2 100-BC

The 100-BC groundwater interest area includes the 100-BC-5 OU and surrounding region (Figure 1-1). DOE has remediated 93% of the waste sites in 100-BC, and groundwater contaminant concentrations are declining.

2.1 Overview

Two nuclear reactors formerly operated in 100-BC. The B Reactor was the first of its kind and 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; details are provided in DOE/RL-2010-96, Draft A, Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units. Figure 2-1 shows the locations of groundwater monitoring wells and aquifer sampling tubes. Data from monitoring seeps and springs are shown on each of the plume figures presented but were not used for plume development due to their transient nature. Plume mapping details, including descriptions of terms (e.g., Type 1 control point) used in the figure legends, are provided in Section 1.5.

DOE monitors 100-BC groundwater to meet CERCLA and AEA requirements. Previous assessments have not resulted in any interim remedial measures for groundwater. DOE has identified Cr(VI), strontium-90, TCE, and tritium as groundwater contaminants of concern (COCs). Figure 2-2 shows the change in estimated plume areas (in the upper portion of the unconfined aquifer) since 2003. The TCE contamination is limited to a single well screened in the lower part of the unconfined aquifer.

The vadose zone in 100-BC is primarily Hanford formation sand and gravel (Figure 2-3). The water table is at a depth of 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 unconfined aquifer and the entire aquifer near the Columbia River is present in 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 (Chapter 3 of DOE/RL-2010-96, Draft A). Water-bearing RUM units in 100-BC are not contaminated.

Figure 2-4 illustrates the water table contours based on data collected in early March 2017, when the river stage was near average for the year. In the northern 100-BC Area, groundwater flowed to the north and northeast, discharging to the Columbia River. In the southern 100-BC Area, the hydraulic gradient is very low because the water table is in the highly permeable Hanford formation. Groundwater flow varied from east to north-northeast. The average direction of groundwater flow in the southern 100-BC Area is interpreted to be to the northeast based on water-level data and movement of the Cr(VI) plume (Section 3.6.3 of DOE/RL-2010-96, Draft A).

A high river stage in spring and early summer 2017 reversed the hydraulic gradient. Groundwater flowed toward the southeast, and near the shore there was the potential for river water to flow into the unconfined aquifer and mix with groundwater.

Water levels in wells screened in the lower part of the unconfined aquifer, near the bottom of Ringold unit E, define a potentiometric surface that determines a northward flow direction in the deep part of the aquifer. This potentiometric surface is different from the water table (top of the unconfined aquifer), with a more uniform gradient across 100-BC.
### Table 2-1. 100-BC Groundwater Conditions at a Glance

**Reactor operations:** B Reactor, 1944 to 1968; C Reactor: 1952 to 1969

<table>
<thead>
<tr>
<th>Contaminant, Water Quality Standard, Units</th>
<th>Year</th>
<th>Maximum Concentration (Well)</th>
<th>Plume Area(^a) (km(^2))</th>
<th>Shoreline Impact (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexavalent chromium, 48 µg/L/ 10 µg/L(^b)</td>
<td>2017</td>
<td>50 (199-B3-47)</td>
<td>0.04/1.3</td>
<td>0/1,546</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>58 (aquifer tube C6230)</td>
<td>0.05/1.6</td>
<td>162/1,838</td>
</tr>
<tr>
<td>Strontium-90, 8 pCi/L</td>
<td>2017</td>
<td>43.6 (199-B3-52)</td>
<td>0.50</td>
<td>443</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>49.7 (199-B3-52)</td>
<td>0.45</td>
<td>251</td>
</tr>
<tr>
<td>Trichloroethene, 5 µg/L</td>
<td>2017</td>
<td>5.49 (199-B5-11)</td>
<td>Not calculated(^c)</td>
<td>Not calculated(^c)</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>6.69 (199-B5-11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tritium, 20,000 pCi/L</td>
<td>2017</td>
<td>11,900 (199-B5-2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>15,600 (199-B5-2)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Remediation**

- **Waste sites:** 93% complete.\(^d\)
- **Groundwater:** No interim actions. Record of Decision for final remedial action is anticipated in 2019.

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\(a\). Estimated area at a concentration greater than the listed water quality standard in the upper part of the unconfined aquifer.


\(c\). Single well exceeded water quality standard; no plume defined.

\(d\). Sites with status of closed, interim closed, final closed, no action, not accepted, or rejected as of December 31, 2017.

Within the unconfined aquifer, the vertical hydraulic gradient in the southern 100-BC is generally downward, particularly when the water table is dropping in late summer and fall. The vertical gradient in the northern 100-BC is upward, indicative of a groundwater discharge area.

Estimates of average linear velocity of groundwater in the Hanford formation at 100-BC (based on the migration of Cr(VI) peaks) range from 0.77 to 1.2 m/d (2.5 to 3.9 ft/d) (**ECF-100BC5-15-0123, Estimating Chromium Migration Rate by Correlating Concentration Peaks**).
Figure 2-1. 100-BC Sampling Locations, 2017
2.2 Hexavalent Chromium

Sources of Cr(VI) 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 Cr(VI) sources were the sodium dichromate spills at the 100-C-7 and 100-C-7:1 sites in the southern 100-BC and the 100-B-27 sodium dichromate spill site in the northwest.

Movement of Cr(VI) 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 15 m (3 to 49 ft) of the Hanford formation. The Cr(VI) plume moves rapidly through these highly permeable sediments. In the northern 100-BC, the Hanford formation is unsaturated, and the aquifer is entirely within Ringold unit E. Cr(VI) concentrations in the upper part of the aquifer in the northern 100-BC are more stable than in the upper part of the aquifer in the southern 100-BC.

The Cr(VI) plume exceeding the 10 μg/L surface water standard covers a large area at relatively low concentrations (Figure 2-5). The areal extent of the plume in the upper part of the aquifer decreased between 2016 and 2017 at the 10 and 20 μg/L levels. The most notable changes were in the southern part of the plume.

The Cr(VI) trends in 100-BC wells (Figure 2-6) illustrate the migration of the plume. Well 199-B4-14 is located in the southern 100-BC, near the former Cr(VI) source at the 100-C-7:1 site (remediated in 2011 and 2012). The Cr(VI) peak in 2012 was caused by activities related to waste site remediation. The subsequent lower peaks are related to seasonal variations in vertical groundwater flow. Concentrations were below 10 μg/L during both 2017 sampling events. The increase and decrease of concentrations in downgradient wells 199-B4-7 (central 100-BC) and 199-B5-2 (farther north) illustrate downgradient migration of the 100-C-7:1 contaminant plume.
The eastern boundary of the Cr(VI) plume at 10 and 20 µg/L reached its maximum extent in 2014 and then began to contract as concentrations declined. In 2017, concentrations continued to decline in well 199-B4-16 and stabilized in well 199-B3-50 (Figure 2-6). Concentrations increased in well 199-B3-46 in June and declined in October. This direct relationship with the water table may suggest some residual contamination in the lower part of the vadose zone near the well.

Figure 2-3. 100-BC Geology

Figure 2-4. 100-BC Water Table, March 2017
Figure 2-5. 100-BC Cr(VI) Plumes in Upper and Lower Parts of the Unconfined Aquifer, 2017
Figure 2-6. 100-BC Cr(VI) Trends in Selected Wells
One well (199-B3-47, screened at the water table and located near the Columbia River) had Cr(VI) concentrations above 48 µg/L in fall 2017 (Figure 2-7). In June 2017, when the river stage was high, the Cr(VI) concentration and specific conductance dropped sharply, indicating mixing with river water. Except when influenced by high river stage, concentrations have remained generally stable in well 199-B3-47 since 2003. Remediation of nearby Cr(VI) waste sites was completed in the late 1990s, and the persistence of Cr(VI) in groundwater may suggest that residual sources remain in the deep vadose zone.

Figure 2-8 illustrates Cr(VI) concentrations in selected wells screened in the lower part of the aquifer in Ringold unit E. Concentrations increased in 2016 and 2017 in well 199-B5-11, reaching a maximum of 45 µg/L. The Cr(VI) distribution in the lower part of the unconfined aquifer (illustrated by dashed lines in Figure 2-5) did not change significantly between 2016 and 2017. The vertical distribution of Cr(VI) in the western 100-BC is attributed to contaminant releases of different ages.

The Cr(VI) exceeds the surface water standard in groundwater approaching the Columbia River but not in the river itself. The highest Cr(VI) concentration in a 100-BC aquifer tube in 2017 was 39 µg/L in tube 06-M. The concentration in tube C6230, which had the highest concentration in 2016 (58 µg/L), was 30 µg/L in 2017. Water samples from the river had Cr(VI) concentrations below the surface water standard (Chapter 4 of DOE/RL-2010-96, Draft A).
2.3 Strontium-90

Liquid effluent containing strontium-90 was disposed to cribs near the reactor buildings and to cribs, trenches, and retention basins in the northeastern 100-BC Area. Figure 2-9 shows an interpretation of the plume based on 2017 data; there was no significant change from 2016.

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

Strontium-90 concentrations in some wells have not declined at the rate expected from radioactive decay and downgradient migration, which may suggest the presence of some residual source in the vadose zone, but the amount appears to be minor. If a significant mass of contamination remained in the lower vadose zone, concentrations would increase when the water table rose (e.g., 100-N [see Section 6.2]). However, during June 2017, when the water table was high, strontium-90 concentrations in 100-BC wells did not increase, indicating that the residual contamination is minor. Figure 2-10 shows the strontium-90 trends in the northern 100-BC Area near some of the remediated waste sites: well 199-B3-46 near the 116-C-1 Trench, well 199-B3-47 near the 116-B-11 Retention Basin and 116-B-14 Trench, and well 199-B3-52 near the 116-C-5 Retention Basin.

Strontium-90 concentrations in several 100-BC aquifer tubes continued to exceed the DWS in 2017 (Figure 2-9), with a maximum of 18.3 pCi/L in tube C6230. Concentrations are typically lower in deeper tubes, reflecting the distribution in the aquifer. This contamination does not extend to the shallow hyporheic zone; strontium-90 was near or below detection limits in 100-BC hyporheic sampling points (HSPs) in 2017.
Figure 2-9. 100-BC Strontium-90 Plume, Fall 2017
2.4 Tritium

Tritium was present in effluent discharged to former cribs near B Reactor and near the Columbia River. The former 118-B-1 Burial Ground in the southwestern 100-BC was another source of tritium. All of these waste sites have been remediated, although some tritium remains in the vadose zone beneath the 118-B-1 Burial Ground (Section 4.2.4.7 of DOE/RL-2010-96, Draft A).

Tritium concentrations in 100-BC monitoring wells and aquifer tubes have been below the 20,000 pCi/L DWS since 2013 and continued to decline in 2017. The highest concentration was 11,900 pCi/L in well 199-B5-2, located in the northern 100-BC. Downgradient of the 118-B-1 Burial Ground, tritium was undetected in well 199-B8-6.

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

2.5 Trichloroethene

During RI characterization drilling in 2010 and 2011, low concentrations of TCE were detected in groundwater samples, with the most persistent detections in the lower part of the unconfined aquifer. The source of this contamination is not known, and its presence in the lower part of the aquifer suggests that it is related to older releases during operational periods when the hydraulic gradient was downward. Only well 199-B5-11 had concentrations above the 5 µg/L DWS (Figure 2-11), at a concentration of 5.49 µg/L in 2017.
2.6 CERCLA Remediation and Monitoring

In 2017, CERCLA activities for 100-BC included routine groundwater monitoring and continued progress on an RI/FS report and proposed plan.

Routine groundwater monitoring was performed in accordance with the SAP (DOE/RL-2003-38, 100-BC-5 Operable Unit Sampling and Analysis Plan), as modified by TPA-CN-0734, Tri-Party Agreement Change Notice Form: DOE/RL-2003-38, Rev 2, 100-BC-5 Operable Unit Sampling and Analysis Plan. The SAP was designed to meet sampling objectives during the period of time after the conclusion of RI studies until a groundwater remediation method is selected and implemented under an upcoming ROD. Wells and aquifer tubes were sampled successfully in 2017.

In 2017, EPA reviewed the Draft A RI/FS report (DOE/RL-2010-96) and proposed plan (DOE/RL-2016-43, Proposed Plan for Remediation of the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units). DOE is revising the documents, which will undergo public review in 2018. These documents propose MNA as the preferred remedy for groundwater. A ROD is expected in 2019.

2.7 Atomic Energy Act Monitoring

AEA groundwater monitoring was conducted at 22 groundwater wells and aquifer tubes in the 100-BC groundwater interest area in accordance with the SAP (DOE/RL-2015-56). The primary AEA constituents for 100-BC are strontium-90 and tritium. Wells were sampled in accordance with SAP requirements in 2017.
Concentrations of radionuclides detected in groundwater samples from 23\(^1\) wells and aquifer tubes were used to estimate the cumulative TED and to compare the cumulative beta/photon emitters, alpha emitters, and uranium mass to DWSs, as described in Section 1.2.4. The estimated TED did not exceed the 100 mrem/yr standard in 100-BC. The DWSs for cumulative alpha emitters and uranium mass were not exceeded. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 10 locations in this interest area (Table 2-2). Some of these locations are adjacent to the Columbia River, which is the primary potential pathway for offsite exposure to Hanford Site contaminated groundwater. Members of the public are protected from exposure to groundwater through the implementation of institutional controls (ICs) that restrict access to groundwater. CERCLA remedial action decisions will provide longer term protection of the public and the environment.

<table>
<thead>
<tr>
<th>Monitoring Location/Well Name</th>
<th>Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>06-M</td>
<td>4.39</td>
</tr>
<tr>
<td>199-B3-1</td>
<td>12.13</td>
</tr>
<tr>
<td>199-B3-46</td>
<td>7.7</td>
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<tr>
<td>199-B3-47</td>
<td>5.71</td>
</tr>
<tr>
<td>199-B3-52</td>
<td>18.65</td>
</tr>
<tr>
<td>199-B4-4</td>
<td>8.02</td>
</tr>
<tr>
<td>199-B5-2</td>
<td>10.03</td>
</tr>
<tr>
<td>AT-B-3-S</td>
<td>6.67</td>
</tr>
<tr>
<td>C6230</td>
<td>9.15</td>
</tr>
<tr>
<td>C7725</td>
<td>8.76</td>
</tr>
</tbody>
</table>


Note: None of the wells in 100-BC had total effective dose ≥100 mrem/yr, cumulative alpha activity ≥15 pCi/L, or uranium mass concentration ≥30 µg/L.

\(^1\) The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.
3 100-FR

This chapter presents information for the 100-FR groundwater interest area (Figure 1-1), which includes the former 100-F operational area, the 100-FR-3 OU, and surrounding region (Figures 1-1 and 3-1).

3.1 Overview

One nuclear reactor operated at 100-FR between 1945 and 1965. Groundwater contamination originated from waste sources related to reactor operations and biological experiments that continued until 1976. Table 3-1 summarizes key facts about 100-FR, and additional details about 100-FR history and waste sites are provided in Chapter 1 of DOE/RL-2010-98, Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units. Waste site remediation in 100-FR is 100% complete.

EPA signed a CERCLA ROD in September 2014 (EPA et al., 2014, Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units). The selected remedy for groundwater is MNA. The groundwater COCs are nitrate, TCE, Cr(VI), and strontium-90.

DOE monitors 100-FR groundwater to meet CERCLA and AEA requirements. Figure 3-1 shows the locations of groundwater monitoring wells and aquifer sampling tubes. Figure 3-2 depicts how the plume areas have changed over the years.

The vadose zone and the unconfined aquifer in 100-FR comprise mostly Hanford formation sand and gravel (Figure 3-3). Ringold unit E is largely absent in this region, but a remnant of Ringold unit E is interpreted to exist in the southwestern 100-F Area and smaller remnants in the central and eastern 100-F Area. In two locations, Ringold unit E extends above the water table, comprising the entire aquifer thickness.

The base of the unconfined aquifer in 100-FR is the RUM. In two regions south of the 100-F Area, the RUM extends above the regional water table and the unconfined aquifer is absent (Figure 3-1). SGW-61298, Evaluation of 100-FR-3 Groundwater Monitoring Results from Phase 1 Wells, contains an updated geologic map and cross sections.

As stated above, the unconfined aquifer is not present in some locations. Where present, the unconfined aquifer may be as thick as 8 m (26 ft), as in the eastern portions of 100-FR. Most of the 100-FR monitoring wells are screened across all (or nearly all) of the aquifer. Two wells are screened in water-bearing units of the RUM, contamination has not been detected in these wells, and the wells are no longer sampled.

Figure 3-4 illustrates the water table in late February 2017, when the Columbia River was at a moderate stage. In the 100-F Area, the gradient was nearly flat, and groundwater flowed generally to the east or southeast. Farther south, groundwater flow is constrained by the areas where the RUM is above the water table. East of the RUM ridge near the river, water flowed out of the river into the aquifer, then toward the southeast. West of the RUM ridge, groundwater flows toward the southeast.