

# **100-NR**

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## 100-NR Overview

The 100-NR groundwater interest area encompasses the 100-N Area, located adjacent to the Columbia River (Figure NR.1). Among the Hanford Site plutonium-production reactors, the design of N Reactor was unique. The N Reactor, which operated in the 100-N Area from 1964 to 1986, was a dual-purpose reactor that produced plutonium for defense purposes and steam for commercial electrical power generation. Groundwater contamination in 100-NR is primarily associated with waste produced by the reactor and associated processes. Additional details about 100-NR history and waste sites are provided in Section 1.3 of [DOE/RL-2012-15 Draft A](#).

Strontium-90 is the principal groundwater contaminant. Other groundwater contaminants include nitrate, total petroleum hydrocarbon (TPH)-diesel, hexavalent chromium, and tritium. A summary of 100-NR, including key contaminants, is shown in Table NR.1. Strontium-90 and TPH-diesel are being remediated under a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) interim action ([EPA/ROD/R10-99/112 as amended](#)). An apatite permeable reactive barrier was installed between 2006 and 2011 to enhance attenuation of the strontium-90 in groundwater moving toward the Columbia River. TPH-diesel free product is being removed from groundwater in one well (199-N-18). Groundwater is monitored at four waste sites to meet requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA) and [WAC-173-303](#).

The vadose zone in 100-NR is 0 to 23 meters thick and is composed of gravels and sands of the Hanford formation and upper Ringold Formation unit E (Figure NR.2). The unconfined aquifer is approximately 6.5 to 14 meters thick. When the Columbia River stage is high, the water table can rise into the Hanford formation in wells near the shoreline. The Ringold upper mud unit (RUM) forms the base of the unconfined aquifer.

Groundwater in 100-NR generally flows northwest toward the Columbia River. As shown in Figure NR.1, the magnitude of the change in groundwater hydraulic head across 100-NR in March 2013 was about 2 meters. Groundwater flow was influenced in 2013 by groundwater extraction and injection for the KX Pump and Treat (P&T) remediation system located in the southwest portion of 100-NR. A small groundwater mound approximately 1 meter high surrounding KX injection wells 199-K-159, 199-K-160, and 199-K-164 creates local radial flow (Figure NR.1).

In 2013, the high river stage lasted from late March through late August (Figure HR.6). Water levels in well 199-N-146 near the river rose approximately 2.5 meters between mid-March and mid-April. Water levels in well 199-N-2, 170 meters inland from the river, rose approximately 1.5 meters with a lag time of a few days. Changing river stage influences groundwater elevations over 1 kilometer inland from the river (Section 3.6 of [DOE/RL-2012-15](#)).

Figure NR.3 illustrates how the estimated areas of the contaminant plumes have changed since 2003.

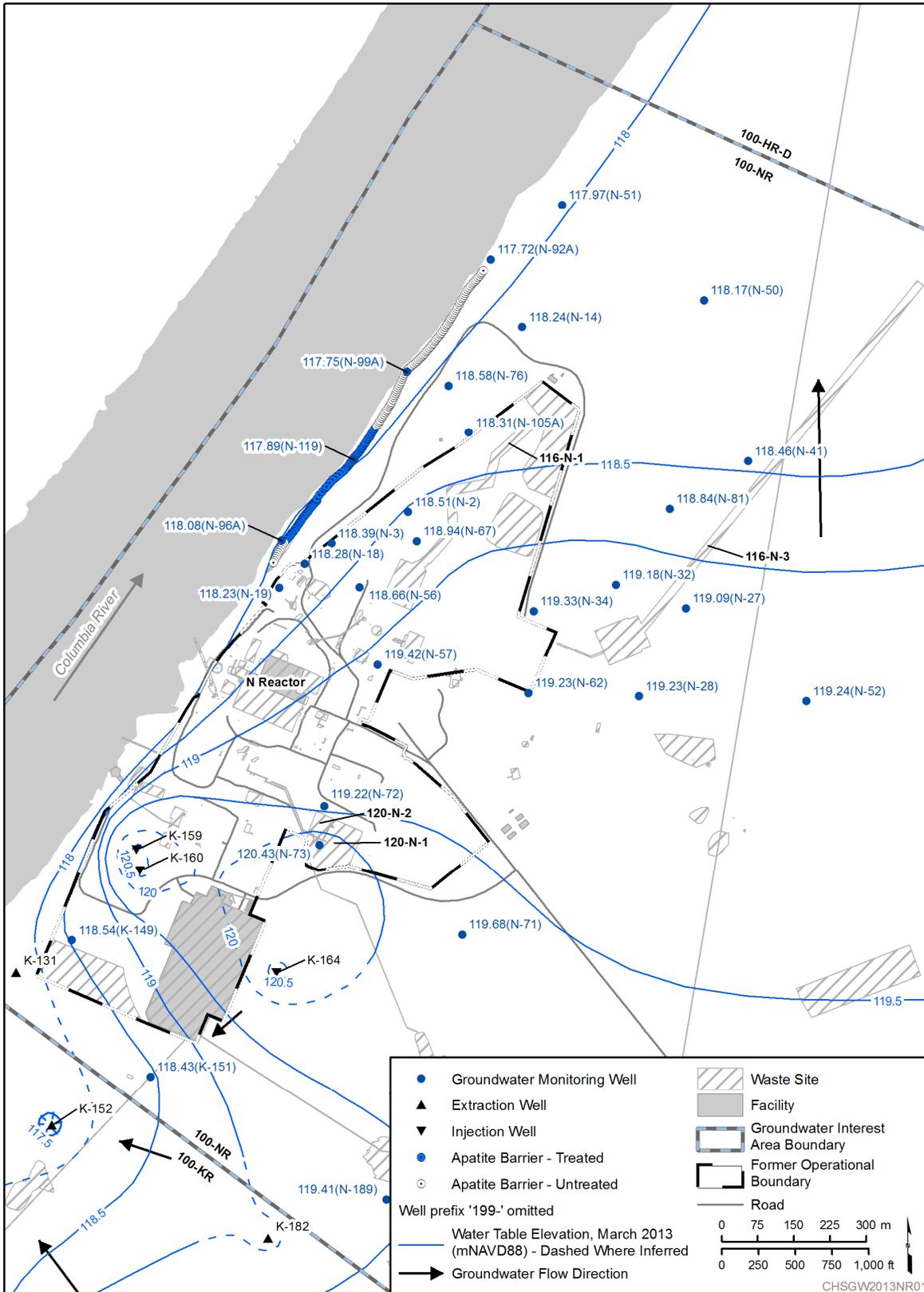


Figure NR.1 100-NR Overview Map with Groundwater Flow

**Table NR.1 100-NR at a Glance**

| <b>N Reactor Operations: 1964–1986</b>  |                               |                              |                               |                             |
|---|-------------------------------|------------------------------|-------------------------------|-----------------------------|
| <b>2013 Groundwater Monitoring</b>  |                               |                              |                               |                             |
| <b>Contaminant</b>  | <b>Water Quality Standard</b> | <b>Maximum Concentration</b> | <b>Plume Area<sup>a</sup></b> | <b>Shoreline Impact (m)</b> |
| Strontium-90  | 8 pCi/L                       | 14,000 pCi/L<br>(199-N-67)   | 0.61 km <sup>2</sup>          | 600                         |
| Nitrate   | 45 mg/L <sup>b</sup>          | 168 mg/L<br>(199-N-186)      | 0.49 km <sup>2</sup>          | 180                         |
| Diesel (as Total Petroleum Hydrocarbons)  | 0.5 mg/L                      | 9.45 mg/L<br>(199-N-171)     | 0.016 <sup>c</sup>            | 55                          |
| Chromium  | 100 µg/L                      | 177 µg/L<br>(199-N-80)       | 0.22                          | 0                           |
| Tritium   | 20,000 pCi/L                  | 120,000<br>(C7934)           | NC <sup>e</sup>               | NC                          |
| <b>Remediation</b>  |                               |                              |                               |                             |
| Waste Sites (interim action): 79% complete <sup>d</sup><br>Groundwater (interim action): <ul style="list-style-type: none"> <li>• Pump and Treat: 1995-2006, 1.8 Ci strontium-90 removed</li> <li>• Apatite permeable reactive barrier: 2006-2013</li> </ul> Final record of decision anticipated in 2015 |                               |                              |                               |                             |

- a. Estimated area at a concentration greater than the water quality standard.  
 b. 45 mg/L Nitrate ≈ 10 mg/L NO<sub>3</sub>-N; DWS  
 c. Area at 200 µg/L.  
 d. Sites with status of closed, interim closed, no action, not accepted, or rejected.  
 e. Plume area not calculated due to infrequent detection of tritium greater than 20,000 pCi/L. Shoreline impact not calculated since tritium only detected above 20,000 pCi/L in one aquifer tube cluster.

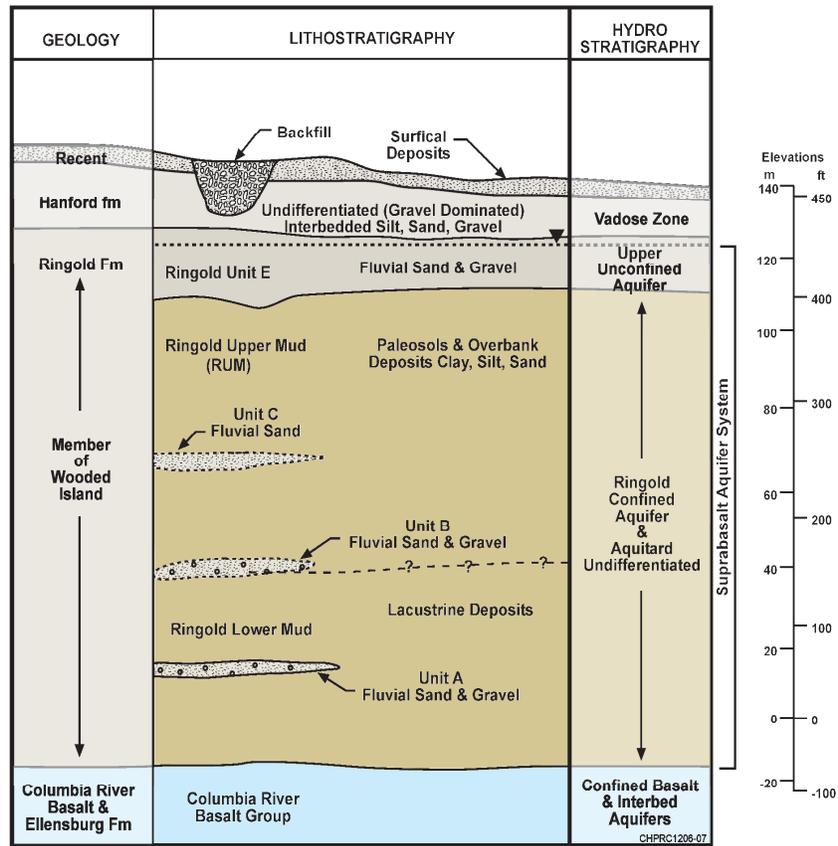


Figure NR.2 100-NR Geology

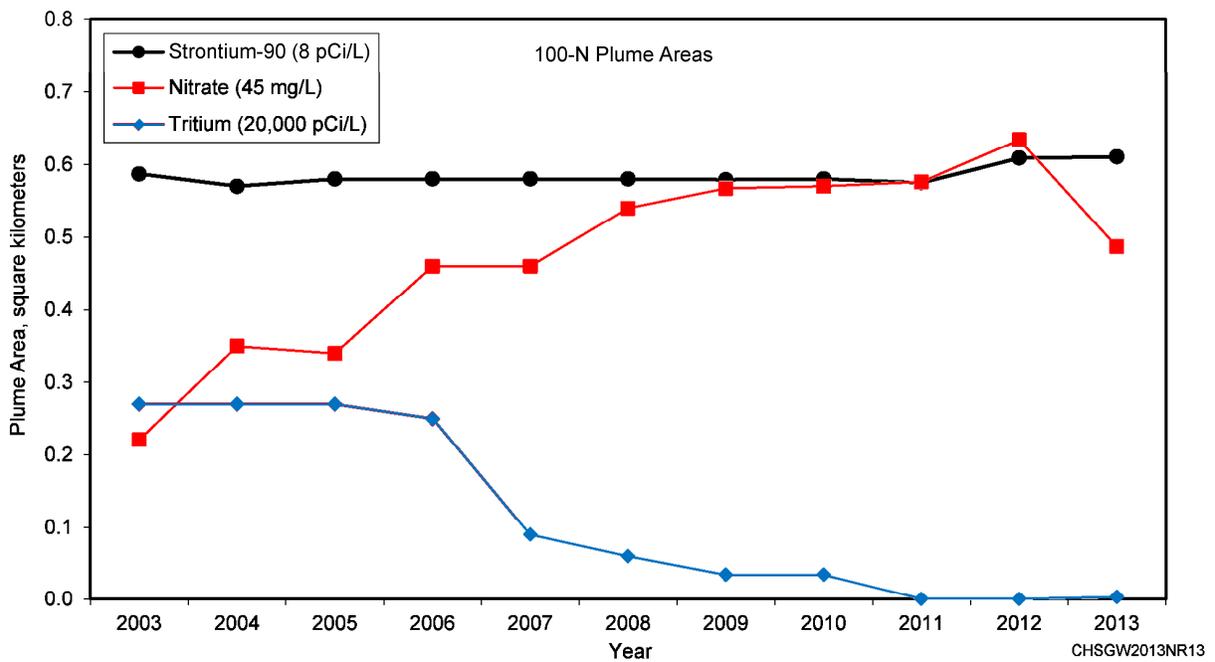


Figure NR.3 100-NR Plume Areas

## 100-NR CERCLA Activities

CERCLA activities for the 100-NR-2 operable unit (OU) in 2013 included continued groundwater monitoring, completion of Draft A of the remedial investigation/feasibility study (RI/FS) report ([DOE/RL-2012-15](#)) and proposed plan ([DOE/RL-2012-68](#)), and continued interim remediation of strontium-90 and TPH-diesel contamination.

**CERCLA Groundwater Monitoring.** Wells, aquifer tubes (Figure NR.4), and constituents monitored for the 100-NR-2 OU under CERCLA in 2013 were defined in the following documents:

- *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* ([DOE/RL-2001-27](#)), as modified by:
  - *Change Notice For Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan Section 9.0 Documentation and Records DOE/RL-2001-27 Rev. 0 Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit DOE/RL-2000-41 Rev. 1* ([TPA-CN-256](#))
  - *Change Notice For Modifying Approved Documents/Workplans in Accordance with the TPA Action Plan Section 9.0 Documentation and Records DOE/RL-2001-27 Rev. 0 Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* ([TPA-CN-569](#))
- *Integrated 100 Area Remedial Investigation Feasibility Study Work Plan Addendum 5, 100-NR-1 and 100-NR-2 Operable Units* ([DOE/RL-2008-46-ADD5](#)) and associated *Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study* ([DOE/RL-2009-42](#)), as modified by:
  - *Change Notice For Modifying Approved Documents/Workplans in Accordance with the TPA Action Plan Section 9.0 Documentation and Records DOE/RL-2009-42 Rev. 0 Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study* ([TPA-CN-478](#))
- *Sampling and Analysis Plan for Aquifer Sampling Tubes* ([DOE/RL-2000-59](#)), as modified by:
  - *Change Notice For Modifying Approved Documents/Workplans in Accordance with the TPA Action Plan Section 9.0 Documentation and Records DOE/RL-2000-59 Rev. 1 Sampling and Analysis Plan for Aquifer Tubes* ([TPA-CN-353](#))

The CERCLA sampling is conducted primarily in September, with selected wells monitored in March. A summary of the wells scheduled and sampled is provided in Table A.5 of Appendix A.

One river shore seep at 100-NR was sampled in 2013 during low river stage. Seeps occur when groundwater drains from the aquifer and the groundwater elevation locally is higher than the river elevation. The seep, which is exposed on the ground surface, is considered surface water rather than groundwater. The results of the seep analyses for hexavalent chromium, nitrate, and strontium-90 are shown as information on the plume maps for those contaminants but are not used during preparation of the plume configurations.



**Remedial Investigation (RI)/Feasibility Study (FS).** The RI/FS Work Plan (WP) ([DOE/RL-2008-46-ADD5](#)) and sampling and analysis plan ([DOE/RL-2009-42](#)) for 100-N were issued in March 2011 and December 2010, respectively. In 2011, eight boreholes were drilled, sampled, and completed as wells as part of the RI. These new wells have been incorporated into the CERCLA groundwater monitoring program. Initial sampling of the wells began in March 2012.

Data collected for the RI were used to update the conceptual site model for the vadose zone and groundwater, support the baseline risk assessment, and identify and evaluate technologies for remedial alternatives. Details regarding sample collection and analysis and data interpretation are provided in the 100-N Area RI/FS report ([DOE/RL-2012-15](#)); Draft A of the RI/FS report was submitted to the Washington Department of Ecology (Ecology), the lead regulatory agency for the 100-NR-1 and 100-NR-2 OUs, in June 2013 for review. The RI/FS information will be used to make decisions for remediation of waste sites and groundwater. Draft A of the Proposed Plan ([DOE/RL-2012-68](#)), which identifies a preferred remedy for the 100-NR-1 and 100-NR-2 OUs, also was submitted to Ecology in June 2013 for review. The Record of Decision (ROD) for these OUs, which will specify the remedies for cleanup of waste sites and groundwater, is anticipated in 2015.

**Groundwater Remediation.** Interim actions are being conducted for cleanup of strontium-90 and TPH-diesel contamination in 100-NR-2 groundwater. The activities and results for 2013 are summarized in this section. Additional details are available in DOE/RL-2014-25, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 P&T Operations, and 100-NR-2 Groundwater Remediation*.

## 100-NR Strontium-90

The primary source of the strontium-90 contamination in 100-NR was liquid waste disposal to the 116-N-1 and 116-N-3 waste sites. The size and shape of the strontium-90 plume changes very little from year to year, except near the apatite permeable reactive barrier (Figure NR.5). The plume extends from beneath the 116-N-1 and 116-N-3 waste sites to the Columbia River at concentrations exceeding the drinking water standard (DWS) (8 pCi/L). The highest concentration portion of the strontium-90 groundwater plume (i.e., the area with concentrations exceeding 800 pCi/L) primarily underlies the 116-N-1 Trench and the 116-N-3 Crib. The highest concentration is found beneath, and inferred downgradient of, 116-N-1. The lateral distribution of the groundwater plume with concentrations between 8 and 800 pCi/L is found peripheral to the highest concentration in a distribution consistent with historical radial flow away from the two trenches and elongated toward the river.

The highest strontium-90 groundwater concentration detected at 100-NR in 2013 was 12,000 pCi/L in a sample from well 199-N-187, which was drilled through the 116-N-1 site. Concentrations exceeding 100 pCi/L are limited to the very upper portion of the aquifer. Strontium-90 contamination is either not detected or is detected at very low concentrations in wells monitoring the base of the unconfined aquifer or the RUM.

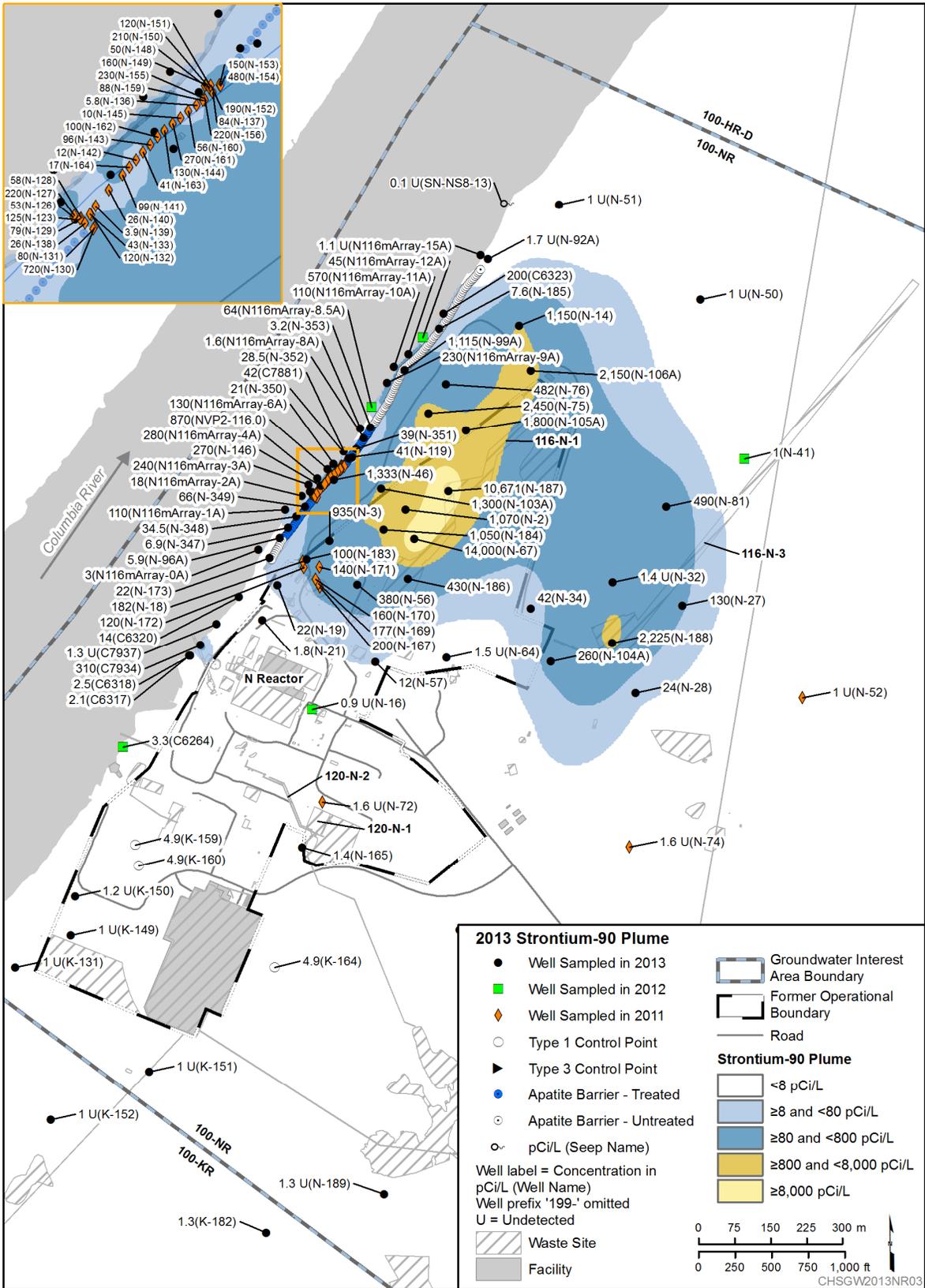


Figure NR.5 100-NR 2013 Strontium-90 Plume

Water levels were higher beneath the 116-N-1 and 116-N-3 waste sites when discharges were occurring. As the water level declined, strontium-90 remained sorbed in the lower vadose zone. As a result, when the water table rises beneath these former waste sites, strontium-90 from the vadose zone may be remobilized, increasing the concentrations in groundwater. Strontium-90 concentrations in well 199-N-81 downgradient of the 116-N-3 trench have declined since the late 1990s. However, high water table elevations over the last two years have caused a slight increase in the strontium-90 concentration that continues into the fall 2013 sample (Figure NR.6). Strontium-90 concentrations in well 199-N-67 near the 116-N-1 crib show no obvious long-term decline, but generally increase when the water level is elevated and decrease when it is lower (Figure NR.7). The positive variation of concentration with water level may be more pronounced at wells near the 116-N-1 waste site, which received a much larger mass of strontium-90 than the 116-N-3 waste site and presumably has more residual strontium-90 in the lower vadose zone. Strontium-90 concentrations at the apatite permeable reactive barrier are discussed in a separate section of this chapter.

Strontium-90 concentrations in aquifer tubes are consistent with those seen in near-shore monitoring wells. The only strontium-90 detections outside the area where the strontium-90 groundwater plume intersects the Columbia River are at aquifer tube cluster C7934/C7935/C7936 (Figure NR.8). These aquifer tubes are located close to the engineered fill around the 1908-N Outfall, which suggests that outfall construction created a preferential pathway in the fill for migration of contaminated groundwater to the river (Section 4.2 of [SGW-49370](#)).

Seep number "100-N SPRING 8-13", on the river shore near aquifer tube 116mArray-16A, was sampled on September 23, 2013. The strontium-90 result (< 0.047 pCi/L) is posted on the strontium-90 plume map for the low river stage (Figure NR.5).

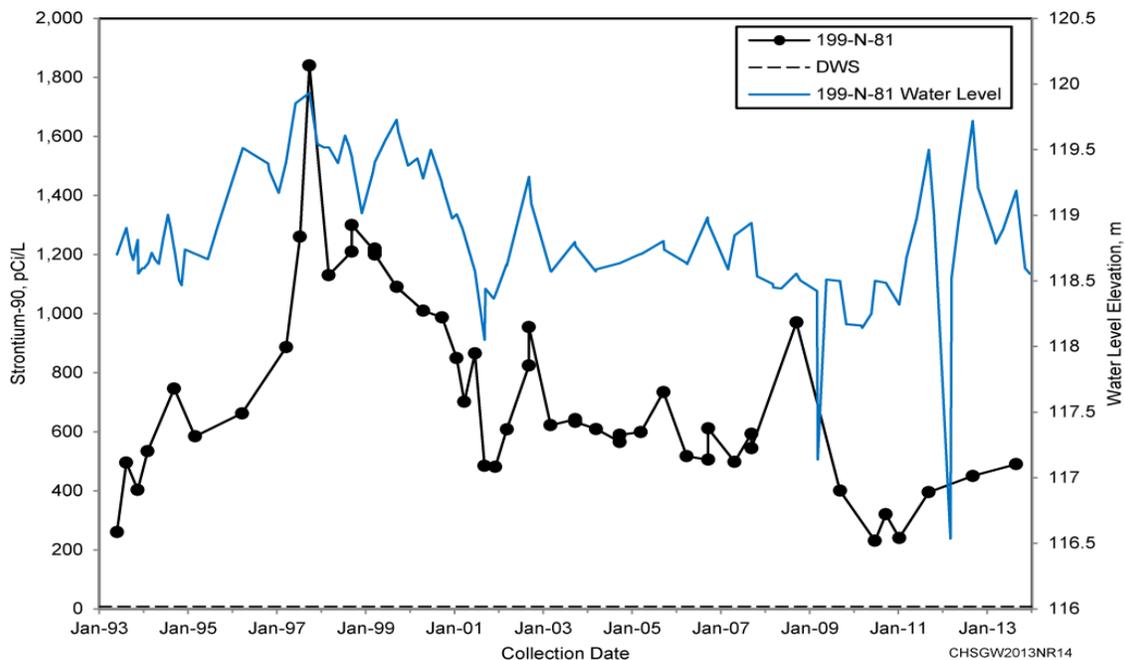


Figure NR.6 100-NR Strontium-90 Data for Well 199-N-81

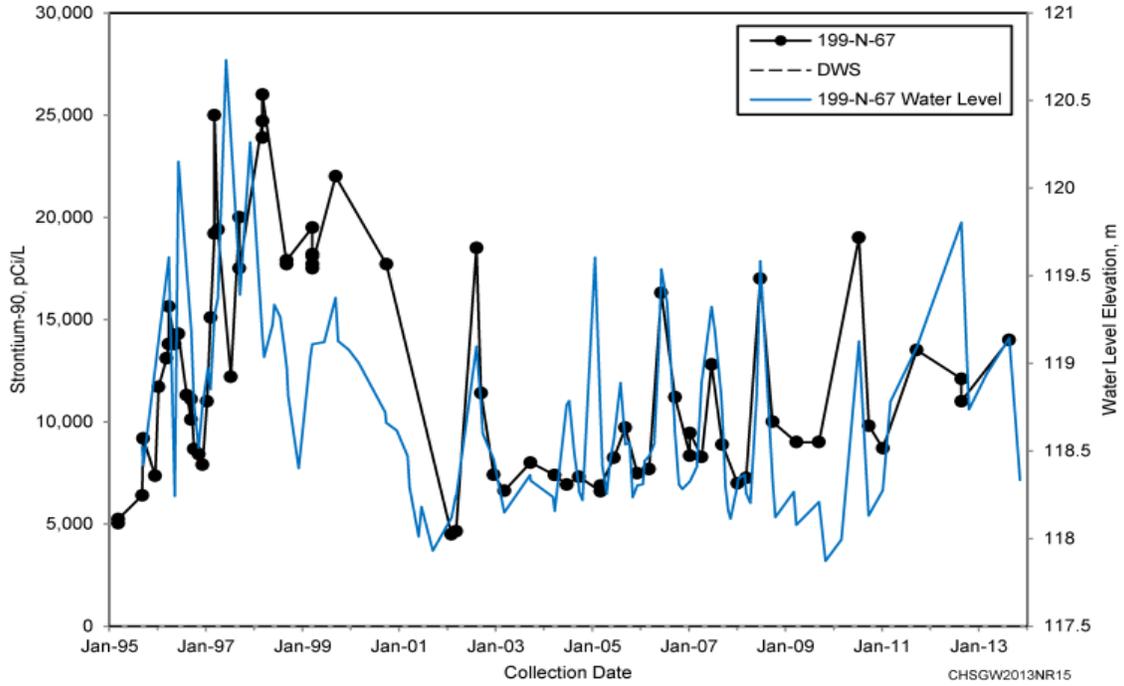


Figure NR.7 100-NR Strontium-90 Data for Well 199-N-67

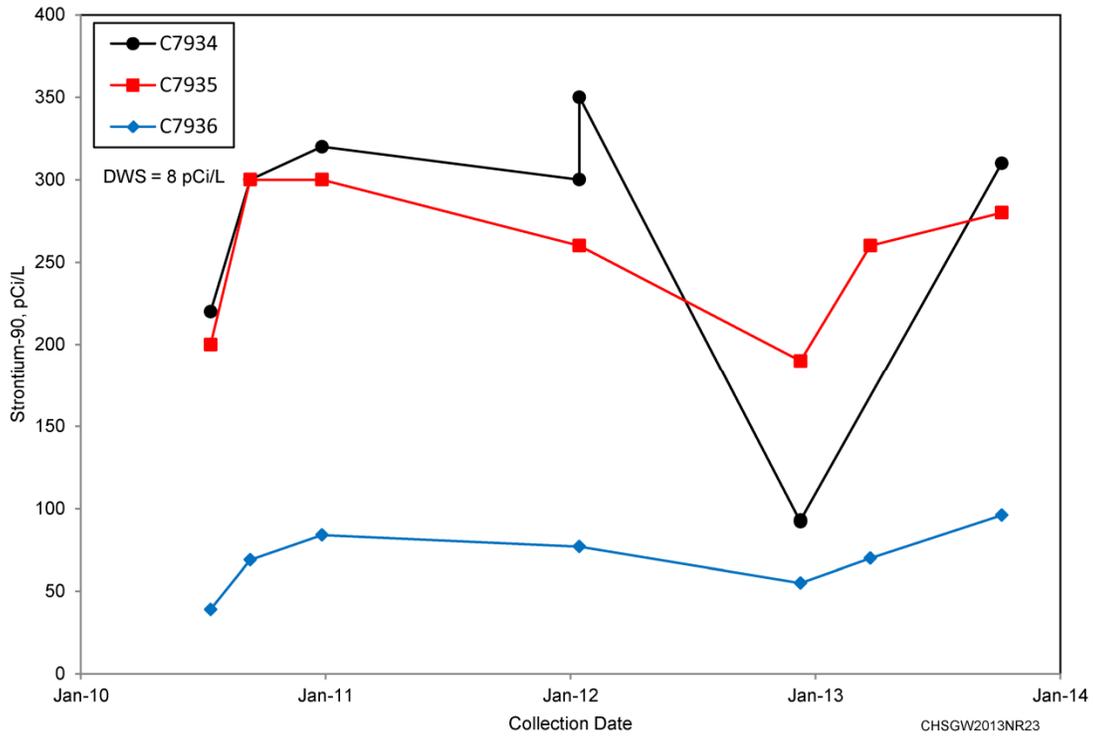


Figure NR.8 100-NR Strontium-90 Data for Aquifer Tubes C7934, C7935, and C7936

## 100-NR Tritium

Tritium concentrations were elevated in 2013 at aquifer tube cluster C7934/C7935/C7936 (Figure NR.9). The increases are likely due to existing soil contamination that was mobilized by the application of water for dust suppression during nearby field remedial activities in 2012 and 2013. These aquifer tubes are located close to the engineered fill around the 1908-N Outfall, which suggests that outfall construction created a preferential pathway in the fill for migration of contaminated groundwater to the river (Section 4.2 of [SGW-49370](#)).

Tritium concentrations exceeded the DWS (20,000 pCi/L) in well 199-N-186 in 2013 (the maximum value was 41,000 pCi/L) and have been detected above the DWS since the well was installed in 2011. The 116-N-1 Crib was a source of tritium contamination in 100-NR groundwater. With the exception of this localized tritium hotspot beneath the 116-N-1 Crib, tritium results for 100-NR wells were all below the DWS in 2013.

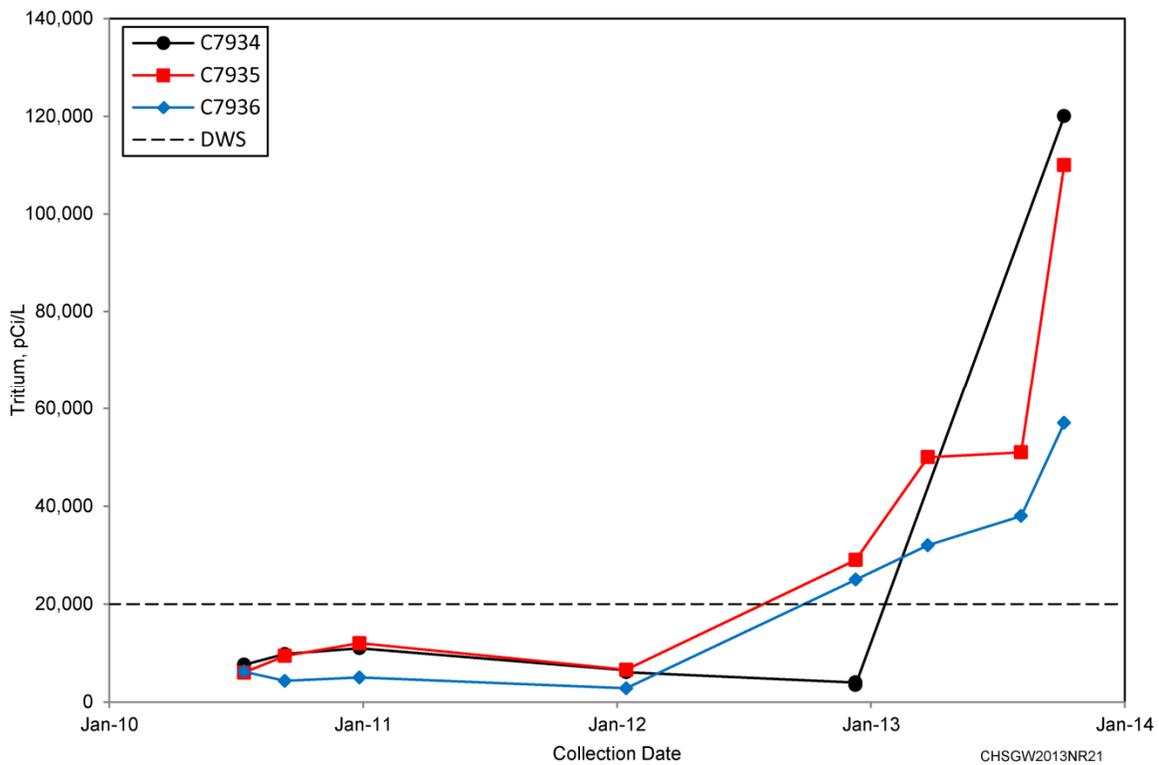


Figure NR.9 100-NR Tritium Data for Aquifer Tubes C7934, C7935, and C7936

## 100-NR Nitrate

Nitrate exceeds 45 mg/L in groundwater beneath the 116-N-1 and 116-N-3 waste sites and the 100-N Reactor area to the southwest (Figure NR.10). The highest concentration detected in 2013 was 168 mg/L in well 199-N-186 in the 116-N-1 crib. The 116-N-1 and 116-N-3 waste sites are implicated as the primary source of nitrate based on the persistent groundwater plume beneath them.

Nitrate concentrations were relatively low during disposal operations at the 116-N-1 and 116-N-3 sites (Figures NR.11 and NR.12). The highest nitrate concentrations were detected following remediation activities at these two sites from 2000 to 2006, which included excavation, application of dust suppression water and soil fixatives, and backfill. Increases in nitrate concentrations in 2013 may be due to delayed drainage from the deep vadose zone caused by additional surface water applied during waste site remediation several years ago.

Nitrate concentrations near the 120-N-1 waste site were very low when the waste site was in use, but began to increase in the mid-1990s (Figure NR.13). Only low levels of nitrate (approximately 1 mg/L) were detected in the 120-N-1 effluent (Section 2.4.4 of [DOE/RL-96-39](#)). These factors suggest that the 120-N-1 site was not the source of the nitrate plume in the southwest region of 100-NR. The increase in nitrate concentrations in 2013 may be a delayed or ongoing response to dust suppression water applied during past and ongoing waste site remediation activities.

The nitrate plume in 2011 through 2013 has a more limited extent to the southwest than in previous years because of the impact of treated water entering the aquifer through nearby 100-K injection wells.

Nitrate concentrations are anomalously low in wells in the area of the TPH-diesel groundwater plume (Figure NR.19). The lower concentrations are caused by the chemical reduction of nitrate during biodegradation of the TPH-diesel contamination. Low dissolved oxygen levels, lower pH, detectable nitrite, and elevated concentrations of iron and manganese support the interpretation of reducing conditions in this part of the aquifer.

Nitrate concentrations are highest in the upper part of the unconfined aquifer but are fairly well dispersed throughout the unconfined aquifer. Wells 199-N-69, 199-N-70, and 199-N-182, screened near the bottom of the aquifer, consistently have lower concentrations than the adjacent, shallow wells.

Nitrate concentrations in several aquifer tubes in southwestern 100-NR exceeded the DWS in 2013 (Figure NR.10).

Seep number "100-N SPRING 8-13", on the river shore near aquifer tube N116mArray-16A, was sampled on September 23, 2013. The nitrate result (16.7 mg/L) is posted on the nitrate plume map (Figure NR.10).

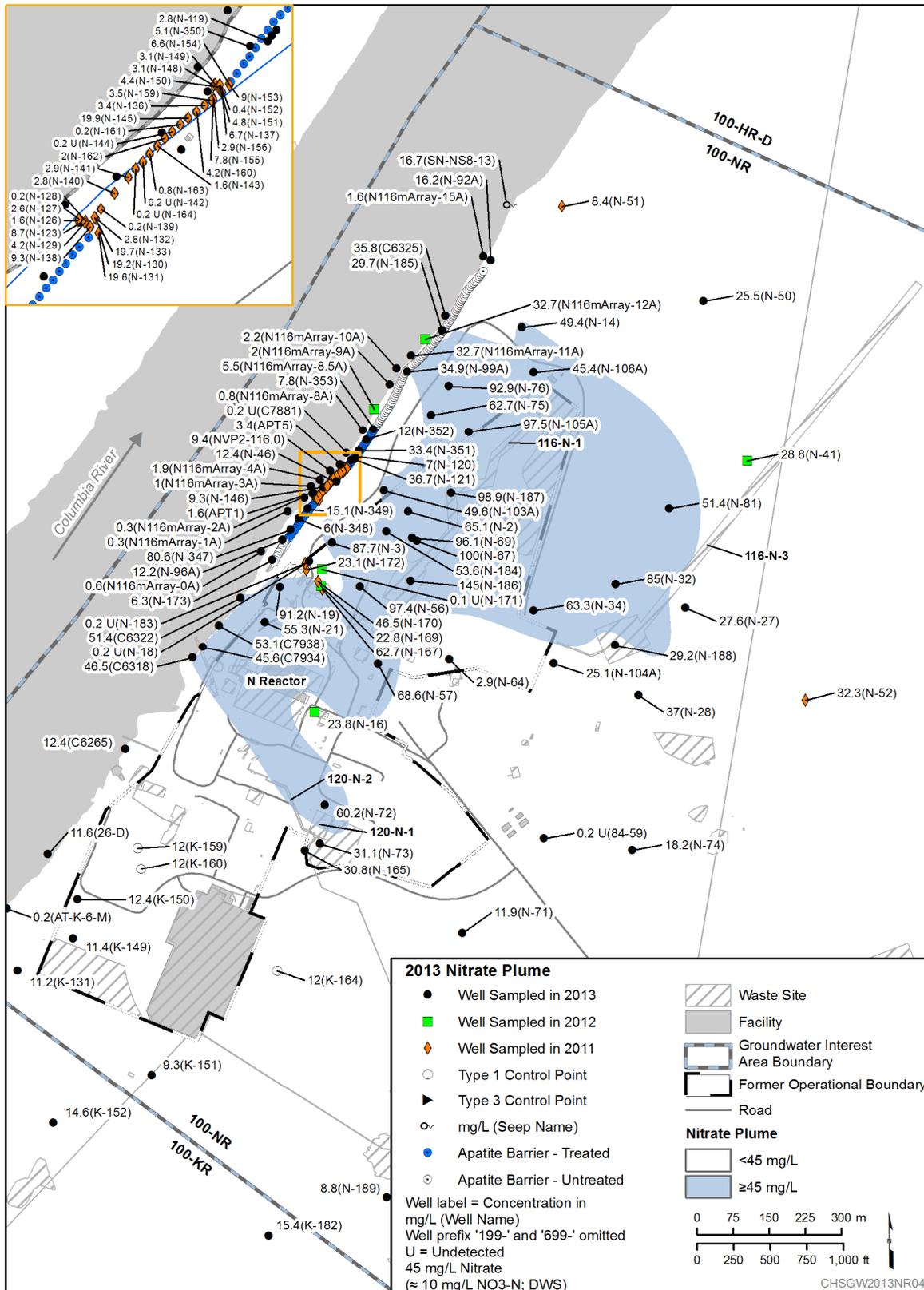


Figure NR.10 100-NR 2013 Nitrate Plume

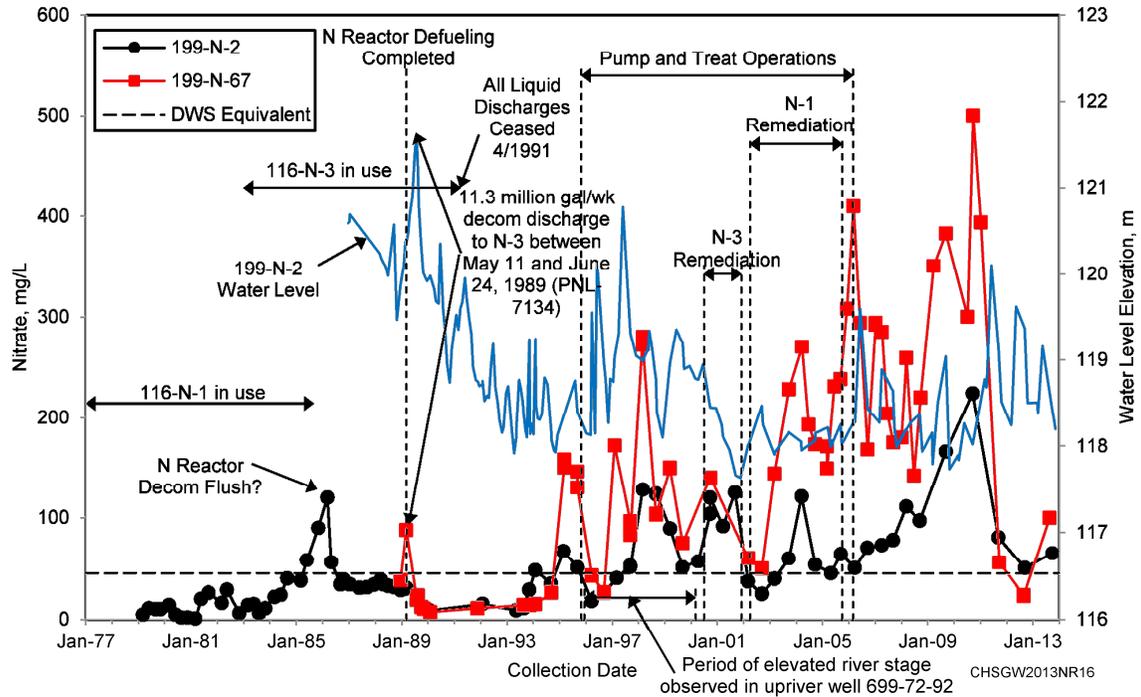


Figure NR.11 100-NR Nitrate Data for Wells 199-N-2 and 199-N-67

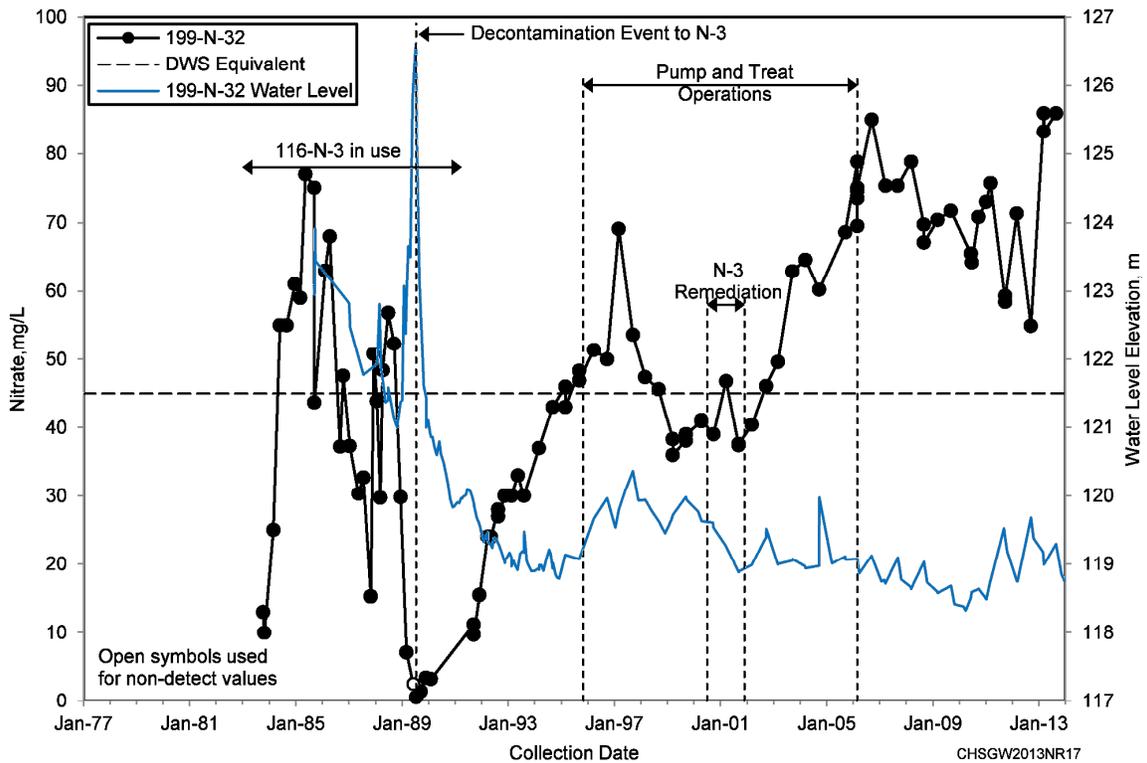


Figure NR.12 100-NR Nitrate Data for Well 199-N-32

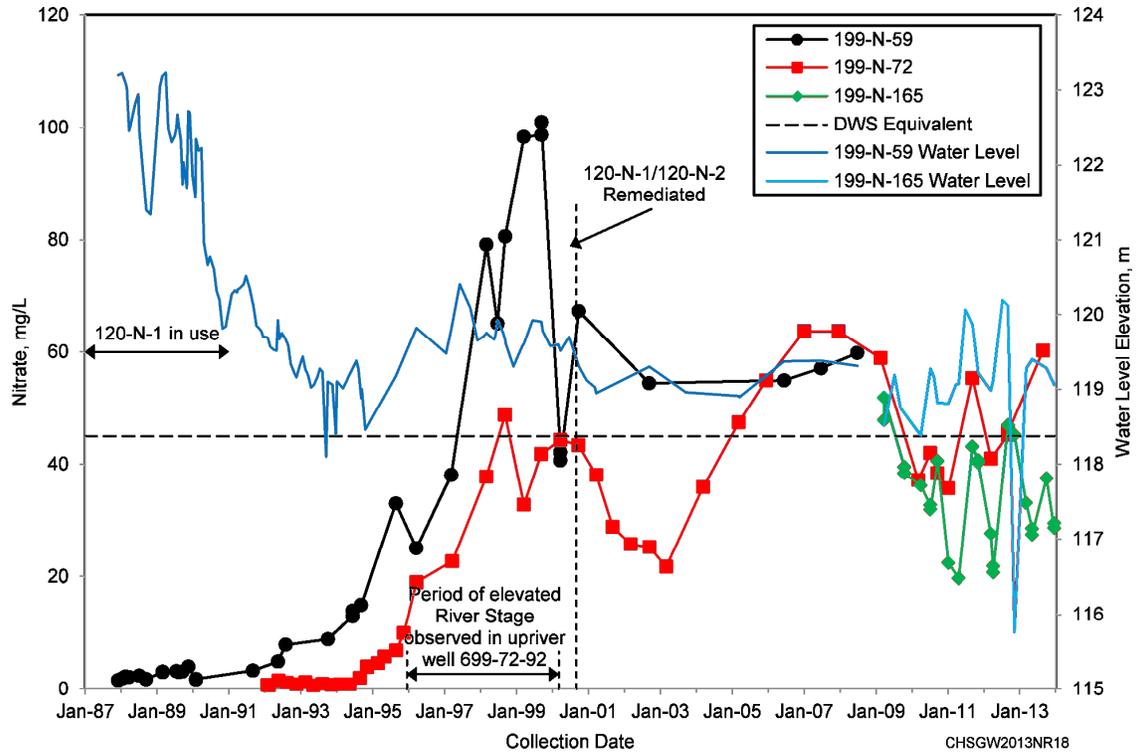


Figure NR.13 100-NR Nitrate Data for Wells 199-N-59, 100N-72, and 199-N-165

## 100-NR Total Petroleum Hydrocarbons (TPH) - Diesel

The primary source of the TPH-diesel groundwater contamination is a 1966 diesel fuel spill (UPR-100-N-17). A small, relatively narrow groundwater plume extends downgradient from the spill location to the river (Figure NR.14). The highest groundwater concentration in 2013 was 9,450 µg/L (Well 199-N-171), which is a substantial decrease from the 2011 and 2010 maximum concentrations (well 199-N-18) of 48,000 and 420,000 µg/L, respectively, but an increase from the 2012 maximum concentration (well 199-N-171) of 4,620 µg/L. The overall plume reduction in concentration in 2012 and 2013 is attributed primarily to the bioventing pilot test conducted by Washington Closure Hanford in 2010 and 2011 for remediation of diesel in the deep vadose zone at UPR-100-N-17 ([WCH-490](#)).

In situ bioventing introduces oxygen to promote in situ aerobic biodegradation of the TPH-diesel in the deep vadose zone to carbon dioxide and water. The data from the bioventing pilot test were used to support the design of a full-scale bioventing system. Full scale bioventing system operations began at UPR-100-N-17 in December 2012 using two injection wells (199-N-167 and 199-N-172) and eight monitoring wells (199-N-3, 199-N-19, 199-N-56, 199-N-96A, 199-N-169, 199-N-171, 199-N-173, and 199-N-183) (Appendix H of [DOE/RL-2005-93](#)).

Some natural biodegradation of diesel occurs in groundwater, as shown by the anomalously low nitrate groundwater concentrations in this area (discussed in the “100-NR Nitrate” section).

In 2013, the two aquifer tubes near the intersection of the groundwater plume and the Columbia River showed detections of TPH-diesel (C6132 and N116mArray-0A [Figure NR.14]). A third aquifer tube (C6135) sampled in previous years was broken and could not be sampled in 2013.

The extent of the TPH-diesel groundwater plume for 2013 is broader than shown for 2012. The difference reflects a change in the assumptions used for preparing plume maps. For the 2012 plume map, non-detections were plotted on the map as 0 µg/L. For the 2013 plume map, non-detections were plotted on the map as the reported value. For a non-detection, the reported value is the method detection limit (MDL), which typically was 70 µg/L in 2013. If the 2012 data are plotted using the reported value for the non-detections, the 2012 plume extent appears similar to the 2013 plume (Figure NR.15).

The data used to prepare the 2013 plume maps include routine groundwater monitoring data and monitoring data for the in-situ bioventing project. In 2013, the in-situ bioventing project collected groundwater performance monitoring data in June and December 2013, at high and low water table, respectively. The performance monitoring results quantified petroleum contamination in the diesel to motor oil range (C10 through C36). The routine monitoring program analyzes diesel range only (C10-C28). The extent of the petroleum plumes using the June and December performance monitoring results are shown in Figures NR.16 and NR.17, and are similar in extent to the annual average TPH-diesel plume (Figure NR.14).

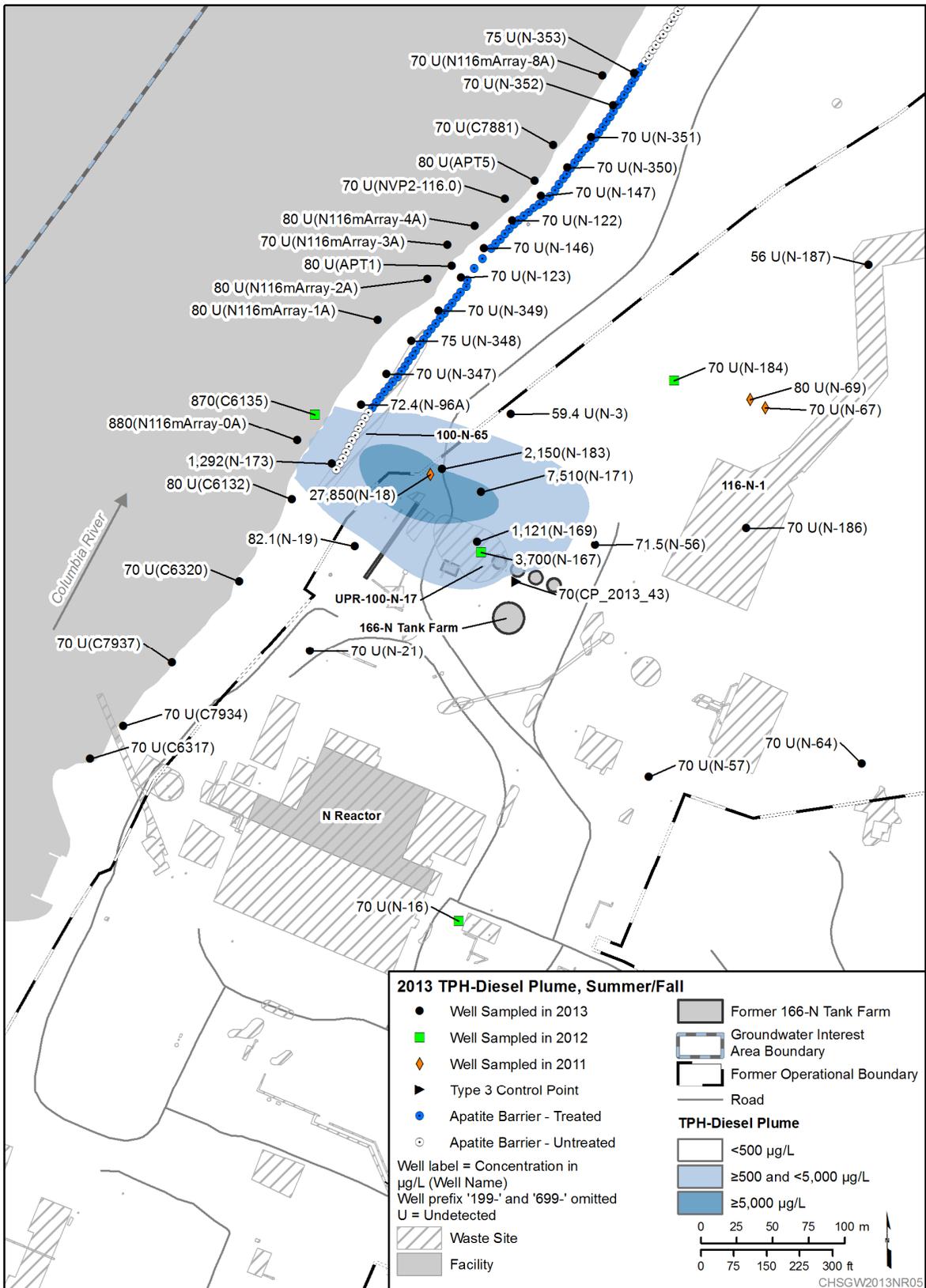


Figure NR.14 100-NR Total Petroleum Hydrocarbons (TPH)-Diesel Plume 2013

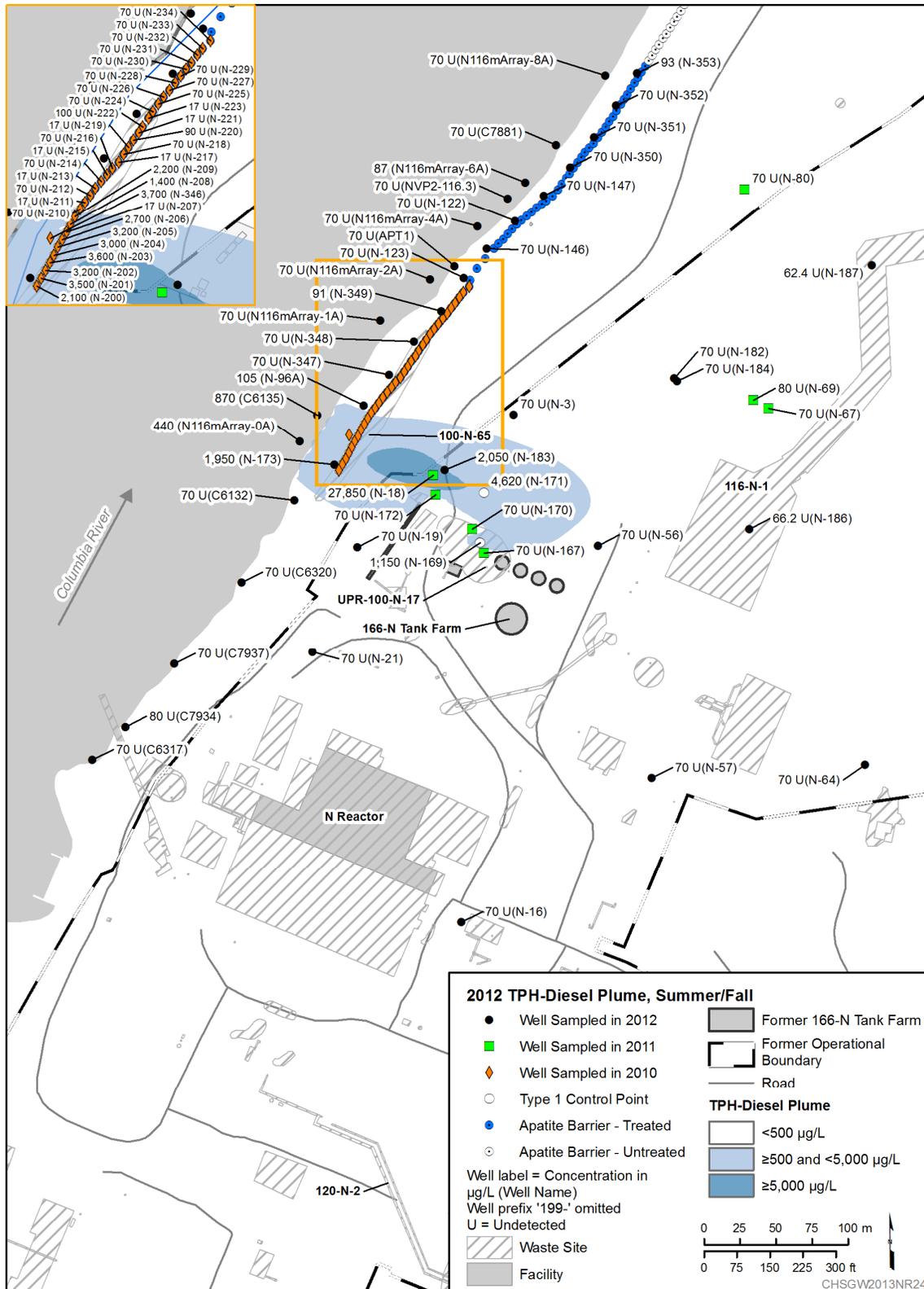


Figure NR.15 100-NR Total Petroleum Hydrocarbons (TPH)-Diesel Plume 2012 (prepared using same assumptions as used to prepare 2013 plume map)

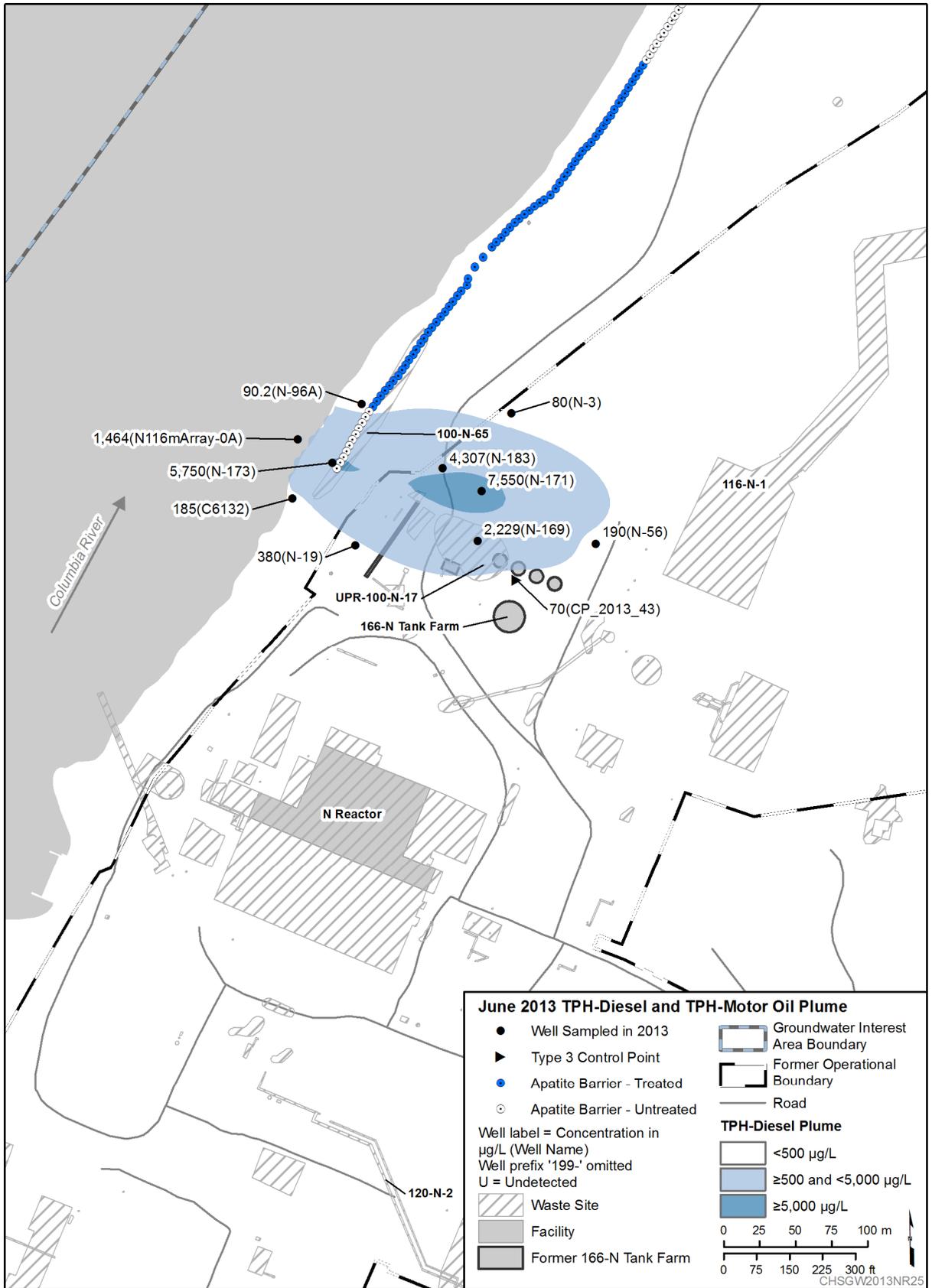


Figure NR.16 100-NR Total Petroleum Hydrocarbons (TPH) Plume – June 2013

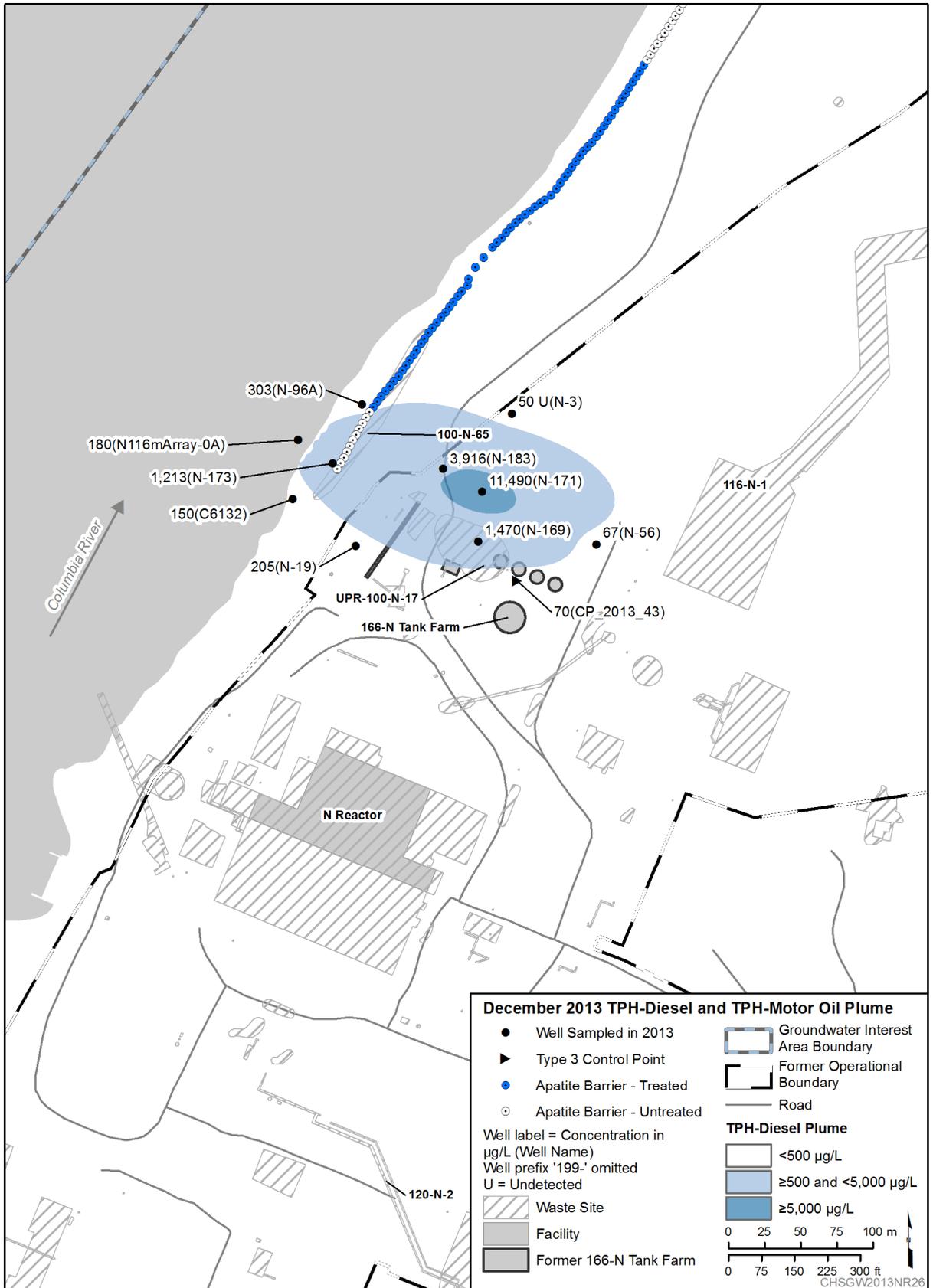


Figure NR.17 100-NR Total Petroleum Hydrocarbons (TPH) Plume – December 2013

If present as a non-aqueous phase (free product), the TPH-diesel in groundwater is found in the shallowest portion of the aquifer or floating on top of the water table (Section 4.4 of [DOE/RL-2011-25](#)). Removal of free product from well 199-N-18 continued in 2013 in accordance with the interim action ROD ([EPA/ROD/R10-99/112](#)). The diesel is removed using a polymer “smart sponge” that selectively absorbs petroleum products from the surface of the water within the well. Approximately every two months, two sponges are lowered to the surface of the aquifer in well 199-N-18 and left to soak up the diesel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of diesel fuel removed from the well. In 2013, 750 grams of diesel were removed from well 199-N-18 (Table NR.2). Removal of petroleum product from well 199-N-18 will continue in 2014.

**Table NR.2 100-NR Hydrocarbon Product Removal from Well 199-N 18, 2003-2013**

| Year              | Product Removed (gram) | Notes  |
|-------------------|------------------------|--|
| 2003 <sup>a</sup> | ~1,200 <sup>b</sup>    | Estimate provided per information given in table note; data records lost when original work package was lost in the field. |
| 2004              | 3,475                  | Changed out twice per month.   |
| 2005              | 780                    | Changed approximately every two months.  |
| 2006              | 1,370                  | Changed every two months.  |
| 2007              | 1,294                  | Changed every two months.  |
| 2008              | 920                    | Changed every two months.  |
| 2009              | 1,380                  | Changed approximately every two months.  |
| 2010              | 225.5                  | Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.               |
| 2011              | 500                    | Changed every two months.  |
| 2012              | 600                    | Changed in January, April, June, and August 2012   |
| 2013              | 750                    | Changed in January, March, May, July, September, and November 2013   |
| <b>Total</b>      |                        | <b>12,494.5 grams (approximately 12.5 kilograms) removed through end of 2013</b>   |

a. [DOE/RL-2004-21](#), *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal started in October 2003.

b. [DOE/RL-2005-18](#), *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for fiscal year 2004 (October 2003 through October 2004) was approximately 0.4 kilogram per month; therefore, an estimate is provided for the 3 months missing in 2003.

## 100-NR Chromium

Sodium dichromate was used in N Reactor operations only from 1964 to 1972 and in lesser amounts than in the other 100 Area reactors because of the design of the N Reactor cooling system and the use of corrosion-resistant metals (such as zircaloy) in the fuel and facility (Section 1.3.2 of [DOE/RL-2012-15](#)). Although chromium was present in the effluent discharged to the 116-N-1 waste site, it was never detected in samples of the effluent (Section 3.1.1.4 of [DOE/RL-90-22](#)). Given the mobility and nonsorbing nature of chromium in solution, the high continuous discharge rates and high temperatures while chromium was being delivered to the 116-N-1 waste site, and the fact that liquid discharges to 116-N-1 continued for another 10 years after use of sodium dichromate had ceased, the mobile portion of chromium was thoroughly flushed from the subsurface and into the Columbia River by the end of the N Reactor’s operational period (Section 4.8.1.4 of [DOE/RL-2012-15](#)).

Only one well in 100-NR had chromium concentrations above the DWS (100 µg/L) in 2013. The dissolved (filtered) chromium concentration in well 199-N-80, which was completed in a thin, confined water-bearing zone in the upper portion of the RUM, was 177 µg/L; consistent with previous results and relatively unchanged since monitoring began (Figure NR.18). Additional wells are proposed in this area to define the extent of the contamination. This water-bearing zone is not believed to be laterally continuous (Section 4.4.3. of [DOE/RL-2012-15](#)), but will be evaluated based on the new well installations. .

The chromium detected in well 199-N-80 is likely the result of past disposal of chromium-bearing liquid waste that was driven into this confined interval during extremely high unconfined aquifer heads and today remains relatively stagnant (Section 4.8.1.4 of [DOE/RL-2012-15](#)). Well maintenance activities in 2001 confirmed stainless steel well screen corrosion was occurring, which could also release chromium into this well.

In 2013, chromium continued to be detected below the DWS in wells approximately 750 meters inland from 105-N Reactor and not associated with a 100-N waste site (Figure KR.6). This chromium contamination migrated inland while the 100-K-2 Trench was in use and a groundwater mound was present. A portion of this 100-KR chromium plume has migrated northward into 100-NR near wells 199-N-74 and 199-N-189.

Chromium concentrations were near or below detection limits in 100-NR aquifer tube samples in 2013. All were below the 10 µg/L ambient water quality standard.

Seep number "100-N SPRING 8-13", on the river shore near aquifer tube 116mArray-16A, was sampled on September 23, 2013. The hexavalent chromium result (4.0 B µg/L) is posted on the hexavalent chromium plume map for the low river.

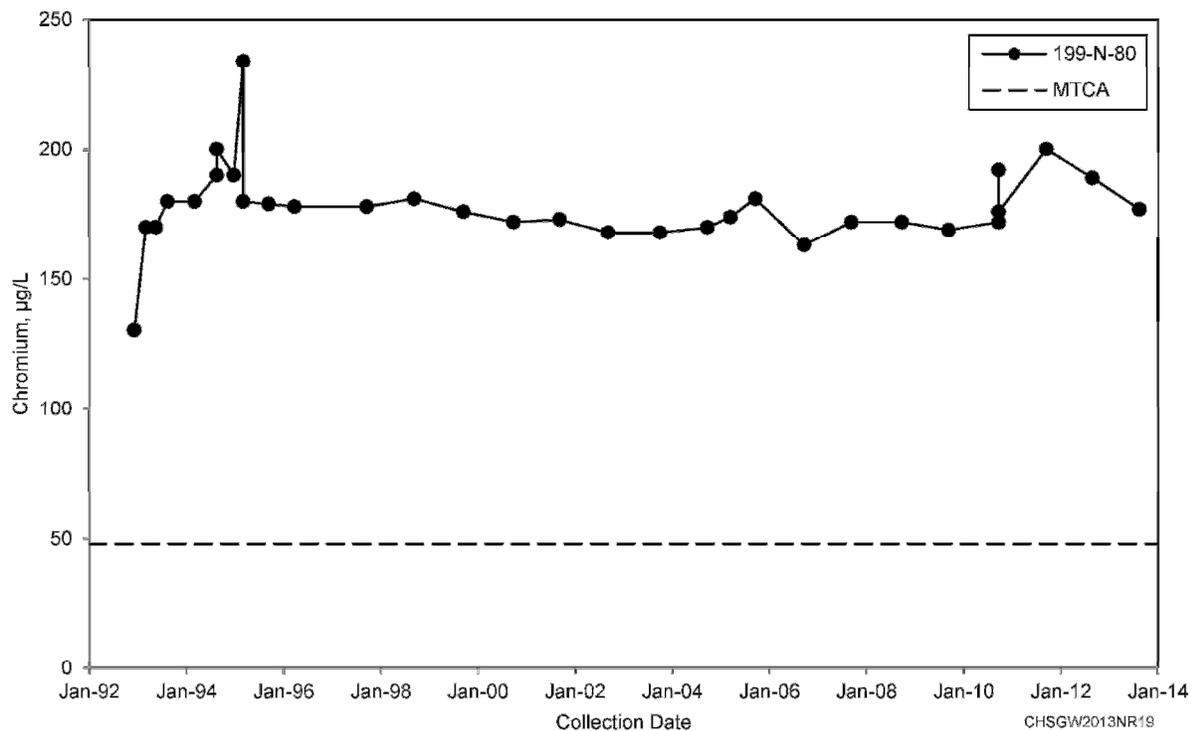


Figure NR.18 100-NR Chromium Data for Well 199-N-80

## 100-NR Remedies – Introduction

Interim actions are being conducted for cleanup of strontium-90 and TPH-diesel contamination in 100-NR-2 (Figure NR.19). The activities and results for 2013 are summarized in this section. Additional details are available in DOE/RL-2014-25, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 P&T Operations, and 100-NR-2 Groundwater Remediation*.

The CERCLA remediation of strontium-90 in groundwater is identified in the Interim Action ROD ([EPA/ROD/R10-99/112](#)). When the Interim Action ROD was issued in 1995, the interim action for remediation of strontium-90 in groundwater was P&T. The 100-NR-2 groundwater P&T system operated from 1995 until 2006. The system removed approximately 1.8 Ci of strontium-90 from the aquifer, which was less than the amount removed by radioactive decay during the same period. Because strontium-90 binds strongly to the sediment, the P&T system was not effective in the cleanup of strontium-90 from the aquifer.

One of the requirements of the Interim Action ROD was to evaluate alternative technologies for groundwater cleanup. Therefore, in 2006, Ecology, EPA, and DOE approved placing the P&T system in cold-standby status and constructing a permeable reactive barrier. A 90-meter-long apatite permeable reactive barrier was completed as a treatability test in accordance with [DOE/RL-2005-96](#). Based on the treatability test results ([PNNL-17429](#); [PNNL-SA-70033](#)), the apatite technology showed promise as a remediation option. As a result, the Interim Action ROD was amended in 2010 to allow for expansion of the apatite barrier and permanent decommissioning of the 100-NR-2 P&T system.

The CERCLA interim action for remediation of TPH-diesel in groundwater is identified in the Interim Action ROD ([EPA/ROD/R10-99/112](#)). The Interim Action ROD specifies that petroleum hydrocarbons (free product) will be removed if observed in a monitoring well. The removal of the TPH-diesel is discussed in the 100-NR TPH-Diesel section.

## 100-NR Remedies – Apatite Barrier

The original, 90-meter-long apatite permeable reactive barrier was created by injection of apatite-forming solutions into 16 wells from 2006 through 2008 ([PNNL-19572](#)). The expanded apatite permeable reactive barrier well network was installed between late 2009 and early 2010, extending the original barrier well network upriver and downriver for a total length of 760 meters (Figure NR.20). In September 2011, two segments of the extended well network, one upriver and one downriver of the original barrier, were injected with apatite-forming solution to extend the length of the apatite permeable reactive barrier to approximately 300 meters (SGW-56970, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*). The barrier was expanded in accordance with the design optimization study ([DOE/RL-2010-29](#)). The design optimization study ([DOE/RL-2010-29](#)) had seven objectives for evaluating barrier implementation and effectiveness. Data from the injections and subsequent performance monitoring are used to evaluate these objectives in SGW-56970.

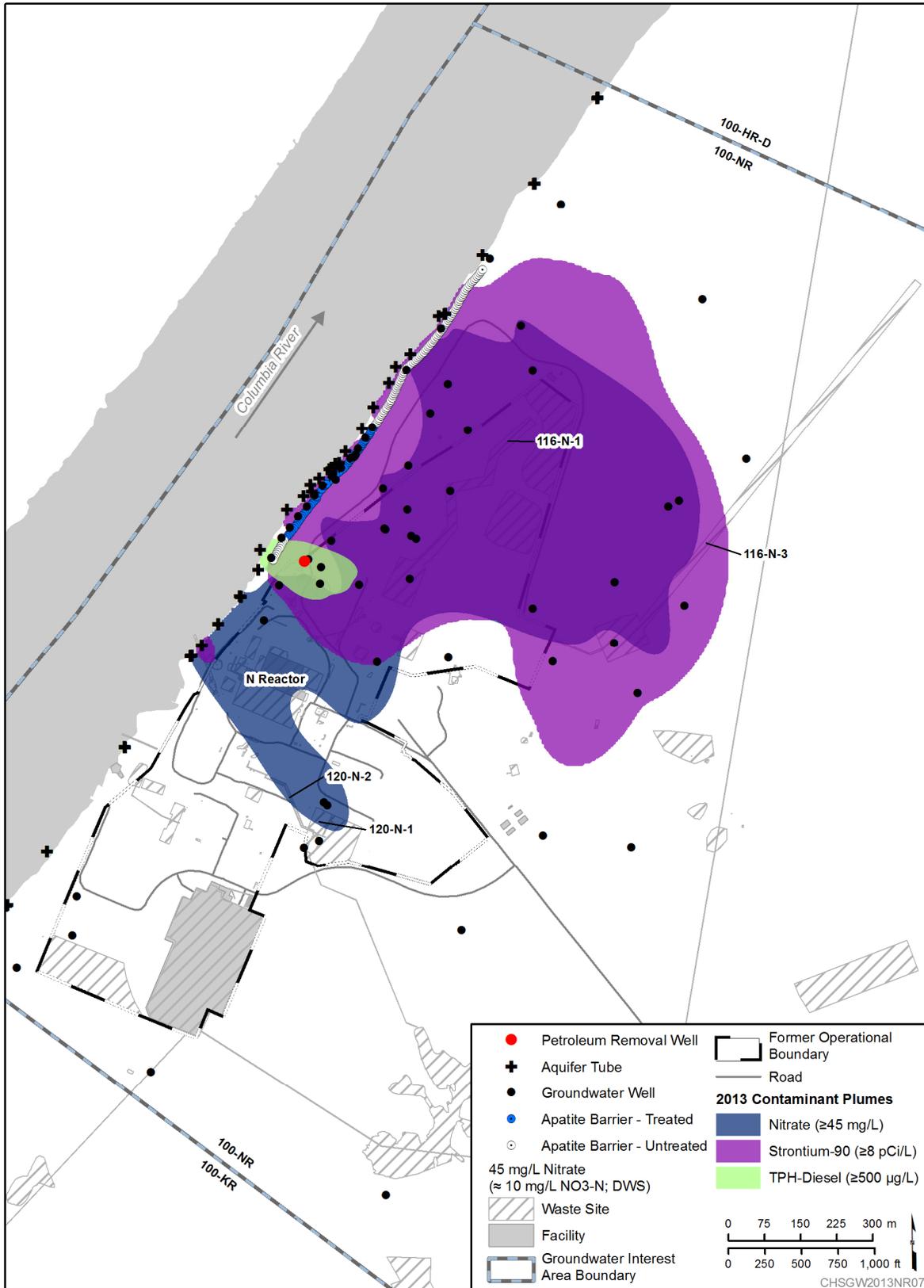


Figure NR.19 100-NR Remedy Plumes

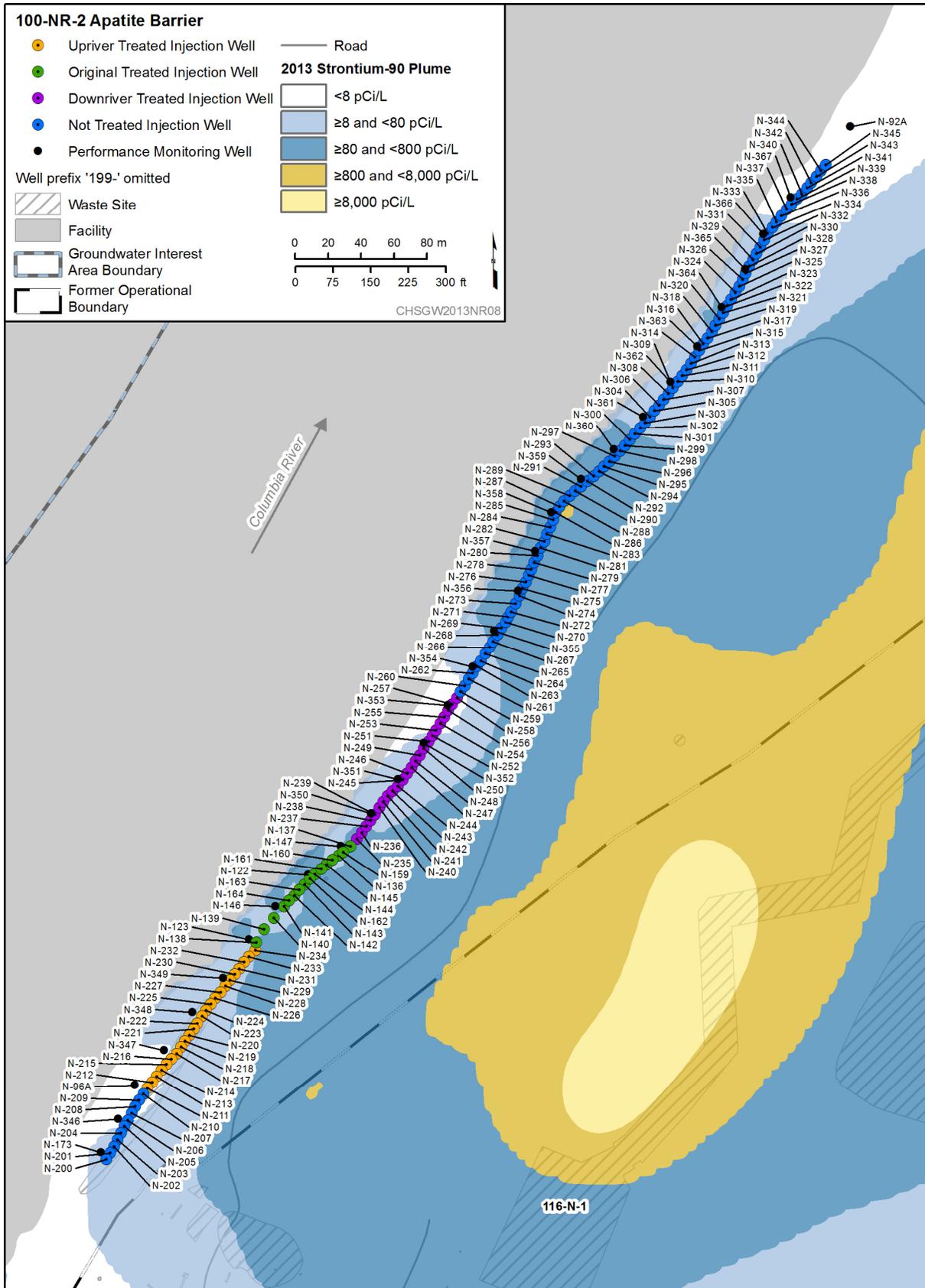


Figure NR.20 100-NR Apatite Barrier

**Apatite Permeable Reactive Barrier Technology.** The apatite permeable reactive barrier is formed by injecting a calcium-citrate-phosphate solution into the aquifer through a network of vertical wells (i.e., the barrier well network). After the solution is injected, biodegradation of the citrate releases the calcium, which results in formation of apatite (a calcium phosphate mineral  $[\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})]$ ). Strontium-90 (and strontium) ions in groundwater substitute for calcium ions in the apatite via cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization (Section 1.3 of [PNNL-16891](#)). The strontium-90 in groundwater is sequestered within the apatite permeable reactive barrier as contaminant-laden groundwater flows through the barrier. The sequestered strontium-90 continues to decay in place within the barrier.

**Apatite Permeable Reactive Barrier Performance Monitoring.** Performance monitoring at the apatite barrier was conducted twice in 2013. Groundwater samples were collected from performance monitoring wells and aquifer tubes during high river stage in May and during low river stage in September. A comparison of Fall 2013 data to baseline conditions is shown in Table NR.3.

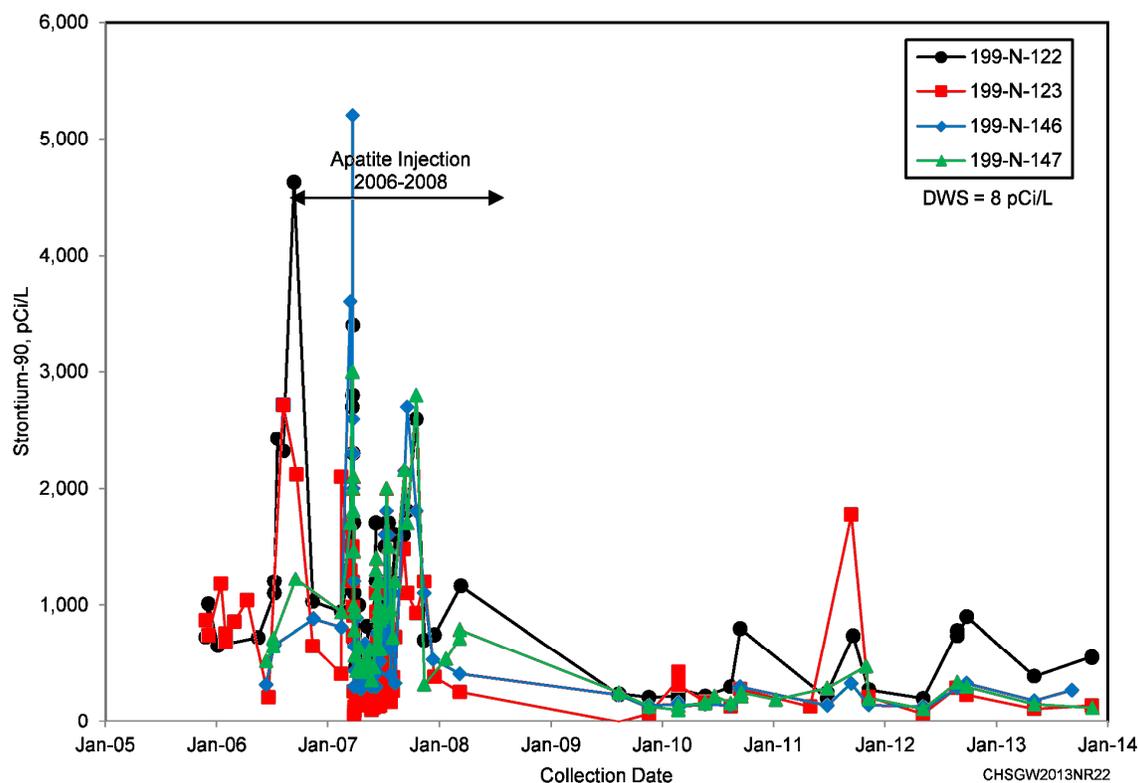
Semiannual performance monitoring (high and low river stages) will continue for the apatite permeable reactive barrier in 2014.

Following the apatite injections in 2008 in wells in the central (original) segment of the barrier, strontium-90 concentrations declined in the performance monitoring wells (Figure NR.21). The wells showed temporary, higher strontium-90 concentrations immediately following the injections of the apatite solution, which had a higher ionic strength than groundwater and temporarily mobilized cations and anions, causing their concentrations in groundwater to increase. Strontium-90 concentrations in wells 199-N-122 and 199-N-123, which are near the upriver and downriver ends of the central barrier segment, temporarily increased following injections into the nearby barrier extension wells in 2011.

As of Fall 2013, the strontium-90 concentrations were still considerably lower in the wells monitored along the central segment of the barrier than before the injections started in 2006. The treatability test plan objective was a 90 percent reduction in strontium-90 concentrations in the performance monitoring wells (Section 4.4.3 of [DOE/RL-2005-96](#)). The 2013 data indicate that the strontium-90 concentrations in groundwater have been reduced by approximately 90 percent in three of the four performance monitoring wells (Table NR.3). The percent reduction in strontium-90 concentrations in Fall 2013 ranged from 73 percent (well 199-N-146) to 93 percent (well 199-N-147).

In the performance monitoring wells along the upriver barrier extension, the percent reduction in strontium-90 concentrations in September 2013 (the end of the second year following the injections) ranged from 17 percent (well 199-N-347) to 98 percent (well 199-N-348). The relatively low percent reduction in well 199-N-347 reflects comparison to the low baseline strontium-90 concentration. Both the baseline and the September 2013 sample concentrations were below the DWS (8 pCi/L). In the performance monitoring wells along the downriver barrier extension, the percent reduction in strontium-90 concentrations in September 2013 ranged from 87 percent (well 199-N-351) to 97 percent (well 199-N-353). Ongoing monitoring will allow the determination of the continued effectiveness of the apatite barrier and support decisions regarding additional future apatite treatments.

| Table NR.3 Performance Monitoring at the Apatite Permeable Reactive Barrier, 100-NR-2 OU  |                            |                                |                                    |                  |             |              |   |                  |
|---|----------------------------|--------------------------------|------------------------------------|------------------|-------------|--------------|---|------------------|
| Well Name   | Number of Baseline Samples | Number of Baseline Non-Detects | Strontium-90 Concentration (pCi/L) |                  |             |              | Percent Reduction in Strontium-90 (Baseline to Fall 2013) (g) |                  |
|   |                            |                                | Minimum Detected Baseline          | Maximum Baseline | Spring 2013 | Fall 2013    | Minimum Baseline  | Maximum Baseline |
|   |                            |                                |                                    |                  |             |              |   |                  |
| Upriver Apatite Permeable Reactive Barrier  |                            |                                |                                    |                  |             |              |   |                  |
|   |                            |                                | 04/06/10                           |                  | 05/06/13    | 09/06/13     |   |                  |
| 199-N-96A   | 56                         | 8                              | 1.54 (a)                           | 37.9 (a)         | 2.3         | 5.9          | -283  | 84               |
| 199-N-347   | 1                          | 1                              | 7 (b)                              | 7 (b)            | 8.5         | 5.8          | 17  | 17               |
| 199-N-348   | 1                          | 0                              | 1800                               | 1800             | 28          | 41           | 98  | 98               |
| 199-N-349   | 2                          | 0                              | 220                                | 230              | 27          | 66           | 70  | 71               |
| Central (Original) Apatite Permeable Reactive Barrier   |                            |                                |                                    |                  |             |              |   |                  |
| (e)   |                            |                                | (f)                                |                  | 05/06/13    | 09/06/13     |   |                  |
| 199-N-122   | 10                         | 0                              | 657                                | 4630             | 390, 390    | 550, 560 (c) |   | 16 88            |
| 199-N-146   | 4                          | 0                              | 318                                | 985              | 180         | 270          |   | 15 73            |
| 199-N-147   | 3                          | 0                              | 522                                | 1842             | 150         | 120 (d)      |   | 77 93            |
| 199-N-123   | 6                          | 0                              | 689                                | 1180             | 110         | 140 (c)      |   | 80 88            |
| Downriver Apatite Permeable Reactive Barrier  |                            |                                |                                    |                  |             |              |   |                  |
|   |                            |                                | 07/28/10, 07/29/10                 |                  | 05/06/13    | 09/06/13     |   |                  |
| 199-N-350   | 1                          | 0                              | 240                                | 240              | 13          | 29           |   | 88 88            |
| 199-N-351   | 1                          | 0                              | 350                                | 350              | 32          | 46           |   | 87 87            |
| 199-N-352   | 1                          | 0                              | 580                                | 580              | 26          | 31           |   | 95 95            |
| 199-N-353   | 1                          | 0                              | 83                                 | 83               | 3.5         | 2.8          |   | 97 97            |
| <p>(a) Between 1995 and 2011, the maximum baseline was measured on 12/06/1995; the minimum detected baseline was measured on 06/13/2006 and 06/22/2007.</p> <p>(b) Strontium-90 is a beta emitter. Gross beta concentrations are approximately two times the strontium-90 concentrations. The strontium-90 concentration was 1.1 U pCi/L. The gross beta concentration, 14 pCi/L, was divided by two to approximate the strontium-90 concentration of 7 pCi/L.</p> <p>(c) Sampled on 11/11/13.</p> <p>(d) Sampled on 11/13/13.</p> <p>(e) From Table 8.1 in PNNL-17429, Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization</p> <p>(f) From Table 4.1 in PNNL-19572, 100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization</p> <p>(g) The percent reduction in strontium-90 concentration is calculated as:<br/> <math display="block">\frac{([\text{baseline value}] - [\text{Fall 2013 value}])}{[\text{baseline value}]} \times 100.</math>                     For Well 199-N-96A the minimum baseline value used in the calculation was the lowest detected value.</p> <p>U = analyzed for but not detected</p> |                            |                                |                                    |                  |             |              |   |                  |



**Figure NR.21 100-NR Strontium-90 Data for Performance Monitoring Wells along the Central Segment of the Apatite Permeable Reactive Barrier**

## 100-NR RCRA – Introduction

This section describes the monitoring results for the following four RCRA facilities in 100-NR: the 116-N-1 Crib and Trench (1301-N Liquid Waste Disposal Facility), the 116-N-3 Crib and Trench (1325-N Liquid Waste Disposal Facility), the 120-N-1 Pond (1324-NA Percolation Pond), and the 120-N-2 Surface Impoundment (1324-N Surface Impoundment)(Figure NR.1). Groundwater is monitored at these facilities to meet the requirements of RCRA and [WAC 173-303](#) for dangerous waste constituents. Groundwater data for these facilities are available in the Hanford Environmental Information System (HEIS) database and in the data files accompanying this report. Appendix B includes well and constituent lists, flow rates, and statistical tables for the four RCRA units in 100-NR.

## 100-NR RCRA – 116-N-1 Crib and Trench

The 116-N-1 waste site (1301-N Liquid Waste Disposal Facility [Figure NR.22]) was an unlined crib and trench used for disposal of liquid effluent from the 1960s through 1985. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site excavation varied from 4.6 to 6.1 meters (15 to 20 feet) below ground surface depending on location to remove shallow vadose zone sediment (where most of the radionuclide contamination resided) and was backfilled with clean fill.

The direction of groundwater flow beneath the 116-N-1 site in 2013 remained the same as in 2012; the area is not likely affected by the influence of groundwater injection in 100-KR-4 to the south (Figure NR.1). On February 28, 2013 the water table gradient beneath the 116-N-1 site was to the north at  $3.0 \times 10^{-3}$  meters per meter, and estimates of the groundwater flow rate ranged from 0.06 to 1.11 meter per day (Table B.1, Appendix B).

Two upgradient wells (199-N-34 and 199-N-57) and three downgradient wells (199-N-2, 199-N-3, and 199-N-105A) monitor the 116-N-1 waste site (Table B.2, Appendix B). No changes to the monitoring network were made in 2013.

The 116-N-1 facility is included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of [BHI-00725](#). That plan, and a supplemental plan ([PNNL-13914](#)), are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#)), as referenced by [WAC 173-303-400](#).

Upgradient and downgradient wells are scheduled for sampling twice each year for RCRA contamination indicator parameters (that is, pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters. The wells were sampled as scheduled during 2013, and there were no critical mean exceedances (Table B.4, Appendix B).

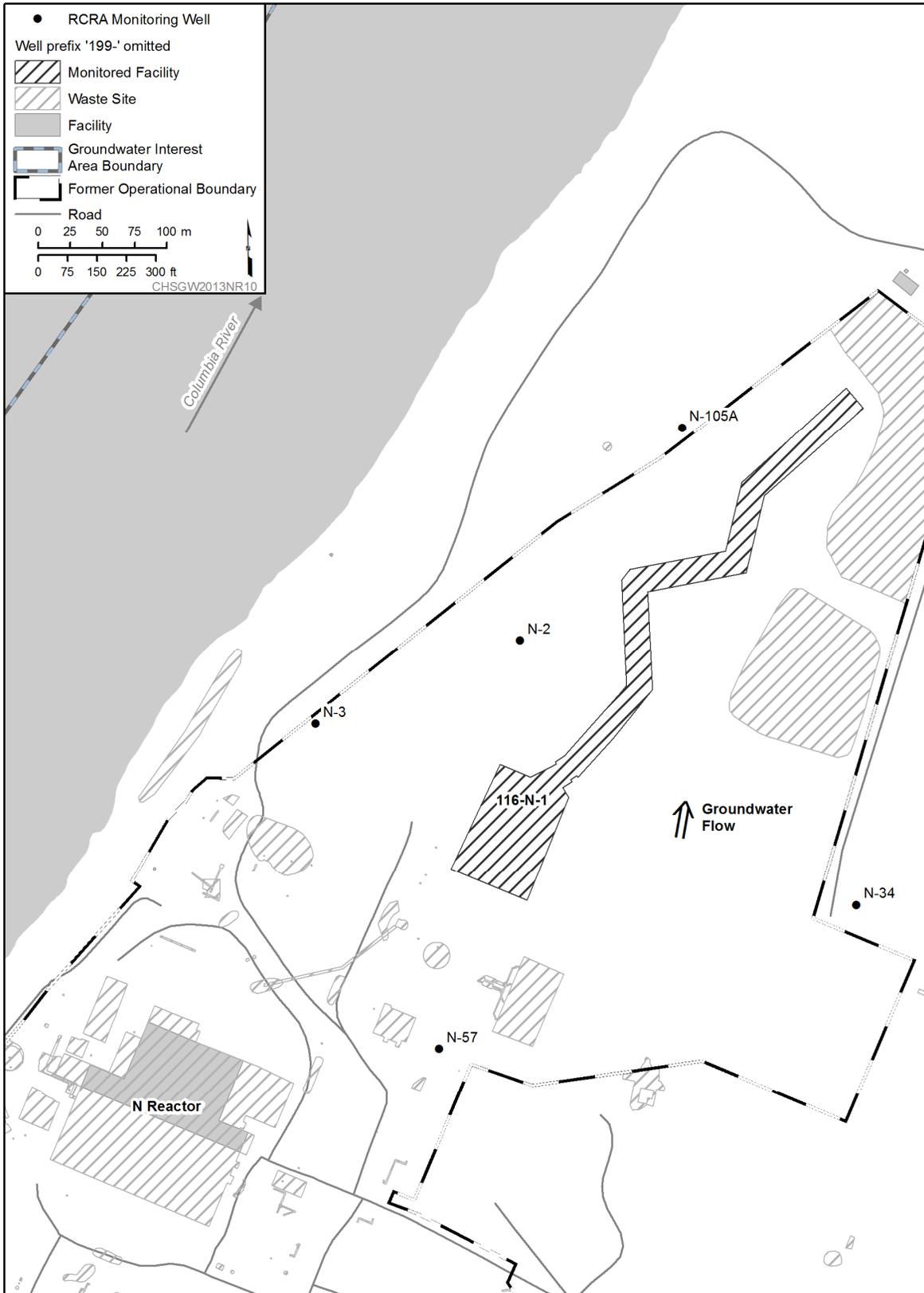


Figure NR.22 100-NR RCRA 116-N-1 Monitoring Well Locations

## 100-NR RCRA – 116-N-3 Crib and Trench

The 116-N-3 waste site (1325-N Liquid Waste Disposal Facility, Figure NR.23) was an unlined crib and trench used to dispose of liquid effluent from 1983 through 1991. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site was excavated to 5 feet below the engineered structure to remove vadose zone material (which contained the highest concentrations of radionuclides) and was backfilled.

Groundwater flows to the north beneath the 116-N-3 site, turns to the northwest, and discharges to the Columbia River. The hydraulic gradient in March 2013 was to the north at  $1.2 \times 10^{-3}$  meters per meter with the groundwater flow rate estimated from 0.02 to 0.43 m/d (Table B.1, Appendix B).

The 116-N-3 facility is included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of [BHI-00725](#), [BHI-00725](#) and a supplemental plan ([PNNL-13914](#)) are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#)), as referenced by [WAC 173-303-400](#).

Upgradient well 199-N-74 and downgradient wells 199-N-32, 199-N-41, and 199-N-81 monitor the 116-N-3 waste site. Well 199-N-28 is monitored for supporting information, but its data are not evaluated statistically. No changes to the monitoring network were made in 2013.

All five wells in the RCRA network were scheduled to be sampled twice for RCRA contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters in 2013. Four of the five wells were sampled successfully as planned in 2013. Well 199-N-41 was only sampled once in 2013 during the spring time period. The well sample scheduled in the fall could not be completed for well 199-N-41 because excavation activities associated with soil site remediation impeded into the well access road making the well inaccessible. Road repair is scheduled to be completed in 2014.

Average specific conductance values in all three of the downgradient wells (199-N-41, 199-N-81, and 199-N-32) exceeded the 2013 critical mean of 461  $\mu\text{S}/\text{cm}$  (Table B.10, Appendix B). This is a continuation of previous exceedances noted from 1999 through 2012. The assessment report for the original 1999 exceedance (at well 199-N-41) concluded that the exceedance was caused by past discharges of nonregulated contaminants to the 120-N-1 site ([00-GWVZ-054](#)). Recent data indicate that this conclusion in the 1999 assessment report ([00-GWVZ-054](#)) remains valid.

In September 2013, average TOC values in downgradient wells 199-N-32 and 199-N-81 and upgradient well 199-N-74 exceeded the 2013 critical mean of 493  $\mu\text{g}/\text{L}$ . Verification sampling at the wells was scheduled per the sampling and analysis plan groundwater monitoring requirements, and verification samples were collected on December 18, 2013 with splits for TOC sent to the Waste Sampling and Characterization Facility (WSCF) and TestAmerica. TOC results from sample splits sent to TestAmerica were below the critical mean, while TOC results from sample splits sent to WSCF exceeded the critical mean. High TOC results in the December verification samples results from WSCF were suspect due to residual contamination in the analyzer which led to high TOC results for all samples analyzed at WSCF during this time period.

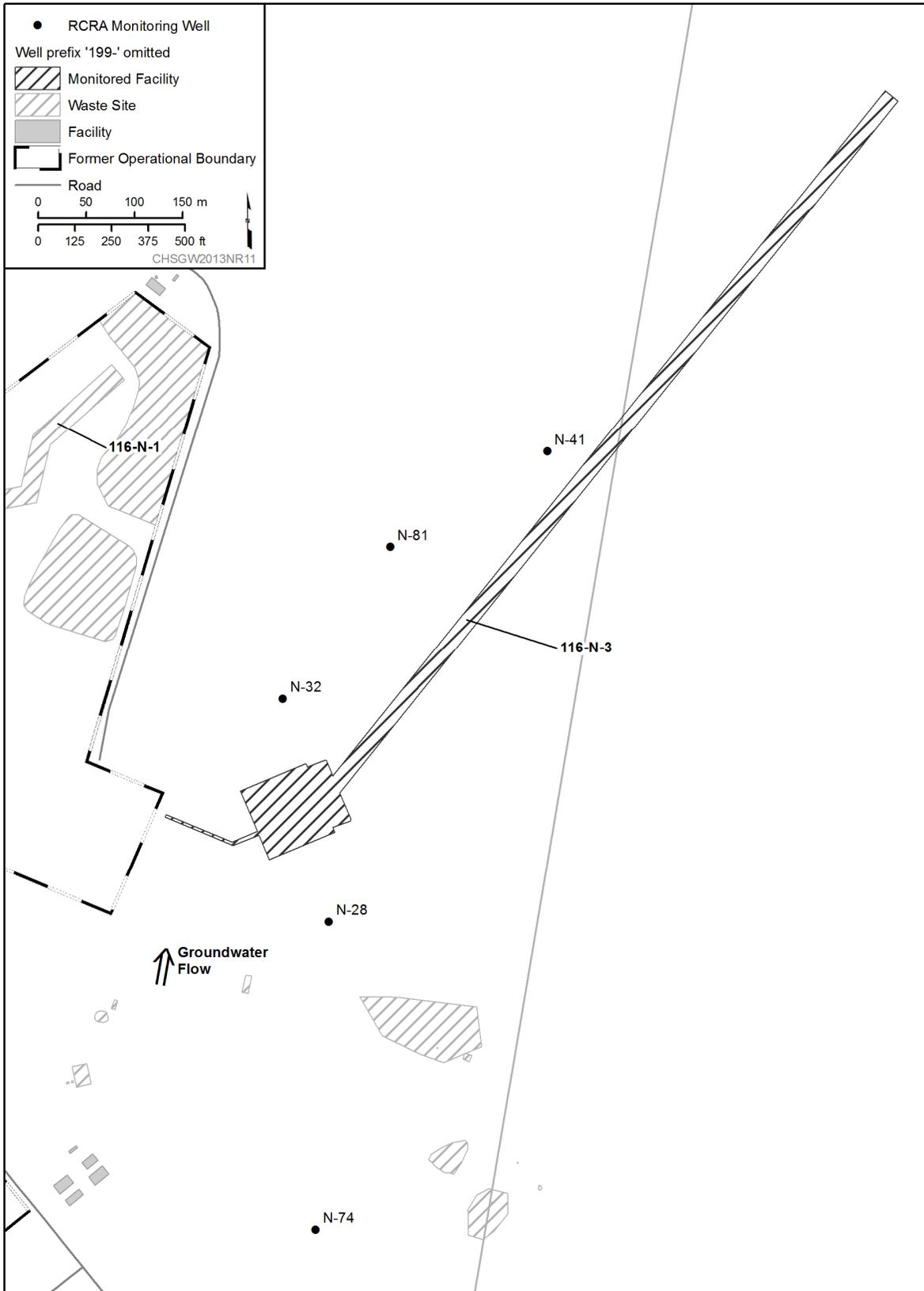


Figure NR.23 100-NR RCRA 116-N-3 Monitoring Well Locations

A subsequent verification sampling event was conducted in February 2014 because of the issues with the TOC results from WSCF. Samples were collected on February 24, 2014 and February 25, 2014 with splits for TOC sent to WSCF and GEL. TOC results from WSCF for the second set of verification samples were below the critical mean value. TOC results from GEL for the second set of verification samples were above the critical mean value for all samples. All TOC results from GEL had lab qualifier that TOC was detected in the Quality Control (QC) blank. In both verification sampling events, the verification samples do not confirm the critical mean for TOC was exceeded, and the site remains in interim status monitoring.

## **100-NR RCRA – 120-N-1 and 120-N-2**

The 120-N-1 waste site (1324-NA Percolation Pond) and the 120-N-2 waste site (1324-N Surface Impoundment) were used to treat and dispose of corrosive, nonradioactive waste from 1977 to 1990. Both facilities have been remediated and backfilled. The remediation consisted of the removal and disposal of the miscellaneous site structures, including the 120-N-2 liner system, a small sampling shed, fencing, and other miscellaneous debris.

The 120-N-1 and 120-N-2 facilities (Figure NR.24) are included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of [BHI-00725](#), [BHI-00725](#) and a supplemental plan ([PNNL-13914](#)) are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#)), as referenced by [WAC 173-303-400](#)). The two units are monitored as a single site (waste management area) because of their proximity and similar waste types.

Upgradient well 199-N-71 and downgradient wells 199-N-72, 199-N-73, 199-N-77, and 199-N-165 monitor the 120-N-1 and 120-N-2 waste sites. Well 199-N-77 is screened at the base of the unconfined aquifer, and statistical comparisons are not performed on data from this well. No changes to the monitoring network were made in 2013.

All five of the monitoring wells for these sites were sampled as planned during 2013, twice for RCRA contamination indicator parameters and groundwater quality, and once for site-specific parameters (Table B.2, Appendix B).

100-KR-4 injection wells south and west of the 120-N-1 and 120-N-2 sites affected groundwater flow in 2013 (Figure NR.1). On February 28, 2013 the hydraulic gradient was to the north-northeast at approximately  $1.2 \times 10^{-3}$  meters per meter, and estimated flow rates ranged from 0.03 to 0.12 meter per day (Table B.1, Appendix B).

Average specific conductance values in downgradient wells continued to exceed the critical mean value of 605  $\mu\text{S}/\text{cm}$  in 2013. A previous groundwater quality assessment indicated that the high specific conductance is caused by the nonregulated constituents sulfate and sodium ([WHC-SD-EN-EV-003](#)). These constituents, along with calcium, nitrate, other ions, and the indicator specific conductance, increased during the time of unusually high water levels in the aquifer in 2011 and 2012. The concentrations dropped coincident with lower water table levels in 2013. These data suggest that residual contamination may be present in the lower vadose zone near the water table beneath the 120-N-1 and 120-N-2 and is released into the aquifer during unusually high water levels that saturated the

normally unsaturated lower vadose zone. Recent data indicate that this conclusion in the 1992 assessment report ([WHC-SD-EN-EV-003](#)) remains valid.

In September 2013, average TOC values in downgradient wells 199-N-72, 199-N-73, and 199-N-165 exceeded the 2013 critical mean value of 771 µg/L. Verification sampling at the wells was scheduled per the sampling and analysis plan groundwater monitoring requirements, and verification samples were collected on December 18, 2013 with splits for TOC sent to WSCF and TestAmerica. TOC results from sample splits sent to TestAmerica were below the critical mean, while TOC results from sample splits sent to WSCF exceeded the critical mean. High TOC results in the December verification samples results from WSCF were suspect due to residual contamination in analyzer which led to high TOC results for all samples analyzed at WSCF during this time period.

A subsequent verification sampling event was conducted in February 2014 because of the issues with the TOC results from WSCF. TOC results from WSCF for the second set of verification samples were below the critical mean value. TOC results from GEL for the second set of verification samples were below the critical mean value except for the sample split from 199-N-72 which had a value of 845 µg/L. All TOC results from GEL had lab qualifiers that TOC was detected in the QC blank. In both verification sampling events, the verification samples do not confirm the critical mean for TOC was exceeded.

The pH measurements in the verification samples collected in February 2014 exceeded the critical mean upper limit for wells 199-N-73 and 199-N-165. The pH measurements were 8.46 and 8.45 which is 0.06 and 0.05 pH units above the critical mean pH high value of 8.4. The pH measurements in both wells have since dropped to less than the critical mean high pH value in samples collected in 2014. The pH critical mean range has narrowed since 2009 with each subsequent recalculation of the critical means where the pH difference between the upgradient and downgradient monitoring wells have been fairly stable or smaller since completion of the waste site remediation in 2000. The pH measurements for wells 199-N-73 and 199-N-165 have fluctuated between 8.09 and 8.57 since 2000. Based on the pH trends there does not appear to be any exceedance caused by releases from the 120-N-1 and 120-N-2 waste sites.

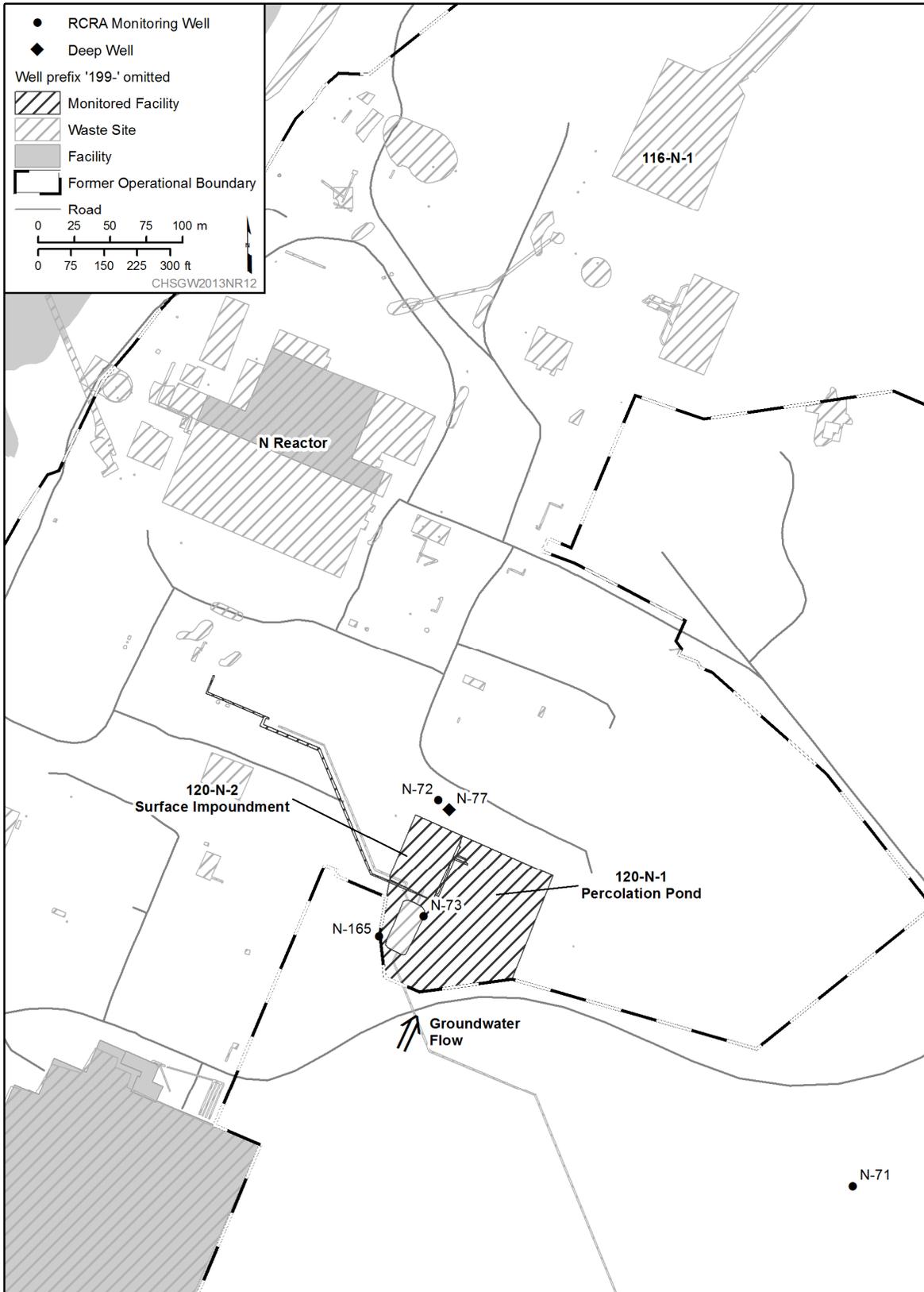


Figure NR.24 100-NR RCRA 120-N-1 and 120-N-2 Monitoring Well Locations

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