8.0 Groundwater Monitoring

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This section summarizes results of Hanford Site groundwater monitoring for 2016. The Hanford Site Groundwater Monitoring Report for 2016 (DOE/RL-2016-67) contains detailed information and is accessible through the Internet at http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports. DOE provides groundwater data to the public via the Internet at https://ehs.hanford.gov/eda.

During World War II and the Cold War period (1945–1991), the U.S. government built a total of nine reactors for the production of plutonium and other nuclear materials on the Hanford Site. During reactor operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the Site, mostly in the 200-East, 200-West, 300, and 100 Reactor Areas along the river (e.g., 100-BC, 100-K). Since 1989, using its authority under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), U.S. Department of Energy (DOE) has worked to remediate this contamination. Key elements associated with managing the Hanford Site’s groundwater and vadose zone contamination are to protect the Columbia River and groundwater from further contamination, develop a cleanup decision process, and restore groundwater to its highest beneficial use.

Groundwater occurs in an unconfined aquifer within unconsolidated gravel and sand units. Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge areas along the Columbia River (Figure 8-1).

DOE has taken the following actions to protect the Columbia River from contaminated groundwater:

- Ceased discharge of unpermitted liquids
- Remediated waste sites in the 100 and 300 Areas
- Operated remedial actions such as pump and treat (P&T) to contain groundwater plumes and reduce the mass of contaminants.

DOE operates an extensive groundwater monitoring program on the Hanford Site. In addition to groundwater wells, DOE monitors hundreds of sampling points near the Columbia River, known as aquifer sampling tubes, for general information about groundwater approaching the river. In 2016, DOE sampled 1,053 wells and 227 aquifer tubes. Many of them were sampled multiple times, for a total of 4,300 sampling events. The samples were analyzed for a variety of radionuclides and chemicals.

Some regions of Hanford Site groundwater are contaminated with chemicals and radionuclides (Figure 8-2). Tritium and iodine-129 form the largest groundwater plumes on the Hanford Site. The size of the largest plumes have gradually declined with time (Figure 8-3). The graph shows changes in plume areas at concentrations above drinking water standards (DWS), primarily based on data from wells screened near the top of the unconfined aquifer. In addition to the five major plumes shown in Figure 8-3, the area of the combined plume footprint also includes carbon-14, cyanide, strontium-90, technetium-99, trichloroethene (TCE), total petroleum hydrocarbon-diesel, and uranium.
The maximum concentrations of contaminants in Hanford Site groundwater have generally declined since the 1980s (Figure 8-4). The apparent increases in maxima for some contaminants between 2000 and 2010 are a result of new monitoring wells being installed to characterize and remediate contamination. Declining concentrations since 2010 are often a result of groundwater and waste site remediation.

The remainder of this section is organized by geographic regions known as “groundwater interest areas” (Figure 8-2). Seven interest areas are adjacent to the Columbia River, a region known as the River Corridor. Four interest areas in the inland region of the Hanford Site comprise the Central Plateau.

### 8.1 River Corridor

The River Corridor includes former operational areas along the Columbia River: the 100, 300, and 1100 Areas. Table 8-1 summarizes the River Corridor groundwater interest areas and associated contaminant plumes. In the 100 Area, groundwater contamination is related to past disposal of waste associated with water cooled nuclear reactors. The primary groundwater contaminants of concern (COCs) in the 100 Area are hexavalent chromium, strontium-90, nitrate, TCE, and tritium (Figure 8-2). Sources of hexavalent chromium contamination included the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate, and unplanned spills and leaks of the high concentration sodium dichromate stock solution. In the 300 Area, the groundwater COCs are uranium, tritium, nitrate, gross alpha, TCE, carbon-14, and cis-1,2-dichloroethene (cis-1,2-DCE).

Since the 1990s, DOE has remediated waste sites and groundwater in the River Corridor under interim action and final action records of decision (RODs). Removal of contaminated soil has reduced the potential for exposure to contaminants, including future groundwater impacts. By the end of 2016, 92% of the potential waste sites in the River Corridor had been remediated or were classified as not needing remediation.

Under interim action RODs, groundwater remediation systems in the 100-HR-3 and 100-KR-4 Operable Units (OUs) are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants. The primary contaminant addressed is hexavalent chromium and the remedial action target is 20 µg/L in groundwater, with the remedial action goal for groundwater discharging to the Columbia River to not exceed 10 µg/L.

Final action RODs have been signed for the 100-FR source and groundwater OUs, 300-FF-5 OU, and 1100-EM-1 OU. Final action RODs for the other portions of the River Corridor are expected to be developed in the next few years.

#### 8.1.1 100-BC

Groundwater contaminants of potential concern (COPCs) in 100-BC include hexavalent chromium, strontium-90, TCE, and tritium. Hexavalent chromium concentrations and the size of the plume declined between 2015 and 2016. The strontium-90 plume remained stable and tritium concentrations remained below the DWS in 2016. TCE exceeds the DWS in a single well screened at the base of the unconfined aquifer.
Figure 8-1. Hanford Site Water Table and Directions of Groundwater Flow, 2016.
Figure 8-2. Groundwater Contaminant Plumes, 2016.
Figure 8-3. Hanford Site Plume Areas.
Figure 8-4. Maximum Concentrations of Radioactive and Chemical Contaminants in Hanford Site Groundwater over Time.
Table 8-1. Overview of River Corridor Groundwater Interest Areas.

<table>
<thead>
<tr>
<th>Groundwater Interest Area</th>
<th>Primary Operations</th>
<th>Status of Waste Site Remediation</th>
<th>Status of Groundwater ROD</th>
<th>Groundwater Contamination: Maximum Concentration and Plume Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbon-14 (pCi/L) Hexavalent Chromium (µg/L) Nitrate (mg/L) Strontium-90 (pCi/L) Trichloroethene (µg/L) Tritium (pCi/L) Uranium (µg/L)</td>
</tr>
<tr>
<td>100-BC</td>
<td>Reactor operations -- B Reactor 1944-69; C Reactor 1952-69</td>
<td>93% complete</td>
<td>None to date</td>
<td>N 55 19.9 49.7 6.69 15,600 5.5</td>
</tr>
<tr>
<td>100-FR</td>
<td>Reactor operations -- F Reactor 1945-65; Biological experiments until 1976</td>
<td>100% complete</td>
<td>Final action MNA</td>
<td>N 70 124 126 15 3,330 12.5</td>
</tr>
<tr>
<td>100-HR</td>
<td>Reactor operations -- D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65</td>
<td>98% complete</td>
<td>Interim action pump and treat</td>
<td>N 640 66.4 30.1 N 10,600 50</td>
</tr>
<tr>
<td>100-KR</td>
<td>Reactor operations -- KE Reactor 1955-71; KW Reactor 1955-70</td>
<td>56% complete</td>
<td>Interim action pump and treat</td>
<td>40,100 380 753.1 164 9.48 730,000 27</td>
</tr>
<tr>
<td>100-NR</td>
<td>Reactor operations -- N Reactor 1963-87</td>
<td>92% complete</td>
<td>Interim action permeable reactive barrier</td>
<td>357 110 443 12,600 0.18 303,000 9.45</td>
</tr>
<tr>
<td>300-FF</td>
<td>Nuclear fuel fabrication and research -- 1940s-1960s</td>
<td>95% complete</td>
<td>Final action enhanced attenuation, MNA</td>
<td>N 47 (b) N 2.09 799,000 1,180</td>
</tr>
<tr>
<td>1100-EM and Offsite</td>
<td>Vehicle maintenance, 1954-85; solid waste landfill --1950s-1970</td>
<td>100% complete</td>
<td>Final action MNA; goals met</td>
<td>N N (b) N 0.47 N (b)</td>
</tr>
</tbody>
</table>

Standards

| Standards | 2,000 | 10 | 45 | 8 | 5 | 20,000 | 30 |

Half-life

| 5730 yr | N/A | 28.8 yr | N/A | 12 yr | >159,000 yr |

Mobility in subsurface

| High | High to Moderate | High | Slight | Moderate | High | Moderate |

Legend

Colors and listed values indicate maximum concentration in 2016

- ≥1000 x standard
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard
- N Not detected or not analyzed

Height of bar indicates plume area above standard (km²)

(a) Approximate percentage by number of waste sites classified as closed, interim closed, no action, rejected, or not accepted (December 31, 2016).
(b) Nitrate in 300-FF, and nitrate and uranium in 1100-EM, originate from offsite sources so plume areas and maximum concentrations are not shown.
(c) Drinking water standards for all but hexavalent chromium (aquatic standard).

NOTES

ABBREVIATIONS

MNA Monitored natural attenuation
N/A Not applicable
ROD Record of decision
DOE has remediated most 100-BC waste sites, and vadose zone sampling indicated that no substantive quantities of contamination remain in the vadose zone. However, at a few sites, data from deep vadose soils and the rewetted zone, and the presence of persistent groundwater contamination, suggest that minor quantities of residual contamination may remain.

Remedial investigation (RI) studies concluded in 100-BC in January 2016. DOE submitted an RI report (DOE/RL-2010-96) and proposed plan (DOE/RL-2016-43) to support remedy decisions for groundwater cleanup to EPA in 2016.

### 8.1.2 100-FR

Groundwater contamination in 100-FR originated from disposal of solid and liquid waste associated with operation of the water-cooled F Reactor and biological experiments. Nitrate, hexavalent chromium, strontium-90, and TCE are the groundwater COCs. Contaminant concentrations are declining overall and are below cleanup levels near the Columbia River in aquifer tubes.

DOE has completed remediation of 100-FR waste sites. Sampling indicated no substantive quantities of contamination remain in the vadose zone.

In 2016 six new wells were installed to support the groundwater remedy, monitored natural attenuation (MNA) of groundwater COCs under a 2014 ROD (EPA and DOE 2014). Data from the new wells showed that a low-permeability mud unit extends above the water table and the unconfined aquifer is absent beneath portions of the groundwater OU. This new interpretation, along with sampling data from the new wells, changed the interpretation of the nitrate plume.

### 8.1.3 100-HR

The 100-HR-3 Groundwater OU in the northern part of the Hanford Site includes the 100-HR-D and 100-HR-H groundwater interest areas, referred to collectively as 100-HR. About 98% of the potential waste sites have been remediated or were determined not to require remediation under an interim action ROD. Groundwater is contaminated with hexavalent chromium, strontium-90, and nitrate.

Two P&T systems continued to operate under an interim action ROD (EPA/ROD/R10-96/134) to remove hexavalent chromium from groundwater. In 2016, 2.6 billion L (688 million gal) of groundwater was pumped from 86 extraction wells, removing over 85 kg of hexavalent chromium. Since 1997, the P&T systems have removed 2,474 kg of hexavalent chromium.

The overall areal extent of the hexavalent chromium plumes and the length of affected shoreline have declined between 1999 and 2016 (Figure 8-5). The changes are a result of groundwater contaminant removal, remediation of sources, hydraulic control, and natural processes. Fifteen new wells were installed in 100-HR in 2016.

In 2016 the proposed plan (DOE/RL-2011-111) for remediation of waste sites and groundwater was made available for public comment. DOE has proposed ongoing P&T as the preferred alternative for remediating hexavalent chromium in groundwater.

The former 183-H Solar Evaporation Basins constitute the only Resource Conservation and Recovery Act of 1976 (RCRA) unit in 100-HR. The unit is monitored in accordance with RCRA corrective action.
requirements during the post-closure period to track contaminant trends during operation of the CERCLA P&T interim action.

Figure 8-5. 100-HR Hexavalent Chromium Plume in 1999 (early in interim action period) and 2016 (during interim action).
8.1.4 100-KR

Hexavalent chromium is the primary COC in 100-KR groundwater. Smaller plumes of carbon 14, tritium, strontium 90, nitrate, and TCE also are present. About 56% of the potential waste sites have been remediated or were determined not to require remediation under an interim action ROD (EPA/ROD/R10-96/134).

Three P&T systems continued to operate in 100-KR in 2016, extracting over 2.5 billion L (650 million gal) of groundwater from 43 extraction wells. A total of 867 kg of hexavalent chromium has been removed from 100-KR groundwater to date, and the size and concentrations of the plumes have decreased over time (Figure 8-6). Four new extraction wells were installed in 2016.

Because hexavalent chromium concentrations were below the cleanup goal in the western plume, the extraction wells in that region were shut off in May 2016 to begin a rebound test. Hexavalent chromium concentrations subsequently increased in monitoring wells, suggesting the presence of ongoing contaminant sources in the vadose zone.

Groundwater monitoring in 2016 did not show new groundwater impacts from the KW and former KE fuel storage basins. The KW Basin has been emptied of fuel rods but remains a depository for contaminated sludge from the KE and KW Basins.

Figure 8-6. 100-KR Hexavalent Chromium Plume in 1996 (before interim action) and 2016 (during interim action).
8.1.5 100-NR
About 92% of the potential waste sites in 100-NR have been remediated or classified as not requiring remediation. The groundwater COPCs are strontium-90, total petroleum hydrocarbons, nitrate, total chromium, hexavalent chromium, and tritium. Six new monitoring wells were installed in 2016. To reduce the amount of strontium-90 migrating to the Columbia River, DOE is applying an in situ technology called strontium-90 sequestration, using an apatite chemical solution.

DOE submitted a draft RI/feasibility study (FS) report (DOE/RL-2012-15) and proposed plan (DOE/RL-2012-68) to Ecology for review in 2013. In 2016 DOE continued to respond to Ecology comments on these documents. When finalized, they will be used to develop a ROD for remediation of 100-NR waste sites and groundwater.

In 2016, RCRA monitoring continued under final status detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities. Results indicated no releases of dangerous waste constituents from the RCRA units.

8.1.6 300-FF
Three geographic regions comprise 300-FF: the 300 Area Industrial Complex, the 618-11 Burial Ground region, and a region including the 618-10 Burial Ground and 316-4 Cribs. About 95% of the potential waste sites have been remediated or classified as not requiring remediation. Remediation is continuing at the remaining sites.

A final action ROD (EPA et al. 2013) calls for enhanced attenuation of uranium and MNA of TCE, cis-1,2-DCE, tritium, and nitrate. The enhanced attenuation component of the groundwater remedy involves infiltrating and injecting phosphate solutions to the ground to bind with uranium and form insoluble minerals. The first stage of enhanced attenuation was completed in 2015, and monitoring data were collected and evaluated in 2016. Initial amorphous phosphate minerals appear to be sequestering uranium, as expected. Figure 8-7 shows how the uranium plume has attenuated between 1996 and 2016.

In 2016 three characterization boreholes were drilled and decommissioned and one monitoring well was decommissioned.

RCRA groundwater monitoring continued at the 300 Area Process Trenches. The unit is monitored in accordance with post-closure corrective action requirements. Uranium and cis-1,2-DCE continued to exceed Permit limits in 2016. Remediation will be coordinated under the 300-FF-5 Groundwater OU.
8.1.7 1100-EM and Richland North

The 1100-EM-1 Groundwater OU was removed from the National Priorities List (40 CFR 300, Appendix B5) in 1996. The selected remedy was MNA for volatile organic compounds, with institutional controls preventing drilling of new water supply wells. Cleanup goals were met, and no further remedial action or groundwater monitoring is required.

DOE monitors wells in and near the North Richland well field, which is part of the municipal water supply system. Groundwater in this region has not been impacted by Hanford Site contamination.

Uranium concentrations in two wells near the southern border of the Hanford Site have increased gradually since 1996, continuing to exceed the DWS in 2016. The presence of uranium at these locations is attributed to a plume moving northeast from a former surface impoundment at AREVA NP, Inc., an offsite nuclear fuel production facility, which has been remediated.

8.2 Central Plateau

The Central Plateau, located in the middle of the Hanford Site, includes the 200-West and 200-East Areas. When the Hanford Site was operating as a plutonium-production facility, irradiated fuel
reprocessing, isotope recovery, and associated waste management activities occurred in the 200 Areas. Ponds, cribs, and ditches used for liquid waste disposal were primary sources of groundwater contamination. There are also seven single shell tank waste management areas (WMAs) in the 200 Areas. Some of these tanks have leaked, contaminating the vadose zone and groundwater.

Contamination is still present in many parts of the thick Central Plateau vadose zone and may continue to migrate into the groundwater, and DOE is beginning to characterize and remediate these sites. In 2016 DOE drilled characterization boreholes to study deep vadose zone contamination in the 200-East and 200-West Areas. Groundwater and deep vadose zone remediation on the Central Plateau include the 200-West P&T, U Plant and S-SX extraction systems, a deep vadose zone treatability test in B Complex, and a removal action for the 200-BP-5 groundwater OU at the B Complex.

Large groundwater contaminant plumes of tritium, nitrate, and iodine-129 formed when the waste discharged to ponds and cribs in the Central Plateau reached the aquifer (Figure 8-2). Plume sizes have decreased over the years because of dispersion and, in the case of tritium, radioactive decay. A large carbon tetrachloride plume originated in the Plutonium Finishing Plant area of the 200-West Area. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, TCE, hexavalent chromium, cyanide, and other dangerous waste constituents (Table 8-2).

8.2.1 200-BP

Most of the groundwater contamination in the 200-BP groundwater interest area is associated with waste sites in the northwestern portion of the 200-East Area. Nitrate, iodine-129, and technetium-99 exceed DWS and form the largest contaminant plumes. Smaller plumes of uranium, cyanide, strontium-90, and tritium also exceed their DWS. Cesium-137 and plutonium-239/240 contamination is limited to only one or two wells.

An action memorandum (DOE/RL-2016-41) was released in December 2016 to implement a non-time-critical removal action for the B Complex high-concentration technetium-99 and uranium plumes. This action will target groundwater extraction from plume areas that exceed 10 times the 900 pCi/L DWS for technetium-99 and the 30 µg/L DWS for uranium. Extracted groundwater will be treated at the 200 West P&T and reinjected into the aquifer in the 200-West Area. A groundwater treatability test was conducted in this vicinity during 2015 and 2016, demonstrating successful extraction of groundwater and removal of 14 kg of uranium. Since initiation of this extraction system in September 2015, 13.9 kg of uranium, 70,160 kg of nitrate, and 1.3 Ci of technetium-99 have been removed (Figure 8-8).

Extraction of perched water, contaminated with uranium and nitrate, resumed in December 2016. The system was expanded from one to three extraction wells. Since startup the system has removed 84.5 kg of uranium and 778 kg of nitrate from the ground.

In 2016 RCRA groundwater monitoring continued at WMA B-BX-BY, WMA C, the 216-B-63 Trench, Low-Level Waste Management Area (LLWMA)-1, LLWMA-2, and the Liquid Effluent Retention Facility. A replacement monitoring well was installed in 2016 for WMA C. New monitoring plans for LLWMA-1 and WMA C are expected to be implemented in 2017.
### Table 8-2. Overview of Central Plateau Groundwater Interest Areas.

<table>
<thead>
<tr>
<th>Groundwater Interest Area</th>
<th>Status of Groundwater ROD</th>
<th>Central Plateau Overview</th>
<th>Groundwater Remedial Action</th>
<th>Groundwater Contamination: Maximum Concentration and Plume Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-BP</td>
<td>FS Drafted in 2015 (with 200-PO-1)</td>
<td>B Complex groundwater extraction treatability test 2015; Perched water P&amp;T 2011-2015</td>
<td>N</td>
<td>TRIPLET &lt;10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>160</td>
<td>1,350</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>32,700</td>
<td>61,400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>460</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2,320</td>
<td>420</td>
</tr>
<tr>
<td>Standards^b</td>
<td>5</td>
<td>48</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>Half-life (years)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1.60E+07</td>
</tr>
<tr>
<td>Mobility in subsurface</td>
<td>Multi-phase</td>
<td>High to Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

**Legend**
- Colors and listed values indicate maximum concentration in groundwater in 2016
- Height of bar indicates plume area above standard (km²)
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard
- N = Not detected or not analyzed
- TRIPLET = TCE in a 100K well within footprint of 200-BP.
- Drinking water standards for all but (MTCA standard for hexavalent chromium)
- ABBREVIATIONS

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8-14
8.2.2 200-PO

The southern portion of the 200-East Area and a large region to the east and southeast comprise 200-PO. Disposal of large volumes of liquid waste created regional groundwater plumes of tritium, iodine-129, and nitrate. Other 200-PO contaminants include strontium-90, technetium-99, and uranium in smaller areas near their discharge sources (Figure 8-2).
The size of the regional tritium plume (Figure 8-9) from 200-PO has decreased by 65% since 1980 (from 185 to 65 km² [71.4 to 25 mi²]). The maximum concentration has declined from over 6 million pCi/L in the 1980s to 418,000 pCi/L in 2016.


The Solid Waste Landfill is regulated under Washington State solid waste handling regulations. A new monitoring plan was implemented in 2016.

8.2.3 200-UP
The southern portion of the 200-West Area and adjacent areas to the east and south comprise 200-UP. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and hexavalent chromium plumes are present. Carbon tetrachloride in this region originated from sources in 200-ZP. An interim action ROD (EPA et al. 2012) includes P&T, hydraulic control, and MNA. Eight new monitoring wells were installed for the 200-UP-1 OU in 2016. Data from these wells will help characterize and monitor groundwater contaminants.

The U Plant uranium/technetium-99 groundwater extraction system continued to operate in 2016, and contaminant concentrations have declined (Figure 8-10). In 2016, 9.9 kg of uranium, 0.47 Ci of technetium-99, 71,100 kg of nitrate, and 29.7 kg of carbon tetrachloride were removed from the aquifer.

A P&T system at WMA S-SX continued to operate in 2016, and contaminant concentrations are declining (Figure 8-10). In 2016, the system removed 0.38 Ci of technetium-99, 4,190 kg of nitrate, 5.4 kg of hexavalent chromium, and 11.4 kg of carbon tetrachloride from groundwater.

An iodine-129 hydraulic containment system, composed of three injection wells east of 200-West Area, continued to operate in 2016.


The Environmental Restoration Disposal Facility is a CERCLA disposal facility used for disposal of low level radioactive mixed waste generated by remedial actions. The results of 2016 groundwater monitoring continued to indicate that the facility has not impacted groundwater.

8.2.4 200-ZP
Contaminant sources in 200-ZP, located in the 200-West Area, included cribs, ponds, and single shell storage tanks. A final action ROD (EPA et al. 2008) for the 200-ZP-1 OU groundwater identified carbon tetrachloride as the primary COC (Figure 8-11). Other COCs are TCE, iodine-129, technetium-99, nitrate, hexavalent chromium, and tritium.
In 2016, 26 extraction wells and 27 injection wells were in use to remediate groundwater in the 200-ZP-1 groundwater OU. The system processed 3.0 billion L (800 million gal) of groundwater, removing 1,721 kg of carbon tetrachloride, 330,900 kg of nitrate, and other contaminants from groundwater. Combined, the final action system, the interim action system, and the former soil vapor extraction system have removed 104,913 kg of carbon tetrachloride from the subsurface (Figure 8-12). The soil vapor extraction system successfully removed contamination from the vadose zone. Continued operation of the system was no longer beneficial so it was permanently shut down in 2015.

RCRA groundwater monitoring continued at WMA T, WMA TX-TY, LLWMA-3, and LLWMA-4 in 2016. Groundwater monitoring continued at the State-Approved Land Disposal Site, which receives treated water from the Hanford Site Effluent Treatment Facility. It is regulated under a State Waste Discharge Permit and has created a local tritium plume.

![Figure 8-9. Hanford Site Tritium Plumes in 1980 and 2016.](image-url)
Figure 8-10. Changes in 200-UP Contaminant Concentrations Before and During Pump and Treat.
Figure 8-11. 200-West Carbon Tetrachloride Plume in 1996 and 2016.

Figure 8-12. 200-ZP Carbon Tetrachloride Mass Removed by Final P&T, Interim P&T, and Soil Vapor Extraction.
8.3 Confined Aquifers

Most Hanford Site groundwater contamination is found in the unconfined aquifer, but DOE monitors wells in deeper aquifers because of potential downward movement of contamination.

One confined aquifer occurs within sand and gravel at the base of the Ringold Formation. Carbon tetrachloride, hexavalent chromium, and nitrate have entered this unit in a portion of the 200-West Area (200-ZP) where the upper confining unit is absent. Newer wells have been installed to monitor and remediate this contamination. The Ringold confined aquifer is the uppermost aquifer in a local region east of the 200-East Area (within portions of 200-BP and 200-PO). Iodine-129 and tritium are detected in wells at this location, but the contamination has not migrated farther to the east and/or southeast.

In the northern Hanford Site, fine-grained sedimentary units, informally called the Ringold upper mud unit, confine deeper sediments in the Ringold Formation. In some parts of 100-HR, this unit is contaminated with hexavalent chromium at concentrations over 100 µg/L and is being remediated by a P&T system.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system. The vertical hydraulic gradient between the basalt confined aquifer and the unconfined aquifer is upward beneath most of the Hanford Site. Groundwater monitoring data do not indicate that contamination has migrated into the upper basalt confined aquifer.