits and restrict groundwater use until such time as groundwater achieves levels protective of unlimited use/unrestricted exposure (UU/UE). Groundwater use will be restricted through ICs to limited research purposes and for monitoring and treatment, as approved by EPA or the Washington State Department of Ecology.

Contaminated groundwater that migrates into 100-F/IU from other OUs is not part of the 100-FR-3 OU and is not addressed by the 100-F/IU ROD (EPA and DOE, 2014).

1.3 Site Description and Background

The site description and background for 100-F/IU is provided in the Section 1.3 of the Integrated RDR/RAWP (DOE/RL-2014-44).

1.3.1 Physical Setting

The physical setting for 100-F/IU is provided in the Integrated RDR/RAWP (DOE/RL-2014-44).

1.3.2 Nature and Extent of Contamination

The groundwater evaluation in DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2 and 100-IU-6 Operable Units*, hereinafter called the 100-F/IU remedial investigation/feasibility study (RI/FS), compared exposure point concentrations for each contaminant to federal and state drinking water standards (DWSs) and Washington State groundwater cleanup levels. Contaminant concentrations in groundwater were also compared to surface water standards for protection of aquatic organisms because the groundwater discharges to the Columbia River. This comparison included state surface water quality standards for fresh water and federal ambient water quality criteria. The 100-F/IU RI/FS (DOE/RL-2010-98) identified nitrate, trichloroethene (TCE), strontium-90, and hexavalent chromium (Cr(VI)) as contaminants of concern (COCs).

Groundwater plume areas, where COC concentrations exceed federal or state DWSs or ambient water quality criteria, were identified based on calendar year (CY) 2013 groundwater monitoring results (DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). Groundwater within the

100-FR-3 OU contains nitrate at concentrations greater than the DWS[1] of 45,000 µg/L with an estimated nitrate plume area of 931 ha (2,302 ac) (Figure 1-1). A TCE plume at concentrations greater than the 4.0 µg/L 2007 WAC 173-340, "Model Toxics Control Act—Cleanup," level is approximately 105 ha (259 ac) (Figure 1-1). Strontium-90 was detected at concentrations above the 8 pCi/L DWS with an estimated plume area of 16 ha (40 ac) (Figure 1-1). Cr(VI) concentrations greater than the state surface water quality standard (WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington") of 10 µg/L were identified in a plume area estimated at 29 ha (72 ac) (Figure 1-1). The CY 2013 groundwater monitoring results did not identify any Cr(VI) concentrations that exceeded the 2007 WAC 173-340-720, "Groundwater Cleanup Standards," level of 48 µg/L.

[1] Nitrate may be expressed as nitrate-nitrogen (NO_3-N) or nitrate (NO_3). The DWS for NO_3-N is 10,000 µg/L, and the mathematical equivalent value for NO_3 is 45,000 µg/L.

2 Basis for Remedial Action

The RA basis for the 100-FR-3 OU is described in the Integrated RDR/RAWP (DOE/RL-2014-44), which includes the selected remedy, RAOs, and applicable or relevant and appropriate requirements (ARARs). Cleanup levels for the 100-FR-3 OU COCs are presented in Table 2-1.

Table 2-1. Cleanup Levels for 100-FR-3 Operable Unit Contaminants of Concern

Contaminant of Concern	Cleanup Level	Units	Basis for Cleanup Level
Nitrate (as NO_3)	45,000	µg/L	DWS[a]
Trichloroethene	4	µg/L	WAC 173-340-720
Hexavalent Chromium[b]	10	µg/L	WAC 173-201A
	48	µg/L	WAC 173-340-720
Strontium-90	8	pCi/L	DWS
Media: Groundwater Operable Unit: 100-FR-3 Available Use: Drinking water and all other uses Controls to Ensure Restricted Use: Yes			

Note: Bases for these cleanup levels are risk limits and DWS applicable or relevant and appropriate requirements to protect drinking water uses, which also are protective of the river.

Sources: WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

a. Nitrate may be expressed as nitrate-nitrogen (NO_3-N) or as nitrate (NO_3). The DWS for NO_3-N is 10,000 µg/L, and the mathematical equivalent value for nitrate (NO3) is 45,000 µg/L.

b. Cleanup levels for hexavalent chromium are 48 µg/L in the upland groundwater and 10 µg/L where groundwater discharges to surface water.DWS = drinking water standard

The following RAOs for the 100-FR-3 OU are identified in the 100-F/IU ROD (EPA and DOE, 2014):

- RAO 1—Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.
- RAO 2—Prevent unacceptable risk to human health and ecological receptors from groundwater discharges to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- RAO 7—Restore groundwater impacted from 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 releases to proposed cleanup levels, which include DWSs, within a time frame that is reasonable given the particular circumstances of the site.

Details of the specific remedial design approach for groundwater are described in Chapter 3.

MNA is the remedy for all COCs in the 100-FR-3 OU to reduce groundwater concentrations to less than cleanup levels. Overall plume behavior is controlled by a combination of the source strength (flux of contaminants into the groundwater) and the rate and capacity of attenuation in the groundwater. Without a

continuing source, the net plume response will be to diminish over time. The primary natural attenuation processes for COCs present in the 100-FR-3 OU include biodegradation and abiotic degradation, radioactive decay, dispersion, volatilization, and sorption. The estimated time frame required for COC concentrations to decrease to below the cleanup levels is presented in Table 2-2. These estimates were determined by computer modeling and are presented in the 100-F/IU RI/FS (DOE/RL-2010-98).

Table 2-2. Remedial Action Time Frame Estimates

Contaminant of Concern	Cleanup Level	Years[a]
Nitrate	45,000 µg/L	80
Trichloroethene	4 µg/L	50
Hexavalent Chromium[b]	10 µg/L	35
	48 µg/L	20
Strontium-90	8 pCi/L	150

a. The time frame required to attain the cleanup levels will vary in different areas of the contaminant of concern plume.

b. Cleanup levels for hexavalent chromium are 48 µg/L in the upland groundwater and 10 µg/L where groundwater discharges to surface water.

3 Remedial Design Approach

This chapter provides the remedial design approach for implementing the selected remedy of MNA for 100-FR-3 OU groundwater. The performance monitoring component of MNA includes periodic sampling, laboratory analysis, and data evaluation to assess the attenuation process and overall protectiveness. Performance monitoring results will be used to demonstrate that cleanup levels have been attained and the RA is complete. The two phases of MNA performance monitoring (remediation monitoring and attainment monitoring) are discussed in Section 3.1.1.

The performance monitoring design, including identification of monitoring networks, installation of new wells, periodic sampling, and laboratory analysis, is presented in this chapter. Data evaluation to assess the natural attenuation processes, rates of attenuation, and overall protectiveness during performance monitoring is presented in Chapter 6. ICs that are part of the remedy are described in Section 2.1.2 of the Integrated RDR/RAWP (DOE/RL-2014-44).

The companion documents associated with this Groundwater Addendum are summarized in Table 3-1. The Groundwater SAP, Waste Management Plan, and Operations and Maintenance (O&M) Plan are included as appendices to this document. Reporting of yearly performance monitoring results will be presented in the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2014-32).

Table 3-1. Companion Documents to Groundwater Addendum

Document Title	Purpose/Content	Document Status
Sampling and Analysis Plan	Describes well installation and sampling procedures, locations, parameters, and frequency of sampling for MNA performance monitoring	Included as Appendix A.
Operations and Maintenance Plan	Operations and maintenance activities including inspection, maintenance, and periodic replacement of monitoring wells	Included as Appendix B.
Waste Management Plan	Describes the waste management procedures	Included as Appendix C.
Performance Monitoring Reports	Evaluates performance monitoring results, progress toward attainment of cleanup levels, and cleanup level attainment calculations when applicable. Includes updates to groundwater flow and transport model and plume area determinations. Report schedule will support the CERCLA 5-year reviews for the Hanford Site.	Prepared as a separate report at 5-year frequencies during MNA. The first 5-year report is anticipated to be prepared in 2020 to support the 2016 to 2021 Hanford Site 5-year CERCLA review.
Phase 1 Well Report	Prepared after the first year of monitoring of Phase 1 wells. This report will summarize the findings from the Phase 1 well installation, updates to groundwater model and plumes, early water level measurement results, and recommendations for Phase 2 wells.	Preparation of report planned for fiscal year 2017 after all Phase 1 wells have completed the first year of performance monitoring.

Table 3-1. Companion Documents to Groundwater Addendum

Document Title	Purpose/Content	Document Status
Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions (DOE/RL-2001-41)	Describes implementation and maintenance of ICs for the Hanford Site	Independent document identifying Hanford Site ICs, revised as needed

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
IC = institutional control
MNA = monitored natural attenuation

3.1 Performance Monitoring Design Basis

This section discusses the approach for implementing and evaluating the MNA component of the 100-F/IU ROD (EPA and DOE, 2014).

3.1.1 Implementation Approach

The MNA remedy relies upon natural attenuation processes to reduce groundwater COC concentrations during the estimated time periods to concentrations less than the cleanup levels for 100-FR-3 OU groundwater. Natural attenuation processes include a variety of physical, chemical, or biological processes, which under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater.

MNA includes performance monitoring to assess the effectiveness of natural attenuation to meet cleanup levels. Performance monitoring will continue until COCs have attained the cleanup levels, and are expected to continue to meet cleanup levels, and EPA approves termination of the monitoring. The 100-FR-3 OU groundwater plumes are shown in Figure 1-1.

As discussed in OSWER 9355.0-129, *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*, performance monitoring consists of two phases: remediation monitoring and attainment monitoring. The first phase (remediation monitoring) refers to the phase of the remedy where remedial activities are being implemented to reach groundwater cleanup levels. During this phase, groundwater sampling and monitoring data are collected to evaluate contaminant migration and changes in COC concentrations over time. Progress towards attaining the cleanup level is evaluated during the remediation phase on a well-by-well basis for each COC. Remediation monitoring for a specific monitoring well and COC is complete when the data evaluation demonstrates that the groundwater has reached the cleanup level. Some wells will monitor for multiple COCs. In these cases, conclusions may be made, at any time during groundwater remediation, to remove certain COCs from the monitoring program because the data indicate that they have met their cleanup level before other, more recalcitrant, COCs in the well (OSWER 9355.0-129).

The attainment monitoring phase occurs after the remediation monitoring phase is complete. Once the groundwater is observed to have reached the cleanup level, data are collected and evaluated to confirm that the attainment monitoring phase has been completed. The attainment monitoring phase at a monitoring well is complete when contaminant-specific data provide both of the following technical and scientific bases:

- The contaminant cleanup level for each COC has been met.

- Groundwater will continue to meet the contaminant cleanup level for each COC in the future (OSWER 9355.0-129).

3.1.2 Performance Monitoring Design Considerations

A site-specific data quality objective (DQO) process was performed to identify monitoring networks, frequency and timing of sample collection, data assessments, and progress evaluations required for the design of an effective performance monitoring and data evaluation program for 100-FR-3 OU groundwater. The following guidance documents were utilized during the DQO process:

- OSWER Directive 9200.4-17P, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*
- OSWER Directive 9283.1-44, *Recommended Approach for Evaluating Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well*
- OSWER 9355.0-129, *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*
- EPA 230-R-92-014, *Methods for Evaluating The Attainment Of Cleanup Standards Volume 2: Ground Water*
- EPA/600/R-04/027, *Performance Monitoring of MNA Remedies for VOCs in Ground Water*
- EPA/600/R-07/139, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 1 – Technical Basis for Assessment*
- EPA/600/R-07/140, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*
- EPA/600/R-10/093, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 3 – Assessment for Radionuclides Including Tritium, Radon, Strontium, Technetium, Uranium, Iodine, Radium, Thorium, Cesium, and Plutonium-Americium*
- EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*

Guidance from the preceding documents was utilized to supplement the existing well locations and optimize a monitoring network designed to monitor changes in plume size, identify target zones for monitoring, refine the understanding of hydraulic gradients, and collect sufficient data to support decision making. The Groundwater SAP (Appendix A) presents the performance monitoring approach, including locations of new and existing monitoring wells, aquifer tubes, and a riverbank seep to be sampled, sampling frequency, and analytes. The DQO report (SGW-58291, *Data Quality Objectives for 100-FR-3 Monitored Natural Attenuation*) will be published in 2015 as a separate report. The report is included with Appendix A (Groundwater SAP) for convenience.

Groundwater monitoring will consist of sampling monitoring wells, aquifer tubes, and riverbank seeps for COCs, degradation products, and geochemical parameters to support the overall remedy performance evaluation. The geochemical groundwater parameters used for assessing MNA effectiveness include pH, dissolved oxygen (DO), specific conductance, temperature, and turbidity. Only monitoring well sample results will be used in determining compliance with cleanup levels.

Due to analytical uncertainties identified in the 100-F/IU RI/FS (DOE/RL-2010-98), sampling and analysis will also be conducted for antimony, cadmium, and cobalt to determine if these analytes are

below the action level. Degradation products of TCE are also identified for sampling. These chemicals include *cis*-1,2-dichloroethene and vinyl chloride.

The monitoring network locations and frequency of performance monitoring will vary, depending on the progress of MNA. As sample results demonstrate that the COC plumes decrease in area and/or migrate, monitoring locations will be evaluated and adjusted accordingly. Sample frequencies vary, depending on the monitoring stage. Initial remediation phase monitoring will be performed quarterly for all new wells during the first year of monitoring, followed by annual sampling in years 2 through 5. Existing wells will be sampled annually or, at specified locations, semiannually (two times per year) during the first 5 years of sample collection. Sampling frequencies are reduced to biennial sampling (one time every 2 years) after the first 5 years of sampling have established contaminant concentration trends.

3.2 Performance Monitoring Design Summary

The summary for the 100-FR-3 OU performance monitoring design describes the following elements:

- MNA overview
- Performance monitoring
- DQO outputs
- Remediation phase monitoring network and evaluation
- Attainment phase monitoring network and evaluation

MNA performance monitoring is achieved through establishing a monitoring network to produce data sufficient to evaluate the attenuation of COCs. The network design includes existing monitoring wells, aquifer tubes, and a riverbank seep. New monitoring wells are also included in the design.

3.2.1 Monitored Natural Attenuation of Groundwater

As part of the 100-F/IU RI/FS (DOE/RL-2010-98), an evaluation was performed to demonstrate that MNA was a viable remedy for the 100-FR-3 OU. The evaluation used a multiple lines of evidence approach that considered the occurrence, mechanisms, rates, and expected performance of natural attenuation processes in site conditions. MNA evaluation in the 100-F/IU RI/FS (DOE/RL-2010-98) demonstrated the following elements:

- Effective source control
- Clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points
- Directly or indirectly, the type(s) of natural attenuation processes that are active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels

Additional details of the MNA evaluation are presented in Appendix M of the 100-F/IU RI/FS (DOE/RL-2010-98).

3.2.2 Performance Monitoring

The MNA remedy includes performance monitoring to ensure the effectiveness of natural attenuation to meet cleanup levels. Performance monitoring will continue until COCs have attained cleanup levels, and are expected to continue to meet cleanup levels, and EPA approves termination of the monitoring. Groundwater plumes are shown in Figure 1-1. The Groundwater SAP (Appendix A) presents the performance monitoring approach, including locations of new and existing wells, aquifer tubes, and the riverbank seep within the monitoring network, sampling frequency, and analytes.

As the RA progresses, the extent of the contaminated aquifer is expected to change. The groundwater monitoring network will be evaluated during the RA to ensure adequate and accurate evaluation of contaminant concentrations and contaminated aquifer boundary changes over time.

Yearly performance monitoring sampling will be summarized and presented in the annual groundwater report (e.g., DOE/RL-2014-32). A separate report summarizing the Phase 1 well results, groundwater model updates, water level measurement results, network optimizations, and any Phase 2 well recommendations will be prepared after Phase 1 wells have completed the first year of performance monitoring. Comprehensive performance monitoring reports will be prepared at 5-year intervals to evaluate progress of the MNA remedy. Details on the analysis and reporting of results are presented in Section 3.3.

3.2.2.1 Principal Study Questions

A site-specific DQO process was performed to identify the data needs for performance monitoring. The following principal study questions (PSQs) were identified during the DQO (methods for use of monitoring results to evaluate PSQs are described in Chapter 6, and additional details on development of PSQs are described in the DQO report [SGW-58291], presented in the Groundwater SAP [Appendix A]):

- PSQ 1— Is natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater occurring as expected?
  - PSQ 1a—Are contaminant concentrations and plume area/mass decreasing?
  - PSQ 1b—Are rates of decline consistent with expectations?
  - PSQ 1c—Are there changes in environmental conditions that may reduce the efficacy of natural attenuation?
  - PSQ 1d—Are there unacceptable impacts to the Columbia River?
  - PSQ 1e—Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy?
- PSQ 2—Are concentrations of antimony, cadmium, and cobalt below action levels?
- PSQ 3— Do new geologic and hydrogeologic data confirm the conceptual site model (CSM)?
- PSQ 4—Have RAOs been achieved?
  - PSQ 4a—Are concentrations of COCs below cleanup levels?
  - PSQ 4b—Will groundwater continue to meet the cleanup level in the future?

3.2.2.2 Decision Rules

The following decision rules requiring sampling and analysis were identified in the DQO (methods for use of the monitoring results to evaluate the decision rules are described in Chapter 6):

- Decision Rule No. 1—If the weight of evidence indicates that natural attenuation is occurring as expected, then continue MNA; otherwise, evaluate other options.
- Decision Rule No. 2—If monitoring indicates that concentrations of antimony, cadmium, and cobalt are not greater than the action level or practical quantitation limit (PQL), then discontinue monitoring; otherwise, perform risk assessment.

- Decision Rule No. 3—If new geologic and hydrogeologic data confirm the CSM, then retain the model; otherwise, update it.
- Decision Rule No. 4—If RAOs have been achieved for an individual COC, then proceed to attainment monitoring for that COC; otherwise, continue MNA.

3.2.3 Contaminants of Concern and Other Analytes

Sampling will include analyses for the following COCs at the respective plume locations: Cr(VI), nitrate, strontium-90, and TCE. Samples to monitor TCE attenuation will also include analysis for vinyl chloride and *cis*-1,2-dichloroethene, which are TCE degradation products. Field measurements, including specific conductance, pH, DO, turbidity, and temperature, will be collected during groundwater sample events. Sampling for antimony, cadmium, and cobalt will be conducted during the first 10 years of sampling at the monitoring wells identified in Table A-8 of the Groundwater SAP (Appendix A) to determine if these analytes are present below action levels.

3.2.4 Sample Frequency

The performance monitoring sample frequency is determined, based on the type of well and the expected variability of results. New wells will be sampled quarterly for 1 year to establish the baseline and seasonal variability. For existing wells and aquifer tubes, a minimum of annual sampling will be performed for the first 5 years to establish a new baseline. Selected existing wells, at locations where changes in water table are likely to affect concentrations, will be sampled semiannually at high and low river stage for the first 5 years.

The sampling frequency for the performance monitoring network will be evaluated after the initial 5 years of monitoring. After the first 5 years, it is anticipated that the sample frequency will be reduced to every 2 years (biennial). Biennial sampling will provide at least two sampling events for subsequent 5-year performance monitoring reports. During the 5 years of attainment monitoring, the sampling frequency may be quarterly for 2 years to detect seasonal variability and may be reduced to annual for the next 3 years.

Annual and biennial sampling events will be scheduled for fall when river stage is low (September or October). Semiannual wells (twice per year) will also be sampled at high river stage (mid-May through mid-July).

3.2.5 Performance Monitoring Network

The performance monitoring component includes identification of the groundwater monitoring network for each COC, installation of new wells, periodic sampling of new and existing wells, laboratory analysis, and periodic evaluation to assess the natural attenuation processes, rates of attenuation, and overall protectiveness.

Groundwater monitoring will be performed to document changes in contaminant concentrations and extent for all groundwater COCs. Monitoring networks for each COC were identified during the DQO process. Locations were identified to monitor COC concentrations, detect changes in plume areas, and refine the understanding of local hydraulic gradients. In total, 28 existing wells, 8 new Phase 1 wells, 6 aquifer tubes, and 1 riverbank seep were identified for analytical sampling, based on the DQO process. An additional four existing wells were identified for water level measures only. The locations of the monitoring network components are presented in the Groundwater SAP (Appendix A).

Information on hydraulic gradients will be obtained using an automated water level network (AWLN), encompassing 19 wells and the 100-F river gauge station. The information will provide refinements to the groundwater model and be utilized for natural attenuation evaluation. The AWLN will be operated for at

least the first 5 years of performance monitoring; then, continuation of AWLN monitoring will be re-evaluated. Manual water level measurements will also be obtained from other wells in the monitoring network at low, moderate, and high river stage periods during the first 10 years of performance monitoring.

As COC plumes decrease in size or migrate over time, adjustments to the monitoring network will be evaluated. Adjustments may include removing upgradient wells from the monitoring network. At a minimum, COC monitoring networks will be evaluated at 5-year intervals during the remedy.

3.2.5.1 New Groundwater Monitoring Wells

New groundwater monitoring wells will be installed to further define the natural attenuation processes and update the rates of attenuation that are occurring to reflect post-source remediation conditions. The need and location for new wells will be determined in two phases based on existing groundwater monitoring results and results from the first phase of new well installation. Based on the DQO process, a total of eight locations were identified for Phase 1 well installation.

A phased approach was implemented to site new wells required for performance monitoring at locations determined to most efficiently assess the effectiveness of the MNA remedy. Phase 1 wells were identified in the DQO process and Phase 2 new wells, if needed, will be determined after evaluation of data collected from all wells in the monitoring network. An evaluation of Phase 1 wells results will be reported after all wells have completed the first year of monitoring. The report will include recommendations for Phase 2 wells.

The eight wells identified for Phase 1, as well as any Phase 2 wells, will be drilled 3 m (10 ft) into the top of the Ringold upper mud unit.

3.2.5.2 Operations and Maintenance

Appendix B describes O&M activities associated with the monitoring network. Activities include inspection, maintenance, and periodic replacement of monitoring wells. The plan describes routine maintenance activities for the monitoring network. Any well maintenance activities that affect sample quality will be summarized in the annual groundwater report (e.g., DOE/RL-2014-32). Due to the long-term nature of MNA remedy for the 100-FR-3 OU COCs, roadway access and associated maintenance will be required to support sample collection through the performance monitoring period at the specified sample locations.

3.3 Performance Monitoring Analysis and Reporting

Yearly results of performance monitoring sampling will be summarized and presented in the annual groundwater report (e.g., DOE/RL-2014-32).

A separate report of the Phase 1 well results and any Phase 2 well recommendations will be prepared after all Phase 1 wells have completed the first year of performance monitoring. The report will summarize the findings from Phase 1 well installation, updates to the groundwater model projections and plumes, early water level measurement results, and optimizations for the monitoring network.

Comprehensive performance monitoring evaluation reports will be prepared at a 5-year frequency throughout the remedy. Progress evaluations, including any groundwater modeling updates, will be presented in the reports. PSQs and decision rules identified in the DQO will be evaluated in the reports, as described in Chapter 6. Evaluation of antimony, cadmium, and cobalt results, as well as any detections of TCE degradation products in excess of the required detection limit, will be included using methods addressed in Chapter 6. The initial 5-year performance monitoring report is anticipated to be prepared in

2020 to align with the 2016 to 2020 Hanford Site 5-year review period. Subsequent reports will be prepared at 5-year intervals.

3.3.1 Remediation Monitoring Progress Evaluation

During the remediation monitoring phase, natural attenuation rates for each COC will be calculated for the performance monitoring reports to evaluate the progress of the MNA remedy, relative to the expected time frames. Evaluations used to demonstrate attainment of the cleanup levels during the remediation monitoring phase will be performed with data from monitoring wells only. The description of methods used to determine COC attenuation rates and evaluate COC progress toward meeting the cleanup levels, and triggers for re-assessing MNA performance are presented in Chapter 6.

As discussed in OSWER 9355.0-129, the remediation phase at a monitoring well is completed when the data collected and evaluated from that well demonstrate that groundwater has reached cleanup levels for all COCs. OSWER 9355.0-129 specifies that, at any time during groundwater remediation, conclusions may be made to remove certain COCs from the monitoring program because the data indicate that they have met their cleanup level before other, more recalcitrant COCs, in the well. This conclusion will be documented in the monitoring report and used, in conjunction with the current well data at the time of RA completion, to make the conclusion that all COCs have reached their cleanup level.

Progress evaluations will be performed and documented in the 5-year performance monitoring reports through the remediation monitoring phase. When the progress evaluation demonstrates that concentrations of a COC have met the cleanup level at a specific well, attainment monitoring for that COC/well will begin. Depending on timing, a progress evaluation may be performed separately from the 5-year performance monitoring report if a given COC/well has met the cleanup level and is ready to enter the attainment monitoring phase. In this case, the evaluation will be included in the subsequent 5-year report. After the attainment monitoring results demonstrate that the COC/well has met the cleanup level, the well will be considered to have completed RA for that COC. Details of evaluations to be performed with monitoring data are presented in Section 6.4.

3.3.2 Suggested Format for MNA Performance Monitoring Report

A suggested outline for the 5-year performance monitoring report is presented in the following subsection. Sections of the outline are more applicable to the earlier years of monitoring. Not all sections of the suggested format may be applicable for a given performance period and may be omitted. Additional sections may be added, as needed.

The format of the MNA performance monitoring report may be used to report both remediation and attainment phase results.

3.3.2.1 MNA Performance Monitoring Report

1. Introduction
    - 1.1. Purpose
    - 1.2. Period of Performance
    - 1.3. Report Organization
2. Contaminant Monitoring
    - 2.1. Contaminant Monitoring Network and Parameters
        - 2.1.1. Installation of New Wells
        - 2.1.2. Well Maintenance and Repair
    - 2.2. Contaminant Monitoring Data
        - 2.2.1. Contaminants of Concern

2.2.2. Contaminant Degradation Products, Field Parameters, and Other Analytes
2.2.3. Analysis of Contaminant Monitoring Data
2.2.3.1. Plume Boundaries
2.2.3.2. Natural Attenuation Rate Determinations
2.2.3.3. Environmental Conditions Affecting Natural Attenuation
2.2.3.4. Contaminant Impacts to the Columbia River
2.2.3.5. New or Continuing Releases of COCs
2.2.3.6. Contaminant Degradation Products and Trace Metals
3. Hydraulic Gradients
3.1. AWLN Results
3.2. Manual Water Level Results
3.3. Seasonal Variation
3.4. Influence of Geology and Hydrogeology in Southern 100-FR-3 OU
4. Contaminant Transport Modeling
4.1. Contaminant Transport Parameters
4.2. Contaminant Transport Model Calibration
4.3. Predictive Contaminant Transport Simulations
5. Remediation Phase Monitoring Evaluation
5.1. Progress Toward Meeting RAOs
5.2. Evaluations for Contaminants of Concern at Individual Wells
5.2.1. Attenuation Rate Evaluation and Cleanup Level Attainment Estimate
5.2.2. Evaluation of Cleanup Level Attainment at Individual Wells
5.3. Contaminant Evaluation Throughout Plume
5.4. Updates to Monitoring Network
6. Attainment Phase Monitoring Evaluation
6.1. Evaluation of Cleanup Level Attainment at Individual Wells
6.2. Contaminant Evaluation Throughout Plume
6.3. Summary of Cleanup Level Attainment
7. Conclusions
7.1. Changes to the Site Conceptual Model
7.2. Remediation Monitoring Evaluation of PSQs and Decision Rules
7.2.1. PSQ #1a through 1e; Decision Rule #1
7.2.2. PSQ #2; Decision Rule #2
7.2.3. PSQ #3; Decision Rule #3
7.2.4. PSQ #4a and #4b; Decision Rule #4
8. Recommendations
9. References

3.3.3 Attainment Monitoring Evaluation

When the remediation monitoring progress evaluation demonstrates that COC concentrations have attained cleanup levels at a specific well, the attainment monitoring phase will commence for that specific COC/well. Attainment monitoring will be performed for 5 years for each COC/well. Attainment monitoring wells may be sampled quarterly for the first 2 years and may be reduced to annually for the remaining 3 years. If the results of attainment monitoring demonstrate that a COC/well has attained the cleanup level, using the methods presented in Section 6.4.2, then attainment monitoring for that COC/well will cease. However, additional monitoring may be performed, if needed, to support preparing plume maps and performance monitoring reports.

Some areas of the COC plume will attain the cleanup level more rapidly than other areas. Therefore, both remediation monitoring and attainment monitoring may be performed for the same COC at different wells during the same sample period.

Only monitoring well results will be used for demonstrating that a COC plume has attained the cleanup level. When attainment monitoring is completed at each well within the monitoring network, and COC concentrations have attained the cleanup level throughout the plume(s) and are expected to continue to meet the cleanup level, then the RA for that COC will be complete. The subsequent evaluation of cleanup level attainment and RA completion for that COC will be documented either in the next 5-year performance monitoring report or in the final RA report, whichever is appropriate. If attainment monitoring results for a given COC do not demonstrate that the cleanup level has been attained, then DOE and the regulators will evaluate the results and determine the path forward. When all COCs have completed attainment monitoring, data evaluations demonstrate attainment of the cleanup levels, and it is expected that groundwater will continue to meet the cleanup levels, then the RA will be complete and a final RA report for the 100-FR-3 OU will be prepared.

3.4 CERCLA 5 Year Review

In accordance with 40 CFR 300.430(f)(4)(ii), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," DOE and EPA have agreed to conduct 5-year reviews for the 100 Area because the selected remedy will not achieve levels that allow for UU/UE within 5 years. Reviews are conducted 5 years after initiation of RA and every 5 years until cleanup levels established in the ROD (EPA and DOE, 2014) are attained. The reviews are conducted pursuant to CERCLA Section 121(c), "Cleanup Standards," and as provided in EPA 540-R-01-007, *Comprehensive Five-Year Review Guidance*.

The following three 5-year review reports for the Hanford Site have been completed (in 2001, 2006, and 2012, respectively):

- EPA, 2001, *USDOE Hanford Site First Five Year Review Report*
- DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*
- DOE/RL-2011-56, *Hanford Site Third CERCLA Five-Year Review Report*

Upcoming 5-year reviews will include the following time periods:

- Fourth 5-year review – 2011 through 2016
- Fifth 5-year review – 2016 through 2021

3.5 Final Remedial Action Report

This section describes the final RA closure report and provides a brief summary of typical report content.

A final RA report will be prepared to document cleanup activities that occurred and to demonstrate compliance with ROD requirements.

The final RA report will be prepared using the format provided in EPA 540-R-98-016, *Close Out Procedures for National Priorities List Sites*. The final RA report outline includes the following suggested primary sections:

1. Introduction
2. Summary of Site Conditions
3. Demonstration of Cleanup Activity Quality Assurance (QA)/Quality Control (QC)

4. Monitoring Results
5. Performance Standards and Construction QC
6. Summary of Operation and Maintenance
7. Summary of Remediation Costs
8. Protectiveness
9. Five-Year Review
10. References

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4 Remedial Action Management and Approach

The Integrated RDR/RAWP (DOE/RL-2014-44) presents a project team and change management approach associated with implementation of the selected remedies. For the groundwater remedy component, CH2M HILL Plateau Remediation Company is responsible for remedial design and RA activities associated with MNA and performance monitoring. RA work tasks specific to the groundwater remedy are described in Section 4.1.

4.1 Remedial Action Work Tasks

RA tasks associated with MNA and ICs are described in the following subsections.

4.1.1 Procurement and Construction

Performance monitoring activities include installation of new wells. Eight locations were identified for Phase 1 new well installation. Additional Phase 2 wells may be identified, depending on evaluation of Phase 1 results.

Procurement activities will include contracts for well drilling and construction, geophysical services, and analytical services. The work will be accomplished using the most efficient combination of onsite resources and service vendors.

Access to the new well locations may require construction of new access roads. The new roads will require maintenance through the monitoring period until the wells are decommissioned. Maintenance of existing roads to existing wells, and other locations within the identified monitoring network, will be required to provide access through the applicable monitoring periods until the wells are decommissioned.

An AWLN will be established and tracked at 19 wells and the 100-F river gauge station for at least the first 5 years of monitoring. The AWLN includes 7 new wells and 12 existing wells. Locations within the AWLN will be equipped, as required, for the automated measurements.

4.1.2 Rehabilitation of Old Wells and River Gauge Station Repairs

Several older wells with missing or unverified construction information were identified for potential use in the monitoring networks. These wells will be investigated to determine suitability in the monitoring network. Investigation includes a review of documentation, where available; camera surveys; borehole geophysics; and field inspections. Table A-10 of the Groundwater SAP (Appendix A) identifies the wells requiring investigation.

Several existing wells identified for use in the monitoring network extend deeper than the base of the unconfined aquifer. Grouting of these wells will be performed to allow sampling within the unconfined aquifer. Table A-10 of the Groundwater SAP (Appendix A) identifies the wells requiring rehabilitation.

Repairs will be made to the existing 100-F river gauge station on the Columbia River to allow safe access and use of station.

4.1.3 Implementation of Institutional Controls

ICs for the 100-FR-3 OU groundwater are presented in Section 2.1.2 of the Integrated RDR/RAWP (DOE/RL-2014-44). ICs to be implemented by DOE include administrative controls that control well drilling through excavation permits and restrict groundwater use until such time as the groundwater achieves levels protective of UU/UE where groundwater is above cleanup levels. These ICs are implemented through DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

4.1.4 Project Status Reporting

Progress will be communicated in the Unit Managers Meetings, including sample and analysis results, operations, and general project status and timelines.

5 Environmental Management and Controls

This chapter describes the environmental management and controls associated with implementation of the 100-FR-3 OU remedy.

5.1 Air Emissions

Radiological and nonradiological air emissions associated with MNA of groundwater are not anticipated.

5.2 Reporting Requirements for Non-Routine Releases

40 CFR 302, "Designation, Reportable Quantities, and Notification," requires immediate notification to the National Response Center on discovery of a hazardous substance release into the environment in excess of a reportable quantity in a 24-hour period. 40 CFR 355, "Emergency Planning and Notification," requires immediate notification to the community emergency coordinator for the local emergency planning committee and to the State Emergency Response Commission for release of a reportable quantity of an extremely hazardous substance or a CERCLA hazardous substance in a 24 hour period, except for releases exempted from reporting under 40 CFR 355.31, "What Types of Releases are Exempt from the Emergency Release Notification Requirements of this Subpart?" The Hanford Site has comprehensive policies and procedures in place to report nonroutine releases to the environment; these procedures will be followed at the 100-FR-3 Groundwater OU.

5.3 Waste Management

The waste management plan for the RA is provided in Appendix C. The plan provides details on the specific requirements for waste identification, characterization, segregation, packaging, labeling, storage, and inspection for waste generation activities associated with the new well installation, sample collection, and well maintenance. The following projected waste streams are included in the waste management plan:

- Drill cuttings (both dry soil and saturated slurries)
- Purgewater generated during well or aquifer tube installation, development, testing, monitoring, maintenance, decommissioning, and decanting of saturated soils
- Decontamination fluids

Miscellaneous solid wastes may include, but are not limited to, the following:

- Filter paper, syringes, wipes, personal protective equipment (PPE), cloth, plastic, equipment, tools, pumps, wire, metal and plastic piping, and materials from cleanup of unplanned releases
- Decommissioning debris, such as concrete, wood, rebar, metal/plastic pipe and screens, wire, liners, bentonite/sand/gravel, equipment, pumps, and tanks
- Spent/excess chemicals/reagent and used oil

5.4 Cultural/Ecological Resources

Protection of cultural resources is addressed, in part, during the ARAR identification process based on CERCLA and 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan." The lead and non-lead regulatory agencies identify ARARs for the release or RA at a CERCLA site (40 CFR 300.400[g], "General"). ARARs for the 100-F/IU RA are provided in Appendix A of the Integrated RDR/RAWP (DOE/RL-2014-44).

As identified in Appendix A of the Integrated RDR/RAWP (DOE/RL-2014-44), the following ARAR protects ecological resources for work within the 100-FR-3 OU:

- *Endangered Species Act of 1973*—100-FR-3 OU groundwater discharges into the Hanford Reach of the Columbia River contains three species listed as threatened or endangered. The spring-run Chinook salmon do not spawn in the Hanford Reach but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach. The bull trout is not considered a resident species and is rarely observed in the Hanford Reach. Remediation actions and investigation activities will be managed to avoid jeopardy and/or adversely affect a listed species or critical habitat.

Ecological, cultural, historical, and Native American sites and artifacts will be protected, as identified in the Integrated RDR/RAWP (DOE/RL-2014-44), Appendix A ARARs. Prior to disturbing the earth (e.g., drilling and excavation), the DOE Richland Operations Office will initiate discussions with the affected parties, and an analysis of cultural and ecological resource impacts will be undertaken. This analysis will include an assessment of the resources present and a qualitative comparison to the risk posed by contaminants present in the OU.

A cultural resources review is part of work planning activities, and the project will involve cultural resources staff early in the planning stage to address potential concerns and consider the effects that the planned project activities could have.

5.5 Safety and Health Program

The remediation contractor's hazardous waste operations safety and health program was developed for employees involved in hazardous waste site activities. The program was developed to comply with the requirements of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response," and 10 CFR 835, "Occupational Radiation Protection," to ensure the safety and health of workers during hazardous waste operations.

The health and safety program was developed in accordance with the overall remediation contractor's health and safety program to define the chemical, radiological, and physical hazards and to specify the controls and requirements for day-to-day work activities on the overall Hanford Site. It also incorporates applicable core functions and guiding principles, outlined in the Integrated Safety Management System, and governs minimum personal training; control of industrial safety and radiological hazards; PPE; site control; and general emergency response to spills, fire, accidents, injury, and incident reporting.

Access and work activities will be controlled in accordance with approved work packages, as required by established internal work requirements and processes. The health and safety plan (HASP), which addresses the health and safety hazards of each phase of site operation, includes the requirements for hazardous waste operations and/or construction activities, as specified in 29 CFR 1910.120.

Project field staff will be required to comply with the HASP at all times. Unescorted site visitors are required to read and sign the HASP before entering the construction area and must have completed the required training outlined in the HASP. Escorted visitors are briefed on health and safety concerns and must be escorted by the site superintendent (or designee) at all times when they are in the construction area.

During operations and construction, emergency response for the 100-FR-3 OU remedial activities will be covered by the HASP. The HASP specifies primary emergency response actions for site personnel, area alarms, implementation of the emergency action plan and emergency equipment at the task site, emergency coordinators, emergency response procedures, and spill containment procedures.

5.6 Emergency Response

During construction and operations, emergency response for project activities will be covered by the project-specific HASP and related health and safety procedures and work instructions. The HASP, health and safety procedures, and work instructions contain primary emergency response actions for site personnel, area alarms, implementation of the emergency action plan, and emergency equipment at each task site, as well as emergency coordinators, emergency response procedures, and spill containment. A copy of the HASP will be kept in the construction field office. When emergencies arise that are beyond the limitations of the project-specific HASP, DOE-0223, *Emergency Plan Implementing Procedures*, will govern project staff response, as specified in the HASP.

5.7 Quality Assurance Program

Overall QA for the RDR/RAWP (DOE/RL-2014-44) will be planned and implemented in accordance with 10 CFR 830, "Nuclear Safety Management," Subpart A, "Quality Assurance Requirements"; EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5); EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans* (EPA QA/G-5); EPA/240/B-05/001, *Guidance on Quality Assurance for Environmental Technology Design, Construction, and Operation* (EPA QA/G-11); and SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*. QA activities will use a graded approach, based on potential impact to the environment, safety, health, reliability, and continuity of operations. QA for groundwater monitoring will be discussed in the Groundwater SAP (Appendix A) and will comply with the following requirements:

- DOE/RL-96-68, Hanford Analytical Services Quality Assurance Requirements Document (HASQARD)
- DOE O 414.1D, *Quality Assurance*

The Groundwater SAP (Appendix A) contains a QA project plan, which establishes the quality requirements for environmental data collection, including planning, implementation, and assessment of sampling, field measurements, and laboratory analysis.

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6 Remedial Action Completion

This chapter describes the strategy that will be used to assess progress toward the attainment of RAOs and determine when site closure can be implemented. This discussion includes details of the methods that will be used to determine when remediation can end and demonstrate attainment of cleanup levels in groundwater. Methods to answer PSQs and address decision rules are also identified.

Objectives for groundwater cleanup are summarized in the RAOs discussed in Chapter 2. Cleanup levels for the 100-FR-3 OU COCs are presented in Table 2-1. The estimated time frame required for COC concentrations to reduce to levels below cleanup levels is presented in Table 2-2. RAOs will be achieved through MNA, while maintaining ICs to prevent groundwater use until cleanup levels are achieved.

6.1 Strategy for Completing Site Closure

General guidance and recommendations, as part of a general framework for the implementation of MNA, are discussed in EPA 600/R-11/204 and summarized in the following eight steps:

1. Demonstrate that natural attenuation is occurring according to expectations.
2. Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes.
3. Identify any potentially toxic and/or mobile transformation products.
4. Verify that the plume(s) is not expanding downgradient, laterally, or vertically.
5. Verify that no unacceptable impact exists to downgradient receptors.
6. Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy.
7. Demonstrate the efficacy of ICs that were put in place to protect potential receptors.
8. Verify attainment of RAOs.

Progress toward achieving RAOs in the 100-FR-3 OU will be evaluated based on a strategy employing multiple lines of evidence to address each of the steps of the framework for MNA implementation proposed by EPA 600/R-11/204 and answering PSQs presented in Chapter 3. The principal lines of evidence include the following:

- Monitoring and characterization to identify processes, evaluate current conditions, and determine rates of change in conditions
- Groundwater modeling to make projections
- Statistical analysis of both the monitoring data and groundwater model projections to assess conformance with expectations for ultimate attainment of and compliance with RAOs

The strategy for completing site closure is implemented in two phases: remediation monitoring phase and attainment monitoring phase. The remediation phase consists of three stages that are briefly described in Table 6-1, which also provides a general timeline for monitoring, analysis, and reporting activities. Table 6-2 relates PSQs and decision rules to EPA 600/R-11/204 and to evaluation methods discussed in this chapter.

Table 6-1. Stages of Remediation Phase Monitoring and Associated Activities

Stage	Duration	Actions
I	2 years	• Installation of new monitoring wells (Phase 1) • Commencement of performance monitoring sampling • Evaluation of MNA processes and associated indicators • Phase 1 well report to include year 1 monitoring results, model updates, and Phase 2 well recommendations • Reporting of performance monitoring sampling results in the annual groundwater report
II	3 years	• Model updates and historical/predictive simulations and statistical characterization of monitoring data • Identification and reduction of data gaps: new well installation (Phase 2), and data collection • MNA progress evaluation presented in the 5-year performance monitoring report: – Evaluate changes to the monitoring network – Evaluate need for continuing automated water level network – Evaluate PSQs and decision rules • Reporting of performance monitoring sampling results in the annual groundwater report
III	Ongoing	• Scheduled monitoring and analyses: – Reporting of performance monitoring sampling results in the annual groundwater report – Evaluation of any deviations from expectations • Comprehensive 5-year performance monitoring evaluation and reports: – Update statistical analyses and complete ongoing progress evaluations – Model updates, including use of historical data for model validation and calibration to improve model predictions – Model simulations to evaluate progress of MNA and project cleanup dates – Identification and reduction of data gaps – Evaluate PSQs and decision rules – If data suggest MNA objectives attained for any contaminant of concern/well combination: ▪ Confirm and document cleanup level attainment ▪ Evaluate monitoring network – Provide input to the Hanford Site *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* 5-year review

MNA = monitored natural attenuation

PSQ = principal study question

Remediation monitoring will continue as the COC concentration attenuates. Over time, new monitoring locations may be added to the network as a COC plume migrates away from the original network. New wells will undergo remediation and attainment monitoring and associated evaluations as prescribed for the initial network.

When remediation monitoring results of a specific COC/well combination demonstrate that the cleanup level has been met as described in Section 6.4.1, then the attainment monitoring phase will begin for that specific COC/well combination. As such, attainment monitoring will occur on a well-by-well basis throughout the attenuation period.

Because MNA is a passive system and no active systems are being employed at the site, OSWER Directive 9283.1-44 recommends that data used to evaluate completion of the remediation phase may also be used as part of the attainment phase evaluation. Assuming that the attainment monitoring evaluation shows that the COC has met the cleanup level and will continue to meet the cleanup level, as described in Section 6.4.2, then that COC/well combination may be removed from the monitoring network. When all wells monitoring a given COC have completed the attainment monitoring phase and successfully demonstrated cleanup level attainment, then the RA for that COC will be complete.

In the following sections, elements of the strategy for completing site closure will be presented in detail as they relate to each of the steps of the EPA framework for MNA implementation.

6.2 Monitoring Activities and Refinement of the Conceptual Site Model

Monitoring data from existing and new wells will be collected, compiled, reviewed, and evaluated to provide the basis for the following activities that will be performed as part of the remediation monitoring phase to refine the CSM and evaluate progress toward attainment of cleanup goals:

1. Documenting processes and associated indicators of MNA
2. Identifying geochemical indicators of MNA efficacy
3. Developing plume maps for each COC to delineate plume extents, evaluate spread of contamination, assess plume migration over time, and determine whether there are unacceptable impacts to the Columbia River
4. Mapping of water levels from manual measurements and AWLN continuous data and evaluating seasonal river stage variations, as well as data obtained during installation of new monitoring wells, to refine the CSM and determine changes in the distribution of hydraulic gradient magnitude and direction in the aquifer and assess factors that may impact plume migration
5. Monitoring aquifer tubes and a riverbank seep
6. Evaluating presence of trace metals (antimony, cadmium, and cobalt)
7. Evaluating IC efficacy

Details on implementation of these activities are provided in the following subsections.

6.2.1 Document Processes and Associated Indicators of MNA

The type(s) of natural attenuation processes that are active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels, will be evaluated during the remediation monitoring phase based on the MNA evaluation presented in Appendix M of the 100-F/IU RI/FS (DOE/RL-2010-98).

Monitoring of COC concentrations and identified degradation products, per the identified sampling frequency, will provide necessary information to document these processes and evaluate MNA progress on the basis of those processes by assessing the COC concentration reduction trends.

Implementation of this activity answers PSQs 1a, 1b, and 4a and addresses *Step 1* of the EPA framework for MNA implementation, as part of demonstrating that natural attenuation is occurring according to expectations. It also addresses *Step 3* by identifying potential toxic and/or mobile transformation products.

6.2.2 Identify Geochemical Indicators of MNA Efficacy

Although it is not expected that geochemical conditions will significantly change in the future in 100-F/IU, it is unlikely that any such change would significantly alter the geochemical environment towards one that is less favorable to attenuation. This is because the environment is already fairly oxidizing, and any shift to more reducing conditions would only favor reductive degradation of COCs. During the remediation monitoring phase, monitoring of the geochemical environment will include sampling for and evaluating changes in specific conductance, pH, DO, turbidity, and temperature.

Implementation of this activity answers PSQ 1c and addresses *Step 2* of the EPA framework for MNA implementation.

6.2.3 Plume Mapping

Contaminant plume mapping will be performed annually during the initial years when annual monitoring samples are collected. Updated plume maps will then be generated when new results are available (based on the sampling frequency [e.g., biennial]) as well as to support the Phase 1 well report and 5-year performance monitoring reports. Plume mapping will follow the integrated numerical interpolation procedure implemented as part of the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2014-32). For each COC, the systematic plume mapping approach is based on implementing an integrated procedure of compiling and aggregating data sets in a comprehensive database, developing input files, and executing batch processes using the open source statistical computing/programming language R (The R Development Core Team, 2012, *The R Project for Statistical Computing*) to develop piece-wise continuous contaminant distributions.

The numerically interpolated piece-wise continuous COC distributions allow for estimating contaminant mass, plume center of mass, and spread of the contaminant across the plume area for each COC plume. As a result, the area and spread of contamination, as well as the migration of contamination, will be evaluated over time to monitor potential expansion of the contaminant. Plume mass may be determined, based on estimates of plume thickness and aquifer porosity. Estimates of area and mass answer PSQ 1a and address *Step 4* of the EPA framework for MNA implementation.

Evaluation of numerically interpolated COC distributions will assist in assessing uncertainties in plume spread and attenuation. Plume maps will also enhance understanding of potential COC migration toward the Columbia River and, when considered together with the distinct concentration measurements at each monitoring location along the shoreline, will assist in determining any unacceptable impacts to the Columbia River, thereby answering PSQ 1d and addressing *Step 5* of the EPA framework for MNA implementation.

Evaluation of monitoring data for plume maps would also reveal unexpected increases in COC contamination, which might indicate new or continuing releases of contaminants, answering PSQ 1e and addressing *Step 6* of the EPA framework for MNA implementation.

The updated COC plumes will also be used as initial conditions for the 100 Area Groundwater Model (100-AGWM) to validate previous predictions and update projections, as discussed in Section 6.3.

6.2.4 Water Level Mapping and Refining CSM

Mapping of groundwater level data will be performed using the methods detailed in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*. This methodology is routinely implemented for the purposes of the 100 Areas annual pump-and-treat operations report (e.g., DOE/RL-2014-25, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*), but it is also directly applicable to the evaluation of MNA remedy performance.

The groundwater level mapping method uses an extension of the hybrid universal kriging/analytic element method technique detailed in SGW-42305. First, hydraulic gradients are calculated for triangular elements developed from the network of monitoring wells. Next, groundwater elevation contours are constructed to depict the patterns of groundwater flow and corresponding directions of contaminant migration throughout the groundwater OU. The calculated hydraulic gradients and groundwater elevation contours together provide the basis for evaluating flow patterns and determining whether adverse conditions are being developed that could impact plume migration. Seasonal river stage variations will also be evaluated to determine their influence on flow patterns and the region of river-aquifer interaction where patterns of shoreline inundation vary extensively over the course of the year.

Data obtained during the installation of new monitoring wells will be evaluated to refine the CSM and further refine the representation of aquifer hydraulic parameters, with emphasis on aquifer transmissivity throughout the 100-FR-3 OU, particularly in the southern part of the groundwater OU. As described in Section A3.2.1.3 of the Groundwater SAP (Appendix A), the new well installation data will include the elevation of geologic contacts, transmissivity of unconfined aquifer, and water table elevation.
The refined CSM will improve the evaluation of the magnitude and direction of hydraulic gradients across the OU and the resulting flow patterns to determine the potential for plume migration toward downgradient potential receptors. The refined CSM will also be used to update the parameterization of the 100-AGWM, as discussed in Section 6.3.

Implementation of this activity responds to PSQs 1c and 3 and also addresses *Step 2* of the EPA framework for MNA implementation and, in particular, detection of any changes in hydrologic conditions that may reduce the efficacy of the natural attenuation processes.

6.2.5 Monitoring Aquifer Tubes and Riverbank Seep

A network of aquifer tubes and a natural riverbank seep will be monitored, as described in the Groundwater SAP (Appendix A). Concentration data for each of these sources will be used to support plume mapping and to confirm that there are no unacceptable impacts to the Columbia River, thereby answering PSQ 1d and addressing *Step 5* of the EPA framework for MNA implementation. Data from aquifer tubes and the seep will not be used to determine attainment of groundwater cleanup levels. However, if COC concentrations increase in aquifer tubes or the seep, the monitoring well network may be re-evaluated to determine if sufficient coverage exists.

6.2.6 Trace Metals

Antimony, cadmium, and cobalt will be analyzed at four monitoring wells identified in Table A-8 of the Groundwater SAP (Appendix A). The wells were chosen based on a review of the analytical data as detailed in the DQO summary report (SGW-58291), presented in Appendix A. After a sufficient number of data points have been collected, data will be evaluated using statistical methods described in

Section 6.4. If concentrations of any of these analytes exceed action levels or PQLs, a risk assessment will be performed. This activity answers PSQ 2.

6.2.7 Institutional Controls

ICs required for contaminated 100-FR-3 groundwater are implemented on a sitewide basis by DOE through DOE/RL-2001-41, as discussed in Section 4.1.3. DOE prepares an annual report on the effectiveness of ICs for the Hanford Site. Information from the annual IC reports will be used to evaluate the IC efficacy for the 100-FR-3 OU. Implementation of this activity addresses *Step 7* of the EPA framework for MNA implementation.

6.3 Groundwater Modeling

Groundwater flow and contaminant transport simulations will be performed for each COC using 100-AGWM, which is documented in SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*. 100-AGWM integrates site-specific features, events, and processes, including site geology, aquifer heterogeneity, natural recharge, anthropogenic water discharges, interim and final RAs (such as the pump-and-treat systems in other 100 Area groundwater OUs), together with the interaction between the aquifer and the Columbia River, while considering river bathymetry and time varying river stage conditions. As data from existing and new monitoring locations become available, 100-AGWM will be updated and refined, as necessary, to improve model calibration and the reliability of future projections simulated using the model.

100-AGWM will be used to project the time required to attain RAOs at individual monitoring locations (consistent with EPA guidance) and throughout the entire groundwater OU. Projections will be systematically updated, as new data and information become available, to refine the numerical representation of the CSM. Future projections made using the 100-AGWM will provide one basis for expectation of the rate-of-change in contaminant concentrations at individual monitoring locations, and throughout the entire groundwater OU, to supplement projections that are based upon direct analysis of the monitoring data. Projections made with 100-AGWM will be reported in terms of a best estimate, together with one or more measures of uncertainty that accompany the best estimate projection. Methods that may be used to describe and depict uncertainty in projected cleanup times are described in the following subsections.

Implementation of this activity answers PSQs 1a, 1b, 1d, 3, 4a, and 4b, and it addresses *Steps 1, 4, 5, and 8* of the EPA framework for MNA implementation.

6.3.1 Expectations and Rates-of-Change

As described in the 100-F/IU RI/FS (DOE/RL-2010-98), MNA is expected to achieve RAOs in the time frames set forth. For most COCs in most areas of the groundwater OU, contaminant concentrations exceed final cleanup standards by a factor of 2 to 5. As a result, attenuation rates required to achieve RAOs within the time frame detailed in the ROD (EPA and DOE, 2014) are relatively low, which means that the rates-of-change in contaminant concentrations due to natural attenuation processes will be quite small.

Since expected rates-of-change will be small, cleanup projections calculated in the years soon after commencement of the MNA remedy will likely be accompanied by more uncertainty, as depicted by wide confidence (prediction) intervals, than cleanup projections that are calculated as more data become available. Uncertainty in the cleanup projections is expected to narrow over time, as illustrated by narrowing confidence (prediction) intervals calculated about the best estimate projection, as the number of data points increases and knowledge of the attenuation processes and their rates increases.

This expectation of narrowing confidence (prediction) intervals reflecting increased data and knowledge over time is a common feature of long-term monitoring programs, including those accompanying MNA remedies, and will apply both to projections made using the 100-AGWM and projections made on the basis of regression analysis using the monitoring data (as described in Section 6.4). A consequence of this expectation is that it may require several reporting periods and review cycles for conclusive identification of trends at some locations and for some COCs throughout the groundwater OU. This expectation is one basis for using multiple lines of evidence to ensure that progress is being made toward attainment, and that any potential receptors are protected.

6.3.2 Uncertainty of Projected Cleanup Times

As data become available, the uncertainty in the projected time to achieve RAOs will be depicted using confidence (prediction) intervals constructed about a best estimate; this will be done for both projections made using the 100-AGWM and for projections based upon direct analysis of the monitoring data. When making projections on the basis of the monitoring data directly, these intervals will be computed from the results of regression analysis performed on the monitoring data. When making projections on the basis of modeling completed using 100-AGWM, intervals can be computed using one of the following methods:

- First order/second moment methods that are conceptually similar to the methods used to compute confidence intervals from sample data (USGS Techniques and Methods 6-E2, *OPR-PPR, a Computer Program for Assessing Data Importance to Model Predictions Using Linear Statistics*; Maskey and Guinot, 2003, “Improved first-order second moment method for uncertainty estimation in flood forecasting”)
- Monte-Carlo techniques that create multiple realizations each constrained by historical data and process knowledge (USGS, 2010, *Approaches to Highly Parameterized Inversion: A Guide to Using PEST for Model-Parameter and Predictive-Uncertainty Analysis*)

In either case, the best estimate and confidence (prediction) intervals calculated using 100-AGWM can be compared with those calculated from the sample data obtained from individual wells.

6.4 Statistical Analysis

OSWER 9355.0-129 recommends evaluating COC concentration levels on a well-by-well basis, separately for each COC, to assess aquifer restoration. As discussed in OSWER Directive 9283.1-44, it may be appropriate to conclude that the remediation phase is complete at a monitoring well based on a nonstatistical or visual analysis of the data. Nonstatistical methods are appropriate if all results are less than the cleanup level and the quantitation limit is less than the cleanup level. If these conditions do not apply, COC concentrations will be evaluated on a well-by-well (i.e., intrawell) basis based on statistical analyses of monitoring data and supporting modeling projections.

The strategy for completing site closure is implemented in two phases: (a) the remediation monitoring phase and (b) the attainment monitoring phase. Certain key statistical tests, referred to as fundamental tests, will be applied during both the remediation and attainment monitoring phases to evaluate performance and determine whether additional actions are required, as detailed in Sections 6.4.1 through 6.4.4.

Attainment monitoring for each COC at each well will be undertaken when data demonstrate that concentrations of each COC have met the cleanup level. Data obtained during the remediation monitoring phase may also be employed in the attainment monitoring phase statistical tests to assess the status of attainment of remedial objectives (i.e., cleanup levels), which is consistent with the recommendations of OSWER Directive 9283.1-44.

Attainment of cleanup levels is a quantitative procedure, which is assessed through the application of appropriate statistical tests as detailed below. However, assessment of MNA performance and progress toward the attainment of cleanup levels during the remediation monitoring phase also requires qualitative interpretation of data, such as geochemical data, groundwater flow and contaminant migration rates and directions, and other factors, in addition to the application of statistical tests detailed in the following sections.

6.4.1 Remediation Monitoring Phase: Fundamental Tests

As recommended in OSWER Directive 9283.1-44, for each combination of COC and monitoring well, a statistical analysis of the groundwater water sample data set will be performed to evaluate if MNA progress is consistent with expectations and assess the attainment of cleanup levels. During the remediation monitoring phase, the fundament test is the *trend test*. The trend test evaluates the time-dependent sample concentrations for each COC at each well, using parametric or nonparametric methods: if a trend is identified, then the slope of the trend can be calculated, together with confidence limits around this slope.

During the remediation monitoring phase, the *mean test* will also be implemented in addition to the trend test. The mean test is based on calculating the mean contaminant concentration for the particular COC at the particular well, as well as upper confidence limits (UCLs) and lower confidence limits (LCLs) around the mean to account for variability around the true mean. Cleanup level attainment during remediation monitoring evaluation is determined by calculating the 95 percent UCL on the mean, as described in Section 6.4.3, and comparing to the cleanup level.

These statistical analyses will be used during the remediation monitoring phase to evaluate MNA progress toward, and attainment of, cleanup levels. The outcomes of the application of these tests provide the basis for MNA progress evaluation by considering the following:

- If the 95 percent UCL is at or below the cleanup level, then that COC/well combination has attained the cleanup level, and the remediation monitoring phase is complete for this COC/well combination. Attainment monitoring can commence.
- If the slope of the trend indicates that the mean and the LCL will fall below the cleanup level sooner than the estimated time frame presented in Table 2-2, MNA progress is on target to meet the cleanup goals.
- If the slope of the trend indicates that the mean and the UCL will fall below the cleanup level later than the estimated time frame presented in Table 2-2, but the LCL indicates cleanup levels will be met sooner than the estimated time frame, then the confidence interval must be narrowed.
- If the slope of the trend indicates that the mean and the LCL will fall below the cleanup level later than the estimated time frame presented in Table 2-2, then:
  - If the confidence interval is unacceptably large, the confidence interval must be further narrowed.
  - If the confidence interval is acceptable, further investigation is required to identify the cause.

Application of these tests during the remediation monitoring phase answers PSQs 1a, 1b, and 4a, and addresses *Step 1* of the EPA framework for MNA implementation, assisting in demonstrating that natural attenuation is occurring according to expectations. As applied to near-river wells, it answers PSQ 1d and addresses *Step 5* of the EPA framework for MNA implementation regarding unacceptable impacts to the Columbia River. Evaluation of monitoring data for trends may reveal unexpected increases in COC

contamination that may indicate new or continuing releases of contaminants that will require further investigation, answering PSQ 1e and addressing *Step 6* of the EPA framework for MNA implementation.

6.4.2 Attainment Monitoring Phase: Fundamental Tests

Similarly to the remediation monitoring phase, a statistical analysis of the groundwater sample data for each combination of COC and monitoring well will be performed during the attainment monitoring phase to evaluate whether the cleanup level has been attained for the particular COC/well combination. Attainment monitoring will be performed for 5 years for each COC/well combination. The attainment monitoring evaluation may include data used to evaluate remediation monitoring completion.

The 95 percent UCL on the mean will be determined, as described in Section 6.4.3, and used for comparison to the cleanup level. The fundamental test during the attainment monitoring phase comprises the following:

- If the 95 percent UCL is at or below the cleanup level,

  and

- The time-dependent slope of the trend is zero or statistically significantly negative,

  then

  It is appropriate to conclude that the attainment monitoring phase is complete and the cleanup level is attained for that COC/well combination.

Evaluation of cleanup level attainment will be performed on a well-by-well basis following the approach described above. Monitoring wells where it is determined that cleanup levels are attained will be removed from the monitoring network, unless monitoring is required for some other purpose.

Because the time frames for each of the COCs to meet the cleanup levels vary from 35 to 150 years, the RA for each COC will be completed at different times. RA completion for each COC plume and the entire 100-FR-3 OU is described in Section 6.7.

Application of these fundamental tests is the basis for verifying attainment of the remediation objectives, answering PSQ 4b and addressing *Step 8* of the EPA framework for MNA implementation. Similar tests will be applied to answer PSQ 2 regarding trace metals considering the action levels presented in Table A-4 in the Groundwater SAP (Appendix A).

6.4.3 Methods for Calculating Means and Confidence Levels

The 95 percent UCL calculated with ProUCL, Version 5.0.00 (EPA, 2013) will be used for comparison to cleanup levels. Updated versions of ProUCL will be used as they become available. ProUCL calculates an accurate 95 percent UCL considering data distribution, data set size, skewness of the data, and percentage of nondetects.

In some cases, ProUCL will suggest more than one UCL. Confidence levels on the mean value for a sample data set can be calculated using a wide variety of statistical methods, each of which relies upon a set of assumptions. For example, some methods for calculating confidence levels are strictly applicable only for certain sample data distributions, such as Gaussian (normal), or lognormal. Some confidence levels estimate methods are not suitable when there are a large number of nondetect (i.e., “censored”) data. In the event that multiple UCLs are suggested by ProUCL, the sample data distribution may be tested and the most suitable of the suggested UCLs will be used in accordance to a sample data distribution.

The UCL suggested by ProUCL may correspond to a higher percentile UCL (e.g., 97.5 percent or 99 percent UCL), depending on the method selected for calculating the UCL and considering the sample size and its standard deviation. In these cases, the higher percentile UCL suggested by ProUCL will be used for comparison with the cleanup level.

6.4.4 Methods for Trend Testing and Slope Estimation

For each COC/well combination, the analysis of concentration trends is a fundamental element of both the remediation and attainment monitoring phases. In all cases, common nonparametric methods will be used to test for the presence of a trend, and to quantify the slope of the trend: these methods comprise the Mann-Kendall (standard or seasonal) trend test, which identifies the presence of a trend but does not quantify the slope, and the Theil-Sen trend estimator (standard or seasonal), which calculates the slope value. These tests are typically conducted on the logarithm of the concentration value, rather than the native concentration value.

These trend tests are strictly applicable in the case of a monotonic trend either in the entire data set or within seasonal subsets. In some instances, however, trends may not be monotonic either in the entire data set or within seasonal subsets; this occurs when changes in concentration are related to other factors, such as the impact of remediation or changes in groundwater levels. In such cases, the influence of these other factors may be incorporated in the trend estimation by presenting them as an independent variable using parametric multiple linear regression. Depending on the variability of COC concentrations at each monitoring well, global application of a single slope estimation technique or regression equation for every COC/well combination may result in the calculation of misleading trends and slopes. Therefore, the dependency of COC concentrations on river-stage variations and/or other hydrological factors will be evaluated in order to determine the most suitable methods for trend and slope estimation.

With regard to the selection of the number of samples required to estimate the slope, as presented in OSWER Directive 9200.4-17P, the first line of evidence regarding the use of MNA requires that, regression analysis provides rate constants for attenuation that provide a precise definition of a “clear and meaningful trend of decreasing contaminant concentration over time.” In Wilson, 2008, “Extracting rate constants for MNA from long-term monitoring data,” a “clear and meaningful trend” is defined as the first order rate constant for attenuation over time that is greater than zero at some predetermined level of confidence (Wilson, 2008, “Extracting rate constants for MNA from long-term monitoring data”). Although eight samples is an efficient criterion for a minimal data set to evaluate natural attenuation, Wilson concluded that, in examples that he presented, 8 sample dates would have failed to detect successful attenuation at 6 of 14 sites. Therefore, it may be necessary to gather more data to be able to clearly identify statistically significant attenuation, as short data sets can potentially lead to inaccurate projections of the true trend.

Finally, there are cases when a statistically significant rate of attenuation can be calculated based on short-term data, but rates calculated based on longer term data sets may not be statistically significant. It is therefore important to determine the appropriate data set to perform any statistical analysis in order to calculate meaningful attenuation rates and evaluate the efficacy of the natural attenuation processes. For that reason, pre-/post-source-removal trends will be analyzed to discern the right starting point in time to conduct the statistical analysis for the fundamental tests.

6.5 Indicators of Unacceptable Performance

Evaluation of the performance monitoring results will consider criteria that will indicate unacceptable performance of the remedy and that may trigger response actions. General conditions to be considered during data reviews and performance evaluations are discussed in OSWER Directive 9200.4-17P:

- Contaminant concentrations in soil or groundwater at specified locations exhibit an increasing trend not originally predicted during remedy selection.
- Near-source wells exhibit large concentration increases indicative of a new or renewed release.
- Contaminants are identified in monitoring wells located outside of the original plume boundary.
- Contaminant concentrations are not decreasing at a sufficiently rapid rate to meet the remediation objective.
- Changes in land and/or groundwater use will adversely affect the protectiveness of the MNA remedy.

As detailed in Section 6.3, it is expected that some performance evaluations, particularly in the early years of monitoring which will include data from new monitoring wells, may indicate variable attenuation rates and plume extents. Some of this variation may be attributable to sampling variability and seasonal fluctuation. However, this will be expected to diminish as the number of data increases. If evaluation of the sampling results indicate that any of the conditions persist over multiple review cycles, and are not attributable to other factors, then DOE and the regulators will evaluate the protectiveness of the remedy and, if the remedy is deemed not protective, determine a path forward.

6.6 Monitoring Optimization

The monitoring well network and sampling frequency will be optimized over time, as more data become available and conclusions from data evaluations are drawn. Analyses during the early stages of the remediation monitoring phase will focus on obtaining sufficient data to estimate trends within acceptable confidence intervals. Once sufficient data are available, attainment of the cleanup goals will be assessed for each COC/well combination over time.

The monitoring network will ultimately reduce as the plumes attenuate and individual wells attain the cleanup level for each COC. However, additional monitoring locations may be added to the monitoring network to track plumes that migrate off the initial network as they attenuate. Even after cleanup level attainment, sampling at monitoring locations may continue at reduced frequency for other purposes, such as preparing plume maps and supporting performance monitoring reports.

6.7 Remedial Action Completion

Completion of the 100-FR-3 OU MNA remedy will be demonstrated by attainment of the groundwater cleanup levels for each COC. During remediation monitoring, contaminant migration and changes in COC concentrations over time for each COC/well combination are evaluated, as described in Section 6.4.1. The time-dependent slope for the COC concentration at each well is determined to assess progress towards cleanup level attainment relative to expectations. Cleanup level attainment is determined on a well-by-well basis for each COC by calculating the 95 percent UCL on the mean and comparing the value to the cleanup level. When the evaluation demonstrates that a specific COC/well combination has attained the cleanup level, then attainment monitoring for that COC/well will commence.

Attainment monitoring results are evaluated on a well-by-well basis to verify COC attenuation, as described in Section 6.4.2. Evaluation consists of calculating the 95 percent UCL on the mean and determining the COC concentration trend slope. If the 95 percent UCL is at or below the cleanup level and the COC trend slope is zero or negative, then the specific COC/well combination is considered to have met the cleanup level and groundwater has completed attenuation in that monitoring area. No further monitoring is required for the COC/well combination, although additional sampling may be performed to support other purposes such as plume mapping. When attainment monitoring and subsequent data

evaluation are successfully completed at all wells monitored for a given COC, then the RA for that COC plume will be complete and no further monitoring for that COC is required.

Additional wells may be added to the monitoring network as COC plumes migrate. Over time, as groundwater COCs attenuate and evaluation of well data demonstrates attainment, the number of wells within the monitoring network will decrease until all wells have attained cleanup levels and RA is complete. The evaluation of cleanup level attainment on a well-by-well basis and eventual RA completion for each COC will be documented in the 5-year performance monitoring reports described in Section 3.3, as well as the final RA report. Any wells where COC attainment is achieved will be listed in a table in the applicable 5-year performance monitoring report with EPA concurrence on the report serving to document agreement that attainment was reached. EPA approval of termination of monitoring or other changes in monitoring will be documented by change notices or revisions to the Groundwater SAP (Appendix A).

Depending on timing, a progress evaluation may be performed separately from the 5-year performance monitoring report if a given COC/well has met the cleanup level and is ready to enter the attainment monitoring phase. In this case, the evaluation will be included in the subsequent 5-year report.

If attainment monitoring results for a given COC do not demonstrate that the cleanup levels have been attained, then DOE and the regulators will evaluate the results and determine the path forward.

The 100-FR-3 OU RA will be complete when all COC/well combinations have successfully completed attainment monitoring and demonstrated cleanup level attainment as described in this chapter.
The groundwater plumes are projected to attain the cleanup levels at time frames varying from 35 to 150 years, with strontium-90 requiring the longest attenuation period. Therefore, performance monitoring for Cr(VI), TCE, and nitrate will be completed with cleanup level attainment documented in 5-year performance monitoring reports prior to the strontium-90 attainment. When the well-by-well evaluation of the strontium-90 plume demonstrates attainment of the cleanup level, a final RA report for the 100-FR-3 OU will be prepared, as described in Section 3.5.

Table 6-2. Evaluation of Performance Monitoring Principal Study Questions and Corresponding Decision Rules with Crosswalk to Applicable EPA Guidance

Principal Study Question	Decision Rule	Evaluation Method	EPA Guidance (Section 6.1)
PSQ 1a. Are contaminant concentrations and plume area/mass decreasing?	Decision Rule 1. If the weight of evidence indicates that natural attenuation is occurring as expected then continue MNA; otherwise, evaluate other options.	Document processes and associated indicators of MNA (Sec. 6.2.1) Plume mapping (Sec. 6.2.3) Groundwater modeling (Sec. 6.3) Statistical analysis (Sec. 6.4)	Step 1: Demonstrate that natural attenuation is occurring according to expectations. Step 3: Identify any potentially toxic and/or mobile transformation products. Step 4: Verify the plume is not expanding downgradient, laterally or vertically.
PSQ 1b. Are rates of decline consistent with expectations?		Document processes and associated indicators of MNA (Sec. 6.2.1) Groundwater modeling (Sec. 6.3) Statistical analysis (Sec. 6.4)	Step 1: Demonstrate that natural attenuation is occurring according to expectations. Step 3: Identify any potentially toxic and/or mobile transformation products.
PSQ 1c. Are there changes in environmental conditions that may reduce the efficacy of natural attenuation?		Identify geochemical indicators of MNA efficacy (Sec. 6.2.2) Water level mapping and refining CSM (Sec. 6.2.4)	Step 2: Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes.
PSQ 1d. Are there unacceptable impacts to the Columbia River?		Plume mapping (Sec. 6.2.3) Monitoring aquifer tubes and riverbank seep (Sec. 6.2.5) Groundwater modeling (Sec. 6.3) Statistical analysis (Sec. 6.4)	Step 5: Verify no unacceptable impact to downgradient receptors.
PSQ 1e. Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy?		Plume mapping (Sec. 6.2.3)	Step 6: Detect new releases of contaminants to the environment that could impact effectiveness.
PSQ 2. Are concentrations of antimony, cadmium, and cobalt below action levels?	Decision Rule 2. If monitoring indicates concentrations are not greater than the action level or practical quantitation limit, then discontinue monitoring; otherwise, perform risk assessment.	Trace metals (Sec. 6.2.6) Attainment monitoring statistical analysis (Sec. 6.4.2)	Not in EPA guidance; required to resolve previous analytical uncertainty.

Table 6-2. Evaluation of Performance Monitoring Principal Study Questions and Corresponding Decision Rules with Crosswalk to Applicable EPA Guidance

Principal Study Question	Decision Rule	Evaluation Method	EPA Guidance (Section 6.1)
PSQ 3. Do new geologic and hydrogeologic data confirm the conceptual site model?	Decision Rule 3. If new geologic and hydrogeologic data confirm the conceptual site model, then retain the model; otherwise, update it.	Water level mapping and refining CSM (Sec. 6.2.4) Groundwater modeling (Sec. 6.3)	Step 1: Demonstrate that natural attenuation is occurring according to expectations. Step 2: Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes. Step 4: Verify the plume is not expanding downgradient, laterally or vertically.
PSQ 4a. Are concentrations of COCs below cleanup levels?	Decision Rule 4. If RAO has been achieved for an individual COC, then proceed to attainment monitoring for that COC; otherwise, continue MNA.	Document processes and associated indicators of MNA (Sec. 6.2.1) Groundwater modeling (Sec. 6.3) Statistical analysis (Sec. 6.4)	Step 8: Verify attainment of the remediation objectives.
PSQ 4b. Will groundwater continue to meet the cleanup level in the future?		Groundwater modeling (Sec. 6.3)	
Not an identified PSQ; evaluated within EPA performance monitoring guidance	Not applicable.	Institutional controls (Sec. 6.2.8)	Step 7: Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors.

AWLN = automated water level network
COC = contaminant of concern
CSM = conceptual site model
EPA = U.S. Environmental Protection Agency
MNA = monitored natural attenuation
PSQ = principal study question
RAO = remedial action objective

7 Cost and Schedule

The cost and schedule for the 100-FR-3 groundwater OU remedy components are presented in this chapter.

7.1 Cost Summary

The cost for the 100-FR-3 groundwater OU MNA is $19.5 million (Table 7-1) (ECE-100FR314-00007, *Environmental Cost Estimate for 100 F/IU RD/RAWP*). The costs for ICs restricting 100-FR-3 OU groundwater use are included in the overall 100-F/IU IC cost presented in the Integrated RDR/RAWP (DOE/RL-2014-44).

Performance monitoring includes periodic sampling and analysis from 28 existing monitoring wells, 8 new Phase 1 wells, 6 aquifer tubes, and 1 riverbank seep. An additional 6 Phase 2 wells may be identified for the monitoring network and are included in the cost estimate. For cost estimating purposes, new monitoring wells are assumed to be sampled quarterly for Year 1, annually for Years 2 through 5, and biennially thereafter. Existing monitoring wells, aquifer tubes, and the seep will be sampled annually for Years 1 through 5, and biennially thereafter.

Performance monitoring sampling results will be presented in the annual groundwater monitoring report (e.g., DOE/RL-2014-32). A separate report detailing Phase 1 well results, modeling updates, water level measurement results, and any Phase 2 well recommendations will be prepared after Phase 1 wells have completed the first year of performance monitoring. Detailed evaluation of the results and modeling updates will be presented in separate performance monitoring reports. The performance monitoring reports will be generated at 5-year frequencies to support the Hanford Site CERCLA 5-year review cycles.

Table 7-1. Summary of Costs for Monitored Natural Attenuation Remedy

Activity	Total Costs
Project Management	$3,366,932
Well Drilling (New and Replacement Wells)	$2,988,090
Well Rehabilitation, Upgrades to River Gauge Station, Automated Water Level Network, and Operations and Maintenance	$4,380,851
Performance Monitoring, Reporting, and Well Decommissioning	$8,811,823
Total Costs	**$19,547,696**

7.2 Schedule

Implementation of the 100-FR-3 OU performance monitoring will begin after approval of the Integrated RDR/RAWP (DOE/RL-2014-44), as shown in Figure 7-1. Installation of new monitoring wells is projected to be initiated immediately following RDR/RAWP approval and is anticipated to be completed 6 months after RDR/RAWP approval.

Data from the new and existing wells will be obtained in the first monitoring year; however, completion of quarterly sampling for all Phase 1 wells will extend into the next monitoring year. The first full year of

monitoring at Phase 1 wells will be completed 1 year from the final Phase 1 well acceptance date. A report detailing an initial evaluation of the monitoring program and recommendations of Phase 2 monitoring wells is projected to be completed 6 months after the first year of monitoring data is obtained for all Phase 1 wells. Additional Phase 2 monitoring wells, if required, will be completed within approximately 1 year after recommendation. Approval of cultural resource reviews for Phase 2 wells is estimated to take 6 months. Results from the monitoring network will be evaluated for changes to the sampling plan, including additional wells or aquifer tubes, after the first 5 years of monitoring. The first comprehensive 5-year performance monitoring report is anticipated to be prepared in 2020 to support the sitewide CERCLA 5-year review.

The duration of MNA performance monitoring is based on the 2011 model estimated time frame for each COC to achieve its cleanup level as described in the 100-F/IU RI/FS (DOE/RL-2010-98). The estimated time frames are rounded up to account for model uncertainties. The following time frames are estimated for each COC:

- Cr(VI) = 35 years (based on 10 µg/L cleanup level)
- Trichloroethene = 50 years
- Nitrate = 80 years
- Strontium-90 = 150 years

Estimated time frames will be refined and updated based on the performance monitoring reports. Once the cleanup level for each COC is achieved, 5 years of attainment monitoring will be performed at each well. The 5-year attainment monitoring period is not included in the time frame estimates for cleanup level attainment.

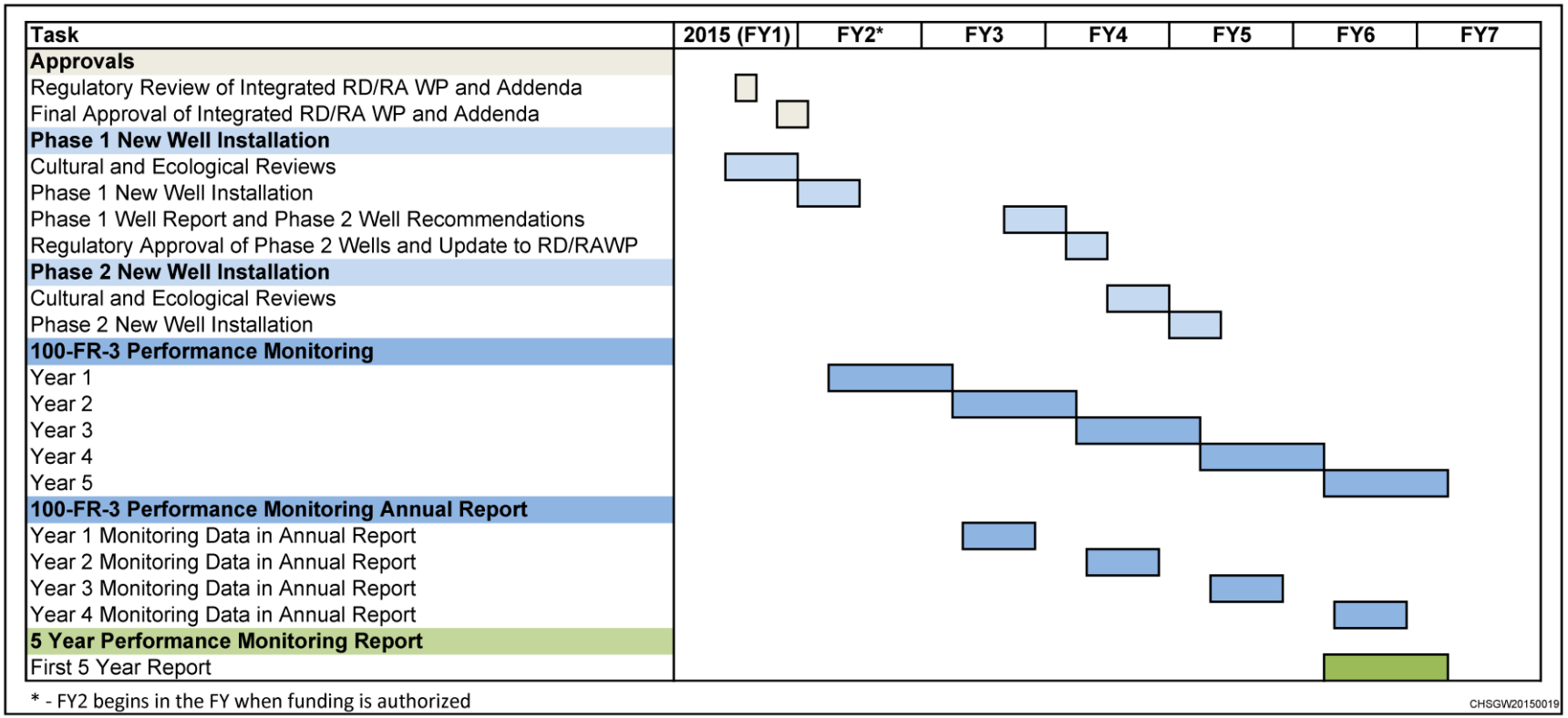

Figure 7-1. Schedule for 100-FR-3 Operable Unit Performance Monitoring Implementation

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Appendix A

100-FR-3 Groundwater Sampling and Analysis Plan

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Terms

ALARA	as low as reasonably achievable
ASTM	ASTM International, formerly American Society for Testing and Materials
AWLN	automated water level network
BTR	Buyer's Technical Representative
CFR	*Code of Federal Regulations*
COC	contaminant of concern
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy-Richland Operations Office
DOT	U.S. Department of Transportation
DQA	data quality assessment
DQI	data quality indicator
DQO	data quality objective
DUP	field duplicate
DWS	drinking water standard
EAF	Experimental Animal Farm
EB	equipment blank
ECO	Environmental Compliance Officer
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FEAD	Format for Electronic Analytical Data
FSO	Field Sampling Operations
FTB	full trip blank
FWS	Field Work Supervisor
FXR	field transfer blank
HASP	health and safety plan
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
HEIS	Hanford Environmental Information System

LCS	laboratory control sample
LRA	lead regulatory agency
MB	method blank
MNA	monitored natural attenuation
MS	matrix spike
MSA	Mission Support Alliance
MSD	matrix spike duplicate
NCO	nuclear chemical operator
OU	operable unit
PPE	personal protective equipment
PSQ	principal study question
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RAO	remedial action objective
RCT	Radiological Control Technician
RDR	request for data review
RDR/RAWP	remedial design report/remedial action work plan
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RUM	Ringold Formation upper mud unit
SAF	sample authorization form
SAP	sampling and analysis plan
SMILE	*Sample Management Integrated Lifecycle Environment*
SMR	Sample Management and Reporting
SPLIT	field split sample
SUR	surrogate
TCE	trichloroethene
TPA	Tri-Party Agreement
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

VOC	volatile organic compound
WAC	*Washington Administrative Code*

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A1 Introduction

This sampling and analysis plan (SAP) presents the performance monitoring plan for the 100-FR-3 groundwater operable unit (OU). The 100-FR-3 OU comprises groundwater contaminated by releases from facilities and waste sites associated with past operation of the 100-F Reactor and biological experiments (Figure A-1). In September 2014, the 100-F/IU record of decision (ROD) (EPA and DOE, 2014, *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*) was issued for the 100-FR-3 Groundwater OU. The 100-F/IU ROD (EPA and DOE, 2014) selected monitored natural attenuation (MNA) of groundwater and institutional controls (ICs) to restrict groundwater use as the final remedial actions. MNA will be implemented for hexavalent chromium (Cr(VI)), nitrate, strontium-90, and trichloroethene (TCE) in the 100-FR-3 OU groundwater. Performance monitoring of these contaminants of concern (COCs) in the groundwater as a component of the MNA remedy will be performed until cleanup levels are met.

This SAP consists of five chapters. The remainder of this chapter addresses the project scope and objectives, background, data quality objectives (DQOs), groundwater contaminants, and project schedule; Chapter A2 presents the quality assurance project plan (QAPjP); and Chapter A3 provides the field sampling plan. Chapters A4 and A5 address waste management and health and safety requirements.

Upon approval of DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU* (Integrated Remedial Design Report/Remedial Action Work Plan [RDR/RAWP]) and Groundwater Addendum, to which this document is an appendix, this SAP will supersede DOE/RL-2003-49, *100-FR-3 Operable Unit Sampling and Analysis Plan*, and DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

A1.1 Project Scope and Objectives

The scope of groundwater monitoring presented in this SAP satisfies the requirements for performance monitoring of the MNA remedy identified in the 100-F/IU ROD (EPA and DOE, 2014) and described in the *Remedial Design Report/Remedial Action Work Plan for 100-F/IU Groundwater* (hereinafter called the Groundwater Addendum), to which this document is an appendix. This includes identification of the groundwater monitoring network; installation of new monitoring wells; periodic sampling of new and existing wells, aquifer tubes, and a riverbank seep; laboratory analysis; and data evaluation.
The monitoring locations are designed to collect groundwater data sufficient to evaluate natural attenuation processes, rates of attenuation, and overall protectiveness with respect to the following 100-FR-3 remedial action objectives (RAOs) identified in the 100-F/IU ROD (EPA and DOE, 2014):

- **RAO 1:** Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 2:** Prevent unacceptable risk to human health and ecological receptors from groundwater discharges to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 7:** Restore groundwater impacted from 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 releases to proposed cleanup levels, which include drinking water standards (DWSs), within a time frame that is reasonable given the particular circumstances of the site.

Performance monitoring of natural attenuation for Cr(VI), strontium-90, nitrate, and TCE and the COCs identified in the 100-F/IU ROD (EPA and DOE, 2014) is included in this SAP. As discussed in the Groundwater Addendum (Section 3.1.1), performance monitoring consists of two phases: remediation

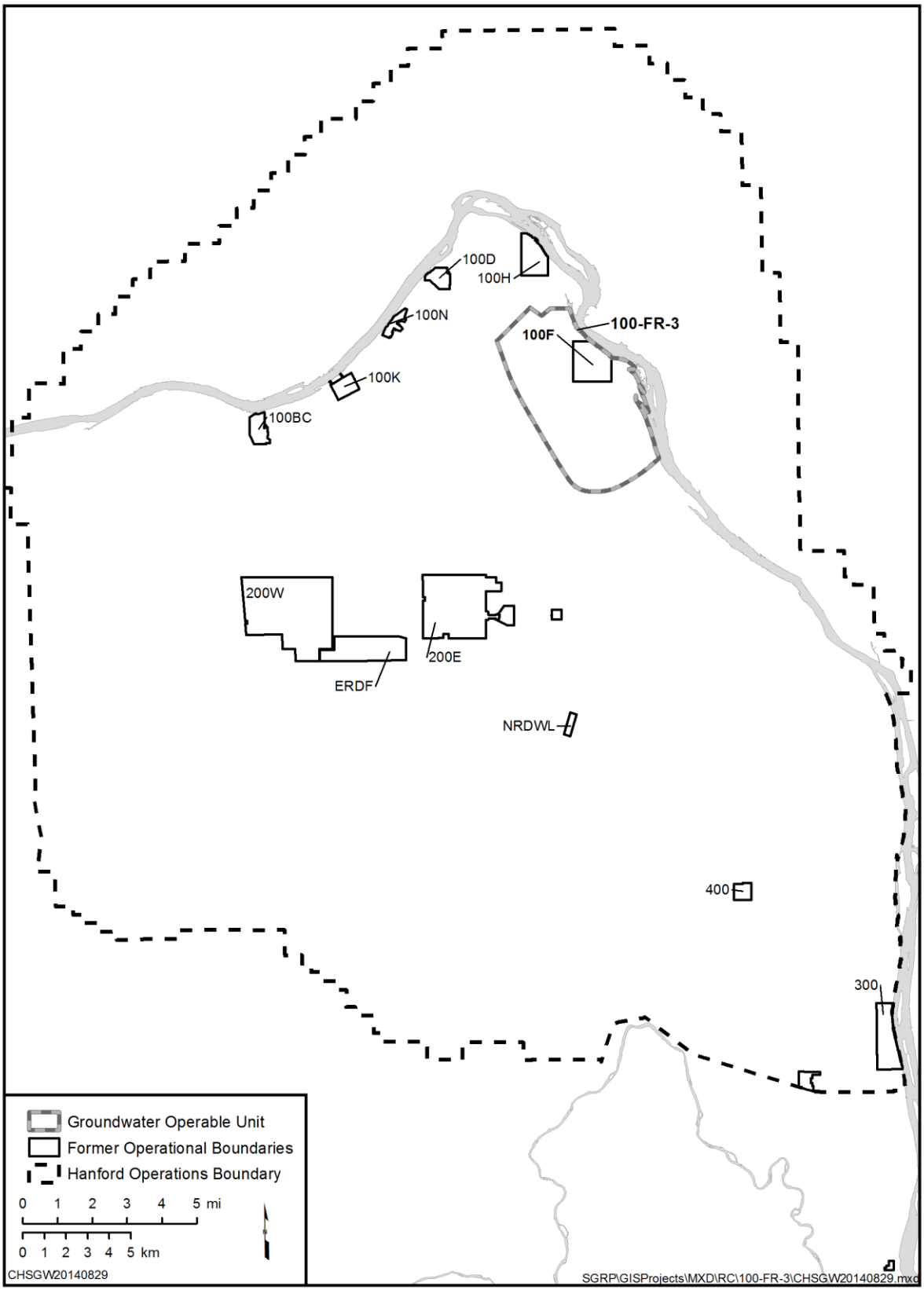


Figure A-1. Location of the 100-FR-3 Groundwater Operable Unit

monitoring and attainment monitoring. The first phase (remediation monitoring) refers to the phase of the remedy where remedial activities are being implemented to reach groundwater cleanup levels. During this phase, groundwater monitoring data are collected to evaluate contaminant migration and changes in COC concentrations over time.

A description of methods used to evaluate the progress of attenuation and determine cleanup level attainment is presented in Chapter 6 of the Groundwater Addendum.

The attainment monitoring phase occurs after the remediation monitoring phase is complete. Once the groundwater is observed to have reached steady-state conditions, data are collected and evaluated to confirm that the cleanup level has been attained.

Protection of Columbia River aquatic receptors is monitored using data collected to track COC plumes in the aquifer near the point of discharge. Protection of human health is accomplished by preventing exposure through implementing ICs to restrict groundwater use. The sample data collected will be used to monitor the progress of natural attenuation and determine when cleanup levels have been achieved.

Degradation products of TCE are also identified for sampling. These chemicals include *cis*-1,2-dichloroethene and vinyl chloride. Due to analytical uncertainties identified in the 100-F/IU remedial investigation/feasibility study (RI/FS) report (DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*), sampling and analysis will also be conducted for antimony, cadmium, and cobalt.

The objectives of this SAP are as follows:

- MNA of identified COCs (Cr(VI), strontium-90, nitrate, and TCE) in meeting the RAOs identified in the 100-F/IU ROD (EPA and DOE, 2014).
- Determine if antimony, cadmium, and cobalt are present below action levels.
- Evaluate the influence of seasonal variation and geology and hydrogeology in the southern portion of the 100-FR-3 OU on hydraulic gradients.
- Determine if RAOs and cleanup levels have been achieved.

Implementation of this plan provides groundwater monitoring data that will be evaluated and reported as part of the Hanford Site annual groundwater report and in separate reports on a less frequent basis. The remediation monitoring phase for Cr(VI), strontium-90, nitrate, and TCE natural attenuation will continue until the progress evaluations demonstrate that cleanup levels have been attained, as described in the Groundwater Addendum. After the remediation monitoring evaluation at a given well demonstrates that cleanup levels have been attained, each COC will undergo an attainment monitoring phase at that well.

The DQO process supporting the performance monitoring design included an evaluation of existing monitoring wells, aquifer tubes, and riverbank seeps with respect to the 2013 Cr(VI), strontium-90, TCE, and nitrate plume configurations. Historical sampling locations and analytical results generated during groundwater monitoring in the 100-FR-3 OU through 2013 were reviewed. The objective of the evaluation was to select a representative monitoring network and identify sampling requirements to address the principal study questions (PSQs) and meet data needs. The evaluation defined locations needed for contaminant monitoring and determined an appropriate sampling frequency. The criteria applied to identify monitoring locations and select an appropriate sampling frequency are provided in a

DQO report (SGW-58291, *Data Quality Objectives for 100-FR-3 Monitored Natural Attenuation*). The report is included with this appendix for convenience.

Water levels will be measured manually at periods of low, high, and moderate river stage. A network of wells will be incorporated into an automated water level network (AWLN) for hourly measurements. Water level data will be used to improve interpretations and models of groundwater flow in the 100-FR-3 OU.

A1.2 Background

This section summarizes hydrogeology, groundwater flow, contaminant sources, and contaminant plumes of the 100-FR-3 OU.

A1.2.1 Site Hydrogeology

A detailed description of the 100-F/IU site history and hydrogeologic conditions is included in Sections 1.2 and 3.4 through 3.6 of the 100-F/IU RI/FS (DOE/RL-2010-98). The primary geologic units are the Hanford formation, the Ringold Formation upper mud unit (RUM), deeper units of the Ringold Formation, and Columbia River Basalt (Figure A-2). Chapter 3 of the 100-F/IU RI/FS (DOE/RL-2010-98) includes detailed information about site geology.

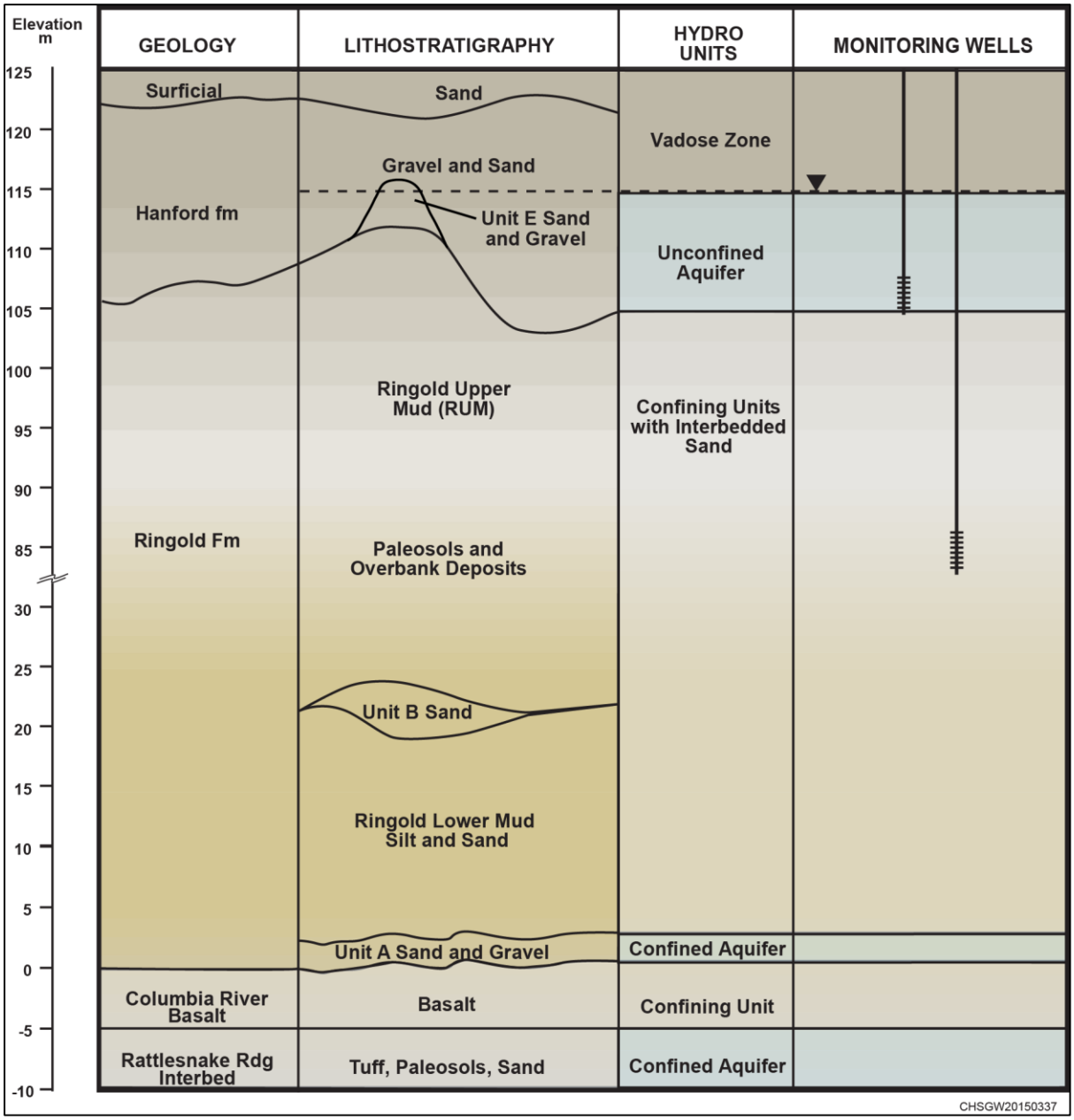
Figure A-3 is a geologic cross section through 100-F Area, trending southwest to northeast. A thick unit of Ringold Formation mud (silt) forms the base of the section. In some locations, remnants of Ringold unit E (silty gravelly sand) overlie the mud. The uppermost geologic unit (Hanford formation) varies in thickness from approximately 6 m (20 ft) in the southwest to approximately 21 m (69 ft) in the northeast. Gravel-rich strata appear to be most common. Sand-dominated intervals also are present but appear to be local in extent. Silt-dominated strata have not been identified at 100-F.

Figure A-4 is a geologic cross section through the eastern end of Gable Mountain to the Columbia River. The cross section parallels the northern section of the 100-FR-3 OU nitrate plume. Most of the well logs do not provide sufficient detail to distinguish between Hanford and Ringold E sediments, nor between RUM and other Ringold silt/clay units. The top of the RUM north of Gable Mountain is at approximately the same elevation as the Ringold lower mud south of the structure.

Ringold unit E is not present beneath much of the 100-FR-3 OU. However, recent interpretations of borehole logs from some wells suggest the presence of remnants of this unit. Figure A-5 illustrates the elevation extent of these remnants, with the largest one in southwestern 100-F Area and smaller remnants in central and eastern 100-F Area. Where unit E extends above the water table, it comprises the entire unconfined aquifer. Ringold unit E is less transmissive than the Hanford formation, which may contribute to the persistence of the TCE plume in groundwater (Figure A-5; Section A1.2.4).

The RUM underlies the Hanford formation (and Ringold unit E, where present) beneath the 100-F Area. Figure A-6 illustrates a recent interpretation of the RUM surface beneath 100-F Area. It slopes generally from southwest to northeast.

The unconfined aquifer beneath the 100-F Area comprises Hanford formation gravels or Ringold Formation silty sandy gravels (Figure A-2). The thickness of the uppermost aquifer in the 100-FR-3 OU ranges from less than 1 to 8 m (3 to 26 ft). The unconfined aquifer is absent in a region just north of Gable Mountain. Below the unconfined aquifer, the Ringold Formation consists of a series of aquitards and water bearing zones. The low-permeability RUM is the base of the unconfined aquifer.



Source: DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*.

Figure A-2. Stratigraphy and Hydrogeologic Units of 100-F Area

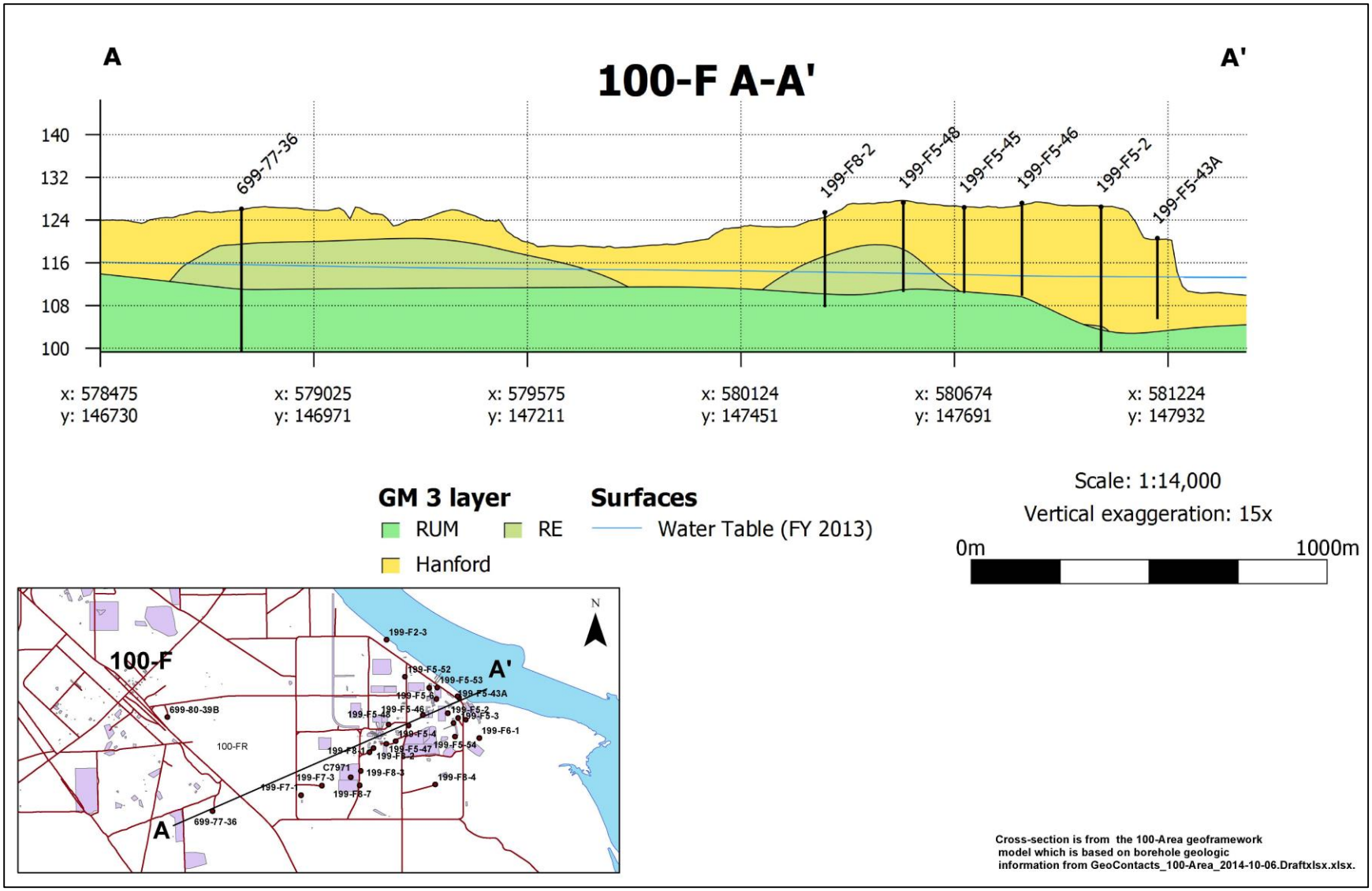
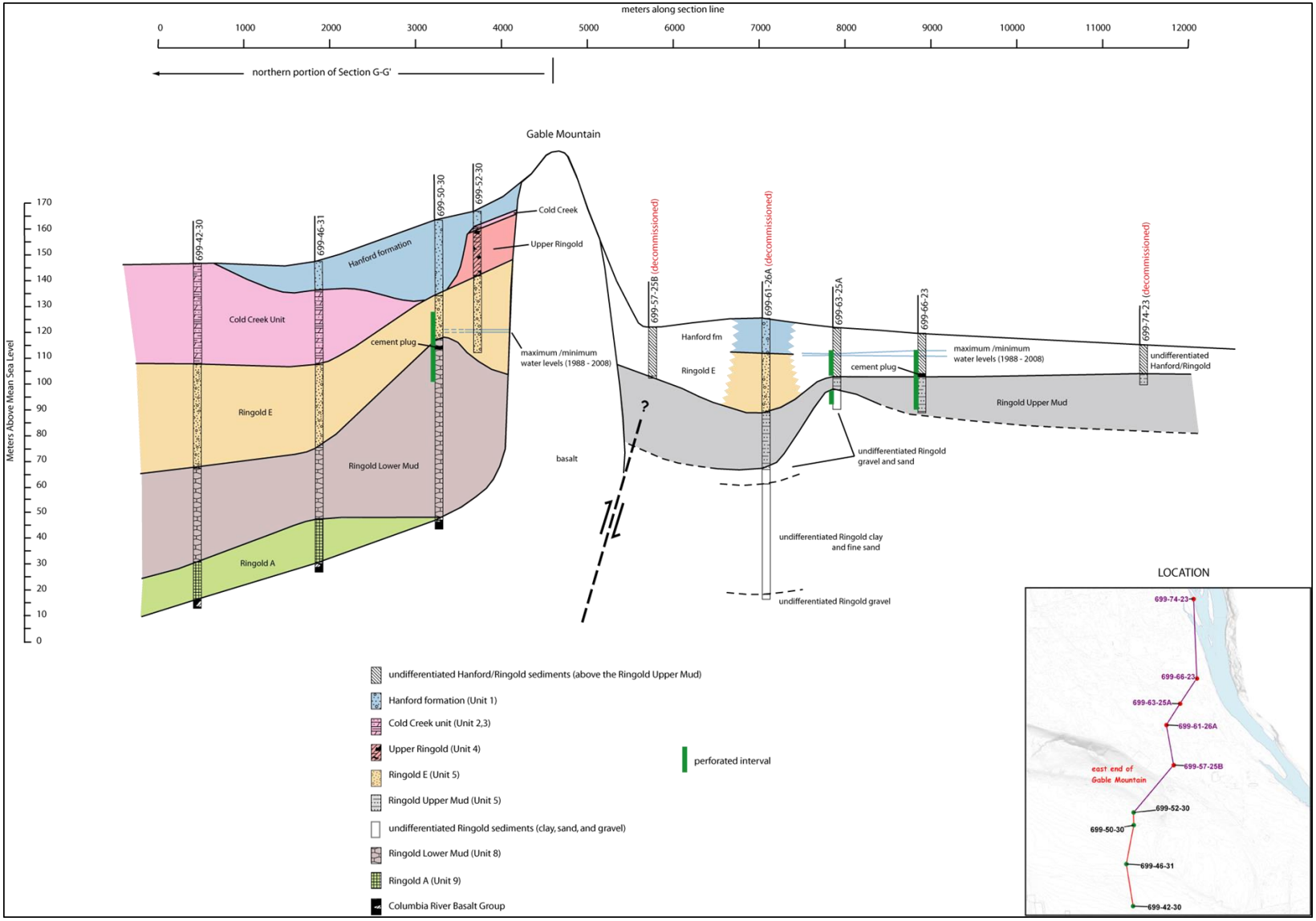


Figure A-3. Geologic Cross Section through 100-F Area



Source: DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*.

Figure A-4. Geologic Cross Section South to North across Gable Mountain Paralleling 100-F Nitrate Plume in Northern Section

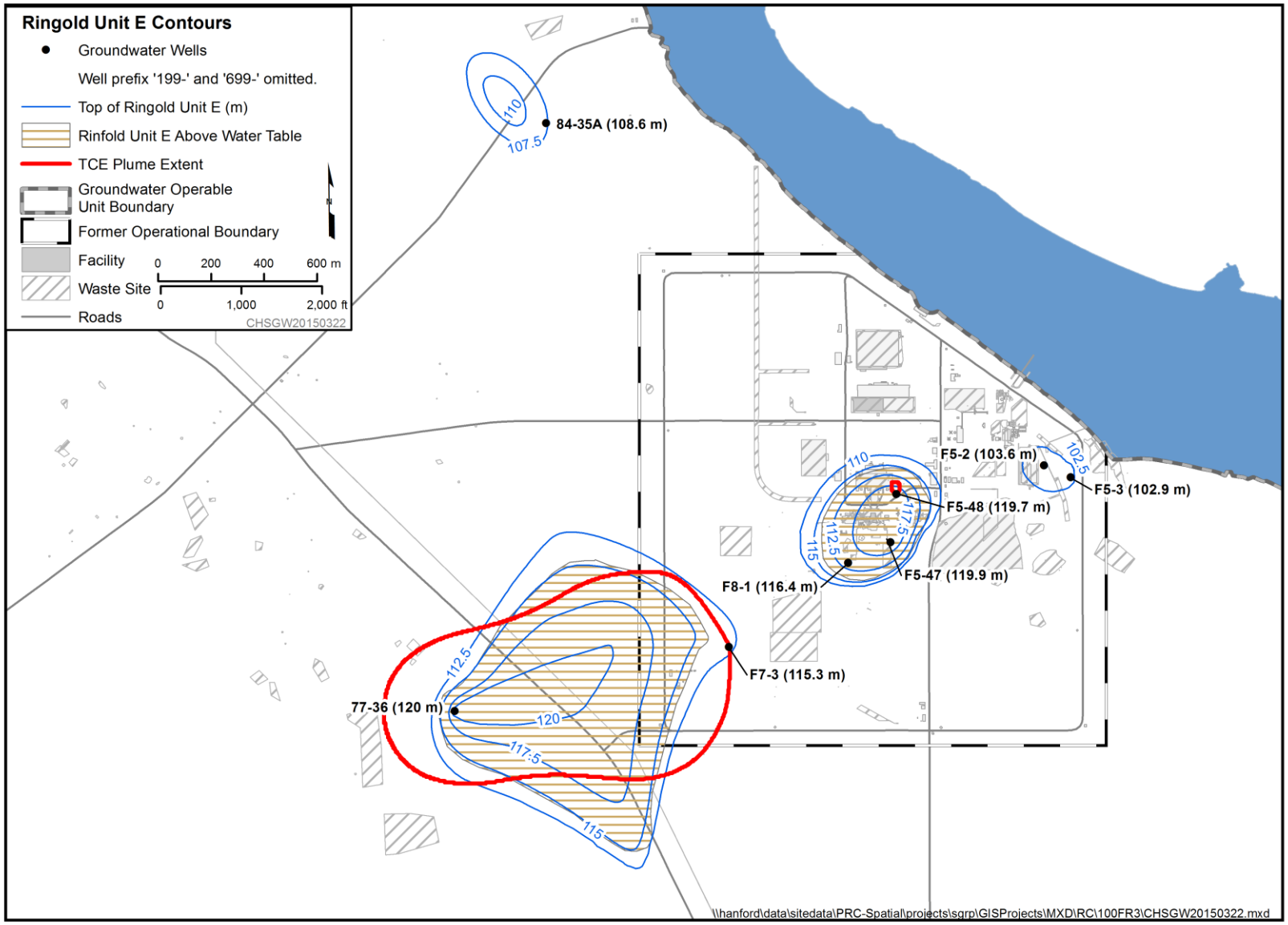


Figure A-5. Extent and Elevation of Top of Ringold Formation Unit E in 100-F Area

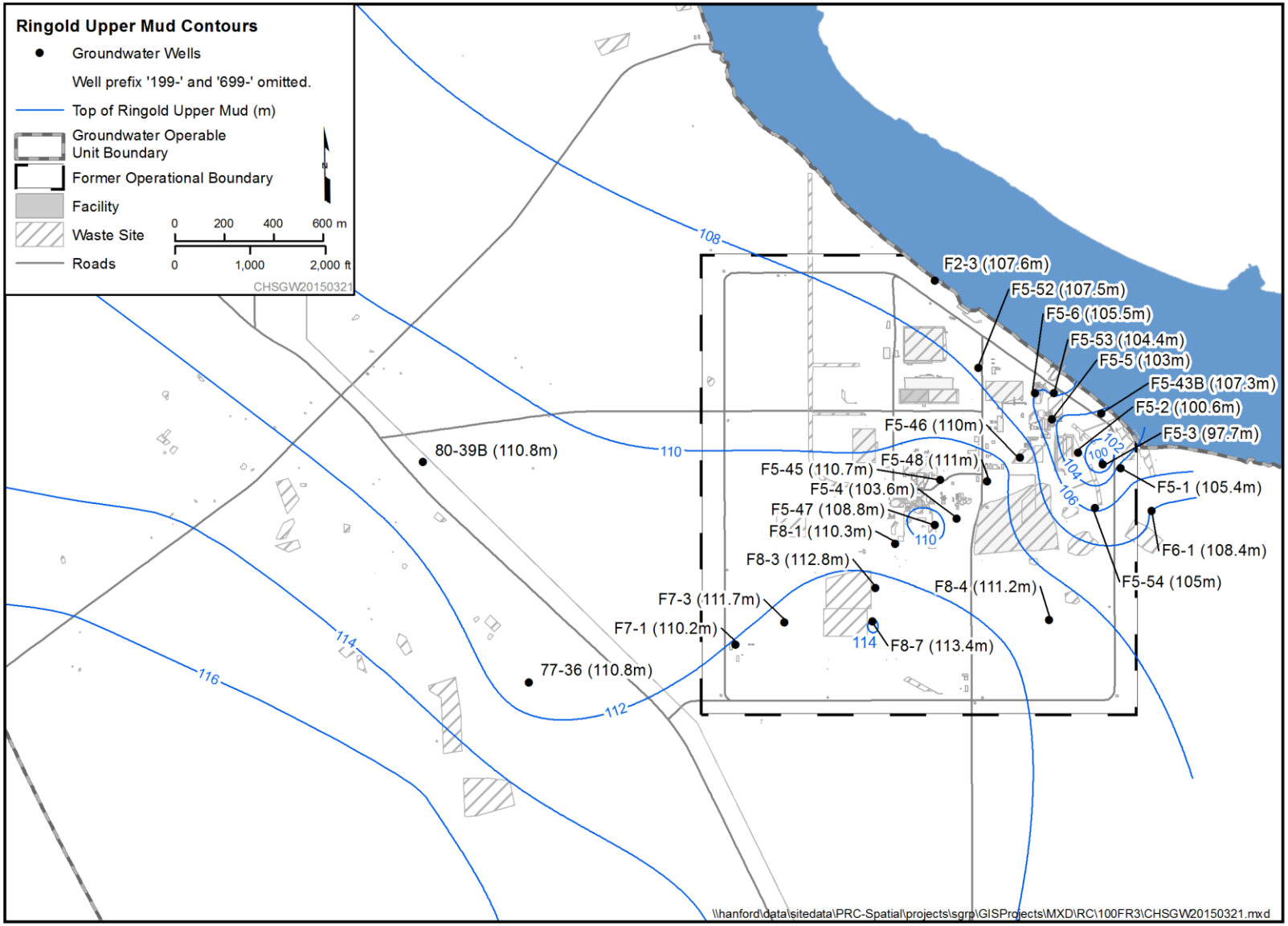


Figure A-6. Elevation of Top of Ringold Formation Upper Mud Unit in 100-F Area

Well 199-F5-43B is screened in a clayey silt or silty clay 39 m (129 ft) below the water table. Well 199-F5-53 is screened in silt 19 m (62 ft) below the water table. These sediments are considered part of the RUM or underlying, fine grained sediments but produce sufficient water for sampling.

No wells are screened below the RUM in the 100-F Area. A series of piezometers monitors deeper units in Well 699-84-35A, located northwest of 100-F Area. Documentation of the geology and well completion is limited, but the piezometers appear to monitor the Ringold units below the RUM, with the deepest piezometer monitoring the Ringold lower mud.

Hydraulic conductivity of the Hanford formation aquifer, based on slug tests, ranges from 14 to 48 m/d (46 to 157 ft/d). Slug tests in RUM wells 199-F5-43B and 199-F5-53 yielded hydraulic conductivity two orders of magnitude lower (0.8 and 0.2 m/d [3 and 1 ft/d]), respectively.

A1.2.2 Groundwater Flow

Figures A-7 and A-8 illustrate locations of monitoring wells and aquifer tubes and include water table contours based on data collected in March 2014. In the northern portion of 100-F Area, groundwater flow is to the northeast, discharging to the Columbia River. In the southern 100-F Area, groundwater flows primarily to the east and then curves to the southeast. Southeast of 100-F Area (Figure A-8), the water table slopes very gently at elevations ranging from 111 to 112 m (364 to 367 ft). This is approximately the same elevation as the Columbia River at this location. Consequently, the average direction of groundwater flow is approximately parallel to the river. Groundwater discharge is believed to occur ~2 to 3 km (1.2 to 1.9 mi) downstream of 100-F Area, where aquifer tubes such as 75-D exhibit higher specific conductance and detectable levels of groundwater contaminants. A recent study of groundwater upwelling (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*) supported the interpretation that little groundwater discharge occurs at 100-F Area.

Normal seasonal variability in the water table at 100-F Area is more than 3 m (10 ft) in wells near the river and decreases farther inland. When the river stage is high (e.g., June 2014; Figure A-9), groundwater flow near the river in northeastern 100-F Area reverses, and water flows from the river into the aquifer. Figure A-10 illustrates the magnitude and direction of the hydraulic gradient in three regions of 100-F over various time periods. In southwestern 100-F Area, direction of the gradient varies from northeast to southeast. The gradient south of 100-F Area slopes toward the south or southeast even in March and October when the river stage is low to moderate. The magnitude of the gradients range from 9×10^{-4} to 1×10^{-3} m/m (Figure A-10).

Vertical hydraulic gradients within the unconfined aquifer at 100-F Area (Hanford formation) have not been quantified. The aquifer is thin, and the vertical component of flow is probably minor.

The vertical gradient between the unconfined aquifer and the RUM is variable, based on data from pressure transducers in well pair 199-F5-43A and 199-F5-43B. During a period of low river stage, the overall difference in head between the two wells was negligible, indicating only a slight vertical gradient. During a period of high river stage, there was a consistently downward hydraulic gradient that averaged 2×10^{-3} m/m.

A1.2.3 Sources of Groundwater Contamination

The 100-F Reactor was supported by multiple facilities associated with services for water treatment, air filtration, nuclear fuel handling, effluent disposal, and laboratories, with various other administrative buildings. The 100-F Area also included the Experimental Animal Farm (EAF), where biological research studies were performed to examine the effects of radiation and radioactive contamination on plants, animals, and fish. All of the former waste sites in 100-F have been remediated or were determined not to

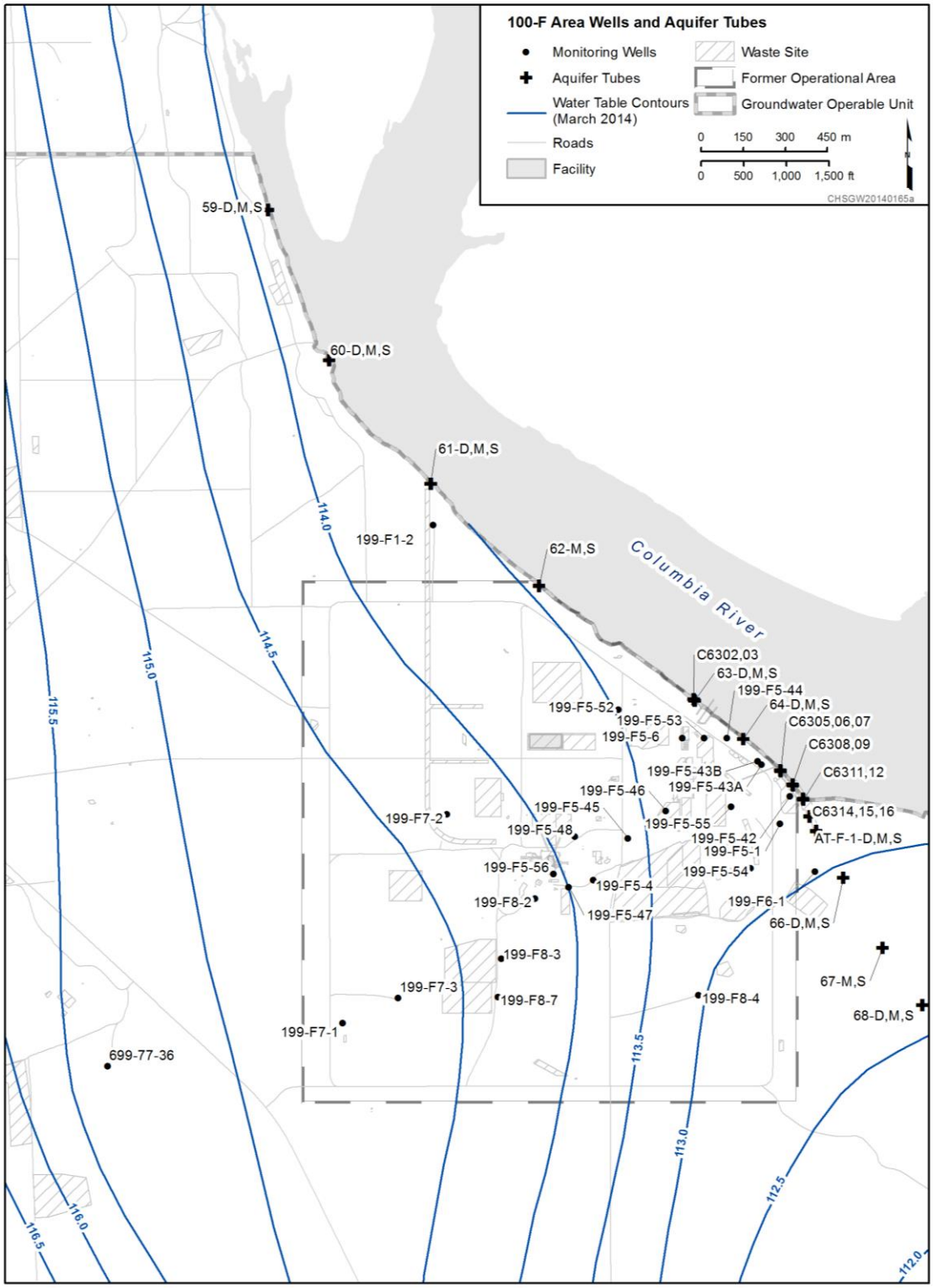


Figure A-7. Groundwater Monitoring Wells, Aquifer Tubes, and March 2014 Water Table in 100-F Area (Moderate River Stage)

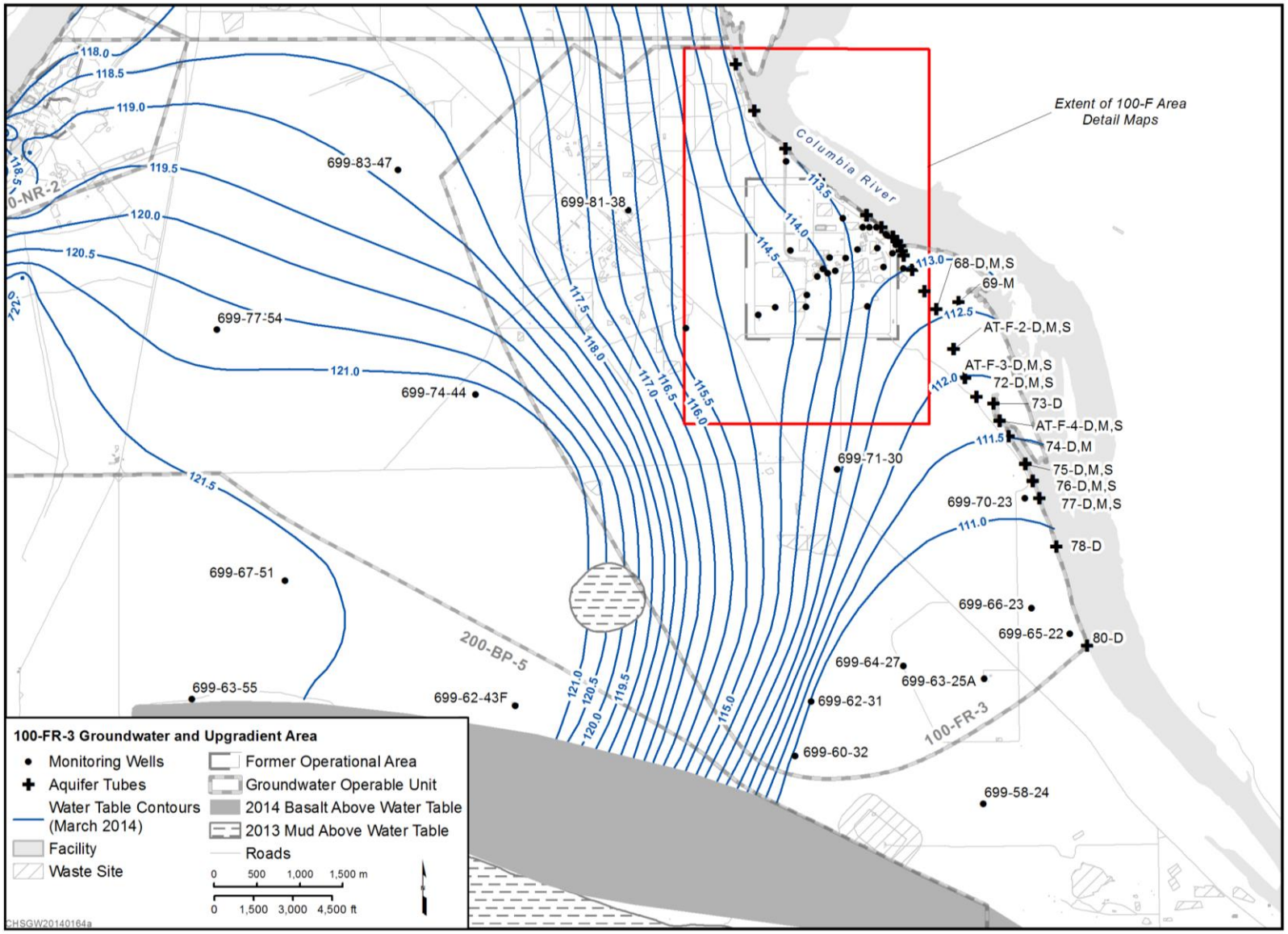
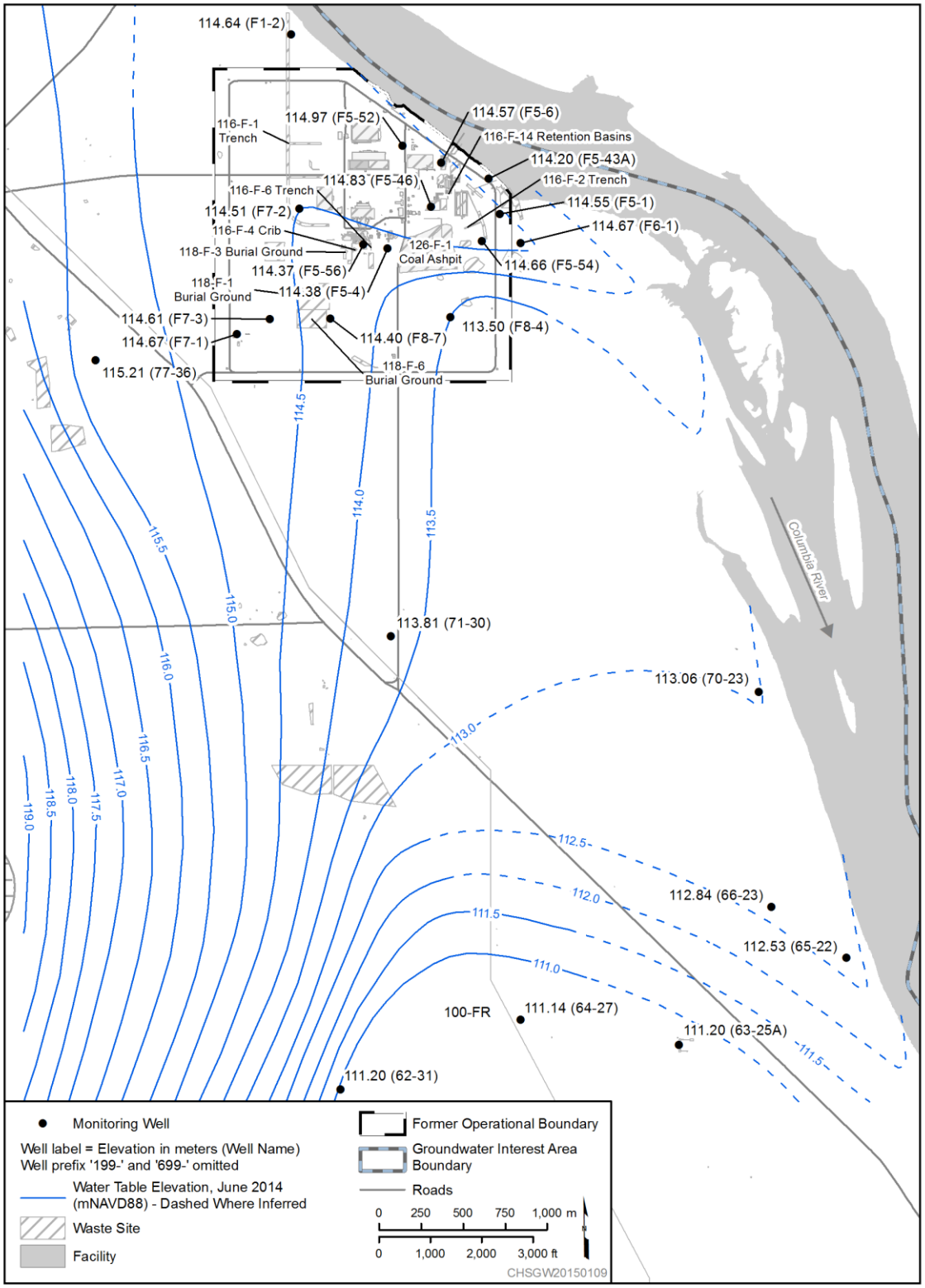
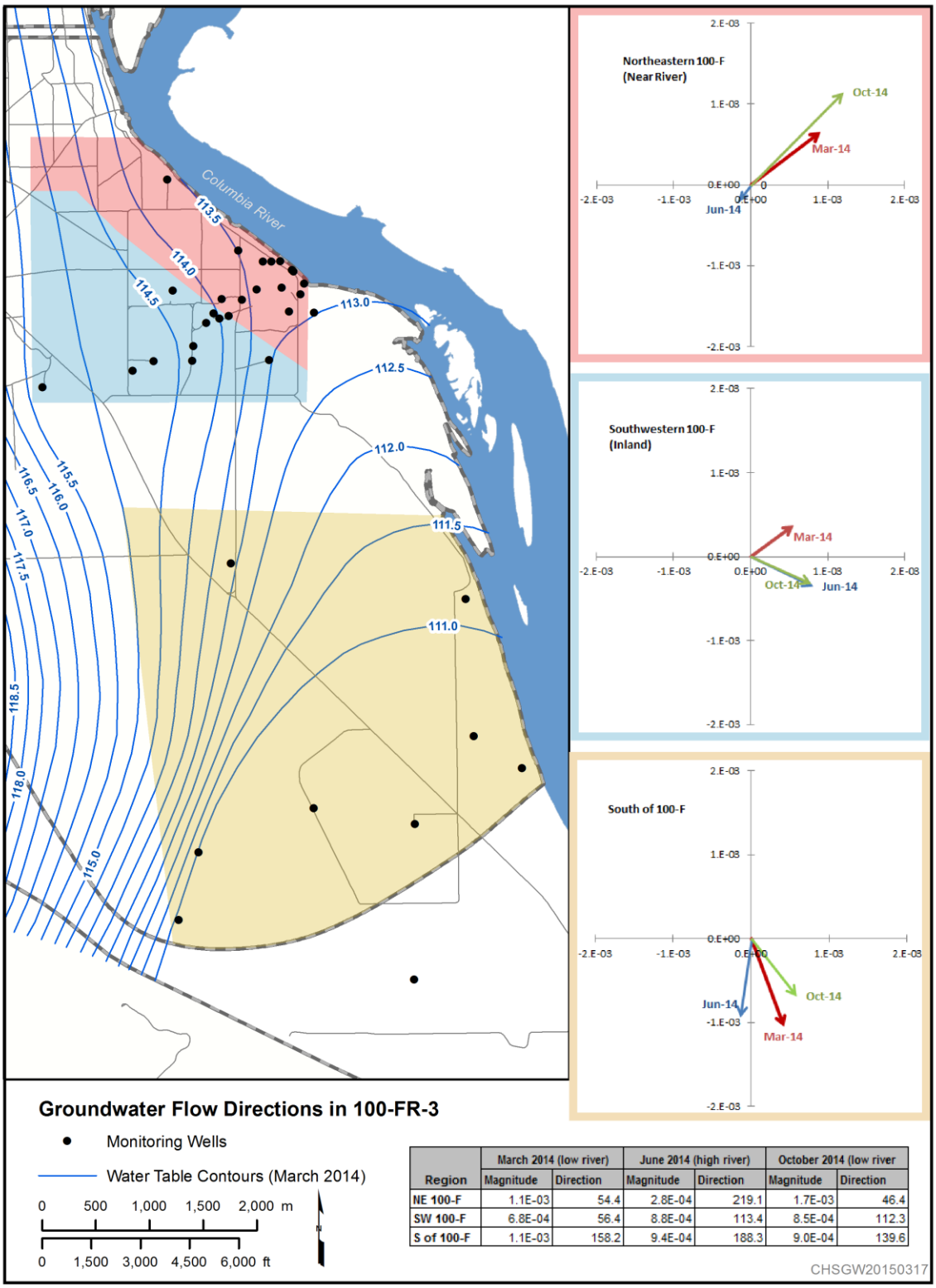


Figure A-8. Groundwater Monitoring Wells, Aquifer Tubes, and March 2014 Water Table at the 100-FR-3 Operable Unit



Source: NAVD88, *North American Vertical Datum of 1988*.

Figure A-9. June 2014 Water Table (High River Stage)



Region	March 2014 (low river)		June 2014 (high river)		October 2014 (low river	
	Magnitude	Direction	Magnitude	Direction	Magnitude	Direction
NE 100-F	1.1E-03	54.4	2.8E-04	219.1	1.7E-03	46.4
SW 100-F	6.8E-04	56.4	8.8E-04	113.4	8.5E-04	112.3
S of 100-F	1.1E-03	158.2	9.4E-04	188.3	9.0E-04	139.6

Figure A-10. Magnitude and Direction of Hydraulic Gradient in 100-F Area

require remediation. Operations within 100-IU-2 and 100-IU-6 were primarily related to other uses, such as historical agricultural uses and uses associated with human occupation.

Liquid wastes from reactor operations and associated facilities were released to the soil column and the Columbia River. Solid wastes were disposed in burial grounds associated with the facilities. Wastes released to or buried within the environment created secondary sources of contamination, such as liquid waste sites (ponds, trenches, cribs, and french drains), burial grounds, and numerous small miscellaneous waste sites scattered throughout the River Corridor.

Former sources of Cr(VI) in 100-F included facilities near the reactor building, trenches and retention basins near the Columbia River, and pipelines from the reactor building to these near-river facilities, primarily in northern and eastern 100-F. Past sources of nitrate contamination included EAF and various septic tanks and leach fields located throughout 100-F. Nitrate contamination was likely transported inland during operations when effluent discharge resulted in groundwater mounding and changes in hydraulic gradients.

Major sources of strontium-90 included the 116-F-14 Retention Basin and the 116-F-2 Trench, located in northeastern 100-F Area. The main groundwater plume is in eastern 100-F Area near these former sources. A smaller plume is present in the central 100-F Area.

The source of TCE contamination in the 100-FR-3 OU is believed to have been from a number of waste sites, including a group of waste sites west of the 100-F Area that have been remediated. TCE can be present as a gas in the vadose zone and as a dissolved species in soil moisture and groundwater.

A1.2.4 Contaminant Plumes

A large nitrate plume with concentrations above 45 mg/L extends from 100-F Area approximately 5 km (3.1 mi) to the south (Figure A-11). The highest concentrations (greater than 120 mg/L) are in central 100-F Area. Wells near the Columbia River have low nitrate concentrations. The water in these wells has low specific conductance (160 to 250 µS/cm), indicating the influence of inflowing river water even during periods of low river stage. Thus, the highest nitrate concentrations do not flow directly into the Columbia River adjacent to the 100-F Area.

The fact that the nitrate plume migrated southward is explained by the location of some of the nitrate sources in southern 100-F Area, where groundwater flow is toward the south and south-southeast. Because there are relatively few monitoring wells to define the western portion of the plume, the western extent of nitrate contamination above 45 mg/L is uncertain.

TCE concentrations exceed the 4 µg/L cleanup level in three wells in southwestern 100-F Area and sporadically in wells in central 100-F Area (Figure A-12). Process knowledge of the former 600-127 waste site, located just west of 100-F Area, suggests that it may have contributed to the TCE plume. This site was remediated in 2010. The lack of wells to the south creates uncertainty in the interpretation, and the plume may extend farther south than can be interpreted based on available data. Well 699-71-30, approximately 2 km (1.2 mi) to the south, had no detectable TCE in 2013 (<0.5 µg/L).

TCE concentrations have declined since 1992 in Wells 699-77-36 and 199-F7-1 in southwestern 100-F Area. The trend in 199-F7-3 shows the arrival of the plume in the late 1990s and stable or declining concentrations since 2002. The monitoring wells in this location are screened across the entire aquifer thickness, which is less than 3 m (10 ft).

Cr(VI) in the 100-FR-3 OU is present in a relatively small, low-concentration plume (Figure A-13). Historically, the highest concentrations were in Well 199-F5-46, where levels have declined from greater than 300 µg/L in the early 1990s to 26 µg/L in 2013. Concentrations in wells near the Columbia River are lower, and concentrations in aquifer tubes in 2013 continued to be below the 10 µg/L cleanup level.

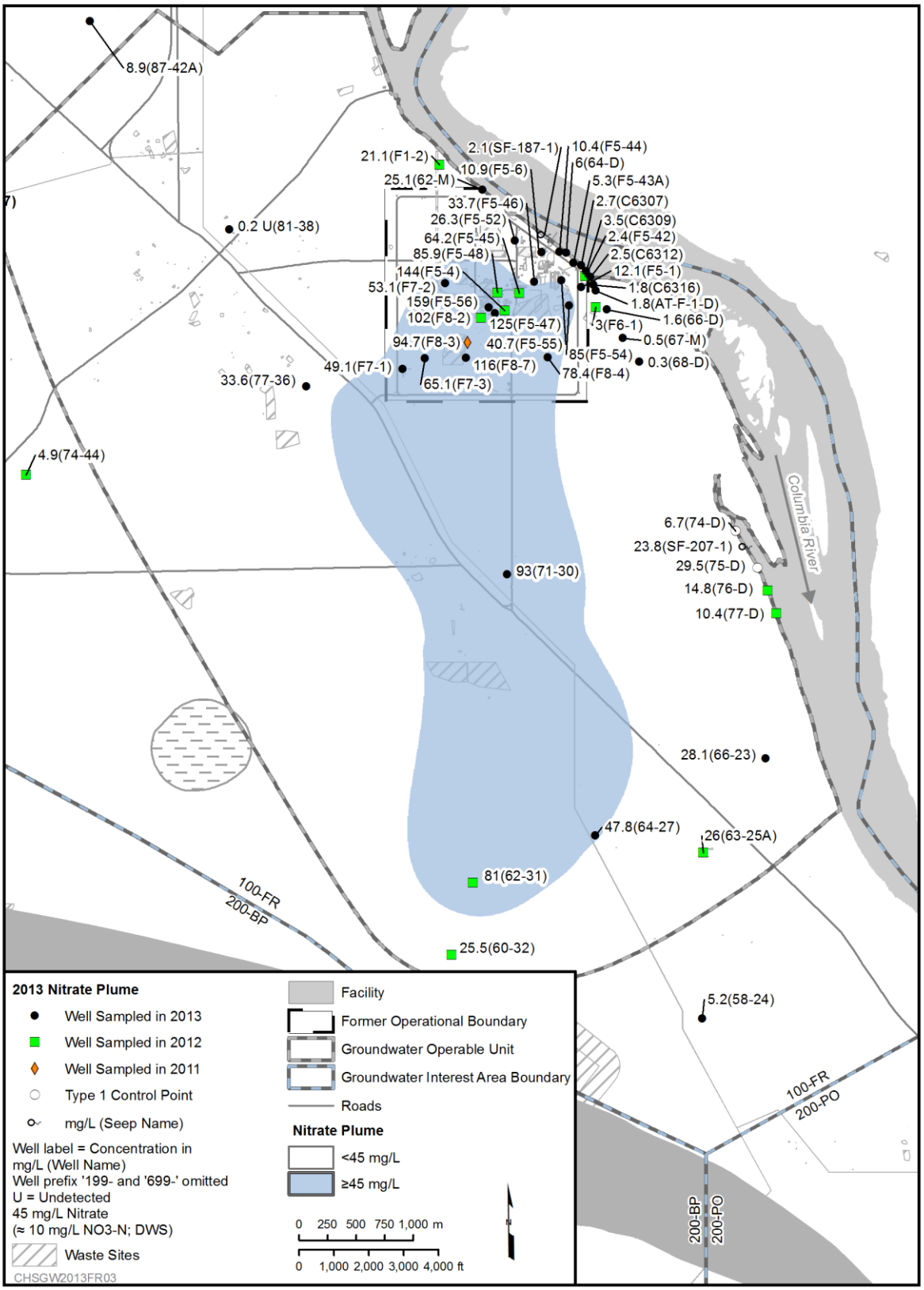


Figure A-11. Nitrate Plume in the 100-FR-3 Operable Unit

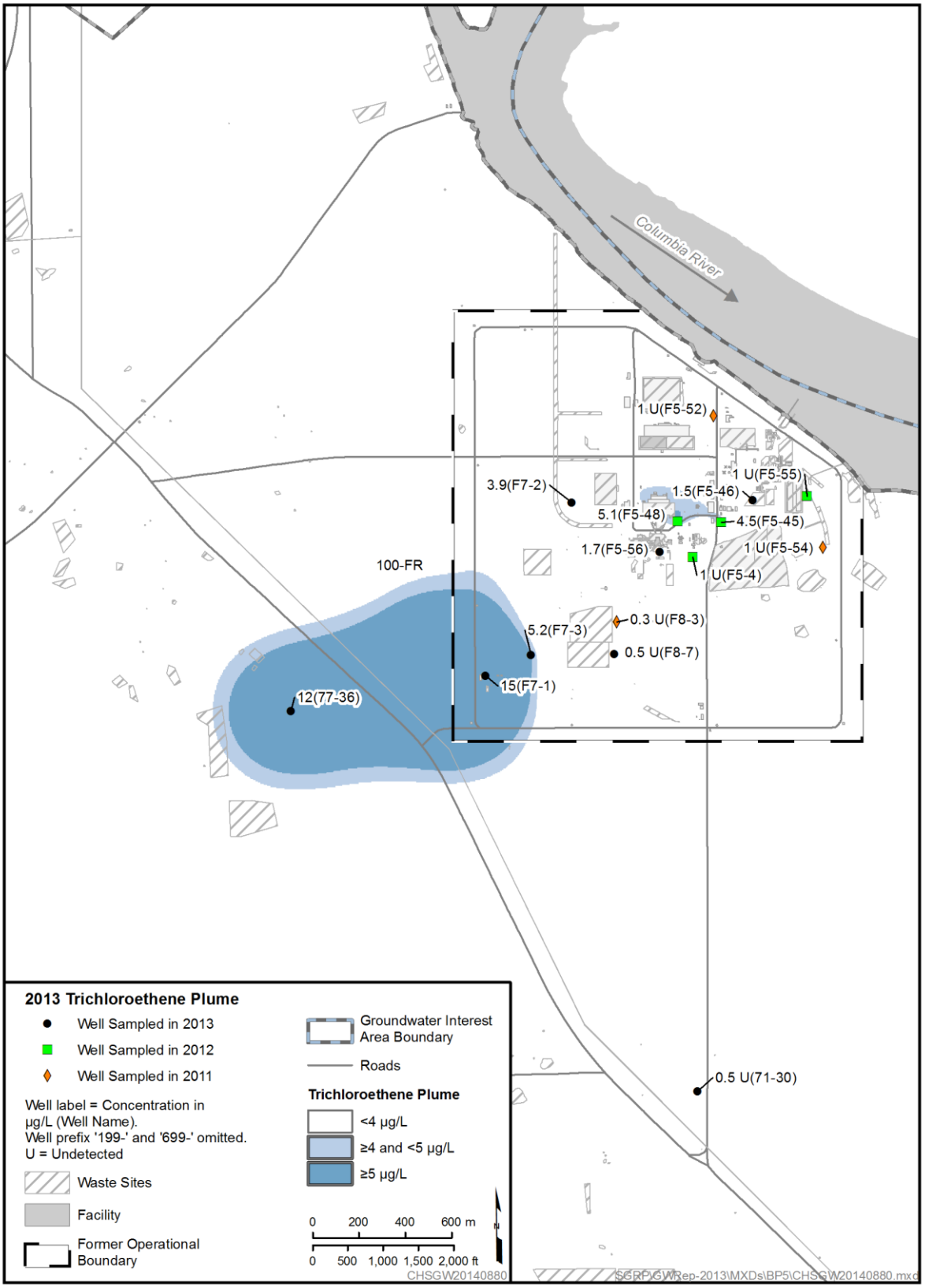


Figure A-12. Trichloroethene Plume in the 100-FR-3 Operable Unit

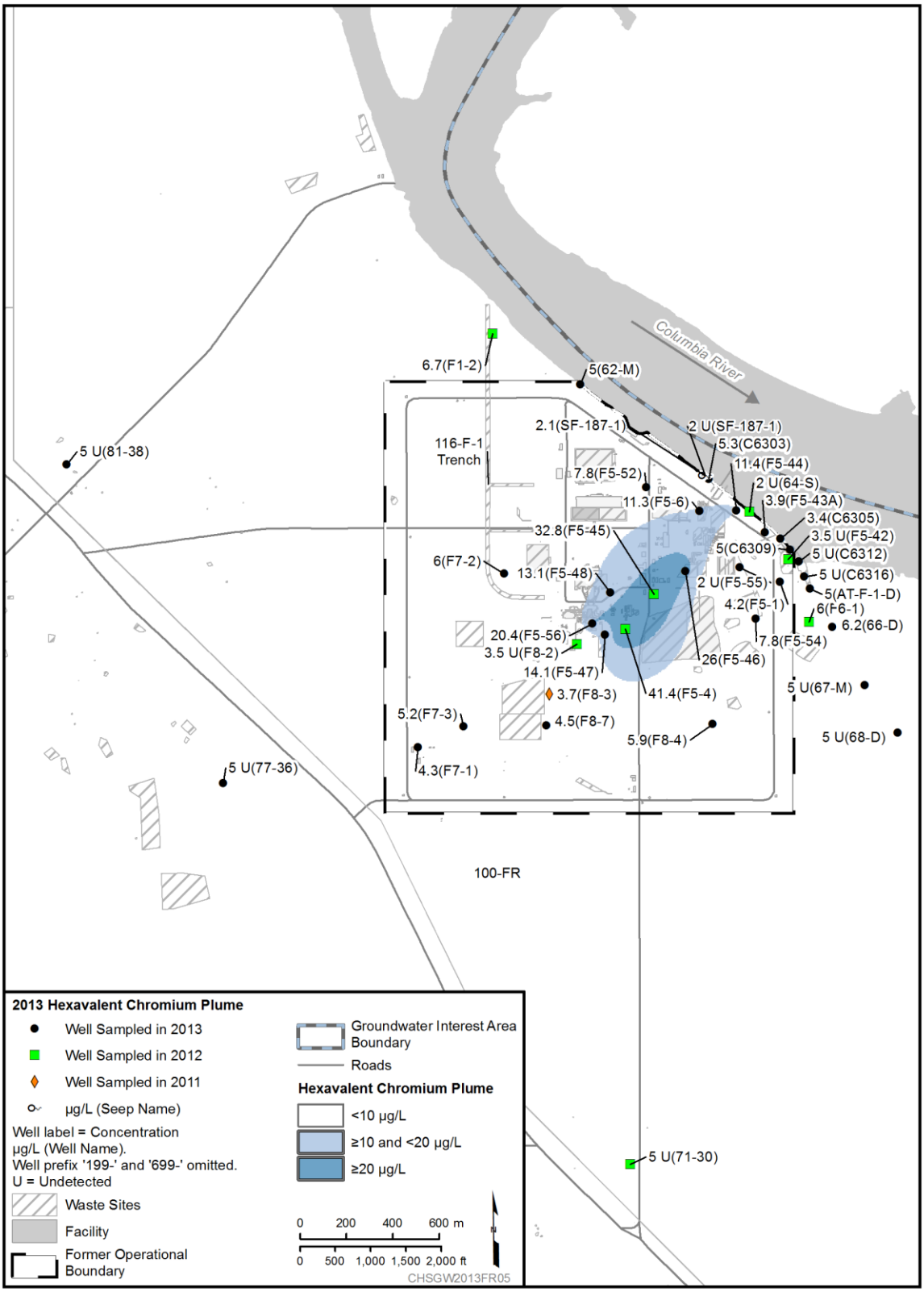


Figure A-13. Hexavalent Chromium Plume in the 100-FR-3 Operable Unit

Two aquifer tubes formerly had concentrations slightly above the cleanup level, but levels have declined. Previous data from pore water samples indicate that the plume does not reach the Columbia River at concentrations above the 10 µg/L cleanup level (DOE/RL-2010-98).

Primary sources of strontium-90 included the 116-F-14 Retention Basins and 116-F-2 Trench in eastern 100-F Area. Additional sources of strontium-90 were present near the reactor building and burial grounds. The main plume in groundwater is in eastern 100-F Area. A smaller plume is present in the central 100-F Area (Figure A-14).

In eastern 100-F Area, two wells (199-F5-55 and 199-F5-1) continued to have strontium-90 concentrations above the 8 pCi/L cleanup level in 2013 (Figure A-14). Concentrations in aquifer tubes have been below the standard, except in a single sample collected in 2012, at 9.6 pCi/L. The concentration declined to 2.7 pCi/L in that aquifer tube in 2013. Previous data from pore water samples indicate that the plume does not reach the Columbia River at concentrations above the 8 pCi/L cleanup level (DOE/RL-2010-98).

Well 199-F5-55 had the highest strontium-90 concentrations in 2013 (Figure A-14), with an annual average of 170 pCi/L. This borehole was installed in the former 116-F-14 Retention Basin to characterize the vadose zone and was completed as a monitoring well to obtain representative groundwater samples. The next nearest downgradient well (199-F5-1) has much lower concentrations.

Well 199-F5-56, near the 105-F Reactor building, had an annual average strontium-90 concentration of 44 pCi/L in 2013. This borehole was drilled to characterize a waste site and completed as a well to obtain representative groundwater samples. It was the only well in the central 100-F Area with detectable strontium-90.

Contaminants are not present beneath the unconfined aquifer. Wells screened in RUM water producing zones consistently have low or nondetectable levels of Cr(VI), strontium-90, TCE, and nitrate.

A1.3 Data Quality Objective Summary

A site-specific DQO process was performed to identify the data needs for the 100-FR-3 OU MNA remedy performance monitoring. The groundwater monitoring network for each COC was identified during the DQO process. Locations were identified to monitor COC concentrations, detect changes in plume area, and refine the understanding of local hydraulic gradients. The DQO report (SGW-58291) is included with this appendix for convenience.

A1.4 Contaminants

Table A-1 identifies the specific contaminants for MNA performance monitoring. The contaminants listed were identified in the 100-F/IU ROD (EPA and DOE, 2014) and RI/FS report (DOE/RL-2010-98).

A1.5 Project Schedule

This SAP will direct performance monitoring activities for the 100-FR-3 OU as described in the Groundwater Addendum. Implementation of 100-FR-3 OU performance monitoring will begin after approval of the Integrated RDR/RAWP (DOE/RL-2014-44). Installation of new monitoring wells is projected to be initiated immediately following RDR/RAWP approval and are anticipated to be completed 6 months after RDR/RAWP approval.

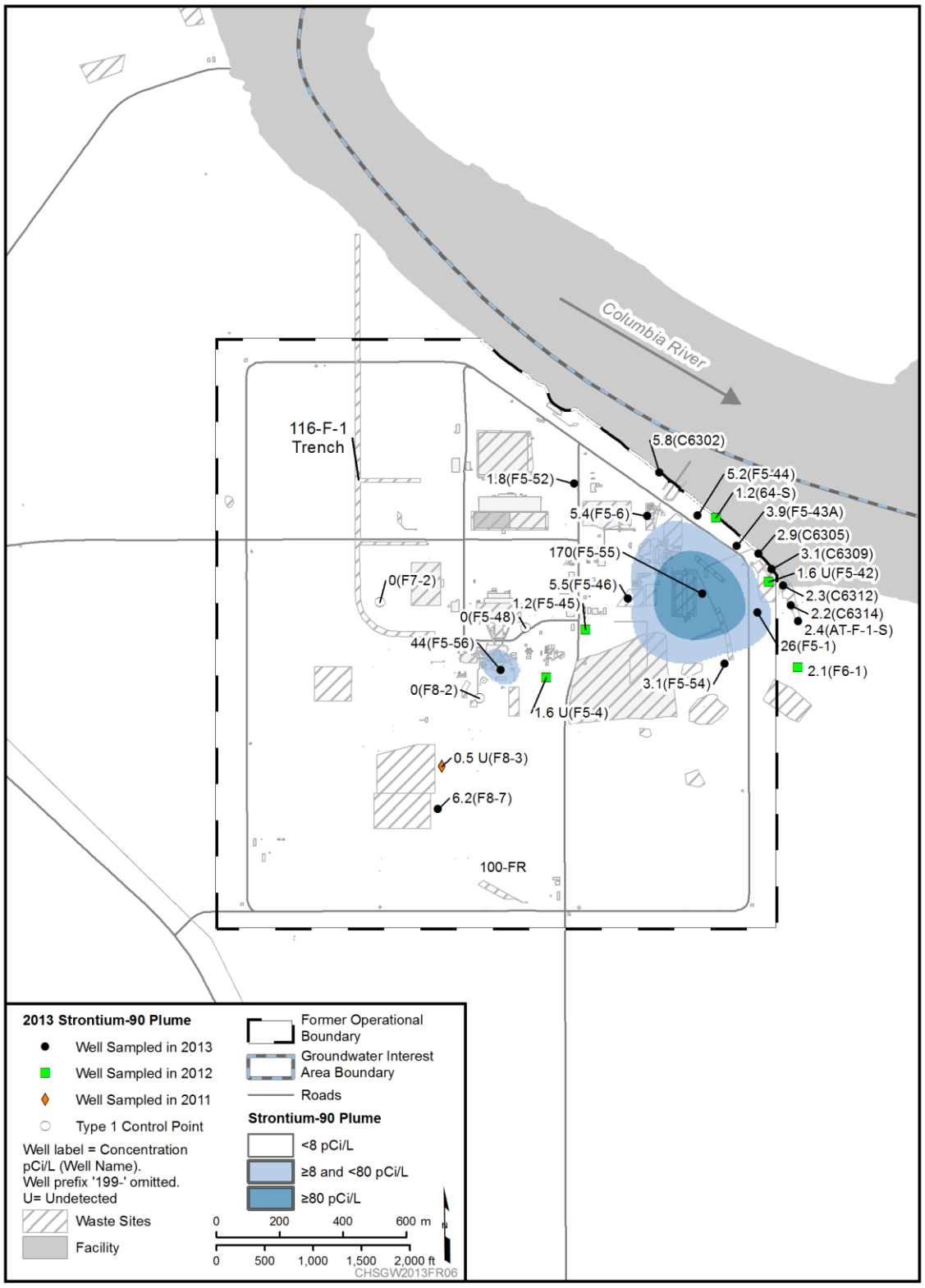


Figure A-14. Strontium-90 Plume in the 100-FR-3 Operable Unit

Table A-1. Analytes for 100-FR-3 Operable Unit Groundwater Monitoring

Contaminant	Chemical Abstracts Service Number
Inorganics – Metals	
Antimony	7440-36-0
Cadmium	7440-43-6
Chromium (Hexavalent)	18540-29-9
Cobalt	7440-48-4
Inorganics – Anions	
Nitrate	14797-55-8
Volatile Organics	
Trichloroethene	79-01-6
cis-1,2-Dichloroethene	156-59-2
Vinyl Chloride	75-01-4
Radionuclides	
Strontium-90	10098-97-2
Field Measurements	
Dissolved Oxygen	Not applicable
pH	Not applicable
Specific Conductance	Not applicable
Temperature	Not applicable
Turbidity	Not applicable
Depth to Groundwater	Not applicable

Data from the new and existing wells will be obtained in the first monitoring year; however, completion of quarterly sampling for all Phase 1 wells will extend into the second monitoring year. The first full year of monitoring at Phase 1 wells will be completed 1 year from the final Phase 1 well acceptance date. A report detailing Phase 1 well results and an initial evaluation of the monitoring program and recommendations of Phase 2 monitoring wells is projected to be completed 6 months after the first year of monitoring data is obtained for all Phase 1 wells. Additional Phase 2 monitoring wells, if required, will be completed within approximately 1 year after regulatory approval of the well recommendations. Approval of the cultural resource reviews may require up to 6 months. Results from the monitoring network will be evaluated for changes to the sampling plan, including additional wells or aquifer tubes, after the first 5 years of monitoring.

The duration of the performance monitoring sampling, analysis, and data evaluation period is based on the model estimated time frame for each COC to achieve its cleanup level as described in the 100-F/IU RI/FS (DOE/RL-2010-98). The estimated time frames are rounded up to account for model uncertainties. The following time frames are estimated for each COC:

- Cr(VI) = 35 years (based on 10 µg/L cleanup level)
- Strontium-90 = 150 years
- Trichloroethene = 50 years
- Nitrate = 80 years

Once cleanup levels for each COC are achieved, 5 years of attainment monitoring will be performed. The 5-year attainment monitoring period is not included in the time frame estimates.

The sampling schedule will be established through the *Sample Management Integrated Lifecycle Environment* (SMILE), or equivalent system, which optimizes the overall number of well trips and limits schedule redundancy. SMILE allows for the tracking of overlapping requirements, so single well trips can co-sample wells and optimize schedules.

A2 Quality Assurance Project Plan

A QAPjP establishes the quality requirements for environmental data collection. It includes planning, implementation, and assessment of sampling tasks, field measurements, and laboratory analysis and data review. This QAPjP complies with requirements from the following documents:

- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5)*
- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document (HASQARD)*

This chapter describes the applicable quality requirements and controls. Sections 6.5 and 7.8 of the *Hanford Federal Facility Agreement and Consent Ord*er [Tri-Party Agreement (TPA)] Action Plan (Ecology et al., 1989b) require quality assurance (QA)/quality control (QC) and sampling and analysis activities to specify the QA requirements for treatment, storage, and disposal units, as well as for past-practice processes. Therefore, this QAPjP follows the QA elements of EPA/240/B-01/003. This QAPjP also demonstrates conformance to Ecology Publication No. 04-03-030, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*, and EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans (EPA QA/G-5)*. This QAPjP is intended to supplement the contractor's environmental QA program plan.

This QAPjP is divided into the following four sections, which describe the quality requirements and controls applicable to Hanford Site OU groundwater monitoring activities: Project Management, Data Generation and Acquisition, Assessment and Oversight, and Data Review and Usability.

A2.1 Project Management

This section addresses project goals, management approaches planned, and planned output documentation.

A2.1.1 Project/Task Organization

The contractor, or its approved subcontractor, is responsible for planning, coordinating, sampling, and shipping samples to the laboratory. The contractor is also responsible for preparing and maintaining configuration control of the SAP and assisting the U.S. Department of Energy (DOE)-Richland Operations Office (RL) Project Manager in obtaining approval of the SAP and future proposed revisions.

The project organization (regarding routine groundwater monitoring) is described in the following subsections and illustrated in Figure A-15.

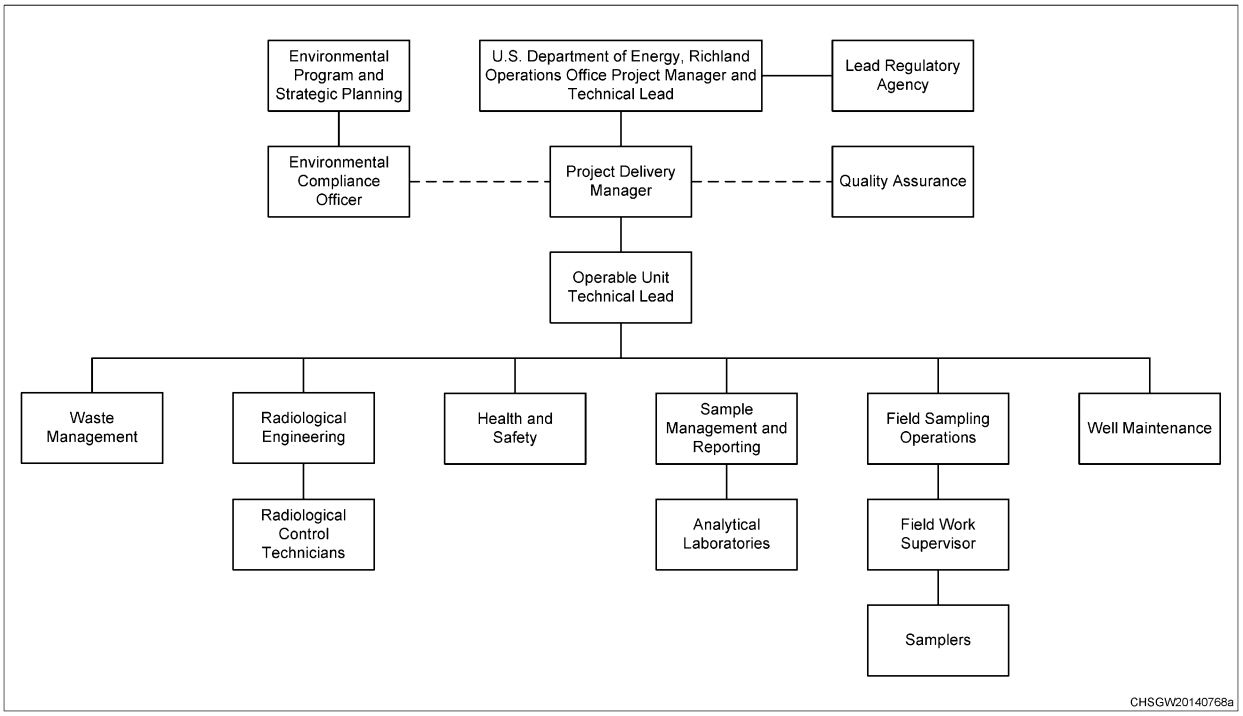


Figure A-15. Project Organization

A2.1.1.1 Regulatory Lead

The lead regulatory agency (LRA) is responsible for regulatory oversight of cleanup projects and activities. LRA has SAP approval authority for the OUs managed and works with DOE-RL to resolve concerns over the work described in this SAP in accordance with the TPA (Ecology et al., 1989a).

A2.1.1.2 DOE-RL Project Manager

The DOE-RL Project Manager is responsible for the following activities:

- Monitoring the contractor's performance of activities under the TPA (Ecology et al., 1989a), *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; *Resource Conservation and Recovery Act of 1976*; and *Atomic Energy Act of 1954* for the Hanford Site
- Obtaining LRA approval of the SAP
- Authorizing field sampling activities

A2.1.1.3 DOE-RL Technical Lead

The DOE-RL Technical Lead is responsible for the following activities:

- Providing day-to-day oversight of the contractor's work scope performance, for working with the contractor and the regulatory agencies to identify and resolve technical issues
- Providing technical input to the DOE-RL Project Manager

A2.1.1.4 Operable Unit Project Manager

The OU Project Manager (or designee) is responsible and accountable for the following activities:

- Project-related activities
- Coordinating with DOE-RL, regulators, and contactor management in support of sampling activities to ensure that work is performed safely and cost effectively
- Managing sampling documents and requirements, field activities, and subcontracted tasks and ensuring that the project file is properly maintained

A2.1.1.5 Operable Unit Technical Lead

The OU Technical Lead is responsible for the following activities:

- Developing specific sampling design, analytical requirements, and QC requirements either independently or as defined through a systematic planning process
- Ensuring that sampling and analysis activities, as delegated by the OU Project Manager, are carried out in accordance with the SAP
- Working closely with the Environmental Compliance Officer (ECO), QA, Health and Safety, Field Work Supervisor (FWS), and Sample Management and Reporting (SMR) organization to integrate these and other technical disciplines in planning and implementing the work scope

A2.1.1.6 Environmental Compliance Officer

The ECO is responsible for the following activities:

- Providing technical oversight, direction, and acceptance of project and subcontracted environmental work
- Developing appropriate mitigation measures to minimize adverse environmental impacts
- Overseeing project implementation for compliance with applicable internal and external environmental requirements

A2.1.1.7 Quality Assurance

The QA point-of-contact is responsible for the following activities:

- Addressing QA issues on the project
- Overseeing implementation of the project QA requirements
- Reviewing project documents (including DQO summary report, QAPjP, and SAP)
- Reviewing data validation reports from third-party data validation contractors, as appropriate
- Participating in QA assessments on sample collection and analysis activities, as appropriate

A2.1.1.8 Health and Safety

The Health and Safety organization is responsible for the following activities:

- Coordinating industrial safety and health support within the project, in accordance with the health and safety program, job hazard analyses, and other pertinent federal regulations
- Assisting project personnel in complying with the applicable health and safety program

- Coordinating with Radiological Engineering to determine personal protective equipment (PPE) requirements

A2.1.1.9 Radiological Engineering

Radiological Engineering is responsible for the following activities:

- Supporting radiological engineering and project health physics
- Conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization
- Identifying radiological hazards and ensuring that appropriate controls are implemented to maintain worker exposures to hazards at ALARA levels
- Interfacing with the project Health and Safety representative, and other appropriate personnel as needed, to plan and direct project Radiological Control Technician (RCT) support

A2.1.1.10 Sample Management and Reporting

The SMR organization is responsible for the following activities:

- Interfacing between the OU Technical Lead, Field Sampling Operations (FSO), Well Maintenance Organization, and analytical laboratories
- Generating field sampling documents, labels, and instructions for field sampling personnel
- Monitoring the entire sample and data process
- Coordinating laboratory analytical work, and ensuring that the laboratories conform to Hanford Site QA requirements (or their equivalent), as approved by DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology)
- Resolving sample documentation deficiencies or issues associated with FSO, laboratories, or other entities to ensure that project needs are met
- Receiving analytical data from the laboratories
- Ensuring that data are uploaded into the Hanford Environmental Information System (HEIS)
- Arranging for and overseeing data validation, as requested
- Informing the OU Project Manager and/or OU Technical Lead of any issues reported by the analytical laboratory
- Developing the sample authorization form (SAF), which provides information and instruction to the analytical laboratories
- Providing instructions to FSO samplers on the collection of samples, as specified in a SAP

A2.1.1.11 Analytical Laboratories

Analytical laboratories are responsible for the following activities:

- Analyzing samples in accordance with established methods
- Providing data packages containing analytical and QC results

- Providing explanations in response to resolution of analytical issues
- Meeting HASQARD (DOE/RL-96-68) QA requirements
- Being on the Mission Support Alliance (MSA) Evaluated Suppliers List
- Being accredited by Ecology for the analyses performed for the Soil and Groundwater Remediation Project

A2.1.1.12Waste Management

Waste Management is responsible for the following activities:

- Communicating policies and protocols
- Ensuring compliance for waste storage, transportation, disposal, and tracking in a safe and cost effective manner
- Identifying waste management sampling/characterization requirements to ensure regulatory compliance
- Interpreting data to determine waste designations and profiles
- Preparing and maintaining other documents confirming compliance with waste acceptance criteria

A2.1.1.13Field Sampling Organization

FSO is responsible for the following activities:

- Planning, coordinating, and conducting field sampling activities
- Ensuring that samplers are appropriately trained and available
- Ensuring that the sampling design is understood and can be performed, as specified by the nuclear chemical operators (NCOs), which is achieved by directing NCO training, performing mock-ups, and holding practice sessions with field personnel
- Directing NCOs
- Ensuring that NCOs collect all salient samples, in accordance with sampling documentation
- Completing field logbook entries and chain-of-custody forms and shipping paperwork and ensuring delivery of samples to the analytical laboratory
- Acting as a technical interface between the OU Project Manager and the field crew supervisors (such as the Drilling Buyer's Technical Representative [BTR], and Geologist-BTR) and ensuring that technical aspects of the field work are met
- Reviewing the SAP for field sample collection concerns, analytical requirements, and special sampling requirements
- Resolving issues regarding implementing technical requirements to field operations and coordinating resolution of sampling issues through consultation with the OU Project Manager and SMR

A2.1.1.14Well Maintenance

The Well Maintenance Manager is responsible for the following activities:

- Completing well maintenance activities

- Coordinating with the OU Technical Lead to identify field constraints that could affect groundwater sampling

A2.1.2 Quality Objectives and Criteria

The QA objective of this plan is to ensure that generation of analytical data of known and appropriate quality are acceptable and useful for decision making. In support of this objective, statistics and data descriptors, known as data quality indicators (DQIs), help determine the acceptability and utility of data to the user. Principal DQIs are precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity. Analytical methods, detection limits, and precision and accuracy requirements for each analysis to be performed are summarized in Table A-2.

Table A-2. Data Quality Indicators

DQI	Definition	Determination Methodologies	Corrective Actions
Precision	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of field duplicates. Analytical precision is estimated by duplicate/replicate analyses, usually on laboratory control samples, spiked samples, and/or field samples. The most commonly used estimates of precision are the relative standard deviation and, when only two samples are available, the relative percent difference.	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory. Acquire replicate field samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	If duplicate data do not meet objective: • Evaluate apparent cause (e.g., sample heterogeneity) • Request reanalysis or re-measurement • Qualify the data before use
Accuracy	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. Quality control analyses used to measure accuracy include standard recoveries, laboratory control samples, spiked samples, and surrogates.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample).	If recovery does not meet objective: • Qualify the data before use • Request reanalysis or re-measurement
Representativeness	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for them not being representative • Flag for further review • Review data for usability • If data are usable, qualify the data for limited use and define the portion of the system that the data represent • If data are not usable, flag as appropriate

Table A-2. Data Quality Indicators

DQI	Definition	Determination Methodologies	Corrective Actions
			• Redefine sampling and measurement requirements and protocols • Resample and reanalyze, as appropriate
Comparability	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and quality assurance protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods • Identify quantifiable bias, if applicable • Qualify the data as appropriate • Resample and/or reanalyze if needed • Revise sampling/analysis protocols to ensure future comparability
Completeness	Completeness is a measure of the amount of valid data collected compared to the amount planned. Measurements are considered valid if they are unqualified or qualified as estimated data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (data quality objectives or performance/ acceptance criteria).	If data set does not meet completeness objective: • Identify appropriate changes to data collection and/or analysis methods • Identify quantifiable bias, if applicable • Resample and/or reanalyze if needed • Revise sampling/analysis protocols to ensure future completeness.
Bias	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools • Institute correct sampling and subsampling procedures to limit preferential selection or loss of sample media • Use sample handling procedures, including proper sample preservation, that limit the loss or gain of constituents to the sample media Analytical data that are known to be affected by either sampling or analytical bias are

Table A-2. Data Quality Indicators

DQI	Definition	Determination Methodologies	Corrective Actions
			flagged to indicate possible bias. Laboratories that are known to generate biased data for a specific analyte are asked to correct their methods to remove the bias as best as practicable. Otherwise, samples are sent to other laboratories for analysis.
Sensitivity	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet objective: • Request reanalysis or re-measurement using methods or analytical conditions that will meet required detection or limit of quantitation • Qualify/reject the data before use

Source: SW-846, Pending, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*, as amended.

Data quality is defined by the degree of rigor in the acceptance criteria assigned to the DQIs. Typically, acceptance criteria are set by the analytical method itself; however, project-specific requirements, as indicated by DQOs, may result in more stringent acceptance criteria. The applicable QC guidelines, DQI acceptance criteria, and levels of effort for assessing data quality are dictated by the intended use of the data and the requirements of the analytical method. DQIs are evaluated during the data quality assessment (DQA) process (Section A2.4).

A2.1.3 Special Training/Certification

A graded approach is used to ensure that workers receive a level of training commensurate with their responsibilities and compliant with applicable DOE orders and government regulations. The FWS, in coordination with line management, will ensure that special training requirements for field personnel are met.

Typical training requirements or qualifications have been instituted by the contractor management team to meet training and qualification programs to satisfy multiple training drivers imposed by the applicable *Code of Federal Regulations* (CFR) and *Washington Administrative Code* (WAC) requirements. For example, the environmental, safety, and health training program provides workers with the knowledge and skills necessary to execute assigned duties safely. Field personnel typically complete the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training and supervised 24-hour hazardous waste site experience
- 8-Hour Hazardous Waste Worker Refresher Training (as required)
- Hanford General Employee Training (including Hanford General Employee Radiation Training)

- Radiological Worker Training

Project-specific safety training, focused specifically to project activities, is provided in OU-specific addenda. Project-specific training may include the following:

- Training qualifications needed to comply with QA requirements
- Requirement that samplers have training and certifications for the type of sampling being performed
- RCT qualifications established by the Radiation Protection Program (RCTs assigned to projects will be qualified through the prescribed training program and will undergo ongoing training and qualification activities)

In addition, pre-job briefings, in accordance with work management and work release document evaluation activities and associated hazards, include the following:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Facility where the job will be performed
- Equipment and material required
- Safety protocols applicable to the job
- Training requirements for individuals assigned to perform the work
- Level of management control
- Proximity of emergency contacts

Training records are maintained for each employee in an electronic training record database. The contractor's training organization maintains the training records system. Line management confirms that an employee's training is appropriate and up-to-date prior to performing any field work.

A2.1.4 Documents and Records

The OU Project Manager (or delegate) is responsible for ensuring that the current version of the SAP is being used and providing updates to field personnel. Version control is maintained by the administrative document control process. Changes to the sampling document are handled consistent with HASQARD (DOE/RL-96-68) and the TPA Action Plan (Ecology et al., 1989b). The OU Project Manager is responsible for tracking all SAP changes, obtaining appropriate review, and alerting DOE-RL of these changes. Appropriate documentation will follow, in accordance with the requirements for the type of change. Table A-3 summarizes the changes that may be made and their documentation requirements.

Table A-3. Change Control for Sampling Projects

Type of Change[a]	Type of Change (TPA Action Plan[b])	Action	Documentation
Minor Change. Change has no impact on the sample or field analytical result, and little or no impact on performance or cost. Further, the change does not affect the DQOs specified in the SAP.	**Minor Field Change.** Changes that have no adverse effect on the technical adequacy of the job or the work schedule.	The field personnel recognizing the need for a field change will consult with the OU Project Manager or designee prior to implementing the field change.	Minor field changes will be documented in the field logbook. The logbook entry will include the field change, the reason for the field change, and the names and titles of those approving the field change.
Significant Change. Change has a considerable effect on performance or cost but still allows for meeting the DQOs specified in the SAP.	**Minor Change.** Changes to approved plans that do not affect the overall intent of the plan or schedule.	The OU Project Manager will inform the DOE-RL Project Manager and the Regulatory Lead of the change and seek concurrence at a Unit Manager's Meeting or comparable forum. LRA determines there is no need to revise the document.	Documentation of this change approval would be in the Unit Manager's Meeting minutes or comparable record such as a change notice[c].
Fundamental Change. Change has significant effect on the sample or the field analytical result, performance, or cost, and the change does not meet the requirements specified in the DQOs in the sampling document.	**Revision Necessary.** LRA determines changes to approved plans require revision to document.	If it is anticipated that a fundamental change will require the approval of the Regulatory Lead, the applicable DOE-RL Project Manager will be notified by the OU Project Manager and will be involved in the decision prior to implementation of a fundamental change. The LRA determines the change requires a revision to the document.	Formal revision of the sampling document.

a. Consistent with DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD).

b. Consistent with Sections 9.3 and 12.4 of the TPA Action Plan (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*).

c. The TPA Action Plan, Section 9.3, defines the minimum elements of a change notice.

DOE-RL = U.S. Department of Energy-Richland Operations Office

DQO = data quality objective

LRA = lead regulatory agency

OU = operable unit

SAP = sampling and analysis plan

TPA = Tri-Party Agreement

The FWS, SMR, and appropriate BTR are responsible for ensuring that field instructions are maintained and aligned with any revisions or approved changes to the SAP. SMR will ensure that any deviations from the SAP are reflected in revised paperwork for the samplers and analytical laboratory. The FWS or appropriate BTR will ensure that deviations from the SAP or problems encountered in the field are documented appropriately (e.g., in the field logbook or on nonconformance report forms) in accordance with corrective action protocols.

The OU Project Manager, FWS, or designee is responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities.
The OU Project Manager is also responsible for ensuring that project files are maintained. The project files will contain project records or references to their storage locations. Project files may include, as appropriate, the following information:

- Operational records and logbooks
- Data forms
- Global positioning system data (a copy will be provided to SMR)
- Inspection or assessment reports and corrective action reports
- Field summary reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," and the master drilling contract

The following records are managed and maintained by SMR personnel:

- Field sampling logbooks
- Groundwater sample reports and field sample reports
- Chain-of-custody forms
- Sample receipt records
- Laboratory data packages
- Analytical data verification and validation reports
- Analytical data "case file purges" (i.e., raw data purged from laboratory files) provided by offsite analytical laboratories

The laboratory is responsible for maintaining, and having available upon request, the following items:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Instrument calibration information

Records may be stored in either electronic or hard copy format. Documentation and records, regardless of medium or format, are controlled in accordance with work requirements and processes to ensure that stored records are accurate and can be retrieved. Records required by the TPA (Ecology et al., 1989a) will be managed in accordance with the requirements therein.

A2.2 Data Generation and Acquisition

The following sections present the requirements for analytical methods, measurement and analysis, data collection or generation, data handling, and field and laboratory QC. Requirements for instrument calibration and maintenance, supply inspections, and data management also are addressed.

A2.2.1 Analytical Methods Requirements

Analytical method performance requirements for samples collected are presented in Table A-4. Laboratory operations and analytical services must comply with HASQARD (DOE/RL-96-68).

In consultation with the laboratory and OU Project Manager, SMR can approve changes to analytical methods as long as the new method is based upon a nationally recognized standard method (e.g., EPA and ASTM International, formerly the American Society for Testing and Materials [ASTM]), and the new method delivers analytical data that are comparable to those provided by the old method. The new method must achieve project DQOs, as well as or better than the replaced method, and is required due to the nature of the sample (e.g., high radioactivity). The laboratory using the new method must be accredited by Ecology to perform that method. Issues that may affect analytical results are resolved by SMR in coordination with the OU Project Manager.

Table A-4. Performance Requirements for Groundwater Analysis

Constituent	CAS Number	Action Level[a]	Analytical Method[b]	Highest Allowable PQL[c]	Accuracy (Percent)	Precision (Percent)
Inorganics – Metals (µg/L)						
Antimony	7440-36-0	6.0	EPA 200.8 – ICP/MS	5	80 to 120[d]	≤20[d]
Cadmium	7440-43-6	5/0.25[e]	EPA 200.8 – ICP/MS	2	80 to 120[d]	≤20[d]
Chromium (Hexavalent)	18540-29-9	10	EPA 7196	10[f]	80 to 120[d]	≤20[d]
Cobalt	7440-48-4	4.8	EPA 200.8 – ICP/MS	2.6	80 to 120[d]	≤20[d]
Inorganics – Anions (µg/L)						
Nitrate	14797-55-8	45,000	EPA 300.0	250	80 to 120[d]	≤20[d]
Organics – Volatile Organics (µg/L)						
Trichloroethene	79-01-6	4.0	EPA 8260	1	80 to 120[d]	≤20[d]
cis-1,2-dichloroethene	156-59-2	16	EPA 8260	5	80 to 120[d]	≤20[d]
Vinyl Chloride	75-01-4	0.061	EPA 8260	10[g]	80 to 120[d]	≤20[d]

Table A-4. Performance Requirements for Groundwater Analysis

Constituent	CAS Number	Action Level[a]	Analytical Method[b]	Highest Allowable PQL[c]	Accuracy (Percent)	Precision (Percent)
Radionuclides (pCi/L)						
Strontium-90	10098-97-2	8	Strontium-90 CS/GPC Laboratory Specific	2.0	80 to 120[h]	≤20[h]
Field Measurements[i]						
Dissolved Oxygen	N/A	N/A	Probe	N/A	N/A	N/A
Oxidation Reduction Potential	N/A	N/A	Probe	N/A	N/A	N/A
pH	N/A	N/A	EPA 150.1 Probe	0.1 pH unit	N/A	N/A
Specific Conductance	N/A	N/A	Probe	1 µS/cm	N/A	N/A
Temperature	N/A	N/A	Probe	N/A	N/A	N/A
Turbidity	N/A	N/A	Probe	N/A	N/A	N/A
Depth to Groundwater	N/A	N/A	Probe	N/A	N/A	N/A

a. Action level as presented in DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*. Sources include the following:

40 CFR 131, "Water Quality Standards.

40 CFR 141, "National Primary Drinking Water Regulations."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720(4)(b)(ii)(A) and (B), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

b. Equivalent methods may be substituted. For EPA Method 200.8, see EPA-600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*. For EPA Methods 150.1 and 300.0, see EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*. For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*. Field measurements are carried out using various probes in accordance with manufacturer specifications and standard methods.

c. Highest allowable practical quantitation limits are specified in contracts with analytical laboratories. Actual quantitation limits vary by laboratory and may be lower. Method detection limits are three to five times lower than quantitation limits. For radionuclides, values in this column are the highest allowable minimum detectable concentrations. For a given constituent of concern nearing the end of remediation monitoring phase at a specific well, the quantitation limit may be reviewed to determine if advanced analytical capabilities are available and should be utilized to assist in confirmation of cleanup level attainment at that well.

d. The accuracy criterion shown is the minimum for associated batch laboratory control sample percent recoveries. Laboratories must meet statistically based control, if more stringent. Additional accuracy criteria include analyte-specific evaluations performed for matrix spike, and surrogate recoveries as appropriate to the method. The precision criterion shown is for batch laboratory replicate matrix spike analysis RPDs.

e. The action level for inland wells should meet the cleanup level of 5 µg/L. Wells that will be used to determine if state and federal surface water quality standards are attained should meet the ambient water quality criteria of 0.25 µg/L. The best available quantitation limit is higher than the lower action level.

Table A-4. Performance Requirements for Groundwater Analysis

Constituent	CAS Number	Action Level[a]	Analytical Method[b]	Highest Allowable PQL[c]	Accuracy (Percent)	Precision (Percent)

f. The practical quantitation limit and method detection limit for hexavalent chromium are currently 5 and 1.8 µg/L, respectively, at the primary analytical laboratory that will be used for this analysis for this sampling and analysis plan.

g. The practical quantitation limit and method detection limit for vinyl chloride are currently 2 µg/L and 0.3 µg/L, respectively, at the primary analytical laboratory that will be used for this analysis for this sampling and analysis plan.

h. For radionuclides, the accuracy criterion shown is for associated batch laboratory control sample percent recoveries. Additional accuracy criteria include analysis-specific evaluations performed for matrix spike, tracer, and/or carrier recoveries as appropriate to the method. The precision criterion shown is for batch laboratory replicate sample RPDs.

i. Field measurements have no specific quality control except to perform the manufacturer's required performance checks.

CAS = Chemical Abstracts Service

CS = chemical separation

EPA = U.S. Environmental Protection Agency

GPC = gas proportional counting

MS = mass spectrometry

N/A = not applicable

ICP = inductively coupled plasma

PQL = practical quantitation limit

RPD = relative percent difference

A2.2.2 Field Analytical Methods

Chemical field screening and radiological field survey data used for site characteristics will be measured in accordance with HASQARD (DOE/RL-96-68) approved methodology (as applicable). Field analytical methods are also carried out in accordance with manufacturer specifications and standard methods. Chapter A3 provides the parameters identified for field survey analyses.

A2.2.3 Quality Control

QC requirements specified in the SAP must be followed in the field and analytical laboratory to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Field and laboratory QC sample requirements are summarized in Table A-5. Acceptance criteria for field QC are shown in Table A-6.

Data will be qualified, and a data qualifier will be assigned in HEIS, as appropriate. Data qualifier descriptions are provided in CP-15383, *Common Requirements of the Format for Electronic Analytical Data (FEAD)*.

Table A-5. Project Quality Control Requirements

Sample Type	Frequency	Characteristics Evaluated
Field Quality Control		
Field Duplicates	1 in 20 well trips	Precision, including sampling and analytical variability
Field Splits	As needed. When needed, the minimum is one for every analytical method, for analyses performed where detection limit and precision and accuracy criteria have been defined in the Analytical Performance Requirements table (Table A-4).	Precision, including sampling, analytical, and interlaboratory
Full Trip Blanks	1 per 20 well trips	Cross-contamination from containers or transportation
Field Transfer Blanks	1 per 20 well trips when VOCs are sampled	VOC contamination from sampling site
Equipment Blanks	As needed. If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment blank is not required. Otherwise, one for every 20 samples for each media.[a,b]	Adequacy of sampling equipment decontamination and contamination from nondedicated equipment
Analytical Quality Control[c]		
Laboratory Duplicates	1 per analytical batch[d]	Laboratory Reproducibility and Precision
Matrix Spikes	1 per analytical batch[d]	Matrix Effect/Laboratory Accuracy
Post-Preparation Spike	1 per analytical batch[d]	Matrix Effect/Laboratory Accuracy
Matrix Spike Duplicates	1 per analytical batch[d]	Laboratory Reproducibility and Precision
Laboratory Control Samples	1 per analytical batch[d]	Evaluate Laboratory Accuracy
Method Blanks	1 per analytical batch[d]	Laboratory Contamination
Surrogates	1 per analytical batch[d]	Recovery/Yield
Tracers	1 per analytical batch[d]	Recovery/Yield

a. For portable pumps, an equipment blank is collected for every 10 well trips. Whenever a new type of nondedicated equipment is used, an equipment blank will be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination methods for nondedicated equipment.

b. Vendor provided borehole equipment is considered dedicated equipment, and equipment blanks are not typically performed.

c. Batching across projects is allowed for similar matrices (e.g., all Hanford groundwater).

d. Unless not required by, or different frequency is called out in, laboratory analysis methods.

VOC = volatile organic compound

Table A-6. Field and Laboratory Quality Control Elements and Acceptance Criteria

Analysis	Quality Control Element	Acceptance Criteria	Corrective Action
General Chemical Parameters			
Hexavalent Chromium	MB	< MDL < 5% Sample Concentration	Flagged with "C"
	LCS	80 to 120% Recovery[a]	Data Reviewed[b]
	Laboratory Matrix Duplicate or MS/MSD	≤ 20% RPD	Data Reviewed[b]
	MS[b]	75 to 125% Recovery[a]	Flagged with "N"
	EB	< 2 Times MDL	Flagged with "Q"
	DUP	≤ 20% RPD[c]	Flagged with "Q"
Anions			
Anions by IC	MB	< MDL < 5% Sample Concentration	Flagged with "C"
	LCS	80 to 120% Recovery[a]	Data Reviewed[b]
	Laboratory Matrix Duplicate or MS/MSD	≤ 20% RPD	Data Reviewed[b]
	MS	75 to 125% Recovery[a]	Flagged with "N"
	EB, FTB	< 2 Times MDL	Flagged with "Q"
	DUP	≤ 20% RPD[c]	Flagged with "Q"
Metals			
Metals by ICP or ICP/MS	MB	< Required Detection Limit < 5% Sample Concentration	Flagged with "C"
	LCS	80 to 120% Recovery[a]	Data reviewed [b]
	MS	75 to 125% Recovery[a]	Flagged with "N"
	MSD	75 to 125% Recovery[a]	Flagged with "N"
	MS/MSD	≤ 20% RPD	Data Reviewed[b]
	EB, FTB	< 2 Times MDL	Flagged with "Q"
	DUP	≤ 20% RPD[c]	Flagged with "Q"
Volatile Organic Compounds			
Volatiles by GC/MS	MB	< MDL[d] < 5% Sample Concentration	Flagged with "B"
	LCS	Statistically Derived[c]	Data Reviewed[b]
	MS	% Recovery Statistically Derived[c]	Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD

Table A-6. Field and Laboratory Quality Control Elements and Acceptance Criteria

Analysis	Quality Control Element	Acceptance Criteria	Corrective Action
	MSD	% Recovery Statistically Derived[c]	Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD
	MS/MSD	%RPD Statistically Derived[c]	Data reviewed[b]
	SUR	Statistically Derived[c]	Data reviewed[b]
	EB, FTB, FXR	<2 Times MDL[d]	Flagged with "Q"
	DUP	≤20% RPD[c]	Flagged with "Q"
Radiochemical Analyses			
Strontium-90	MB	<MDA <5% Sample Concentration	Flagged with "B"
	LCS	70 to 130% Recovery	Data Reviewed[b]
	MS	60 to 140% Recovery	Flagged with "N"
	Tracer (Where Applicable)	20 to 105% Recovery	Data Reviewed[b]
	Carrier (Where Applicable)	30 to 105% Recovery	Data Reviewed[b]
	EB, FTB	<2 Times MDA	Flagged with "Q"
	DUP	≤20% RPD[c]	Flagged with "Q"

a. Determined by the laboratory based on historical data or statistically-derived control limits. Limits are reported with the data. Where specific acceptance criteria are listed, those acceptance criteria may be used in place of statistically derived acceptance criteria.

b. After review, corrective actions are determined on a case-by-case basis.

c. Applies only in cases where both results are greater than 5 times the minimum detectable concentration.

d. For common laboratory contaminants, such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is <5 times the MDL.

DUP = field duplicate
EB = equipment blank
FEAD = Format for Electronic Analytical Data
FTB = full trip blank
FXR = field transfer blank
GC/MS = gas chromatography/mass spectrometry
IC = ion chromatography
ICP = inductively coupled plasma
ICP/MS = inductively coupled plasma/mass spectrometry
LCS = laboratory control sample
MB = method blank
MDA = minimum detectable activity
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference
SUR = surrogate

Data Flags:

B (organics)/C (inorganics/wetchem) = Analyte was detected in both the associated quality control blank and the sample
N = All except GC/MS – matrix spike outlier
Q = Associated quality control sample is out of limits
T = Volatile organic analyte and semivolatile organic analyte GC/MS – matrix spike outlier

A2.2.3.1 Field Quality Control Samples

Field QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field sampling variability and laboratory performance to help ensure reliable data are obtained. Field QC samples include field duplicates (DUPs), split samples, and three types of field blanks (full trip blanks [FTBs], field transfer blanks [FXRs], and equipment blanks [EBs]). Field blanks are typically prepared using high-purity reagent water. QC sample definitions and their required frequency for collection are described in this section.

Field Duplicates (DUPs): independent samples collected as close as possible to the same time and same location as the schedule sample, and are intended to be identical. DUPs are placed in separate sample containers and analyzed independently. DUPs are used to determine precision for both sampling and laboratory measurements.

Field Splits (SPLITs): two samples collected as close as possible to the same time and same location that are intended to be identical. SPLITs will be stored in separate containers and analyzed by different laboratories for the same analytes. SPLITs are inter-laboratory comparison samples used to evaluate comparability between laboratories.

Full Trip Blanks (FTBs): bottles prepared by the sampling team prior to traveling to the sampling site. The preserved bottle set is either for volatile organic analysis only or identical to the set that will be collected in the field. It is filled with high-purity reagent water (or dead water from Well 699-S11-E12AP for low-level tritium FTBs[1]), and the bottles are sealed and transported, unopened, to the field in the same storage containers used for samples collected that day. Collected FTBs are typically analyzed for the same constituents as the samples from the associated sampling event. FTBs are used to evaluate potential contamination of the samples attributable to the sample bottles, preservative, handling, storage, and transportation.

Field Transfer Blanks (FXR): filled at the sampling site by pouring reagent water from a cleaned glass container into volatile organic compound (VOC) sample vials pre-loaded with any required preservative. After collection, the FXR is treated in the same manner as the other samples collected during the sampling event. One FXR is collected each day groundwater samples are collected for VOCs. If the VOC samples collected on a given day will be shipped to multiple laboratories, then an FXR is collected for each laboratory for that day. FXRs are used to check for VOC contamination associated with sampling activities.

Equipment Blanks (EBs): reagent water passed through or poured over the decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the SAF. EB sample bottles are placed in the same storage containers with the samples from the associated sampling event. EB samples will be analyzed for the same constituents as the samples from the associated sampling event. EBs are used to evaluate the effectiveness of the decontamination process. EBs are not required for disposable sampling equipment.

A2.2.3.2 Laboratory Quality Control Samples

Internal QA/QC programs are maintained by the laboratories used by the project. Laboratory QA includes a comprehensive QC program that includes the use of matrix spikes (MSs), matrix duplicates, matrix spike duplicates (MSDs), laboratory control samples (LCSs), surrogates (SURs), tracers, and method blanks (MBs). These samples are recommended in the guidance documents and are required by

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[1] Because of the low detection levels achieved in the low-level tritium analysis, special low-level tritium water must be used. This low-level tritium water, known as “dead water,” is collected yearly, or as needed, from Well 699-S11-E12AP or other approved source.

EP-600/4-79-20, *Methods for Chemical Analysis of Water and Wastes*. QC checks outside of control limits are documented in analytical laboratory reports during DQAs. Laboratory QC and their typical frequencies are listed in Table A-5. Acceptance criteria are shown in Table A-6. The following text describes the various laboratory QC samples.

Sample Duplicate: an intralaboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.

Matrix Spike: an aliquot of a sample spiked with a known concentration of target analyte(s). MS is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.

Post-preparation Spike: the same as an MS; however, the spiking occurs after sample preparation.

Matrix Spike Duplicate: a replicate spiked aliquot of a sample that is subjected to the entire sample preparation and analytical process. MSD results are used to determine the bias and precision of a method in a given sample matrix.

Laboratory Control Sample: a control matrix (e.g., reagent water) spiked with analytes representative of the target analytes or a certified reference material that is used to evaluate laboratory accuracy.

Method Blank: an analyte-free matrix to which all reagents are added in the same volumes or proportions as used in the sample processing. The MB is carried through the complete sample preparations and analytical procedure and is used to quantify contamination resulting from the analytical process.

Surrogate: a compound added to all samples in the analysis batch (field samples and QC samples) prior to preparation. SURs are typically similar in chemical composition to the analyte being determined, yet is not normally encountered. SURs are expected to respond to the preparation and measurement systems in a manner similar to the analytes of interest. Because SURs are added to all standards, samples, and QC samples, they are used to evaluate overall method performance in a given matrix. SURs are used only in organic analyses.

Tracer: a known quantity of radioactive isotope that is different from that of the isotope of interest but is expected to behave similarly and is added to an aliquot of sample. Sample results are generally corrected based on tracer recovery.

Sample Storage Blanks: will be used as appropriate. Storage blanks are used to monitor potential cross-contamination of samples due to improper storage conditions. This type of monitoring should be described in laboratory-specific standard operating procedures.

The laboratories are required to analyze samples within the holding time specified in Table A-7. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilizing, decomposing, or other chemical changes. Data from samples analyzed outside the holding times are flagged in the HEIS database with an “H.”

Table A-7. Sample Container, Preservation, and Holding Time Guidelines for Groundwater Samples by Analytical Method

Method Name	Number of Bottles	Bottle Type	Volume (mL)	Preservation Requirement	Holding Time
Metals by EPA 200.8 – ICP/MS	1	G/P	500	Nitric Acid to pH <2	6 Months (Mercury – 28 Days)
Anions by EPA 300.0	1	G/P	500	Cool ≤6°C	28 Days/ 48 Hours
Hexavalent Chromium by EPA 7196	1	aG	500	Cool ≤6°C	24 Hours
VOCs by EPA 8260	4	aG Volatile Organic Analysis Vial with Teflon® Lined Septum	40	Cool ≤6°C, Hydrochloric Acid to pH <2	14 Days
Strontium-90 CS/GPC	1	G/P	1,000	Nitric Acid to pH <2	6 Months

Sources: For EPA Method 200.8, see EPA-600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*.

For EPA Method 300.0, see EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*.

For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, 3rd Edition; Final Update IV-B*.

Note: Teflon is a registered trademark of E.I. du Pont de Nemours and Company, Wilmington, Delaware.

aG = amber glass
CS = chemical separation
EPA = U.S. Environmental Protection Agency
G = glass
GPC = gas proportional counting
ICP/MS = inductively coupled plasma/mass spectrometry
P = plastic

A2.2.4 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that equipment is functioning as expected, properly handled, and properly calibrated at required frequencies in accordance with methods governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved methods. Field screening instruments will be used, maintained, and calibrated in accordance with manufacturer specifications and other approved methods.

A2.2.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment should meet applicable standards (e.g., ASTM) or have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

Measurement and testing equipment used in the field or in the laboratory will be subject to preventive maintenance measures to ensure minimization of downtime. Laboratories must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included

in the individual laboratory and onsite organization's QA plan or operating protocols, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with maintenance requirements specified in HASQARD (DOE/RL-96-68) and applicable Hanford Site requirements.

A2.2.6 Instrument/Equipment Calibration and Frequency

Specific field equipment calibration information is provided in Section A3.5. Analytical laboratory instruments are calibrated in accordance with the laboratory's QA plan and HASQARD (DOE/RL-96-68).

A2.2.7 Inspection/Acceptance of Supplies and Consumables

Consumables, supplies, and reagents will be reviewed in accordance with SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, requirements and will be appropriate for their use. Supplies and consumables used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes. Responsibilities and interfaces necessary to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements must be in place. The procurement system ensures that purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

A2.2.8 Nondirect Measurements

Data obtained from sources such as computer databases, programs, literature files, and historical databases will be technically reviewed to the same extent as the data generated as part of any sampling and analysis QA/QC effort. All data used in evaluations will be identified by source.

A2.2.9 Data Management

The SMR organization, in coordination with the OU Project Manager, is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with the applicable programmatic requirements governing data management methods.

Electronic data access, when appropriate, will be through a Hanford Site database (e.g., HEIS) or a project-specific database, whichever is applicable for the data being stored. Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the TPA Action Plan (Ecology et al., 1989b).

Laboratory errors are reported to the SMR organization on a routine basis. For reported laboratory errors, a sample issue resolution form will be initiated in accordance with applicable methods. This process is used to document analytical errors and establish their resolution with the OU Project Manager. The sample issue resolution forms become a permanent part of the analytical data package for records and future reference.

A2.3 Assessment and Oversight

Assessment and oversight activities address the effectiveness of project implementation and associated QA/QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

A2.3.1 Assessments and Response Actions

Random surveillances and assessments verify compliance with the requirements outlined in this SAP, OU-specific addenda, project field instructions, the project quality management plan, methods, and regulatory requirements. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project's line management chain coordinates the corrective actions/deficiencies resolutions in accordance with the QA program, corrective action management

program, and associated methods implementing these programs. When appropriate, corrective actions will be taken by the OU Project Manager (or designee).

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratories' QA plans. The contractor oversees offsite analytical laboratories and verifies that laboratories are qualified to perform Hanford Site analytical work.

A2.3.2 Reports to Management

Management will be made aware of deficiencies identified by self-assessments, corrective actions from ECOs, and findings from QA assessments and surveillances. Issues reported by laboratories are communicated to the SMR organization, which then initiates a sample issue resolution form. This process is used to document analytical or sample issues and establish resolution with the OU Project Manager.

A2.4 Data Review and Usability

This section addresses the QA activities that occur after data collection. Implementation of these activities determines whether the data conform to the specified criteria, thus satisfying the project objectives.

A2.4.1 Data Review and Verification

Data review and verification are performed to confirm that sampling and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations, reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times have been met, and reviewing QC data to determine whether analyses have met the data quality requirements specified in this SAP.

The criteria for verification include, but are not limited to, review for contractual compliance (samples were analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors.

Errors identified by the laboratories are reported to the SMR organization's project coordinator, who initiates a sample issue resolution form. This process is used to document analytical errors and establish resolution with the OU Technical Lead.

Relative to analytical data in sample media, field screening results are of lesser importance in making inferences regarding risk. Field QA/QC results will be reviewed to ensure that they are usable.

The OU Technical Lead data review will help determine if observed changes reflect improved/degraded groundwater quality or potential data errors and may submit a request for data review (RDR) on questionable data. The laboratory may be asked to check calculations, re-analyze the sample, or resample the well. Results of the RDR process are used to flag the data appropriately in the HEIS database and/or to add comments.

A2.4.2 Data Validation

Data validation activities will be performed at the discretion of the OU Project Manager and under the direction of SMR.

A2.4.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the DQA is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to

meet the project DQOs. For routine groundwater monitoring undertaken through this SAP, the DQA is captured in QC associated with the annual groundwater report (e.g., DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*), evaluating field and lab QC, and usability of data. Further DQAs will be performed at the discretion of the OU Project Manager and documented in a report overseen by SMR.

A3 Field Sampling Plan

This chapter lists the groundwater wells and aquifer tubes to be monitored, sampling frequency, and constituents to be analyzed.

The data will be evaluated as described in Chapter 6 of the Groundwater Addendum.

A3.1 Sampling Objectives

The primary objective of groundwater sampling in the 100-FR-3 OU is to monitor the natural attenuation of groundwater COCs in accordance with the data requirements identified in the DQO report (SGW-58291). Monitoring results will be used to assess the effectiveness of natural attenuation in meeting cleanup levels. Contaminants in groundwater in 100-FR-3 OU that will be managed through MNA are nitrate, Cr(VI), TCE, and strontium-90. Monitoring for TCE degradation products (*cis*-1,2-dichloroethene and vinyl chloride) will also be performed.

Due to analytical uncertainties identified in the 100-F/IU RI/FS (DOE/RL-2010-98), an investigation of antimony, cadmium, and cobalt was identified in the DQO report (SGW-58291) to determine if these analytes are present below the action level. Sampling for these metals will be performed using an analytical method with a sufficiently low detection limit.

These objectives are accomplished in the field by sampling groundwater at designated wells, aquifer tubes, and a riverbank seep and analyzing the samples for the COCs and other identified analytes.

A3.2 Sample Location, Frequency, and Constituents to be Monitored

The DQO process was used to identify sample locations, frequencies for collection, and constituents for monitoring. Problem statements were used to identify PSQs that can be answered using data inputs to satisfy specific data needs. PSQs are discussed in Section A3.2.1 and in the DQO report. (SGW-58291). The locations of the 100-FR-3 OU monitoring network, including wells, aquifer tubes, and a seep, are presented in Figures A-16 and A-17.

Based on the DQO (SGW-58291), eight locations were identified for installation of new Phase 1 monitoring wells. Details on the installation of the wells are presented in Section A3.2.2. The sample locations, frequency, and constituents to be monitored are identified in Table A-8. Additional samples may be collected on an as needed basis.

A3.2.1 Principal Study Questions

The following subsections present a brief summary of the criteria that were used in the DQO process for each PSQ, with the results of the DQO selection process identified in Table A-8. Groundwater data will be used to evaluate the PSQs, as described in Chapter 6 of the Groundwater Addendum.

A3.2.1.1 PSQ 1: Is natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater occurring as expected?

PSQ 1a: Are contaminant concentrations and plume area/mass decreasing?

PSQ 1b: Are rates of decline consistent with expectations?

PSQ 1c: Are there changes in environmental conditions that may reduce the efficacy of natural attenuation?

PSQ 1d: Are there unacceptable impacts to the Columbia River?

and

PSQ 1e: Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy?

To address PSQ 1a and 1b, monitoring wells (as well as aquifer tubes and the seep) were selected based on locations relative to the contaminant plumes, proximity to the Columbia River, distance between wells, and review of historical and recent sampling results. New wells are in locations that will refine interpretations of contaminant distribution, thereby improving estimates of plume size and shrinkage.

Environmental conditions that might affect the efficacy of MNA (PSQ 1c) include groundwater flow direction and rate and general chemistry of groundwater. To address PSQ 1c, water levels will be measured in a robust network of wells; pH and dissolved oxygen will be monitored.

Sampling of aquifer tubes and the seep primarily addresses PSQ 1d. Aquifer tubes identified for sampling were selected based on location relative to the contaminant plumes and a review of historical and recent sampling results. Aquifer tubes are screened 5.2 to 8.8 m (17 to 29 ft) below ground surface and do not represent discharge to the river. However, along with near-river monitoring wells, they provide data on contaminant concentrations closest to the river. Seeps are natural features that represent discharge to the river.

Contaminant sources were removed during previous remedial action. Monitoring wells in the 100-F Area would detect any unanticipated releases from remaining sources (PSQ 1e).

Sampling will be scheduled with consideration for high and low river stages, which affect water table elevation and hydraulic gradients. Annual and biennial sampling will be scheduled for September through November (low river stage). Wells scheduled semiannually will have an additional sample collected in May through early July (high river stage). Quarterly wells will have two additional sample events scheduled between high and low stage periods. Sampling events will be scheduled to collect at all the sample locations within a relatively short time period so a representative point in time is collected for the entire area. Sampling will be scheduled for the same time each year to attempt to enhance year-to-year comparability of results.

The analytical methods meet desired cleanup levels for the four COCs (Table A-4). Cr(VI) samples will be filtered to eliminate interference in the analysis.

A3.2.1.2 PSQ 2: Are concentrations of antimony, cadmium, and cobalt below action levels?

Monitoring locations for sampling analytes identified for further quantitation were identified based on previous detections and spatial distribution of wells. These constituents will be analyzed using methods with detection limits below action levels, where available (Table A-4). Samples will be collected during the first 10 years of performance monitoring until sufficient data are obtained for evaluation (8 samples). The results will be used to determine if a risk assessment should be performed for these analytes.

Section 7.1.12 of the DQO report (SGW-58291) explains the rationale for selection of wells for trace metals analyses.

A3.2.1.3 PSQ 3: Do new geologic and hydrogeologic data confirm the conceptual site model?

Geologic interpretation of the region south of 100-F Area will be refined, based on geophysical logging of existing wells and geologic and geophysical logging of new wells. Installation of the new wells will provide data on the elevation of geologic contacts (between Hanford and Ringold E, where present, and top of RUM) from the borehole geologic log and from borehole geophysical logging, where performed. Slug tests and/or single-well pumping tests will provide data on the transmissivity of the unconfined aquifer. Water level measurements will provide data on the water table elevation.

Table A-8. 100-FR-3 Operable Unit Summary of Monitoring Locations, Frequencies, and Constituents

Monitoring Location	Analytes					Water Level[a]		Data Need							Sample Frequency		
	Cr(VI) (Filtered)	TCE and Degradation Products	Nitrate	Strontium-90	Trace Metals[b]	AWLN	Manual	PSQ 1a, 1b: Contamination Decreasing as expected?	PSQ 1c: Changes in environmental conditions that reduce effectiveness?	PSQ 1d: Unacceptable impacts to river?	PSQ 1e: Evidence of new contaminant releases?	PSQ 2: Trace metals below action levels?	PSQ 3: Geologic and hydrologic data confirm Conceptual Site Model?	PSQ 4a, 4b: Remediation objectives achieved?	Year 1	Year 2 to Year 5	Year 6 and Onward
Existing Monitoring Wells																	
199-F5-1			X	X			X	X	X		X			X	A, S[c]	A, S[c]	B
199-F5-4	X	X	X		X		X	X	X		X	X		X	A, S[d]	A, S[d]	B[e]
199-F5-42	X		X	X			X	X	X	X				X	A	A	B
199-F5-43A	X		X	X	X		X	X	X	X		X	X	X	A	A	B[e]
199-F5-44	X		X	X			X	X	X	X				X	A	A	B
199-F5-45	X	X	X				X	X	X		X		X	X	A	A	B
199-F5-46	X	X	X	X			X	X	X		X			X	S	S	B
199-F5-47	X		X	X			X	X	X		X			X	A	A	B
199-F5-48	X	X	X		X		X	X	X		X	X		X	A	A	B[e]
199-F5-52	X		X			X	X	X	X	X	X		X	X	A	A	B
199-F5-54	X		X	X			X	X	X		X			X	A	A	B
199-F5-55	X		X	X			X	X	X		X			X	A, S[c]	A, S[c]	B
199-F5-56	X	X	X	X			X	X	X		X			X	A	A	B
199-F5-6	X		X	X			X	X	X	X	X			X	A, S[f]	A, S[f]	B
199-F6-1	X		X	X		X	X	X	X	X	X		X	X	A	A	B
199-F7-1		X	X			X	X	X	X		X		X	X	A	A	B
199-F7-2		X	X			X	X	X	X		X		X	X	A	A	B
199-F7-3		X	X				X	X	X		X			X	A	A	B
199-F8-2	X			X			X	X	X		X			X	A	A	B
199-F8-4			X			X	X	X	X				X	X	A	A	B
199-F8-7		X	X	X	X		X	X	X		X	X		X	A	A	B[e]
699-58-24							X		X						A[g]	A[g]	B[g]
699-59-32[h]			X			X	X	X	X				X	X	A	A	B

Table A-8. 100-FR-3 Operable Unit Summary of Monitoring Locations, Frequencies, and Constituents

Monitoring Location	Analytes					Water Level[a]		Data Need							Sample Frequency		
	Cr(VI) (Filtered)	TCE and Degradation Products	Nitrate	Strontium-90	Trace Metals[b]	AWLN	Manual	PSQ 1a, 1b: Contamination Decreasing as expected?	PSQ 1c: Changes in environmental conditions that reduce effectiveness?	PSQ 1d: Unacceptable impacts to river?	PSQ 1e: Evidence of new contaminant releases?	PSQ 2: Trace metals below action levels?	PSQ 3: Geologic and hydrologic data confirm Conceptual Site Model?	PSQ 4a, 4b: Remediation objectives achieved?	Year 1	Year 2 to Year 5	Year 6 and Onward
699-60-32[h]			X			X	X	X	X				X	X	A	A	B
699-61-37						X	X						X		A[g]	A[g]	B[g]
699-62-31			X				X	X	X				X	X	A	A	B
699-63-25A			X				X	X	X				X	X	A	A	B
699-64-27			X			X	X	X	X				X	X	A	A	B
699-66-23			X			X	X	X	X	X			X	X	A	A	B
699-70-23						X	X		X				X		A[g]	A[g]	B[g]
699-71-30		X	X			X	X	X	X				X	X	A	A	B
699-74-44							X		X				X		A[g]	A[g]	B[g]
699-77-36		X	X			X	X	X	X				X	X	A	A	B
New Monitoring Wells (Phase 1)																	
C9472		X	X				X	X	X				X	X	Q	A	B
C9474			X			X	X	X	X	X			X	X	Q	A	B
C9475		X	X			X	X	X	X				X	X	Q	A	B
C9476		X	X			X	X	X	X				X	X	Q	A	B
C9477			X			X	X	X	X	X			X	X	Q	A	B
C9478			X			X	X	X	X				X	X	Q	A	B
C9479			X			X	X	X	X				X	X	Q	A	B
C9480			X			X	X	X	X	X			X	X	Q	A	B

Table A-8. 100-FR-3 Operable Unit Summary of Monitoring Locations, Frequencies, and Constituents

Monitoring Location	Analytes					Water Level[a]		Data Need							Sample Frequency		
	Cr(VI) (Filtered)	TCE and Degradation Products	Nitrate	Strontium-90	Trace Metals[b]	AWLN	Manual	PSQ 1a, 1b: Contamination Decreasing as expected?	PSQ 1c: Changes in environmental conditions that reduce effectiveness?	PSQ 1d: Unacceptable impacts to river?	PSQ 1e: Evidence of new contaminant releases?	PSQ 2: Trace metals below action levels?	PSQ 3: Geologic and hydrologic data confirm Conceptual Site Model?	PSQ 4a, 4b: Remediation objectives achieved?	Year 1	Year 2 to Year 5	Year 6 and Onward
Aquifer Tubes																	
64-M	X		X	X				X		X					A	A	B
C6302	X		X	X				X		X					A	A	B
C6303	X		X					X		X					A	A	B
C6306	X		X	X				X		X					A	A	B
C6309	X		X	X				X		X					A	A	B
C6315	X		X	X				X		X					A	A	B
Riverbank Seep																	
Seep 187-1	X		X					X		X					A	A	B
River Gauge																	
100-F River Gauge						X			X	X			X				

a. Manual water level measurements will be obtained at low, high, and moderate river stage during sample years for the first 10 years of performance monitoring. For wells identified for only manual water level measurements, measurements will be taken each year for the first 5 years, and biennially thereafter. Manual water level measurements will not be obtained from wells within the AWLN during the operational period.

b. Trace metals include antimony, cadmium, and cobalt. These analytes are included for samples collected only during the first 10 years of monitoring until sufficient data are obtained for evaluation (eight samples).

c. Semiannual sample frequency will be performed for strontium-90. Other analytes are sampled at an annual frequency.

d. Semiannual sample frequency will be performed for Cr(VI), TCE, and nitrate. Trace metals sampled at an annual frequency.

e. Antimony, cadmium, and cobalt are not included for analysis after year 10.

f. Semiannual sample frequency will be performed for Cr(VI). Other analytes sampled at an annual frequency.

g. Water level measurements only.

h. Only one of Wells 699-59-32 and 699-60-32 will be included in the monitoring network. The decision of which well to be included will be based on well investigation results.

A = annual
B = biennial
AWLN = automated water level network
Cr(VI) = hexavalent chromium
PSQ = principal study question
S = semiannual
TCE = trichloroethene

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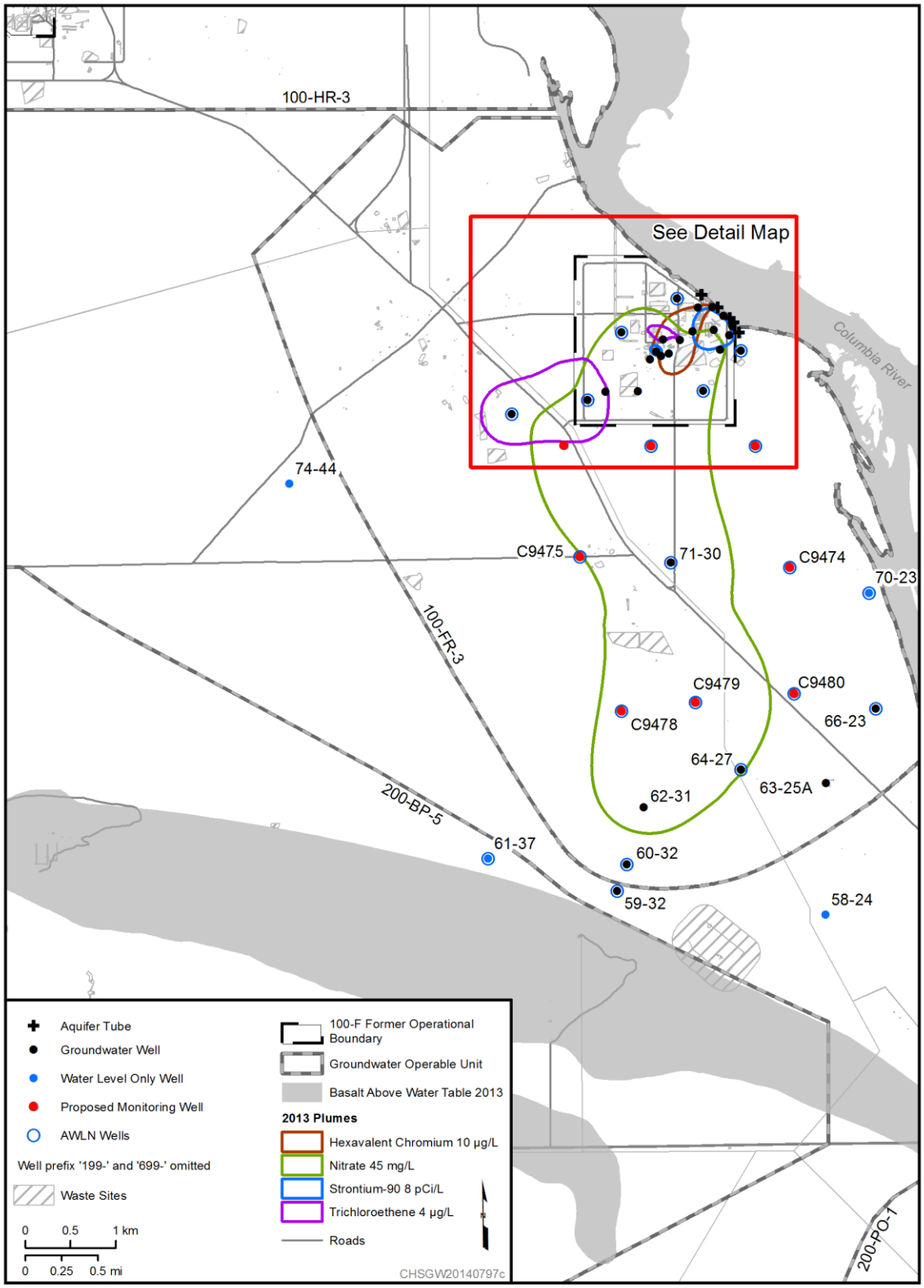

Note: Either Well 59-32 or 60-32 will be included in the network depending on field investigation results.

Figure A-16. 100-FR-3 Operable Unit Performance Monitoring Network

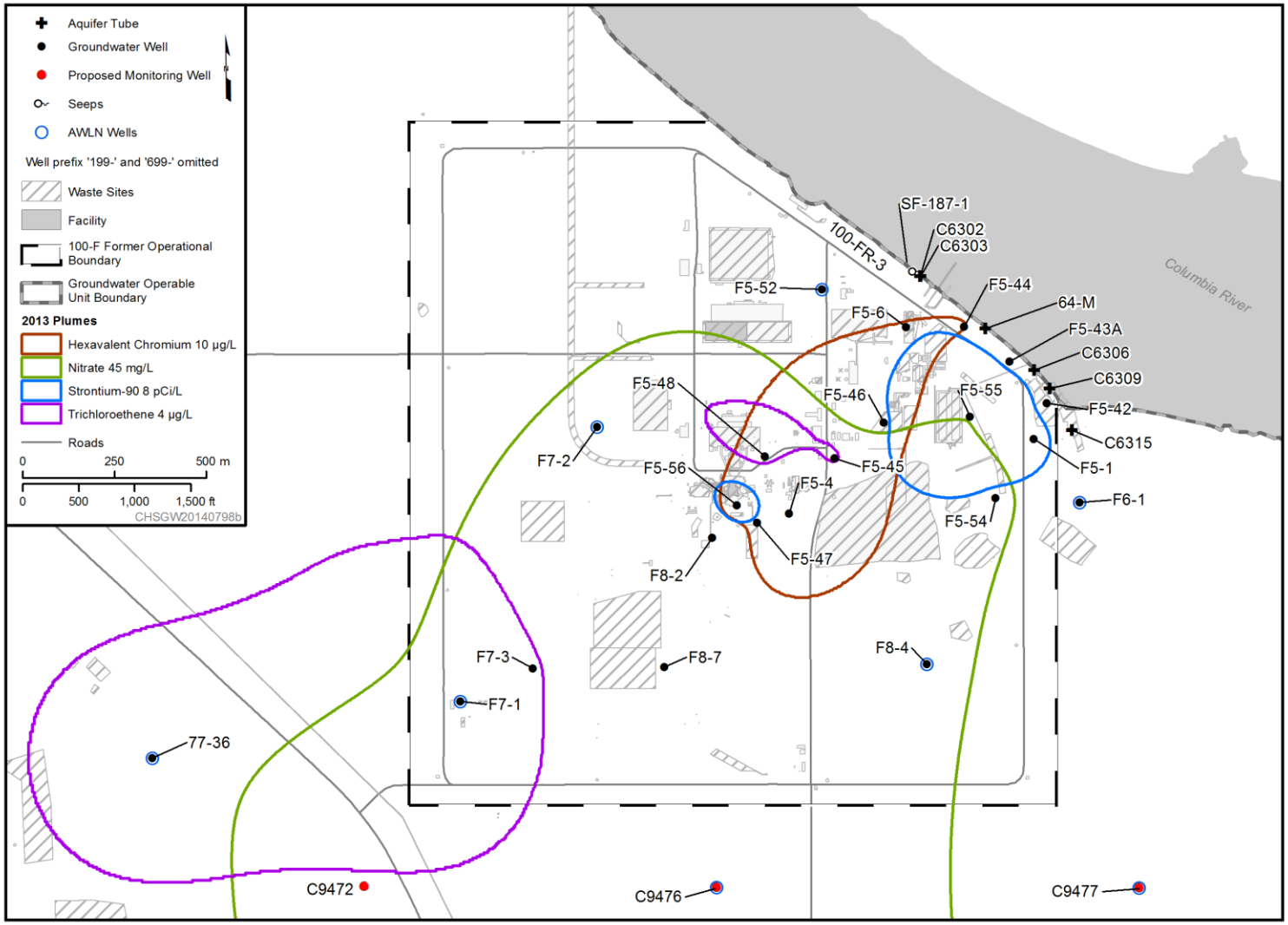

Figure A-17. Detail Map of 100-FR-3 Operable Unit Performance Monitoring Network near 100-F Area

The 100-F river gauge station and 19 monitoring wells were identified for creating the AWLN for the first 5 years of monitoring. AWLN measurements will be recorded hourly. The need for continuation of the AWLN will be evaluated as part of the 5-year performance reports.

Groundwater levels are measured annually in March across the Hanford Site to construct water table maps that are used to determine the direction and rate of groundwater flow in the unconfined aquifer (SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*). In addition to the March water table map, at a minimum, the high and low river stage maps will be provided in the Phase 1 well report and the comprehensive 5-year performance monitoring reports for as long as the AWLN remains active.

Groundwater measurements also will be recorded at monitoring locations concurrent with collection of groundwater samples.

A3.2.1.4 PSQ 4: Have RAOs been achieved?

PSQ 4a: Are concentrations of COCs below cleanup levels?

PSQ 4b. Will groundwater continue to meet the cleanup levels in the future?

Performance monitoring of the 100-FR-3 OU will produce data usable for determining if groundwater RAOs have been achieved. The following groundwater specific RAOs are identified in the 100-F/IU ROD (EPA and DOE, 2014):

RAO 1: Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.

RAO 2: Prevent unacceptable risk to human health and ecological receptors from groundwater discharges to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.

RAO 7: Restore groundwater impacted from 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 releases to proposed cleanup levels, which include DWSs, within a time frame that is reasonable given the particular circumstances of the site.

Only data from monitoring wells will be used in calculations and evaluation of compliance with cleanup levels. Results from aquifer tubes and the seep will be used to determine changes in plume size and, in the case of aquifer tubes, assess COC concentrations nearest the surface water.

A3.2.2 New Groundwater Monitoring Well Installation

The first phase of new wells to support performance monitoring includes eight locations. Approximate coordinates for the new well locations are presented in Table A-9. Field walk downs of the identified locations will be performed prior to drilling. These locations may require adjustment based on accessibility or results of ecological/cultural reviews. Well locations may also require change if the aquifer is not present at the drilling location. If the new location is more than 100 m (330 ft) from the original location, EPA and DOE will be consulted for concurrence prior to drilling.

During drilling, a well site geologist will collect drill cutting samples for archive approximately every 1.5 m (5 ft) and complete geologic logs according to project procedures. Samples from the desired screen depth will be collected for sieve analyses. No other soil or water samples are required during drilling. When the boreholes reach total depth, project staff will determine whether borehole geophysical logging is needed.

After wells are completed and developed, project staff will determine whether slug tests and/or single-well pumping tests will be performed to characterize hydraulic conductivity.

Additional Phase 2 monitoring wells may be identified based on evaluation of results from the Phase 1 well samples. Phase 2 wells will be constructed using the same instruction as the Phase 1 wells.

A3.2.2.1 Well Depth and Screen Placement

Each new well will be drilled approximately 3 m (10 ft) into the RUM unit to facilitate geologic and geophysical interpretations. Estimated depths of each well are presented in Table A-9. A 6.1 m (20 ft) screen will be installed at the top of the unconfined aquifer, with approximately 1 to 1.5 m (3 to 5 ft) of screen above the water table.

A3.2.2.2 Well Drilling, Completion, and Development

Well drilling and completion will be performed in accordance with WAC 173-160. The wells will be drilled using 20 cm (8 in.) diameter (or larger) temporary casing. Each well will be constructed with 10 cm (4 in.) diameter stainless steel casing and a 6.1 m (20 ft) long, continuous wire-wrap stainless steel screen, atop a 1.0 to 1.5 m (3 to 5 ft) long stainless steel sump with end cap.

Table A-9. 100-FR-3 Operable Unit Phase 1 Monitoring Well Locations

Well Identification	Northing (m)	Easting (m)	Estimated Drill Depth (ft)*
C9472	146518.7	579424.8	46
C9474	145173.9	581917.5	49
C9475	145292.3	579601.4	23
C9476	146516.3	580385.7	33
C9477	146514.8	581538.1	43
C9478	143589.5	580059.3	76
C9479	143688.6	580874.3	43
C9480	143783.7	581960.7	62

* Estimated depth is to top of Ringold Formation upper mud unit plus 3 m (10 ft).

Colorado silica sand (unless otherwise determined by the drilling contract) will be used for the sand pack. Sodium bentonite pellets and/or natural sodium bentonite chunks, crumbles, or powdered bentonite will be used for bentonite sealing material, and Portland cement will be used for cement grout.

Wells will be properly developed to restore natural hydraulic properties and chemistry that may be altered by the drilling process. Development requirements will be specified in drilling contract documents.

Surface construction consisting of protective casing, protective guard posts, and cement pad must be in place before job completion.

Final well design, including screen placement and length, will be determined by concurrence of the field geologist, drilling lead, and OU lead based upon field conditions.

Following completion, well locations and elevations will be surveyed, and dedicated sampling pumps will be installed in each well.

A3.2.3 Automated Water Level Network

AWLN is the combination of equipment, hardware, and software for the measurement, collection, transmittal, storage, and management of water level data in the aquifer. Water-level data are measured by submersible pressure transducers installed in a network of monitoring locations. The data are then directly transmitted to a base station via telemetry or can be manually downloaded to portable computers.

The 100-F automated river gauge and 19 monitoring wells will comprise the AWLN for the 100-FR-3 OU (Table A-8). Twelve existing wells and seven new wells will be incorporated into the AWLN and equipped as required for the automated measurements. Two of the existing wells (699-61-37 and 699-70-23) are included in the network for the purpose of the AWLN only. For new wells, equipment necessary for automated measurements will be installed when the wells are completed. The 100-F river gauge station will also be re-established to allow safe access to the location. The AWLN may be modified based on field conditions and data needs.

The AWLN will be operated for the first 5 years of the performance monitoring period. At the end of the fifth year, the continuing need for AWLN will be evaluated. When AWLN is no longer needed, the associated equipment will be removed from the wells.

A3.2.4 Rehabilitation of Old Wells

Several existing wells that were installed prior to 1987 were identified for the monitoring network (Table A-10). Some of these wells require investigation and/or rehabilitation prior to use. Investigation of the wells will be performed with a downhole camera survey. Geophysical logging will be performed on selected wells to determine the depth of geologic contacts.

Several pre-1987 wells that extend into the RUM will require rehabilitation to isolate the unconfined aquifer. Grout will be added to the base of these wells to fill the portion of the well in the RUM. Information from the geophysical investigation will be used to determine the depth of grout needed to ensure sampling of the unconfined aquifer.

A3.3 Sampling Methods

Sampling may include, but not be limited to, the following methods:

- Field screening measurements
- Radiological screening
- Groundwater sampling
- Aquifer tube sampling
- Riverbank seep sampling
- Water level measurements

Table A-10. Pre-1987 Monitoring Wells Requiring Investigation and/or Rehabilitation

Well	Construction Year	Depth to Bottom (ft Below Top of Casing)	Camera Survey?	Geophysical Logging?	Rehabilitation?	Comment
199-F7-1	1956	60.7	Yes	No	Yes	Grout to approximately 10 m (33 ft) below ground surface to isolate unconfined aquifer
699-59-32	1971	74.8	Yes	No	No	Either 699-59-32 or 699-60-32 to be within monitoring network depending on investigation results
699-60-32	1971	83.1	Yes	Yes	No	
699-63-25A	1949	102.4	Yes	Yes	Yes	Grout to top of the RUM
699-66-23	1961	74.1	Yes	Yes	Yes	Grout to top of the RUM
699-71-30	1957	79.5	Yes	Yes	Yes	Grout to top of the RUM
699-77-36	1957	78.4	Yes	Yes	Yes	Grout to top of the RUM

RUM = Ringold Formation upper mud unit

Water samples will be collected according to the current revision of applicable operating methods. Water samples are collected after field measurements of purged groundwater have stabilized:

- pH – two consecutive measurements agree within 0.2 pH units
- Temperature – two consecutive measurements agree within 0.2ºC
- Conductivity – two consecutive measurements agree within 10 percent of each other
- Turbidity – less than 5 nephelometric turbidity units prior to sampling (or project scientist's recommendation)

For certain types of samples, preservatives are required. While the preservative may be added to collection bottles before their use in the field, it is allowable to add the preservative at the sampling vehicle immediately after collection. Samples may require filtering in the field, as noted on the chain-of-custody forms. All Cr(VI) samples will be filtered.

To ensure sample and data usability, sampling associated with this SAP will be performed according to HASQARD (DOE/RL-96-68) pertaining to sample collection, collection equipment, and sample handling.

Suggested sample container, preservation, and holding time requirements are specified in Table A-7 for groundwater samples. These requirements are in accordance with the analytical method specified. The final container type and volumes will be identified on the SAF and chain-of-custody form. This SAP defines a sample as a filled sample bottle for starting the clock for holding time restrictions.

Holding time is the elapsed period between sample collection and analysis. Exceeding required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Required holding times depend on the analytical method, as specified for appropriate EPA methods (EPA-600/4-79-020 and SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*).

A3.3.1 Decontamination of Sampling Equipment

To prevent potential contamination of the samples, care should be taken to use decontaminated equipment for each sampling activity. Wells will be equipped with dedicated sampling pumps, and aquifer tubes are sampled with a peristaltic pump that does not contact sample water. If a nondedicated sampling pump needs to be used, it will be decontaminated in accordance with the sampling equipment decontamination methods.

Special care should be taken to avoid the following common ways in which cross-contamination or background contamination may compromise the samples:

- Improperly storing or transporting sampling equipment and sample containers
- Contaminating the equipment or sample bottles by setting the equipment/sample bottle on or near potential contamination sources (e.g., uncovered ground)
- Handling bottles or equipment with dirty hands or gloves
- Improperly decontaminating equipment before sampling or between sampling events

A3.3.2 Field Screening

Appropriate radiological and volatile organic field screening will be performed by the RCT or other qualified personnel to support drilling efforts. The RCT will record field measurements, noting the depth of the sample and the instrument reading. Measurements will be relayed to the field geologist (for boreholes and wells) for daily inclusion in the field logbook or operational records, as applicable.

The following information will be distributed to personnel performing work in support of this SAP:

- Instructions to RCTs on the methods required to measure sample activity and media for gamma, alpha, and/or beta emissions, and VOCs, as appropriate.
- Information regarding the portable radiological field instrumentation, including a physical description of the instruments, radiation and energy response characteristics, calibration/maintenance and performance testing descriptions, and the application/operation of the instrument (these instruments are commonly used on the Hanford Site to obtain measurements of removable surface contamination measurements and direct measurements of the total surface contamination)
- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, “Occupational Radiation Protection”
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of radiological information
- Minimum standards and practices necessary for preparing, performing, and retaining radiological related information
- Requirements associated with preparing and transporting regulated material

- Daily reports of radiological surveys and measurements collected during conduct of field investigation activities (data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results)

A3.3.3 Water Levels (Manual)

Manual water level measurements will be obtained at periods of low, high, and moderate river stage for the first 10 years of the monitoring period at the wells identified in Table A-8. The monitoring years during which manual measurements are obtained correspond to the years in which analytical samples are obtained (three times each year for years 1 through 5 and three times every other year thereafter). Two wells (699-58-24 and 699-74-44) are identified for only manual water level measurement with no analytical sampling (Table A-8). Wells 699-61-37 and 699-70-23 are included in the AWLN and will have manual water level measures performed three times every other year at the conclusion of the AWLN period.

Groundwater levels are measured annually across the Hanford Site to construct water table maps that are used to determine the direction and rate of groundwater flow in the unconfined aquifer (SGW-38815). These measures may be used in conjunction with the water level measures prescribed by this SAP.

A measurement of depth to water also is recorded in each well prior to sampling, using calibrated depth measurement tapes. Two consecutive measurements are taken that agree within 6 mm (0.02 ft). These are recorded along with the date, time, measuring tape number, and so forth. The depth to groundwater is subtracted from the elevation of a reference point (usually the top of casing) to obtain the water level elevation. Tops of casings are known elevation reference points because they have been surveyed to local reference data.

A3.4 Documentation of Field Activities

Logbooks or data forms are required for field activities. A logbook must be identified with a unique project name and number. The individual(s) responsible for logbooks will be identified in the front of the logbook, and only authorized persons may make entries in logbooks. Logbook entries will be reviewed by the FWS, cognizant scientist/engineer, or other responsible manager; the review will be documented with a signature and date. Logbooks will be permanently bound, waterproof, and ruled with sequentially numbered pages. Pages will not be removed from logbooks for any reason. Entries will be made in indelible ink. Corrections will be made by marking through the erroneous data with a single line, entering the correct data, and initialing and dating the changes.

Data forms may be used to collect field information; however, the information recorded on data forms must follow the same requirements as those for logbooks. The data forms must be referenced in the logbooks.

A summary of information to be recorded in logbooks is as follows:

- Purpose of activity
- Day, date, time, and weather conditions
- Names, titles, and organizations of personnel present
- Deviations from the QAPjP
- All site activities, including field tests
- Materials quality documentation (e.g., certifications)

- Details of samples collected (e.g., preparation, splits, DUPs, MS, and EBs)
- Location and types of samples
- Chain-of-custody details and variances relating to chain-of-custody
- Field measurements
- Field calibrations testing, inspections, maintenance and surveys, and equipment identification numbers, as applicable
- Equipment decontaminated, number of decontaminations, and variations to decontamination methods
- Equipment failures or breakdowns and descriptions of any corrective actions
- Telephone calls relating to field activities

A3.4.1 Corrective Actions and Deviations for Sampling Activities

The OU Project Manager, FWS, appropriate BTR (or designee), and SMR personnel must document deviations from protocols, problems pertaining to sample collection, chain-of-custody forms, target analytes, contaminants, sample transport, or noncompliant monitoring. Examples of deviations include samples not collected because of field conditions, changes in sample locations because of physical obstructions, or additions of sample depth(s).

As appropriate, such deviations or problems will be documented in the field logbook or on nonconformance report forms in accordance with internal corrective action methods. The OU Project Manager, FWS, appropriate BTR (or designee), or SMR personnel will be responsible for communicating field corrective action requirements and for ensuring immediate corrective actions are applied to field activities.

Changes in sample activities that require notification, approval, and documentation will be performed as specified in Table A-3.

A3.5 Calibration of Field Equipment

Construction management, the appropriate BTR, or the FWS is responsible for ensuring that field equipment is calibrated appropriately. Onsite environmental instruments are calibrated in accordance with the manufacturer's operating instructions, internal work requirements and processes, and/or field instructions that provide direction for equipment calibration or verification of accuracy by analytical methods. The results from all instrument calibration activities are recorded according to HASQARD (DOE/RL-96-68).

Field instrumentation, calibration, and QA checks will be performed as follows:

- Prior to initial use of a field analytical measurement system
- At the frequency recommended by the manufacturer or methods, or as required by regulations
- Upon failure to meet specified QC criteria
- Calibration of radiological field instruments on the Hanford Site is performed by the MSA prime contractor, as specified by their calibration program
- Daily calibration checks that will be performed and documented for each instrument used to characterize areas under investigation (these checks will be made on standard materials sufficiently

like the matrix under consideration for direct comparison of data; analysis times will be sufficient to establish detection efficiency and resolution)

- Standards used for calibration that are traceable to nationally or internationally recognized standard agency source or measurement system, if available

A3.6 Sample Handling

Sample handling and transfer will be in accordance with established methods to preclude loss of identity, damage, deterioration, and loss of sample. Custody seals or custody tape will be used to verify that sample integrity has been maintained during sample transport. The custody seal will be inscribed with the sampler's initials and date.

A sampling and tracking database is used to track the samples from the point of collection through the laboratory analysis process.

A3.6.1 Containers

Pre-cleaned sample containers with certificates of analysis denoting compliance with EPA specifications (EPA 540/R-93/051, *Specifications and Guidance for Contaminant-Free Sample Containers*) for the intended analyses will be used for samples collected for chemical analysis. Container sizes may vary depending on laboratory-specific volumes/requirements for meeting analytical detection limits.
The Radiological Engineering organization will measure both the contamination levels and dose rates associated with the filled sample containers. This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's radioactivity acceptance criteria. If the dose rate on the outside of a sample container or the curie content exceeds levels acceptable by an offsite laboratory, the FWS (in consultation with the SMR organization), can send smaller volumes to the laboratory. Container types and sample amounts/volumes are identified in Table A-7.

A3.6.2 Container Labeling

Each sample container will be labeled with the following information on firmly affixed, water-resistant labels:

- SAF
- HEIS number
- Sample collection date and time
- Analysis required
- Preservation method (if applicable)
- Chain-of-custody number
- Bottle type and size
- Laboratory performing the analyses
- Sampler's name
- Sample location

In addition, sample records must include the following information:

- Analysis required
- Source of sample
- Matrix (water)

- Field data (pH, temperature, turbidity, and conductivity)
- Radiological readings

The following information may be specified by the project:

- Dissolved oxygen
- Redox potential

A3.6.3 Sample Custody

Sample custody will be maintained in accordance with existing protocols to ensure the maintenance of sample integrity throughout the analytical process. Chain-of-custody protocols will be followed throughout sample collection, transfer, analysis, and disposal to ensure sample integrity is maintained. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to any laboratory.

Shipping requirements will determine how sample shipping containers are prepared for shipment. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Each time the responsibility for the custody of the sample changes, the new and previous custodians will sign the record and note the date and time. The sampler will make a copy of the signed record before sample shipment and will transmit the copy to the SMR organization within 48 hours of shipping.

The following information is required on a completed chain-of-custody form:

- Project name
- Signature of sampler
- Unique sample number
- Date and time of collection
- Matrix
- Preservatives
- Signatures of individual involved in sample transfer
- Requested analyses (or reference thereto)

Samplers should note any anomalies with the samples that would prevent batching. If anomalies are found, the samplers should inform SMR before adding any information regarding batching on the chain-of-custody form.

A3.6.4 Sample Transportation

All packaging and transportation instructions will comply with applicable transportation regulations and DOE requirements. Regulations for classifying, describing, packaging, marking, labeling, and transporting hazardous materials, hazardous substances, and hazardous wastes are enforced by the U.S. Department of Transportation (DOT) as described in 49 CFR 171, “Transportation,” “General Information, Regulations, and Definitions,” through 177, “Carriage by Public Highway.” Sample shipments conveyed by air freight providers shall also comply with carrier-specific requirements defined in the International Air Transportation Association Dangerous Goods Regulations.

Samples containing hazardous constituents will be considered hazardous material in transportation and transported according to DOT 49 CFR and International Air Transportation Association requirements. If the sample material is known or can be identified, then it will be classified, described, packaged, marked, labeled, and transported according to the specific instructions for that material.

Materials are classified by DOT as radioactive when the isotope-specific activity concentration and the exempt consignment limits described in 49 CFR 173, "Shippers—General Requirements for Shipments and Packagings," are both exceeded. Samples will be screened, or relevant historical data will be used, to determine whether these values are exceeded. When screening or historical data indicate samples are radioactive, they will be properly classified, described, packaged, marked, labeled, and transported according to DOT requirements.

A4 Management of Waste

Appendix C of the Groundwater Addendum, "Waste Management Plan for the 100-FR-3 Operable Unit," provides details on the specific requirements for waste identification, characterization, segregation, packaging, labeling, storage, and inspection for waste generation activities associated with the 100-FR-3 OU performance monitoring activities.

Offsite analytical laboratories are responsible for disposal of unused sample quantities. Pursuant to 40 CFR 300.440, "National Oil and Hazardous Substances Pollution Contingency Plan," "Procedures for Planning and Implementing Off Site Response Actions," approval from the DOE Remedial Project Manager is required before returning unused samples or waste from offsite laboratories.

A5 Health and Safety

The remediation contractor's hazardous waste operations safety and health program was developed for employees involved in hazardous waste site activities. The program was developed to comply with the requirements of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response," and 10 CFR 835, to ensure the safety and health of workers during hazardous waste operations.

The health and safety program was developed in accordance with the overall remediation contractor's health and safety program to define the chemical, radiological, and physical hazards and to specify the controls and requirements for day-to-day work activities on the overall Hanford Site. It also incorporates applicable core functions and guiding principles, outlined in the Integrated Safety Management System, and governs minimal personal training, control of industrial safety and radiological hazards, PPE, site control, and general emergency response to spills, fire, accidents, injury, and incident reporting.

Access and work activities will be controlled in accordance with approved work packages, as required by established internal work requirements and processes. The health and safety plan (HASP), which addresses the health and safety hazards of each phase of site operation, includes the requirements for hazardous waste operations and/or construction activities, as specified in 29 CFR 1910.120.

Project field staff will be required to comply with the HASP at all times. Unescorted site visitors are required to read and sign the HASP before entering the construction area and must have completed the required training outlined in the HASP. Escorted visitors are briefed on health and safety concerns and must be escorted by the site superintendent (or designee) at all times when they are in the construction area.

During operations, emergency response for the 100-FR-3 OU remedial activities will be covered by the HASP. The HASP specifies primary emergency response actions for site personnel, area alarms, implementation of the emergency action plan and emergency equipment at the task site, emergency coordinators, emergency response procedures, and spill containment procedures.

A6 References

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Data Quality Assessment for Appendix A

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

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

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Terms

COC	contaminant of concern
Cr(VI)	hexavalent chromium
CSM	conceptual site model
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HEIS	Hanford Environmental Information System
MNA	monitored natural attenuation
OU	operable unit
PSQ	principal study question
QA	quality assurance
QC	quality control
RAO	remedial action objective
RDR/RAWP	remedial design report/remedial action work plan
RI	remedial investigation
ROD	record of decision
RUM	Ringold Formation upper mud
SAP	sampling and analysis plan
TCE	trichloroethene

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Data Quality Objectives for 100-FR-3 Monitored Natural Attenuation

The 100-FR-3 Groundwater Operable Unit (OU) comprises groundwater contaminated by releases from facilities and waste sites associated with past operation of the 100-F Reactor and biological experiments. The U.S. Environmental Protection Agency (EPA) issued the 100-F/IU record of decision (ROD) for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 in September 2014 (EPA and DOE, 2014, *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*). The ROD (EPA and DOE, 2014) specifies monitored natural attenuation (MNA) of groundwater and institutional controls to restrict groundwater use as the final remedial actions. MNA will be implemented for hexavalent chromium (Cr(VI)), nitrate, strontium-90, and trichloroethene (TCE) in 100-FR-3 groundwater. Performance monitoring of these contaminants of concern (COCs) in the groundwater is a component of the MNA remedy. Performance monitoring includes two phases:

1. The remediation monitoring phase occurs while remedial activities (in this case, natural attenuation processes) are being implemented to reach groundwater cleanup levels.
2. The attainment monitoring phase occurs after the remediation phase is complete. Data are collected and evaluated to confirm that the cleanup level for each COC has been met and that groundwater will continue to meet cleanup levels in the future.

A data quality objectives (DQOs) workshop was conducted August 6 and 7, 2014 (when the ROD [EPA and DOE, 2014] was still in draft form), to support design of a groundwater sampling and analysis plan (SAP). Additional work was performed after the workshop, including review and contribution from the U.S. Department of Energy (DOE) SAP panel. This report summarizes the output of the DQO process.

Several EPA documents provide criteria and guidance for MNA. Section 3.1.2 of DOE/RL-2014-44-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for 100-F/IU Groundwater* (Groundwater Addendum), and DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU* (Integrated RDR/RAWP), lists applicable documents that were considered in DQO planning. Table 1 cross-references EPA criteria with the principal study questions (PSQs) presented in this DQO document.

1 Step 1: State the Problem

Summary: *The problem statement is created to clearly define the issue that requires new environmental data so that the focus of the study will be clear and unambiguous. Pertinent information from similar studies and assumptions should be organized, reviewed, identified, evaluated, and documented.*

- Give a concise description of the problem.
- Identify planning team.
- Develop conceptual site model (CSM).
- Determine resources.

Output of Step 1: Document the four elements listed in this step.

1.1 100-FR-3 Problem Statements

- There is a need to monitor the performance of the natural attenuation remedy.
- There is a need to demonstrate at the end of the remedial action period that cleanup levels for groundwater have been attained.
- There is a need to confirm that concentrations of antimony, cadmium, and cobalt are below action levels.

Table 1. 100-FR-3 Principal Study Questions as Related to EPA Guidance on Monitored Natural Attenuation

Principal Study Question	EPA Guidance*
PSQ 1a. Are contaminant concentrations and plume area/mass decreasing?	**Step 1:** Demonstrate that natural attenuation is occurring according to expectations **Step 3:** Identify any potentially toxic and/or mobile transformation products **Step 4:** Verify the plume is not expanding downgradient, laterally or vertically
PSQ 1b. Are rates of decline consistent with expectations?	**Step 1:** Demonstrate that natural attenuation is occurring according to expectations **Step 3:** Identify any potentially toxic and/or mobile transformation products
PSQ 1c. Are there changes in environmental conditions that may reduce the efficacy of natural attenuation?	**Step 2:** Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes
PSQ 1d. Are there unacceptable impacts to the Columbia River?	**Step 5:** Verify no unacceptable impact to down-gradient receptors
PSQ 1e. Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy?	**Step 6:** Detect new releases of contaminants to the environment that could impact effectiveness
PSQ 2. Are concentrations of antimony, cadmium, and cobalt below action levels?	Not in EPA guidance; required to resolve previous analytical uncertainty
PSQ 3. Do new geologic and hydrogeologic data confirm the conceptual site model?	**Step 1:** Demonstrate that natural attenuation is occurring according to expectations **Step 2:** Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes **Step 4:** Verify the plume is not expanding downgradient, laterally or vertically
PSQ 4a. Are concentrations of COCs below cleanup levels?	**Step 8:** Verify attainment of the remediation objectives
PSQ 4b. Will groundwater continue to meet the cleanup level in the future?	
Not an identified PSQ; evaluated within EPA performance monitoring guidance	**Step 7:** Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors

* Source: EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*.

COC = contaminant of concern

EPA = U.S. Environmental Protection Agency

PSQ = principal study question

1.2 Planning Team

Table 2 lists planning team members and roles.

Table 2. 100-F/IU Planning Team

Name	Organization	Role
Brad Bessinger*	SSPA	MNA and performance monitoring
Phil Burke*	CHPRC	OU Lead
Chris Guzzetti	EPA	EPA Project Manager
Mary Hartman*	CHPRC	OU Project Scientist; DQO Facilitator
Scott McKinley	CH2M HILL	Senior Review
Leland Scantlebury*	CHPRC Intern	Support
Greg Sinton*	DOE/RL	DOE Project Manager
Alex Spiliotopoulos*	SSPA	Groundwater Modeling Support
Heather Sulloway*	CH2M HILL	Performance Monitoring Plan lead
Matt Tonkin*	SSPA	Groundwater Modeling Support
DOE SAP Panel	DOE and others	Review DQO output; later review SAP

* Workshop participant

CHPRC = CH2M HILL Plateau Remediation Company
DOE = U.S. Department of Energy
DOE/RL = DOE Richland Operations Office
DQO = data quality objective
EPA = U.S. Environmental Protection Agency
MNA = monitored natural attenuation
OU = operable unit
SAP = sampling and analysis plan
SSPA = S.S. Papadopulos and Associates, Inc.

1.3 Conceptual Site Model

The CSM is described in the remedial investigation (RI)/feasibility study (FS) (DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2 and 100-IU-6 Operable Units*), and supplemented by data in the Hanford Environmental Information System (HEIS). The CSM will be refined with collection of additional data and an updated computer model. Figure 1 illustrates a water table map for the region. Figures 2 through 6 show contaminant plumes.

1.4 Resources

Resources are to be planned outside of the workshop.

2 Step 2: Identify the Goals of the Study

***Summary**: Identify the question(s) that the study will address and alternative actions or outcomes that may result based on the results. Define the decision that will be resolved using the data collected to address the problem.*

- Identify PSQs.
- Consider alternative outcomes.
- For decision problems, develop decision statements. For estimation problems, state what needs to be estimated and key assumptions.

Outputs of Step 2:

- Well-defined PSQs
- A listing of alternative outcomes or actions as a result of addressing PSQs
- For decision problems, a list of decision statements that address the study question
- For estimation problems, a list of estimation statements that address the study question

2.1 100-F/IU Principal Study Questions

1. Is natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater occurring as expected?
   a. Are contaminant concentrations and plume area/mass decreasing?
   b. Are rates of decline consistent with expectations?
   c. Are there changes in environmental conditions that may reduce the efficacy of NA?
   d. Are there unacceptable impacts to the Columbia River?
   e. Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the MNA remedy?
2. Are concentrations of antimony, cadmium, and cobalt below action levels?
3. Do new geologic and hydrogeologic data confirm the conceptual site model?
4. Have remedial action objective (RAOs) been achieved?
   a. Are concentrations of COCs below cleanup levels?
   b. Will groundwater continue to meet cleanup levels in the future?

2.2 Alternative Outcomes

- Continue monitoring program with no change.
- Modify monitoring program.
- Reconsider another alternative for remediation.

2.3 Decision Statements

1. Determine whether natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater is occurring as expected so that natural attenuation may continue, or if other options should be evaluated.
2. Determine whether antimony, cadmium, and cobalt concentrations are below action levels so that monitoring for these metals may cease, or if risks need to be assessed.
3. Determine whether new geologic and hydrogeologic data confirm the conceptual site model, or if the model needs updating.
4. Determine whether COC concentrations are below cleanup levels and attainment monitoring may proceed, or if MNA should continue.

3 Step 3: Identify Information Inputs

Summary: *The third step of the DQO process is to identify information inputs needed to support the decision statements and to specify which inputs will require environmental measurements.*

- Identify types and sources of information needed to produce estimates or resolve decisions.
- Identify the basis of information that will guide or support choices to be made in later steps of the DQO process.
- Select appropriate sampling and analysis methods for generating the information.

Outputs of Step 3:

- Lists of environmental characteristics that will resolve the decision or estimate and potential sources for the desired information inputs
- Information on the number of variables that will need to be collected
- Type of information needed to meet performance or acceptance criteria
- Information on the performance of appropriate sampling and analysis methods

3.1 Action Levels

Table 3 lists action levels for COCs, trace metals, and degradation products of TCE.

Table 3. 100-FR-3 Action Levels

Contaminant	Category	Cleanup or Action Level	Type
Hexavalent Chromium	COC	10 µg/L at Columbia River	Cleanup level
Trichloroethene	COC	4 µg/L	Cleanup level
Nitrate	COC	45 mg/L as NO_3^-*	Cleanup level
Stronium-90	COC	8 pCi/L	Cleanup level
Antimony	Trace metal	6 µg/L	Action level in RI
Cadmium	Trace metal	0.25 µg/L surface water; 5 µg/L DWS	Action level in RI

Table 3. 100-FR-3 Action Levels

Contaminant	Category	Cleanup or Action Level	Type
Cobalt	Trace metal	4.8 µg/L	Action level in RI
cis-1,2-dichloroethene	Degradation product	16 µg/L	Action level in RI
Vinyl Chloride	Degradation product	0.061 µg/L	Action level in RI

* Nitrate may be expressed as nitrate nitrogen (NO_3-N) or as nitrate (NO_3^-). The cleanup level of 45 mg/L as NO_3^- is derived from the DWS of 10 mg/L as NO_3-N.

COC = contaminant of concern

DWS = drinking water standard

RI = remedial investigation

3.1.1 Other Input

- Groundwater sample data from new and existing wells and aquifer tubes (COCs and supporting parameters)
- Historical chemistry and water level data
- Sample data from riverbank seeps
- Groundwater levels
- River stage
- Geologic information
- Updated geologic interpretations from existing wells

3.2 Sampling and Analysis Methods

- Continue current methods of sampling monitoring wells, aquifer tubes, and seeps (per project procedures).
- Analytical methods will be selected to meet required action levels.

4 Step 4: Define the Boundaries of the Study

Summary: *Define the specific spatial and temporal boundaries that are included in the decision.*

- Define the target population of interest and its relevant spatial boundaries.
- Define what constitutes a sampling unit.
- Specify temporal boundaries and other practical constraints associated with data collection.
- Specify the smallest unit on which decisions or estimates will be made.

Outputs of Step 4:

- Definition of the target population with detailed descriptions of geographic limits (spatial boundaries)
- Detailed descriptions of what constitutes a sampling unit

- Time frame appropriate for collecting data and making the decision or estimate, together with those practical constraints that may interfere with data collection
- Appropriate scale for decision making or estimation

4.1 Target Population and Spatial Boundaries

Unconfined groundwater in the 100-FR-3 OU includes 100-F, region south, and region west (upgradient).

4.2 Temporal Boundaries

- Predicted time to cleanup based on the maximum concentrations calculated by the RI model:
  - Cr(VI) at 10 µg/L cleanup level (state surface water quality standard) – 35 years
  - Cr(VI) at 48 µg/L WAC 173-340, "Model Toxics Control Act—Cleanup," groundwater cleanup level – 20 years
  - Nitrate at 45 mg/L cleanup level – 80 years
  - Strontium-90 at 8 pCi/L cleanup level – 150 years
  - TCE at 4 µg/L cleanup level – 50 years
- Trace metals – Time necessary to collect at least 8 independent samples
- As specified in the RI/FS (DOE/RL-2010-98), monitoring will be performed for an additional 5 years after cleanup level for each COC is initially achieved to confirm remediation goals (see Section 7.1.13)
- Automated water level measurements – operate robust network for at least 5 years, then re-evaluate

4.3 Decision Units

- Spatial:
  - Nitrate plume boundaries at >45 mg/L
  - Nitrate plume high-concentration core at >90 mg/L
  - Cr(VI) plume boundaries at >10 µg/L
  - TCE plume boundaries at >4 µg/L
  - Strontium-90 plume boundaries at >8 pCi/L
  - Selected wells for trace metals (see rationale in Step 7)
- Time: 5-year periods (to facilitate 5-year reviews)

4.4 Practical Constraints

- Resource availability for well installation, sample collection, and laboratory analysis (funding)
- Analytical detection limits
- Cultural and ecological constraints on new well locations
- Seasonal variability of river stage and water table

5 Step 5: Develop the Analytic Approach

Summary: *Integrate the outputs from the previous steps into a statement(s) that describes the logical basis to select amongst the alternative actions. This includes specifying the population parameter (e.g., mean, percentile), determining the action level, and constructing the decision rule. A decision rule is determined for each PSQ. At this point, it is assumed that perfect information is available for decision making.*

- Specify appropriate population parameters for making decisions or estimates.
- For decision problems, choose a workable action level and generate and "If… then… else" decision rule.
- For estimation problems, specify the estimator and estimation procedure.

Outputs of Step 5:

- Identification of the population parameters most relevant for making inferences and conclusions on the target population.
- For decision problems, the "if..., then...else..." theoretical decision rule based upon a chosen action level.
- For estimation problems, the specification of the estimator to be used.

5.1 100-FR-3 Parameters of Interest

- Concentrations/trends for each COC and trace metal (as expressed by statistical parameters)
- Plume area or mass for each COC (changes with time)
- Comparison of observations to modeled conditions

5.2 Decision Rules (If/Then)

Table 4 lists decision rules associated with each PSQ.

Table 4. 100-FR-3 Principal Study Questions and Decision Rules

	Principal Study Question	Decision Rule
1	Is natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater occurring as expected?	If the weight of evidence indicates that natural attenuation is occurring as expected, then continue MNA; otherwise evaluate other options.
2	Are concentrations of antimony, cadmium, and cobalt below action levels?	If monitoring indicates that concentrations are not greater than the action level or practical quantitation limit, then discontinue monitoring; otherwise perform risk assessment.
3	Do new geologic and hydrogeologic data confirm the CSM?	If new geologic and hydrogeologic data confirm the CSM, then retain the model; otherwise update it.
4	Have RAOs been achieved? Are concentrations of COCs below cleanup levels? Will groundwater continue to meet cleanup levels in the future?	If RAO has been achieved for an individual COC, then proceed to attainment monitoring for that COC; otherwise continue MNA.

COC = contaminant of concern
CSM = conceptual site model
MNA = monitored natural attenuation
NA = natural attenuation
OU = operable unit
RAO = remedial action objective

6 Step 6: Specify Performance or Acceptance Criteria

Summary: *Define how much uncertainty can be tolerated when making the decision of interest, and establish appropriate performance goals for limiting uncertainty in the data. The guidance document says this is where you "face the reality that you will not have perfect information from which to formulate your conclusions." Discuss severity of consequences of making wrong decisions.*

- For decision problems, specify the decision rule as a statistical hypothesis test, examine consequences of making incorrect decisions from the test, and place acceptable limits on the likelihood of making decision errors.
- For estimation problems, specify acceptable limits on estimation uncertainty.

Output of Step 6:

- A set of performance or acceptance criteria (i.e., DQOs) that data should achieve in order to minimize the possibility of either making a decision error or failing to keep uncertainty in estimates to within acceptable levels

6.1 100-FR-3 Criteria

Traditional statistical sample designs are not typically identified for groundwater investigations. Sampling design will be judgmental.

Criteria for evaluating the data with respect to the PSQs will employ both statistical and nonstatistical methods. Methods of evaluation will be derived from sources such as OSWER 9283.1-44, *Recommended Approach for Evaluating Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well*. Details are included in Chapter 6 of the Groundwater Addendum (DOE/RL-2014-44-ADD2). Table 1 relates 100-FR-3 PSQs to EPA's criteria for evaluating MNA.

1. Is natural attenuation of Cr(VI), nitrate, TCE, and strontium-90 in groundwater occurring as expected?
    a. Are contaminant concentrations and plume area/mass decreasing? *Statistical evaluation.*
    b. Are rates of decline consistent with expectations? *Statistical evaluation.*
    c. Are there changes in environmental conditions that may reduce the efficacy of NA? *Nonstatistical evaluation*
    d. Are there unacceptable impacts to the Columbia River? *Statistical and nonstatistical evaluation.*
    e. Is there evidence of new or continuing releases of contaminants to the environment that could impact the effectiveness of the MNA remedy? *Nonstatistical evaluation.*
2. Are concentrations of antimony, cadmium, and cobalt below action levels? *Statistical evaluation.*
3. Do new geologic and hydrogeologic data confirm the conceptual site model? *Nonstatistical evaluation.*
4. Have RAOs been achieved?
    a. Are concentrations of COCs below cleanup levels? *Statistical evaluation.*
    b. Will groundwater continue to meet cleanup levels in the future? *Statistical evaluation.*

6.2 Decision Errors and Mitigating Measures

This section describes possible errors for each of the major decision rules. The sources of errors that lead to those decision errors, and factors to mitigate them, are listed in Table 5.

Decision Rule 1: If the weight of evidence indicates that natural attenuation is occurring as expected, then continue MNA; otherwise evaluate other options.

- Decision Error 1a: MNA is deemed ineffective, and a more aggressive form of remediation is implemented unnecessarily. Consequence: Funding could be diverted from higher-priority projects. Severity: Low to moderate.
- Decision Error 1b: MNA is deemed effective and, in fact, it is not. Consequences: Remediation timeline is longer than predicted. Severity: Low.

Decision Rule 2: If monitoring indicates that concentrations of antimony, cadmium, and cobalt are not above action levels or quantitation limits, then discontinue monitoring; otherwise perform risk assessment.

- Decision Error 2a: Monitoring for metals continues even though they are not above action levels. Consequence: Funding could be diverted from higher-priority projects. Severity: Low to moderate.
- Decision Error 2b: Monitoring for metals is discontinued, but they are in fact above action levels. Consequence: Contamination remains in the aquifer or migrates to receptors. Severity: Low to moderate.

Decision Rule 3: If new geologic and hydrologic data confirm the conceptual site model, then retain the model; otherwise update it.

- Decision Error 3a: Conceptual site model is updated unnecessarily. Consequence: Minor outlay of resources. Severity: Low.
- Decision Error 3b: Conceptual site model is not updated, and results do not reflect the natural system accurately. Severity: Low to moderate.

Decision Rule 4: If RAO has been achieved for an individual COC, then proceed to attainment monitoring for that COC; otherwise continue MNA.

- Decision Error 4a: MNA continues longer than needed. Consequences: Continued monitoring would reveal that goals have been achieved. Severity: Low.
- Decision Error 4b: Attainment monitoring begins prematurely. Consequence: Attainment monitoring would reveal the error, and MNA would continue. Severity: Low.

Table 5. Sources of Error and Mitigating Measures

Source of Error	Mitigating Measures
Variability in concentrations causing inaccurate estimates of attenuation rates (e.g., variability due to seasonal or longer-term changes in water table; plume migration)	Consistent schedule for sampling to increase comparability; more frequent monitoring in wells with variable concentrations
Uncertainty in estimates of plume size (interpolation, extrapolation)	Robust monitoring network, including new monitoring wells to reduce uncertainty in plume interpretations; geostatistical methods to evaluate plume size

Table 5. Sources of Error and Mitigating Measures

Source of Error	Mitigating Measures
Uncertainties in model predictions (limitations of model input)	Improvements to model based on new geologic information and expanded automated water level network
New or unknown sources of contamination	Monitor near former source areas with greater density of wells and higher sampling frequency
Analytical error	Robust quality assurance/quality control program to minimize analytical uncertainties

7 Step 7: Develop the Plan for Obtaining Data

***Summary**: Using results from the previous steps, identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs.*

1. Compile all information and outputs generated in Steps 1 through 6.
2. Use this information to identify alternative sampling and analysis designs that are appropriate for your intended use.
3. Select and document a design that will yield data for best achievement of performance or acceptance criteria.

Outputs of Step 7:

- Full documentation of the final sampling and analysis design, along with a discussion of the key assumptions underlying this design
- Details on how the design should be implemented together with contingency plans for unexpected events
- Quality assurance (QA) and quality control (QC) procedures that would be performed to detect and correct problems and so ensure defensible results
- Documentation of these items in a SAP

7.1 100-FR-3 Sampling and Analysis Plan

The team designed a monitoring network, analyte list, and sampling frequencies, summarized in the following subsections. Table 6 lists all of the wells and aquifer tubes considered for sampling, and which (if any) PSQs they address. Plume maps with available well locations are attached as Figures 2 through 6. Figures 7 and 8 show locations of the proposed monitoring networks, including new wells.

7.1.1 Monitoring Network for Water Samples (Table 6)

Monitoring wells were selected within and downgradient of contaminant plumes to monitor attenuation and possible migration (PSQs 1a and 1b). Near-river wells, aquifer tubes, or seeps were selected to monitor potential impacts to the Columbia River (PSQ 1d). Wells were preferred over aquifer tubes or seeps. Aquifer tubes or seeps were only selected where there are no wells between the shoreline and the plume boundary.

Wells within the former operational area were selected to monitor for new releases (PSQ 1e). Section 7.1.2 describes the rationale for selection of wells for trace metals (PSQ 2).

The monitoring network comprises the following:

- 28 existing wells, 8 new wells (phase 1), and up to 6 possible additional wells based on results of phase 1
- 6 existing aquifer tubes
- 1 riverbank seep
- Monitoring networks for the attainment phase (PSQ 4) will be determined closer to the end of remediation monitoring phase for each COC.

7.1.2 Rationale for New Well Locations (Phase 1; Figures 7 and 8)

- C9472: South of TCE – monitor plume shrinkage and migration
- C9474: East of 699-71-30 – sentinel well for nitrate
- C9475: West of 699-71-30 – monitor nitrate plume shrinkage
- C9476: Nitrate near south (in plume) – monitor shrinkage of >90 mg/L contour
- C9477: Nitrate near south (east of plume) – monitor plume shrinkage and sentinel well
- C9478: Nitrate far south (upgradient) – monitor nitrate plume shrinkage
- C9479: Nitrate far south (in plume) – monitor plume shrinkage
- C9480: Nitrate far south (east of plume) – monitor plume shrinkage and sentinel well

Proposed locations may need to be moved based on accessibility or results of ecological/cultural reviews. If a location is moved more than ~100 m (330 ft), DOE and EPA will be consulted for concurrence.

Several other locations were considered for new wells during the DQO workshop. After subsequent reviews by the DOE Panel, the team concluded that the following wells were not needed for decision making and were, therefore, eliminated:

- Southeast of Cr(VI) plume and south of strontium-90 plume to delimit plumes and monitor shrinkage (C9469): Plumes are sufficiently delineated by existing wells.
- Northwest edge of Cr(VI) plume to refine plume interpretation and monitor plume shrinkage (C9470): Plume is sufficiently delineated by existing wells.
- North of TCE in area of 1995 study to refine interpretation and monitor plume shrinkage (C9471): This location is within an area where TCE was elevated in groundwater in 1995. However, groundwater flow to the east and south would have decreased concentrations in this region since then, and continued declines can be assumed.
- West of TCE and nitrate to monitor upgradient conditions and refine interpretation of TCE plume (C9473): This location was outside the boundary of the TCE plume in 1995. Because groundwater flow is to the east and south, it is reasonable to assume that the upgradient area remains clean.
- Southeast of nitrate plume to monitor plume shrinkage and possible migration (C9481): Concentrations in wells within the 45 mg/L contour at the south end of the plume are declining or stable. The plume can be monitored adequately with existing wells.

7.1.3 Rationale for Phase 2 Wells

Locations of additional wells will be determined based on evaluation of monitoring data approximately 2 years after the final phase 1 well installation.

7.1.4 Additional Data from New Wells

- Geologic samples
- Aquifer properties

7.1.5 Use of Old Wells

- Evaluate pre-WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," wells for suitability (e.g., review documentation where available and perform camera surveys, borehole geophysics, and field inspections).
- Rehabilitate wells as appropriate (e.g., grout in lower portions of wells with long perforated intervals that span unconfined and part of the Ringold Formation upper mud [RUM]).
- It is unclear if Well 699-60-32 monitors the unconfined aquifer or the RUM. It will be evaluated and, if it monitors the RUM, nearby Well 699-59-32 may be substituted into the monitoring network.

7.1.6 Water Level Monitoring

- Supports PSQs 1c and 4 (Table 6)
- Automated water level stations in 19 wells
- Automated river gauge
- Manual measurements in 41 wells

7.1.7 Analytes

- COCs specific to each location (Table 6)
- TCE degradation products (vinyl chloride and *cis*-1,2-dichloroethene)
- Trace metals in selected wells (Table 6)
- Field parameters (specific conductance, pH, dissolved oxygen, turbidity, and temperature)

7.1.8 Sampling Frequency

- Frequency intervals listed in Table 6
- Minimum of annual sampling for first 5 years to establish new baseline that (a) reflects conditions after completion of source remediation, (b) determines conditions based on consistent set of wells, and (c) provides more data for input to regression calculations
- New wells quarterly for 1 year to establish baseline and seasonal variability
- Selected wells semiannually (high and low river stage) where changes in water table are likely to affect concentrations
- Frequency reduced after 5 years unless data indicate a need for more frequent monitoring
- Attainment monitoring frequency (see Section 7.1.13)
- Major sampling campaigns scheduled for fall when river stage is low (September or October). Semiannual wells (twice per year) also to be sampled at high river stage (mid-May through mid-July)

7.1.9 Quality Assurance and Quality Control Program

QA/QC will be integrated with the entire Soil and Groundwater Remediation Project.

7.1.10 Rationale for Automated Water Level Network

Obtain a good distribution of wells to create triangles for calculating hydraulic gradients. Assume these stations need to be maintained for first 5 years of monitoring, then re-evaluate.

7.1.11 Rationale for Manual Water Levels

Obtain comprehensive set of water level measurements during low river stage (October, concurrent with sampling), high river stage (June), and moderate stage (March, in conjunction with sitewide measurements).

7.1.12 Rationale for Trace Metal Wells

Select a subset of wells to evaluate antimony, cadmium, and cobalt, based on previous exceedances of action levels (Table 7). These wells will go into the SAP for trace metals analysis, and Decision Rule 2 will apply. The process included the following steps:

1. The process began with well lists from the 100-F spatial/temporal network of the RI/FS (DOE/RL-2010-98). Section 4.3.1.2 of the RI/FS (DOE/RL-2010-98) states that no further groundwater monitoring is required for 100-IU-2 and 100-IU-6.
2. The HEIS database was queried for antimony, cadmium, and cobalt data from January 1, 2007 through August 1, 2014.
3. The data were filtered for values above action levels and not flagged U.
4. Four wells with exceedances (~20 percent of available wells in 100-F Area) were selected for further analysis of trace metals.
5. No wells exceeded more than one analyte, and none had a high frequency of exceedance. Concentrations did not vary greatly. Therefore, wells were selected based on spatial spread.

7.1.13 Attainment Monitoring

After a cleanup level is achieved for a COC, a subset of monitoring wells will be sampled for 5 years to verify that cleanup is complete. The well network will be selected based on the location of contamination at the time. Sampling frequency may be quarterly for two years to detect seasonal variability and may be reduced to annually for the next 3 years. Actual number of wells is not known; assumptions for cost estimation are given in Table 8.

7.1.14 Rationale for Wells and Aquifer Tubes Not Sampled

Additional existing wells and aquifer tubes were considered and excluded from the monitoring network. Table 6 lists rationale for not sampling.

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual[a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
EXISTING WELLS																														
199-F1-2	Unconfined	1992	SS, Screen	115.5	110.9								N																	Not in or downgradient of any plume
199-F5-1	Unconfined	1948	CS, Perf	113.9	105.4	X	X		X			X	Y		X			A	S				A	S				B	B	Possible seasonal variation
199-F5-4	Unconfined[d]	1953	CS, Perf	116.0	94.6	X	X		X	X		X	Y		X	S	S	S		A	S	S	S		A	B	B	B		Possible seasonal variation
199-F5-42	Unconfined	1992	SS, Screen	114.7	108.6	X	X	X				X	Y		X	A		A	A		A		A	A		B		B	B	
199-F5-43A	Unconfined	1992	SS, Screen	114.7	108.6	X	X	X		X	X	X	Y		X	A		A	A	A	A		A	A	A	B		B	B	
199-F5-43B	RUM	1992	SS, Screen	76.3	73.3								N																	Monitors RUM; not in scope
199-F5-44	Unconfined	1992	SS, Screen	114.4	108.3	X	X	X				X	Y		X	A		A	A		A		A	A		B		B	B	
199-F5-45	Unconfined	1992	SS, Screen	115.3	110.6	X	X		X		X	X	Y		X	A	A	A			A	A	A			B	B	B		
199-F5-46	Unconfined	1992	SS, Screen	114.8	110.2	X	X		X			X	Y		X	S	S	S	S		S	S	S	S		B	B	B	B	Possible seasonal variation
199-F5-47	Unconfined	1992	SS, Screen	115.8	109.7	X	X		X			X	Y		X	A		A	A		A		A	A		B		B	B	
199-F5-48	Unconfined	1992	SS, Screen	115.7	111.1	X	X		X	X		X	Y		X	A	A	A		A	A	A	A		A	B	B	B		
199-F5-52	Unconfined	2010	SS, Screen	115.5	109.4	X	X	X	X		X	X	Y	X	X	A		A			A		A			B		B		
199-F5-53	RUM	2010	SS, Screen	96.1	93.1								N																	Monitors RUM; not in scope
199-F5-54	Unconfined	2010	SS, Screen	115.0	108.9	X	X		X			X	Y		X	A		A	A		A		A	A		B		B	B	
199-F5-55	Unconfined	2011	PVC, Screen	114.7	111.7	X	X		X			X	Y		X	A		A	S		A		A	S		B		B	B	Possible seasonal variation
199-F5-56	Unconfined	2011	PVC, Screen	115.3	112.2	X	X		X			X	Y		X	A	A	A	A		A	A	A	A		B	B	B	B	
199-F5-6	Unconfined[d]	1956	CS, Perf	116.4	104.5	X	X	X	X			X	Y		X	S		A	A		S		A	A		B		B	B	Possible seasonal variation
199-F6-1	Unconfined	1992	SS, Screen	114.5	108.6	X	X	X	X		X	X	Y	X	X	A		A	A		A		A	A		B		B	B	
199-F7-1	Unconfined	1956	CS, Perf	117.0	112.4	X	X		X		X	X	Y	X	X		A	A				A	A				B	B		Blank casing below perf'd interval; rehab
199-F7-2	Unconfined	1988	SS, Screen	116.1	111.3	X	X		X		X	X	Y	X	X		A	A				A	A				B	B		
199-F7-3	Unconfined	1992	SS, Screen	115.3	110.7	X	X		X			X	Y		X		A	A				A	A				B	B		
199-F8-2	Unconfined	1960	CS, Perf	123.2	110.1	X	X		X			X	Y		X	A			A		A			A		B			B	
199-F8-3	Unconfined	1992	SS, Screen	115.6	112.5								N																	Redundant with nearby wells
199-F8-4	Unconfined	1992	SS, Screen	114.4	111.3	X	X				X	X	Y	X	X			A					A					B		
199-F8-7	Unconfined	2008	SS, Screen	116.5	113.4	X	X		X	X		X	Y		X		A	A	A	A		A	A	A	A		B	B	B	

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual[a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
699-58-24	Unconfined	1971	CS, Perf	113.7	110.7		X				X		N		X															Far downgradient of nitrate plume; water levels only
699-59-32	Unconfined	1971	CS, Screen	110.5	107.5	X?	X?						?	X?	X?															Redundant with nearby well
699-60-32	RUM?	1971	CS, Screen	107.8	104.7	X	X				X	X	Y	X	X			A					A					B		Evaluate; 59-32 instead?
699-61-37	Unconfined	1971	CS, Screen	114.9	111.9						X		N	X	X															No monitoring objective; water levels only
699-62-31	Unconfined	1972	CS, Screen	109.9	106.9	X	X				X	X	Y		X			A					A					B		In south part nitrate plume
699-62-43F	Unconfined	1959	CS, Perf	125.2	110.6								N																	No monitoring objective
699-63-25A	Unconfined[d]	1949	CS, Perf	112.7	92.0	X	X				X	X	Y		X			A					A					B		Long perf interval; may need rehab
699-64-27	Unconfined	1974	CS, Perf	112.0	104.7	X	X				X	X	Y	X	X			A					A					B		
699-65-22	Unknown	Unknown	Galv, unkn										N																	Redundant with nearby well
699-66-23	Unconfined[d]	1961	CS, Perf	113.5	95.2	X	X	X			X	X	Y	X	X			A					A					B		Long perf interval; may need rehab
699-66-38	Unconfined[d]	1962	CS, Perf	125.1	111.1								N																	Monitors mud; not in scope
699-66-39	Unconfined[d]	1971	CS, Perf	126.7	118.5								N																	Monitors mud; not in scope
699-67-51	Unconfined[d]	1962	CS, Perf	130.4	84.7								N																	No monitoring objective; Host well with piezometers
699-69-38	Unknown	Unknown	ABS, unkn										N																	ABS casing in cement well; no monitoring objective
699-69-45	Unconfined[d]	1961	CS, Perf	125.0	58.0								N																	No monitoring objective; host well with piezometers
699-70-23	Unknown	Unknown	CS, unkn								X		N	X	X															Redundant with nearby well for sampling; water levels only
699-71-30	Unconfined[d]	1957	CS, Perf	115.1	96.5	X	X				X	X	Y	X	X		A	A				A	A				B	B		Long perf interval; may need rehab
699-71-52	Unconfined	1954	CS, Perf	123.9	111.7								N																	No monitoring objective
699-74-44	Unconfined	1957	CS, Perf	131.1	115.9		X				X		N		X															No monitoring objective; water levels only
699-77-36	Unconfined[d]	1957	CS, Perf	116.4	101.2	X	X				X	X	Y	X	X		A	A				A	A				B	B		Long perf interval; may need rehab
699-77-54	Unconfined	1957	CS, Perf	125.8	111.5								N																	No monitoring objective
699-80-43P	Lower Mud/ Basalt Top	1965	CS, Screen	-5.5	-8.5								N																	Monitors mud; not in scope

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual[a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
699-80-43S	Unknown	1965	CS, Screen	117.7	111.6								N																	No monitoring objective; piezometer; uncertain completion
699-81-38	Unconfined	Unknown	Galv, unkn										N																	No monitoring objective; strange and uncertain construction
699-83-47	Unconfined	1957	CS, Perf	122.5	107.3								N																	No monitoring objective
699-84-34B	Basalt	1981	Unknown										N																	Artesian well (basalt); not in scope
699-86-42	Unconfined	Unknown	Galv, unkn	125.9	117.9								N																	No monitoring objective
699-87-42A	Unconfined	Unknown	Galv, unkn	128.0	117.7								N																	No monitoring objective
PHASE 1 NEW WELLS																														
C9472	Unconfined	FY16	SS, Screen			X	X				X	X	Y		X		Q	Q				A	A				B	B		
C9474	Unconfined	FY16	SS, Screen			X	X	X			X	X	Y	X	X			Q					A					B		
C9475	Unconfined	FY16	SS, Screen			X	X				X	X	Y	X	X		Q	Q				A	A				B	B		
C9476	Unconfined	FY16	SS, Screen			X	X				X	X	Y	X	X		Q	Q				A	A				B	B		
C9477	Unconfined	FY16	SS, Screen			X	X	X			X	X	Y	X	X			Q					A					B		
C9478	Unconfined	FY16	SS, Screen			X	X				X	X	Y	X	X			Q					A					B		
C9479	Unconfined	FY16	SS, Screen			X	X				X	X	Y	X	X			Q					A					B		
C9480	Unconfined	FY16	SS, Screen			X	X	X			X	X	Y	X	X			Q					A					B		
PHASE 2 NEW WELLS (temporary well names)																														
FIU-A	Unconfined	TBD	SS, Screen										Y																	
FIU-B	Unconfined	TBD	SS, Screen										Y																	
FIU-C	Unconfined	TBD	SS, Screen										Y																	
FIU-D	Unconfined	TBD	SS, Screen										Y																	
FIU-E	Unconfined	TBD	SS, Screen										Y																	
FIU-F	Unconfined	TBD	SS, Screen										Y																	
AQUIFER SAMPLING TUBES																														
59-D	Unconfined	1997	Poly, mesh	108.0	107.8								N																	No monitoring objective
59-M	Unconfined	1997	Poly, mesh	109.8	109.7								N																	No monitoring objective

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual[a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
59-S	Unconfined	1997	Poly, mesh	111.5	111.4								N																	No monitoring objective
60-D	Unconfined	1997	Poly, mesh	106.9	106.8								N																	No monitoring objective
60-M	Unconfined	1997	Poly, mesh	109.7	109.5								N																	No monitoring objective
60-S	Unconfined	1997	Poly, mesh	112.4	112.3								N																	No monitoring objective
61-D	Unconfined	1997	Poly, mesh	106.9	106.8								N																	No monitoring objective
61-M	Unconfined	1997	Poly, mesh	109.7	109.5								N																	No monitoring objective
61-S	Unconfined	1997	Poly, mesh	112.5	112.3								N																	No monitoring objective
62-M	Unconfined	1997	Poly, mesh	109.8	109.6								N																	No monitoring objective
62-S	Unconfined	1997	Poly, mesh	112.7	112.6								N																	Single depth sufficient
63-D	Unconfined	1997	Poly, mesh	108.1	107.9								N																	Redundant with nearby tubes
63-M	Unconfined	1997	Poly, mesh	110.2	110.1								N																	Redundant with nearby tubes
63-S	Unconfined	1997	Poly, mesh	112.0	111.9								N																	Redundant with nearby tubes
64-D	Unconfined	1997	Poly, mesh	106.8	106.7								N																	Single depth sufficient
64-M	Unconfined	1997	Poly, mesh	109.9	109.7	X		X					Y			A		A	A		A		A	A		B		B	B	
64-S	Unconfined	1997	Poly, mesh	113.1	112.9								N																	Single depth sufficient
66-D	Unconfined	1997	Poly, mesh	105.9	105.7								N																	No monitoring objective
66-M	Unconfined	1997	Poly, mesh	108.6	108.4								N																	No monitoring objective
66-S	Unconfined	1997	Poly, mesh	111.4	111.2								N																	No monitoring objective
67-M	Unconfined	1997	Poly, mesh	108.8	108.7								N																	No monitoring objective
67-S	Unconfined	1997	Poly, mesh	111.9	111.7								N																	No monitoring objective
68-D	Unconfined	1997	Poly, mesh	107.8	107.7								N																	No monitoring objective
68-M	Unconfined	1997	Poly, mesh	109.9	109.7								N																	No monitoring objective
68-S	Unconfined	1997	Poly, mesh	112.3	112.1								N																	No monitoring objective
69-D	Unconfined	1997	Poly, mesh	110.4	110.3								N																	No monitoring objective
72-D	Unconfined	1997	Poly, mesh	103.6	103.5								N																	No monitoring objective
72-M	Unconfined	1997	Poly, mesh	106.7	106.5								N																	No monitoring objective

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual [a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
72-S	Unconfined	1997	Poly, mesh	109.3	109.1								N																	No monitoring objective
74-D	Unconfined	1997	Poly, mesh	103.3	103.1								N																	No monitoring objective
74-M	Unconfined	1997	Poly, mesh	106.9	106.8								N																	No monitoring objective
75-D	Unconfined	1997	Poly, mesh	103.9	103.7								N																	No monitoring objective
75-M	Unconfined	1997	Poly, mesh	106.3	106.2								N																	No monitoring objective
75-S	Unconfined	1997	Poly, mesh	108.8	108.6								N																	No monitoring objective
76-D	Unconfined	1997	Poly, mesh	104.5	104.3								N																	No monitoring objective
76-M	Unconfined	1997	Poly, mesh	106.3	106.2								N																	No monitoring objective
76-S	Unconfined	1997	Poly, mesh	108.8	108.6								N																	No monitoring objective
77-D	Unconfined	1997	Poly, mesh	104.1	103.9								N																	No monitoring objective
77-M	Unconfined	1997	Poly, mesh	106.5	106.4								N																	No monitoring objective
77-S	Unconfined	1997	Poly, mesh	108.9	108.8								N																	No monitoring objective
80-D	Unconfined	1997	Poly, mesh	104.2	104.0								N																	No monitoring objective
AT-F-1-D	Unconfined	2004	Poly, mesh	106.8	106.6								N																	Redundant with nearby tubes
AT-F-1-M	Unconfined	2004	Poly, mesh	109.2	109.1								N																	Redundant with nearby tubes
AT-F-1-S	Unconfined	2004	Poly, mesh	111.6	111.5								N																	Redundant with nearby tubes
AT-F-3-D	Unconfined	2004	Poly, mesh	108.4	108.2								N																	Redundant with nearby tubes
AT-F-3-M	Unconfined	2004	Poly, mesh	109.4	109.2								N																	Redundant with nearby tubes
AT-F-3-S	Unconfined	2004	Poly, mesh	110.8	110.6								N																	Redundant with nearby tubes
AT-F-4-D	Unconfined	2004	Poly, mesh	102.3	102.1								N																	Redundant with nearby tubes
AT-F-4-M	Unconfined	2004	Poly, mesh	106.6	106.5								N																	Redundant with nearby tubes
AT-F-4-S	Unconfined	2004	Poly, mesh	109.9	109.8								N																	Redundant with nearby tubes
C6302	Unconfined	2008	Poly, mesh	111.3	111.1	X		X					Y			A		A	A		A		A	A		B		B	B	
C6303	Unconfined	2008	Poly, mesh	109.4	109.3	X		X					Y			A		A			A		A			B		B		
C6305	Unconfined	2008	Poly, mesh	111.1	111.0								N																	Single depth sufficient
C6306	Unconfined	2008	Poly, mesh	109.4	109.2	X		X					Y			A		A	A		A		A	A		B		B	B	

Table 6. Monitoring Wells, Aquifer Sampling Tubes, and Seeps Considered for 100-FR-3 Monitoring Network

Well Name	Screened Unit	Year Installed	Casing and Screen Type	Elevation Top Screen or Perf (m)	Elevation Bottom Screen or Perf (m)	Rationale								Wtr Lvl		Yr 1 Frequency					Yr 2 to 5 Frequency					Yr 6+ Frequency[b]				Rationale for Not Monitoring, or Other Comment
						PSQ 1a, 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 2	PSQ 3	PSQ 4	Sample	Automated	Manual[a]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	Trace Metals[c]	Cr(VI)	TCE & Deg. Prod.	Nitrate	Sr-90	
C6307	Unconfined	2008	Poly, mesh	108.6	108.4								N																	Single depth sufficient
C6308	Unconfined	2008	Poly, mesh	111.0	110.8								N																	Single depth sufficient
C6309	Unconfined	2008	Poly, mesh	108.9	108.7	X		X					Y			A		A	A		A		A	A		B		B	B	
C6311	Unconfined	2008	Poly, mesh	110.8	110.7								N																	Redundant with nearby tubes
C6312	Unconfined	2008	Poly, mesh	108.9	108.7								N																	Redundant with nearby tubes
C6314	Unconfined	2008	Poly, mesh	111.1	110.9								N																	Single depth sufficient
C6315	Unconfined	2008	Poly, mesh	109.0	108.9	X		X					Y			A		A	A		A		A	A		B		B	B	
C6316	Unconfined	2008	Poly, mesh	106.3	106.2								N																	Single depth sufficient
SEEPS																														
Seep 207-1	Shoreline	N/A	N/A	N/A	N/A								N																	No monitoring objective
Seep 187-1	Shoreline	N/A	N/A	N/A	N/A	X		X					Y			A		A			A		A			B		B		
RIVER STAGE																														
100-F gauge	River Stage						X	X			X			X																

Note: "X?" and "N?" indicate contingency wells. If evaluation indicates that 699-60-32 does not monitor the unconfined aquifer, 699-59-32 will be sampled instead. If 699-60-32 monitors the unconfined aquifer, then 699-59-32 will be used for water levels only.

a. Manual measurements three times per year at low, moderate, and high river stages.

b. Frequency will be evaluated during year 5; assume biennial for planning purposes.

c. Monitoring for trace metals will cease after eight independent samples have concentrations below action levels or practical quantitation limits.

d. Monitors unconfined aquifer and >1 m of the RUM.

A = to be sampled annually
B = to be sampled biennially (every other year)
Cr(VI) = hexavalent chromium
CS, Perf = carbon steel casing, perforated casing
FY = fiscal year
Galv, unkn = galvanized metal casing; unknown material screen
N or Y in sample column = no (not sampled) or yes (sampled)
N/A = not applicable
Poly, mesh = flexible polyethylene tubing with stainless steel mesh screen
PSQ = principal study question
PVC = polyvinyl chloride casing and screen
Q = to be sampled quarterly
RUM = Ringold upper mud unit
S = to be sampled semiannually (twice per year)
Sr-90 = strontium-90
Wtr Lvl = water level
Yr = year
SS, Screen = stainless steel casing and screen
TBD = to be determined
TCE & Deg Prod = trichloroethene and degradation products
Trace Metals = antimony, cadmium, and cobalt

Table 7. 100-F Wells with Action Level Exceedances for Trace Metals

Antimony (5.6 µg/L)		Cadmium (0.25 µg/L[a,b])		Cobalt (4.8 µg/L)	
Well	**Result, Method**	**Well**	**Result, Method**	**Well**	**Result, Method**
199-F5-4	51.7, 6010	None	None	199-F5-43A	13.1 C, 6010
199-F5-4	43.6 C Y, 6010			199-F5-43A	11.6 C, 6010
199-F8-7	34.8 B, 6010			199-F5-44	12.1 C, 6010
				199-F5-44	12.7 C, 6010
				199-F5-48	9 B, 6010

Note: Highlighted wells selected for further analysis of antimony, cadmium, and cobalt.

a. Applies to river.

b. Only 114 of 370 results had detection limits below the 0.25 µg/L action level. Thus, cadmium is included despite no exceedances.

B = below required detection limit and above method detection limit

C = blank contamination

Y = suspected error

Table 8. Assumed Number of Wells for Attainment Monitoring

COC	Number of Wells[a]	Number Samples[b]	Total Samples
Hexavalent Chromium	10	11	110
Nitrate	20	11	220
Strontium-90	7	11	77
Trichloroethene	10	11	110

a. Assumed to be approximately half the number of wells sampled for the COC before cleanup levels achieved. Excludes aquifer tubes and seeps.

b. Assume quarterly sampling for 2 years and annual sampling for 3 years.

COC = contaminant of concern

8 References

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WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-160.

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

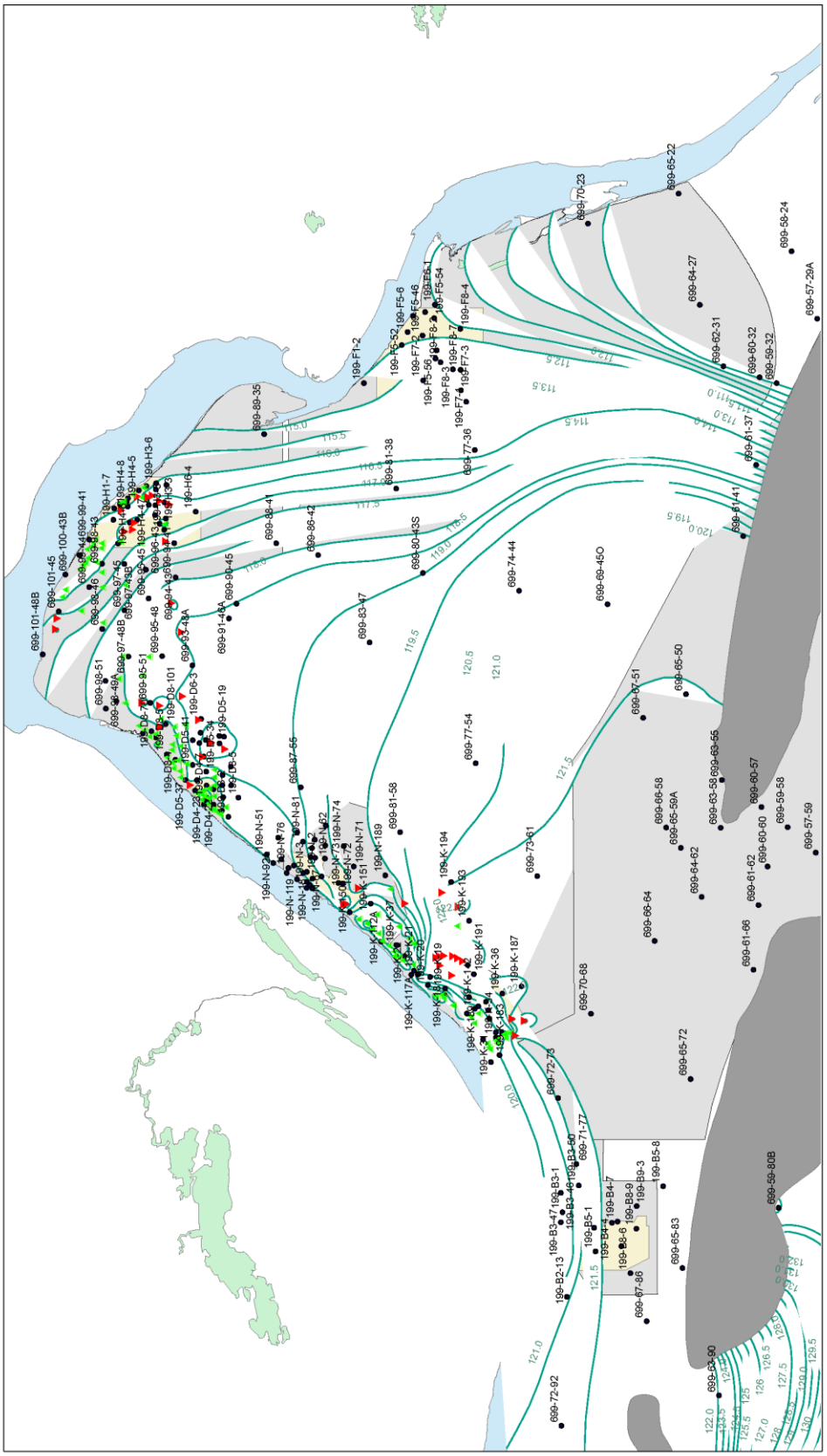

Figure 1. March 2014 Water Table in the Northern Portion of the Hanford Site (Showing Wells Used to Interpret Water Table)

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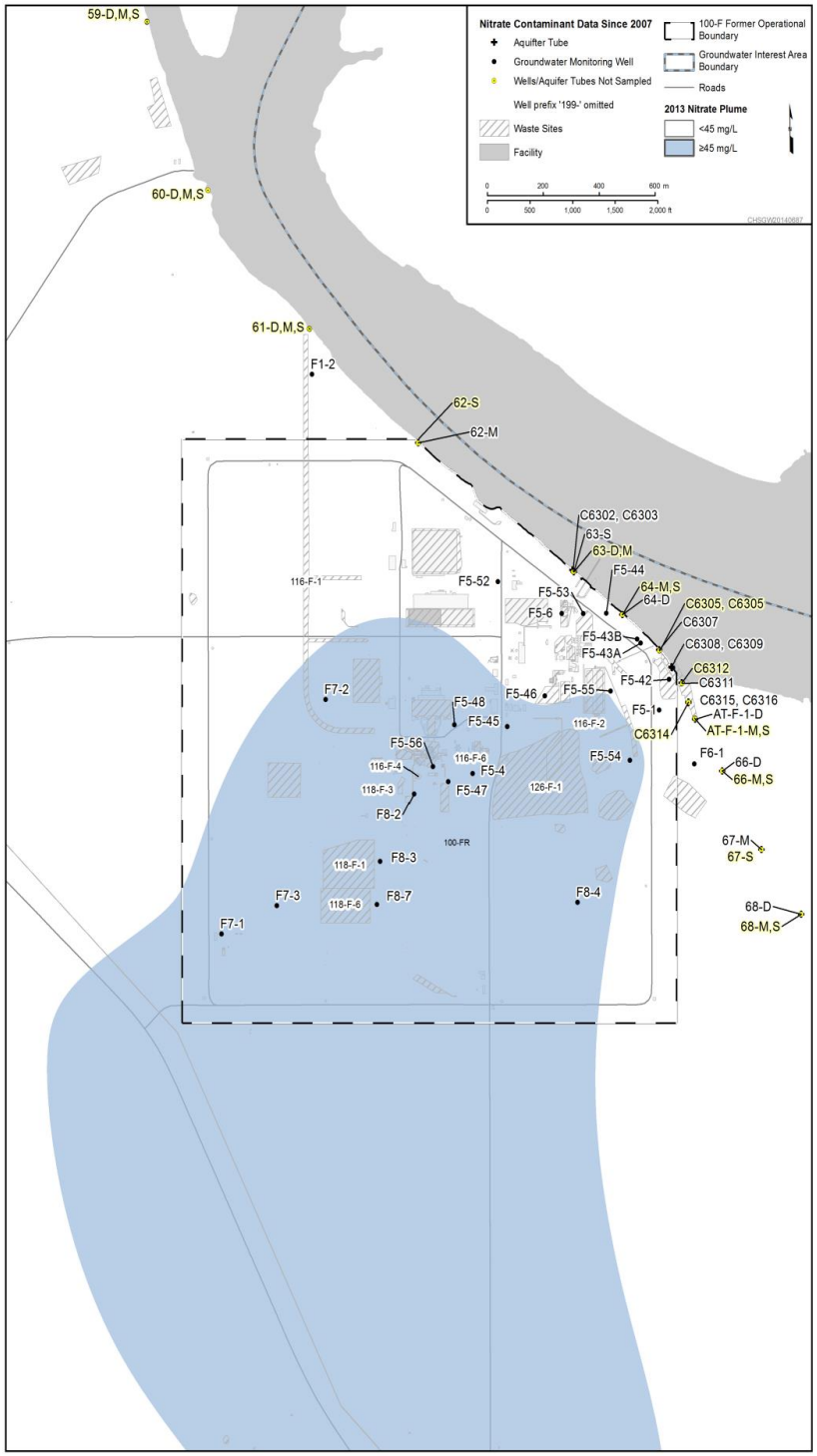

Figure 2. 2013 Nitrate Plume (with Wells Sampled for Nitrate since 2007)

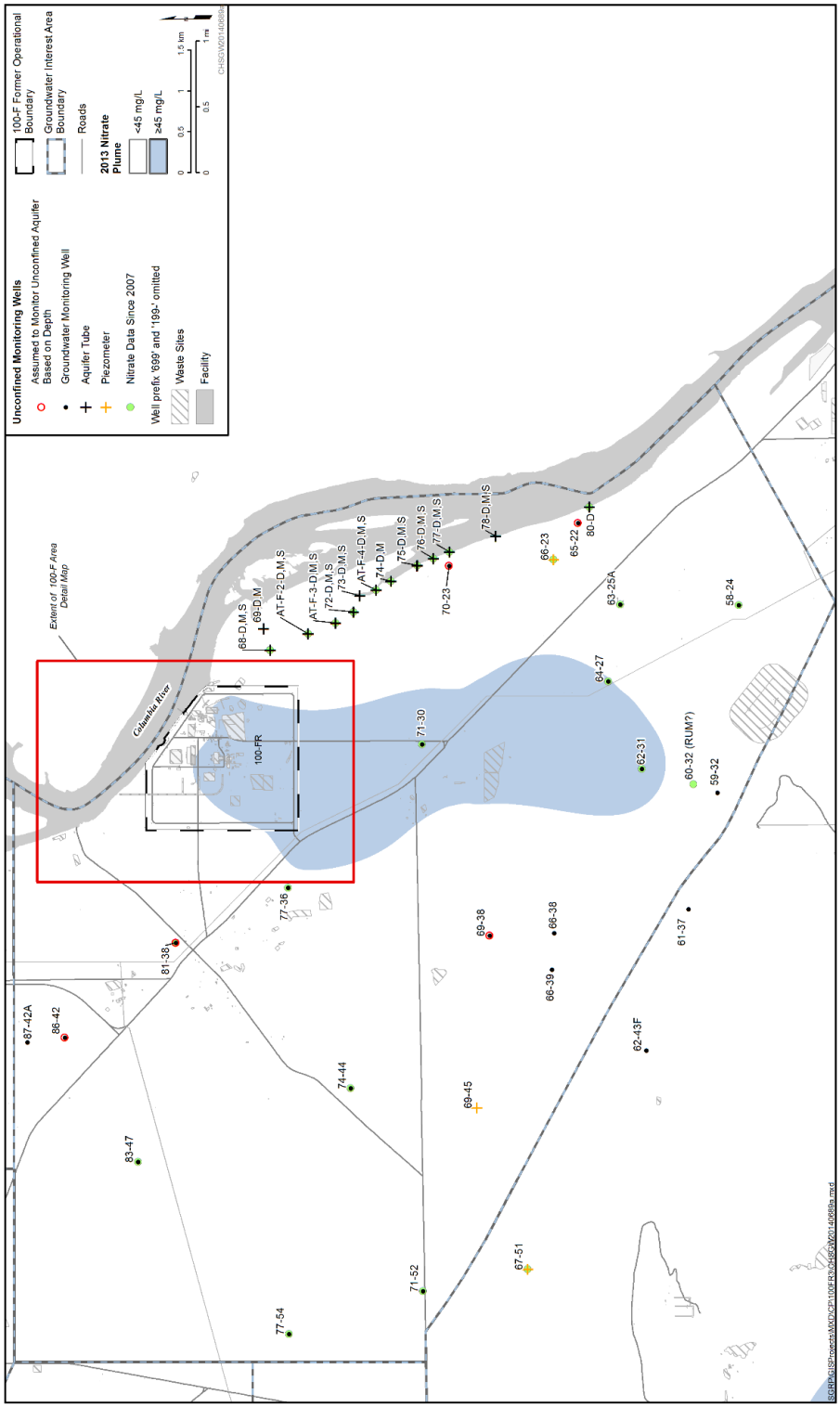

Figure 3. Available Unconfined Aquifer Monitoring Wells in the 600 Area Near 100-F (with 2013 Nitrate Plume)

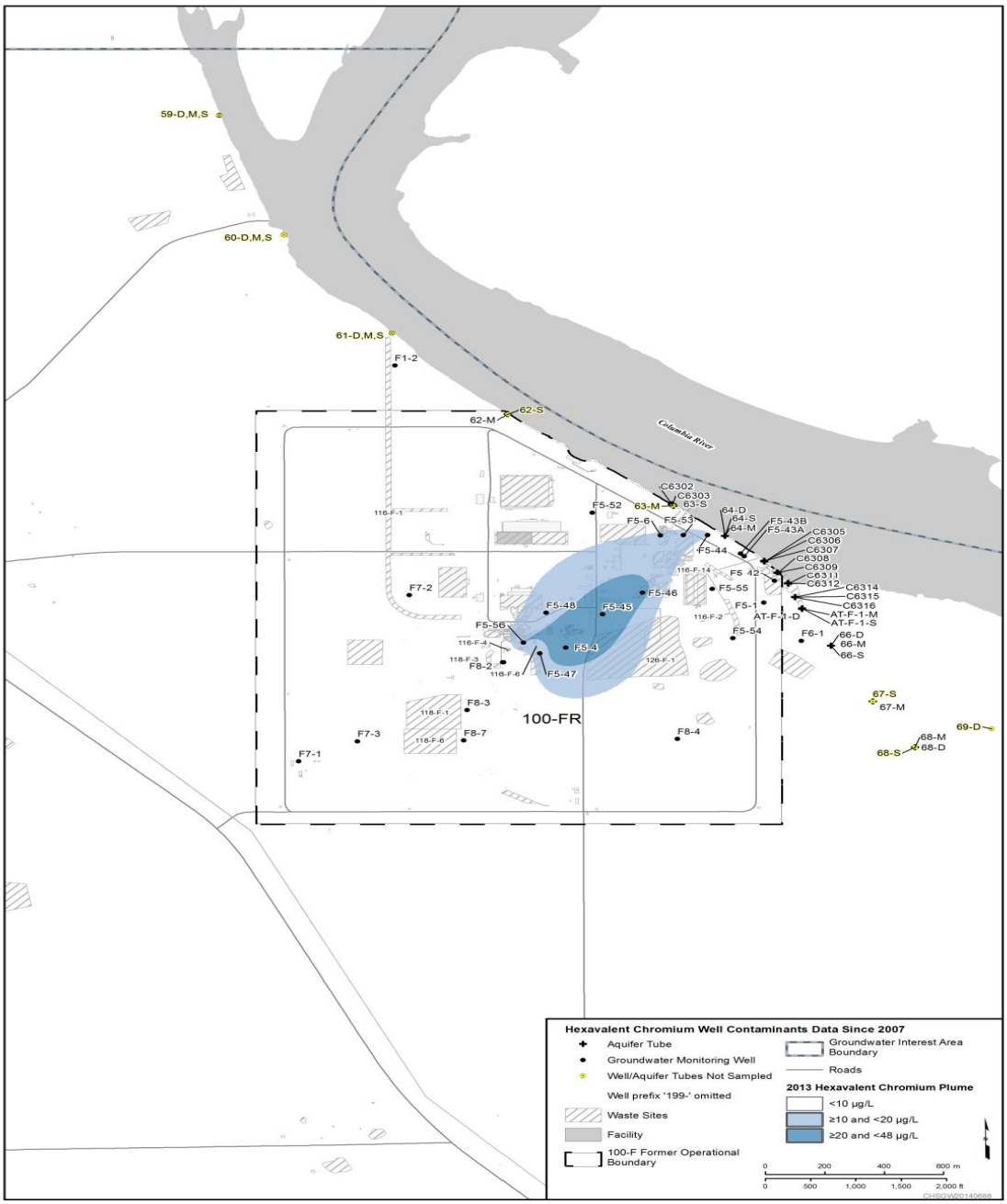

Figure 4. 2013 Chromium Plume (with Wells Sampled for Chromium since 2007)

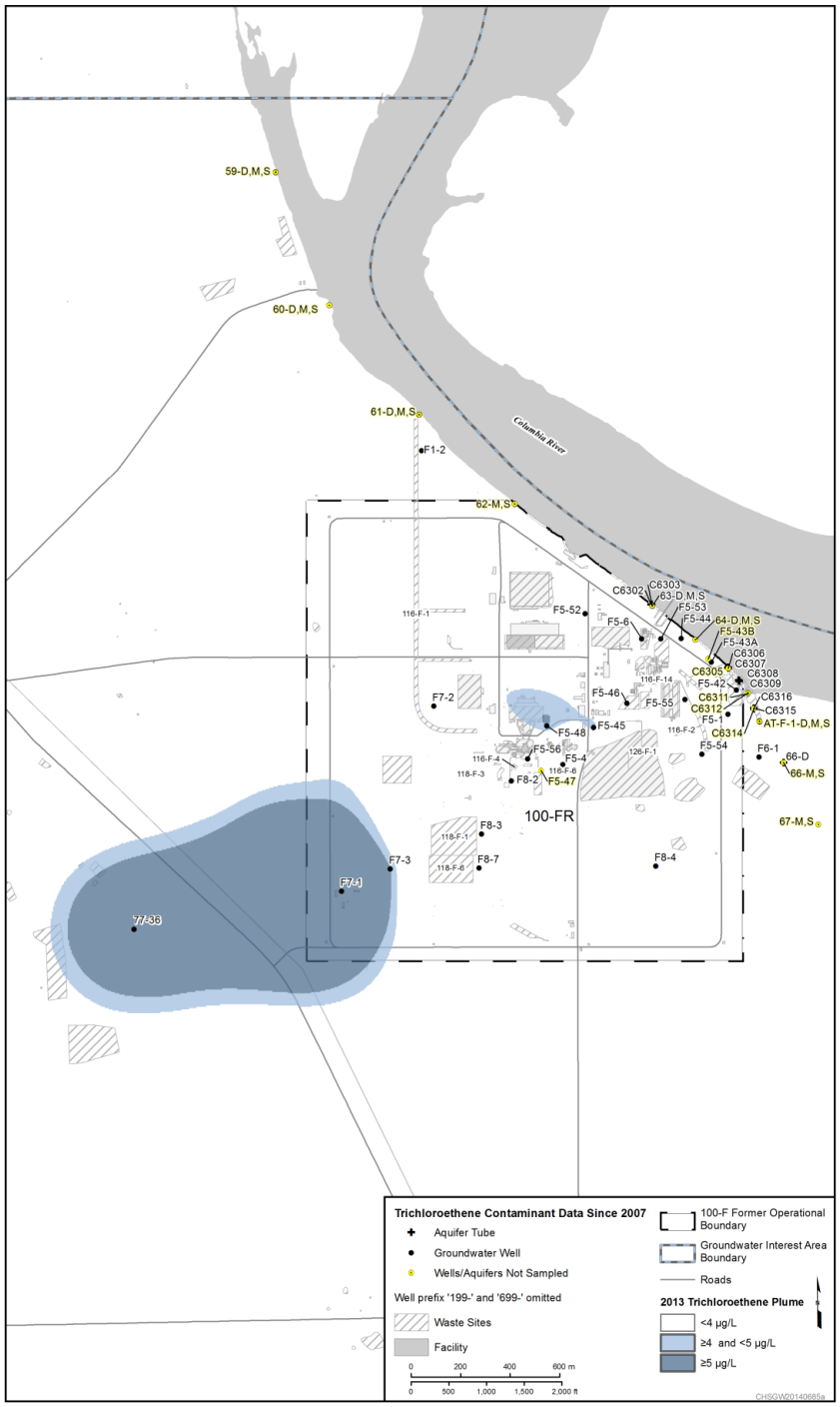

Figure 5. 2013 Trichloroethene Plume (with Wells Sampled for TCE since 2007)

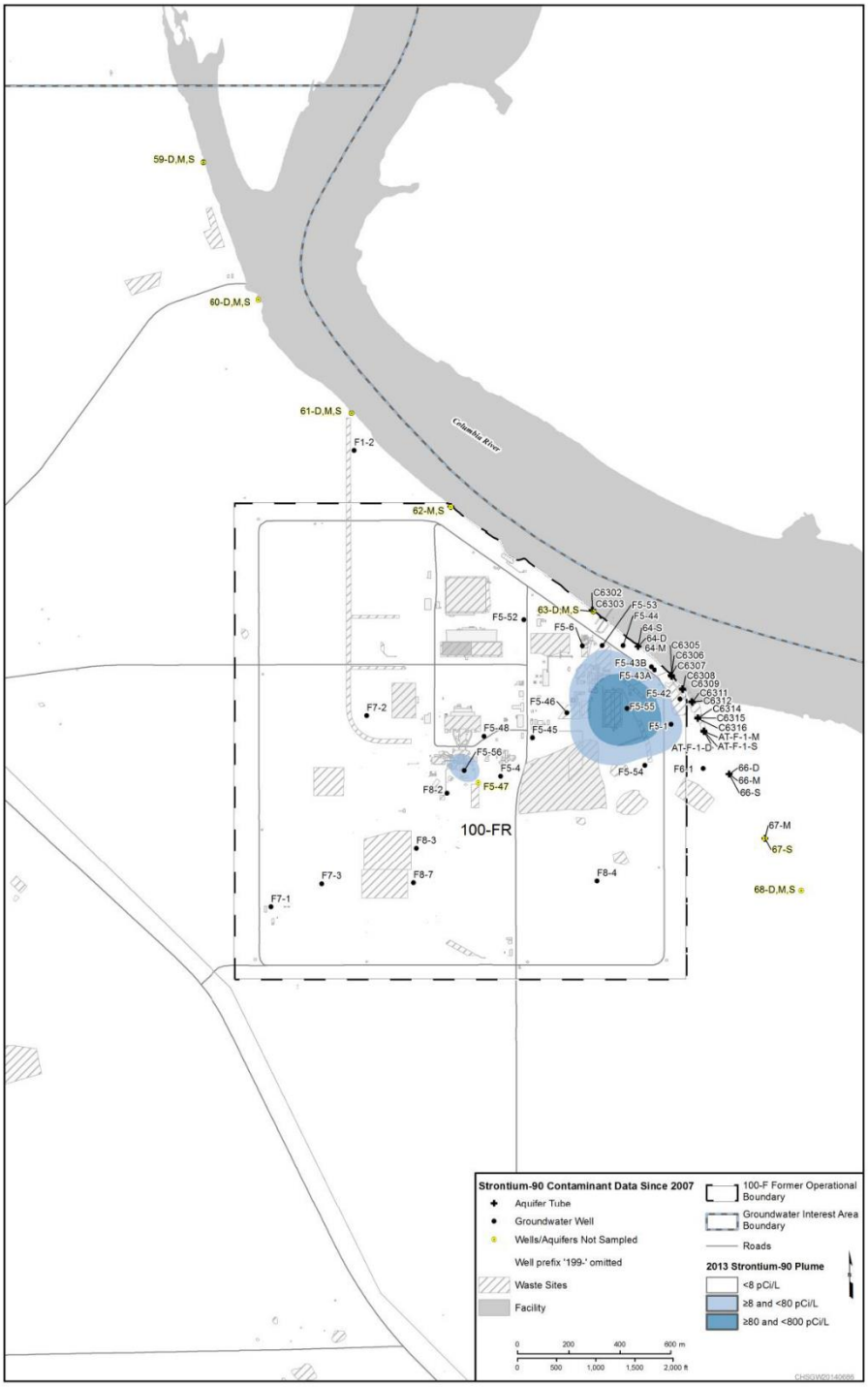

Figure 6. 2013 Stronium-90 Plume (with Wells Sampled for Strontium-90 since 2007)

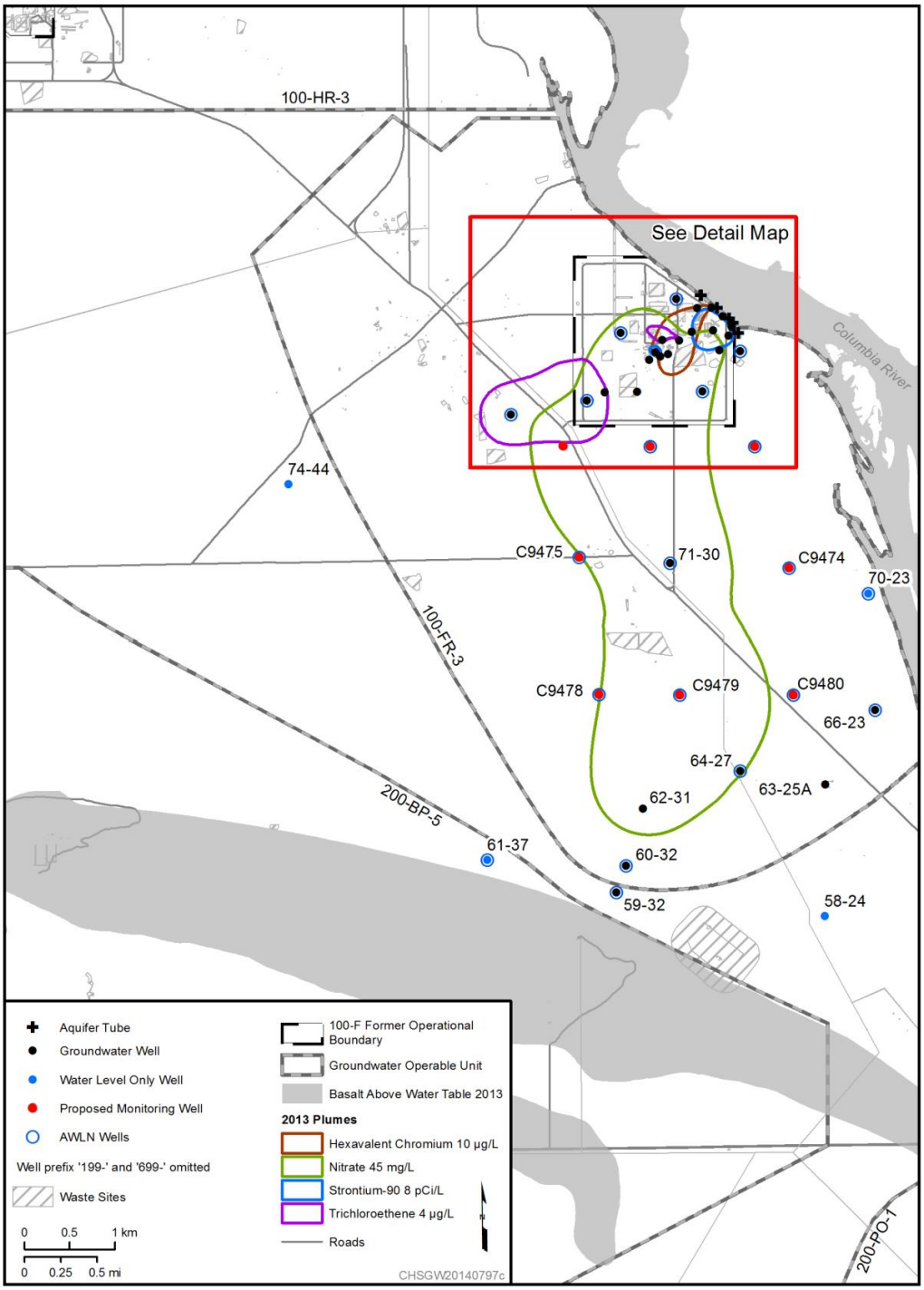

Figure 7. Proposed Monitoring Network, Including New Well Locations (Phase 1)

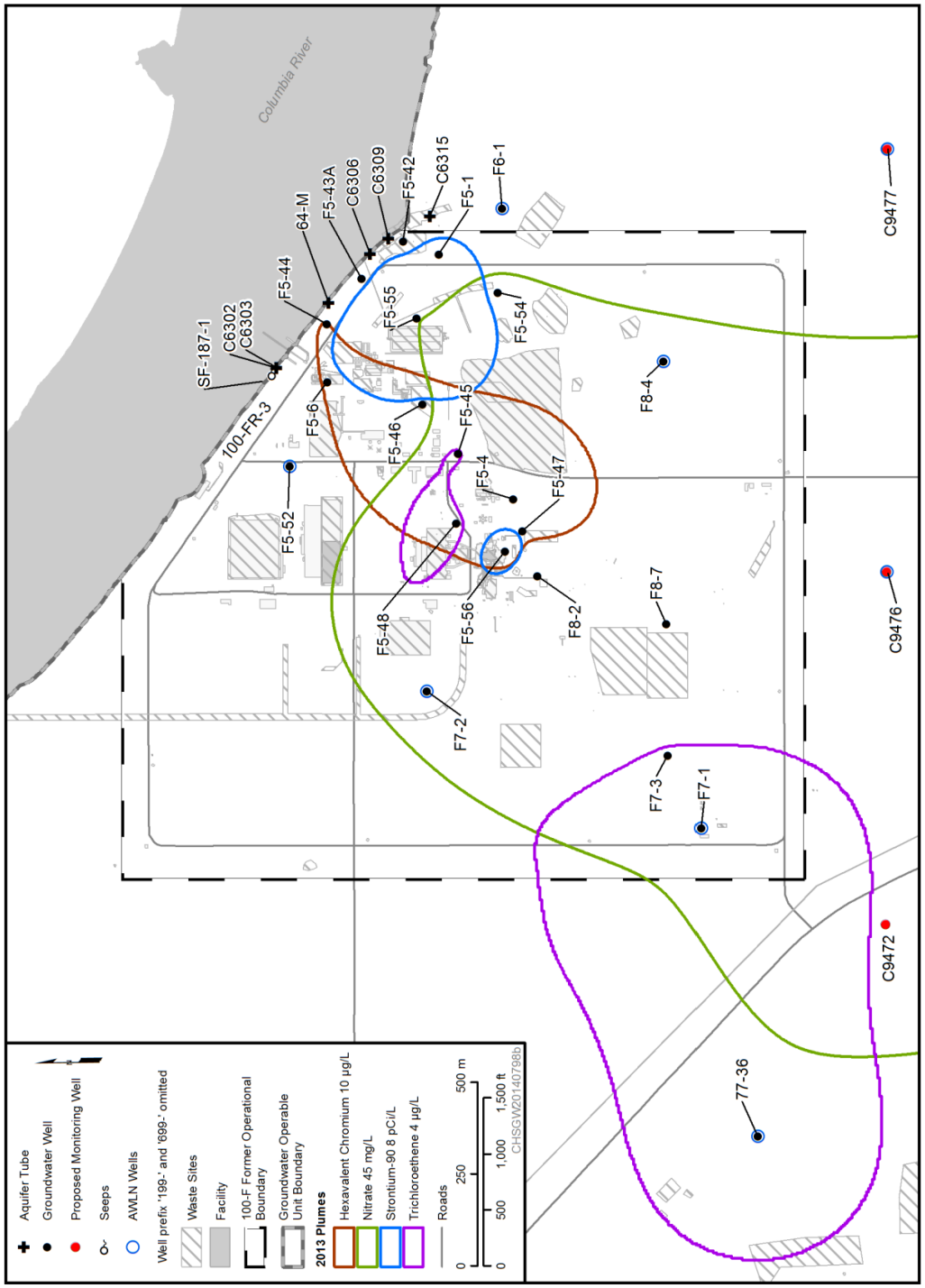

Figure 8. Proposed Monitoring Network (100-F Area Detail)

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Appendix B

100-FR-3 Monitoring Network Operations and Maintenance Plan

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Terms

AWLN	automated water level network
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
MNA	monitored natural attenuation
O&M	operations and maintenance
OU	operable unit
ROD	record of decision
SAP	sampling and analysis plan

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B1 Introduction

This operations and maintenance (O&M) plan outlines the activities necessary to operate and maintain the network identified for groundwater monitoring of the 100-FR-3 Groundwater Operable Unit (OU) (Figures B-1 and B-2). In September 2014, the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) issued *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*, hereinafter called the 100-F/IU Record of Decision (ROD), for the 100-FR-3 Groundwater OU. The 100-F/IU ROD (EPA and DOE, 2014) selected monitored natural attenuation (MNA) of groundwater and institutional controls to restrict groundwater use as the final remedial actions. MNA will be implemented for hexavalent chromium, nitrate, strontium-90, and trichloroethene in groundwater. Performance monitoring of these contaminants in the groundwater as a component of the MNA remedy will be performed until cleanup levels are met.

The remedial design report/remedial action work plan (DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU*) addresses the soil and groundwater OUs and is accompanied by two addenda. The two addenda correspond to the two distinct media (soil and groundwater). The groundwater monitoring network components identified for MNA performance monitoring, including wells, aquifer tubes, a riverbank seep, and the 100-F river gauge station, are presented in a groundwater sampling and analysis plan (SAP) in Appendix A of *Remedial Design Report/ Remedial Action Work Plan for 100-F/IU Groundwater* (hereinafter called the Groundwater Addendum). Selected monitoring wells and the 100-F river gauge station will be included in an automated water level network (AWLN). This O&M plan is also an appendix to the Groundwater Addendum.

B1.1 Purpose

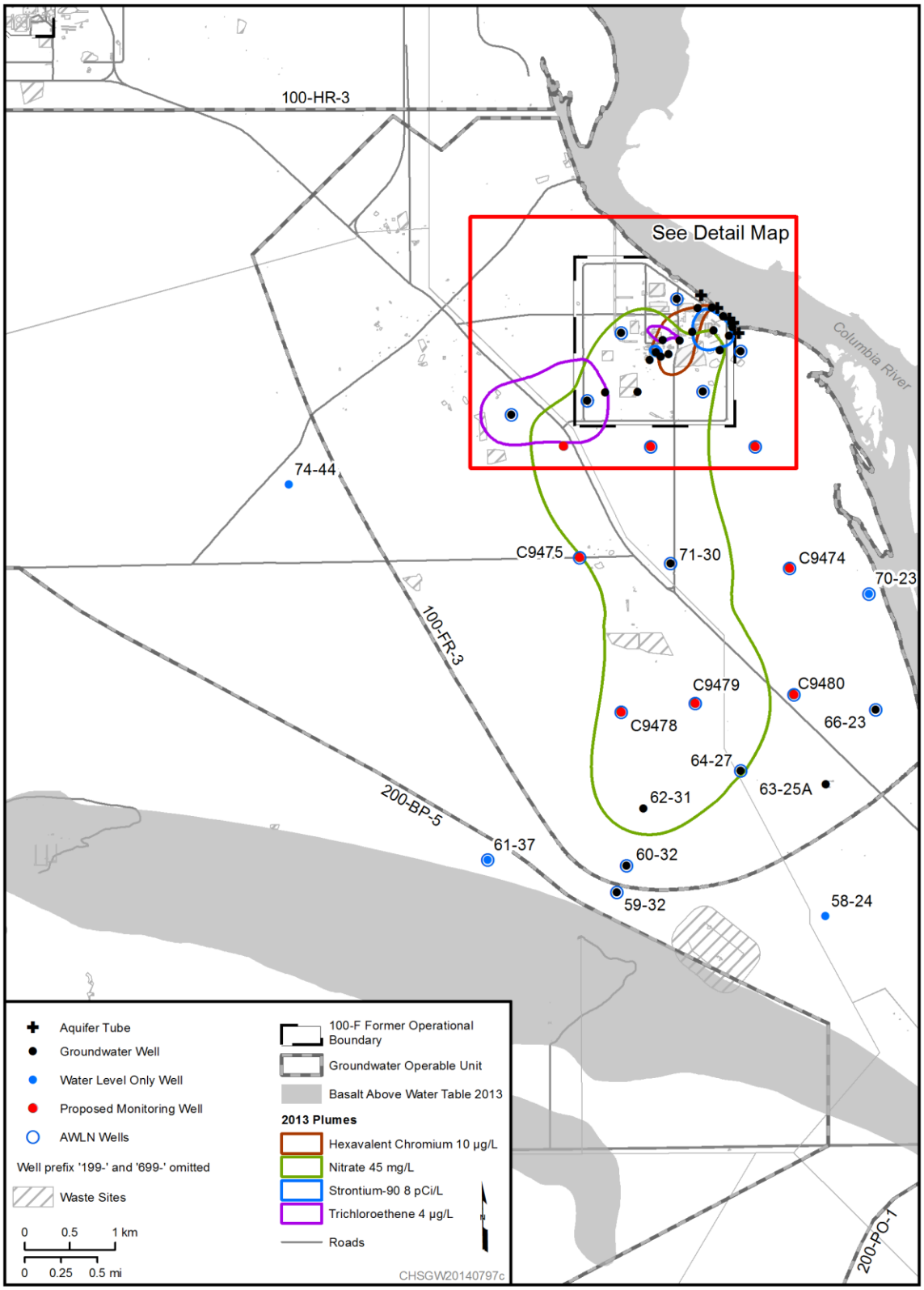
An O&M plan is needed to operate and maintain the performance monitoring network as a necessary component of the MNA remedy.

B1.2 Scope

This O&M plan scope encompasses monitoring wells and aquifer tubes within the performance monitoring network for the 100-FR-3 OU. This O&M plan also includes the 100-F river gauge station.

B1.3 Objectives

The objective of this O&M plan is to maintain the monitoring network needed for performance monitoring of the MNA remedy at the 100-FR-3 OU. The time frame for groundwater monitoring for individual plumes varies depending on the contaminant of concern (COC). The strontium-90 plume, estimated to require 150 years to achieve the cleanup level, has the longest monitoring period.



Note: Either Well 59-32 or 60-32 will be included in the network, depending on field investigation results.

Figure B-1. 100-FR-3 Operable Unit Monitoring Network

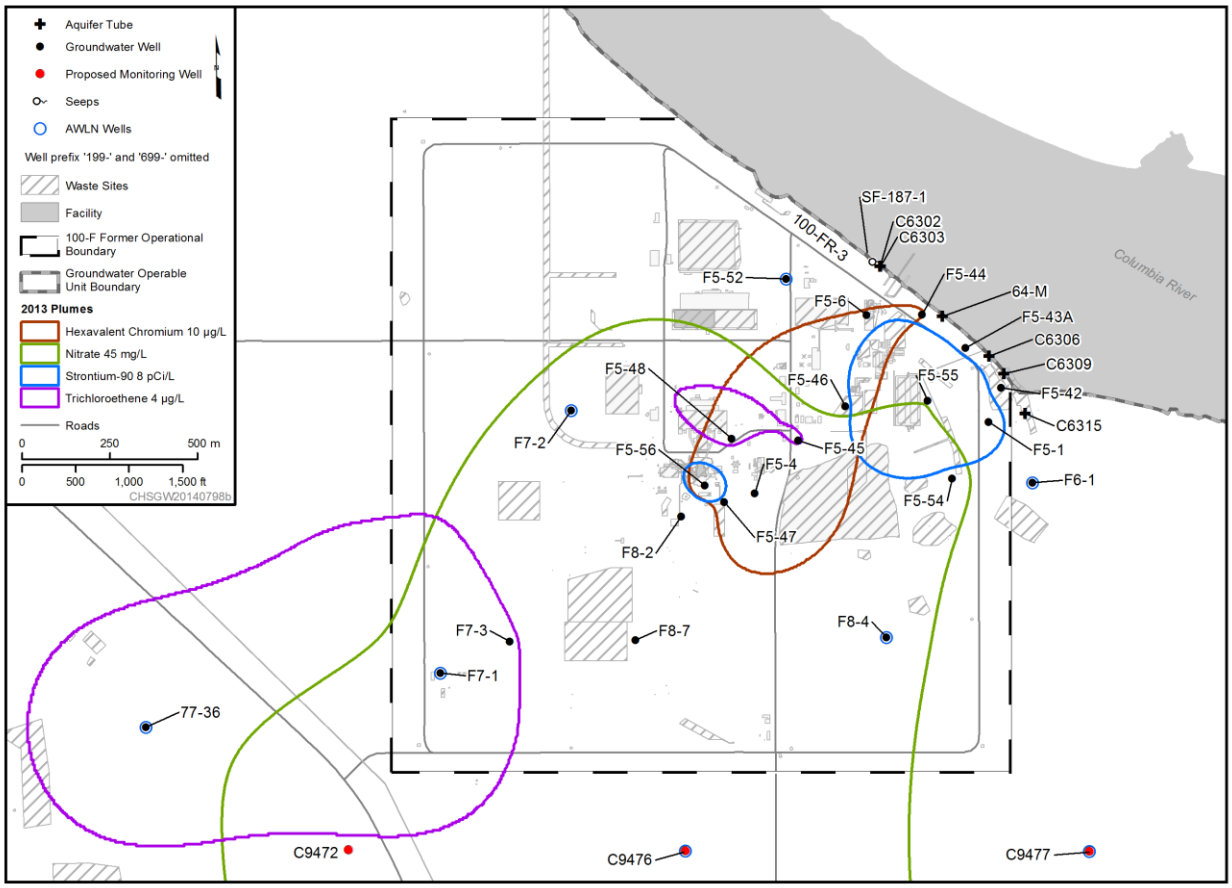


Figure B-2. Detail Map of 100-FR-3 Operable Unit Monitoring Network near 100-F Area

B2 Operations

The operational goal is to sample at designated monitoring wells, aquifer tubes, and the river gauge station during the natural attenuation performance monitoring period. An AWLN will be operated continuously through at least the initial 5 years of monitoring. As the concentrations of COCs are reduced and the plume sizes reduce, the monitoring network will be adjusted. Wells and aquifer tubes will not be arbitrarily removed from service unless they are determined to be no longer needed in the groundwater monitoring network due to decreasing COC plume size. Wells taken out of service due to shrinking of the COC plumes will be scheduled for future decommissioning if it is determined that they are not potentially needed for future monitoring.

B3 Monitoring Network Maintenance

B3.1 Well Maintenance

Well maintenance will be necessary for some wells during the time frame of the MNA remedy. Maintenance includes repair or replacement of pumps and wellhead inspection and maintenance.

Well maintenance will be performed on an as-needed basis. During scheduled sample collection events, sampling crews will inspect the wells. If problems with the wellhead or pump are observed, or if there is a problem obtaining samples (e.g., excessive drawdown or high turbidity), well maintenance will be performed. Well maintenance may also be performed based on unusual sampling results.

The following activities may be initiated if a well is determined to require maintenance:

- Removal and inspection of all downhole well components (e.g., pump and riser pipe, level transducer, and wiring)
- Downhole camera inspection (includes recording the inspection)
- Swabbing the well to loosen any accumulated solids from the well casing and screen
- Surging (with a dual-plate surge block) and pumping to redevelop the well screen and filter pack and remove accumulated solids from the well (continue surging the well until no more than 30 cm [0.1 ft] infill during 15 minutes surge is achieved)
- Final camera survey (includes recording the inspection)

During the performance monitoring period, which extends up to 150 years for strontium-90, it is highly likely that some wells will require replacement. In the event that the condition of a well has deteriorated and is not repairable, the DOE-Richland Operations Office and lead regulatory agency will determine if the well should be replaced.

B3.2 AWLN Maintenance

An AWLN will be installed and operated for a 5-year period at selected monitoring locations identified in the Groundwater Addendum SAP (Appendix A). After 5 years, the project will evaluate the need for continued AWLN operation.

AWLN data will be checked against manual water level measurements at least once per year, and instruments will be recalibrated when necessary. Stations within the AWLN will undergo installation, maintenance, upgrades, removal, and replacement in accordance with specific maintenance procedures. Maintenance may include troubleshooting, component change-outs, and upgrades to station telemetry equipment in support of the AWLN.

At the end of the AWLN monitoring period, system components will be removed from the monitoring wells.

B3.3 Aquifer Tube Maintenance

During scheduled sample collection events, sampling crews will inspect the aquifer tubes. Repairs to the aquifer tubes will be performed, as needed.

B4 Waste Management

Appendix C of the Groundwater Addendum, “Waste Management Plan for the 100-FR-3 Operable Unit,” establishes the requirements for management and disposal of waste generated from the installation, monitoring, sampling, maintenance, and decommissioning activities associated with the performance monitoring network at the 100-FR-3 OU. Waste is managed in accordance with Appendix C.

B5 Monitoring Network Maintenance Reporting

Any well maintenance activities that affect sample quality will be summarized in the Hanford Site annual groundwater report (e.g., DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). The performance monitoring results will be included as part of the annual groundwater report following each sample collection year.

B6 References

DOE/RL-2014-32, 2014, *Hanford Site Groundwater Monitoring Report for 2013*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084842.

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Appendix C

Waste Management Plan for the 100-FR-3 Operable Unit

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Terms

COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
MNA	monitored natural attenuation
OU	operable unit
RDR/RAWP	remedial design report/remedial action work plan
ROD	record of decision
SAP	sampling and analysis plan
TBD	to be determined

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C1 Introduction

This waste management plan establishes the requirements for management and disposal of waste associated with the groundwater remedial action identified in 2014 by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) in *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (100-F/IU record of decision [ROD]). The 100-F/IU ROD (EPA and DOE, 2014) encompasses the 100-FR-3 Groundwater Operable Unit (OU) (Figure C-1), which comprises groundwater contaminated by releases from facilities and waste sites associated with past operation of the 100-F Reactor and the Experimental Animal Farm. The 100-F/IU ROD (EPA and DOE, 2014) selected monitored natural attenuation (MNA) of groundwater and institutional controls to restrict groundwater use as the final remedial actions. MNA will be implemented for the 100-FR-3 OU contaminants of concern (COCs): hexavalent chromium, nitrate, strontium-90, and trichloroethene.

Performance monitoring of the 100-FR-3 OU COCs as a component of the MNA remedy is identified in the 100-F/IU ROD (EPA and DOE, 2014) and described in DOE/RL-2014-44, *Integrated Remedial Design Report/Remedial Action Work Plan for 100-F/IU* (Integrated RDR/RAWP), and *Remedial Design Report/Remedial Action Work Plan for 100-F/IU Groundwater* (Groundwater Addendum), to which this document is an appendix. Performance monitoring includes identification of the groundwater monitoring network, installation of new monitoring wells, and periodic sampling of the monitoring network. Monitoring will be performed until cleanup levels are achieved.

This document includes the requirements for management and disposal of waste generated from the installation of new monitoring wells and monitoring activities at monitoring wells, aquifer tubes, riverbank seeps, and the 100-F Area automated river gauge station. The components of the performance monitoring network are presented in a Groundwater Sampling and Analysis Plan (SAP) (Appendix A of the Groundwater Addendum). Complete lists of wells and aquifer tubes associated with the 100-FR-3 OU that are under the purview of this plan are presented in Tables C-1 and C-2, respectively. The tables will be updated as wells or aquifer tubes are added, decommissioned, or removed from service.

The following activities will likely generate waste:

- Groundwater well installation
- Groundwater well or aquifer tube development, sampling, maintenance, and decommissioning
- Water level and other in situ groundwater measurements
- Seep sampling
- River gauge sampling
- Screening and analysis of samples
- Decontamination of equipment and material

Upon approval of the Integrated RDR/RAWP (DOE/RL-2014-44) and the Groundwater Addendum, to which this document is an appendix, this waste management plan will supersede DOE/RL-2004-31, *Waste Control Plan for the 100-FR-3 Operable Unit*.

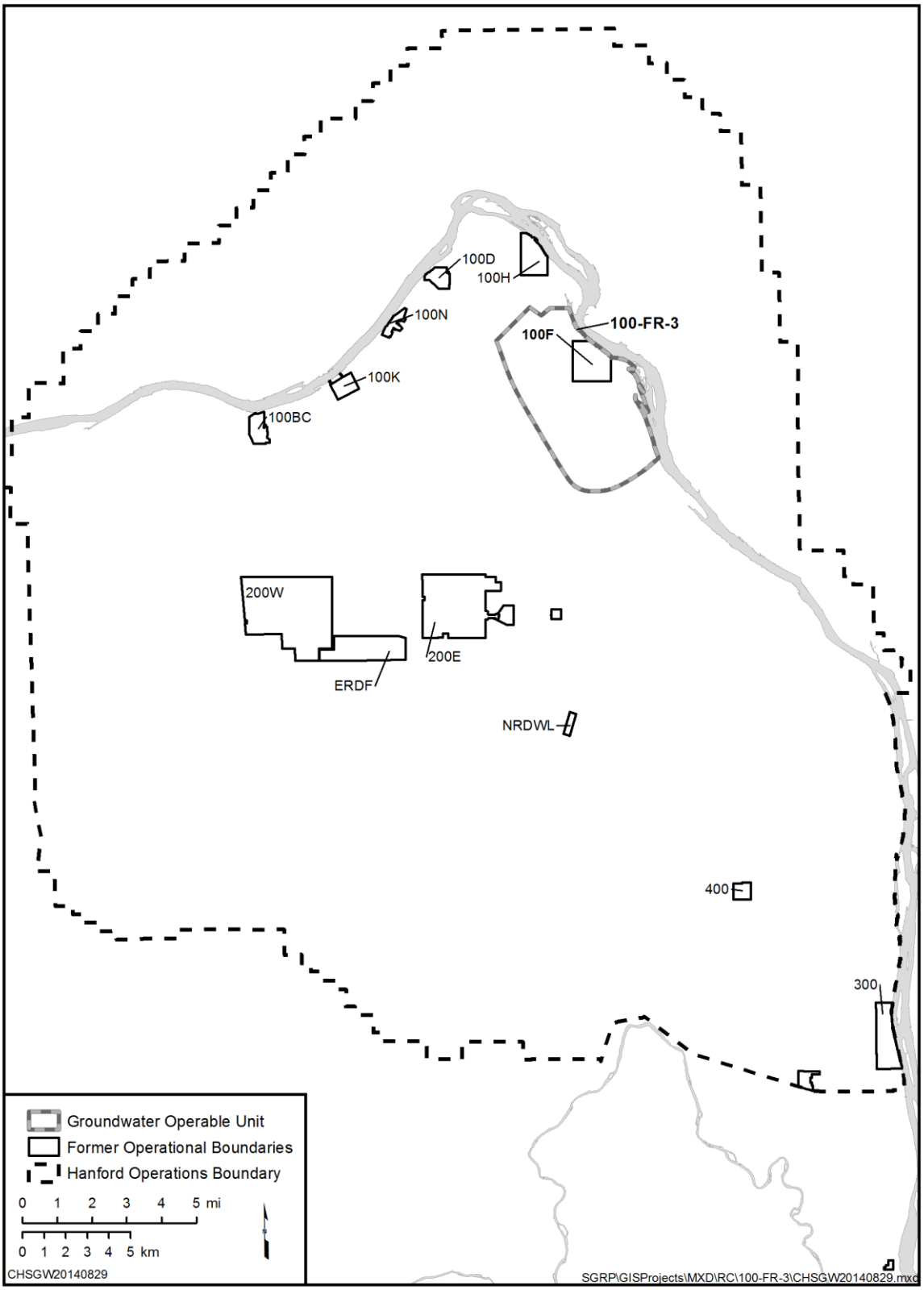

Figure C-1. Location of the 100-FR-3 Groundwater Operable Unit

Table C-1. Wells Associated with the 100-FR-3 Operable Unit

Well Name	Well Identification	Well Name	Well Identification	Well Name	Well Identification
199-F1-2	A4586	199-F8-2	A4607	699-69-45R	A9761
199-F5-1	A4587	199-F8-3	A4608	699-70-23	A5318
199-F5-4	A4590	199-F8-4	A4609	699-71-30	A5320
199-F5-42	A4591	199-F8-7	C6834	699-71-52	A5321
199-F5-43A	A4592	699-57-29A	A5267	699-74-44	A5328
199-F5-43B	A4593	699-57-29B	A5268	699-77-36	A5330
199-F5-44	A4594	699-58-24	A5275	699-77-54	A5331
199-F5-45	A4595	699-59-32	A5276	699-80-43P	A8993
199-F5-46	A4596	699-60-32	A5279	699-80-43S	A5336
199-F5-47	A4597	699-62-31	A5287	699-81-38	A5337
199-F5-48	A4598	699-63-25A	A5289	699-83-47	A5341
199-F5-52	C7790	699-64-27	A5295	699-84-34B	A9021
199-F5-53	C7791	699-65-22	A5297	699-84-35A	A5342
199-F5-54	C7792	699-66-23	A5306	699-84-35AO	A9769
199-F5-55	C7970	699-66-38	A5307	699-84-35AP	A9770
199-F5-56	C7972	699-66-39	A5308	699-84-35AQ	A9771
199-F5-6	A4600	699-69-38	A5316	699-84-35AR	A9772
199-F6-1	A4602	699-69-45	A8967	699-84-35AS	A9773
199-F7-1	A4603	699-69-45O	A5317	699-86-42	A5344
199-F7-2	A4604	699-69-45P	A9759	699-87-42A	A5345
199-F7-3	A4605	699-69-45Q	A9760		
Phase 1 Wells To Be Installed					
TBD	C9472	TBD	C9476	TBD	C9479
TBD	C9474	TBD	C9477	TBD	C9480
TBD	C9475	TBD	C9478		

Note: Wells identified in Table C-1 are associated with the 100-FR-3 groundwater interest area as of January 2015.

TBD = to be determined

Table C-2. Aquifer Tubes Associated with the 100-FR-3 Operable Unit

Well Name	Well Identification	Well Name	Well Identification	Well Name	Well Identification
59-D	B8325	68-D	B8352	AT-F-2-D	C4392
59-M	B8326	68-M	B8353	AT-F-2-M	C4393
59-S	B8327	68-S	B8354	AT-F-2-S	C4394
60-D	B8328	69-D	B8355	AT-F-3-D	C4383
60-M	B8329	72-D	B8364	AT-F-3-M	C4384
60-S	B8330	72-M	B8365	AT-F-3-S	C4385
61-D	B8331	72-S	B8366	AT-F-4-D	C4386
61-M	B8332	74-D	B8370	AT-F-4-M	C4387
61-S	B8333	74-M	B8371	AT-F-4-S	C4388
62-M	B8335	75-D	B8373	C6302	C6302
62-S	B8336	75-M	B8374	C6303	C6303
63-D	B8337	75-S	B8375	C6305	C6305
63-M	B8338	76-D	B8376	C6306	C6306
63-S	B8339	76-M	B8377	C6307	C6307
64-D	B8340	76-S	B8378	C6308	C6308
64-M	B8341	77-D	B8379	C6309	C6309
64-S	B8342	77-M	B8380	C6311	C6311
66-D	B8346	77-S	B8381	C6312	C6312
66-M	B8347	80-D	B8388	C6314	C6314
66-S	B8348	AT-F-1-D	C4389	C6315	C6315
67-M	B8350	AT-F-1-M	C4390	C6316	C6316
67-S	B8351	AT-F-1-S	C4391		

Note: Aquifer tubes identified in Table C-2 are associated with the 100-FR-3 groundwater interest area as of January 2015.

C2 Projected Waste Streams

Similar types of waste specific to the 100-FR-3 OU will be managed uniformly. Projected waste streams may include the following:

- Miscellaneous solid waste, such as filters, wipes, gloves, and other personal protective equipment, cloth, sampling and measuring equipment, pumps, pipe, wire, plastic sheeting, tools, bentonite, sand, paper, wood, construction debris, metal, and glass

- Drill cuttings and associated waste
- Purgewater generated during groundwater well or aquifer sampling tube installation, development, testing, monitoring, maintenance, and decommissioning
- Purgewater generated during decanting of soils and slurries
- Decontamination fluids
- Liquids generated during screening analysis
- Materials generated from cleanup of unplanned releases
- Equipment and construction material (e.g., well casings, drill string, drive barrel, construction equipment and materials, decommissioning materials, and wooden pallets)

C3 Waste Designation and Disposal

Waste will be designated in accordance with WAC 173-303, "Dangerous Waste Regulations," using process knowledge, historical analytical data, or analyses of samples identified in the referenced documents or Groundwater SAP (Groundwater Addendum, Appendix A), as appropriate.
The 100-FR-3 OU has an extensive groundwater well and aquifer tube sampling network. Many years of historical analytical data are available to be used as the basis of waste designation. New waste streams are not anticipated but would be characterized as necessary for designation purposes.

Miscellaneous solid waste and decommissioning debris that have contacted potentially contaminated materials may be segregated from other materials and will be disposed of based on the waste designation. Contaminated materials or materials that have contacted contaminated media may be disposed of to the Environmental Restoration Disposal Facility (ERDF) if the acceptance criteria can be met or, if the criteria cannot be met, to another facility that is approved by the lead regulatory agency (EPA).

Contact solid waste that is nonhazardous and radiologically released, or waste that has not contacted potentially contaminated materials, may be disposed offsite to a Subtitle D solid waste landfill or recycled, as appropriate.

Purgewater that is generated will be managed as specified in Section C4.2.

C4 Waste Stream-Specific Management

This chapter describes the management of waste streams produced from well installation, sample collection, maintenance activities, decommissioning, and miscellaneous solid waste.

C4.1 Drill Cuttings

Drill cuttings (soils and slurries) from outside an area of known or suspected contamination will be collected in stockpiles near the point of generation. Soils and slurries from known or suspect contaminated areas will be placed on a tarp or in containers. Contained soil slurries will be decanted, and free liquids remaining in the container will be eliminated by evaporation and/or the addition of absorbent material prior to disposal, as necessary. Decanted water will be managed as purgewater. Soils and slurries may be placed on the ground, near the point of generation, if they meet the following criteria:

- Soil cleanup criteria in the 100-F/IU ROD (EPA and DOE, 2014)
- Not designated as a dangerous waste

- Below WAC 173-340-740 “Model Toxics Control Act—Cleanup,” “Unrestricted Land Use Soil Cleanup Standards”
- Radiologically released

Decanting slurries and eliminating free liquids are authorized without prior approval. Decanted slurries may be disposed as purgewater.

C4.2 Purgewater

Purgewater is generated during well or aquifer tube installation, development, testing, monitoring, sampling, maintenance, and decanting of saturated soils during drilling activities. Purgewater will be dispositioned in accordance with this section.

C4.2.1 Purgewater Discharge

All extracted groundwater, including purgewater and free liquids separated from sediments and/or other materials generated during well drilling, well construction, and well development, will be discharged to the ground surface in accordance with the following subsections, collected for management at the modular storage unit(s), or transported to another appropriate unit (e.g., 200 Area Effluent Treatment Facility or pump-andtreat facilities). Transportation of the groundwater by truck, storage of nonempty trucks during off-hours, and collection of groundwater at the modular storage unit is governed by DOE/RL-2009-39 (as amended), *Investigation Derived Waste Purgewater Management Action Memorandum*, and DOE/RL-2009-80 (as amended), *Investigation Derived Waste Purgewater Management Work Plan*.

For returning groundwater to the environment, DOE can discharge according to guidelines found in the Purgewater Management Work Plan (DOE/RL-2009-80, as amended). When a discharge request is required, DOE can propose a discharge to EPA for a well or group of wells through Tri-Party Agreement (TPA) (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*) project manager meetings. EPA will evaluate the discharge request and, when approved, the discharge request will be recorded in TPA (Ecology et al., 1989) Project Manager Meeting minutes.

C4.2.2 Groundwater Discharge Guidelines

The following guidelines may be used to evaluate and discharge purgewater. DOE can discharge without a discharge request for purgewater meeting the following criteria:

Purgewater may be discharged to the ground surface in accordance with Section C4.2.2.2 under the following criteria:

- Water from wells where groundwater is below cleanup levels, when purgewater is generated in support of monitoring (e.g., aquifer testing), or
- Low-purge and low-flow sampling methods for groundwater sample collection resulting in purgewater volumes of 19 L (5 gal) or less, or
- Purgewater from aquifer tube samples

For purgewater not meeting these criteria, DOE will prepare a discharge request. Discharge requests will be prepared with the information required by Sections C4.2.2.1 through C4.2.2.3. Before EPA will grant a new discharge request allowing groundwater to be discharged to the environment, the EPA will evaluate the potential impact of the proposed action based on the criteria in Sections C4.2.2.1 through C4.2.2.3. If EPA does not approve the discharge request within 30 days, the request will be considered denied.

If the request is denied, purgewater will be collected and transported to the modular storage unit(s) or other appropriate Hanford location.

Some aquifer tubes are located within the seasonal high-water mark of the Columbia River. When these tubes are sampled during high-water periods, these very low-volume discharges to the Columbia River are allowed.

C4.2.2.1 Chemistry

DOE will evaluate radiological groundwater data to meet the requirements of DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, or subsequent replacement. DOE will submit discharge requests relating to nonradiological parameters for purgewater to EPA. Decisions will be based on existing data and will consider the following:

- Applicable regulatory requirements
- Approved, applicable TPA (Ecology et al., 1989) decision documents
- Previously approved contained-in determinations

The discharge request will contain applicable analytical data and associated quality assurance/quality control data to demonstrate that the discharge decision is appropriate.

C4.2.2.2 Location

Discharge to the ground is not allowed where it may remobilize potential existing contamination and may not occur within or on the following areas:

- 100-F/IU waste site boundary
- No irrigation institutional control waste site
- Burial grounds
- Effluent disposal sites (ponds, cribs, ditches, or trenches)
- Surface or subsurface soil contamination areas

Discharges will be 6.1 m (20 ft) or greater from the well head to prevent channeling of water along the annulus of the well. DOE shall not propose to establish new waste sites by the approval of discharge requests.

C4.2.2.3 Volume

DOE will evaluate purgewater volume along with chemistry and location considerations. Purgewater discharges to the ground are exempt from WAC 173-216, “State Waste Discharge Permit Program,” permitting based on condition G.12.A of Ecology, 2005, *State Waste Discharge Permit Number ST 4511*.

C4.3 Decontamination Fluids

Decontamination fluids (water and/or nonhazardous cleaning solutions), generated from cleaning equipment and tools in the OU, will be managed as purgewater.

Small volumes of decontamination fluids may be stabilized to eliminate free liquids and then disposed to ERDF, provided the waste acceptance criteria can be met (WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*).

Following removal of visible residue, decontamination of sample equipment may be conducted at the centralized sample equipment cleaning facility located in Building 6269 in the 600 Area.

C4.4 Analysis Screening Fluids

Unaltered liquid waste generated during screening analysis may be managed as purgewater, as previously described. Altered sample wastes will be disposed to the Effluent Treatment Facility, ERDF, modular storage units, or another appropriate facility, as authorized by the regulatory agency, depending on the waste designation. Some liquids may be neutralized and/or stabilized to meet disposal facility waste acceptance criteria.

C4.5 Miscellaneous Solid Wastes

Solid wastes are generated during groundwater well, aquifer tube, and seep sampling; aquifer testing; groundwater well or aquifer tube installation and development; well maintenance; decommissioning and alteration; water level measurements (both manual and transducer); screening of analysis liquids; and equipment decontamination. Miscellaneous solid waste that has contacted potentially contaminated materials will be segregated from other materials and placed in containers that are appropriate for the material and disposal facility. Miscellaneous solid waste that has contacted contaminated media may be disposed of at ERDF if the waste acceptance criteria can be met (WCH-191). If the ERDF waste acceptance criteria (WCH-191) cannot be met, the waste will be shipped to an offsite facility, as appropriate, and authorized by the lead regulatory agency (EPA), depending on the waste designation.

Miscellaneous solid waste that has not contacted contaminated media, has contacted miscellaneous solid waste that is nondangerous, and has been released for radionuclides may be disposed of at an offsite solid waste landfill.

C4.6 Decommissioning Debris

Decommissioning debris, such as concrete, wood, rebar, metal/plastic pipe and screens, wire, liners, bentonite/sand/gravel, equipment, and pumps, is generated during well decommissioning. Debris that has contacted contaminated media may be disposed of at ERDF if the ERDF waste acceptance criteria can be met, or at an approved offsite facility if the ERDF waste acceptance criteria cannot be met (WCH-191). Contact debris that is nondangerous and radiologically released, or materials that have not contacted potentially contaminated materials, may be disposed of offsite at a solid waste landfill or a Subtitle D solid waste landfill or recycled, as appropriate.

C4.7 Well Decommissioning

Wells that are identified for decommissioning will be removed from the wells listed in Table C-1. Aquifer tubes that are no longer in service will be removed from Table C-2.

C5 Packaging and Labeling

Materials requiring collection will generally be placed in drums or other suitable containers. However, packaging for large or irregular-shaped waste (e.g., well casing) may include containment other than drums. The packaging will provide insurance against migration of contaminants and protection from environmental degradation. The packaging may include, but is not limited to, plastic wrap.

Low-volume miscellaneous materials associated with activities such as groundwater well sampling, water level measurements, and groundwater well maintenance may be temporarily stored near the wellhead in an appropriate container (e.g., 208 L [55 gal] drum) or may be bagged, taped, and labeled with the well

number at the well head. The bagged material will be transported in a protective manner (i.e., containment of the material is maintained) with the workers while proceeding from well to well in the OU. Upon arrival at the storage location, materials will be placed in an accumulation container and managed as waste. The material may also be taken directly to ERDF for disposal, if appropriate, without storage.

State regulatory requirements for management of containers are established in WAC 173-303-630, "Use and Management of Containers," and WAC 173-303-160, "Containers." All containers of waste will be managed in accordance with the applicable substantive federal and/or state requirements, including labels which define the known major risk(s), dangerous waste codes, and if awaiting analysis, wording which states "waste pending analysis" with the date of initial sampling.

C6 Storage and Transportation

This chapter describes the storage and transportation of waste produced from well installation, sample collection, maintenance activities, decommissioning, and miscellaneous solid waste.

C6.1 Storage Location

Much of the waste is generated in small quantities on an ongoing basis. Waste will be stored at the centralized location identified in Figure C-2 until analytical data are evaluated for proper waste designation. Some waste (e.g., field decontamination fluids) may be temporarily (generally less than 2 weeks after generation) accumulated near the point of generation in the 100-FR-3 OU, then staged at the centralized storage location identified in Figure C-2. Because of the low volumes of waste generated, EPA has agreed that waste associated with the 100-FR-3 OU may be stored for up to 12 months, measured from the time waste is first placed in the container.

While in storage, waste will be managed in accordance with this plan. Most contaminated waste will be disposed at ERDF if it meets the waste acceptance criteria (WCH-191). However, based upon field screening instrumentation and/or analytical data, it may be determined that it is appropriate to manage certain types of waste at another approved facility, rather than at the ERDF. Waste that cannot be treated to meet the waste acceptance criteria for the approved disposal facility will remain on the waste site or in the centralized storage location pending disposal at an appropriate facility.

C6.2 Substantive Container Management Requirements

Federal and state regulatory requirements for management of containers are established in WAC 173-303-630 and WAC 173-303-160. All containers of waste will be managed in accordance with the applicable substantive state requirements including labels which define the known major risk(s), dangerous waste codes, and if awaiting analysis, wording which states "waste pending analysis" with the date of initial sampling.

C6.3 Release Reporting

Reporting of any release of waste shall be done in accordance with applicable provisions of WAC 173-303-145, "Spills and Discharges into the Environment," and 40 CFR 302, "Designation, Reportable Quantities, and Notification."

C6.4 Transportation

Waste will be transported in accordance with WAC 173-303 and U.S. Department of Transportation requirements (49 CFR, "Transportation"), as appropriate.

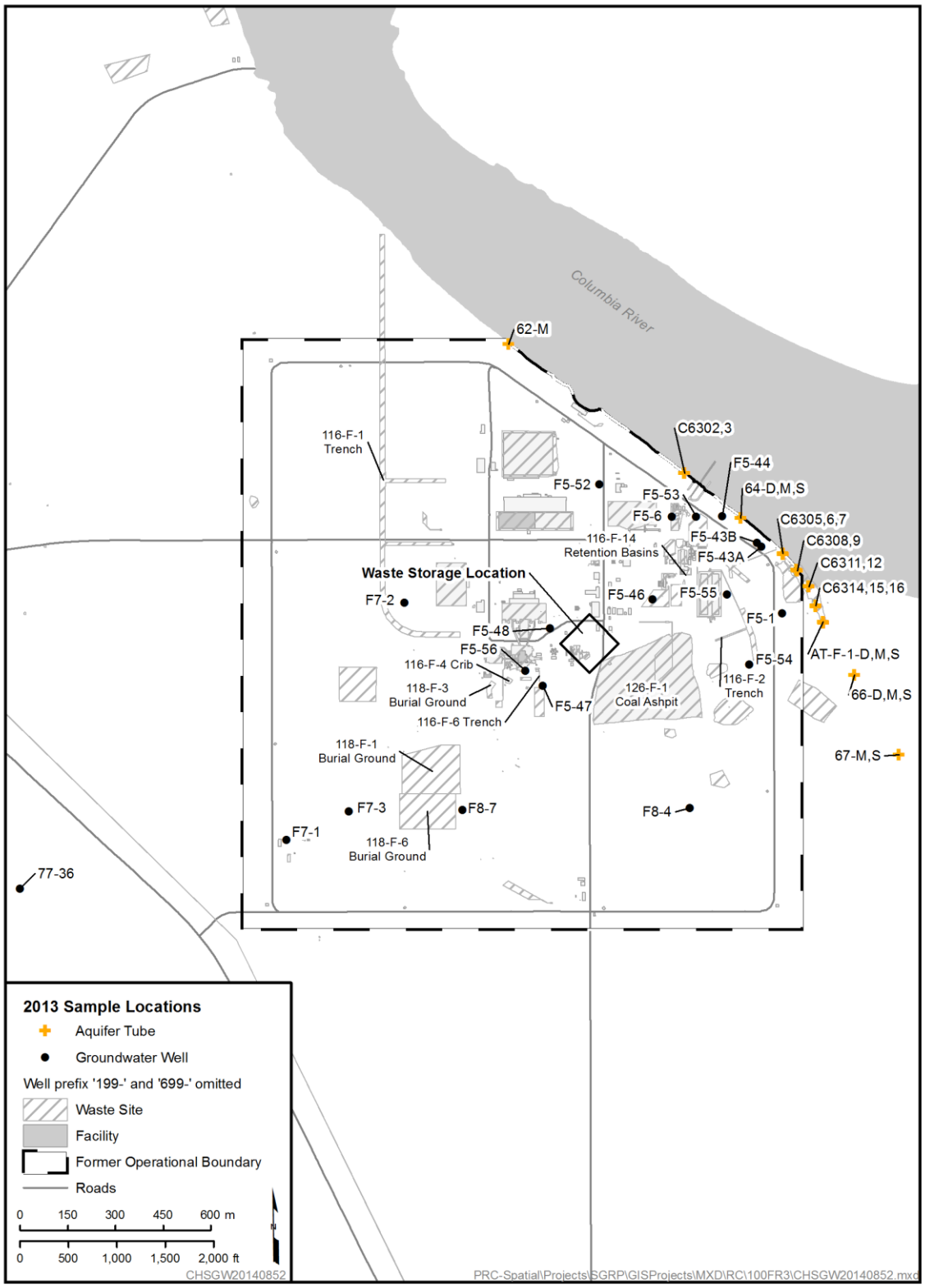

Figure C-2. 100-FR-3 Operable Unit Centralized Storage Location

C7 References

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