



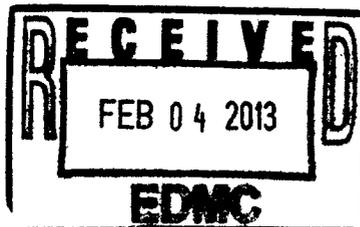
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Department of Energy  
Richland Operations Office  
P.O. Box 550  
Richland, Washington 99352

13-AMRP-0092

JAN 28 2013

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



Dear Mr. Faulk:

COMPLETION OF PROPOSED HANFORD FEDERAL FACILITY AGREEMENT AND  
CONSENT ORDER (TRI-PARTY AGREEMENT) INTERIM MILESTONE M-015-74

~~0089913~~  
This letter notifies the U.S. Environmental Protection Agency of the Completion of Proposed Tri-Party Agreement Interim Milestone M-015-74. The Proposed Tri-Party Agreement Interim Milestone M-015-74 requires revision of the 100-BC Remedial Investigation/Feasibility Study Work Plan, DOE/RL-2008-46-ADD3, Revision 0 and Sampling and Analysis Plan, DOE/RL-2009-44, Revision 0 to include enhanced groundwater monitoring. These revisions are being accomplished through submittal of Tri-Party Agreement Change Notices to revise these documents. The revisions have been developed as stand-alone appendices, one for the Work Plan (TPA-CN-558) and one for the Sampling and Analysis Plan (TPA-CN-559). These changes support additional studies needed to assist in evaluation of remedial action alternatives for groundwater in the 100-BC Area. Submittal of the attached change notices for review meets the proposed Tri-Party Agreement Interim Milestone M-015-74, with proposed due date of January 31, 2013.

~~122028~~  
Please provide comments within 45 days of receipt of this letter. As documented in the October 2012 Project Managers meeting, the schedule proposed in Tri-Party Agreement Change Number M-15-12-03 is based on the streamlined process normally used for preparation and approval of change notices and assumed that if the change notices were submitted by January 31, 2013, final approval of the Work Plan and Sampling and Analysis Plan revisions would be obtained by March 1, 2013. If approval is not obtained by that time the dates of the associated subsequent proposed milestones will need to be re-evaluated, possibly to incorporate a day for day slip.

Attached to:

~~0089913~~ + 0089913

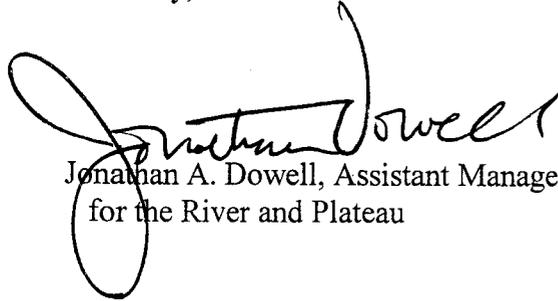
Mr. D. A. Faulk  
13-AMRP-0092

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JAN 28 2013

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

Sincerely,



Jonathan A. Dowell, Assistant Manager  
for the River and Plateau

AMRP:GLS

Attachments

cc w/attachs:

G. Bohnee, NPT  
R. Buck, Wanapum  
L. C. Buelow, EPA  
S. Harris, CTUIR  
J. A. Hedges, Ecology  
S. Hudson, HAB  
R. Jim, YN  
N. M. Menard, Ecology  
K. Niles, ODOE  
D. Rowland, YN  
Administrative Record  
Environmental Portal

cc w/o attachs:

F. H. Biebesheimer, CHPRC  
P. A. Burke, CHPRC  
L. M. Dittmer, CHPRC  
D. E. Dooley, CHPRC  
R. A. Kaldor, MSA  
T. W. Noland, MSA  
R. E. Piippo, MSA

## TRI-PARTY AGREEMENT

Change Notice Number TPA-CN- 558	TPA CHANGE NOTICE FORM	Date: January 28, 2013									
Document Number, Title, and Revision: DOE/RL-2008-46-ADD3, <i>Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units, Rev. 0</i>		Date Document Last Issued: March 2010									
Originator: Phil Burke		Phone: 376-0023									
<p><b>Description of Change:</b> This change notice adds a new appendix to the work plan, describing additional studies of groundwater and the hyporheic zone in the 100-BC-5 Groundwater Operable Unit.</p>											
<p>Briant Charboneau _____ and Laura Buelow _____ agree that the proposed change  <div style="display: flex; justify-content: space-around; width: 100%;"> <span>DOE</span> <span>EPA</span> </div> modifies an approved work plan/document and will be processed in accordance with the Tri-Party Agreement Action Plan, Section 9.0, <i>Documentation and Records</i>, and not Chapter 12.0, <i>Changes to the Agreement</i>.</p> <ul style="list-style-type: none"> <li>Replace Table of Contents (pp. xvii and xviii) with the attached revision (<u>new text shown with double underline</u>).</li> <li>Add the attached text, tables, and figures as a new appendix (Appendix E), pages E-i through E-24. (<i>The new text added as Appendix E is not double underlined. Because the entire appendix is new, the double underline would have made it difficult to read.</i>)</li> </ul>											
<p>Note: Include affected page number(s)</p>											
<p><b>Justification and Impacts of Change:</b>  After completion of tasks identified in the original work plan, waste site remediation and groundwater monitoring reveals additional uncertainties. Additional studies are needed to reduce uncertainties relating to (a) the upcoming completion of vadose zone (waste site) remediation; (b) short-term changes in groundwater contaminant concentrations related to waste site remediation activities; (c) modeling results that show it will likely take a long time for the large, low-concentration hexavalent chromium [Cr(VI)] plume to attenuate; and (d) variable contaminant concentrations in Columbia River pore water, creating uncertainties about the level of risk.  DOE and EPA have agreed that additional studies are needed before remedial action alternatives for groundwater can be evaluated (proposed TPA Milestone M-015-74, "Revise and submit the 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan, including the SAP, to include additional groundwater well installation and associated monitoring by 1/31/2013").  The appendix provided in this change notice describes the objective of the planned studies, the work plan rationale, and tasks. Details of the work are described in a revision to the RI sampling and analysis plan (DOE/RL-2009-44), included in TPA-CN-559.</p>											
<p><b>Approvals:</b></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding-bottom: 5px;">DOE Project Manager</td> <td style="width: 15%; border-bottom: 1px solid black; padding-bottom: 5px;">Date</td> <td style="width: 35%; text-align: right; padding-bottom: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> <tr> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">EPA Project Manager</td> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">Date</td> <td style="text-align: right; padding-bottom: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> <tr> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">Ecology Project Manager</td> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">Date</td> <td style="text-align: right; padding-bottom: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> </table>			DOE Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved	EPA Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved	Ecology Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved
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EPA Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved									
Ecology Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved									

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## Contents

<b>1</b>	<b>Introduction .....</b>	<b>1-1</b>
1.1	Scope .....	1-2
1.2	100-BC Remediation Accomplishments .....	1-2
<b>2</b>	<b>Site Background and Environmental Setting .....</b>	<b>2-1</b>
2.1	Environmental Setting .....	2-1
2.1.1	Topography .....	2-1
2.1.2	Geology .....	2-1
2.1.3	Hydrogeology .....	2-6
2.1.4	Environmental Resources .....	2-12
2.1.5	Human Resources .....	2-13
2.2	100-BC OUs – Overview .....	2-14
2.2.1	B and C Reactor History and Description .....	2-15
2.2.2	Facility History and Description .....	2-18
2.2.3	Export Water System .....	2-21
2.2.4	Process History .....	2-22
<b>3</b>	<b>Initial Evaluation .....</b>	<b>3-1</b>
3.1	Contaminant Sources .....	3-1
3.1.1	Primary Sources of Contamination .....	3-1
3.1.2	Secondary Sources of Contamination .....	3-1
3.2	Previous Investigations .....	3-2
3.2.1	Initial Vadose Zone Radiological Characterization–1975 .....	3-2
3.2.2	100-BC Limited Field Investigations – Vadose Zone .....	3-4
3.2.3	100-BC Limited Field Investigations – Groundwater .....	3-11
3.2.4	Previous Studies and Treatability Tests .....	3-11
3.2.5	100-BC Hexavalent Chromium Leach Test Studies .....	3-12
3.2.6	100-BC Orphan Site Evaluation .....	3-12
3.3	Interim Remedial Actions and Existing Waste Site Contamination .....	3-13
3.3.1	Waste Sites Description and History .....	3-13
3.3.2	118-B-1 Solid Waste Burial Ground: Explanation of Significant Difference .....	3-19
3.3.3	100-B-15 River Effluent Pipelines .....	3-19
3.3.4	High Volume Liquid Waste Sites .....	3-20
3.3.5	Ongoing Investigation at Waste Site 100-C-7 .....	3-21
3.4	Nature and Extent of Groundwater Contaminants .....	3-22
3.4.1	Chromium .....	3-23
3.4.2	Strontium-90 .....	3-29
3.4.3	Tritium .....	3-31

3.4.4	Other Contaminants.....	3-34
3.5	Contaminant Fate and Transport .....	3-34
3.5.1	Contaminant Distribution in the Vadose Zone.....	3-34
3.5.2	Distribution of Contaminants in Groundwater .....	3-36
3.6	Human Receptors and Exposure Pathways .....	3-41
3.7	Ecological Receptors and Exposure Pathways.....	3-42
3.8	Conceptual Site Model Summary.....	3-42
3.8.1	Conceptual Site Model for Hexavalent Chromium .....	3-42
3.8.2	Conceptual Site Model for Tritium .....	3-44
3.8.3	Conceptual Site Model for Low Mobility Contaminants.....	3-45
3.8.4	RUM and Lower Hydrogeologic Units .....	3-45
3.8.5	Groundwater/River Interactions .....	3-45
<b>4</b>	<b>Work Plan Rationale and Tasks .....</b>	<b>4-1</b>
4.1	Approach .....	4-1
4.2	Development of Vadose Zone Soil Target Analyte Lists and Groundwater Contaminants of Potential Concern.....	4-2
4.2.1	Vadose Zone Soil Target Analyte List .....	4-2
4.2.2	Groundwater Contaminants of Potential Concern.....	4-5
4.3	Identification of Data Gaps .....	4-6
4.3.1	100-BC Data Gaps – Vadose Zone .....	4-11
4.3.2	100-BC Data Gaps – Groundwater.....	4-19
4.3.3	100-BC – Additional Scope of Work .....	4-24
<b>5</b>	<b>Project Schedule.....</b>	<b>5-1</b>
<b>6</b>	<b>References .....</b>	<b>6-1</b>

## Appendices

<b>A</b>	<b>100-BC-1, 100-BC-2, and 100-BC-5 Operable Unit Maps.....</b>	<b>A-i</b>
<b>B</b>	<b>100-BC Waste Sites Description and History .....</b>	<b>B-i</b>
<b>C</b>	<b>Summary of 100-BC Facilities .....</b>	<b>C-i</b>
<b>D</b>	<b>Identification of Contaminants of Potential Concern for Groundwater Portion of the 100-BC Remedial Investigation/Feasibility Study Work Plan and Reprint of WCH-329, 100-B/C Target Analyte List Development for Soil, Rev. 0.....</b>	<b>D-i</b>
<b>E</b>	<b><u>Additional Hyporheic Zone and Groundwater Monitoring.....</u></b>	<b><u>E-i</u></b>

## **Appendix E**

### **Additional Hyporheic Zone and Groundwater Monitoring**

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## Contents

<b>E1</b>	<b>Introduction</b> .....	<b>E-1</b>
	E1.1 Scope .....	E-1
	E1.2 Draft Remedial Investigation Results.....	E-2
	E1.2.1 Physical Setting .....	E-2
	E1.2.2 Nature and Extent of Contamination .....	E-3
	E1.2.3 Contaminant Fate and Transport .....	E-5
	E1.3 Data Quality Objectives .....	E-6
	E1.3.1 Hyporheic Zone .....	E-6
	E1.3.2 Groundwater .....	E-14
<b>E2</b>	<b>Work Plan Tasks</b> .....	<b>E-17</b>
	E2.1 Hyporheic Zone.....	E-17
	E2.2 Groundwater.....	E-18
<b>E3</b>	<b>References</b> .....	<b>E-20</b>

## Figures

Figure E-1.	Hexavalent Chromium in the Upper Unconfined Aquifer at 100-BC-5, 2011.....	E-4
Figure E-2.	Proposed Locations of Hyporheic Zone Sampling Stations (Aquifer Tubes).....	E-9
Figure E-3.	Proposed Groundwater Monitoring Wells.....	E-10

## Tables

Table E-1.	DQOs for Additional Hyporheic Zone and Groundwater Monitoring .....	E-7
Table E-2.	Proposed Monitoring Wells.....	E-19

## Terms

BCG	biota concentration guide
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FS	feasibility study
MTCA	<i>Model Toxics Control Act</i>
OU	operable unit
PNNL	Pacific Northwest National Laboratory
RCBRA	River Corridor Baseline Risk Assessment
RI	remedial investigation
SAP	sampling and analysis plan
TPA	<i>Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)</i>

## E1 Introduction

The tasks outlined in the main body of this document and the related *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (hereafter referred to as the Remedial Investigation Sampling and Analysis Plan [RI SAP]) (DOE/RL-2009-44), were designed to fill data gaps related to the nature and extent of contamination and its fate and transport in the environment. Recent developments have revealed additional uncertainties and a need to collect additional data before making a decision about remediation.

In 2012, deep excavation of soil at the 100-C-7:1 waste site to just above the water table identified that some hexavalent chromium (Cr[VI]) contamination was still present at the bottom of the excavation. In addition, Cr(VI) concentrations in a downgradient well (199-B4-14) had started increasing significantly, from 40 µg/L in October 2011 to 179 µg/L in April 2012. In order to address this emerging condition and clarify the potential extent of groundwater contamination in the area, additional investigation of this Cr(VI) contamination was initiated under a *Hanford Federal Facility Agreement and Consent Order* (TPA) Change Notice modifying Chapter 4 of the main text of this document (TPA-CN-543). That additional investigation was described in the *Sampling Instruction: Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site* (PNNL-21393). The results of the investigation are provided in *Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site* (PNNL-21845).

Additional studies are needed to reduce uncertainties relating to the following:

- Upcoming completion of vadose zone (waste site) remediation
- Short-term changes in groundwater contaminant concentrations related to waste site remediation activities
- Modeling results that show it will likely take a long time for the large, low-concentration Cr(VI) plume to attenuate
- Variable contaminant concentrations in Columbia River pore water, creating uncertainties about the level of risk

The U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) have agreed that additional studies are needed before remedial action alternatives for groundwater can be evaluated (proposed TPA Change M-15-12-03). This appendix describes the objective of the planned studies, the work plan rationale, and tasks. Details of the work are described in a revision to the RI SAP (DOE/RL-2009-44).

### E1.1 Scope

This appendix addresses additional data needs identified subsequent to completion of RI studies performed under the main text (Chapter 4) of this document. These additional data needs pertain to (1) the hyporheic zone of the Columbia River adjacent to the 100-BC-5 Groundwater Operable Unit (OU), and (2) groundwater in the unconfined aquifer in the 100-BC-5 OU.

The *hyporheic zone* is a region beneath and alongside a stream where shallow groundwater mixes with surface water. The thickness of this zone varies with physical conditions such as sediment type and hydraulic head. The hyporheic zone has strong impact upon aquatic life, so for the purposes of this study, it is defined as the portion of the streambed where aquatic life may be present. This may be as little as 10 cm (4 in.) for some species or as much as 0.5 m (18 in.) for salmon redds (i.e., depressions in gravel

where salmon lay eggs during spawning season). As described in Appendix A (SAP) of the *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (DOE/RL-2008-11), pore water samples for the Columbia River risk assessment were collected from 15 to 30 cm (6 to 12 in.) below the riverbed. As acknowledged in the *Columbia River Component Risk Assessment, Volume 1: Ecological Risk Assessment* (hereafter referred to as the CRC) (DOE/RL-2010-117), pore water at this depth is below the zone inhabited by most (but not all) benthic invertebrates (*Aquatic Insect Ecology: Biology and Habitat* [Ward, 1992]). For this study, the hyporheic zone that will be evaluated is the upper 0.5 m (1.6 ft) of the river bed.<sup>1</sup> The 10 µg/L Cr(VI) chronic water quality standard for surface waters in the state of Washington (Table 240[3] of WAC 173-201A-240, “Water Quality Standards for Surface Waters of the state of Washington”) is assumed here to apply to water in the hyporheic zone, as well as to surface water in the Columbia River.

Section E1.2 provides a brief summary of previous RI studies that relate to groundwater and the hyporheic zone. Those studies, as described in Chapter 4 of the main text of this document and in a related SAP (DOE/RL-2009-44), included installing and sampling groundwater monitoring wells, defining hydrogeologic units and groundwater flow, and determining the nature and extent of groundwater contamination. The resulting data were used to create a conceptual site model.

The additional studies outlined in this appendix will be used to refine the conceptual site model and form the basis for recommending a remedial action alternative. The planning team developed the studies using EPA’s *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA/240/B-06-001). The seven steps of that process are outlined in Section E1.3, and the resulting studies are summarized in Section E.2.

## E1.2 Draft Remedial Investigation Results

DOE completed the work plan tasks outlined in Chapter 4 of this document in 2010 and 2011. The results were evaluated and interpreted to fill the data gaps identified in the work plan. Staff began compiling those results and interpretations into a RI/feasibility study (FS) report. Before the report was finalized, DOE and EPA recognized the need for additional studies. While not complete, that draft report contains a wealth of information about the 100-BC Area and is being published in draft form as the *Remedial Investigation/Feasibility Study Report for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* (DOE/RL-2010-96). This section briefly summarizes main points that pertain to groundwater and the hyporheic zone.

### E1.2.1 Physical Setting

The vadose zone comprises unconsolidated gravel and sand of the Hanford formation. This formation in the 100-BC-5 OU is characterized by cobble- to boulder-size gravels that include discrete sand lenses with very little silt and clay material. The vadose zone is up to 30 m (98 ft) thick in inland portions of 100-BC-5.

The RI activities provided data that helped characterize the uppermost aquifer and aquitard. The uppermost aquifer is unconfined and comprises primarily the sands and gravels of Ringold Formation unit E. Beneath most of the area, the bottom portion of the Hanford formation is also saturated. The saturated thickness of the Hanford formation generally increases to the south, ranging up to 6 m (20 ft). The Ringold upper mud, a low-permeability geologic unit, forms the bottom of the unconfined

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<sup>1</sup> This depth is selected to minimize river water infiltration and, thereby, be more reflective of the 100-BC-5 Groundwater OU source than the river. In addition, samples from this depth will be characteristic of potential exposure in salmon redds, should they be established in the area of upwelling.

aquifer. RI data showed that this unit is continuous in the 100-BC-5 OU and slopes toward the west. Aquifer thickness ranges from 29 to 47 m (95 to 154 ft), increasing to the west.

Slug tests were performed for the RI to determine horizontal hydraulic conductivity. The two wells screened in the Ringold upper mud unit had the lowest hydraulic conductivity, approximately 1 m/d (3 ft/d). Wells screened in Ringold unit E had hydraulic conductivity ranging from 2.5 to 16 m/d (8.2 to 52 ft/d). Wells screened in the Hanford formation had the highest hydraulic conductivity, beyond the range suitable for determining with slug tests. A subsequent study determined this unit has a hydraulic conductivity of 6,100 m/d (20,000 ft/d) (PNNL-21845).

The water table lies at a depth of 0 m (0 ft) adjacent to the river to 30 m (98 ft) inland. The water table is nearly flat in southern 100-BC-5 and steepens toward the Columbia River. In the southern 100-BC-5, water-level data and tracer tests showed that the gradient dips to the northeast, and flow rates may be as high as 7 m/d (23 ft/d) (PNNL-21845). In the northern 100-BC-5, the aquifer is in the Ringold unit E, where hydraulic conductivity is lower and the hydraulic gradient is steeper. Groundwater flow rates range from 0.03 to 0.29 m/d (0.1 to 1 ft/d) toward the north, except when river stage is very high and the gradient is reversed.

Groundwater discharges via springs and areas of upwelling through the river bed. Recent studies of the river created maps of these areas of upwelling (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume 1: Ecological Risk Assessment* [RCBRA]; DOE/RL-2010-117 [Volume 1 of the CRC]; WCH-380, Rev. 1, *Field Summary Report for Remedial Investigation of the Hanford Site Releases to the Columbia River, Hanford Site, Washington*; WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*; and SGW-49368, *Columbia River Pore Water Sampling in 100-BC Area, November 2010*).

## **E1.2.2 Nature and Extent of Contamination**

Data collected for the RI helped to characterize the extent of contaminant concentrations in the groundwater and the hyporheic zone of the Columbia River.

### ***E1.2.2.1 Groundwater***

Contaminants of potential concern in 100-BC-5 groundwater include Cr(VI), strontium-90, and tritium. Data from 10 wells installed for the RI helped define the extent of these contaminants horizontally and vertically. Key elements of the nature and extent of groundwater contamination include the following.

- Cr(VI) exceeds 10 µg/L in much of the 100-BC-5 OU (Figure E-1). Three wells had concentrations above the groundwater cleanup standards (WAC 173-340-720, “Model Toxics Control Act–Cleanup,” “Groundwater Cleanup Standards”) of 48 µg/L at least once in 2010 through early 2012. The extent of the 10 µg/L plume contour remains uncertain.
- Groundwater data collected during the RI indicated that Cr(VI) concentrations decrease with depth in the eastern 100-BC-5. In the western 100-BC-5, concentrations are the highest at the top and bottom of the aquifer, and lower in between. Uncertainties remain in some areas.
- Strontium-90 exceeds the 8 pCi/L drinking water standard (DWS) in a plume in northeastern 100-BC-5. Concentrations decline with depth in the aquifer. All concentrations in groundwater are below the biota concentration guide (BCG) of 278 pCi/L (DOE STD-1153-2002).

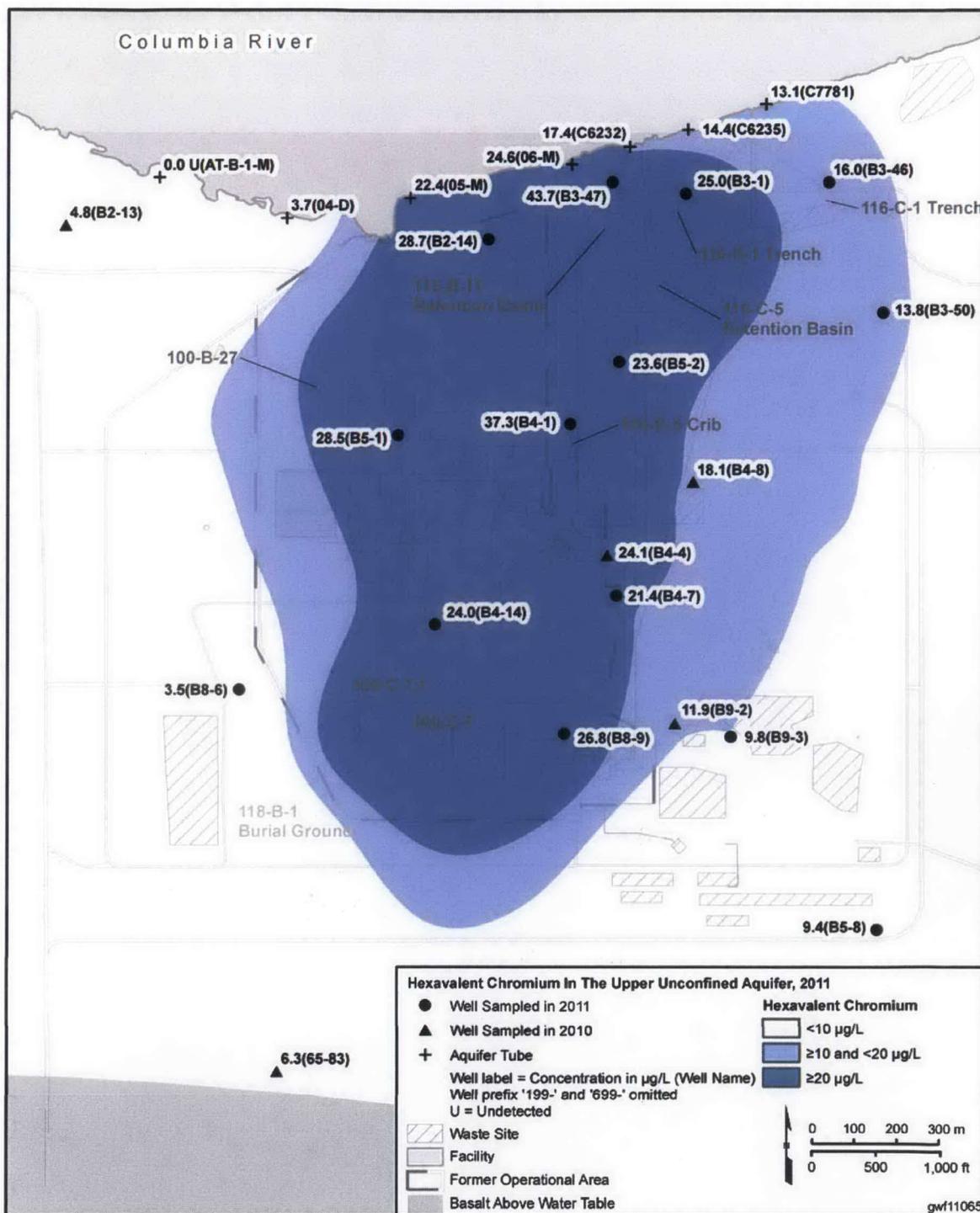


Figure E-1. Hexavalent Chromium in the Upper Unconfined Aquifer at 100-BC-5, 2011

- Tritium concentrations exceed the 20,000 pCi/L DWS in a narrow plume in northern 100-BC-5 and a larger, less-defined plume in southern 100-BC-5. Concentrations generally decline with depth. Current concentrations in groundwater are below the 265,000 pCi/L BCG (DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*).
- Trends in Cr(VI) and tritium concentrations indicate that the plumes are migrating from the southern portion of 100-BC-5 toward the northeast.
- Groundwater contamination is limited to the unconfined aquifer. Wells screened in a confined aquifer of the Ringold Formation are uncontaminated.

#### ***E1.2.2.2 Hyporheic Zone***

As groundwater approaches the Columbia River, it enters a zone of interaction with river water. The water in the zone of interaction is a mixture of groundwater and river water, as evidenced by lower specific conductance. Mixing continues in the pore water of shallow river sediments. Recent studies show that specific conductance of pore water rapidly declines as the river rises.

Groundwater from the unconfined aquifer in 100-BC-5 eventually discharges to the Columbia River near the shoreline and farther out in the channel. Columbia River pore water was sampled during periods of low river flow three times (WCH-380, WCH-398, SGW-49368). The results of the three pore water sampling campaigns included the following:

- Cr(VI) concentrations in the first campaign ranged from below detection limits to a maximum of 112 µg/L.
- During the second campaign, Cr(VI) concentrations were lower (maximum of 46 µg/L). Concentrations of tritium and strontium-90 were below applicable standards in pore water. All contaminant concentrations, including Cr(VI), were below standards in river water.
- Cr(VI) concentrations were lower still in the third pore water sampling campaign (maximum of 13.6 µg/L), but 3 of 11 samples remained slightly above 10 µg/L.

All three pore water sampling campaigns were conducted during times of low river stage and specifically investigated zones of demonstrated groundwater upwelling. Thus, these studies were designed to reflect a worst-case scenario for pore water contamination. When the river level rises, less groundwater discharges to the river. Thus, Cr(VI) concentrations during periods of higher river stage are expected to be lower than concentrations during low river stage. Seasonal variability is an area of uncertainty that will be investigated by the additional tasks outlined in Section E2.1.

#### **E1.2.3 Contaminant Fate and Transport**

Understanding contaminant fate and transport in the environment is an important part of the RI/FS process. Projections of future contaminant behavior and concentrations at points of exposure are needed to assess potential threats to human health and the environment. The results support decisions about cleanup of waste sites and groundwater. Final decisions for 100-BC have not yet been made, but some of the highlights of initial fate and transport evaluations (DOE/RL-2010-96) are as follows:

- Eighty-one previously remediated waste sites were evaluated to assess the potential for groundwater and surface water quality impacts under native vegetation and irrigation conditions. A few of those waste sites may pose a threat to groundwater or surface water quality and require further consideration.

- Contaminant transport simulations indicate that Cr(VI) concentrations in groundwater along the river shoreline may persist at concentrations above 10 µg/L for more than 100 years, and above the 48 µg/L groundwater cleanup level for up to 11 years. The persistence of Cr(VI) in 100-BC-5 groundwater is attributed to slow transport and degradation rates. However, it is likely that results of the model will change, based on updated input parameters.
- The computer simulations estimated that tritium will decay to concentrations below the DWS in 5 to 15 years, and strontium-90 within 50 to 75 years.

### E1.3 Data Quality Objectives

The data quality objective (DQO) process is a series of logical steps that guide managers or staff to a plan for the resource-effective acquisition of environmental data (EPA/240/B-06-001). The seven-step DQO process was applied to the two major areas of uncertainty: (1) the hyporheic zone, and (2) groundwater.

#### E1.3.1 Hyporheic Zone

The DQO process should identify which aquatic life receptors or receptor groups to protect in order to focus each of the components of the analysis. For some sites, the analysis would be focused on protecting the benthic community made up of multiple species fulfilling various functions in the aquatic food web. At other sites, protection of a single population of a specific benthic species (e.g., a culturally significant, commercially significant, or indicator species bivalve) may be more appropriate. Threatened or endangered species would be protected at the individual level. Thus, identifying these entities, the attributes of these entities to protect, and the measure (threshold) at which to protect them is tied to how the DQOs are developed and the data are evaluated. These entities, attributes, and measures are commonly referred to as assessment and measurement endpoints (EPA/630/R-95/002F; *Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]) and are typically developed as part of the ecological risk assessment (ERA) presented within the RI/FS. For the Columbia River, assessment and measurement endpoints for the near-shore environment were presented in the RCBRA (DOE/RL-2007-21) and for the mid-channel were presented in the CRC (DOE/RL-2010-117).

From the aquatic food webs and the endpoints presented in the documents cited above, benthic organisms are the most sensitive species, with effect thresholds for Cr(VI) several times lower than those for fish species. The 10 µg/L chronic water quality standard is based upon toxicity to benthic organisms, not fish. The data used to develop Cr(VI) ambient water quality criteria show chronic values for fish from seven tests with a range of 51 to 1,122 µg/L, with a geometric mean of 177 µg/L (EPA 440/5-80-035, *Ambient Water Quality Criteria for Chromium*), whereas the value that was used to set the ambient water quality criterion is 10 µg/L. Studies at Pacific Northwest National Laboratory (PNNL) conducted with Hanford Site groundwater are consistent with the studies reported in the ambient water quality criteria document, showing that the survival, development, and growth of early life-stage fall Chinook salmon from the eyed-egg stage to swim-up stage were not adversely affected by Cr(VI) concentrations of 11 to 266 µg/L (PNNL-13471, *Chromium Toxicity Test for Fall Chinook Salmon [*Oncorhynchus tshawytscha*] Using Hanford Site Groundwater: Onsite Early Life-Stage Toxicity Evaluation*). Therefore, the primary focus of the DQOs for the hyporheic zone will be benthic organisms. However, if the magnitude of detection reaches levels observed to result in toxicity to fish or salmon, then they will also be included in the analysis.

The first page of Table E-1 summarizes the DQO results for investigating the hyporheic zone.

Table E-1. DQOs for Additional Hyporheic Zone and Groundwater Monitoring

Hyporheic Zone			
<b>Problem Statement (Step 1):</b> There are detectable levels of Cr(VI) in the hyporheic zone adjacent to 100-BC-5 but it is uncertain whether these levels reflect an exposure that poses a risk to aquatic receptors warranting remedial action.			
<b>Study Goals (Step 2):</b> (1) Characterize the risk to aquatic receptors posed by Cr(VI) in pore water within the hyporheic zone potentially impacted by releases from 100-BC-5, and (2) obtain data to support selecting a preferred alternative for the RI/FS for 100-BC-5 groundwater.			
Study Input (Step 3)	Study Boundaries (Step 4)	Data Evaluation Approach (Step 5)	Performance and Acceptance Criteria (Step 6)
<ol style="list-style-type: none"> <li>1. Conceptual site model</li> <li>2. Scientific literature regarding the fate and transport of chromium in the environment</li> <li>3. Measured concentrations of Cr(VI) and other chemicals in groundwater, surface water, pore water, and sediment</li> <li>4. Measurements of geochemical parameters that influence chromium speciation and bioavailability</li> <li>5. Delineation of groundwater upwelling areas</li> <li>6. Delineation of surface water column</li> <li>7. Geophysical survey results (bathymetry and sub-bottom profiling)</li> <li>8. Toxicological data supporting the surface water quality standards</li> <li>9. Geologic data</li> <li>10. Water-level data</li> <li>11. Historical site-specific community survey and toxicological data</li> </ol>	<ol style="list-style-type: none"> <li>1. Lateral:               <ol style="list-style-type: none"> <li>a. Study area extends from the 100-BC Area shoreline (high watermark) to a point past the low watermark where river depth is approximately 1 m.</li> </ol> </li> <li>2. Vertical:               <ol style="list-style-type: none"> <li>a. The biologically active zone (approximately 0.5 m).</li> </ol> </li> <li>3. Temporal:               <ol style="list-style-type: none"> <li>a. Seasonal variations in river stage</li> <li>b. Daily 24-hour cycles at low flow and other periods</li> <li>c. Sampling equipment must be installed no later than November 30, 2013</li> <li>d. Initial sampling must be conducted in fall 2013 (at time of low water)</li> <li>e. All sampling must be completed by fall 2015</li> </ol> </li> <li>4. Chemical:               <ol style="list-style-type: none"> <li>a. Cr(VI) and total chromium</li> <li>b. Hydrogen and strontium-90 periodically for a reduced lateral extent</li> </ol> </li> </ol>	<p>Analytical data will be reviewed to assess the magnitude and spatial and temporal patterns of Cr(VI) concentrations by answering the following questions with respect to Cr(VI) in the hyporheic zone of the Columbia River in the vicinity of 100-BC:</p> <ol style="list-style-type: none"> <li>1. Is groundwater upwelling a potential source of Cr(VI) concentrations in pore water that are continuing to exceed the surface water quality standards?</li> <li>2. Is exposure to organisms in hyporheic zone above toxicity thresholds for the most sensitive receptor group (e.g., benthic organisms or salmonids) present at the time of sampling?</li> <li>3. Is the area of groundwater upwelling with concentrations above the surface water quality standards or toxicity thresholds large enough to result in an adverse effect to the receptor groups present in the hyporheic zone (e.g., benthic community or salmonid population)?</li> <li>4. Do the measured concentrations of Cr(VI) warrant remedial action and, if so, where? See text for additional detail.</li> </ol>	<ul style="list-style-type: none"> <li>• Analytical data collected must have a practical quantitation limit at or below 10 µg/L.</li> <li>• Samples will be collected and analyzed via procedures specified in the project quality assurance project plan found in the remedial investigation sampling and analysis plan (DOE/RL-2009-44).</li> <li>• The data will be collected in a manner and frequency to support the calculation of both a 1-hour average and 4-day running arithmetic mean concentration of Cr(VI).</li> </ul>
<p><b>Plan for Obtaining the Data (Step 7):</b></p> <p>Aquifer tube sampling:</p> <ol style="list-style-type: none"> <li>1. Locations for pore water (see Figure E-2).</li> <li>2. Establish new shallow aquifer tube stations: three upstream stations, eight stations within the plume (paired with existing aquifer tubes), and three downstream stations.</li> <li>3. On a monthly basis, sample in-stream hyporheic zone pore water at all new locations.</li> <li>4. Sample in-stream hyporheic zone pore water at eight stations, every 6 hours over a 96-hour period, once per month.</li> <li>5. Sample in-stream hyporheic zone pore water at eight stations hourly for a 24-hour period once per month.</li> <li>6. Collect overlying river water with pore water samples to understand conductivity and temperature.</li> <li>7. Analyze samples from new stations for the following parameters: total chromium, Cr(VI), geochemical parameters (dissolved oxygen, pH, temperature, conductivity, reduction-oxidation, dissolved organic carbon, Fe[II], and Mn[II]).</li> <li>8. Analyze all or a subset of samples from new stations for tritium and strontium-90 during low-flow conditions.</li> </ol>			

Table E-1. DQOs for Additional Hyporheic Zone and Groundwater Monitoring

Groundwater			
<p><b>Step 1 Problem Statement:</b> Remediation of waste sites (secondary contaminant sources) in 100-BC is virtually complete, and groundwater contaminant concentrations are expected to change in response. Uncertainties in the hydrogeologic information (nature and extent vertically and laterally; natural attenuation processes in aquifer and approaching river, hydrogeologic layers, and hydraulic head) need to be resolved prior to the selection of a preferred alternative.</p> <p><b>Step 2 Goal of the Study:</b> Obtain data to support selecting a preferred alternative for the RI/FS for 100-BC-5 groundwater.</p>			
Study Input (Step 3)	Study Boundaries (Step 4)	Data Evaluation Approach (Step 5)	Performance and Acceptance Criteria (Decision Rules) (Step 6)
<ol style="list-style-type: none"> <li>Conceptual site model</li> <li>Scientific literature regarding the fate and transport of chromium in the environment</li> <li>Measured concentrations of Cr(VI) and other chemicals in groundwater</li> <li>Measurements of geochemical parameters that influence chromium speciation</li> <li>Geologic data</li> <li>Water-level data</li> <li>RI/FS groundwater model</li> <li>Removal of Cr(VI) sources at 100-C-7 and 100-C-7.1</li> <li>Pacific Northwest National Laboratory test results at 100-C-7.1</li> </ol>	<ol style="list-style-type: none"> <li>Lateral: general 100-BC Area.</li> <li>Vertical: unconfined aquifer.</li> <li>Temporal:               <ol style="list-style-type: none"> <li>Sampling equipment must be installed no later than September 30, 2013.</li> <li>Sampling must be completed by fall 2015.</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>Nature and extent of Cr(VI):               <ol style="list-style-type: none"> <li>Concentrations of Cr(VI) in groundwater will be compared with the MTCA standard (48 µg/L) and the chronic surface water quality standards (10 µg/L). If the extent exceeding the standards is delineated, then the extent of contamination will be defined.</li> <li>If the extent of contamination is not delineated, then consider extending the study boundaries.</li> </ol> </li> <li>Groundwater model: If hydrogeologic conditions are significantly different from the previous conceptual site model, then update the groundwater model.</li> <li>Determine natural attenuation processes for Cr(VI) in the unconfined aquifer in the 100-BC-5 Operable Unit.               <ol style="list-style-type: none"> <li>Is the plume is stable or shrinking?</li> <li>Are concentrations along flow path declining?</li> <li>Are reduction, dispersion, and/or dilution driving the contaminant reduction?</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>Nature and extent: If the horizontal and vertical extent of Cr(VI) contamination has been determined and is sufficient to select the preferred alternative, then goal is achieved.</li> <li>If hydrogeologic conditions have been determined and are sufficient to update the model, then the goal is achieved.</li> <li>If sufficient data have been collected to determine if attenuation is occurring based on plume stability, concentration trends, and natural processes, then evaluate monitored natural attenuation as an alternative.</li> </ol>
<p><b>Plan for Obtaining the Data (Step 7):</b></p> <ol style="list-style-type: none"> <li>Install shallow and deep monitoring wells (see Figure E-3).</li> <li>Sample groundwater during drilling to obtain Cr(VI) profiles with depth through the unconfined aquifer.</li> <li>Perform geologic sampling during drilling to identify contacts between the Hanford formation and Ringold Formation unit E, and the Ringold unit E and the Ringold upper mud.</li> <li>Equip selected wells with pressure transducers and data loggers for hydraulic head.</li> <li>Sample monitoring well network for Cr(VI) and reduction-oxidation-affecting parameters.</li> <li>Install aquifer tubes at various depths in the hyporheic zone and monitor reduction-oxidation-affecting parameters to determine if chemical reduction is occurring.</li> </ol> <p>MTCA – Model Toxics Control Act RI/FS – remedial investigation/feasibility study</p>			

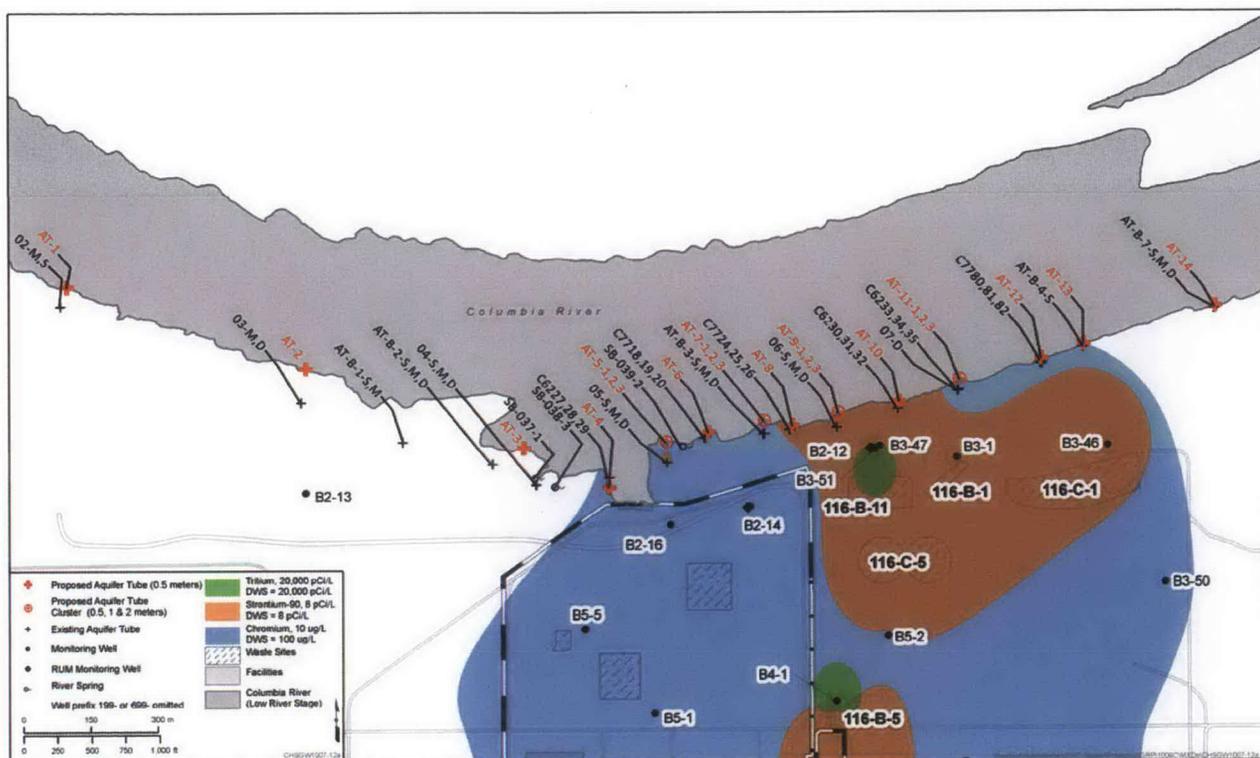


Figure E-2. Proposed Locations of Hyporheic Zone Sampling Stations (Aquifer Tubes)



- **Step 1, Problem Statement:** There are detectable levels of Cr(VI) in the hyporheic zone adjacent to 100-BC-5, but it is uncertain whether these levels reflect an exposure that poses a risk to aquatic receptors warranting remedial action.

Three rounds of sampling the hyporheic zone found Cr(VI) concentrations in some zones of groundwater upwelling exceeded 10 µg/L (WCH-380, WCH-398, SGW-49368). Concentrations were not consistent among the three rounds of sampling at many of the locations, and it is not known how the concentrations vary seasonally. Further, it is not known whether the observed levels are actually posing a risk to aquatic receptors.

- **Step 2, Study Goals:** (1) Characterize the risk to aquatic receptors posed by Cr(VI) in pore water within the hyporheic zone potentially impacted by releases from 100-BC-5 groundwater, and (2) obtain data to support selecting a preferred alternative for the 100-BC-5 RI/FS.

The goal of all of the RI studies is to obtain the data needed to make an informed, defensible decision about cleaning up the vadose zone and groundwater in 100-BC. The additional studies described in this section relate specifically to the hyporheic zone and will support the recommendation of a preferred alternative for groundwater remediation.

- **Step 3, Study Input:** What are the kinds of information needed to formulate and investigate the problem?

Input to this phase of the investigation includes the conceptual site model, as described in the draft RI report (DOE/RL-2010-96). The conceptual site model was based on groundwater studies and sampling of river water, pore water, and sediment in the Columbia River near 100-BC-5 (WCH-380, WCH-398, SGW-49368). Other input includes scientific literature regarding the fate, transport, and potential toxicity of chromium and Cr(VI) to aquatic and benthic organisms in the environment, measurements of geochemical parameters that influence chromium speciation and bioavailability, and historic site-specific community survey and toxicological data.

- **Step 4, Study Boundaries:** Define the target population, the geographic and temporal boundaries, and examine any practical constraints to collecting data.

EPA/240/B-06-001 defines the “target population” as “the total collection... of sampling units to be studied... When the target population consists of continuous media, such as air, water, or soil, the sampling unit must be defined as some area, volume, or mass that may be selected from the target population.” For this study, the target population comprises all possible samples of water from the Columbia River hyporheic zone in 100-BC. Previous studies (WCH-398, DOE/RL-2007-21, DOE/RL-2010-117) have shown that water from the river itself meets water quality standards.

Lateral boundaries extend along the shoreline from the ordinary high water mark to a point past the low water mark where river depth is approximately 1 m (3 ft). Although upwelling has been found to occur in deeper portions of the river (WCH-380), practical constraints limit the use of ongoing sampling at those locations. Results from near-shore monitoring will be applicable to the entire hyporheic zone. It is also recognized that in the previous three rounds of hyporheic zone sampling, sampling sites with Cr(VI) concentrations persistently above 10 µg/L were located in areas where the water depth was 1 m (3 ft) or less during low river stage (SGW-49368).

It is desirable to locate new hyporheic zone sampling points near existing groundwater sampling points to study the interaction of groundwater and surface water. The shoreline at 100-BC-5 currently has shallow groundwater sampling points (aquifer tubes) that are sampled to monitor groundwater approaching the river. Because the screens on these tubes are 2 to 8 m (6.6 to 26 ft) deep, they do not

monitor the hyporheic zone; however, they provide useful information on the zone of groundwater and surface water interaction. The existing aquifer tubes, which are spaced approximately 100 m (330 ft) apart, are available for continued monitoring.

Vertical boundaries include the biologically active zone (upper approximately 0.5 m [1.6 ft]) of the riverbed. Most aquatic life is expected to reside in the upper few inches. However, sampling that zone is constrained by the likelihood that when the aquifer tubes are pumped, river water would be drawn into the sample. Therefore, it is more conservative to sample deeper in the riverbed.

Temporal boundaries are defined by TPA Change M-15-12-03 and were developed based on the need to monitor daily and seasonal variations in river stage. The milestone specifies that aquifer tubes be installed no later than November 30, 2013. The initial round of sampling must be conducted at time of low water in 2013. Two years of sampling will include two seasonal cycles of river stage changes. Sampling must be completed by fall 2015 so the results can be evaluated for a revised RI/FS report in 2016.

Chemical boundaries focus on Cr(VI), which was the only contaminant of potential concern that exceeded a water quality standard in the hyporheic zone during previous sampling. Total chromium, tritium, and strontium-90 will be monitored periodically to determine their lateral extent, but they are not the primary focus of this investigation.

Practical constraints include the following:

- **River stage:** Typically varies more than 4 m (13 ft) over the year; aquifer tubes need to be extended above the high water mark for sampling during periods of high river stage.
- **Water depth:** To access sample locations that are submerged at all times of the year, aquifer tubes need to be installed through the water column.
- **Durability:** Aquifer tubes need to withstand river currents that shift rocks and carry vegetation, and need to be protected from wildlife.
- **Pumping rates:** Pumping rates from the aquifer tubes must be low to avoid drawing river water into the tubes.
- **Substrate conditions:** In most locations in the study area, the riverbed is made up of cobble- to boulder-size gravel. Installation procedures must take this into account.
- **Weather conditions:** Weather conditions may prevent obtaining samples (e.g., water frozen in aquifer tubes).
- **Step 5, Data Evaluation Approach:** What approach will be used to draw conclusions from the study results?

Analytical data will be reviewed to assess the magnitude, spatial, and temporal patterns of Cr(VI) concentrations relative to toxicity thresholds (including the surface water quality standard). For significant risk to aquatic life to exist in the hyporheic zone, aquatic life must be exposed to a source of a contaminant at a level (magnitude) that will result in an adverse effect (i.e., toxic threshold). This exposure must be for a period of time (temporal pattern) great enough to affect the organisms. Finally, the area over which the upwelling of elevated concentrations of significant duration is occurring (spatial pattern) must be large enough to result in an impact to the aquatic community or local populations of sensitive organisms.

The analysis will address the following questions:

1. Is upwelling groundwater a potential source of Cr(VI) concentrations in pore water that are continuing to exceed the surface water quality standards?
2. Is exposure to organisms in the hyporheic zone above toxicity thresholds for the most sensitive receptor group (e.g., benthic organisms or salmonids) present at the time samples were collected?
3. Is the area of groundwater upwelling with concentrations above the surface water quality standards or toxicity thresholds large enough to result in an adverse effect to the receptor groups present in the hyporheic zone (e.g., benthic community or salmonid population)?
4. Do the measured concentrations of Cr(VI) warrant remedial action and, if so, where?

**Magnitude:** Evaluations of the magnitude of Cr(VI) in the hyporheic zone will focus on how concentrations compare to the 10 µg/L surface water quality standard. As such, the data to compare to the standard will be compiled as described in the state of Washington standard (Table 240[3] of WAC 173-201A-240) as 4-day averages compared to the 10 µg/L standard for chronic exposures and a 1-hour average compared to the 15 µg/L standard for acute exposures. An exceedance of these standards could be indicative of adverse effects to aquatic life (e.g., benthic organisms, fish, aquatic plants, etc.). Therefore, when an exceedance is observed, further analysis of spatial and temporal trends of the source should be conducted to understand the likelihood of an adverse effect occurring.

**Temporal:** Evaluations of the temporal trends in the hyporheic zone will focus on whether concentrations of Cr(VI) above the surface water quality standards coincide with the presence of a sensitive life stage for organisms in the hyporheic zone. Exposure to the various organisms in the hyporheic zone will vary seasonally as each has a unique lifecycle pattern. Sensitivity of each organism differs, and the effects to all organisms do not occur at the same exposure concentrations. Thus, the most sensitive organisms for a given season could vary. The temporal analysis will map out the life stages of the key aquatic life receptor groups identified in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) to determine the most sensitive receptor groups during each of the monitoring periods proposed in this work plan so the Cr(VI) measurements can be compared with the toxicity thresholds for the relevant receptors present at that time. The temporal analysis will also include a time-trend component to help evaluate if there are any increasing, static, or decreasing trends in Cr(VI) concentrations in upwelling areas.

**Spatial:** The Columbia River, even at its lowest river stage, is a massive water body with natural drift of thousands of benthic organisms on a daily basis. If elevated Cr(VI) concentrations do potentially impact benthic organisms, this natural drift brings a continuous source of organisms that would help to re-colonize the impacted community. Each year, salmon are creating large areas of redds (i.e., depression in gravel for laying eggs during spawning season) up and down the Columbia River, including both upstream of the 100-BC-5 OU upwelling area and downstream near Wooded Island. With aquifer tube monitoring stations spaced approximately 100 m (330 ft) apart, each station represents approximately 100 m (330 ft) of shoreline. The spatial analysis will consider the proximity of any exceedances of the surface water quality standards or toxicity thresholds to each other and to salmon redds or benthic habitat. Exceedances at contiguous locations could suggest potential adverse effects. Conversely, the further apart exceedances occur, the less likely the exceedances are to have any significant impact to aquatic organisms. The spatial analysis will be combined with a temporal analysis to note any repeated trends of spatial patterns and help ascertain if spatial patterns warrant further evaluation.

**Support to selecting a preferred alternative for the 100-BC-5 RI/FS:** The evaluation of the magnitude, temporal, and spatial trends of Cr(VI) concentrations in the areas of upwelling from 100-BC-5 groundwater will be used within the ecological risk assessment presented in the RI to help make a risk management decision. The results of the evaluation will help in deciding whether there is risk to aquatic organisms, where that risk is occurring, and whether the risk is decreasing with time. This information will help risk managers decide if the identified risks are acceptable or unacceptable. These risk outcomes and the results of the magnitude, spatial, and temporal analyses will also help with development of the FS, selecting a preferred alternative (e.g., monitoring actions versus active remedies), focusing where to implement the alternative, and establishing performance criteria.

- **Step 6, Performance and Acceptance Criteria:** Specify decision rules.

The following performance criteria for the data are required to support the decisions specified in Step 5:

- Analytical data collected must have a practical quantitation limit at or below 10 µg/L.
- Samples will be collected and analyzed via procedures specified in the project quality assurance project plan, found in Appendix B of the RI SAP (DOE/RL-2009-44).
- The data will be collected in a manner and a frequency to support the calculation of a 1-hour average and 4-day running arithmetic mean concentration of Cr(VI).

- **Step 7, Plan for Obtaining the Data:** Compile all information and outputs generated in Steps 1 through 6. Use this information to identify sampling and analysis designs.

Table E-1 lists the tasks designed to gather the data necessary to meet the project's goal (Step 2) and resolve the problem (Step 1). These tasks involve installing and sampling aquifer tubes screened in the hyporheic zone. Section E.2.1 summarizes the scope of work. An appendix to the RI SAP (DOE/RL-2009-44) will provide details.

### E1.3.2 Groundwater

The second page of Table E-1 summarizes the DQO results for investigating groundwater in the 100-BC-5 OU.

- **Step 1, Problem Statement:** Remediation of waste sites (secondary contaminant sources) in 100-BC is virtually complete, and groundwater contaminant concentrations are expected to change in response. Uncertainties in the hydrogeologic information (nature and extent, vertically and laterally; natural attenuation processes in the aquifer and approaching the river; hydrogeologic layers; and hydraulic head) need to be resolved prior to the selection of a preferred alternative.

Contamination from the 100-C-7 and 100-C-7:1 waste sites moves rapidly through the upper portion of the aquifer, which is in the highly permeable Hanford formation. The effects of the remediation are not yet evident in the deeper part of the aquifer in Ringold unit E. Concentrations downgradient of the sites are elevated but stable in this deeper portion of the aquifer.

When remediation of the 100-C-7:1 waste site is complete, there will be no more known secondary sources of contamination. The effects of remediation will pass through the aquifer and contamination will begin to attenuate. Additional data are needed to track the effects of the remediation and answer the following questions to determine if natural attenuation is occurring.

1. Is the plume stable or shrinking?
2. Are concentrations along the flow path declining?
3. Are reduction, dispersion, and/or dilution driving the contaminant reduction?

To determine if natural attenuation is a viable remedial alternative, the Cr(VI) plume needs to be defined more accurately, concentrations monitored, and the processes contributing to attenuation need to be identified.

- **Step 2, Goal of the Study:** Obtain data to support selecting a preferred alternative for the RI/FS for 100-BC-5 groundwater.

The goal of all of the 100-BC RI studies is to obtain the data needed to make an informed, defensible decision about cleaning up the vadose zone and groundwater. The additional studies described in this section relate specifically to groundwater and will support the recommendation of a preferred alternative for groundwater remediation.

- **Step 3, Study Input:** What are the kinds of information needed to formulate and investigate the problem?

Much is already known about the 100-BC-5 Groundwater OU. Entering the next phase of the investigation, input includes the conceptual site model to date, as described in the draft RI report (DOE/RL-2010-96). The conceptual site model incorporates geologic data, water levels, and hydrogeologic properties. The draft RI report also includes computer simulations of contaminant plume migration and attenuation. Additional groundwater monitoring data continued to be collected after completing the RI tasks, including Cr(VI) trends in wells downgradient of the active remediation waste sites 100-C-7 and 100-C-7:1. Other input includes scientific literature regarding the fate and transport of chromium in the environment, and measurements of geochemical parameters that influence chromium speciation.

- **Step 4, Study Boundaries:** Define the target population, the geographic and temporal boundaries, and examine any practical constraints to collecting data.

The target population comprises all possible samples of groundwater from the unconfined aquifer in the 100-BC-5 OU.

The lateral boundaries are the general 100-BC Area. Vertically, the study includes the unconfined aquifer. There is no need to collect additional data on water-bearing units in the Ringold upper mud unit, which is uncontaminated (DOE/RL-2010-96).

Practical constraints include access to groundwater samples (i.e., practical limits on the number of monitoring wells and sampling events) and sampling priorities of the overall Hanford Site groundwater monitoring program.

A significant practical constraint to sample collection during drilling is the potential to chemically reduce the groundwater, which results in lower concentrations of Cr(VI) in samples than are actually present in the groundwater. The drilling process exposes fresh iron surfaces in the aquifer, which affect reduction-oxidation-sensitive metals like chromium and manganese. The effects can be minimized by adequate purging of the borehole until dissolved oxygen levels recover.

Constraints related to sampling aquifer tubes include weather (tubes are likely to be plugged when temperature is below freezing) and limits on pumping rates.

Temporal boundaries are defined by TPA Change M-15-12-03. The wells must be sample-ready by September 30, 2013, and sampling must be completed by the fall of 2015 so the results can be evaluated to support an RI report in 2016.

Chemical boundaries focus the study on Cr(VI) because computer models show this contaminant is the slowest to attenuate, and because Cr(VI) discharges to the Columbia River at levels above 10 µg/L. Tritium and strontium-90 may be monitored to determine their lateral and vertical extent, but they are not the primary focus of this investigation.

- **Step 5, Data Evaluation Approach:** What approach will be used to draw conclusions from the study results?

The approach has three broad areas of investigation:

1. To define the **nature and extent of Cr(VI)**, concentrations in groundwater will be compared with the groundwater cleanup standard (48 µg/L) and the chronic surface water quality standard (10 µg/L). If the extent exceeding the standards is delineated, then the extent of contamination will be adequately defined. If the extent of contamination at these levels is not delineated, then consider extending the study boundaries.
2. For the **groundwater model**, if hydrogeologic conditions are significantly different from the previous conceptual site model, then update the groundwater model. It is almost certain that the model will be updated because refining geologic contacts and updating the groundwater monitoring data set will, at a minimum, be input to the model.
3. The following questions will be asked to **determine natural attenuation processes** for Cr(VI) in the unconfined aquifer in 100-BC-5.
  - a. Is the plume stable or shrinking? Uncertainties about the plume's dimensions will be reduced by installing additional monitoring wells and characterizing the plume with depth in the aquifer. The size of the plume will be monitored over time to determine if it is stable, shrinking, or growing.
  - b. Are concentrations along the flow path declining? As groundwater flows from former source areas toward the Columbia River, Cr(VI) concentrations should decline due to natural processes. The recent remediation activities at the 100-C-7 and 100-C-7:1 waste sites mobilized Cr(VI), so it is expected that concentrations will temporarily increase in downgradient wells as the pulse of Cr(VI) moves through the subsurface. After passage of that pulse, however, decreasing concentrations along the flow paths will indicate natural attenuation.
  - c. Are reduction, dispersion, and/or dilution driving the contaminant reduction? Natural attenuation processes applicable to Cr(VI) include chemical reduction to trivalent chromium, dispersion (spreading), and dilution (mixing with cleaner groundwater). By measuring parameters relating to reduction-oxidation conditions, the importance of chemical reduction can be evaluated. In the absence of reducing conditions, dispersion and dilution would be presumed to be the applicable processes.

If the plume is not stable or shrinking, concentrations along the flow path are not declining, and reduction, dispersion, and dilution are not occurring, then natural attenuation is not occurring or unidentified, continuing sources may be present.

- **Step 6, Performance and Acceptance Criteria:** Specify decision rules.

In many DQO evaluations, this step includes developing decision rules with statistical tests and associated limits on decision errors. That approach is not taken in the present case because the outcome of the tasks described in this appendix will not stand alone in the decision-making process for 100-BC-5 groundwater. Additional factors will be discussed and weighed in the RI/FS report to develop with a preferred alternative for a groundwater remedy. Hence the decision rules are more general in nature:

1. **Nature and extent:** If the horizontal and vertical extent of Cr(VI) contamination has been determined and knowledge is sufficient to select the preferred alternative, then the goal is achieved.
2. **Groundwater model:** If hydrogeologic conditions have been determined and knowledge is sufficient to update the groundwater model, then the goal is achieved.
3. **Natural attenuation:** If sufficient data have been collected to determine if attenuation is occurring based on plume stability, concentration trends, and natural processes, then evaluate monitored natural attenuation as an alternative.

- **Step 7: Develop the Plan for Obtaining the Data:** Compile all information and outputs generated in Steps 1 through 6. Use this information to identify sampling and analysis designs.

Table E-1 lists tasks for gathering the data necessary to meet the project's goal (Step 2) and resolve the problem (Step 1). The tasks are divided into three parts: (1) nature and extent, (2) groundwater model refinement, and (3) natural attenuation processes. Section E.2.2 summarizes the scope of work. Appendix B of the RI SAP (DOE/RL-2009-44) provides details.

## E2 Work Plan Tasks

This section summarizes the tasks that will be performed to gather the data needed to support remedial action decisions. Details of these studies will be described in a revision of the RI SAP (DOE/RL-2009-44).

### E2.1 Hyporheic Zone

The tasks for the hyporheic zone investigation include hyporheic zone sampling and analysis:

1. Establish new, shallow aquifer tube stations (Figure E-2): three stations upstream, eight stations within the Cr(VI) plume, and three downstream stations. The new tubes will be located near the existing, deeper aquifer tubes. Four of the stations will also include mid-depth aquifer tubes to support the groundwater portion of this investigation (Section E2.2).
2. Perform sampling at frequencies that meet the needs of the decision rules outlined in the previous section. Details of sampling will be provided in a revision of the RI SAP (DOE/RL-2009-44).
3. Analyze samples from new stations and nearby river water for the following field parameters: Cr(VI), dissolved oxygen, pH, temperature, specific conductance, and reduction-oxidation potential.
4. During periods of low river stage, analyze all or a subset of samples from new stations for supporting parameters that may include total chromium, dissolved organic carbon, ferrous iron, manganese, tritium, and strontium-90.

## E2.2 Groundwater

The tasks for the groundwater portion of this investigation are divided into three general parts. These parts overlap, and the data will support more than one part:

1. Nature and Extent:
  - a. Install shallow and deep monitoring wells (Figure E-3). The exact number of wells and their screened depths will depend on results of groundwater sampling during drilling. Table E-2 explains the intended purpose of each well.
  - b. Sample groundwater during drilling to obtain Cr(VI) profiles with depth through the unconfined aquifer. Results will help define vertical contaminant distribution and will determine the placement of well screens and contingent wells (Table E-2).
2. Groundwater model:
  - a. Perform geologic sampling during drilling to identify geologic contacts between the Hanford formation, Ringold unit E, and the Ringold upper mud. These contacts are important in defining the layers of the groundwater model because they have different hydraulic properties.
  - b. Equip selected wells with pressure transducers and data loggers for hydraulic head. Water levels at the top of the aquifer are well known, but the head at depth in the aquifer is currently measured in only a few wells. The existing transducer network will be modified by equipping some of the new, deep wells with transducers. The data will be used to refine groundwater flow directions in the model.
3. Natural attenuation processes:
  - a. Sample the monitoring well network for Cr(VI) and reduction-oxidation-affecting parameters. These parameters may include dissolved oxygen, dissolved organic carbon, sulfide, and ferrous iron. Compound-specific isotope analysis will be used on selected samples to provide direct evidence of biological or abiotic degradation of Cr(VI).
  - b. Install aquifer tubes at various depths in the hyporheic zone and monitor reduction-oxidation-affecting parameters to determine if chemical reduction is occurring in the last few meters before the groundwater discharges to the river. This sampling will be integrated with the hyporheic zone investigations outlined in Section E.2.1.

Details of these tasks will be included in a revision to the RI SAP (DOE/RL-2009-44).

Table E-2. Proposed Monitoring Wells

Number <sup>a</sup>	Location	Approach and Objectives
E1, E2 <sup>b</sup>	Northeast of 100-C-7:1 (near site)	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during drilling of second well.</p> <ol style="list-style-type: none"> <li>1. Monitor Cr(VI) concentrations and trends downgradient of former source in Hanford formation and at bottom of aquifer.</li> <li>2. Define Cr(VI) distribution with depth.</li> </ol>
E3, E4 <sup>b</sup>	Northeast of 100-C-7 (mid-distance)	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during drilling of second well.</p> <ol style="list-style-type: none"> <li>1. Monitor Cr(VI) concentrations and trends downgradient of former source in Hanford formation and at bottom of aquifer.</li> <li>2. Define Cr(VI) distribution with depth.</li> </ol>
E5	Partner with 199-B5-1	<p>Drill and sample through unconfined aquifer. Screen in lower part of aquifer.</p> <ol style="list-style-type: none"> <li>1. Define extent of Cr(VI) and trends in Ringold unit E in southern 100-BC-5 (recent decrease to &lt;10 µg/L in shallow well).</li> <li>2. Monitor hydraulic head at depth.</li> <li>3. Define geologic contacts.</li> </ol>
E6, E7 <sup>b</sup>	Eastern 100-BC-5	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during drilling of second well.</p> <ol style="list-style-type: none"> <li>1. Define extent of Cr(VI) in eastern 100-BC-5.</li> <li>2. Monitor trends in Cr(VI) in direction of migration from southern 100-BC-5.</li> <li>3. Define geologic contacts.</li> </ol>
E8, E9 <sup>b</sup>	Western 100-BC-5	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during drilling of second well.</p> <ol style="list-style-type: none"> <li>1. Define extent of Cr(VI) in western 100-BC-5.</li> <li>2. Define geologic contacts in area of high uncertainty.</li> <li>3. Monitor hydraulic head in western part of 100-BC-5.</li> </ol>

Table E-2. Proposed Monitoring Wells

Number <sup>a</sup>	Location	Approach and Objectives
E10	Partner with 199-B4-7	<ol style="list-style-type: none"> <li>1. Drill and sample through unconfined aquifer. Screen in lower part of aquifer.</li> <li>2. Define extent of Cr(VI) in Ringold E in southern 100-BC-5.</li> <li>3. Monitor trends downgradient of 100-C-7 (trends increasing in shallow well).</li> <li>4. Monitor hydraulic head at depth.</li> <li>5. Define geologic contacts.</li> </ol>
E11	Between 199-B2-16 and 199-B2-13	<ol style="list-style-type: none"> <li>1. Drill and sample through entire aquifer thickness. Screen at depth of Cr(VI) contamination, if any. Otherwise screen at water table.</li> <li>2. Define extent of Cr(VI) in northwestern 100-BC-5 (formerly elevated in well 199-B2-13).</li> <li>3. Define geologic contacts in area of high uncertainty.</li> </ol>

a. Temporary well number for identification in this appendix.

b. Installation is contingent on characterization results from another well. May not be installed.

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## TRI-PARTY AGREEMENT

Change Notice Number TPA-CN- 559	TPA CHANGE NOTICE FORM	Date: January 28, 2013									
Document Number, Title, and Revision: DOE/RL-2009-44, <i>Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study, Rev. 0</i>		Date Document Last Issued: March 2010									
Originator: Phil Burke		Phone: 376-0023									
<p><b>Description of Change:</b> This change notice adds a new appendix to the sampling and analysis plan, describing additional investigations to support the 100-BC remedial investigation. Additional data needs were identified that pertain to (1) the hyporheic zone where groundwater discharges to the Columbia River, and (2) groundwater in the unconfined aquifer of 100-BC-5.</p>											
<p><u>Briant Charboneau</u> and <u>Laura Buelow</u> agree that the proposed change  <div style="display: flex; justify-content: space-around; width: 100%;"> <span><b>DOE</b></span> <span><b>EPA</b></span> </div> modifies an approved work plan/document and will be processed in accordance with the Tri-Party Agreement Action Plan, Section 9.0, <i>Documentation and Records</i>, and not Chapter 12.0, <i>Changes to the Agreement</i>.</p> <ul style="list-style-type: none"> <li>Replace Table of Contents (pp. v and vi) with the attached revision (<u>new text shown with double underline</u>).</li> <li>Add the attached text, tables, and figures as a new appendix (Appendix B), pages B-i through B-26. (<i>The new text added as Appendix B is not double underlined. Because the entire appendix is new, the double underline would have made it difficult to read.</i>)</li> </ul>											
<p>Note: Include affected page number(s)</p>											
<p><b>Justification and Impacts of Change:</b> DOE and EPA have agreed that additional studies are needed before remedial action alternatives for groundwater can be evaluated (proposed TPA Milestone M-015-74, "Revise and submit the 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan, including the SAP, to include additional groundwater well installation and associated monitoring by 1/31/2013"). The Work Plan revision is included in TPA-CN-558.</p> <p>The additional studies include installing and monitoring new wells and shallow aquifer tubes.</p>											
<p><b>Approvals:</b></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-top: 1px solid black; padding-top: 5px;">DOE Project Manager</td> <td style="width: 15%; border-top: 1px solid black; padding-top: 5px;">Date</td> <td style="width: 35%; text-align: right; padding-top: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> <tr> <td style="border-top: 1px solid black; padding-top: 5px;">EPA Project Manager</td> <td style="border-top: 1px solid black; padding-top: 5px;">Date</td> <td style="text-align: right; padding-top: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> <tr> <td style="border-top: 1px solid black; padding-top: 5px;">Ecology Project Manager</td> <td style="border-top: 1px solid black; padding-top: 5px;">Date</td> <td style="text-align: right; padding-top: 5px;"><input type="checkbox"/> Approved <input type="checkbox"/> Disapproved</td> </tr> </table>			DOE Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved	EPA Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved	Ecology Project Manager	Date	<input type="checkbox"/> Approved <input type="checkbox"/> Disapproved
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## Contents

<b>B1</b>	<b>Introduction.....</b>	<b>1</b>
	B1.1 Data Needs .....	1
	B1.2 Contaminants of Concern.....	1
	B1.3 Project Schedule.....	1
<b>B2</b>	<b>Quality Assurance Project Plan.....</b>	<b>2</b>
	B2.1 Project Management.....	2
	B2.1.1 Quality Objectives and Criteria .....	2
	B2.1.2 Special Training/Certification.....	5
	B2.1.3 Documents and Records .....	5
	B2.2 Data Generation and Acquisition .....	5
	B2.2.1 Sampling Process Design (Experimental Design).....	5
	B2.2.2 Sampling Methods.....	5
	B2.2.3 Sample Handling and Custody .....	6
	B2.2.4 Analytical Methods.....	6
	B2.2.5 Quality Control .....	6
	B2.2.6 Instrument/Equipment Testing, Inspection, and Maintenance.....	7
	B2.2.7 Instrument/Equipment Calibration and Frequency .....	7
	B2.2.8 Inspection/Acceptance of Supplies and Consumables.....	7
	B2.2.9 Nondirect Measurements .....	7
	B2.2.10 Data Management.....	7
	B2.3 Assessment and Oversight.....	7
	B2.4 Data Validation and Usability .....	7
	B2.4.1 Data Review, Verification, and Validation.....	7
	B2.4.2 Verification and Validation Methods.....	8
	B2.4.3 Reconciliation with User Requirements .....	8
	B2.4.4 Corrective Actions .....	8
<b>B3</b>	<b>Field Sampling Plan.....</b>	<b>8</b>
	B3.1 Site Background and Objectives .....	8
	B3.2 Documentation of Field Activities .....	9
	B3.3 Sampling Design .....	9
	B3.4 Calibration of Field Equipment.....	9
	B3.5 Sample Location and Frequency .....	9
	B3.5.1 Hyporheic Zone Sampling Requirements.....	9
	B3.5.2 Groundwater Sampling Requirements.....	15
	B3.6 Sampling Methods.....	23
	B3.6.1 Hyporheic Zone Sampling Methods .....	23

B3.6.2	Groundwater Sampling Methods.....	25
B3.6.3	Corrective Actions and Deviations for Sampling Activities.....	25
B3.6.4	Decontamination of Sampling Equipment.....	25
B3.6.5	Radiological Field Data .....	25
B3.7	Sample Handling .....	25
B3.8	Waste Management .....	25
<b>B4</b>	<b>Health and Safety.....</b>	<b>26</b>
<b>B5</b>	<b>References.....</b>	<b>26</b>

## Appendixes

<b>A</b>	<b>Laboratory Standard Compound List .....</b>	<b>A-i</b>
<b><u>B</u></b>	<b><u>Sampling and Analysis Plan for Additional Hyporheic and Groundwater</u></b>	
	<b><u>Monitoring.....</u></b>	<b><u>B-j</u></b>

## Figures

Figure 1-1.	100-BC Planned New Sampling Locations.....	1-3
Figure 2-1.	Project Organization.....	2-2

## **Appendix B**

### **Sampling and Analysis Plan for Additional Hyporheic and Groundwater Monitoring**

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## Contents

<b>B1</b>	<b>Introduction .....</b>	<b>B-1</b>
	B1.1 Data Needs .....	B-1
	B1.2 Contaminants of Concern .....	B-1
	B1.3 Project Schedule .....	B-1
<b>B2</b>	<b>Quality Assurance Project Plan .....</b>	<b>B-2</b>
	B2.1 Project Management.....	B-2
	B2.1.1 Quality Objectives and Criteria .....	B-2
	B2.1.2 Special Training/Certification.....	B-3
	B2.1.3 Documents and Records .....	B-3
	B2.2 Data Generation and Acquisition .....	B-3
	B2.2.1 Sampling Process Design (Experimental Design).....	B-3
	B2.2.2 Sampling Methods .....	B-3
	B2.2.3 Sample Handling and Custody .....	B-3
	B2.2.4 Analytical Methods.....	B-6
	B2.2.5 Quality Control .....	B-6
	B2.2.6 Instrument/Equipment Testing, Inspection, and Maintenance .....	B-6
	B2.2.7 Instrument/Equipment Calibration and Frequency .....	B-6
	B2.2.8 Inspection/Acceptance of Supplies and Consumables.....	B-6
	B2.2.9 Nondirect Measurements .....	B-7
	B2.2.10 Data Management.....	B-7
	B2.3 Assessment and Oversight.....	B-7
	B2.4 Data Validation and Usability .....	B-7
	B2.4.1 Data Review, Verification, and Validation.....	B-7
	B2.4.2 Verification and Validation Methods .....	B-7
	B2.4.3 Reconciliation with User Requirements .....	B-8
	B2.4.4 Corrective Actions .....	B-8
<b>B3</b>	<b>Field Sampling Plan .....</b>	<b>B-8</b>
	B3.1 Site Background and Objectives .....	B-8
	B3.2 Documentation of Field Activities .....	B-8
	B3.3 Sampling Design .....	B-8
	B3.4 Calibration of Field Equipment.....	B-8
	B3.5 Sample Location and Frequency .....	B-9
	B3.5.1 Hyporheic Zone Sampling Requirements .....	B-9
	B3.5.2 Groundwater Sampling Requirements.....	B-14
	B3.6 Sampling Methods.....	B-23
	B3.6.1 Hyporheic Zone Sampling Methods.....	B-23

B3.6.2	Groundwater Sampling Methods .....	B-23
B3.6.3	Corrective Actions and Deviations for Sampling Activities.....	B-24
B3.6.4	Decontamination of Sampling Equipment.....	B-24
B3.6.5	Radiological Field Data .....	B-25
B3.7	Sample Handling .....	B-25
B3.8	Waste Management .....	B-25
<b>B4</b>	<b>Health and Safety .....</b>	<b>B-25</b>
<b>B5</b>	<b>References .....</b>	<b>B-25</b>

## Figures

Figure B-1.	Locations of Proposed Shallow Aquifer Sampling Tubes.....	B-10
Figure B-2.	Schematic Diagram of 100-BC Shoreline Monitoring Points: Wells, Existing Aquifer Tubes, and Proposed Shallow Aquifer Tubes .....	B-11
Figure B-3.	Monthly Average River Stage Compared to Data Percentiles .....	B-12
Figure B-4.	Locations of Existing and Planned Monitoring Wells.....	B-17

## Tables

Table B-1.	Problem Statements and Study Goals.....	B-2
Table B-2.	Analytical Performance Requirements for Chemical Analyses .....	B-4
Table B-3.	Sample Locations, Frequencies, and Sampling Methods for Hyporheic Zone Pore Water.....	B-13
Table B-4.	Proposed Monitoring Wells.....	B-15
Table B-5.	Groundwater Sampling During Drilling.....	B-18
Table B-6.	Periodic Groundwater Sampling .....	B-19
Table B-7.	Tentative AWLN for 100-BC-5 .....	B-22
Table B-8.	Sample Preservation, Containers, and Holding Times .....	B-24

## Terms

AWLN	automated water-level network
CAS	Chemical Abstract Services
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
HASQARD	<i>Hanford Analytical Services Quality Assurance Requirements Documents</i>
IC	ion chromatography
ICP	inductively coupled plasma
ID	identification
LCS	liquid scintillation counting
MS	mass spectrometry
N/A	not applicable
NTU	nephelometric turbidity unit
OU	operable unit
PVC	polyvinyl chloride
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RPD	relative percent difference
RUM	Ringold upper mud unit
SAP	sampling and analysis plan
TPA	<i>Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)</i>
VOA	volatile organic analysis

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## B1 Introduction

This appendix presents a sampling and analysis plan (SAP) for additional investigations to support the 100-BC remedial investigation (RI). Many of the required elements of the SAP are shared with those described in the main text of this document. In those cases, this appendix provides cross references to the applicable sections in the main text and does not repeat the information here. Elements of the SAP that relate specifically to the additional investigations are described in this appendix.

### B1.1 Data Needs

After completion of RI studies under the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* (DOE/RL-2008-46-ADD3), additional data needs were identified. These pertain to (1) the hyporheic zone where 100-BC-5 groundwater discharges to the Columbia River, and (2) groundwater in the unconfined aquifer in 100-BC-5. Table B-1 lists the problem statements and goals of the study that were identified by applying the data quality objective (DQO) process. Appendix E of DOE/RL-2008-46-ADD3 describes the outcome of the DQO process in more detail.

### B1.2 Contaminants of Concern

The primary contaminant of concern for this investigation is hexavalent chromium (Cr[VI]). Other groundwater contaminants of potential concern are strontium-90 and tritium; these will be analyzed to provide supplemental information on their nature and extent, but they are not the focus of the investigation. Other parameters and analytes are needed to support the interpretation of the nature, extent, fate, and transport of Cr(VI) (e.g., specific conductance, pH, temperature, dissolved oxygen, dissolved organic carbon, total chromium, and other metals).

### B1.3 Project Schedule

The schedule is driven by milestones established in the proposed *Hanford Federal Facility Agreement and Consent Order* (TPA) (Ecology et al., 1989) Change M-15-12-03 (TPA Change M-15-12-03):

- Revise and submit the 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan, including the SAP, to include additional groundwater well installation and associated monitoring by 1/31/2013. (M-015-74)
- Install additional monitoring wells to supplement the existing groundwater monitoring network as specified in revised 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan/SAP by 9/30/2013. (M-015-76)
- Install additional aquifer tubes as specified in revised 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan/SAP by 11/30/2013. (M-015-77)
- Complete 2 years of groundwater and aquifer tube sampling at the 100-BC expanded monitoring network in accordance with the revised 100-BC-1, 100-BC-2, and 100-BC-5 RI/FS Work Plan by 11/30/2015. (M-015-78)
- Submit CERCLA remedial investigation/feasibility study report and proposed plan for the 100-BC-1 and 100-BC-2 Source Operable Units (OUs) and the 100-BC-5 Groundwater OU by 12/15/2016. (M-015-79).

Table B-1. Problem Statements and Study Goals

Problem Statement	Study Goals	Approach
<b>Hyporheic Zone</b>		
There are detectable levels of Cr(VI) in the hyporheic zone adjacent to 100-BC-5 but it is uncertain whether or not these levels reflect an exposure that poses a risk to aquatic receptors warranting remedial action.	(1) Characterize the risk to aquatic receptors posed by Cr(VI) in pore water within the hyporheic zone potentially impacted by releases from 100-BC-5 groundwater.  (2) Obtain data to support selecting a preferred alternative for the RI/FS for 100-BC.	Install a series of shallow aquifer tubes screened in the hyporheic zone. Over a period of 2 years, sample shallow aquifer tubes, analyze for Cr(VI) and other parameters.
<b>Groundwater</b>		
Remediation of waste sites in 100-BC is virtually complete and groundwater contaminant concentrations are expected to change in response. Uncertainties in the hydrogeologic information (nature and extent vertically and laterally; natural attenuation processes in aquifer and approaching river; hydrogeologic layers; and hydraulic head) need to be resolved prior to the selection of a preferred alternative.	Obtain data to support selecting a preferred alternative for the RI/FS.	Install additional groundwater monitoring wells. Characterize geology and vertical distribution of contaminants in areas of uncertainty. Monitor groundwater for 2 years and analyze for Cr(VI) and other parameters. Evaluate (1) the nature and extent of Cr(VI) contamination, (2) groundwater model input parameters, and (3) which natural attenuation processes are occurring.

RI/FS = remedial investigation/feasibility study

## B2 Quality Assurance Project Plan

The quality assurance project plan (QAPjP) establishes the quality requirements for data collection, including planning, implementation, and assessment of sampling, field measurements, and laboratory analysis. Chapter 2 of the main text provides information for 100-BC RI studies. This appendix includes any requirements that are specific to the additional studies of the hyporheic zone and groundwater.

### B2.1 Project Management

See Section 2.1 of the main text of this document for project and task organization.

See Section B1.1 for the problem definition and approach.

#### B2.1.1 Quality Objectives and Criteria

The quality assurance (QA) objective of this plan is to develop implementation guidance providing data of known and appropriate quality. Data quality indicators describe data quality by evaluation against identified DQOs and the work activities identified in this SAP. The applicable quality control (QC) guidelines, quantitative target limits, and levels of effort for assessing data quality are dictated by the intended use of the data and the nature of the analytical method. The principal data quality indicators are precision, bias or accuracy, representativeness, comparability, completeness, and sensitivity. These data quality indicators are defined for the purposes of this document in Table 2-1 of the main text.

Table B-2 presents the analytical performance requirements for chemical analyses.<sup>1</sup> Laboratory operations and analytical services shall comply with Volume 4 (*Laboratory Technical Requirements*) of *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD) (DOE/RL-96-68) and any specific criteria identified in Table B-2. Criteria in Table B-2 take precedence over similar criteria in the HASQARD. The project lead and the Sample Management and Reporting organization may approve the use of different analytical methods if (a) the laboratory has accreditation from a recognized accrediting authority for the different method and (b) the method achieves the analytical performance requirements in this QAPjP.

### **B2.1.2 Special Training/Certification**

See Section 2.1.5 of the main text.

### **B2.1.3 Documents and Records**

See Section 2.1.6 of the main text.

## **B2.2 Data Generation and Acquisition**

This section addresses aspects of project design and implementation. Implementation of these elements ensures that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are used and are properly documented.

### **B2.2.1 Sampling Process Design (Experimental Design)**

The sampling design is judgmental sampling. In judgmental sampling, the selection of sampling units (i.e., the number, location, and/or timing of collecting samples) is based on knowledge of the feature or condition under investigation and on professional judgment. Judgmental sampling is distinguished from probability-based sampling in that inferences are based on professional judgment rather than a statistical sampling design.

Section B3.5 discusses the types, number, and locations of samples.

### **B2.2.2 Sampling Methods**

Section B3.6 describes sampling methods. Specific information includes the following:

- Field sampling methods
- Sample preservation, containers, and holding times
- Corrective actions for sampling activities (the task lead will be responsible for corrective action)
- Decontamination of sampling equipment

### **B2.2.3 Sample Handling and Custody**

See Section 2.2.3 of the main text and Section B3.7 of this appendix.

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<sup>1</sup> The analytes in Table B-2 differ from those in Table 2-14 of the main text (Chapter 2) of this SAP because the focus of the current investigation is narrower. Previous RI studies characterized groundwater for the comprehensive list of analytes in Table 2-14. The current study is focused on reducing uncertainties related to Cr(VI). Thus, the analyte list includes Cr(VI), total chromium, parameters indicative of Cr(VI) reduction, and supporting parameters (e.g., major cations, anions, and field parameters).

Table B-2. Analytical Performance Requirements for Chemical Analyses

CAS Number	Analyte	Analytical Method <sup>a</sup>	Units of Measure	Required Detection Limit	Accuracy Req't (Percent Recovery) <sup>b</sup>	Precision Req't (RPD) <sup>b</sup>
<b>Field Measurements</b>						
—	Dissolved oxygen	Probe	mg/L	0.2	— <sup>c</sup>	— <sup>c</sup>
—	Oxidation-reduction potential <sup>d</sup>	Probe	mV	50 <sup>e</sup>	— <sup>c</sup>	— <sup>c</sup>
—	pH measurement	Probe	—	0.1 <sup>e</sup>	— <sup>c</sup>	— <sup>c</sup>
—	Specific conductance	Probe	μS/cm	10 <sup>e</sup>	— <sup>c</sup>	— <sup>c</sup>
—	Temperature	Probe	°C	0.1 <sup>e</sup>	— <sup>c</sup>	— <sup>c</sup>
—	Turbidity	Probe	NTU	0.1 <sup>e</sup>	— <sup>c</sup>	— <sup>c</sup>
18540-29-9	Cr(VI)	Hach Method 8023	μg/L	5	— <sup>c</sup>	— <sup>c</sup>
15438-31-0	Fe(II)	Hach Method 8146	μg/L	20	— <sup>c</sup>	— <sup>c</sup>
<b>Laboratory Measurements – Metals</b>						
18540-29-9	Cr(VI)	EPA 7196 or 218.7	μg/L	2	80-120	≤20
7440-70-2	Calcium	EPA 6010 (ICP metals)	μg/L	100	80-120	≤20
7440-47-3	Chromium	EPA 6020 or 200.8 (ICP/MS)	μg/L	2	80-120	≤20
7440-48-4	Cobalt	EPA 6020 or 200.8 (ICP/MS)	μg/L	4	80-120	≤20
7439-89-6	Iron	EPA 6010 (ICP metals)	μg/L	20	80-120	≤20
7439-95-4	Magnesium	EPA 6010 (ICP metals)	μg/L	100	80-120	≤20
7439-96-5	Manganese	EPA 6010 (ICP metals)	μg/L	5	80-120	≤20
7440-09-7	Potassium	EPA 6010 (ICP metals)	μg/L	100	80-120	≤20
7440-23-5	Sodium	EPA 6010 (ICP metals)	μg/L	100	80-120	≤20

Table B-2. Analytical Performance Requirements for Chemical Analyses

CAS Number	Analyte	Analytical Method <sup>a</sup>	Units of Measure	Required Detection Limit	Accuracy Req't (Percent Recovery) <sup>b</sup>	Precision Req't (RPD) <sup>b</sup>
<b>Laboratory Measurements – Anions</b>						
16887-00-6	Chloride	EPA 300.0 (IC)	mg/L	0.5	80-120	≤20
14797-55-8	Nitrate	EPA 300.0 (IC)	mg/L	0.5	80-120	≤20
14808-79-8	Sulfate	EPA 300.0 (IC)	mg/L	0.5	80-120	≤20
18496-25-8	Sulfide	EPA 9030/9034	mg/L	0.5	80-120	≤20
<b>Laboratory Measurements – Other</b>						
10098-97-2	Strontium-90	Strontium-90 or total beta radiostrontium	pCi/L	2	70-130	≤30
10028-17-8	Tritium	LCS – Tritium	pCi/L	500	70-130	≤30
ALKALINITY	Alkalinity	2320_ALKALINITY	mg/L	1	80-120	≤20
	Dissolved organic carbon	EPA 9060	µg/L	0.5	80-120	≤20
	Chromium isotope analysis <sup>f</sup>	ICP/MS (Nu Plasma)	δ <sup>53</sup> Cr ‰ (per mil)	2‰	— <sup>g</sup>	+/-0.2‰

a. Equivalent methods may be substituted. For EPA Method 300.0, see EPA/600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*. For EPA Method 200.8, see EPA/600/R-94-111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*. For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*.

b. Accuracy criteria for associated batch laboratory control sample recoveries. Evaluation based on statistical control of laboratory control samples is also performed. Precision criteria for batch laboratory replicate matrix spike analyses or replicate sample analyses.

c. Field measurements have no specific quality control requirements, except to perform checks to verify manufacturer's expected performance.

d. Relative to standard hydrogen electrode.

e. Values are the sensitivity of the method, not the required detection limit. Detection limit is not a relevant parameter for these measurements.

f. δ<sup>53</sup>Cr is the notation for the ratio of Cr-53 to Cr-52. The units for δ<sup>53</sup>Cr are parts per thousand, often expressed as ‰, or per mil. A measurement of +2 ‰ indicates degradation. The initial chromium isotope analysis shall also include submittal of a sodium dichromate sample from a solid and liquid parent. In the event that samples of parent material cannot be obtained, isotope analysis results from locations containing a range of Cr(VI) samples will be used.

g. Accuracy and precision are established against National Institute of Standards and Technology Reference Material SRM979.

CAS = Chemical Abstract Services

LCS = liquid scintillation counting

EPA = U.S. Environmental Protection Agency

MS = mass spectrometry

IC = ion chromatography

NTU = nephelometric turbidity unit

ICP = inductively coupled plasma

RPD = relative percent difference

### B2.2.4 Analytical Methods

Analytical methods are listed in Table B-2. These analytical methods are controlled in accordance with the laboratory's QA plan and the requirements of this QAPjP. The primary contractor participates in overseeing offsite analytical laboratories to qualify the laboratories for performing Hanford Site analytical work.

The analyte list includes the following:

- **Primary contaminant of concern:** Cr(VI).
- **Co-contaminants in groundwater:** Strontium-90 and tritium.
- **Analytes that provide supporting information on Cr(VI) reduction:** Total chromium, Fe(II), total iron, manganese, dissolved oxygen, oxidation-reduction potential, sulfide, dissolved organic carbon, and chromium isotope analysis.
- **General chemistry parameters:** pH, specific conductance, temperature, turbidity, calcium, magnesium, potassium, sodium, chloride, nitrate, sulfate, and alkalinity.
- **Cobalt trace metal analysis:** A risk assessment evaluation of data collected during previous groundwater sampling events determined that there was uncertainty about whether cobalt exceeded action levels. In many cases, detection limits were too high to provide quantifiable data. Groundwater samples collected during the current investigation will be analyzed for cobalt by a method with a lower detection limit to obtain additional information to reduce this uncertainty.

Analytes with high sampling frequencies will be analyzed in the field (e.g., Cr[VI] via Hach Method 8023). The field results will be used to select a subset of samples to be analyzed in the laboratory. Samples from groundwater monitoring wells will be analyzed for Cr(VI) in the laboratory.

Laboratories may use nonstandard analytical methods, but the laboratory must be accredited for those methods by a relevant accrediting authority. If the laboratory uses a non-accredited method, the laboratory must provide method validation data to confirm that the method is adequate for the intended use of the data. This includes information such as determination of detection limits, quantitation limits, typical recoveries, and analytical precision and bias. Deviations from the analytical methods noted in Table B-2 must be approved by the Sample Management and Reporting organization in consultation with project quality assurance personnel and the project lead.

### B2.2.5 Quality Control

Standard operating procedures for sample collection, field measurements, and laboratory analyses must be followed in the field and laboratory to ensure reliable data are obtained. The QC requirements are described in Section 2.2.5 of the main text.

### B2.2.6 Instrument/Equipment Testing, Inspection, and Maintenance

See Section 2.2.6 of the main text

### B2.2.7 Instrument/Equipment Calibration and Frequency

See Section 3.4 of the main text.

### B2.2.8 Inspection/Acceptance of Supplies and Consumables

See Section 2.2.8 of the main text.

### **B2.2.9 Nondirect Measurements**

Nondirect measurements include data obtained from sources such as computer databases, programs, literature files, and historical databases. Nondirect measurements will not be evaluated as part of this activity.

### **B2.2.10 Data Management**

See Section 2.2.10 of the main text.

## **B2.3 Assessment and Oversight**

See Section 2.3 of the main text.

## **B2.4 Data Validation and Usability**

The elements in this group address the QA activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether the data conform to the specified criteria, thus satisfying the project objectives.

### **B2.4.1 Data Review, Verification, and Validation**

The criteria for verification include, but are not limited to, the following: review for completeness (samples were analyzed as requested), correct and complete sample chains of custody, sample holding times, use of the correct analytical method/procedure, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, correct application of conversion factors, and any applicable laboratory flags on the data. Laboratory personnel may perform data verification.

Data validation will be performed to ensure that the data quality goals established during the planning phase have been achieved. Data validation will be based on U.S. Environmental Protection Agency (EPA) functional guidelines. The criteria for data validation are based on a graded approach. The primary contractor has defined five levels of validation (Levels A through E). Level A is the lowest level and is the same as verification. Level E is a 100 percent review of all data (e.g. calibration data, calculations of representative samples from the dataset). Data validation is typically performed by independent third-party contractors.

Data validation will be performed to contractor Level C. Level C validation consists of a review of the QC data and specifically requires validation of deliverables, requested versus reported analytes, and qualification of the results based on evaluation of analytical holding times, method blank results, matrix spike/matrix spike duplicate results, surrogate recoveries, and duplicate sample results. Level C data validation will be performed on at least 5 percent of the data by matrix and analyte group. Analyte group refers to categories such as radionuclides, metals, anions, etc. The goal is to cover the various analyte groups and matrices during the data validation process.

Relative to analytical data in sample media, physical data and/or field screening results are of lesser importance in making inferences regarding risk. However, these parameters are highly important for characterizing reducing conditions, the nature of Cr(VI), and the environment for transport. Physical data and field QA/QC results will be reviewed to ensure that physical property data and/or field screening results are usable.

### **B2.4.2 Verification and Validation Methods**

See Section 2.4.2 of the main text.

### **B2.4.3 Reconciliation with User Requirements**

The data quality assessment (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 data evaluation is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs, and ensures that the data can support the decision-making processes for the project. (Table B-1 and DOE/RL-2008-46-ADD3, Appendix E). At the conclusion of the 2-year project, the results of the DQA will be used in interpreting the data and determining if the objectives of this activity have been met. The DQA will be in accordance with *Data Quality Assessment: A Reviewer's Guide* (EPA/240/B-06/002) and *Data Quality Assessment: Statistical Methods for Practitioners* (EPA/240/B-06/003).

As part of the DQA process, a project scientist performs an independent evaluation of the representativeness and completeness of the hyporheic zone and groundwater data. This technical data review includes evaluating field parameters, spatial and temporal trends, and comparison of related analytes (e.g., Cr[VI] and total chromium). Anomalous data may warrant additional review, which may result in reanalysis of samples, re-reported (corrected) data, or, if corrections are not possible, flagging suspect or rejected data in the Hanford Environmental Information System database. Practical considerations will also be included, particularly with respect to meeting DQOs for the hyporheic zone tied to analyzing temporal trends.<sup>2</sup>

### **B2.4.4 Corrective Actions**

The responses to data quality defects identified through the DQA process will vary and may be data- or measurement-specific. Some pre-identified corrective actions (e.g., reanalyze samples or qualify data) are included in Table 2-1 of the main text.

## **B3 Field Sampling Plan**

The purpose of the field sampling plan is to define project sampling and analytical requirements. These include defining the number and location of samples, sampling methods, and analyses that will be performed.

### **B3.1 Site Background and Objectives**

Site background information is included in DOE/RL-2008-46-ADD3 (Chapter 2 and Appendix E). Appendix E of that document also includes a description of the DQO process that resulted in the studies included in this field sampling plan.

### **B3.2 Documentation of Field Activities**

See Section 3.2 of the main text.

### **B3.3 Sampling Design**

See Section B2.2.1.

### **B3.4 Calibration of Field Equipment**

See Section 3.4 of the main text.

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<sup>2</sup> Weather conditions will limit the ability to generate a 4-day average or hourly average when water freezes within the tubes during winter months. Data will be considered sufficient as long the 4-day average or hourly average includes samples collected during the lowest flow period.

## B3.5 Sample Location and Frequency

This section identifies sampling and analysis requirements for hyporheic zone and groundwater investigations.

### B3.5.1 Hyporheic Zone Sampling Requirements

Approximately 22 shallow aquifer tubes<sup>3</sup> will be installed in the riverbed at 14 locations as part of this study (Figure B-1). The tubes will be sampled at various frequencies for a period of 2 years, as described in the following subsections.

#### ***B3.5.1.1 Aquifer Tube Installation***

The hyporheic zone will be sampled with devices similar in design to the aquifer sampling tubes that already exist in 100-BC-5, but they will be screened at shallower depths (Figure B-2). The tubes will be placed at an elevation where they are submerged beneath approximately 1 m (3 ft) of water during low river stage, with attached tubing running to the shore to an elevation above the ordinary high water mark.

The method to install the new aquifer tubes will be determined by project staff and will likely be similar to methods used to install other aquifer tubes on the Hanford Site (see inset on Figure B-2). This method involves driving a hollow, steel rod with a stainless-steel tip into the ground to the desired depth. Flexible tubing (0.25 in. diameter) with a 6 in. long, stainless-steel screen attached to the end is inserted into the hollow rod. The rod is then removed, leaving the tubing and drive tip in place. Existing aquifer tubes in 100-BC-5 have screens 2 to 8 m (6.6 to 26 ft) below the riverbed. The new devices will be placed so the screens are approximately 50 cm (20 in.) below the riverbed.

As the drive rod is removed, aquifer sediments collapse against the tubing and screen, preventing river water from flowing directly down the annulus of the hole (“short circuiting”). The possibility of short circuiting is more likely with the planned, shallow aquifer tubes than with the older aquifer tubes because (1) their locations will be submerged at all times of the year, unlike the previous aquifer tubes that usually have their heads above water when they are sampled in the fall; and (2) their limited depth means there is less vertical distance for the aquifer sediments to form a seal.

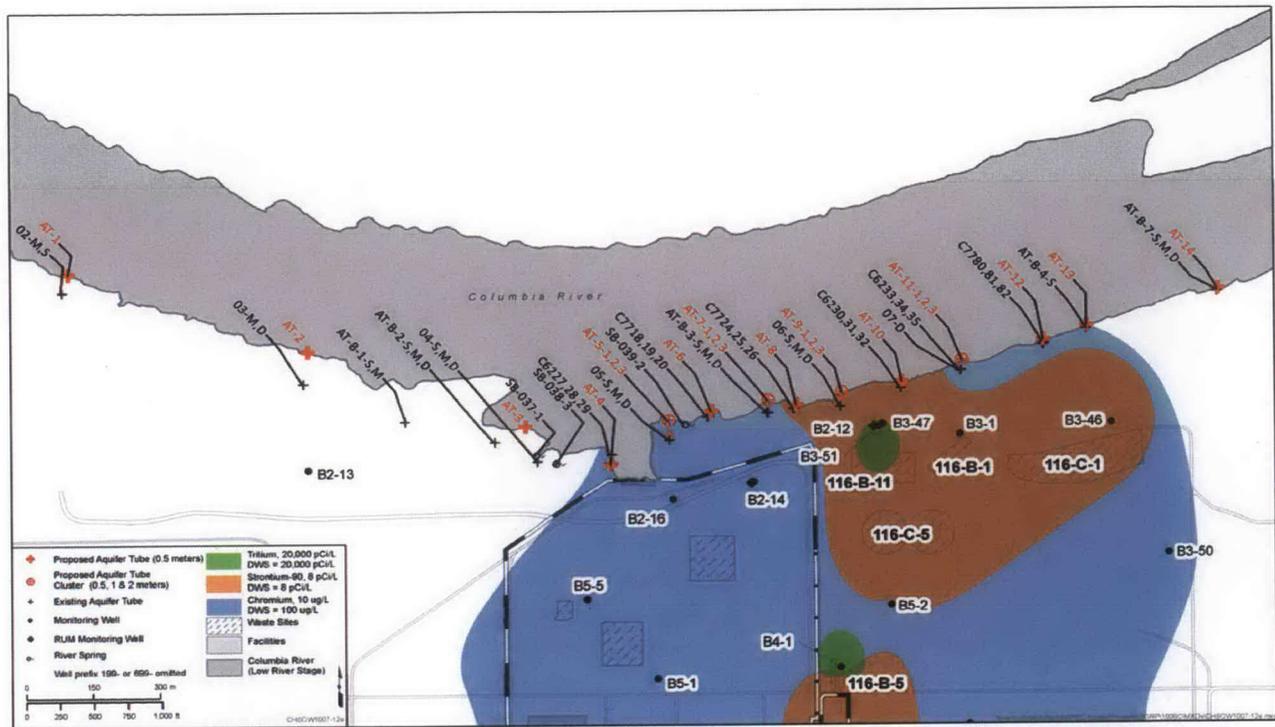
Additional elements of design or testing may be needed to ensure that short circuiting does not occur. Previous pore water sampling (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*) used real-time monitoring of specific conductance and temperature to watch for signs of short circuiting. If the pumping process drew river water into the annulus, the specific conductance of the sample dropped. That technique can be used here in some cases but will not be useful in locations or at times when pore water conductance is naturally low (e.g., when river stage is high, or in an area without groundwater upwelling). Details of the additional design or testing will be determined with approval by the U.S. Department of Energy (DOE) and EPA.

The flexible tubing will be extended up the riverbank to a location above the high water mark so the tubes can be sampled when the river stage is high. Rigid tubing (e.g., polyvinyl chloride [PVC]) is used to protect the flexible tubing from rocks and debris that move in the river current, and also from wildlife.

Locations and elevations of each tube head will be determined by global positioning system or another suitable method. Each tube will be labeled with a Hanford well identification number.

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<sup>3</sup> Three tubes will be installed at different depths at four of the locations in order to better understand how reducing conditions change with proximity to the hyporheic zone (Section B3.5.2). Locations for multiple tubes were selected by spacing these out across the plume zone at previously sampled aquifer locations.



Note: Contaminant plumes represent 2011 average (DOE/RL-2011-118, Hanford Site Groundwater Monitoring for 2011).

Figure B-1. Locations of Proposed Shallow Aquifer Sampling Tubes

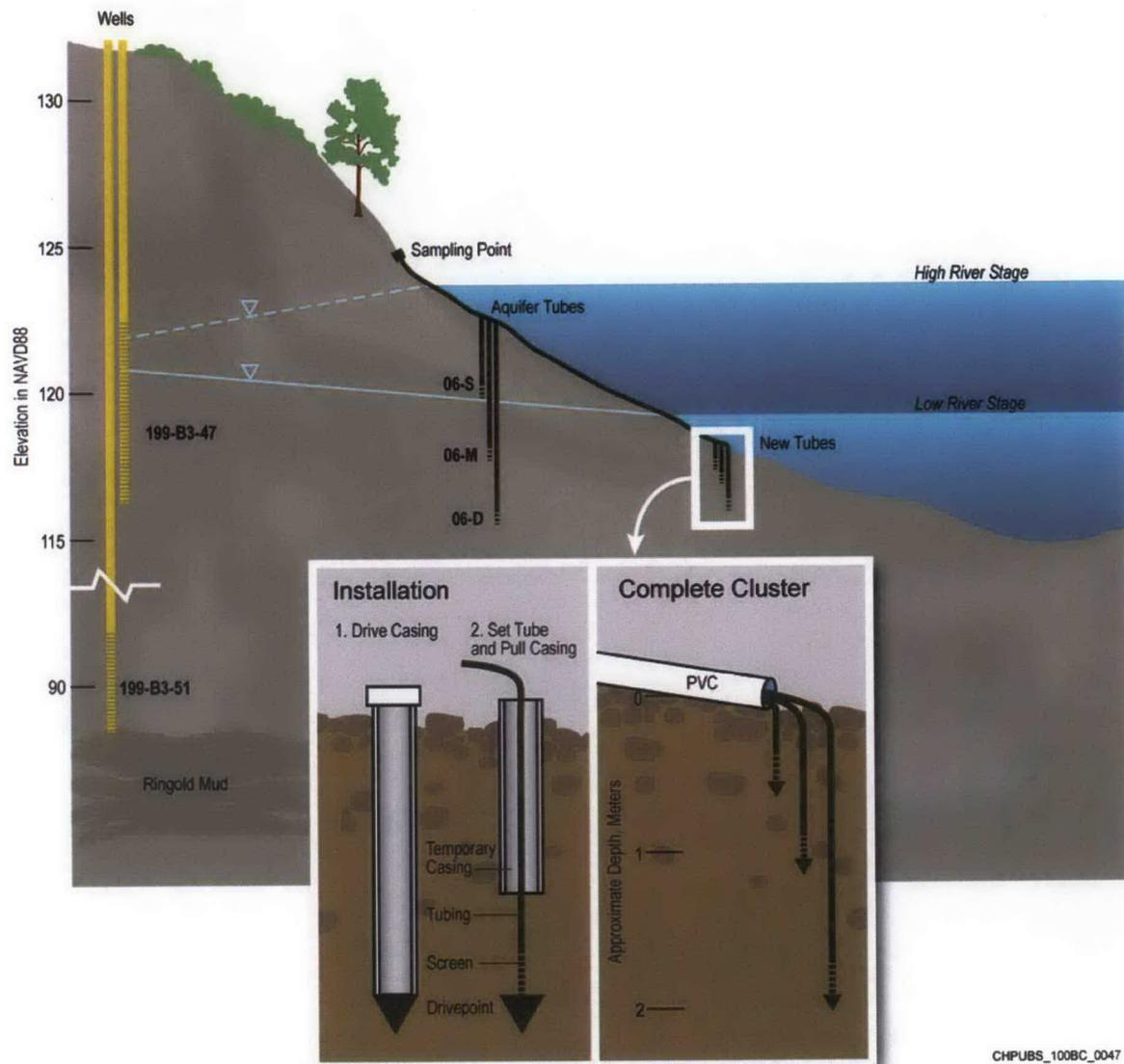


Figure B-2. Schematic Diagram of 100-BC Shoreline Monitoring Points: Wells, Existing Aquifer Tubes, and Proposed Shallow Aquifer Tubes

### B3.5.1.2 Aquifer Tube Sampling

Hourly river stage data from the 100-BC gauge from 2006 through 2011 were evaluated to support the choice of an appropriate frequency and schedule for aquifer tube sampling. The goal of sampling is to collect data that represent the full range of river stage conditions. Representing low river stage conditions is of particular interest because Cr(VI) concentrations in 100 Area groundwater tend to be highest when the river stage is low.

Figure B-3 shows average river stage for each month of the 6 years evaluated. The dashed lines in the figure represent data percentiles based on all of the hourly data. September and October consistently showed the lowest average river stage, with all years less than the 30<sup>th</sup> percentile, and many years below the 20<sup>th</sup> percentile. June had the highest average river stage, with all years above the 80<sup>th</sup> percentile.

May also had high river stage, with all 6 years above the 60<sup>th</sup> percentile. Hydrographs show that high river stage generally persists from mid-May through early July. A monthly sampling frequency will reflect a full range of river stage conditions.

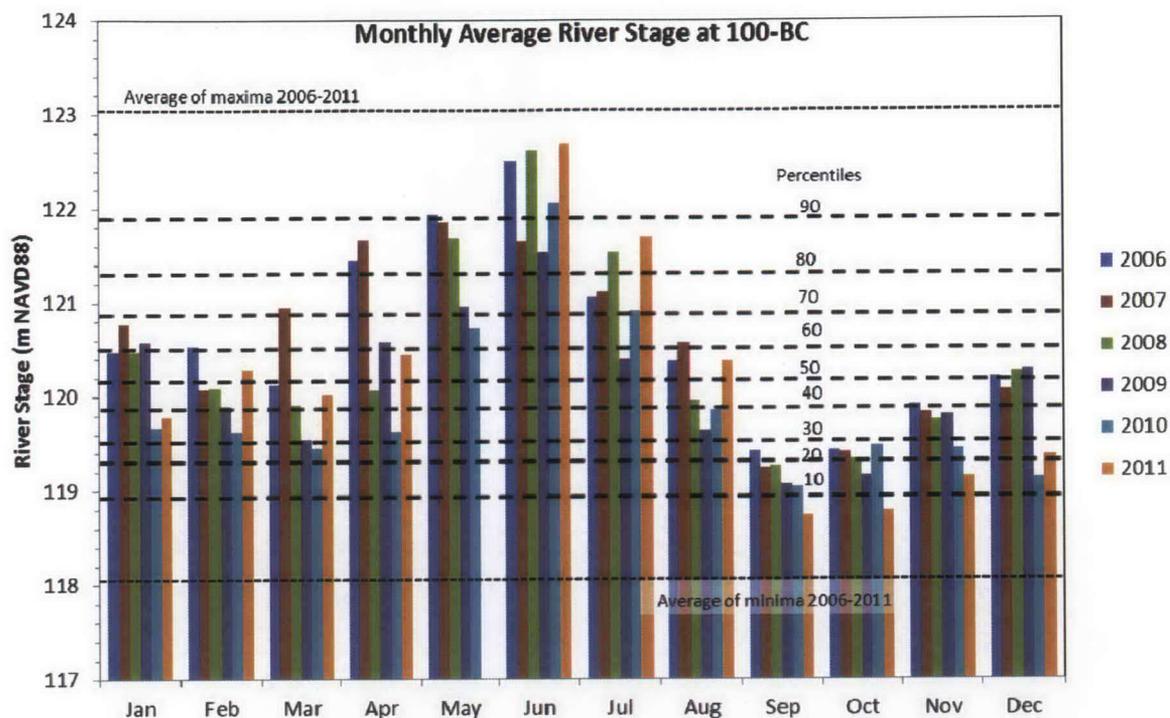


Figure B-3. Monthly Average River Stage Compared to Data Percentiles

For the current study, short-term variability is also of concern. Monthly average river stages in September and October are the lowest of the year, but short-term fluctuations of greater than 2 m (6.6 ft) are common. Hence, if sampling frequency during the fall is low, samplers could miss a true low river stage condition. Hourly sample data from September and October 2006 through 2011 were evaluated to determine how many days did not have low water levels for at least one of the 24 hourly measurements. The following conclusions were drawn from the data:

- The data covered 366 days (61 days in each of 6 years).
- Water levels were all above the 20<sup>th</sup> percentile on 16 days (4 percent). Most of these were isolated occurrences. Twice, water levels were all above the 20<sup>th</sup> percentile for 2 consecutive days.
- Water levels were all above the 30<sup>th</sup> percentile on 3 days (0.8 percent); all were isolated occurrences.
- Water levels were all above the 40<sup>th</sup> percentile on 1 day (0.3 percent).

These data indicate that hourly sampling for at least a 24-hour period in September and October are very likely to include periods of low river stage.

The new aquifer tubes will be sampled periodically over a period of 2 years, as indicated in Table B-3. Frequencies vary depending on the purpose of sampling.

Table B-3. Sample Locations, Frequencies, and Sampling Methods for Hyporheic Zone Pore Water

New Tube <sup>a</sup>	Location	Approx. Depth (m)	Adjacent Tubes	Cr(VI) <sup>b</sup> (field; filtered)	Field Parameters	Total Cr (filtered)	Anions	Alkalinity	ICP Metals (filtered)	Strontium-90	Tritium	Fe(II) <sup>c</sup> (field; filtered)	Organic Carbon	Cr Isotope Analysis
AT1	Upstream	0.5	02-S,M	M	M	S	S	S	S					
AT2	Upstream	0.5	03-M,D	M	M	S	S	S	S					
AT3	Upstream	0.5	04-S,M,D	M	M	S	S	S	S					
AT4	In plume	0.5	C6227,28,29	M4/H	M4/H	S	S	S	S	A	A			
AT5-1	In plume	0.5	05-S,M,D	M4/H	M4/H	S	S	S	S	A	A	S	S	S
AT5-2	In plume	1		S	S	S	S	S	S			S	S	S
AT5-3	In plume	2		S	S	S	S	S	S			S	S	S
AT6	In plume	0.5	C7718,19,20	M4/H	M4/H	S	S	S	S	A	A			
AT7-1	In plume	0.5	AT-B-3-S,M,D	M4/H	M4/H	S	S	S	S	A	A	S	S	
AT7-2	In plume	1		S	S	S	S	S	S			S	S	
AT7-3	In plume	2		S	S	S	S	S	S			S	S	
AT8	In plume	0.5	C7724,25,26	M4/H	M4/H	S	S	S	S	A	A			
AT9-1	In plume	0.5	06-S,M,D	M4/H	M4/H	S	S	S	S	A	A	S	S	S
AT9-2	In plume	1		S	S	S	S	S	S			S	S	S
AT9-3	In plume	2		S	S	S	S	S	S			S	S	S
AT10	In plume	0.5	C6230,31,32	M4/H	M4/H	S	S	S	S	A	A			
AT11-1	In plume	0.5	C6233,34,35	M4/H	M4/H	S	S	S	S	A	A	S	S	
AT11-2	In plume	1		S	S	S	S	S	S			S	S	
AT11-3	In plume	2		S	S	S	S	S	S			S	S	
AT12	Downstream	0.5	C7780,81,82	M	M	S	S	S	S					
AT13	Downstream	0.5	AT-B-4-S	M	M	S	S	S	S					
AT14	Downstream	0.5	AT-B-7-S,M,D	M	M	S	S	S	S					

Note: See text for further explanation of the following sampling frequencies listed in this table: A = annual; M = monthly grab sample; M4 = sampled at frequency to determine 4-day average each month (see text); H = hourly for one day per month; S = semiannual.

a. Temporary designation.

b. Hach method 8023.

c. Hach method 8146.

ICP = inductively coupled plasma

- **Monthly 4-day averages:** To monitor short-term variability and to assess compliance with the chronic surface water quality standard for Cr(VI),<sup>4</sup> samples from eight tubes (AT-4 through AT-11) will be collected hourly for 96 hours for the very first month only (September or October 2013). These samples will be analyzed for Cr(VI) and specific conductance in the field; the field results will be used to select a subset of the sites for laboratory analysis of Cr(VI) and total chromium for comparison. The results of the first month's samples will be used to determine an appropriate frequency for the remainder of the 2-year period. Sampling at a lower frequency over a 96-hour period, or collecting sets of composite samples may be evaluated to obtain data adequate for calculating a 4-day average. Changes to sampling frequency require DOE and EPA approval.
- **Monthly grab samples:** Aquifer tubes upstream and downstream of the Cr(VI) plume (AT-1, AT-2, AT-3, AT-12, AT-13, and AT-14) will be sampled monthly during the same period as the 4-day sampling campaigns at the in-plume aquifer tubes.<sup>5</sup> Samples will be analyzed for Cr(VI) and supporting parameters in the field and the field results will be used to select a subset of samples for laboratory analysis of Cr(VI).
- **Hourly:** To monitor short-term variability and to assess compliance with the acute water quality standard for Cr(VI),<sup>6</sup> samples from eight tubes (AT-4 through AT-11) will be collected hourly for 24 hours, once per month. These hourly samples will be a subset of the samples collected to determine monthly 4-day averages, as described above. The hourly samples will be analyzed for Cr(VI) and specific conductance in the field. The frequency of this sampling may be reduced based on the results of initial samples. Changes to sampling frequency require DOE and EPA approval.
- **Semiannual:** The new tube clusters with multiple depths (AT-5, AT-7, AT-9, and AT-11) will be sampled twice each year for Cr(VI) and reduction-oxidation-sensitive parameters to investigate natural attenuation factors as groundwater approaches its discharge point. The adjacent, existing (deeper) aquifer tube clusters (Table B-3) will be sampled in conjunction with the new tubes. This sampling will be coordinated with groundwater sampling (Section B3.5.2).
- **Annual:** Groundwater co-contaminants strontium-90 and tritium will be analyzed from aquifer tube samples collected in the fall at selected new tubes to provide supplemental information on their nature and extent in the hyporheic zone. Annual sampling of previously existing aquifer tubes will also continue as specified in the *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59).

River water field parameters will be measured at each station for comparison with hyporheic zone field parameters.

Sampling methods are described in Section B3.6 and analytical requirements in Section B2.2.

### B3.5.2 Groundwater Sampling Requirements

Groundwater sampling under this plan includes samples collected during drilling of new wells and ongoing sampling of the new and selected older wells over a 2-year period.

<sup>4</sup> 10 µg/L; Table 240(3) of WAC 173-201A-240, "Water Quality Standards for Surface Waters of the state of Washington."

<sup>5</sup> The goal of monthly sampling is to reflect normal variability over a year. Thus, except for the very first month, sampling will not focus on periods of low river stage. Sample dates will be planned approximately one month apart, although field conditions may require some deviation from the planned schedule.

<sup>6</sup> 15 µg/L; Table 240(3) of WAC 173-201A-240.

**B3.5.2.1 Well Installation**

Table B-4 lists the wells that may be installed under this SAP. Between 7 and 11 wells will be installed; possible installation of 4 of the wells is contingent on characterization results. Figure B-4 shows planned well locations.

**Table B-4. Proposed Monitoring Wells**

Number <sup>a</sup> (Well ID)	Location	Approach and Objectives
E1, E2 <sup>b</sup> (C8779, C8780)	Northeast of 100-C-7:1 (near site)	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during installation of the second well.</p> <ul style="list-style-type: none"> <li>• Monitor Cr(VI) concentrations and trends downgradient of former source in Hanford formation and at bottom of aquifer</li> <li>• Define Cr(VI) distribution with depth</li> </ul>
E3, E4 <sup>b</sup> (C8781, C8782)	Northeast of 100-C-7 (mid-distance)	<p>Drill and sample through unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during installation of the second well.</p> <ul style="list-style-type: none"> <li>• Monitor Cr(VI) concentrations and trends downgradient of former source in Hanford formation and at bottom of aquifer</li> <li>• Define Cr(VI) distribution with depth</li> </ul>
E5 (C8783)	Partner with 199-B5-1	<p>Drill and sample through unconfined aquifer. Screen in lower part of aquifer.</p> <ul style="list-style-type: none"> <li>• Define extent of Cr(VI) and trends in Ringold E in southern 100-BC-5 (recent decrease to &lt;10 µg/L in shallow well)</li> <li>• Monitor hydraulic head at depth</li> <li>• Define geologic contacts</li> </ul>
E6, E7 <sup>b</sup> (C8776, C8777)	East of central 100-BC-5	<p>Drill and sample through unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during installation of the second well.</p> <ul style="list-style-type: none"> <li>• Define extent of Cr(VI) in eastern 100-BC-5</li> <li>• Monitor trends in Cr(VI) in direction of migration from southern 100-BC</li> <li>• Define geologic contacts</li> </ul>
E8, E9 <sup>b</sup> (C8784, C8785)	West of central 100-BC-5	<p>Drill and sample through entire unconfined aquifer. If Cr(VI) concentrations decline with depth or if there is no significant contamination, screen at water table only. Otherwise screen at depth of contamination and consider installing a second well at the water table. No characterization sampling required during installation of the second well.</p> <ul style="list-style-type: none"> <li>• Define extent of Cr(VI) in western 100-BC-5</li> <li>• Define geologic contacts in area of high uncertainty</li> <li>• Monitor hydraulic head west of 100-BC</li> </ul>

Table B-4. Proposed Monitoring Wells

Number <sup>a</sup> (Well ID)	Location	Approach and Objectives
E10 (C8778)	Partner with 199-B4-7	Drill and sample through unconfined aquifer. Screen in lower part of aquifer. <ul style="list-style-type: none"> <li>• Define extent of Cr(VI) in Ringold unit E in southern 100-BC-5</li> <li>• Monitor trends downgradient of 100-C-7 (trends increasing in shallow well)</li> <li>• Monitor hydraulic head at depth</li> <li>• Define geologic contacts</li> </ul>
E11 (C8775)	Between 199-B2-16 and 199-B2-13	Drill and sample through unconfined aquifer. Screen at depth of Cr(VI) contamination, if any. Otherwise, screen at water table. <ul style="list-style-type: none"> <li>• Define extent of Cr(VI) in northwestern 100-BC-5 (formerly elevated in B2-13)</li> <li>• Define geologic contacts in area of high uncertainty</li> </ul>

a. Temporary well number for identification in this appendix.

b. Installation is contingent on characterization results from another well; may not be installed.

ID = identification

One well at each location will be drilled through the entire unconfined aquifer (that is, until the Ringold upper mud unit has been confirmed). Groundwater samples will be collected approximately every 3 m (10 ft) and at the bottom of the borehole. Wells E5 and E10 will be screened in the lower portion of the aquifer, forming well pairs with water table wells 199-B5-1 and 199-B4-7. Well E11 will be screened at the water table, unless contamination is unexpectedly found deeper in the aquifer. The other new wells are planned in pairs, monitoring the top and bottom of the unconfined aquifer (Table B-4). However, the need for two wells at each location is not certain and will depend on results the vertical characterization of Cr(VI). Final well design will be determined by the project scientist, drilling lead, DOE, and EPA.

Well drilling will be performed in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." The wells will be drilled using 8 in. diameter (or larger) temporary casing to total depth. The drilling method will be determined based on discussions between the drilling lead and drilling contractor.

During drilling, a well site geologist will describe the geology of the vadose zone and aquifer sediments based on drill cuttings. It is important to identify fine-grained lenses that are likely to contain higher concentrations of reactive iron/sulfide minerals that promote abiotic Cr(VI) reduction. The contact between the Hanford formation and Ringold Formation unit E is difficult to identify in 100-BC-5, so a detailed geologic log is important.

When the boreholes reach total depth, project staff will determine whether borehole geophysical logging with the Spectral Gamma Logging System will be conducted. Geophysical log data may be useful to help delineate geologic contacts, contrasting sediment layers, and saturated zones. If performed, geophysical logging will be conducted only in the first borehole drilled at each location (i.e., the boreholes that reach the Ringold upper mud unit).



Wells will be constructed with 4 in. diameter permanent casing and screen. Casing and screen may be either PVC or stainless steel. Screen length and placement will be determined after geologic data and initial groundwater samples are reviewed, with approval by DOE and EPA. Colorado silica sand or equivalent 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 Type I/II Portland cement will be used for cement grout.

Surface construction consisting of protective casing, protective guard posts, and cement pad must be in place before job completion. The protective casing will be a minimum of 2 in. larger in diameter than the permanent casing. Protective casing will have a lockable well cap.

Wells will be surveyed for elevation of the brass survey marker and top of casing, and easting and northing of center of casing.

### ***B3.5.2.2 Groundwater Sampling***

Two types of groundwater sampling are included in this section: (1) characterization samples collected during drilling, and (2) periodic sampling for a period of 2 years after wells are completed.

During drilling, groundwater samples will be collected approximately every 3 m (10 ft) through the unconfined aquifer, as described in Table B-5. If conditions prevent sample collection at the planned depth (e.g., insufficient yield or heaving sands), the project scientist and field geologist will recommend a course of action (e.g., advance borehole and attempt another sample). For wells installed in pairs, characterization sampling is not required in the second well, except for a single sample from the planned screened interval. Section B3.6 provides additional requirements for groundwater characterization sampling.

**Table B-5. Groundwater Sampling During Drilling**

Well	Estimated Aquifer Thickness		Estimated Number of Samples (one per 10 ft in aquifer)				
	m	ft	Field Parameters	Cr(VI) (filtered)	Metals (filtered)	Strontium-90	Tritium
E1 (C8779)	39	128	13	13	13		13
E2* (C8780)			1	1	1		1
E3 (C8781)	36	118	12	12	12		12
E4* (C8782)			1	1	1		1
E5 (C8783)	44	144	14	14	14		14
E6 (C8776)	33	108	11	11	11		11
E7* (C8777)			1	1	1		1
E8 (C8784)	49	161	16	16	16		16
E9* (C8785)			1	1	1		1

Table B-5. Groundwater Sampling During Drilling

Well	Estimated Aquifer Thickness		Estimated Number of Samples (one per 10 ft in aquifer)				
	m	ft	Field Parameters	Cr(VI) (filtered)	Metals (filtered)	Strontium-90	Tritium
E10 (C8778)	35	115	11	11	11	11	11
E11 (C8775)	45	148	15	15	15		15
Total number samples			96	96	96	11	96

\* These wells may not be drilled, depending on results of characterization sampling in adjacent well.

After completion, the new wells will be sampled quarterly for one year. With the approval of DOE and EPA, sampling frequency may be decreased after that time based on initial results. Most of the existing monitoring wells in 100-BC-5 will be sampled at semiannual or annual frequencies (Table B-6). This schedule will remain in place until the fall of 2015. The routine groundwater monitoring SAP (DOE/RL-2003-38, *100-BC-5 Operable Unit Sampling and Analysis Plan* [as modified by TPA-CN-522]) remains in effect during and after this period. Sampling for the two programs will be integrated to avoid duplication of effort.

Table B-6. Periodic Groundwater Sampling

Well	Well ID	Field Parameters <sup>a</sup>	Cr(VI) (filtered)	Anions	Alkalinity	Metals <sup>b</sup> (filtered)	Strontium-90	Tritium	Dissolved Organic Carbon (filtered)	Cr Isotope Analysis	Vertical Profiling	Notes
<b>Paired Wells</b>												
E1	C8779	Q	Q	Q	Q	Q	—	Q	Q	—	Yes	
E2 <sup>c</sup>	C8780	Q	Q	Q	Q	Q	—	Q	Q	—	Yes	
E3	C8781	Q	Q	Q	Q	Q	—	Q	Q	—	Yes	
E4 <sup>c</sup>	C8782	Q	Q	Q	Q	Q	—	Q	Q	—	Yes	
E6	C8776	Q	Q	Q	Q	Q	—	A	Q	—	Yes	
E7 <sup>c</sup>	C8777	Q	Q	Q	Q	Q	—	A	Q	—	Yes	
E8	C8784	Q	Q	Q	Q	Q	—	A	—	—	Yes	
E9 <sup>c</sup>	C8785	Q	Q	Q	Q	Q	—	A	—	—	Yes	

Table B-6. Periodic Groundwater Sampling

Well	Well ID	Field Parameters <sup>a</sup>	Cr(VI) (filtered)	Anions	Alkalinity	Metals <sup>b</sup> (filtered)	Strontium-90	Tritium	Dissolved Organic Carbon (filtered)	Cr Isotope Analysis	Vertical Profiling	Notes
199-B3-47	A4552	S	S	S	S	S	A	A	S	S	Yes	
199-B3-51	C7785	A	A	A	A	A	A	A	A	—	Yes	Bottom of aquifer; clean
199-B4-7	A5541	Q	Q	S	S	Q	A	S	S	—	—	Cr(VI) and tritium rising
E10	C8778	Q	Q	Q	Q	Q	Q	Q	Q	—	Yes	
199-B5-1	A4561	S	S	S	S	S	A	A	S	—	—	
E5	C8783	Q	Q	Q	Q	Q	Q	A	Q	—	—	
199-B4-14	C7786	Q	Q	S	S	Q	—	Q	S	S	Yes	100-C-7:1 flow path
199-B5-6	C7507	Q	Q	S	S	Q	—	Q	S	—	—	100-C-7:1 flow path
Single Wells												
E11	C8775	Q	Q	Q	Q	Q	—	A	Q	—	Yes	
199-B2-13	A4551	A	A	A	A	A	—	—	A	—	—	Not in migration pathway
199-B2-14	C7665	S	S	A	A	S	A	A	S	S	Yes	
199-B2-16	C7785	S	S	A	A	S	A	A	S	—	Yes	
199-B3-1	A4552	S	S	A	A	S	A	A	S	—	Yes	
199-B3-46	A4553	S	S	A	A	S	A	A	S	—	Yes	
199-B3-50	C7785	S	S	A	A	S	A	A	S	—	—	
199-B4-1	A4555	S	S	A	A	S	A	A	S	S	Yes	
199-B4-4	A4557	A	A	A	A	A	—	—	A	—	—	Near 199-B4-7
199-B4-8	A4559	S	S	A	A	S	—	—	S	—	—	
199-B5-2	A4562	S	S	A	A	S	A	A	S	—	—	
199-B5-5	C7505	S	S	A	A	S	—	A	S	—	—	
199-B5-8	C8244	A	A	A	A	A	—	A	A	—	—	Not in migration pathway
199-B8-6	A4563	S	S	A	A	S	—	A	S	—	Yes	

Table B-6. Periodic Groundwater Sampling

Well	Well ID	Field Parameters <sup>a</sup>	Cr(VI) (filtered)	Anions	Alkalinity	Metals <sup>b</sup> (filtered)	Strontium-90	Tritium	Dissolved Organic Carbon (filtered)	Cr Isotope Analysis	Vertical Profiling	Notes
199-B8-9	C7508	Q	Q	S	S	Q	—	S	S	S	Yes	Variable Cr(VI)
199-B9-2	A4565	A	A	A	A	A	—	—	A	—	—	Near 199-B9-3
199-B9-3	A4566	S	S	A	A	S	—	—	S	—	—	
699-65-83	A5303	A	A	A	A	A	—	—	A	S	Yes	Not in migration pathway
Trips per year	—	92 <sup>d</sup>	—	—	—	—	—	—	—	—	—	
Sodium dichromate	—	—	—	—	—	—	—	—	—	S	—	Liquid and solid

Note: The sampling frequencies listed in this table are as follows: A = annually, Q = quarterly, and S = semiannually.

a. Field parameters include dissolved oxygen, pH, specific conductance, and turbidity.

b. Trace metals by ICP/MS and major cations by ICP (see Table B-2).

c. These wells may not be drilled, depending on results of groundwater samples collected during drilling of adjacent wells.

d. Assumes that all 11 new wells are installed.

General rules:

- New wells are sampled quarterly the first year; may reduce sampling frequency for second year with DOE and EPA approval.
- Sample wells with Cr(VI) variable or rising trends quarterly.
- Sample older wells semiannually to evaluate natural attenuation.
- Sample older wells not on migration pathway annually.
- Strontium-90 and tritium are secondary contaminants; sample annually in selected wells.
- Routine sampling under DOE/RL-2003-38 (as modified by TPA-CN-522) will continue.

DOE = U.S. Department of Energy

ID = identification

EPA = U.S. Environmental Protection Agency

MS = mass spectrometry

ICP = inductively coupled plasma

### ***B3.5.2.3 Water Level Monitoring***

A subset of 100-BC-5 wells will be equipped with pressure transducers, data loggers, and transmitters as part of the automated water-level network (AWLN). The instruments will be calibrated and maintained, and measurements will be corrected for instrument drift as needed during the period of monitoring.

Table B-7 lists a tentative set of wells to be part of the AWLN. Final well choices will depend on which new wells are installed. The river stage gauge at 100-BC-5 also will be maintained.

Water levels are also measured manually before wells are sampled following a documented procedure.

Table B-7. Tentative AWLN for 100-BC-5

Station	Well	Screened	Purpose	Status/Recommendation*
1	River	—	Monitor local river stage	Current/retain
2	199-B3-47	Water table	Water table in north	Current/retain
	199-B3-51	Bottom unconfined	Gradient at depth	Current/retain
	199-B2-12	RUM	Vertical gradient between RUM and unconfined aquifer	Current/remove. RUM gradient understood; RUM uncontaminated
3	199-B2-14	Water table	Water table in north	Current/remove; will be redundant with others
	199-B2-15	RUM	Vertical gradient between RUM and unconfined aquifer	Current/remove; RUM gradient understood; RUM uncontaminated
4	199-B5-1	Water table	Water table in west	Add to AWLN
	E5 (C8783)	Bottom unconfined	Gradient at depth	New well
5	199-B5-6	Bottom unconfined	Water table in south-central 100-BC-5	Current/retain
	199-B4-14	Water table	Gradient at depth in unconfined aquifer	Current/retain
6	199-B4-7	Water table	Water table in central 100-BC-5	Add to AWLN
	E10 (C8778)	Bottom unconfined	Gradient at depth	New well
7	E6 (C8776)	Water table	Water table in east	New well
	E7 (C8777)	Bottom unconfined	Gradient at depth	New well
8	E8 (C8784)	Water table	Water table in west	New well
	E9 (C8785)	Bottom unconfined	Gradient at depth	New well
9	199-B5-8	Water table	Water table in southeast	Current/retain
	199-B8-6	Water table	Water table in southwest	Current/retain

\* Some wells were previously equipped as AWLN stations ("current"). The equipment will either remain in the well or be removed and placed elsewhere.

AWLN = automated water-level network

RUM = Ringold upper mud unit

## B3.6 Sampling Methods

This section describes methods for sampling the hyporheic zone and groundwater.

### B3.6.1 Hyporheic Zone Sampling Methods

Aquifer tubes will be sampled according to an approved procedure. At each site during grab sampling, samplers measure field parameters of river water adjacent to the aquifer tubes. Aquifer tubes are purged using a peristaltic pump until specific conductance stabilizes. After sample bottles are filled, field parameters are again measured and recorded. Sample packaging and shipping will be performed in accordance with standard procedures.

An automated water sampler may be used to collect high-frequency (e.g., hourly) samples.

Samples to be analyzed for Cr(VI) will be filtered to eliminate interference of turbidity on the colorimetric analytical method. Samples for other metals also will be filtered so the results reflect dissolved concentrations. Samples for dissolved organic carbon will be filtered by the laboratory due to the specialized filter type. Filtration requirements will be specified in the laboratory instructions and confirmed on the chain-of-custody form. Samples not being analyzed for metals or dissolved organic carbon will not be filtered.

Table B-8 lists sample preservation, containers, and holding times.

### B3.6.2 Groundwater Sampling Methods

Groundwater will be sampled according to approved procedures.

For groundwater samples collected during drilling, the borehole must be carefully purged before collecting water samples because drilling can affect local reduction-oxidation conditions, creating nonrepresentative Cr(VI) results. The goal is to purge the borehole of standing water without pumping it dry and until the dissolved oxygen level has stabilized at or above 7 mg/L. During drilling and sampling of 100-BC-5 wells in 2009 and 2010, purge rates between 4 and 76 L/min (1 and 20 gallons per minute [gpm]) produced satisfactory results. Thus, the pump should have an adjustable discharge down to approximately 4 L/min (1 gpm). If dissolved oxygen does not reach at least 7 mg/L during the purge, sampling requirements will be determined by the project scientist or field geologist. Because the samples collected during drilling will be turbid, they should be filtered in the field.

After the new wells are developed, but before the permanent sampling pumps are installed, vertical profiling of temperature, dissolved oxygen, and reduction-oxidation will be performed at selected well locations to identify the presence of potentially reactive zones where Cr(VI) reduction may occur. The profiling will be performed by gradually lowering a sonde down the well (at a rate of approximately 0.9 to 1.5 m/min [3 to 5 ft/min]) and continuously recording each parameter from the water table surface to the base of the screen interval using a data logger. Vertical profiling will also be performed in selected existing wells (Table B-6). Following the two initial reconnaissance events, the data will be evaluated and a determination made on whether the vertical profiling should be continued.

For routine sampling of the completed wells, the pump will be operated until three casing volumes are purged or until field parameters stabilize, as required under groundwater sampling procedures.

Table B-8. Sample Preservation, Containers, and Holding Times

Method	Preservation Requirement	Holding Time	Bottle Type <sup>a</sup>	Minimum Sample Size
EPA 7196 (Cr[VI])	Cool <6°C	24 hours	aG	500 mL
EPA 6020 or 200.8 (trace metals)	HNO <sub>3</sub> to pH <2	6 months	G/P	300 mL
EPA 6010 (ICP metals)	HNO <sub>3</sub> to pH <2	6 months	G/P	300 mL
EPA 300 (anions)	Cool <6°C	48 hours/ 28 days <sup>b</sup>	P	125 mL
Sulfide	ZnAc+NaOH to pH >9, cool <6°C	7 days	G/P	250 mL
Alkalinity	Cool <6°C	14 days	G/P	50 mL
Dissolved organic carbon	HCl or H <sub>2</sub> SO <sub>4</sub> to pH <2, cool <6°C	28 days	aG – VOA	3 to 40 mL
Cr isotope <sup>c</sup> – groundwater	Cool <6°C	N/A	LDPE/HDPE	1 L
Bulk sodium dichromate liquid and solid	Cool <6°C	N/A	G	4 mL
Strontium-90	HNO <sub>3</sub> to pH <2	6 months	G/P	1,000 mL
LCS – Tritium	None	6 months	G	500 mL

a. G = glass; P = plastic; aG = amber glass; LDPE/HDPE = low-/high-density polyethylene.

b. 48 hours for nitrate, nitrite, and phosphate; 28 days for others.

c. Contact Yi Wang at [yi.wang@zymaxusa.com](mailto:yi.wang@zymaxusa.com) for containers, packaging, and shipping instructions prior to collection.

ICP = inductively coupled plasma

EPA = U.S. Environmental Protection Agency

LCS = liquid scintillation counting

N/A = not applicable

VOA = volatile organic analysis

Chromium (<sup>53</sup>Cr/<sup>52</sup>Cr) isotope analysis will be performed on selected groundwater samples (Table B-6) and on samples of the sodium dichromate liquid and sodium dichromate solid, similar to what was originally used for water treatment at the Hanford Site. In the event that samples of the parent material are not available, isotope analysis results from monitoring well locations exhibiting a range of Cr(VI) concentrations will be used to estimate the <sup>53</sup>Cr enrichment factor of the material originally released.

Sample preservation, containers, and holding times are presented in Table B-8.

### B3.6.3 Corrective Actions and Deviations for Sampling Activities

See Section 3.6.1 of the main text.

### B3.6.4 Decontamination of Sampling Equipment

See Section 3.6.2 of the main text.

### **B3.6.5 Radiological Field Data**

See Section 3.6.3 of the main text.

### **B3.7 Sample Handling**

See Section 3.7 of the main text for requirements related to packaging, labeling, custody, and transportation. Preliminary container types and volumes are identified in Table B-8.

### **B3.8 Waste Management**

See Section 3.8 of the main text.

## **B4 Health and Safety**

See Chapter 4 of the main text.

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