

## 2 100-BC

### 2.1 Overview

The 100-BC groundwater interest area includes the 100-BC-5 OU and surrounding region. Two nuclear reactors formerly operated in 100-BC. The B Reactor was the first of its kind, and it operated from 1944 to 1968. The C Reactor operated from 1952 to 1969.

Groundwater contamination in 100-BC is mainly associated with waste produced by the reactors and related processes. Table 2-1 summarizes key facts about 100-BC. Additional details about 100-BC history and waste sites are provided in [DOE/RL-2010-96](#). As of 2014, waste site remediation in 100-BC is 93 percent complete (Table 2-1). Figure 2-1 shows the locations of groundwater monitoring wells and aquifer sampling tubes. Section 1.3 provides plume mapping details, including descriptions of terms in figure legends (e.g., Type 1 Control Point).

Table 2-1. 100-BC at a Glance

<b>Reactor operations:</b> B Reactor, 1944–1968; C Reactor: 1952–1969				
<b>2014 Groundwater Monitoring</b>				
<b>Contaminant</b>	<b>Water Quality Standard</b>	<b>Maximum Concentration</b>	<b>Plume Area<sup>a</sup> (km<sup>2</sup>)</b>	<b>Shoreline Impact (m)</b>
Hexavalent chromium	48 µg/L <sup>b</sup> / 10 µg/L <sup>c</sup>	63 µg/L (199-B3-47)	0.1 <sup>b</sup> /2.0 <sup>c</sup>	0 <sup>b</sup> /1,800 <sup>c</sup>
Strontium-90	8 pCi/L <sup>d</sup>	43 pCi/L (199-B3-46)	0.52	450
Tritium	20,000 pCi/L <sup>d</sup>	17,000 pCi/L (199-B8-9)	0	0
<b>Remediation</b>				
<b>Waste sites (interim action):</b> 93 percent complete <sup>e</sup>				
<b>Groundwater (interim action):</b> None				
Final ROD anticipated in 2017				

a. Estimated area at a concentration greater than the listed water quality standard.

b. 48 µg/L MTCA groundwater cleanup level.

c. 10 µg/L surface water standard.

d. Drinking water standard

e. Sites with status of closed, interim closed, no action, not accepted, or rejected.

COCs = contaminants of concern

MTCA = Model Toxic Control Act

ROD = Record of Decision

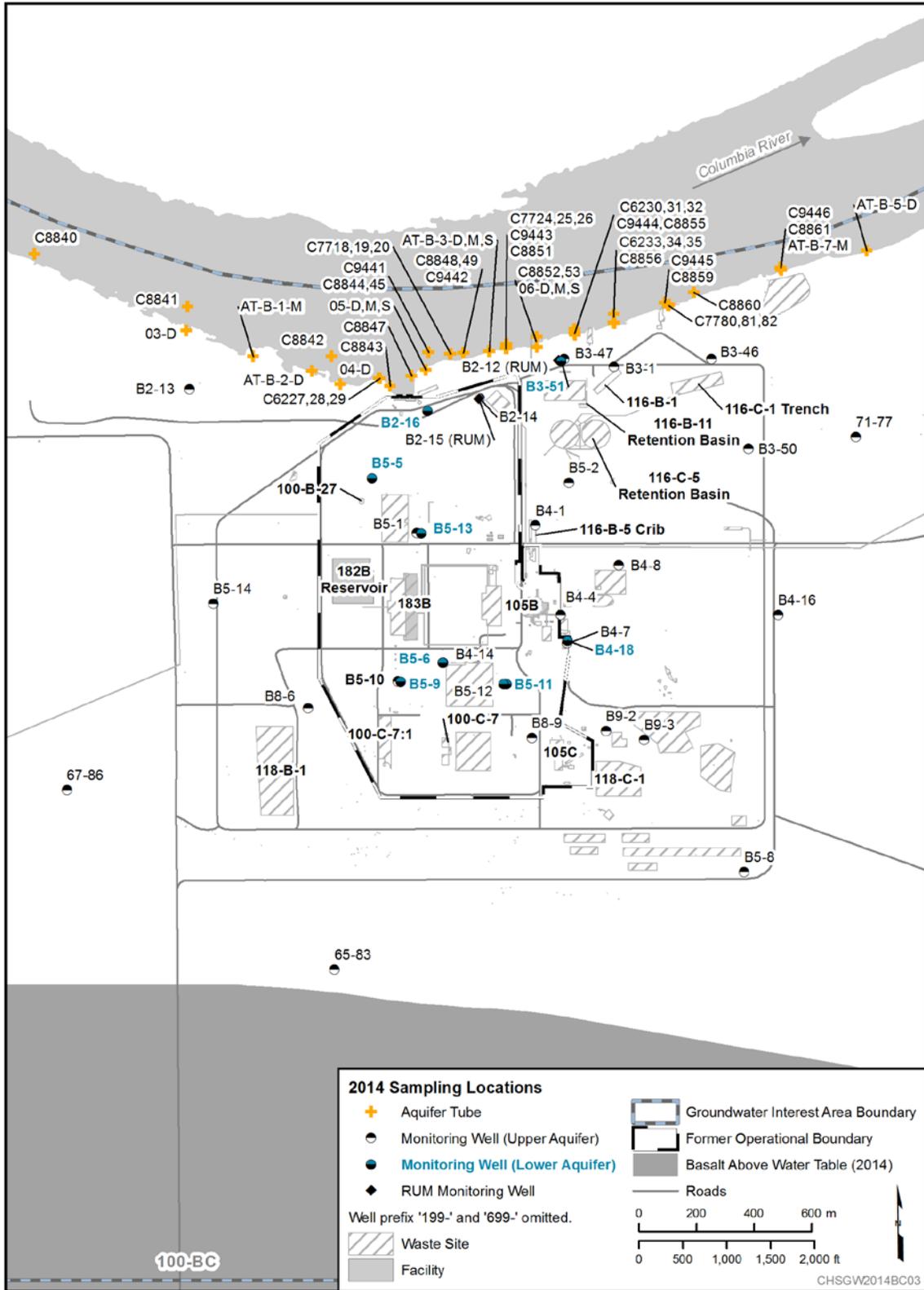


Figure 2-1. 100-BC Sampling Locations, 2014

DOE monitors 100-BC groundwater to meet CERCLA and AEA requirements. Groundwater contaminants of concern (COCs) are hexavalent chromium, strontium-90, and tritium ([DOE/RL-2010-96](#)). Previous assessments have not resulted in any interim remedial measures for groundwater. Figure 2-2 shows how estimated plume areas (in the upper part of the unconfined aquifer) have changed since 2003.

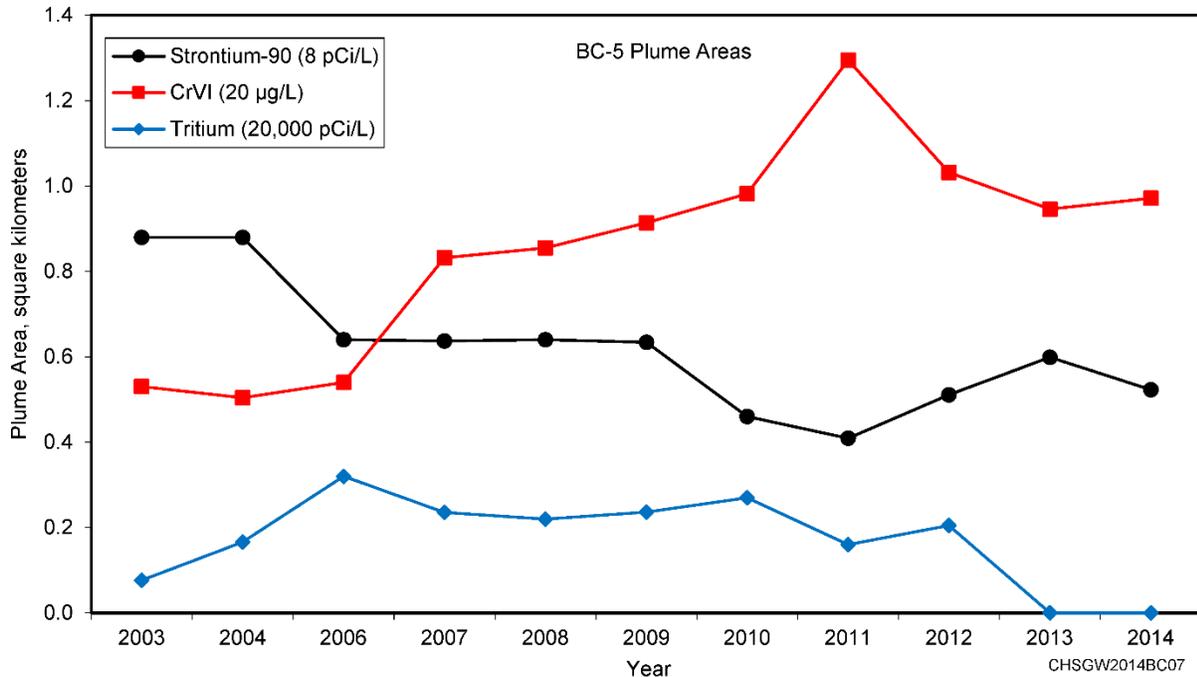
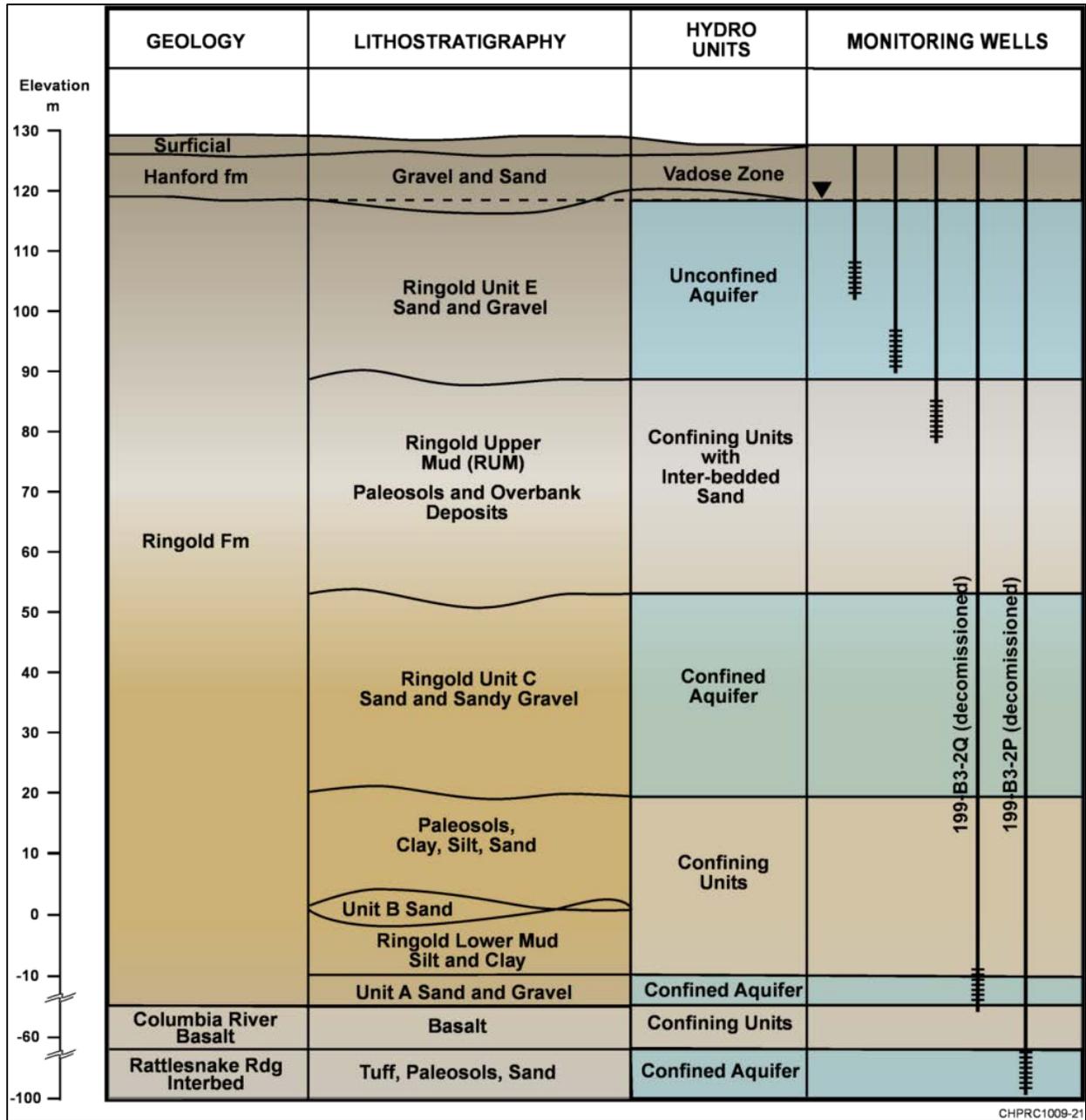


Figure 2-2. 100-BC Plume Areas

One of the last waste sites in 100-BC to undergo remediation under an interim action ROD ([EPA/ROD/R10-95/126](#); [EPA/ROD/R10-99/039](#); [EPA/ROD/R10-00/121](#)) was 100-C-7:1. This was the location of the former 183-C Head House, where unplanned releases of hexavalent chromium occurred. The contamination extended through the entire thickness of the vadose zone and the excavation reached the water table. After the completion of this remediation in 2013, there were no known remaining sources of significant contamination that could migrate to groundwater.

The vadose zone in 100-BC comprises Hanford formation sand and gravel (Figure 2-3). The water table is at a depth of approximately 18 to 24 m (59 to 79 ft). The upper portion of the unconfined aquifer beneath most of 100-BC is in the highly permeable sediments of the Hanford formation. The lower portion of the aquifer, and the entire aquifer near the Columbia River, is within the Ringold unit E sands and gravels. The unconfined aquifer is 32 to 48 m (105 to 158 ft) thick, and the base of the aquifer is a silt/clay-rich unit commonly called the RUM ([DOE/RL-2010-96](#)). [SGW-58308](#) includes updated geologic maps of 100-BC.

Figure 2-4 illustrates water table contours based on data collected on February 28, 2014, when the river stage was low. The hydraulic gradient is steepest in the north near the Columbia River, where the water table is in Ringold unit E. The gradient is very low in southern 100-BC where the water table is in the highly permeable Hanford formation.



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Figure 2-3. 100-BC Geology

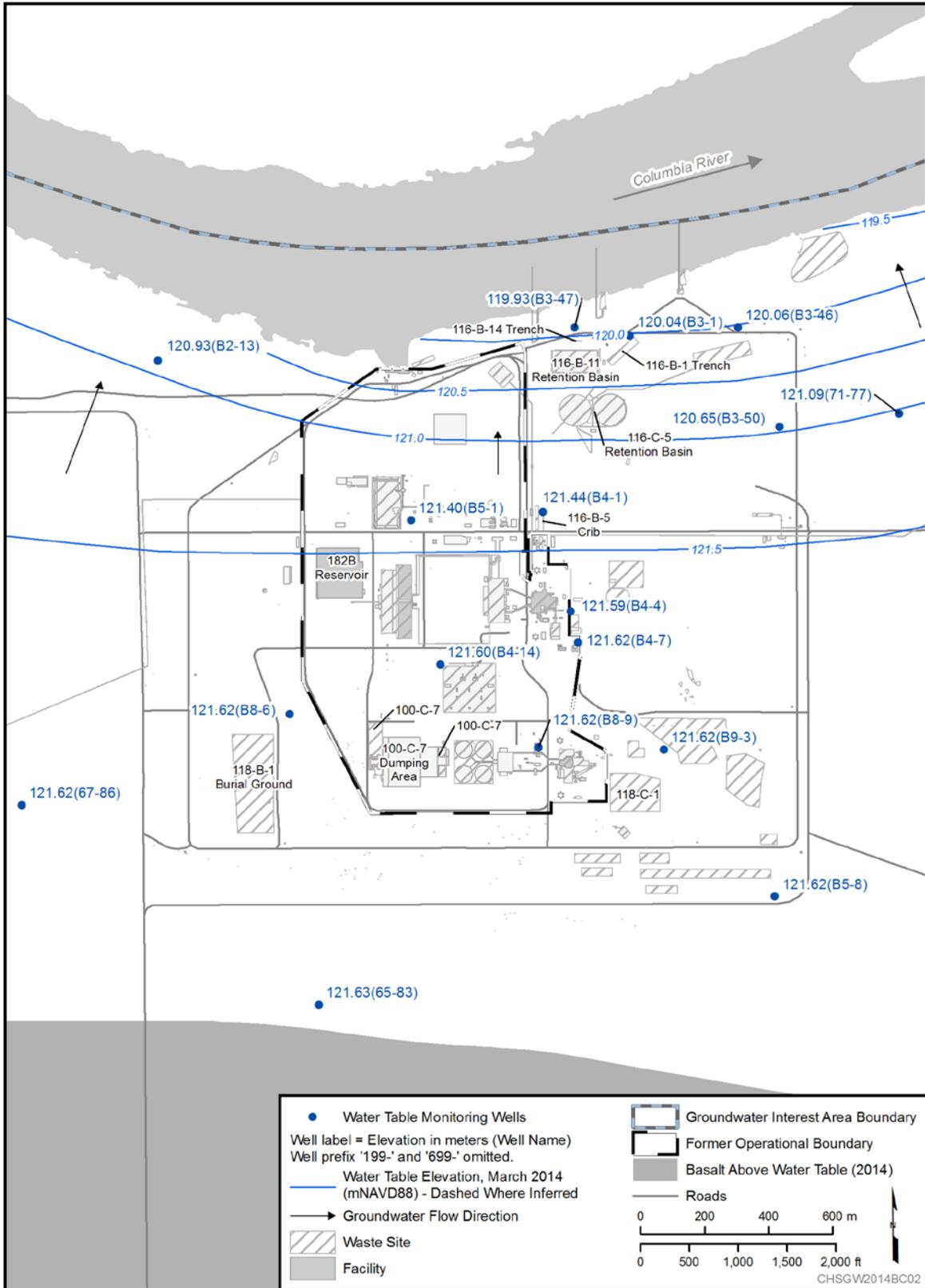


Figure 2-4. 100-BC Water Table, 2014

Table 2-2 summarizes the results of trend surface analysis of water-level data for three time periods in 2014. Three data sets are available for 2014: late February (low river stage), mid-June (high river stage) and mid-October (low river stage). The 100-BC Area is divided into two parts for gradient determination. In northern 100-BC, the gradient dipped consistently toward the north in 2014, ranging from  $1.5 \times 10^{-3}$  to  $2.8 \times 10^{-3}$  m/m. In southern 100-BC, the gradient is nearly flat. The average direction of groundwater flow is interpreted to be toward the northeast, based on water-level data and movement of the chromium plume. The magnitude and direction of the gradient vary seasonally. The gradient in February 2014 was approximately  $2 \times 10^{-5}$  m/m, dipping to the north. The largest gradient was in June at  $2 \times 10^{-4}$  m/m toward the northeast. In October 2014, calculated gradients varied from  $10^{-5}$  to  $10^{-4}$  m/m and estimated flow directions varied from northwest to northeast, depending on which set of wells were selected.

Table 2-2. Hydraulic Gradient and Groundwater Flow Directions in 100-BC

Date	Southern 100-BC		Northern 100-BC	
	Magnitude	Degrees East of North	Magnitude	Degrees East of North
February 28, 2014	1.8E-05*	0*	2.1E-03	9.3
Mid-June 2014	1.9E-04	47	1.5-03	5.6
Mid-October 2014	1.1E-04*	354*	2.8E-03	4.2

Source: [SGW-58308](#).

\* Results uncertain; little difference in water levels across region

Vertical hydraulic gradients in southern 100-BC generally are downward, particularly when the water table is dropping in late summer and fall. The vertical gradient in northern 100-BC is upward, indicative of a groundwater discharge area. The upward gradient is strongest in the fall when the water table and average river stage are low.

## 2.2 CERCLA Activities

In 2014, CERCLA activities in 100-BC included routine groundwater monitoring and RI studies.

Routine groundwater monitoring is described in the SAP for the OU ([DOE/RL-2003-38 Rev. 1](#), as modified by [TPA-CN-522](#)). Groundwater monitoring wells in 100-BC are sampled at frequencies ranging from biennially to monthly. The comprehensive annual sampling event was completed in October. Table A-1 of Appendix A lists the wells and constituents monitored. Aquifer tubes in 100-BC were sampled late August and September 2014 (Appendix C). River stage was low during this time and the head ends of the aquifer tubes were above the water level.

DOE is conducting additional studies in 100-BC between 2013 and 2015 to reduce uncertainties relating to (1) the completion of waste site remediation, (2) short-term changes in groundwater contaminants related to waste site remediation, (3) modeling results predicting that the hexavalent chromium plume could persist for over 100 years, and (4) the level of risk associated with variable contaminant concentrations in Columbia River pore water. To address these uncertainties, a change was initiated in Tri-Party Agreement Milestone M-015-74, and the RI/FS work plan and SAP were amended ([TPA-CN-558](#), [TPA-CN-559](#), [TPA-CN-592](#), [TPA-CN-593](#), and [TPA-CN-602](#)).

In 2014, workers continued to sample a series of shallow aquifer tubes called hyporheic sampling points (HSP) to monitor Columbia River pore water. Their locations are shown on Figure 2-1. The HSPs are being monitored for hexavalent chromium monthly for 2 years to identify seasonal changes and characterize the level of risk to aquatic receptors.

The revised work plan also includes groundwater monitoring, including eight wells installed in 2013 and early 2014. The new wells and older wells will be monitored for 2 years to evaluate (1) the nature and extent of hexavalent chromium and co-contaminants, (2) groundwater model input parameters, and (3) which natural attenuation processes are occurring. Monitoring frequency is quarterly for the new wells and older wells with rapid changes in chromium concentration, and semiannually or annually for wells with less variability.

A recent report describes results of the RI studies from fall 2013 through December 2014 in detail ([SGW-58308](#)). The sections below summarize results for 2014.

## 2.3 Hexavalent Chromium

Sources of hexavalent chromium included cribs near the reactor buildings, trenches and retention basins near the Columbia River, and pipelines from the reactor buildings to the near-river facilities. Other chromium sources were the 100-C-7 and 100-C-7:1 sites in southern 100-BC and the 100-B-27 sodium dichromate spill site in the northwest.

Movement of chromium in 100-BC groundwater is influenced by differences in permeability in the Hanford formation and the underlying Ringold unit E. In most of 100-BC, the top of the aquifer includes 1 to 12 m (3 to 39 ft) of the Hanford formation. The chromium plume moves rapidly through these highly permeable sediments. In northern 100-BC, the Hanford formation is unsaturated and the aquifer is entirely within Ringold unit E. Chromium concentrations in the upper aquifer in this location are more stable than in the upper aquifer of southern 100-BC.

The hexavalent chromium plume with concentrations greater than 10 µg/L covers a large area at relatively low concentrations (Figure 2-5). The plume map illustrates distribution in the upper part of the aquifer, based on data collected in fall 2014. The following changes are evident when comparing the 2013 and 2014 plume maps:

- The 48 µg/L contour that originated in southern 100-BC (with former sources at 100-C-7:1 and 100-C-7) continued to migrate downgradient. The portion of the plume with concentrations greater than 48 µg/L formerly seen in the south has merged with the greater than 48 µg/L portion near the Columbia River.
- The 10 and 20 µg/L contours on the east side of the plume have migrated eastward.
- Chromium concentrations increased to levels above 10 µg/L in 199-B2-13 and some aquifer tubes west (upstream) of the main chromium plume (Figure 2-5).

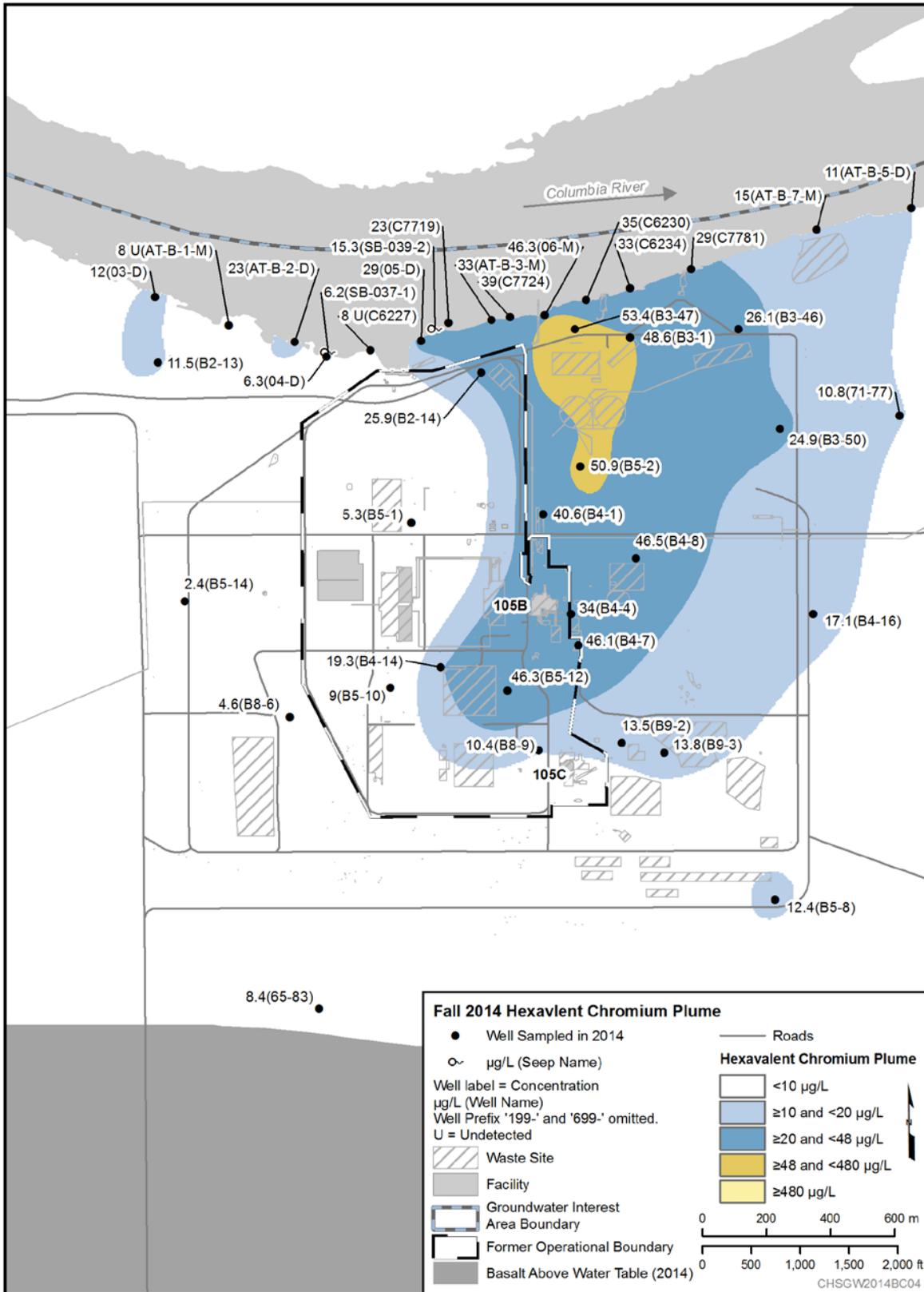


Figure 2-5. 100-BC Hexavalent Chromium Plume, 2014

Concentrations are variable in wells near the former hexavalent chromium sources at the 100-C-7 and 100-C-7:1 sites, which were remediated in 2011 and 2012 (Figure 2-6). The large peak seen in 199-B4-14 in 2012 was caused by activities related to waste site remediation. The subsequent, lower peaks are related to seasonal variations in groundwater flow direction. Well 199-B5-10 is located closer to the former source; its concentrations declined from 24  $\mu\text{g/L}$  when the well was first sampled in January 2014 to 9  $\mu\text{g/L}$  in October.

As the 100-C-7:1 contamination migrated to the northeast, concentrations in wells in northern 100-BC increased (Figure 2-7). The peak concentrations appear to have passed wells in central 100-BC (199-B4-4, 199-B4-7, and 199-B4-8; Figure 2-8).

The eastern boundary of the chromium plume at 10 and 20  $\mu\text{g/L}$  is farther east than it was in 2013. The southern plume appears to have migrated downgradient (northeast), and then moved north toward the river. Concentrations have increased in 199-B3-46, 199-B3-50, and 699-71-77 (Figure 2-9) and in nearby aquifer tubes (AT-B-7-M and AT-B-5-D). Concentrations have also increased in the next well to the east, 699-72-73, but the average concentration in fall 2014 was slightly less than 10  $\mu\text{g/L}$ .

Chromium concentrations increased in one well and two aquifer tubes located upstream of the main plume in 2014. The highest concentration was 23  $\mu\text{g/L}$  in AT-B-2-D, a four-fold increase from the previous year. Analytical problems with hexavalent chromium analyses in 2014 created some uncertainty in unfiltered samples. However, during a data review, several samples were filtered and reanalyzed and results were consistent with the initial results. There is no known source of chromium in this region.

In recent years, chromium concentrations have declined in water table wells in western 100-BC, such as 199-B5-1 and 199-B8-6. This change indicates clean groundwater moving into 100-BC from the west and south. The low concentrations in these wells persisted in 2014.

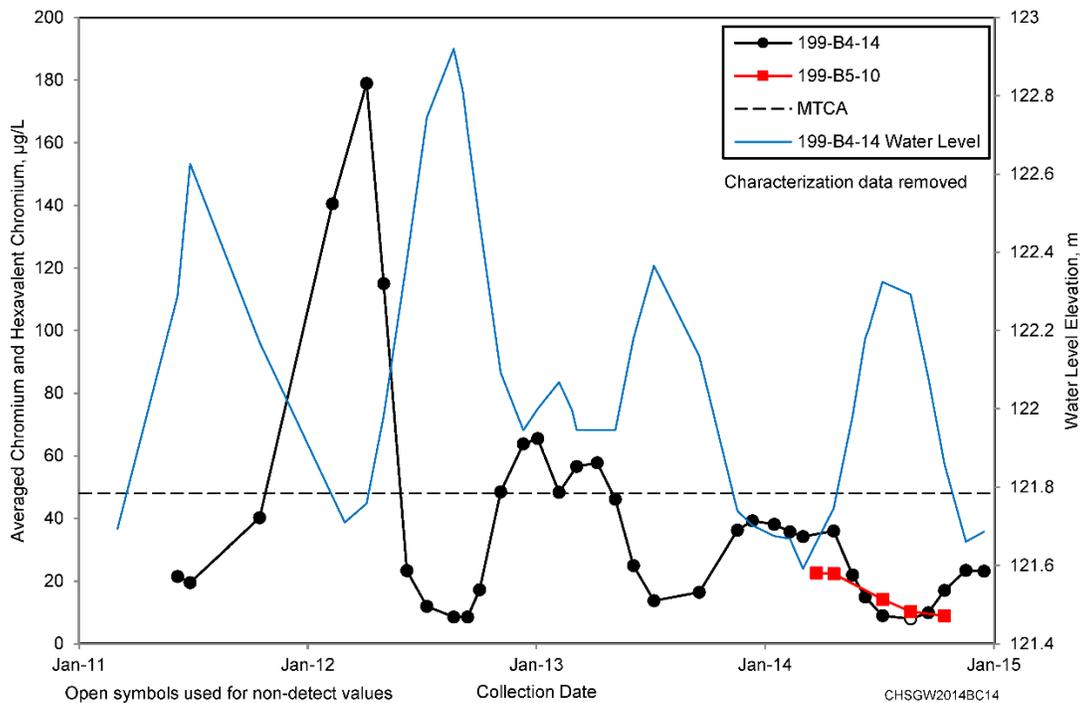


Figure 2-6. 100-BC Hexavalent Chromium and Water-Level Data in Wells 199-B4-14 and 199-B5-10 in Southern 100-BC

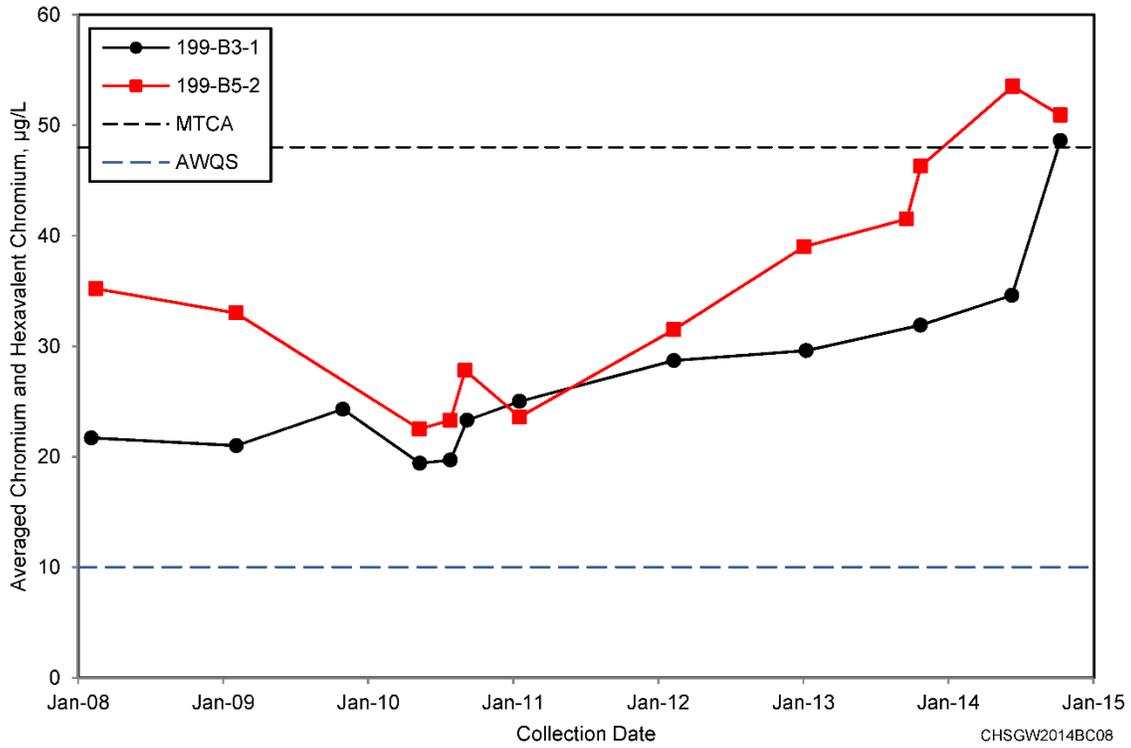


Figure 2-7. 100-BC Hexavalent Chromium Data for Wells 199-B3-1 and 199-B5-2 in Northern 100-BC

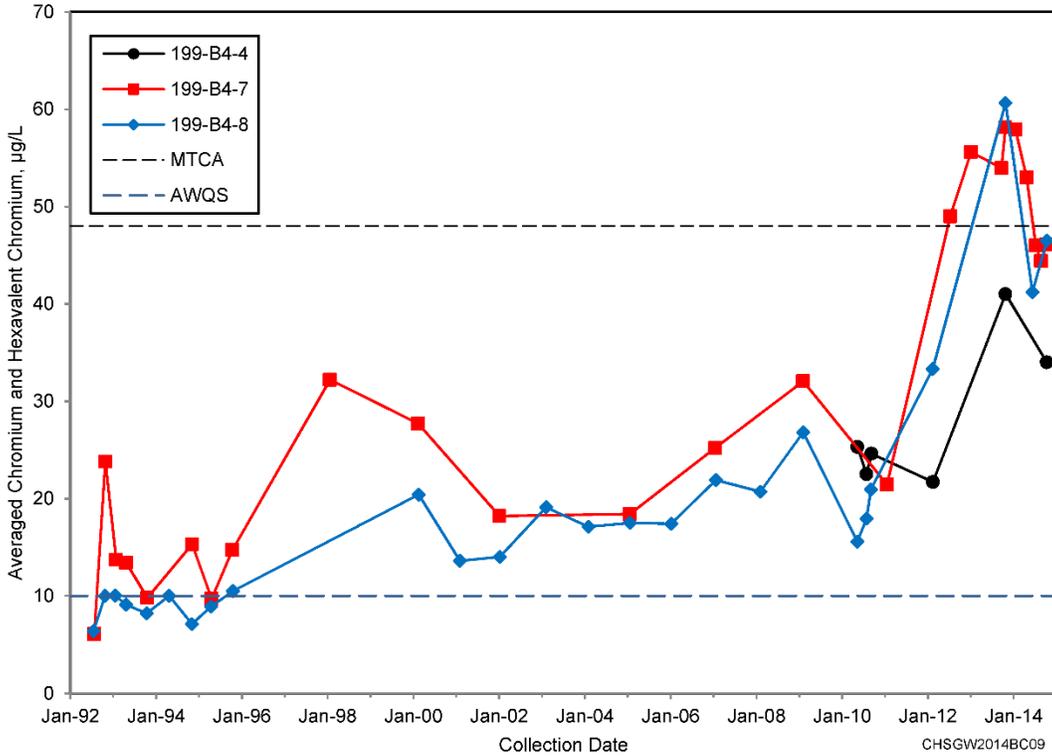


Figure 2-8. 100-BC Hexavalent Chromium Data in Wells 199-B4-4, 199-B4-7, and 199-B4-8 in Central 100-BC

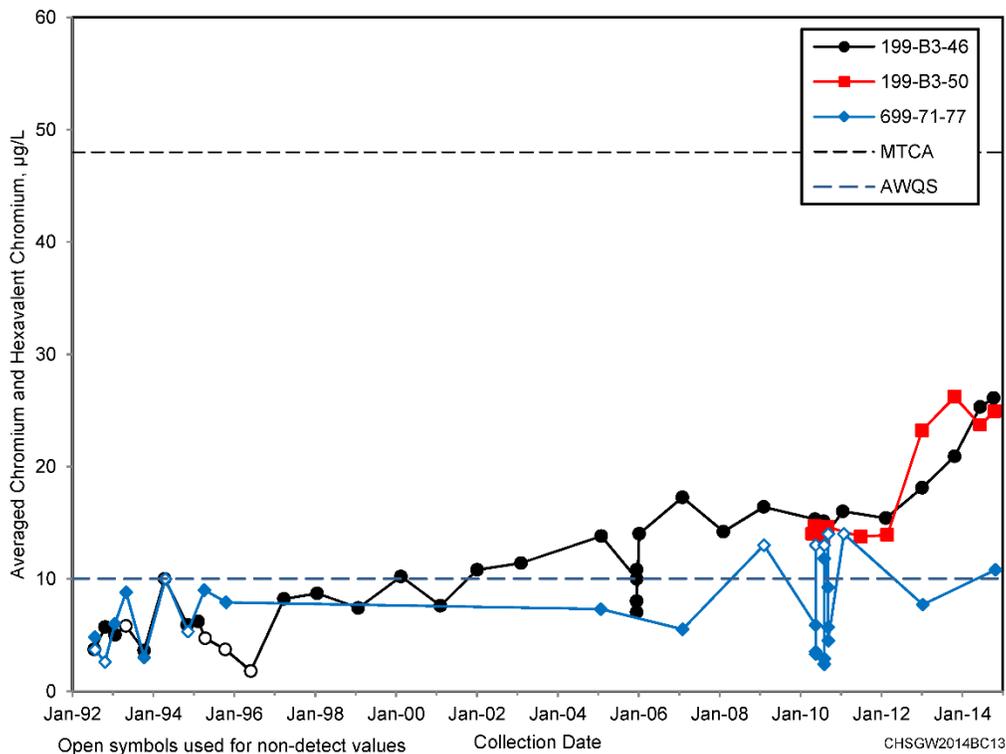


Figure 2-9. 100-BC Hexavalent Chromium Data in Wells 199-B3-46, 199-B3-50, and 699-71-77 in Northeastern 100-BC

Chromium concentrations are relatively stable in wells screened in Ringold unit E, which is less permeable than the Hanford formation. Figure 2-10 illustrates chromium trends in 199-B5-5 and 199-B5-6, which are screened in the lower part of Ringold unit E, and 199-B3-47, which is screened at the top of the aquifer where the water table is in the Ringold Formation. Ringold unit E is not as permeable as the Hanford formation in 100-BC, so groundwater moves more slowly.

Figure 2-11 shows chromium distribution in the lower part of the unconfined aquifer in fall 2014. Between 2009 and 2014, eight wells were installed and screened in the lower part of the aquifer. Deep contamination is present in southern and western 100-BC. No deep contamination is found in northeastern 100-BC (199-B3-51). The bimodal distribution of contamination in western 100-BC is attributed to contaminant releases of different ages. Older releases at a time when there was a strong, downward hydraulic gradient drove contamination into the lower part of the aquifer, which is less transmissive than the upper sediments.

Figures 2-12 and 2-13 are cross sections showing vertical distribution of hexavalent chromium in fall 2014. The interpretation is based on monitoring data wells screened at different depths, and supplemented by characterization data collected during drilling that were presented in the 2013 annual report ([DOE/RL-2014-32](#)). Deep contamination is now present in 199-B5-9, 199-B5-13 (Figure 2-12), and 199-B4-18 (Figure 2-13), which were previously thought to be uncontaminated based on characterization data. Note that early data from some of the newest deep wells may have been biased low because of residual effects of drilling, which create a locally reductive environment. This effect dissipates over time.



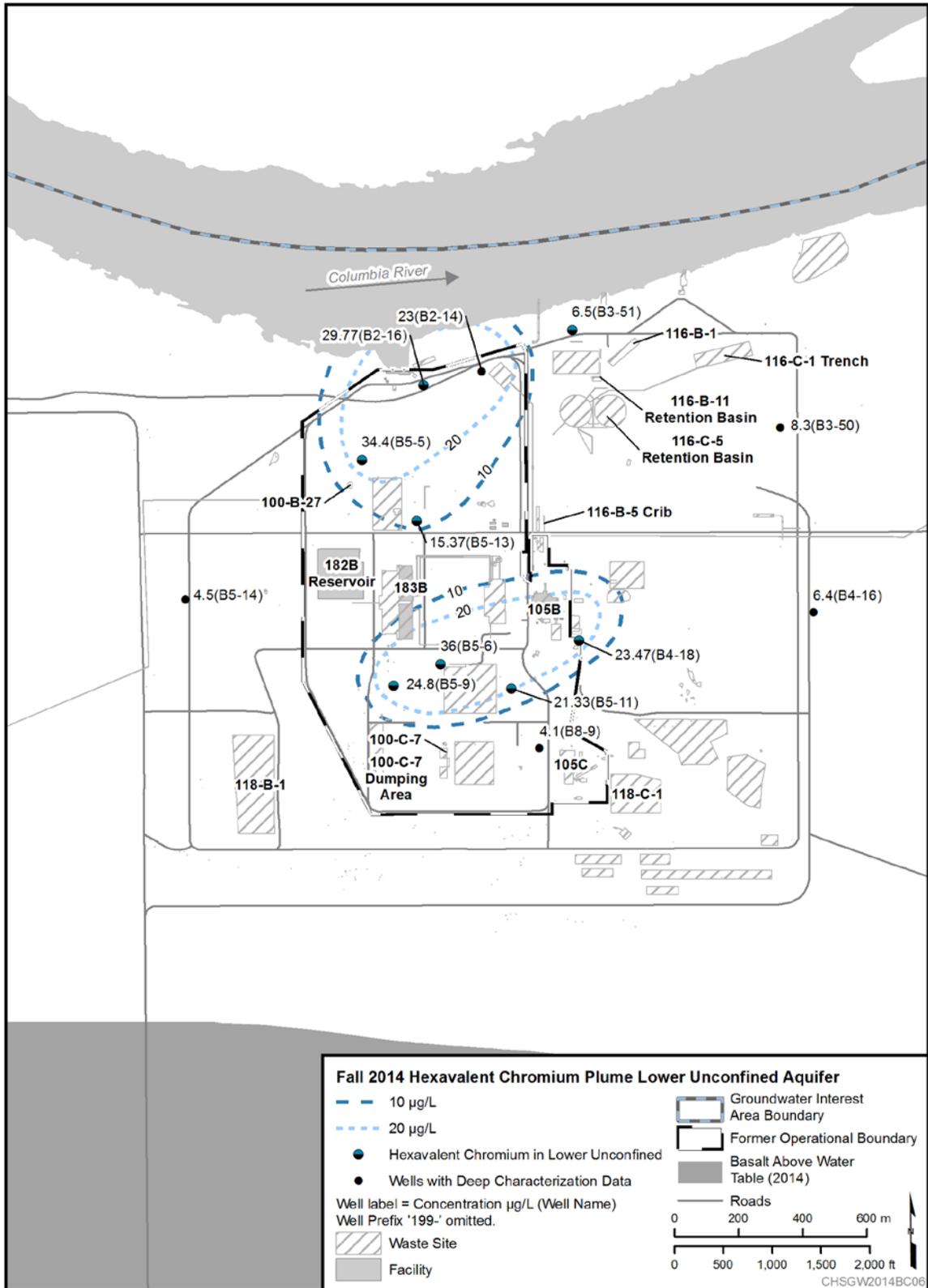


Figure 2-11. 100-BC Hexavalent Chromium in the Lower Part of the Unconfined Aquifer

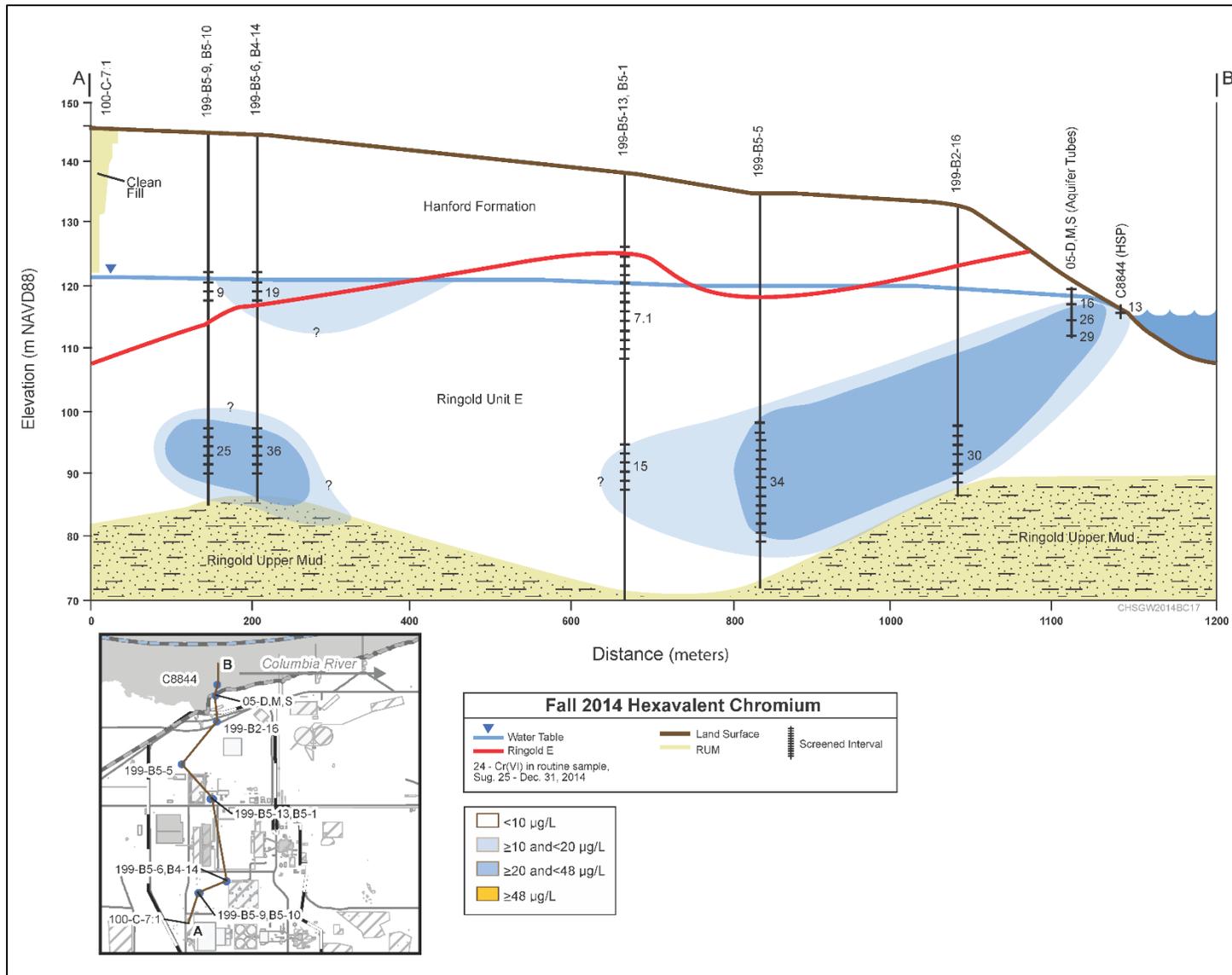


Figure 2-12. 100-BC Cross Section Showing Hexavalent Chromium Distribution, South to North in Western 100-BC

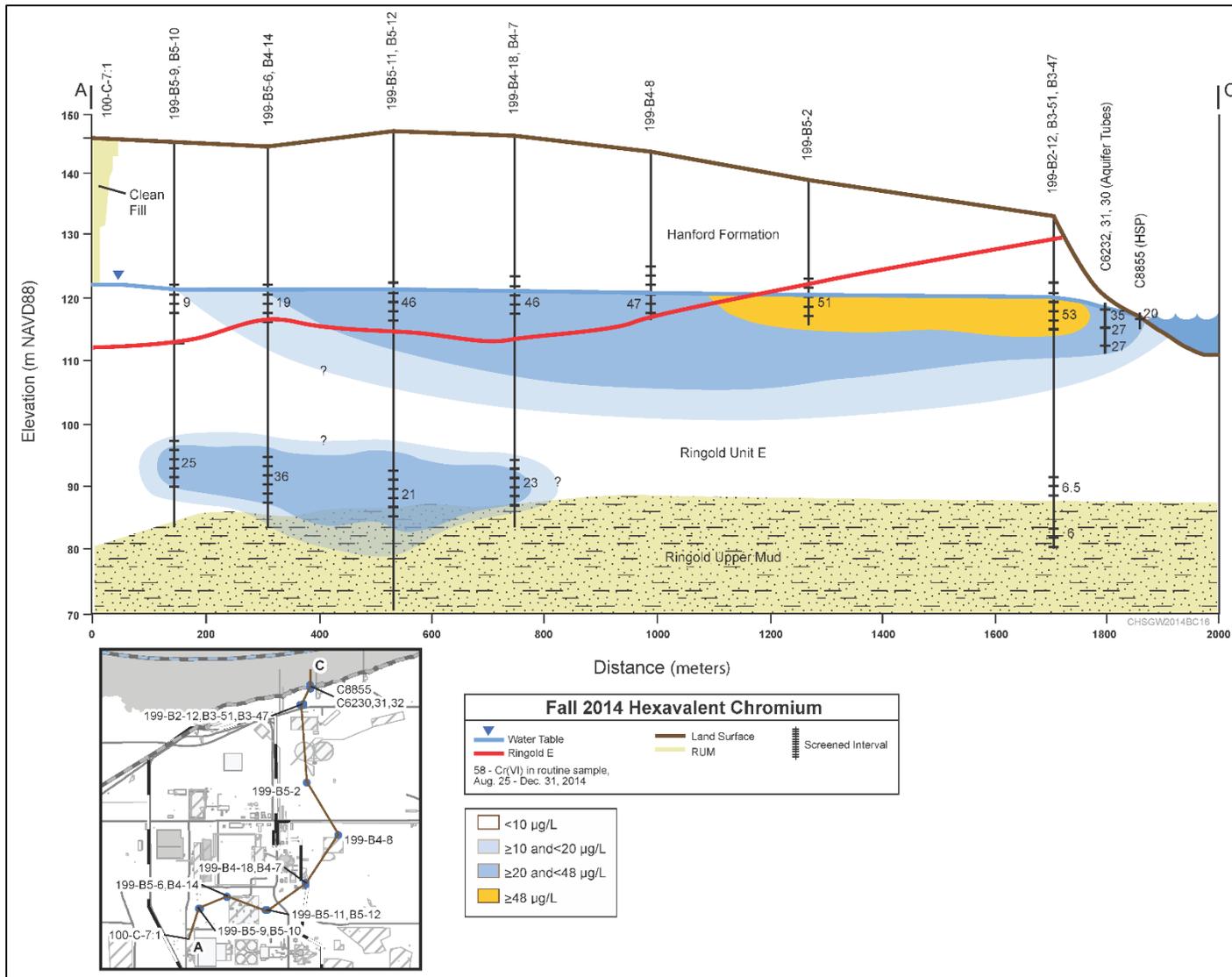


Figure 2-13. 100-BC Cross Section Showing Hexavalent Chromium Distribution, Southwest to Northeast

**Aquifer Tubes and Hyporheic Sampling Points (HSPs).** Thirty-five aquifer sampling tubes in 100-BC are monitored annually (Appendix C). These aquifer tubes range from 2 to 8 m (6.6 to 26.2 ft) in depth and provide an indication of groundwater quality approaching its point of discharge to the Columbia River. The heads of these tubes are on the shoreline above the low water mark, and they are sampled from the shore. The plume map of hexavalent chromium (Figure 2-5) includes the maximum concentration in each cluster sampled in fall 2014.

The RI project installed 23 shallower sampling points in 2013 and 2014 that are more indicative of concentrations in the accessible river environment. These range in depth from 15 cm (5.9 in.) to 1 m (3.3 ft). They are submerged even at low river stage and are sampled from a boat. Results of these studies are described in detail in [SGW-58308](#).

Figure 2-14 shows results of October 2014 grab samples collected from 14 HSPs screened at 0.5 m (1.6 ft) depth. Concentrations ranged from below detection levels (upstream HSPs) to 22 µg/L adjacent to the contaminant plume. These samples were collected during a period when average river stage was low and groundwater was discharging to the river.

During periods of sustained high river stage, hexavalent chromium concentrations tended to be lower in HSP samples (Figure 2-15). Higher head pushes river water into the hyporheic zone where it mixes with or displaces groundwater.

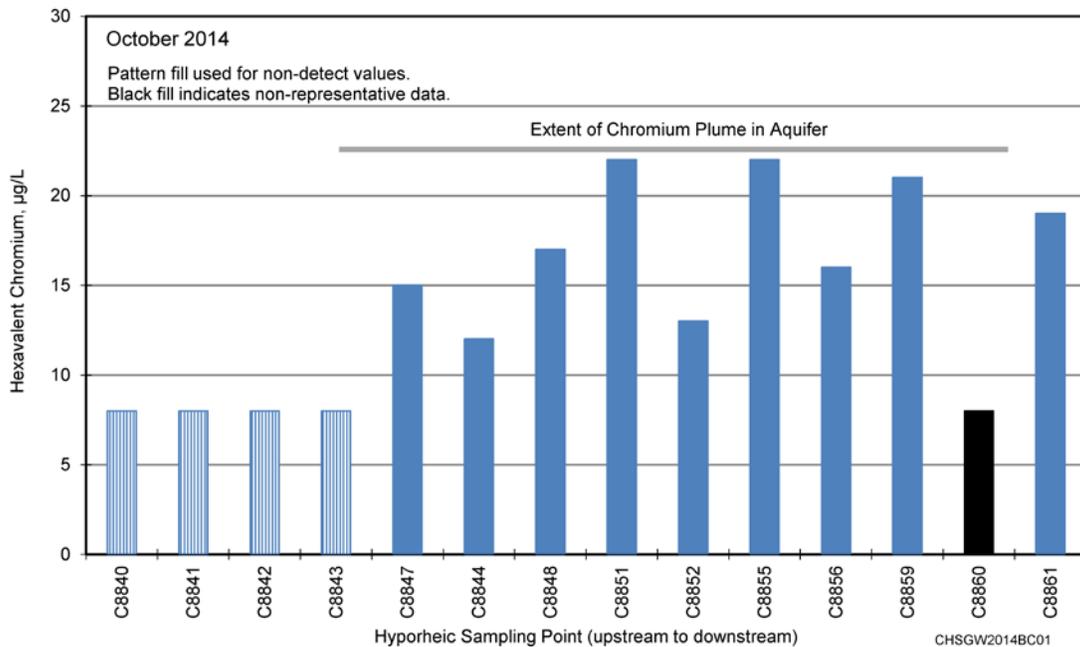


Figure 2-14. 100-BC Hexavalent Chromium in 0.5 m Deep Hyporheic Sampling Points, October 2014

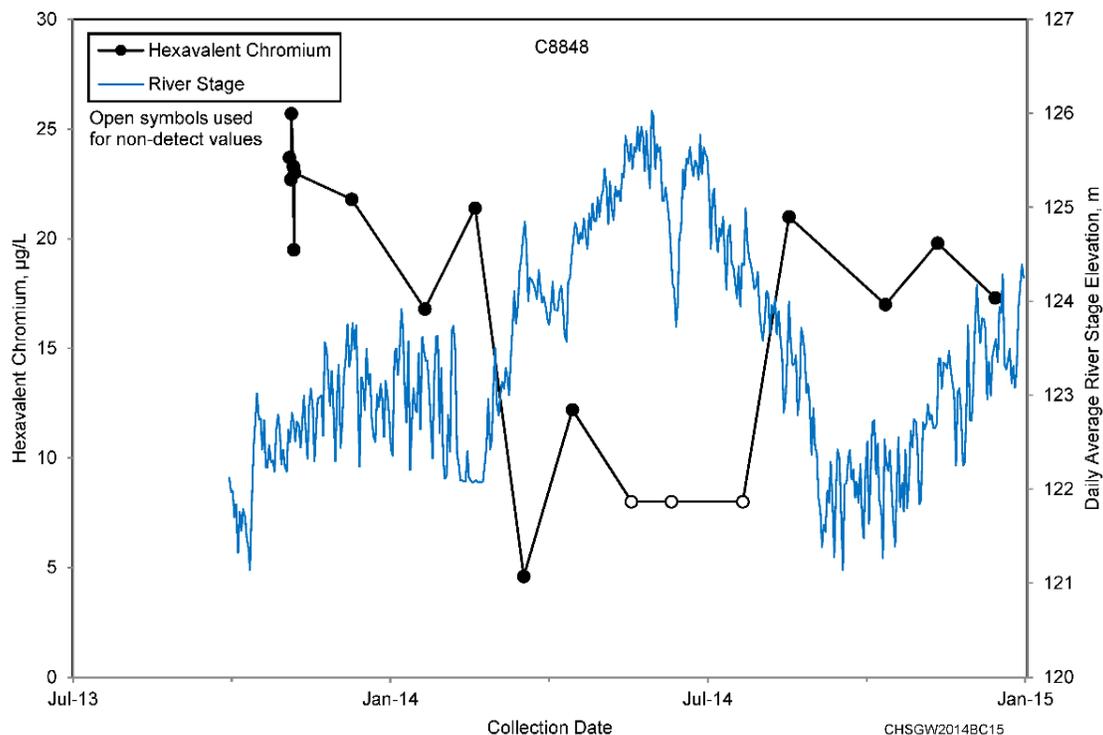


Figure 2-15. 100-BC Example of Monthly Hexavalent Chromium Concentrations in an HSP, in Relation to Daily Average River Stage Elevation below Priest Rapids Dam

Samplers collected river water from approximately 15 cm (5.9 in.) above the bottom at seven of the HSP sites during December 2014. Hexavalent chromium concentrations were near or below detection limits (maximum 3.2 µg/L). These results confirmed previous studies that showed chromium concentrations in the river at 100-BC were below the aquatic standard ([WCH-380, Rev. 1](#)).

DOE will continue to sample the HSPs monthly in 2015 to study the effects of seasonal river stage changes and plume migration.

## 2.4 Strontium-90

Liquid effluent containing strontium-90 was disposed to cribs near the reactor buildings and to cribs, trenches, and retention basins in northeastern 100-BC. Figure 2-16 shows an interpretation of the plume based on 2014 data. Concentrations ranged from below detection limits to 43 pCi/L, similar to previous years.

Figure 2-17 shows the strontium-90 trends in northern 100-BC near some of the former contaminant sources: 199-B3-47 near the 116-B-11 Retention Basin and 116-B-14 Trench, 199-B3-1 near the 116-B Trench, and 199-B3-46 near the 116-C-1 Trench. These sites have been remediated. The concentrations in groundwater have declined since the 1990s.

Groundwater samples indicate that strontium-90 contamination in 100-BC groundwater is limited to the upper portion of the unconfined aquifer. Strontium-90 concentrations in 199-B3-51, screened at the bottom of the aquifer, are below detection limits, while the adjacent (199-B3-47), screened at the water table, has concentrations above the DWS.

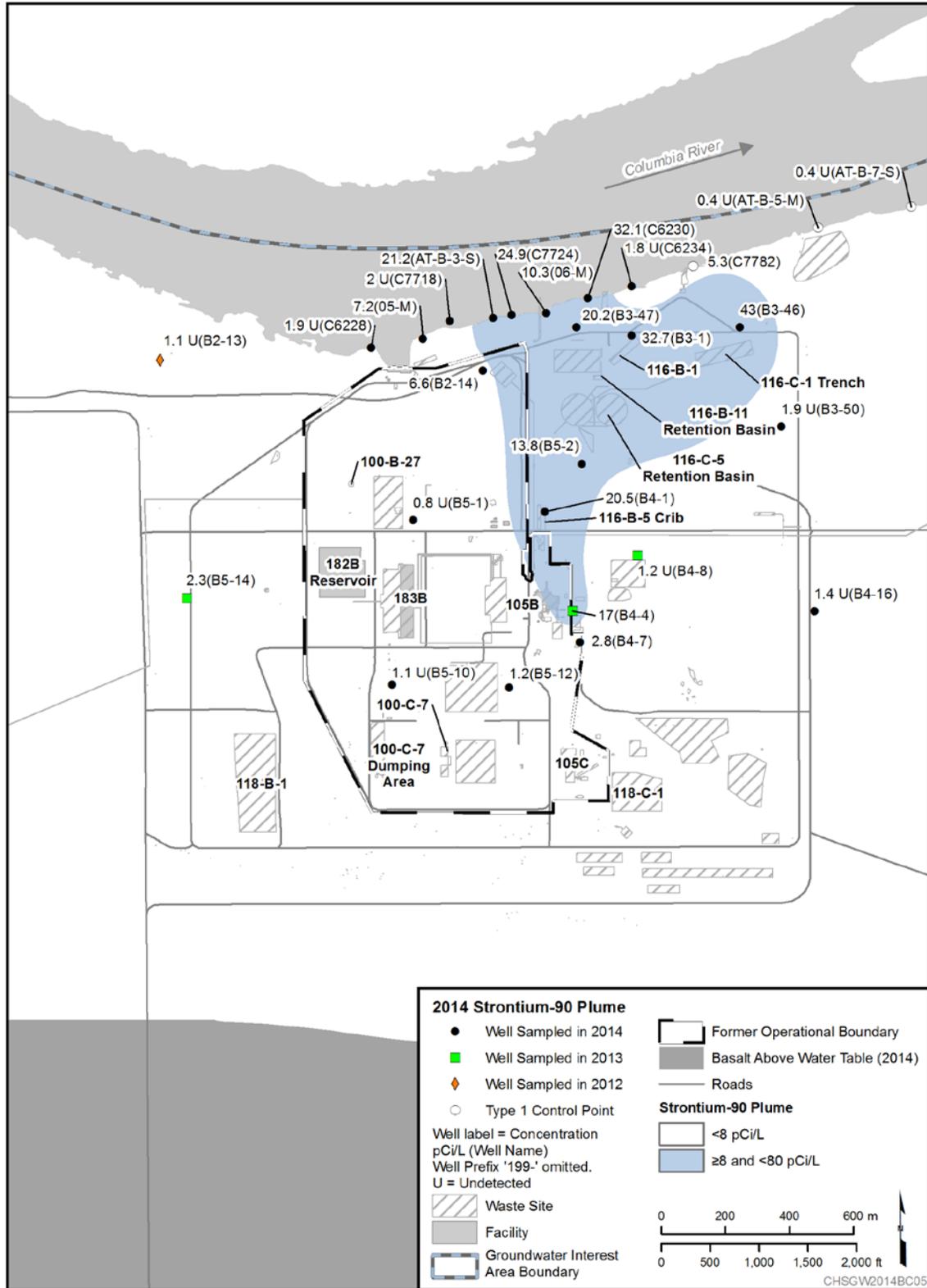


Figure 2-16. 100-BC Strontium-90 Plume, 2014

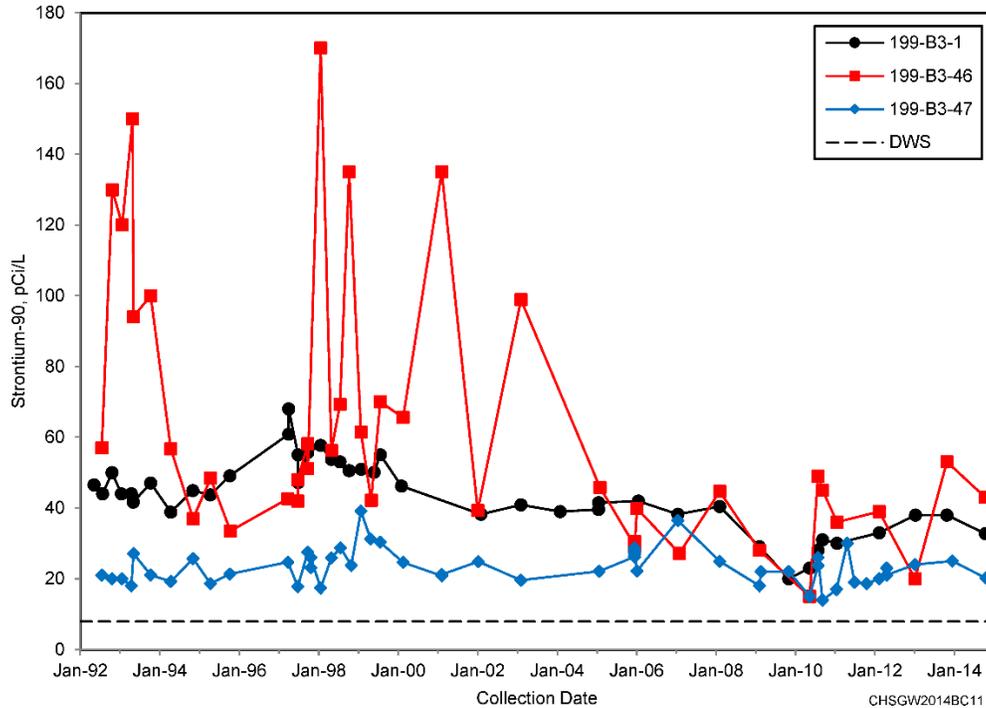


Figure 2-17. 100-BC Strontium-90 Data in Wells 199-B3-1, 199-B3-46, and 199-B3-47

Strontium-90 concentrations in several 100-BC aquifer tubes continued to exceed the DWS in 2014. The highest concentrations are in the shallow or mid-depth tubes, reflecting the distribution in the aquifer. Strontium-90 was not analyzed in HSPs in 2014 because they must be sampled at such low flow rates that it makes collecting large-volume samples like strontium-90 impractical. Five HSP samples were analyzed for strontium-90 in 2013, and the only detection was at 3.9 pCi/L in HSP C8847.

## 2.5 Tritium

Tritium was present in effluent discharged to former cribs near the B Reactor and near the Columbia River. The former 118-B-1 Burial Ground in southwestern 100-BC was another source of contamination. All of these waste sites have been remediated.

In 2014, as in 2013, no tritium concentrations exceeded the DWS in 100-BC monitoring wells or aquifer tubes. In 2012, two portions of 100-BC had tritium concentrations slightly above the DWS: one in northern 100-BC, and one in southern 100-BC. Concentrations continued to decline in 2014 (Figure 2-18).

Vertical characterization data from wells drilled in 2009, 2010, and 2013 indicated that tritium concentrations are generally highest near the top or middle of the aquifer, and lower at the bottom of the aquifer.

In the past, tritium contamination that originated in the 200 Areas migrated between Gable Butte and Gable Mountain to the region between 100-BC and 100-KR. The concentration peaked at 21,300 pCi/L in 699-72-73 in 2000 and subsequently declined to 2,580 pCi/L in 2014. In 2014, the maximum tritium concentration between 100-BC and 100-KR was 5,830 pCi/L in an aquifer tube (14-D). With the decline of the water table in the 200 Areas, there is little potential for continued migration of contamination through Gable Gap.

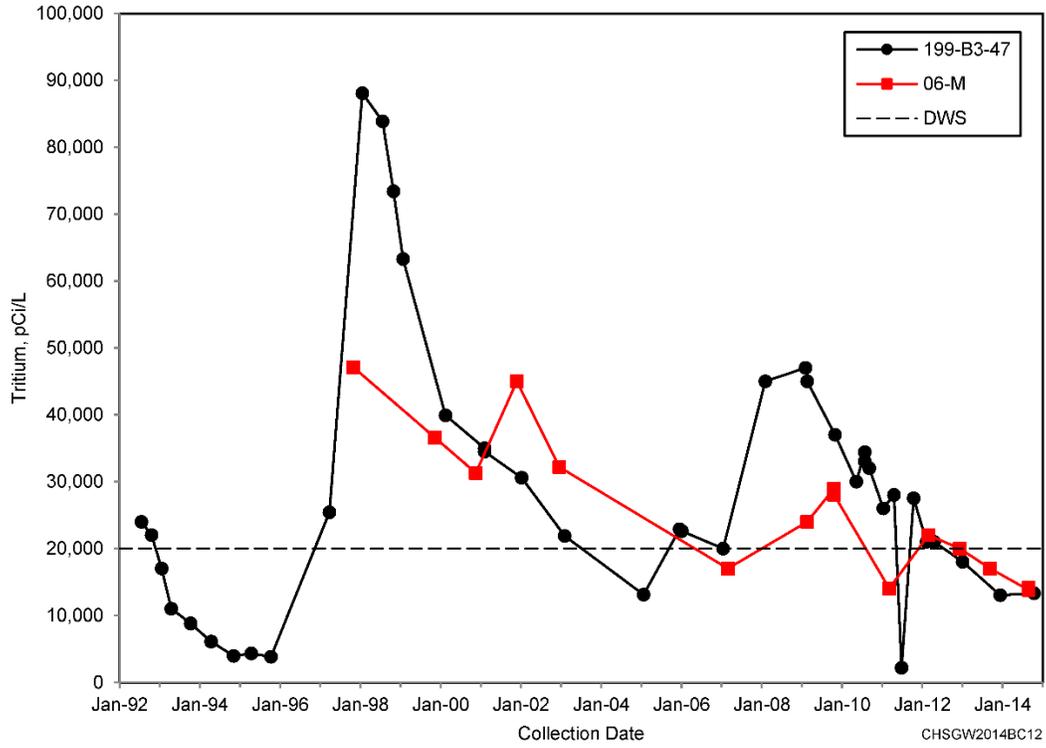


Figure 2-18. 100-BC Tritium Data for Well 199-B3-47 and Aquifer Tube 06-M in Northern 100-BC