DOE/RL-2019-66
Revision 0

Hanford Site Groundwater Monitoring Report for 2019

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

Releases of chemical and radioactive liquid wastes have contaminated the soil and groundwater beneath portions of the U.S. Department of Energy (DOE) Hanford Site. Figure ES-1 shows the location and extent of the most widespread groundwater contaminants: iodine-129, nitrate, carbon tetrachloride, and tritium. Figure ES-2 shows how the contaminant plume sizes have changed over the years.

DOE operates an extensive groundwater monitoring program at the Hanford Site. Groundwater is monitored for requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA)[1]; *Washington Administrative Code*; the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[2]; and the *Atomic Energy Act of 1954*,[3] as required by DOE orders.

River Corridor

The 100 and 300 Areas form the River Corridor of the Hanford Site. About 94% of the waste sites in this region have been remediated or were determined not to require remediation, reducing the possibility of continued contaminant migration to groundwater. Remedial action decisions for the remaining 6% of the waste sites are in progress.

Figure ES-3 illustrates the contaminant plumes along the River Corridor where concentrations exceeded cleanup levels in 2019. Beyond the mapped plume boundaries, additional contamination may be present at concentrations below contour levels. Maps in the main body of this report provide all of the data, whether above or below contour levels. Table ES-1 compares the maximum concentrations measured in 2019 and 2018 for the contaminants in each of the River Corridor groundwater interest areas.

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[1] *Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq. Pub. L. 94-580, 90 Stat. 2795. Available at: https://elr.info/sites/default/files/docs/statutes/full/rcra.pdf.

[2] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, Pub. L. 107-377, as amended, 42 USC 9601, et seq., December 31, 2002. Available at: https://www.csu.edu/cerc/researchreports/documents/CERCLASummary1980.pdf.

[3] *Atomic Energy Act of 1954*, as amended, 42 USC 2011, Pub. L. 83-703, 68 Stat. 919. Available at: https://legcounsel.house.gov/Comps/Atomic%20Energy%20Act%20Of%201954.pdf.

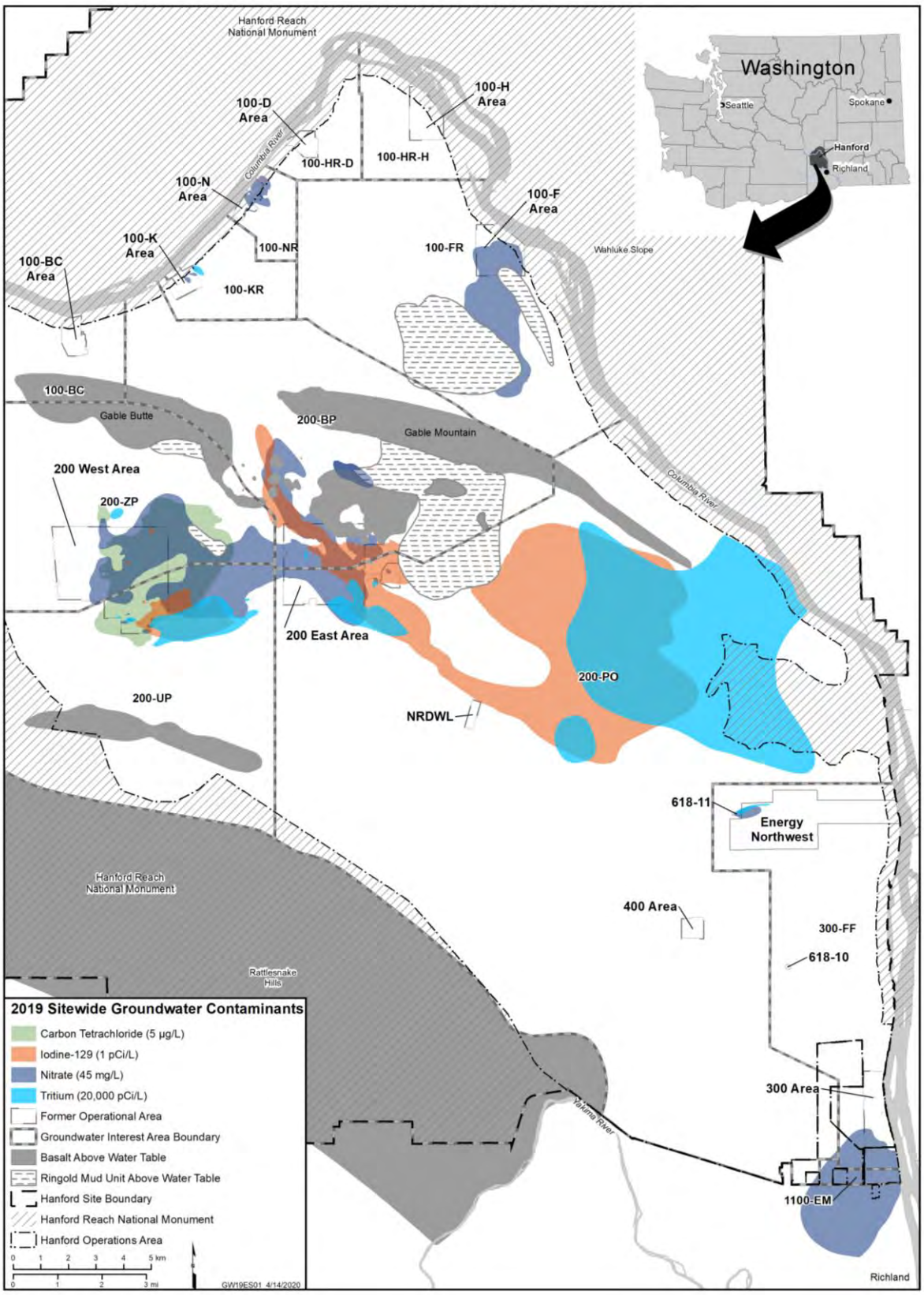

Figure ES-1. Regions of the Hanford Site and Most Extensive Groundwater Contaminant Plumes

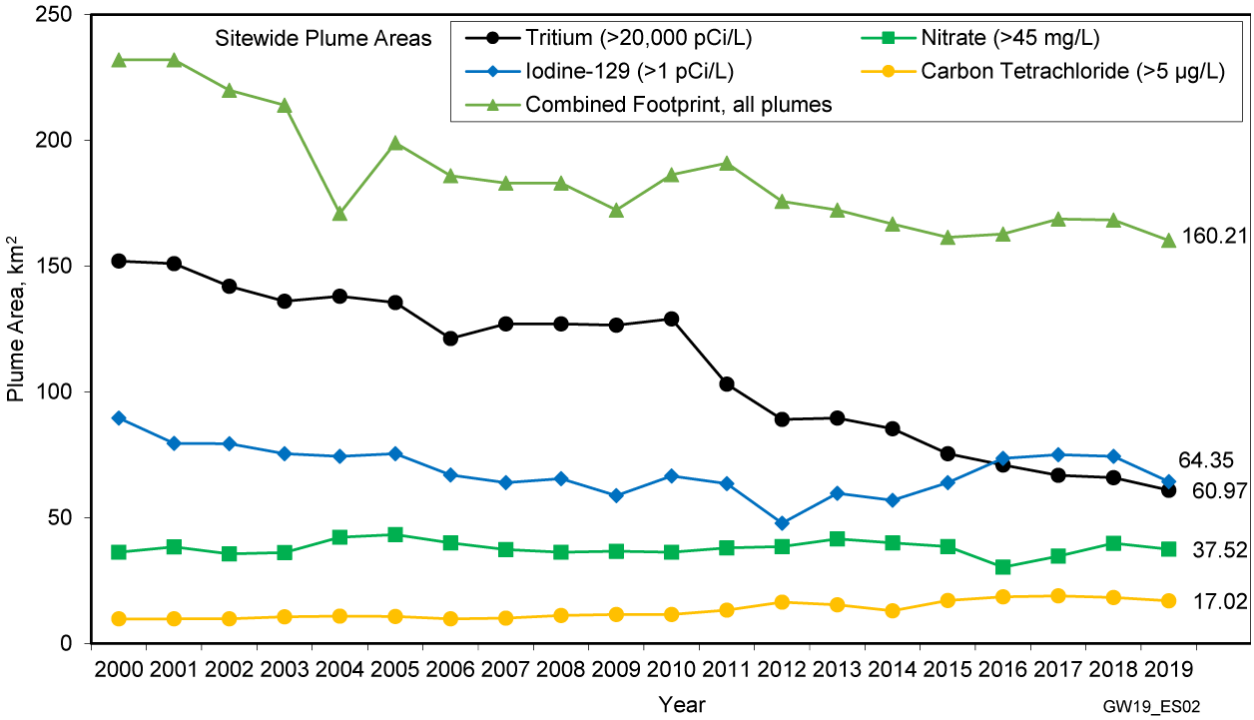

Figure ES-2. Hanford Site Plume Areas

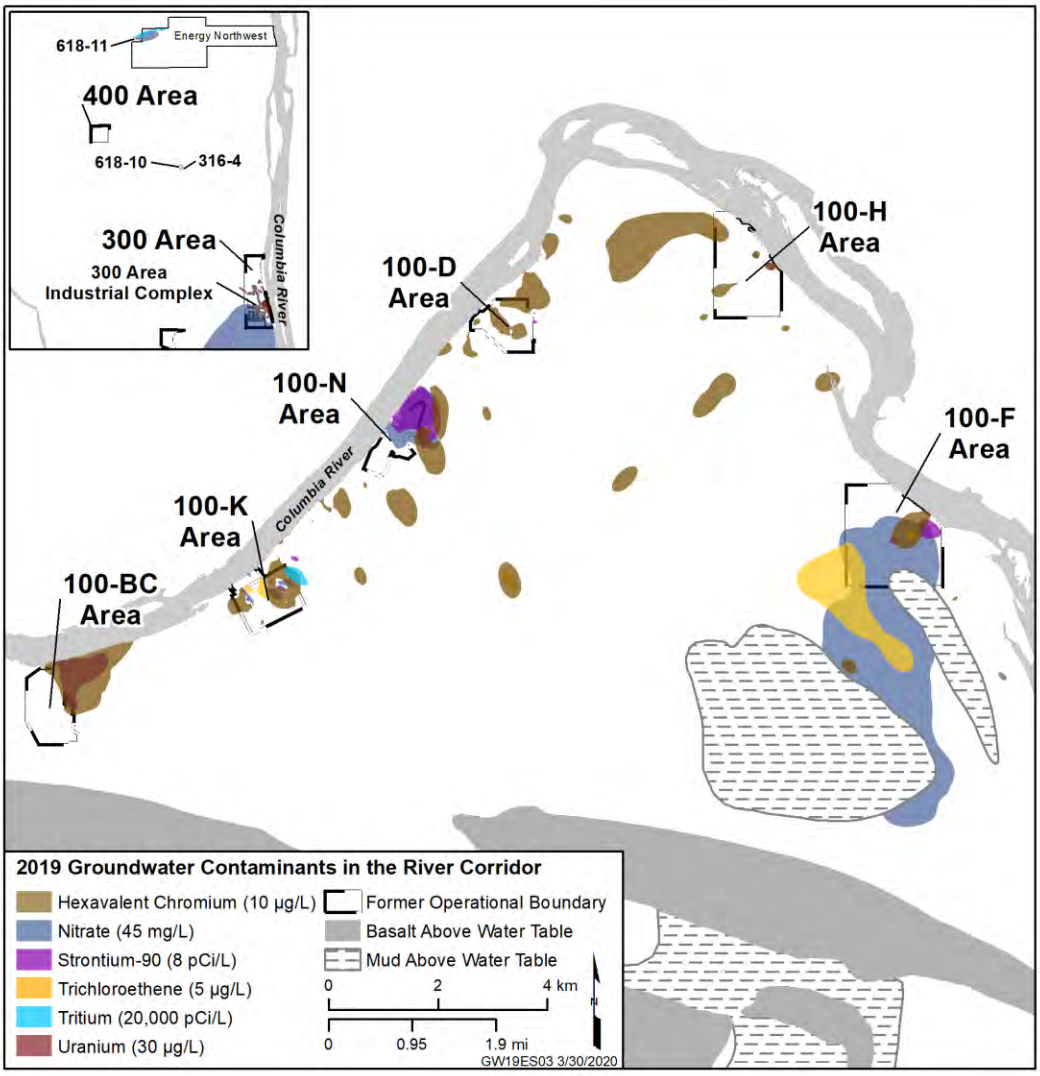

Figure ES-3. Groundwater Contaminant Plumes in the River Corridor

Table ES-1. Maximum Concentrations of Groundwater Contaminants in the River Corridor, 2019 and 2018

Groundwater Interest Area	Maximum Concentrations							
	Year	Carbon-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	2019	N	63.1	12.0	34.3	4.6	9,860	5.1
	2018	N	57	19.5	61.8	6.19	8,840	6.9
100-FR	2019	N	53.8	281	112	20.1	3,050	11.0
	2018	63.8	58.0	304	135	15	3,180	27.7

Table ES-1. Maximum Concentrations of Groundwater Contaminants in the River Corridor, 2019 and 2018

Groundwater Interest Area	Maximum Concentrations							
	Year	Carbon-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-HR	2019	N	833	345	29.0	N	5,690	49.0
	2018	N	800	416	24.5	N	16,200	89
100-KR	2019	42,600	1,700	102	1,230	7.6	405,000	14.8
	2018	32,900	528	88.5	4,050	7.3	225,000	22.4
100-NR	2019	485	124	319	11,400	N	326,000	9.3
	2018	274	123	190	11,600	N	383,000	13.4
300-FF	2019	N	8.88	252	N	1.57	251,000	1,510
	2018	N	20.5	208	4.38	1.5	450,000	3,600
1100-EM	2019	N	3.4	137[a]	N	N	N	32.2[a]
	2018	14	N	137[a]	N	N	N	35.4[a]
Standard[b]		2,000	10	45	8	5	20,000	30
Half-life (years)		5,730	N/A	N/A	28.8	N/A	12	>159,000
Mobility		High	High to moderate	High	Slight	Moderate	High	Moderate

Note: Colors and listed values indicate maximum concentration, as follows:

- ≤ Standard
- > Standard and ≤10 × standard
- >10 × standard and ≤100 × standard
- >100 × standard and ≤1,000 × standard
- >1,000 × standard

a. Originates from offsite sources.

b. Drinking water standards for all but Cr(VI) (aquatic standard).

Cr(VI) = hexavalent chromium

N = not detected or not analyzed

N/A = not applicable

River Corridor groundwater is being remediated under CERCLA (Table ES-2). The total area of the hexavalent chromium (Cr[VI]) plumes has decreased markedly since 2002 due to waste site removal, groundwater remediation by pump and treat (P&T) systems, and natural attenuation (Figure ES-4). The size of the tritium plume has declined due to natural attenuation, but the uranium and strontium-90 plumes are attenuating more slowly. The interpreted size of the 100-FR trichloroethene (TCE) plume increased in 2019 based on data from new monitoring wells.

Table ES-2. Summary of CERCLA Groundwater Remediation in the River Corridor

Groundwater OU	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern*	Current Groundwater Remediation	Mass Removed in 2019 (and Since Startup)
100-BC-5	RI/FS report and proposed plan released in 2019	Cr(VI), strontium-90, TCE, and tritium	No interim action required; final action pending	N/A
100-FR-3	ROD for final action signed in 2014	Cr(VI), nitrate strontium-90, and TCE	MNA	N/A
100-HR-3	ROD for final action signed in 2018	Cr(VI), total chromium, nitrate, and strontium-90	P&T for Cr(VI) and total chromium 1997–2019; MNA for nitrate and strontium-90	Cr(VI): 54.7 kg (2,601 kg)
100-KR-4	Interim ROD; Draft B RI report released for regulatory agency review in 2019; FS report in progress	Cr(VI), total chromium, carbon-14, nitrate, strontium-90, TCE, and tritium	Interim action P&T for Cr(VI) 1997–2019; soil flushing in 2019	Cr(VI): 48.6 kg (988 kg)
100-NR-2	Draft B RI/FS report released for regulatory agency review in 2019	Strontium-90, TPH-D, nitrate, Cr(VI), total chromium, and tritium	Interim action permeable reactive barrier for strontium-90; removal of TPH-D	Strontium-90: not applicable TPH-D: 1.23 kg (20 kg)
300-FF-5	ROD for final action signed in 2013	Uranium, gross alpha, *cis*-1,2-dichloroethene, TCE, nitrate, and tritium	Enhanced attenuation (sequestration) for uranium; MNA for others	N/A
1100-EM-1	ROD signed in 1993	TCE	No longer required; remedial action objectives achieved	N/A

*Contaminants of concern are listed for OUs with RODs for final action. The primary contaminants of potential concern are listed for the other OUs.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cr(VI) = hexavalent chromium
FS = feasibility study
MNA = monitored natural attenuation
N/A = not applicable
OU = operable unit
P&T = pump and treat
RI = remedial investigation
ROD = Record of Decision
TCE = trichloroethene
TPH-D = total petroleum hydrocarbons-diesel range

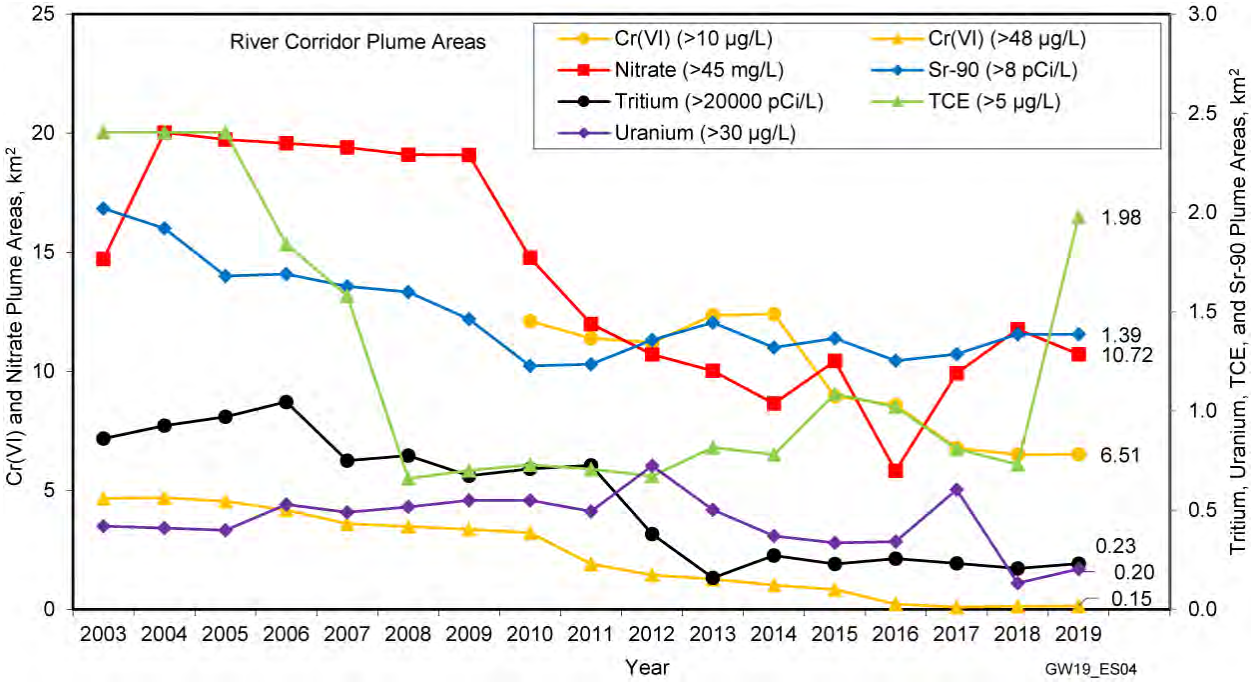

Figure ES-4. River Corridor Plume Areas

Figure ES-5 illustrates the maximum contaminant concentrations in the River Corridor over time. Maximum concentrations of contaminants such as tritium, strontium-90, and nitrate have declined.

DOE has established derived concentration standards for use in conducting the radiological environmental protection program. The standards represent the concentration of a given radionuclide in water or air that would result in a person receiving a 100 mrem total effective dose following continuous exposure for one year. Figure ES-6 illustrates the total effective dose that would occur if a person consumed River Corridor groundwater for one year. The dose in wells with values >100 mrem/yr in the River Corridor is primarily from strontium-90 in the 100-N Area and uranium in the 300 Area.

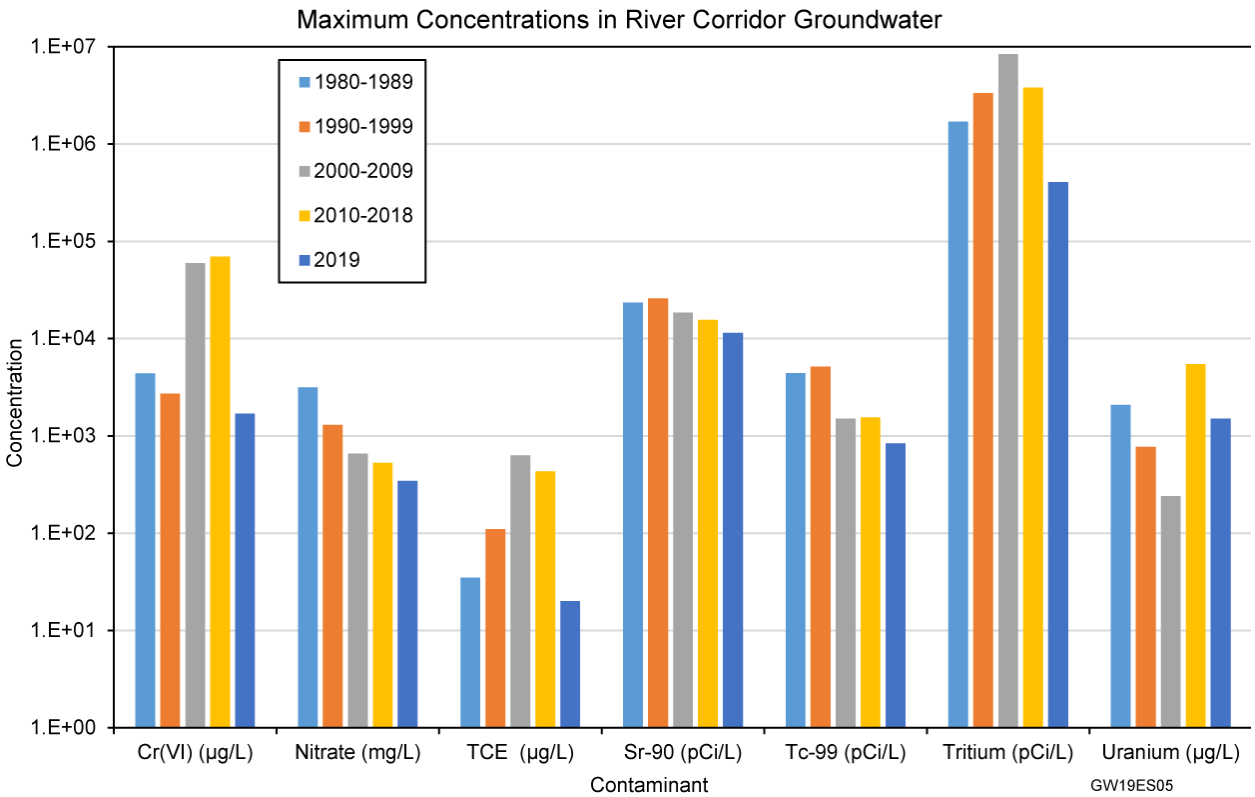

Figure ES-5. Maximum Concentrations of River Corridor Contaminants Over Time

The following activities or changes occurred in the River Corridor in 2019:

- **100-BC:** A remedial investigation (RI)/feasibility study (FS) report[4] and proposed plan[5] for remediation were released, and public comments on the proposed plan were received.
- **100-FR:** Six new monitoring wells were installed. Data from the new wells resulted in the interpreted nitrate plume to shrink and the TCE plume to expand.

[4] DOE/RL-2010-96, 2019, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-02510.

[5] DOE/RL-2016-43, 2019, *Proposed Plan for Remediation of the 100-BC-1, 100-BC-2, ad 100-BC-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03055.

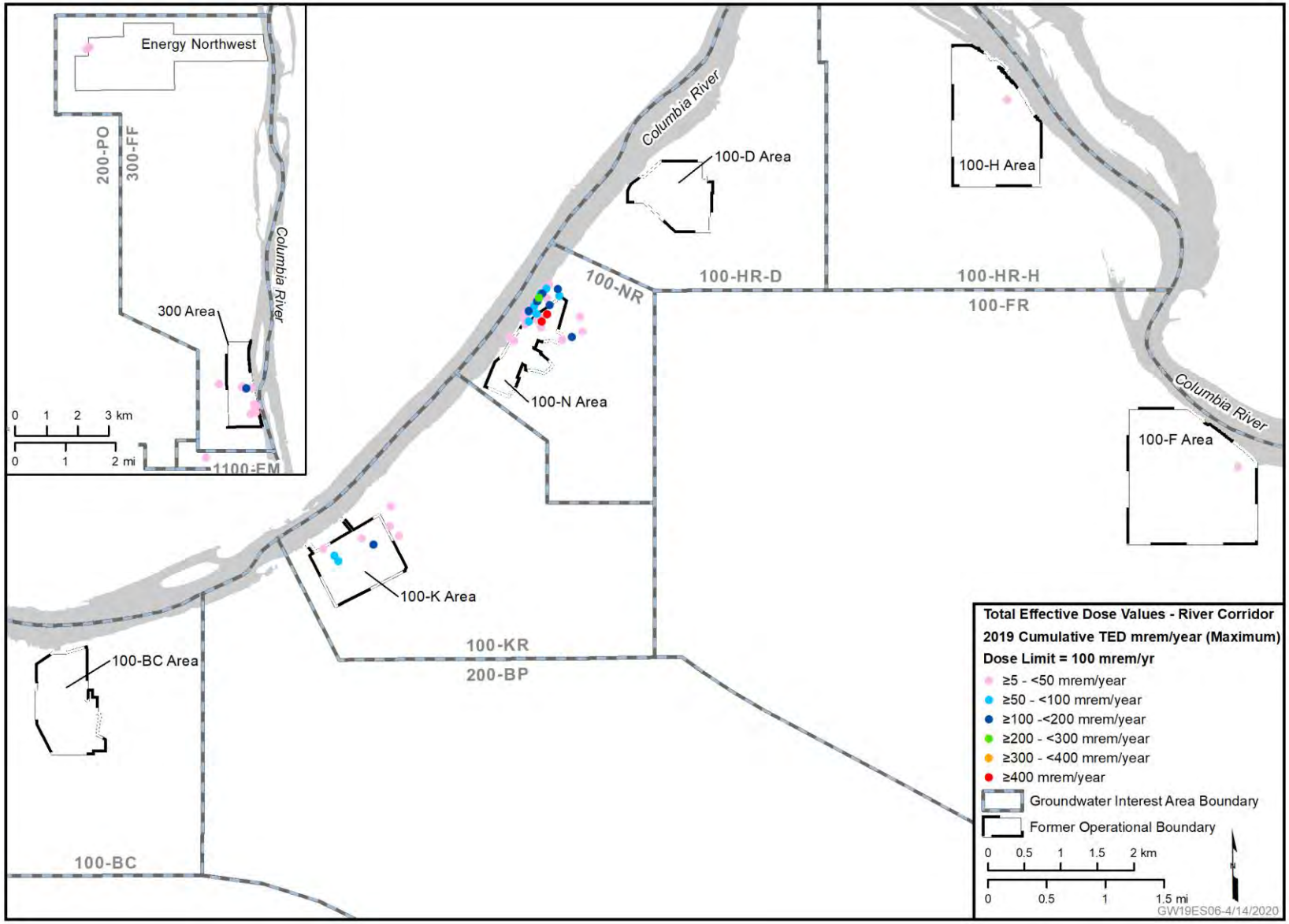

Figure ES-6. Groundwater Dose Calculation for the River Corridor

- **100-HR:**
  - The Cr(VI) plumes in the unconfined aquifer continued to shrink in response to ongoing groundwater remediation, and concentrations continue to decline. One extraction well and two injection wells were installed in the unconfined aquifer to support remediation in 2019.
  - A potentiometric map and Cr(VI) plume map were created for the Ringold upper mud aquifer for the first time in 2019. Six new monitoring wells and one new extraction well were installed in 2019 to improve monitoring and remediation of that aquifer.
  - Draft A of the remedial design/remedial action work plan[6] was released in 2019 for regulatory review.
- **100-KR:**
  - In 2019, a soil flushing treatability test was implemented at the 183.1KW Headhouse area to address a continuing source of groundwater contamination.[7] The goal of soil flushing was to flush Cr(VI) from the deep portions of the vadose zone into the groundwater and then capture the material with the active P&T system.
  - Draft B of the 100-K RI report[8] was released in 2019 for regulatory agency review. The revision incorporates supplemental data associated with the 105-KE fuel storage basins and 116-KE-3 Crib and reverse well, as well as data collected to support soil and groundwater interim remedial actions.

[6] DOE/RL-2017-13, 2019, *Remedial Design/Remedial Action Work Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0063897H.

[7] DOE/RL-2017-30, 2018, *KW Soil Flushing/Infiltration Treatability Test Plan,* Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0065840H.

[8] DOE/RL-2010-97, 2019, *Remedial Investigation for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-01221.

- **100-NR:**

– Draft B of the 100-N Area RI/FS report[9] was released in November 2019 for regulatory agency review. The RI/FS report will be used to support future cleanup decisions specified in a proposed plan and Record of Decision (ROD) planned for 2021.

- **300-FF:**

– Two stages of uranium sequestration have been conducted in the 300 Area Industrial Complex, and monitoring of the Stage B wells continued in 2019.

– One new monitoring well was installed in the 300 Area to monitor the 324 Building, and a replacement monitoring well was installed at the 618-10 Burial Ground.

– Nine uranium sequestration boreholes were drilled for post-treatment soil samples.

– Nitrate concentrations increased in one monitoring well near the 618-11 Burial Ground.

- **RCRA:**

– Post-closure corrective action monitoring continued at the 183-H Solar Evaporation Basins and the 300 Area Process Trenches in 2019.

Central Plateau

The Central Plateau, located in the middle of the Hanford Site, includes the 200 West and 200 East Areas. Ponds, cribs, and ditches used for liquid waste disposal were the primary sources of groundwater contamination. Seven single-shell tank waste management areas are also located in the 200 Areas. Contamination is still present at some locations in the thick Central Plateau vadose zone and in some areas continues to migrate into the groundwater. DOE is expanding remediation activities in the 200 Areas to contain and remove contamination from the vadose zone and groundwater.

[9] DOE/RL-2012-15, 2019, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03286.

Figure ES-7 shows the Central Plateau groundwater contaminant plumes in 2019, and Table ES-3 compares the maximum contaminant concentrations measured in 2019 and 2018 in the Central Plateau groundwater interest areas.

Groundwater beneath portions of the Central Plateau is being remediated under CERCLA. Table ES-4 summarizes the status of CERCLA remediation for the Central Plateau groundwater and deep vadose zone operable units (OUs). In 2019, P&T systems continued to remove carbon tetrachloride, technetium-99, uranium, and other contaminants from groundwater.

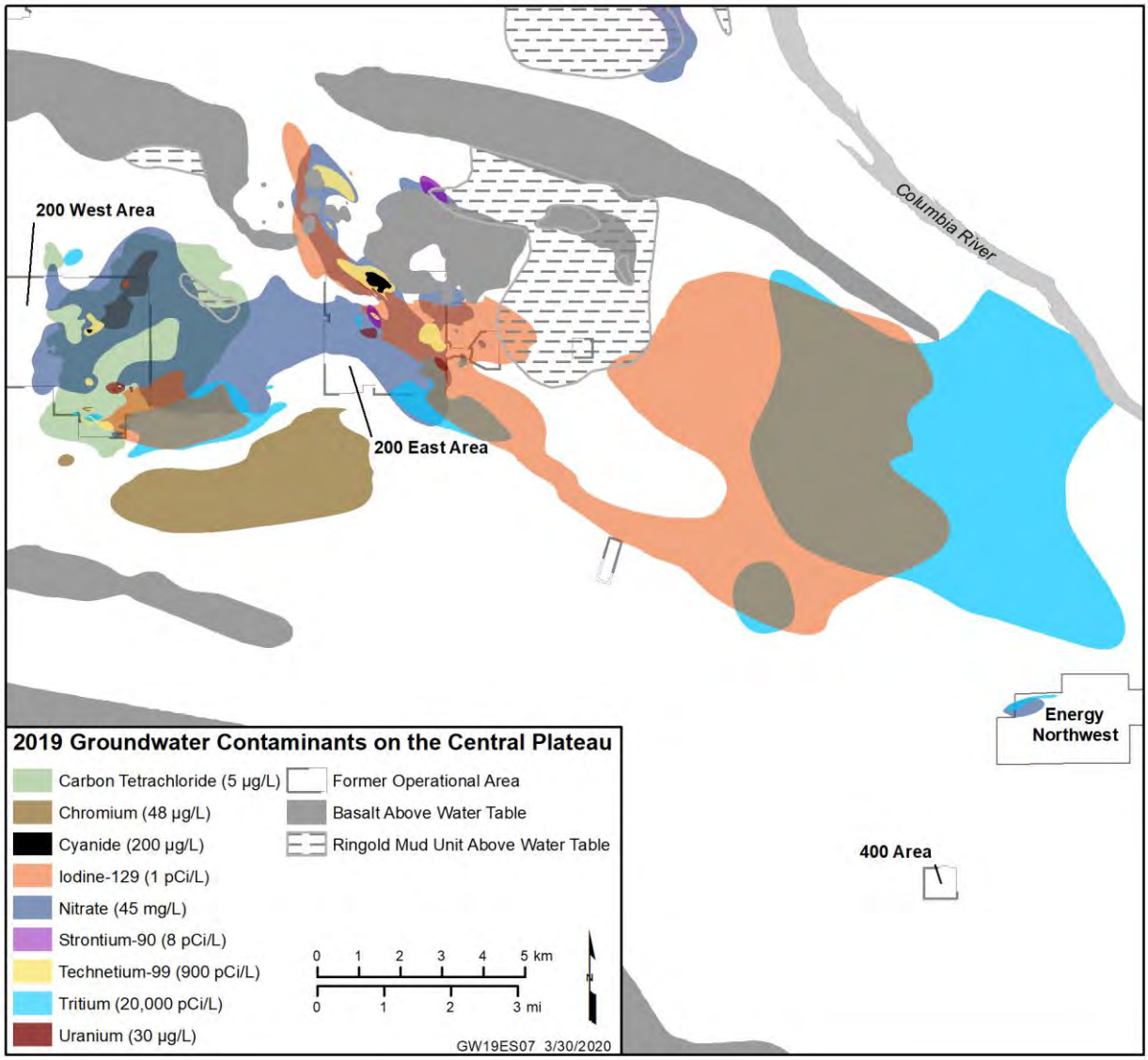

Figure ES-7. Groundwater Contaminant Plumes in the Central Plateau

Table ES-3. Maximum Concentrations of Groundwater Contaminants in the Central Plateau, 2019 and 2018

Groundwater Interest Area	Year	Maximum Concentrations							
		Carbon Tetrachloride (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	2019	0.83	38.2	7.14	974	337	25,500	28,700	641
	2018	0.80	39.0	9.87	1,060	602	29,100	33,700	1,100
200-PO	2019	N	159	12.2	133	11.9	6,300	4,240,000	68
	2018	N	130	13.1	159	14.8	4,850	365,000	71
200-UP	2019	408	463	23.7	211	37.1	15,200	222,000	2,100
	2018	428	373	23.0	270	23.5	30,900	187,000	3,520
200-ZP	2019	1,830	175	2.15	553	N	25,200	58,100	4.9
	2018	1,750	140	1.87	664	N	13,800	56,000	3.5
Regulatory standard		5	48	1	45	8	900	20,000	30
Half-life (years)		N/A	N/A	1.6E+07	N/A	28.8	212,000	12.3	>159,000
Mobility		Multi-phase	High to moderate	High	High	Slight	High	High	Moderate

Note: Colors and listed values indicate maximum concentration, as follows:

- ≤ Standard
- > Standard and ≤10 × standard
- >10 × standard and ≤100 × standard
- >100 × standard and ≤1,000 × standard

N = not detected or not analyzed

N/A = not applicable

Table ES-4. Summary of CERCLA Groundwater Remediation on the Central Plateau

OU	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern[a]	Current Groundwater Remediation	Mass Removed in 2019 (and Since Startup)
200-BP-5	Implemented action memorandum (2016); FS and draft proposed plan released in 2019	Cyanide, iodine-129, nitrate, strontium-90, technetium-99, tritium, and uranium	Groundwater extraction removal action (2015–2019)	Cyanide: 47 kg (207 kg) Nitrate: 63,411 kg (285,774 kg) Technetium-99: 56.5 g (313.5 g) Uranium: 22.4 kg (187 kg)
200-PO-1	FS and draft proposed plan released in 2019	Iodine-129, tritium, nitrate, strontium-90, technetium-99, and uranium	None to date; pending interim action decision	Not applicable
200-UP-1	ROD for interim remedial action signed (2012); submitted remedial design investigation report for the southeast chromium plume (2019)	Technetium-99, uranium, carbon tetrachloride, Cr(VI), total chromium, iodine-129, nitrate, tritium, trichloroethene, chloroform, tetrachloroethene, strontium-90, and 1,4-dioxane	Interim actions: • P&T near U Plant (2015–2019) • P&T at WMA S-SX (2012–2019) • Hydraulic containment for iodine-129 (2015–2019) • MNA	Nitrate: 21,646 kg (223,924 kg[b]) Technetium-99: 23 g (401 g[b]) Uranium: 14 kg (967 kg[b])
200-ZP-1	ROD for final remedial action signed (2008)	Carbon tetrachloride, Cr(VI), total chromium, iodine-129, nitrate, technetium-99, trichloroethene, and tritium	P&T and MNA (2012-2019)	Carbon tetrachloride: 1,917 kg (30,951 kg[b]) Chromium: 68.5 kg (506 kg) Nitrate: 245,982 kg (2,186,276 kg)
200-DV-1[c]	Implemented action memorandum (2016); characterization of the deep vadose zone in progress	Nitrate, technetium-99, uranium, tritium, total chromium, and Cr(VI) (perched water)	Removal action: Perched water extraction (2011–2019)	Nitrate: 1,280 kg (5,364 kg[b]) Technetium-99: 2.7 g (10.7 g[b]) Uranium: 63 kg (294 kg[b])

a. Contaminants of concern are listed for OUs with RODs for final action and implemented action memoranda. The primary contaminants of potential concern are listed for the other OUs.

b. Totals includes mass from P&T system under earlier RODs for interim action and 200-DV-1 OU treatability test.

c. Deep vadose zone OU.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cr(VI) = hexavalent chromium
FS = feasibility study
MNA = monitored natural attenuation
OU = operable unit
P&T = pump and treat
ROD = Record of Decision
WMA = waste management area

The size of the Central Plateau tritium plume continued to decline in 2019 due to natural attenuation, which includes radioactive decay (Figure ES-8). The technetium-99 and uranium plume areas continued to decline gradually due to groundwater remediation. The interpreted nitrate plume increased in 2019 because of changes in the 200 West P&T as part of an optimization study. The size of the carbon tetrachloride plume declined between 2018 and 2019. The Cr(VI) plume area increased in recent years as data from new wells became available.

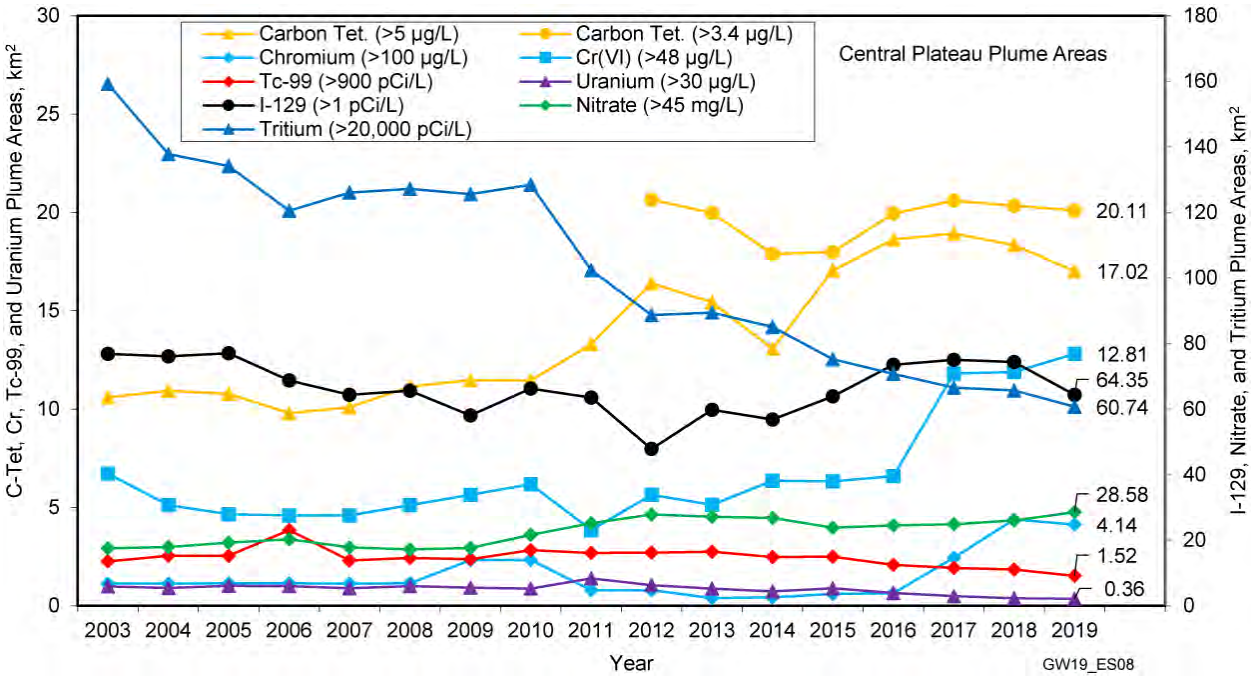

Figure ES-8. Central Plateau Plume Areas

Maximum concentrations of most Central Plateau groundwater contaminants have decreased over time (Figure ES-9) due to remediation, migration, dispersion, and radioactive decay.

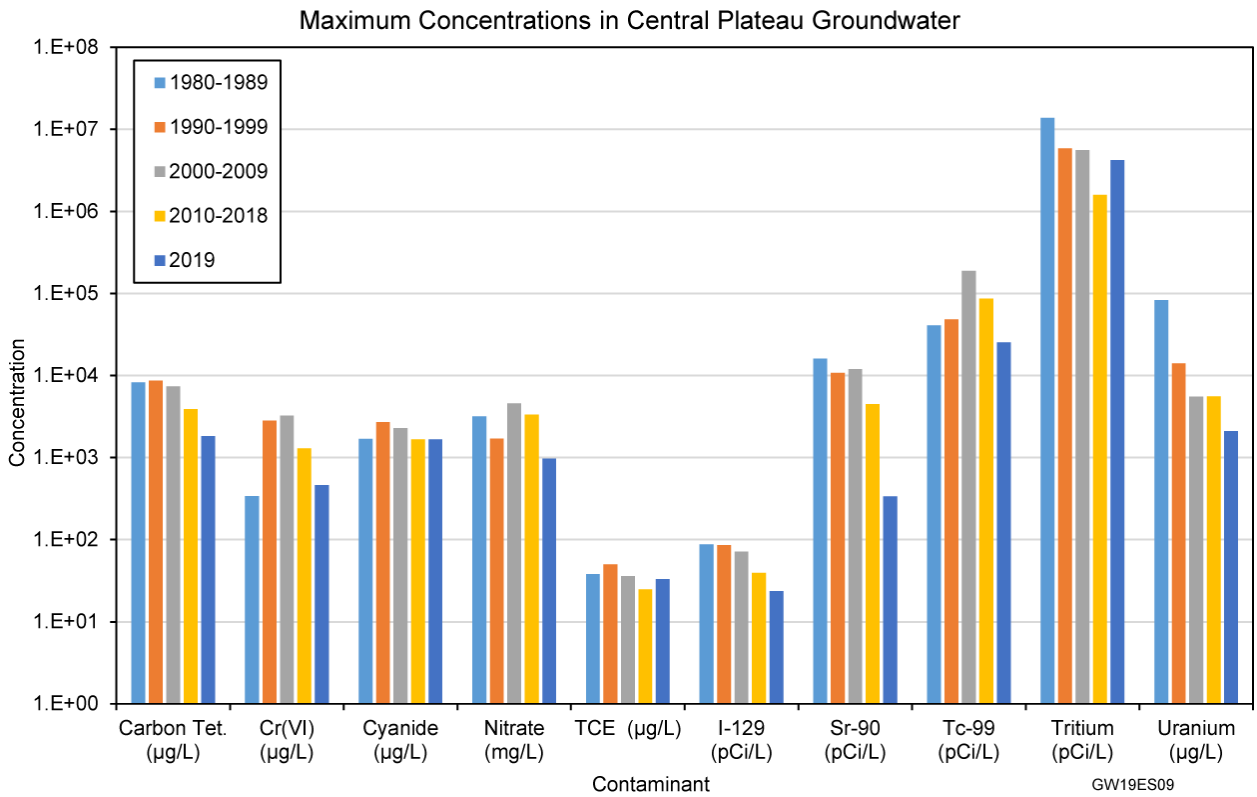

Figure ES-9. Maximum Concentrations of Central Plateau Contaminants Over Time

Figure ES-10 illustrates the total effective dose from hypothetical exposure to members of the public by drinking Central Plateau groundwater. Radionuclides contributing to doses >100 mrem/yr include iodine-129, strontium-90, technetium-99, tritium, and uranium.

The following activities or changes occurred in the Central Plateau in 2019:

- **200-BP:**

  – Groundwater was extracted from two wells in the B Complex area in 2019, and concentrations and plume sizes of nitrate, technetium-99, uranium, and cyanide continued to decline in monitoring wells.

  – Perched water continued to be extracted from three wells in the B Complex area to reduce migration of contamination to groundwater.

  – Four new monitoring wells were drilled in 2019 to complete the B Complex removal action performance monitoring network.

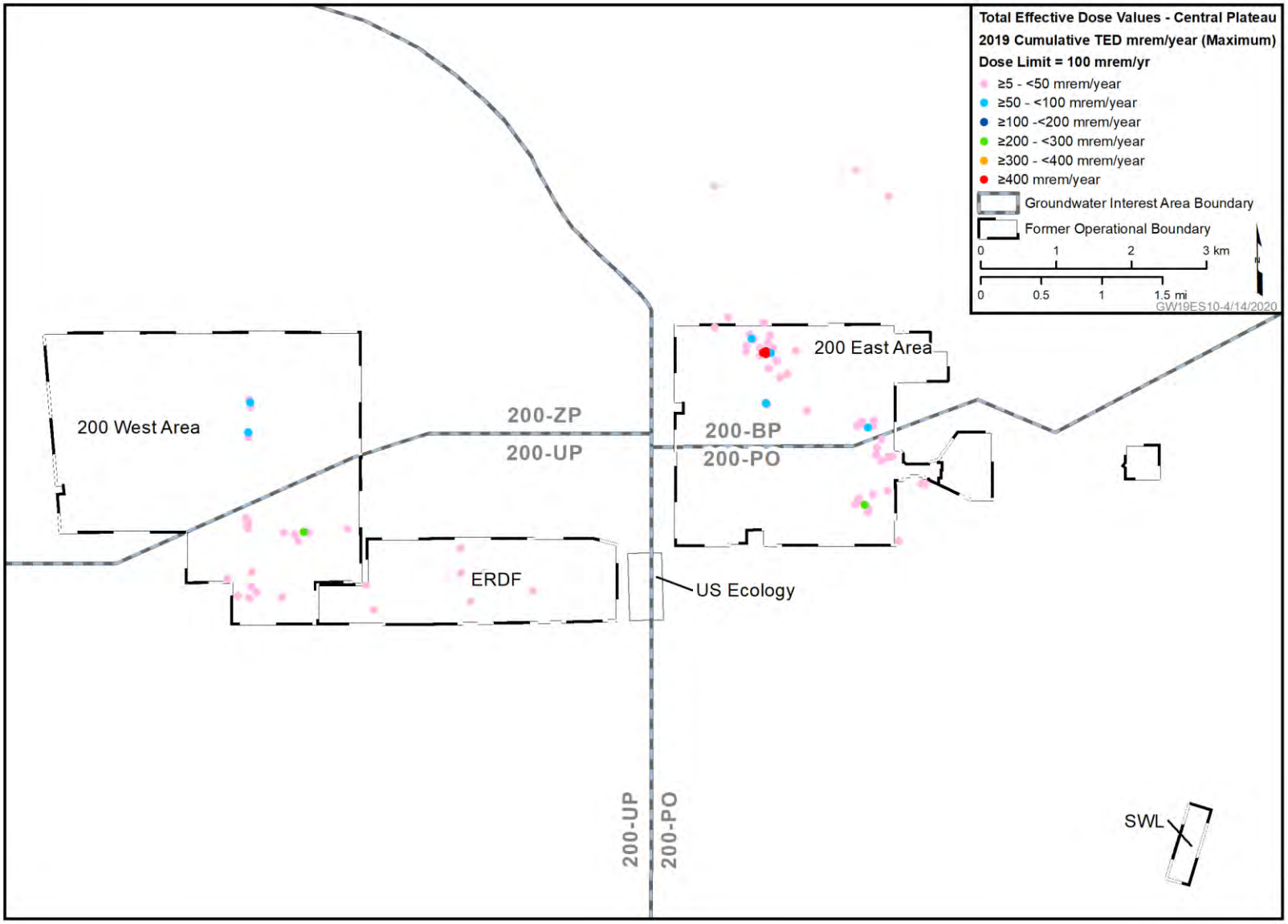

Figure ES-10. Groundwater Dose Calculation for the Central Plateau

- DOE issued an interim action FS for the 200-BP-5 and 200-PO-1 OUs[10] and Draft A of a proposed plan for interim action remediation.[11] The U.S. Environmental Protection Agency, Washington State Department of Ecology, and DOE are pursuing an interim ROD for these two groundwater OUs to expedite remediation of the technetium-99 and uranium groundwater plumes.

- **200-PO:**

- The large tritium plume originating from sources in the 200 East Area continued to shrink in 2019 due to dispersion and radioactive decay.
- In 2019, the highest tritium concentration in groundwater was 4,240,000 pCi/L in a well near the 216-A-36A Crib. This concentration was much higher than the maxima in recent years (Figure ES-9). The well, which is nearly dry, had not been sampled since 2002, when the concentration was 5,570,000 pCi/L.
- Three new wells were installed to monitor the Integrated Disposal Facility.

- **200-UP:**

- Groundwater extraction and treatment for Waste Management Area S-SX and the U Plant area continued in 2019. Contaminant concentrations have declined in many monitoring wells in response to remediation.
- In 2019, three new wells were installed to characterize the uranium plume near U Plant, and two wells were installed to monitor the Environmental Restoration Disposal Facility.

- **200-ZP:**

- As a result of remediation by the 200 West P&T, carbon tetrachloride concentrations have declined in locations where the highest levels were formerly present. The downgradient, lower concentration portion of the plume

[10] DOE/RL-2018-30, 2019, *200-BP-5 and 200-PO-1 Groundwater Operable Units Feasibility Study for Interim Action*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03387.

[11] DOE/RL-2018-58, 2019, *Proposed Plan for Interim Action Remediation of the 200-BP-5 and 200-PO-1 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-01134.

not captured by the P&T system is expected to attenuate naturally over time, as described in the 200-ZP-1 OU ROD.[12]

– In 2019, an optimization study plan[13] was implemented, and biological treatment was suspended to improve contaminant capture and increase removal of carbon tetrachloride. This resulted in higher nitrate concentrations in treated water reinjected into the aquifer, which are expected to be remediated by monitored natural attenuation.

– Three new monitoring wells, one new injection well, and one new extraction well were installed for the 200 West P&T in 2019.

- **RCRA:**

– RCRA groundwater monitoring continued at 20 dangerous waste management units in the Central Plateau in 2019.

Additional Information

The monitoring data presented in this report and information on monitoring well locations, construction details, and screened intervals can be found through the DOE Environmental Dashboard Application at https://ehs.hanford.gov/eda/, in the interactive version of this document at https://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports, or on the Pacific Northwest National Laboratory PHOENIX website at https://phoenix.pnnl.gov.

[12] EPA, Ecology, and DOE, 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: https://pdw.hanford.gov/document/00098825.

[13] DOE/RL-2019-28, 2019, *200-ZP-1 Operable Unit Optimization Study Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03236.

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Contents

1 Introduction 1-1
1.1 Purpose and Scope 1-3
1.2 Groundwater Monitoring 1-5
1.2.1 CERCLA Remediation and Monitoring 1-5
1.2.2 RCRA Units 1-6
1.2.3 Washington Administrative Code Units 1-7
1.2.4 Atomic Energy Act Monitoring 1-7
1.3 Water Levels 1-8
1.4 Well Installation, Maintenance, and Decommissioning 1-9
1.5 Conventions Used in This Report 1-12
1.6 River Corridor 1-17
1.6.1 River Corridor Hydrogeology 1-18
1.6.2 River Corridor Groundwater Contamination 1-20
1.6.3 Shoreline Monitoring 1-20
1.7 Central Plateau 1-25
1.7.1 Central Plateau Hydrogeology 1-27
1.7.2 Central Plateau Groundwater Contamination 1-27
1.8 CERCLA 5-Year Review 1-27
1.9 Quality Control 1-29
1.10 Sources of Additional Information 1-29
2 100-BC 2-1
2.1 Overview 2-1
2.2 Hexavalent Chromium 2-4
2.3 Strontium-90 2-10
2.4 Tritium 2-12
2.5 Trichloroethene 2-12
2.6 CERCLA Remediation and Monitoring 2-13
2.7 Atomic Energy Act Monitoring 2-13
3 100-FR 3-1
3.1 Overview 3-1
3.2 Nitrate 3-7
3.3 Trichloroethene 3-11
3.4 Hexavalent Chromium 3-15
3.5 Strontium-90 3-18
3.6 Other Analytes 3-20
3.7 CERCLA Remediation and Monitoring 3-21
3.8 Atomic Energy Act Monitoring 3-21

4 100-HR 4-1
4.1 Overview 4-1
4.2 100-HR Groundwater Flow 4-6
4.3 100-HR-D Hexavalent Chromium 4-11
4.3.1 Southern Plumes in the 100-D Area 4-11
4.3.2 Northern Plumes in the 100-D Area 4-13
4.4 100-HR-H Hexavalent Chromium 4-14
4.4.1 Plume in the Horn 4-17
4.4.2 Plume in the 100-H Area 4-19
4.5 Hexavalent Chromium in the Ringold Upper Mud Aquifer 4-19
4.6 Nitrate 4-23
4.7 Strontium-90 4-23
4.8 Uranium 4-25
4.9 CERCLA Remediation and Monitoring 4-25
4.9.1 Pump and Treat 4-26
4.9.2 Metals Uncertainty Analysis 4-29
4.10 RCRA Monitoring at the 183-H Solar Evaporation Basins 4-30
4.11 Atomic Energy Act Monitoring 4-32
5 100-KR 5-1
5.1 Overview 5-1
5.2 Hexavalent Chromium 5-5
5.2.1 K West Associated Plume 5-11
5.2.2 K East Associated Plume 5-12
5.2.3 K North and 100-K/N Boundary Associated Plumes 5-13
5.3 Tritium 5-15
5.4 Nitrate 5-17
5.5 Strontium-90 5-19
5.6 Carbon-14 5-23
5.7 Trichloroethene 5-25
5.8 CERCLA Remediation and Monitoring 5-27
5.8.1 CERCLA Decision Documents and Plans 5-27
5.8.2 Pump and Treat 5-28
5.9 Atomic Energy Act Monitoring 5-30
6 100-NR 6-1
6.1 Overview 6-1
6.2 Strontium-90 6-6
6.3 Tritium 6-10
6.4 Nitrate 6-13
6.5 Total Petroleum Hydrocarbons-Diesel 6-17
6.6 Hexavalent Chromium 6-21

6.7 CERCLA Remediation and Monitoring 6-23
6.7.1 CERCLA Decision Documents and Plans 6-24
6.7.2 Apatite Permeable Reactive Barrier 6-24
6.7.3 Petroleum Hydrocarbons 6-28
6.8 Atomic Energy Act Monitoring 6-29

7 300-FF 7-1

7.1 Overview 7-1
7.2 Uranium 7-7
7.3 Tritium 7-14
7.4 Nitrate 7-16
7.5 Trichloroethene and *cis*-1,2-Dichloroethene 7-18
7.6 CERCLA Remediation and Monitoring 7-19
7.6.1 CERCLA Decision Documents and Plans 7-19
7.6.2 Groundwater Remediation 7-22
7.7 RCRA Monitoring at 300 Area Process Trenches 7-26
7.8 Atomic Energy Act Monitoring 7-29

8 1100-EM 8-1

8.1 Overview 8-1
8.2 Nitrate 8-5
8.3 Tritium 8-7
8.4 Uranium 8-7
8.5 CERCLA Remediation and Monitoring 8-9
8.6 Atomic Energy Act Monitoring 8-9

9 200-BP 9-1

9.1 Overview 9-1
9.2 Nitrate 9-8
9.2.1 B Complex 9-8
9.2.2 B Plant 9-12
9.2.3 216-B-2 Ditches, Trench 94, and Liquid Effluent Retention Facility 9-12
9.2.4 Waste Management Area C 9-13
9.2.5 Gable Mountain Pond 9-15
9.3 Iodine-129 9-16
9.4 Technetium-99 9-18
9.4.1 B Complex 9-20
9.4.2 Gable Gap 9-22
9.4.3 Waste Management Area C 9-23
9.5 Uranium 9-26
9.5.1 B Complex 9-26
9.5.2 B Plant 9-28

9.6 Strontium-90 9-30
9.6.1 Former Gable Mountain Pond 9-30
9.6.2 216-B-5 Reverse Well 9-30
9.7 Cyanide 9-33
9.8 CERCLA Remediation and Monitoring 9-35
9.8.1 200-BP-5 Operable Unit 9-35
9.8.2 200-DV-1 Operable Unit 9-36
9.9 RCRA Monitoring 9-38
9.9.1 Waste Management Area B-BX-BY 9-38
9.9.2 Waste Management Area C 9-41
9.9.3 216-B-63 Trench 9-44
9.9.4 Liquid Effluent Retention Facility 9-46
9.9.5 Low-Level Burial Grounds Waste Management Area 1 9-48
9.9.6 Low-Level Burial Grounds Waste Management Area 2 9-50
9.10 Atomic Energy Act Monitoring 9-53
9.10.1 Low Level Burial Grounds Waste Management Area 1 9-53
9.10.2 Low Level Burial Grounds Waste Management Area 2 9-53

10 200-PO 10-1

10.1 Overview 10-1
10.2 Tritium 10-4
10.3 Iodine-129 10-12
10.4 Nitrate 10-17
10.5 Technetium-99 10-21
10.6 Uranium 10-24
10.7 Strontium-90 10-24
10.8 Tetrachloroethene and Trichloroethene 10-24
10.9 CERCLA Monitoring 10-28
10.10 RCRA Monitoring 10-28
10.10.1 Waste Management Area A-AX 10-29
10.10.2 216-A-36B Crib 10-31
10.10.3 216-A-37-1 Crib 10-33
10.10.4 216-A-29 Ditch 10-35
10.10.5 216-B-3 Main Pond 10-37
10.10.6 Integrated Disposal Facility 10-39
10.10.7 Nonradioactive Dangerous Waste Landfill 10-41
10.11 Washington Administrative Code Monitoring – Solid Waste Landfill 10-43
10.12 Atomic Energy Act Monitoring 10-45
10.12.1 400 Area 10-49
10.12.2 Integrated Disposal Facility 10-49

11 200-UP 11-1
11.1 Overview 11-1
11.2 Uranium 11-4
11.2.1 216-U-1 and 216-U-2 Cribs Plume 11-4
11.2.2 U Pond 11-12
11.3 Technetium-99 11-12
11.3.1 Waste Management Area S-SX 11-12
11.3.2 216-U-1 and 216-U-2 Cribs 11-22
11.3.3 Waste Management Area U 11-23
11.4 Chromium 11-23
11.4.1 Waste Management Area S-SX 11-23
11.4.2 216-S-10 Pond, 216-S-11 Pond, and 216-S-20 Crib 11-23
11.4.3 Southeast Chromium Plume 11-30
11.5 Nitrate 11-31
11.6 Iodine-129 11-34
11.7 Tritium 11-37
11.7.1 Main Tritium Plume 11-37
11.7.2 216-S-21 Crib 11-39
11.7.3 216-S-25 Crib 11-39
11.8 Carbon Tetrachloride 11-39
11.9 Contaminants of Potential Concern 11-39
11.9.1 Trichloroethene 11-39
11.9.2 Chloroform 11-41
11.9.3 Tetrachloroethene 11-41
11.9.4 Strontium-90 11-41
11.9.5 1,4-Dioxane 11-41
11.10 CERCLA Remediation and Monitoring 11-41
11.10.1 CERCLA Decision Documents and Plans 11-42
11.10.2 S-SX Groundwater Extraction 11-44
11.10.3 U Plant Area Groundwater Extraction 11-45
11.10.4 Iodine-129 Plume Hydraulic Containment 11-45
11.10.5 Monitored Natural Attenuation 11-46
11.10.6 Environmental Restoration Disposal Facility Monitoring 11-47
11.11 RCRA Monitoring 11-49
11.11.1 Waste Management Area S-SX 11-49
11.11.2 Waste Management Area U 11-52
11.11.3 216-S-10 Pond and Ditch 11-54
11.12 Atomic Energy Act Monitoring 11-56
12 200-ZP 12-1
12.1 Overview 12-1
12.2 Carbon Tetrachloride 12-5
12.3 Chromium 12-11

12.4 Iodine-129 12-14
12.5 Nitrate 12-16
12.6 Technetium-99 12-19
12.7 Trichloroethene 12-22
12.8 Tritium 12-22
12.9 Cyanide 12-25
12.10 CERCLA Remediation and Monitoring 12-25
12.10.1 CERCLA Decision Documents and Plans 12-25
12.10.2 Pump and Treat 12-25
12.11 RCRA Monitoring 12-31
12.11.1 Waste Management Area T 12-31
12.11.2 Waste Management Area TX-TY 12-34
12.11.3 Low-Level Burial Grounds Waste Management Area 3 12-37
12.11.4 Low-Level Burial Grounds Waste Management Area 4 12-39
12.12 Washington Administrative Code Monitoring at the State-Approved Land Disposal Site 12-41
12.13 Atomic Energy Act Monitoring 12-43
12.13.1 State-Approved Land Disposal Site 12-45
12.13.2 Low-Level Burial Ground Waste Management Areas 3 and 4 12-46

13 References 13-1

Appendices

A Supporting Information for CERCLA Operable Units ..... A-i

B Supporting Information for RCRA Units ..... B-i

C Supporting Information for Atomic Energy Act Monitoring ..... C-i

D Confined Aquifers ..... D-i

E Groundwater Monitoring Data Usability Assessment ..... E-i

Figures

Figure 1-1. DOE Hanford Site, Groundwater Interest Areas, and Operable Units 1-2
Figure 1-2. Hanford Site Water Table and Directions of Groundwater Flow, 2019 1-10
Figure 1-3. Categories of Unique Well Identification Numbers 1-11
Figure 1-4. River Corridor Geology 1-19
Figure 1-5. Daily Average River Stage at the 100-D Area 1-23
Figure 1-6. Central Plateau Geology 1-28
Figure 2-1. 100-BC Sampling Locations, 2019 2-3
Figure 2-2. 100-BC Plume Areas 2-4

Figure 2-3. 100-BC Geology 2-5
Figure 2-4. 100-BC Water Table, March 2019 2-6
Figure 2-5. 100-BC Cr(VI) Plumes in Upper and Lower Parts of the Unconfined Aquifer, Fall 2019 2-7
Figure 2-6. 100-BC Cr(VI) Data in Selected Wells 2-8
Figure 2-7. 100-BC Cr(VI) Data in HSPs and Aquifer Tubes Near C8861 2-9
Figure 2-8. 100-BC Cr(VI) in Wells Screened in the Lower Part of the Unconfined Aquifer 2-10
Figure 2-9. 100-BC Strontium-90 Plume, 2019 2-11
Figure 2-10. 100-BC Strontium-90 Data in Selected Wells 2-12
Figure 2-11. 100-BC TCE Data in Selected Deep Wells 2-13
Figure 3-1. 100-FR Sampling Locations, 2019 3-2
Figure 3-2. 100-FR Plume Areas 3-5
Figure 3-3. 100-FR Geology 3-5
Figure 3-4. 100-FR Water Table, March 2019 3-6
Figure 3-5. 100-FR Nitrate Plume, Fall 2019 3-8
Figure 3-6. 100-FR Nitrate and Water Level Data for Well 199-F5-56 in Central 100-F Area 3-9
Figure 3-7. 100-FR Nitrate and Water Level Data for Well 199-F8-7 in Southwestern 100-F Area 3-9
Figure 3-8. 100-FR Nitrate Data in Wells 699-71-30, 699-71-34, and 699-75-34B, South of 100-F Area 3-10
Figure 3-9. 100-FR Nitrate Data in Wells Located in the Southern 100-FR 3-10
Figure 3-10. 100-FR TCE Plume, Fall 2019 3-12
Figure 3-11. TCE Data in Wells 699-71-30, 699-71-30C, and 699-73-30 in Southern 100-FR 3-13
Figure 3-12. 100-FR TCE Data for Wells in the Southwestern 100-F Area 3-14
Figure 3-13. 100-FR TCE Data for Wells in the Central 100-F Area 3-14
Figure 3-14. 100-FR Cr(VI) Plume, Fall 2019 3-16
Figure 3-15. 100-FR Cr(VI) and Water-Level Data in Wells 199-F5-4, 199-F5-44, and 199-F5-45 3-17
Figure 3-16. 100-FR Cr(VI) and Water-Level Data in Well 199-F5-46 3-17
Figure 3-17. 100-FR Strontium-90 Plume, Fall 2019 3-19
Figure 3-18. 100-FR Strontium-90 Data in Selected Wells 3-20
Figure 4-1. 100-HR-D Groundwater Sampling Locations, 2019 4-3
Figure 4-2. 100-HR-H Groundwater Sampling Locations, 2019 4-4
Figure 4-3. 100-HR Hydrogeology 4-5
Figure 4-4. 100-HR Plume Areas 4-6
Figure 4-5. 100-HR Cr(VI) Plume in 1999 (Early in Interim Action Period) and 2019 (During Remedial Action) 4-7
Figure 4-6. 100-HR-D Water Table, March 2019 4-8
Figure 4-7. 100-HR-H Water Table, March 2019 4-9
Figure 4-8. 100-HR RUM Potentiometric Surface Map, May 2019 4-10

Figure 4-9. 100-HR-D Cr(VI) Plume, Fall 2019 (Low River Stage) 4-12
Figure 4-10. 100-HR Filtered Total Chromium and Cr(VI) Data for Wells 199-D5-103 and 199-D5-160 4-13
Figure 4-11. 100-HR Filtered Total Chromium and Cr(VI) Data for Extraction Wells 199-D8-95 and 199-D8-96 4-14
Figure 4-12. 100-HR-H Cr(VI) Plume, Fall 2019 (Low River Stage) 4-15
Figure 4-13. 100-H Area Cr(VI) Plume, Fall 2019 (Low River Stage) 4-16
Figure 4-14. 100-HR Filtered Total Chromium and Cr(VI) Data and Water Level for Well 199-H4-88 4-19
Figure 4-15. 100-HR Cr(VI) Plume in the RUM Aquifer, 2019 4-21
Figure 4-16. 100-HR Filtered Total Chromium and Cr(VI) Data for RUM Aquifer Wells Near the 100 µg/L Contour 4-22
Figure 4-17. 100-HR Filtered Total Chromium and Cr(VI) Data for RUM Aquifer Wells Near the 183-H Solar Evaporation Basins 4-22
Figure 4-18. 100-HR-H Strontium-90 Plume, 2019 4-24
Figure 4-19. 100-HR Uranium, Nitrate, Cr(VI), and Water Levels in Well 199-H4-84 4-25
Figure 4-20. 100-HR-3 Remedy Overview 4-28
Figure 4-21. 100-HR-3 P&T Cr(VI) Annual Mass Removal 4-29
Figure 4-22. 183-H Solar Evaporation Basins (116-H-6) 4-31
Figure 5-1. 100-KR Sampling Locations, 2019 5-3
Figure 5-2. 100-KR Geology 5-4
Figure 5-3. 100-KR Water Table, March 2019 5-6
Figure 5-4. 100-KR Plume Areas 5-7
Figure 5-5. 100-KR Cr(VI) Plume in 1996 (Before Interim Action) and 2019 (During Interim Action) 5-7
Figure 5-6. 100-KR Cr(VI) Plume, KE and KW Vicinity (2019 Low River Stage) 5-8
Figure 5-7. 100-KR Cr(VI) Plume, 116-K-2 Trench (2019 Low River Stage) 5-9
Figure 5-8. 100-KR Location of KW Soil Flushing Treatability Test 5-10
Figure 5-9. 100-KR Cr(VI) Data for Key Soil Flushing Observation Wells 5-11
Figure 5-10. 100-KR Specific Conductance (2019 Low River Stage) 5-14
Figure 5-11. 100-KR Tritium Plume, 2019 5-16
Figure 5-12. 100-KR Tritium Data for Wells 199-K-111A and 199-K-207 (Located Northeast of KE Reactor) 5-17
Figure 5-13. 100-KR Nitrate Plume, 2019 5-18
Figure 5-14. 100-KR Strontium-90 Plume, 2019 5-21
Figure 5-15. 100-KR Strontium-90 and Water Level Data for Well 199-K-222 5-22
Figure 5-16. 100-KR Strontium-90 and Water Level Data for Well 199-K-221 5-22
Figure 5-17. 100-KR Strontium-90 Data for Wells 199-K-32A, 199-K-141, and 199-K-178 (Located Downgradient of KE Reactor) 5-23
Figure 5-18. 100-KR Carbon-14 Plume, 2019 5-24

Figure 5-19. 100-KR Carbon 14 Data for Wells Downgradient of the 116-KW-1 Gas Condensate Crib 5-25
Figure 5-20. 100-KR Maximum TCE Plume, 2019 5-26
Figure 5-21. 100-KR P&T Well Locations 5-29
Figure 6-1. 100-NR Water Table, March 2019 6-2
Figure 6-2. 100-NR Sampling Locations, 2019 6-3
Figure 6-3. 100-NR Plume Areas 6-5
Figure 6-4. 100-NR Geology 6-6
Figure 6-5. 100-NR Strontium-90 Plume, 2019 6-7
Figure 6-6. 100-NR Strontium-90 Data for Wells 199-N-67 and 199-N-187 6-8
Figure 6-7. 100-NR Strontium-90 Data and Water Levels in Well 199-N-184 6-9
Figure 6-8. 100-NR Strontium-90 Data for Aquifer Tube Cluster C7934/C7935/C7936 and Well 199-N-374 6-10
Figure 6-9. 100-NR Tritium Plume, 2019 6-11
Figure 6-10. 100-NR Tritium Data for Aquifer Tubes C7934, C7935, and C7936 6-12
Figure 6-11. 100-NR Tritium Data and Water Level at Well 199-N-186 6-13
Figure 6-12. 100-NR Nitrate Plume, 2019 6-14
Figure 6-13. 100-NR Nitrate Data for Wells Downgradient of 116-N-1 Trench 6-15
Figure 6-14. 100-NR Nitrate Data for Wells Downgradient of 116-N-3 Trench 6-16
Figure 6-15. 100-NR Nitrate Data for Wells 199-N-92A (Northern Edge of Plume), 199-N-81, and 199-N-41 (Eastern Edge of Plume) 6-16
Figure 6-16. 100-NR Nitrate Data for Wells Downgradient of the 120-N-1 Waste Site 6-17
Figure 6-17. 100-NR TPH-D Plume, 2019 6-18
Figure 6-18. 100-NR Dissolved Oxygen and TPH-D Data at Well 199-N-169 6-19
Figure 6-19. 100-NR Dissolved Oxygen and TPH-D Data at Well 199-N-171 6-20
Figure 6-20. 100-NR Manganese and Sulfate Data at Well 199-N-169 6-20
Figure 6-21. 100-NR Manganese and Sulfate Data at Well 199-N-171 6-21
Figure 6-22. 100-NR Chromium Plume, 2019 6-22
Figure 6-23. 100-NR Dissolved Chromium Data for RUM Well 199-N-80 6-23
Figure 6-24. 100-NR Apatite PRB 6-25
Figure 6-25. 100-NR Strontium-90 Data for Performance Monitoring Wells Along the Central Segment of the Apatite PRB 6-28
Figure 7-1. 300-FF Sampling Locations, 2019 7-3
Figure 7-2. 300-FF Water Table, March 2019 7-4
Figure 7-3. 300-FF Geology 7-5
Figure 7-4. 300-FF Plume Areas 7-6
Figure 7-5. 300-FF Uranium Plume in 1996 and December 2019 7-6
Figure 7-6. 300-FF Uranium Plume, June 2019 7-8
Figure 7-7. 300-FF Uranium Plume, December 2019 7-9
Figure 7-8. 300-FF Uranium and Water-Level Data for Well 399-1-17A (Inland) 7-10

Figure 7-9. 300-FF Uranium and Water-Level Data for Well 399-1-16A (Near River).....7-10
Figure 7-10. 300-FF Uranium Data for Wells Downgradient of the 618-7 Burial Ground 7-11
Figure 7-11. 300-FF Uranium and Water Level Data for Wells 399-3-6 and 399-6-3 7-12
Figure 7-12. 300-FF Uranium and Water-Level Data for Wells Near the Former 618-10 Burial Ground and 316-4 Crib 7-13
Figure 7-13. 300-FF Tritium Near the 618-11 Burial Ground, 2019 7-15
Figure 7-14. 300-FF Tritium Data for Wells Downgradient of the 618-11 Burial Ground 7-16
Figure 7-15. 300-FF Nitrate Near the 618-11 Burial Ground, 2019 7-17
Figure 7-16. 300-FF Nitrate Data for Well 699-13-3A.....7-18
Figure 7-17. 300-FF cis-1,2-DCE, 1,2-DCE, TCE, and PCE Data for Well 399-1-16B 7-19
Figure 7-18. Location of 300-FF-5 Enhanced Attenuation Treatment Area and 2019 Monitoring Wells 7-23
Figure 7-19. 300-FF Uranium Data for Stage B Aquifer Monitoring Wells.....7-25
Figure 7-20. 300-FF Strontium-90 Data for Wells 399-4-15 and 399-4-16.....7-26
Figure 7-21. 300 Area Process Trenches (316-5).....7-27
Figure 8-1. 1100-EM and Richland North Sampling Locations, 2019 8-2
Figure 8-2. 1100-EM and Richland North Water Table, March 2019 8-4
Figure 8-3. 1100-EM Geology 8-5
Figure 8-4. Nitrate Plume in 1100-EM, Richland North, and the 300 Area, 2019 8-6
Figure 8-5. 1100-EM Nitrate Data for Selected Wells in 1100-EM, Richland North, and the 300 Area 8-7
Figure 8-6. Framatome Uranium Plume, 1100-EM and Richland North, 2019.....8-8
Figure 8-7. 1100-EM Uranium Data for Wells Downgradient of Framatome and Inactive Horn Rapids Landfill.....8-9
Figure 9-1. 200-BP Groundwater Interest Area and Geometry of Groundwater Contaminant Plumes 9-2
Figure 9-2. 200-BP Sampling Locations, 2019.....9-3
Figure 9-3. 200-BP Plume Areas 9-6
Figure 9-4. 200 East Area Water Table, March 2019 9-7
Figure 9-5. 200-BP Nitrate Plume, 2019.....9-10
Figure 9-6. 200-BP Nitrate Data in Wells East of the B Complex.....9-12
Figure 9-7. 200-BP Nitrate Data for Wells Beneath the 218-E-12B Burial Grounds, Trench 94, and LERF 9-13
Figure 9-8. 200-BP Nitrate Data in WMA C Wells 9-14
Figure 9-9. 200-BP Nitrate Data Comparison Between Upgradient and Downgradient WMA C Wells.....9-15
Figure 9-10. 200-BP Nitrate Plume at the A-AX and C Tank Farms and Proposed Extraction Well Locations.....9-16
Figure 9-11. 200-BP Iodine-129 Plume, 2019 9-17
Figure 9-12. 200-BP Technetium-99 Plume, 2019 9-19
Figure 9-13. 200-BP Comparison of 2015 and 2019 Technetium-99 Plumes at B Complex 9-21

Figure 9-14. 200-BP Technetium-99 Data in Gable Gap Wells 9-22
Figure 9-15. 200-BP Technetium-99 Data in WMA C Wells....9-24
Figure 9-16. 200-BP Technetium-99 Data in Wells 299-E27-137B and 299-E27-155 9-26
Figure 9-17. 200-BP Uranium Plume, 2019 9-27
Figure 9-18. 200-BP Comparison of 2015 and 2019 Uranium Plumes 9-29
Figure 9-19. 200-BP Strontium-90 Plume, 2019 9-31
Figure 9-20. 200-BP Strontium-90 Data for Wells at the Former Gable Mountain Pond 9-32
Figure 9-21. 200-BP Strontium-90 Data for Wells Near the Former 216-B-5 Reverse Well....9-32
Figure 9-22. 200-BP Total Cyanide Plume, 2019 9-34
Figure 9-23. 200-BP Contamination Removed from Groundwater and Perched Water in the B Complex Area....9-37
Figure 9-24. Waste Management Area B-BX-BY 9-39
Figure 9-25. Waste Management Area C....9-42
Figure 9-26. 216-B-63 Trench 9-45
Figure 9-27. Liquid Effluent Retention Facility....9-47
Figure 9-28. Low-Level Burial Grounds Waste Management Area 1 9-49
Figure 9-29. Low-Level Burial Grounds Waste Management Area 2 9-51
Figure 10-1. 200-PO Sampling Locations, 2019....10-2
Figure 10-2. 200-PO Plume Areas 10-4
Figure 10-3. Hanford Site Tritium Plumes, 1980 and 2019....10-5
Figure 10-4. 200-PO Near-Field Tritium Plume, 2019 10-6
Figure 10-5. 200-PO Far-Field Tritium Plume, 2019 10-7
Figure 10-6. 200-PO Tritium Data for Selected Wells in the Near-Field Region....10-9
Figure 10-7. 200-PO Tritium Data for Selected Wells in the Far-Field Region 10-10
Figure 10-8. 200-PO Tritium Data in Ringold Semiconfined Wells 10-11
Figure 10-9. 200-PO Tritium Data for Basalt Confined Well 699-42-40C 10-12
Figure 10-10. 200-PO Far-Field Iodine-129 Plume, 2019 10-13
Figure 10-11. 200-PO Near-Field Iodine-129 Plume, 2019....10-14
Figure 10-12. 200-PO Iodine-129 Data for Wells 299-E26-13, 299-E17-14, 299-E25-41, and 699-43-45 10-15
Figure 10-13. Local Groundwater Flow Near the 216-B-3 Pond and 216-A-29 Ditch 10-16
Figure 10-14. 200-PO Nitrate Plume, 2019 10-18
Figure 10-15. 200-PO Nitrate Data for Wells 299-E17-14, 299-E17-19, and 299-E17-20 10-19
Figure 10-16. 200-PO Nitrate Data for Wells in Southeastern 200 East Area....10-20
Figure 10-17. 200-PO Nitrate Data and Hydraulic Head in Ringold Confined Well 699-39-39 10-20
Figure 10-18. 200-PO Technetium-99 Plume, 2019 10-22
Figure 10-19. 200-PO Technetium-99 Data for WMA A-AX Upgradient and Downgradient Wells....10-23

Figure 10-20. 200-PO Technetium-99 Data for Wells 699-37-47A, 299-E17-22, and 299-E24-18 10-23
Figure 10-21. 200-PO Uranium Plume, 2019 10-25
Figure 10-22. 200-PO Uranium Data for Wells 299-E17-14 (216-A 36B Crib), 299-E24-23 (216-A-4 Crib), 299 E24-16 (216-A-10 Crib), and 299-E25-36 10-26
Figure 10-23. 200-PO Strontium-90 Data for Wells 299-E17-14 and 299-E24-16 10-26
Figure 10-24. Central Plateau TCE Plume 10-27
Figure 10-25. Waste Management Area A-AX 10-30
Figure 10-26. 216-A-36B Crib 10-32
Figure 10-27. 216-A-37-1 Crib 10-34
Figure 10-28. 216-A-29 Ditch 10-36
Figure 10-29. 216-B-3 Main Pond (B Pond) 10-38
Figure 10-30. Integrated Disposal Facility 10-40
Figure 10-31. Nonradioactive Dangerous Waste Landfill 10-42
Figure 10-32. Solid Waste Landfill 10-44
Figure 11-1. 200-UP Sampling Locations, 2019 11-3
Figure 11-2. 200 West Water Table Map, March 2019 11-5
Figure 11-3. Water Table Map in Vicinity of 200-UP Groundwater Extraction Systems, March 2019 11-6
Figure 11-4. 200-UP Plume Areas 11-7
Figure 11-5. 200-UP Uranium Plume, 2019 11-8
Figure 11-6. 200-UP Uranium Concentrations Near the U Plant Area Plume, 2010–2019 11-9
Figure 11-7. 200-UP Capture Zones for U Plant Area Extraction Wells 11-11
Figure 11-8. 200-UP Technetium-99 Plumes, 2019 11-13
Figure 11-9. 200-UP Technetium-99 Concentrations in Selected Monitoring Wells Near WMA S-SX, 2010–2019 11-15
Figure 11-10. 200-UP Capture Zones for WMA S-SX Extraction Wells with 2019 Technetium-99 Plumes 11-17
Figure 11-11. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W23-19 11-18
Figure 11-12. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-50 and Replacement Well 299-W22-116 11-18
Figure 11-13. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-96 11-19
Figure 11-14. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-45 and Replacement Well 299-W22-115 11-19
Figure 11-15. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-10 11-20
Figure 11-16. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-72 11-20
Figure 11-17. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-44 and Replacement Well 299-W22-93 11-21

Figure 11-18. 200-UP Technetium-99 Concentrations for Well 299-W22-87 and Upgradient Well 299-W22-95 11-22
Figure 11-19. 200-UP Technetium-99 Concentrations in Selected Monitoring Wells Near the U Tank Farm and U Plant, 2010–2019 11-25
Figure 11-20. 200-UP Chromium Plumes Near WMA S-SX, REDOX Plant, and 216-S-10 Pond, 2019 11-27
Figure 11-21. 200-UP Southeast Chromium Plume, 2019 11-28
Figure 11-22. 200-UP Chromium Concentrations at Select WMA S-SX Wells 11-29
Figure 11-23. 200-UP Chromium Concentrations at Well 299-W26-13 11-29
Figure 11-24. 200-UP Chromium Concentrations at Selected Southeast Chromium Plume Wells 11-31
Figure 11-25. 200-UP Nitrate Plume, 2019 11-32
Figure 11-26. 200-UP Wells with Nitrate Concentrations >10 Times the Cleanup Level (>450 mg/L) Since 2000 11-33
Figure 11-27. 200-UP Nitrate Concentrations at WMA U Wells 11-34
Figure 11-28. 200-UP Iodine-129 Plume, 2019 11-35
Figure 11-29. 200-UP Iodine-129 Concentrations for Wells with Recent Concentrations >4 pCi/L 11-37
Figure 11-30. 200-UP Tritium Plume, 2019 11-38
Figure 11-31. Carbon Tetrachloride Plume, 2019 11-40
Figure 11-32. 200-UP Iodine-129 Plume Hydraulic Control Remedy Effect on Water Table 11-46
Figure 11-33. 200-UP ERDF Monitoring Well Locations and Groundwater Gradients 11-48
Figure 11-34. Waste Management Area S-SX 11-50
Figure 11-35. Chromium Concentration in Well 299-W23-19 in WMA S-SX 11-51
Figure 11-36. Waste Management Area U 11-53
Figure 11-37. 216-S-10 Pond and Ditch 11-55
Figure 12-1. 200-ZP Sampling Locations, 2019 12-2
Figure 12-2. 200-ZP Plume Areas 12-4
Figure 12-3. Extent of the Ringold Formation Lower Mud Unit 12-5
Figure 12-4. 200-ZP Carbon Tetrachloride Plume, 2019 12-7
Figure 12-5. 200-ZP Cut-Away View of the Three-Dimensional Carbon Tetrachloride Plume Simulation, 2019 12-8
Figure 12-6. 200 West Carbon Tetrachloride Plume in 2012 (Start of Final Action P&T) and 2019 12-9
Figure 12-7. 200-ZP Carbon Tetrachloride Data for Wells 299-W6-17, 299-W11-87, 299-W13-1, and 299-W14-72 12-10
Figure 12-8. 200-ZP Cr(VI) Plume, 2019 12-12
Figure 12-9. 200-ZP Cr(VI) Concentrations in Wells at WMA T 12-13
Figure 12-10. 200-ZP Cr(VI) Concentrations in Wells on the East Side of the WMA T Plume 12-13
Figure 12-11. 200-ZP Cr(VI) Concentrations in Wells at WMA TX-TY 12-14

Figure 12-12. 200-ZP Iodine-129 Plume, 2019 12-15
Figure 12-13. 200-ZP Nitrate Plume, 2019 12-17
Figure 12-14. 200-ZP Nitrate Data in Wells 299-W10-28, 299-W14-16, and 299-W14-18 12-18
Figure 12-15. 200-ZP Nitrate Data in Wells 299-W5-2P, 299-W18-16, and 699-48-71 12-18
Figure 12-16. 200-ZP Technetium-99 Plume, 2019 12-20
Figure 12-17. 200-ZP Technetium-99 Data in Wells East of WMA T and WMA TX-TY 12-21
Figure 12-18. 200-ZP TCE Plume, 2019 12-23
Figure 12-19. 200-ZP Tritium Plume, 2019 12-24
Figure 12-20. Total and Free Cyanide in WMA TX-TY Wells 299-W10-26 and 299-W14-18 12-26
Figure 12-21. 200 West Extraction and Injection Well Network 12-27
Figure 12-22. 200-ZP Groundwater Elevation Contours: (a) Above the Lower Mud at the End of 2019; (b) Below the Lower Mud at the End of 2019 12-30
Figure 12-23. Waste Management Area T 12-33
Figure 12-24. Waste Management Area TX-TY 12-35
Figure 12-25. Low-Level Burial Grounds Waste Management Area 3 12-38
Figure 12-26. Low-Level Burial Grounds Waste Management Area 4 12-40
Figure 12-27. State-Approved Land Disposal Site 12-42
Figure 12-28. 200-ZP Tritium Data for Wells Monitoring the SALDS 12-44

Tables

Table 1-1. Reporting Requirements for Groundwater Monitoring 1-3
Table 1-2. Groundwater Sampling Trips, 2019 1-6
Table 1-3. Water Quality Criteria and Background for Hanford Site Groundwater Contaminants 1-13
Table 1-4. Derived Concentration Standards, 4 mrem Effective Dose Equivalent Concentrations, and Risk-Based Concentrations for Hanford Site Radionuclides 1-16
Table 1-5. River Corridor at a Glance 1-17
Table 1-6. Maximum Concentrations of Selected Constituents in Hanford Site Groundwater, 2019 1-21
Table 1-7. Hanford Site Contaminants in Columbia River Seeps, 2019 1-23
Table 1-8. Comparison of Contaminant Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site, 2018 1-25
Table 1-9. Central Plateau Groundwater and Source OUs 1-26
Table 2-1. 100-BC at a Glance 2-2
Table 2-2. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-BC in 2019 2-14
Table 3-1. 100-FR at a Glance 3-3
Table 3-2. Wells Drilled in 100-FR in 2019 3-4
Table 3-3. Summary of 100-FR-3 OU Trace Metals (Unfiltered Samples), 2014–2019 3-20

Table 3-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-FR for 2019 3-22
Table 4-1. 100-HR at a Glance 4-2
Table 4-2. New Wells Installed in 100-HR in 2019 4-18
Table 4-3. 100-HR-3 Remedy Summary 4-27
Table 4-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-HR in 2019 4-33
Table 5-1. 100-KR at a Glance 5-2
Table 5-2. 100-KR-4 P&T Summary 5-28
Table 5-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-KR in 2019 5-31
Table 6-1. 100-NR at a Glance 6-4
Table 6-2. 100-NR Remedy Summary 6-26
Table 6-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-NR in 2019 6-29
Table 7-1. 300-FF at a Glance 7-2
Table 7-2. Wells and Boreholes Installed or Decommissioned in 300-FF in 2019 7-21
Table 7-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 300-FF for 2019 7-29
Table 8-1. 1100-EM at a Glance 8-3
Table 8-2. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 1100-EM and Richland North in 2019 8-10
Table 9-1. 200-BP at a Glance 9-5
Table 9-2. Change in Nitrate Concentrations in B Complex Wells, 2015–2019 9-9
Table 9-3. Change in Nitrate Concentrations in Wells North of 200 East Area to Gable Gap, 2015–2019 9-11
Table 9-4. Change in Nitrate Concentrations in Wells East of B Complex, Fall 2018 Through Fall 2019 9-11
Table 9-5. Iodine-129 Concentration Declines in Wells Near the Current 1 pCi/L Contour 9-18
Table 9-6. Change in Technetium-99 Concentration in Selected B Complex Wells, 2016–2019 9-20
Table 9-7. Change in Technetium-99 Concentration at Wells 699-49-57A and 699-50-59, 2013–2019 9-23
Table 9-8. Change in Technetium-99 Concentration at Four Gable Gap Wells, 2013–2019 9-23
Table 9-9. Technetium-99 Concentrations at Five WMA C Wells, 2016–2019 9-25
Table 9-10. Change in Uranium Concentration at Selected B Complex Wells in 2019 9-28
Table 9-11. Wells Drilled in 200-BP in 2019 9-35
Table 9-12. 200-BP Remediation Summary 9-36
Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019 9-54
Table 10-1. 200-PO at a Glance 10-3

Table 10-2. Wells Drilled in 200-PO in 2019 10-28
Table 10-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-PO in 2019 10-46
Table 11-1. 200-UP at a Glance 11-2
Table 11-2. Wells and Boreholes Installed in 200-UP in 2019 11-43
Table 11-3. 200-UP-1 Remedy Summary 11-44
Table 11-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-UP in 2019 11-57
Table 12-1. 200-ZP at a Glance 12-3
Table 12-2. 200-ZP-1 Remedy Summary 12-28
Table 12-3. Wells Installed in 200-ZP in 2019 12-32
Table 12-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-ZP in 2019 12-45

Terms

AEA	*Atomic Energy Act of 1954*
AWLN	automated water level network
bgs	below ground surface
BTV	background threshold value
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
cis-1,2-DCE	*cis*-1,2-dichloroethene
COC	contaminant of concern
COPC	contaminant of potential concern
Cr(VI)	hexavalent chromium
CSM	conceptual site model
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EDA	Environmental Dashboard Application
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FS	feasibility study
HEIS	Hanford Environmental Information System
HSP	hyporheic sampling point
IDF	Integrated Disposal Facility
ISRM	in situ redox manipulation
LERF	Liquid Effluent Retention Facility
LLBG	low-level burial ground
LWDF	Liquid Waste Disposal Facility
MDA	minimum detectable activity
MDL	method detection limit

MNA	monitored natural attenuation
MSA	Mission Support Alliance
MTCA	Model Toxics Control Act
NPL	National Priorities List
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	operable unit
P&T	pump and treat
PCE	tetrachloroethene
PFP	Plutonium Finishing Plant
PHOENIX	PNNL Hanford Online Environmental Information Exchange
PNNL	Pacific Northwest National Laboratory
PQL	practical quantitation limit
PRB	permeable reactive barrier
PRZ	periodically rewetted zone
PUREX	Plutonium-Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RD/RAWP	remedial design/remedial action work plan
RDR	request for data review
REDOX	Reduction-Oxidation (Plant)
RI	remedial investigation
ROD	Record of Decision
RUM	Ringold upper mud unit
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SST	single-shell tank
SWL	Solid Waste Landfill
TARL	Test American Richland Laboratory

TCE	trichloroethene
TED	total effective dose
TEDF	Treated Effluent Disposal Facility
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbon
TPH-D	total petroleum hydrocarbon–diesel range
TRIM	Tikhonov regularized inverse method
Tri-Parties	U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
UCL	upper confidence limit
VOC	volatile organic compound
WMA	waste management area

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Glossary[1]

Aquifer: An underground geological formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring. The top of an unconfined aquifer is known as the *water table*.

Confined aquifer: An *aquifer* having defined, relatively impermeable upper and lower boundaries and the pressure of which is significantly greater than atmospheric.

Crib: An underground structure designed to receive liquid waste that could percolate into the soil directly or after traveling through a connected tile field. Numerous cribs were used in the 100, 200, and 300 Areas.

Feasibility study: A study performed by an agency to develop and evaluate options for *remedial action* that emphasizes data analysis and is generally performed concurrently with the *remedial investigation*.

Groundwater: Water that fills the spaces between soil, sand, rock, and gravel particles beneath the earth's surface.

Half-life: The length of time in which any radioactive substance will lose one-half of its radioactivity. The half-lives of some Hanford Site radionuclides are listed below:

Radionuclide	Half-Life
Carbon-14	5,730 years
Iodine-129	16 million years
Plutonium (various isotopes)	88 to 24,000 years
Strontium-90	28.8 years
Technetium-99	212,000 years
Tritium	12 years
Uranium (various isotopes)	160,000 to 4.5 billion years

Hanford Reach: The segment of the Columbia River that extends 85 km (51 mi) downstream from Priest Rapids Dam to the head of the McNary Pool near the city of Richland, Washington. The Hanford Reach National Monument, which the U.S. government established in 2000, includes the River Corridor and other undisturbed portions of the Hanford Site.

Hydraulic conductivity: A property of an *aquifer* or *vadose zone* material that describes the ease at which water can move through pores or cracks. It is related to *permeability*.

Hydraulic gradient: The difference in water-level elevations divided by the distance between the points; the "slope" of the water table. *Groundwater* flows from higher to lower gradient, in a direction generally perpendicular to the contour lines of a *water table* map.

Hyporheic zone: The region of sediment beneath and adjacent to a stream or lake where *groundwater* and surface water mix.

[1] Terminology shown in italics indicates cross reference to another term defined in this glossary.

Mobility: Ability of a contaminant to move through the subsurface. The distance that contaminants migrate from waste sites depends on the properties of the contaminant, the volume of effluent, and subsequent *recharge*.

Low-mobility contaminants:	Many metals and radionuclides adhere to sediment grains in the vadose zone. When little or no liquid effluent was discharged, contamination remains in the shallow sediment within the waste site. Disposal of high volumes of liquid waste may spread low-mobility contaminants deeper in the soil. Natural and artificial recharge also can increase contaminant migration.
Slightly mobile contaminants:	Some contaminants such as strontium-90 can migrate in the subsurface but at a much slower rate than water. Strontium-90 was present in numerous Hanford Site waste sites. Where large volumes of liquid effluent were discharged, contaminants migrated through the vadose zone and moved a limited distance vertically and horizontally in groundwater.
Mobile contaminants:	Mobile contaminants migrate at the same or nearly the same rate as water. Common mobile contaminants in Hanford Site groundwater include tritium, iodine-129, technetium-99, nitrate, and hexavalent chromium. Large groundwater mounds developed when high-volume discharge sites were active, spreading mobile contaminants.

Monitored natural attenuation: Remediation that relies on natural processes to decrease or "attenuate" concentrations of contaminants in soil and groundwater. Scientists monitor these conditions to ensure that natural attenuation is working.

Operable unit: A discrete portion of the Hanford Site, as identified in Section 3.3 of the Tri-Party Agreement Action Plan;[2] a group of land disposal sites placed together for the purposes of cleanup actions. The primary criteria for placing a site into an operable unit includes geographic proximity, similarity of waste characteristics and site type, and the possibility for economies of scale.

Permeability: Ability of sediment or rocks to allow the passage of a liquid such as water. Permeable materials such as gravel and sand allow water to move quickly through them, whereas impermeable materials such as clay or solid basalt do not allow water to flow freely.

Plume: Volume of air, soil, or water containing contaminants. Groundwater plumes are usually depicted as two-dimensional maps but are present in three dimensions in an *aquifer*. Plume maps use contour lines or shading to illustrate areas of similar concentration.

Porosity: The ratio (usually expressed as a percentage) of the total volume of pores in a geologic unit to the total volume of the unit. Effective porosity reflects how many of the pores are connected and able to transmit water.

Pump and treat: A common method for remediating contaminated groundwater by pumping water from wells to an aboveground treatment system that removes the contaminants.

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[2] Ecology, EPA, and DOE, 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=82.

Radionuclide (radioisotope): Any naturally occurring or artificially produced radioactive element or isotope. An atom that has excess nuclear energy, making it unstable. As the excess energy is emitted, the radionuclide is said to undergo radioactive decay. Also see *half-life*.

Recharge: Water added to an *aquifer* from natural processes such as precipitation or artificial sources such as irrigation or effluent disposal to the ground.

Record of Decision: The CERCLA document used to select the method of *remedial action* to be implemented at a site after the *feasibility study* and proposed plan have been completed.

Remedial action: An action taken under CERCLA authority to permanently resolve a hazardous substance release or to significantly reduce the potential for a release from a unit or group of units.

Remedial investigation: The CERCLA process for determining the extent of contamination and, as appropriate, conducting treatability investigations, which is performed in conjunction with a *feasibility study*.

Seep: An area on the river bank where *groundwater* flows out of the *aquifer* into a river or lake; also known as a spring.

Sodium dichromate: A chemical added to reactor cooling water as an anticorrosion agent. Typical sodium dichromate concentrations in the cooling water during the early years of Hanford Site operations were 2,000 µg/L (700 µg/L as hexavalent chromium). Concentrations decreased to 1,000 µg/L in the mid-1960s, and then to 500 µg/L (170 µg/L as hexavalent chromium) in the final stages of operations.

Trench: A narrow ditch dug into the soil, formerly used to dispose solid and liquid waste from Hanford Site operations.

Vadose zone: The unsaturated region of soil between the ground surface and the *water table*.

Waste management area: A grouping of waste sources regulated as one unit under RCRA (e.g., a group of underground storage tanks and associated pipelines).

Water table: Top of an unconfined *aquifer*; top of the saturated sediment or rock. The water table can have high and low points similar to the topography of the land surface. Also see *hydraulic gradient*.

Well: An excavation or structure created in the ground by drilling, digging, or driving to access *groundwater*. The following well types are present on the Hanford Site:

Aquifer tube:	A groundwater monitoring point installed where the water table is very shallow, such as along the river shoreline. Generally consists of a small-diameter tube and screen installed using push technology.
Boring:	A borehole that was decommissioned immediately after drilling. Decommissioning is generally performed before the drill rig is removed from the site.
Groundwater well:	A well with the open interval extending below the water table. Most Hanford Site groundwater wells are used for monitoring or groundwater remediation (e.g., pump and treat).
Hosted piezometer:	Small-diameter groundwater well inside a host well, often part of a group monitoring different depths.
Independent piezometer:	Small-diameter groundwater well not constructed inside a host well.

Lysimeter:	Generally, an in situ open bottom cylindrical core where the top is coincident with the ground surface and with walls that prevent horizontal movement of moisture. A lysimeter is used to measure moisture or contaminant changes through time over a specific depth interval.
Piezometer host:	A well with one or more piezometers constructed inside of it.
Soil tube:	Vadose zone monitoring site consisting of a small-diameter tube and possibly a screen left in place after drilling is completed for sampling.
Vadose well:	A vadose zone monitoring site where casing is left in place after drilling activities are completed. May have a screen, open bottom, or may be closed.

Glossary Sources

Definitions in this glossary were adapted from the following sources (complete citations are provided in Chapter 13):

DOE/EH-413/9713, *Glossary of Terms Related to CERCLA, EPCRA, PPA, RCRA and TSCA:* https://public.ornl.gov/sesa/environment/guidance/cercla/gloss97.pdf.

EPA 542-F-12-014, *A Citizen's Guide to Monitored Natural Attenuation:* https://clu-in.org/download/Citizens/a_citizens_guide_to_monitored_natural_attenuation.pdf.

EPA 542-F-12-017, *A Citizen's Guide to Pump and Treat:* https://clu-in.org/download/Citizens/a_citizens_guide_to_pump_and_treat.pdf.

PNNL-14187-SUM, *Summary of Hanford Site Groundwater Monitoring for Fiscal Year 2002:* https://pdw.hanford.gov/document/D2984289.

Tri-Party Agreement (Appendix A of the Tri-Party Agreement Action Plan): https://www.hanford.gov/files.cfm/ap-App-A.pdf.

USGS Glossary of Hydrologic Terms: https://or.water.usgs.gov/projs_dir/willgw/glossary.html.

1 Introduction

The Hanford Site, part of the U.S. Department of Energy (DOE) nuclear weapons complex, encompasses an area of about 1,500 km^2 (580 mi^2) northwest of the city of Richland along the Columbia River in southeastern Washington State (Figure 1-1). In 1943, as part of the top-secret Manhattan Project, the federal government took possession of the Hanford Site to build the world's first large-scale plutonium-production reactor. Between 1943 and 1963, nine nuclear reactors were built, mainly to produce weapons-grade plutonium. During reactor operations (the last reactor operated through 1987), large amounts of chemical and radioactive wastes were released into the environment that have contaminated the soil and groundwater beneath portions of the Hanford Site. Groundwater at the Hanford Site flows toward the Columbia River, which is the primary exposure route for contaminants to reach human and ecological receptors.

DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (hereinafter referred to as the Tri-Parties) signed a comprehensive cleanup and compliance agreement in 1989. The Tri-Party Agreement (Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*) is an agreement for achieving compliance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the *Resource Conservation and Recovery Act of 1976* (RCRA). The Tri-Party Agreement (1) defines and ranks CERCLA and RCRA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects a concerted goal of achieving full regulatory compliance and remediation with enforceable milestones.

The Tri-Party Agreement is legally binding and consists of two main documents:

- The "Agreement" (Ecology et al., 1989a) describes the agency roles, responsibilities, and authority regarding the compliance and permitting processes. It also establishes dispute resolution processes and describes how the agreement will be enforced.
- The "Action Plan" (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*) includes milestones for initiating and completing specific work and describes procedures that the Tri-Parties will follow.

Additionally, an associated public involvement plan (DOE et al., 2017, *Hanford Federal Facility Agreement and Consent Order Hanford Public Involvement Plan*) describes how the public will be informed and involved throughout the cleanup process.

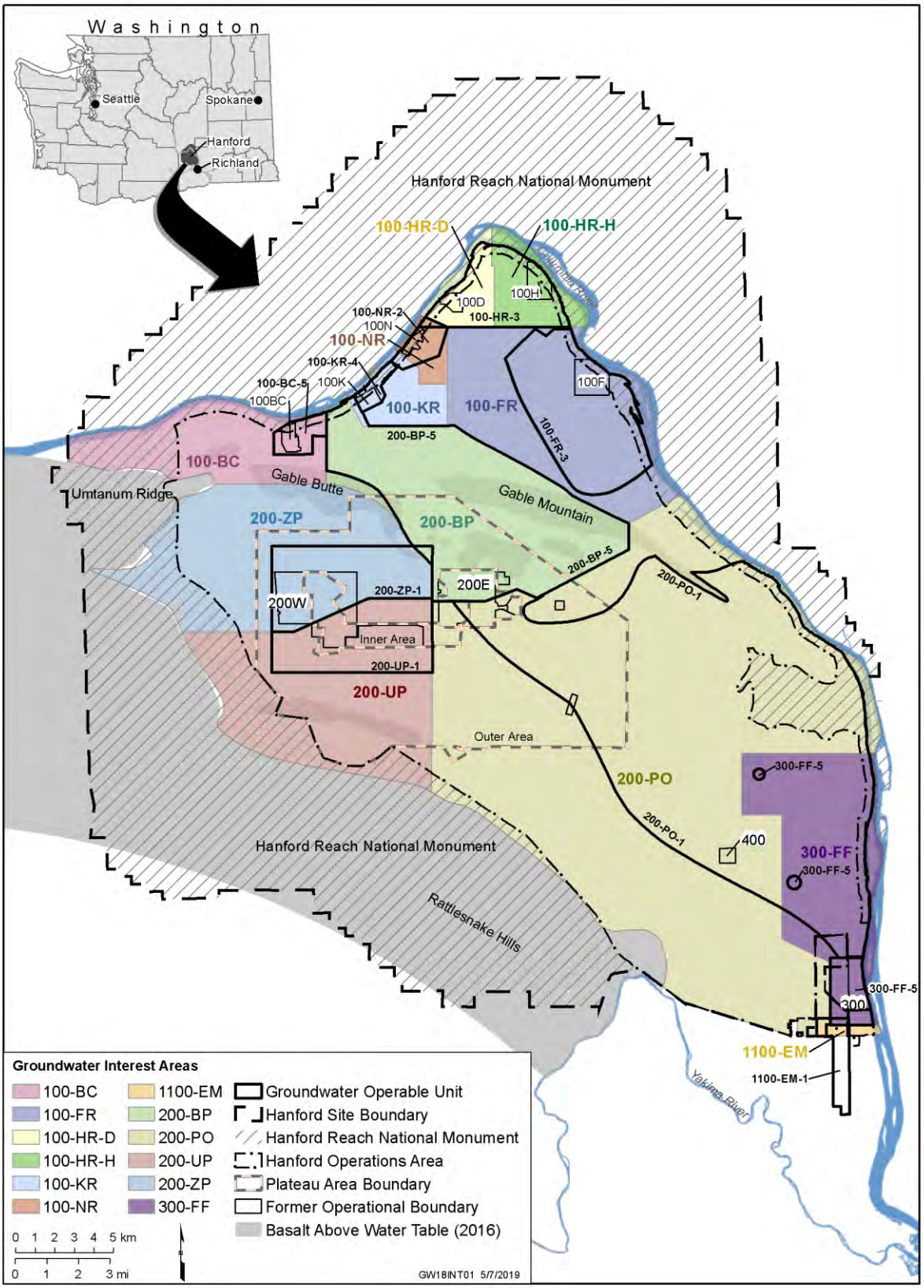


Figure 1-1. DOE Hanford Site, Groundwater Interest Areas, and Operable Units

The key elements associated with managing Hanford Site groundwater and vadose zone contamination are (1) to protect the Columbia River and groundwater from further contamination, (2) to develop a cleanup decision process, and (3) to restore groundwater to its highest beneficial use. DOE has already taken many actions to protect the Columbia River and groundwater, including the following:

- Ceased discharge of all unpermitted liquid effluents
- Remediated waste sites near the Columbia River to reduce the potential for future groundwater contamination
- Contained groundwater plumes and reduced the mass of mobile contaminants through remedial actions such as pump and treat (P&T) and contaminant immobilization technologies.

1.1 Purpose and Scope

DOE monitors and remediates Hanford Site groundwater to protect workers, the public, and the environment. This report presents the 2019 results for Hanford Site groundwater monitoring in accordance with the requirements for CERCLA groundwater operable units (OUs), the *Atomic Energy Act of 1954* (AEA), as required by DOE orders, and two facilities regulated under the *Washington Administrative Code* (Table 1-1). A separate groundwater annual report for the RCRA units (DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*) was previously published, and that information is also included in this report for completeness. Separate CERCLA reports are being published with additional details for OUs with ongoing groundwater remediation. Appendices A, B, and C provide supporting information on CERCLA, RCRA, and the AEA, respectively. Appendix D summarizes confined aquifer monitoring results, and Appendix E summarizes the results of a data usability assessment.

Table 1-1. Reporting Requirements for Groundwater Monitoring

Operable Unit or Facility	Formal Report	Supplemental Report or Summaries
CERCLA		
100-BC-5, 200-BP-5, and 200-PO-1	This report	Unit managers' meeting presentations
100-KR-4, 100-NR-2, 100-HR-3, 200-UP-1, and 200-ZP-1	DOE/RL-2019-67; DOE/RL-2019-68	Unit managers' meeting presentations; this report
300-FF-5 and 100-FR-3	Periodic performance evaluation reports	Unit managers' meeting presentations; this report
Environmental Restoration Disposal Facility	Separate annual report	This report
RCRA		
Operating RCRA units (IDF, LERF, and LLBG)	DOE/RL-2019-65	This report
Closure RCRA units (1301-N, 1324-N/NA, and 1325-N)	DOE/RL-2019-65	This report
Post-closure RCRA units (116-H-6 and 316-5)	Semiannual reports to Ecology; DOE/RL-2019-65	This report
Interim status groundwater quality assessment RCRA sites (216-A-29; NRDWL; WMAs A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U)	DOE/RL-2019-65	This report

Table 1-1. Reporting Requirements for Groundwater Monitoring

Operable Unit or Facility	Formal Report	Supplemental Report or Summaries
Interim status indicator evaluation RCRA sites (216-A-36B, 216-A-37-1, 216-B-3, 216-B-63, and 216-S-10 Pond)	DOE/RL-2019-65	This report
Other Facilities		
AEA sites (K Basins; LLBG, IDF, Richland North, 400 Area water supply wells, and confined aquifers)	This report	Unit managers' meeting presentations
State-Approved Land Disposal Site (WAC 173-216)	Quarterly discharge monitoring reports; annual report	This report
Solid Waste Landfill (WAC 173-350)	Fiscal year report (DOE/RL-2015-21)	This report

References:

DOE/RL-2015-21, Rev. 5, *Hanford Site Solid Waste Landfill Annual Monitoring Report October 2018 through September 2019*.

DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*.

DOE/RL-2019-67, *Calendar Year 2019 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*.

DOE/RL-2019-68, *Calendar Year 2019 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations in the Hanford Central Plateau Operable Units.*

WAC 173-216, "State Waste Discharge Permit Program."

WAC 173-350, "Solid Waste Handling Standards."

AEA = *Atomic Energy Act of 1954*
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Ecology = Washington State Department of Ecology
IDF = Integrated Disposal Facility
LERF = Liquid Effluent Retention Facility
LLBG = low-level burial ground
NRDWL = Nonradioactive Dangerous Waste Landfill
RCRA = *Resource Conservation and Recovery Act of 1976*
WMA = waste management area

This report focuses on the 2019 groundwater monitoring results and changes from the previous year. Details of previous studies (e.g., remedial investigations [RIs]) are published in separate reports that are cited in applicable chapters of this report. Readers are referred to other documents for details regarding hydrogeology, characterization results, detailed conceptual site models (CSMs), and descriptions of waste sites and the shallow vadose zone.

The groundwater monitoring objectives of RCRA, CERCLA, and AEA differ slightly, and the contaminants monitored are not always the same. For RCRA-regulated units, monitoring focuses on nonradioactive dangerous waste constituents or indicator parameters. While radionuclides (source, special nuclear, and byproduct materials) may be monitored in some wells associated with RCRA units to support objectives of monitoring under the AEA and/or CERCLA, they are not subject to RCRA regulation. Pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority.

The Hanford Site is broadly divided into the River Corridor and Central Plateau regions. The River Corridor is located along the Columbia River, and the Central Plateau is in the middle of the Hanford Site. Within these broad regions, this report is organized by groundwater interest areas and groundwater OUs (Figure 1-1). Key characteristics of the groundwater OUs include the following:

- CERCLA groundwater OUs include groundwater beneath one or more source OUs (i.e., sites that received waste from the same or similar sources) and may include larger regions where contaminated groundwater has migrated.
- The formal groundwater OUs do not cover the entire Hanford Site. DOE has defined informal groundwater interest areas, which include the groundwater OUs and the intervening regions, to provide scheduling, data review, and data interpretation for the entire Hanford Site.

The following geographic divisions are sometimes used to describe aspects of the Hanford Site:

- The Hanford Site's former operational areas were given alphanumeric names (Figure 1-1). These include the 100-BC, 100-K, 100-N, 100-D, 100-H, and 100-F Areas, which housed the nuclear reactors; and the 200 West and 200 East Areas, where chemical separations occurred. The 300 Area was the location of fuel manufacturing operations, as well as experimental and laboratory facilities, and the 400 Area included a research nuclear reactor. Maintenance services were located in the 1100 Area. The remainder of the Hanford Site is referred to as the 600 Area.
- For purposes of remediation under CERCLA, waste sites have been sorted into source OUs. The source OUs focus on contamination in the vadose zone.

1.2 Groundwater Monitoring

DOE coordinates groundwater sampling for the CERCLA, RCRA, *Washington Administrative Code*, and AEA programs to avoid duplication. Specific groundwater monitoring plans and sampling and analysis plans (SAPs) define which wells to sample, how often to sample, and what constituents to analyze. The sampling objectives are based on the data needs such as interpreting the extent of contamination, evaluating vertical contaminant distribution, refining geologic models, complying with regulations, evaluating the performance of remediation activities, defining concentration trends, or identifying emerging contaminants.

During 2019, DOE sampled 1,084 wells (Table 1-2). Many of the wells were sampled numerous times, for a total of 4,294 successful well sampling trips. During the year, 194 aquifer tubes were sampled, and many were sampled more than once, for a total of 250 sampling trips.

1.2.1 CERCLA Remediation and Monitoring

Executive Order 12580, *Superfund Implementation*, assigns DOE the responsibility and authority (under CERCLA Section 104, "Response Authorities") to clean up soil and groundwater contaminated by waste sites. CERCLA Section 120, "Federal Facilities," gives EPA an oversight role at the Hanford Site and other federal facilities on the CERCLA National Priorities List (NPL) (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List"). Cleanup decisions are based on the results of environmental investigations that include the vadose zone, saturated soils, and groundwater.

Table 1-2. Groundwater Sampling Trips, 2019

Interest Area	Number of Wells Sampled	Number of Successful Well Trips	Number of Aquifer Tubes Sampled	Number of Successful Aquifer Tube Trips
100-BC	33	41	25	35
100-FR	44	90	7	7
100-HR-D	118	718	18	18
100-HR-H	106	559	19	20
100-KR	106	1,185*	51	64
100-NR	91	182	40	72
300-FF	96	294	15	15
1100-EM and offsite	11	11	0	0
200-BP	150	357	4	4
200-PO	138	266	15	15
200-UP	107	305	0	0
200-ZP	84	286	0	0
Total	**1,084**	**4,294**	**194**	**250**

Note: A successful sampling trip is determined by the presence of data in the Hanford Environmental Information System database. A trip may consist of routine sampling, characterization sampling, or sampling conducted to support groundwater remediation systems.

*A treatability test was implemented in 2019, which included intensive groundwater sampling in 100-KR.

The CERCLA groundwater activities at the Hanford Site include defining the nature and extent of contamination, implementing remedial actions such as P&T systems, and evaluating the effectiveness of remedial actions. DOE publishes separate groundwater annual reports for CERCLA OUs with remedial actions (DOE/RL-2019-67, *Calendar Year 2019 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*; DOE/RL-2019-68, *Calendar Year 2019 Annual Summary Report for Pump-and-Treat Operations in the Hanford Central Plateau Operable Units*).

1.2.2 RCRA Units

RCRA regulates the management of solid waste, hazardous waste, and certain underground storage tanks. It applies to active or recently active dangerous waste management units (DWMUs). Groundwater monitoring requirements for Hanford Site RCRA units fall into two broad categories: interim status or final status. Final status units have been incorporated into WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended (hereinafter referred to as the Hanford RCRA Permit). A permitted RCRA unit requires final status monitoring under WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring under WAC 173-303-400(3)(c)(v),

"Interim Status Facility Standards," as implemented by 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart F, "Ground-Water Monitoring."

DOE reported the 2019 RCRA groundwater monitoring results to Ecology in the annual RCRA groundwater monitoring report (DOE/RL-2019-65). The contents of that report are repeated in Chapters 4, 7, 9 through 12, and Appendix B of this report for convenience and completeness.

1.2.3 *Washington Administrative Code* Units

Two Hanford Site facilities require groundwater monitoring under the *Washington Administrative Code*: the Solid Waste Landfill (SWL) (under WAC 173-350, "Solid Waste Handling Standards") and the State-Approved Land Disposal Site (SALDS), associated with the Effluent Treatment Facility (ETF) (WAC 173-216, "State Waste Discharge Permit Program"). Chapters 10 and 12 of this report summarize the 2019 monitoring results for these facilities.

1.2.4 Atomic Energy Act Monitoring

The AEA was promulgated to ensure the proper management of radioactive materials. Through the AEA, DOE regulates the control of radioactive materials under its authority. Accordingly, DOE promulgated a series of regulations and directives to protect human health and the environment from potential risks associated with radioactive materials. Sections of the AEA authorize DOE to establish radiation protection standards for itself and its contractors through DOE orders and contractor requirements documents.

Requirements for groundwater monitoring associated with environmental surveillance under the AEA are implemented through DOE O 458.1, *Radiation Protection of the Public and the Environment*; DOE O 436.1, *Departmental Sustainability*; and DOE O 435.1, *Radioactive Waste Management* (primarily applied in DOE M 435.1-1, *Radioactive Waste Management Manual*). These DOE orders and their associated manuals, standards, guidance, and contractor requirements documents implement the AEA across the DOE complex and include groundwater monitoring to detect, characterize, and respond to releases of radionuclides. DOE has not relinquished this responsibility under the Tri-Party Agreement (Ecology et al., 1989a); rather, DOE conducts activities in accordance with both the Tri-Party Agreement and DOE orders.

DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan*, describes AEA monitoring requirements. Chapters 2 through 12 of this report summarize the results of AEA monitoring, and Appendix C provides supporting information.

The objectives of AEA monitoring are to determine the location and movement of radionuclide contamination in Hanford Site groundwater and to estimate impacts to human health and the environment in terms of the total effective dose (TED) received by potential receptors. The analytical results were used to estimate the TED from hypothetical exposure of members of the public by drinking radiologically contaminated groundwater. The TED at each groundwater well was calculated as the cumulative dose from all radionuclides detected in groundwater samples from that well in 2019, including samples collected for CERCLA and RCRA. The doses were calculated separately for each sampling event if more than one sampling event occurred in 2019.

The TED was calculated under AEA standards in accordance with DOE O 458.1. DOE-STD-1196-2011, *Derived Concentration Technical Standard*, was released in 2011 to support determining compliance with DOE O 458.1. This standard establishes derived concentration standards on a radionuclide- and pathway-specific basis, reflecting the current state of knowledge and practice in radiation protection.

These derived concentration standards are used to calculate doses from exposure to groundwater and represent the activity concentration of a given radionuclide in groundwater that results in a member of the public receiving a 100 mrem TED from drinking groundwater for one year. The cumulative dose from all radionuclides detected at a monitoring location is calculated and compared to the 100 mrem/yr TED criterion.

Although groundwater at the Hanford Site is not used as a source of drinking water, remedial actions have focused on restoring groundwater quality to its highest use, which is considered to be as a source of drinking water. To this end, the radionuclide concentrations in groundwater were also used to evaluate whether contaminated Hanford Site groundwater would exceed drinking water standards (DWSs) under a hypothetical drinking water exposure scenario. The cumulative drinking water dose was calculated under the EPA DWSs in accordance with 40 CFR 141, "National Primary Drinking Water Regulations," and the process described in EPA 816-F-00-002, *Implementation Guidance for Radionuclides*. The DWSs for beta and photon emitters are established at 4 mrem/yr cumulative dose from all beta and photon emitters present in the water supply. The dose is calculated using a sum-of-fractions approach to determine the cumulative dose to the whole body or any critical organ from beta- and photon-emitting radionuclides and compared to the 4 mrem/yr beta/photon DWS. The DWS is calculated using a defined set of radionuclide-specific dose factors that differs from those established by DOE in DOE-STD-1196-2011. The numerical activity concentration values frequently used for comparison of individual beta- or photon-emitting radionuclide concentrations (e.g., 1 pCi/L iodine-129, 8 pCi/L strontium-90, 900 pCi/L technetium-99, and 20,000 pCi/L tritium) are actually not the DWSs for those radionuclides. These values are the individual single nuclide, DWS-equivalent derived activity concentrations. If a single nuclide is present in drinking water at the corresponding derived concentration (e.g., 8 pCi/L strontium-90), then the corresponding dose would be 4 mrem/yr, which equals the DWS. If more than one nuclide is present in drinking water, then the cumulative dose effects must be calculated using the sum of fractions to determine the actual drinking water dose for comparison to the 4 mrem/yr DWS.

Activity concentrations of the alpha-emitting radionuclides were summed to derive the cumulative alpha-emitter activity concentration, which is compared to the 15 pCi/L alpha-emitter DWS (EPA 816-F-00-002). This calculation excludes uranium and radium-226 (which are regulated under separate standards). Uranium may be measured as mass (total uranium, reported in µg/L) or as activity (isotopic uranium, reported in pCi/L). Total uranium concentrations are compared to the 30 µg/L DWS. If only isotopic uranium is measured, the activity concentrations are converted to mass and summed for comparison to the DWS.

The calculations of cumulative TED, beta/photon-emitter dose, alpha-emitter activity, and uranium mass concentration are provided in ECF-HANFORD-20-0031, *Calculation of Radiological Dose based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

1.3 Water Levels

DOE measures water levels in monitoring wells to discern the direction of groundwater flow. Water levels are measured manually and with an automated system. Water levels are used to determine rates of contaminant migration, groundwater flow direction, adequacy of monitoring networks, and radial influence of remedial actions.

In March of each year, field crews measure water levels from an extensive network of wells. In many areas of the Hanford Site, water levels are measured more frequently to evaluate seasonal changes. SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*, describes the collection and analysis of manual water-level measurements at the Hanford Site. ECF-HANFORD-19-0114, *Preparation of the March 2019 Hanford Site Water Table Map*, describes how the water table map was constructed. Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge areas along the Columbia River (Figure 1-2).

For the 200 East Area where the water table is very flat, a regularized inverse interpolation technique was applied, the Tikhonov regularized inverse method (TRIM). TRIM is founded upon a formal mathematical method that seeks a trade-off between the complexity of the method or model that is used to interpret measured data versus the "fit" to those measured data that the chosen method or model attains. Chapter 9 presents a TRIM map for the 200 East Area.

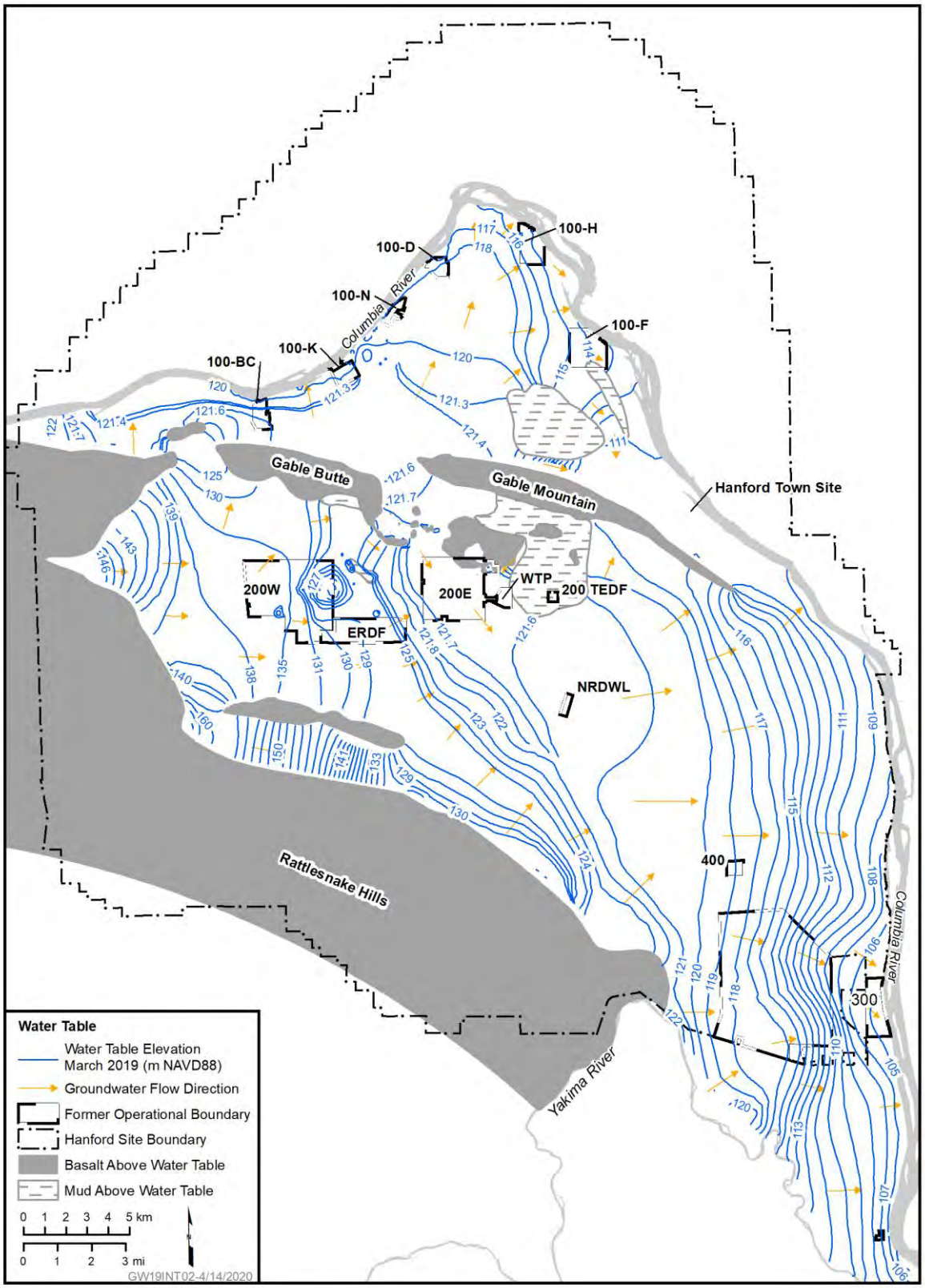
The automated water-level network (AWLN) is an array of remote monitoring stations connected by a telemetry network to a central base station (SGW-53543, *Automated Water Level Network Functional Requirements Document*). Each monitoring station consists of a pressure transducer connected to a data collection telemetry unit. Hourly pressure data from the AWLN are used to calculate water levels, which are used to estimate the level of hydraulic containment achieved by P&T systems, determine hydraulic gradients in areas with variable conditions, and measure changes in the stage of the Columbia River in the 100 and 300 Areas. By the end of December 2019, a total of 205 AWLN stations were operating at the Hanford Site, including new stations in 100-KR (two stations), 100-HR (seven stations), 200-ZP (three stations), and 200-UP (two stations).

1.4 Well Installation, Maintenance, and Decommissioning

Over the lifetime of the Hanford Site, DOE has installed and maintained thousands of wells to monitor and remediate groundwater and provide geologic data. When wells are no longer useful or are in poor condition, they are decommissioned. Figure 1-3 presents the categories of wells and their geographic designations.

DOE works with the appropriate regulatory agencies to define the need for new wells. Each year, DOE proposes new wells to meet the requirements of RCRA, CERCLA, or other regulations. These efforts may include conducting new or expanded RCRA assessments, replacing dry or noncompliant wells, optimizing monitoring and remediation networks, and conducting remedial investigations.

New monitoring well proposals are reviewed, prioritized, and approved annually in accordance with Tri-Party Agreement Milestone M-024. All new wells are constructed as either resource protection wells or water supply wells in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." Well requirements are integrated, prioritized, and documented through the budget development process, discussions between DOE and the regulatory agencies, and specific monitoring and characterization requirements.



Reference: NAVD88, 1988, *North American Vertical Datum of 1988*.

Figure 1-2. Hanford Site Water Table and Directions of Groundwater Flow, 2019

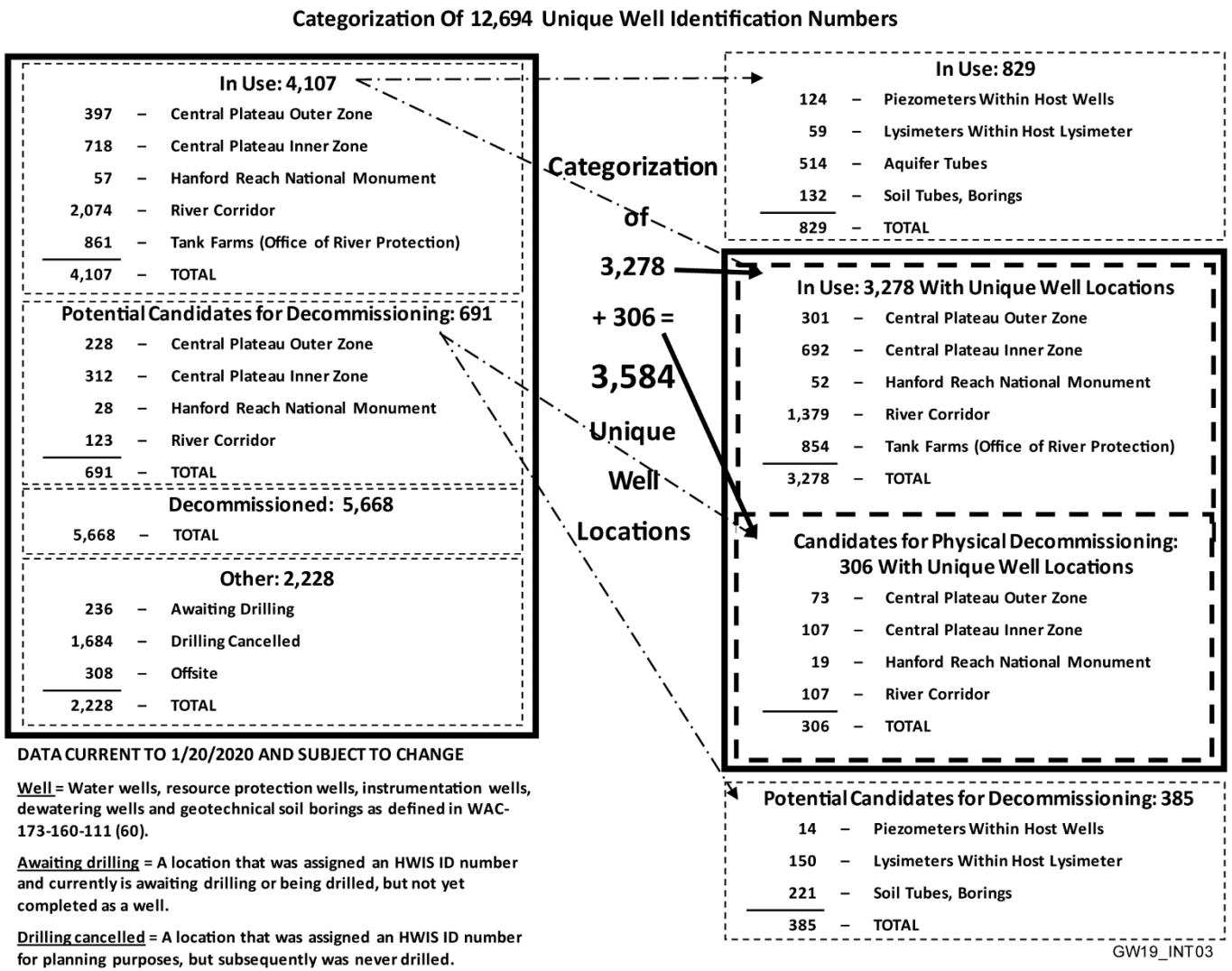


Figure 1-3. Categories of Unique Well Identification Numbers

1.5 Conventions Used in This Report

This section describes conventions for creating maps and trend plots and for depicting groundwater contaminant concentrations.

Contaminant plume maps illustrate the extent of groundwater contamination at concentrations above certain thresholds and are developed by interpolating sample data using computer software and professional interpretation. Details regarding the development of the groundwater plume maps for 2019 are provided in ECF-HANFORD-20-0018, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2019 Hanford Site Groundwater Monitoring Report*. The following general rules were applied to select representative data sets:

- Use data collected during 2019 (or a specific portion of 2019, such as low river-stage months) from monitoring wells, injection wells, extraction wells, and aquifer tubes.
- If more than one data point was available for a well in 2019, use the average value. In cases where concentrations are variable because of seasonal effects or remedial actions, shorter time periods are selected.
- If data were not collected from a well in 2019, data from 2018 or 2017 were used and noted on the maps.
- Data flagged as "R" (rejected) were excluded.
- Nondetect data were displayed and interpreted at the method detection limit (MDL) (for chemical constituents) or minimum detectable activity (MDA) (for radionuclides).

In some instances, older measurements or data based on other site-specific information were included to improve the plume interpretations. These supplemental data (control points) are shown on the plume maps as Type 1, Type 2, and Type 3 data, which the computer software uses in the same way as measured data. On plume maps, these control points are given distinct symbols and are labeled "CPxx" or with an applicable well name, depending on the nature of the control point. A brief description of each type of data is as follows:

- **Type 1 data:** Point values based on contaminant concentration measurements that are outside of the data selection rules described above. Examples include P&T effluent concentrations (at injection wells), contaminant measurements outside the 2017 through 2019 data period, and data from non-Hanford Site sources (e.g., US Ecology).
- **Type 2 data:** Point values determined by geology. Examples include "zero" concentrations in locations where basalt above the water table is a barrier to contaminant migration, and estimated concentrations in locations where zones of higher hydraulic conductivity may be conduits of contaminant migration.
- **Type 3 data:** Point values based on site-specific or historical information. Examples include estimated concentrations based on knowledge of plume sources and disposal history, calculations of inferred plume migration, and radioactive decay calculations from wells that are no longer available for sampling.

The highest concentrations of most Hanford Site groundwater contaminants are found in the upper part of the unconfined aquifer, and most monitoring wells are screened accordingly. However, some contaminants have more variable concentrations with depth and are monitored by wells that are deeper

or have longer screens. Most of the plume maps provided in this report are based on the well with the highest concentration in the unconfined aquifer, no matter what depth, thus depicting the full plume footprint. ECF-HANFORD-20-0018 provides details on which wells were included and excluded for each contaminant in each groundwater interest area.

The areal extent of contaminant plumes is calculated from the plume maps for comparisons over time. Plumes are three-dimensional so the volume of contaminated groundwater would provide a more complete comparison. However, because the thickness of contamination is not well defined in many areas (fewer wells are screened in deeper parts of the aquifer), volume calculations have higher uncertainty.

Groundwater remediation goals (cleanup levels), set as part of the CERCLA process, are often based on water quality standards such as those listed in Table 1-3. However, cleanup levels vary among the groundwater OUs. For consistency in plume maps, contour levels are chosen as follows:

- DWSs and multiples of 10 (e.g., 8 pCi/L, 80 pCi/L, and 800 pCi/L for strontium-90)
- Intermediate levels to help define plumes (e.g., 100 µg/L for carbon tetrachloride)
- Additional contour levels for hexavalent chromium (Cr(VI)):
  - Aquatic standard (10 µg/L near the Columbia River)
  - WAC 173-340, "Model Toxics Control Act—Cleanup" (MTCA) (48 µg/L)
- Other cleanup levels established through Records of Decision (RODs) (e.g., 3.4 µg/L for carbon tetrachloride in the 200-ZP-1 OU, and 4 µg/L for trichloroethene [TCE] in the 100-FR-3 OU)

Table 1-3. Water Quality Criteria and Background for Hanford Site Groundwater Contaminants

Constituent	Unit	Drinking Water Standard[a]	Model Toxics Control Act[b]	Ambient Surface Water Quality Criteria[c]	Background[d]
Chemical Constituents					
Aluminum	µg/L	50 to 200[e]	16,000	—	7.11
Antimony	µg/L	6	6.4	—	55.1
Arsenic	µg/L	10	0.058	190	7.85
Barium	µg/L	2,000	3,200	—	105
Cadmium	µg/L	5	8.0	Hardness dependent	0.916
Carbon tetrachloride	µg/L	5	0.63	—	NC
Chloride	mg/L	250[e]	—	230	15.63
Chloroform [f]	µg/L	80	1.41	--	NC
Chromium (total and hexavalent)	µg/L	100[g]	24,000[g]/48[h]	10 [h]	2.4 [g]
cis-1,2-Dichloroethene	µg/L	70	16	—	NC
Copper	µg/L	1,300[i] 1,000[e]	640	Hardness dependent	0.81
Cyanide (free)	µg/L	200	4.8	5.2	NC

Table 1-3. Water Quality Criteria and Background for Hanford Site Groundwater Contaminants

Constituent	Unit	Drinking Water Standard[a]	Model Toxics Control Act[b]	Ambient Surface Water Quality Criteria[c]	Background[d]
Fluoride	mg/L	4	960	—	1.047
		2[e]	—	—	
Iron	µg/L	300[e]	11,200	—	570
Lead	µg/L	15[i]	—	Hardness dependent	0.917
Manganese	µg/L	50[e]	384	—	38.5
Mercury (inorganic)	µg/L	2	4.8	0.012	0.003
Methylene chloride (dichloromethane)	µg/L	5	22	—	NC
Nitrate, as NO_3-	mg/L	45[j]	114	—	26.871
Nitrite, as NO_2-	mg/L	3.3[j]	4.8	—	0.0937
pH	--	6.5 to 8.5[e]	—	6.5 to 8.5	8.23
Selenium	µg/L	50	80	5.0	10.5
Silver	µg/L	100[e]	80	—	5.28
Sulfate	mg/L	250[e]	—	—	47.014
Tetrachloroethene	µg/L	5	21	—	NC
Thallium	µg/L	2	0.16	—	1.67
Total dissolved solids	mg/L	500[e]	—	—	258
1,1,1-Trichloroethane	µg/L	200	16,000	—	NC
Trichloroethene	µg/L	5	0.54	—	NC
Uranium (total)	µg/L	30	48	—	9.85
Zinc	µg/L	5,000[d]	4,800	Hardness dependent	21.8
Radionuclides[k, l]					
Antimony-125 (β^- emitter)	pCi/L	300	—	—	0.00695
Beta particle and photon activity	pCi/L	4 mrem/yr[l]	—	—	8.08
Carbon-14 (β^- emitter)	pCi/L	2,000	—	—	NC
Cesium-137 (β^- emitter)	pCi/L	200	—	—	0.00843
Cobalt-60 (β^- emitter)	pCi/L	100	—	—	0.0225
Iodine-129 (β^- emitter)	pCi/L	1	—	—	0.0000939
Ruthenium-106 (β^- emitter)	pCi/L	30	—	—	0.00368
Strontium-90 (β^- emitter)	pCi/L	8	—	—	0.0146
Technetium-99 (β^- emitter)	pCi/L	900	—	—	0.83
Total alpha (excluding uranium and radium)	pCi/L	15	—	—	2.70

Table 1-3. Water Quality Criteria and Background for Hanford Site Groundwater Contaminants

Constituent	Unit	Drinking Water Standard[a]	Model Toxics Control Act[b]	Ambient Surface Water Quality Criteria[c]	Background[d]
Tritium (β^- emitter)	pCi/L	20,000	—	—	119

a. Primary DWS from 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels." Secondary DWS from 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

b. Individual risk based concentration levels as derived from WAC 173-340-720, "Groundwater Cleanup Standards."

c. Criteria for chronic exposure in fresh water, WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances," Table 240(3).

d. DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*, 90th percentile, as corrected.

e. Secondary standards are not associated with health effects, but associated with taste, odor, staining, or other aesthetic qualities.

f. Standard is for total trihalomethanes.

g. Total chromium.

h. Hexavalent chromium.

i. Action level (40 CFR 141, Subpart I, "Control of Lead and Copper").

j. The federal DWS for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to approximately 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

k. The DWS for beta/photon emitters is a cumulative dose of 4 mrem/yr. The activity concentrations shown are the single-nuclide-derived concentrations equivalent to a 4 mrem/yr dose from each radionuclide (40 CFR 141, Subpart G).

l. Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr.

— = no criterion

β^- emitter = radionuclide is a beta-emitting isotope and contributes to sum-of-fractions dose for comparison to the 4 mrem/yr DWS

DWS = drinking water standards

NC = not calculated in DOE/RL-96-61

Wells outside of the mapped contour levels are not necessarily free of contamination. The contaminant plumes may be more extensive at lower concentrations. Maps presented in the main body of this report show all of the data, whether above or below contour levels.

In addition to DWSs (Table 1-3), radionuclide concentrations may also be compared with DOE-derived concentration standards and risk-based protectiveness values for human health and the environment (Table 1-4).

Unless otherwise specified, maps showing chromium include total chromium in filtered samples and Cr(VI) in filtered or unfiltered samples. Dissolved chromium in Hanford Site groundwater is nearly all hexavalent (Chapter 7 in WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*; Appendix C of DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*), so filtered total chromium data effectively represent Cr(VI) concentrations.

Table 1-4. Derived Concentration Standards, 4 mrem Effective Dose Equivalent Concentrations, and Risk-Based Concentrations for Hanford Site Radionuclides

Radionuclide	100 mrem/yr Derived Concentration Standard[a] (pCi/L)	4 mrem Effective Dose Equivalent[b] (pCi/L)	Risk-Based Concentration[c] (pCi/L)	
			10^{-6} Risk	10^{-4} Risk
Antimony-125	27,000	1,100	10	1,000
Carbon-14	62,000	2,500	0.72	71.7
Cesium-137	3,000	120	1.71	171
Cobalt-60	7,200	290	3.32	332
Iodine-129	330	13	0.346	34.6
Plutonium-239/240	140	6	0.0603	0.603
Ruthenium-106	4,100	160	727,000	7,270,000
Selenium-79	8,500	340	7.55	755
Strontium-90	1,100	44	0.707	70.7
Technetium-99	44,000	1,800	19.0	1,900
Tritium	1,900,000	76,000	14.5	1,450
Uranium-234	680	27	0.016	1.67
Uranium-235	720	29	0.071	7.14
Uranium-238	750	30	0.016	1.58

a. Concentration of a specific radionuclide in water that could be continuously consumed at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr. From Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

b. Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/yr if consumed at average annual rates. The EPA DWSs for radionuclides listed in Table 1-3 were derived based on a 4 mrem/yr dose standard using maximum permissible concentrations in water specified in NBS Handbook 69, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*. The 4 mrem/yr dose standard listed in this table was calculated using a more recent dosimetry system adopted by the U.S. Department of Energy (see footnote a). The values shown in this column are not comparable to DWS and should not be used for that purpose.

c. From EPA, 2019, *PRGs for Radionuclides* website (January 2019 update). These values represent the concentration of each radionuclide that an individual could consume over a lifetime that would not result in one additional cancer in a population of 1,000,000 and a population of 10,000, respectively. Potentially complete exposure pathways for all radionuclides include ingestion and immersion. Concentrations of tritium and carbon-14 also includes inhalation; the inhalation pathway is incomplete for all other radionuclides.

DWS = drinking water standard

EPA = U.S. Environmental Protection Agency

Nitrate concentrations in this document are expressed as the NO_3^- ion. The federal and state DWS for nitrate is 10 mg/L expressed as NO_3-N. Converting NO_3-N values to nitrate as the NO_3^- ion requires multiplying the NO_3-N value by 4.43. Nitrate data provided in this report are the converted values and, as such, the DWS is equivalent to approximately 45 mg/L as NO_3^-. Similarly, nitrite is expressed as the NO_2^- ion.

The time-series plots presented in this report use open symbols to show values below laboratory detection limits. These results are typically plotted as values that represent the detection limit for chemical parameters and reported values for radiological parameters (negative values are converted to zero). Discussion of increasing or decreasing trends is generally based on qualitative observations, not statistical evaluations.

When potential anomalies are encountered during reviews of analytical data or water-level measurements, a formal request for data review (RDR) process is initiated. Resolution of the RDR may involve a laboratory recheck, sample reanalysis, review of sampling documents, or other actions. Data are corrected if possible (and flagged as "G"); otherwise, the data are flagged as "Y" (suspect), "R" (reject), or with another flag, as appropriate. The "R"-flagged data are excluded from plume maps and trend plots in this report. The "Y"-flagged data are excluded if they create an unsupported interpretation of the data. Data excluded from plume maps are listed in ECF-HANFORD-20-0018. All of the data with appropriate data quality flags are available through the interactive online version of this report and are available in the Hanford Environmental Information System (HEIS) database via the Environmental Dashboard Application (EDA).

1.6 River Corridor

The Columbia River flows through the northern Hanford Site before turning south toward the city of Richland. The region along the shoreline is known as the River Corridor, where former operations included nine nuclear reactors in the 100-BC, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. Fabrication of nuclear fuel assemblies, related research, and maintenance services were located in the 300 and 1100 Areas. Six groundwater OUs (Table 1-5) and 15 source OUs are associated with the River Corridor.

Table 1-5. River Corridor at a Glance

	100 Area	300 Area and Outlying Regions	Former 1100 Area
Groundwater Operable Units	100-BC-5, 100-KR-4, 100-NR-2, 100-HR-3,[a] and 100-FR-3	300-FF-5 (includes 300 Area Industrial Complex, 618-10/316-4 and 618-11 facilities)	Formerly 1100-EM-1
Type of Operations	Nine former nuclear reactors and associated facilities	Historically used for nuclear fuel fabrication and research	Historically used for vehicle maintenance and solid waste disposal
Types of Waste Sites	Inactive liquid waste cribs, ditches, trenches, retention basins, pipelines, and spills; one RCRA site requiring groundwater monitoring	Inactive liquid waste cribs, trenches, ponds, pipelines, and spills; one RCRA site requiring groundwater monitoring	Former waste sites remediated
Waste Site Remediation	93% complete overall[b]	95% complete overall[b]	100% complete
Groundwater Remediation	Final action in progress in 100-FR-3; ROD approved for final action in 100-HR-3[c]; interim actions in progress in 100-KR-4 and 100-NR-2	Final action in progress	Complete

Table 1-5. River Corridor at a Glance

	100 Area	300 Area and Outlying Regions	Former 1100 Area
CERCLA Status	ROD for final remedial action signed in 2014 for 100-FR-3 and in 2018 for 100-HR-3; RI/FS underway for others	ROD for final remedial action signed in 2013	ROD for final remedial action signed in 1993; remedial action goals met
Fast Facts	There is a total of 82 km (51 mi) of Columbia River shoreline. River stage is controlled by Priest Rapids Dam. The Hanford Reach National Monument was established in 2000.		

a. The 100-HR-3 Operable Unit includes the 100-D and 100-H Areas.

b. Percent of sites that have been interim or final remediated or classified as not requiring remediation.

c. Interim remedial action continues at 100-HR-3 during development of the final action.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

RCRA = *Resource Conservation and Recovery Act of 1976*

RI/FS = remedial investigation/feasibility study

ROD = Record of Decision

Contaminant sources in the 100 Area included cooling water conditioning and handling facilities, underground pipe leaks, liquid and solid waste disposal sites, and unplanned releases. During reactor operation, large volumes of effluent were discharged in the 100 Area, creating large groundwater mounds, and modifying groundwater flow. Sources of 300 Area groundwater contamination included routine disposal of liquid effluent associated with nuclear fuel assembly fabrication prior to the 1980s and research involving irradiated fuel processing. The 1100-EM groundwater interest area and the adjacent region include a variety of onsite and neighboring offsite land uses. Numerous municipal, industrial, and agricultural activities affect groundwater quality in this area.

DOE has focused efforts on remediating River Corridor waste sites to protect the Columbia River and reduce the active cleanup footprint to 120 km^2 (75 mi^2) in the center of the Hanford Site (Section 3.3 in DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*). By the end of 2019, 94% of the waste sites in the River Corridor had been remediated or classified as not requiring remediation.

The 100-FR-3, 100-HR-3, and 300-FF-5 Groundwater OUs and associated source OUs have RODs for final action. The 1100-EM-1 OU was removed from the NPL in 2006 because remediation is complete. The CERCLA decision process is underway to develop RODs for final remedial action at the other source and groundwater OUs (Table 1-5).

1.6.1 River Corridor Hydrogeology

Figure 1-4 illustrates the general stratigraphy and hydrogeologic units of the 100 Area. The vadose zone comprises the sand and gravel of the Hanford formation and, in some locations, a portion of Ringold unit E. The vadose zone can be <1 m (3 ft) thick near the Columbia River and up to 30 m (100 ft) thick beneath inland portions of the River Corridor.

The unconfined aquifer consists of the saturated sand and gravel of Ringold unit E and portions of the Hanford formation. This aquifer is thickest in the western portion of the region (up to 50 m [160 ft] in 100-BC) and thinnest near the 100-H and 100-F Areas, where in some places it is <2 m (6 ft) thick. The base of the unconfined aquifer is one of a number of fine-grained layers of the Ringold Formation (informally called the Ringold upper mud unit [RUM]), which contains numerous distinct layers of sand and gravel. These layers typically contain water and act as local confined or semiconfined aquifers.

A series of confined aquifers within and beneath the RUM is present through most of the 100 Area. Basalt aquitards and basalt confined aquifers are present beneath the Ringold Formation.

Beneath the 300 Area and 1100-EM, the vadose zone is entirely within the gravel and sand of the Hanford formation, and the unconfined aquifer includes the lower portion of the Hanford formation. Beneath the 300 Area, the undulating contact between the bottom of the saturated Hanford formation and the underlying Ringold unit E sediment reveals paleochannels that act as preferential groundwater flow paths. Saturated Hanford formation sediment is much more permeable than the underlying Ringold sediment. The Ringold lower mud unit underlies Ringold unit E. Coarse-grained sediments of Ringold unit A underlie the lower mud in some areas; elsewhere, the mud overlies basalt.

Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge area north and east along the Columbia River. In the 100 Area, the local groundwater flow is generally toward the Columbia River, although groundwater P&T systems in the 100-KR and 100-HR groundwater interest areas alter this flow pattern locally to capture contaminants.

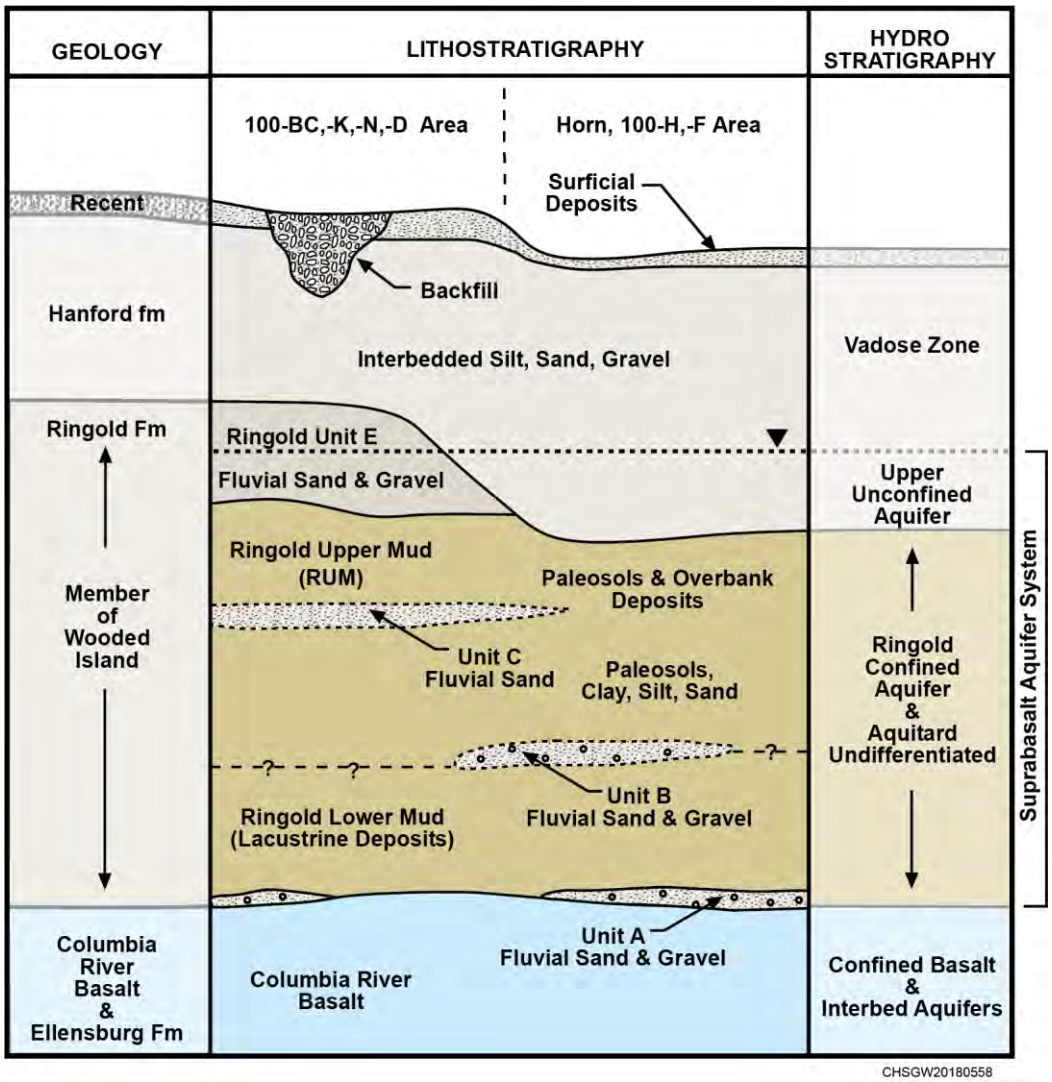


Figure 1-4. River Corridor Geology

1.6.2 River Corridor Groundwater Contamination

The predominant contaminants in River Corridor groundwater include Cr(VI), nitrate, and strontium-90. Table 1-6 lists maximum concentrations detected in River Corridor wells and aquifer tubes during 2019. The Executive Summary of this report provides a general plume map, and Chapters 2 through 8 provide details.

In 2019, DOE continued to remediate groundwater in the River Corridor. Cleanup actions included P&T systems for Cr(VI) in the 100-HR-3 and 100-KR-4 OUs, a permeable reactive barrier (PRB) for strontium-90 in the 100-NR-2 OU, enhanced attenuation of uranium in the 300-FF-5 OU, and monitored natural attenuation (MNA) in the 100-FR-3 OU.

1.6.3 Shoreline Monitoring

Groundwater is a potential pathway for contaminants to enter the Columbia River. Groundwater flows into the river from seeps located above the water line and through areas of upwelling in the river bed. Hydrologists estimate that groundwater flows from the Hanford unconfined aquifer to the Columbia River at a rate of approximately 0.000012 m^3/s (0.00042 ft^3/s) (Section 4.1 in PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*). For comparison, the average flow of the Columbia River is approximately 3,400 m^3/s (120,000 ft^3/s), which means that every liter of groundwater flowing into the river is mixed with about 283 million L (74.8 million gal) of river water.

The rise and fall of the Columbia River creates a zone of interaction of surface water and groundwater. River stage varies over short (e.g., hourly) and long (e.g., seasonal) intervals in response to natural influences and the operation of dams on the Columbia River system. During high river-stage periods, the groundwater elevation increases in response to the change in boundary condition, and the gradient toward the river decreases. Transport of river water into the aquifer during high river stage can affect contaminant concentrations. As would be expected, longer-term changes in the river stage produce more extensive and longer-lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. These relationships are most evident in wells located closest to the Columbia River, although apparent relationships are also evident in water levels and sample data obtained from wells hundreds of meters inland of the shoreline.

High river stage during 2019 was from late April to the end of June (Figure 1-5). High river stage in 2019 had less impact on groundwater flow and contaminant concentrations than usual because the 2019 maximum was lower than a typical year (1.1 m [3.6 ft] lower than the average maximum for 2010 through 2019). The 2019 average river stage was also lower than a typical year. Low river stage in 2019 occurred from September through December, with the minimum in September and October.

DOE samples water near the Columbia River shoreline via near-shore monitoring wells, natural seeps, and aquifer tubes. Aquifer tubes are small-diameter, flexible tubes that are screened on one end. Most aquifer tube sites include two or three individual tubes monitoring at different depths, from about 1 to 8 m (3 to 26 ft) below ground surface (bgs). They are not constructed as resource protection wells (as specified in WAC 173-160) and are not currently used as compliance points for groundwater decisions. The aquifer tube sampling results for 2019 are included with groundwater results in Chapters 2 through 8 and Chapter 10 of this report.

Seeps represent groundwater leaving the aquifer in areas where the groundwater elevation remains higher than the river elevation for some period of time. DOE collects samples from seeps in the fall when the river stage is low. Table 1-7 lists the concentrations of contaminants of interest in seeps along each shoreline segment sampled in fall 2019. Results were consistent with previous years. The DWSs were exceeded for strontium-90 in a 100-N Area seep and tritium in a Hanford town site (200-PO) seep.

Table 1-6. Maximum Concentrations of Selected Constituents in Hanford Site Groundwater, 2019

Contaminant	Water Quality Standard[a]	Site Max	100-BC		100-FR		100-HR-D		100-HR-H		100-KR		100-NR		300-FF		1100-EM and Offsite	200-BP		200-PO		200-UP	200-ZP
			Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Wells
Radionuclides (pCi/L)																							
Carbon-14	2,000	42,600	—	—	—	—	—	—	—	—	42,600	398	485	54.8	—	—	—	129	—	34.8	—	43.6	—
Cesium-137	200	511	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	511	—	—	—	—	—
Gross alpha	15	86.9	—	—	—	—	3.08	—	8.7	—	16.5	2.07	8.73	—	41.7	12.0	—	30.4 X	—	55.5 X	5.24	28.8	50.0
Gross beta	50	27,900	—	—	—	—	5.75	—	642	—	2,190	13.0	27,900	4,320	18.7	6.81 A	—	13,800	16.8	3,520 X	55.4	614	3,350
Iodine-129	1	23.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7.14	—	12.2	—	23.7 Q	2.15
Plutonium-239/240	30	20.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20.9	—	—	—	—	—
Strontium-90	8	11,400	34.3	10.1	112	4.19	17.3	4.04	29	2.25 Q	1,230	5.32	11,400	2,080	—	—	—	337	—	11.9	—	37.1	—
Technetium-99	900	25,500	—	—	34.6	—	—	—	833	—	79	7.56	18.8	—	79.8	—	—	25,500	19.6	6,300	97.6	15,200	25,200
Tritium	20,000	4,240,000	9,860	7,910	3,050	—	5,690	2,090	1,220	—	405,000	6,830	326,000	109,000	251,000	3,690	—	28,700	—	4,240,000 N	20,300	222,000 N	58,100 O
Metals (µg/L)																							
Antimony (filtered)	6	17.5	—	—	—	—	0.71 BC	—	1.2 BC	—	17.5[b]	0.22 B	10.6 BCQ	2.2	4.9 BD	—	—	2.9 BCD	—	3.6 Q	—	9.65 B	4.37 BCQ
Antimony	6	104	—	—	—	—	0.94 BC	—	104[b] D	—	1.2 B	0.18	8.65 BC	1.2 B	4.8 BD	—	—	2.8	—	3.4 BD	—	10.2 B	8.66 BC
Arsenic (filtered)	10	160	—	—	5.8 BD	—	3.46 B	—	8.13 BC	—	10.1	3.59 B	20.7 Q	17.9	160 D	—	—	10.7 D	5	17.6 BC	—	23.3 BC	16
Arsenic	10	150	—	—	5.9 BD	—	3.55 B	—	64.5 D	—	9.88	3.44 B	20.6 Q	19.7	150 D	—	—	12.6 BC	5.19	14.6 BC	—	25.7 BC	17.2 B
Beryllium (filtered)	4	0.43	—	—	—	—	0.12 BC	—	0.27 B	—	—	—	—	0.23 B	0.2 BC	—	—	0.16 B	—	0.43 BQ	—	0.2 B	—
Beryllium	4	9.5	—	—	—	—	0.17	—	9.5[b]	—	0.08	—	0.22	0.096 B	0.15	—	—	0.81	—	1.3	—	0.13	0.12
Cadmium (filtered)	5	2.7	—	—	—	—	—	—	—	—	—	0.59 BCAQ	0.29	2.7 D	—	—	—	0.69	—	0.47	—	0.49	0.23
Cadmium	5	60.9	—	—	—	—	—	—	1.6 D	—	—	0.75 BCAQ	0.97 B	—	—	—	—	60.9	—	5.9 D	—	1.5 B	—
Chromium (filtered)	100	1,650	57	—	53.8 D	—	239	—	833	—	1,650 D	36.7 D	124	38.9 D	31.7[b] D	—	1.4 B	38.2 D	9 B	134	—	433 D	111
Chromium	100	1,400	59	—	104	—	251	—	882	—	1,400	36.5 D	129	19	45.2	—	18.7	100	9.8 B	352	—	438	576
Chromium (hexavalent)	48	1,700	63.1	43.2 XH	48.2	6.43 XH	263	14.5 XHQ	802	20.3 XH	1,700	36	118	2.87 BXH	—	—	—	26.1	8.73	159	4.63	463	175
Selenium (filtered)	50	94	—	—	4.3 BD	—	2.6 BD	—	2.1 B	—	2.5 BD	—	4.1 BD	2.8 BD	5.6 D	—	—	94	1.8 B	18	—	13.3	9.07
Selenium	50	96	—	—	3.9 BD	—	2.5 BD	—	26.3 D	—	2.8 BD		4 BD	2.28	5.6 D	—	—	96	2.0	19	—	15	8.31

Table 1-6. Maximum Concentrations of Selected Constituents in Hanford Site Groundwater, 2019

Contaminant	Water Quality Standard[a]	Site Max	100-BC		100-FR		100-HR-D		100-HR-H		100-KR		100-NR		300-FF		1100-EM and Offsite	200-BP		200-PO		200-UP	200-ZP
			Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Wells
Uranium	30	2,100	5.1	4.0	11.0	—	4.3 D	1.2	49	0.129 B	14.8	2.52	9.3	5.3 D	1,510	119	32.2	641	1.87	68	—	2,100	4.9
Anions																							
Cyanide (total) (µg/L)	—	1,680	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,000 D	—	5.2	—	29.3 NZHQ	1,680 D
Cyanide (free) (µg/L)	200	24.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8.76	—	—	—	2.45	24.5
Fluoride (mg/L)	4.0	9.1	0.373 B	—	0.912	0.279 B	0.432 B	0.083 BD	0.53	0.086 BD	0.684	0.332 B	1.1	0.661	1.7	0.411 B	1.6	1.8	0.362 B	9.05 D	0.243 B	0.779 BD	4.9
Nitrate (mg/L)	45	974	10.2	12.0	281 DXH	33.2 D	35 D	7.5 D	345 D	0.885 DZH	102 ZDH	66.4	319 ZDH	79.2 D	252 D	41 D	137	974 D	13	133 D	37	211 DXH	553 D
Nitrite (mg/L)	3.3	9.2	—	—	1.5	0.72 H	0.92 H	—	0.92	—	2.7[b] ZNDH	0.95 CQ	5.3 XH	1.1 Q	1.3 H	—	—	0.84 XH	—	9.2[b] NH	1.1 C	0.79 Q	4.6[b] DNZH
Volatile Organic Compounds (µg/L)																							
Carbon tetrachloride	5	1,830	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.83 J	—	—	—	408 D	1,830 D
cis-1,2-Dichloroethylene	70	169	—	—	—	—	—	—	—	—	—	—	—	—	169 DXH	—	—	—	—	—	—	—	—
Trichloroethene	5	33.1	4.6 J	—	20.1	—	—	—	—	—	7.6	2.1	—	—	1.57 J	—	—	2.03 JQ	—	0.52 JTQ	—	33.1 T	27 DJ

Notes:

Table lists the highest values for 2019 for each groundwater interest area, excluding data flagged as suspect ("Y"), under review ("F"), or rejected ("R"), and data from perched zones.

Blank cells (—) indicate not detected or not analyzed.

Yellow-shaded cells indicate that the contaminant exceeded the listed water quality standards.

a. Listed values are based on standards listed in Table 1-3. Specific cleanup levels may apply at individual groundwater operable units.

b. Value is out of trend and a request for data review was submitted after the data were downloaded for this report.

Laboratory and review qualifiers:

A	=	documentation discrepancy (e.g., chain of custody not fully filled out)	N	=	spike and/or spike duplicate recovery is outside control limits
B (inorganics, anions)	=	analyte was detected at less than the quantitation limit	O	=	associated laboratory control sample recovery is outside control limits
C (inorganics, Wetchem)	=	analyte was detected in both the sample and the quality control blank	Q	=	associated quality control sample is out of limits
D	=	analyte was reported at a secondary dilution factor	T (organics)	=	spike and/or spike duplicate sample recovery is outside control limits
H	=	laboratory holding time exceeded before the sample was analyzed	X or Z	=	miscellaneous circumstances exist; additional information available in database comment fields
J (organics)	=	estimated value; analyte was detected at less than the quantitation limit			

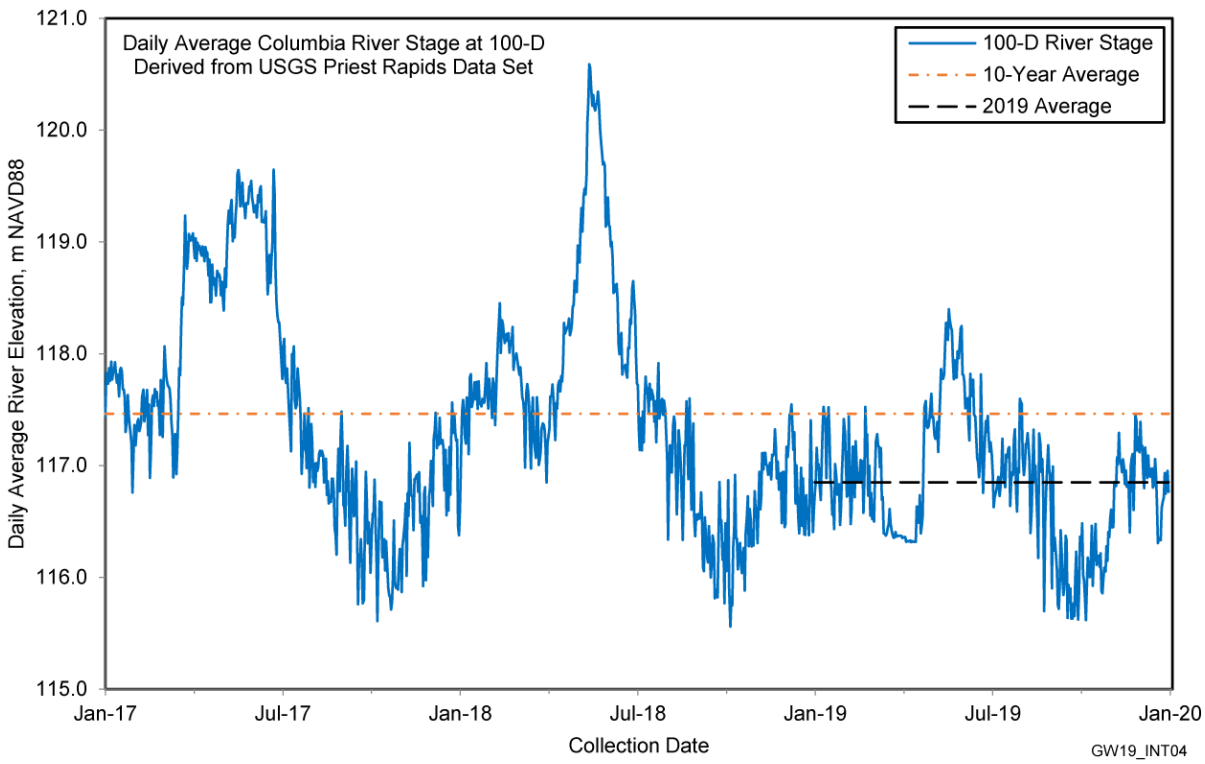


Figure 1-5. Daily Average River Stage at the 100-D Area

Table 1-7. Hanford Site Contaminants in Columbia River Seeps, 2019

Seep*	Sample Date	Chromium, Unfiltered/ Filtered (µg/L)	Hexavalent Chromium (µg/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	Tritium (pCi/L)	Uranium, Unfiltered/ Filtered (µg/L)
Water quality standard		100	10	45	8	20,000	30
B Seep 038-3	10/7/2019	6.16 B / 4.34 B	—	6.51	-0.00479 U	297	2.08 / 2.04
B Seep 039-2	9/30/2019	6.59 B / 8.32 B	—	3.02	1.17	802	1.04 / 1.17
D Seep 110-1	9/26/2019	3.0 U / 3.0 U	—	1.95	0.187	426	0.709 / 0.727
F Seep 207-1	10/24/2019	19.4 / 6.13 B	—	26.8 D	0.0206 U	252	6.22 / 4.85
F Seep 211-1	10/24/2019	6.36 B / 6.2 B	—	31.3 D	0.000501 U	242	4.77 / 4.8
H Seep 152-2	9/25/2019	5.02 B / 3.0 U	—	1.24	0.648	43.4 U	0.998 / 0.659
K Seep 063-1	10/2/2019	12.4 / 3.0 B	—	4.35	0.0568 U	142 U	2.58 / 0.325
K Seep 063-1	11/4/2019	2.1 B / 1.4 B	2.29 B	2.39 DZH	-0.166 U	176 U	0.45 / 0.33
K Seep 068-1	11/4/2019	0.89 B / 3.7 B	1.3 U	0.173 BDZH	1.37 U	-128 U	0.28 / 0.17

Table 1-7. Hanford Site Contaminants in Columbia River Seeps, 2019

Seep*	Sample Date	Chromium, Unfiltered/ Filtered (µg/L)	Hexavalent Chromium (µg/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	Tritium (pCi/L)	Uranium, Unfiltered/ Filtered (µg/L)
K Seep 082-2	11/5/2019	2.2 B / 2.3 B	2.03 BX	10.0	-0.38 UA	2,330	—
N Seep 8-13	10/2/2019	5.06 B / 4.67 B	—	26.4 D	-6.5E-04 U	3,670	0.908 / 0.842
N Seep 089-1	10/21/2019	3.0 U / 3.0 U	—	25.4 DX	55.2	1,060	0.53 / 0.432
300 Seep DR 42-2	10/10/2019	3.0 U / 3.0 U	—	18.9	—	2,300	27 / 22.7
		3.0 U / 3.0 U	—	20.1	—	2,350	26 / 21.1
300 Seep 42-2	10/8/2019	3.0 U / 3.0 U	—	1.46	—	1,040	13.9 / 13.6
HTS Seep 28-2	9/24/2019	3.0 U / 3.0 U	—	22.2 D	—	24,100	2.88 / 2.97
HTS Seep 25-4	10/8/2019	3.0 U / 3.0 U	—	7.44	0.0561 U	-36.5 U	2.04 / 1.86
K Seep 077-1	11/5/2019	3.0 U / 3.0 U	1.3 UXH	0.425 B	-0.43 U	-69.7 U	—
		3.0 U / 3.0 U	1.3 UXH	0.673 B	-0.0066 UA	-128 U	—

Note: Blank cells (—) indicate no data.

*Common names are listed. Seep designations in the Hanford Environmental Information System database vary.

Data qualifiers:

A = documentation discrepancy (e.g., chain of custody not fully filled out)
B = less than required detection limit but greater than method detection limit (inorganics)
D = analyte was reported at a secondary dilution factor
H = recommended holding time exceeded
U = less than detection limit
X, Z = specific translation of this qualifier is provided in the hardcopy data report or case narrative

DOE monitors Columbia River water by collecting samples along several cross-river transects and at near-shore river locations adjacent to groundwater plumes where humans and aquatic biota are potentially exposed to contaminants. The surveillance data provide a historical record of radionuclides and chemicals in the environment. The results of water quality monitoring along the shoreline and in the river are presented annually in the Hanford Site environmental report (e.g., DOE/RL-2019-33, *Hanford Annual Site Environmental Report for Calendar Year 2018*). Publication of the 2019 environmental report follows the publication of this groundwater report, so the 2018 results are summarized here. Table 1-8 lists the results of composite samples collected upstream and downstream of the Hanford Site.

The maximum tritium activity downstream of the Hanford Site (near the city of Richland) was 45 pCi/L compared to 21 pCi/L upstream of the Hanford Site. No other radionuclides were statistically higher in downstream samples in 2018. Chromium was undetected in river transect samples on the Hanford Site.

Table 1-8. Comparison of Contaminant Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site, 2018

Constituent	Upstream of Hanford Site (Priest Rapids Dam)			Downstream of Hanford Site (Richland)		
	Number of Samples	Number of Detections	Maximum Concentration (pCi/L)	Number of Samples	Number of Detections	Maximum Concentration (pCi/L)
Strontium-90	13	0	0.035 ±0.036	13	0	0.044 ±0.031
Technetium-99	13	0	1.5 ±1.0	13	2	1.1 ±0.57
Tritium	13	13	21 ±7.3	13	13	***45*** ±14
Uranium-234	13	13	0.44 ±0.087	13	13	0.41 ±0.080
Uranium-235	13	7	0.065 ±0.032	13	7	0.079 ±0.030
Uranium-238	13	13	0.29 ±0.059	13	13	0.30 ±0.82
Total of uranium isotopes	—	—	0.795	—	—	0.789

Reference: Tables C-5 and C-6 in DOE/RL-2019-32, *Hanford Annual Site Environmental Report for Calendar Year 2018*.

Notes:

Concentrations shown in bold/italic are higher downstream of the Hanford Site than upstream of the Hanford Site.

Blank cells (—) indicate no data.

1.7 Central Plateau

Four groundwater OUs, numerous source OUs, and one vadose zone OU are associated with the Central Plateau (Table 1-9). The groundwater OUs encompass groundwater contamination from the 200 East and 200 West Areas and regions where this contamination has migrated beyond the Central Plateau.

When the Hanford Site was operational, spent fuel reprocessing, isotope recovery operations, and associated waste management activities occurred in the 200 East and 200 West Areas. Each chemical processing facility generated multiple waste streams and used multiple locations for waste management and disposal. This resulted in a complex mixture of soil and groundwater contamination that complicates linking specific contaminant sources to specific groundwater contaminant plumes. Waste disposal was associated with the Plutonium-Uranium Extraction (PUREX) Plant, B Plant, and Hot Semiworks Facility in the 200 East Area; and the Reduction-Oxidation (REDOX) Plant, T Plant, U Plant, and Plutonium Finishing Plant (PFP) in the 200 West Area. Additional liquid waste and wastewater were released to ground from ancillary facilities such as the 200 East and 200 West Area steam plants, high-level waste evaporators, and waste-processing activities conducted in the single-shell tank (SST) farms.

The 200 Areas contain seven SST waste management areas (WMAs): A-AX, B-BX-BY, and C within the 200 East Area; and S-SX, T, TX-TY, and U within the 200 West Area. Leaks or overfill events associated with some of the WMAs have contaminated the vadose zone, and some of this contamination has migrated to groundwater.

Table 1-9. Central Plateau Groundwater and Source OUs

OU	OU Type	Description
200-UP-1	Groundwater	Groundwater contamination in the southern 200 West Area and surrounding 600 Area primarily originating from U Plant and REDOX Plant waste sites.
200-ZP-1	Groundwater	Groundwater contamination in the northern 200 West Area and surrounding 600 Area primarily originating from T Plant and Plutonium Finishing Plant waste sites.
200-BP-5	Groundwater	Groundwater contamination in the northern 200 East Area and surrounding 600 Area primarily originating from B Plant and the Hot Semiworks Facility.
200-PO-1	Groundwater	Groundwater contamination in the southern 200 East Area and surrounding 600 Area primarily originating from PUREX Plant.
200-DV-1	Vadose zone	Addresses selected waste sites with deep vadose zone contamination in the soil or perched water) posing a threat to groundwater quality and for which standard surface-based remedies are not practicable. It currently consists of waste sites in the vicinity of WMA B-BX-BY in the 200 East Area and WMA T, WMA TX-TY, and WMA S-SX in the 200 West Area, although other waste sites may be added in the future.
200-PW-1, 200-PW-3, and 200-PW-6; 200-CW-5	Source	Waste sites in the Inner Area contaminated primarily with plutonium and/or cesium.
200-WA-1 200-BC-1	Source	Majority of the waste sites in the 200 West Inner Area and the BC Cribs and Trenches.
200-EA-1; 200-IS-1	Source	Majority of the waste sites in the 200 East Inner Area and pipelines in the Inner Area.
200-SW-1	Source	Central landfill (nonradioactive).
200-SW-2	Source	Burial grounds and landfills located in the Inner Area.
200-CB-1	Source	B Plant canyon and associated waste sites.
200-CP-1	Source	PUREX Plant canyon and associated waste sites.
200-CR-1	Source	REDOX Plant canyon and associated waste sites.
200-CU-1	Source	U Plant canyon.
200-OA-1; 200-CW-1 and 200-CW-3	Source	Waste sites located in the Outer Area.

OU = operable unit
PUREX = Plutonium-Uranium Extraction (Plant)
REDOX = Reduction-Oxidation (Plant)
WMA = waste management area

DOE has finished remediating most of the River Corridor waste sites and is now shifting its focus to the Central Plateau. Groundwater and deep vadose zone remediation on the Central Plateau include the 200 West P&T, U Plant and S-SX extraction systems, a perched water removal action at the B Complex, and groundwater extraction in the 200-BP-5 OU.

1.7.1 Central Plateau Hydrogeology

The stratigraphic units beneath the Central Plateau consist of (in ascending sequence) bedrock of the Saddle Mountains Basalt, semiconsolidated sand and gravel of Ringold unit A, silt and clay of the Ringold lower mud unit, semiconsolidated sand and gravel of Ringold unit E, coarse- to fine-grained Cold Creek unit, and unconsolidated sand and gravel of the Hanford formation (Figure 1-6). Section 2.1 in DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010*, describes these units in detail. The unconfined aquifer is mostly within the Hanford formation and Ringold unit E. The low-permeability lower mud unit forms the base of the unconfined aquifer in most areas. The thickness of the unconfined aquifer varies within the Central Plateau, from >200 m (656 ft) southeast of the 200 East Area to zero where the aquifer pinches out against mud units and basalt above the water table. The depth to the water table is up to 106 m (348 ft) beneath the Central Plateau.

Groundwater beneath the Central Plateau flows generally from west to east, although local conditions may vary, particularly near groundwater extraction and injection wells. Natural recharge to the unconfined aquifer comes from upland areas in the west and infiltrating precipitation.

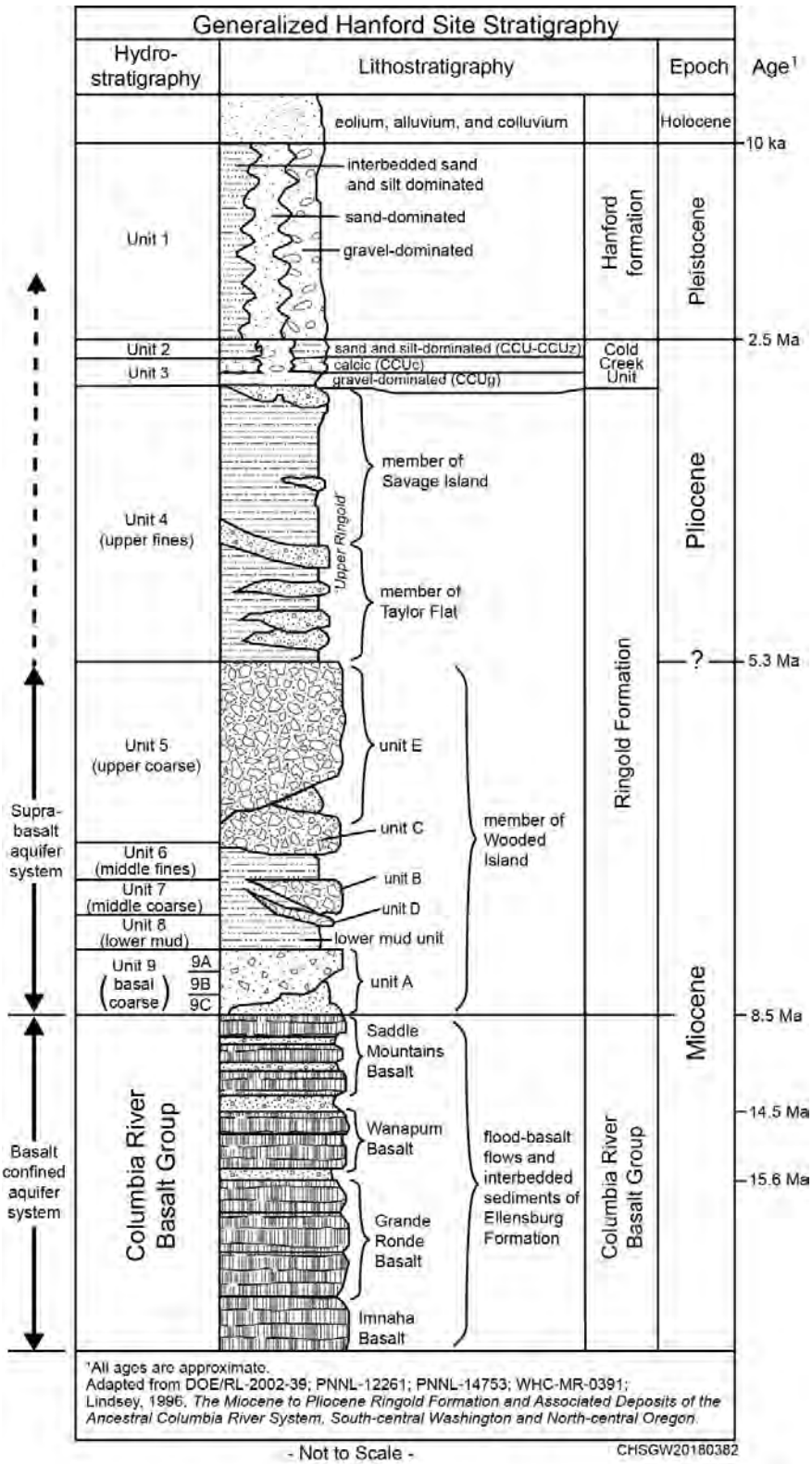
1.7.2 Central Plateau Groundwater Contamination

Central Plateau groundwater contaminants include tritium, iodine-129, nitrate, technetium-99, uranium, Cr(VI), cyanide, strontium-90, and carbon tetrachloride. Liquid effluent facilities such as cribs, ponds, and ditches were past sources of the most widespread contamination. In some areas, contaminants from cribs, ditches, and SSTs continue to form local groundwater plumes with increasing concentrations, indicating that contaminants continue to enter groundwater from the vadose zone. To minimize the probability of future SST leaks, all of the SSTs have been interim stabilized, with the pumpable liquid in each tank being transferred to double-shell tanks.

Table 1-6 lists the maximum concentrations of groundwater contaminants in the Central Plateau groundwater interest areas in 2019. The Executive Summary of this report provides a general plume map, and Chapters 9 through 12 provide details.

1.8 CERCLA 5-Year Review

Whenever contaminants remain in the environment above levels that would allow for unrestricted use, CERCLA regulations require the regulatory agency to conduct a review of the decision at least every 5 years. DOE issued the most recent report (DOE/RL-2016-01, *Hanford Site Fourth CERCLA Five-Year Review Report*) in 2017. The review covered the period from 2011 through 2015 and includes technical assessments of remedy implementation and performance for Hanford Site OUs engaged in cleanup in the River Corridor and on the Central Plateau.



Note: Complete reference citations are provided in Chapter 13.

Figure 1-6. Central Plateau Geology

1.9 Quality Control

Groundwater data quality is assessed and enhanced by a multifaceted quality assurance (QA)/quality control (QC) program. Appendix E presents a detailed description of the data usability assessment for 2019. This assessment evaluated routine groundwater samples collected during 2019 from wells, aquifer tubes, and seeps and is based on three QC components:

- Field QC samples consist of field blanks, sample replicates, and sample splits. Field blanks provide a measure of possible sample contamination during field sampling, transportation, and laboratory operations. Sample replicates (sent to the same laboratory) provide a measure of precision for field sampling and laboratory analysis. Sample splits (replicate samples sent to different laboratories) provide an interlaboratory comparison of analytical results.
- Laboratory QC samples consist of method blanks, sample duplicates, laboratory control samples/laboratory control sample duplicates, matrix spikes/matrix spike duplicates, and surrogates/surrogate duplicates. Method blanks provide a measure of possible sample contamination during laboratory analysis. Laboratory control samples, matrix spikes, and surrogates provide a measure of analytical accuracy. The various duplicate samples provide a measure of analytical precision.
- Laboratory performance measures consist of groundwater monitoring program blind standards and commercial performance evaluation samples. Both the blind standards and performance evaluation samples provide a measure of laboratory analytical accuracy and bias; the blind standards also provide a measure of laboratory analytical precision.

Based on the results of the 2019 data usability assessment, sample results appear to accurately represent target analyte concentrations in Hanford Site groundwater, and the analytical data are sufficient in quantity and quality to be usable for the groundwater monitoring program. Overall, 95.8% of the 2019 results have no identified quality issues, which exceeds the groundwater monitoring requirement of 85% data usability (Section 8.3.1 in DOE/RL-91-50, *Hanford Site Environmental Monitoring Plan*).

1.10 Sources of Additional Information

All of the groundwater data presented in this report are available via the internet through the DOE EDA available at https://ehs.hanford.gov/eda/.

The documents referenced in this report are generally available at the DOE Public Reading Rooms at locations around Washington State. Most documents are also available online as part of the Administrative Record at http://pdw.hanford.gov/arpir/ or other online libraries. Requests for documents can also be made through interlibrary loan directly to DOE. References to documents in this report are provided as a direct electronic link when possible. If reports are not accessible through the internet, the document number (if applicable) and full title are provided.

Other reports and databases relating to Hanford Site groundwater are cited or summarized in this report as needed, including the following:

- The HEIS database is used to store groundwater chemistry data and other environmental data (e.g., soil and surface water chemistry, soil physical properties, and survey data for the Hanford Site). HEIS data are available through the DOE EDA at https://ehs.hanford.gov/eda/.
- Previous Hanford Site groundwater monitoring reports are accessible at the following location: http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports.

- Hanford Site environmental reports present the results of monitoring, including groundwater, riverbank seeps, river water, sediment, air, and biota. The reports also describe environmental management performance and report the status of compliance with environmental regulations. These reports are available through the Mission Support Alliance (MSA) website at http://msa.hanford.gov/page.cfm/EnviroReports.
- Tank monitoring and groundwater data, and other information are available from the Pacific Northwest National Laboratory (PNNL) Hanford Online Environmental Information Exchange (PHOENIX) dashboard available at http://phoenix.pnnl.gov/.
- Groundwater remediation reports describe the progress of groundwater remediation systems at the Hanford Site. The annual reports discuss the removal and treatment efficiencies during the year, as well as any operational issues for the groundwater remediation systems. Previous groundwater remediation reports are accessible at the following location: http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports.

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 the 100-BC Area. 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, *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 maps but were not used for plume development due to their transient nature. Section 1.5 provides plume mapping details, including descriptions of terms (e.g., Type 1 control point) used in the figure legends.

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) (Chapter 8 in DOE/RL-2010-96). Figure 2-2 shows the change in estimated plume areas in the upper portion of the unconfined aquifer since 2003. The TCE contamination exceeds the proposed groundwater cleanup level in 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 Hanford formation sediments. The lower portion of the unconfined aquifer and the entire aquifer near the Columbia River are 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 referred to as the RUM (Chapter 3 in DOE/RL-2010-96). Water-bearing units within the RUM are not contaminated in 100-BC.

Figure 2-4 illustrates the water table contours based on data collected in March 2019 when the river stage was near average for the year. In northern 100-BC, groundwater flowed to the north, discharging to the Columbia River. In southern 100-BC, 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 southern 100-BC is interpreted to be to the northeast based on water-level data and movement of the Cr(VI) plume (Section 3.6.3 in DOE/RL-2010-96).

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 at a Glance

Reactor operations: B Reactor, 1944 to 1968; C Reactor: 1952 to 1969				
Groundwater Monitoring				
Contaminant, Water Quality Standard	**Year**	**Maximum Concentration (Well)**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Hexavalent chromium, 48 µg/L/10 µg/L[b]	2019	63.1 (199-B3-47)	0.05 / 1.1	0 / 1,938
	2018	57.0 (199-B3-47)	0.06 / 1.0	0 / 1,947
Strontium-90, 8 pCi/L	2019	34.3 (199-B3-52)	0.51	357
	2018	61.8 (199-B3-52)	0.55	552
Trichloroethene, 4 µg/L	2019	4.60 (199-B5-11)	Not calculated[c]	Not calculated[c]
	2018	6.19 (199-B5-11)		
Tritium, 20,000 pCi/L	2019	9,860 (199-B3-52)	0	0
	2018	8,840 (199-B5-2)	0	0
Remediation				
Waste sites: 93% complete.[d] **Groundwater:** No interim actions. Record of Decision for final remedial action is anticipated in 2020.				

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

b. 48 µg/L in the upland area (WAC 173-340, "Model Toxics Control Act—Cleanup") and 10 µg/L where groundwater discharges to surface water (WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances").

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, 2019.

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

Estimates of average linear groundwater velocity 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*).

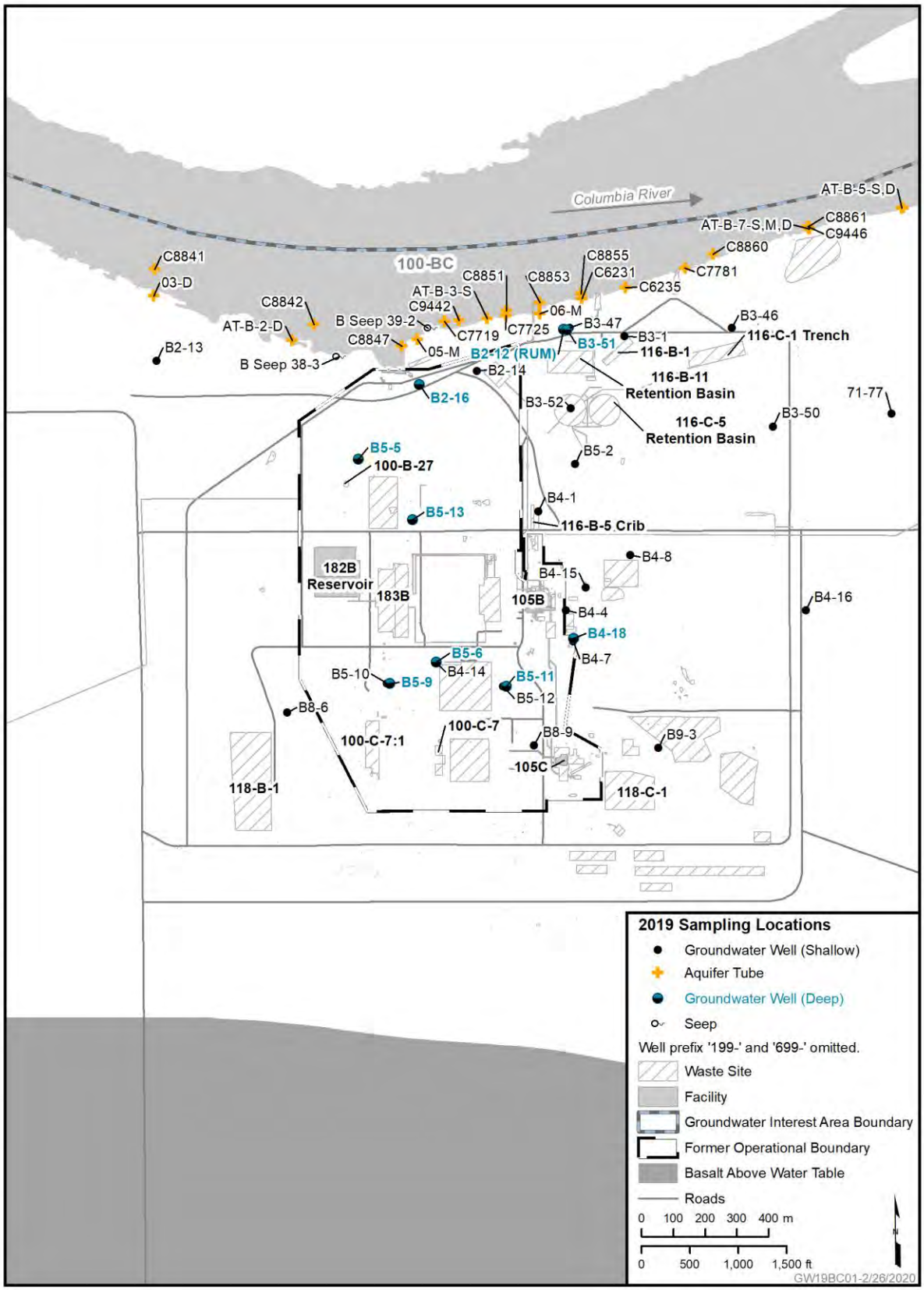


Figure 2-1. 100-BC Sampling Locations, 2019

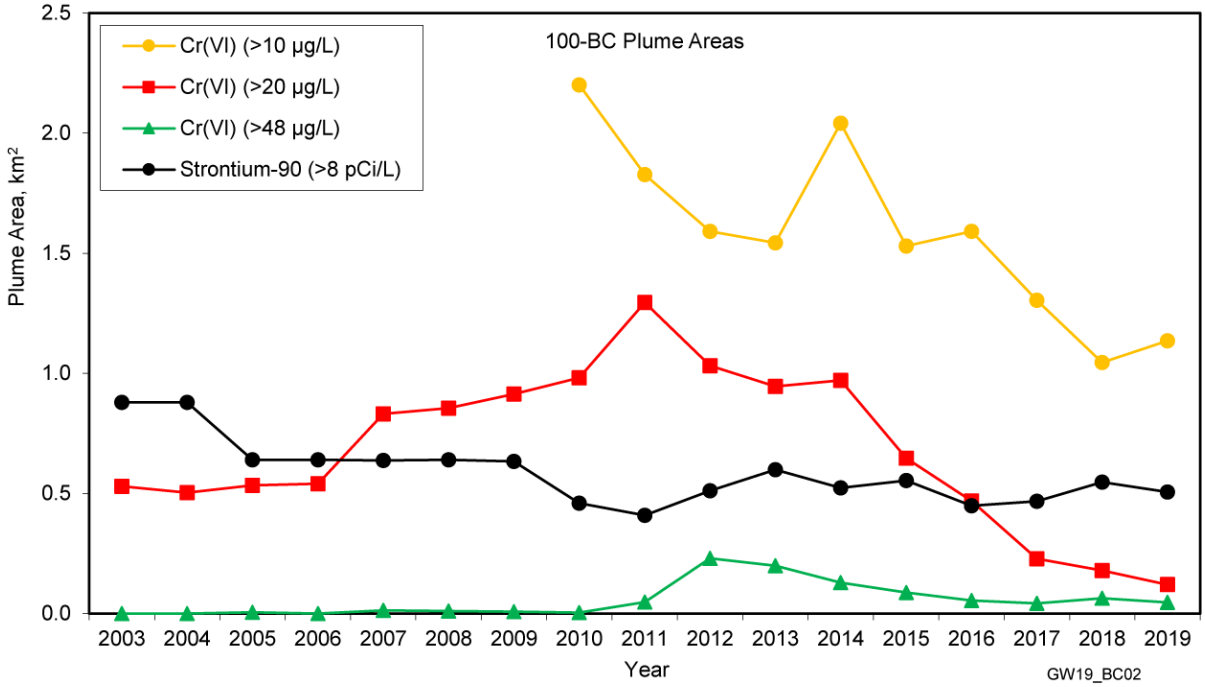


Figure 2-2. 100-BC Plume Areas

2.2 Hexavalent Chromium

Former 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 sodium dichromate spills at the 100-C-7 and 100-C-7:1 waste sites in southern 100-BC and the 100-B-27 sodium dichromate spill waste site in the northwest.

In the 100-BC groundwater interest area, Cr(VI) is present in a broad plume at concentrations above the surface water standard but only exceeds the MTCA groundwater standard in one well. Separate plumes are present in the upper and lower parts of the aquifer (Figure 2-5).

With few exceptions, Cr(VI) concentrations continued to decline gradually in 2019, with trends illustrating plume migration and attenuation (Figure 2-6). Well 199-B4-14 is located in southern 100-BC, near the former Cr(VI) source at the 100-C-7:1 waste site (remediated in 2011 and 2012). The Cr(VI) peak in 2012 was caused by waste site remediation activities. The subsequent lower peaks are related to seasonal variations in vertical groundwater flow. The annual average concentration was <10 µg/L in 2018 and 2019. The increase and decrease of concentrations in downgradient wells 199-B4-7 (central 100-BC) and 199-B5-2 (farther north) illustrate downgradient passage of the 100-C-7:1 contaminant plume.

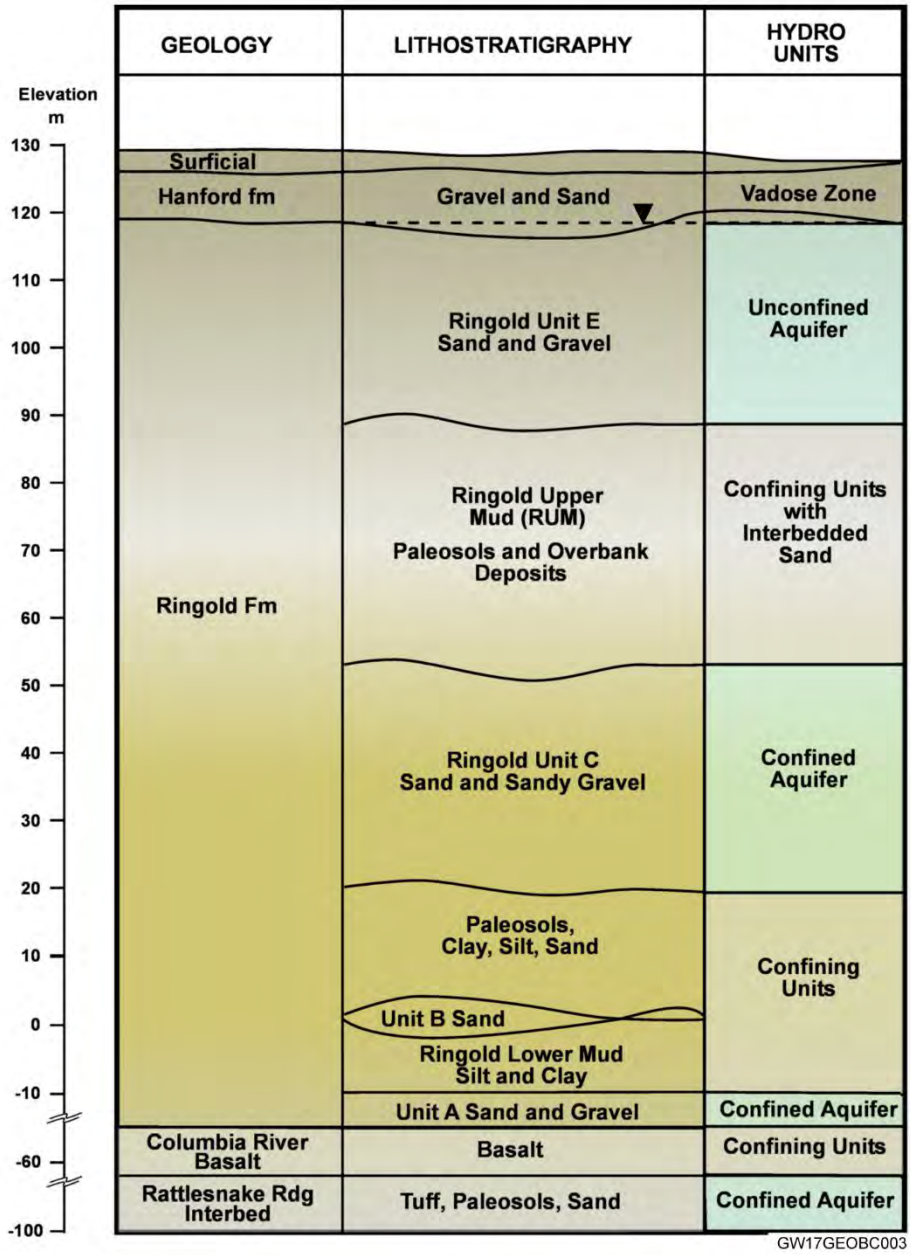
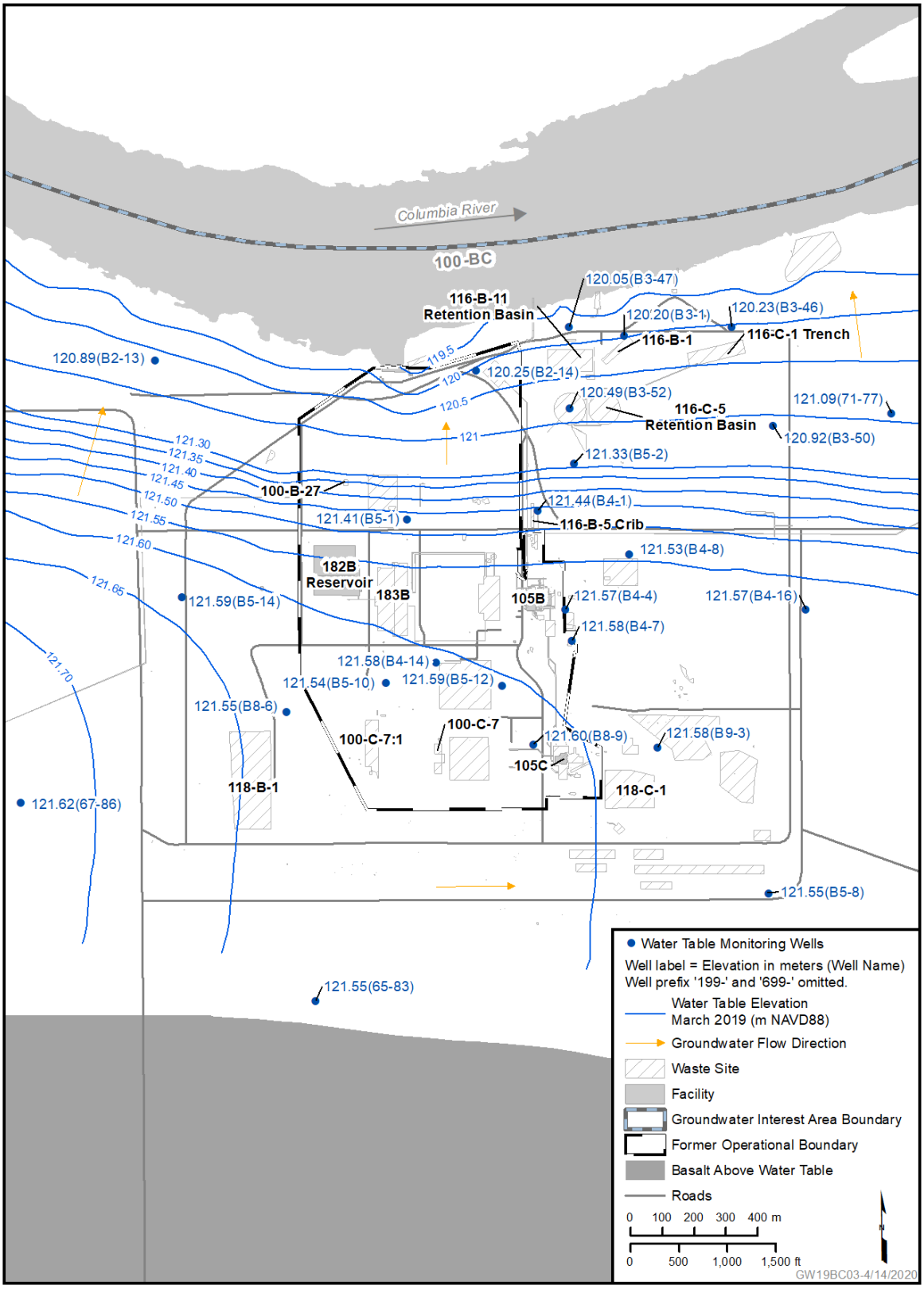


Figure 2-3. 100-BC Geology



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 2-4. 100-BC Water Table, March 2019

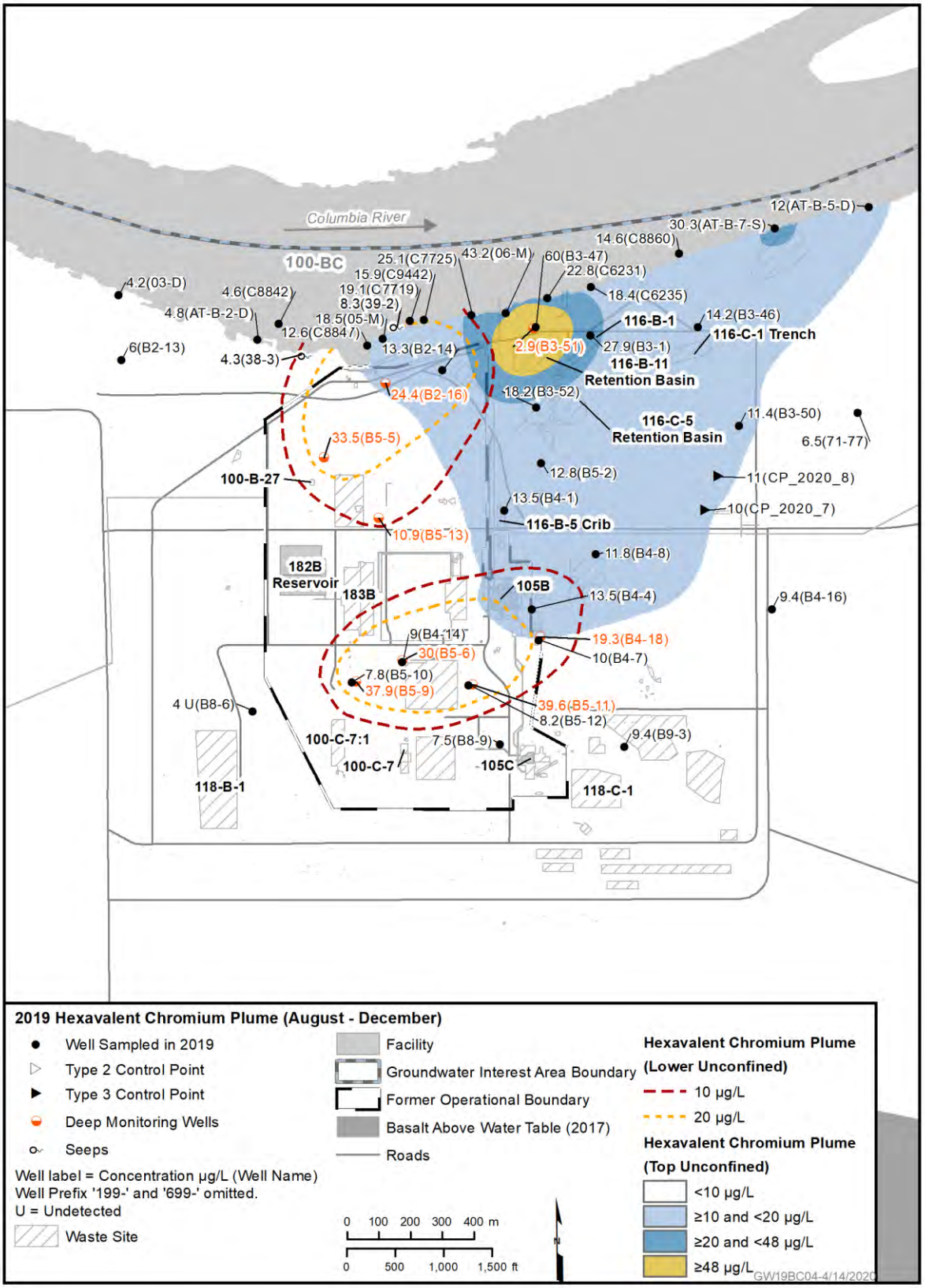


Figure 2-5. 100-BC Cr(VI) Plumes in Upper and Lower Parts of the Unconfined Aquifer, Fall 2019

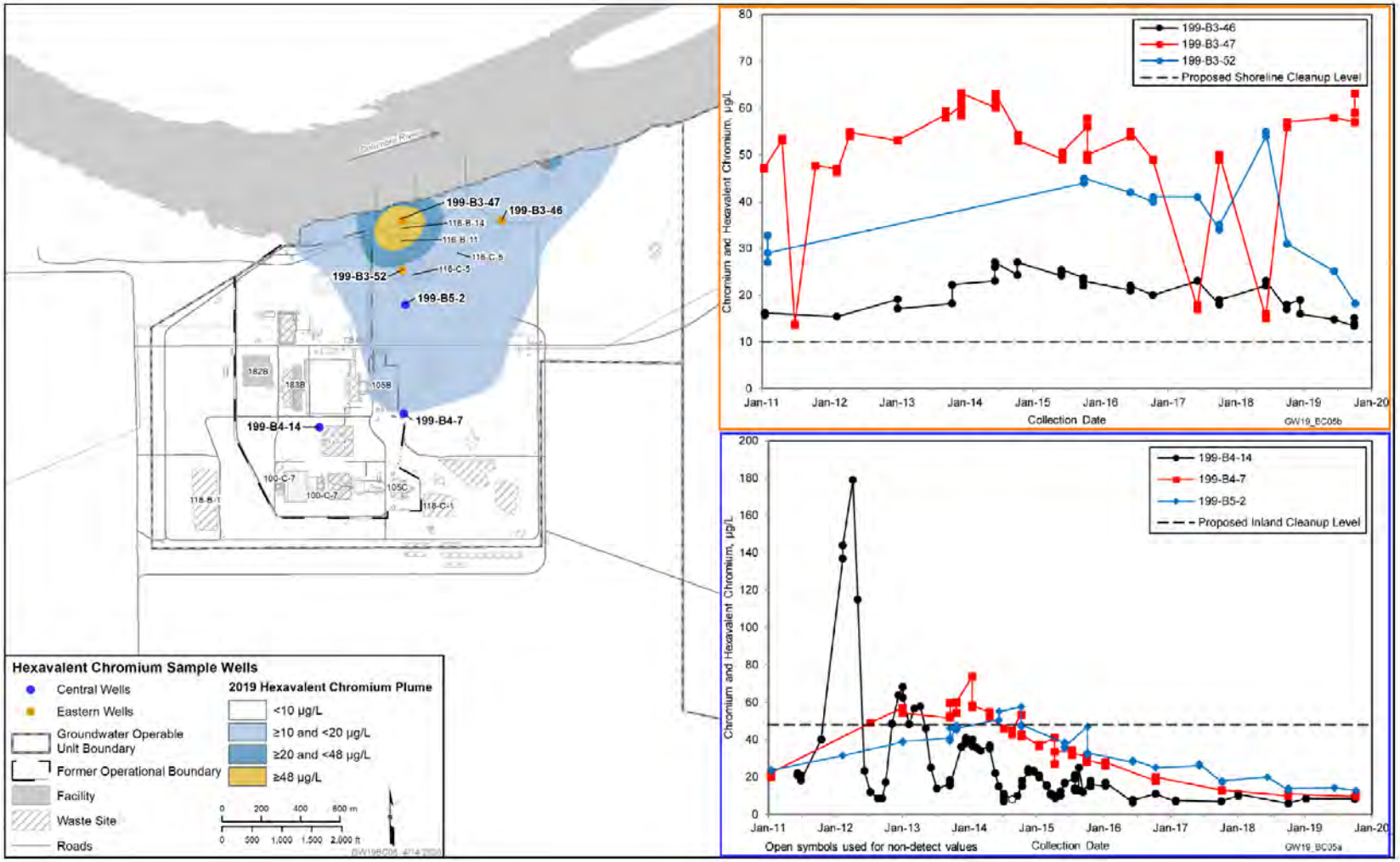


Figure 2-6. 100-BC Cr(VI) Data in Selected Wells

The Cr(VI) concentrations are not declining in some wells, most notably 199-B3-47, near the Colombia River where the unconfined aquifer is entirely within Ringold unit E. With a 2019 maximum of 63.1 µg/L, well 199-B3-47 had the only Cr(VI) concentration above the 48 µg/L groundwater standard (Figure 2-6). When the river stage was high in 2017 and 2018, concentrations in the well decline sharply as river water mixes with the groundwater. The river did not rise as high in 2019, and a mixing effect was not observed. The persistent concentrations in well 199-B3-47 may indicate the presence of residual contamination in the vadose zone near the well. Cr(VI) concentrations in other wells in northern 100-BC decreased in 2019 (e.g., wells 199-B3-46 and 199-B3-52) (Figure 2-6).

The Cr(VI) concentrations exceed the surface water standard in groundwater approaching the Columbia River but not in river water. The highest concentrations in 100-BC aquifer tubes are typically in 06-M, located near the center of the plume (43.2 µg/L in 2019). When previously sampled, water from the river had Cr(VI) concentrations below the surface water standard (Chapter 4 in DOE/RL-2010-96).

As discussed in Section 2.2 of DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*, a local Cr(VI) hot spot was identified in the hyporheic zone in eastern 100-BC in hyporheic sampling point[1] (HSP) C8861 in October 2018. Follow-up sampling of C8861 and other HSPs and aquifer tubes was conducted in December 2018 and quarterly in 2019. Hyporheic zone Cr(VI) concentrations declined in C8861 and did not increase in nearby aquifer tubes and HSPs (Figure 2-7).

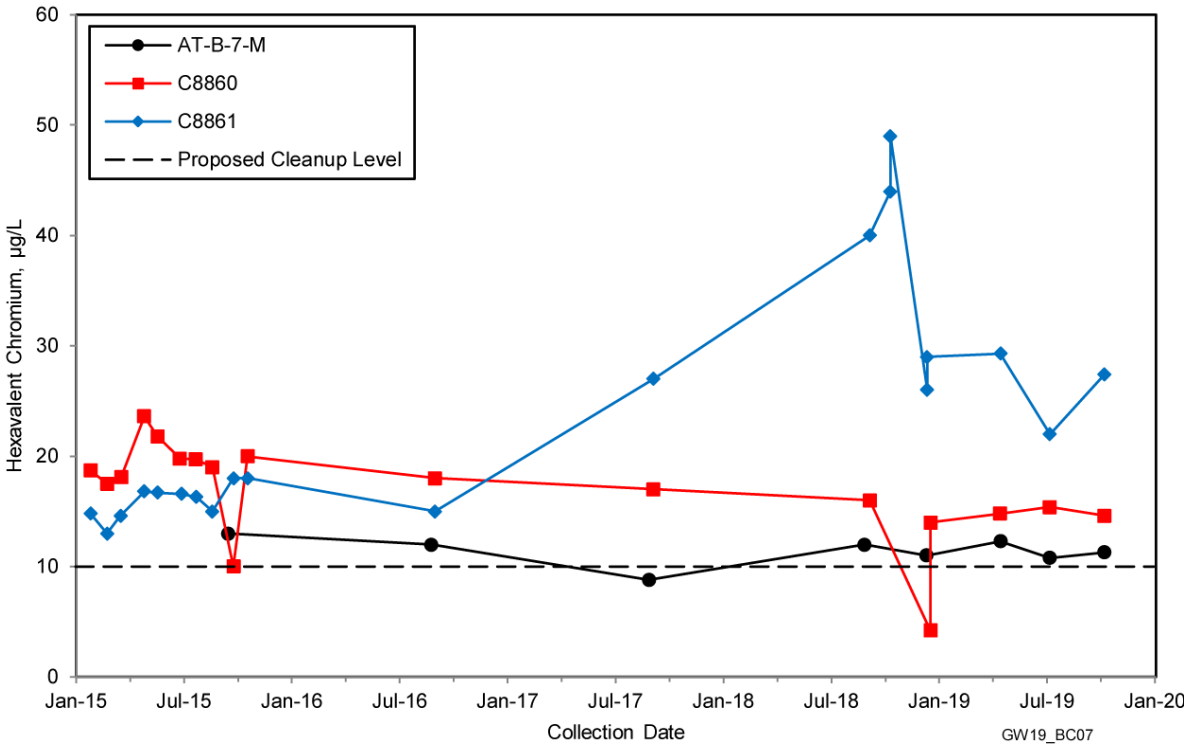


Figure 2-7. 100-BC Cr(VI) Data in HSPs and Aquifer Tubes Near C8861

[1] HSPs are dedicated sampling points installed in the riverbed, screened at depths of 0.5 m (1.5 ft) or less.

The dashed lines shown in Figure 2-5 illustrate the Cr(VI) plumes in the lower part of the aquifer in Ringold unit E. Concentrations are gradually declining or stable in the deep wells (Figure 2-8). The highest concentration in 2019 was 42.3 µg/L in well 199-B5-11, similar to 2018 (44 µg/L). The vertical distribution of Cr(VI) in the western 100-BC is attributed to contaminant releases at different times under different vertical gradients.

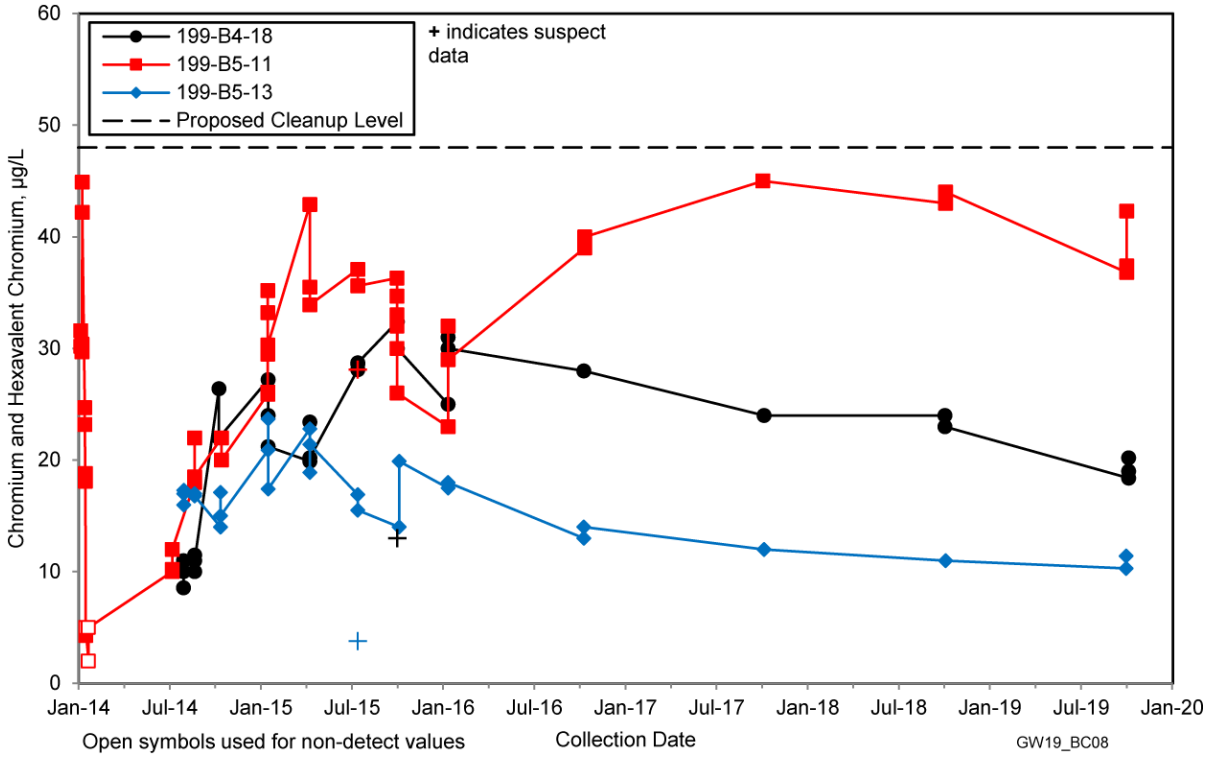


Figure 2-8. 100-BC Cr(VI) in Wells Screened in the Lower Part of the Unconfined Aquifer

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 northeastern 100-BC. Figure 2-9 shows the strontium-90 plume based on 2019 data; there was no notable change from 2018.

Strontium-90 contamination in 100-BC groundwater is limited to the upper portion of the unconfined aquifer, as indicated by characterization sampling of boreholes drilled in the past and routine sampling of deep well 199-B3-51 during previous years (Section 4.3.3 in DOE/RL-2010-96). The deep wells are no longer sampled for strontium-90.

The highest strontium-90 concentrations in 2019 were detected in well 199-B3-52 (in the former 116-C-5 Retention Basins waste site), well 199-B3-46 (near the 116-C-1 Trench), and well 199-B3-1 (near the 116-B-1 Trench) (Figure 2-10). The decline in concentrations since 2000 in some wells is less than expected based on radioactive decay, which may indicate residual strontium-90 in the lower vadose zone (Section 4.3.3 in DOE/RL-2010-96). However, concentrations do not increase notably when the water table rises, suggesting that the amount of contamination is limited.

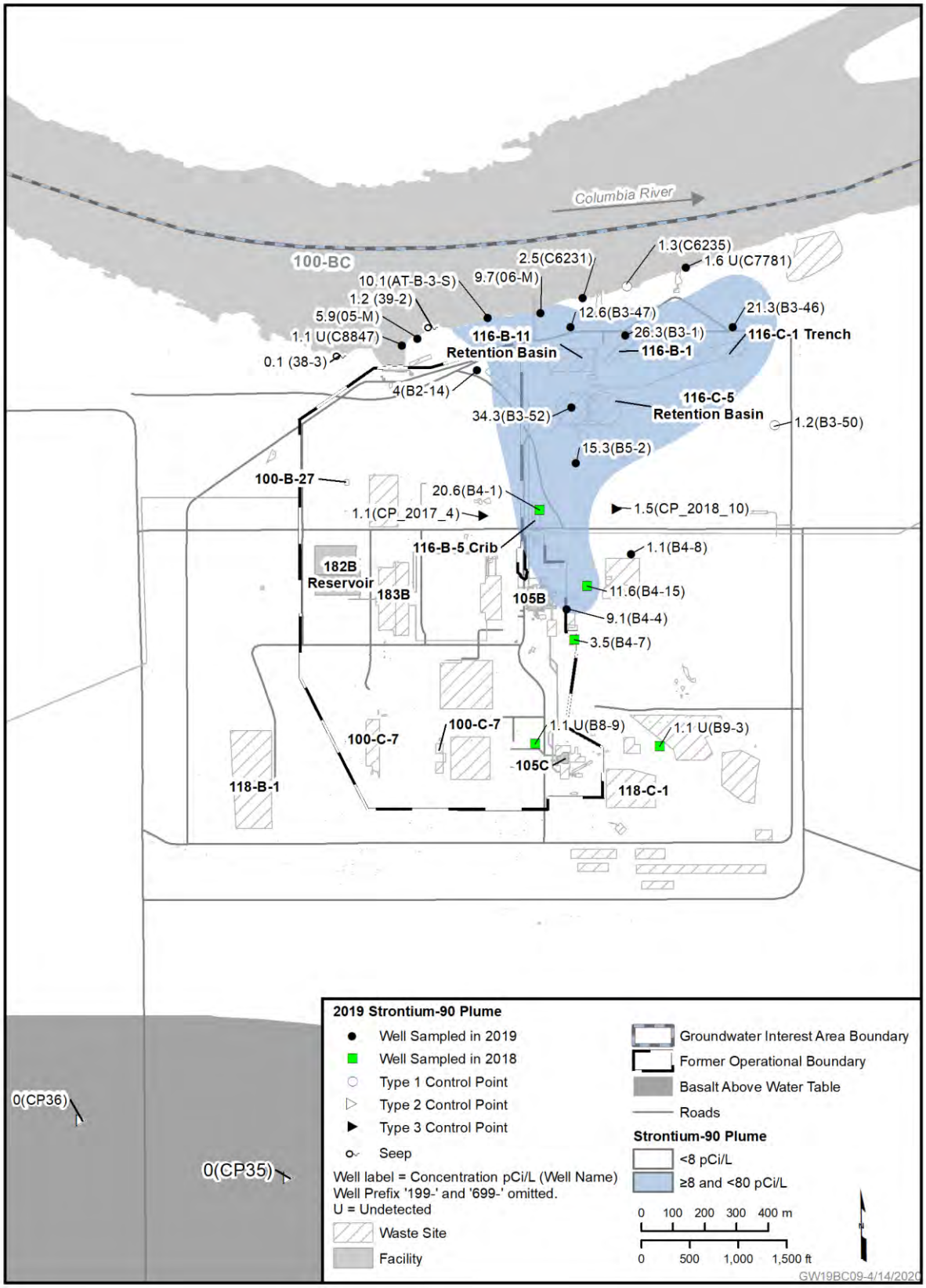


Figure 2-9. 100-BC Strontium-90 Plume, 2019

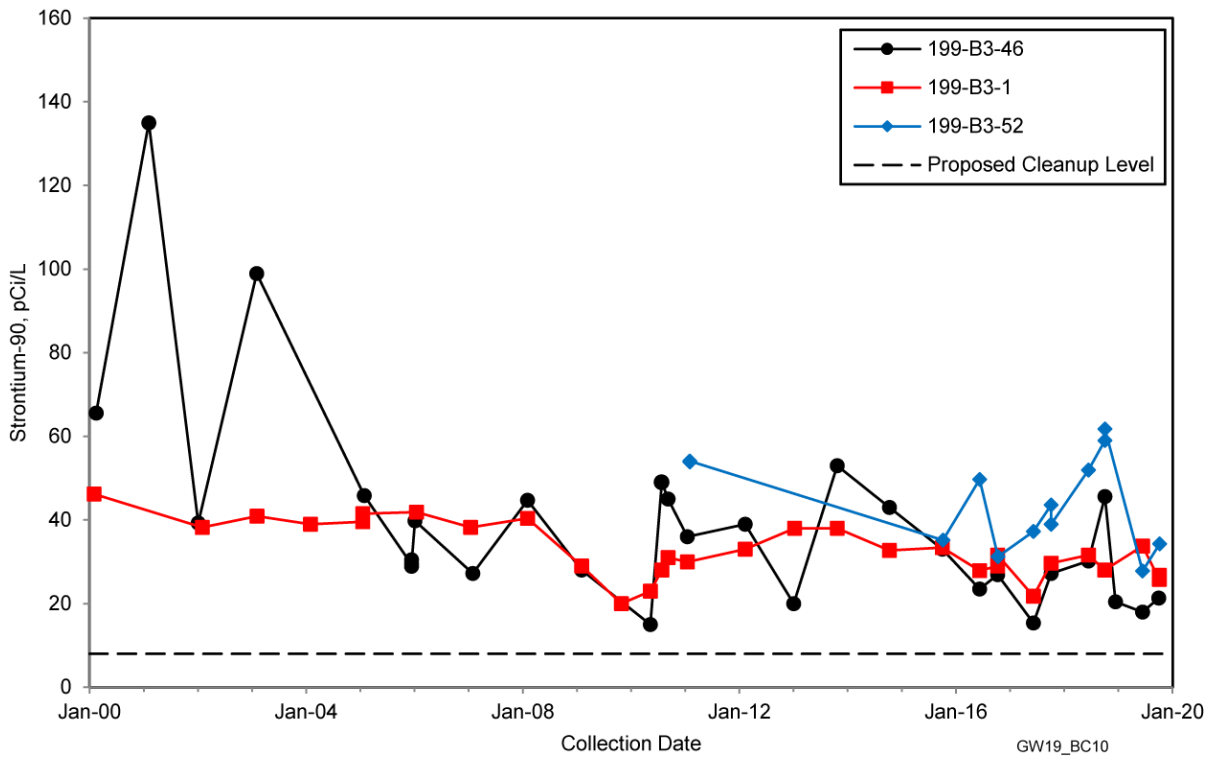


Figure 2-10. 100-BC Strontium-90 Data in Selected Wells

Strontium-90 concentrations in several 100-BC aquifer tubes continued to exceed the DWS in 2019 (Figure 2-9), with a maximum of 10.1 pCi/L in tube AT-B-3-S. 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 continued to be below detection limits in 100-BC HSPs in 2019.

2.4 Tritium

Tritium was present in effluent discharged to former cribs near B Reactor and the Columbia River. The former 118-B-1 Burial Ground in 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 in DOE/RL-2010-96).

Tritium concentrations in 100-BC monitoring wells and aquifer tubes have been below the 20,000 pCi/L proposed cleanup level since 2013 and continued to decline in 2019. The highest concentration was 9,860 pCi/L in well 199-B3-52, located in northern 100-BC. Near the 118-B-1 Burial Ground, a potential source of tritium, the concentration in well 199-B8-6 was 932 µg/L.

2.5 Trichloroethene

TCE continued to be detected in groundwater samples from some wells screened in the lower part of the unconfined aquifer. The contamination source is unknown. Its presence in the lower part of the aquifer suggests that the TCE is related to older releases during operational periods when the hydraulic gradient was downward. Only well 199-B5-11 had concentrations above the 4 µg/L proposed cleanup level (Figure 2-11) in 2019 (at 4.6 µg/L).

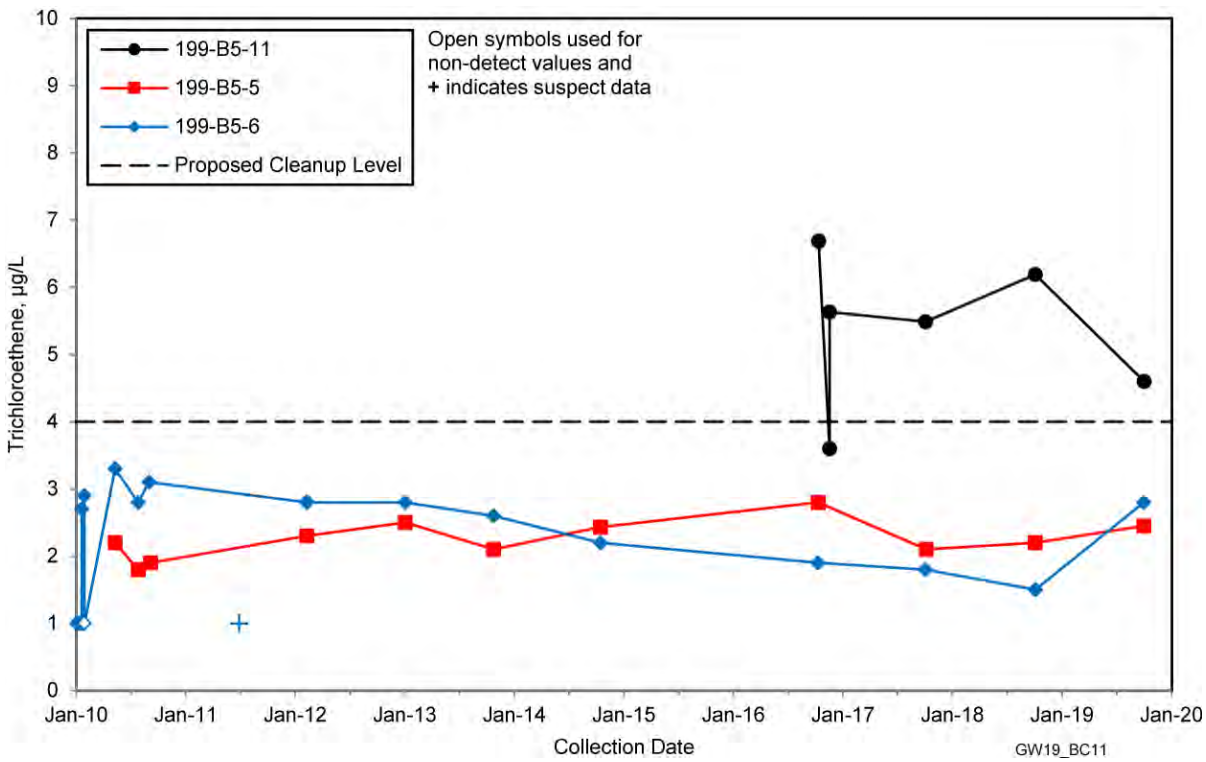


Figure 2-11. 100-BC TCE Data in Selected Deep Wells

2.6 CERCLA Remediation and Monitoring

In 2019, CERCLA activities for 100-BC included routine groundwater monitoring and continued progress on documents supporting a ROD for cleanup.

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. The SAP was designed to meet sampling objectives during the period of time after the conclusion of RI studies and until a groundwater remediation method is selected under an upcoming ROD and implemented through a remedial design/remedial action work plan (RD/RAWP). Wells and aquifer tubes were sampled successfully in 2019 (Table A-1 in Appendix A).

In 2019, DOE released an RI/feasibility study (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 and EPA will respond to public comments on the proposed plan, and develop a ROD. The proposed remedy for 100-BC-5 OU groundwater is monitored natural attenuation.

2.7 Atomic Energy Act Monitoring

AEA groundwater monitoring was conducted at 22 groundwater wells and aquifer tubes in 100-BC in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 100-BC are strontium-90 and tritium. Wells and aquifer tubes in 100-BC were sampled in accordance with SAP requirements in 2019.

Radionuclide concentrations detected in groundwater samples from 19[2] 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 (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 eight locations in 100-BC (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 that restrict access to groundwater. CERCLA remedial actions will provide longer-term protection of the public and the environment.

Table 2-2. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-BC in 2019

Monitoring Location/ Well Name	Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum
06-M	6.44	6.44
199-B3-1	15.12	18.49
199-B3-46	9.00	11.54
199-B3-47	7.73	12.26
199-B3-52	13.90	19.12
199-B4-4	5.43	5.43
199-B5-2	9.12	9.12
AT-B-3-S	5.05	5.05

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

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.

[2] 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, 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, F 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 for 100-FR is 100% complete.

A CERCLA ROD issued in September 2014 includes groundwater in the 100-FR-3 OU (EPA and DOE, 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 groundwater remedy is MNA, and six new CERCLA monitoring wells were installed in 2019 (Table 3-2). Nitrate, TCE, Cr(VI), and strontium-90 are monitored as groundwater COCs throughout the 100-FR-3 OU.

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 the unit is interpreted to exist in the southwestern 100-F Area[3] and smaller remnants in the central and eastern 100-F Area. In two locations, Ringold unit E extends above the water table and comprises the entire aquifer thickness. New wells and boreholes drilled in 2019 provided additional geologic data (Table 3-2). Geologic data from the new wells will be incorporated into future geologic maps and groundwater models.

The RUM forms the base of the unconfined aquifer in most of 100-FR. In two regions south of 100-F Area, the RUM extends above the regional water table and the unconfined aquifer is absent (Figure 3-4). Chapter 2 in SGW-61298, *Evaluation of 100-FR-3 Groundwater Monitoring Results from Phase 1 Wells*, provides a geologic map and cross sections. In 2019, geologic data from well 699-60-27 showed that the RUM is not present in the southernmost part of the interest area. The shallowest silt and clay unit in that well is at a depth of 79.9 m (262 ft) and is interpreted as the Ringold Formation lower mud unit. The unconfined aquifer at this location is about 31 m (103 ft) thick.

Except in the southernmost part of 100-FR, the unconfined aquifer ranges from 0 to 8 m (0 to 26 ft) thick. Most of the 100-FR monitoring wells are screened across all (or nearly all) of the aquifer. Contamination has not been detected in two wells that are screened in water-bearing units of the RUM, and the two wells are no longer sampled.

Figure 3-4 shows the water table in 100-FR in March 2019, when the Columbia River was at a moderate stage. In the 100-F Area, groundwater flowed generally to the east-northeast. Farther south, groundwater flow was controlled by the areas where the RUM is above the water table, and flows generally to the south-southeast.

[3] This chapter uses “100-F Area” to refer to the former operational area. The term “100-FR” indicates the larger groundwater interest area and “100-FR-3” indicates the CERCLA groundwater OU.

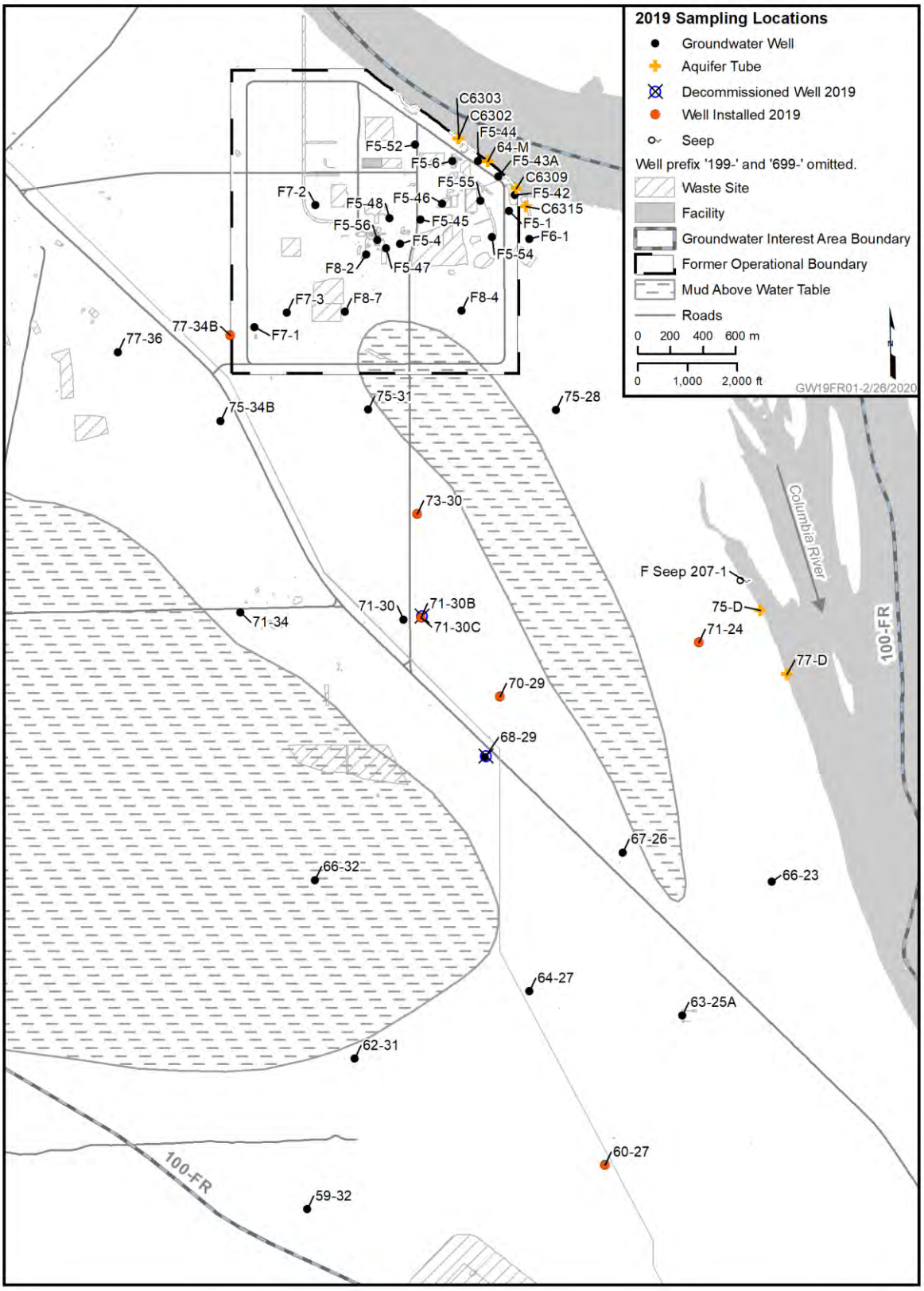


Figure 3-1. 100-FR Sampling Locations, 2019

Table 3-1. 100-FR at a Glance

F Reactor operations: 1945 to 1965 **Biological experiments:** 1945 to 1976				
Groundwater Monitoring				
Contaminants of Concern, Cleanup Level[a]	**Year**	**Maximum Concentration (Well)**	**Plume Area[b] (km^2)**	**Shoreline Impact (m)**
Nitrate, 45 mg/L	2019	281 (699-71-34)	7.8	0
	2018	304 (199-F5-56)	8.2	0
Hexavalent chromium, 48 µg/L[c]/10 µg/L[c]	2019	48.2 (199-F5-46)	0.01 / 0.14[d]	0 / 137
	2018	58 (199-F5-45)	0 / 0.29[d]	0 / 92
Strontium-90, 8 pCi/L	2019	112 (199-F5-55)	0.12	0
	2018	135 (199-F5-55)	0.15	0
Trichloroethene, 4 µg/L	2019	20.1 (699-77-34B)	2.5	0
	2018	15 (699-75-34B)	0.93	0
Remediation				
Waste sites in the 100-FR-1 and 100-FR-2 Operable Units: 100% complete.[e] Record of Decision for final remedial action was signed in 2014, with monitored natural attenuation for groundwater.				

a. From EPA and DOE, 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.*

b. Estimated area at a concentration greater than the listed cleanup level.

c. 48 µg/L in the upland area (WAC 173-340, "Model Toxics Control Act—Cleanup") and 10 µg/L where groundwater discharges to surface water (WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances").

d. Plume area >10 µg/L in the 100-F Area and near the Columbia River. Wells in other parts of the 100-FR are not included because the 10 µg/L standard does not apply to inland areas.

e. Sites with status of closed, interim closed, final closed, no action, not accepted, or rejected as of December 31, 2019.

Table 3-2. Wells Drilled in 100-FR in 2019

Well Name	Well ID	Purpose*	Drill Depth (ft)	Drill Depth (m)	Construction Depth (ft)	Construction Depth (m)	Accepted or Decommissioned Date	Comments
699-60-27	C9874	Monitoring	152.2	46.4	68.7	20.9	8/20/2019	
699-68-29	C9873	Monitoring	37.7	11.5	0.0	0.0	8/5/2019	No aquifer present; borehole was decommissioned and 699-70-29 was drilled and constructed instead.
699-70-29	C9985	Monitoring	49.0	14.9	39.5	12.0	8/20/2019	
699-71-24	C9872	Monitoring	58.7	17.9	47.3	14.4	8/20/2019	
699-71-30B	C9876	Monitoring	51.4	15.7	0.0	0.0	8/7/2019	Construction unsuccessful. Well was decommissioned and replaced by 699-71-30C.
699-71-30C	D0130	Monitoring	43.4	13.2	36.3	11.1	8/20/2019	
699-73-30	C9875	Monitoring	40.5	12.3	31.4	9.6	8/20/2019	
699-77-34B	C9877	Monitoring	40.0	12.2	24.5	7.5	8/20/2019	

Reference: SGW-63998, *Borehole Summary Report for the Installation of Six Wells and Two Boreholes in the 100-FR-3 Operable Unit, FY2019.*

*Phase 2 wells in Appendix A of DOE/RL-2014-44-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater*, as modified by TPA-CN-708, TPA-CN-0736, TPA-CN-0814, and TPA-CN-0874.

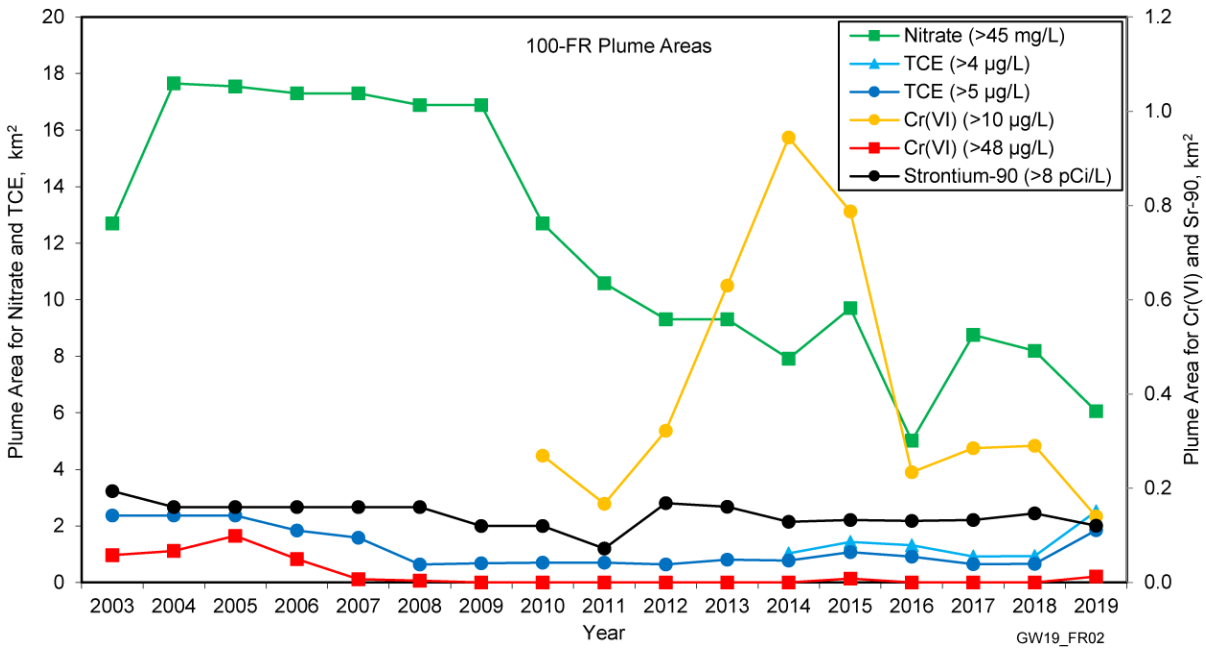


Figure 3-2. 100-FR Plume Areas

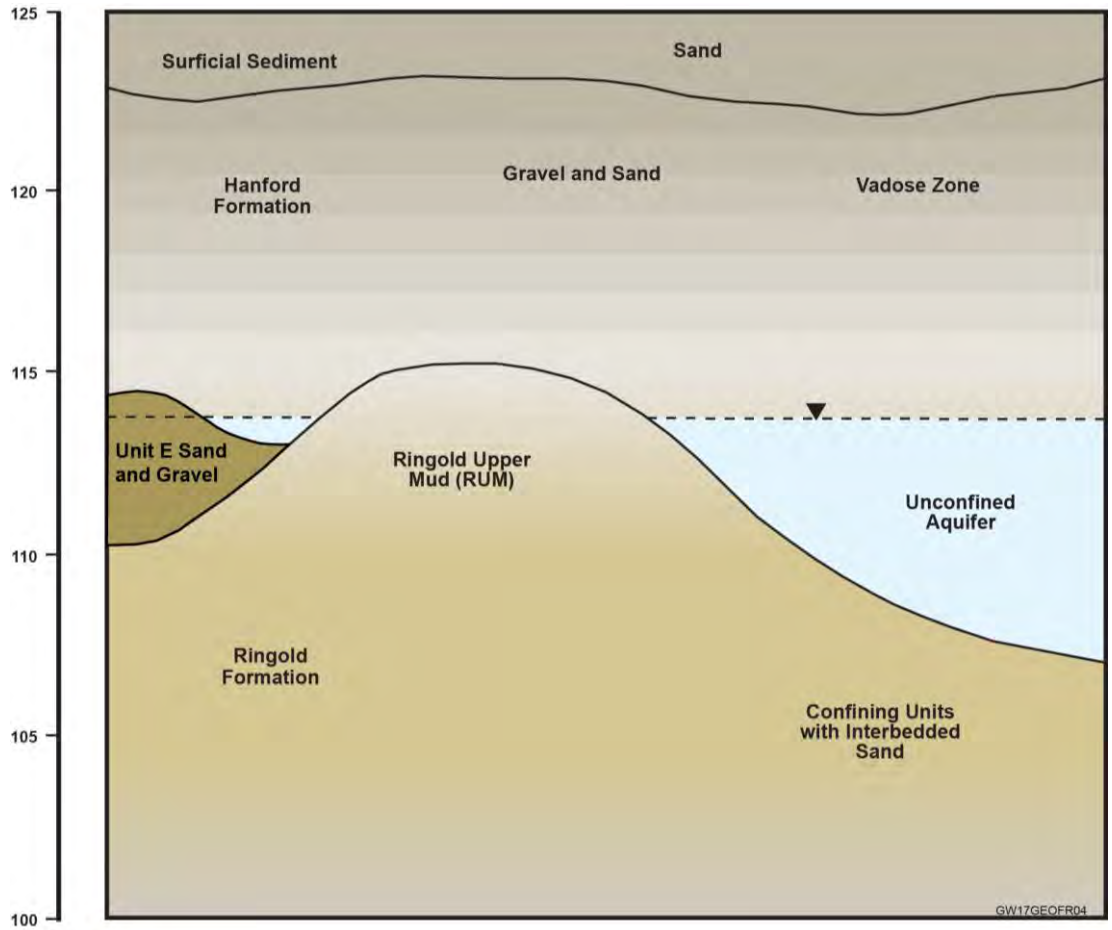
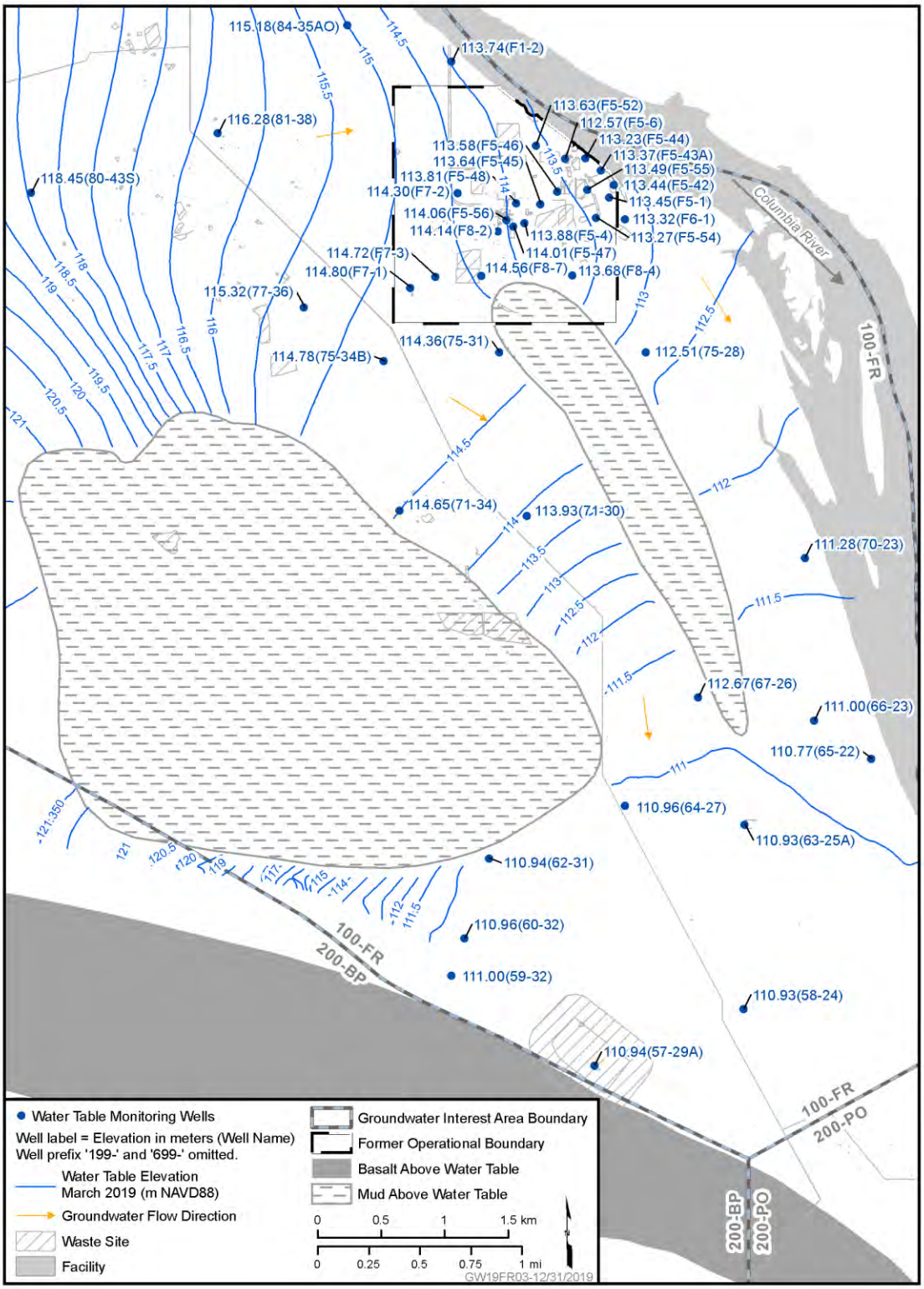


Figure 3-3. 100-FR Geology



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 3-4. 100-FR Water Table, March 2019

3.2 Nitrate

A large nitrate plume with concentrations above the 45 mg/L cleanup level extends from the 100-F Area to the south (Figure 3-5). Past sources of nitrate contamination included the experimental animal farm (e.g., 116-F-9 animal leach trench and 118-F-6 Burial Ground) and various septic tanks and leach fields located throughout the 100-F Area. These sites have been remediated. Pre-Hanford Site agriculture is another apparent source of nitrate contamination, especially in the southern part of 100-FR (Section 6.1 in SGW-61298).

The interpretation of 100-FR nitrate contamination changed between 2018 and 2019 as follows:

- The southern portion of the plume was narrower in 2019 based on data from new well 699-70-29, along with persistently low concentrations in well 699-67-26 (installed in 2016).
- New well 699-71-24 identified an area of contamination at concentrations above the cleanup level east of the RUM ridge.
- New well 699-60-27 delimited the southern extent of the plume.
- A 2019 grab sample of water from the RUM in borehole 699-68-29 showed nitrate concentrations above the cleanup level.

In the central 100-F Area, nitrate concentrations in well 199-F5-56 showed peaks in 2017 and 2018 and then declined to more typical levels in 2019 (Figure 3-6). The increases coincided with periods when the water table increased, which may suggest the presence of residual contamination in the lower vadose zone. Concentrations in nearby wells (e.g., 199-F5-4, 199-F5-46, and 199-F5-47) remained near previous ranges. Well 199-F5-56 was originally drilled in 2011 as a characterization borehole through the 118-F-8 fuel storage basin waste site to assess the nature and extent of contamination in the vadose zone around the F Reactor structure.

In the southwestern 100-F Area, nitrate concentrations decreased in 2019 after temporarily increasing in 2018. Well 199-F8-7 provides the most notable example of these variations (Figure 3-7). The 2018 increase may have been related to a higher water table, but the relationship is not clear.

The highest nitrate concentration in 100-FR in 2019 was 281 mg/L in well 699-71-34, located about 1.5 km (0.93 mi) south of the 100-F Area (Figure 3-8). Concentrations are much lower in surrounding wells 699-71-30, 699-71-30C, and 699-75-34B. There are no waste sites near well 699-71-34 that are likely nitrate sources, but pre-Hanford Site agriculture was active throughout the area. The initial increase in 2017 occurred during a period of greater-than-normal recharge to the aquifer (Section 3.2 in SGW-61298).

Concentrations of nitrate below the cleanup level in wells 699-70-29 and 699-67-26 changed the interpretation of the nitrate plume in the south part of 100-FR (Figures 3-5 and 3-9). Type 3 control points (judgmental data) were added to infer a connection between the southern and northern parts of the plume, consistent with previous interpretations.

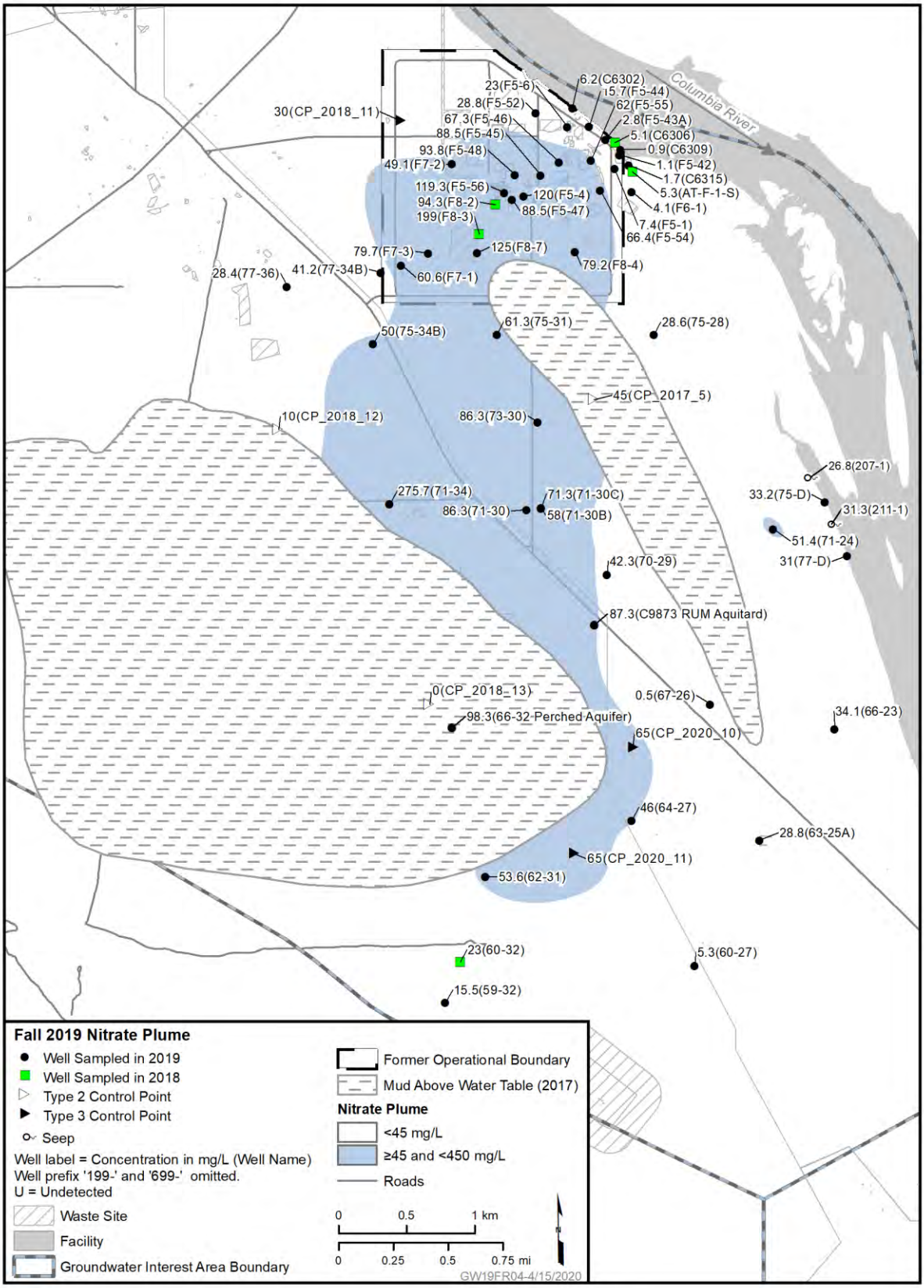


Figure 3-5. 100-FR Nitrate Plume, Fall 2019

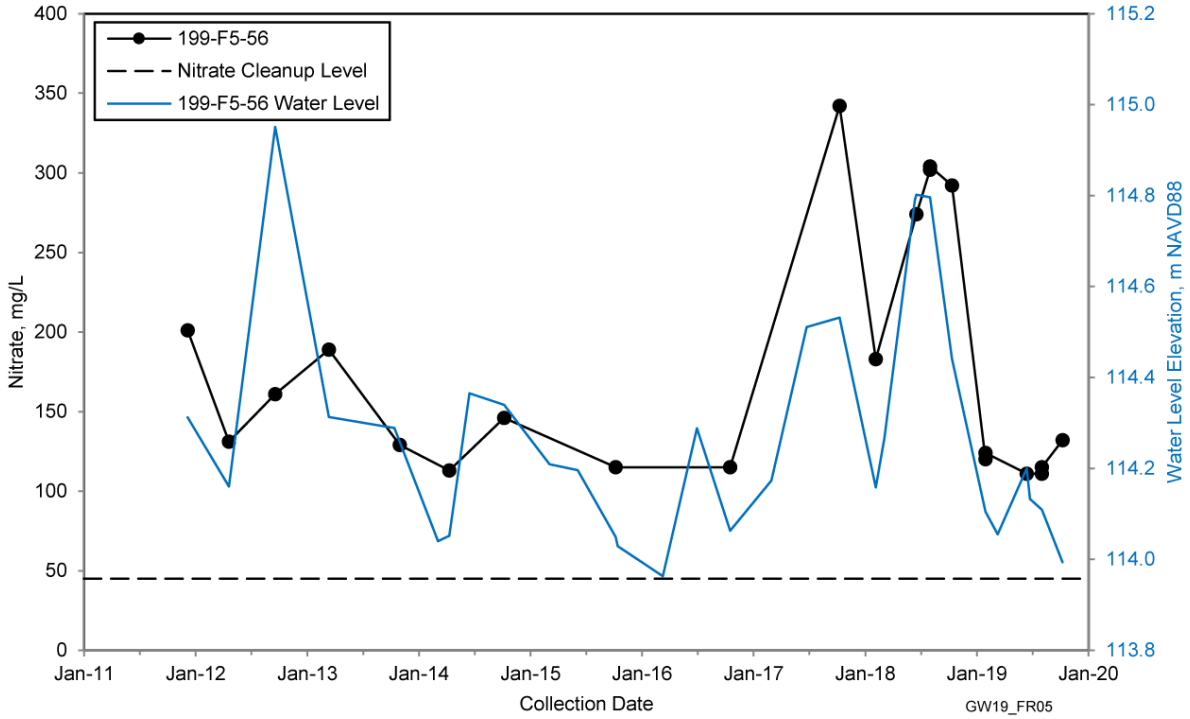


Figure 3-6. 100-FR Nitrate and Water Level Data for Well 199-F5-56 in Central 100-F Area

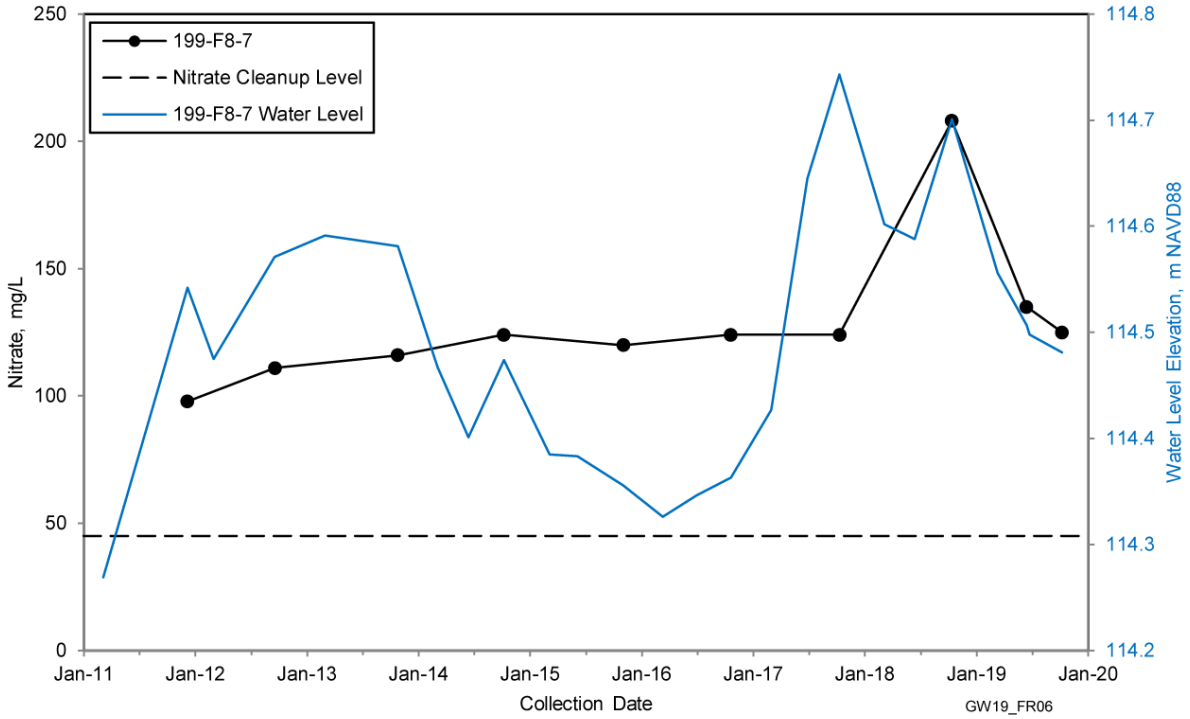


Figure 3-7. 100-FR Nitrate and Water Level Data for Well 199-F8-7 in Southwestern 100-F Area

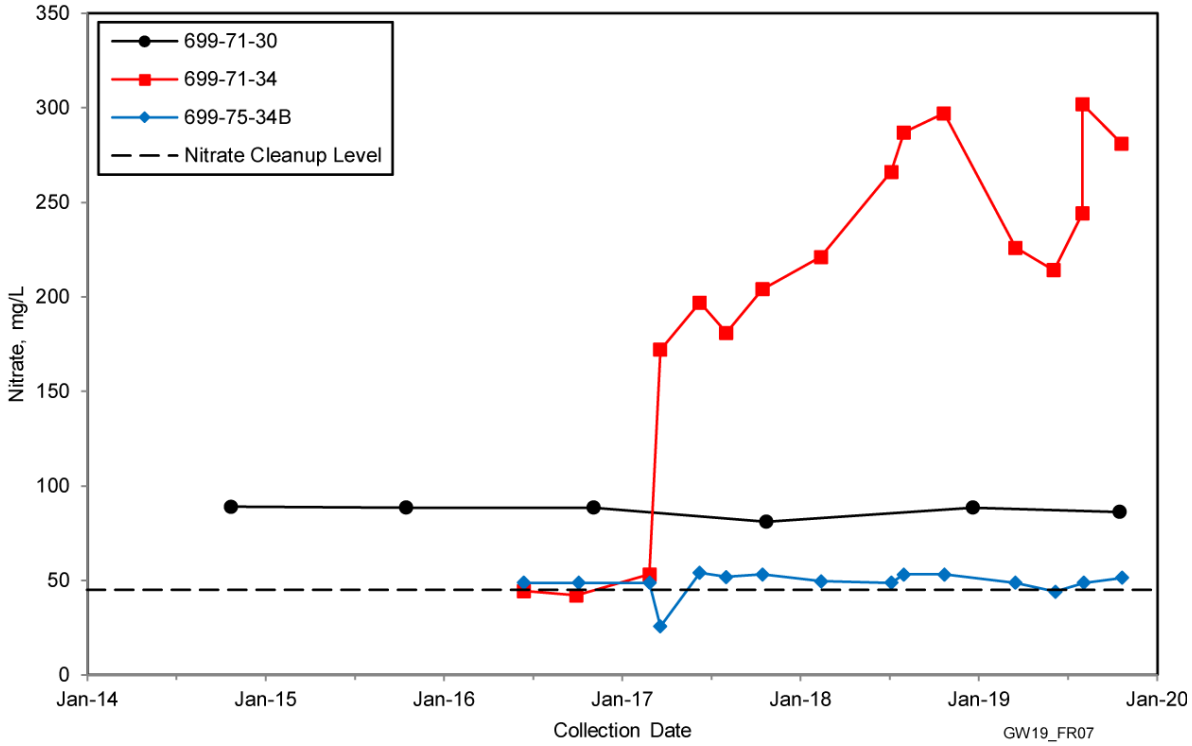


Figure 3-8. 100-FR Nitrate Data in Wells 699-71-30, 699-71-34, and 699-75-34B, South of 100-F Area

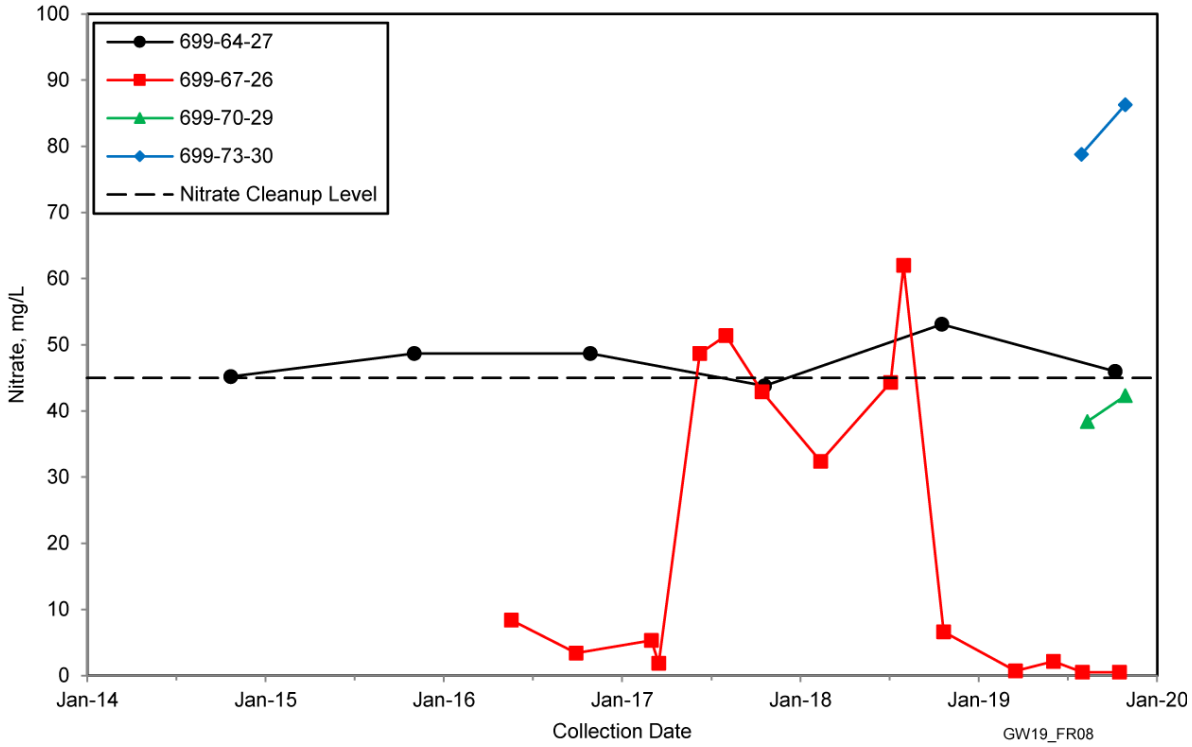


Figure 3-9. 100-FR Nitrate Data in Wells Located in the Southern 100-FR

In well 699-67-26, located about 3 km (2 mi) south of the 100-F Area, nitrate concentrations have ranged over three orders of magnitude since 2016 (Figure 3-9). The concentration in October 2019 was 0.52 mg/L, which was much lower than in nearby wells and atypical for unconfined groundwater on the Hanford Site. Higher concentrations of nitrate in well 699-67-26 in 2017 and 2018 directly correlated with specific conductance and water levels. A possible explanation for the variability is that nitrate in the lower vadose zone enters groundwater when the water table rises. There are no Hanford Site waste sites near the well, but pre-Hanford Site agriculture was active throughout the area.

New well 699-71-24 identified a small area of contamination at concentrations above the cleanup level east of the RUM ridge (Figure 3-5). This plume is delimited on the west by the RUM and on the east by data from aquifer tubes. Nitrate concentrations are low in other wells near the Columbia River in 100-FR. The water in wells nearest the river in the 100-F Area has low specific conductance (160 to 250 µS/cm), indicating the influence of inflowing river water, even during periods of low river stage. The highest nitrate concentrations in aquifer tubes have historically been detected in tube 75-D, which is 2 km (1.2 mi) downstream from the 100-F Area. Concentrations ranged from 25 to 36 mg/L between 2011 and 2019.

The definition of the southern extent of the plume improved in 2019 with the installation of well 699-60-27 (Figure 3-5). The concentration in October was 5.3 mg/L.

Borehole 699-68-29 was drilled in 2019 with the intention of installing a monitoring well, but the RUM (silt and clay) was encountered above the water table at that location (Figure 3-1). The borehole was drilled 3 m (10 ft) into the RUM. Over time, some water seeped into the borehole from the silt, and a sample was bailed. The nitrate concentration was 83.7 mg/L. The borehole was decommissioned because no unconfined aquifer was present, and well 699-70-29 was installed as a replacement.

Well 699-66-32, located >3 km (2 mi) south of the 100-F Area, monitors perched groundwater that is not connected to the unconfined aquifer. The nitrate concentration increased from 58.4 to 98.3 mg/L between 2017 and 2019. The well also has sulfate above the secondary DWS (375 mg/L in 2019). This contamination is attributed to agricultural sources present in the region before the Hanford Site was established (Section 4.4 in SGW-61298).

3.3 Trichloroethene

TCE concentrations exceed the 4 µg/L cleanup level in several wells in 100-FR (Figure 3-10). Process knowledge of the former 600-127 waste site, located just west of the 100-F Area, suggests that it may have contributed to the TCE plume. This site has been remediated, removing source material from the vadose zone.

In 2019, the western and southern extent of the plume increased from 2018 as follows:

- The concentration in well 699-77-36 increased above the cleanup level for the first time since 2016, causing the western boundary of the plume to expand.
- The TCE concentration in new well 699-71-30C, located 1.5 km (0.9 mi) south of the 100-F Area, was above the cleanup level. This well will replace well 699-71-30, which has a long, open interval extending through the unconfined aquifer into the RUM and has increasing TCE concentrations (Figure 3-11). TCE was detected at concentrations below the cleanup level in well 699-73-30 to the north and was undetected in well 699-71-34 to the west. Type 3 control points (judgmental data) were added to infer a connection between well 699-71-30C and the main plume.

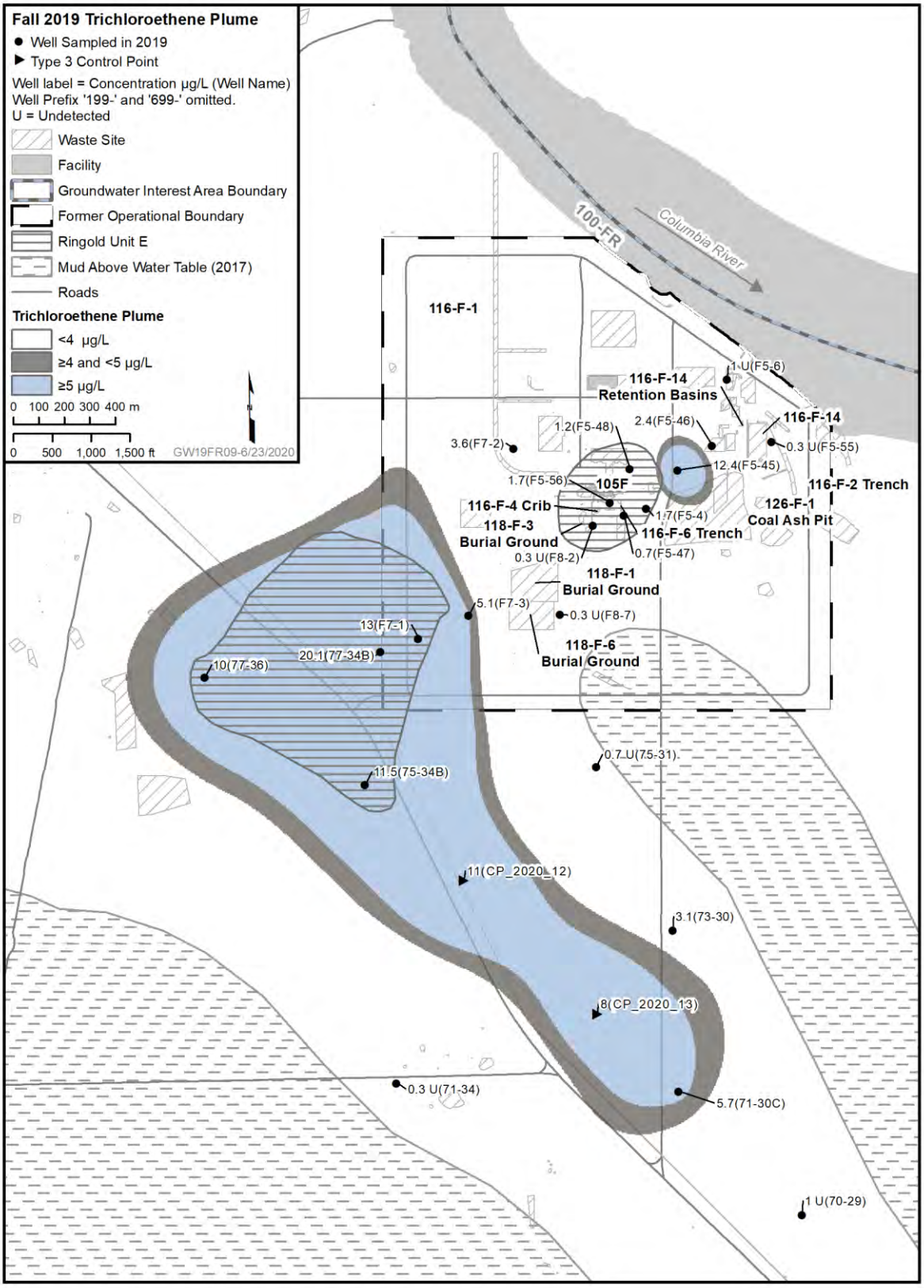


Figure 3-10. 100-FR TCE Plume, Fall 2019

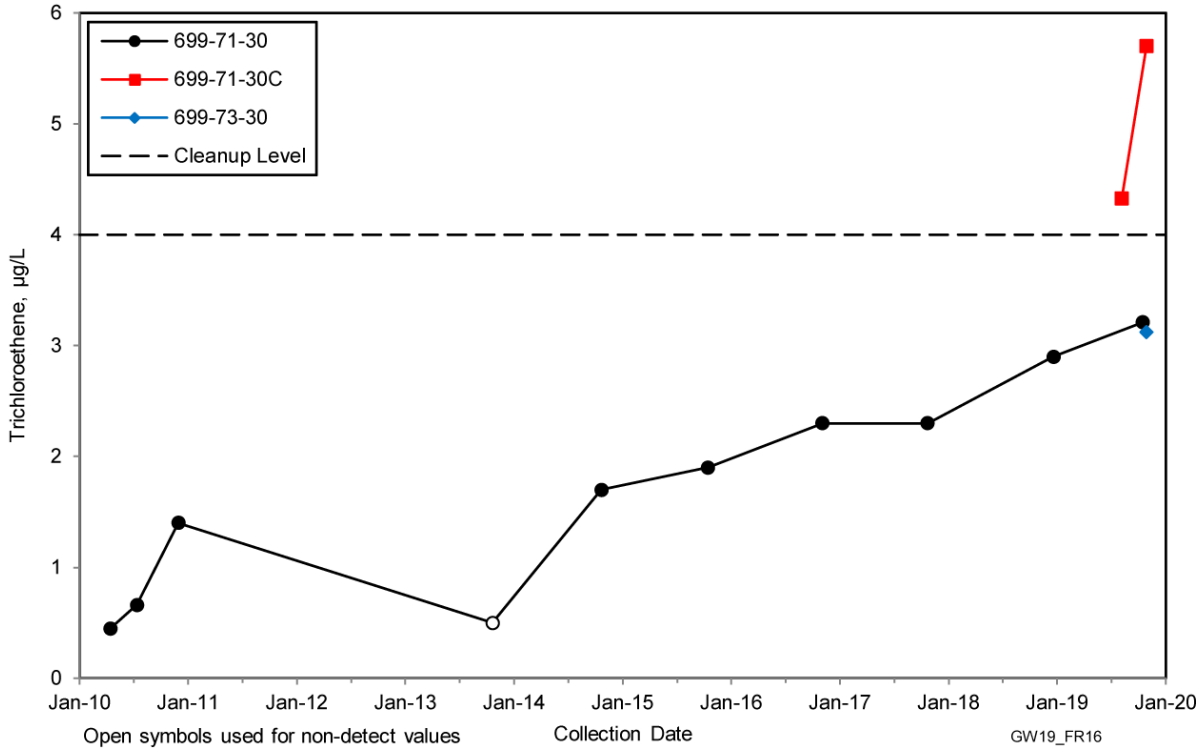


Figure 3-11. TCE Data in Wells 699-71-30, 699-71-30C, and 699-73-30 in Southern 100-FR

TCE concentrations in the southwestern 100-F Area have declined overall since 1992 but have varied in recent years (Figure 3-12). New well 699-77-34B had the highest TCE concentration in 2019 at 20 µg/L. This well was installed to replace well 199-F7-1.

TCE is detected in several wells in the central 100-F Area. In 2019, concentrations exceeded the cleanup level in well 199-F5-45, with an increasing trend (Figure 3-13). The cause of TCE variability in well 199-F5-45 is unknown. There does not appear to be a correlation between TCE concentrations and water levels.

The CERCLA groundwater SAP (Appendix A of DOE/RL-2014-44-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater*, as modified by TPA-CN-708, TPA-CN-0736, TPA-CN-0814, and TPA-CN-0874) requires monitoring the TCE degradation products vinyl chloride and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) in selected wells during the MNA remedy. Results continued to be below detection limits in 2019.

Well 699-77-54, located in the western part of 100-FR, consistently has elevated TCE concentrations, with a 2019 result of 12 µg/L. The well is not needed to meet monitoring objectives defined in the current 100-FR-3 OU SAP (DOE/RL-2014-44-ADD2) and will be evaluated as part of the 100-NR-2 OU. The well also has elevated concentrations of Cr(VI) (22 µg/L in 2019).

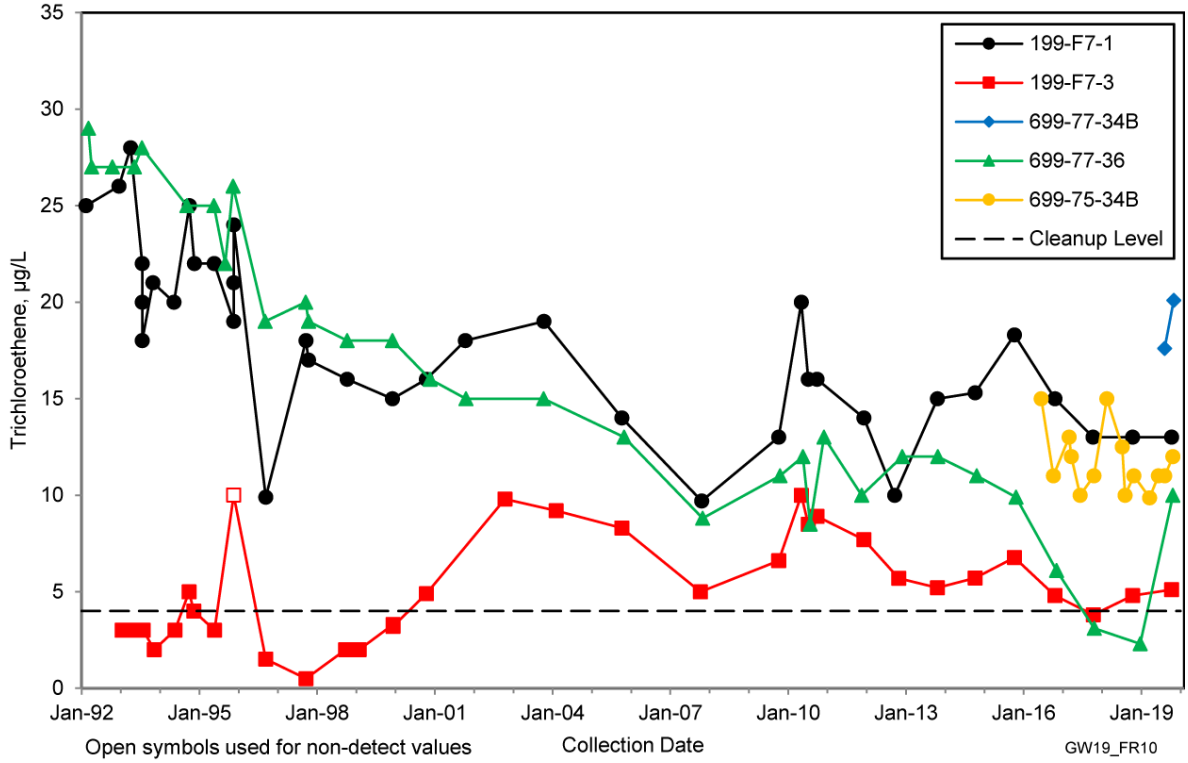


Figure 3-12. 100-FR TCE Data for Wells in the Southwestern 100-F Area

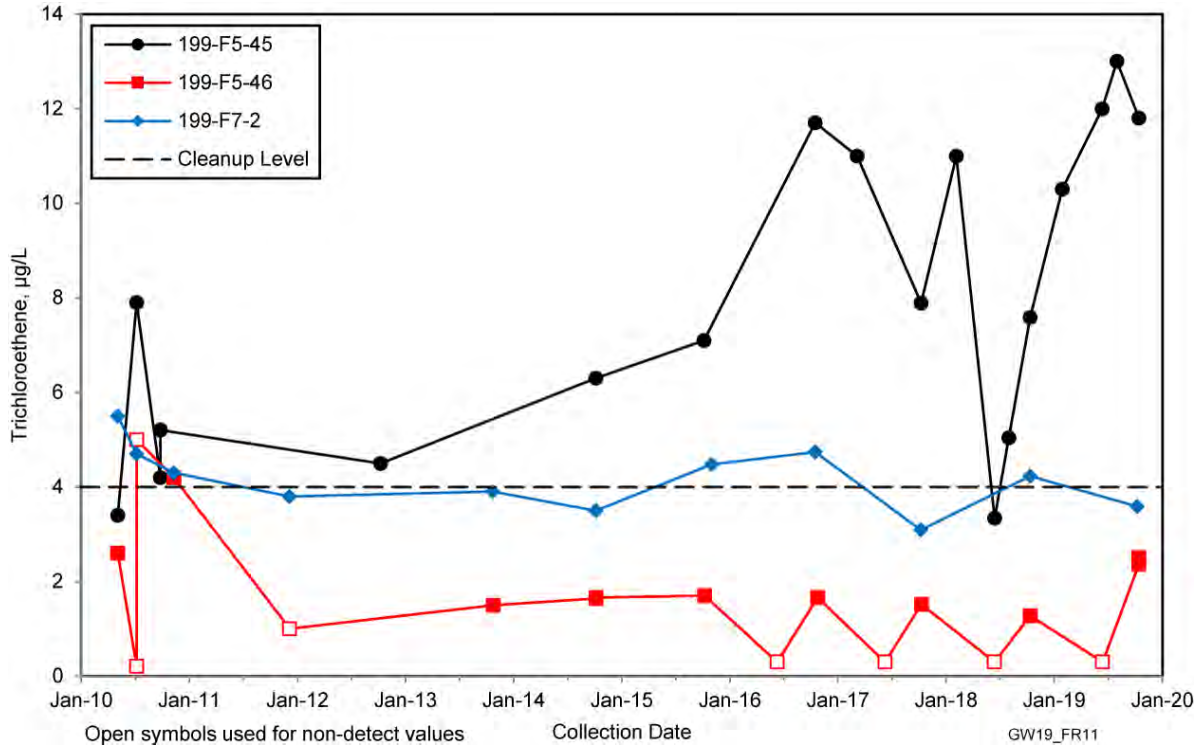


Figure 3-13. 100-FR TCE Data for Wells in the Central 100-F Area

3.4 Hexavalent Chromium

Former sources of Cr(VI) in 100-FR included facilities near the reactor building, trenches and retention basins near the Columbia River, and pipelines from the reactor building to these near-river facilities, primarily in the northern and eastern 100-F Area. The waste sites have been remediated, and concentrations in groundwater are expected to continue declining over time.

The Cr(VI) in 100-FR is present in a relatively small, low-concentration plume (Figure 3-14), which did not change notably between 2018 and 2019. Figure 3-15 shows how concentrations relate to water levels in wells 199-F5-45 and 199-F5-4.

Historically, the highest concentrations were in well 199-F5-46, where levels were >300 µg/L in the early 1990s. Concentrations in this well vary inversely with water levels and increased to about 48 µg/L in October 2019 (Figure 3-16).

Cr(VI) concentrations in aquifer tubes did not exceed the 10 µg/L surface water standard in 2019.

Several 100-FR wells were sampled for total chromium for the first time in 2019, part of an analytical suite used to indicate stainless-steel corrosion when detected in unfiltered samples. Chromium was elevated in filtered samples in well 699-71-34 (20.5 µg/L) and well 699-75-28 (11 µg/L), indicating the presence of dissolved Cr(VI) rather than corrosion. These wells are not located near the known Cr(VI) plume in the 100-F Area, and the sources of contamination are unknown. Concentrations were below the 48 µg/L cleanup level for inland wells.

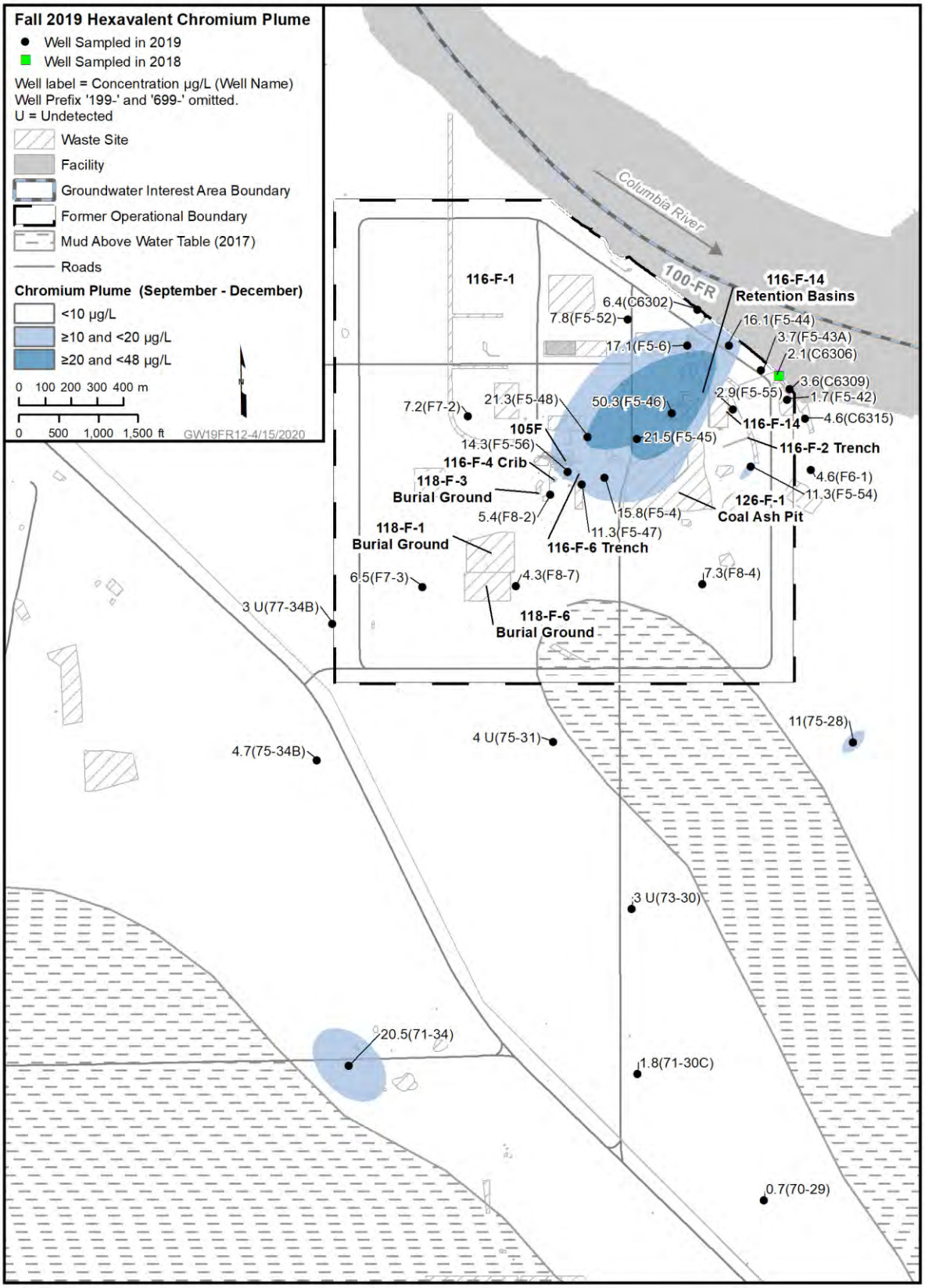


Figure 3-14. 100-FR Cr(VI) Plume, Fall 2019

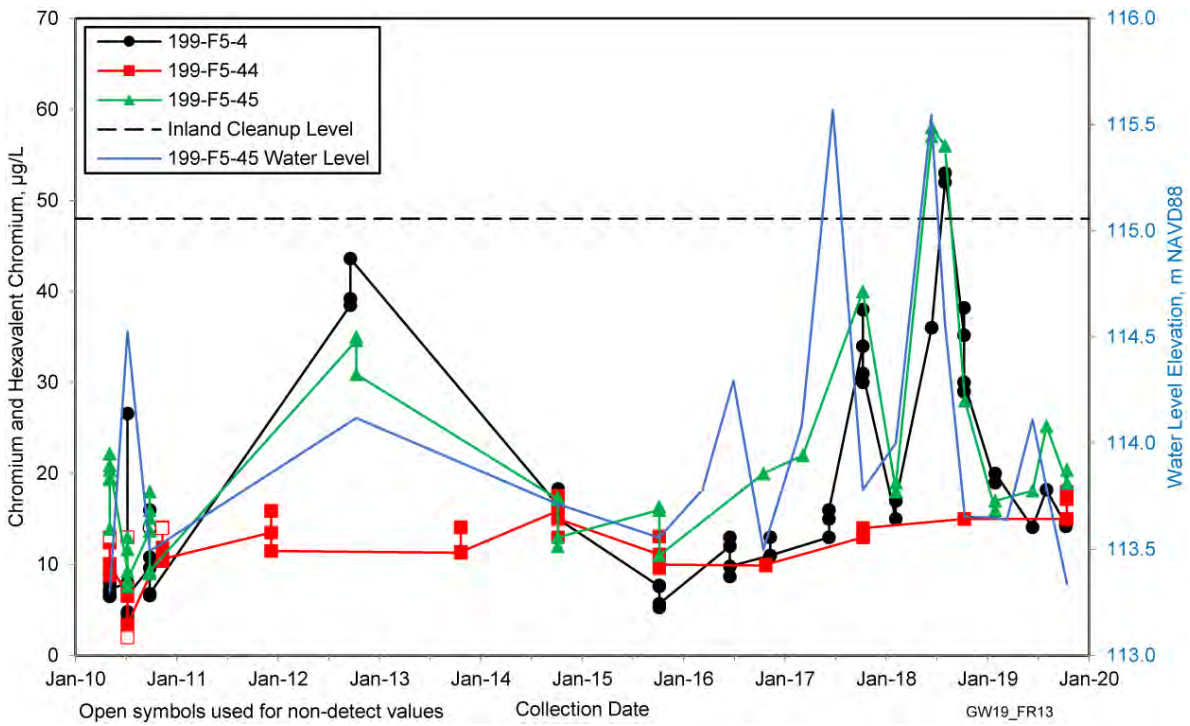


Figure 3-15. 100-FR Cr(VI) and Water-Level Data in Wells 199-F5-4, 199-F5-44, and 199-F5-45

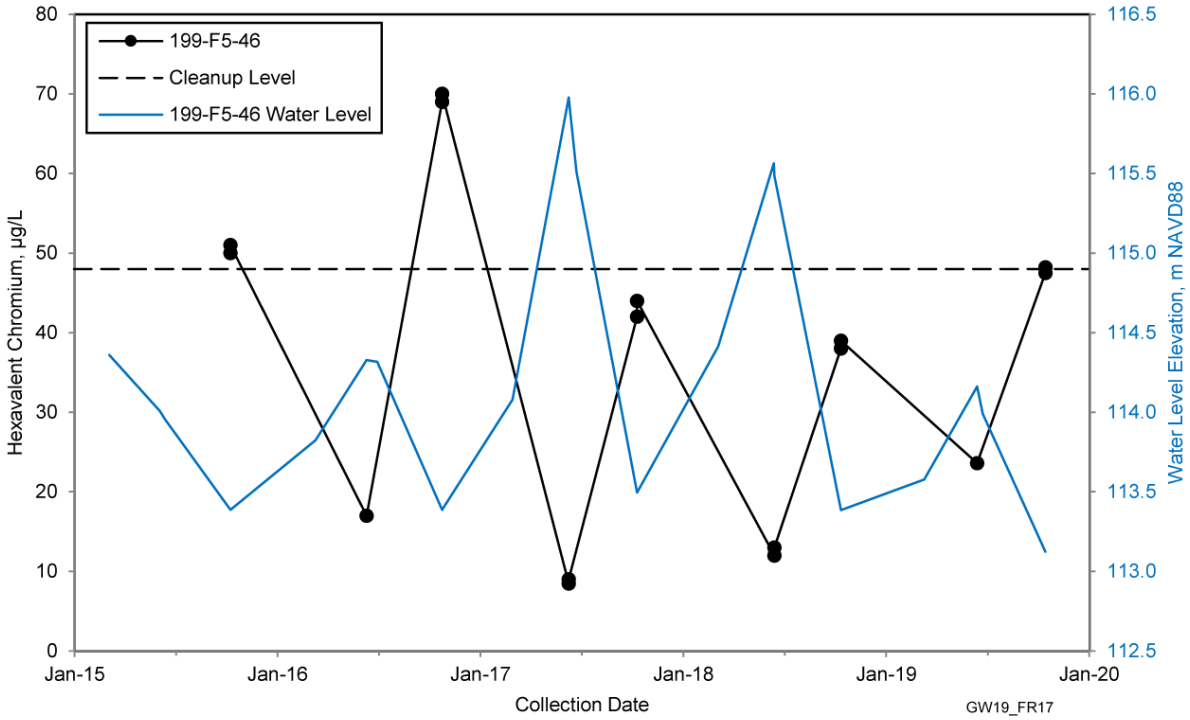


Figure 3-16. 100-FR Cr(VI) and Water-Level Data in Well 199-F5-46

3.5 Strontium-90

Primary sources of strontium-90 included the 116-F-14 Retention Basin and 116-F-2 Trench in the eastern 100-F Area. Additional sources of strontium-90 were present near the F Reactor building and burial grounds. In 2019, concentrations exceeded the 8 pCi/L cleanup level in only three wells (Figure 3-17), which was unchanged from 2018.

Maximum concentrations of strontium-90 in 100-FR groundwater have declined since the 1990s when concentrations were >300 pCi/L in well 199-F5-3, which was located near the 116-F-2 Trench and 116-F-14 Retention Basin and was decommissioned in 2008. In 2019, the highest concentration was 112 pCi/L in well 199-F5-55 (Figures 3-17 and 3-18). The groundwater contamination in the eastern 100-F Area is localized, and the closest downgradient well (199-F5-1) has much lower concentrations. Strontium-90 concentrations in aquifer tubes are below the cleanup level.

Strontium-90 concentrations in well 199-F5-56, near the F Reactor building, also exceeded the cleanup level, reaching 22.8 pCi/L in August 2019 (Figure 3-18). Concentrations generally correlate with water levels. This borehole was drilled to characterize a waste site and was completed as a well to obtain representative groundwater samples. No other wells near well 199-F5-56 had detectable strontium-90.

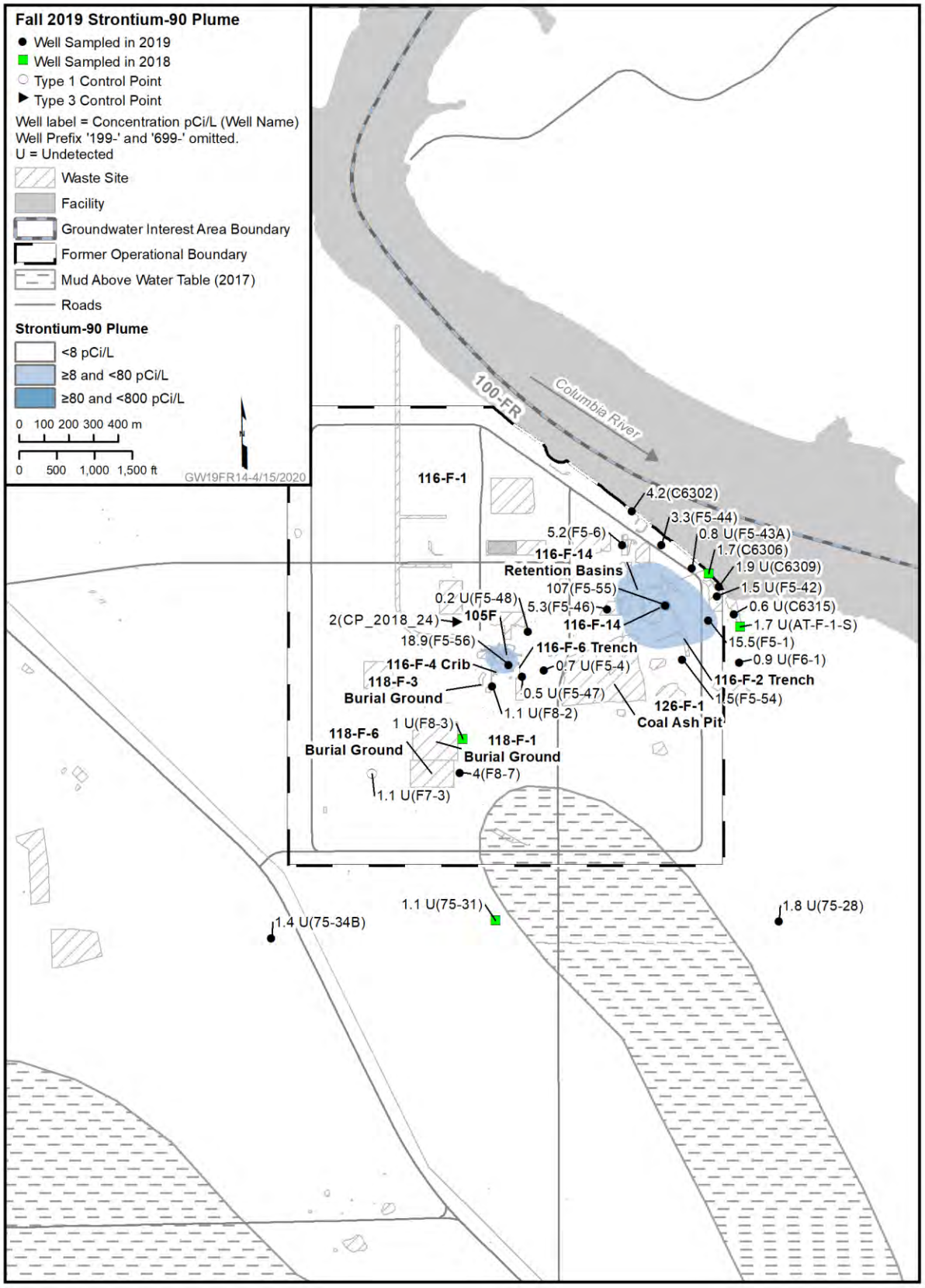


Figure 3-17. 100-FR Strontium-90 Plume, Fall 2019

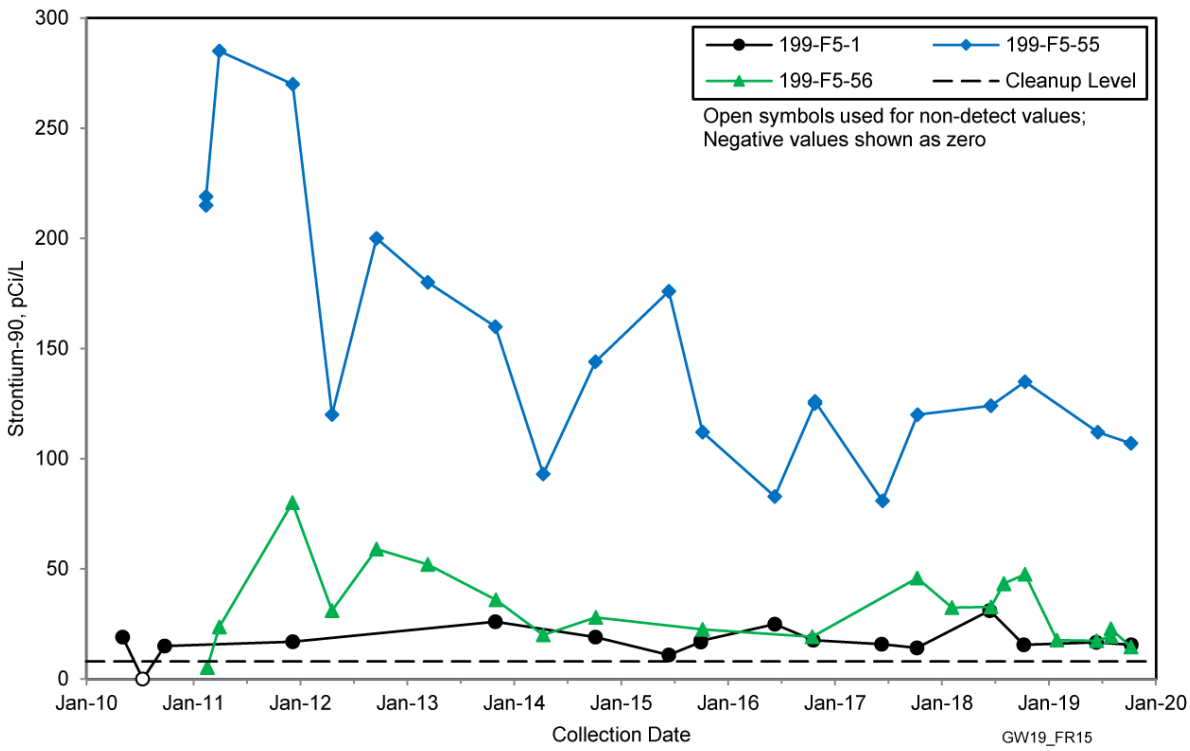


Figure 3-18. 100-FR Strontium-90 Data in Selected Wells

3.6 Other Analytes

Antimony, cadmium, and cobalt are being monitored annually in four wells until eight samples are available to determine if they meet action levels. All results to date were below action levels (Table 3-3).

Table 3-3. Summary of 100-FR-3 OU Trace Metals (Unfiltered Samples), 2014–2019

Well (Number of Unfiltered Samples)	Antimony[a]		Cadmium[b]		Cobalt[a]	
	Detects	Maximum (µg/L)	Detects	Maximum (µg/L)	Detects	Maximum (µg/L)
199-F5-4 (7)	3	0.20 B	1	0.10 B	2	0.240
199-F5-43A (6)	0	< MDL	0	< MDL	2	0.744
199-F5-48 (6)	1	0.56 B	0	< MDL	1	0.065 B
199-F8-7 (6)	0	< MDL	0	< MDL	4	0.386 B

a. Antimony and cobalt results and detection limits were below the action levels (6 µg/L for antimony and 4.8 µg/L for cobalt).

b. All cadmium detections were below the 0.25 µg/L action level. Some detection limits were higher than the action level (0.27 to 0.30 µg/L).

B = analyte was detected at less than the quantitation limit

MDL = method detection limit

The CERCLA groundwater SAP (Appendix A of DOE/RL-2014-44-ADD2) does not identify sulfate as a COC, but it is reported with analytical results for anions. Sulfate concentrations in perched aquifer well 699-66-32 were above the 250 mg/L secondary DWS, with a maximum detection of 375 mg/L in 2019. This concentration was higher than any historical sulfate concentrations in the 100-F Area and, like nitrate, is believed to be related to pre-Hanford Site agriculture (Section 4.3 in SGW-61298). Other wells in southern 100-FR also have elevated sulfate, but levels are below the secondary DWS.

3.7 CERCLA Remediation and Monitoring

The remedy for 100-FR-3 OU groundwater, as described in the 2014 CERCLA ROD (EPA and DOE, 2014), is MNA of Cr(VI), nitrate, strontium-90, and TCE. DOE/RL-2014-44-ADD2 includes a groundwater SAP, modified by TPA-CN-708, TPA-CN-0736, TPA-CN-0814, and TPA-CN-0874. In 2019, TPA-CN-0874 incorporated the monitoring wells installed in 2019.

The first stage of 100-FR-3 OU groundwater remedy implementation included installing new wells, starting performance monitoring sampling, and reporting sampling results in the annual groundwater monitoring report (Table 6-1 in DOE/RL-2014-44-ADD2). Six new monitoring wells were installed in 2019 (Table 3-2). Subsequent remediation stages will include evaluating MNA progress to support the sitewide CERCLA 5-year review. The first 100-FR performance report, evaluating data through 2020, is anticipated to be prepared in 2021.

Most of the 100-FR-3 OU monitoring wells and aquifer tubes were sampled as planned in 2019 (Appendix A). One aquifer tube could not be located and may have broken off, and one seep was not flowing in 2019. Sections 3.2 through 3.6 discuss the 2019 data.

3.8 Atomic Energy Act Monitoring

AEA groundwater monitoring was conducted at nine groundwater wells and aquifer tubes in 100-FR in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 100-FR are nitrate, strontium-90, and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Of the nine wells sampled in 100-FR for AEA monitoring requirements, eight wells were sampled for radionuclides. One well was sampled for nitrate and dissolved oxygen only and, therefore, was not included in the count for wells used to calculate the radionuclide dose concentration. Wells in 100-FR were sampled in accordance with SAP requirements in 2019.

Radionuclide concentrations detected in groundwater samples from 17 wells[4] 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. 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 three locations in 100-FR (Table 3-4). Two of the locations are near 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 institutional controls implemented to restrict groundwater access. CERCLA remedial actions (i.e., MNA for the 100-FR-3 OU) provide longer-term protection of the public and the environment.

[4] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 3-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-FR for 2019

Monitoring Location/ Well Name	Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum
199-F5-1	7.75	8.35
199-F5-55	53.50	56.00
199-F5-56	7.30	11.40

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

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

4 100-HR

The 100-HR-3 Groundwater OU, in the northern portion of the Hanford Site, encompasses the 100-HR-D and 100-HR-H groundwater interest areas, which together make up 100-HR (Figure 1-1). This chapter includes an overview; a discussion of CERCLA-, RCRA-, and AEA-related groundwater activities conducted in 2019; and a summary of 2019 groundwater monitoring results.

4.1 Overview

Groundwater in 100-HR was contaminated by waste releases associated with past operation of the D, DR, and H Reactors and associated support facilities. At the end of 2019, 98% of the waste sites had been remediated or did not require remediation. The remainder of the waste sites will be remediated in accordance with EPA et al., 2018, *Record of Decision Hanford 100 Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (hereinafter referred to as the 2018 100-D/H ROD).

Table 4-1 lists key facts about 100-HR, including the plume areas. Details about 100-HR history, waste sites, and hydrogeology are provided in Chapters 1 and 3 of the 100-D/H RI/FS (DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*). Figures 4-1 and 4-2 show the locations of monitoring, extraction, and injection wells and aquifer tubes. Data from monitoring seeps and springs are shown on each of the plume figures 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.

The depth to groundwater averages 20 m (66 ft) in 100-HR-D and 11.3 m (37.1 ft) in 100-HR-H. The thickness of the unconfined aquifer ranges from 12 m (39 ft) in 100-HR-D to <1 m (3.3 ft) in portions of 100-HR-H, with the aquifer generally thinning from west to east. The thickness of the unconfined aquifer mimics the topography of the RUM (DOE/RL-2008-42, *Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit*). The uneven surface of the silt- and clay-rich RUM forms the base of the unconfined aquifer. Water-bearing units are found within the RUM and form confined or semiconfined aquifers. The uppermost water-bearing unit of the RUM is typically referred to as the RUM aquifer and has been determined as semiconfined in the 100-H Area. The extent and hydraulic interconnection of the RUM aquifer (laterally and vertically) and the degree of leakage or confinement of the overlying fine-grained RUM layer remain uncertain and are being investigated.

The unconfined aquifer is primarily present in Ringold unit E in 100-HR-D and in the Hanford formation gravel in 100-HR-H (Figure 4-3). Across the Horn, the geology is transitional, changing from predominantly Ringold unit E in the west to the Hanford formation farther east. Pockets of Ringold unit E are found as remnants in various locations. In the areas across the Horn where Ringold unit E is absent, channels formed and resulted in preferential groundwater flow pathways.

The COCs in 100-HR groundwater were identified in the 2018 100-D/H ROD (Table 6 in EPA et al., 2018) and include Cr(VI), total chromium, nitrate, and strontium-90. Figure 4-4 illustrates how the contaminant plumes areas have changed over time. Figure 4-5 shows the Cr(VI) plume in 1999 (2 years after the first P&T system began operating) and in 2019. Plume size and concentrations of areas at >100 µg/L and 48 µg/L in the unconfined aquifer have been reduced due to continued P&T system operation. A few isolated areas with concentrations remain at >48 µg/L.

Table 4-1. 100-HR at a Glance

Reactor operations: D Reactor: 1944 to 1967; DR Reactor: 1950 to 1964; H Reactor: 1949 to 1965				
Groundwater Monitoring				
Contaminants of Concern, Cleanup Level[a]	**Year**	**Maximum Concentration (Well)**	**Plume Area[b] (km^2)**	**Shoreline[c] (m)**
Hexavalent chromium, 48/10[d] µg/L	2019	802 (199-H3-13[f])	0.01 / 2.9	0 / 983
	2018	800 (199-D5-103)	0.01 / 3.0	0 / 393
Total chromium, 65/100[e] µg/L	2019	882 (unfiltered) (199-H3-13[f])	<0.01	0
	2018	363 (unfiltered) (199-D5-160)	<0.01	0
Nitrate, 45 mg/L	2019	345 (199-H3-13[f])	0.01	0
	2018	416 (199-H3-29[f])	0.02	0
Strontium-90, 8 pCi/L	2019	29 (199-H4-83)	0.02	0
	2018	24.5 (199-D5-132)	0.03	0
Remediation				
Waste sites: 98% complete[g] Interim action pump and treat for hexavalent chromium in groundwater (1997 to 2018). Final Record of Decision (signed in 2018) with continued pump and treat for hexavalent chromium and total chromium and monitored natural attenuation for nitrate and strontium-90 in groundwater (2019).				

a. From EPA et al., 2018, *Record of Decision Hanford 100 Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*.

b. Estimated area in the unconfined aquifer at a concentration greater than the listed water quality standard.

c. Length of shoreline intersected by plume above listed water quality standard.

d. Cleanup levels for hexavalent chromium are 10 µg/L where groundwater discharges to surface water and 48 µg/L in the upland groundwater.

e. Cleanup levels for total chromium are 65 µg/L where groundwater discharges to surface water and 100 µg/L in the upland groundwater. Total chromium is not sampled at the same frequency as hexavalent chromium.

f. Well is completed in the first water-bearing unit of the Ringold upper mud unit.

g. Sites with closed, interim closed, final closed, no action, not accepted, or rejected status as of December 31, 2019.

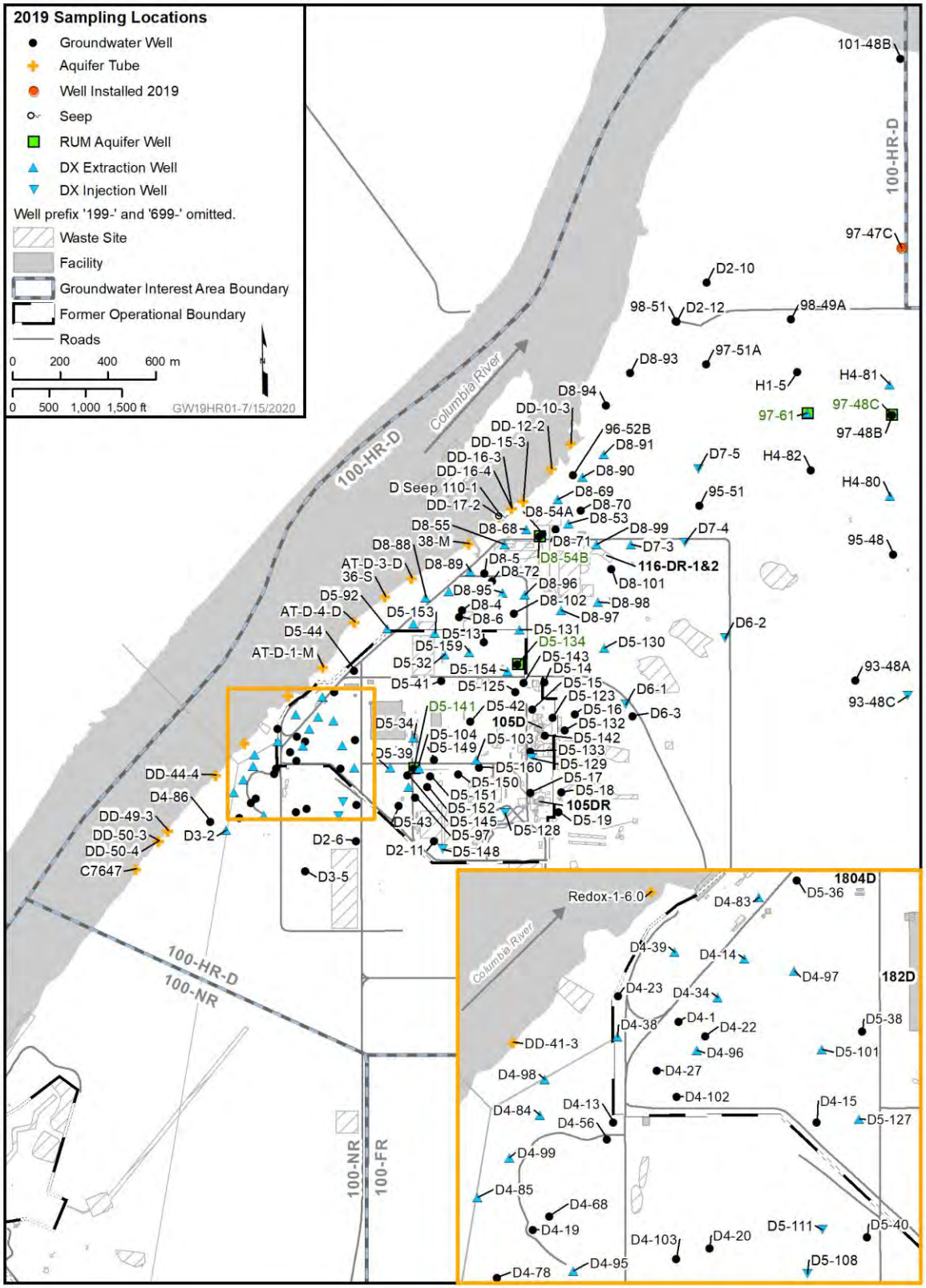


Figure 4-1. 100-HR-D Groundwater Sampling Locations, 2019

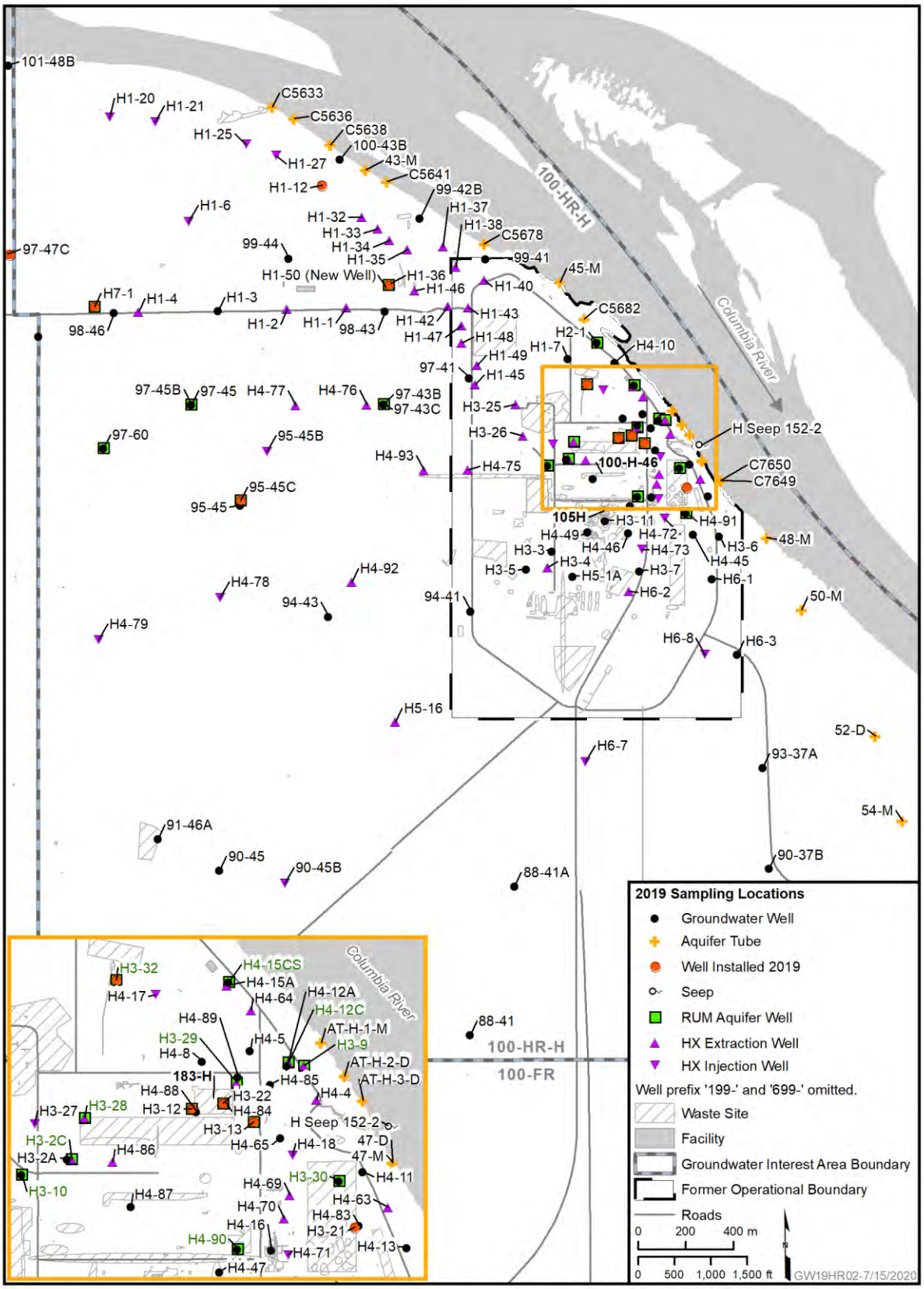


Figure 4-2. 100-HR-H Groundwater Sampling Locations, 2019

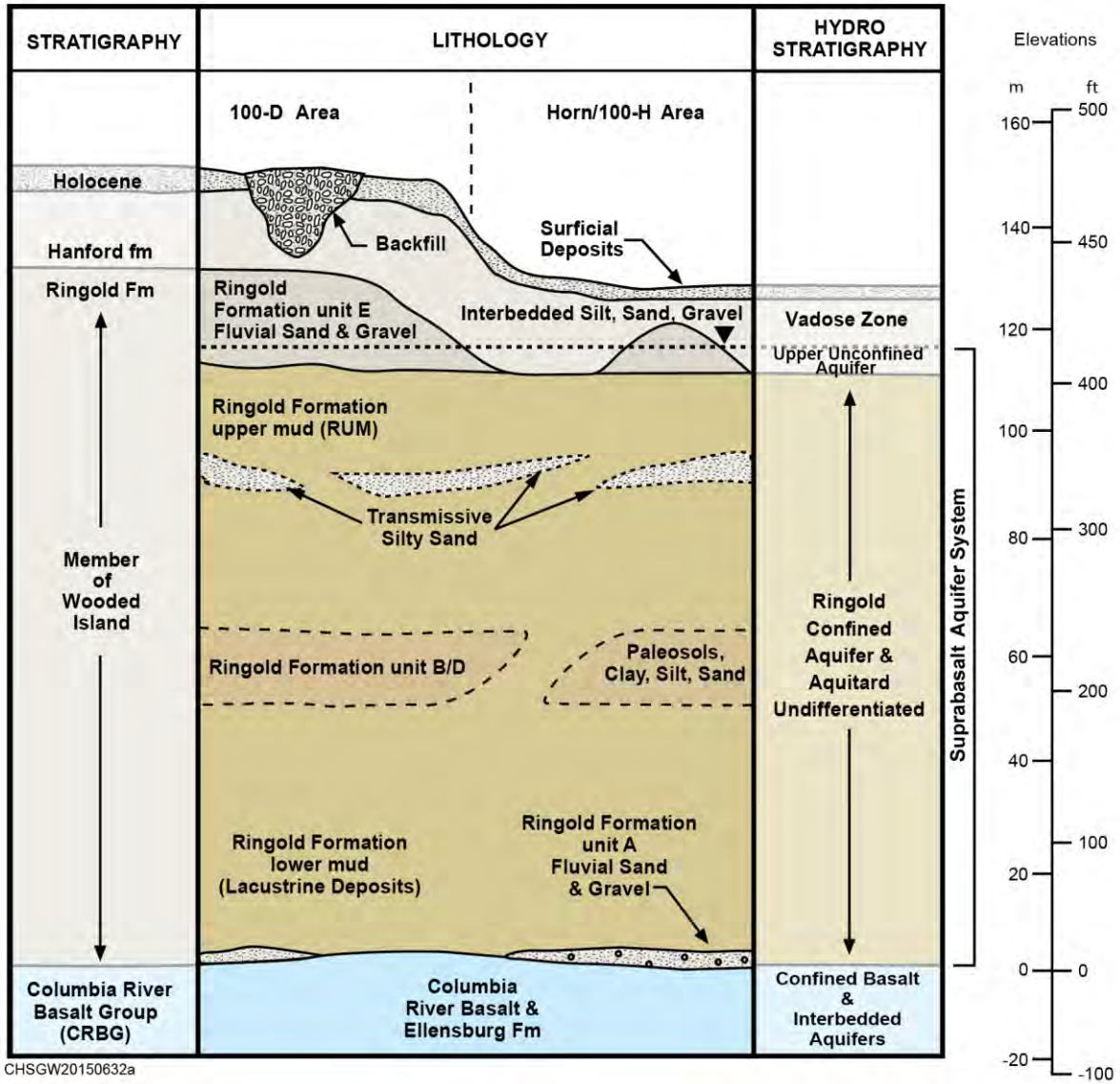


Figure 4-3. 100-HR Hydrogeology

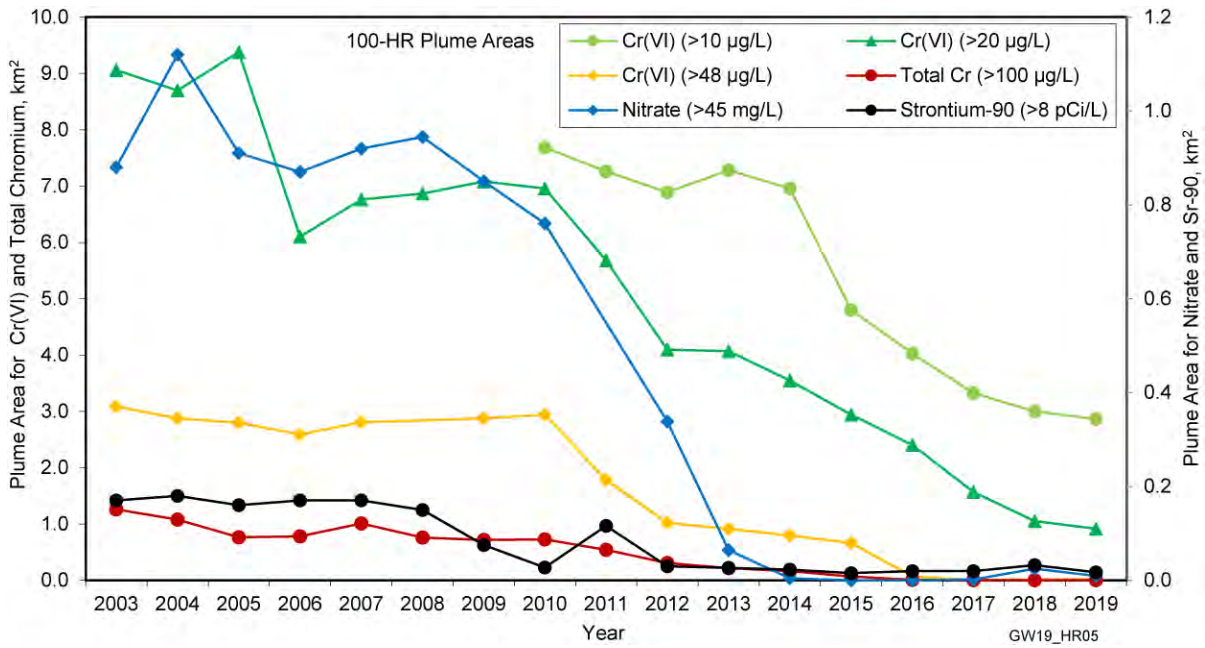


Figure 4-4. 100-HR Plume Areas

4.2 100-HR Groundwater Flow

Groundwater in the 100-HR unconfined aquifer in the 100-D Area flows to the northwest, toward the Columbia River (Figure 4-6). Flow is generally to the north and northeast toward the Columbia River in the central part of the Horn. In the 100-H Area, flow is generally to the east and northeast (Figure 4-7). Operation of P&T systems influences groundwater flow direction and velocity throughout 100-HR, creating localized depressions and mounds in the unconfined aquifer water table.

Changes in river stage formerly dominated the groundwater flow directions in the unconfined aquifer across the entire 100-HR. However, as the P&T system has become more robust over time with the addition of wells in key locations, the effect of the river stage on plume configuration has lessened. Plume changes in the unconfined aquifer are now primarily controlled by modifications to the P&T system during the year, with the natural gradient dominating in those areas with few or no extraction or injection wells.

Figure 4-8 shows the elevation of hydraulic heads in the RUM aquifer for May 2019. The general direction of groundwater flow in the RUM aquifer is west to east across the Horn, similar to the overlying unconfined aquifer. The contours that intersect the river do not imply that the RUM aquifer intersects or is bounded by the river. P&T extraction wells in the RUM aquifer influence groundwater flow direction and velocity and create depressions in the potentiometric surface. A large depression in the potentiometric surface in the 100-H Area is a response to the P&T system in that area, where the largest volume of extraction from the RUM aquifer occurs. The interpretation of hydraulic head in the RUM aquifer (Figure 4-8) assumes that the RUM aquifer is laterally continuous from west to east across the Horn.

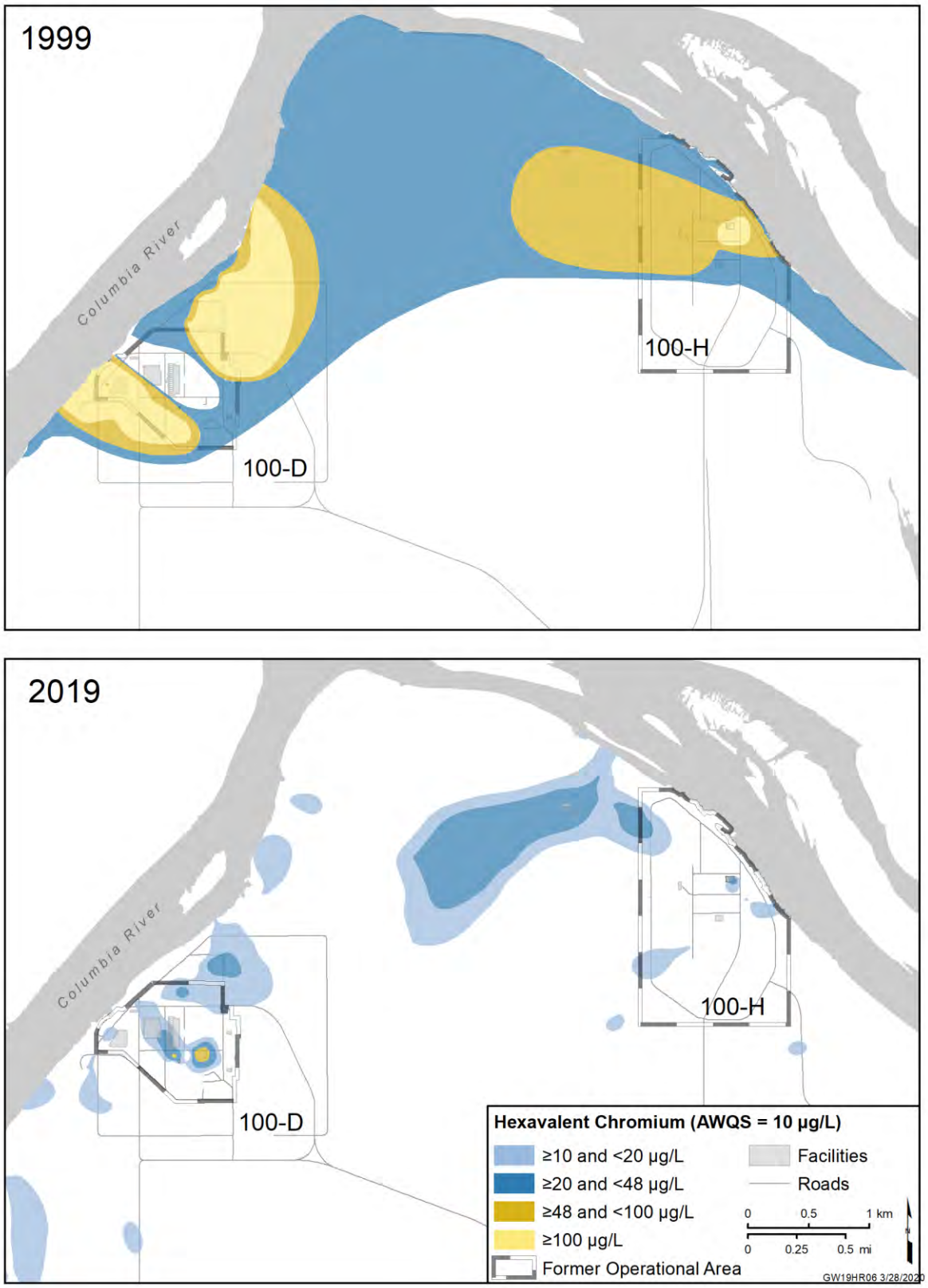
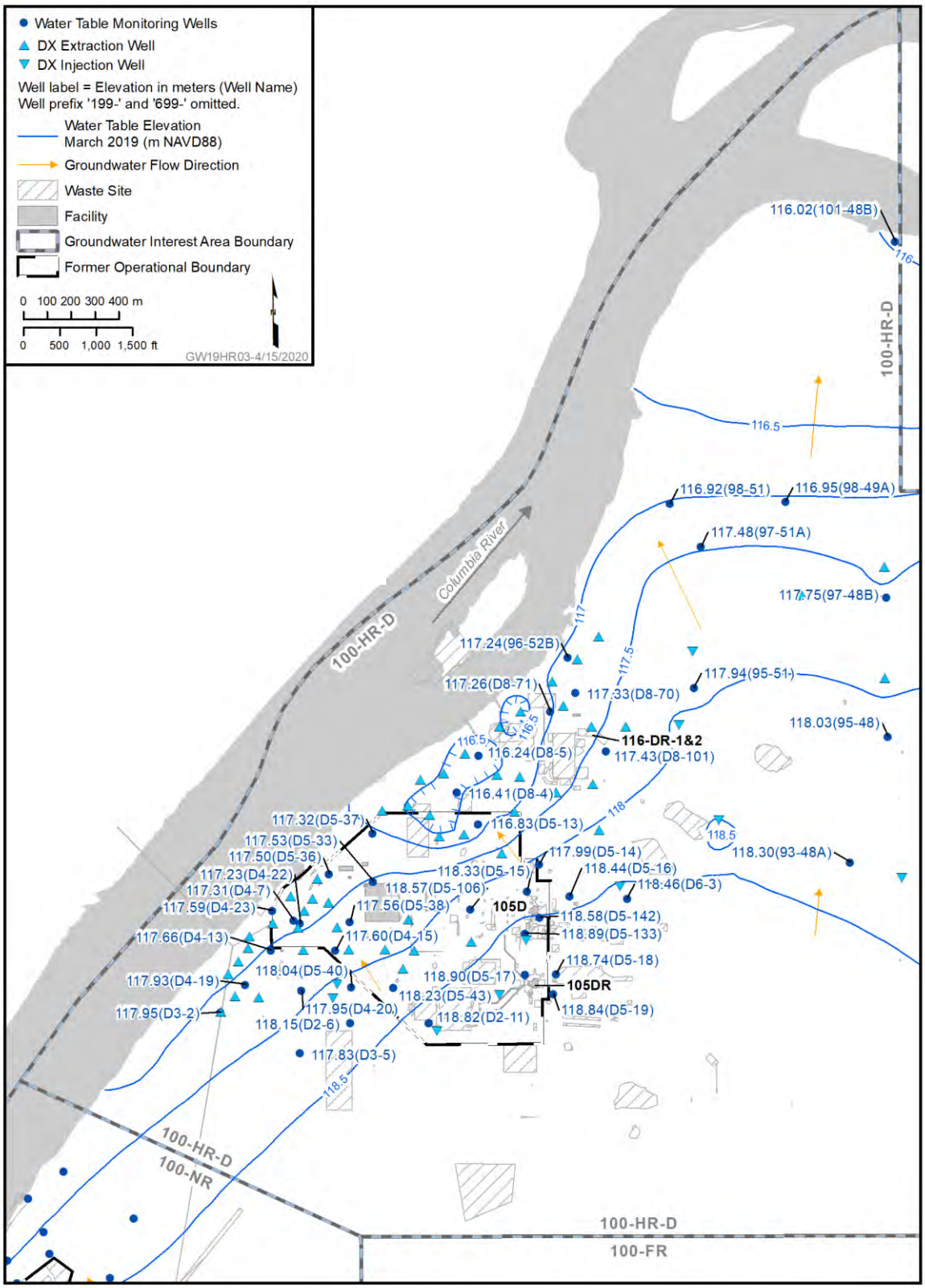
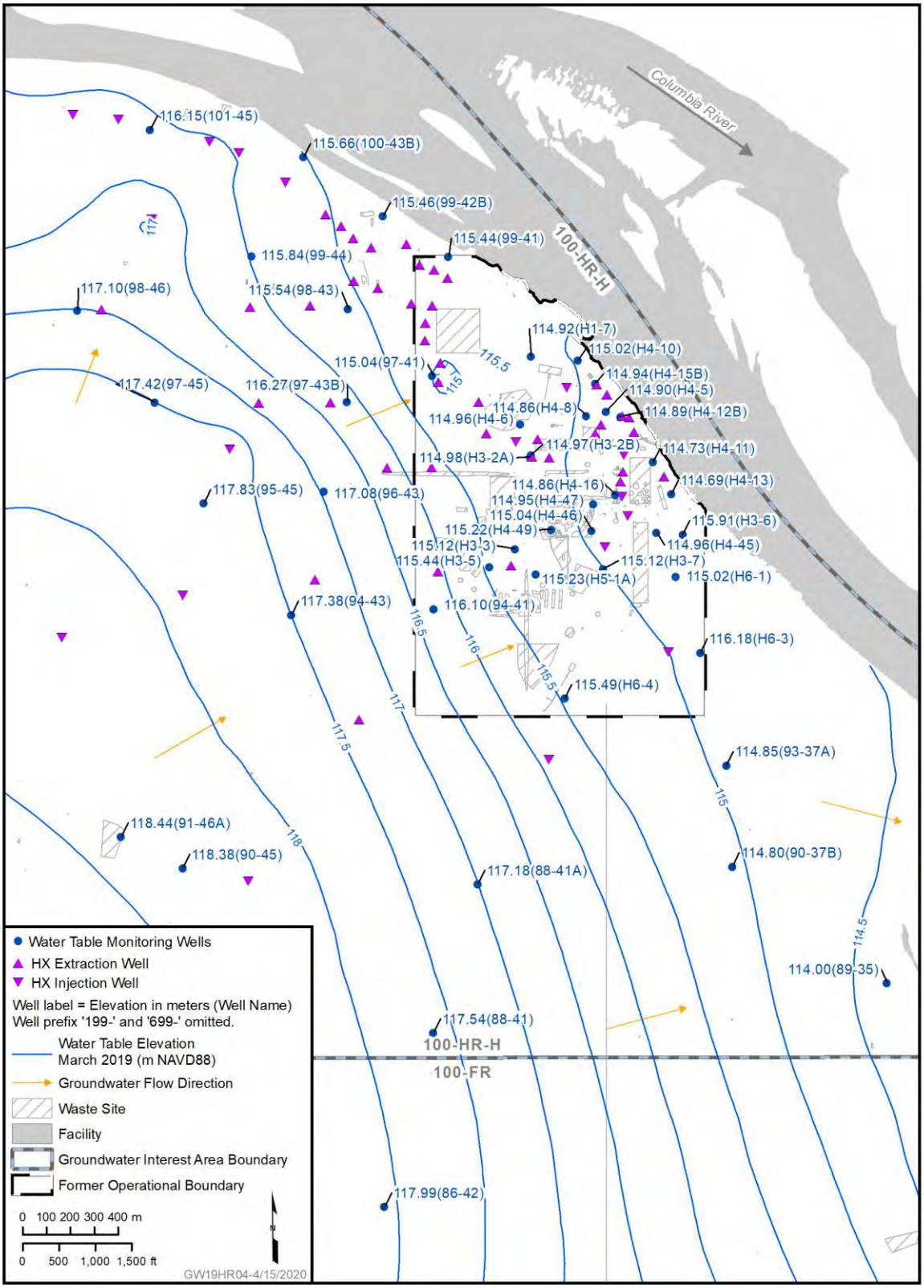


Figure 4-5. 100-HR Cr(VI) Plume in 1999 (Early in Interim Action Period) and 2019 (During Remedial Action)



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-6. 100-HR-D Water Table, March 2019



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-7. 100-HR-H Water Table, March 2019

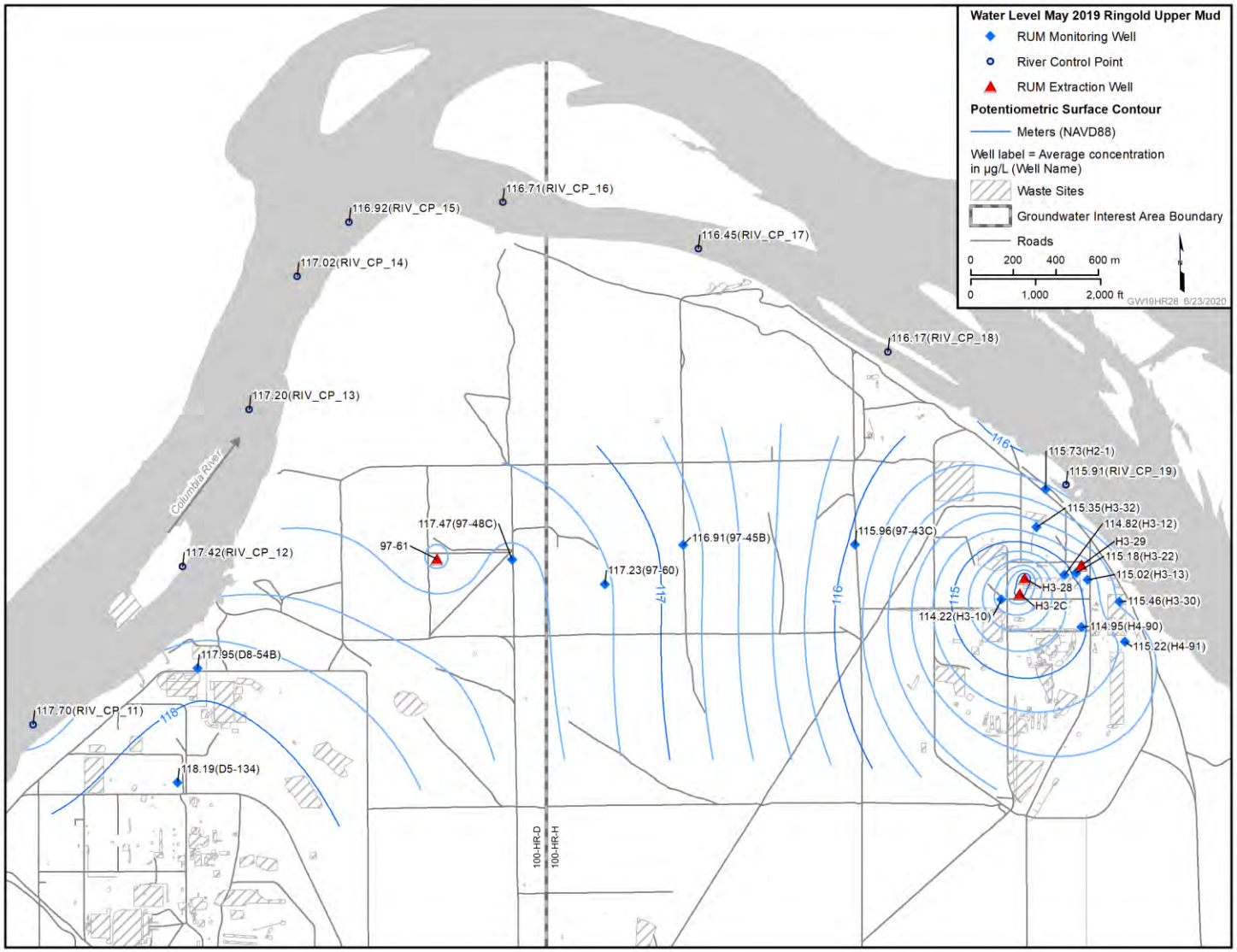


Figure 4-8. 100-HR RUM Potentiometric Surface Map, May 2019

4.3 100-HR-D Hexavalent Chromium

At 100-HR, Cr(VI) is the most widely distributed COC, resulting from historical releases of two different types of wastewater. The first type of release included spills, leaks, and unintentional discharge of concentrated sodium dichromate solutions used as feed chemicals for conditioning reactor cooling water. A high-concentration release of sodium dichromate stock solution is the primary cause of the southern Cr(VI) groundwater plume. The second type of release included reactor cooling water from retention basin leaks and intentional discharges to the 116-DR-1&2 Trenches during operations and during an infiltration test in 1967, which had high volumes of water with lower concentrations of sodium dichromate. The releases to the 116-DR-1&2 Trenches are the primary source of the northern Cr(VI) plume and the plume across the Horn (Section 4.4.1).

Groundwater P&T systems and source removal have decreased the sizes and concentrations of the Cr(VI) plumes (Figure 4-5). Section 4.9 discusses groundwater remediation in more detail.

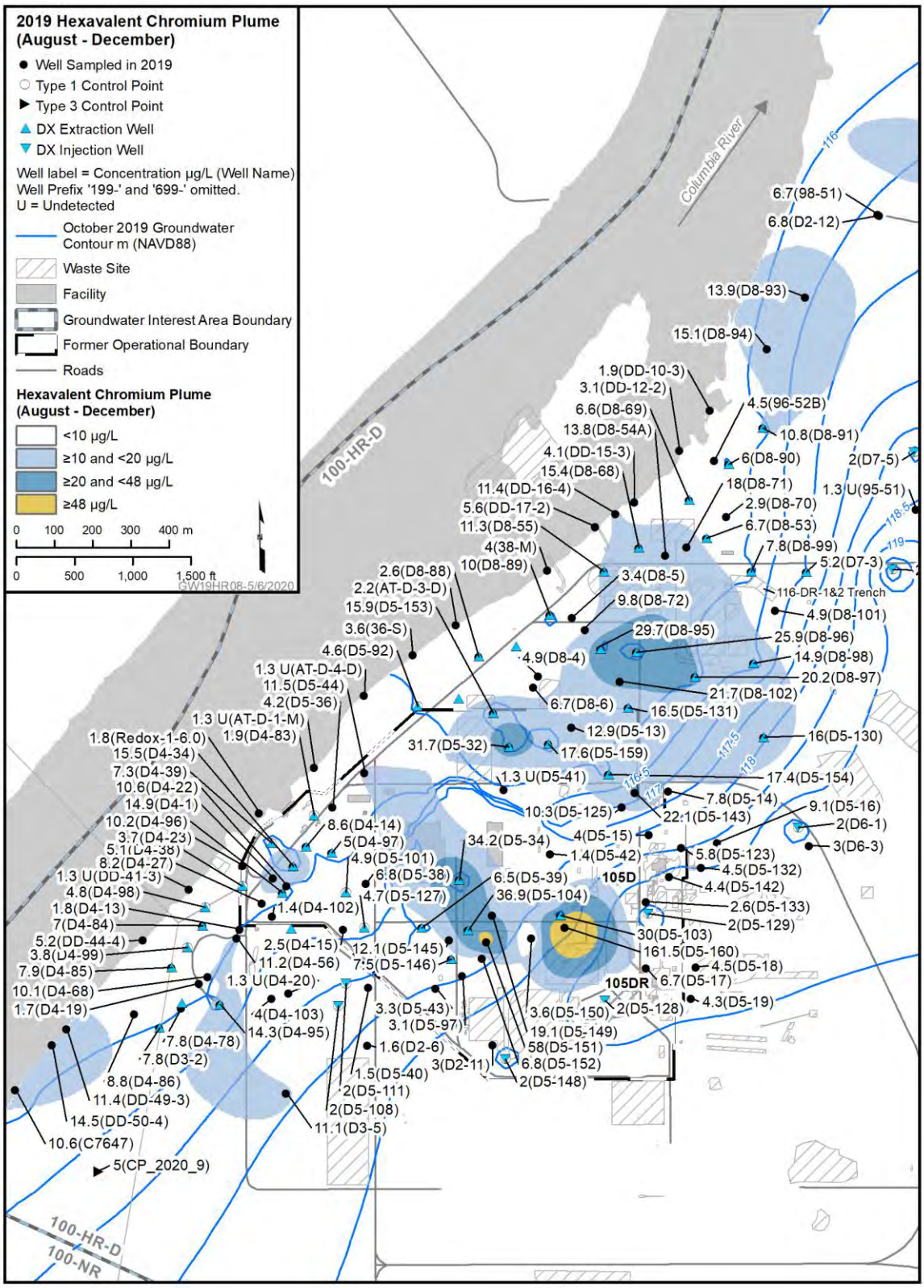
4.3.1 Southern Plumes in the 100-D Area

The Cr(VI) contamination in the southern portion of the 100-D Area has been reduced to several discontinuous plumes due to removal of source material and ongoing groundwater remediation (Figure 4-9). An overall reduction in concentrations across most of the area has resulted in a smaller collective plume area in 2019 than in 2018. Concentrations in most locations in the southern plumes were below the 48 µg/L cleanup level.

The highest Cr(VI) concentrations in the southern 100-D Area were in wells 199-D5-103 and 199-D5-160, located near waste sites 100-D-100, 100-D-30, and 100-D-104, which were excavated to groundwater in 2014 and subsequently backfilled (SGW-58416, *Persistent Source Investigation at 100-D Area*). Concentrations in wells 199-D5-103 and 199-D5-160 continued to decline in 2019 as a result of connection of well 199-D5-103 to the DX P&T system as an extraction well in September 2018. The Cr(VI) concentrations in wells 199-D5-103 and 199-D5-160 declined from 270 and 360 µg/L, respectively, in fall 2018 to 16 and 173 µg/L in fall 2019, respectively (Figure 4-10). The residual Cr(VI) in these wells is likely related to the remaining source material at the northeast corner of the 100-D-100 excavation, where contaminated soil was observed during the excavation.

The only other 100-D Area wells with Cr(VI) concentrations above the 48 µg/L cleanup level in 2019 were 199-D5-34 and 199-D5-151, which are located in the western lobe of the southern plume, northwest of the 100-D-100 waste site. Concentrations in extraction well 199-D5-34 continued to decline in 2019 from 50.0 µg/Lin January to 26.7 µg/L in November. Concentrations in monitoring well 199-D5-151 decreased from 110 µg/L in late 2018 to 37.6 µg/L in early 2019. Cr(VI) concentrations in well 199-D5-151 have fluctuated annually above and below the 48 µg/L cleanup level since 2016, when this well was installed. These annual fluctuations suggest a continuing source of Cr(VI) near this well location.

Consistent with previous years, the fall 2019 samples from aquifer tubes and the nearshore monitoring wells indicate that Cr(VI) continues to reach the Columbia River shoreline in the area upriver of the 100-D Area (Figure 4-9). Aquifer tubes and nearshore monitoring wells with Cr(VI) concentrations >10 µg/L resulted in a larger Cr(VI) plume in 2019 than in 2018 in this area.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-9. 100-HR-D Cr(VI) Plume, Fall 2019 (Low River Stage)

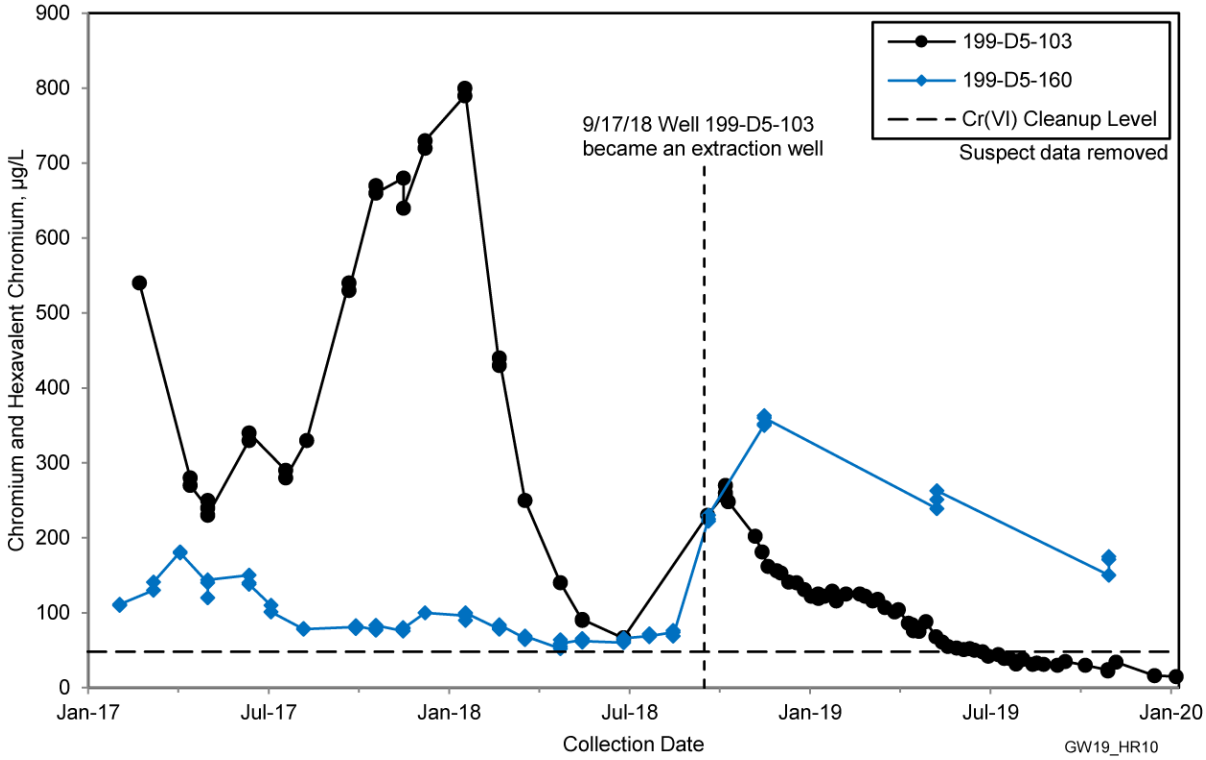


Figure 4-10. 100-HR Filtered Total Chromium and Cr(VI) Data for Wells 199-D5-103 and 199-D5-160

4.3.2 Northern Plumes in the 100-D Area

The overall footprint of the northern 100-D Area Cr(VI) plume at concentrations ≥10 µg/L in 2019 was similar in size as in 2018 except for the southwestern thumb of the main plume, which is influenced by seasonal river stage (Figure 4-9). Cr(VI) concentrations peak to levels >10 µg/L during low river stage (typically during October through December) and decrease to concentrations <10 µg/L during high river stage in the spring. The average low river Cr(VI) concentration in extraction well 199-D5-92 decreased to <10 µg/L between 2018 and 2019, which decreased the size of the plume in this area.

As a result of ongoing remediation, the size of the plume at concentrations >10 µg/L has decreased. The highest concentrations continue to be primarily near wells 199-D8-95 and 199-D8-96. These wells are located near the 120-D-1 (100-D Pond) waste site, the 126-D-1 coal ash waste site, and southwest of the 116-DR-1&2 Trenches. Data from the RI/FS (Chapter 4 in DOE/RL-2010-95) indicate that Cr(VI) and chromium remained in the vadose zone at the 116-DR-1&2 Trenches after remediation; however, Cr(VI) did not exceed the 2 mg/kg soil cleanup level in the RI soil borehole sample locations. Extraction wells 199-D8-95 and 199-D8-96 continued to have the highest concentrations in the northern 100-D Area plume in 2019, with average Cr(VI) concentrations of 29.7 and 25.9 µg/L, respectively, during low river stage. Concentrations in these two wells (Figure 4-11) and several other wells in the central and southern part of the northern plume continued to gradually decline asymptotically in response to extraction.

Downgradient of the 116-DR-1&2 Trenches, aquifer tube DD-16-4 exhibited a Cr(VI) concentration near 10 µg/L in 2019. While plume capture in this area has improved over the years due to P&T system modifications, Cr(VI) continued to reach the shoreline in 2019 at concentrations near 10 µg/L. DOE/RL-2019-67 provides an evaluation of plume capture in this area.

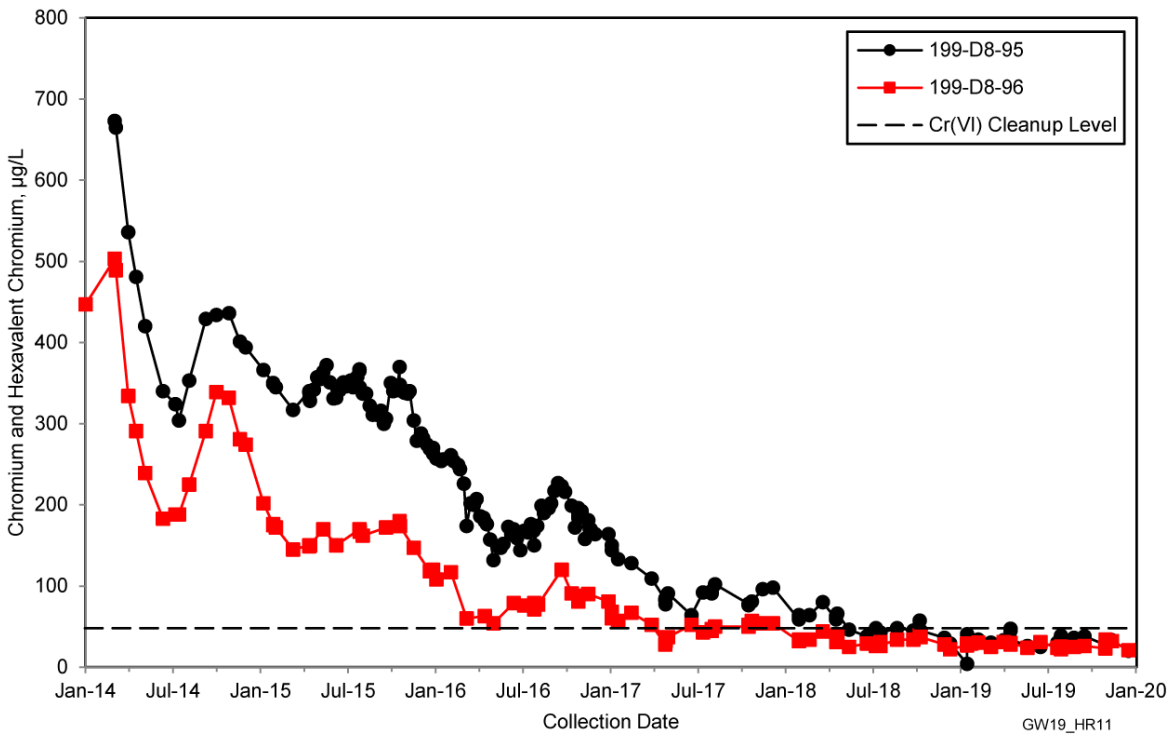


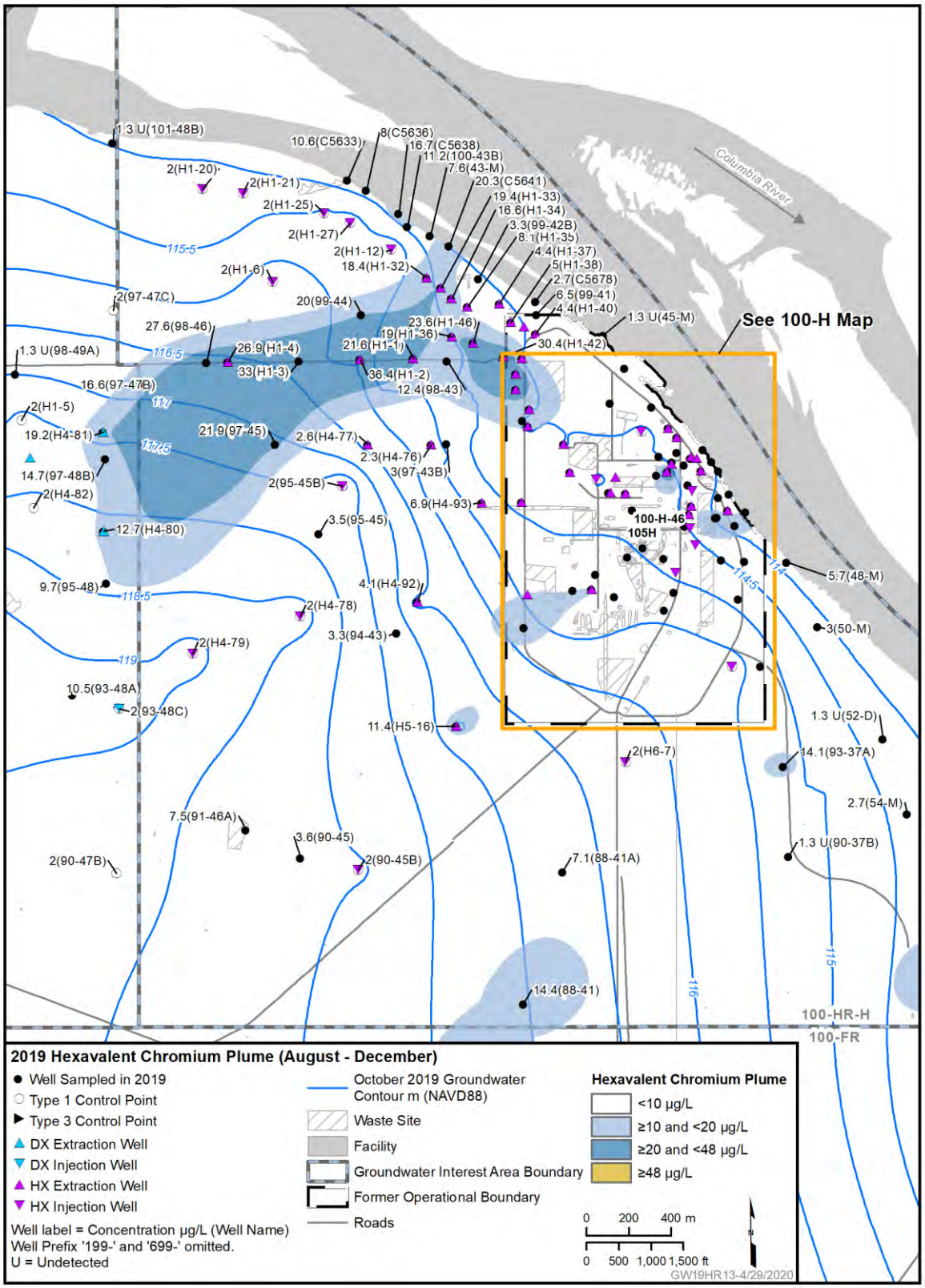
Figure 4-11. 100-HR Filtered Total Chromium and Cr(VI) Data for Extraction Wells 199-D8-95 and 199-D8-96

The Cr(VI) concentrations are increasing in an area north of the 100-D Area, where wells 199-D8-93 and 199-D8-94 had concentrations of 13.9 and 15.1 µg/L in fall 2019 compared to <10 µg/L during fall 2018. The May 2019 result for well 199-D8-94 was 38.4 g/L, which was the highest concentration detected in either well since being converted from injection wells to monitoring wells in 2017. The source of contamination is not known, and the wells will continue to be monitored.

4.4 100-HR-H Hexavalent Chromium

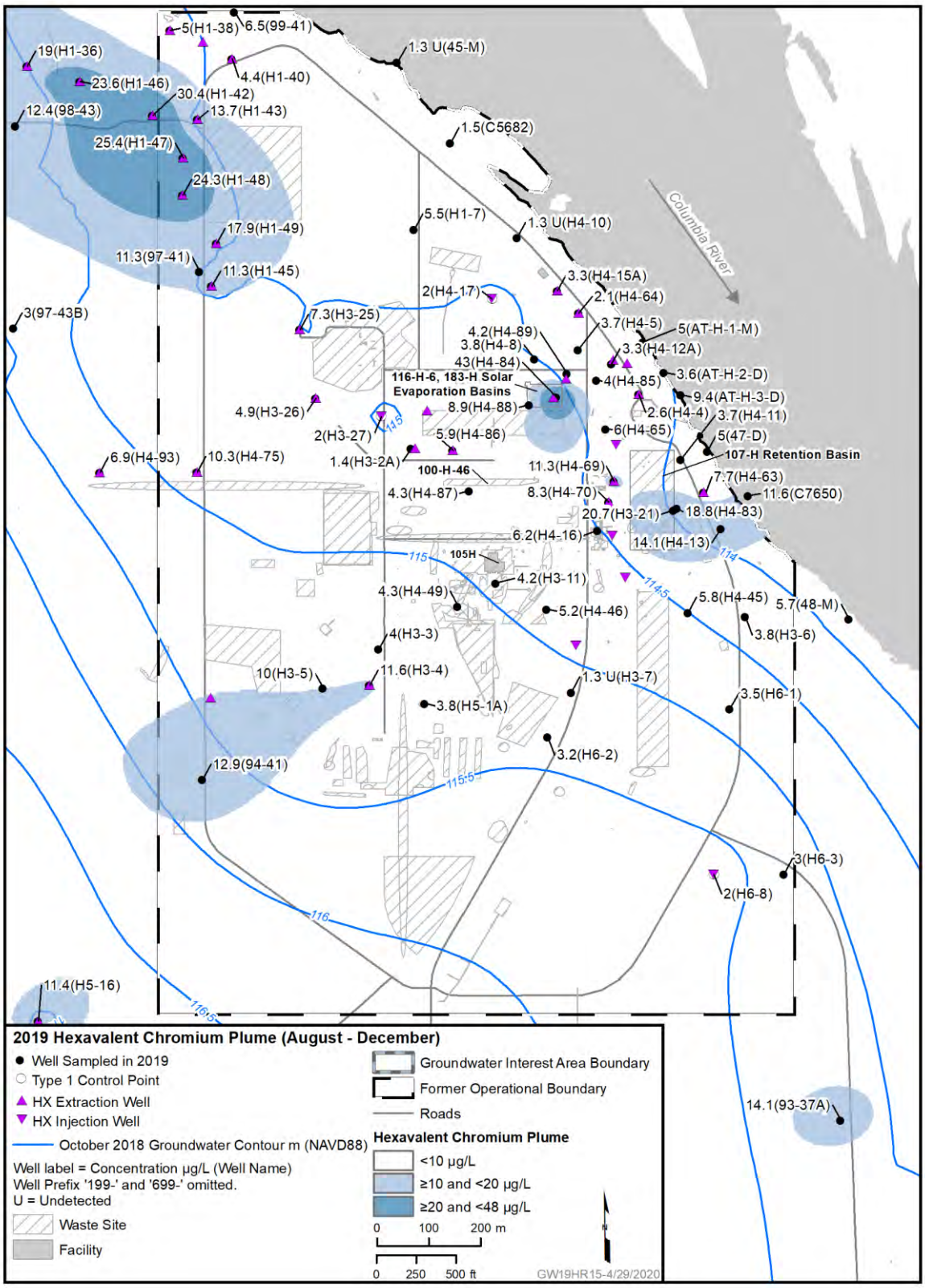
The unconfined aquifer Cr(VI) plume extends across the Horn from the 100-D Area toward the 100-H Area (Figure 4-12) (DOE/RL-2010-95). The Horn plume is largely the result of discharge to the 116-DR-1&2 Trenches in the 100-D Area during the 1967 infiltration test (BNWL-CC-1352, *Ground Disposal of Reactor Coolant Effluent*). In the 100-H Area, the Cr(VI) plume resulted from spills, leaks, and releases from facilities and waste sites associated with past operations at H Reactor. The areas of elevated concentrations are located near the 183-H Solar Evaporation Basins and at the 107H Retention Basin (Figure 4-13).

Due to ongoing P&T remediation, Cr(VI) concentrations in the Horn and 100-H Area were below the 48 µg/L cleanup level (EPA et al., 2018) at unconfined aquifer sampling locations in 2019. Remediation activities continue to reduce contaminant levels slowly, but removal effectiveness is inhibited by the unconfined aquifer thickness in the Horn area. Extraction pumps require a minimum of 0.6 m (2 ft) of water above the pump intake to operate. The aquifer is <1 m (3 ft) thick in some Horn and northern 100-H Area locations during low river stage, with the thinnest locations along the northern portion of the Horn. During low river-stage periods, the amount of water available in the aquifer for pumping is minimal. Even when pumps are set low into well sumps, insufficient water is available for the pumps to operate. The reduced operational period during low river stage adversely affects hydraulic containment of the contaminant plume.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-12. 100-HR-H Cr(VI) Plume, Fall 2019 (Low River Stage)



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-13. 100-H Area Cr(VI) Plume, Fall 2019 (Low River Stage)

4.4.1 Plume in the Horn

Overall, the complex hydrogeology and thin aquifer across the Horn have limited the response to remediation. Many extraction wells in the northern and northeastern portion of the Horn are nonoperational during low river stage due to lack of sufficient water to operate extraction pumps. To improve groundwater movement, injection of P&T system effluent in the Horn has increased in recent years. The result is movement of the remaining Cr(VI) mass toward the extraction locations and a slowly shrinking plume.

With the exception of the eastern portion of the Horn plume that extends to the south, Cr(VI) concentrations in the Horn unconfined aquifer plume continue to decline slowly, with only minimal changes in concentrations in 2019 compared to 2018. For example, concentrations in well 199-H1-3 declined from 40 µg/L in 2018 to 33 µg/L in 2019. As a result, the size of the main (east-west trending) portion of the Horn plume changed little between 2018 and 2019.

The eastern portion of the Horn plume is in an area that extends from near well 199-H1-36, southeast to well 199-H1-45. The plume, at concentrations >10 µg/L, migrated to the southeast between 2018 and 2019 as a result of continued extraction and the hydraulic gradient in this area. As a result, concentrations at extraction well 199-H1-42 increased from 15.5 µg/L in 2018 to 30.4 µg/L in 2019.

The eastern portion of the Horn plume that extends from the area near well 199-H1-45 and to the south began to separate from the main (east-west trending) portion of the Horn plume in 2018. As a result of continued extraction from several wells in this region, this portion of the Horn plume became smaller in 2019 and detached from the main plume, with concentrations in this area south to well 699-94-41 decreasing to near 10 µg/L (Figure 4-12). The largest decrease in concentrations in this area (well 199-H4-75) was from 35 µg/L in early 2018 to <10 µg/L in late 2019.

During 2019, Cr(VI) concentrations >10 µg/L continued to cover a large area in the main (east-west trending) portion of the Horn plume and continued to decline slowly and steadily. The highest Cr(VI) concentrations were in well 199-H1-3 at 33 µg/L and well 199-H1-2 at 36.4 µg/L, with both concentrations observed during low river stage. An injection well (699-97-47C) was installed northwest of the Horn plume to inhibit plume migration to the north from the Horn (Table 4-2).

In the northern portion of the Horn, Cr(VI) was detected along the Columbia River shoreline at concentrations >10 µg/L in aquifer tubes C5633, C5638, and C5641 and in nearshore well 699-100-43B during low river stage (Figure 4-12). Cr(VI) concentrations increased in 2019; the highest concentration was 20.3 µg/L at C5641. These aquifer tubes and well are located in an area where plume capture is difficult due to the thin aquifer. Extraction wells in the vicinity (e.g., 199-H1-32 and 199-H1-33) could not operate during most of the year due to insufficient water column in the extraction wells for the pumps to operate. The pumps in wells 199-H1-32 and 199-H1-33 operated only 13% and 23% of the time, respectively, in 2019.

In 2019, injection well 199-H1-12 was installed northwest of current extraction well 199-H1-32 to mitigate plume migration to the river by providing a barrier of clean water year round and inhibit migration of the Cr(VI) plume toward the river (Table 4-2). This injection well began operating in August 2019.

Table 4-2. New Wells Installed in 100-HR in 2019

Well Name	Well ID	Purpose	Drilled Depth (ft bgs)	Drilled Depth (m bgs)	Construction Depth (ft bgs)	Construction Depth (m bgs)	Acceptance Date	Comment
199-H1-12	C9926	Injection[a]	87.6	26.7	48.2	14.7	6/10/2019	Planned as an unconfined aquifer monitoring well
199-H1-50	C9931	Monitoring[b]	112.5	34.3	89.8	27.4	6/10/2019	RUM aquifer monitoring well
199-H3-12	C9987	Monitoring[b]	126.5	38.6	112.5	34.3	6/10/2019	RUM aquifer monitoring well
199-H3-13	C9989	Monitoring[b]	116.1	35.4	113.1	34.5	6/10/2019	RUM aquifer monitoring well
199-H3-21	C9923	Extraction[a]	60.0	18.3	58.6	17.9	6/10/2019	Unconfined aquifer extraction well
199-H3-22	C9924	Extraction[b]	132.0	40.2	112.5	34.3	6/10/2019	Planned as a RUM aquifer extraction/monitoring well
199-H3-32	C9724	Monitoring[a]	103.0	31.4	101.0	30.8	8/9/2019	RUM aquifer monitoring well
199-H7-1	C9719	Monitoring[a]	111.2	33.9	81.8	24.9	6/10/2019	RUM aquifer monitoring well
699-95-45C	C9933	Monitoring[b]	175.0	53.3	107.3	32.7	6/10/2019	RUM aquifer monitoring well
699-97-47C	C9545	Injection[c]	42.0	12.8	35.2	10.7	6/10/2019	Unconfined aquifer injection well

a. DOE/RL-2013-35-ADD10, *100-HR-3 Groundwater Operable Unit Well Installation Sampling and Analysis Plan, Addendum 10: 199-D1-1, 199-D7-7, 199-H1-12, 199-H3-21, 199-H3-31, 199-H3-32, 199-H7-1, 699-95-48C, and 699-97-47D*, as modified by TPA-CN-0865.

b. DOE/RL-2013-35-ADD11, *100-HR-3 Groundwater Operable Unit Well Installation Sampling and Analysis Plan, Addendum 11: Wells 199-H3-12, 199-H3-13, 199-H3-22, 199-H1-50, and 699-95-45C*.

c. DOE/RL-2013-35-ADD7, *100-HR-3 Groundwater Operable Unit Well Installation Sampling and Analysis Plan, Addendum 7: Wells (199-D5-160, 199-D5-61, 199-D8-102, 699-97-47C, 699-88-41A, 699-93-37A, 699-90-47B, and 699-90-45B)*.

bgs = below ground surface
ID = identification
RUM = Ringold upper mud unit

4.4.2 Plume in the 100-H Area

The 183-H Solar Evaporation Basins and the 107H Retention Basin contaminated the unconfined aquifer in the 100-H Area with Cr(VI) (Figure 4-13). A continuing Cr(VI) source in the lower vadose zone is suspected at both locations (SGW-64372, *100-D/H Hexavalent Chromium Source Evaluation*). In wells 199-H4-84 and 199-H4-88 at the 183-H Solar Evaporation Basins, concentrations increase during periods of higher water levels, which is typical for areas with a contaminant source. Figure 4-14 shows the water table fluctuations in well 199-H4-88 and the corresponding response in Cr(VI). Section 4.10 provides a detailed discussion of contaminant levels and trends at the 183-H Solar Evaporation Basins.

At the 107H Retention Basin, Cr(VI) is present at >10 µg/L in downgradient wells 199-H4-13, 199-H4-63, and 199-H4-83. However, concentrations in wells 199-H4-13 and 199-H4-83 decreased in 2019. Concentrations in extraction well 199-H4-63 continued to fluctuate above and below 10 µg/L, which is consistent with previous years.

Downgradient of the 107H Retention Basin, aquifer tube C7650 showed Cr(VI) concentrations that decreased from an average of 16.6 µg/L in 2018 to 11.6 µg/L in 2019. Cr(VI) concentrations also continued to be >10 µg/L in aquifer tube 51-D, located to the south of the 100-H Area. This appears to be an isolated area of slightly elevated Cr(VI), and concentrations are slowly declining. These aquifer tubes are only sampled during low river stage.

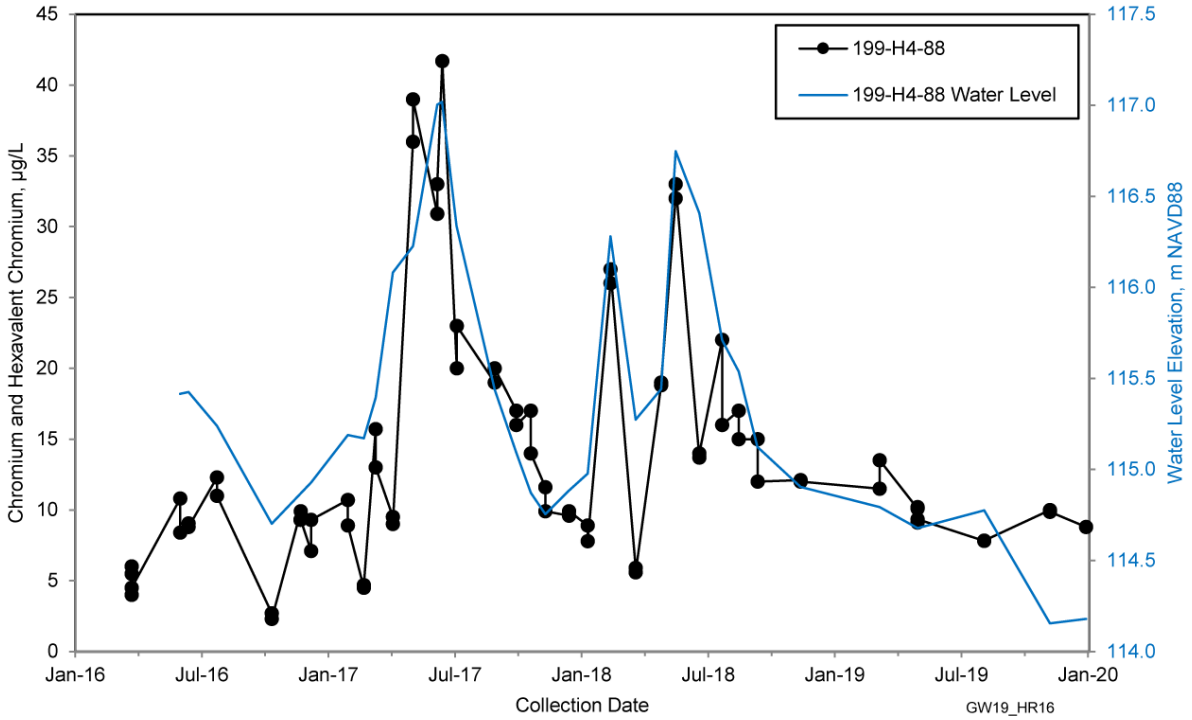


Figure 4-14. 100-HR Filtered Total Chromium and Cr(VI) Data and Water Level for Well 199-H4-88

4.5 Hexavalent Chromium in the Ringold Upper Mud Aquifer

The surface of the RUM forms the base of the unconfined aquifer in 100-HR. In 100-HR-D, the RUM material is primarily silt and clay and is relatively thick (ranging from 7 to 16.8 m [23 to 55 ft] in the three wells in this area), which provides a barrier between the unconfined aquifer and the first water-bearing unit within the RUM. Across the Horn and in 100-HR-H, data from borehole logs indicate that the uppermost RUM material is thinner and contains more sand and gravel than elsewhere at 100-HR.

In addition, reworked RUM material is present in multiple areas, mostly within the Horn and the 100-H Area. This material contains gravel in a silt and clay matrix that represents a transition zone above the more massive silt or clay. A hypothesis is that reworked material results in a less competent barrier between the unconfined aquifer and the RUM aquifer and contributes to hydraulic connectivity between the two units.

Within the RUM, thin sand to gravel layers with variable hydraulic conductivities act as confined or semiconfined leaky aquifers (DOE/RL-2010-95). Multiple water-bearing zones are known to be present in 100-HR. These zones are present at different depths, and the number and connectivity of these various water-bearing zones have not been determined. However, the uppermost water bearing zone (termed the RUM aquifer) is contaminated and is the focus of ongoing characterization and remediation efforts.

With the addition of eight wells installed in the RUM aquifer in 2019, Cr(VI) concentration data were used to generate a plume map (Figure 4-15). Cr(VI) is present at concentrations >48 µg/L in two general locations in the RUM aquifer: the western part of the Horn northeast of the 100-D Area, and the 100-H Area near the Columbia River.

The highest concentrations in the western plume, defined by wells 699-97-48C, 699-97-60, and 699-97-61, generally remained stable between 2018 and 2019. The northern and southern extent of the western plume is not well defined due to a limited number of RUM wells in the region. Additional RUM aquifer monitoring wells are planned for this area to provide better definition of the concentration contours. The conceptual model for the western part of the Horn involves migration of Cr(VI)-contaminated groundwater from the unconfined aquifer through the upper RUM material and into the RUM aquifer under a strong downward hydraulic gradient. High hydraulic head occurred during 100-D Area reactor operations, including the 1967 infiltration test (Section 3.7.1 in DOE/RL-2010-95), resulting in a downward gradient into the RUM aquifer. After reaching the RUM aquifer, the plume migrated eastward, consistent with eastward groundwater flow directions.

The 100-H Area plume in the RUM is better defined than elsewhere across 100-HR due to a higher density of wells completed in that unit. The RUM wells near the 183-H Solar Evaporation Basins exhibit the highest Cr(VI) concentrations in the 100-HR RUM aquifer. Similar to the western part of the Horn, Cr(VI)-contaminated groundwater in 100-H Area moved from the overlying unconfined aquifer through the upper RUM material and into the RUM aquifer under a strong downward hydraulic gradient during reactor operations (Section 3.7.1 in DOE/RL-2010-95). Other factors that support this conceptual model of the migration pathway include a relatively thin zone of silt and clay separating it from the overlying unconfined aquifer and a leaky semiconfined aquifer character. The northern and southern extents of the 100-H Area plume are uncertain due to a lack of RUM monitoring wells in these areas. New wells are planned for installation to provide better plume delineation at the 100-H Area.

The highest Cr(VI) concentrations in the RUM aquifer were measured in four wells in the center of the plume near the 183-H Solar Evaporation Basins (Figure 4-15). Concentrations in this area ranged from 244 to 564 µg/L in 2019. With the exception of well 199-H3-29, wells in this area have not responded to extraction since extraction wells 199-H3-22 and 199-H3-29 began operating in 2018 and 2019. Located within the potentiometric surface depression and upgradient from the 183-H Solar Evaporation Basins (Figure 4-8), Cr(VI) in well 199-H3-29 declined from 269 µg/L in late 2018 to 176 µg/L in late 2019 (Figure 4-16). The RUM aquifer wells farther from the center of the plume (i.e., near the 100 µg/L contour) show elevated but slowly declining Cr(VI) concentrations that are responding to extraction in this area (Figure 4-17).

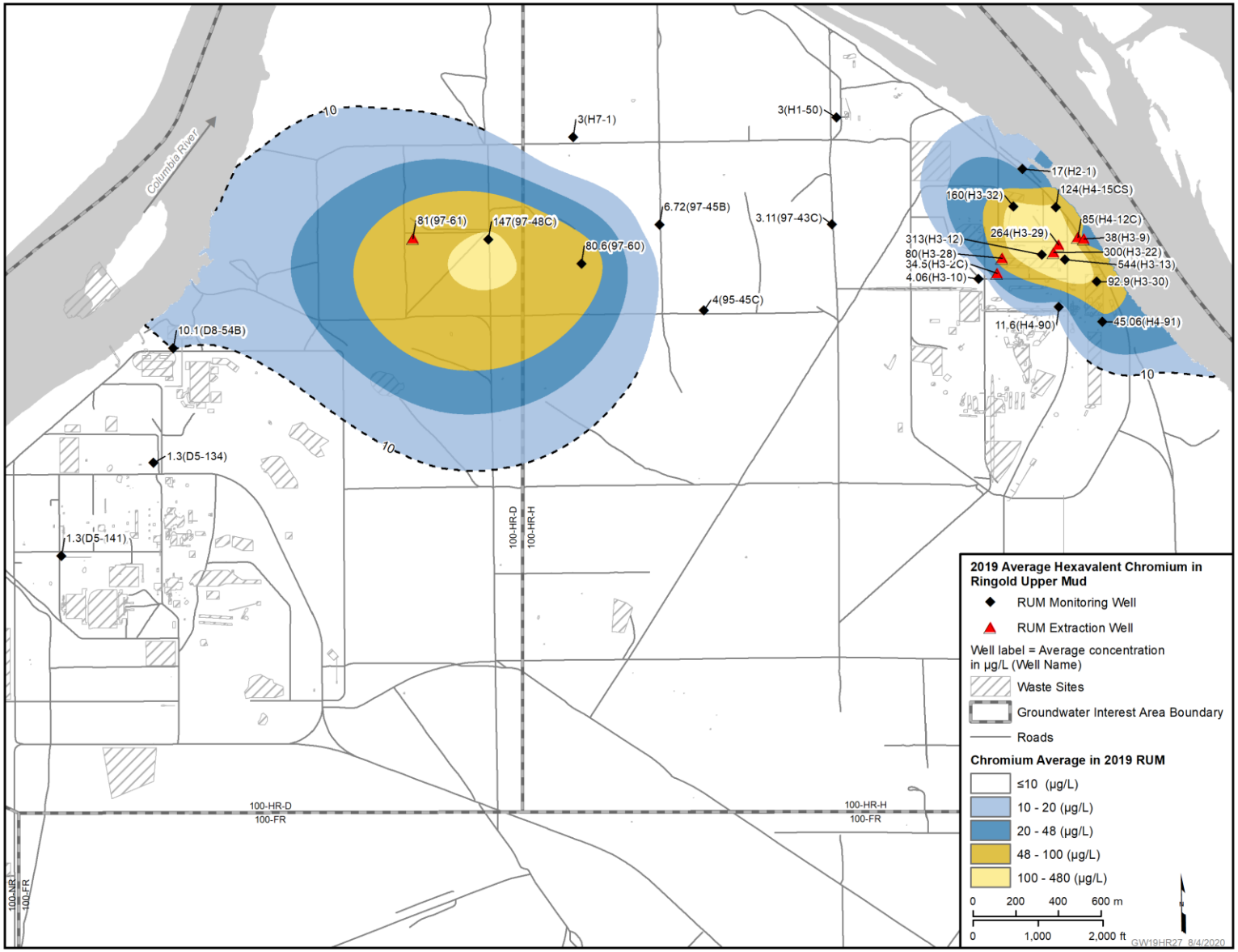


Figure 4-15. 100-HR Cr(VI) Plume in the RUM Aquifer, 2019

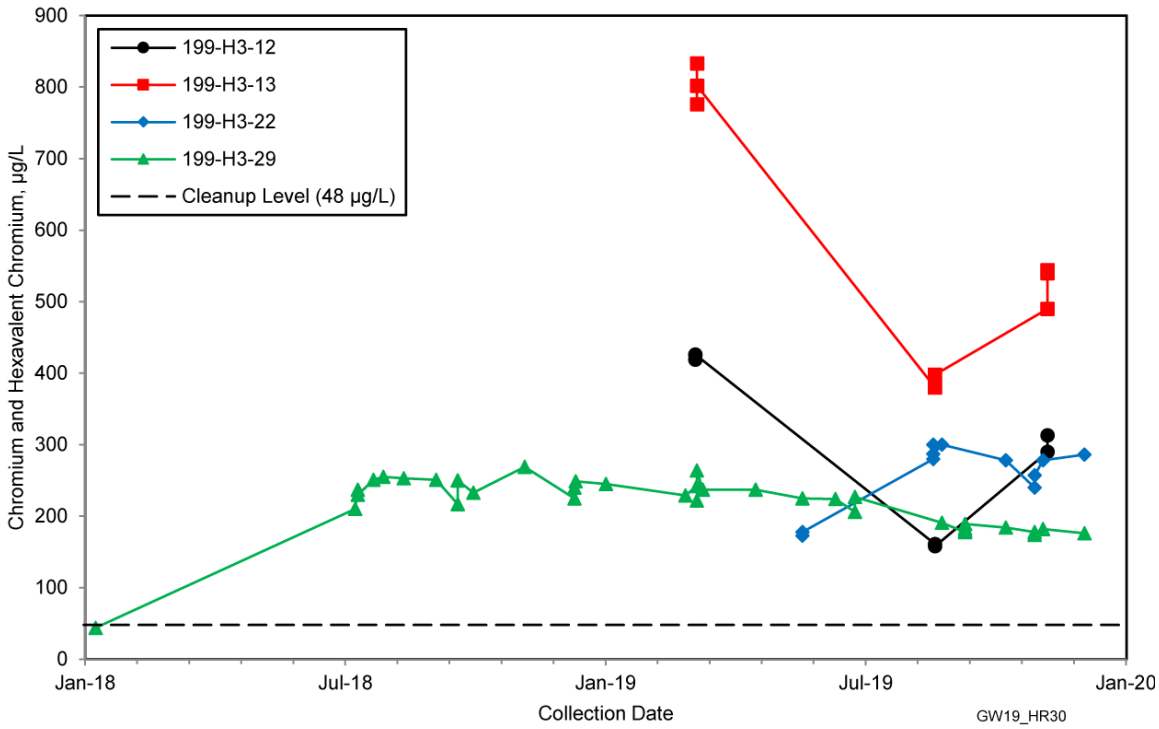


Figure 4-16. 100-HR Filtered Total Chromium and Cr(VI) Data for RUM Aquifer Wells Near the 100 µg/L Contour

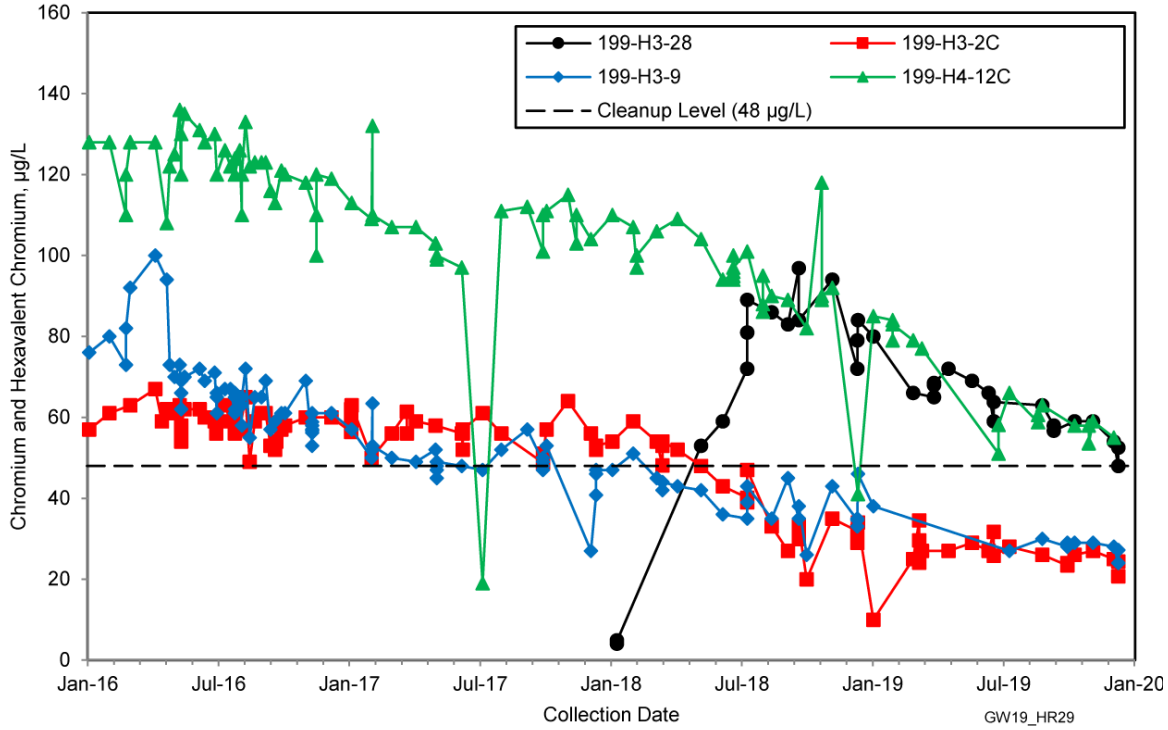


Figure 4-17. 100-HR Filtered Total Chromium and Cr(VI) Data for RUM Aquifer Wells Near the 183-H Solar Evaporation Basins

Other wells completed in the RUM aquifer have Cr(VI) concentrations above the 48 µg/L cleanup level. These wells are located along the river in the northern portion of the 100-H Area (well 199-H4-15CS), and in the south at the 107H Retention Basin (well 199-H3-30). Well 199-H4-15CS is showing an increasing trend, with a maximum concentration of 124 µg/L in November 2019. In the footprint of the 107H Retention Basin, RUM monitoring well 199-H3-30 showed increasing Cr(VI) concentrations that reached a maximum of 92.9 µg/L in October 2019. The presence of Cr(VI) in the RUM aquifer at this location is consistent with the current CSM for the area, which hypothesizes that contamination entered the RUM during operations when the hydraulic head in the unconfined aquifer was much higher, forcing contamination through the RUM material and into the RUM aquifer.

4.6 Nitrate

Primary sources of nitrate in 100-HR groundwater included gas condensate from the reactors, septic systems and sewer lines, former agricultural practices, and waste sites that received nitric acid. The nitrate plumes were historically collocated with the Cr(VI) plumes in most areas and were extracted during P&T operations. In 2019, only two unconfined aquifer monitoring wells had nitrate concentrations above the 45 mg/L cleanup level, both located at the 183-H Solar Evaporation Basins (Section 4.9). MNA is the remedy for reducing nitrate concentrations in groundwater below the cleanup level (EPA et al., 2018).

Nitrate concentrations in the RUM aquifer in 100-H Area exceeded the cleanup level in three wells within or downgradient from the former 183-H Solar Evaporation Basins. The maximum nitrate concentration was 299 mg/L (November 2019) in well 199-H3-13, a new monitoring well installed in January 2019. The RUM aquifer extraction well 199-H3-29 showed a steady decrease in nitrate concentrations to 85.4 mg/L by October 2019. The concentration in new extraction well 199-H3-22, located in the basin, increased from 48.7 mg/L in February 2019 to 107 mg/L in October 2019.

4.7 Strontium-90

Strontium-90 was present in waste disposed at both the 100-D and 100-H Areas. Elevated concentrations are present in groundwater in isolated locations near D Reactor and the 107H Retention Basin. The strontium-90 concentrations and distribution are declining gradually in both areas, consistent with natural radiological decay. MNA is the remedy for reducing strontium-90 concentrations in groundwater below the 8 pCi/L cleanup level (EPA et al., 2018).

Groundwater near the former fuel storage basin at D Reactor is monitored for strontium-90. Groundwater in wells 199-D5-132 and 199-D5-142 located near the basin continue to have elevated strontium-90 concentrations. The yearly average concentration in well 199-D5-132 (which has the highest strontium-90 levels) was 14.5 pCi/L in 2019. Strontium-90 concentrations in downgradient wells exhibit some fluctuation but remained below the cleanup level. The strontium-90 plume in this area is small and did not change in size between 2018 and 2019 (Figure 4-19 in DOE/RL-2018-66).

Strontium-90 concentrations in 100-H Area groundwater continue to exceed the cleanup level near the former 107H Retention Basin and 107H Liquid Waste Disposal Trench (located near the Columbia River and east of H Reactor) (Figure 4-18) and in one well adjacent to the reactor (well 199-H3-11). Near the 107H Retention Basin, concentrations in well 199-H4-83 increased to a yearly average of 24.4 pCi/L in 2019. Strontium-90 concentrations in two other wells downgradient of the basin (199-H4-13 and 199-H4-63) were also above the cleanup level. Strontium-90 concentrations in wells near the retention basin change with the water levels with an inverse relationship.

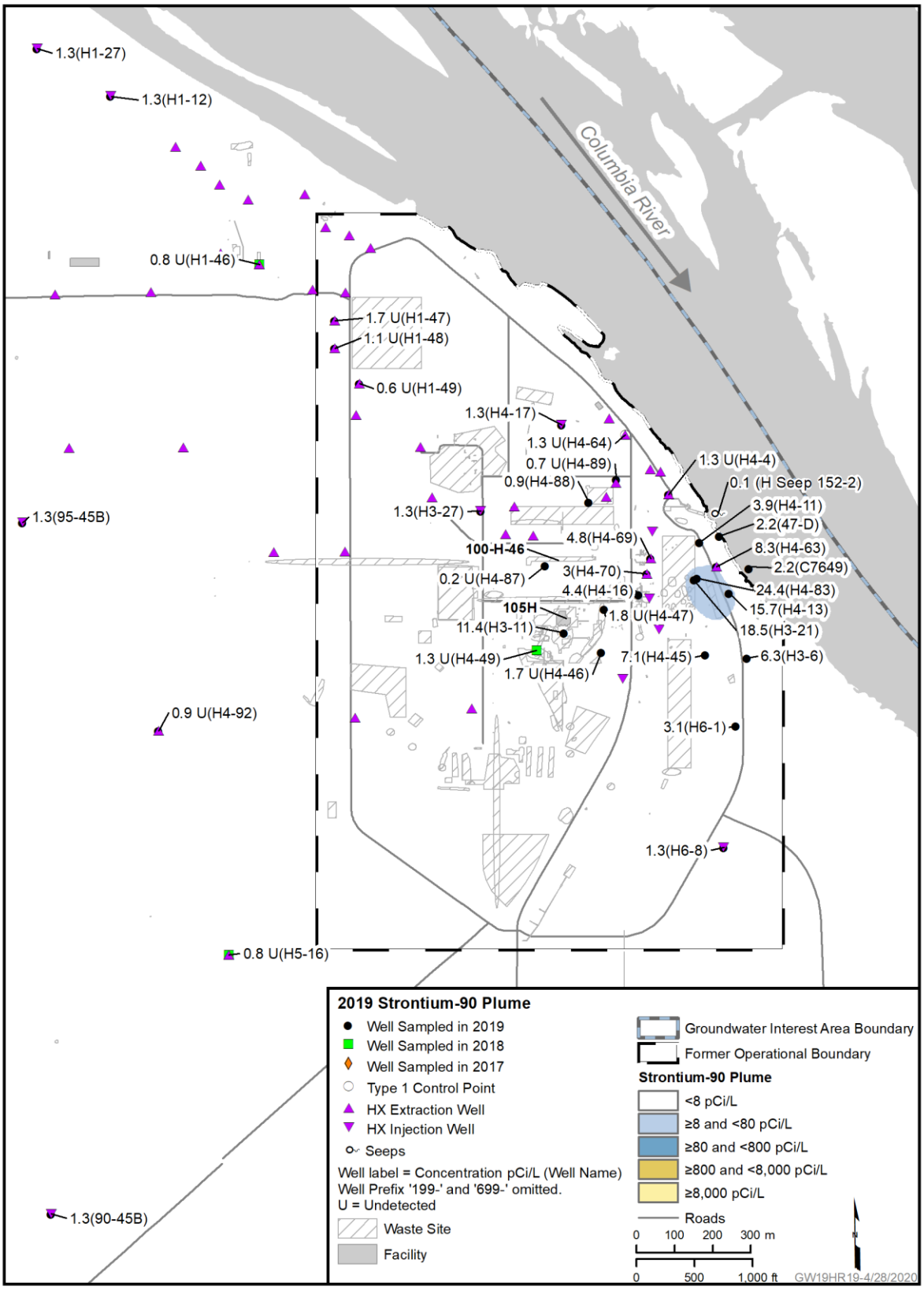


Figure 4-18. 100-HR-H Strontium-90 Plume, 2019

4.8 Uranium

Uranium was not identified as a COC in the 2018 100-HR-3 ROD, but it is present in groundwater at the former 183-H Solar Evaporation Basins in the 100-H Area. Concentrations exceeded the 30 µg/L DWS in well 199-H4-84, with a maximum of 49 µg/L (August 2019). The uranium concentrations near the basins fluctuate seasonally, with higher concentrations present during moderately high river stage (Figure 4-19). Uranium values follow the same trends as nitrate and Cr(VI) (Sections 4.6 and 4.4). This trend is consistent with the presence of a continuing source at the 183-H Solar Evaporation Basins.

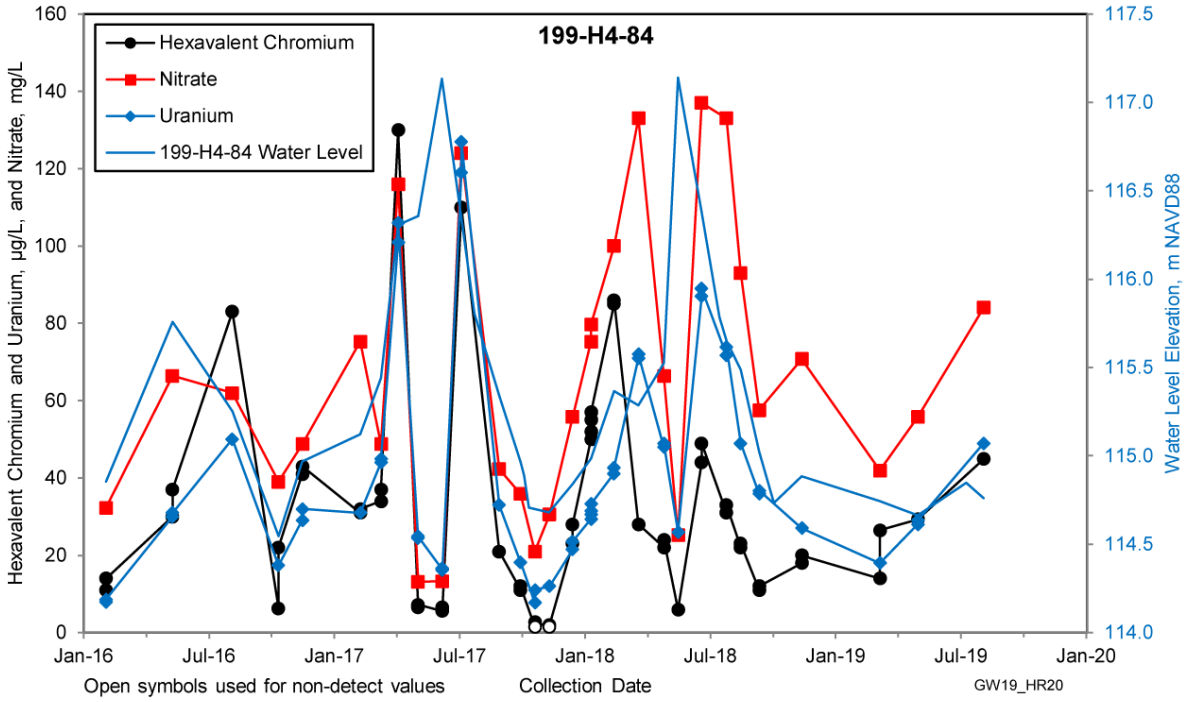


Figure 4-19. 100-HR Uranium, Nitrate, Cr(VI), and Water Levels in Well 199-H4-84

4.9 CERCLA Remediation and Monitoring

CERCLA groundwater activities in the 100-HR-3 OU included groundwater monitoring and also operating and optimizing groundwater remediation systems for Cr(VI) (including adding new wells and realigning existing wells). Up until the first part of 2018, the DX and HX P&T systems were operated under the authority of the 1996 interim action ROD (EPA/ROD/R10-96/134, *Declaration of the Record of Decision, USDOE Hanford 100 Area, 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington*) and the subsequent 2009 explanation of significant differences (EPA et al., 2009, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Benton County, Washington*).

In July 2018, a final ROD was signed (EPA et al., 2018), which selected P&T as the final remedy for Cr(VI) and total chromium, and MNA as the remedy for nitrate and strontium-90. An RD/RAWP was developed and is under review (DOE/RL-2017-13, Draft A, *Remedial Design/Remedial Action Work Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units).* The RD/RAWP outlines actions to address the remedial action objectives (RAOs) as defined in the 2018 100-D/H ROD. Related documents include a waste management plan (DOE/RL-2017-39, Draft A, *Remedial Action Waste Management Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable*

Units), a drilling SAP (DOE/RL-2019-15, *Well Installation Sampling and Analysis Plan for the 100-HR-3 Groundwater Operable Unit*), and a revised groundwater monitoring SAP (under development).

The RAOs specific to groundwater are as follows:

- **RAO #1:** Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO #2:** Prevent unacceptable risk to human health and ecological receptors from groundwater discharges to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO #7:** Restore groundwater in the 100-HR-3 OU to cleanup levels, which include DWSs, within a timeframe that is reasonable given the particular circumstances of the site.

In 2019, groundwater was monitored to evaluate remedial action effectiveness and to track plumes, plume areas (Figure 4-4; Table 4-1), and trends. The current CERCLA SAP is DOE/RL-2013-30, *Sampling and Analysis Plan for 100-HR-3 Groundwater Operable Unit Monitoring*, as modified by TPA-CN-0743, TPA-CN-0798, TPA-CN-0825, and TPA-CN-0863. The 2019 TPA-CN-0863 accounts for the addition of new monitoring wells, adjustments to the schedule requirements for annual water-level measurements, modifications to the P&T systems, and adjustments of the sampling schedule to track changing contaminant concentrations. Table A-1 in Appendix A lists the water-level and sampling exceptions for 2019.

Ten new wells were drilled and completed in 2019 (Table 4-2). Two of these wells were connected to the P&T system as injection wells, and two wells were connected as extraction wells. The remaining six wells were installed as monitoring wells within the RUM aquifer.

4.9.1 Pump and Treat

DOE has operated a groundwater P&T system in the 100-HR-3 OU since 1997 under an interim action ROD (EPA/ROD/R10-96/134), which was amended in 1999 (EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment, USDOE Hanford 100 Area 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*). Table 4-3 summarizes DX and HX P&T operations. These facilities were constructed in response to the 2009 explanation of significant differences (EPA et al., 2009), which expanded the capacities of the P&T system and replaced the older DR-5 and HR-3 systems. Continued operation of DX and HX was authorized in the 2018 100-D/H ROD (EPA et al., 2018), which selected P&T as the final remedy for Cr(VI) in groundwater at the 100-HR-3 OU. These systems are described in previous P&T reports (e.g., DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009, Volumes 1 & 2*). Figure 4-20 shows the well layout for the two systems (as of December 2019).

The DX and HX P&T systems removed a combined total of 54.7 kg of Cr(VI) from 2,288 million L (605 million gal) of groundwater in 2019 (Table 4-3). Due to continuing and effective P&T remediation, the mass of Cr(VI) remaining in the aquifer is declining as expected. This decline results in lower mass available for recovery, as shown in Figure 4-21. Most of the Cr(VI) mass removed from the DX and HX P&T systems during 2019 originated in what remains of the plume interior, where concentrations are higher. As concentrations decrease, the overall areal extent of the plumes continues to decline as expected (Figure 4-4), but at a slower rate than in the past. Operation of the remediation systems and groundwater monitoring results for 2019 are described in DOE/RL-2019-67.

Table 4-3. 100-HR-3 Remedy Summary

100-HR-3 P&T Systems, 2019		
P&T system	DX	HX
Design capacity, L/min (gal/min)	2,935 (775)	3,788 (900)
Extraction wells	46	43
Injection wells	13	19
Average flow rate, L/min (gal/min)	2,448 (647)	1,953 (516)
Volume treated, million L (million gal)	1,275 (337)	1,013 (268)
Cr(VI) mass removed, kg	24.1	30.6
Average Cr(VI) influent concentration, µg/L	18.5	31.2
Average Cr(VI) effluent concentration, µg/L	<2	<2
All 100-HR-3 P&T Systems, 1997–2019		
Volume treated, million L (million gal)		26,165 (6,912)
Cr(VI) mass removed, kg		2,601

Cr(VI) = hexavalent chromium
P&T = pump and treat

Well realignments at the DX and HX P&T systems are part of the overall remedial process optimization strategy for improving cleanup performance and reducing cleanup time frames. System realignments at the DX P&T system in 2019 included converting two monitoring wells (199-H1-5 and 199-H4-82) to injection wells. The realignment of these two wells was intended to help induce movement of the remaining Cr(VI) mass in the middle of the Horn toward the HX P&T extraction wells to the east.
At the HX P&T system, realignments included connecting new unconfined aquifer wells 199-H1-12 and 699-97-47C to the injection system to help improve plume capture in the northern part of the Horn and to prevent plume migration to the north. New unconfined aquifer well 199-H3-21 was connected to the extraction system near the 107H Retention Basin in the 100-H Area to improve river protection and increase mass removal. Well 199-H6-2 was converted from an extraction well to a monitoring well in 2019 to allow for extraction capacity at well 199-H3-21. Located near the 183-H Solar Evaporation Basins, RUM aquifer well 199-H3-22 was connected to the extraction system for mass removal.

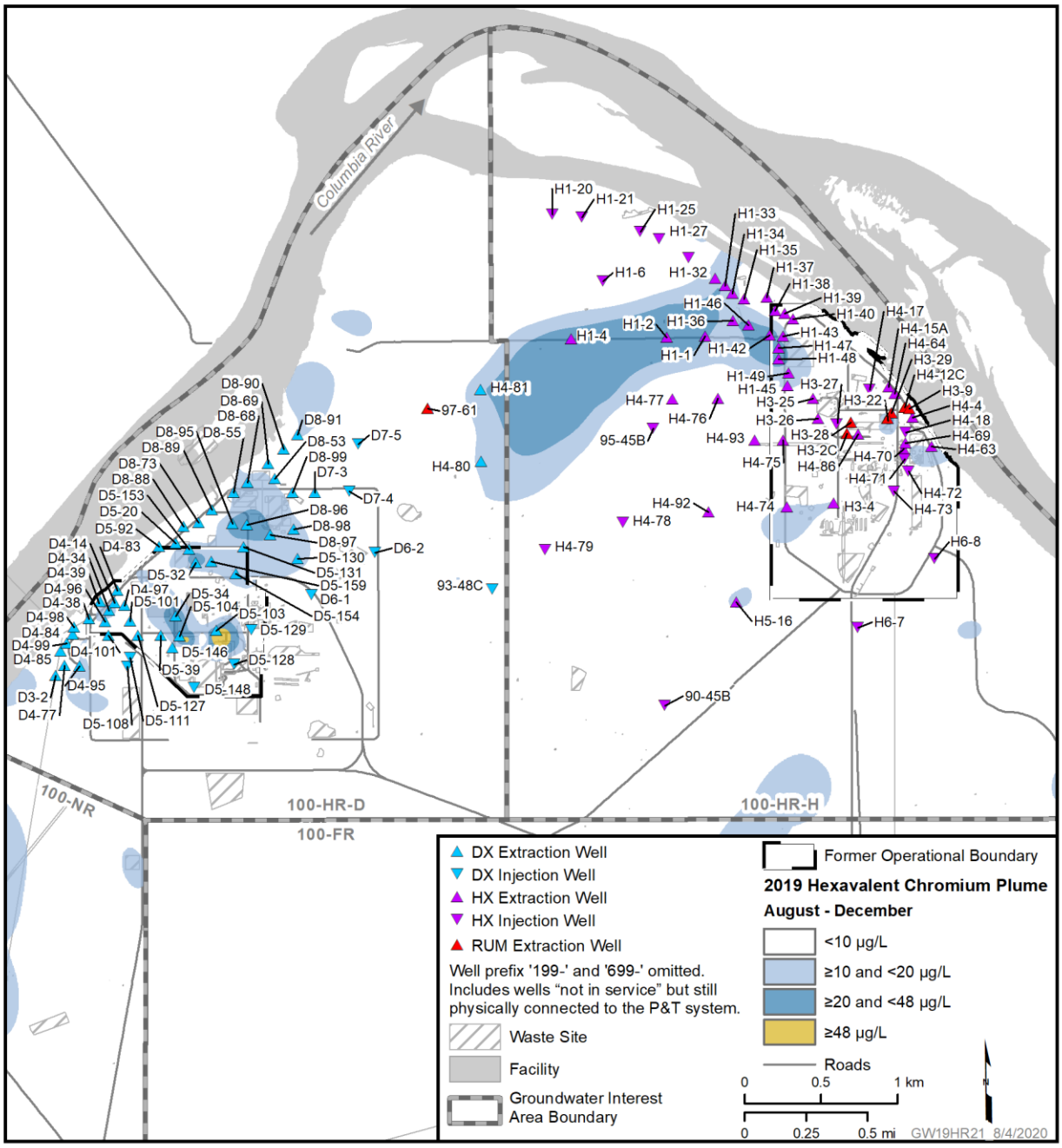


Figure 4-20. 100-HR-3 Remedy Overview

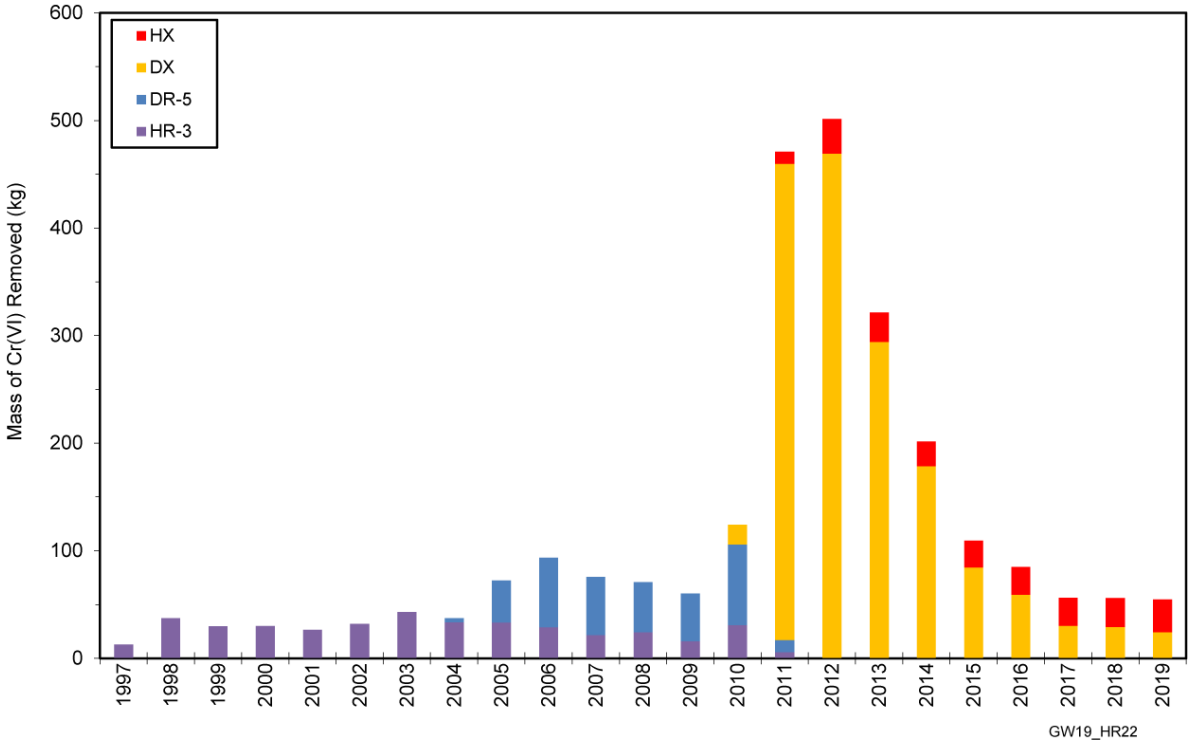


Figure 4-21. 100-HR-3 P&T Cr(VI) Annual Mass Removal

4.9.2 Metals Uncertainty Analysis

Results of a baseline risk assessment identified six metals (antimony, cadmium, cobalt, copper, lead, and silver) in 100-HR-3 groundwater that were detected infrequently or historically at concentrations above their action levels but were not associated with a specific location or a trend (DOE/RL-2010-95). This data set also included metals with detection limit historically above the action levels. DOE agreed with Ecology to collect samples to assess the uncertainties associated with these metals to determine whether to continue monitoring. The monitoring criteria were to monitor at a frequency sufficient to demonstrate the following:

- Infrequently detected analytes are not contaminants of potential (COPCs) concern during low, high, or transitional river stage.
- Analytes with detection limits above action levels are not COPCs during low, high, or transitional river stage.

Three wells screened in the unconfined aquifer in each of three exposure areas (100-D, 100-H, and the Horn) were sampled three times per year from 2016 through 2019.

Groundwater sample results and 95% upper confidence limits (UCLs) from each individual well and all three selected wells from each exposure area were compared to the action levels (SGW-64424, *Evaluation of Uncertain Analytes from 100-HR-3 Operable Unit*). For each of the exposure areas, the uncertainty analysis showed that (1) infrequently detected analytes were not at concentrations greater than the action level, (2) detection limits for each analyte were below the respective action levels, and (3) the monitoring frequency demonstrated that river stage has no effect on the concentrations. The uncertainty analysis concluded that monitoring for antimony, cadmium, cobalt, copper, lead, and silver can be discontinued for each of the exposure areas in 100-D, 100-H, and the Horn.

4.10 RCRA Monitoring at the 183-H Solar Evaporation Basins

The 183-H Solar Evaporation Basins (116-H-6 waste site) (Figure B-1 in Appendix B; Figure 4-22) consisted of four basins in the 100-H Area. The basins were originally part of the larger 183H water treatment facility, which had 12 additional basins. Following decommissioning of the water treatment facility, the four remaining basins were used to evaporate various liquid waste streams, including neutralized spent acid etch solutions from the 300 Area fuel fabrication facilities. The waste solutions contained various contaminants, including chromium, uranium, and nitrate. The basins were used for waste evaporation from July 1973 until November 1985 and were demolished in 1995. The contaminated soil was removed to a depth of 4.6 m (15 ft) below Basin 1 in 1996 (DOE/RL-97-48, *183-H Solar Evaporation Basins Postclosure Plan*).

Groundwater protection was demonstrated through modeling, and Ecology approved a modified RCRA closure in May 1997 (Soper, 1997, "Acceptance of "Closure Certification for the 183-H Solar Evaporation Basins (T-1-4)," 96-EAP-246). Clean closure of the site was not achieved because fluoride and nitrate levels in soil below the 4.6 m (15 ft) deep excavation exceeded the MTCA Method B cleanup levels (WAC 173-340) for groundwater protection. Therefore, the 183-H Solar Evaporation Basins were closed in place under the modified closure provisions of the Hanford RCRA Permit with specified measures for post-closure care.

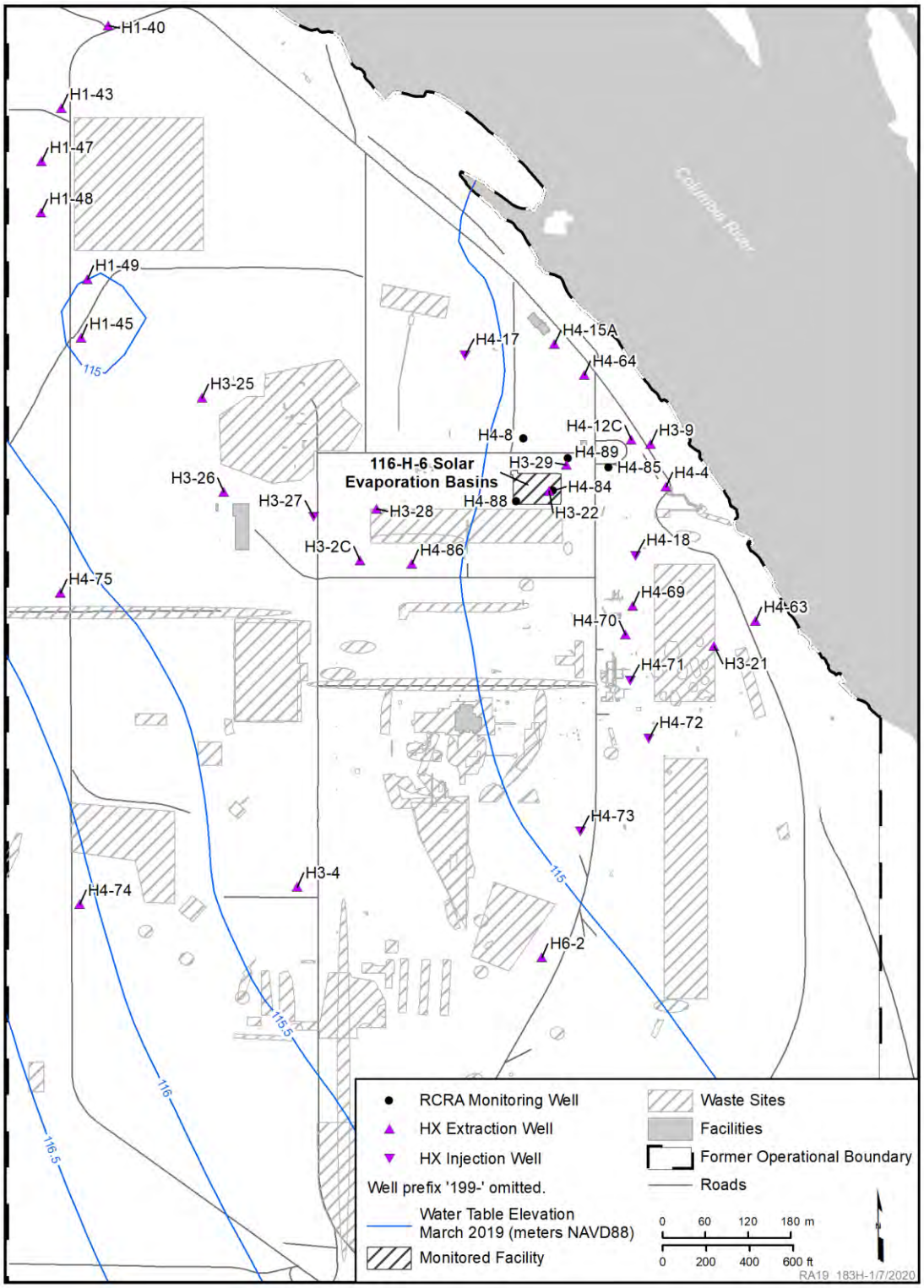
Groundwater monitoring to meet RCRA requirements is conducted in accordance with the Hanford RCRA Permit (Part VI, Post-Closure Unit 2 (PCU-2), Chapter 3.0, "Groundwater Monitoring" [modification date of May 24, 2017]). The plan monitors total chromium (collected as a filtered sample) and nitrate as dangerous waste constituents identified for corrective action monitoring.

The 183-H Solar Evaporation Basins monitoring wells (Table B-3 in Appendix B) are scheduled for semiannual sampling for total chromium (filtered), nitrate, and field parameters. Wells 199-H4-88 and 199-H4-89 were drilled in 2016, and the Hanford RCRA Permit required the wells to be sampled quarterly for 2 years to ensure sufficient samples to support statistical evaluation. The quarterly monitoring requirement was initiated following the permit revision in May 2017, beginning in the third quarter of 2017 and continuing through the second quarter of 2019.

The unconfined aquifer is very thin below the former 183-H Solar Evaporation Basins, and most of the wells are screened across the entire aquifer. In a typical year, the saturated aquifer thickness varies from <1 m (3 ft) in the fall during low river stage to 3 m (10 ft) in the spring and early summer during high river stage; however, the river stage was lower than average during 2019.

As shown in Figure 4-22, the water table in March 2019 generally sloped to the east near the 183-H Solar Evaporation Basins. However, groundwater flow direction and gradients vary due to the influence of the nearby extraction and injection wells and river stage. Therefore, a groundwater velocity table is not provided for the 183-H Solar Evaporation Basins in this report.

The RCRA sampling event scheduled for November 2019 was unsuccessful for three wells (Table B-3 in Appendix B) because the river stage was unusually low and the wells were dry or did not produce sufficient sample water volume. Sampling was attempted initially in November and again in December. Ecology was notified in early December of the unsuccessful November sampling attempts.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-22. 183-H Solar Evaporation Basins (116-H-6)

Table B-4 in Appendix B summarizes the 2019 monitoring results for the 183-H Solar Evaporation Basins. Total chromium (filtered) remained below the Hanford RCRA Permit concentration limit of 48 µg/L in each of the five wells in the monitoring network. Nitrate exceeded the permit concentration limit of 45 mg/L in wells 199-H4-84 and 199-H4-88 during 2019 (Table B-4 in Appendix B).

In a typical year, contaminant concentrations in wells 199-H4-84 and 199-H4-88 (located within the footprint of the former basins) generally rise with the water table in response to changes in river stage. This occurs when contamination remains in the lower vadose zone and the water table rises high enough to encounter the periodically rewetted zone (PRZ), releasing the contaminants into the water column. The river stage remained relatively low in 2019, so the seasonal increase in contaminant concentration was not evident.

The objective of the corrective action monitoring program is to evaluate the effectiveness of the correction action. A statistical evaluation is conducted for wells when eight independent samples are available for the UCL of the mean (or 95% UCL) calculation. Results collected for CERCLA may be included in the data set until a sufficient number of RCRA samples (eight) are collected. As of December 2019, only well 199-H4-85 required the use of CERCLA data. When sample results in the data set are less than the concentration limit, a nonstatistical or visual analysis of the data is conducted. In these cases, each result in the data set (8 to 10 samples) must be less than the concentration limit. In addition, the practical quantitation limit (PQL) for each sample in the data set must not exceed the concentration limit established in the Hanford RCRA Permit.

The statistical evaluation was conducted semiannually in 2019 (SGW-63832, *Post-Closure Corrective Action Groundwater Monitoring Report for the 183-H Solar Evaporation Basins: January – June 2019*; SGW-64454, *Post-Closure Corrective Action Groundwater Monitoring Report for the 183-H Solar Evaporation Basins: July – December 2019*) (Table B-5 in Appendix B). The 95% UCL values exceeded the concentration limit for nitrate at wells 199-H4-84 and 199-H4-88. Both wells with 95% UCL values exceeding the concentrations limits are located within the footprint of the 183-H Solar Evaporation Basins, which indicates the presence of a secondary source at that location.

The results for 183-H Solar Evaporation Basins groundwater monitoring are reported semiannually.

4.11 Atomic Energy Act Monitoring

AEA groundwater monitoring was scheduled at 46 groundwater wells and aquifer tubes in 100-HR in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 100-HR are nitrate, strontium-90, and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Five wells were not sampled in accordance with SAP requirements in 2019. Appendix C lists the sampling exceptions for 2019 AEA monitoring of the 100-HR groundwater wells.

Radionuclide concentrations detected in groundwater samples from 76 wells[5] 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 at any of the groundwater wells in 100-HR. The DWS for cumulative alpha emitters was not exceeded. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at seven locations in 100-HR (Table 4-4). The 30 µg/L DWS for uranium was exceeded at one location (well 199-H4-84). Some of these locations are adjacent to the

[5] The AEA calculations used data from wells sampled for CERCLA, as well as those sampled specifically for the AEA.

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 that restrict access to groundwater. CERCLA remedial action decisions (i.e., P&T for the 100-HR-3 OU) provide additional protection of the public and the environment.

Table 4-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-HR in 2019

Monitoring Location/ Well Name	Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum
199-D5-132	6.80	8.65	—	—
199-D5-142	4.11	4.11	—	—
199-H3-11	5.70	5.70	—	—
199-H3-21	8.30	10.20	—	—
199-H4-13	6.35	8.80	—	—
199-H4-63	4.97	4.97	—	—
199-H4-83	10.25	14.50	—	—
199-H4-84	—	—	49.00	49.00

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

None of the wells in 100-HR had total effective dose ≥100 mrem/yr or cumulative alpha activity ≥15 pCi/L.

Blank cells (—) indicate no exceedances.

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5 100-KR

This chapter presents information for the 100-KR groundwater interest area, which includes the 100-KR-4 OU and an adjacent region to the east (Figure 1-1). This chapter includes an overview, a discussion of CERCLA- and AEA-related groundwater activities conducted in 2019, and a summary of 2019 groundwater monitoring results.

5.1 Overview

Groundwater in 100-KR was contaminated by waste releases associated with past operations of the KE and KW Reactors and from associated support facilities. At the end of 2019, 75% of the waste sites had been remediated or did not require remediation. The remaining waste sites continue to be remediated in accordance with EPA/ROD/R10-99/039, *Interim Action Record of Decision, U.S. Department of Energy Hanford 100 Area and 200 Area 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)*. Removing contaminants from the vadose zone eliminates secondary contamination sources that could migrate to groundwater and reduces the risk of direct exposure at the surface.

Three general regions of 100-KR are discussed in this chapter. “K West” is the region around the former KW Reactor and associated waste sites. “K East” is the region around the former KE Reactor and associated waste sites. The third region consists of two plumes, the “K North” and “100-K/N Boundary” plumes, and is associated with the former 116-K-2 Trench and extends from the 100-K Area to the 100-N Area.

Table 5-1 lists key facts about 100-KR contamination. Chapters 1 and 3 of the 100-K Area RI report (DOE/RL-2010-97, Draft B, *Remedial Investigation for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*) provide additional details about 100-KR history, waste sites, and hydrogeology. The primary waste sites known or suspected to have contributed to groundwater contamination include the 183.1KE and 183.1KW Headhouse tank farms, 116-KE-1 and 116-KW-1 gas condensate cribs, 116-KE-3 and 116-KW-2 fuel storage basin cribs/reverse wells, 116-K-1 Crib, 116-K-2 Trench, leaks from the 105-KE and 105-KW fuel storage basins (e.g., UPR-100-K-1), and 118-K-1 Burial Ground. Figure 5-1 shows the locations of key features in 100-KR and the 2019 groundwater sampling locations. Section 1.5 provides plume mapping details, including descriptions of terms used in the figure legends (e.g., Type 1 control point).

The unconfined aquifer in 100-KR ranges from 5.2 m to >32 m (17.1 to >105 ft) thick and is primarily present in Ringold unit E sand and gravel (Figure 5-2). This unit is overlain by the gravel and interbedded sand and silt of the Hanford formation, which constitutes the bulk of the vadose zone. The vadose zone ranges from <1 m (3.3 ft) thick near the Columbia River to 32 m (105 ft) thick inland. The uneven surface of the silt- and clay-rich RUM forms the bottom of the unconfined aquifer. Contaminant concentrations are generally highest within the uppermost portion of the aquifer near the water table; however, mobile contaminants (e.g., Cr(VI)) have been detected over the entire aquifer thickness, particularly near source areas.

Table 5-1. 100-KR at a Glance

Reactor operations: KE Reactor, 1955 to 1971; KW Reactor, 1955 to 1970				
Groundwater Monitoring				
Contaminant, Water Quality Standard	**Year**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline[b] (m)**
Hexavalent chromium, 48/10[c] µg/L	2019	1,700[d] (199-K-236)	0.07 / 1.05[e]	0 / 357
	2018	528[d] (199-K-111A)	0.06 / 1.53[e]	0 / 262
Tritium, 20,000 pCi/L	2019	405,000 (199-K-207)	0.09	0
	2018	225,000 (199-K-207)	0.09	0
Nitrate, 45 mg/L	2019	103 (199-K-230)	0.09	45
	2018	88.5 (199-K-108A)	0.11	12
Strontium-90, 8 pCi/L	2019	1,230 (199-K-222)	0.02	0
	2018	4,050 (199-K-222)	0.03	0
Carbon-14, 2,000 pCi/L	2019	42,600 (199-K-106A)	0.06	0
	2018	32,900 (199-K-204)	0.03	0
Trichloroethene, 4 µg/L	2019	7.6 (199-K-185)	0.14	0
	2018	7.3 (199-K-11)	0.12	0
Remediation				
Waste sites: 75% complete.[f] Groundwater interim action for hexavalent chromium 1997 through present. Revised remedial investigation report anticipated in 2020.				

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

b. Length of shoreline intersected by plume above listed water quality standard.

c. 48 µg/L in the upland area (WAC 173-340, "Model Toxics Control Act—Cleanup") and 10 µg/L where groundwater discharges to surface water (WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances").

d. The 2019 maximum was observed during a soil flushing treatability test. The 2018 maximum was a filtered total chromium result.

e. Includes the hexavalent chromium plume on the border between 100-KR and 100-NR.

f. Sites with status of closed, interim closed, final closed, no action, not accepted, or rejected as of December 31, 2019.

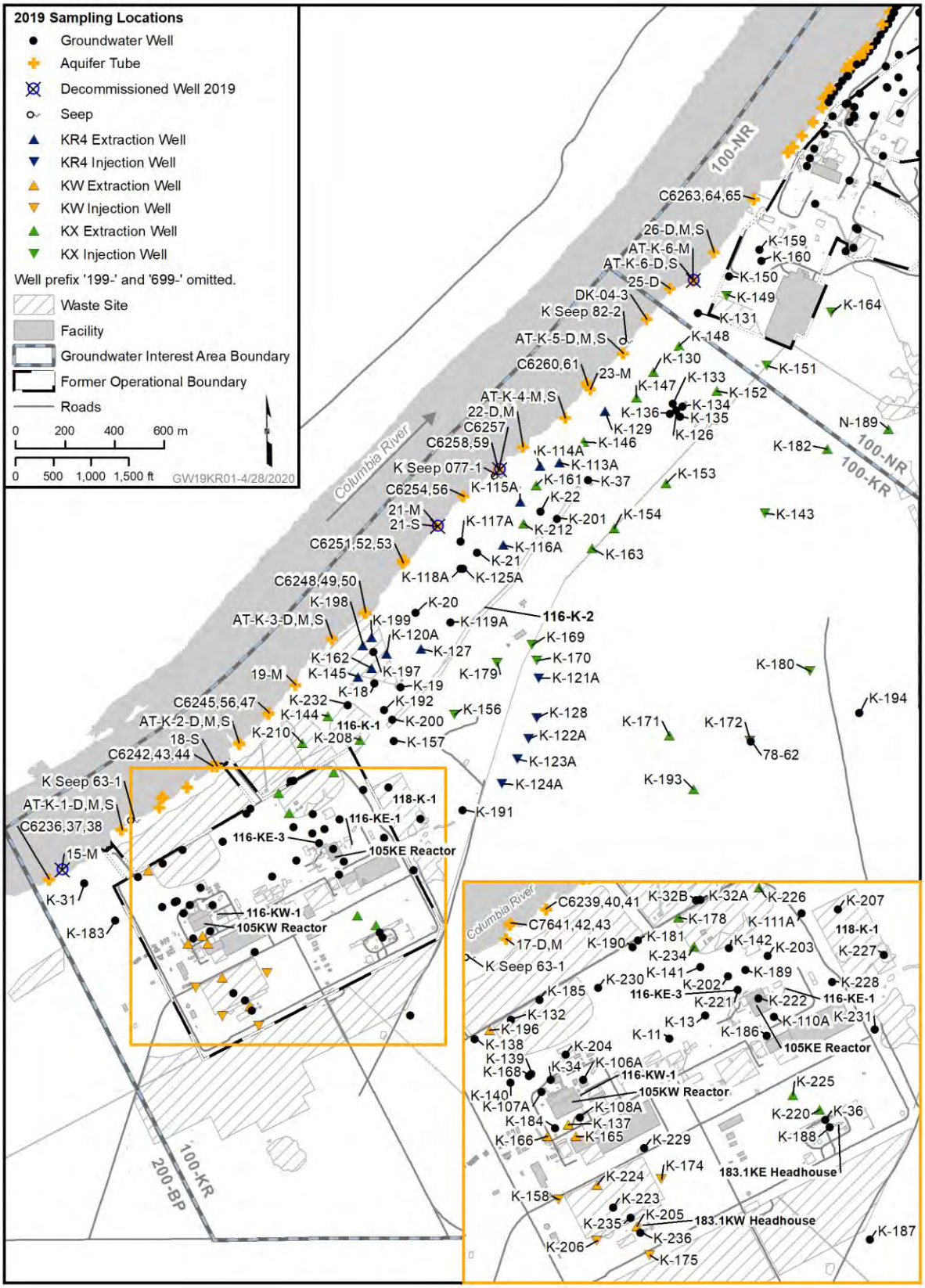


Figure 5-1. 100-KR Sampling Locations, 2019

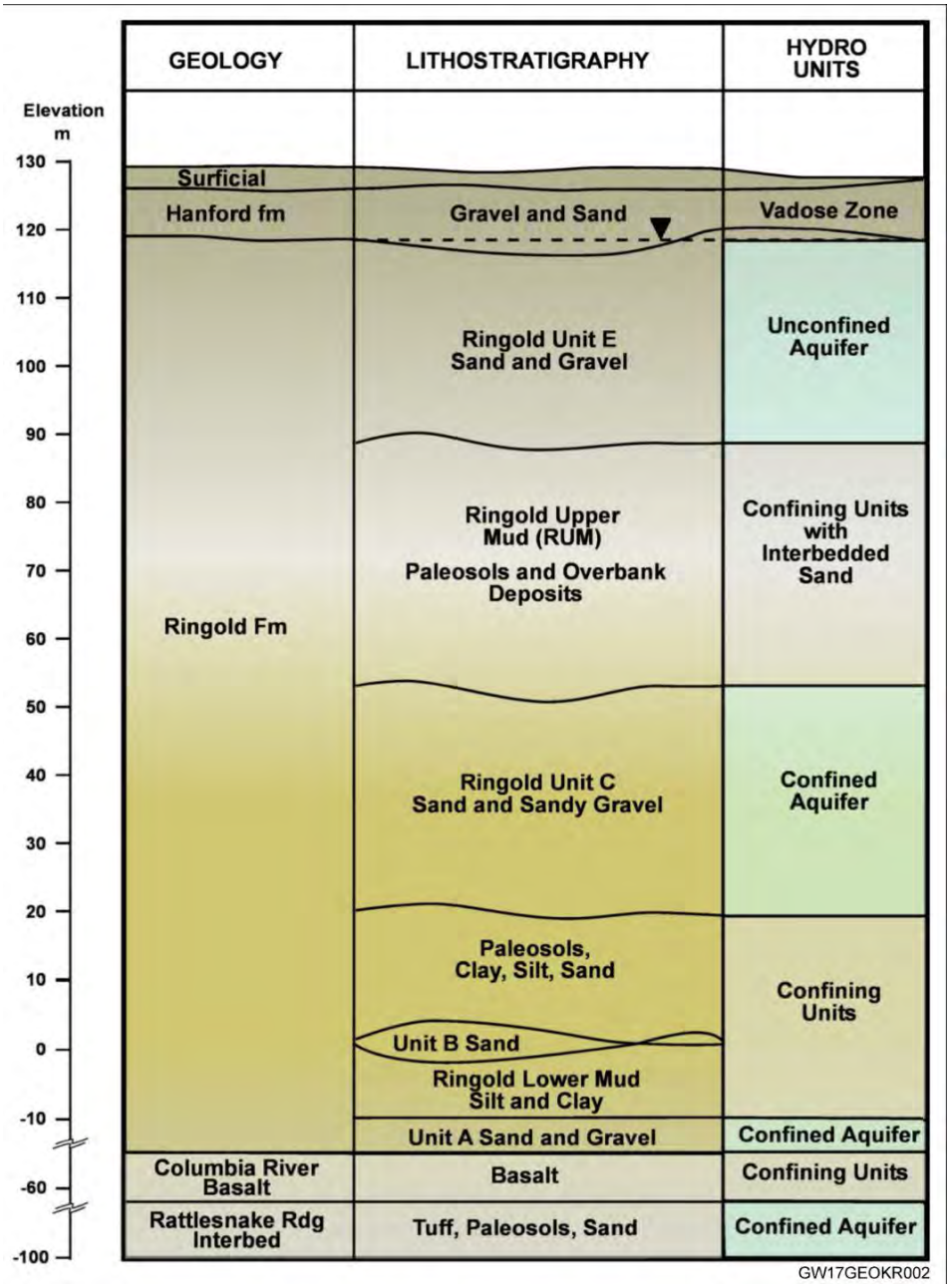


Figure 5-2. 100-KR Geology

Under natural conditions, the Columbia River is the discharge boundary for the unconfined aquifer in 100-KR. Prior to P&T system operations, groundwater flow was predominantly to the north and northwest (toward the river) and influenced by daily and seasonal fluctuations in river stage (Figure 2-12 in DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, as modified by TPA-CN-657 and TPA-CN-0733). Section 1.6.3 discusses the effects of changing river stage on groundwater flow. Operation of three P&T systems has changed groundwater flow direction in 100-KR, as noted by mounds and depressions in the water table surface (Figure 5-3). Injection of treated groundwater from combined discharges from the KR4 and KX P&T systems creates significant mounding (i.e., conditions of radial flow) near the 116-K-2 Trench and near the boundary of 100-KR and 100-NR. Extracting groundwater from the aquifer creates several cones of depression along the river. Groundwater farther inland from 100-KR generally flows to the north and northeast, toward 100-NR (Figure 1-2).

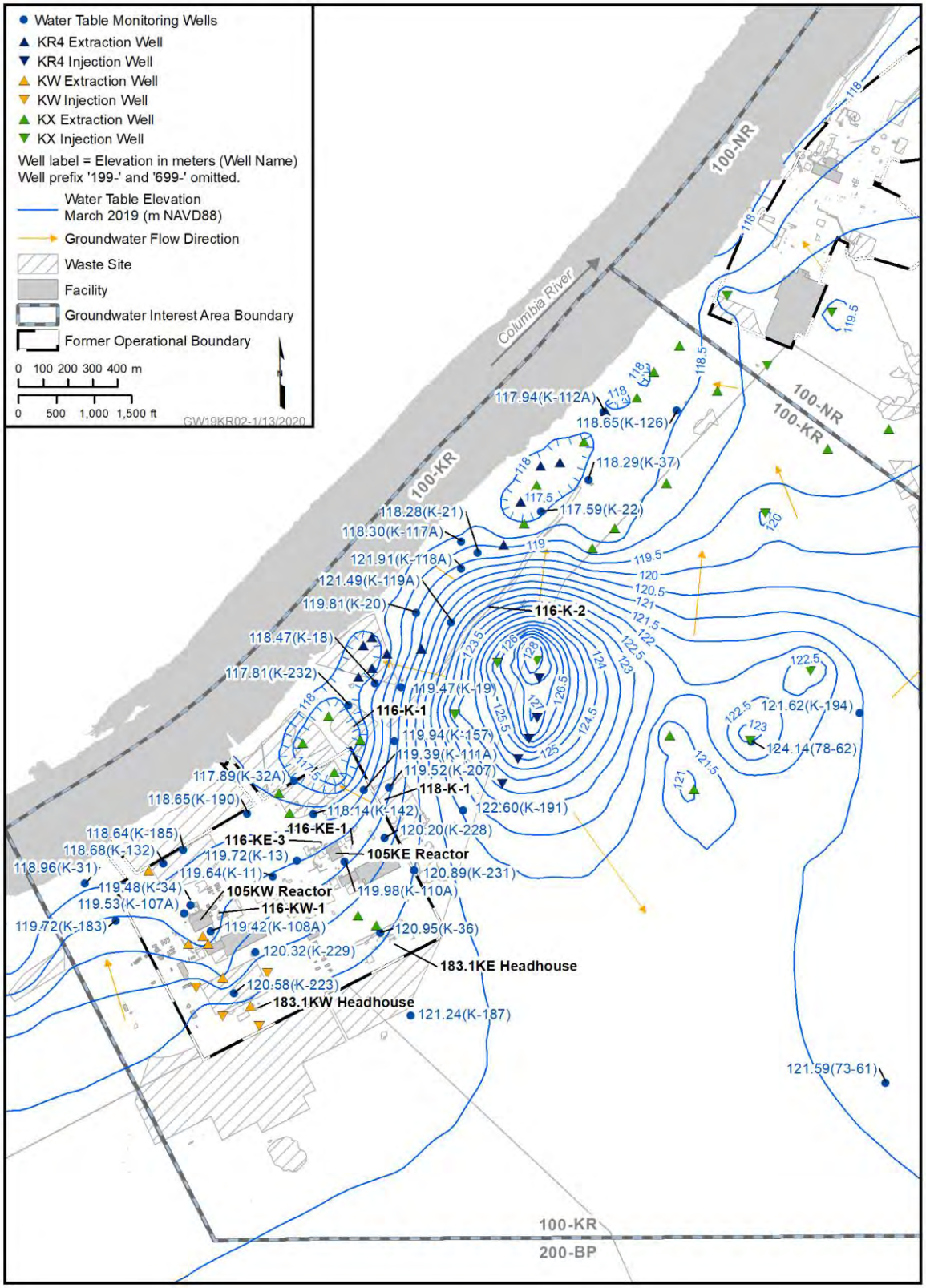
Contaminants in the 100-KR unconfined aquifer were identified in the RI report (DOE/RL-2010-97, Draft B) and include chromium (total and Cr(VI)), tritium, nitrate, strontium-90, carbon-14, and TCE. Figure 5-4 shows how the plume areas have changed since 2003.

5.2 Hexavalent Chromium

The Cr(VI) in groundwater at 100-KR resulted from two different types of historical releases. The first type of release included spills, leaks, and limited intentional discharge of concentrated sodium dichromate dihydrate solutions used as feed chemicals for conditioning reactor cooling water. The second type of release included spent reactor cooling water from retention basin leaks and intentional discharges to the 116-K-1 Crib and 116-K-2 Trench. As a result of these discharges, three general Cr(VI) plume areas developed: (1) a plume originating at or near the 183.1KW Headhouse tank farm and extending riverward (K West plume), (2) a plume originating at or near the 183.1KE Headhouse tank farm and extending riverward (K East plume), and (3) a plume originating at the 116-K-1 Crib and 116-K-2 Trench and spreading outward toward 100-NR (K North and 100-K/N Boundary plumes). These plumes have been reshaped and/or dissected by operation of the groundwater P&T systems at 100-KR, which have reduced the overall area impacted by Cr(VI) since 1996 (Figure 5-5).

Figures 5-6 and 5-7 illustrate the plumes during low river stage in 2019. The K North plume associated with the 116-K-1 Crib and 116-K-2 Trench has been most affected by ongoing remediation and is now separated into several small areas of remaining contamination. The maximum concentration in a 100-KR monitoring well in 2019 was 1,700 µg/L at well 199-K-236, which is located near the former 183.1KW Headhouse (K West plume). This elevated concentration was observed during a soil flushing treatability test (discussed in Section 5.2.1 and location shown in Figure 5-8), which was designed to mobilize residual Cr(VI) in the vadose zone into groundwater where it is extracted by the P&T system (DOE/RL-2017-30, *KW Soil Flushing/Infiltration Treatability Test Plan*).

The extent of Cr(VI) along the river, based on aquifer tube sampling and near-river wells, remained relatively stable compared to previous years. During 2019, Cr(VI) concentrations >10 µg/L were detected in aquifer tubes AT-K-3-D, AT-K-3-M, C6256, and 22-D. The locations are consistent with the previous several years, with average concentrations showing a slight increase during 2019. In addition to measurements collected from the near-river environment at aquifer tubes, shoreline seeps at 100-KR were also sampled in 2019 (Section 1.6.3). The four seeps sampled during 2019 along the 100-KR shoreline had Cr(VI) concentrations below the 10 µg/L surface water standard.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 5-3. 100-KR Water Table, March 2019

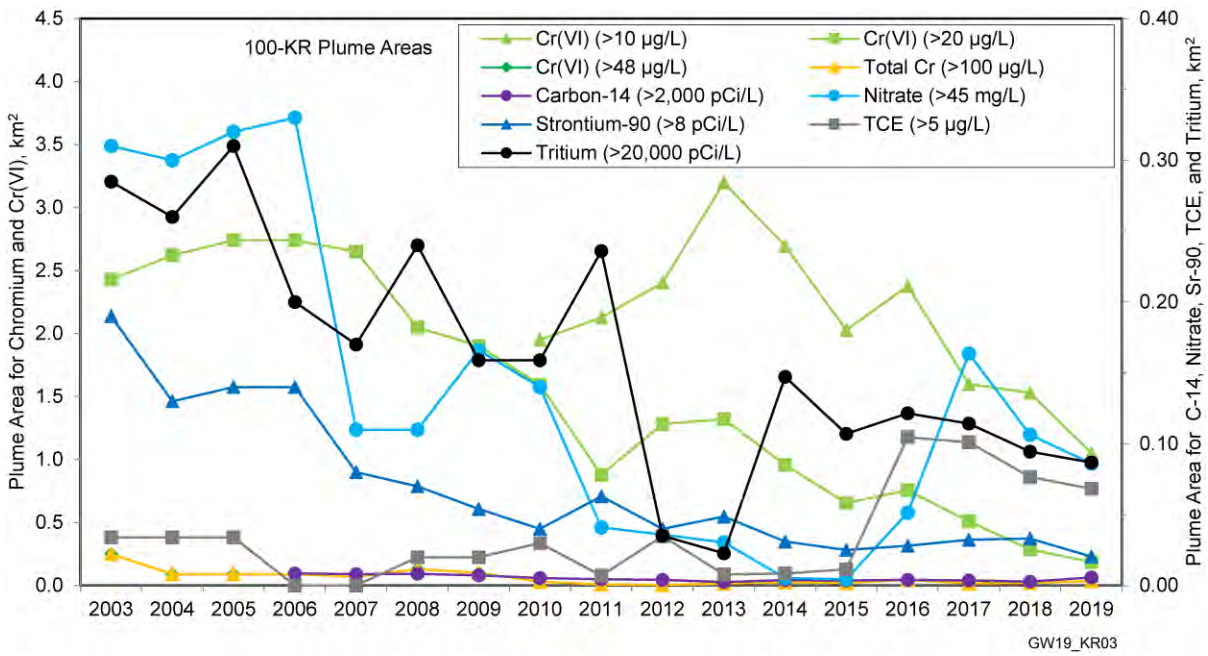


Figure 5-4. 100-KR Plume Areas

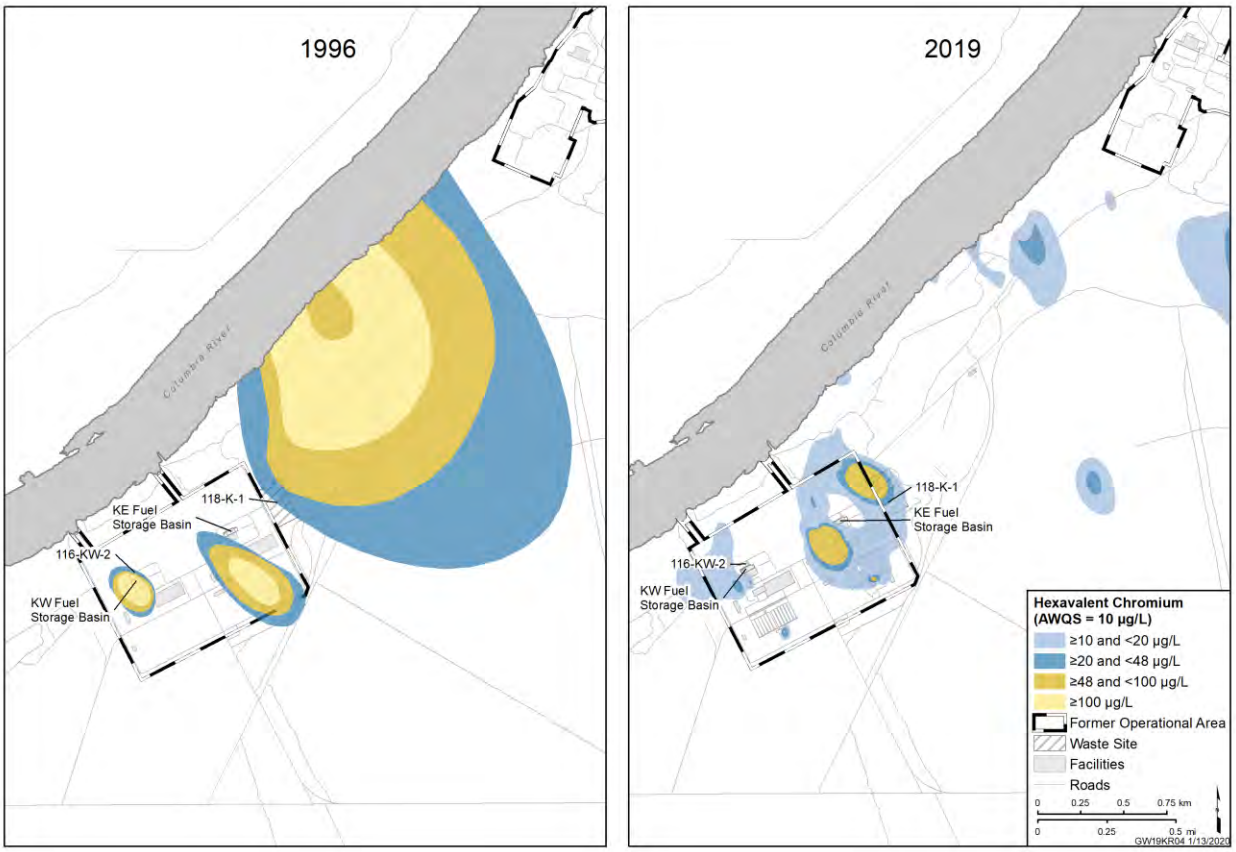
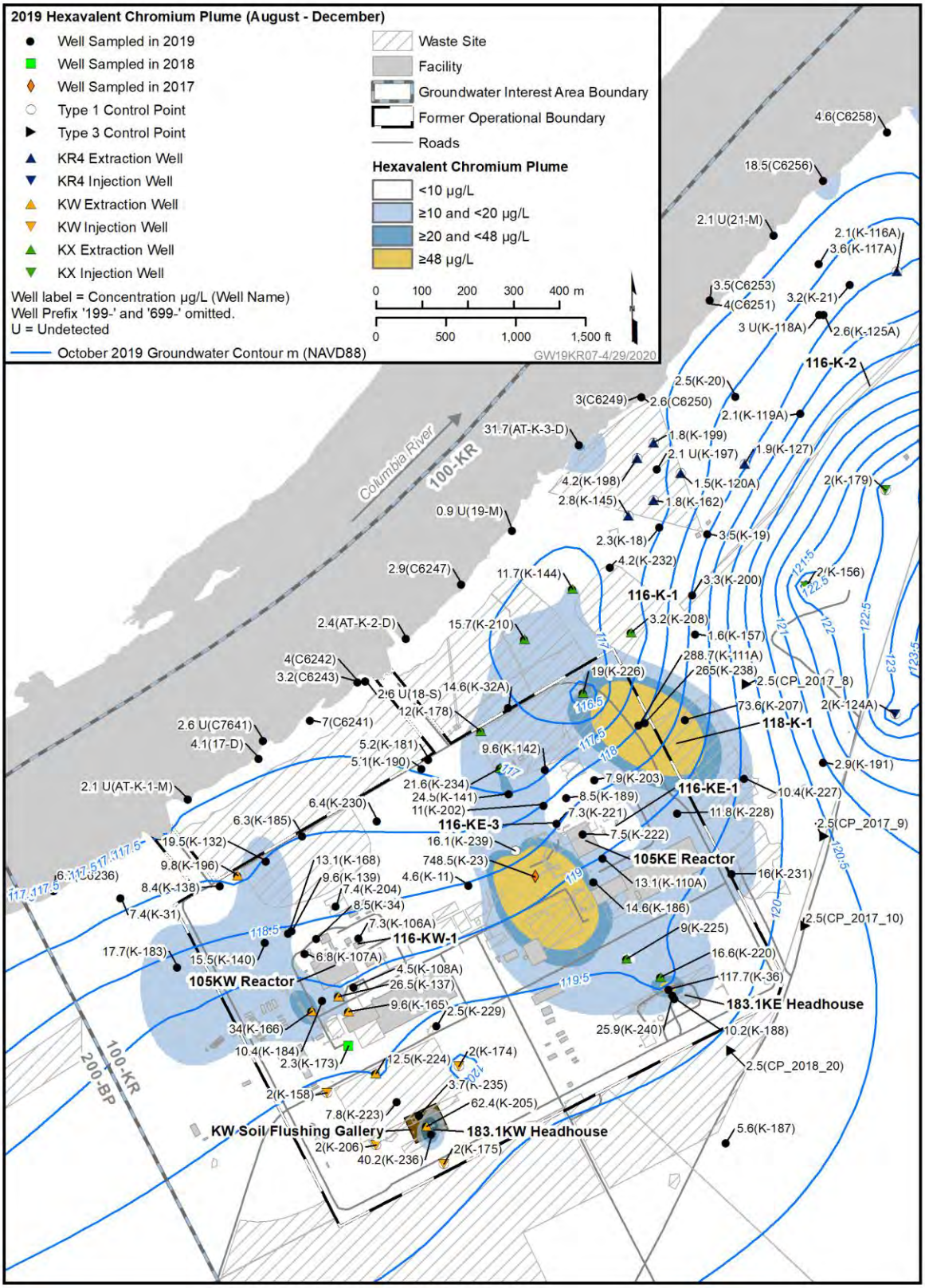
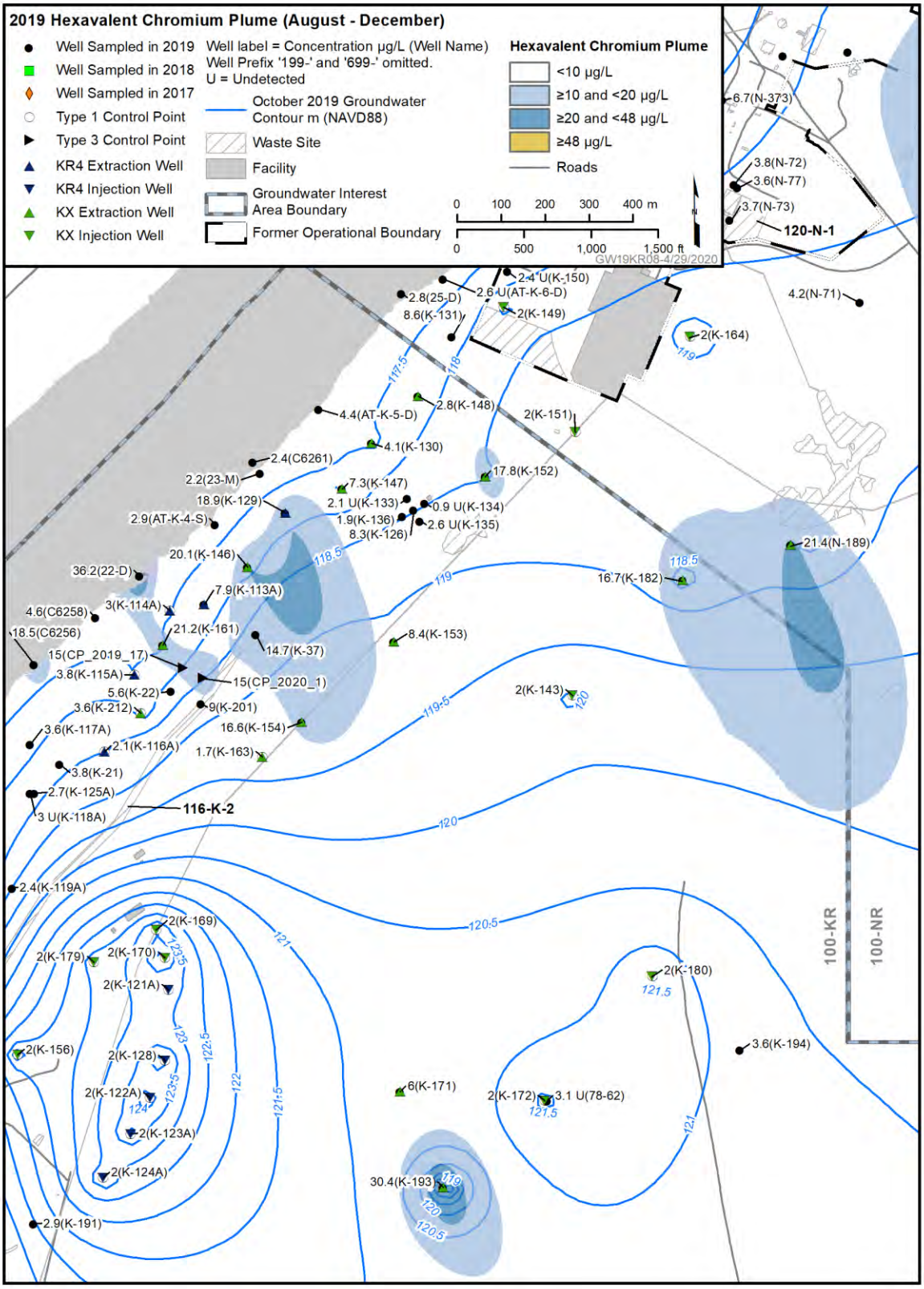


Figure 5-5. 100-KR Cr(VI) Plume in 1996 (Before Interim Action) and 2019 (During Interim Action)



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 5-6. 100-KR Cr(VI) Plume, KE and KW Vicinity (2019 Low River Stage)



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 5-7. 100-KR Cr(VI) Plume, 116-K-2 Trench (2019 Low River Stage)

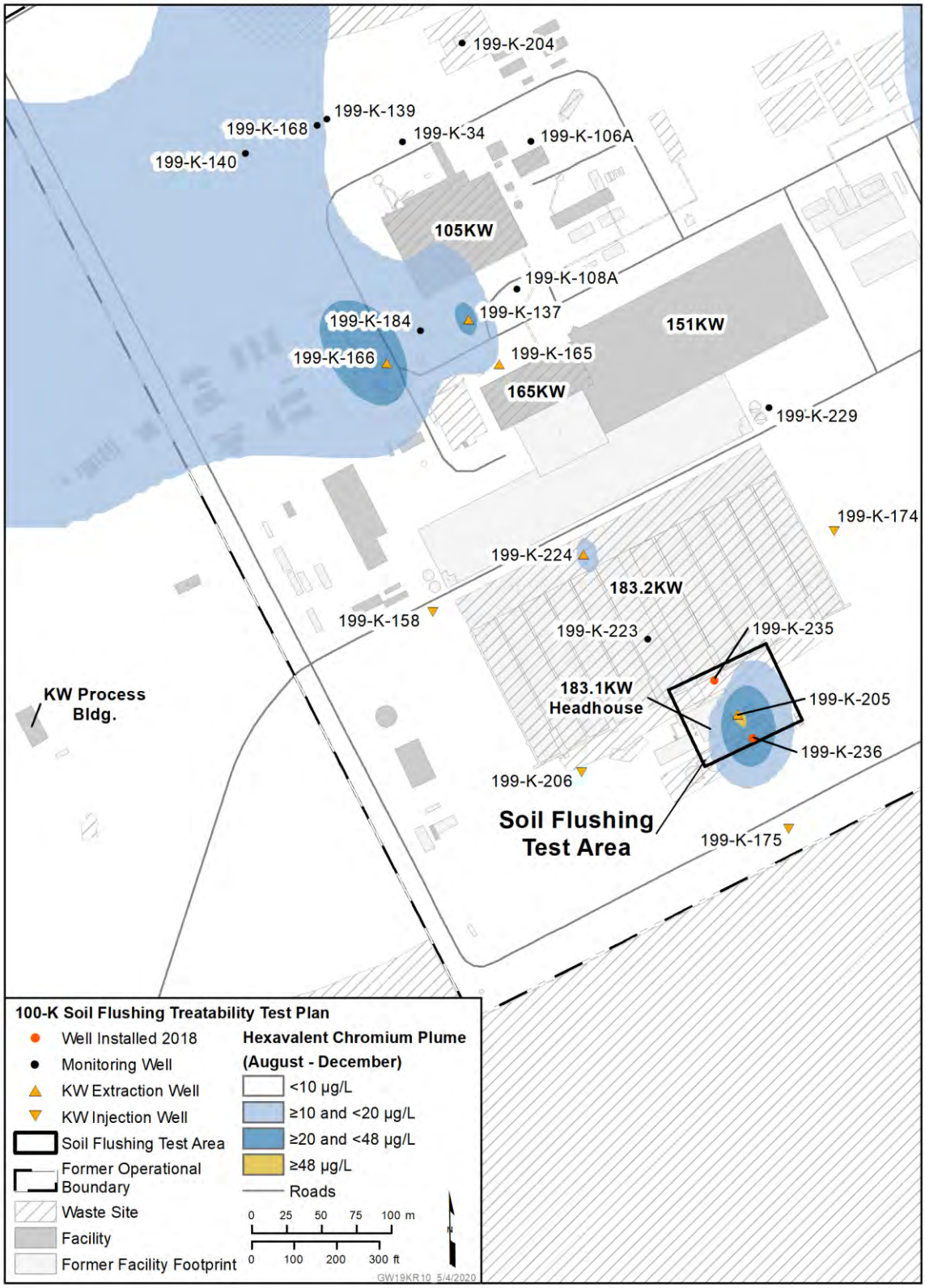


Figure 5-8. 100-KR Location of KW Soil Flushing Treatability Test

5.2.1 K West Associated Plume

Historically, the K West Cr(VI) plume has been depicted as a narrow band with relatively high concentration, starting near the 183.1KW Headhouse and extending toward the Columbia River. Between 2007 and 2016, P&T activities reduced the Cr(VI) plume in size and concentration. A rebound study performed in 2016 to 2017 concluded that sources of Cr(VI) remaining in the vadose zone continue to cause groundwater contamination above applicable water quality standards (SGW-62061, *KW Rebound Study Summary Report and Assessment*).

In 2019, a soil flushing treatability test was implemented in accordance with DOE/RL-2017-30 at the 183.1KW Headhouse area to address a continuing source of groundwater contamination. The goal of soil flushing is to remove Cr(VI) from the deep portions of the vadose zone by flushing contaminant material into the groundwater and then capturing the material with the active P&T system to remove it from the groundwater.

Phase 1 of the treatability test began on May 28, 2019, with treated KW P&T effluent being applied to the soil column through an underground infiltration gallery. Within 24 hours of startup, the effects of infiltration through the vadose zone were observed in increasing water levels at nearby monitoring wells 199-K-235 and 199-K-236. Within 2 to 5 days, Cr(VI) concentrations in monitoring well 199-K-236 and extraction well 199-K-205 increased from <48 µg/L to peak concentrations of 1,700 µg/L and 882 µg/L, respectively (Figure 5-9). On August 12, 2019, the infiltration gallery was shut down to allow the aquifer to return to pre-test conditions. Shortly after the infiltration gallery was shut down, the Cr(VI) concentrations in nearby wells temporarily increased, reaching a maximum concentration of 111 µg/L in extraction well 199-K-205 (Figure 5-9). This increase and then gradual decrease as water levels declined indicated that the secondary source of Cr(VI) in the vadose zone had not been fully depleted.

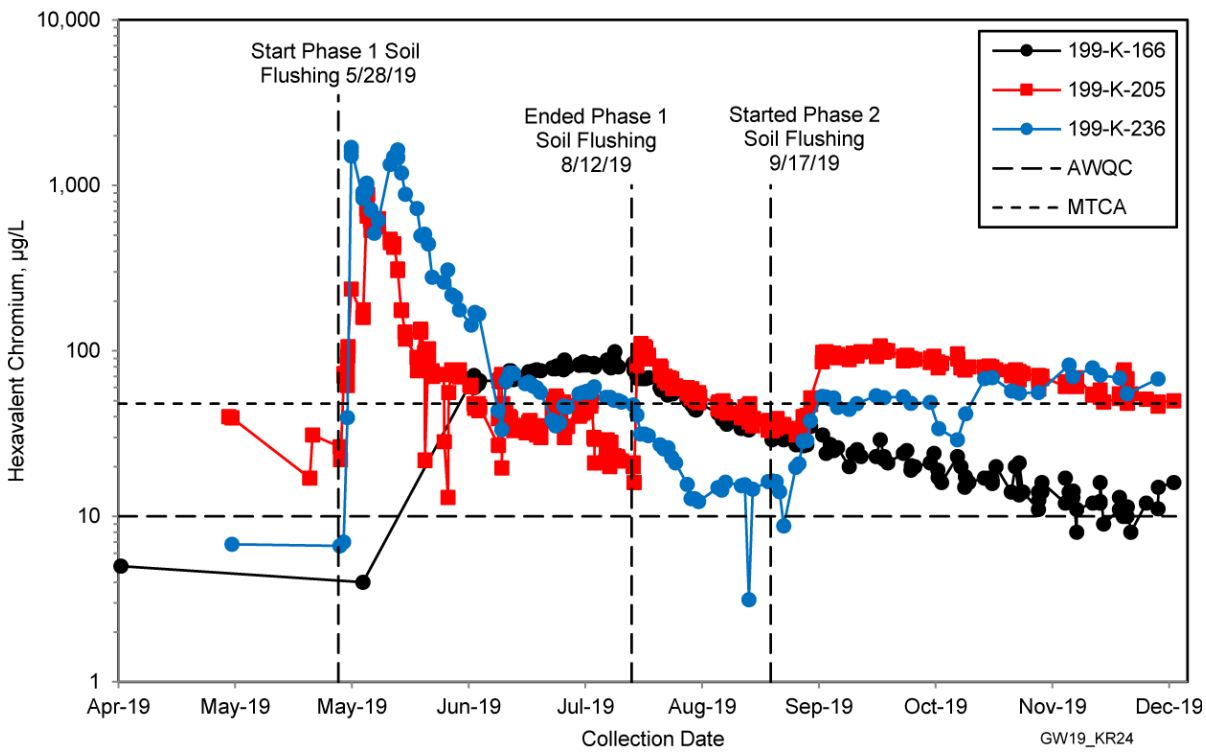


Figure 5-9. 100-KR Cr(VI) Data for Key Soil Flushing Observation Wells

Phase 2 began on September 17, 2019, and included the restart of injection wells that were shut off during Phase 1 to enhance hydraulic control and increase mass removal during Phase 2. As was observed in Phase 1, Cr(VI) concentrations increased quickly as water infiltrated the soil column, followed by Cr(VI) concentrations in wells 199-K-205 and 199-K-236 gradually decreasing to around 48 µg/L. At monitoring well 199-K-140 downgradient from the treatability test area, the annual average Cr(VI) was 15.5 µg/L, but the concentration increased sharply in November 2019 to 38.7 µg/L. This increase is likely similar to what was observed at well 199-K-166 farther inland, indicating observed impacts from soil flushing.

A treatability test report (DOE/RL-2019-77, *KW Soil Flushing Treatability Test Report*) will be prepared in 2020, documenting the results of the treatability test and providing recommendation for future soil flushing operations.

5.2.2 K East Associated Plume

The K East Cr(VI) plume currently includes (1) a high-concentration area near the head of the 116-K-2 Trench, 116-K-1 Crib, and the 118-K-1 Burial Ground; and (2) a high-concentration area originating at the 183.1KE Headhouse (Figures 5-6). The plume near the 118-K-1 Burial Ground is inferred to be commingled with the contamination at the head end of the 116-K-1 Crib and 116-K-2 Trench.

As shown in Figure 5-6, elevated Cr(VI) concentrations extended from the 183.1KE Headhouse and sedimentation basin to the area west of KE Reactor in 2019, consistent with previous years. Well 199-K-36, just north of the 183.1KE Headhouse, had a maximum Cr(VI) concentration of 446 µg/L in April before declining to 77.2 µg/L by November. Concentrations at extraction wells 199-K-220 and 199-K-225, between the 183.1KE Headhouse and former monitoring well 199-K-23, remained consistent between 2017 and 2019. For 2019, the 2017 average Cr(VI) from decommissioned well 199-K-23 continued to be used for plume mapping because a replacement well cannot be installed in the vicinity until ongoing waste site remediation work is completed. Cr(VI) data from well 199-K-13 were not used in the 2019 plume map interpretation because it is believed that this well does not monitor the same portion of the aquifer as well 199-K-23. New monitoring well 199-K-239, which was drilled in late 2019 to replace well 199-K-13, had measurable Cr(VI) at 16.1 µg/L in January 2020, which was used for mapping purposes.

The Cr(VI) plume segment on the northeast side of KE Reactor is inferred to be related to previous releases from the 116-K-1 Crib, 116-K-2 Trench, 118-K-1 Burial Ground, and 183.1KE Headhouse. Cr(VI) concentrations in well 199-K-111A declined from 440 µg/L in November 2018 to a low of 273 µg/L in November 2019. At well 199-K-207, the maximum concentration also declined in 2019 to 80.5 µg/L compared to 170 µg/L in 2018. New well 199-K-238 was installed next to well 199-K-111A in late 2019 and exhibited Cr(VI) concentrations up to 265 µg/L. Well 199-K-238 will operate as an extraction well beginning in 2020 to capture the Cr(VI) mass in that area. This Cr(VI) plume was not targeted for remediation previously due to the collocated tritium plume; however, the tritium concentrations have declined to levels acceptable to the P&T system. Inland at monitoring well 199-K-231, which was installed to better delineate the Cr(VI) plume potentially migrating from the 183.1KE Headhouse, the average Cr(VI) concentration was 16 µg/L in fall 2019. Based on water table elevations, this observed contamination may be Cr(VI) migrating from inland (Figure 5-6) historical releases to the 116-K-2 Trench similarly to inland KX extraction well 199-K-193, where elevated Cr(VI) concentrations continue to be observed.

5.2.3 K North and 100-K/N Boundary Associated Plumes

The K North and 100-K/N Boundary Cr(VI) groundwater plumes are associated with the 116-K-2 Trench and occur in multiple isolated plume segments (Figures 5-7). The continuous plume formerly present beneath the entire length of the 116-K-2 Trench has been dissected as a result of ongoing P&T system operations, including injection in upgradient areas. Near the southwestern end of the trench (the head end) in wells 199-K-111A and 199-K-226, the Cr(VI) plume appears to be commingled with contamination originating from the 183.1KE Headhouse area and/or the 118-K-1 Burial Ground (Section 5.2.2).

At the northern end of the former 116-K-2 Trench, Cr(VI) concentrations continued to decline in monitoring wells in 2019. This decline has generated two separate plume segments at the northern end compared to 2018 (Figure 5-7). The first segment includes two Type 3 control points and well 199-K-161. The two control points were added to represent the inferred connection between residual secondary source material located near the 116-K-2 Trench and the continued downward migration observed at extraction well 199-K-161. This interpretation is consistent with the modeling efforts of the 100-K RI report (DOE/RL-2010-97, Draft B) and 100-K FS (DOE/RL-2018-22, Draft B, *Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*). The second plume segment consists of wells 199-K-37, 199-K-129, 199-K-146, and 199-K-154. Based on hydraulic gradients and observed Cr(VI) trends, it is likely that this plume segment is the result of continued inland Cr(VI) migration toward the river, originating from the inland mass near wells 199-K-171 and 199-K-193. Cr(VI) concentrations at extraction well 199-K-154 continue to decline slowly, ranging from 12 to 21 µg/L in 2019.

Several aquifer tubes along the 116-K-2 shoreline continue to exhibit Cr(VI) concentrations greater than the surface water standard of 10 µg/L. At the head end of the 116-K-2 Trench (Figure 5-7), the fall average Cr(VI) concentration (which include filtered total chromium) in aquifer tube AT-K-3-D increased from 21.5 µg/L to 31.5 µg/L between 2018 and 2019. This may indicate a minor source of Cr(VI) along the shoreline causing this condition, as all inland wells continue to exhibit Cr(VI) concentrations <10 µg/L. At aquifer tube 22-D, Cr(VI) concentrations ranged from 21.1 µg/L in April 2019 in a filtered total chromium sample to 36.7 µg/L in November 2019, also in a filtered total chromium sample. The specific conductance in the aquifer tube remained >200 µS/cm, suggesting that groundwater is continuing to discharge at this location; however, the expected decrease in specific conductance due to the high river stage in June was not observed. Figure 5-10 illustrates specific conductance data for fall 2019. The specific conductance is consistent with the influence of groundwater mixing with river water. The Columbia River water typically has specific conductance of 130 to 140 µS/cm, as opposed to a typical specific conductance in groundwater of 300 µS/cm to >400 µS/cm.

Groundwater elevation contours for 2019 (Figure 5-3) indicate that the P&T systems imposed hydraulic capture of groundwater along the affected shoreline, consistent with the specific conductance observations in neighboring aquifer tubes. This might indicate that the aquifer is sampling from a lower permeable zone and the observed condition is from historical use of the 116-K-2 Trench, not from breakthrough in the current P&T system.

The northeastern portions of the 116-K-2 Trench plume (Figure 5-7) extend northeast into 100-NR, as evidenced by Cr(VI) in KX P&T extraction wells 199-K-182 and 199-N-189. Concentrations in wells 199-K-182 and 199-N-189 continued to decline in 2019 as a result of groundwater extraction. The Cr(VI) concentration in well 199-N-74, located 2 km (1.2 mi) from the end of the trench, was 42.3 µg/L in 2019, which is a slight increase from previous years. Cr(VI) continued to be detected in wells farther northeast in 100-NR, which is discussed in further detail in Chapter 6.

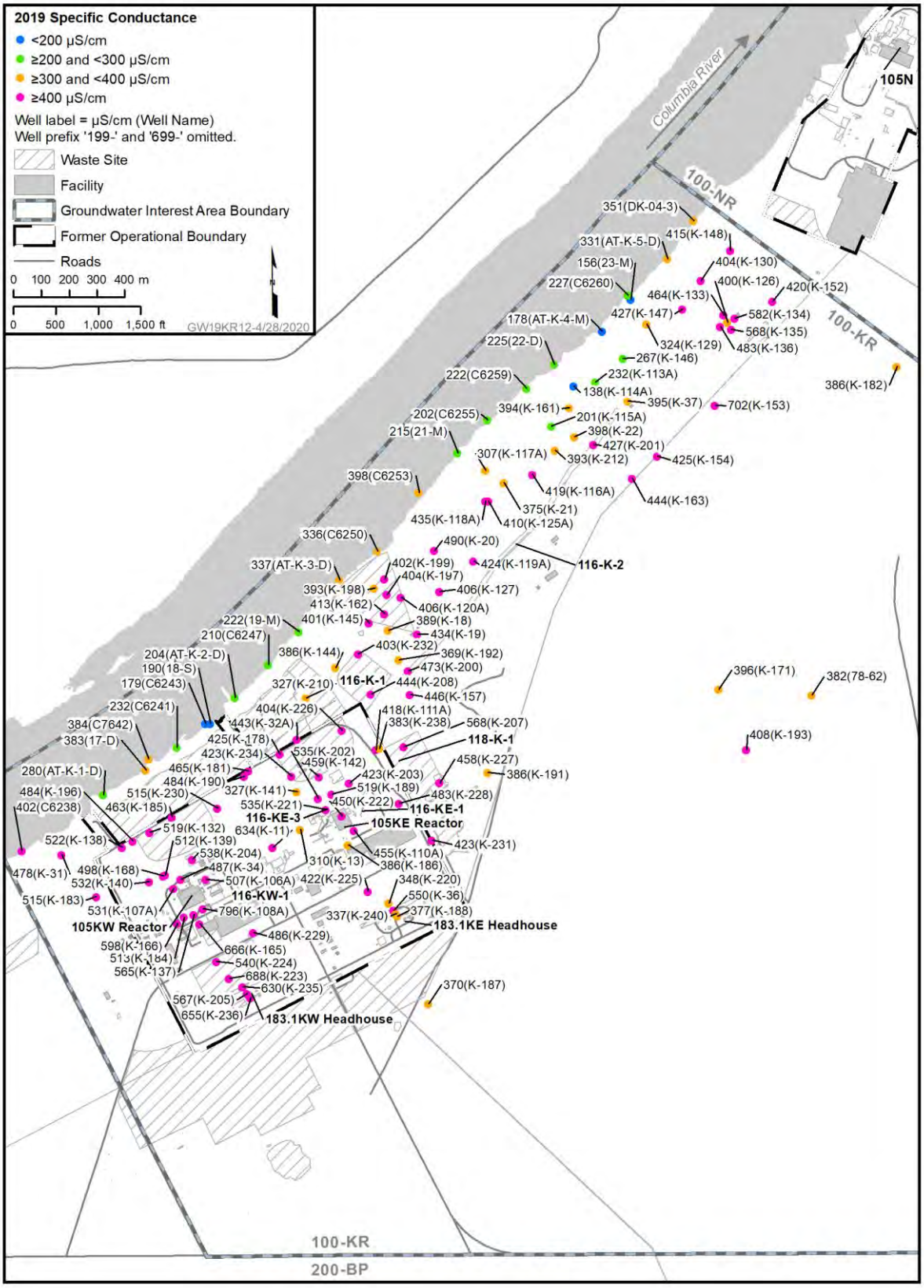


Figure 5-10. 100-KR Specific Conductance (2019 Low River Stage)

Consistent with previous years, Cr(VI) concentrations >10 µg/L are also observed in isolated wells east and northeast of the 100-K Area (e.g., 699-87-55 and 699-77-54). The origin of this contamination is unknown, but it may be related to historical releases in the 100-K or 100-D Areas.

5.3 Tritium

The major historical sources of tritium contamination in 100-KR include the following:

- Releases of reactor gas dryer condensate to the 116-KE-1 and 116-KW-1 Cribs (tritium concentrations up to 1×10^{10} pCi/L in the condensate [HW-76258, *Reactor Gas Drier Condensate Waste – Decontamination Studies*])
- Release of fuel storage basin water to the 116-KE-3 and 116-KW-2 Cribs and reverse wells, and to UPR-100-K-1 (tritium concentrations up to 6×10^{9} pCi/L in the basin water [Section 4.0 in WHC-EP-0877, *K Basin Corrosion Program Report*])
- Contaminated solid waste disposed at the 118-K-1 Burial Ground (tritium concentrations up to 13,400 pCi/g in deep vadose zone soil remaining after surface remediation [CVP-2013-00002, *Cleanup Verification Package for the 118-K-1 Burial Ground*])
- Release of contaminated reactor cooling water from the retention basins, 116-K-1 Crib, and 116-K-2 Trench

In 2019, the average tritium concentrations in the area near KW Reactor were below the 20,000 pCi/L DWS (Figure 5-11). However, the concentration in well 199-K-106A increased from 5,570 pCi/L in May 2019 to 23,500 pCi/L in November. Wells 199-K-132 and 199-K-204, which are both located downgradient of well 199-K-106A and the 116-KW-1 Crib, are the only two locations with tritium concentrations >5,000 pCi/L in K West.

In the KE Reactor area, only well 199-K-202 exhibited average tritium concentrations above the DWS, with concentrations ranging from 12,600 to 30,100 pCi/L.

In 2019, tritium concentrations continued to exceed the DWS near waste site 100-K-132, which is the remaining deep vadose zone contamination from the 118-K-1 Burial Ground. The highest concentration in groundwater during 2019 was in well 199-K-207 (405,000 pCi/L in August 2019), located within the footprint of the former 118-K-1 Burial Ground. Prior to May 2018, concentrations in well 199-K-207 had been declining, reaching a low of 44,500 pCi/L (Figure 5-12). However, an increasing trend started in August 2018 and continued through 2019 in well 199-K-207. At monitoring well 199-K-227, which is upgradient from well 199-K-207 and at the southern end of the 118-K-1 Burial Ground, tritium concentrations ranged from 22,300 to 86,400 pCi/L in 2019. Tritium concentrations in well 199-K-227 have a wide range of fluctuation. Since the well is located on the edge of the injection mound (Figure 5-3) it is possible that the injection flow rate fluctuations are periodically mobilizing tritium from the deep vadose zone waste site 100-K-132.

In monitoring well 199-K-111A, tritium concentrations continued to decline during 2019. The declining tritium trend in this well is consistent with a plume migrating downgradient and away from the former source area. In new monitoring well 199-K-238, located <3 m (10 ft) away from well 199-K-111A, the maximum tritium concentration observed during drilling was below the DWS. Tritium concentrations in wells farther downgradient continue to fluctuate at concentrations around 10,000 pCi/L.

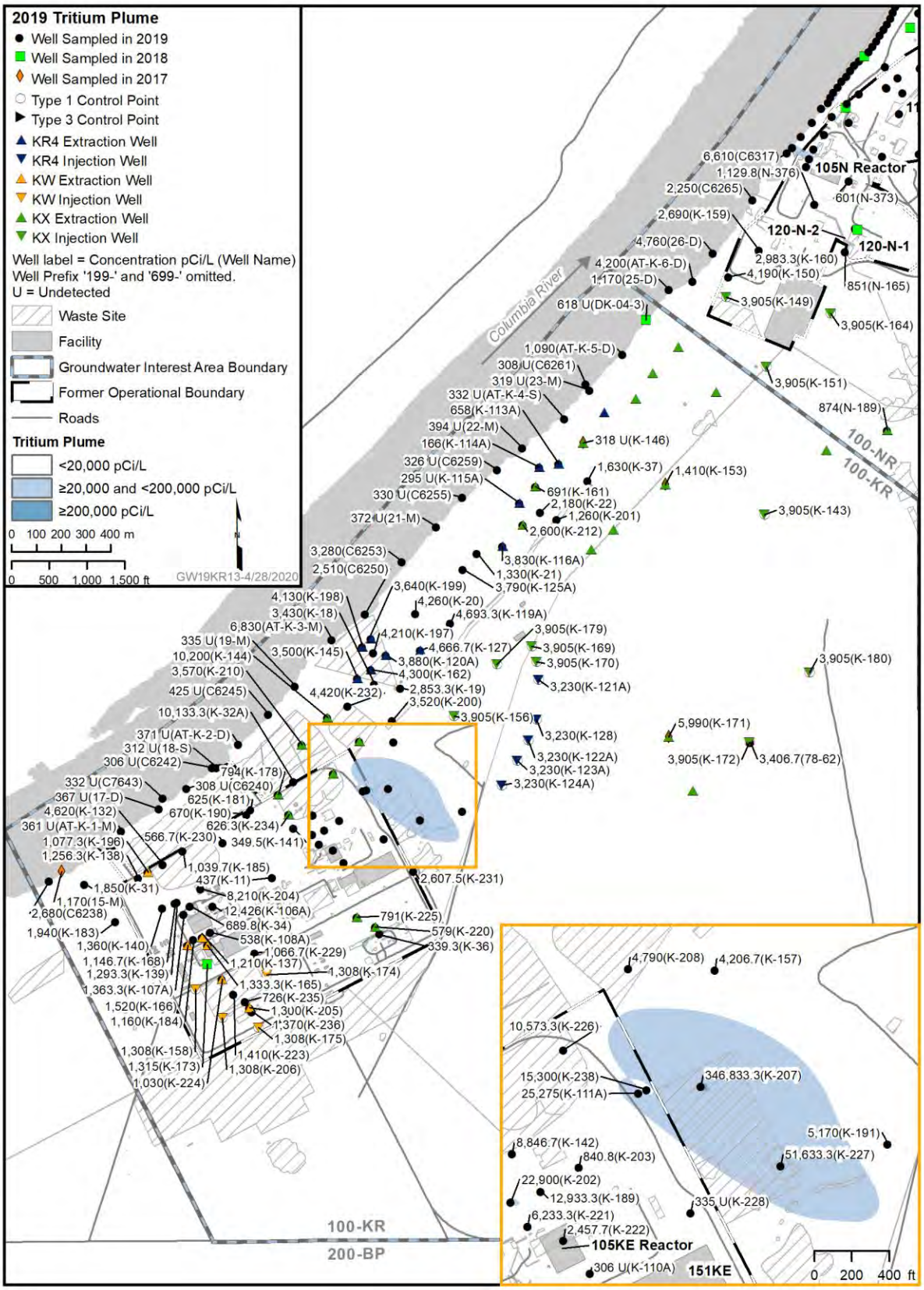


Figure 5-11. 100-KR Tritium Plume, 2019

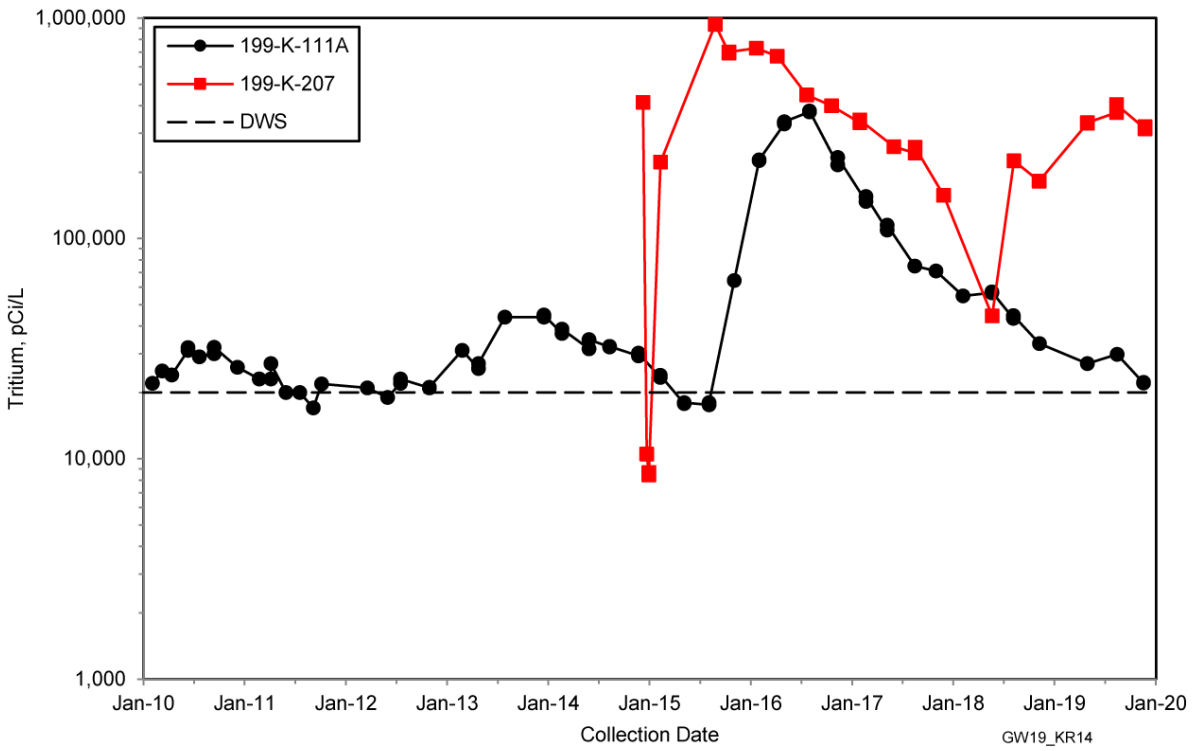


Figure 5-12. 100-KR Tritium Data for Wells 199-K-111A and 199-K-207 (Located Northeast of KE Reactor)

At monitoring and extraction wells along the 116-K-2 Trench, observed tritium concentrations are consistent with the average effluent concentration associated with the KR4 and KX P&T systems. Extraction wells for Cr(VI) remediation also capture tritium; however, because the tritium cannot be treated, it passes through the treatment system and is returned to the aquifer via inland injection wells. Based on P&T system design, much of this water is then recaptured by the downgradient extraction wells, and the tritium recirculates and continues to decay. The average effluent tritium concentrations in 2019 were 3,230 pCi/L for the KR4 P&T system; 3,905 pCi/L for the KX P&T system; and 1,308 pCi/L for the KW P&T system.

5.4 Nitrate

Nitrate concentrations continued to exceed 45 mg/L in several 100-KR wells in 2019 (Figure 5-13). The nitrate observed in 100-KR is primarily attributed to oxidation of high concentrations of ammonia in reactor gas dryer condensate (i.e., up to 36,000 mg/L) that was discharged to the 116-KE-1 and 116-KW-1 Cribs. Additional nitrate contributions to groundwater may have come from sanitary waste drain fields at various locations in 100-KR.

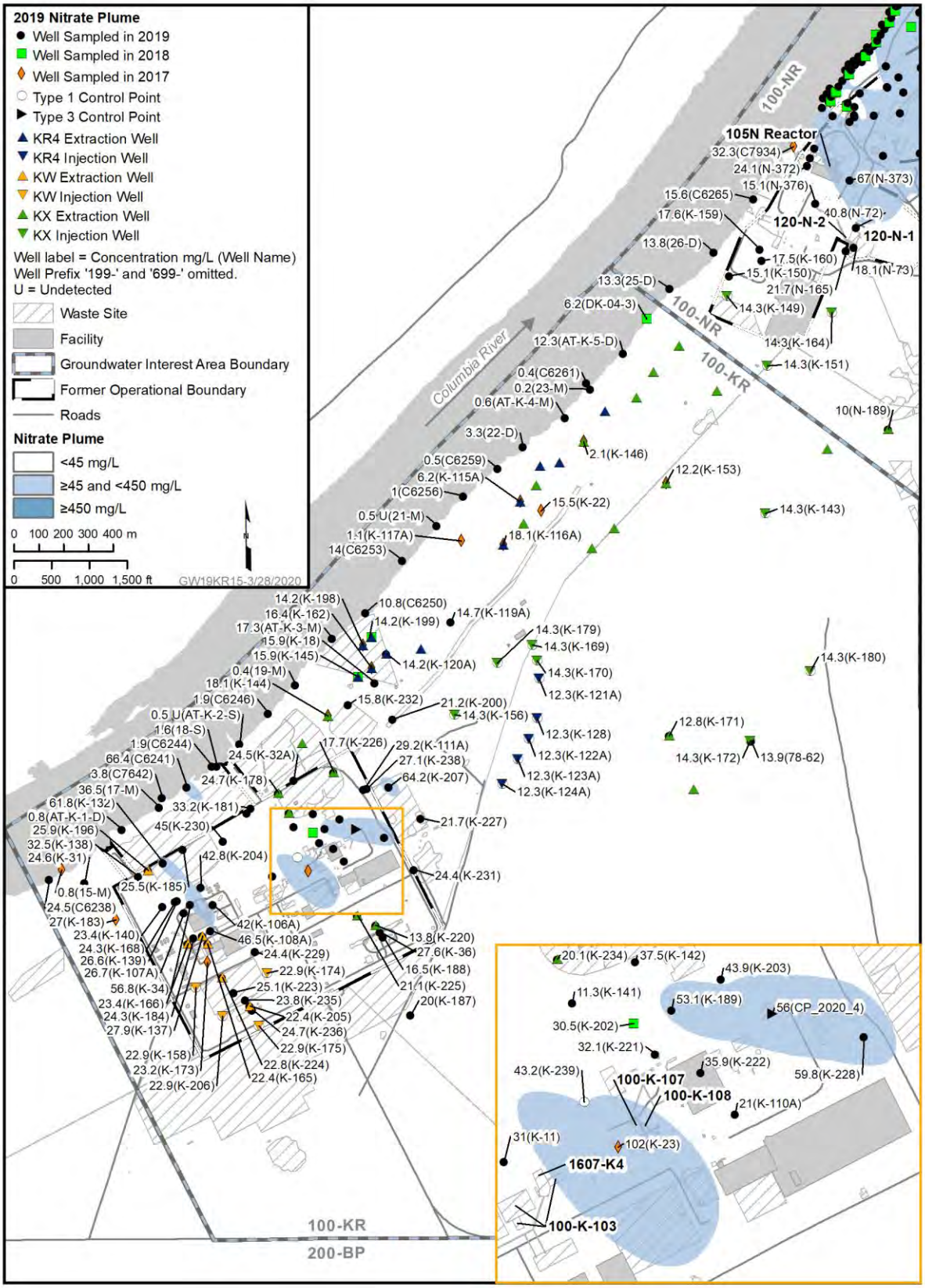


Figure 5-13. 100-KR Nitrate Plume, 2019

Comparing the distribution of nitrate in 2019 (Figure 5-13) and 2018 (Figure 5-16 in DOE/RL-2018-66) shows three differences:

- In 2019, a single plume was present in K West as the annual average concentrations in several wells increased along the axis of this plume (Figure 5-13), compared to 2018 where two disconnected plume segments existed.
- The plume located between the KW and KE Reactors in 2019 decreased in overall areal extent as concentrations decreased in nearby wells.
- New monitoring well 199-K-239, which was drilled in late 2019 to replace monitoring well 199-K-13, had a concentration in January 2020 just below the DWS, which constrained the previously elevated concentration at decommissioned well 199-K-23.

In K West, several wells near and downgradient of the 116-KW-1 gas condensate crib and the active 1607-K-6 septic system exhibited nitrate concentrations above the DWS in 2019 (Figure 5-13). The maximum concentration observed in K West was 70.8 mg/L at wells 199-K-34 and 199-K-132.

The nitrate concentration observed at aquifer tube C6241 (downgradient from K West) increased from 53.1 mg/L in 2018 to 66.4 mg/L in 2019, exceeding the DWS. The 100-K Spring 63-1 (near the K West nitrate plume) had nitrate concentrations ranging from 2.4 to 4.4 mg/L in fall 2019. Nitrate concentrations in aquifer tubes and seeps may increase as the nitrate plume continues to migrate toward the river.

The nitrate plume near the KE Reactor and 116-KE-1 gas condensate crib (Figure 5-13) was consistent in size and concentration levels to the plumes observed during 2017 and 2018. Concentrations in well 199-K-189, downgradient of the gas condensate crib, remained at 53.1 mg/L (similar to 2018). Between 2018 and 2019, the average nitrate concentration in downgradient wells 199-K-142 and 199-K-203 increased, but the average values remained at concentrations less than the DWS. It should be noted, however, that well 199-K-203 had a maximum concentration of 66.4 mg/L in August 2019. In well 199-K-228, which is located upgradient of former septic tank 1607-K5, the average nitrate concentration increased slightly from 57.5 to 59.8 mg/L between 2018 and 2019.

At monitoring wells located between the KE and KW Reactors, nitrate concentrations continue to fluctuate with no discernable pattern. The fluctuations are likely the result of ongoing waste site remediation in the area. New well 199-K-239, which is located downgradient of well 199-K-23, encountered a maximum nitrate concentration of 43.2 mg/L. At monitoring well 199-K-230, located >350 m (1,150 ft) downgradient from decommissioned well 199-K-23, the nitrate concentrations ranged from 21.2 to 102 mg/L, showing that the observed fluctuations in nitrate concentrations are not limited to a small area.

5.5 Strontium-90

Strontium-90 is a fission product generated within reactor fuel during nuclear reactor operation. It was historically released during fuel failure events and resulted in contamination of reactor cooling water. Strontium-90-contaminated cooling water, along with irradiated fuel fragments, was released to the 116-K-2 Trench under off-normal conditions, as well as to the reactor fuel storage basins during discharge of irradiated fuel from the reactors (UNI-946, *Radiological Characterization of the Retired 100 Areas*). Contaminated cooling water was also held in the 107KE or 107KW Retention Basins (known to have leaked) and subsequently discharged to the 116-K-2 Trench. The highest strontium-90 concentrations in groundwater are associated with historical engineered releases from the fuel storage basins and their associated drainage systems (i.e., 116-KW-2 and 116-KE-3 Cribs and reverse wells), as well as leaks from the former fuel storage basin (e.g., UPR-100-K-1).

Strontium-90 is detectable in low levels in many wells across 100-KR and at higher concentrations near KE Reactor. Within 100-KR, strontium-90 concentrations above the 8 pCi/L DWS appear to be limited to four small plumes that do not extend to the Columbia River (Figure 5-14); one at the KW Reactor, two segments of the same plume near the KE Reactor, and one at the head end of the 116-K-2 Trench. Along the river, aquifer tube 22-M exhibited strontium-90 concentrations in 2019 ranging from 3.3 to 5.3 pCi/L. Concentrations observed in aquifer tube 22-M appear to represent downgradient migration of strontium-90 toward the river from the distal end of the trench.

In K West, wells 199-K-34, 199-K-107A, and 199-K-139 had strontium-90 concentrations >8 pCi/L in 2019, which is consistent with the 2018 monitoring results. The plume in this area was essentially unchanged.

Wells near KE Reactor had the highest strontium-90 concentrations in 100-KR during 2019. Strontium-90 concentrations at well 199-K-222, located in the footprint of the former 105-KE fuel storage basins, ranged from 3.64 to 1,230 pCi/L. Strontium-90 concentrations increase as the river stage transitions from high to low stage (Figure 5-15). This behavior is consistent with the continued release of contamination from secondary source material associated with UPR-100-K-1. At well 199-K-221, located near the 116-KE-3 Crib, concentrations ranged from 3.3 to 7.1 pCi/L. Figure 5-16 shows a similar pattern between strontium-90 and water levels, confirming the continued release of contamination from secondary source material associated with 116-KE-3 Crib. Because strontium-90 concentration declined in well 199-K-221, the plume near KE Reactor occurs as two separate plume segments compared to the single plume as it was observed for the past several years.

Downgradient of wells 199-K-221 and 199-K-222, the average 2019 strontium-90 concentration in well 199-K-141 was 81.2 pCi/L (Figure 5-17). In late February 2019, well 199-K-141 was converted from an extraction well to a monitoring well. After the conversion, strontium-90 concentration increased to 117 pCi/L; however, by November the concentration had decreased to 45.4 pCi/L. Well 199-K-141 has been inferred to be on the leading edge of the strontium-90 plume originating from the 116-KE-3 Crib and UPR-100-K-1 based the observed strontium-90 concentration trends shortly after the well was turned into an operating extraction well in 2009.

At the head end of the 116-K-2 Trench, strontium-90 continued to exceed the DWS in well 199-K-200. Concentrations in well 199-K-200 averaged 144.3 pCi/L (Figure 5-14) in 2019, a slight decrease from 158 pCi/L in 2018. At the tail end of the 116-K-2 Trench, the average concentrations in wells 199-K-22 and 199-K-201 decreased to below DWS, eliminating the plume that was observed in that area in 2018. At well 199-K-161, strontium-90 concentration increased from 11.4 to 13 pCi/L between 2018 and 2019. Concentrations above the DWS were also detected in wells 199-K-19 and 199-K-21 at relatively stable levels.

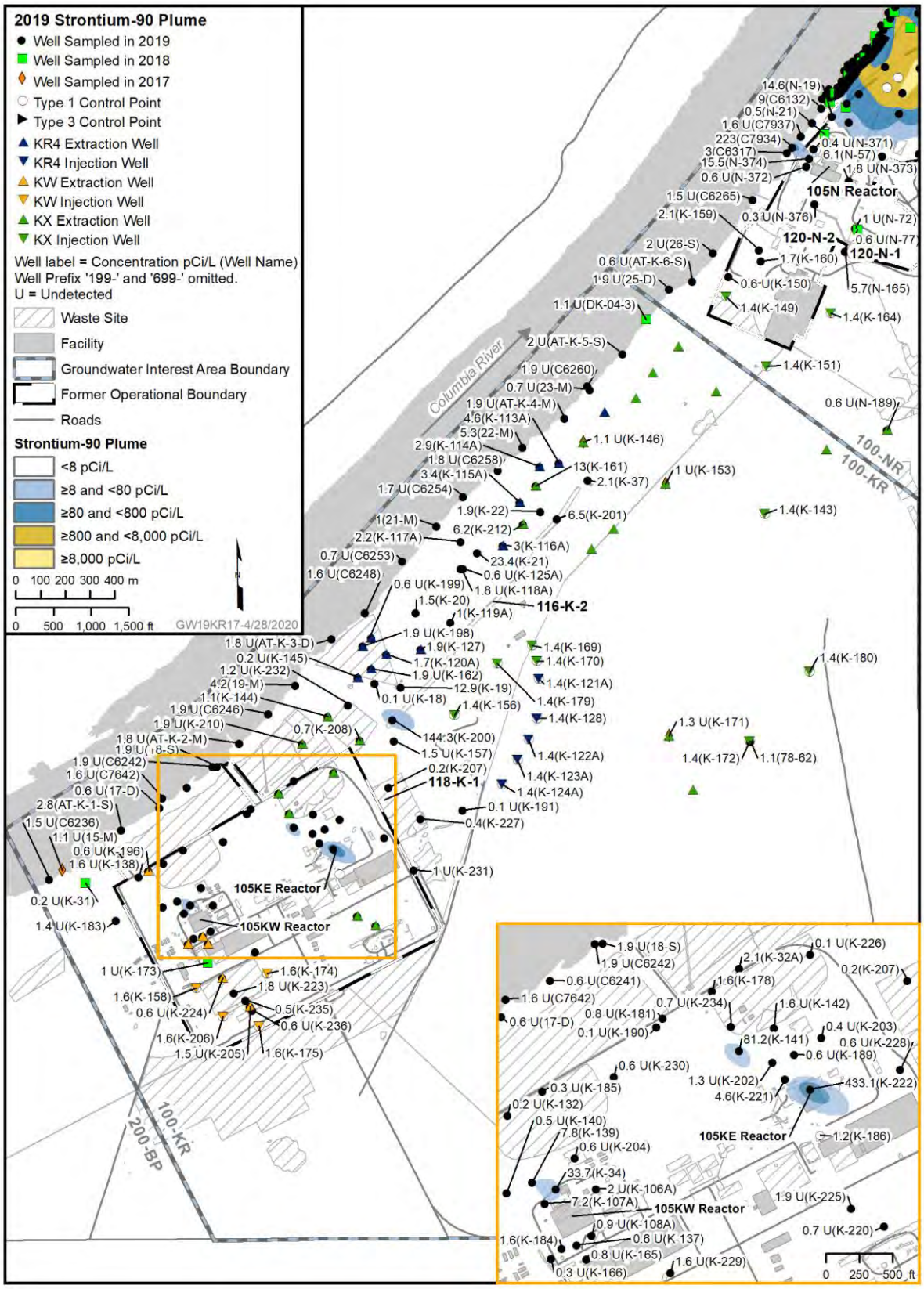


Figure 5-14. 100-KR Strontium-90 Plume, 2019

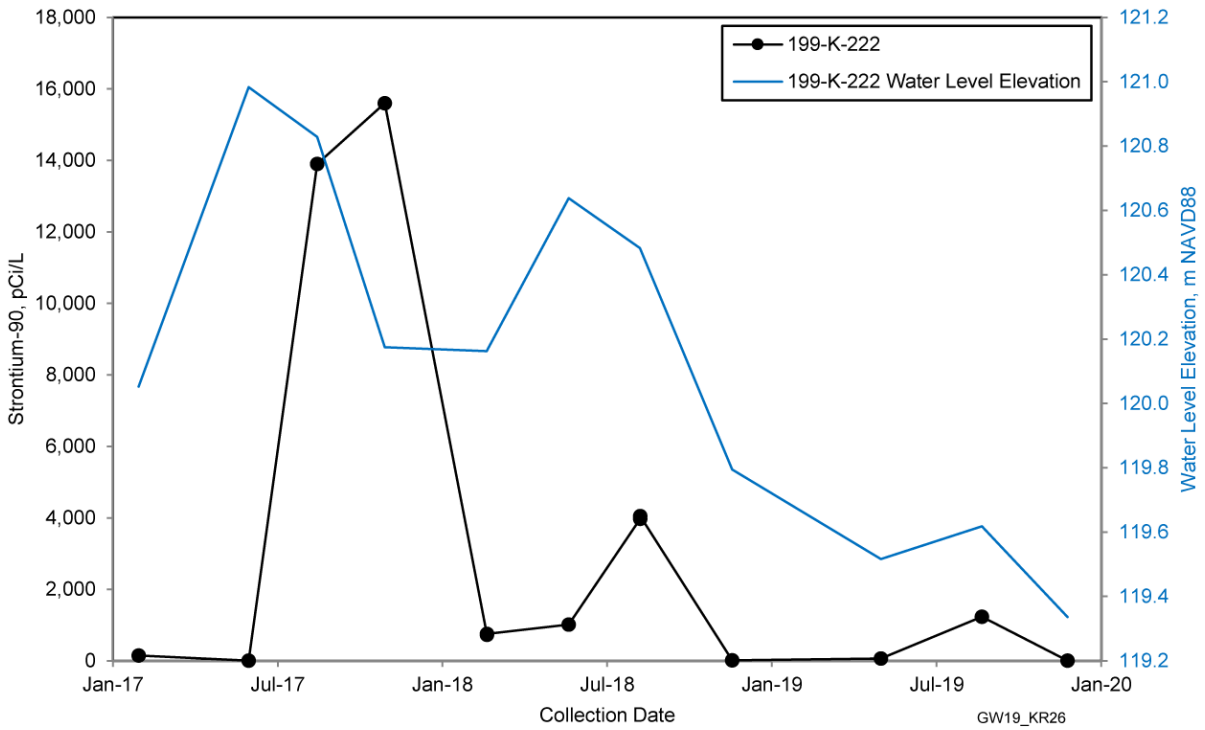


Figure 5-15. 100-KR Strontium-90 and Water Level Data for Well 199-K-222

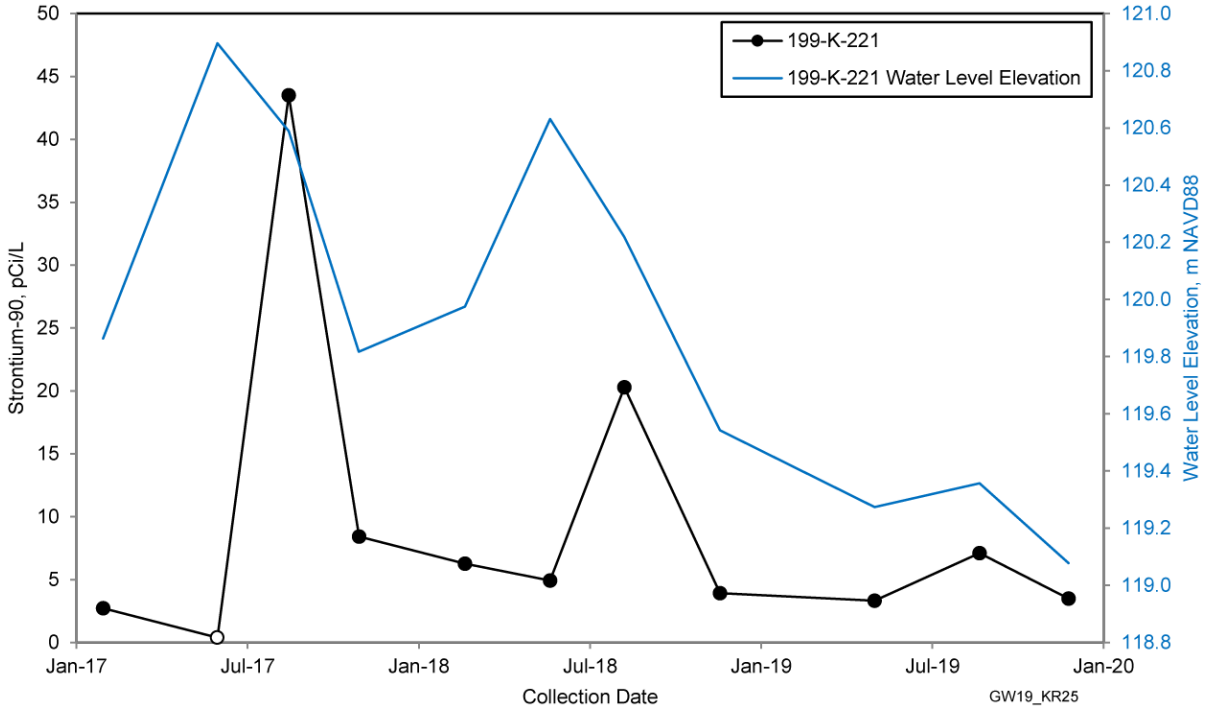


Figure 5-16. 100-KR Strontium-90 and Water Level Data for Well 199-K-221

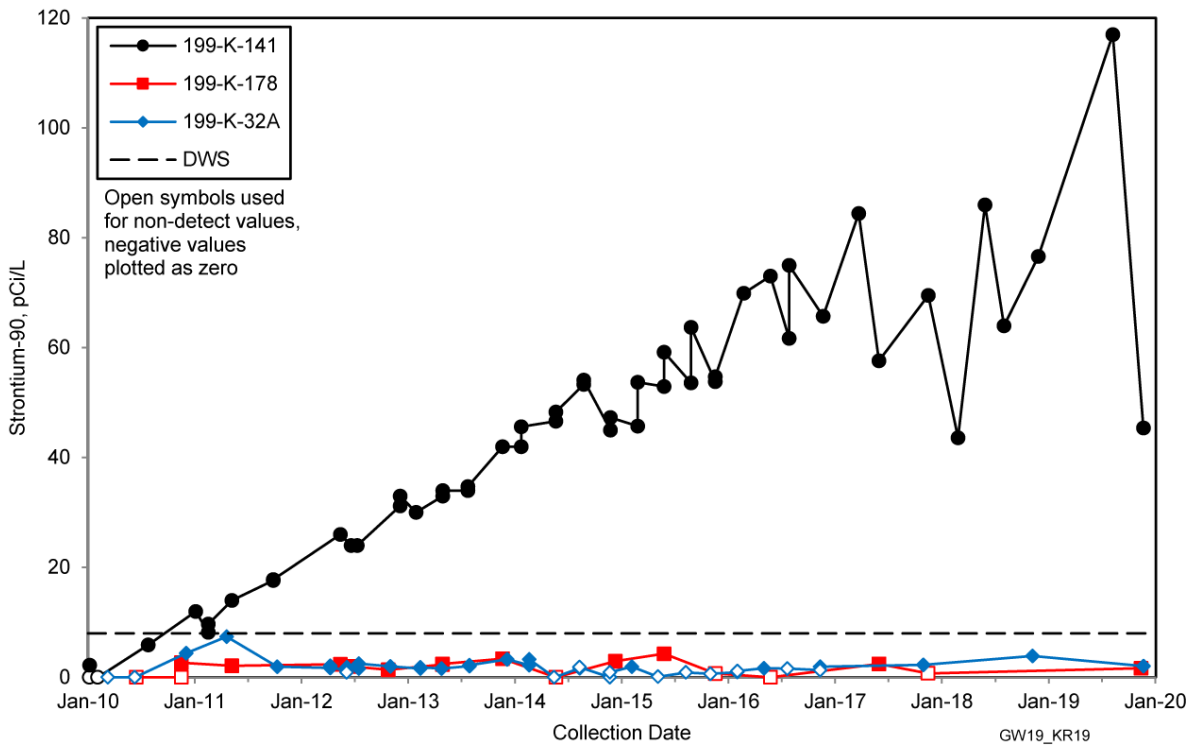


Figure 5-17. 100-KR Strontium-90 Data for Wells 199-K-32A, 199-K-141, and 199-K-178 (Located Downgradient of KE Reactor)

5.6 Carbon-14

Most of the carbon-14 in 100-KR groundwater originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. Carbon-14 in gas dryer condensate collected during operations ranged from 2.9×10^8 pCi/L at KW Reactor to 1.04×10^9 pCi/L at KE Reactor.

The 2019 carbon-14 plumes (Figure 5-18) exhibited little change in extent from 2018. At wells 199-K-106A, 199-K-204, and 199-K-132 (all located progressively farther downgradient of the 116-KW-1 gas condensate crib), the overall average concentration increased between 2018 and 2019. The greatest increase was in well 199-K-106A, with the maximum concentration of 42,600 pCi/L in 2019 as compared to 15,700 pCi/L in 2018. These trends continue to indicate ongoing downgradient migration away from the 116-KW-1 Crib (Figure 5-19).

A carbon-14 plume is also present in K East, which is collocated with the strontium-90 plume. The plume was formerly defined by wells 199-K-29 and 199-K-30, which monitored conditions downgradient of the 116-KE-1 Crib. These two wells were decommissioned during waste site remediation activities. As a result, control points based on estimated migration of historically high carbon-14 detections were used in the 2019 plume mapping. The use of control points in this case allows for a more representative estimation of the extent of carbon-14 in groundwater where monitoring data are limited. In 2019, carbon-14 concentration in wells downgradient of the 116-KE-1 Crib and KE Reactor all increased compared to 2018 but remained below the DWS. The maximum concentration observed was 1,820 pCi/L at well 199-K-203. Carbon-14 continued to be detected at concentrations <500 pCi/L in aquifer tubes near the KE Reactor area.

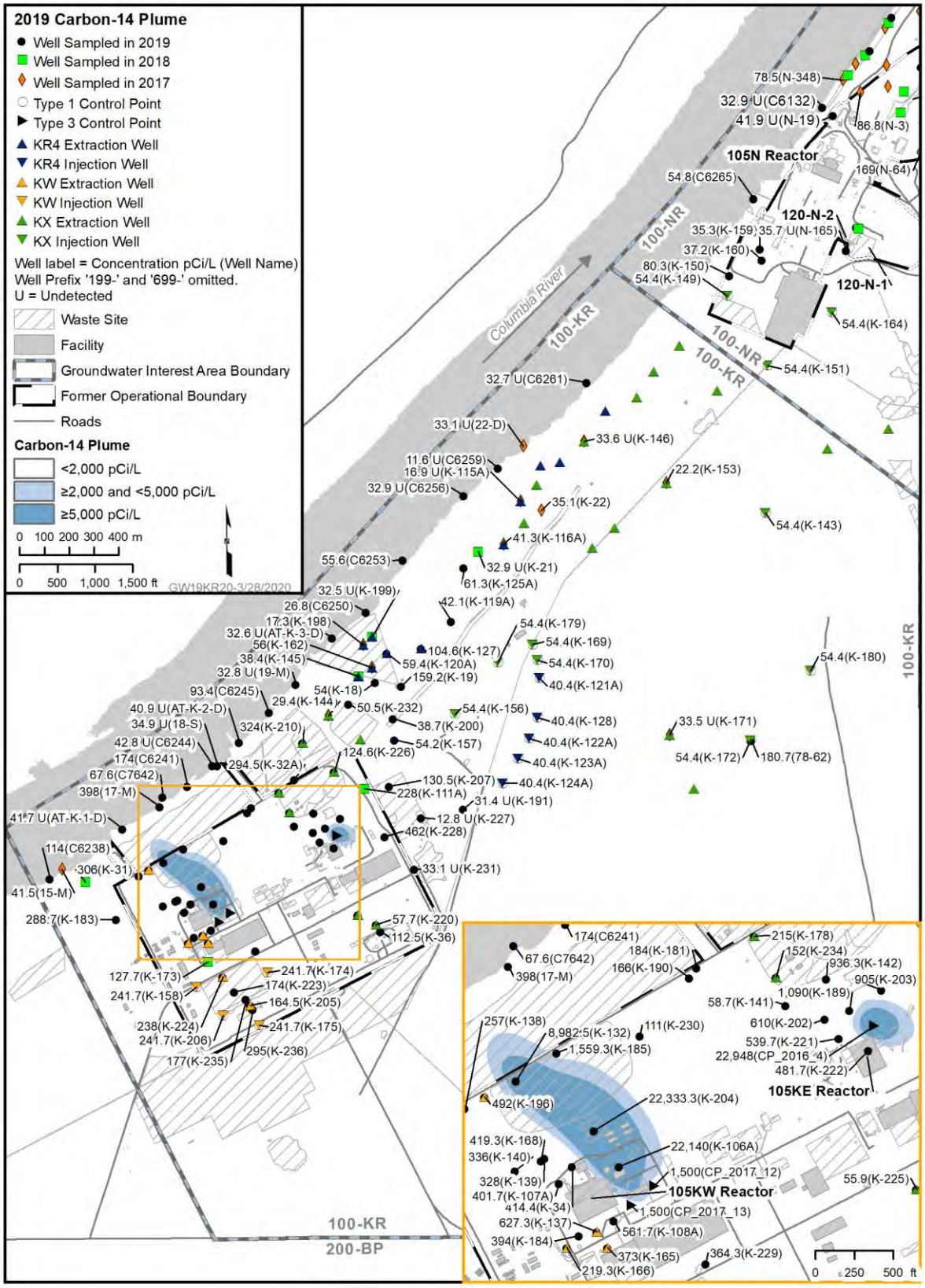


Figure 5-18. 100-KR Carbon-14 Plume, 2019

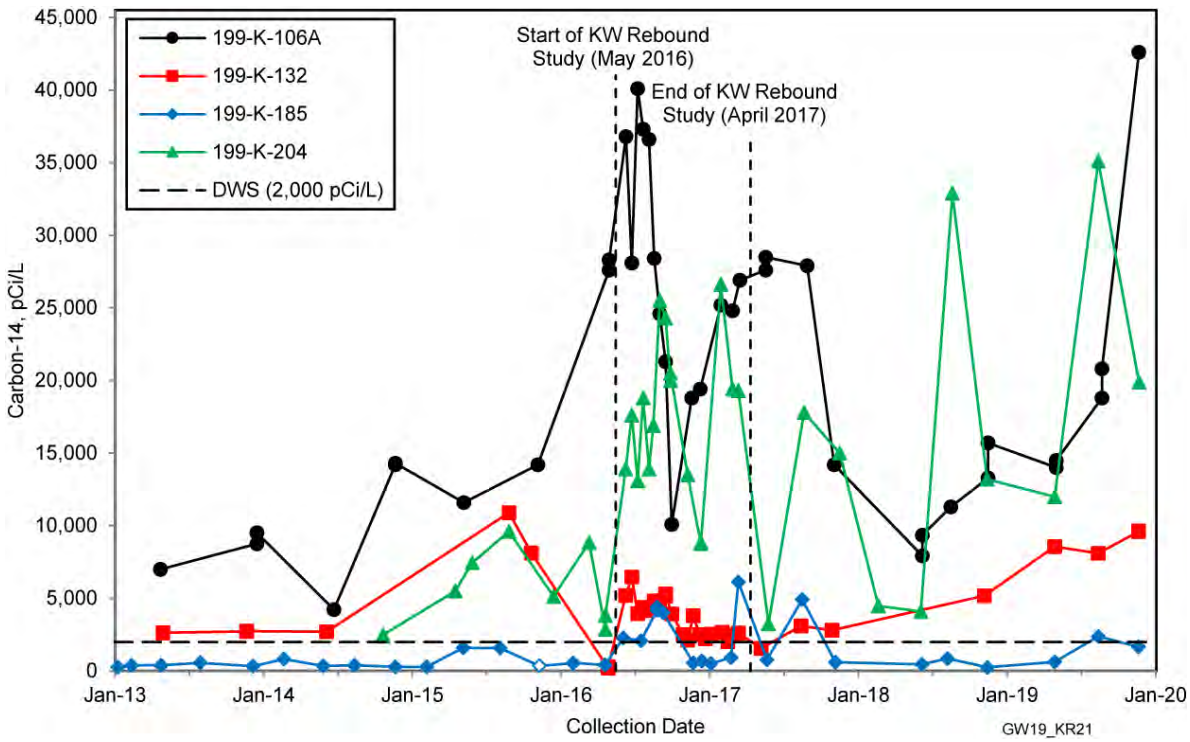


Figure 5-19. 100-KR Carbon-14 Data for Wells Downgradient of the 116-KW-1 Gas Condensate Crib

5.7 Trichloroethene

The sources of TCE at 100-KR are likely related to the use of solvents during equipment maintenance activities, but specific release points have not been identified. In 2019, the observed TCE plume >5 µg/L was slightly smaller than in 2018. At well 199-K-204, the maximum TCE concentration declined from 5.5 to 4.4 µg/L between 2018 and 2019. Figure 5-20 shows the TCE plume using the maximum concentration observed throughout K West rather than the annual average. Figure 5-20 also includes the TCE plume mapped at 4 µg/L, which is the proposed cleanup level in DOE/RL-2010-97, Draft B. TCE is present at stable concentrations below the proposed cleanup standard of 4 µg/L in the treated groundwater being injected into the aquifer through KW P&T injection wells.

TCE concentrations in aquifer tubes downgradient of the K West plume were all <5.0 µg/L. At aquifer tubes 17-D and 17-M, TCE concentrations increased between 2018 and 2019 but remained <5 µg/L. At 100-K Spring 63-1, located riverward of well 199-K-132, TCE concentrations were reported below the detection limit of 0.3 µg/L during 2019.

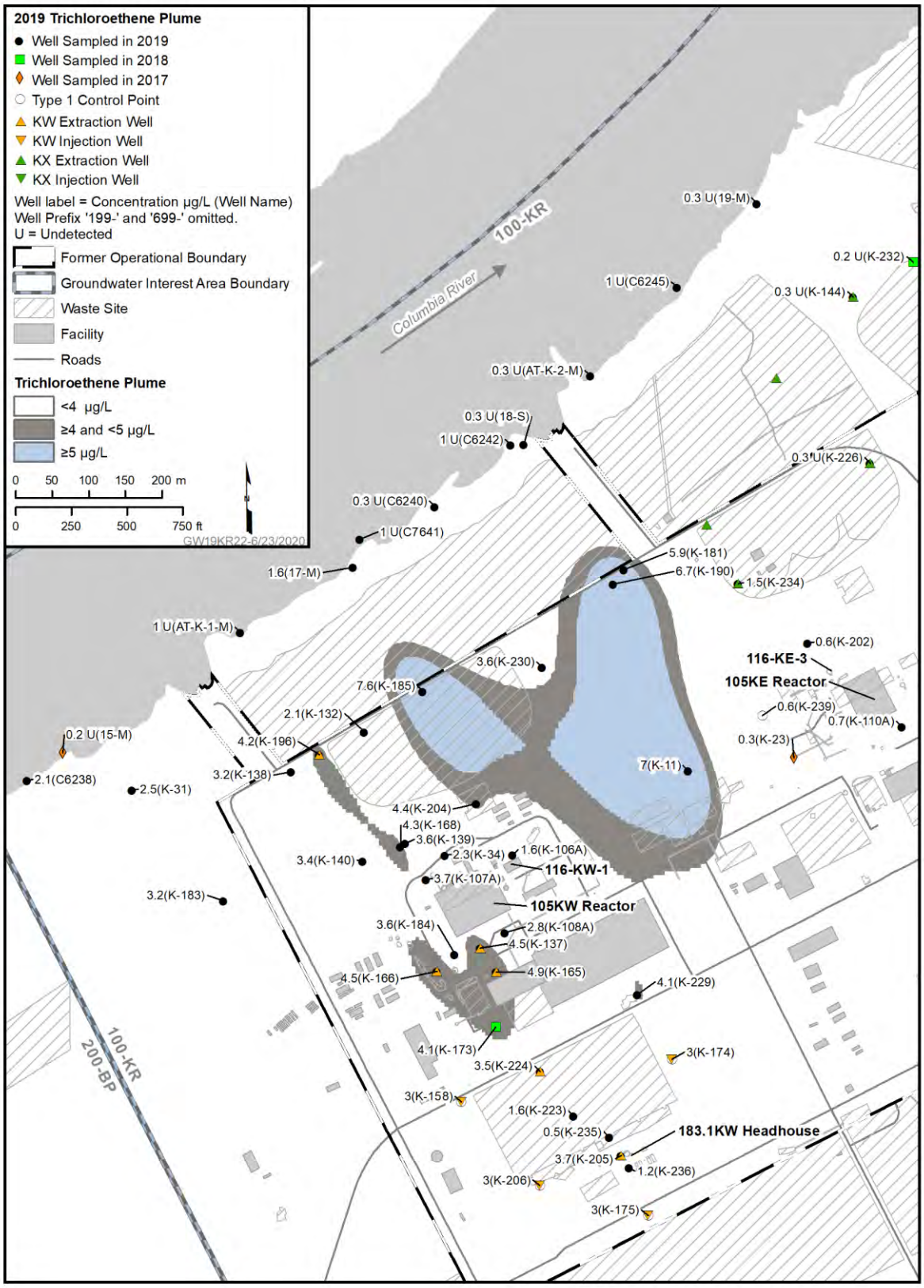


Figure 5-20. 100-KR Maximum TCE Plume, 2019

5.8 CERCLA Remediation and Monitoring

CERCLA groundwater activities at 100-KR included groundwater sampling and analysis and the operation of three interim groundwater remediation systems focusing on removing Cr(VI). CERCLA groundwater sampling is conducted in accordance with the SAP (DOE/RL-2013-29, *Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit Monitoring*, as modified by TPA-CN-0797, TPA-CN-0831, and TPA-CN-0857). Figure 5-1 shows the well locations, and Appendix A lists sampling exceptions for 2019.

Groundwater monitoring is conducted to monitor the effectiveness of the interim remedial action and to track Cr(VI) (which is the primary target of the interim action) and co-contaminants carbon-14, nitrate, strontium-90, TCE, and tritium. These constituents, which have been identified as groundwater COCs through the RI/FS process, may be captured and extracted incidentally by the interim remedial action P&T system. However, these constituents are not treated by the interim action, which is focused on removing chromium and, therefore, the constituents are considered to be co-contaminants under the current interim remedial action.

Sulfate, which is present in groundwater at 100-KR, was detected above the secondary DWS of 250 mg/L at well 199-K-205 (254 mg/L). As discussed in Section 5.2.1, the 183.1KW Headhouse area was subject to a soil flushing treatability test in 2019 (DOE/RL-2017-30). As part of the test, the pH of KW P&T system effluent was dropped from normal operating ranges (i.e., pH 6.5 to 6.7) to around 6.0 through the use of additional sulfuric acid. The additional sulfuric acid resulted in sulfate concentration >200 mg/L in the KW P&T effluent going to the infiltration gallery between June and August 2019. As a result, sulfate concentrations in groundwater at wells at and downgradient of the treatability test increased. Since the end of Phase 1 of the treatability test, sulfate concentrations in the effluent and in monitoring wells have decreased and remained ≤100 mg/L.

5.8.1 CERCLA Decision Documents and Plans

In 2018, the decision was made to separate the 100-K Area RI and FS into two separate documents. Draft B of the RI (DOE/-RL-2010-97, Draft B) was provided to EPA for review during 2019. The RI incorporates supplemental data associated with the 105-KE fuel storage basin, 116-KE-3 Crib, and reverse well, as well as data collected to support soil and groundwater interim remedial actions. Once the RI and FS are completed, they will provide the framework for a proposed plan, which will evaluate alternatives and recommend a preferred alternative for a final remedial action. DOE and EPA will issue a ROD that incorporates stakeholder input and identifies the selected alternatives for waste site and groundwater cleanup. Interim remedial actions will continue until the ROD is issued. Completion of the final RI is anticipated in 2020, while the final FS is anticipated to be completed in 2021.

As discussed in Section 5.2.1, a soil flushing treatability test (DOE/RL-2017-30) was conducted in 2019 using effluent from the KW P&T system to saturate the vadose zone beneath the former 183.1KW Headhouse area. The infiltration gallery was designed to flush residual Cr(VI) into groundwater, where it was extracted by the existing P&T system. The results of the treatability test through the end of 2019 are summarized in Section 5.2.1, as well as in Section 3.2.4.2 of DOE/RL-2019-67. A treatability test report (DOE/RL-2019-77) will be prepared in 2020.

5.8.2 Pump and Treat

In 2019, a total of 39 extraction wells and 19 injection wells operated as part of the P&T groundwater remediation system (Table 5-2; Figure 5-21). The three P&T systems (KR4, KX, and KW) are capable of treating a combined total of >7.9 million L (2.1 million gal) of groundwater per day. The combined P&T systems in 100-KR removed 48.6 kg of Cr(VI) from groundwater in 2019. Since 1997, the P&T systems have removed 988 kg of Cr(VI) from the aquifer. DOE/RL-2019-67 provides additional details.

Table 5-2. 100-KR-4 P&T Summary

P&T System	KW	KR4	KX
100-KR-4 P&T Systems, 2019			
Design capacity, L/min (gal/min)	1,250 (330)	1,250 (330)	3,410 (900)
Extraction wells (post-realignment)*	6	11	22
Injection wells (post-realignment)*	4	5	10
Average flow rate, L/min (gal/min)	1,127.9 (297.8)	964.5 (254.6)	3,141.9 (829.5)
Volume treated, million L (million gal)	536.4 (141.7)	504.1 (133.2)	1,785.7 (471.7)
Cr(VI) mass removed, kg	19.6	1.7	27.3
Average Cr(VI) influent concentration, µg/L	28.8	4.5	16.2
Average Cr(VI) effluent concentration, µg/L	<2	<2	<2
All 100-KR-4 P&T Systems, 1997–2019			
Volume treated, million L (million gal)			29,155 (7,702)
Cr(VI) mass removed, kg			988

*The number of extraction and injection wells does not include those wells that are not operational.

Cr(VI) = hexavalent chromium

P&T = pump and treat

An interim action ROD for the 100-KR-4 OU was issued in April 1996 (EPA/ROD/R10-96/134). One of the RAOs is to protect aquatic receptors in the Columbia River from groundwater contaminants. The interim action ROD included a preliminary estimated dilution factor of 1:1 for groundwater entering the Columbia River at 100-K, 100-D, and 100-H under the assumption that diluting groundwater with river water is expected before the groundwater would reach the aquatic receptor point of concern within the river substrate. This established an operational target for Cr(VI) treatment system effluent at 20 µg/L. For purposes of managing the interim remedial action, the working assumption is that groundwater at 20 µg/L at onshore, near-river monitoring locations will achieve the surface water standard of 10 µg/L at the point where groundwater discharges to the river (EPA et al., 2009).

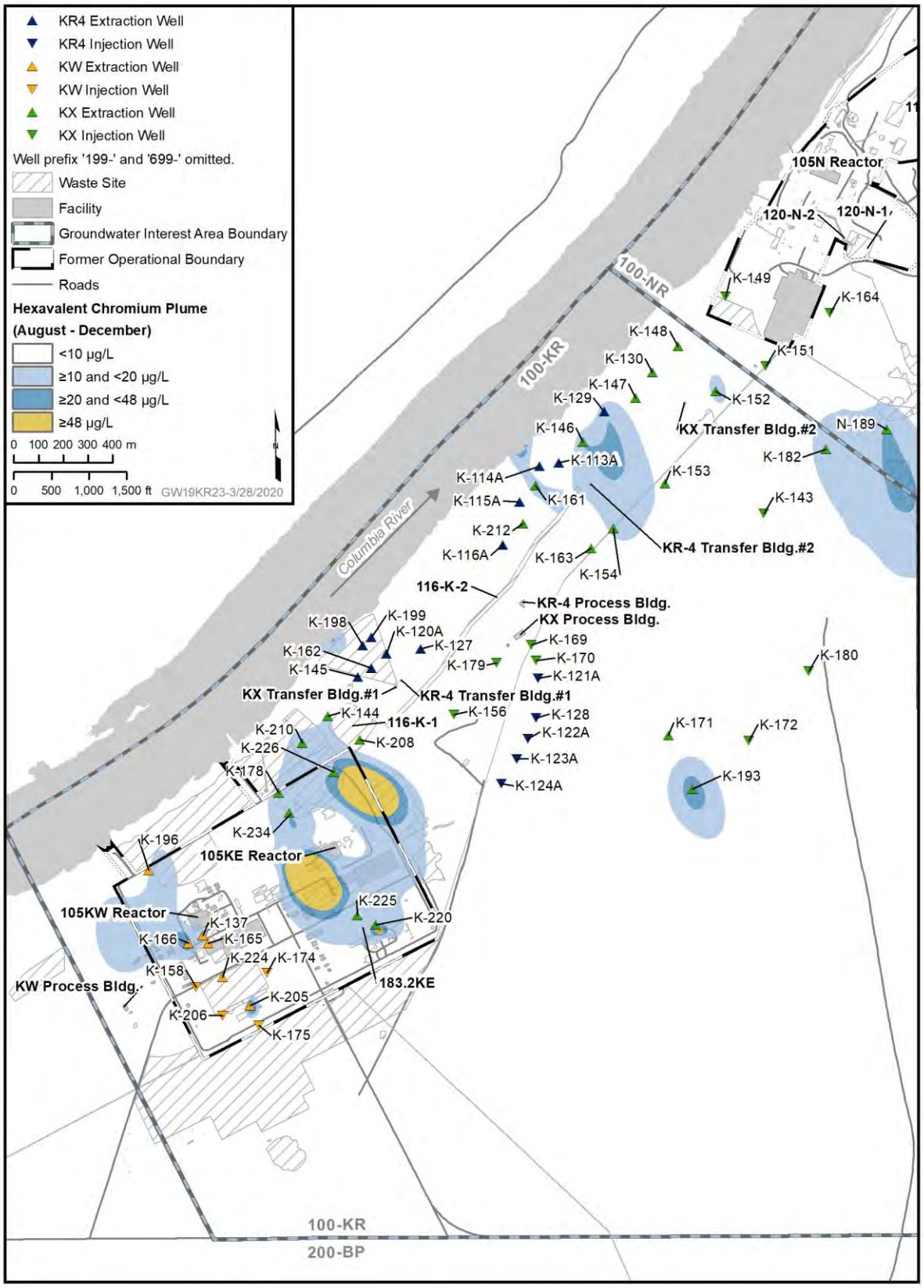


Figure 5-21. 100-KR P&T Well Locations

Since the interim action ROD (EPA/ROD/R10-96/134) was issued, DOE has implemented three P&T systems to remediate Cr(VI) contamination in 100-KR-4 OU groundwater and to protect the Columbia River. A total of 38 compliance and performance monitoring wells have been identified for the three 100-KR P&T systems. Each of the systems operated in 2019, as described below:

- The original P&T system, KR4, began operating in 1997 and focuses on contamination originating beneath the 116-K-2 Trench.
- The KX P&T system is focused on two areas: the northeastern end of the 116-K-2 Trench, where the Cr(VI) plume historically migrated toward 100-NR-2; and near the KE Reactor facilities. The KX system began operating in 2009.
- The KW P&T system began operating in 2007 and focuses on the Cr(VI) plume at the KW Reactor facilities. In 2019, a treatability test was implemented at the 183.1KW Headhouse area designed to target residual Cr(VI) contamination in the vadose zone (SGW-62061).

The groundwater P&T systems will continue to operate in the 100-KR-4 OU. These systems provide protection of the Columbia River from Cr(VI)-contaminated groundwater that would cause an exceedance of the 10 µg/L surface water standard and will help maintain hydraulic containment of the remaining Cr(VI) plumes.

Under the current configuration, the 100-KR-4 P&T systems are demonstrating progress toward the interim RAOs (Table 5-2; Figure 5-5). Operation of the systems and containment of the plumes address the first and third RAOs defined in the interim action ROD (EPA/ROD/R10-96/134):

- **RAO #1:** Protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.
- **RAO #3:** Provide information that will lead to a final remedy.

Plume containment and institutional controls meet the second RAO defined in the interim action ROD (EPA/ROD/R10-96/134):

- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.

5.9 Atomic Energy Act Monitoring

AEA groundwater monitoring was scheduled at 64 groundwater wells and aquifer tubes in 100-KR in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 100-KR are carbon-14, nitrate, strontium-90, and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in accordance with the current AEA SAP. All wells and aquifer tubes, except for aquifer tube 19-D, were sampled in accordance with SAP requirements in 2019. Appendix C lists the sampling exceptions for 2019 AEA monitoring of the 100-KR groundwater wells.

Radionuclide concentrations detected in groundwater samples from 120 wells[6] 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 exceeded the 100 mrem/yr standard at one well (199-K-222) in K East. The DWSs for cumulative alpha emitters were not exceeded. The DWS for net alpha emitters exceeded 15 mrem/year at one well (199-K-221) in K East. The 30 µg/L

[6] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

uranium DWS was not exceeded in 2019. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 21 locations in 100-KR (Table 5-3). 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 that restrict access to groundwater. CERCLA remedial action decisions (i.e., P&T for the 100-KR-4 OU) provide additional protection of the public and the environment.

Table 5-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-KR in 2019

Monitoring Location/ Well Name	Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Net Alpha-Emitter Activity ≥15 pCi/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
199-K-19	—	—	6.54	8.22	—	—
199-K-21	—	—	11.97	11.97	—	—
199-K-32A	—	—	4.17	4.17	—	—
199-K-34	—	—	17.72	18.53	—	—
199-K-106A	—	—	30.10	89.90	—	—
199-K-107A	—	—	4.06	5.78	—	—
199-K-111A	—	—	4.44	5.96	—	—
199-K-132	—	—	17.06	20.19	—	—
199-K-139	—	—	4.06	5.77	—	—
199-K-141	—	—	22.82	58.76	—	—
199-K-142	—	—	4.20	4.20	—	—
199-K-161	—	—	6.64	6.64	—	—
199-K-185	—	—	5.00	5.00	—	—
199-K-189	—	—	4.58	4.58	—	—
199-K-200	—	—	69.21	74.87	—	—
199-K-202	—	—	7.38	7.38	—	—
199-K-204	—	—	26.24	71.87	—	—
199-K-207	—	—	64.59	81.54	—	—
199-K-221	—	—	6.58	6.58	15.00	16.50
199-K-222	113.13	113.13	617.47	617.47	—	—
199-K-227	—	—	4.46	17.63	—	—

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

Blank cells (—) indicate no exceedance.

None of the wells in 100-KR had cumulative alpha activity ≥15 pCi/L or cumulative uranium mass ≥30 µg/L.

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6 100-NR

This chapter presents information for the 100-NR groundwater interest area, which encompasses the 100-NR-2 OU and the surrounding area, adjacent to the Columbia River (Figure 1-1). This chapter includes an overview and discussion of CERCLA and AEA groundwater monitoring and associated waste site (i.e., vadose zone) cleanup efforts.

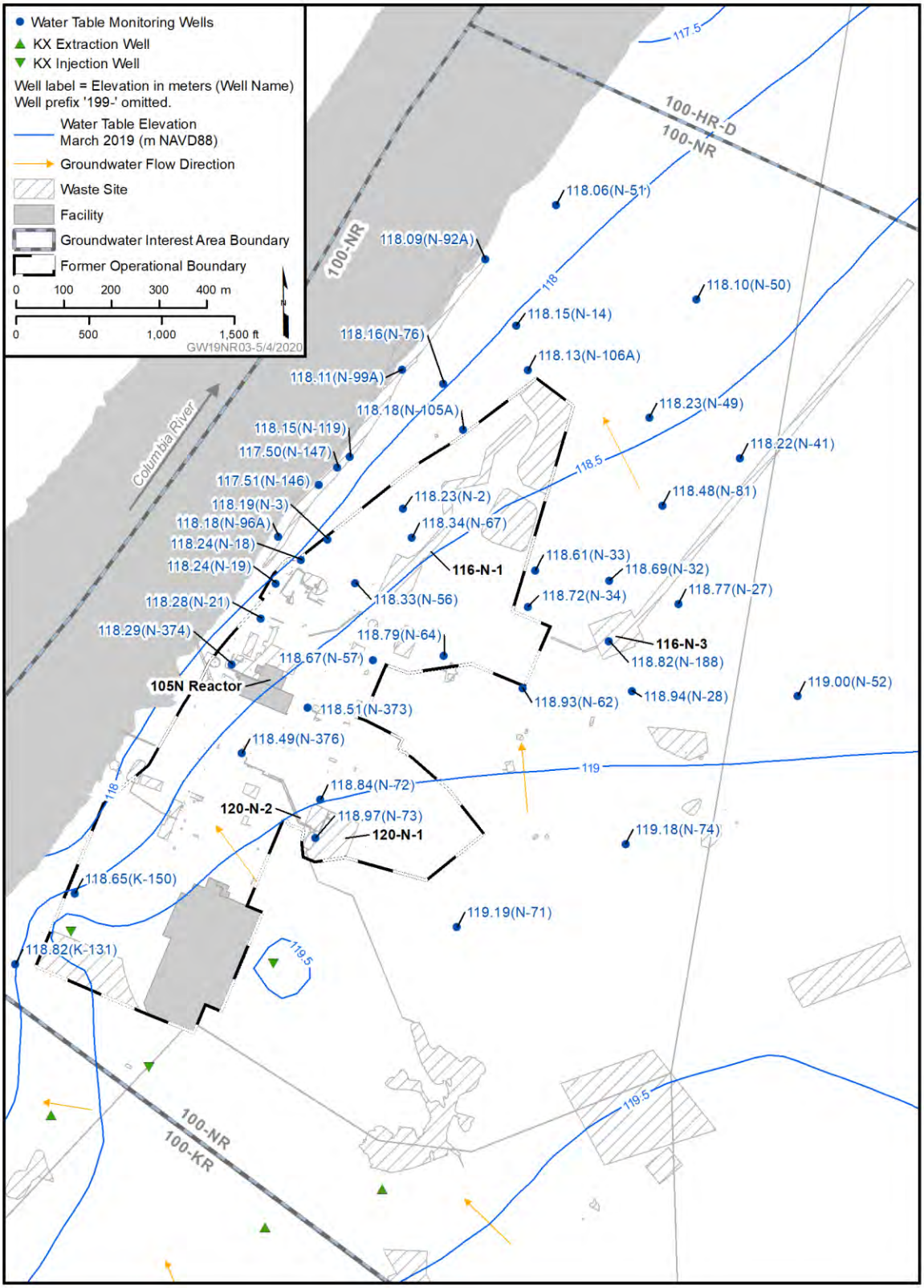
6.1 Overview

Among the Hanford Site plutonium-production reactors, the design of N Reactor (operational from 1964 to 1987) was unique because it was a dual-purpose reactor, producing plutonium for defense and steam for electrical power. Soil and groundwater contamination in 100-NR is primarily associated with waste from the reactor and associated processes. About 92% of the waste sites in 100-NR have been remediated, or determined not to require remediation, under a CERCLA interim action ROD (EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision, U.S. Department of Energy / Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). Groundwater continues to be monitored in accordance with CERCLA and AEA requirements and is being remediated under the interim action ROD. Additionally, DOE/RL-2012-15, Draft B, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*, is being finalized to support decision making that will lead to the issuance of a ROD for final remedial action. Details on the history of 100-NR are provided in Section 1.3 of DOE/RL-2012-15, Draft B.

Strontium-90 is the primary groundwater contaminant in 100-NR. Other contaminants identified in the interim action ROD (EPA/ROD/R10-99/112) include nitrate, petroleum hydrocarbons (primarily as measured by total petroleum hydrocarbons-diesel range [TPH-D]), chromium (total), Cr(VI), tritium, manganese, and sulfate. Strontium-90 and petroleum hydrocarbons are being remediated under the CERCLA interim action ROD, as amended (EPA, 2010). A 311 m (1,020 ft) apatite PRB was installed between 2006 and 2011 to reduce the flux of the strontium-90 in groundwater moving toward the Columbia River. PRB injection wells have been installed for injection of apatite-forming chemicals to extend the length of the PRB to approximately 760 m (2,500 ft) identified in the ROD, as amended, but have not yet been injected, Free-phase petroleum hydrocarbons are also being removed from groundwater in two wells, and a bioventing system (operational since 2012) is being used to remediate petroleum hydrocarbons in the deep vadose zone.

Groundwater across most of 100-NR generally flows to the north and northwest toward the Columbia River (Figure 6-1). Groundwater flow continued to be influenced in 2019 by the KX P&T system, as indicated by mounding and drawdown in the southwestern portion of 100-NR.

Groundwater sampling for 100-NR is conducted in accordance with Appendix A in DOE/RL-2001-27, *Remedial Design/ Remedial Action Work Plan for the 100-NR-2 Operable Unit*, as modified by TPA-CN-0747, TPA-CN-0751, and TPA-CN-0791. Figure 6-2 shows the wells and aquifer tubes sampled in 2019. Table 6-1 summarizes the 100-NR groundwater plume areas and maximum concentration for the contaminants. The water quality standards for manganese and sulfate are secondary DWSs, so plume maps and plume areas are not calculated. Monitoring wells with manganese and sulfate detected above their respective DWSs are located within the total petroleum hydrocarbons (TPH) plume and associated with reducing conditions created by the TPH plume. Figure 6-3 shows the change in groundwater plume areas over time. Section 1.5 provides plume mapping details for the contaminant plume interpretations presented in this chapter, including descriptions of terms (e.g., Type 1 control point) used in the figure legends.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 6-1. 100-NR Water Table, March 2019

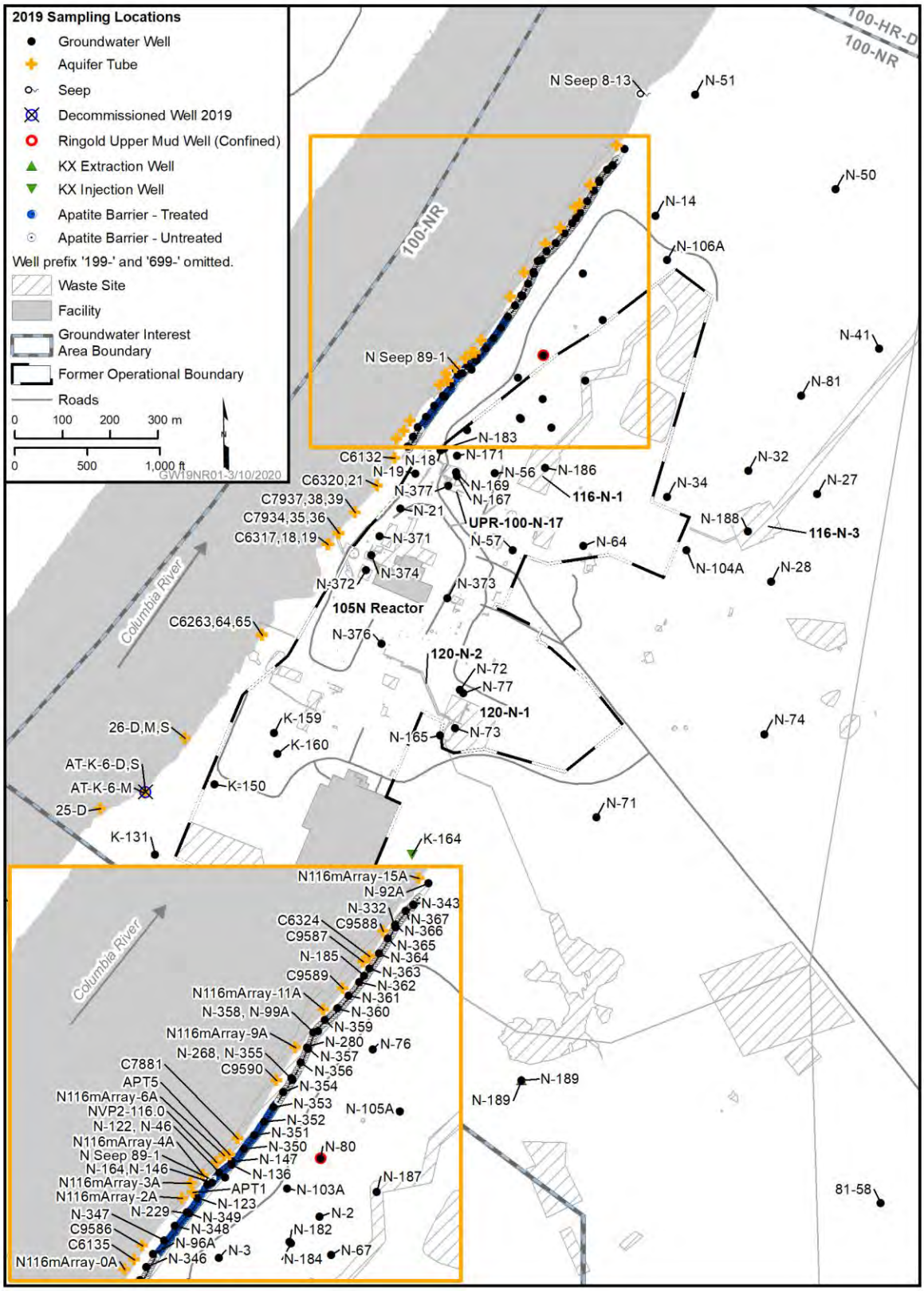


Figure 6-2. 100-NR Sampling Locations, 2019

Table 6-1. 100-NR at a Glance

N Reactor operations: 1964 to 1987				
Groundwater Monitoring				
Contaminant, Water Quality Standard	**Year**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline[b] (m)**
Strontium-90, 8 pCi/L	2019	11,400 (199-N-67)	0.61	678
	2018	11,600 (199-N-67)	0.63	695
Nitrate, 45 mg/L	2019	319 (199-N-67)	0.72	252
	2018	190 (199-N-67)	0.70	100
Diesel (as total petroleum hydrocarbons), 0.5 mg/L	2019	81.9 (199-N-18)	0.02	50
	2018	46.9 (199-N-18)	0.02	50
Hexavalent chromium, 48 µg/L/10 µg/L[c]	2019	42.3 (199-N-74) 118 (RUM 199-N-80)	0 / 0.61[d]	0
	2018	40.7 (199-N-74) 120 (RUM 199-N-80)	0 / 0.57[d]	0
Tritium, 20,000 pCi/L	2019	326,000 (199-N-374)	<0.01	28
	2018	383,000 (199-N-374)	<0.01	26
Manganese, 50 µg/L[e]	2019	13,700 (199-N-18)	—[f]	—[f]
	2018	12,600 (199-N-171)	—[f]	—[f]
Sulfate, 250 mg/L[e]	2019	437 (199-N-171)	—[f]	—[f]
	2018	510 (199-N-167)	—[f]	—[f]
Remediation				
Waste sites: 92% complete.[g] **Groundwater (interim action):** 1995 to present. Record of Decision for final remedial action is anticipated in 2020 or 2021.				

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

b. Length of shoreline intersected by plume above listed water quality standard.

c. 48 µg/L in the upland area (WAC 173-340, "Model Toxics Control Act—Cleanup") and 10 µg/L where groundwater discharges to surface water (WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances").

d. Area of the plume entirely in 100-NR. The plume on the boundary of 100-NR and 100-KR is discussed in Chapter 5.

e. Secondary drinking water standard.

f. Not calculated since standard is a secondary drinking water standard and detected contamination is associated with reducing conditions created by the total petroleum hydrocarbons plume.

g. Sites with status of final closed, interim closed, no action, not accepted, or rejected as of December 31, 2019.

RUM = Ringold upper mud unit

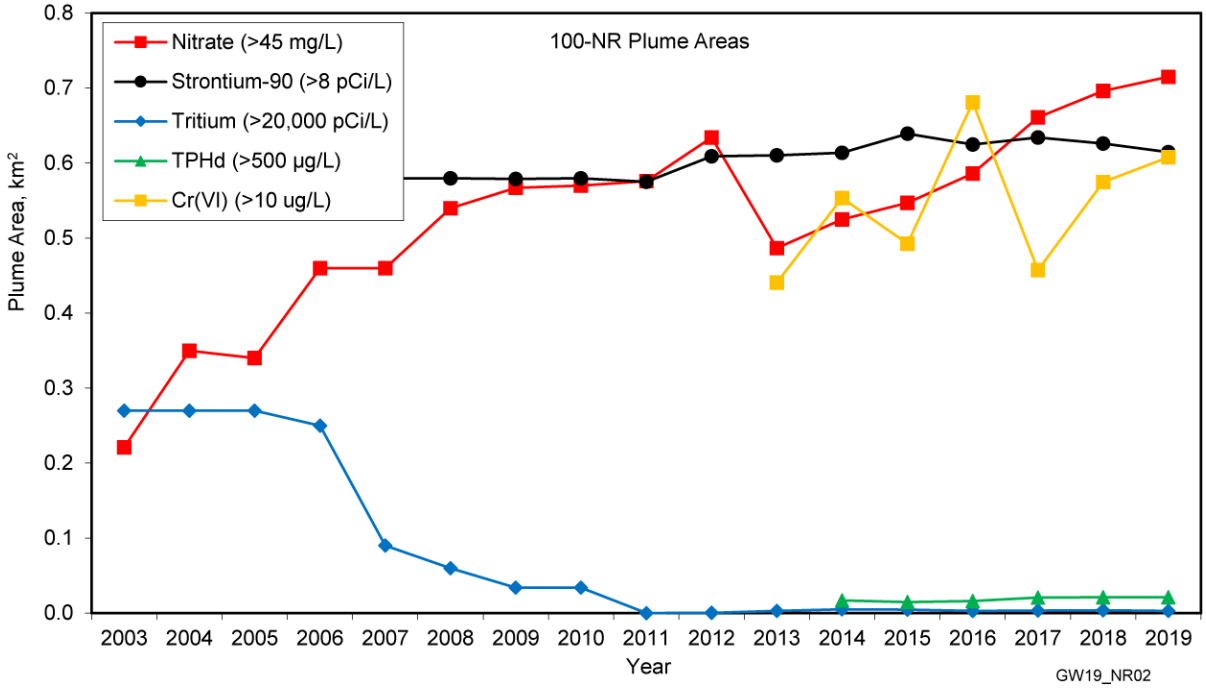


Figure 6-3. 100-NR Plume Areas

The vadose zone in 100-NR is up to 23 m (76 ft) thick and is composed of gravels and sands of the Hanford formation and Ringold unit E (Figure 6-4). The unconfined aquifer is 6.5 to 14 m (21 to 46 ft) thick and is primarily located within Ringold unit E. When the Columbia River stage is high, the water table can rise into the Hanford formation in wells near the shoreline. Groundwater contaminant concentrations vary with changes in water table elevation, which mobilize contamination in the vadose zone. The top of the RUM is the base of the unconfined aquifer. One thin, noncontinuous, confined, water-bearing zone has been documented within the upper portion of the RUM in well 199-N-80.

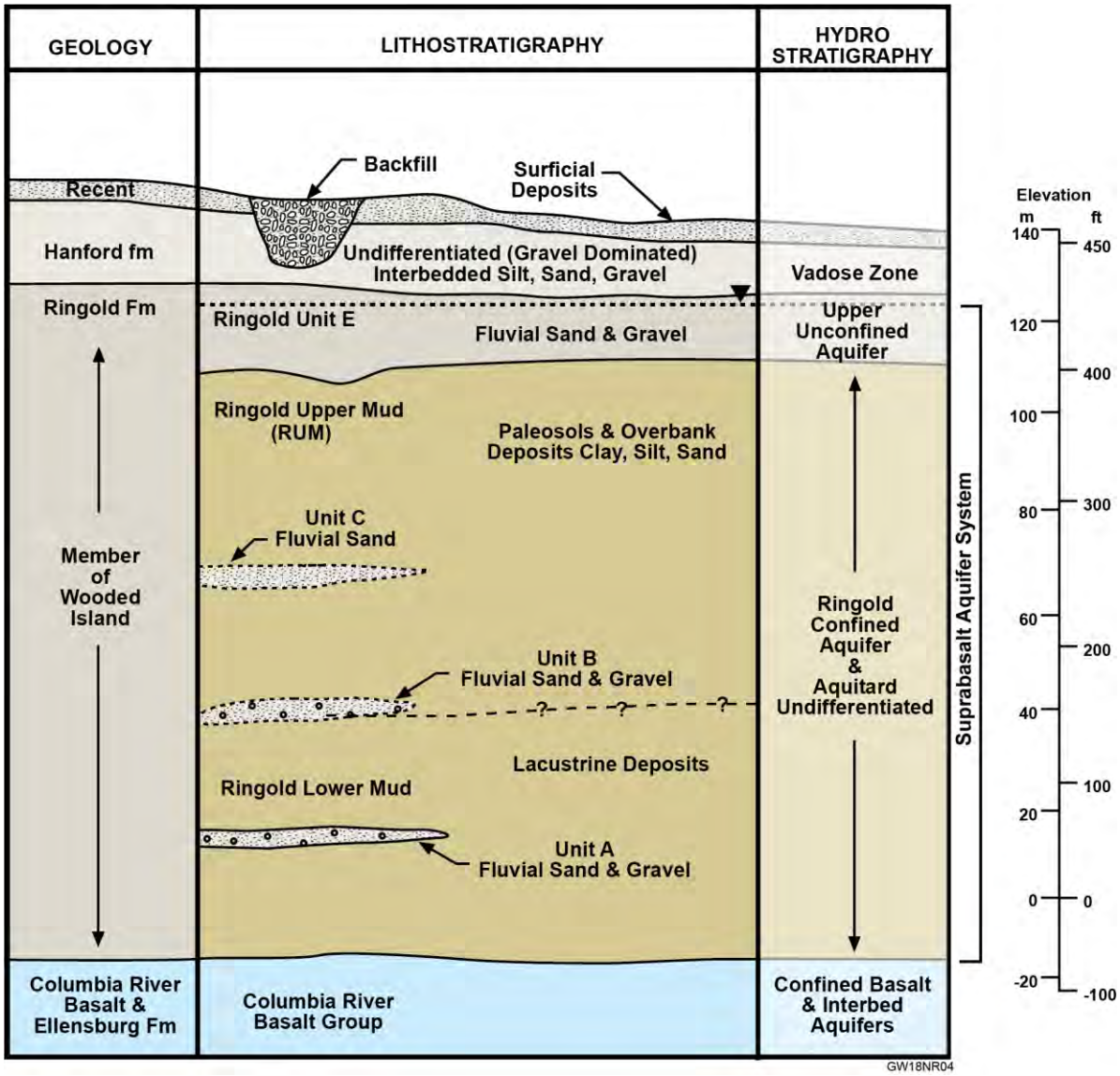


Figure 6-4. 100-NR Geology

6.2 Strontium-90

The primary source of strontium-90 in 100-NR was liquid waste from N Reactor that was disposed to two liquid waste disposal facilities (LWDFs): the 116-N-1 Crib and Trench, and the 116-N-3 Crib and Trench. Groundwater concentrations vary with fluctuating water levels and flow through the PRB along the shoreline. However, the size and shape of the strontium-90 plume (Figure 6-5) change very little from year to year because of the low mobility of strontium-90.

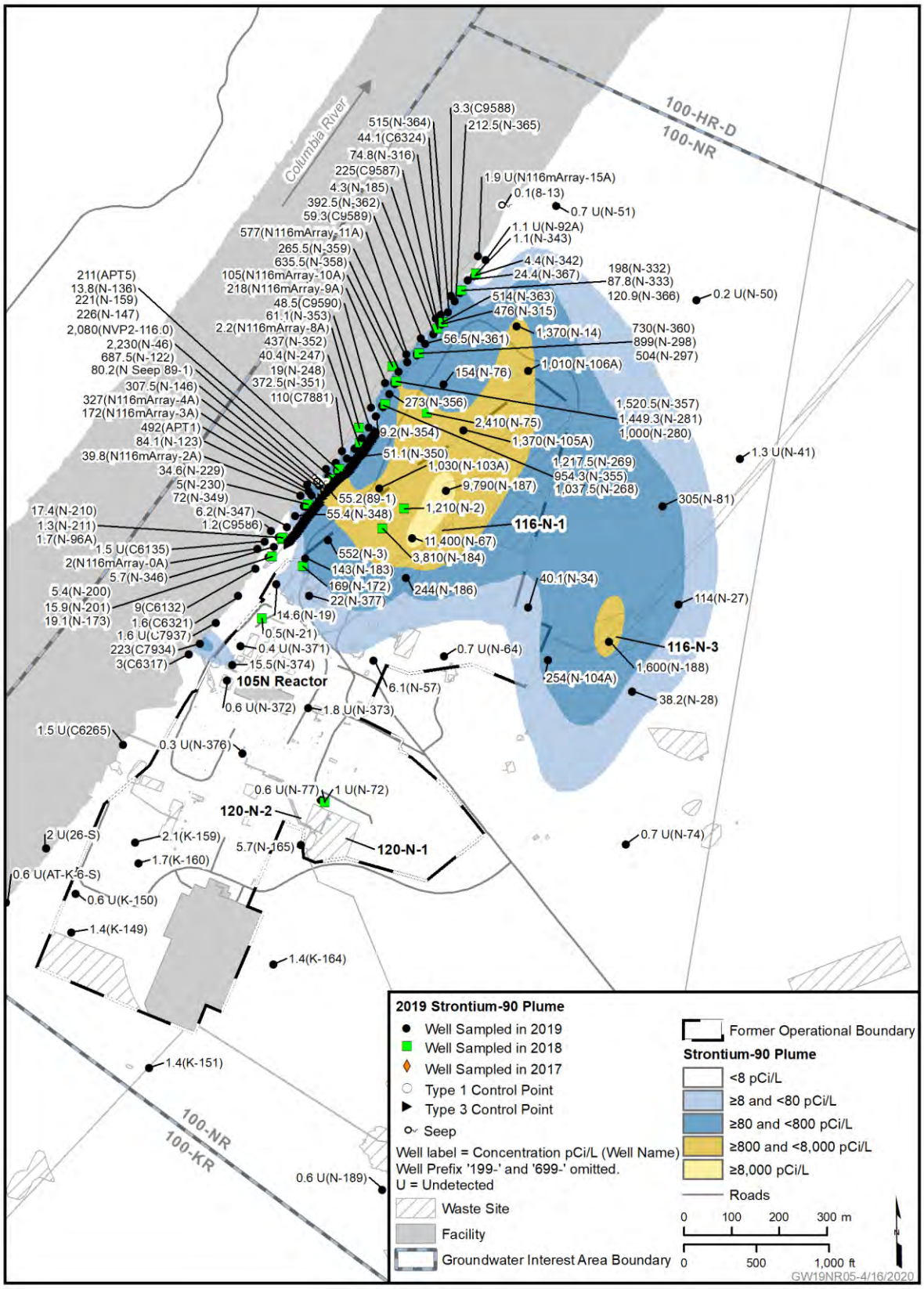


Figure 6-5. 100-NR Strontium-90 Plume, 2019

The strontium-90 plume extends laterally from beneath the LWDFs to the Columbia River at concentrations exceeding the DWS (8 pCi/L). Strontium-90 concentrations >800 pCi/L are found beneath the 116-N-3 Crib, as well as beneath and downgradient of the 116-N-1 Crib and Trench. Below the head end of the 116-N-1 Crib and trench, strontium-90 concentrations are >8,000 pCi/L. Figure 6-6 shows stable trends in strontium-90 concentrations at 116-N-1 Trench wells 199-N-67 and 199-N-187 that fluctuate with water levels. Groundwater concentrations between 8 and 80 pCi/L are peripheral to the highest concentration area and are consistent with historical radial flow away from the LWDFs when the liquid waste disposal sites were receiving effluent.

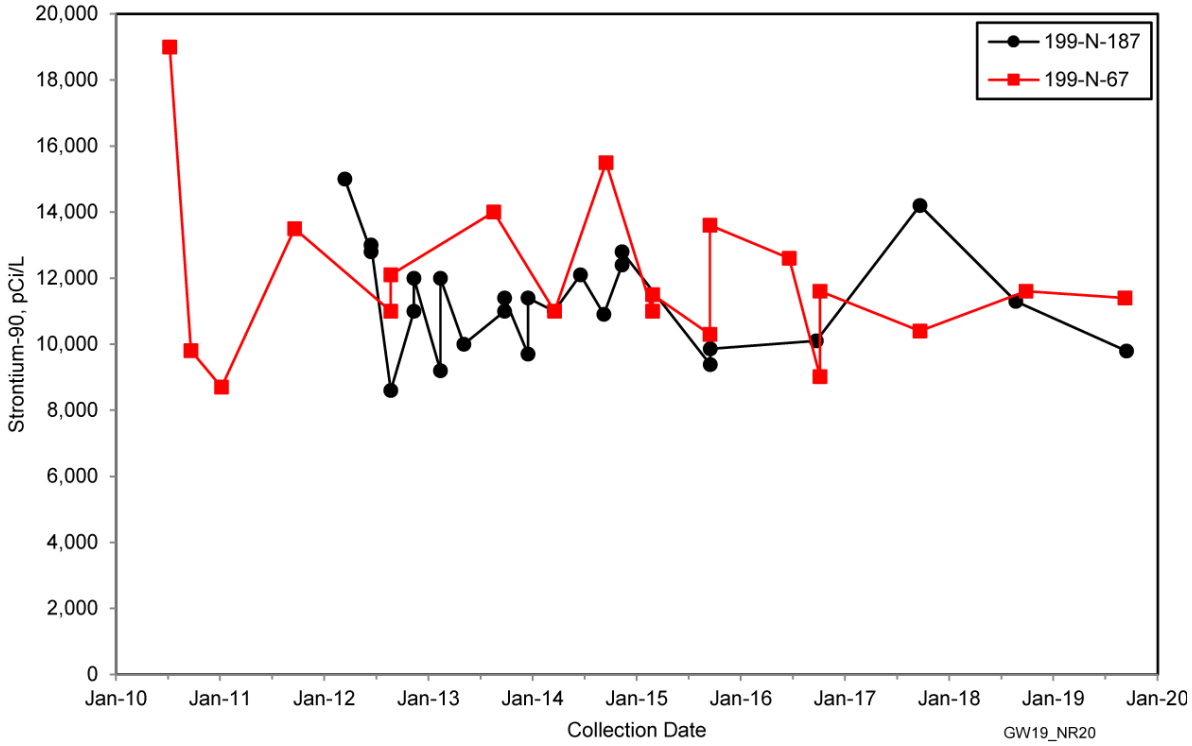


Figure 6-6. 100-NR Strontium-90 Data for Wells 199-N-67 and 199-N-187

As discussed in Chapter 6 of DOE/RL-2018-66, control points located 20 m (66 ft) inland from the apatite PRB injection wells are included in the strontium-90 plume interpretation. The control points were added because the limited number of wells upgradient of the apatite PRB lead to interpreting lower concentrations upgradient of the apatite PRB. The strontium-90 plume interpretation shown in Figure 6-5 includes control points upgradient of the apatite PRB, with strontium-90 values based on decayed pre-apatite PRB installation concentrations at the injection wells. The effect of adding the control points extends the 800 to 8,000 pCi/L contour from the 116-N-1 Crib to the central portion of the apatite PRB.

For the 2019 strontium-90 plume interpretation, the 2018 concentration for well 199-N-184 (3,810 pCi/L) was used rather than the 2019 concentration of 454 pCi/L. The more conservative (i.e., higher) contaminant value was used to maintain a consistent yearly scientific interpretation of the plume. Water levels have fluctuated 1.7 m (5.6 ft) at this well, resulting in an order of magnitude change in measured strontium-90 concentrations (Figure 6-7). Using the 2019 concentration value for the plume interpretation would cut off the 800 to 8,000 pCi/L contour from extending between the 116-N-1 Crib and the central portion of the apatite PRB. Strontium-90 concentrations would increase once water levels increase in the well, so the plume interpretation is that the 800 to 8,000 pCi/L contour extends from the 116-N-1 Crib to

the central portion of the apatite PRB. Strontium-90 concentrations in other wells near 199-N-184 also fluctuate with changing water levels but not to the same extent as well 199-N-184.

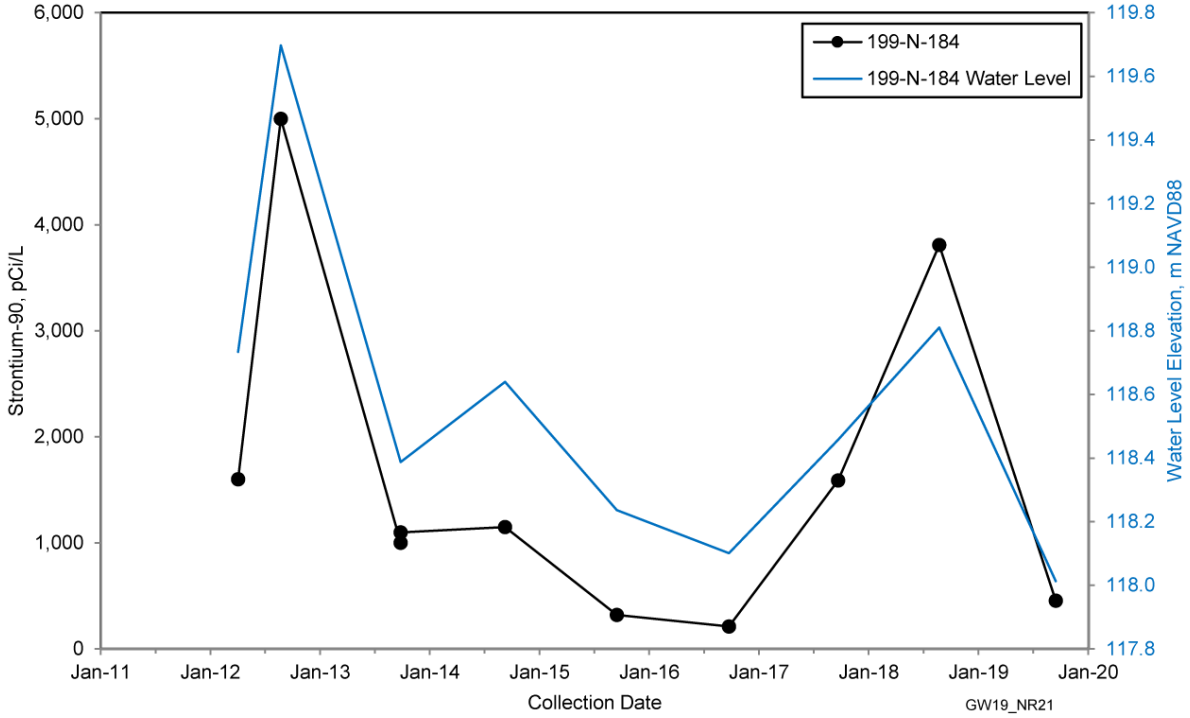


Figure 6-7. 100-NR Strontium-90 Data and Water Levels in Well 199-N-184

The only strontium-90 concentration above the DWS outside of the main plume (described above) is defined by well 199-N-374 and aquifer tube cluster C7934/C7935/C7936, downgradient of N Reactor (Figure 6-5). The presumed strontium-90 sources were unplanned releases from the N Reactor fuel storage basins and associated facilities and pipelines (UPR-100-N-3, UPR-100-N-7, and UPR-100-N-12). The aquifer tubes are located near the engineered fill around the 1908-N outfall, which suggests that outfall construction created a preferential pathway for migration of contaminated groundwater to the river (Section 4.2 in SGW-49370, *Columbia River Pore Water Sampling in 100-N Area, December 2010*). In 2019, the maximum concentrations in this plume ranged from 22.2 pCi/L at well 199-N-374 to 223 pCi/L at the aquifer tube cluster. Concentrations at well 199-N-374 and the aquifer tube cluster fluctuate with changes in river elevation, but overall concentration trends are generally stable or decreasing (Figure 6-8).

Most of the strontium-90 in groundwater is limited to the upper portion of the unconfined aquifer. Strontium-90 concentrations measured in wells screened at the base of the aquifer (199-N-69, 199-N-70, 199-N-77, and 199-N-182) have concentrations <150 pCi/L. The top of the screen in well 199-N-182 is 2.4 m (7.9 ft) below the typical low water table, and this well had a maximum concentration of 144 pCi/L. The bottom of the well screen is 1.6 m (5.2 ft) below the typical low water level in adjacent well 199-N-184, which had strontium-90 concentrations an order of magnitude higher. The other three deep screened wells have the tops of well screens placed more than 5 m (16 ft) below the typical low water level. The maximum strontium-90 concentration was 12 pCi/L at well 199-N-69 (located near well 199-N-67 downgradient of the 116-N-1 Trench).

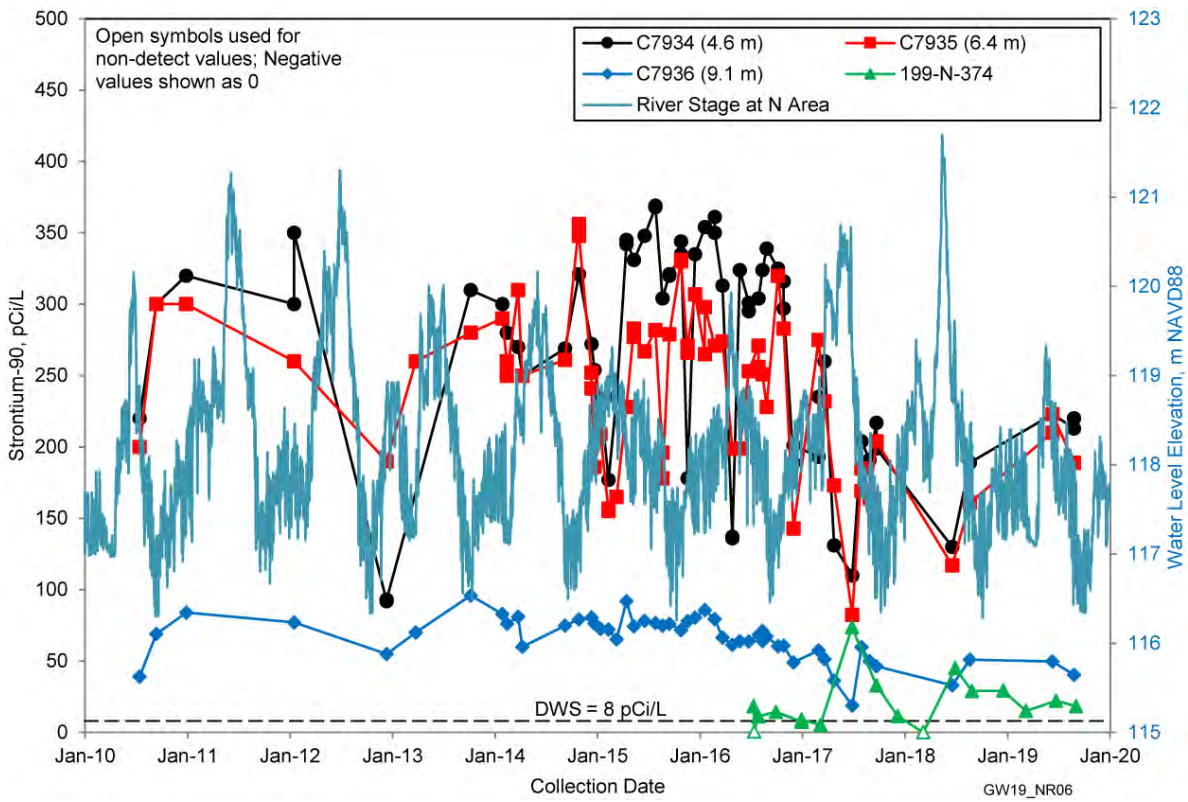


Figure 6-8. 100-NR Strontium-90 Data for Aquifer Tube Cluster C7934/C7935/C7936 and Well 199-N-374

Several wells within the downriver, untreated portion of the apatite PRB (north of well 199-N-354) have strontium-90 concentrations >800 pCi/L. This localized, high-concentration area is interpreted to extend upgradient to the 116-N-1 source based on concentrations >800 pCi/L at wells 199-N-75 and 199-N-105A. Section 6.7.2 provides additional discussion on strontium-90 concentrations at the apatite PRB.

Two seeps at the 100-N shoreline were sampled in 2019: N Seep 89-1 (located near well 199-N-123 in the main strontium-90 plume) and N Seep 8-13 (located north of well 199-N-92A downriver from the main strontium-90 plume) (Figures 6-2 and 6-5). Strontium-90 concentrations were 55.2 pCi/L in N Seep 89-1 and below detection in N Seep 8-13.

6.3 Tritium

Tritium concentrations remained above the 20,000 pCi/L DWS in a small area downgradient of N Reactor, extending from monitoring well 199-N-374 to aquifer tube cluster C7934/C7935/C7936, adjacent to the Columbia River (Figure 6-9). As reported in previous annual groundwater monitoring reports, the source of tritium contamination is likely unplanned releases from the N Reactor fuel storage basin, associated facilities, and pipelines. The tritium observed in this small plume is attributed to residual tritium mobilizing in the lower vadose zone as a result of adding dust-suppression water during interim remedial actions around the reactor. The maximum tritium concentration in 2019 was 326,000 pCi/L in well 199-N-374 compared to 383,000 pCi/L in 2018. The tritium concentrations at the three aquifer tubes have generally been decreasing since the peak concentrations in 2015 (Figure 6-10). Concentrations above the DWS in the aquifer tube cluster ranged from 54,000 to 109,000 pCi/L in 2019, with the higher concentrations in the upper part of the aquifer measured in aquifer tube C7934.

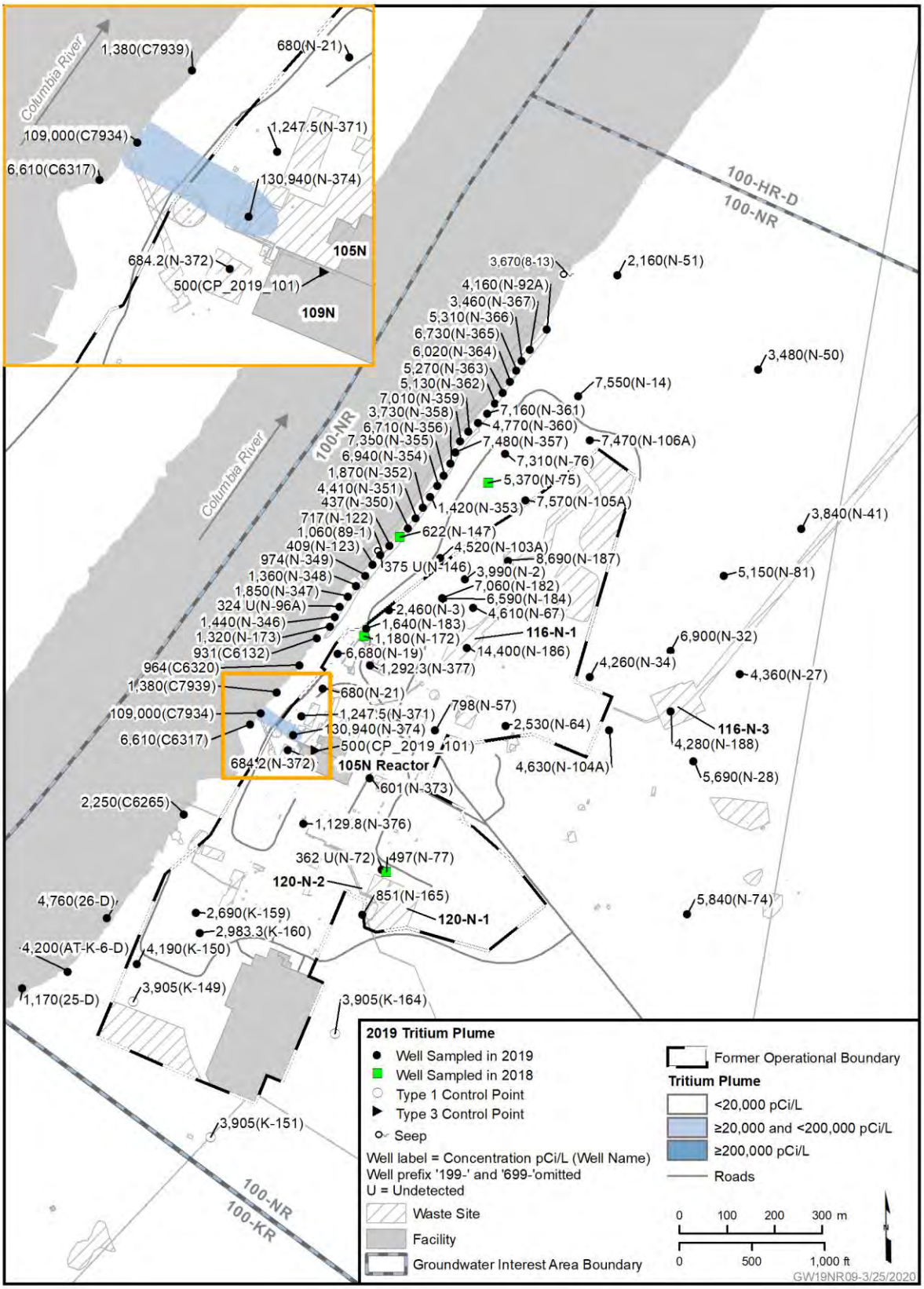


Figure 6-9. 100-NR Tritium Plume, 2019

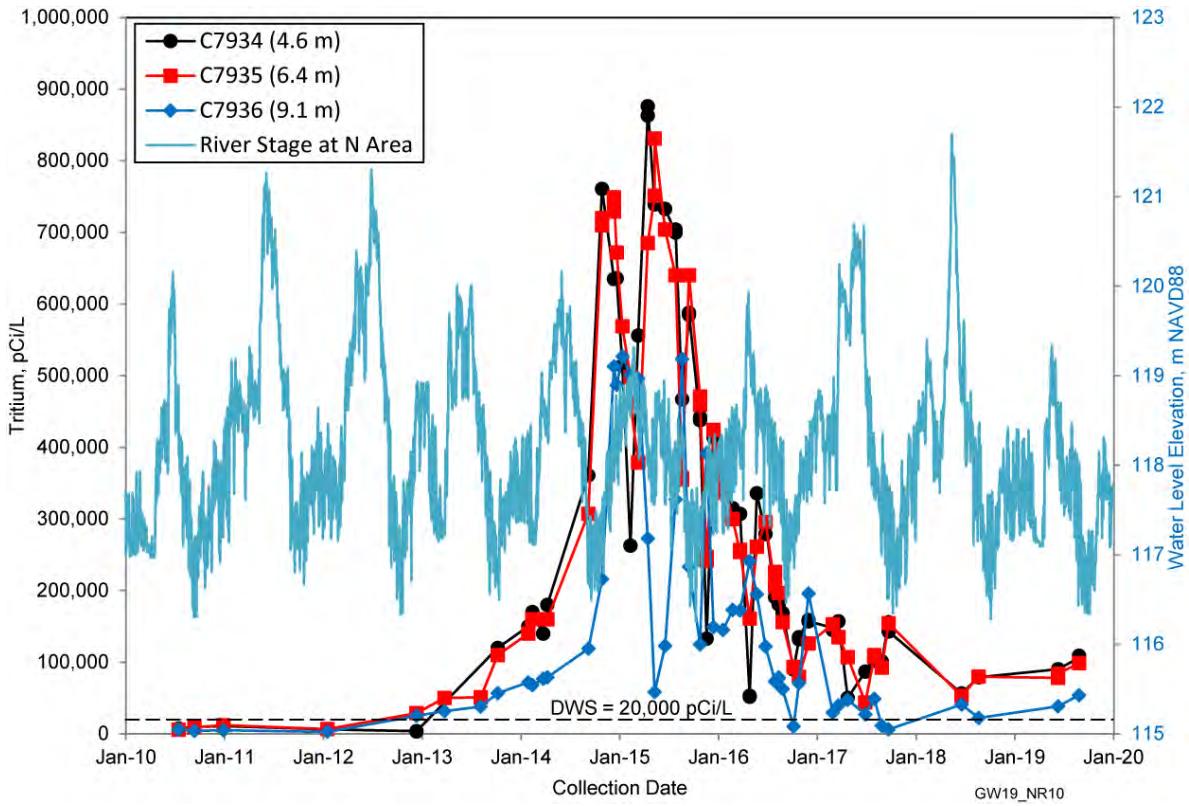


Figure 6-10. 100-NR Tritium Data for Aquifer Tubes C7934, C7935, and C7936

The only other monitoring well in 100-NR with tritium concentrations above the DWS in recent years was well 199-N-186, located in the former 116-N-1 Crib. Since the well was installed in 2011, tritium concentrations have fluctuated above and below the DWS with changes in water level (Figure 6-11). The tritium concentration at this well for the September 2019 sample event was below the DWS at 14,400 pCi/L compared to 26,300 pCi/L in 2018.

Two shoreline seeps were sampled for tritium in 2019. The concentrations from both seeps have historically been less than the DWS. In 2019, concentrations were at 1,606 pCi/L and 3,670 pCi/L at N Seep 89-1 and N Seep 8-13, respectively.

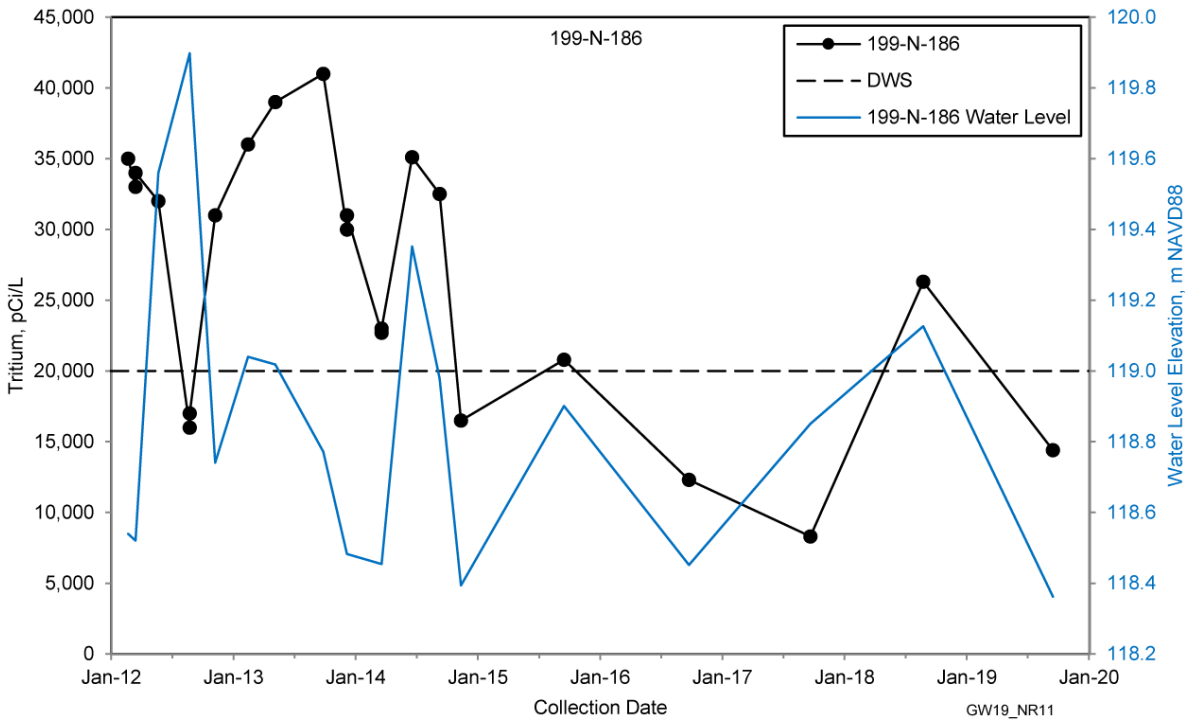


Figure 6-11. 100-NR Tritium Data and Water Level at Well 199-N-186

6.4 Nitrate

Nitrate exceeds 45 mg/L in groundwater beneath the LWDFs and the N Reactor area to the southwest (Figure 6-12). For the 2019 nitrate plume interpretation, the 25.1 mg/L control point value used in 2018 at well 199-N-104A was removed. This control point value (the last sampled value from the well in 2013) was used to limit the southern extent of the plume beneath the LWDFs. Well 199-N-104A was an injection well when the 100-N P&T was in operation where the nitrate concentrations in the treated water were lower than the surrounding plume concentrations. Since 2013, the concentrations at this location likely increased based on the increasing nitrate trend at nearby well 199-N-28. Removing the well 199-N-104A control point results in the 2019 plume extending farther south beneath the 116-N-3 Crib compared to the 2018 plume interpretation. This is consistent with the southern extent observed in the strontium-90 plume also originating from discharges to the LWDFs.

Nitrate concentrations were low in groundwater during 116-N-1 and 116-N-3 liquid waste disposal operations and increased after discharges to the waste sites ceased. Nitrate was not documented as a waste disposed to the sites, but compounds that could break down into nitrate were used and disposed (namely ammonium hydroxide, hydrazine and, to a lesser extent, morpholine [Section 1.3.2.3 in DOE/RL-2012-15, Draft B]). These compounds were used as corrosion inhibitors for the N Reactor cooling water system. It is theorized that the nitrate plume resulted from bacterial nitrification of ammonium released to ground by the large-volume discharges to the waste disposal sites (Section 4.4.4.3 in DOE/RL-2012-15, Draft B).

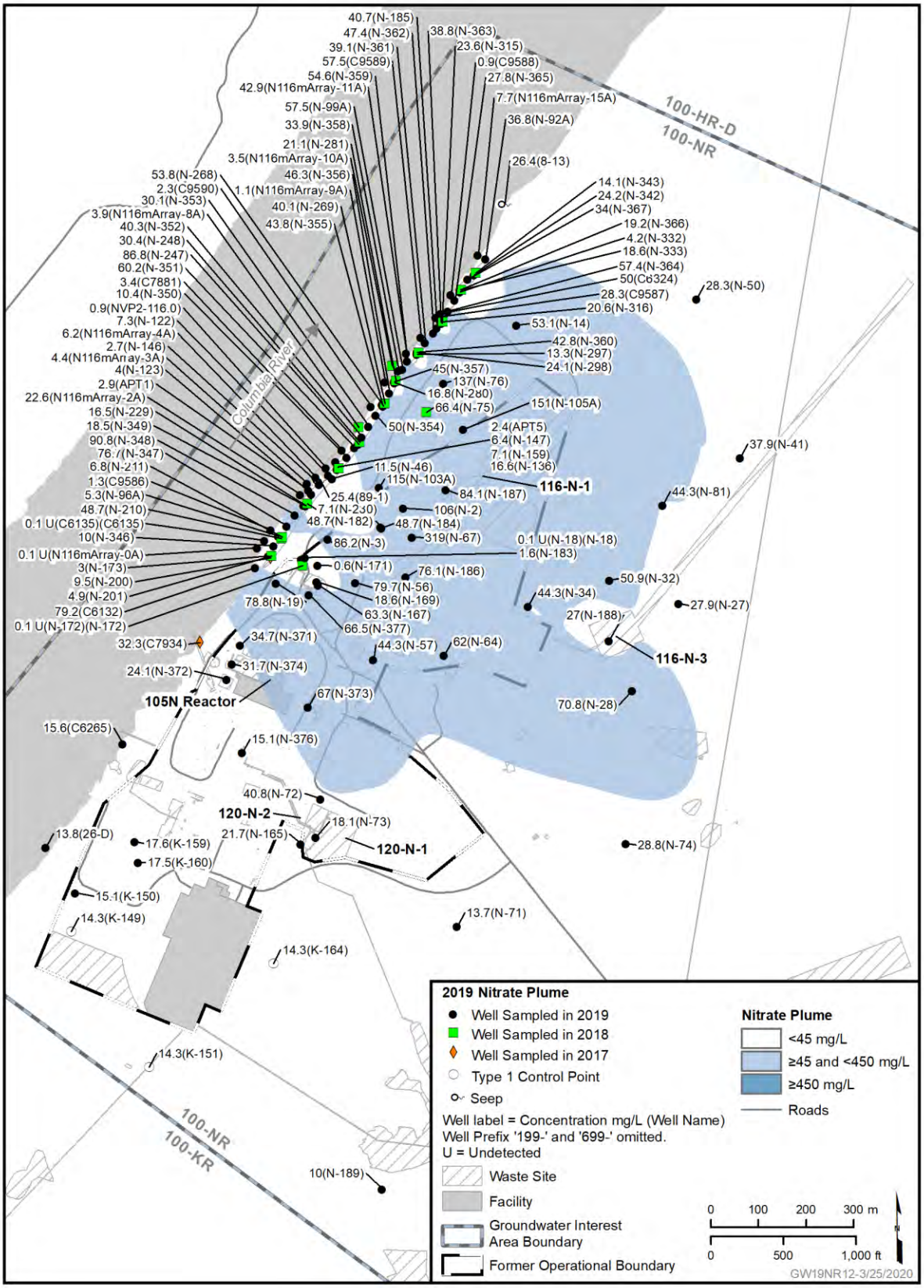


Figure 6-12. 100-NR Nitrate Plume, 2019

Ammonium is much less mobile than nitrate. As the water table receded after cessation of discharges to the LWDFs, ammonium would have remained on the sediments. The vadose zone subsequently returned to near-normal (natural) moisture levels and dissolved oxygen concentrations at levels (>3 mg/L) that support biological nitrification. The increasing nitrate trends since the end of liquid waste disposal are postulated to be the result of nitrate desorption into groundwater from the rewetted and saturated sediments.

Figures 6-13 and 6-14 show nitrate concentration trends from wells downgradient of the 116-N-1 and 116-N-3 Trenches, respectively. Nitrate concentrations were relatively low in groundwater during 116-N-1 and 116-N-3 liquid waste disposal operations and increased after cessation of discharges to the LWDFs and the subsequent water level decrease. Increasing nitrate trends observed in wells near the northern edge of the plume are associated with migration of the plume with groundwater flow (Figure 6-15). The highest concentration in 2019 was 319 mg/L in well 199-N-67. The highest nitrate concentration in an aquifer tube was 79.2 mg/L at C6132. The nitrate concentrations in seeps N Seep 8-13 and N Seep 89-1 were 26.4 mg/L and 25.4 mg/L, respectively.

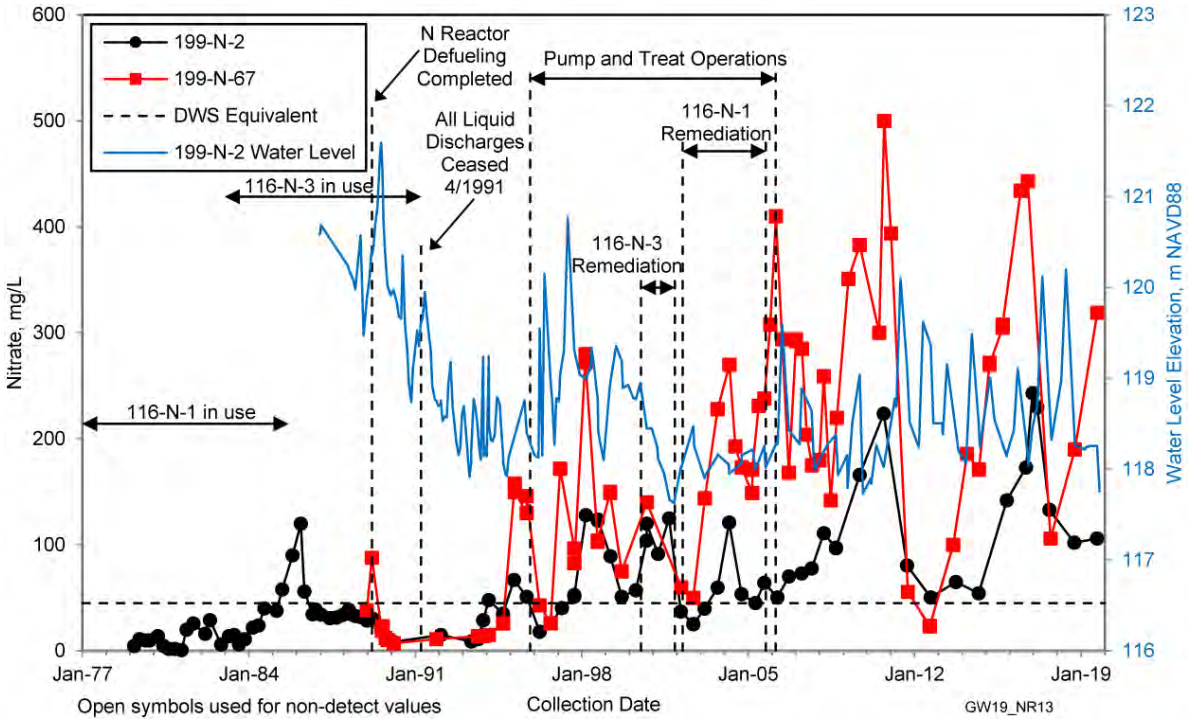


Figure 6-13. 100-NR Nitrate Data for Wells Downgradient of 116-N-1 Trench

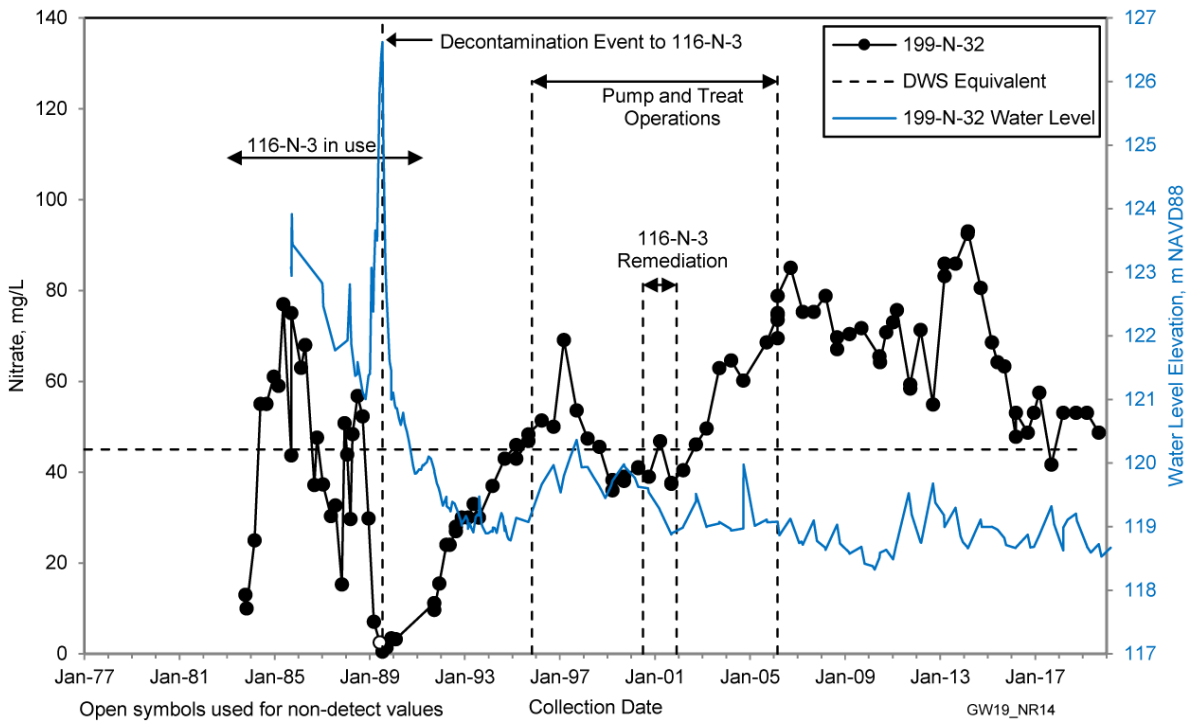


Figure 6-14. 100-NR Nitrate Data for Wells Downgradient of 116-N-3 Trench

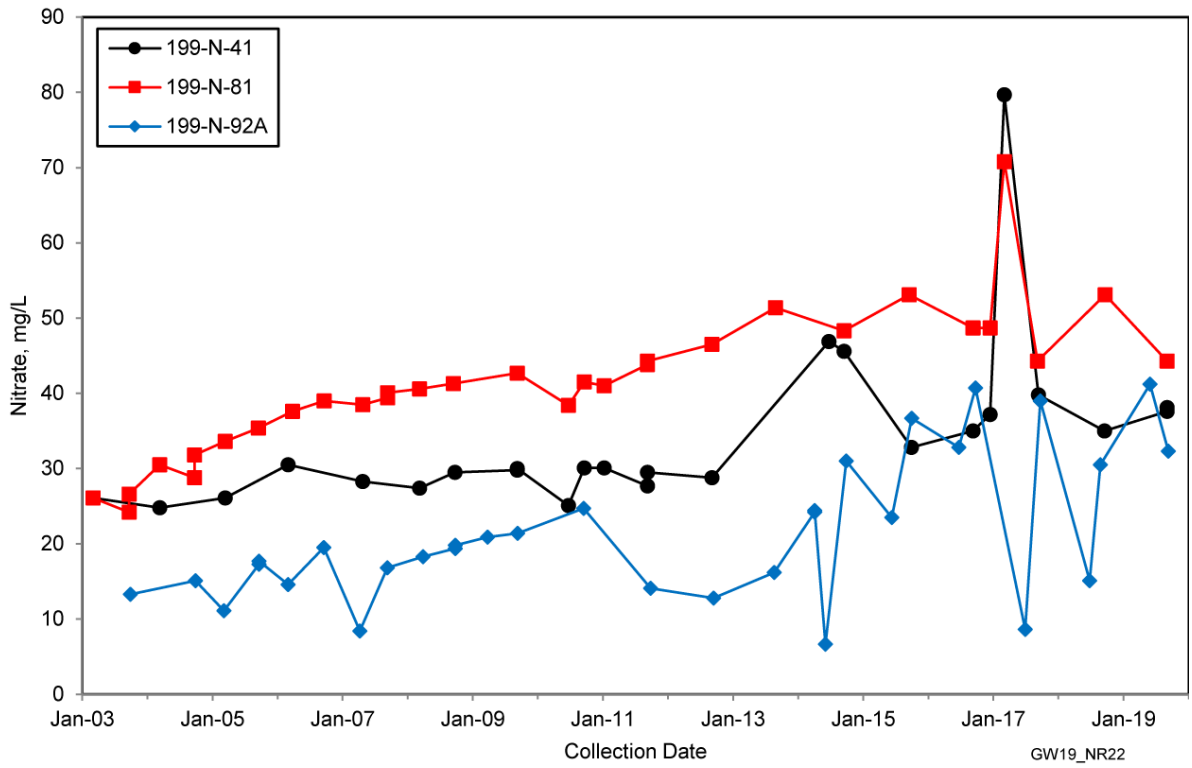


Figure 6-15. 100-NR Nitrate Data for Wells 199-N-92A (Northern Edge of Plume), 199-N-81, and 199-N-41 (Eastern Edge of Plume)

Nitrate concentrations near the 120-N-1 waste site were very low when the site was in use but began to increase in the mid-1990s (Figure 6-16). Only low levels of nitrate (1 mg/L) were detected in the 120-N-1 effluent (Section 2.4.4 in DOE/RL-96-39, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*). These factors suggest that 120-N-1 was not the source of the nitrate plume in the southwestern region of 100-NR. The probable source of the nitrate in wells 199-N-59, 199-N-72, and 199-N-165 (Figure 6-16), as well as the portion of the nitrate plume southwest of N Reactor, was several septic systems located upgradient and west of the 120-N-1 waste site. Large-capacity sanitary sewage systems are an acknowledged source of nitrate.

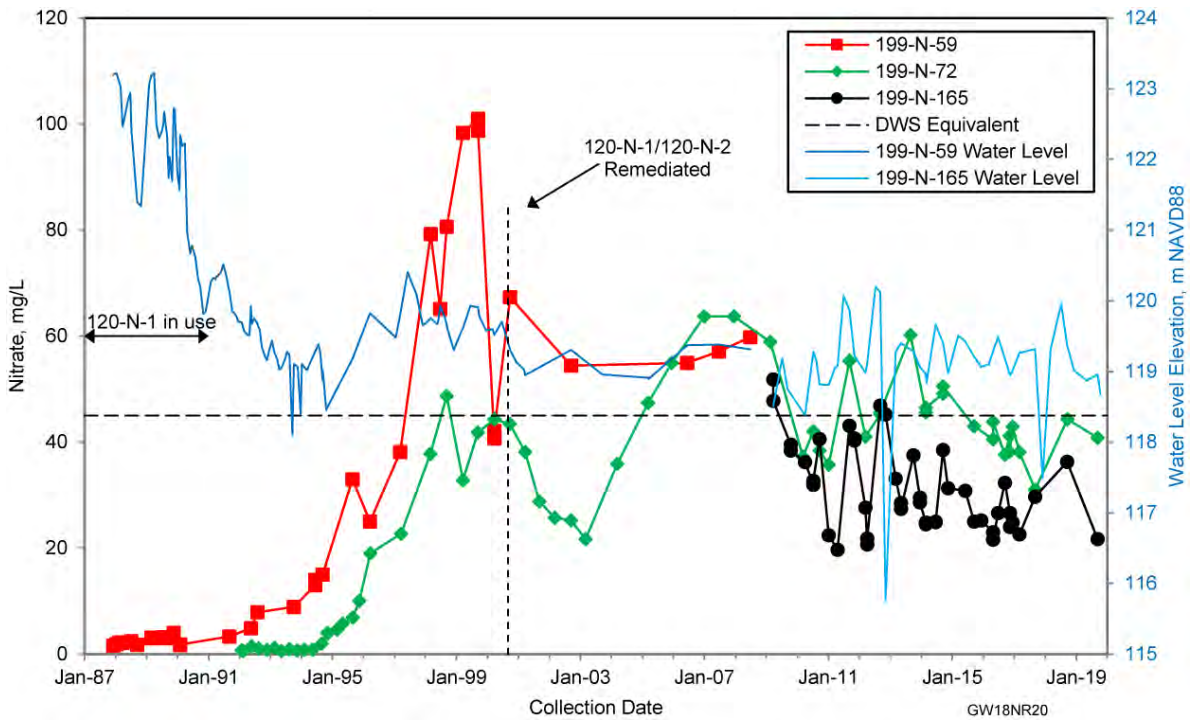


Figure 6-16. 100-NR Nitrate Data for Wells Downgradient of the 120-N-1 Waste Site

Nitrate concentrations are lower in wells associated with the petroleum hydrocarbons groundwater plume (e.g., well 199-N-172) because of chemical reduction during the biodegradation of petroleum hydrocarbon contamination. Low dissolved oxygen levels, lower pH, detectable nitrite, and elevated iron and manganese indicate the presence of reducing conditions in this part of the aquifer.

6.5 Total Petroleum Hydrocarbons–Diesel

The primary source of petroleum hydrocarbons in 100-NR groundwater was a 1966 diesel fuel spill (UPR-100-N-17). Bioventing is currently being used to remediate TPH-D in the deep vadose zone beneath the waste site using two vadose zone injection wells (199-N-167 and 199-N-172) and two vadose zone gas monitoring wells (199-N-169 and 199-N-171). The well screens span about 6 m (20 ft) in the deep vadose zone (for air injection and soil gas monitoring) and extend about 1.5 m (5 ft) into the top of the unconfined aquifer (for groundwater sampling). Additional information on the bioventing system operation is provided in WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014*; and DOE/RL-2016-34, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2015-February 2016*. The bioventing wells are also used for groundwater monitoring. A small, relatively narrow groundwater plume extends downgradient from the spill toward the river (Figure 6-17).

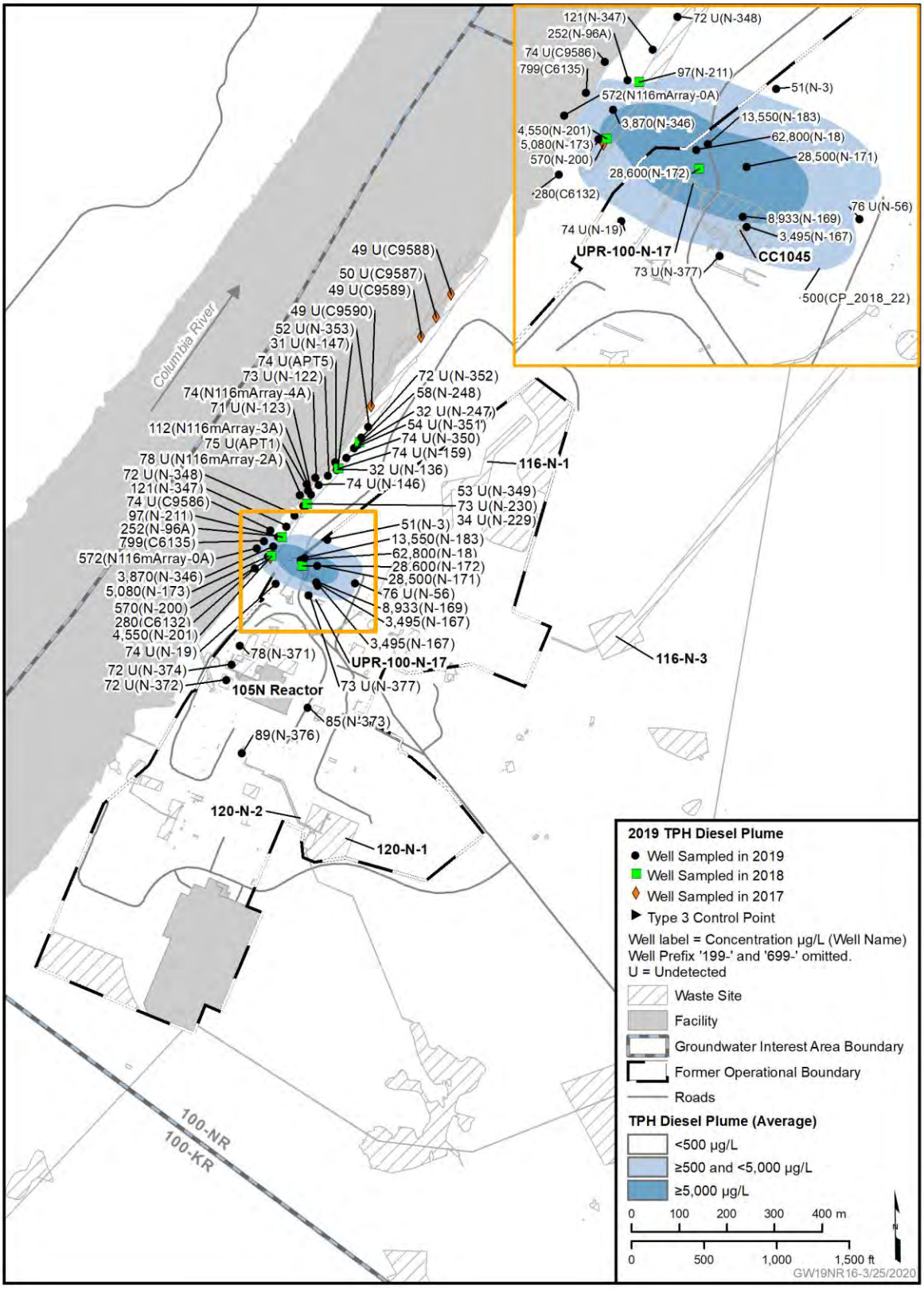


Figure 6-17. 100-NR TPH-D Plume, 2019

The two highest concentrations in 2019 were in wells 199-N-18 and 199-N-171 (81.9 and 29.0 mg/L, respectively). In 2019, the maximum aquifer tube concentration was in C6135 (0.8 mg/L). The concentration of TPH-D in shoreline seep N Seep 89-1 was less than detection.

The TPH-D concentrations in most groundwater monitoring wells downgradient of the UPR-100-N-17 spill have increased since 2017. Increasing TPH-D concentrations at wells 199-N-169 and 199-N-171 and corresponding depletion of dissolved oxygen are an indicator of a continuing source deep within the vadose zone and likely related to the high water table in 2017 and 2018 remobilizing petroleum hydrocarbons in the vadose zone (Figures 6-18 and 6-19, respectively). Manganese and sulfate concentrations have also increased in the TPH plume area corresponding with the reducing conditions created by the depletion of dissolved oxygen in the TPH plume (Figures 6-20 and 6-21). Section 6.7.3 discusses the petroleum hydrocarbon groundwater remediation activities for 2019.

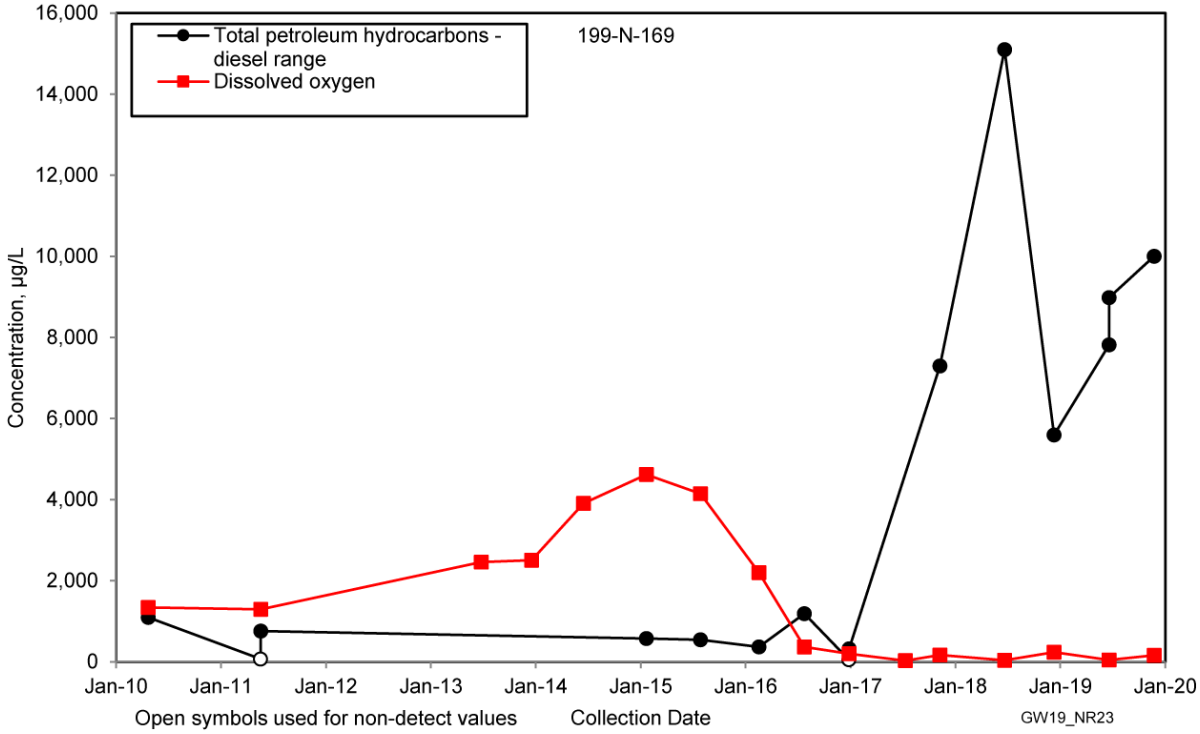


Figure 6-18. 100-NR Dissolved Oxygen and TPH-D Data at Well 199-N-169

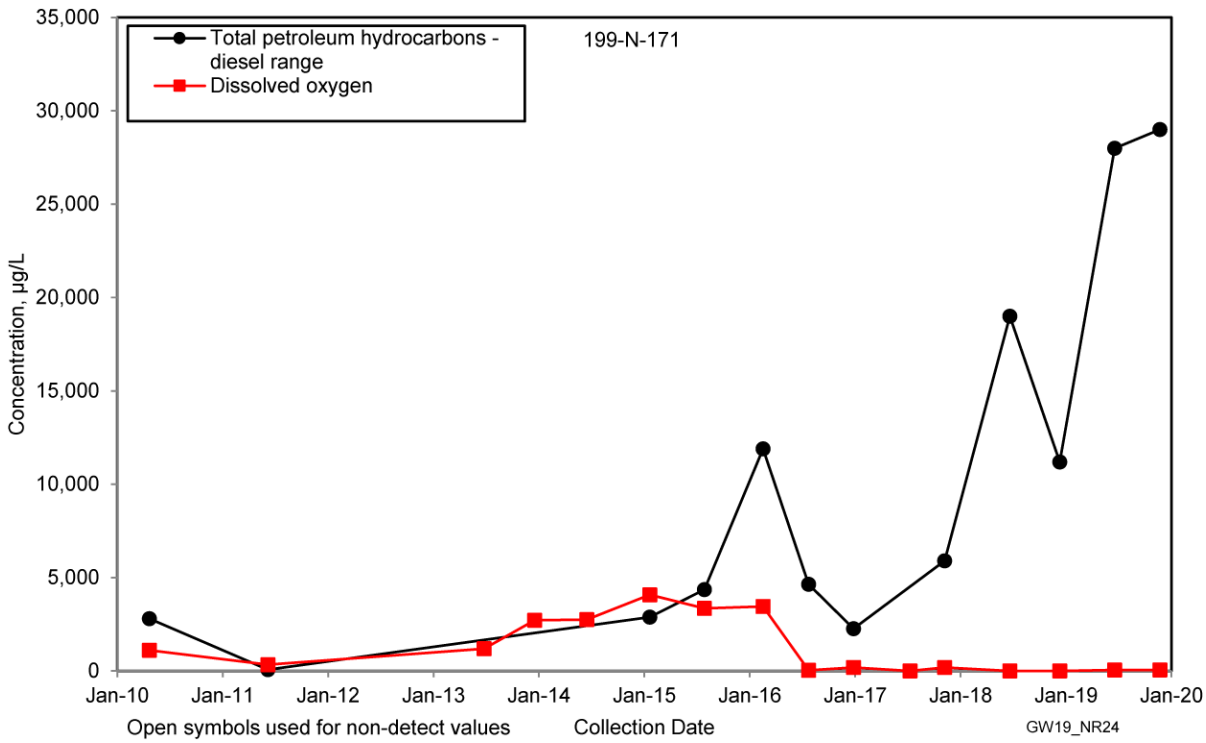


Figure 6-19. 100-NR Dissolved Oxygen and TPH-D Data at Well 199-N-171

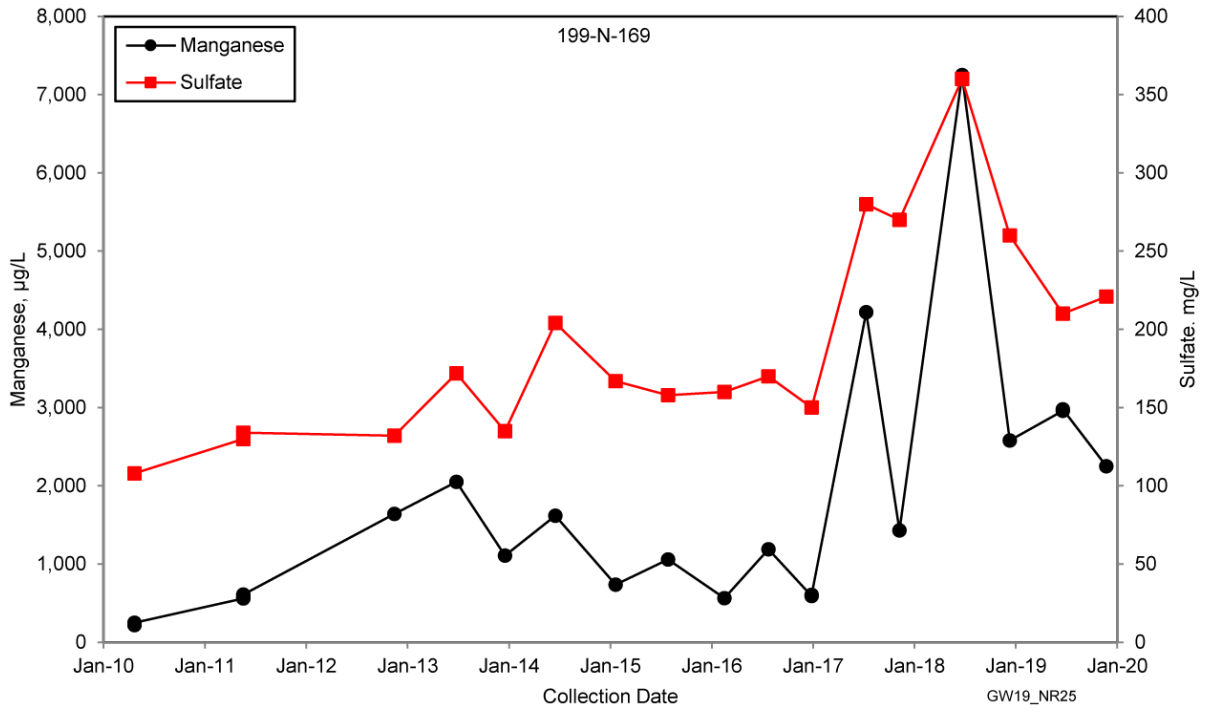


Figure 6-20. 100-NR Manganese and Sulfate Data at Well 199-N-169

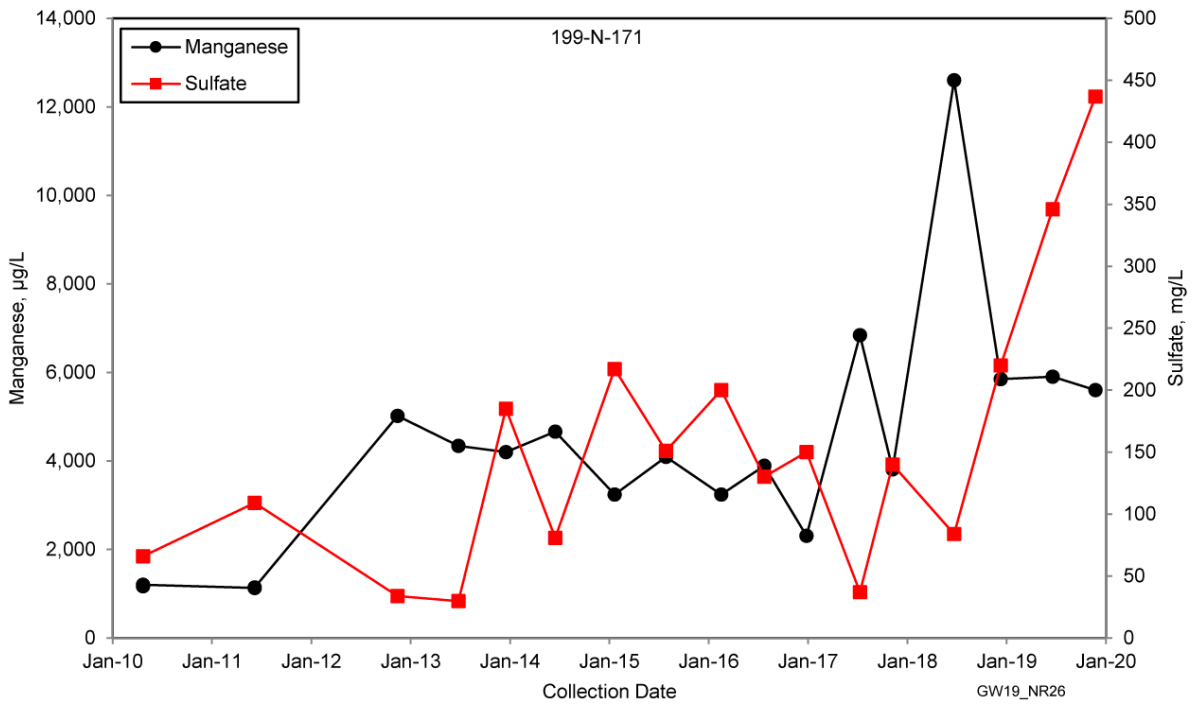


Figure 6-21. 100-NR Manganese and Sulfate Data at Well 199-N-171

6.6 Hexavalent Chromium

Sodium dichromate was used during N Reactor operations. The chemical was used in lesser amounts than at other 100 Area reactors because of the cooling system design and the use of corrosion-resistant metals (e.g., zircaloy) in the fuel and facility (Section 1.3.2 in DOE/RL-2012-15, Draft B). Although chromium was present in the effluent discharged to the 116-N-1 Crib and Trench, it was never detected in effluent samples (Section 3.1.1.4 in DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*). Discharges to 116-N-1 continued for 10 years after the use of sodium dichromate had ceased. As a result, the mobile portion of chromium was flushed from the vadose zone and into the unconfined aquifer. Because a groundwater mound was present, the diluted effluent spread radially, with some portion reaching the Columbia River by the end of the N Reactor operational period (Section 4.4.5.6 in DOE/RL-2012-15, Draft B).

The sources of most of the Cr(VI) contamination in 100-NR are likely from the neighboring 116-K-2 Trench, where a portion of the 100-KR Cr(VI) plume has migrated northward into 100-NR (Section 5.2). The portion of the Cr(VI) plume crossing the 100-KR and 100-NR boundary is being remediated by the 100-KR-4 OU groundwater remedial actions. The Cr(VI) plume that is exclusively in 100-NR continues to be monitored and is being addressed by the 100-N RI/FS (DOE/RL-2012-15, Draft B). In 2019, Cr(VI) (including filtered total chromium) was detected at levels above the 10 µg/L surface water standard in several unconfined wells in 100-NR (Figure 6-22). The Cr(VI) concentrations were less than the MTCA Method B (WAC 173-340) cleanup level of 48 µg/L in all unconfined aquifer wells, with a maximum concentration of 42.3 µg/L in well 199-N-74.

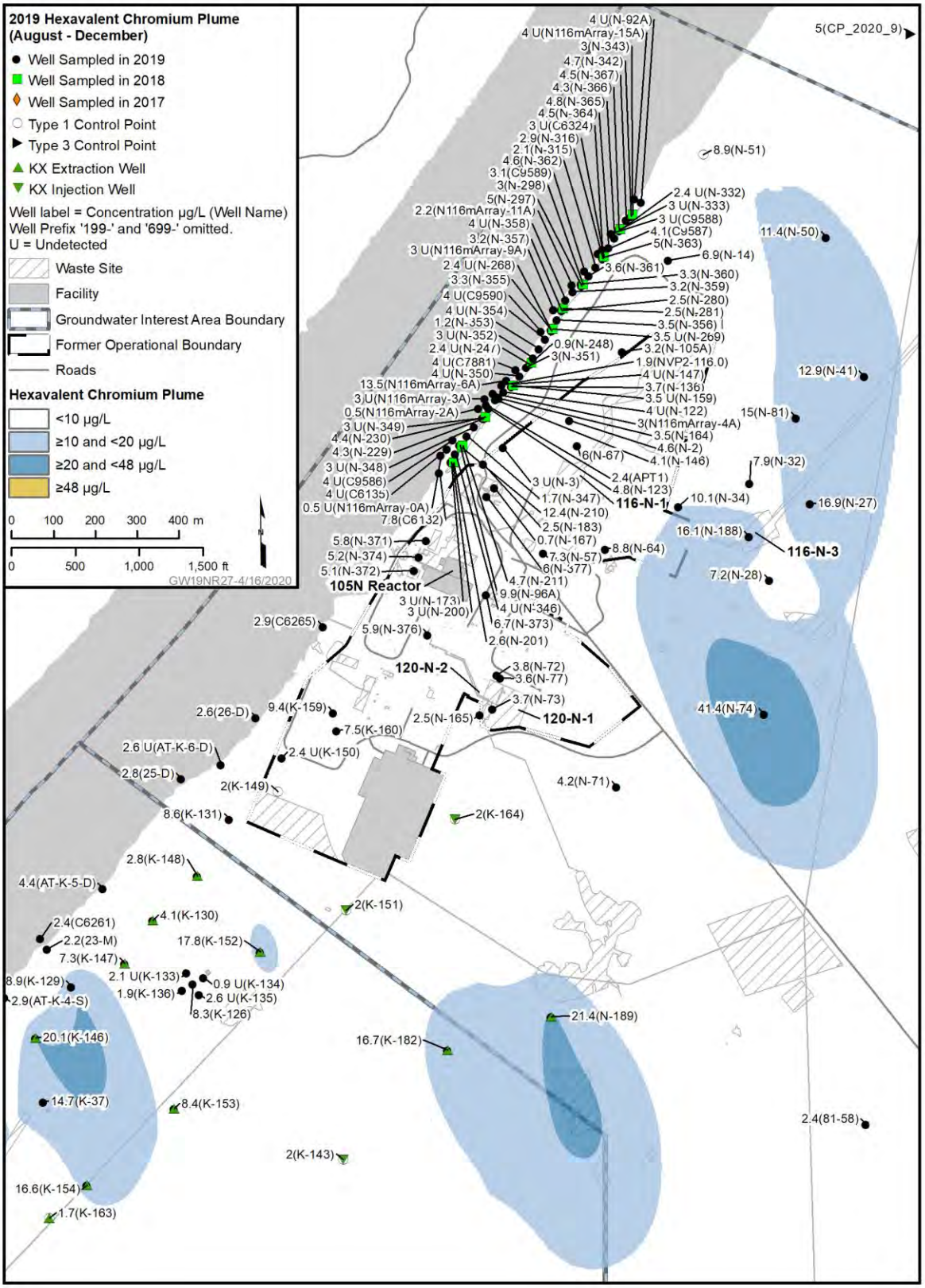


Figure 6-22. 100-NR Chromium Plume, 2019

In 2019, RUM well 199-N-80 had the highest Cr(VI) concentration (124 µg/L) in 100-NR and was the only well with a dissolved chromium concentration above the 100 µg/L DWS for total chromium (Figure 6-23). The well is located downgradient of the 116-N-1 Trench and is screened in a thin, confined, water-bearing zone in the upper portion of the RUM. This water-bearing zone has not been identified in other surrounding wells and boreholes, which indicates that the lens is not laterally continuous (Section 4.4.5.7 in DOE/RL-2012-15, Draft B). The Cr(VI) and filtered total chromium concentrations in this well are similar, indicating that the dissolved chromium is primarily Cr(VI). The Cr(VI) detected in RUM well 199-N-80 likely originated from disposal of chromium-bearing liquid waste that was driven into this relatively shallow, semiconfined interval when there was high hydraulic head. The contamination is relatively stagnant in this locally confined interval.

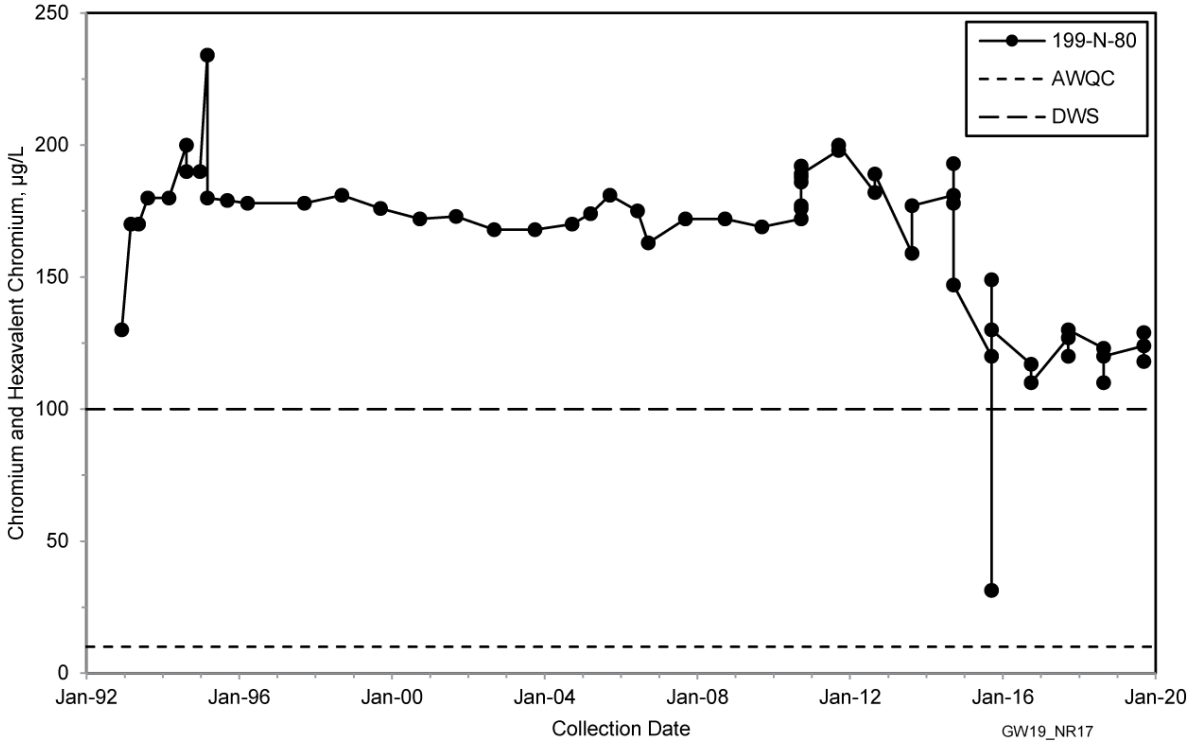


Figure 6-23. 100-NR Dissolved Chromium Data for RUM Well 199-N-80

The Cr(VI) concentrations were below the 10 µg/L surface water standard in aquifer tube and seep samples in 2019. Dissolved chromium concentrations were above the 10 µg/L surface water standard in two filtered samples collected in 2019 from aquifer tubes C9589 and N116mArray-6A at 38.9 µg/L and 13.5 µg/L, respectively. Unfiltered samples collected on the same day from the two aquifer tubes had chromium concentrations were nondetect at <4 µg/L, making the two sample results >10 µg/L suspect. Additionally, historical chromium concentrations (total and dissolved) from the two aquifer tubes have been nondetect or <10 µg/L.

6.7 CERCLA Remediation and Monitoring

In 2019, CERCLA activities at 100-NR included routine groundwater monitoring and continued interim remedial actions for strontium-90 and TPH-D contamination. CERCLA sampling is conducted primarily in June and September for high and low river-stage periods, respectively, with selected wells also monitored in March. Table A-1 in Appendix A lists the 2019 sampling exceptions. DOE/RL-2019-67 provides additional details about CERCLA remediation activities for 2019.

6.7.1 CERCLA Decision Documents and Plans

Groundwater monitoring is described in the RD/RAWP (DOE/RL-2001-27), which presents the approach for implementing the interim remedial actions for the 100-NR-2 OU, as specified in the interim action ROD, as amended (EPA, 2010). The RD/RAWP includes the activities necessary to install and maintain an apatite PRB for the 100-NR-2 OU, as specified in EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington, Amended Record of Decision, Decision Summary and Responsiveness Summary*. Appendix A of the RD/RAWP provides the SAP for interim remedial actions and routine groundwater monitoring.

Draft B of the 100-N Area RI/FS report (DOE/RL-2012-15, Draft B) was issued in November 2019 for regulatory agency review. The RI/FS report will be used to support future cleanup decisions that will be specified in a proposed plan and ROD planned for 2021.

6.7.2 Apatite Permeable Reactive Barrier

A 311 m (1,020 ft) apatite PRB has been installed along the 100-N Area shoreline as part of the CERCLA interim action ROD (EPA/ROD/R10-99/112, as amended by EPA, 2010) remedy for strontium-90 contamination in groundwater in the 100-NR-2 OU (Figure 6-24). Installation of the apatite PRB is documented in PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization Final Report*; and SGW-56970, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*).

In 2019, groundwater samples were collected from performance monitoring wells and aquifer tubes during moderately high river stage in June and during low river stage in September. Table 6-2 compares the June and September 2019 data to pre-treatment baseline conditions and includes a summary of yearly percent reduction in strontium-90 concentrations for the treated apatite PRB segment monitoring wells. Semiannual performance monitoring will continue for the apatite PRB in 2020.

Performance monitoring wells for the central (original) segment of the apatite PRB showed an overall reduction in strontium-90 concentrations following apatite injections in 2008 (Figure 6-25). During injections, a temporary spike in strontium-90 occurred because the high ionic strength of the apatite solution temporarily mobilized cations and anions. The high concentration at monitoring well 199-N-123 in 2011 was associated with the temporary spike during injections for the barrier extension upriver of the original barrier segment. DOE/RL-2019-67 provides additional details on the apatite PRB performance monitoring results for 2019.

In the central part of the PRB, the percent reduction in strontium-90 concentrations in 2019 ranged from 82% to 93% in the spring and from 56% to 93% in the fall (Table 6-2). Concentrations in two of the original PRB segment monitoring wells (199-N-123 and 199-N-147) continued to show >80% reduction, with well 199-N-147 near the 90% reduction target and well 199-N-123 above the target in 2019. Strontium-90 concentrations have been trending upward at wells 199-N-122 and 199-N-146 since 2011 and 2016, respectively, but remain considerably lower than before injections began in 2006.

In the performance monitoring wells along the upriver PRB extension (Figure 6-24), the percent reduction in strontium-90 concentrations in 2019 ranged from 73% to 96% in the fall and from 76% to 98% in the spring at wells with baseline concentrations above the 8 pCi/L DWS. The baseline and the 2019 concentrations were below the DWS at well 199-N-347 (Table 6-2).

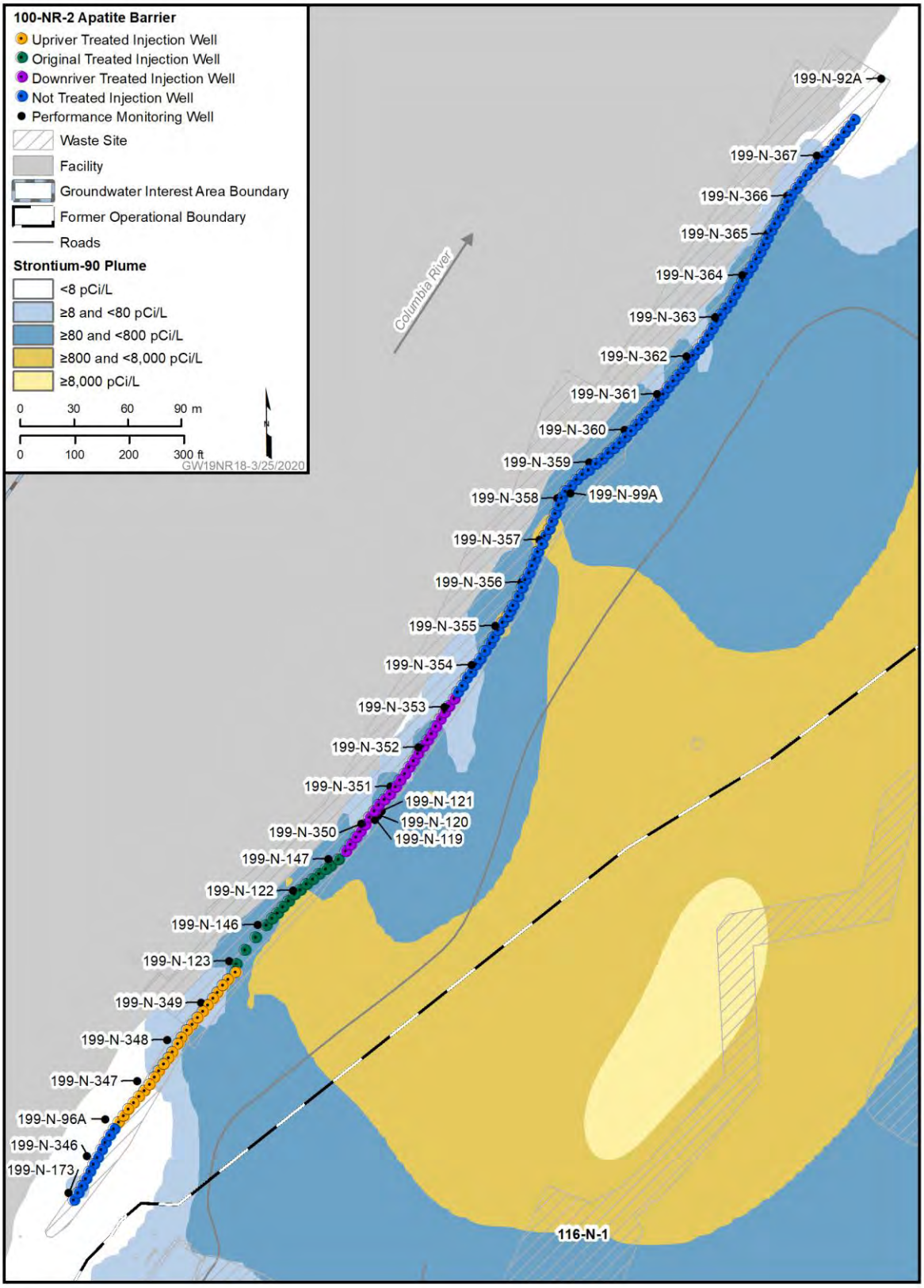


Figure 6-24. 100-NR Apatite PRB

Table 6-2. 100-NR Remedy Summary

Performance Monitoring at the Apatite PRB (2019)								
Well Name	Number of Baseline Samples	Number of Baseline Nondetects	Strontium-90 Concentration (pCi/L)				Percent Reduction in Strontium-90 (Baseline Maximum to 2019[c])	
			Minimum Detected Baseline	Maximum Baseline	Spring 2019[a]	Fall 2019[b]		
Upriver Apatite PRB								
			April 2010		June 2019	Sept. 2019	Spring	Fall
199-N-96A	56	8	1.54[d]	37.9[d]	1.8	1.7[f]	95	96
199-N-347	1	1	7[e]	7[e]	4.9	7.5	30	0
199-N-348	1	0	1,800	1,800	44	67	98	96
199-N-349	2	0	220	230	81	63	76	73
Central (Original) Apatite PRB								
(See footnote g)			(See footnote h)		June 2019	Sept. 2019	Spring	Fall
199-N-122	10	0	657	4,630	403	972	91	79
199-N-146	4	0	318	985	178	437	82	56
199-N-147	3	0	522	1,842	226	215[i]	88	88
199-N-123	6	0	689	1,180	82	87	93	93
Downriver Apatite PRB								
			July 2010		June 2019	Sept. 2019	Spring	Fall
199-N-350	1	0	240	240	46	56	81	77
199-N-351	1	0	350	350	199	546	43	0
199-N-352	1	0	580	580	256	618	56	0
199-N-353	1	0	83	83	34	88	59	0

PRB Monitoring Well Performance Summary (2012–2018)									
Monitoring Well	Pre-Injection Baseline (pCi/L)	Strontium-90 Concentration (pCi/L) (Percent Reduction from Baseline[c])							
		2012	2013	2014	2015	2016	2017	2018	2019
Upriver Apatite PRB (Treated in 2011)									
199-N-96A	37.9	2.3 (94%)	4.1 (89%)	1.6 (96%)	3.8 (90%)	3.04 (92%)	1.6 (96%)	1.1 (97%)	1.7 (95%)
199-N-347	7[e]	7.8 (-12%)	6.9 (1.4%)	5.1 (27%)	4.7 (33%)	4.8 (32%)	6.0 (31%)	6.4 (9%)	6.2 (12%)
199-N-348	1,800	54 (97%)	34 (98%)	35 (98%)	71 (96%)	76 (96%)	37 (98%)	57 (97%)	55 (97%)
199-N-349	230	3 (84%)	46 (80%)	87 (62%)	111 (52%)	90 (61%)	67 (66%)	129 (44%)	72 (69%)

Table 6-2. 100-NR Remedy Summary

PRB Monitoring Well Performance Summary (2011–2018)									
Monitoring Well	Pre-Injection Baseline	Concentration (pCi/L) (Percent Reduction from Baseline[c])							
		2012	2013	2014	2015	2016	2017	2018	2019
Central (Original) Apatite PRB (Treated 2006–2008)									
199-N-122	4,630[g]	656 (86%)	472 (90%)	637 (86%)	809 (82%)	1,083 (77%)	821 (82%)	1,070 (77%)	688 (85%)
199-N-146	985[g]	215 (78%)	225 (77%)	204 (79%)	184 (81%)	232 (77%)	323 (67%)	273 (72%)	308 (69%)
199-N-147	1,842[g]	250 (86%)	135 (93%)	230 (88%)	174 (90%)	235 (87%)	225 (88%)	216 (88%)	221 (88%)
199-N-123	1,180[g]	204 (83%)	125 (89%)	91 (92%)	96 (92%)	126 (89%)	137 (88%)	202 (83%)	84 (93%)
Downriver Apatite PRB (Treated in 2011)									
199-N-350	240	34 (86%)	21 (91%)	27 (89%)	76 (68%)	78 (68%)	75 (69%)	74 (69%)	51 (79%)
199-N-351	350	26 (93%)	39 (89%)	95 (73%)	376 (-7%)	388 (-11%)	258 (27%)	276 (21%)	372 (-6%)
199-N-352	580	30 (95%)	29 (95%)	42 (93%)	368 (37%)	683 (-17%)	494 (15%)	487 (16%)	437 (25%)
199-N-353	83	5.0 (94%)	3.2 (96%)	4.0 (95%)	7.3 (91%)	39 (54%)	31 (63%)	23 (72%)	61 (26%)
Petroleum Hydrocarbons (2003–2019)									
Product removal (top of aquifer)		A total of 590 g removed from well 199-N-18 and 640 g removed from well 199-N-183 in 2019; 20 kg removed since 2003.							
Bioventing (vadose zone)		Introduces oxygen via two vadose zone injection wells to promote aerobic biodegradation of petroleum hydrocarbons. Tested 2010–2011; full-scale December 2012 to present.							
Prior Remedy (1994–2006)									
P&T for strontium-90		1.8 Ci removed by P&T 1995–2006; facility demolition and removal completed in 2017.							

a. Spring 2019 samples were collected in June.

b. Fall 2019 samples were collected in September.

c. The percent reduction in strontium-90 concentration is calculated as follows:
([baseline value] – [2019 value])/[baseline value] × 100.

d. Between 1995 and 2011, the maximum baseline was measured on December 6, 1995; the minimum detected baseline was measured on June 13, 2006, and June 22, 2007.

e. 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 2 to approximate the strontium-90 concentration of 7 pCi/L.

f. The fall sample for this well was collected on November 21, 2019.

g. From Table 8.1 in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injections for In Situ Strontium-90 Immobilization.*

h. 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 Final Report*.

i. Due to low water levels in this well, the fall 2019 sample for this well was collected on January 13, 2020.

P&T = pump and treat
PRB = permeable reactive barrier

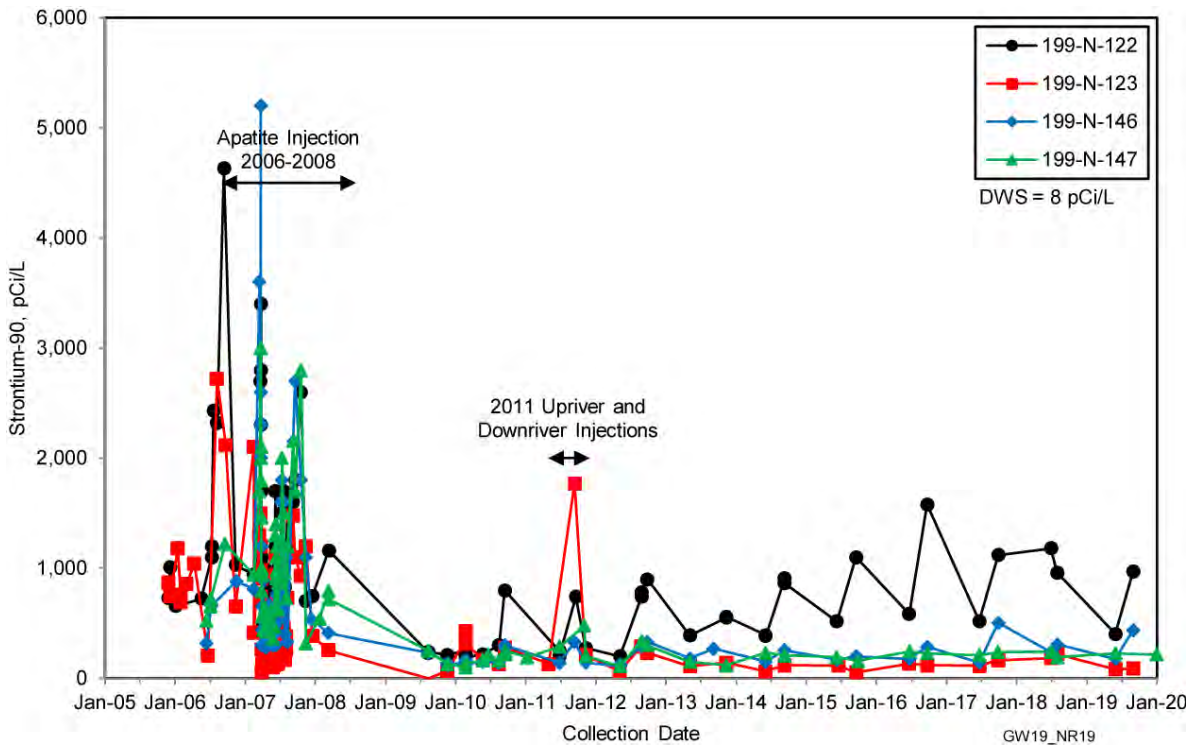


Figure 6-25. 100-NR Strontium-90 Data for Performance Monitoring Wells Along the Central Segment of the Apatite PRB

In the performance monitoring wells along the downriver PRB extension (Figure 6-24), reduction in strontium-90 concentrations ranged from 0% to 77% in the fall and from 43% to 81% in the spring (Table 6-2). Strontium-90 concentrations in downriver PRB segment monitoring wells 199-N-351 and 199-N-352 have rebounded to pre-injection concentrations since 2016. Concentrations at well 199-N-350 increased in 2015, and the fall 2019 concentration rebounded to pre-injection concentrations.

Planning is in progress to reinject poor-performing areas and extend the PRB. Ongoing monitoring will determine the continued effectiveness of the apatite barrier and will support decisions regarding future apatite treatments and the need for reinjection in other portions of the PRB.

6.7.3 Petroleum Hydrocarbons

Removal of free product (diesel) from well 199-N-18 continued in 2019 in accordance with the interim action ROD (EPA/ROD/R10-99/112). Diesel is removed using a polymer "smart sponge" that selectively absorbs petroleum products from the surface of the water in the well. About every 2 months, two sponges are placed into well 199-N-18 and left to remediate the diesel. The sponges are weighed prior to placement and again after removal. The weight difference is the amount of diesel removed from the well.

In 2017, smart sponge assemblies were also installed in well 199-N-183, which was drilled near well 199-N-18 as a replacement. Diesel odor and an oil sheen have been observed in the new well periodically during sampling. The smart sponges were installed and changed out at the same frequency used for well 199-N-18. As a result of the ongoing use of passive remediation, 590 g of diesel were removed from well 199-N-18 and 640 g of diesel were removed from well 199-N-183 during 2019 (Table 6-2). Removal of diesel from wells 199-N-18 and 199-N-183 will continue in 2020.

6.8 Atomic Energy Act Monitoring

The AEA groundwater monitoring was scheduled at 62 groundwater wells and aquifer tubes in 100-NR in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 100-NR are strontium-90, nitrate, and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. One well was not sampled in accordance with SAP requirements in 2019 (Appendix C). Minor exceptions to planned monitoring occurred due to maintenance issues and dry wells. Appendix C lists the sampling exceptions for 2019 AEA monitoring of the 100-NR groundwater wells.

Radionuclide concentrations detected in groundwater samples from 122 wells[7] 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 DWSs for cumulative alpha emitters and net alpha emitters were not exceeded. The 30 µg/L uranium DWS was not exceeded at any location. The estimated TED exceeded the 100 mrem/yr standard at 10 groundwater wells in 100-NR (Table 6-3). The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 74 locations in 100-NR. 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 that restrict access to groundwater. CERCLA remedial actions (e.g., 100-NR PRB) provide additional protection of the public and the environment.

Table 6-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-NR in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum	Minimum	Maximum
199-N-2	—	—	137.80	137.80
199-N-3	—	—	276.49	276.49
199-N-14	125.03	125.03	686.51	686.51
199-N-19	—	—	8.64	8.64
199-N-27	—	—	57.87	57.87
199-N-28	—	—	20.24	20.24
199-N-34	—	—	20.90	20.90
199-N-67	1,036.99	1,036.99	5,700.99	5,700.99
199-N-76	—	—	78.46	78.46
199-N-81	—	—	153.53	153.53
199-N-103A	—	—	515.90	515.90
199-N-104A	—	—	127.93	127.93
199-N-105A	125.72	125.72	687.32	687.32

[7] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 6-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-NR in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum	Minimum	Maximum
199-N-106A	—	—	506.50	506.50
199-N-122	—	—	201.50	486.14
199-N-123	—	—	40.75	43.43
199-N-136	—	—	6.90	6.90
199-N-146	—	—	89.00	218.50
199-N-147	—	—	113.00	113.00
199-N-173	—	—	9.35	10.01
199-N-183	—	—	71.83	71.83
199-N-184	—	—	228.32	228.32
199-N-186	—	—	124.88	124.88
199-N-187	891.55	891.55	4,897.79	4,897.79
199-N-188	145.89	145.89	800.86	800.86
199-N-229	—	—	17.30	17.30
199-N-247	—	—	20.20	20.20
199-N-268	113.64	113.64	412.50	625.00
199-N-280	—	—	500.00	500.00
199-N-297	—	—	252.00	252.00
199-N-315	—	—	238.00	238.00
199-N-332	—	—	99.00	99.00
199-N-346	—	—	—	4.2
199-N-347	—	—	—	4.105
199-N-348	—	—	22.15	33.52
199-N-349	—	—	31.54	40.60
199-N-350	—	—	23.20	28.04
199-N-351	—	—	99.50	273.88
199-N-352	—	—	128.00	309.37
199-N-353	—	—	17.00	44.38
199-N-354	—	—	6.99	6.99
199-N-355	114.16	114.16	411.50	626.47
199-N-356	—	—	93.50	181.12
199-N-357	200.52	200.52	420.50	1,101.50

Table 6-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-NR in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum	Minimum	Maximum
199-N-358	—	—	263.50	372.75
199-N-359	—	—	113.00	153.90
199-N-360	109.40	109.40	130.00	600.95
199-N-361	—	—	13.28	44.60
199-N-362	—	—	165.50	228.52
199-N-363	—	—	161.5	353.55
199-N-364	—	—	253.70	262.50
199-N-365	—	—	64.50	149.35
199-N-366	—	—	28.90	93.06
199-N-367	—	—	11.14	13.90
199-N-374	—	—	21.73	74.40
199-N-377	—	—	9.57	13.87
APT1	—	—	207.00	246.00
APT5	—	—	88.00	105.50
C6132	—	—	4.67	4.67
C6324	—	—	9.70	22.05
C7881	—	—	47.30	55.00
C7934	—	—	129.52	131.80
C7935	—	—	114.26	128.34
C7936	—	—	31.00	32.53
C9587	—	—	13.10	19.90
C9589	—	—	54.50	86.00
C9590	—	—	13.10	19.90
N116mArray-2A	—	—	54.50	86.00
N116mArray-3A	—	—	143.50	163.50
N116mArray-4A	—	—	72.50	72.50
N116mArray-6A	—	—	79.50	109.00
N116mArray-9A	—	—	13.10	19.90

Table 6-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 100-NR in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr	
	Minimum	Maximum	Minimum	Maximum
N116mArray-11A	—	—	209.50	288.50
NVP2-116.0	189.09	189.09	1,040.00	1,040.00

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

None of the wells in 100-NR had cumulative uranium mass ≥30 µg/L or cumulative alpha activity ≥15 pCi/L.

Blank cells (—) indicate no exceedances.

7 300-FF

The 300-FF groundwater interest area in the southeastern Hanford Site includes the 300-FF-5 OU (Figure 1-1). This chapter provides an overview; a discussion of CERCLA-, RCRA-, and AEA-related groundwater activities conducted in 2019; and a summary of 2019 groundwater monitoring results.

7.1 Overview

Groundwater in the 300-FF-5 OU was contaminated by waste releases at the 300 Area Industrial Complex, 618-10 Burial Ground/316-4 Crib, and 618-11 Burial Ground. Table 7-1 summarizes key facts about 300-FF. Section 1.5 provides details about plume mapping, including descriptions of terms (e.g., Type 1 control point) used in the figure legends.

The 300-FF groundwater contamination originated primarily from historical routine disposal of liquid effluent associated with fabrication of nuclear fuel assemblies and research involving the processing of irradiated fuel. Because the principal LWDFs have been out of service for decades and most have been remediated by removing contaminated soil (Section 4.0 in DOE/RL-2004-74, *300-FF-1 Operable Unit Remedial Action Report*), the contamination remaining in the underlying vadose zone and aquifer is residual. In 300-FF, 95% of the waste sites have been remediated or did not require remediation.

The groundwater in 300-FF is monitored under CERCLA, RCRA, and AEA, as discussed in Sections 7.6, 7.7, and 7.8. The CERCLA contaminants in the groundwater are uranium, gross alpha, TCE, *cis*-1,2-DCE, tritium, and nitrate. The former 300 Area Process Trenches (316-5) are regulated under RCRA and are undergoing post-closure monitoring for TCE and *cis*-1,2-DCE. Wells and aquifer tubes are monitored for uranium, nitrate, and radionuclides under the AEA. Figure 7-1 shows the locations of wells sampled in 2019.

Groundwater in the unconfined aquifer beneath the southeastern portion of the Hanford Site flows east or southeast, toward the Columbia River (Figure 7-2). Regional groundwater flow converges from the northwest, west, and southwest. Flow patterns throughout the region are complicated by the variable permeability of sediment in the upper portion of the unconfined aquifer. Near the Columbia River, groundwater flow is also influenced by river-stage fluctuations. In March 2019, groundwater underlying the 300 Area Industrial Complex flowed southeast.

The highest seasonal river elevations typically occur from May through June and the lowest from September through mid-November (Section 4.4.2 in DOE/RL-2010-99, *Remedial Investigation/ Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*). High river stage during 2019 was from late April to the end of June, but it was notably lower than a typical year, so high river stage had less impact on groundwater flow and contaminant concentrations than usual. Low river stage in 2019 occurred from September through December, with the minimum in September and October.

Contamination in 300-FF is generally found in the upper portion of the unconfined aquifer (i.e., the interval of Hanford formation gravelly sediment that lies below the water table) (Figure 7-3). The thickness of the contaminated portion of the unconfined aquifer is variable because of the undulating contact between the Hanford formation and the underlying Ringold unit E. In addition, significant seasonal fluctuations in water table elevation (Section 3.0 in PNNL-17034, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington*) affect the thickness of the contaminated zone.

Table 7-1. 300-FF at a Glance

Fabrication of nuclear fuel assemblies: 1943 to 1987

Research in irradiated fuel processing: 1950s to 1960s

300-FF includes the 300 Area Industrial Complex, former 618-10 Burial Ground/316-4 Crib, and 618-11 Burial Ground.

Groundwater Monitoring

Contaminant, Cleanup Level[a]	Year	Maximum Concentration	Plume Area[b] (km^2)	Shoreline[c] (m)
Uranium (300 Area, 618-10), 30 µg/L	2019	1,510 (399-1-62)	0.20	742
	2018	3,600[d] (399-1-73)	0.45	1,014
Gross alpha (300 Area, 618-10), 15 pCi/L	2019	41.7 (399-3-9)	Not calculated[e]	Not calculated[e]
	2018	394 (399-1-55)		
cis-1,2-DCE (300 Area), 16 µg/L	2019	169 (399-1-16B)	Not calculated[f]	Not calculated[f]
	2018	140 (399-1-16B)		
Trichloroethene (300 Area), 4 µg/L	2019	1.57 (399-1-16B)	Not calculated[f]	Not calculated[f]
	2018	1.50 (399-1-16B)		
Tritium (618-11), 20,000 pCi/L	2019	251,000 (699-13-2D)	0.14	None
	2018	450,000 (699-13-3A)	0.11	
Nitrate (618-11), 45 mg/L	2019	252 (699-13-3A)	0.31[g]	None
	2018	195 (699-13-3A)	0.30[g]	

Remediation

Waste sites: 95% complete.[h]

Groundwater: Monitored natural attenuation, groundwater monitoring, enhanced attenuation, and institutional controls on the use of groundwater.

The Record of Decision for final remedial action was issued in November 2013; implementation began in 2015.

a. EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*.

b. Estimated area at a concentration greater than the cleanup level.

c. Length of shoreline intersected by plume above listed cleanup level.

d. Sample collected during implementation of enhanced attenuation remedy.

e. Because gross alpha activity is associated with uranium, it is being addressed with the remediation of uranium.

f. Organics are locally present in deeper sediments.

g. Excludes nitrate from offsite.

h. Sites with status of final closed, interim closed, no action, not accepted, or rejected as of December 31, 2019.

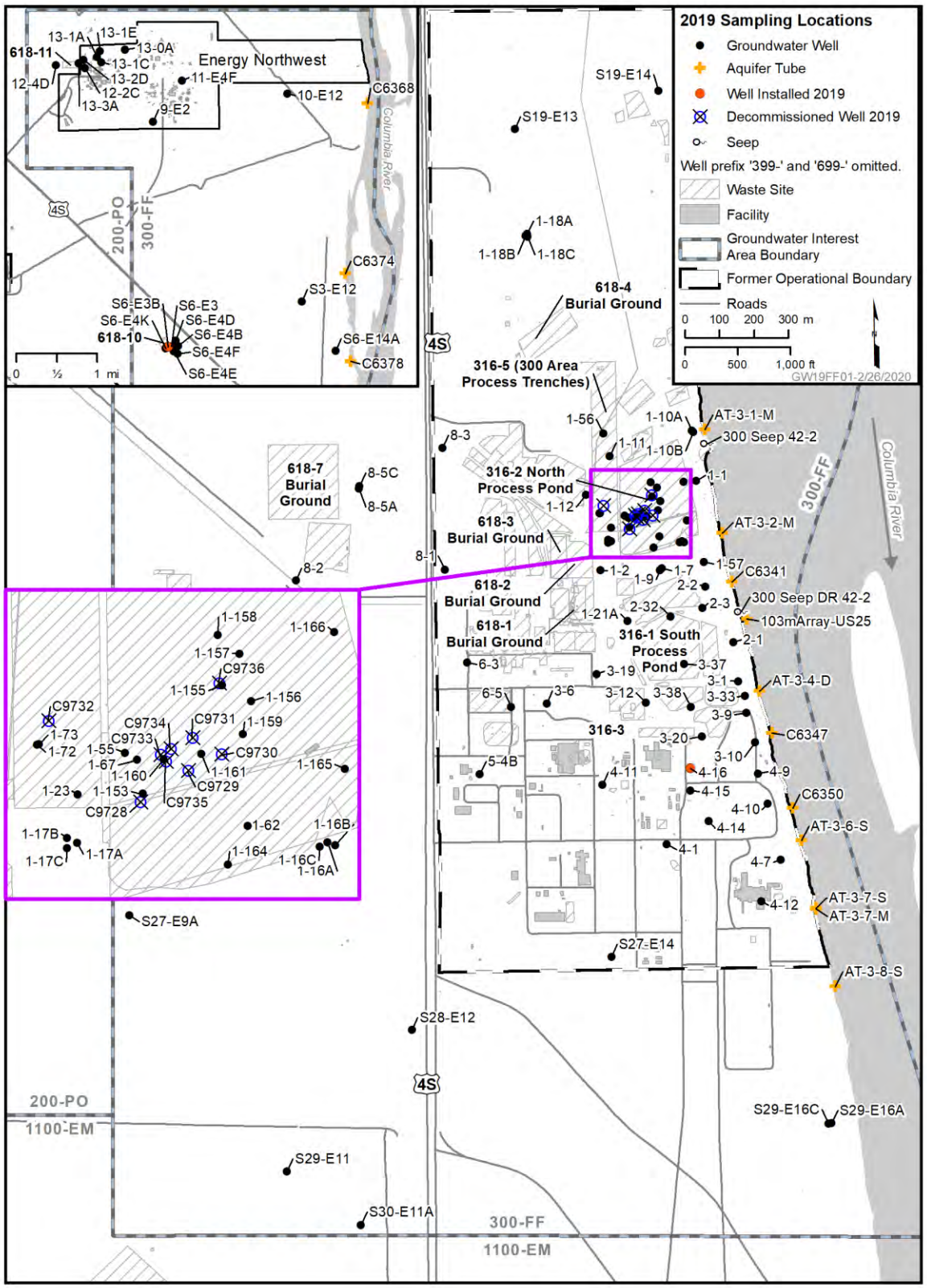
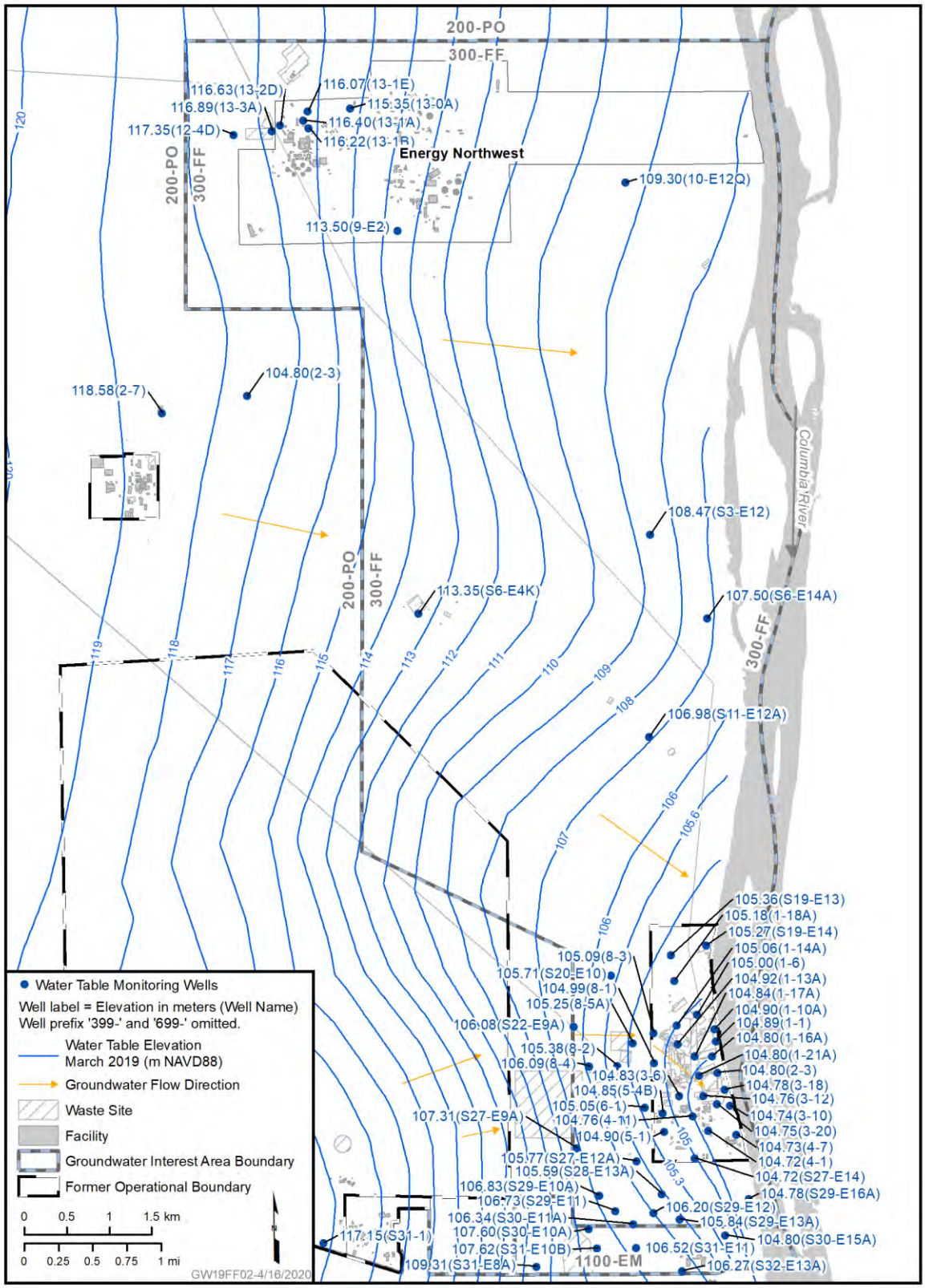


Figure 7-1. 300-FF Sampling Locations, 2019



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 7-2. 300-FF Water Table, March 2019

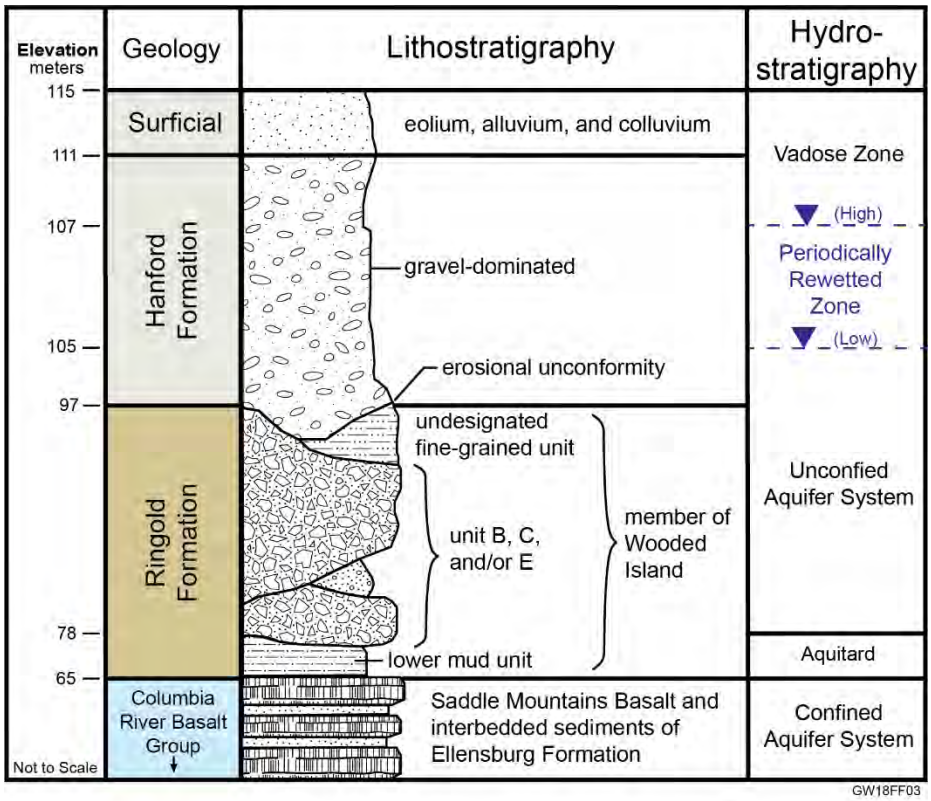


Figure 7-3. 300-FF Geology

In the 300 Area, contaminant discharge to the river occurs via riverbank seeps that flow across the beach region (riparian zone) during periods of low river stage and by groundwater upwelling through the riverbed. The rate of contaminant discharge to the river is influenced by daily and seasonal river-stage fluctuations (Section 3.1 in PNNL-17708, *Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State*; Section 2.4.1 in PNNL-22048, *Updated Conceptual Model for the 300 Area Uranium Groundwater Plume*).

Effects of high river elevations include temporary reversal of flow direction, dilution of contamination in groundwater near the river by the intrusion of clean river water, and possible influences on contaminant mobility caused by changes in the geochemical environment. Changes in the geochemical environment are most pronounced where river water intrudes into the aquifer. River water is lower in alkalinity (lower in bicarbonate content) and lower in specific conductance than groundwater (Section 3.6.1.4 in DOE/RL-2010-99).

Figure 7-4 shows how estimates of plume areas in 300-FF have changed since 2003. Figure 7-5 shows the uranium plume as interpreted in 1996 and December 2019.

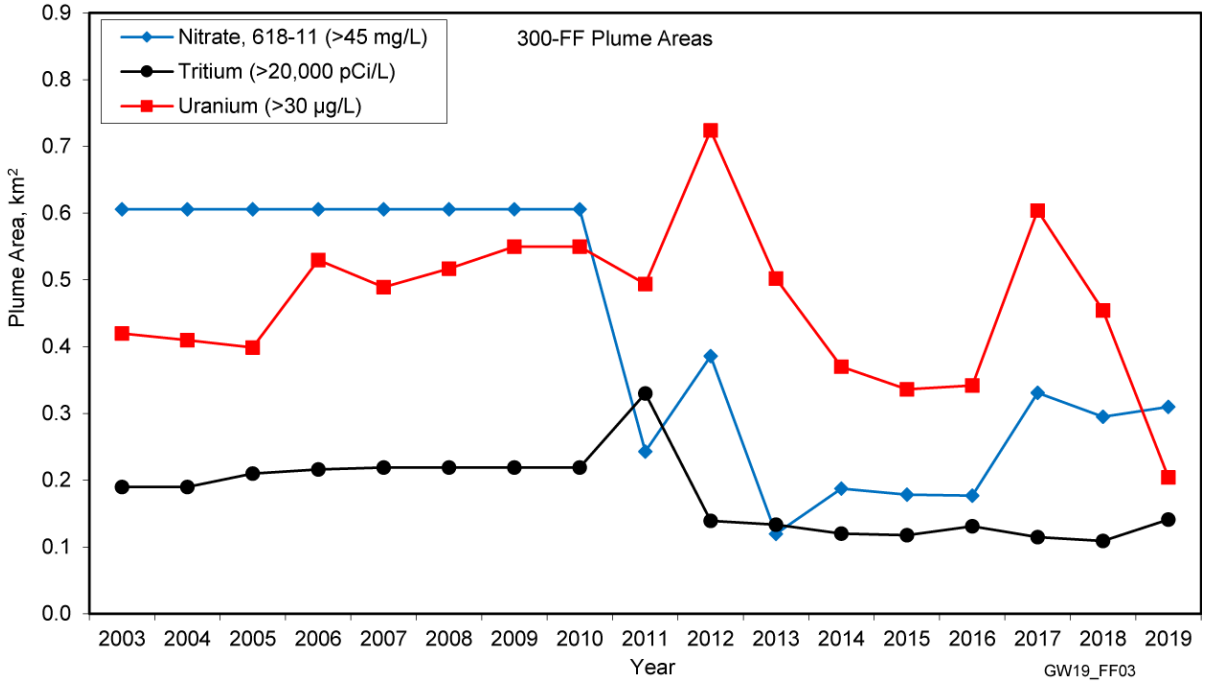


Figure 7-4. 300-FF Plume Areas

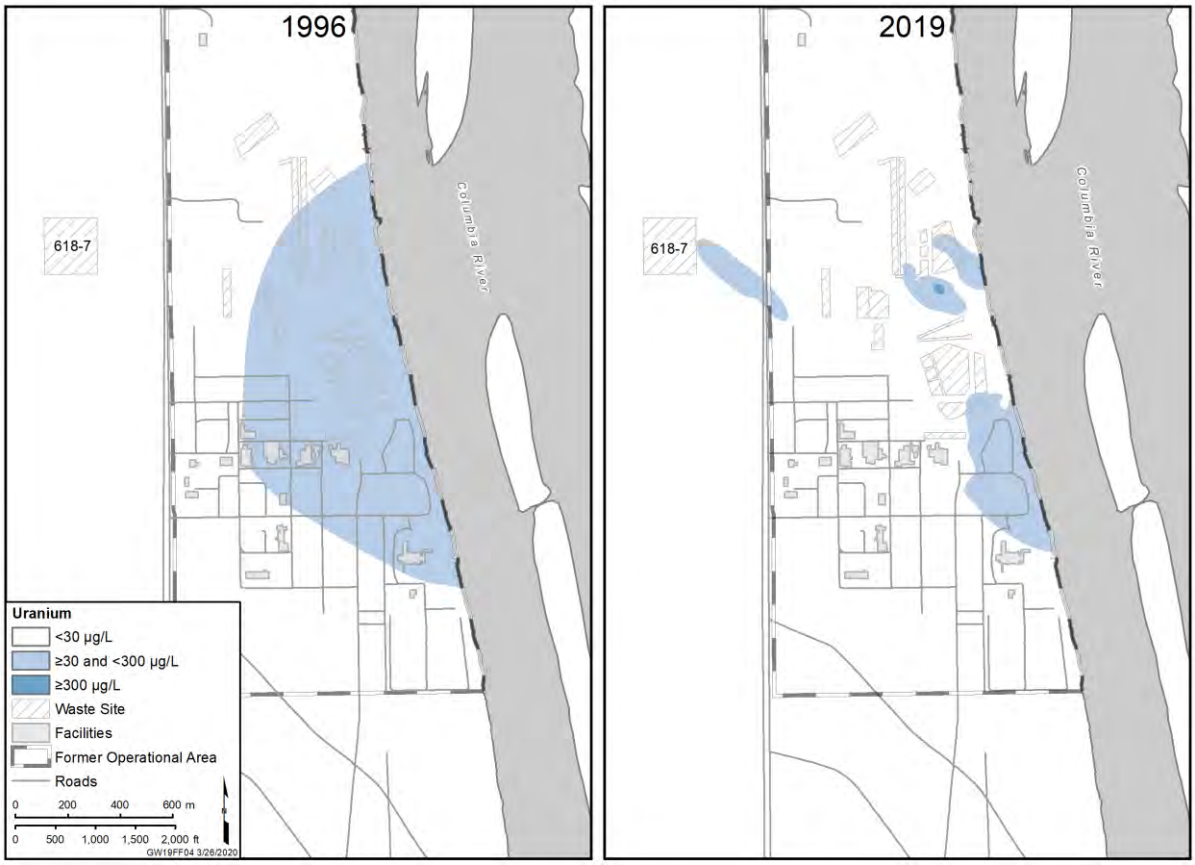


Figure 7-5. 300-FF Uranium Plume in 1996 and December 2019

7.2 Uranium

Large volumes of liquid waste containing uranium were discharged to the former South Process Pond (316-1) (from 1943 to 1975), North Process Pond (316-2) (from 1948 to 1975), and 300 Area Process Trenches (316-5) (from 1975 to 1987). Discharge of cooling water with small quantities of nonhazardous maintenance and process waste continued at the 300 Area Process Trenches until December 1994 (Section 3.1.1 of the final status groundwater monitoring plan for the 300 Area Process Trenches in Part VI of the Hanford RCRA Permit, Revision 8c). Contaminated soil was removed from the 300 Area Process Trenches in 1991. Additional contaminated soil was excavated at this site and at other major liquid waste disposal sites in the 300 Area Industrial Complex from 1997 through 2000.

Figure 7-6 shows the areal extent of the uranium plume exceeding the cleanup level (30 µg/L) beneath the 300 Area Industrial Complex in June 2019 during relatively higher river stage conditions; in 2019, the high river stage was lower than in 2018 (Figure 1-5). Figure 7-7 shows the areal extent of the uranium plume in December 2019 during lower river stage conditions. The persistence of the plume is attributed to resupply of mobile uranium from sources in the vadose zone and the groundwater interface (the deepest part of the vadose zone rewetted when the water table rises during high river stage, referred to as the PRZ) (Section 4.4.4.3 in DOE/RL-2010-99).

The water table maps for June and December 2019 are shown in Figures 7-6 and 7-7. In June, groundwater flow was to the southwest at locations near the river in the northern part of the 300 Area Industrial Complex. In December, the flow direction was to the southeast.

Typical characteristics of the uranium plume during seasonal high water table conditions include lowered concentrations along portions of the Columbia River shoreline and increased concentrations farther inland near the source areas. The reduced concentrations near the shoreline are caused by dilution from the intrusion of river water into the aquifer. The increased concentrations near the source areas are caused by temporary elevation of the water table mobilizing residual contamination in the lower vadose zone. Figure 7-8 depicts the positive variation of uranium concentration with water table elevation at well 399-1-17A, which is a location representative of inland conditions near source areas.

During seasonal low water table conditions, the highest uranium concentrations are often observed near the river, where uranium introduced inland during the preceding period of high water table conditions (due to groundwater contact with residual uranium in the lower vadose zone) has migrated downgradient to the shoreline. Intrusion of river water into the zone beneath the shoreline is lessened because of the lower river stage (Section 3.3 in PNNL-17034). Figure 7-9 depicts the inverse variation of uranium concentration with water table elevation at well 399-1-16A, which is a location representative of near-river conditions.

The enhanced attenuation remedy for uranium was implemented at the southern ends of the former 300 Area Process Trenches and former North Process Pond in November 2015 (Stage A) and September 2018 (Stage B) (Section 7.6.2). The remedy involves injecting and infiltrating polyphosphate solutions, with the goal of sequestering residual mobile uranium that presents a continuing groundwater contamination source. In September 2018, the polyphosphate solutions were injected through wells to the lower vadose zone and PRZ, where seasonally high water table conditions may mobilize residual uranium.

The uranium plume maps are based on samples collected in June and December 2019 (Figures 7-6 and 7-7). The short-term impact of the uranium sequestration remedy is evident in the groundwater near the enhanced attenuation area where uranium concentrations were less than the cleanup level in June and December. Continued monitoring during cycles of high and low water conditions is needed to evaluate the longer-term effectiveness of the remedy (Section 7.6.2).

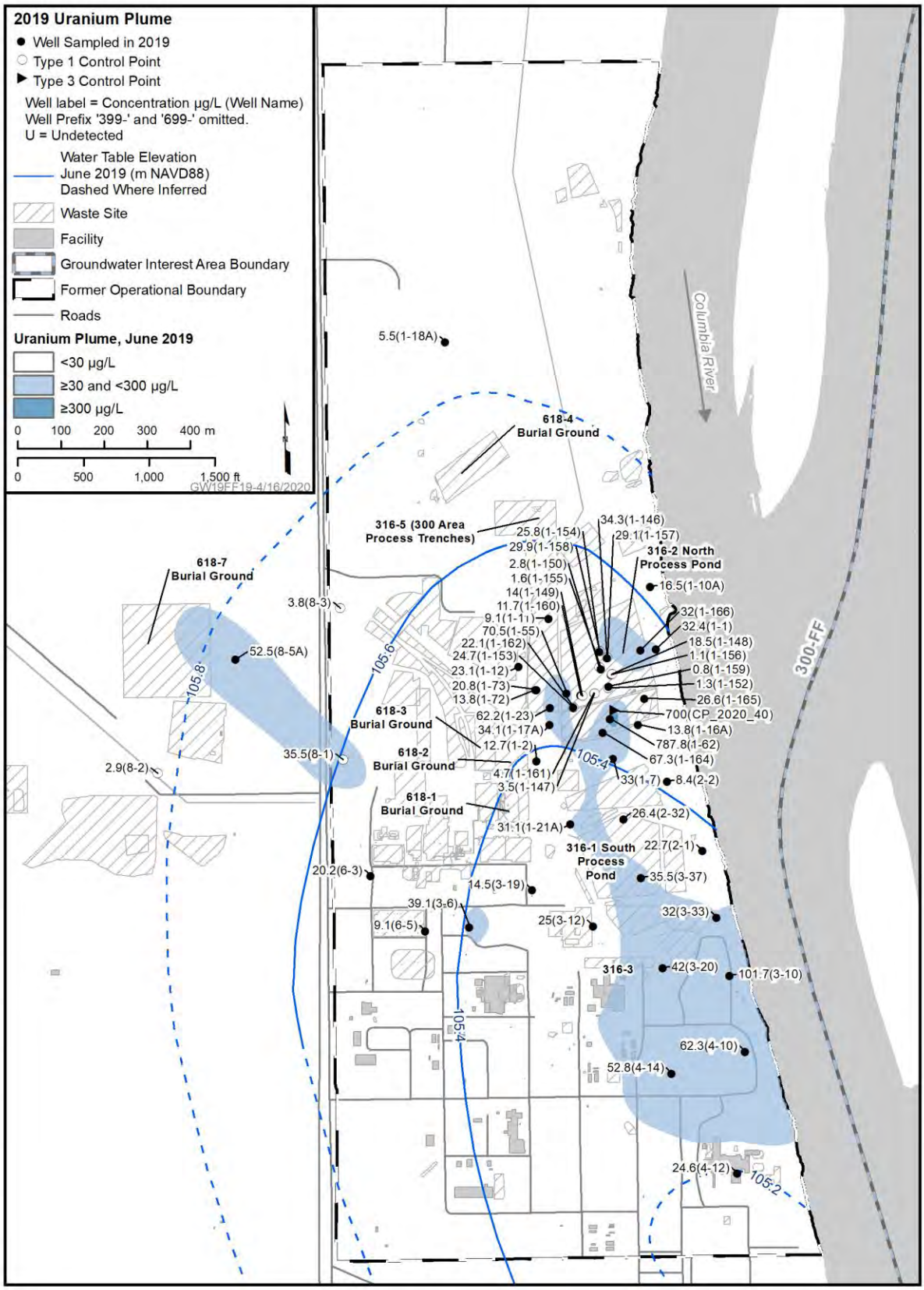


Figure 7-6. 300-FF Uranium Plume, June 2019

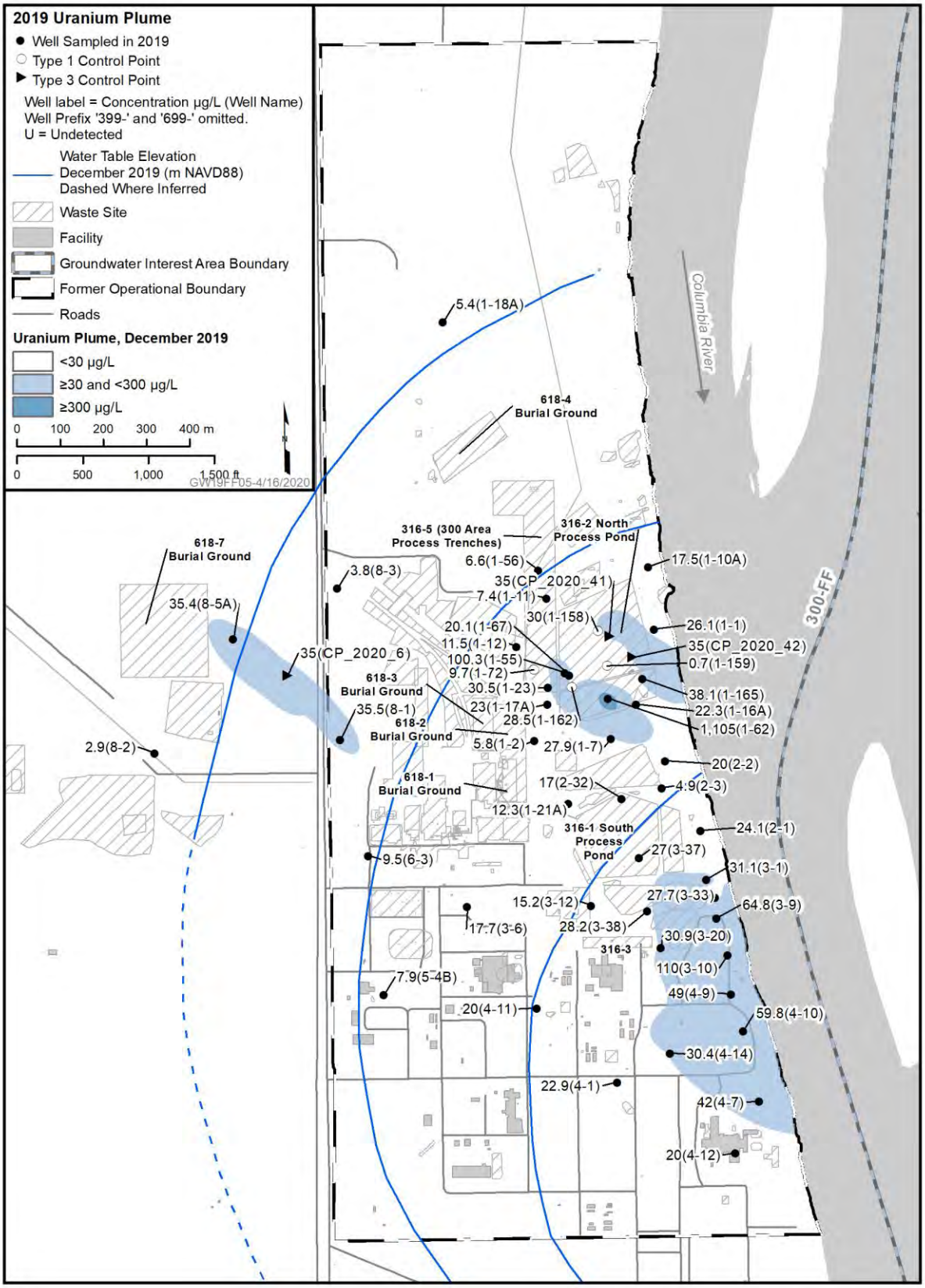


Figure 7-7. 300-FF Uranium Plume, December 2019

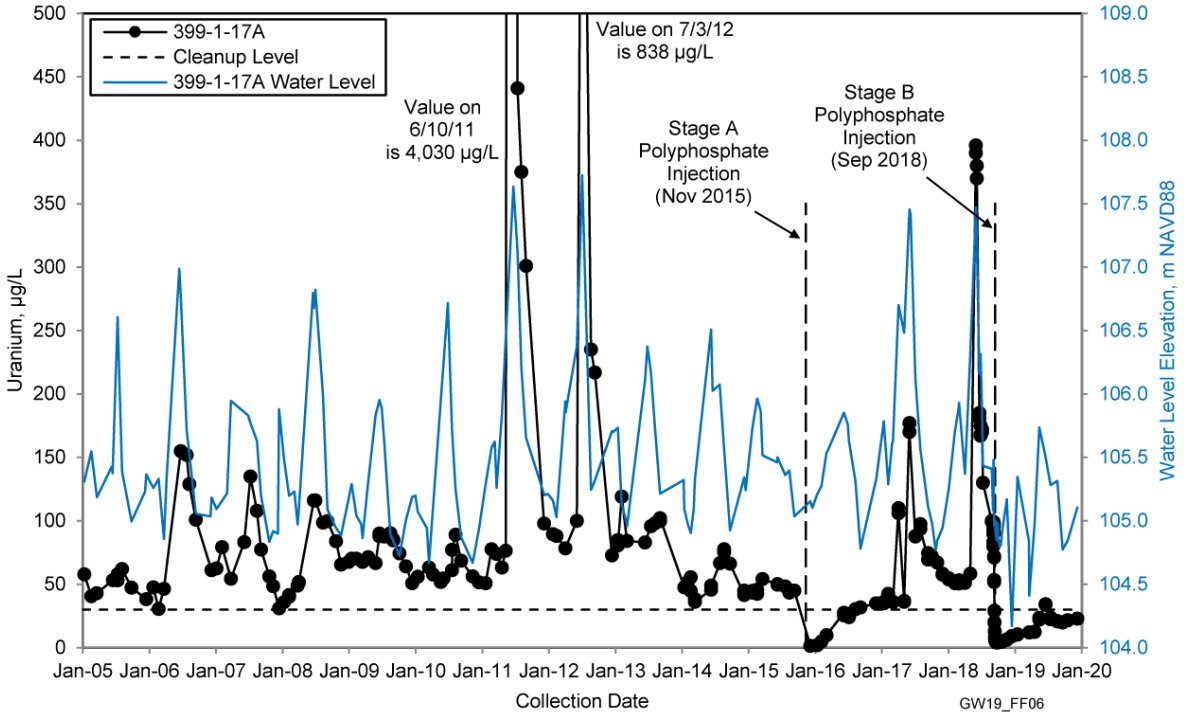


Figure 7-8. 300-FF Uranium and Water-Level Data for Well 399-1-17A (Inland)

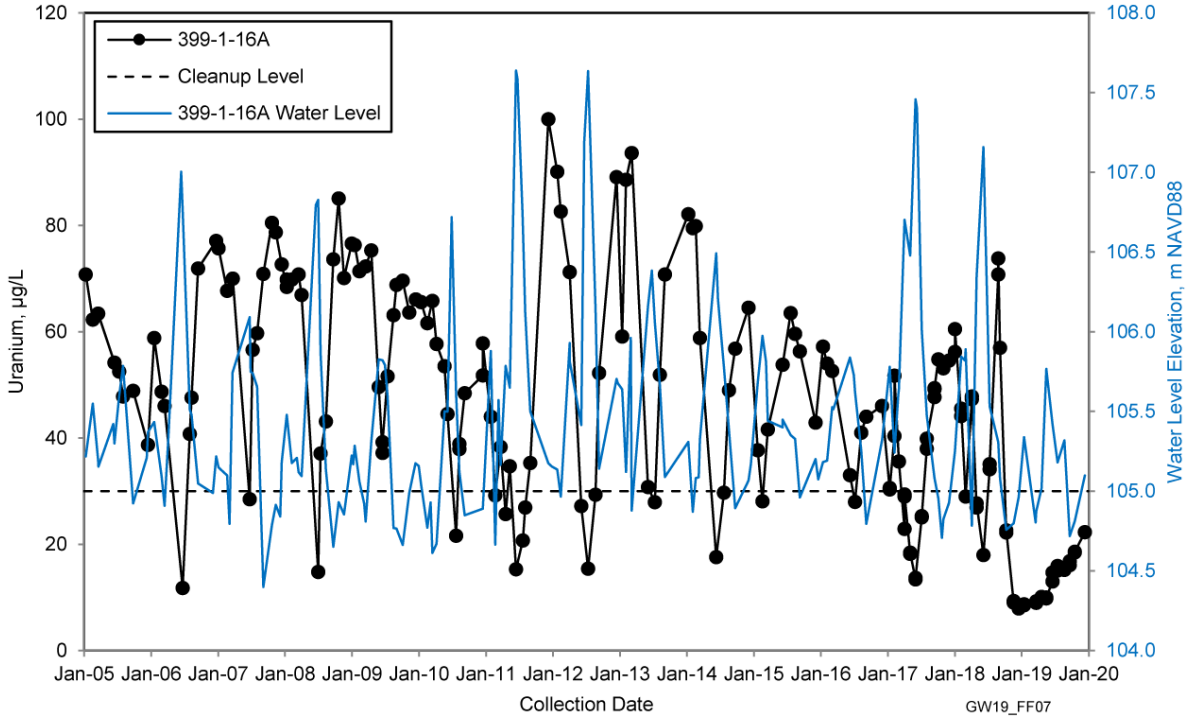


Figure 7-9. 300-FF Uranium and Water-Level Data for Well 399-1-16A (Near River)

The highest uranium concentration in 2019 for routine groundwater monitoring was 1,510 µg/L in well 399-1-62 in October. Uranium concentrations at this well vary inversely with water table elevation. Well 399-1-62 has a 0.6 m (2 ft) long screen near the low water table elevation that may prevent mixing during low water conditions. The elevated uranium concentrations may reflect uranium migrating from nearby upgradient sources.

The highest uranium concentration detected in a shoreline seep in 2019 was 27 µg/L in 300 Seep DR 42-2 (Table 1-7). This seep is located east of the northern end of the former South Process Pond (316-1) (Figure 7-1).

Uranium concentrations decreased in 2019 in wells downgradient of the former 618-7 Burial Ground. A uranium plume developed in this region during remediation activities that were conducted in 2007 and 2008. By the end of 2010, concentrations at nearby downgradient wells 399-8-5A and 399-8-1 continued to decrease, indicating passage of the contaminant plume (Figure 7-10). Since then, uranium concentrations have increased during periods of high water table conditions, suggesting that mobile uranium remains in the lower portion of the vadose zone near well 399-8-5A.

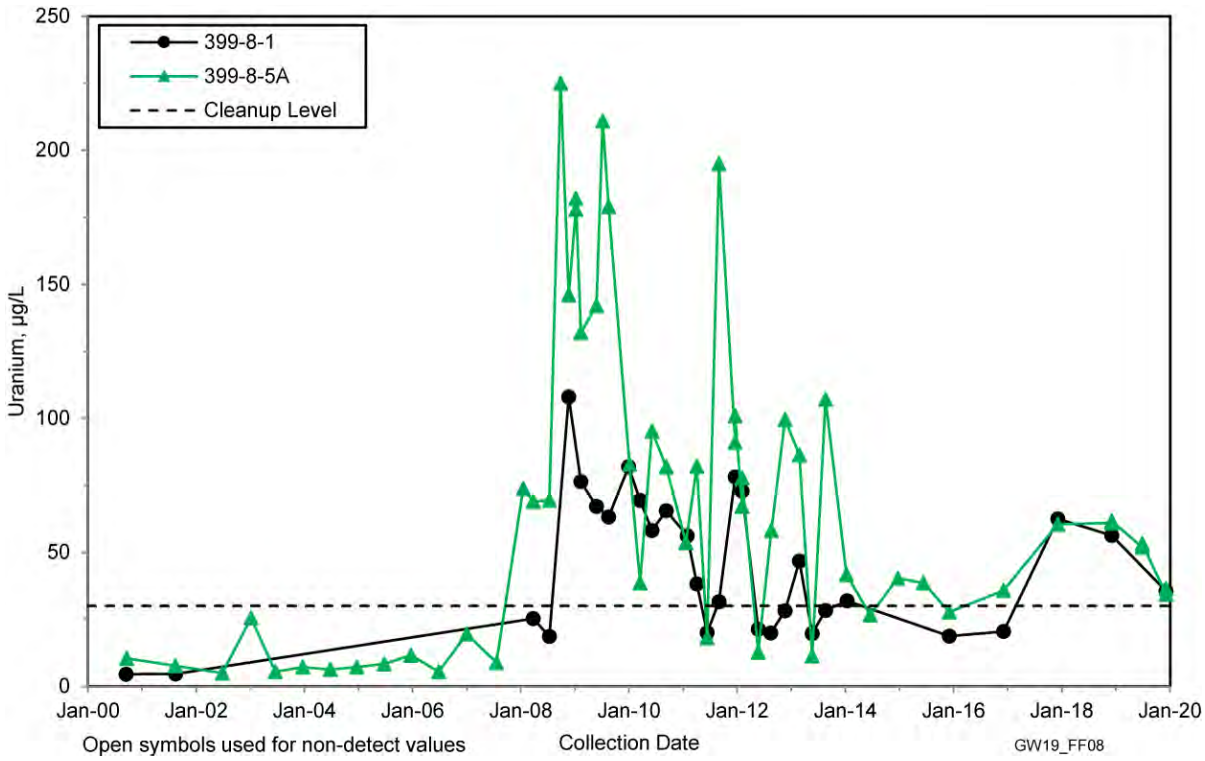


Figure 7-10. 300-FF Uranium Data for Wells Downgradient of the 618-7 Burial Ground

The uranium concentration at well 399-6-3, which is 0.6 km (0.4 mi) southeast of the 618-7 Burial Ground, varied from 2016 through 2019 (Figure 7-11). Increased uranium concentrations at downgradient well 399-3-6 may reflect passage of contamination observed at well 399-6-3 (Figure 7-11). A possible source for the elevated uranium at well 399-6-3 has not been identified.

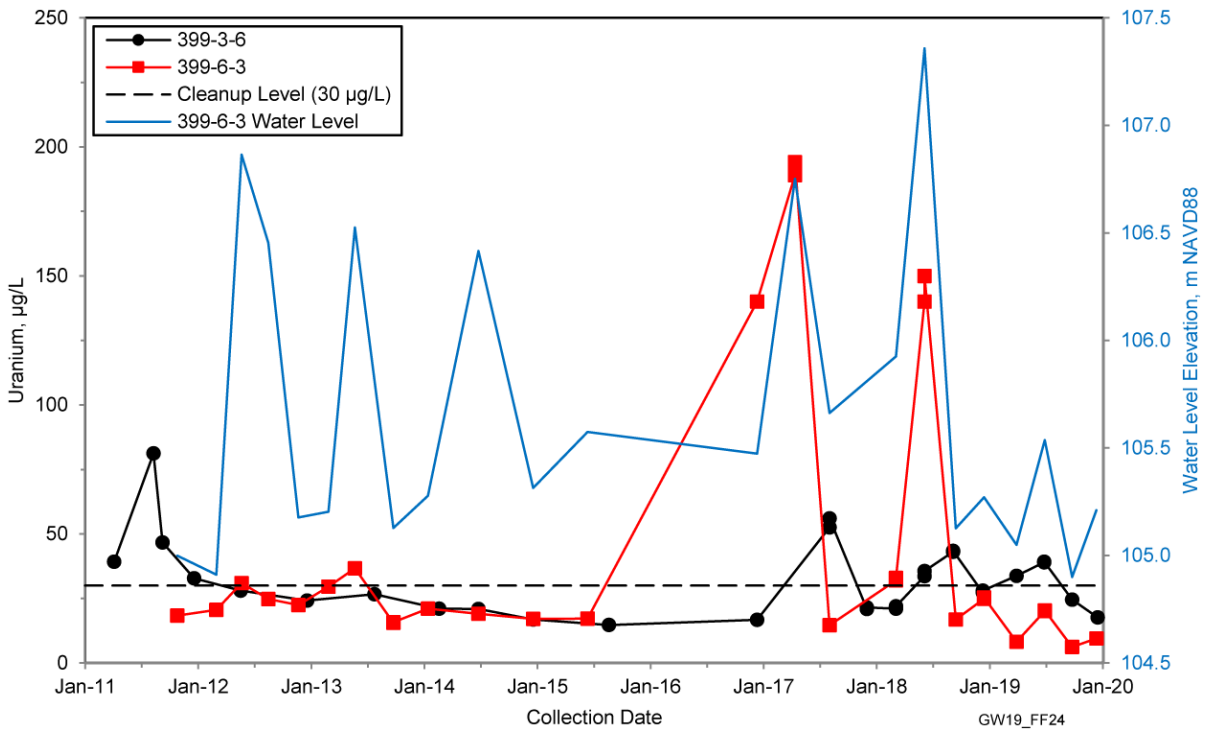


Figure 7-11. 300-FF Uranium and Water Level Data for Wells 399-3-6 and 399-6-3

Uranium is also detected in groundwater near the former 618-10 Burial Ground and adjacent 316-4 Crib, located northwest of the 300 Area Industrial Complex. Final remediation of the 316-4 Crib, which was excavated to the groundwater interface, was completed in 2017. Well 699-S6-E4A was decommissioned in 2016 to support the remediation; replacement well 699-S6-E3 was installed in 2018. Remediation of the 618-10 Burial Ground, where the deepest excavation was 11 m (36 ft) below grade (approximately 13 m [43 ft] above the groundwater interface), was completed in 2017. Well 699-S6-E4L was decommissioned in 2015 to support the excavation, and replacement well 699-S6-E3B was installed in 2019.

Uranium concentrations increased above the cleanup level in 2004 in wells 699-S6-E4A and 699-S6-E4L, near the southeastern fence line of the 618-10 Burial Ground and 316-4 Crib (Figure 7-12). This increase was caused by infiltration of dust-control water applied during 316-4 Crib excavation and backfilling. Concentrations were elevated above the cleanup level again in well 699-S6-E4L in 2012 through 2014 (Figure 7-12), which is attributed to infiltration of dust-control water during remedial actions that started in 2011 at the 618-10 Burial Ground. Because the water table elevation in this area steadily declined by 1 m (3.3 ft) from 1998 through 2017, the increase in uranium is not attributed to rewetting of the vadose zone by seasonal changes in the water table. By 2018, the water table elevation had declined to the top of the Ringold Formation and has remained relatively stable (Figure 7-12).

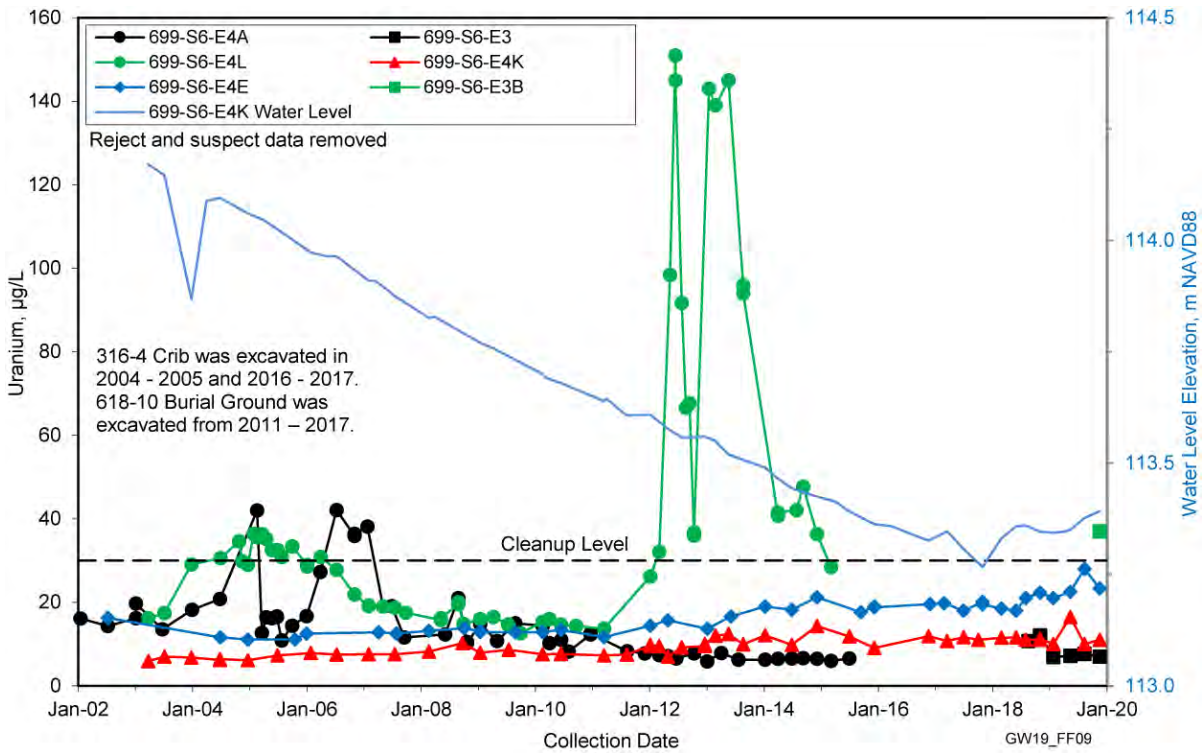


Figure 7-12. 300-FF Uranium and Water-Level Data for Wells Near the Former 618-10 Burial Ground and 316-4 Crib

In 2019, uranium concentrations associated with 618-10 were the highest at well 699-S6-E3B, which is at the location of former well 699-S6-E4L (Figure 7-12). The uranium concentration has remained below the cleanup level in the other four wells (699-S6-E3, 699-S6-E4B, 699-S6-E4E, and 699-S6-E4K).

Uranium concentrations in wells monitoring the lower portion of the unconfined aquifer in the 300 Area Industrial Complex are typical of natural background levels (estimated to range between 0.5 and 12.8 µg/L) (Table ES-1 in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*), indicating little or no downward uranium migration below the saturated Hanford formation sediment. Hydrographs for wells screened in saturated Hanford formation sediment or underlying Ringold unit E sediment are virtually identical, indicating no significant vertical gradients.

Uranium contamination is not present in the few wells that monitor the uppermost confined aquifer, which is a low to moderately permeable interval within the Ringold lower mud unit. Hydrographs for confined wells 399-1-16C and 399-1-17C show a distinct upward hydraulic gradient, with hydraulic heads 8 to 9 m (26 to 30 ft) higher than in adjacent water table wells. These two deep wells are screened across the basalt/Ringold lower mud contact and show basalt confined aquifer conditions. The hydrograph for well 399-1-18C, which monitors the lowest Ringold Formation sediment, shows very little head difference compared to the adjacent water table well.

Gross alpha activity in 300-FF groundwater is attributed to uranium and exceeded the 15 pCi/L cleanup level at numerous wells in the 300 Area Industrial Complex, where uranium concentrations were also elevated in 2019. Gross alpha activity exceeded the cleanup level in well 699-S6-E4E (monitoring the former 618-10 Burial Ground and 316-4 Crib) but was below the cleanup level in the other four wells in the 618-10/316-4 monitoring network.

7.3 Tritium

Tritium is found in groundwater downgradient of the 618-11 Burial Ground at concentrations exceeding the 20,000 pCi/L cleanup level. The plume source is tritium gas released from buried radiological solid waste in a series of caissons located along the north side of the burial ground (PNNL-13675, *Measurement of Helium-3/Helium-4 Ratios in Soil Gas at the 618-11 Burial Ground*). The narrow tritium plume extends for 1.2 km (0.7 mi) to the east of (i.e., downgradient from) the 618-11 Burial Ground. The plume passes just to the north of the Energy Northwest Columbia Generating Station (Figure 7-13) and appears to be contained within the saturated Hanford formation gravels of the unconfined aquifer. The tritium attributed to the 618-11 Burial Ground lies within the larger, lower concentration tritium plume that is part of the 200-PO groundwater interest area (Section 10.2).

Tritium concentrations near the 618-11 Burial Ground have declined from the maximum values observed in 1999 and 2000 (Figure 7-14). The trend in groundwater at well 699-13-3A (adjacent to the eastern fence line of the burial ground) suggests that an episodic event of unknown nature caused a tritium release from buried materials to contaminate groundwater. The tritium concentrations were relatively constant at well 699-13-3A from 2006 until 2016 but declined significantly in 2017, 2018, and 2019. At wells farther downgradient from the 618-11 Burial Ground (e.g., 699-13-2D), trends reflect plume migration. The maximum concentration in 2019 was 251,000 pCi/L in well 699-13-2D, an increase from the 2018 concentration of 215,000 pCi/L. The conceptual model for the plume, including a simulation of plume evolution over time, indicates that tritium concentrations will be below the cleanup level when the plume reaches the Columbia River (Section 5.1 in PNNL-15293, *Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground*). Groundwater wells monitored by Energy Northwest do not show evidence of this plume above the cleanup level, and tritium is not detected in Energy Northwest water supply wells.

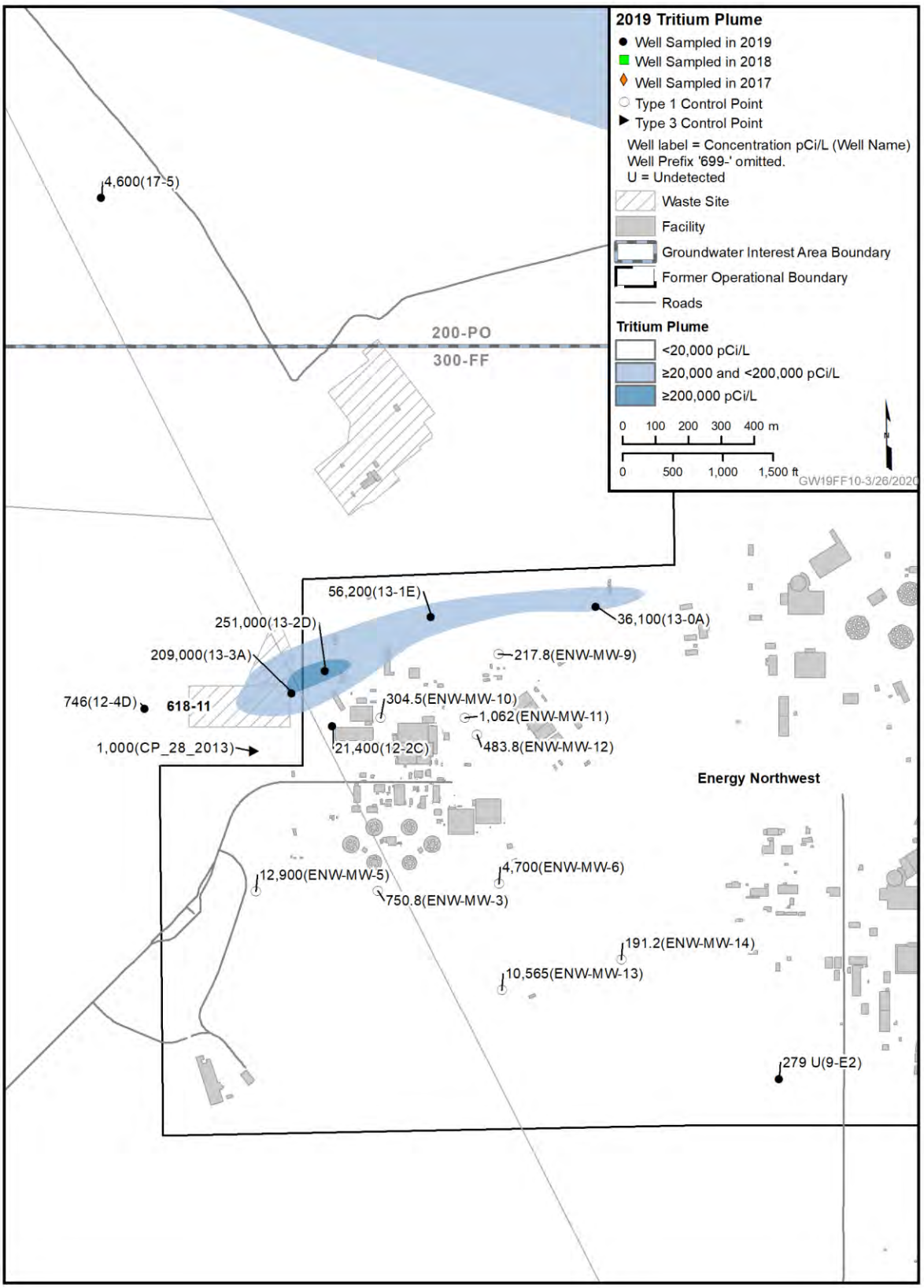


Figure 7-13. 300-FF Tritium Near the 618-11 Burial Ground, 2019

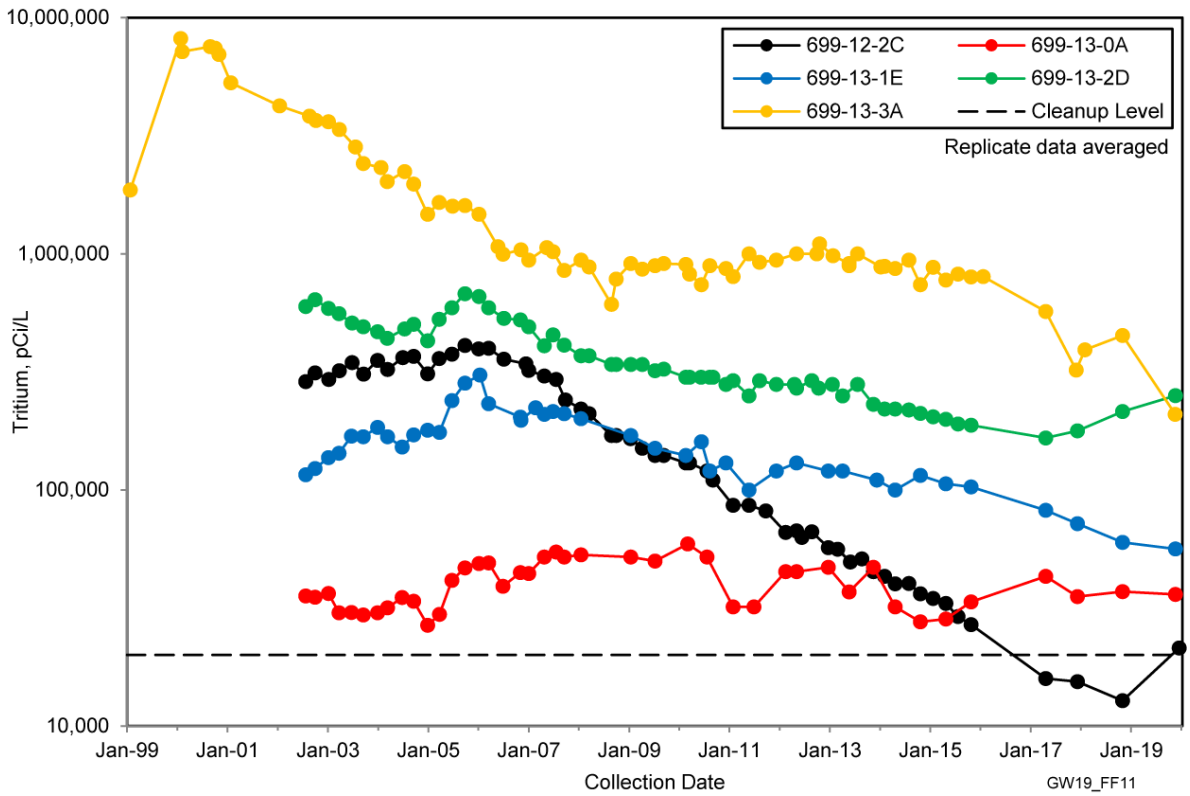


Figure 7-14. 300-FF Tritium Data for Wells Downgradient of the 618-11 Burial Ground

7.4 Nitrate

Nitrate concentrations exceeding the 45 mg/L cleanup level are found near the 618-11 Burial Ground and in the southern portion of the 300 Area Industrial Complex, where the principal sources of nitrate are currently agricultural and industrial activities not associated with the Hanford Site. The nitrate in the southern portion of the 300 Area Industrial Complex is not part of the 300-FF-5 OU (EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*).

Nitrate concentrations near the 618-11 Burial Ground continued to exceed the cleanup level in 2019 (Figure 7-15). Concentrations at well 699-13-3A quadrupled from a maximum concentration of 57.5 mg/L in 2016 to 252 mg/L in 2019 (Figure 7-16). The nitrate increase coincides with the stabilization of the water table elevation and may be caused by a change in vertical or horizontal flow direction. Nitrate concentrations increased at wells 699-12-2C and 699-13-0A in 2019 and decreased at wells 699-13-1E and 699-13-2D. The locally elevated nitrate contamination is attributed to the 618-11 Burial Ground (Section 4.4.5 in DOE/RL-2010-99). Monitoring will continue to evaluate these trends.

Nitrate concentrations >45 mg/L in the southern portion of the 300 Area Industrial Complex reflect contaminated groundwater migrating from sources to the southwest. For example, the maximum nitrate concentration near the southwestern corner of the 300 Area Industrial Complex (at well 699-S28-E12 in the 1100-EM interest area [Figure 8-4 in Chapter 8]) was 154 mg/L in November 2019, and the concentration at well 699-S27-E14 (616 m [2,021 ft] to the northeast) was 91.6 mg/L in November 2019. Nitrate also migrates into the 300 Area Industrial Complex from the northwest as part of the sitewide plume that originates in the 200 East Area, with concentrations typically ranging from 25 to 30 mg/L.

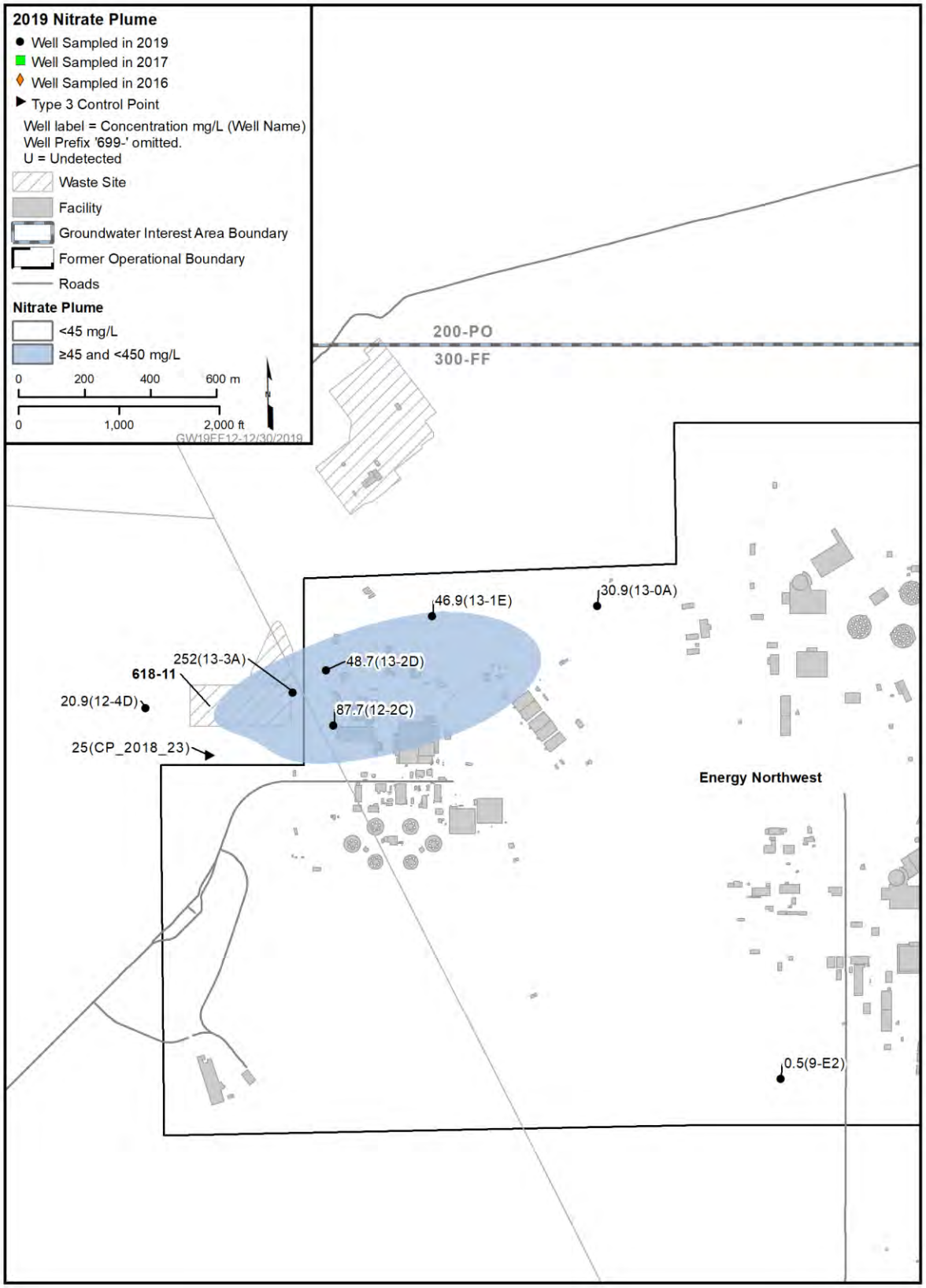


Figure 7-15. 300-FF Nitrate Near the 618-11 Burial Ground, 2019

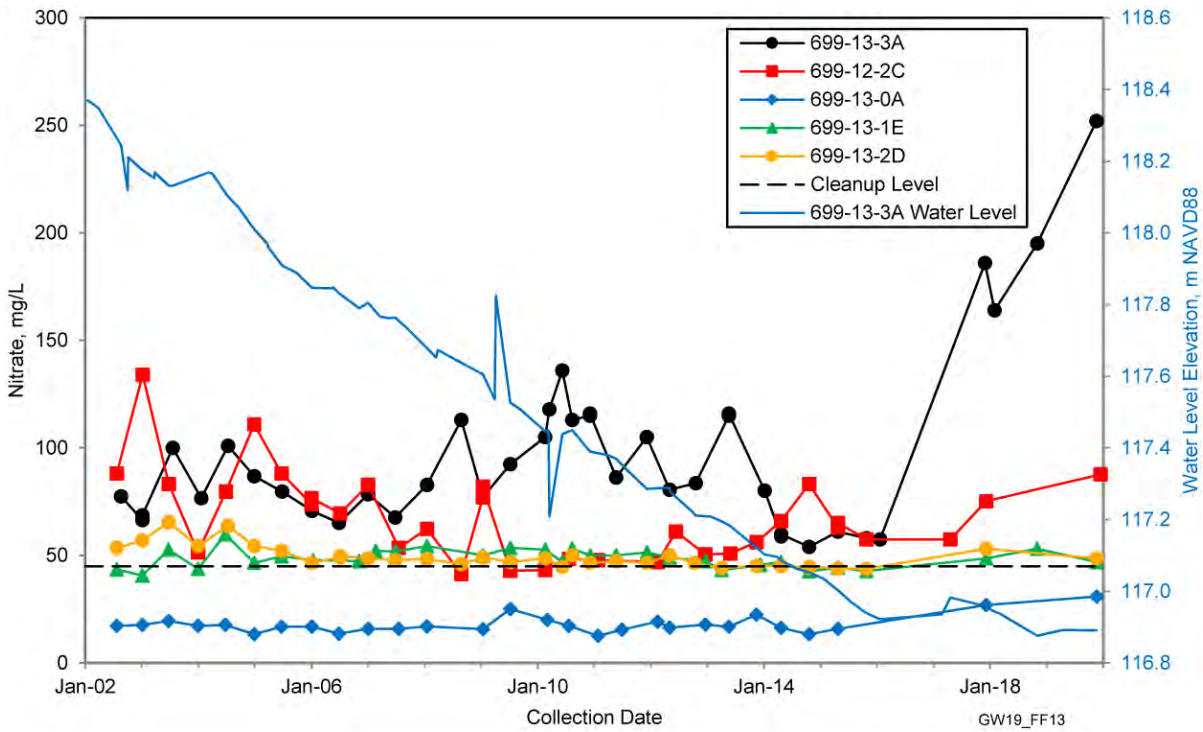


Figure 7-16. 300-FF Nitrate Data for Well 699-13-3A

7.5 Trichloroethene and *cis*-1,2-Dichloroethene

The volatile organic compounds (VOCs) TCE and *cis*-1,2-DCE are 300-FF-5 OU COCs found in localized areas of groundwater beneath the 300 Area Industrial Complex. *Cis*-1,2-DCE is a degradation product of TCE and tetrachloroethene (PCE). These original compounds degrade by dechlorination under conditions that include very low oxygen and the presence of certain types of microbes (Section 1.2 in PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*).

TCE and PCE were widely used in the 300 Area Industrial Complex in degreasing operations associated with the fuel fabrication process (Section 3.1 in PNNL-17666). TCE and PCE were discharged to the South Process Pond (316-1) and North Process Pond (316-2). The RI/FS evaluated PCE and concluded that it was not a COC (Section 6.3.2 in DOE/RL-2010-99). TCE is a COC for 300-FF-5 OU. Eight of the nine wells in the TCE monitoring network had reached the cleanup level by 2015 and did not require additional monitoring (Section 3.5.2.1 on DOE/RL-2014-42, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*, as modified by TPA-CN-0762, TPA-CN-0820, TPA-CN-0827, and TPA-CN-0867). The ninth well, 399-4-14, has now reached the cleanup level (4 µg/L), and monitoring will be discontinued upon approval by DOE and EPA. In 2019, the maximum TCE concentration in well 399-4-14 was 1.1 µg/L.

In the lower portion of the unconfined aquifer, *cis*-1,2-DCE concentrations continued to exceed the cleanup level (16 µg/L) at well 399-1-16B, with a 2019 maximum of 169 µg/L (Figure 7-17). Well 399-1-16B is downgradient of the 300 Area Process Trenches (316-5) and North Process Pond (316-2), and it is screened in Ringold unit E gravel. The elevation of the well screen is 7 m (23 ft) deeper than the elevation of the Columbia River maximum channel depth (Section 4.4.4.5 in DOE/RL-2010-99). The origin for *cis*-1,2-DCE is likely degradation of TCE and/or PCE disposed to the former North Process Pond (316-2) and/or former 300 Area Process Trenches (316-5) (Sections 3.1 and 3.3 in PNNL-17666;

Section 4.4.4.5 in DOE/RL-2010-99). Degradation of TCE as the source of the *cis*-1,2-DCE is consistent with the decrease in TCE concentrations in well 399-1-16B (Figure 7-17).

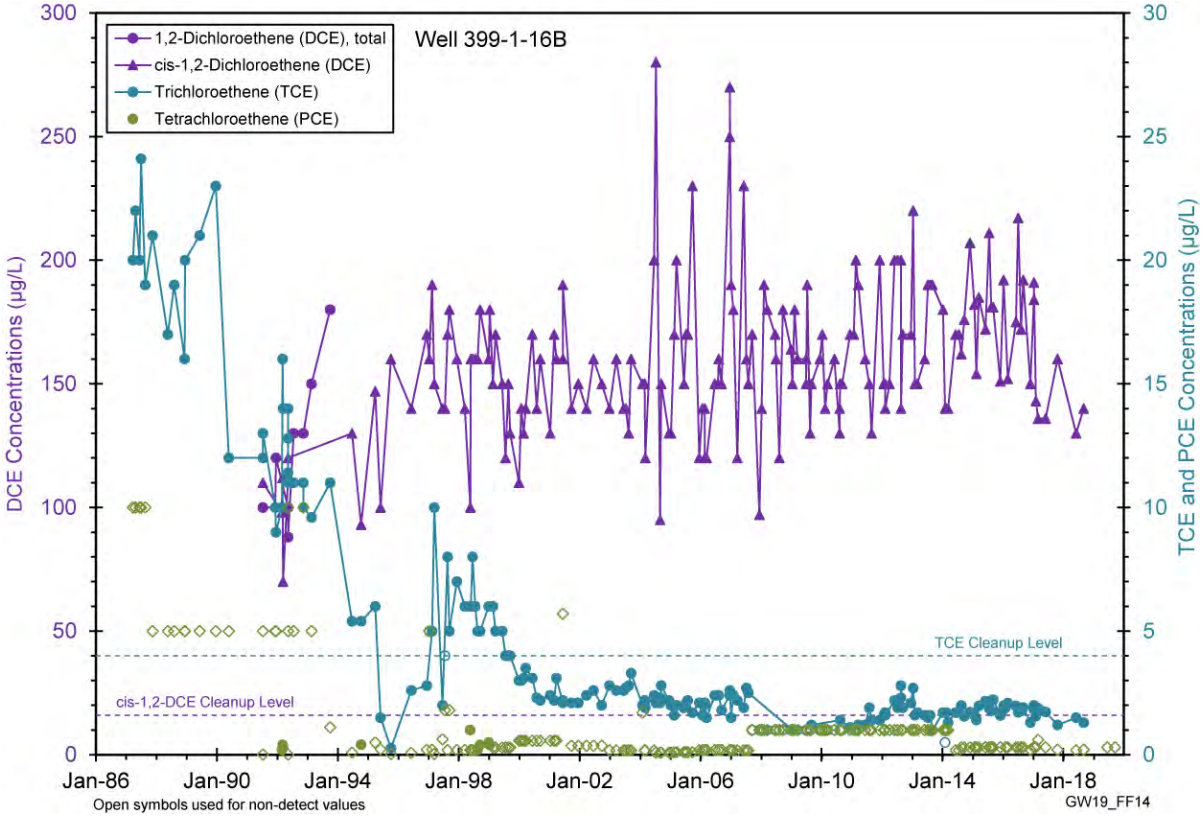


Figure 7-17. 300-FF *cis*-1,2-DCE, 1,2-DCE, TCE, and PCE Data for Well 399-1-16B

Well 399-1-57 is sampled for *cis*-1,2-DCE every 5 years under the CERCLA SAP (DOE/RL-2014-42). The well was most recently sampled in December 2019 and had a concentration (73 µg/L) exceeding the cleanup level, which was consistent with previous results. The well is located 80 m (260 ft) southeast of well 399-1-16B. Well 399-1-57 is screened at mid-depth in the unconfined aquifer in Ringold unit E sandy gravel; the lowest extent of the screen just enters the top of the finer grained interval within Ringold unit E (Section 4.4.4.5 in DOE/RL-2010-99).

7.6 CERCLA Remediation and Monitoring

CERCLA remediation and monitoring activities in 2019 consisted of groundwater monitoring and performance evaluation of the groundwater remedies. Figure 7-1 shows locations of wells sampled in 2019.

7.6.1 CERCLA Decision Documents and Plans

EPA and DOE signed the ROD for the 300-FF-5 OU (EPA and DOE, 2013) in November 2013. The COCs for groundwater are uranium, gross alpha, TCE, and *cis*-1,2-DCE at the 300 Area Industrial Complex; uranium and gross alpha at the 618-7 Burial Ground and 618-10 Burial Ground; and tritium and nitrate at the 618-11 Burial Ground. The ROD selected the following remedy components for these COCs: (1) MNA for nitrate, tritium, TCE, and *cis*-1,2-DCE; (2) groundwater monitoring for uranium, gross alpha, nitrate, tritium, TCE, and *cis*-1,2-DCE; (3) enhanced attenuation of uranium using

sequestration by polyphosphate application in the vadose zone and at the top of the aquifer; and (4) institutional controls.

The remedy components are designed to achieve the RAOs identified in the 2013 ROD (EPA and DOE, 2013). The following three RAOs pertain to groundwater:

- **RAO #1:** Prevent human exposure to groundwater containing COC concentrations above cleanup levels.
- **RAO #2:** Prevent COCs migrating and/or leaching through soil that will result in groundwater concentrations above cleanup levels for protection of groundwater, and of surface water concentrations above cleanup levels for the protection of surface water at locations where groundwater discharges to surface water.
- **RAO #7:** Restore groundwater impacted by Hanford Site releases to cleanup levels that include DWSs, within a timeframe that is reasonable given the particular circumstances of the site.

The RDR/RAWP implementing the remedial actions in accordance with the 2013 ROD (EPA and DOE, 2013) was issued in June 2015 (DOE/RL-2014-13-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 300 Area Groundwater*, as modified by TPA-CN-700 and TPA-CN-0784).

Routine groundwater monitoring required under the 2013 ROD (EPA and DOE, 2013) is implemented through a SAP issued in September 2015 (DOE/RL-2014-42, as modified by TPA-CN-0762, TPA-CN-0820, TPA-CN-0827, and TPA-CN-0867). Sampling frequencies listed in the SAP range from once per quarter to once every 5 years, depending on the COCs and locations. Most monitoring wells are screened at the top of the unconfined aquifer, across the water table. Several wells are screened in the lower portion of the unconfined aquifer, and a few wells are screened in the uppermost confined aquifer.

The 2013 ROD (EPA and DOE, 2013) selected the enhanced attenuation remedy to sequester residual uranium in the 300 Area Industrial Complex at the location determined to be the highest source of contamination to the uranium groundwater plume. The remedy was implemented in two stages (Section 7.6.2). Groundwater monitoring to support Stage A of the remedy was implemented through the SAP. Groundwater monitoring to support Stage B of the remedy was implemented through an addendum to the SAP issued in December 2016 (DOE/RL-2014-42-ADD1, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan Addendum for Stage B Uranium Sequestration*, as modified by TPA-CN-0828, TPA-CN-0835, and TPA-CN-0868). During 2019, the Stage B wells were sampled monthly. Stage B monitoring wells are screened in the PRZ and at the top of the unconfined aquifer.

Wells were sampled in accordance with the SAP (DOE/RL-2014-42) and SAP addendum (DOE/RL-2014-42-ADD1) requirements in 2019, except as indicated in Table A-1 in Appendix A of this report.

Table 7-2 lists the 300-FF wells installed or decommissioned in 2019.

Table 7-2. Wells and Boreholes Installed or Decommissioned in 300-FF in 2019

Well Name	Well ID	Purpose	Acceptance or Decommission Date	Construction Depth		Drill Depth		Comment
				ft	m	ft	m	
399-4-16	C9869	Monitoring downgradient from 324 Building remediation[a]	6/26/2019	69.2	21.1	85.6	26.1	Groundwater sampling began in 2019
699-S6-E3B	D0004	Replacement well for well 699-S6-E4L, which was decommissioned to support 618-10 remediation[b]	8/22/2019	88.9	27.1	94.7	28.9	Groundwater sampling began in 2019
N/A	C9728	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	30.5	9.3	Borehole decommissioned
N/A	C9729	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9730	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9731	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9732	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9733	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9734	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9735	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned
N/A	C9736	Uranium sequestration borehole for post-treatment soil samples[c]	3/28/2019	N/A	N/A	32.5	9.9	Borehole decommissioned

a. SGW-62784, *FY2019 M-24-00 Well Installation Work Instruction for the Environmental Restoration Disposal Facility and 324 Building*.

b. DOE/RL-2019-07, *Hanford Atomic Energy Act Sitewide Well Installation Sampling and Analysis Plan*.

c. DOE/RL-2014-42-ADD1, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan Addendum for Stage B Uranium Sequestration*, as modified by TPA-CN-0828, TPA-CN-0835, and TPA-CN-0868.

ID = identification N/A = not applicable

7.6.2 Groundwater Remediation

Evaluation of the enhanced attenuation remedy performance is continuing using multiple lines of evidence. Although it is too early to draw conclusions based only on the groundwater monitoring data through 2019, the initial results are promising. The estimated time to achieve the groundwater cleanup level identified in the 2013 ROD for uranium is expected to range from 22 to 28 years (2035 to 2041) (Table 6 in EPA and DOE, 2013). The other remedy components selected in the ROD (MNA, groundwater monitoring, and institutional controls) continued during 2019.

Enhanced attenuation involves infiltrating and injecting polyphosphate solutions into the lower vadose zone and PRZ to sequester residual mobile uranium by incorporating the uranium into insoluble minerals, forming insoluble uranium-bearing minerals, or sorbing uranium to insoluble minerals. The polyphosphate applications targeted a 1.2 ha (3 ac) area near the former 300 Area Process Trenches (316-5) and former North Process Pond (316-2) in the 300 Area Industrial Complex. Uranium sequestration was implemented using a staged approach. Stage A consisted of infiltrating and injecting polyphosphate solutions in one quadrant (0.3 ha [0.75 ac]) of the 1.2 ha (3 ac) target area (Figure 7-18). Stage B polyphosphate solutions were injected in the remaining three quadrants (0.9 ha [2.25 ac]). The purpose of Stage A was to perform the remedy on a small area, evaluate the effectiveness in meeting the RAOs, and establish a baseline from which to refine operations for Stage B.

Stage A of the enhanced attenuation remedy was implemented in November 2015 in accordance with the SAP (Chapters 2 and 3 in DOE/RL-2014-42). Installation of the Stage A system is described in SGW-59455, *300-FF-5 Operable Unit Stage A Uranium Sequestration System Installation Report*. Issued in December 2016, SGW-59614, *300-FF-5 Operable Unit Enhanced Attenuation Stage A Delivery Performance Report*, evaluated the performance of the Stage A polyphosphate applications for uranium sequestration and provided the design refinements for Stage B.

Stage B of the remedy was implemented in September 2018 in accordance with the SAP addendum (Chapters 2 and 3 in DOE/RL-2014-42-ADD1). Stage B of the remedy was planned to be implemented in 2017 but was postponed for one year to allow time for additional groundwater monitoring and evaluation (DOE/RL-2014-13-ADD2, as modified by TPA-CN-0784). The Stage B system was installed as described in SGW-60778, *300-FF-5 Operable Unit Stage B Uranium Sequestration System Installation Report*. Nine boreholes were drilled and sampled in 2019 to evaluate the post-treatment mobility of uranium (Table 7-2). An enhanced attenuation completion report evaluating the performance of the polyphosphate applications for uranium sequestration is scheduled to be issued in September 2020 (DOE/RL-2014-42-ADD1, as modified by TPA-CN-0835).

Initial performance indicators are positive for uranium sequestration in the Stage A and Stage B enhanced attenuation areas. Initial amorphous phosphate minerals appear to be sequestering the uranium as expected. The permanence of the sequestration treatment depends on the current meta-stable compounds eventually forming stable minerals. The efficacy of the sequestration process will be evident after longer-term groundwater results are available.

In accordance with the SAP addendum (DOE/RL-2014-42-ADD1), the well network used to monitor groundwater during and after Stage B injections consisted of nine collocated paired wells, one monitoring the aquifer and one monitoring the PRZ, within the Stage B area; and 13 wells monitoring the aquifer near and downgradient of the Stage B area (Figure 7-18). Monitoring of the 9 paired wells in the Stage B area was completed in June 2019 (PRZ wells are dry during periods of low river stage); monitoring of the 13 aquifer wells in the Stage B area was completed in October 2019.

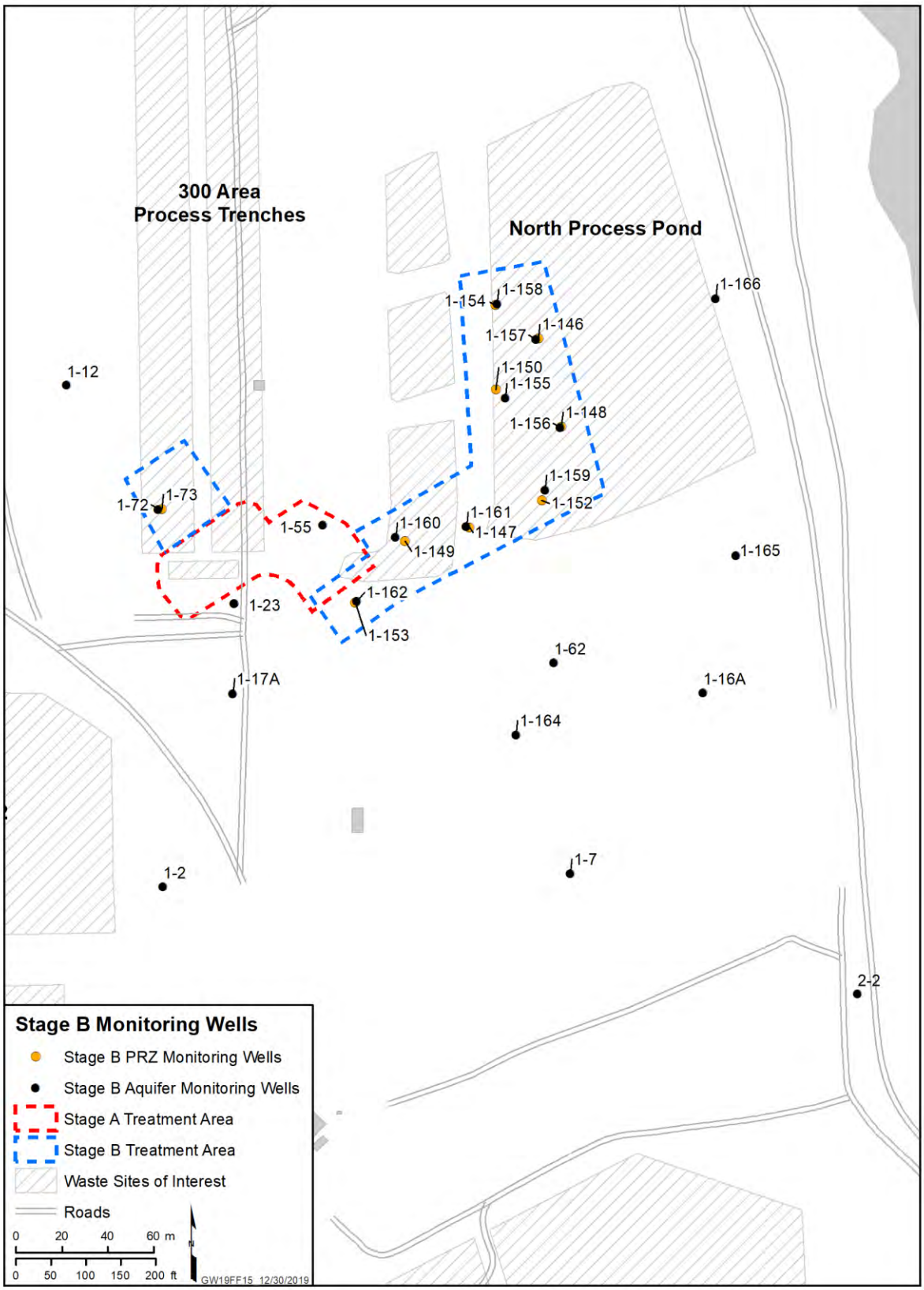


Figure 7-18. Location of 300-FF-5 Enhanced Attenuation Treatment Area and 2019 Monitoring Wells

Figure 7-19 shows the uranium trends for the 13 aquifer monitoring wells outside of the Stage A and Stage B areas. The highest uranium concentration in 2019 was 1,510 µg/L in a sample from well 399-1-62, downgradient of the Stage B area. As anticipated, based on the short-term Stage A results, uranium concentrations decreased in nearby downgradient wells as a result of the polyphosphate injections. For example, the uranium concentration in well 399-1-17A decreased to 1.6 µg/L in December 2015 following implementation of the Stage A remedy and increased to concentrations just above the cleanup level during 2016 (Figure 7-8). Concentrations increased in spring 2017 and spring 2018 during seasonal high water table conditions, which mobilized residual uranium from the deep vadose zone at this location and/or at an upgradient location. Uranium concentrations decreased to <5 µg/L in October 2018 following implementation of the Stage B remedy and have remained at or below the cleanup level (Figures 7-8 and 7-19). Longer-term groundwater monitoring results are needed to evaluate the enhanced attenuation remedy performance.

Long-term groundwater monitoring will continue in accordance with the SAP (DOE/RL-2014-42). In August 2018, the SAP was modified to add an expanded uranium fate and transport model domain that includes the uranium plume in the 300 Area Industrial Complex (DOE/RL-2014-42, as modified by TPA-CN-0827). Uranium concentration data from 28 wells are needed to calibrate the expanded model. The 28 wells will be monitored semiannually in June (high water conditions) and December (low water conditions). All 28 wells were sampled in June 2019 and December 2019.

Calculations were completed in 2019 (using data through 2018) to evaluate whether each well in the long-term groundwater monitoring network had reached the cleanup level for each required COC. The calculations follow the methodology presented in SGW-58883, *Methodology for the Calculation of Concentration Trends, Means, and Confidence Limits for Performance and Attainment Monitoring*. The cleanup level was previously achieved for TCE at well 399-4-14 (SGW-63357, *300-FF-5 Operable Unit Remedial Action Performance Evaluation for 2018*). Well 399-4-14 is the only well monitored for TCE under the CERCLA SAP (DOE/RL-2014-42); monitoring for TCE will be discontinued upon approval by DOE and EPA. Calculations using 2019 data are underway in 2020.

Waste sites are being remediated to reduce continuing contamination sources. Remediation of the 618-10 Burial Ground and 316-4 Crib was completed in 2017. Two wells were decommissioned to support waste site remediation (699-S6-E4A in 2016, and 699-S6-E4L in 2015). A replacement well for 699-S6-E4A (699-S6-E3) was installed in 2018. A replacement well for 699-S6-E4L (699-S6-E3B) was installed in 2019 (Table 7-2).

Planning is continuing for remediation of the 300-296 waste site, which was caused by a leak of radioactive fluid from the 324 Building in the 300 Area Industrial Complex in 1986. The primary constituents in the fluid were cesium-137 and strontium-90. DOE installed a well downgradient of the 324 Building in 2019 to monitor potential migration of the contaminants in groundwater (Table 7-2). Quarterly monitoring of wells 399-4-15 and 399-4-16 began in 2019 for contaminants associated with the leak. Strontium-90 (Figure 7-20) and cesium-137 were not detected in 2019 in either well.

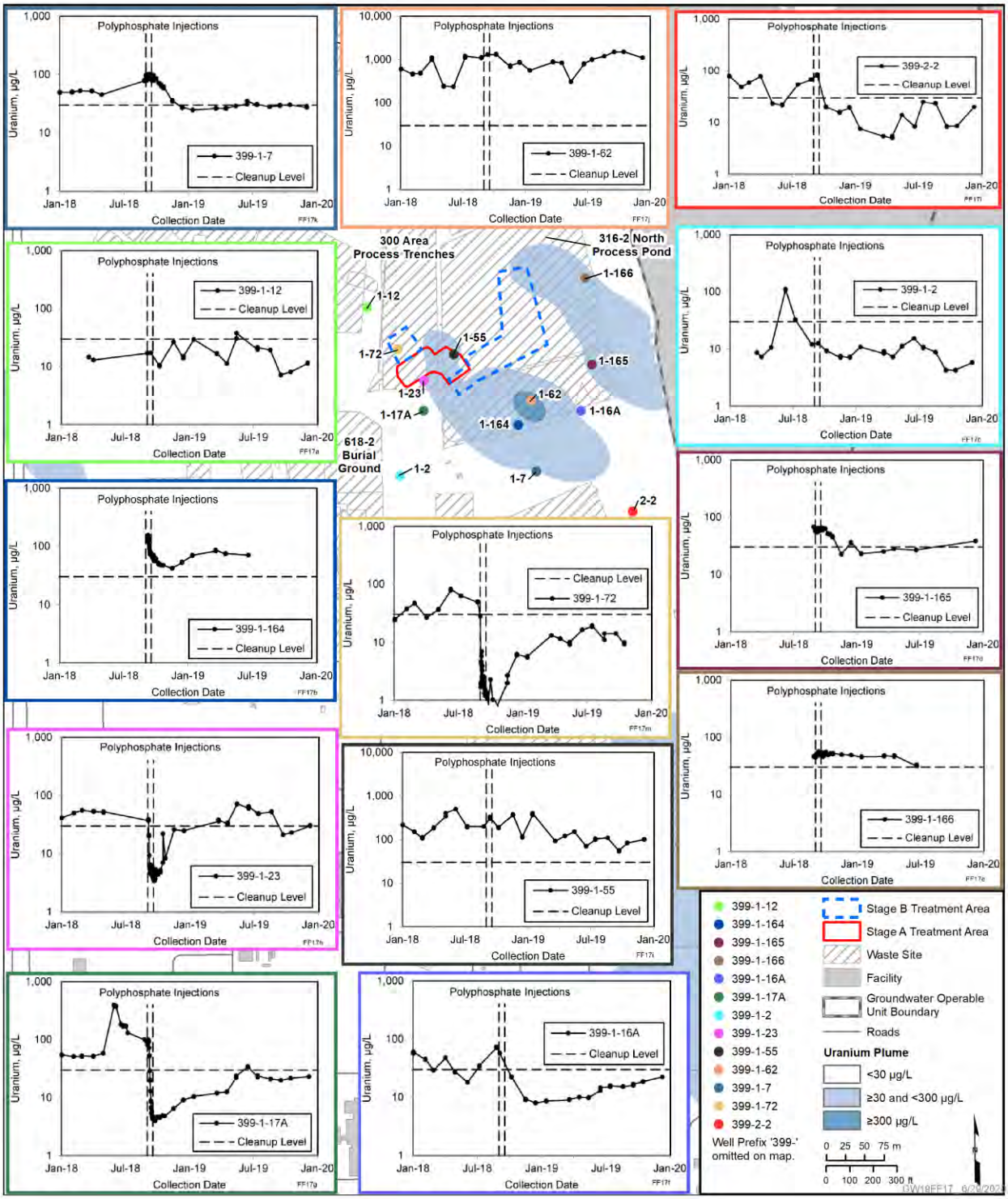


Figure 7-19. 300-FF Uranium Data for Stage B Aquifer Monitoring Wells

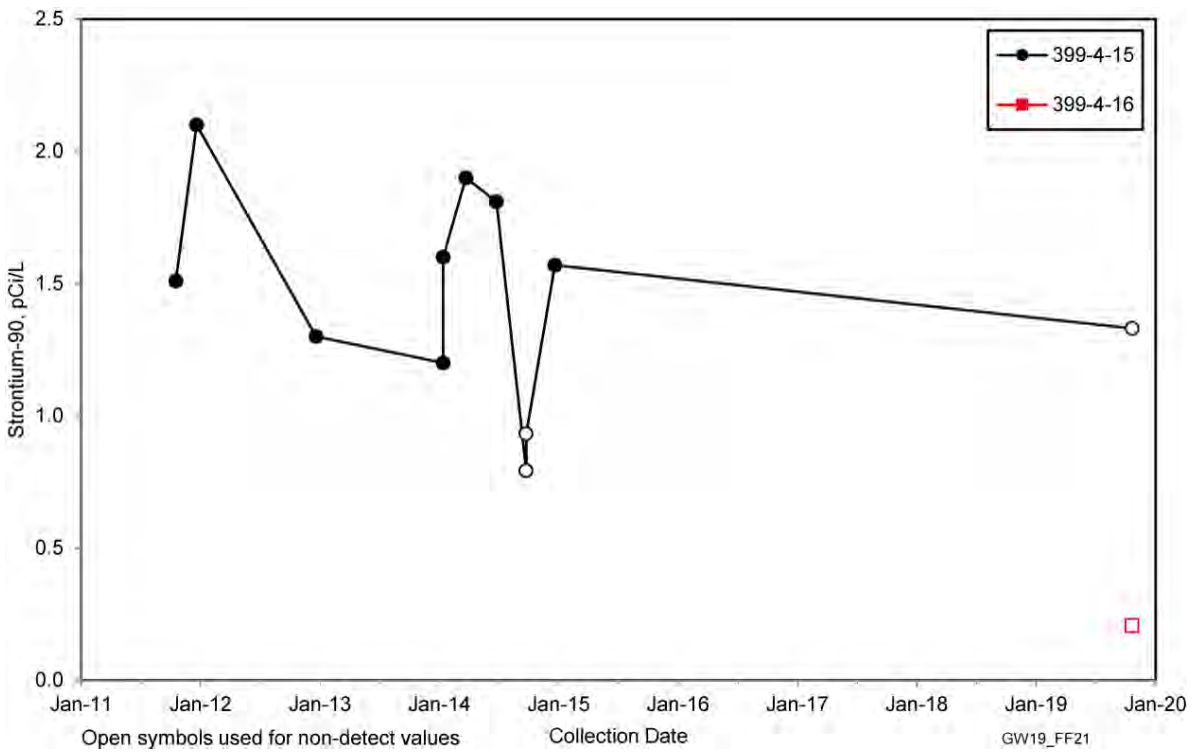


Figure 7-20. 300-FF Strontium-90 Data for Wells 399-4-15 and 399-4-16

7.7 RCRA Monitoring at 300 Area Process Trenches

The 300 Area Process Trenches (also known as the 316-5 waste site) (Figure 7-21) are the only RCRA unit in 300-FF. Groundwater is monitored to meet the requirements of RCRA and WAC 173-303 for dangerous waste constituents. DOE/RL-2019-65 presents the results of RCRA monitoring on the Hanford Site in 2019. The information from the 2019 RCRA report is repeated in this section for completeness. Groundwater data are available in the HEIS database. Appendix B includes well and constituent lists, flow rates, and statistical tables.

The 300 Area Process Trenches (316-5 waste site) (Figure B-1 in Appendix B and Figure 7-21) received mixed waste effluent discharges from fuel fabrication and nuclear research laboratories in the 300 Area Industrial Complex from 1975 to 1987, followed by continued discharge of cooling water with small quantities of nonhazardous maintenance and process waste until December 1994. A comprehensive description, including a history of operations, is provided in Section 3.1.1 of the final status groundwater monitoring plan for the 300 Area Process Trenches in the Hanford RCRA Permit (Part VI, Post-Closure Unit 1 (PCU-1), Chapter 3.0, "Groundwater Monitoring Plan") (hereinafter referred to as the PCU-1 groundwater monitoring plan). The PCU-1 groundwater monitoring plan was incorporated into Part VI of the Hanford RCRA Permit, Revision 8c, on May 24, 2017.[8]

[8] Minor formatting modifications were made to the groundwater monitoring plan on March 15, 2018.

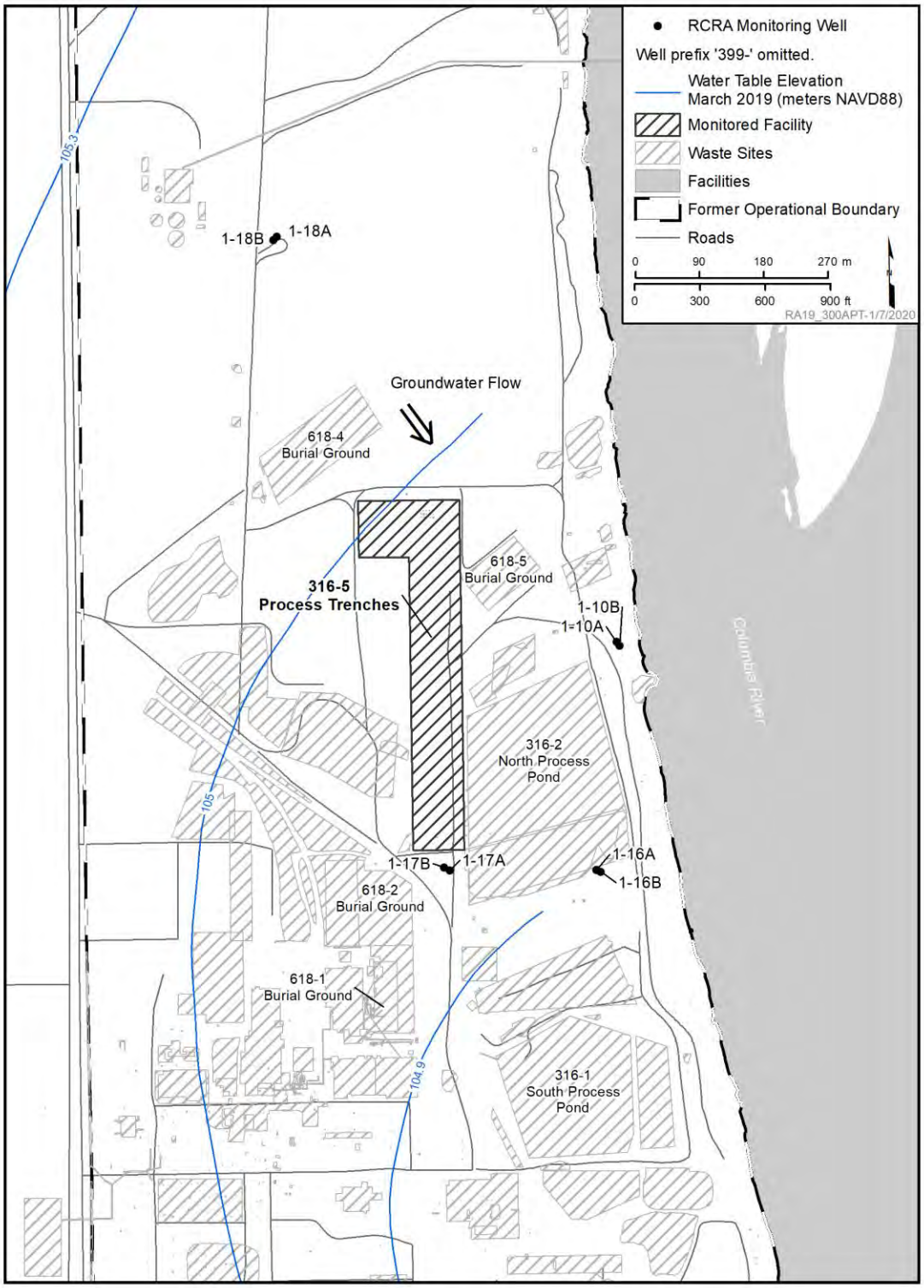


Figure 7-21. 300 Area Process Trenches (316-5)

DOE remediated the 300 Area Process Trenches in 1991 under a CERCLA expedited response action by excavating contaminated soil and transporting the excavated soil to the north end of the trenches (Section 2.4 in DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches*). Additional removal actions were performed in 1997 and 1998, followed by backfilling and surface restoration in 2004 (Chapter 3 in DOE/RL-2004-74). The 300 Area Process Trenches were closed in 1998 under a modified closure with requirements for continued corrective action groundwater monitoring. Corrective action was deferred to the CERCLA program for the 300-FF-5 OU (Executive Summary of the PCU-1 groundwater monitoring plan in the Hanford RCRA Permit).

The RCRA post-closure groundwater monitoring under the WAC 173-303-645 corrective action program uses wells at four locations: one upgradient (northwest) and three downgradient (east, southeast, and south) of the former 300 Area Process Trenches (Figure 7-21; Table B-24 in Appendix B). The most distant downgradient location is about 200 m (660 ft) to the southeast, along the dominant groundwater flow path from the trenches. Two wells are located at each of the four locations. Well names ending in "A" are screened near the water table, and well names ending in "B" are screened in the lower portion of the unconfined aquifer.

The water table near the former trenches is not declining and is directly affected by the Columbia River stage. Dry well conditions are unlikely in the future (Section 3.2.5 in the PCU-1 groundwater monitoring plan in the Hanford RCRA Permit). Groundwater flows generally toward the south-southeast beneath the former trenches. In March 2019, the gradient sloped to the southeast at 4.2×10^{-4}, and the estimated groundwater flow rate was 22 m/d (73 ft/d) (Table B-25 in Appendix B).

The sampling schedule for the monitoring wells is designed to accommodate two sampling events each year, with collection scheduled during high river stage (typically May through June) and low river stage (typically September to November). This annual report for 2019 includes *cis*-1,2-DCE, TCE, and field parameter results for samples collected in June and September. In 2019, sampling was performed as planned (Table B-26 in Appendix B).

The Hanford RCRA Permit concentration limits for *cis*-1,2-DCE and TCE are 16 µg/L and 4 µg/L, respectively, consistent with the cleanup levels in the CERCLA ROD (EPA and DOE, 2013). DOE reports the results of 300 Area Process Trenches groundwater monitoring semiannually (SGW-63850, *Post-Closure Corrective Action Groundwater Monitoring Report for the 300 Area Process Trenches: January – June 2019*; and SGW-64410, *Post-Closure Corrective Action Groundwater Monitoring Report for the 300 Area Process Trenches: July – December 2019*).

During 2019, TCE concentrations were below the Hanford RCRA Permit concentration limit (4 µg/L) and were mostly below the analytical detection limit (Table B-26 in Appendix B). Low-level detections of TCE in well 399-1-16B, with a maximum of 1.6 µg/L, may be from the former 300 Area Process Trenches or the former 316-2 North Process Pond.

In samples from well 399-1-16B, *cis*-1,2-DCE continued to exceed the Hanford RCRA Permit concentration limit (16 µg/L), with concentrations ranging from 147 to 169 µg/L. Lower levels of *cis*-1,2-DCE were detected in well 399-1-17B, with a maximum of 0.69 µg/L.

In accordance with Section 3.3.2 of the PCU-1 groundwater monitoring plan in the Hanford RCRA Permit, a statistical evaluation was performed to compare the dangerous waste constituent results to the permit concentration limits. The evaluation applies to results at individual point-of-compliance (downgradient) wells. The 95% UCL on the mean is used for results that exceed concentration limits. A nonstatistical analysis is used for results that are less than concentration limits. In addition, the PQL for

each sample in the data set must not exceed the concentration limit established in the Hanford RCRA Permit.

The statistical evaluation is conducted semiannually (SGW-63850; SGW-64410). The only 95% UCL that exceeded the Hanford RCRA Permit concentration limit in a downgradient well was for *cis*-1,2-DCE in well 399-1-16B (Table B-27 in Appendix B).

7.8 Atomic Energy Act Monitoring

AEA groundwater monitoring was scheduled at 79 groundwater wells and aquifer tubes in 300-FF in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 300-FF are uranium, tritium, and nitrate. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Wells were sampled in accordance with SAP requirements in 2019 except as indicated in Table C-1 in Appendix C.

Radionuclide concentrations detected in groundwater samples from 99 wells[9] 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 (Table 7-3). One location, well 399-1-62, exceeded the TED of 100 mrem/yr. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at five locations in 300-FF. The DWSs for cumulative alpha emitters and EPA net alpha activity standard were not exceeded. The 30 µg/L uranium DWS was exceeded at 30 locations. 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 that restrict access to groundwater. CERCLA remedial action decisions (e.g., enhanced attenuation in 300-FF-5) provide additional protection of the public and the environment.

Table 7-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 300-FF for 2019

Monitoring Location/ Well Name	Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
399-1-1	—	—	—	—	32.90	32.90
399-1-7	—	—	—	—	35.00	35.00
399-1-12	—	—	—	—	37.80	37.80
399-1-17A	—	—	—	—	34.40	34.40
399-1-21A	—	—	—	—	31.30	31.30
399-1-23	—	—	—	—	72.70	72.70
399-1-55	—	—	—	—	56.00	399.00
399-1-62	153.39	153.39	—	—	308.00	1,510.00
399-1-157	—	—	—	—	30.80	30.80

[9] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 7-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 300-FF for 2019

Monitoring Location/ Well Name	Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
399-1-158	—	—	—	—	37.70	37.70
399-1-162	—	—	—	—	36.10	36.10
399-1-164	—	—	—	—	70.50	86.70
399-1-165	—	—	—	—	38.20	38.20
399-1-166	—	—	—	—	32.80	48.00
399-3-1	—	—	—	—	31.10	31.10
399-3-6	—	—	—	—	39.20	39.20
399-3-9	—	—	—	—	66.20	66.20
399-3-10	—	—	—	—	104.00	110.00
399-3-20	—	—	—	—	32.40	42.60
399-3-33	—	—	—	—	33.10	33.10
399-3-37	—	—	—	—	35.90	35.90
399-4-7	—	—	—	—	42.00	42.00
399-4-9	—	—	—	—	49.00	49.00
399-4-10	—	—	—	—	59.90	63.50
399-4-14	—	—	—	—	30.80	53.00
399-8-1	—	—	—	—	35.50	35.50
399-8-5A	—	—	—	—	36.40	53.10
699-12-2C	—	—	4.63	4.63	—	—
699-13-0A	—	—	7.22	7.22	—	—
699-13-1E	—	—	11.24	11.24	—	—
699-13-2D	—	—	50.45	50.45	—	—
699-13-3A	—	—	41.80	41.80	—	—
699-S6-E3B	—	—	—	—	37.00	37.00
AT-3-2-M	—	—	—	—	54.20	54.20
C6347	—	—	—	—	119.00	119.00

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

Blank cells (—) indicate no exceedances.

None of the wells in 300-FF had cumulative alpha activity ≥15 pCi/L.

8 1100-EM

The 1100-EM groundwater interest area is a small region in the southeastern corner of the Hanford Site, south of the 300 Area (Figures 1-1 and 8-1). The adjacent offsite region, which includes part of the former 1100-EM-1 Groundwater OU, is informally known as Richland North. This chapter discusses the groundwater monitoring results for 1100-EM and Richland North.

8.1 Overview

The former 1100-EM-1 OU included the inactive DOE Horn Rapids Landfill, used from the late 1940s through the 1970s for disposal of office and construction waste, asbestos, sewage sludge, fly ash, and reportedly numerous drums of unidentified organic liquids (Section 1.3 in DOE/RL-90-18, *Phase 1 Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*). Following cleanup of 1100-EM-1 and related source OUs, it was delisted from the NPL and DOE transferred ownership of a portion of the property to the Port of Benton in 1998.

The Richland North area includes the city of Richland north well field and recharge ponds. The city of Richland pumps Columbia River water into the recharge ponds, the water percolates to the groundwater, and it is then pumped through surrounding wells for municipal use during peak demand periods (WHC-MR-0033, *Recharge to the North Richland Well Field*, p. 3). The Richland North area also includes the Framatome[10] nuclear fuel production facility, which is southwest (upgradient) of the inactive DOE Horn Rapids Landfill. Table 8-1 provides some key facts about 1100-EM. Tables 3-12 and 3-13 in the AEA SAP (DOE/RL-2015-56) list the monitoring wells and constituents.

Groundwater beneath 1100-EM and Richland North flows primarily west to east and discharges to the Columbia River (Figure 8-2). Groundwater flow from the west is diverted to the northeast and southeast around a recharge mound beneath the city of Richland's recharge ponds. Other sources of recharge to the unconfined aquifer are the Yakima River, agricultural irrigation, and natural precipitation.

The thickness of the unconfined aquifer in this area is 5.6 to 9 m (18 to 30 ft), with all but the upper few meters residing in Ringold unit E (Figure 8-3). A silt- and clay-dominated facies forms a local, laterally extensive upper aquitard up to 10 m (33 ft) thick.

[10] Formerly AREVA.

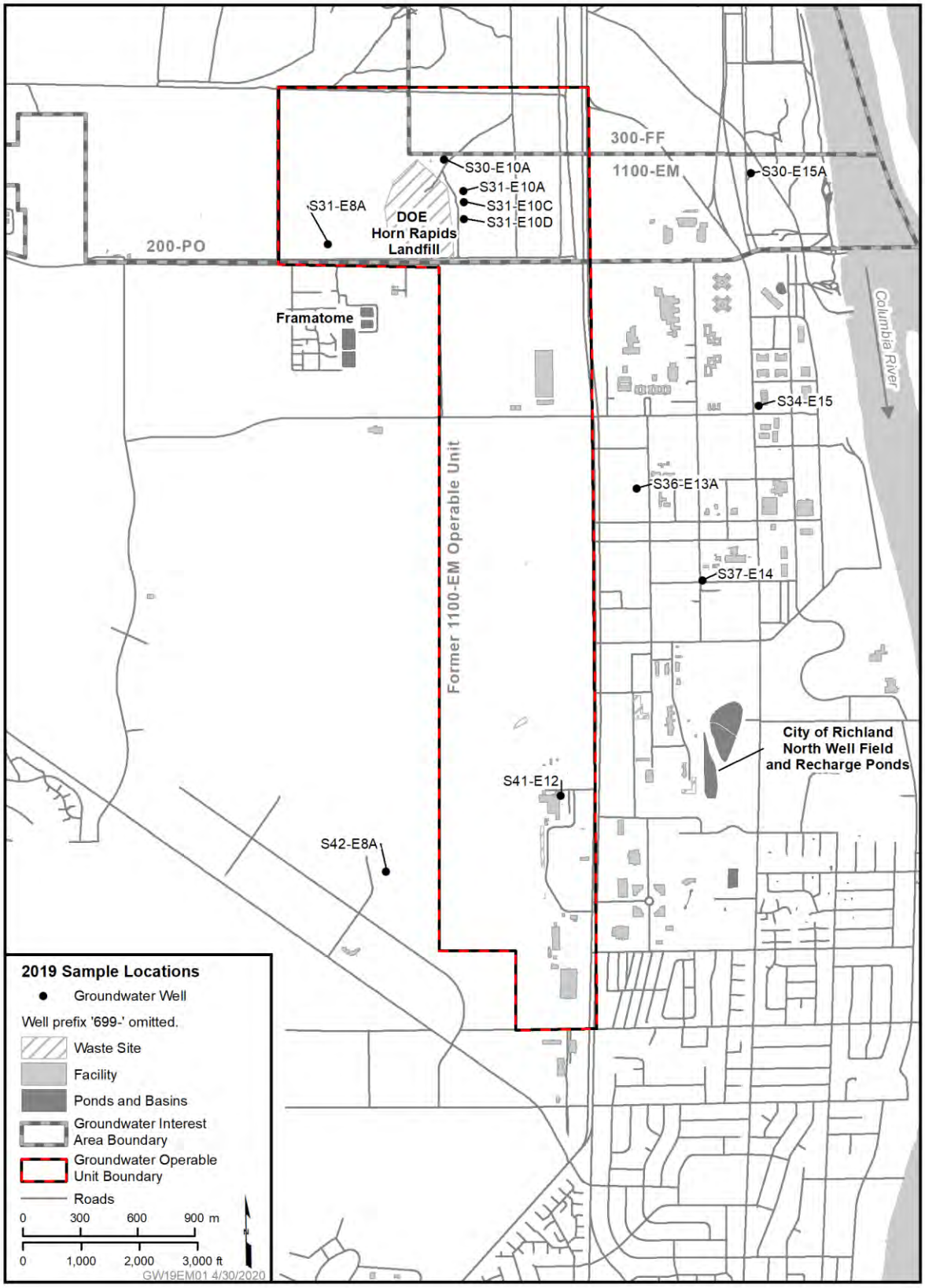


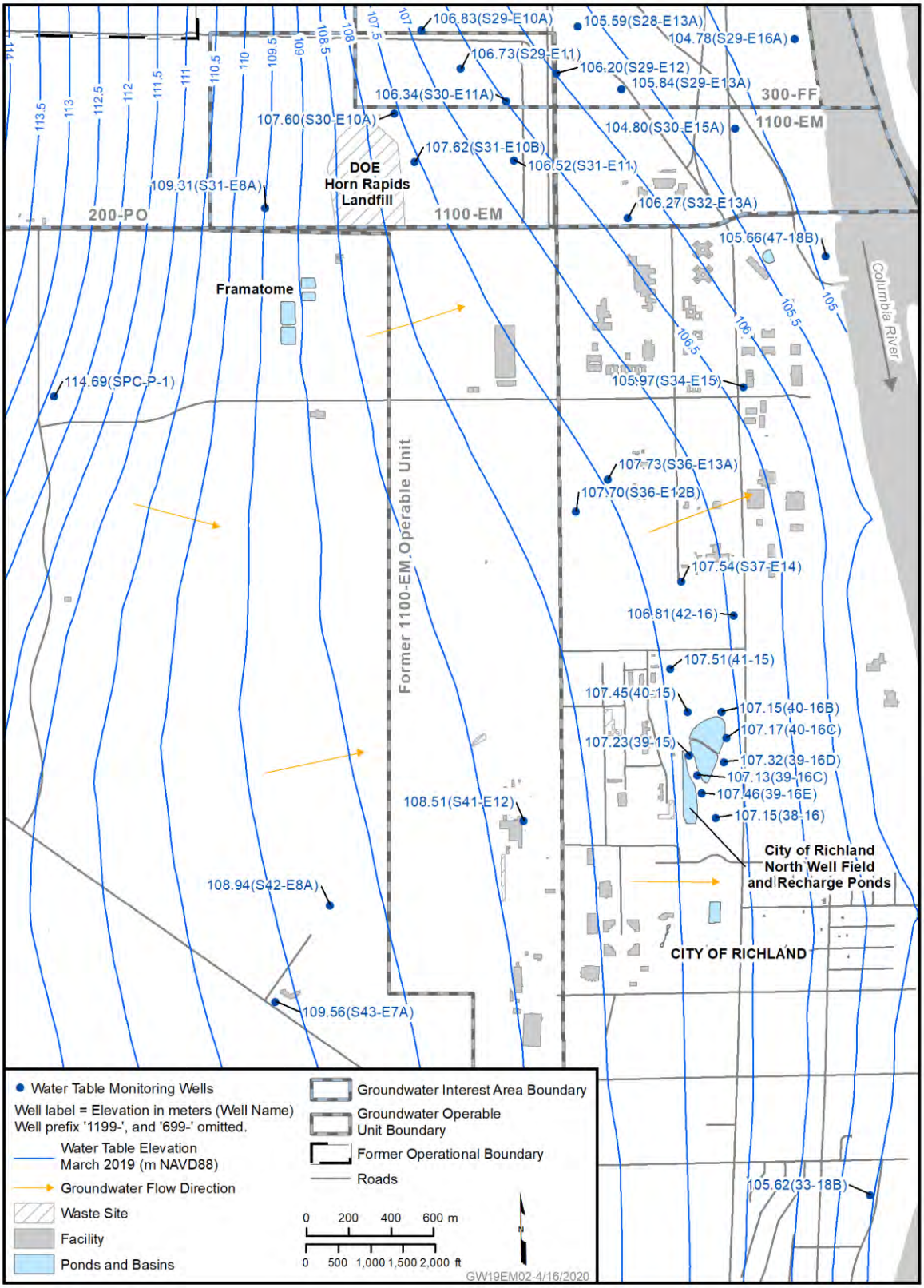
Figure 8-1. 1100-EM and Richland North Sampling Locations, 2019

Table 8-1. 1100-EM at a Glance

Operations included industrial and automotive activities (1954 to 1985) and a landfill (1950s to 1970).		
Groundwater Monitoring		
Contaminant,[a] Drinking Water Standard	**Year**	**Maximum Concentration**
Nitrate, 45 mg/L	2019	137 (699-S31-E10A)
	2018	159 (699-S36-E13A)
Uranium, 30 µg/L	2019	32.2 (699-S31-E10A)
	2018	35.4 (699-S31-E10D)
Remediation		
Waste sites (final action): 100% complete.[b] **Groundwater (final action):** Monitored natural attenuation has met remedial action goals. **Record of Decision for final remedial action:** 1993		

a. Nitrate and uranium in 1100-EM are from offsite sources. Plume areas are not calculated.

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



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 8-2. 1100-EM and Richland North Water Table, March 2019

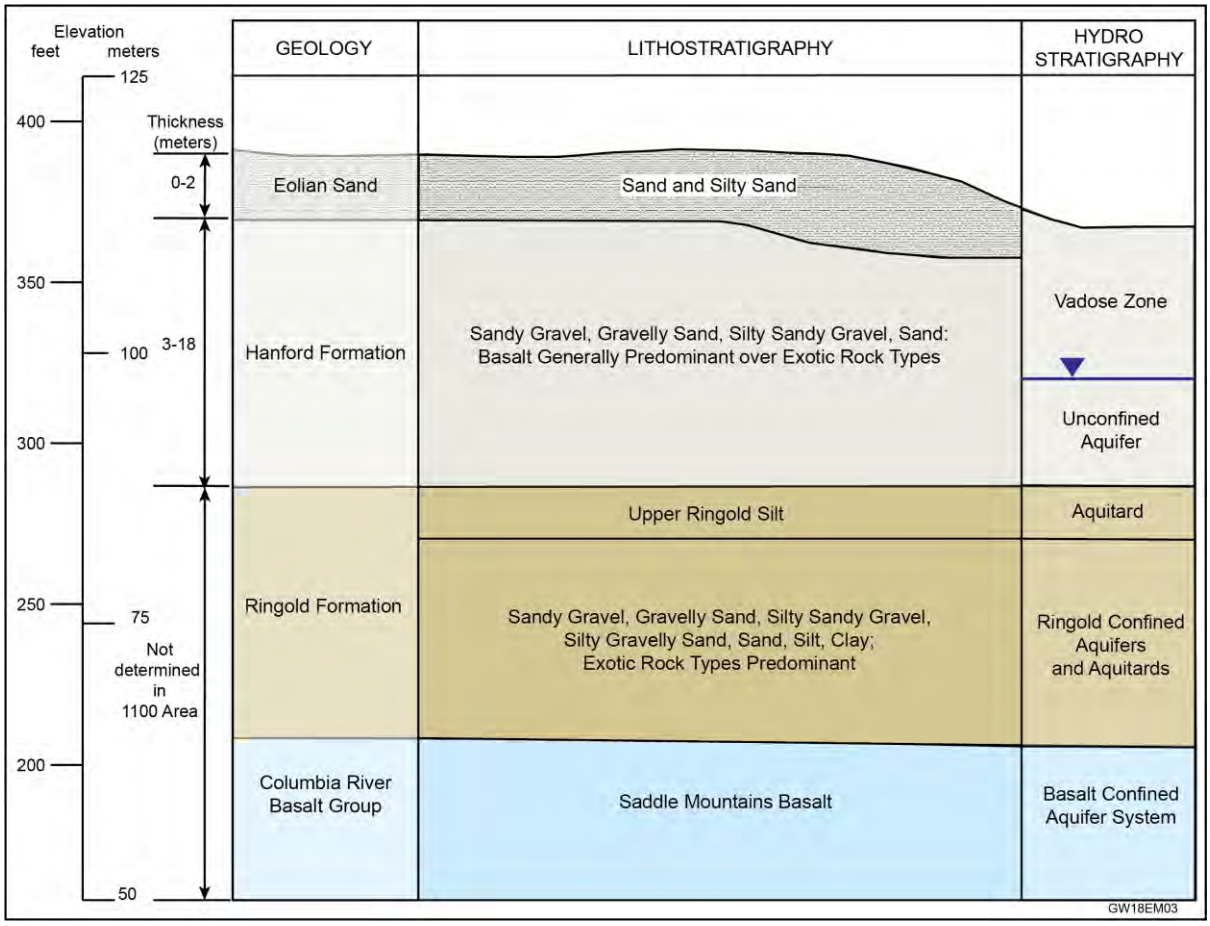


Figure 8-3. 1100-EM Geology

8.2 Nitrate

Nitrate concentrations are >45 mg/L throughout much of 1100-EM, Richland North, and the southern part of 300-FF (Figure 8-4). The southern extent of the plume decreased in 2019 based on a much lower concentration in well 699-S37-E14 (Figure 8-5). The plume extent to the southwest (upgradient) is undefined by current data, but nitrate contamination likely migrated into the area from industrial and agricultural uses off the Hanford Site. Agricultural uses include fertilizer applications to the irrigated fields west of 1100-EM.

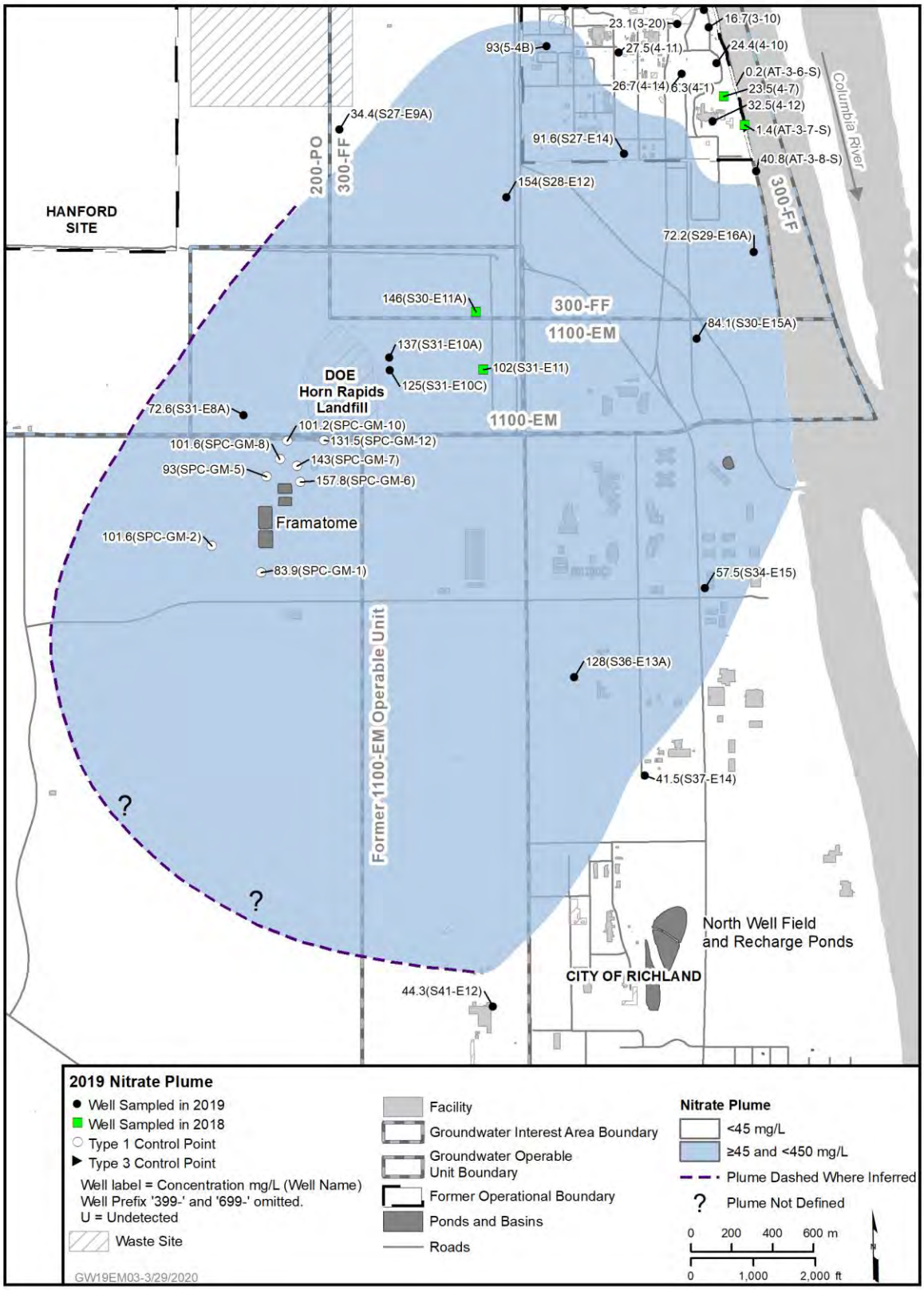


Figure 8-4. Nitrate Plume in 1100-EM, Richland North, and the 300 Area, 2019

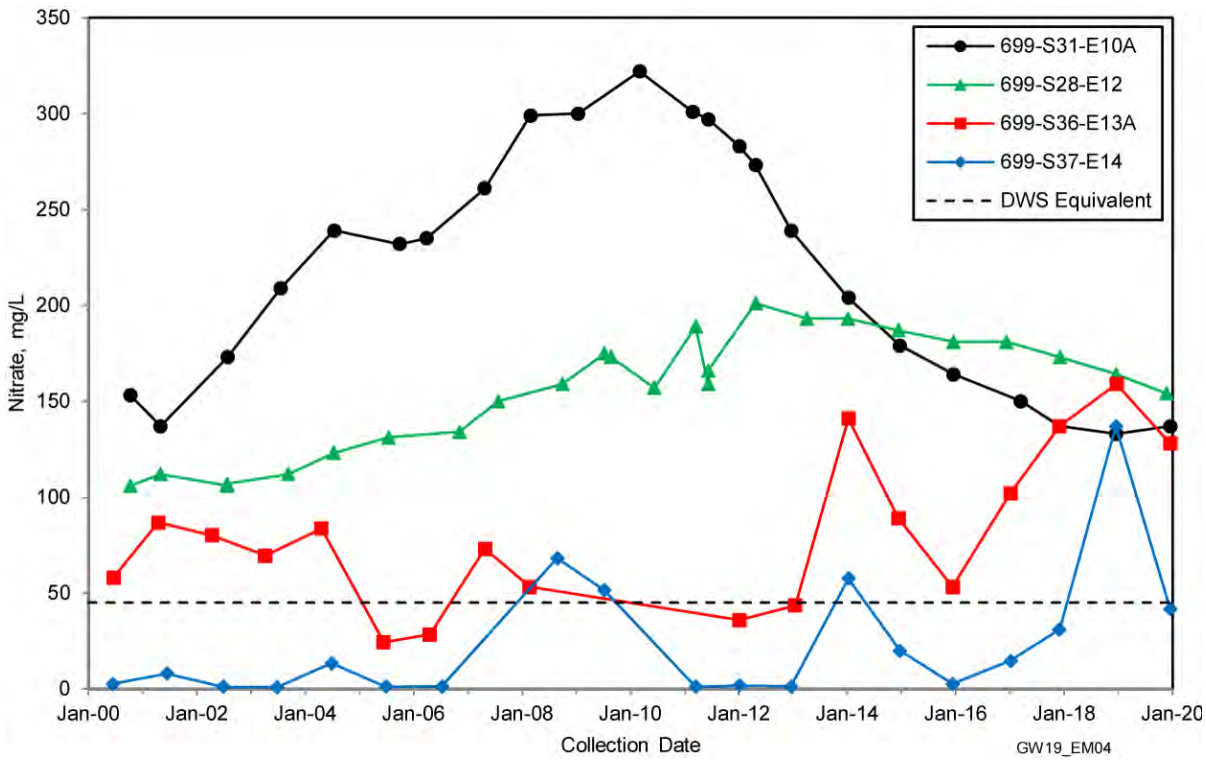


Figure 8-5. 1100-EM Nitrate Data for Selected Wells in 1100-EM, Richland North, and the 300 Area

8.3 Tritium

Tritium is monitored in 1100-EM groundwater to confirm that concentrations are below the DWS in the region around the city of Richland's water supply wells. The Hanford Site tritium plume reached its maximum extent (at one-tenth of the DWS) in about 1999 (Figure 2.1-3 in PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*), and then the plume began to shrink as concentrations in monitoring wells declined. Wells in 1100-EM are sampled for tritium every 6 years under the AEA SAP (Tables 3-12 and 3-13 in DOE/RL-2015-56). In recent years, concentrations remained near or below detection limits (<200 pCi/L).

8.4 Uranium

A uranium plume with concentrations above the 30 µg/L DWS originated from the offsite Framatome facility and affects monitoring wells in the southern part of the Hanford Site (Figure 8-6).
An investigation of the site attributed the groundwater contamination to operation of a surface impoundment system in the 1970s and 1980s when some of the impoundments were single-lined and without leak collection capabilities (Attachment H in Ecology, 2010, *Dangerous Waste Management Permit AREVA NP Inc. (WAD 99082 8402)*). The impoundment system was subsequently removed.

Concentrations in three Hanford Site wells downgradient from Framatome exceeded the 30 µg/L DWS in 2019, with a maximum concentration of 35.4 µg/L in well 699-S31-E10D (Figure 8-7). The maximum uranium concentration in a Framatome well in 2018 was 35.8 µg/L (2019 data are not available).

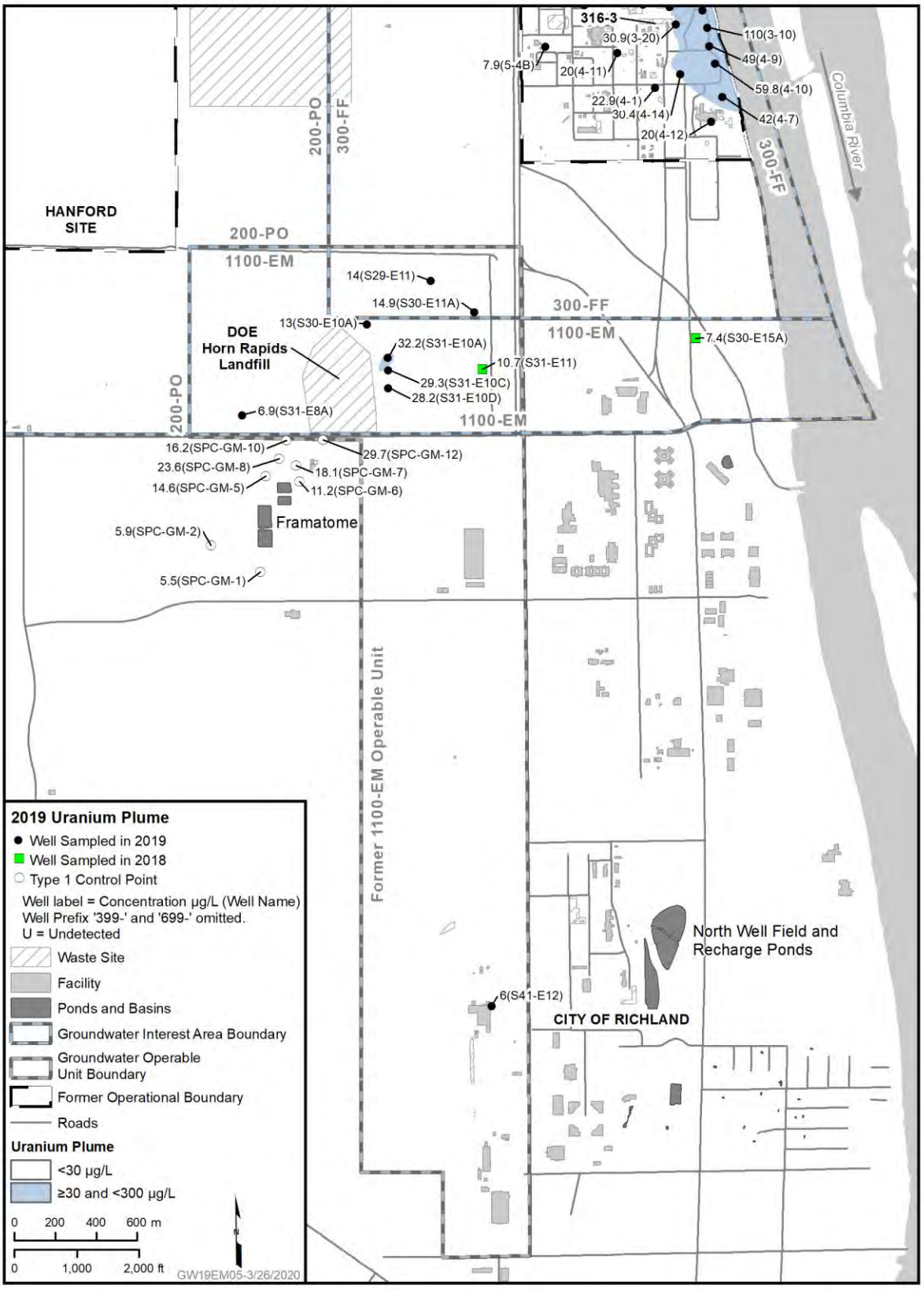


Figure 8-6. Framatome Uranium Plume, 1100-EM and Richland North, 2019

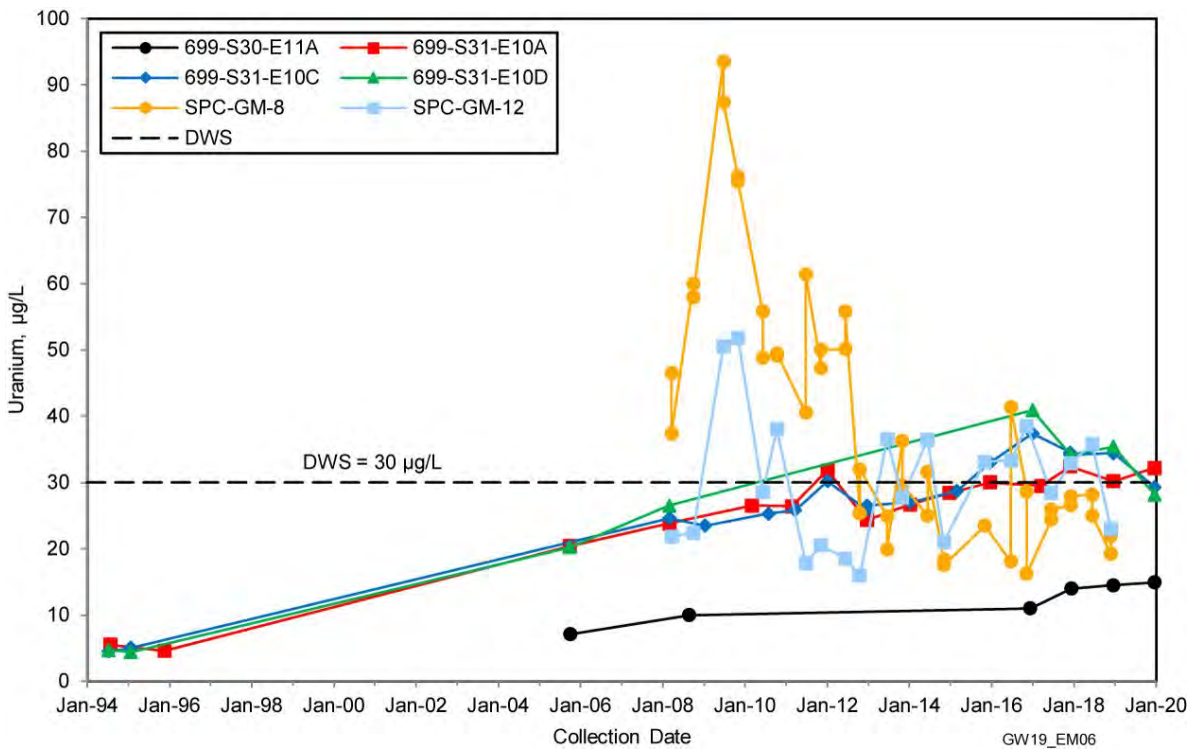


Figure 8-7. 1100-EM Uranium Data for Wells Downgradient of Framatome and Inactive Horn Rapids Landfill

8.5 CERCLA Remediation and Monitoring

In 1993, the Tri-Parties signed a ROD for the 1100 Area, which included the 1100-EM-1 Groundwater OU and the 1100-EM-2 and 1100-EM-3 Source OUs (EPA/ROD/R10-93/063, *Declaration of the Record of Decision, USDOE Hanford 1100 Area, Hanford Site, Benton County, Washington*). The ROD had a groundwater component that relied on MNA for TCE, with a cleanup level of 5 µg/L. In 2006, the second CERCLA 5-year review (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*) concluded that remedies selected for the 1100-EM-1 OU had been completed and the RAOs established in the ROD had been achieved, so the 1100 Area was removed from the NPL In 2015, TPA-CN-679, *Tri-Party Agreement Change Notice Form: PNNL-12220, Sampling and Analysis Plan Update for Groundwater Monitoring 1100-EM-1 Operable Unit*, eliminated the need for groundwater monitoring for the 1100-EM-1 OU.

8.6 Atomic Energy Act Monitoring

The AEA groundwater monitoring was scheduled at seven groundwater wells in 1100-EM and five wells in the Richland North area in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 1100-EM are nitrate and uranium, and for Richland North the primary constituents are nitrate and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Wells in 1100-EM and the Richland North area were sampled in accordance with SAP requirements in 2019.

Radionuclide concentrations detected in groundwater samples from seven wells in 1100-EM and one well in Richland North 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 only exceedances were for uranium above the 30 µg/L DWS at one location in 1100-EM (Table 8-2). As discussed in Section 8.4, this contamination originated offsite. This well is not 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 that restrict access to groundwater.

Table 8-2. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 1100-EM and Richland North in 2019

Monitoring Location/ Well Name	Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum
699-S31-E10A	59.40	59.40

Reference: ECF-HANFORD-2019-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Note: None of the wells in 1100-EM had total effective dose ≥100 mrem/yr, cumulative beta/photon emitters >4 mrem/yr, or cumulative alpha activity ≥15 pCi/L.

9 200-BP

This chapter presents information for the 200-BP groundwater interest area, which includes groundwater and associated contaminant plumes beneath the northern half of the 200 East Area and a region to the north (Figures 9-1 and 9-2). This chapter includes an overview; a discussion of CERCLA-, RCRA-, and AEA-related groundwater activities; and a summary of 2019 groundwater monitoring results.

9.1 Overview

The 200-BP groundwater interest area, which includes the 200-BP-5 Groundwater OU and six RCRA units, extends from the northern portion of the 200 East Area to the northwest, to the Columbia River shoreline. Table 4-4 in the 200-BP-5 RI/FS (DOE/RL-2009-127, *Remedial Investigation Report for the 200-BP-5 Groundwater Operable Unit*) summarizes the following sources of groundwater contamination:

- B Complex (northwestern 200 East Area):
  - Unplanned release from tank 241-BX-102 (highly contaminated waste stream that included uranium, technetium-99, tritium, iodine-129, and nitrate)
  - BY Cribs (moderately contaminated waste stream with technetium-99, iodine-129, cobalt-60, cyanide, and nitrate)
  - Unplanned release near tank 241-B-105 (moderately contaminated waste stream with the same contaminants found at the BY Cribs)
- WMA C:
  - Various unplanned releases (highly contaminated waste streams with technetium-99 and nitrate)
- 216-B-2-1 and 216-B-2-2 Ditches (nitrate)
- Gable Mountain Pond (nitrate and strontium-90)
- B Pond (iodine-129)

Other sources of groundwater contamination discussed in DOE/RL-2009-127 were not apparent in 2019.

Nitrate, iodine-129, and technetium-99 are the most extensive groundwater plumes in 200-BP. Nitrate and technetium-99 originated mainly from local sources. Iodine-129 predominantly migrated into 200-BP from 200-PO in the late 1980s and early 1990s but apparently also had sources in 200-BP (e.g., 216-B-2 Ditches). Cyanide, strontium-90, and uranium are present as smaller contaminant plumes.

In 2019, tritium exceeded the 20,000 pCi/L DWS only at monitoring wells beneath the former B Pond (Section 10.1), with a maximum concentration of 28,700 pCi/L in 200-BP. B Plant wells screened in the deep, low-permeability Ringold Formation were not sampled in 2019 but are scheduled for sampling in 2020 and will be discussed in the 2020 annual report. Chapter 9 of DOE/RL-2018-66 provides details from previous tritium monitoring at B Plant.

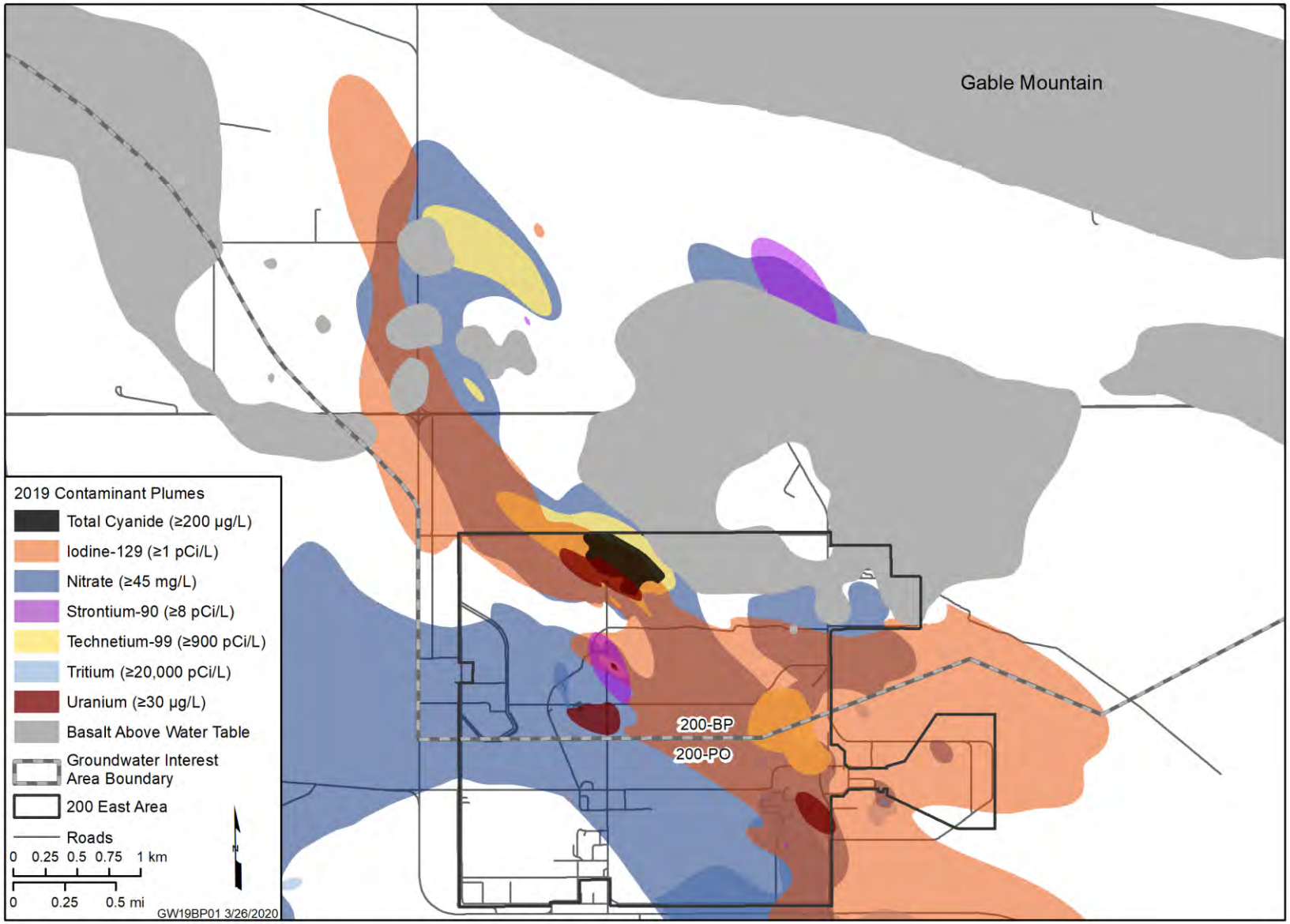


Figure 9-1. 200-BP Groundwater Interest Area and Geometry of Groundwater Contaminant Plumes

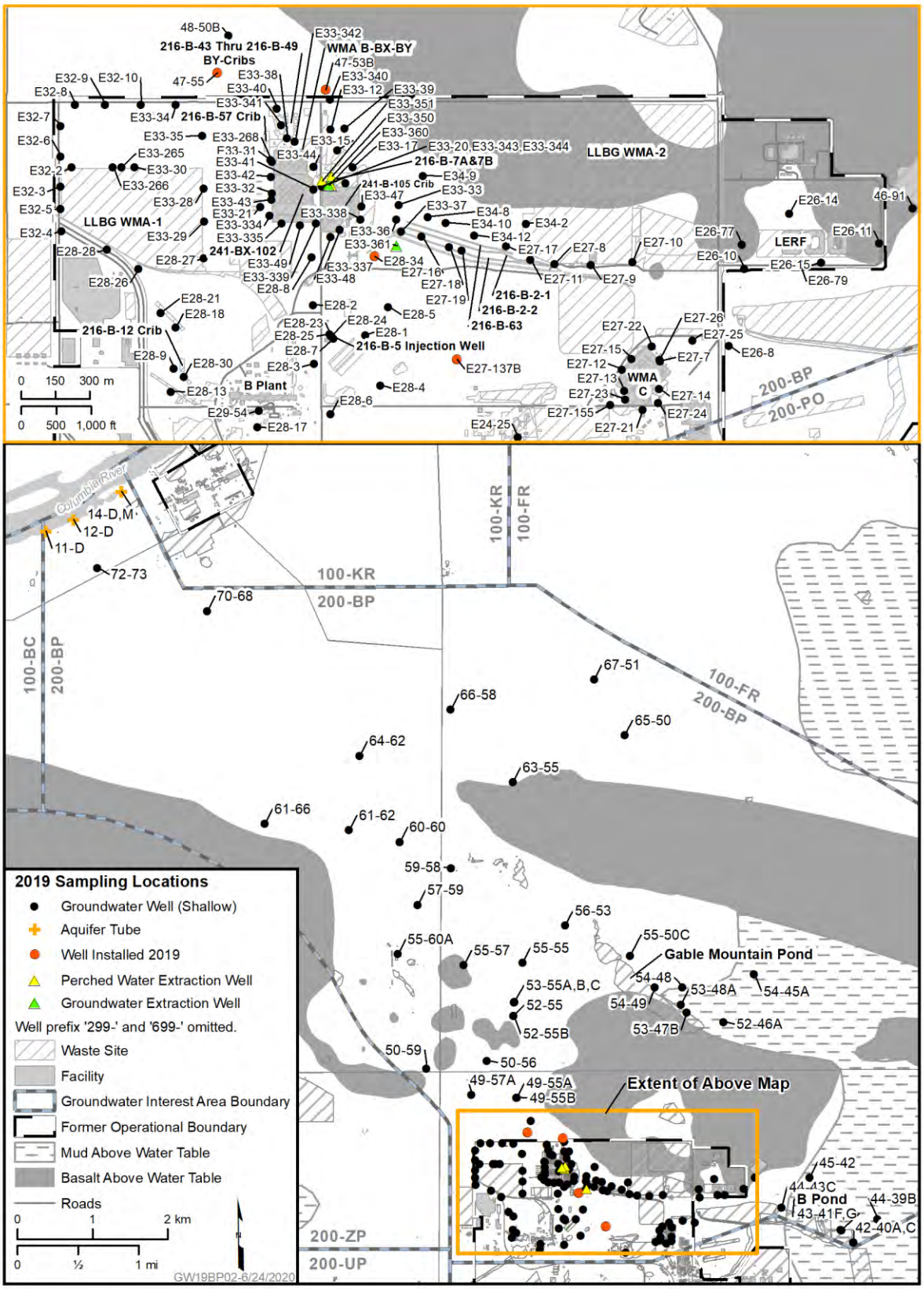


Figure 9-2. 200-BP Sampling Locations, 2019

In 2019, cesium-137, fluoride, and plutonium-239/240 exceeded DWSs at only one monitoring well adjacent to the decommissioned 216-B-5 reverse well, where waste was discharged directly into the aquifer in the past. Arsenic exceeded the 10 µg/L DWS at two wells in 200-BP and appears to be associated with laboratory QC issues or geochemical variability. The highest concentration was an unfiltered result of 12.6 µg/L at Low-Level Burial Grounds (LLBG) WMA-1, upgradient well 299-E33-266, where the filtered and unfiltered results were flagged as "C" (associated with laboratory blank contamination). Previous results at well 299-E33-266 never exceeded 7.5 µg/L. Well 299-E34-12, which also exceeded 10 µg/L in 2019, appears to be associated with natural conditions where arsenic is more prevalent. Arsenic at well 299-E34-12 averages about 9 µg/L, with little variability. Cesium-137, fluoride, plutonium-239/240, and arsenic are not discussed further in this chapter (see Section 4.4 in DOE/RL-2009-127 for additional information).

The highest levels of nitrate and uranium in the unconfined aquifer in 200-BP are detected within the northwest portion of the 200 East Area in an area referred to as the B Complex (e.g., WMA B-BX-BY and adjacent liquid waste sites) (see Figure 2 in DOE/RL-2016-41, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*). Past releases of cyanide, nitrate, technetium-99, and uranium contaminants at the B Complex into a thin, highly permeable, unconfined aquifer resulted in highly concentrated and spatially extensive plumes. These plumes extend to the northwest and southeast within an ancestral Columbia River paleochannel that incised low-permeability Ringold deposits. Continued decay (possibly reduced contaminant loading) and continued groundwater mitigation by the B Complex removal action has reduced tritium levels in B Complex to less than half the 20,000 pCi/L DWS in 2019.

Since 2015, DOE has been extracting groundwater to remove technetium-99, uranium, and other contaminants from B Complex groundwater. Because of the ongoing groundwater extraction, contaminant concentrations in the B Complex have declined. The following sections discuss the concentration changes.

Table 9-1 lists the plume area and maximum concentration for each contaminant within 200-BP. Figure 9-3 provides a graph of plume area changes over time within 200-BP. Abrupt changes in plume area estimates (e.g., uranium in 2011 and strontium-90 in 2012) are caused by changes in interpretation (e.g., due to data from new wells or changes in plume mapping methods). Section 1.5 provides details about plume mapping, including descriptions of the terms (e.g., Type 1 control point) used in the figure legends.

Groundwater conditions in 200-BP include a perched zone and unconfined, semiconfined, and confined aquifers. The perched water horizon lies 3 m (10 ft) above the water table, extending along the north side of the B Tank Farm (Figure 2-10 in DOE/RL-2011-102, *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*). It is contaminated from a 1951 overfill event associated with tank 241-BX-102, when 347,000 L (91,600 gal) of contaminated liquid were released. The derived release inventory is estimated to include 2.27 Ci of technetium-99; 10,100 kg of uranium; 3,800 kg of nitrate; and 3.85 Ci of tritium (Appendix C of RPP-26744, *Hanford Soil Inventory Model, Rev. 1*). The 2011 reassessment of the 1951 release (as presented in Section 4.2.3 of RPP-RPT-47562, *Hanford BX-Farm Leak Assessment Report*) replaced the RPP-26744 estimate with 20,000 kg of released uranium. DOE is extracting water from the perched zone (Section 9.8.2), which is a part of the 200-DV-1 OU. Extraction of B Complex contaminated perched water is designed to minimize contaminant migration into the underlying unconfined aquifer.

Table 9-1. 200-BP at a Glance

B Plant operations: 1945 to 1952 (plutonium separation); 1967 to 1985 (strontium and cesium recovery)			
Groundwater Monitoring			
Contaminant, Water Quality Standard	**Year**	**Maximum Concentration[a] (Well)**	**Plume Area[b] (km^2)**
Nitrate, 45 mg/L	2019	1,090 (299-E33-44)	7.7
	2018	1,060 (299-E33-47)	8.5
Iodine-129, 1 pCi/L[c]	2019	7.14 (299-E27-26)	5.3
	2018	9.87 (299-E27-13)	6.1
Technetium-99, 900 pCi/L[c]	2019	24,800 (299-E27-21)	1.1
	2018	29,100 (299-E27-21)	1.5
Uranium, 30 µg/L	2018	641 (299-E33-20)	0.19
	2018	1,100 (299-E33-20)	0.20
Strontium-90, 8 pCi/L[c]	2019	337 (299-E28-24)	0.41
	2018	602 (299-E28-25)	0.42
Free cyanide, 200 µg/L	2019	8.76 (299-E27-137B)	N/A[d]
	2018	58.2 (299-E33-14)	
Tritium, 20,000 pCi/L[c]	2019	28,700 (699-42-40A)	0.03
	2018	33,700 (699-42-40A)	0.08
Remediation			
Perched water extraction (200-DV-1 Operable Unit). Groundwater extraction as a removal action (200-BP-5 Operable Unit) in the B Complex.			

a. Maximum concentration within the regional unconfined aquifer (i.e., excludes the perched water beneath the B Complex) detected in 2019.

b. Estimated area above the listed water quality standard.

c. Single isotope equivalent drinking water standard. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr.

d. No free cyanide plume defined above 200 µg/L.

N/A = not applicable

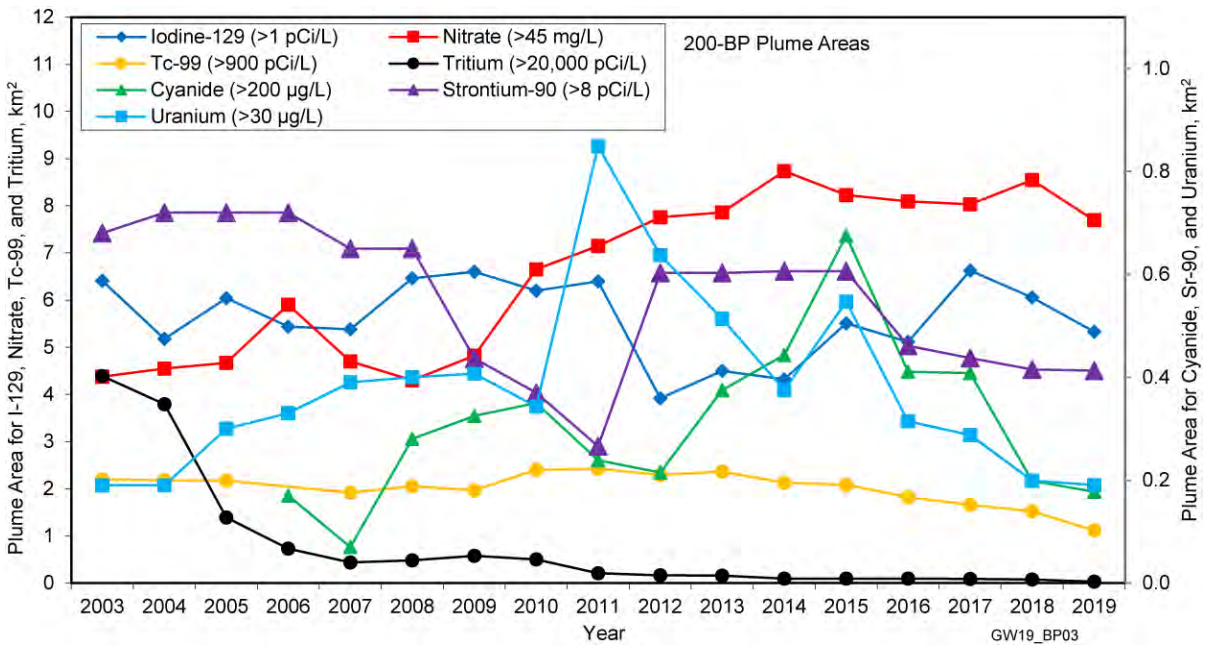


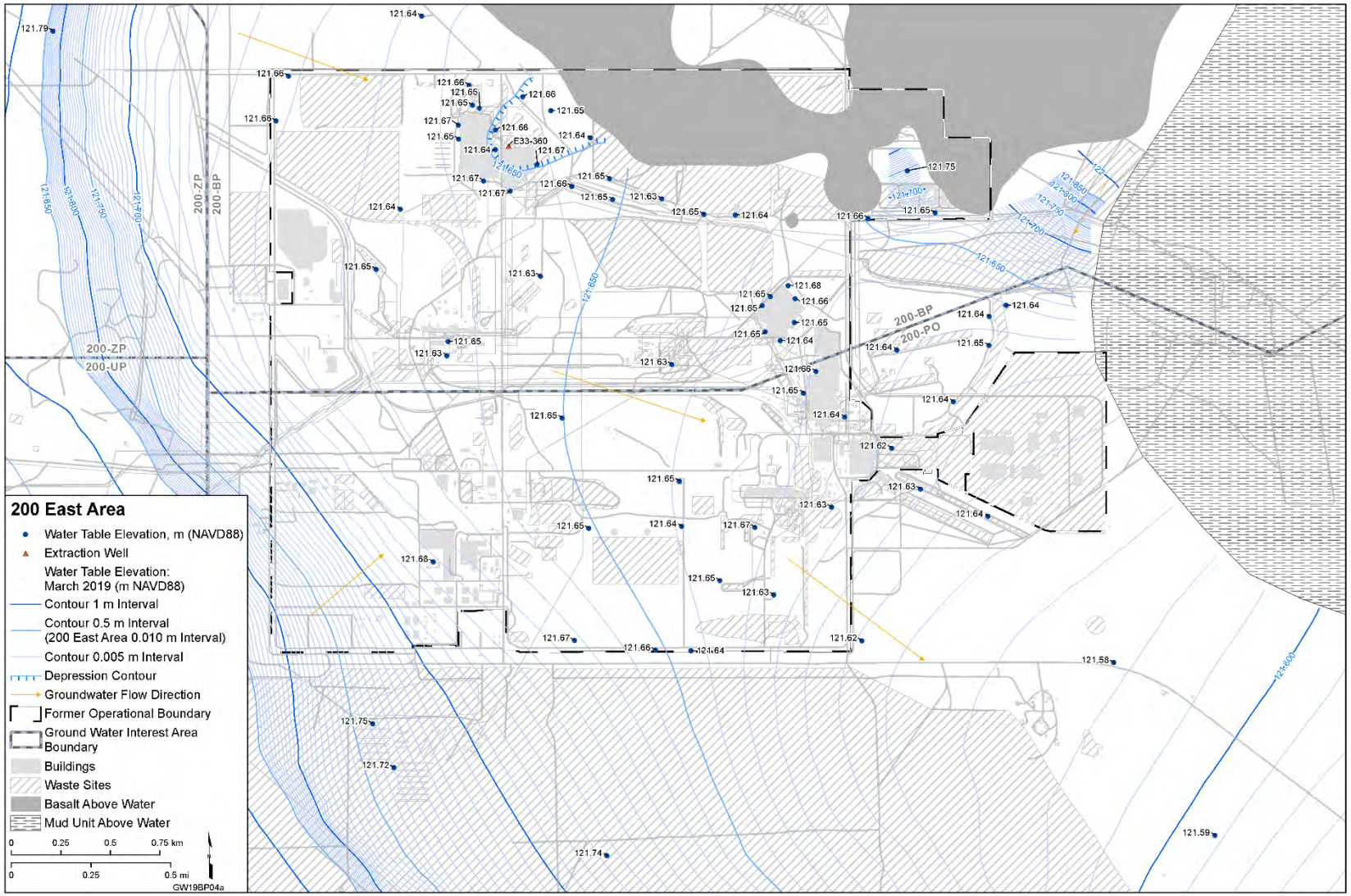
Figure 9-3. 200-BP Plume Areas

The unconfined aquifer within the 200 East Area boundary is the primary aquifer impacted by past waste disposal operations, and it comprises the suprabasalt sediment of the Ringold Formation, Cold Creek unit, and Hanford formation (Figure 1-6). Depths from land surface to the water table in 200-BP range from <1 m (3 ft) near the Columbia River to 105 m (340 ft) in the southern portion of 200-BP. The unconfined aquifer thickness varies from <1 m (3 ft) north of the 200 East Area to >40 m (130 ft) in Gable Gap. Within the northern portion of the 200 East Area, the aquifer is mainly composed of unconsolidated to semiconsolidated gravels of the Hanford formation and Cold Creek unit. Additional details are provided in Section 4 of PNNL-19702, *Hydrologic Model for the Gable Gap Area, Hanford Site*. Within the central portion of the 200 East Area the Ringold Formation underlies, or has been incised by, the Hanford formation and Cold Creek sediments. An ancestral paleochannel of the Columbia River (Hanford/Cold Creek gravels) extends across the 200 East Area from the northwest to the southeast. The base of the aquifer south of Gable Gap is the Elephant Mountain Member of the Columbia River Basalt Group.

Semiconfined aquifers are present in the Ringold Formation beneath and east of the higher permeability paleochannel (shown in Plate 3 of PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*). More specifically, the semiconfined aquifers are associated with hydrostratigraphic units 9B and 9C (Figure 1-6). Contaminants in the semiconfined area east of the 200 East Area are associated with the former B Pond and are limited to iodine-129 and tritium. Contaminants in the semiconfined aquifer in the western half of the 200 East Area are limited to nitrate and tritium, which are thought to be associated with the 216-B-12 Crib. Some portion of this contamination is also likely associated with past northwestward groundwater migration of PUREX cribs contaminants from 200-PO.

Within the uppermost basalt confined aquifer (Rattlesnake Ridge interbed), contamination exceeding the DWS is limited to technetium-99 at only one well (299-E33-12) beneath the B Complex area (Appendix D).

As shown in Figure 9-4, the water table in the 200 East Area is nearly flat, and the overall inferred groundwater flow direction is toward the southeast.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 9-4. 200 East Area Water Table, March 2019

A groundwater divide is present north of the 200 East Area and is interpreted to be located near well 699-50-56, which is north of the 200 East Area and south of Gable Gap. Figure 9-4 of DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*, illustrates the divide to be caused by water flowing in from the west and coincides with a buried basalt anticlinal ridge. North of this ridge, groundwater flows toward the north through the gap between Gable Mountain and Gable Butte. Groundwater to the south of this ridge flows south-southeast into the northwestern quarter of the 200 East Area. The water table in the highly transmissive sediments of the paleochannel responds to seasonal changes in Columbia River stage that propagate from the north. Before 2011, the divide was farther south, and groundwater flow in the northwestern quarter of the 200 East Area was toward the north. Water-level monitoring conducted in 2019 indicates the flow similar to the 2016 conceptual model.

9.2 Nitrate

Groundwater contamination with concentrations above the 45 mg/L DWS covers a large portion of the southern half of 200-BP (Figure 9-5). Concentrations >450 mg/L are detected in the upper part of the unconfined aquifer at the B Complex and deeper in the aquifer at B Plant. These two areas are associated with uranium recovery waste where specific liquid waste sites received over 1 million kg of nitrate waste (Appendix C of RPP-26744). The amount of nitrate disposed in these two areas is over an order of magnitude greater than other areas. Sections 9.2.1 and 9.2.2 discuss changes in contaminant concentration for the B Complex and B Plant plumes between 2015 and 2019.

Three other sources contribute to local nitrate plumes in the southern half of 200-BP: (1) unplanned releases associated with the 216-B-2 Ditches, (2) unplanned releases associated with the C Tank Farm, and (3) Gable Mountain Pond. The southern extent of the 200-BP nitrate plume merges with the 200-PO plume (discussed in Chapter 10).

9.2.1 B Complex

This section describes the groundwater nitrate concentration changes between 2015 and 2019 at the B Complex. The comparison between 2015 and 2019 provides pre-groundwater extraction conditions and current conditions after the removal of 285,774 kg of nitrate. In addition, remnant plumes to the north-northwest and plumes to the east and southeast of the B Complex are discussed.

In 2019, six B Complex wells remain with nitrate concentrations >450 mg/L. The average concentration decline since 2015 at these six wells is 37% (Table 9-2). Between 2015 and 2019, concentrations declined below 450 mg/L beneath the BY Cribs, the BX Tank Farm, and portions of the B and BY Tank Farms.

North of extraction well 299-E33-360, in well 299-E33-39, nitrate concentrations declined below 450 mg/L for the first time since mid-2011, when the groundwater flow direction changed from northwest to southeast (421 mg/L in December 2019). Just north and upgradient of well 299-E33-39, new well 699-47-53B was installed in 2019. The concentration was 237 mg/L in a groundwater sample collected after well 699-47-53B was developed. The lower nitrate concentration at well 699-47-53B suggests that the concentration at well 299-E33-39 should continue to decrease. However, if continued high variable concentrations at well 299-E33-39 persist, the higher concentrations will be evidence of a continued nitrate flux from the BY Cribs vadose zone.

Table 9-2. Change in Nitrate Concentrations in B Complex Wells, 2015–2019

Well	Average 2015 Nitrate Concentration (mg/L)	Average 2019 Nitrate Concentration (mg/L)	Percent Change Between 2015 and 2019
299-E33-15	1,150	664	-42.3
299-E33-17	1,280	717	-44.0
299-E33-20	798	545	-31.7
299-E33-38	663	373	-43.7
299-E33-44	1,118	854	-23.6
299-E33-47	1,296	830	-36.0
		Average	**-36.9**

Nitrate concentrations exceed the DWS in six wells north-northwest of the B Complex (Figure 9-5; Table 9-3). Nitrate concentrations decreased by an average of 4.4% in those six wells between 2015 and 2019 (Table 9-3). The greatest decrease was in well 699-49-57A (33.9%). Farther north, concentrations have not changed significantly (±10% in wells 699-50-56, 699-53-55B, and 699-55-57).

Groundwater nitrate concentrations east of the B Complex decreased an average of 26% between fall 2018 and fall 2019 (Table 9-4). Nitrate concentrations in November 2018 were at or near a historical high concentration at wells 299-E27-19, 299-E34-8, and 299-E34-10 (Figure 9-6). The increasing nitrate in 2018 suggested that these wells may be outside of the capture zone of extraction well 299-E33-360 (Figure 9-5). Well 299-E33-361 was connected to the 200 West P&T and started extracting at 189 L/min (50 gal/min) in April 2019 to ensure declining concentrations throughout the year.

Wells to the west and southwest of the B Complex continue to show decreasing nitrate concentrations due to groundwater flowing into the 200 East Area from the northwest and groundwater capture by extraction well 299-E33-360 (Figure 9-5).

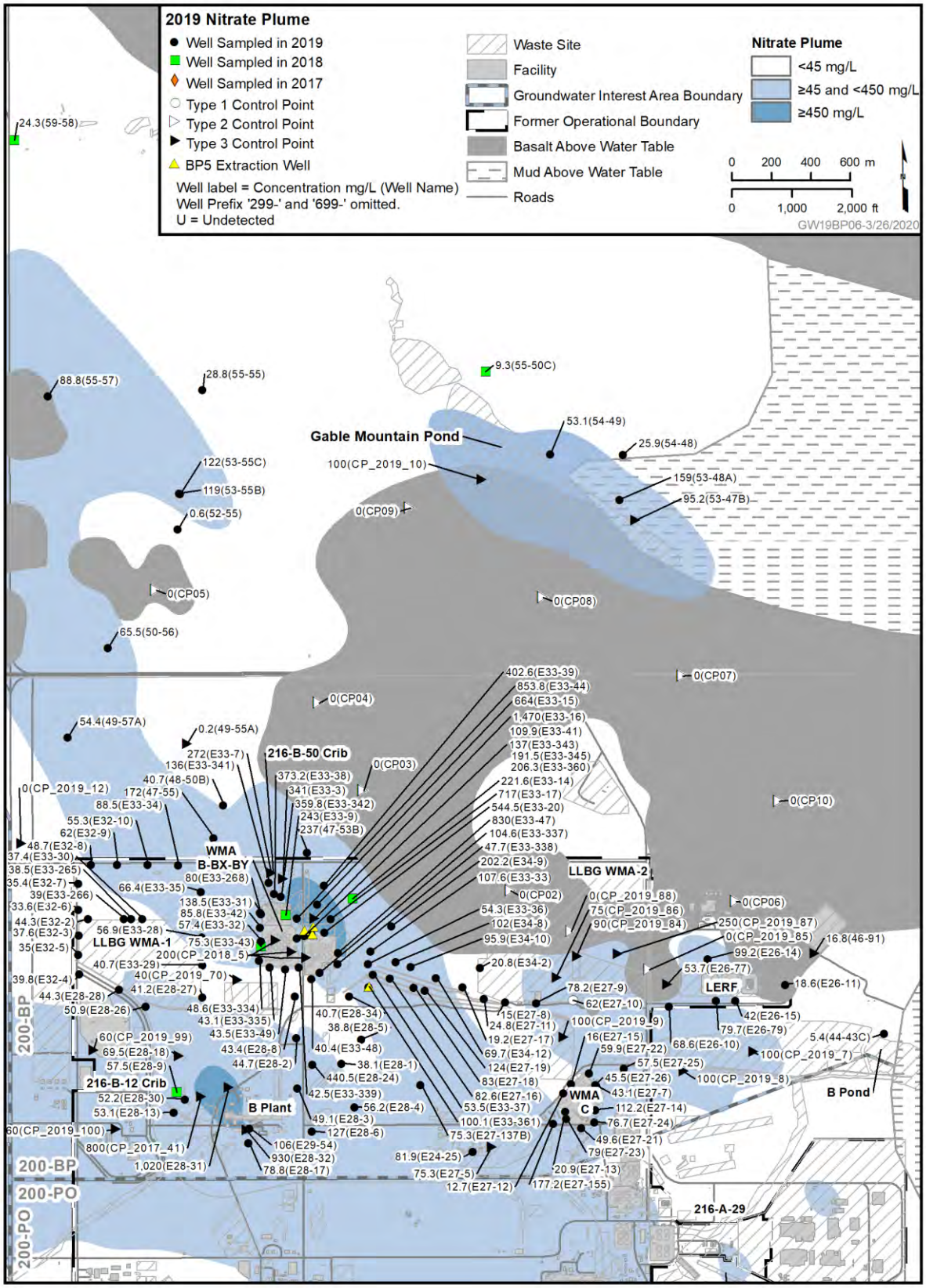


Figure 9-5. 200-BP Nitrate Plume, 2019

Table 9-3. Change in Nitrate Concentrations in Wells North of 200 East Area to Gable Gap, 2015–2019

Wells	Average 2015 Nitrate Concentration (mg/L)	Average 2019 Nitrate Concentration (mg/L)	Percent Change Between 2015 and 2018
699-48-50B	32.5	40.7	+25.2
699-49-57A	82.3	54.4	−33.9
699-50-56	73	65.5	−10.3
699-53-55B	131	119	-9.2
699-53-55C	140	122	−1.6
699-55-57	86*	88.5	+3.3
		Average	**−4.4**

*Average of nitrate results from April 20, 2014, and April 15, 2016.

Table 9-4. Change in Nitrate Concentrations in Wells East of B Complex, Fall 2018 Through Fall 2019

Wells	Fall 2018 Nitrate Concentration[a] (mg/L)	Fall 2019 Nitrate Concentration[b] (mg/L)	Percent Change Between Fall 2018 and Fall 2019
299-E27-19	151	115	-23.8
299-E34-8	133	93	-30.1
299-E34-9	239	157	-34.3
299-E34-10	115	96.5	-16.1
		Average	**-26.1**

a. Nitrate concentration for the identified well from November 2018.

b. Nitrate concentration for the identified well from November 2019.

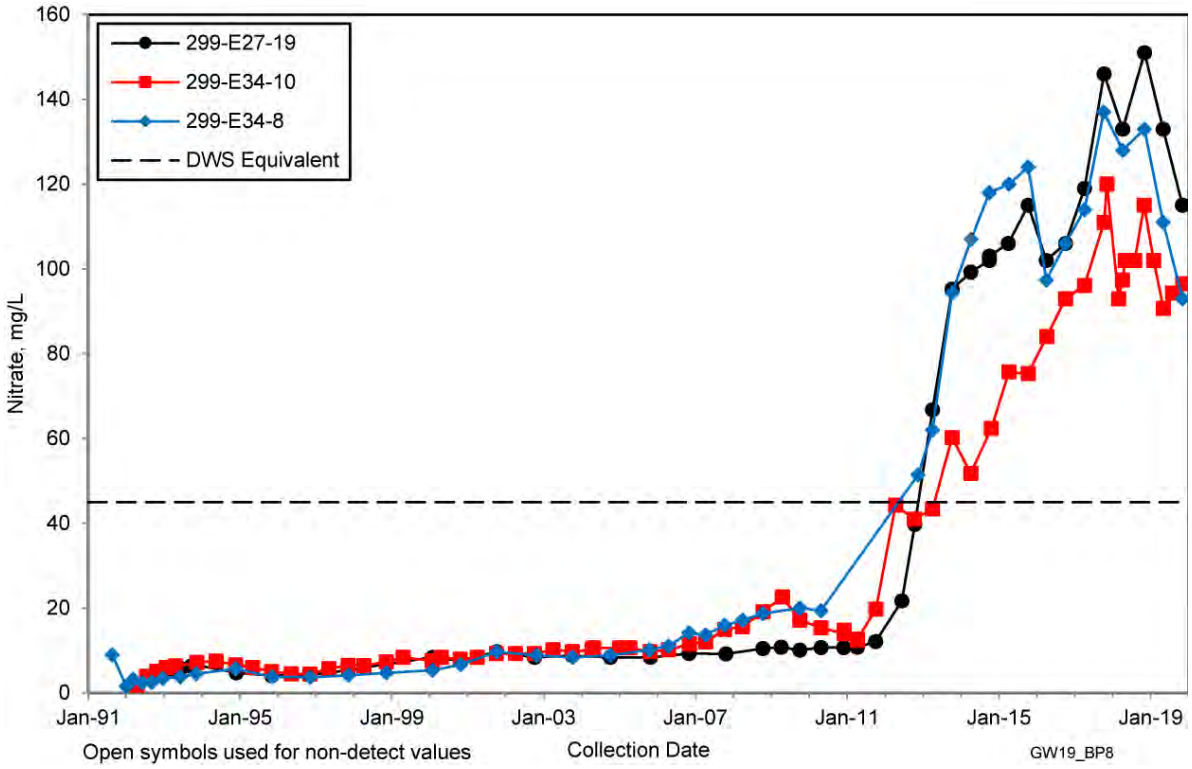


Figure 9-6. 200-BP Nitrate Data in Wells East of the B Complex

9.2.2 B Plant

At B Plant, the main nitrate source was the 216-B-12 Crib, where nitrate concentrations in the upper part of the unconfined aquifer are currently <60 mg/L. Concentrations are much higher within the low-permeability semiconfined aquifer associated with hydrostratigraphic units 9B and 9C. The deep plume presumably developed during active liquid discharges of uranium recovery waste at the 216-B-12 Crib (1952 through 1957), when 371 million L (98 million gal) of liquid waste were discharged containing nearly 3 million kg of nitrate.

A nitrate region with concentrations >450 mg/L is defined near the 216-B-12 Crib (Figure 9-5). The extent of the deep plume near the 216-B-12 Crib is currently defined by wells 299-E28-31 and 299-E28-32, which were installed in 2015 and are screened 12 to 20 m (39 to 66 ft) below the water table. In 2017 (the last time wells 299-E28-31 and 299-E28-32 were sampled), nitrate concentrations were 1,020 and 930 mg/L, respectively. Section 9.2.2 in DOE/RL-2016-67 provides additional information about the distribution of nitrate with depth.

9.2.3 216-B-2 Ditches, Trench 94, and Liquid Effluent Retention Facility

Nitrate concentrations near the 216-B-2 Ditches, Trench 94 (LLBG WMA-2), and the Liquid Effluent Retention Facility (LERF), located in the northeast corner of the 200 East Area, have continued to increase since the mid-1990s (Figure 9-7). The vadose zone soils were affected by unplanned releases beneath and north of the 216-B-2 Ditches, as described in previous annual reports (Section 9.2.3 in DOE/RL-2016-67; Section 9.1.10.3 in DOE/RL-2011-01). In addition, unplanned releases apparently from the 216-A-25 pipeline have affected vadose zone soils just east of Trench 94. It appears that these releases migrated to groundwater near well 299-E34-7 in the mid-1990s, causing increases in nitrate and other constituents (e.g., sulfate and total organic carbon [TOC]). Based on the continued nitrate

concentration increases in wells to the south-southwest (299-E27-8, 299-E27-9, and 299-E27-10) and south-southeast (299-E26-10, 299-E26-14, 299-E26-15, and 299-E26-79), it appears that the nitrate migrates both south-southeast and south-southwest near the southeast corner of Trench 94.

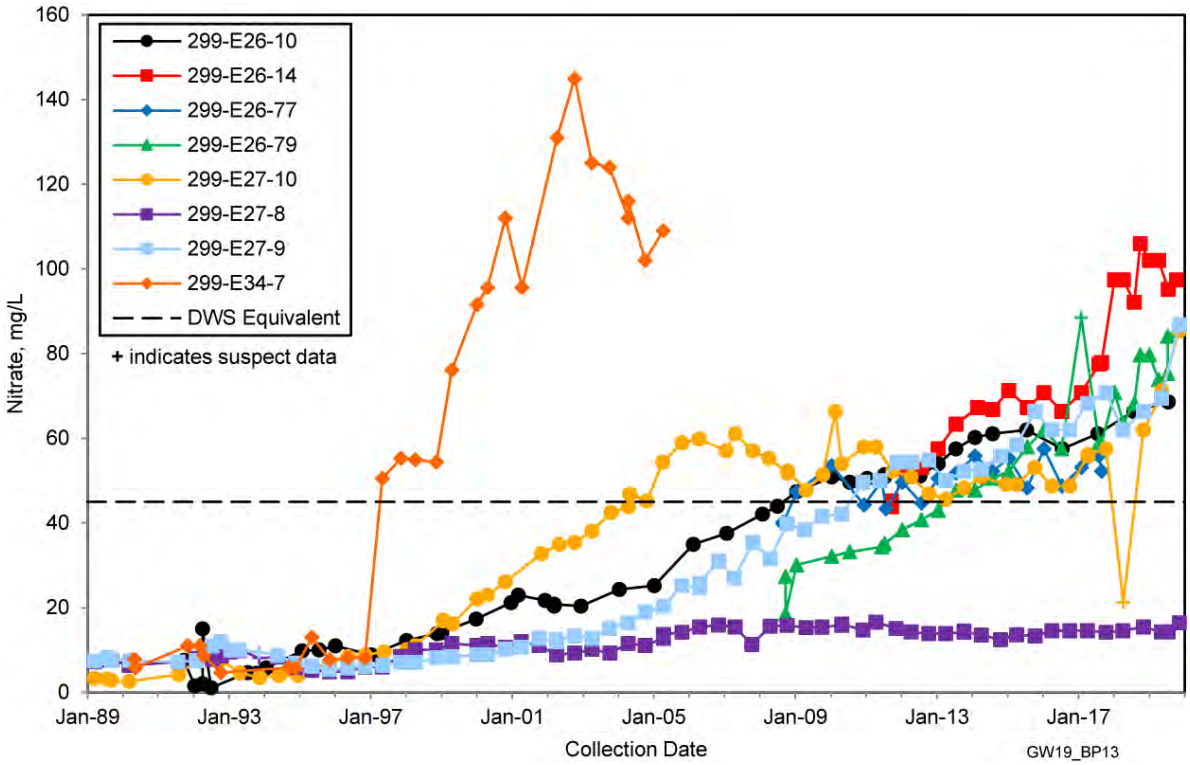


Figure 9-7. 200-BP Nitrate Data for Wells Beneath the 218-E-12B Burial Grounds, Trench 94, and LERF

9.2.4 Waste Management Area C

Nitrate concentrations in the lower part of the aquifer and migrating from the B Complex toward WMA C well 299-E27-155 (Section 9.2.3 in DOE/RL-2018-66) declined during 2019 (Figure 9-8). Nitrate concentrations at well 299-E27-155 decreased from 193 to 159 mg/L in 2019. Upgradient to the northwest at new monitoring well 299-E27-137B (screened in the lower part of the aquifer), nitrate concentrations were 75.3 mg/L in December 2019. The 2019 nitrate concentration trend at well 299-E27-155, along with the single sample at well 299-E27-137B, indicates that nitrate concentrations at well 299-E27-155 may continue to decline.

Nitrate concentrations along the west side of WMA C at well 299-E27-23 may be beginning to decline (Figure 9-8). Chapter 9 in DOE/RL-2018-66 describes how the advancing B Complex nitrate plume had begun to change the technetium-99-to-nitrate signature in 2018 at well 299-E27-23 (e.g., between December 2017 and December 2018, the technetium-99-to-nitrate signature decreased from 290 to 166). The nitrate concentrations at well 299-E27-23 continued to increase while the technetium-99 declined, and by June 2019 the technetium-99-to-nitrate signature decreased 137. However, in September and December 2019, the technetium-99 concentration increased while nitrate concentration dropped to 69.9 mg/L. This well appears to define the east boundary of the advancing deep B Complex nitrate plume.

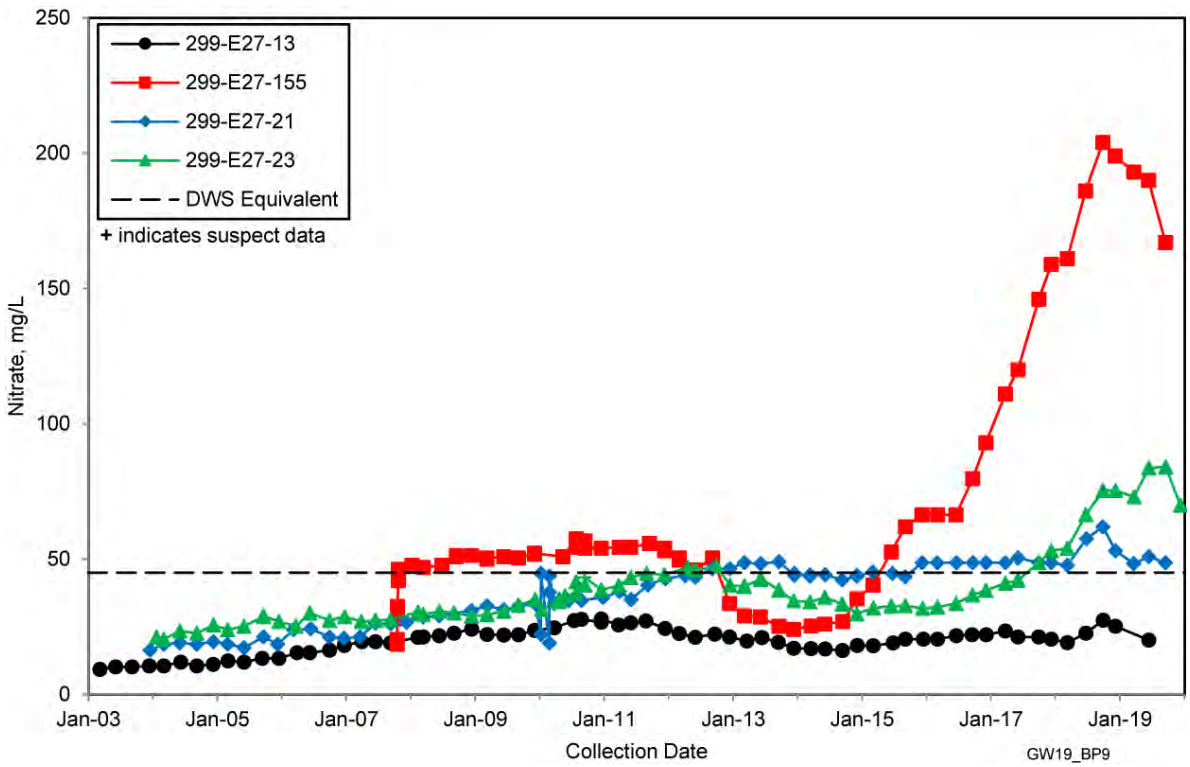


Figure 9-8. 200-BP Nitrate Data in WMA C Wells

In 2019, nitrate concentrations continued to increase at the WMA C upgradient wells 299-E27-12 and 299-E27-22 (Figure 9-9). The nitrate increase is linked to continued nitrate migration from the 216-B-2 Ditches (Section 9.2.3). Nitrate concentrations at well 299-E27-22 increased to 66.4 mg/L by December 2019. Nitrate concentrations in downgradient well 299-E27-14 are higher than in upgradient wells 299-E27-12 and 299-E27-22 (Figure 9-9). Concentrations at well 299-E27-14 increased to 133 mg/L in September 2019 before declining to 112 mg/L in December 2019. The variable nitrate concentrations at well 299-E27-14 may indicate flux changes in nitrate entering the groundwater beneath WMA C.

The B Complex and WMA C nitrate plumes extend into 200-PO at WMA A-AX (Figure 9-10). An interim ROD is being pursued for remediation and containment of technetium-99 in groundwater at the C Tank Farm. Upon completion of the interim ROD, an extraction well downgradient of WMA C and WMA A-AX will be connected to the 200 West P&T, and nitrate concentrations in these areas are expected to decline.

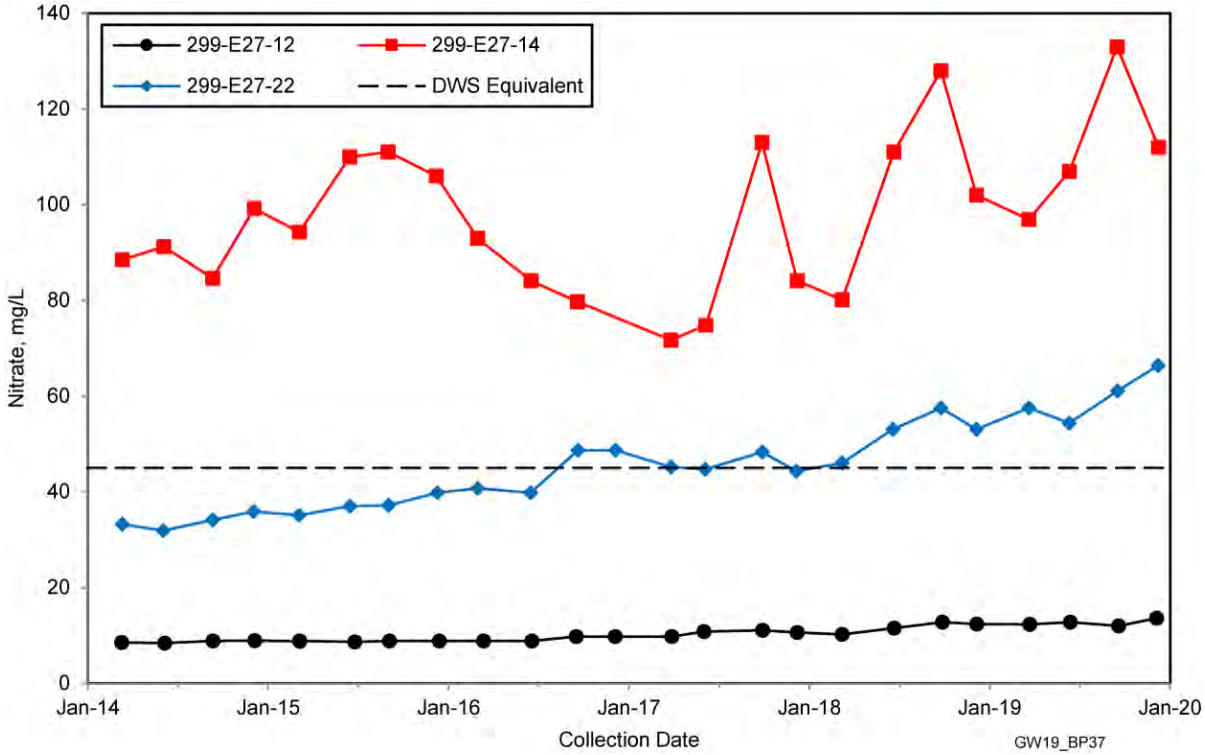


Figure 9-9. 200-BP Nitrate Data Comparison Between Upgradient and Downgradient WMA C Wells

9.2.5 Gable Mountain Pond

The nitrate plume exceeding the DWS beneath the east half of the former Gable Mountain Pond is located within a thin, narrow, saturated channel of Hanford formation gravels bounded by the Ringold mud unit and Elephant Mountain basalt. Beneath the western half of the former Gable Mountain Pond, the saturated Hanford formation gravels thicken and widen while the Ringold mud unit is interpreted to pinch out. As the nitrate plume extends to the west-northwest toward well 699-55-50C, nitrate concentrations decrease to a quarter of the DWS.

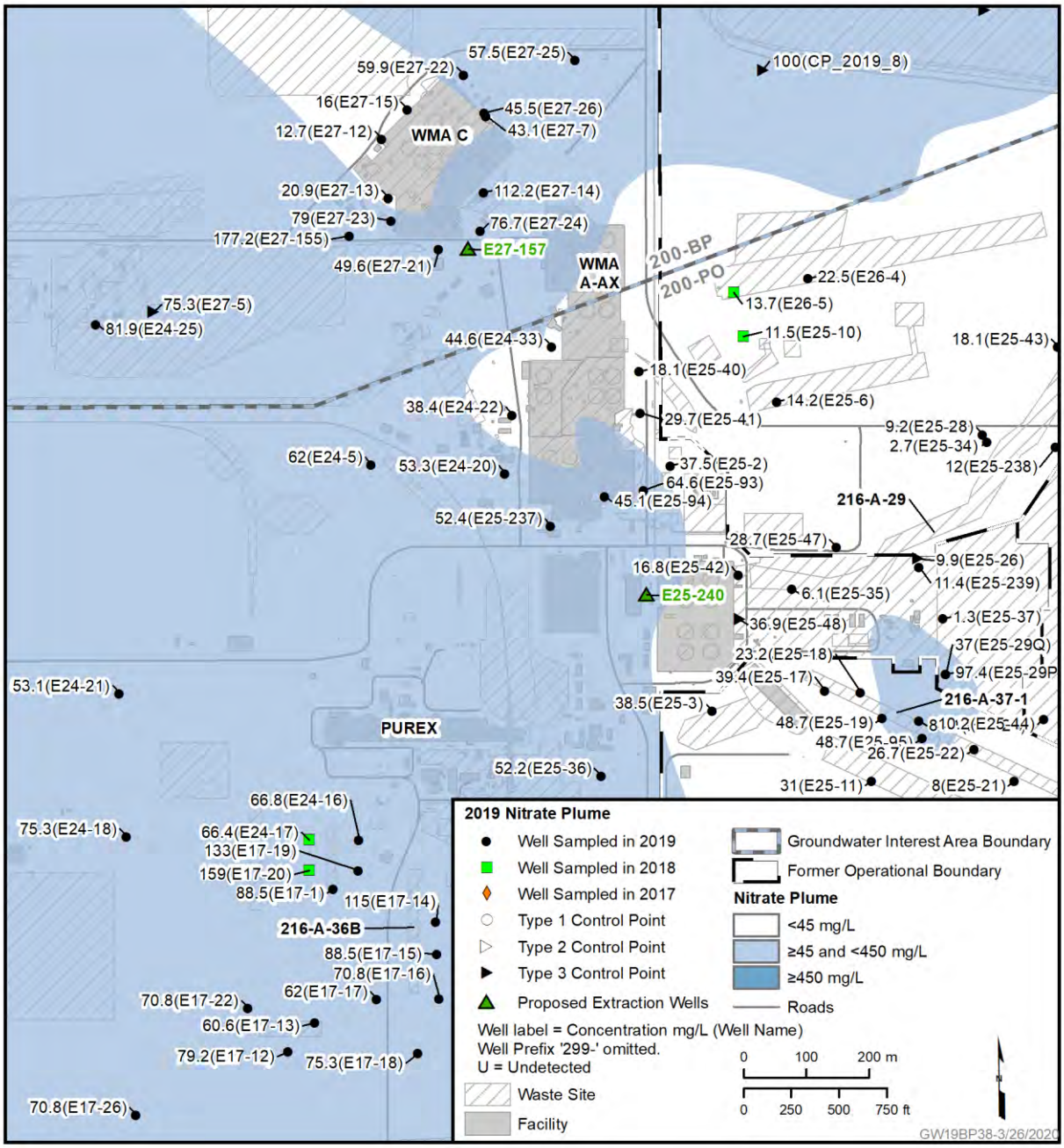


Figure 9-10. 200-BP Nitrate Plume at the A-AX and C Tank Farms and Proposed Extraction Well Locations

9.3 Iodine-129

An iodine-129 plume with concentrations above the 1 pCi/L DWS covers an area from Gable Gap southeast into the 200-PO groundwater interest area (Figure 9-11). The majority of the iodine-129 plume migrated northward from 200-PO into the southern portion of 200-BP beginning in the 1980s (Section 4.4.3 in DOE/RL-2009-127). Possible contributing sources in 200-BP include the 216-B-2 Ditches and B Complex waste sites.

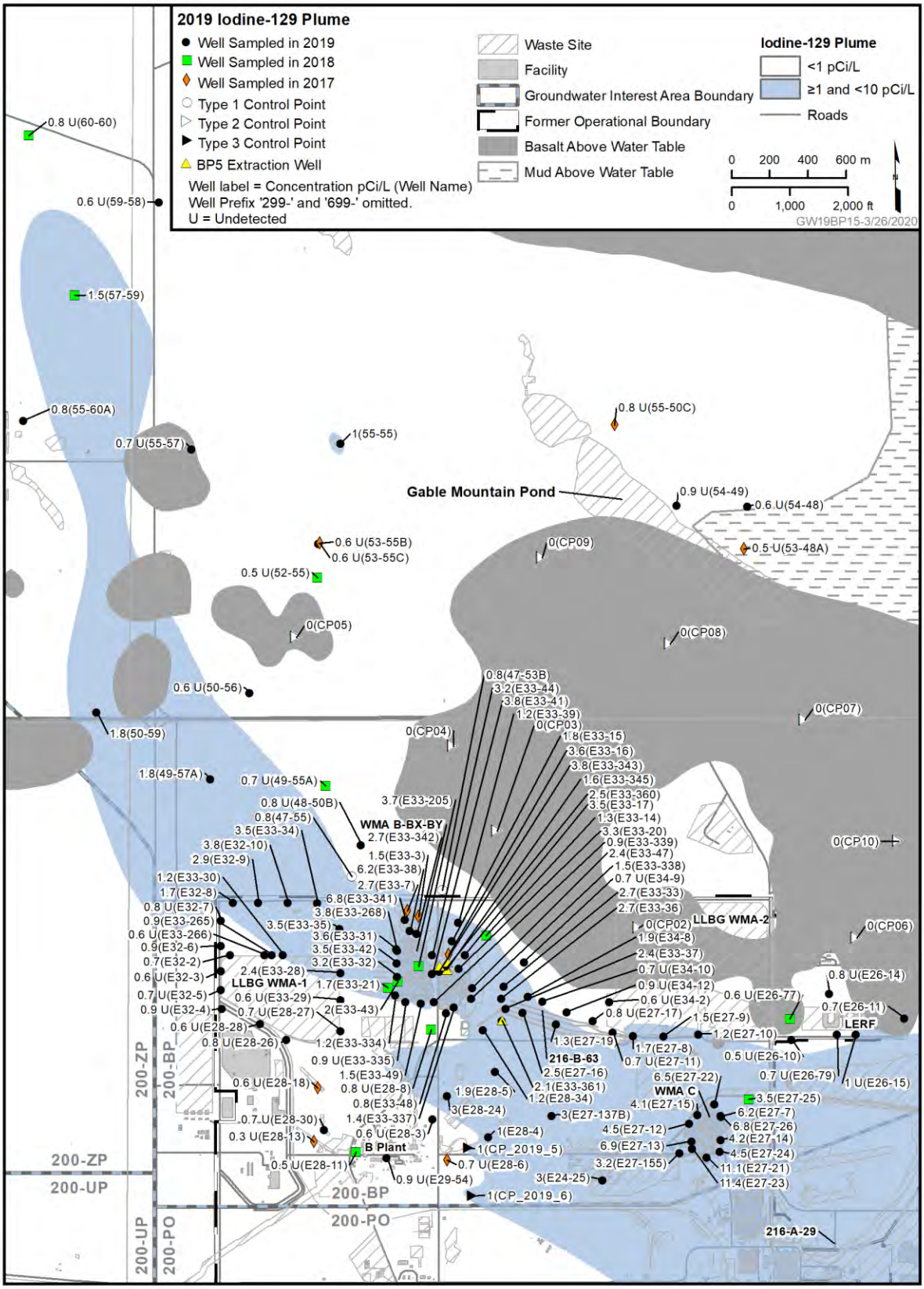


Figure 9-11. 200-BP Iodine-129 Plume, 2019

In general, iodine-129 concentrations within the affected 200-BP monitoring network have declined since the 1990s but often show moderate fluctuations from year to year. The most significant iodine-129 concentration declines are seen on the periphery of the plume boundary (Table 9-5). The main exceptions to declining iodine-129 concentrations are at wells near the southern 200-BP boundary, which show variable concentrations. Iodine-129 concentrations at WMA C are generally highest in the upgradient wells, suggesting a source to the north. An interim ROD is being completed for remediation and containment of technetium-99 in groundwater in this area. Upon completion of the interim ROD, an extraction well will be drilled south of WMA C and connected to the 200 West P&T. As a result of the interim action, iodine-129 concentrations are expected to decline at WMA C.

Table 9-5. Iodine-129 Concentration Declines in Wells Near the Current 1 pCi/L Contour

Well	Maximum Iodine-129 Concentration (pCi/L, Year)	2019 Iodine-129 Concentration (pCi/L)	Percent Change
299-E27-10	7.22, 1995	1.44	-80
299-E27-18	6.20, 1996	<0.28	-95.5
299-E28-8	3.45, 2011	0.42	-88
299-E28-25	3.66, 1994	0.96	-74
299-E32-8	4.76, 1997	1.98	-58.5
299-E33-29	4.93, 1995	0.45	-91
699-50-59	3.99, 2008	1.8	-55

9.4 Technetium-99

Technetium-99 in 200-BP groundwater (Figure 9-12) is primarily associated with past discharge sites and unplanned releases of liquid scavenged waste. The scavenging process was used in the 1950s to precipitate cesium-137 and strontium-90 from uranium-recovery and first-cycle decontamination liquid waste before disposing the liquid to the soil column. Calculation of the mass of technetium-99 within the B Complex groundwater plume suggested that a small portion of the total inventory discharged to the soil column had migrated into the groundwater (6.1 Ci; p. 6.3 in PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*). The technetium-99 discharge to the BY Cribs alone was approximately 130 Ci (RPP-26744). As a result, technetium-99 continues to migrate into the aquifer at the B Complex. At WMA C, recent groundwater flow and transport modeling indicated technetium-99 releases will continue to affect groundwater at concentrations exceeding 900 pCi/L until sometime between 2040 and 2060 (Figure 6-4 in RPP-RPT-59197, *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington*).

Sections 9.4.1, 9.4.2, and 9.4.3 discuss contaminant distribution changes for the B Complex, Gable Gap, and WMA C plumes between 2015 and 2019.

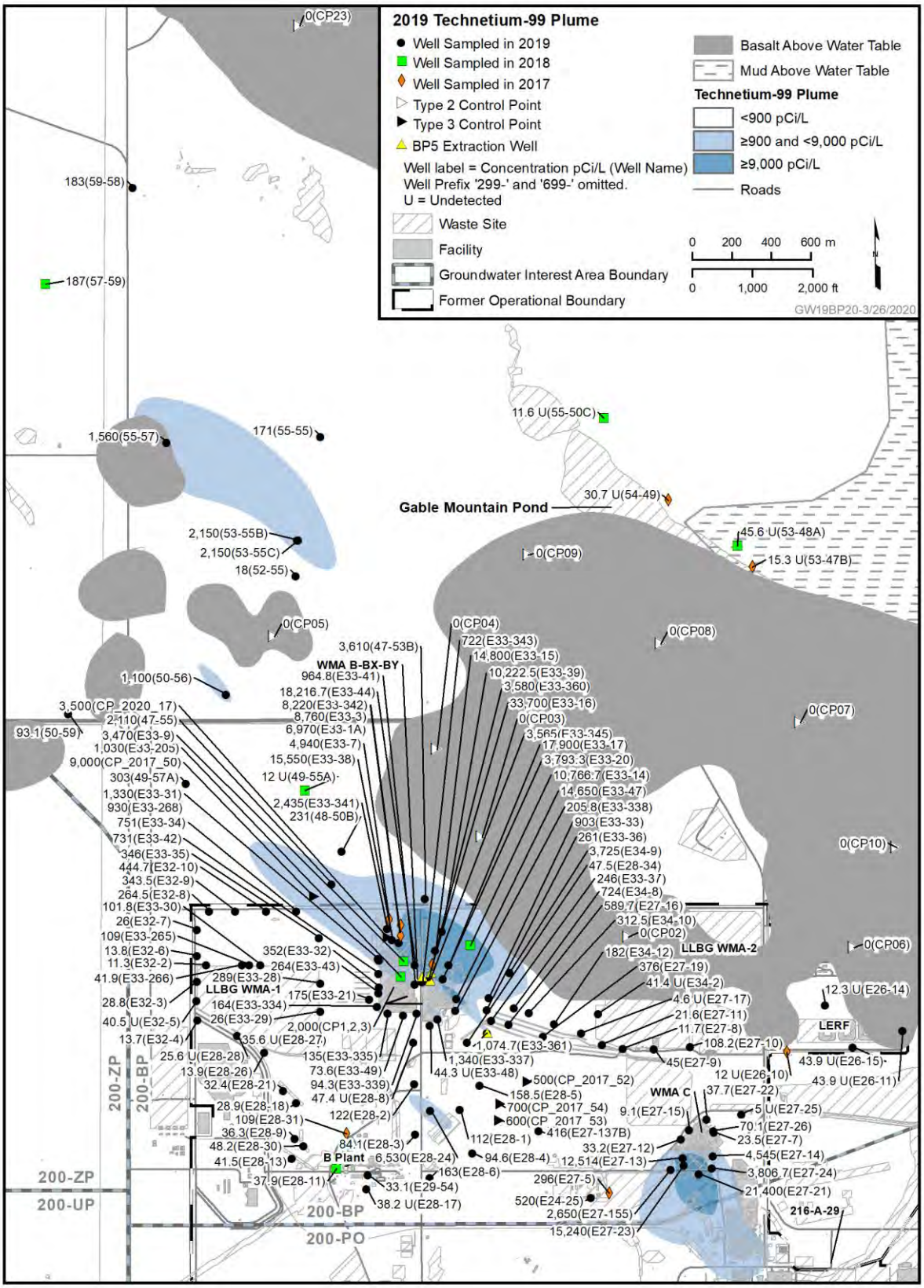


Figure 9-12. 200-BP Technetium-99 Plume, 2019

9.4.1 B Complex

The B Complex technetium-99 plume extends to the northwest and southeast (Figure 9-12). Groundwater extraction from 2015 through 2019 at the B Complex has removed 5.3 Ci of technetium-99, which has led to a reduction in concentrations and plume size. Table 9-6 shows that technetium-99 concentrations within the plume exceeding 10 times the DWS have decreased by an average of 35%, while technetium-99 concentrations to the northwest, southeast, and west of this plume have decreased by an average of 75%. Continued groundwater technetium-99 concentrations near or exceeding 10 times the DWS are observed at wells 299-E33-15, 299-E33-39, and 299-E33-44, downgradient of liquid scavenged waste discharge sites (e.g., BY Cribs) or unplanned liquid releases (e.g., BY Tank Farm) that contained significant inventories of technetium-99. Wells to the west (upgradient of these source sites) have shown much lower technetium-99 concentrations for years. The lower technetium-99 concentrations upgradient and the higher technetium-99 concentrations downgradient of the source sites indicate continuing groundwater impacts from these release sources. Figure 9-13 shows the 2015 through 2019 technetium-99 trends of the wells inside the 2019 DWS plume and the difference in plume sizes for 2015 and 2019.

Table 9-6. Change in Technetium-99 Concentration in Selected B Complex Wells, 2016–2019

Well	2016 Technetium-99 Concentration (pCi/L)	2019 Technetium-99 Concentration (pCi/L)	Percent Change	Well Location Within Technetium-99 Plume
299-E33-15	23,500	14,800	-37	Within plume >9,000 pCi/L
299-E33-17	25,100	17,900	-29	Within plume >9,000 pCi/L
299-E33-20	7,760	2,050	-74	Southeast of the plume >9,000 pCi/L
299-E33-31	9,030	1,140	-87	West of the plume >9,000 pCi/L
299-E33-39	15,900	9,900	-38	Within plume >9,000 pCi/L
299-E33-44	25,900	18,000	-31	Within plume >9,000 pCi/L
299-E33-341	7,980	2,830	-65	Northwest of the plume >9,000 pCi/L
Average technetium-99 concentration decline			**-35**	**Within plume >9,000 pCi/L**
			-75	**Outside plume >9,000 pCi/L**

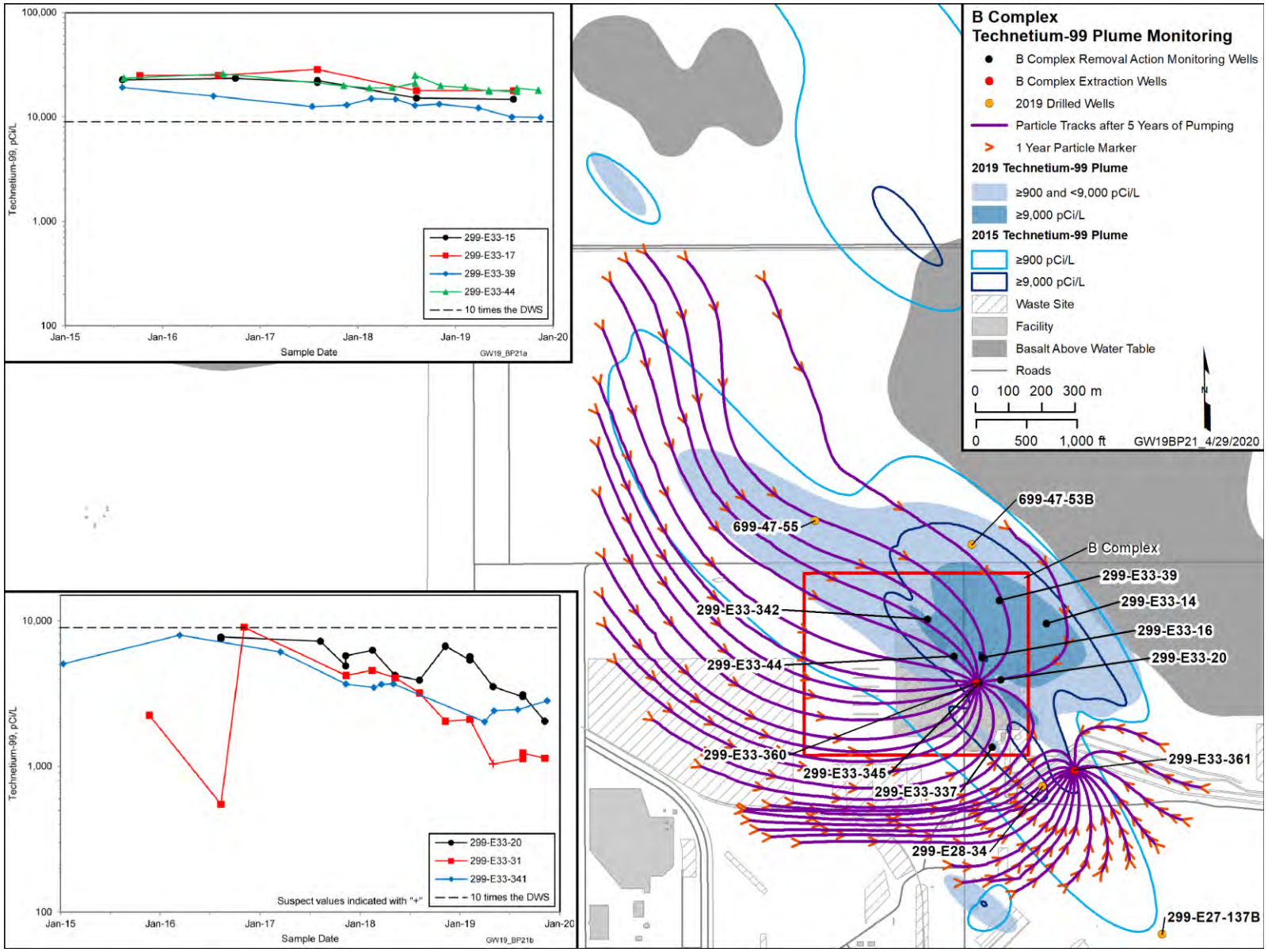


Figure 9-13. 200-BP Comparison of 2015 and 2019 Technetium-99 Plumes at B Complex

9.4.2 Gable Gap

The Gable Gap technetium-99 plumes are an extension of previous migration of technetium-99 from the B Complex (Figure 9-12). Two different flow conditions define how technetium-99 concentrations have changed since 2010 north of the 200 East Area.

The first flow condition is demonstrated by technetium-99 concentration trends from wells 699-49-57A and 699-50-59, which last exceeded the DWS in 2013 and 2011, respectively (Figure 9-14). The technetium-99 concentration decline in these two wells averaged 59% between 2013 and 2019 (Table 9-7). The high rate of technetium-99 concentration decline indicates migration from areas of lower concentration. The flow direction is southeast at these wells, toward the groundwater extraction wells at the B Complex.

The second Gable Gap groundwater flow condition is demonstrated by technetium-99 concentration changes at wells 699-50-56, 699-53-55B, 699-53-55C, and 699-55-57 (Figure 9-14). These four wells are aligned near a double plunging anticlinal fold, as discussed in Section 3 of RHO-BWI-ST-4, *Geologic Studies of the Columbia Plateau A Status Report*. Groundwater technetium-99 concentrations in these four wells were similar to wells 699-49-57A and 699-50-59 in 2011 to 2013 but have not changed significantly since that time. Between 2013 and 2019, these four wells have only averaged an 11% decrease in concentration (Table 9-8). The concentration decline indicates a low groundwater flow rate, where dispersion maybe the dominant transport mechanism.

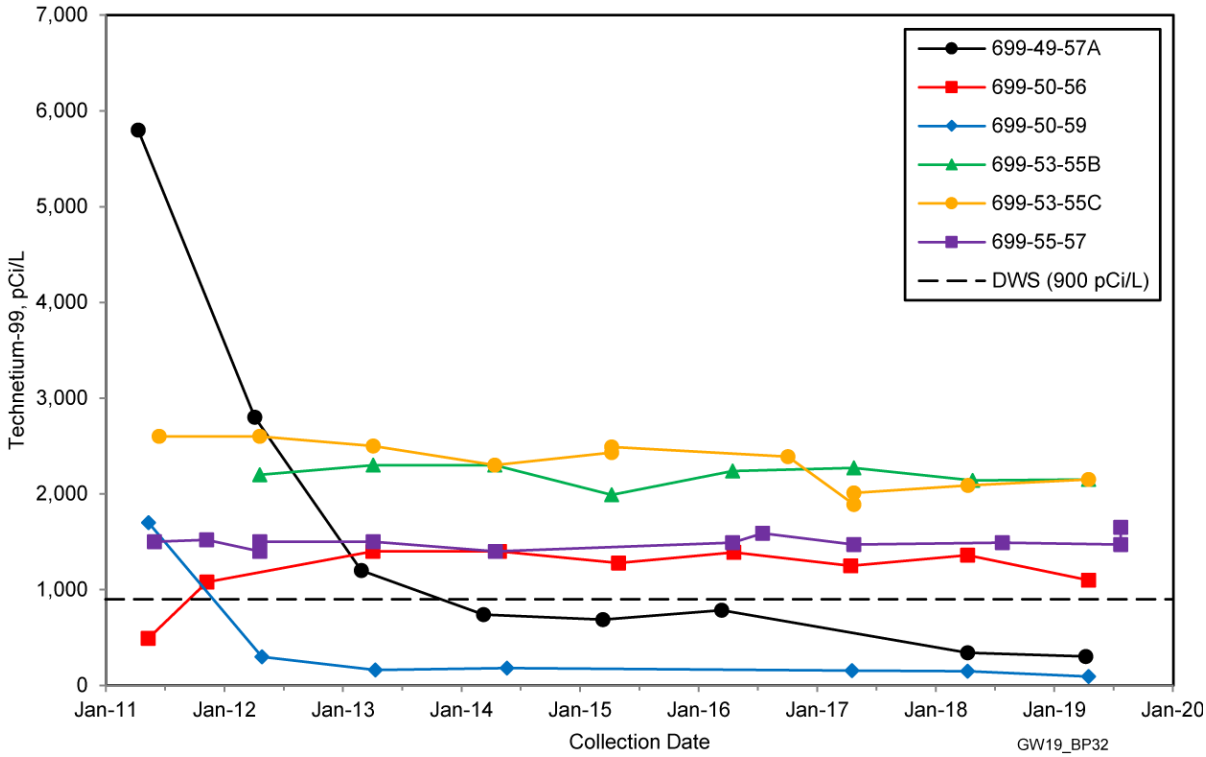


Figure 9-14. 200-BP Technetium-99 Data in Gable Gap Wells

Table 9-7. Change in Technetium-99 Concentration at Wells 699-49-57A and 699-50-59, 2013–2019

Well	2013 Technetium-99 Concentration (pCi/L)	2019 Technetium-99 Concentration (pCi/L)	Percent Change
699-49-57A	1,200	303	-75
699-50-59	160	93.1	-42
		Average	**-59**

Table 9-8. Change in Technetium-99 Concentration at Four Gable Gap Wells, 2013–2019

Well	2013 Technetium-99 Concentration (pCi/L)	2019 Technetium-99 Concentration (pCi/L)	Percent Change
699-50-56	1,400	1,100	-21
699-53-55B	2,300	2,150	-7
699-53-55C	2,500	2,150	-14
699-55-57	1,500	1,470	-2
		Average	**-11**

9.4.3 Waste Management Area C

Continuous technetium-99 contributions to the groundwater from previous WMA C unplanned releases are demonstrated by fluctuating high technetium-99 concentrations at three downgradient wells: 299-E27-14, 299-E27-21, and 299-E27-23 (Figure 9-15). Between 2016 and 2019, technetium-99 concentrations at these three wells ranged between 8,760 to 13,270 pCi/L (Table 9-9). Technetium-99 concentrations deeper in the aquifer show less fluctuation, with a concentration ranging between 1,690 and 1,940 pCi/L for wells 299-E27-24 and 299-E27-155, which are screened at the bottom of the 15 m (50 ft) thick aquifer (Table 9-9). Based on chemical signature similarities at both the WMA C and WMA A-AX wells, the WMA C technetium-99 plume currently extends through the southern part of WMA A-AX. DOE plans to install an extraction well at WMA C to reduce and contain technetium-99 in groundwater. Another extraction well is planned at WMA A-AX in the 200-PO groundwater interest area.

Technetium-99 concentrations in the lower part of the aquifer are monitored by well 299-E27-155 and new well 299-E27-137B. Concentrations increased in well 299-E27-155 between 2015 and 2019. Well 299-E27-137B was installed in 2019 to investigate the vertical extent of technetium-99 within the aquifer between the B Complex and well 299-E27-155 (Figure 9-16). Technetium-99 concentrations from the new well varied from 3,570 pCi/L (sampled from the bottom of the aquifer during drilling) to 1,370 pCi/L (after well development) to 416 pCi/L (first routine sample). A low-flow pump will be installed with its intake near the bottom of the lower screened interval for future quarterly sampling events at well 299-E27-137B.

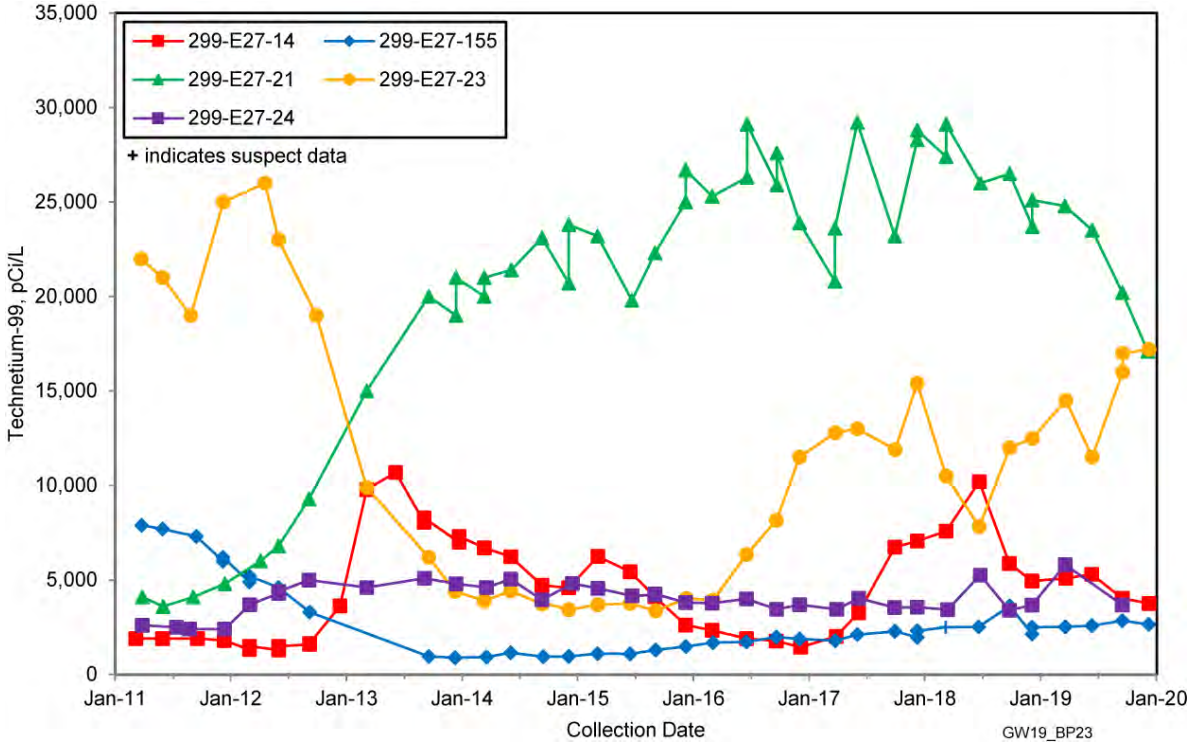


Figure 9-15. 200-BP Technetium-99 Data in WMA C Wells

Table 9-9. Technetium-99 Concentrations at Five WMA C Wells, 2016–2019

Sample Date	299-E27-14 (pCi/L)	299-E27-21 (pCi/L)	299-E27-23 (pCi/L)	299-E27-24 (pCi/L)	299-E27-155 (pCi/L)
3/1/2016	2,340	25,300	3,930	3,780	1,690
6/17/2016	1,900	29,100	6,350	4,000	1,720
9/19/2016	1,770	27,600	8,150	3,450	1,980
12/5/2016	1,440	23,900	11,500	3,700	1,880
3/27/2017	2,020	23,600	12,800	3,450	1,790
6/6/2017	3,270	29,200	13,000	4,030	2,120
9/28/2017	6,740	23,200	11,900	3,550	2,290
12/8/2017	7,070	28,300	15,400	3,570	2,310
3/9/2018	7,590	29,100	10,500	3,430	2,500
6/22/2018	10,200	26,000	7,830	5,260	2,520
9/25/2018	5,870	26,500	12,000	3,400	3,630
12/6/2018	4,950	25,100	12,500	3,670	2,500
3/22/2019	5,090	24,800	14,500	5,810	2,520
6/12/2019	5,300	23,500	11,500	1,940	2,580
9/17/2019	4,040	20,200	17,000	3,670	2,850
12/10/2019	3,750	17,100	17,200	Rejected	2,650
Maximum	**10,200**	**29,200**	**17,200**	**5,810**	**3,630**
Minimum	**1,440**	**17,100**	**3,930**	**1,940**	**1,690**
Range	**8,760**	**12,100**	**13,270**	**3,870**	**1,940**
Average	**4,584**	**25,245**	**11,886**	**3,781**	**2,311**

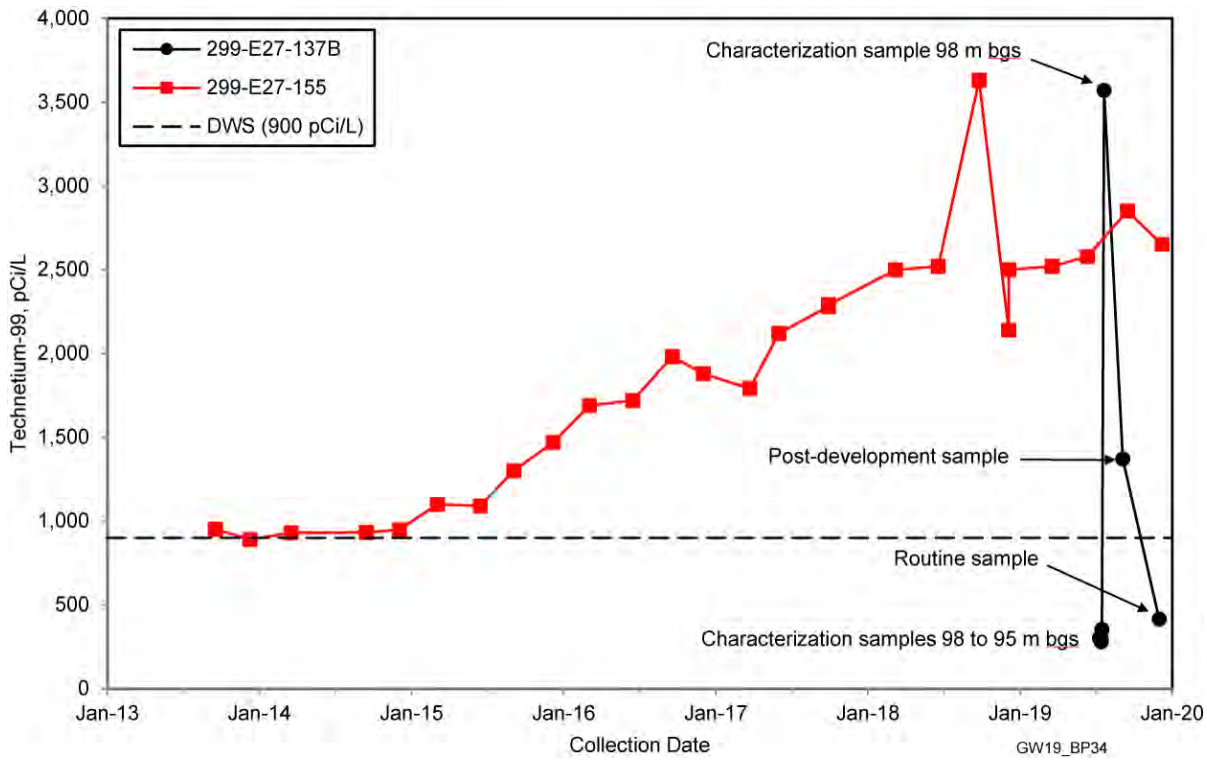


Figure 9-16. 200-BP Technetium-99 Data in Wells 299-E27-137B and 299-E27-155

9.5 Uranium

Uranium contamination in 200-BP is associated with two sources: (1) a 1951 unplanned release of liquid metal waste from tank 241-BX-102 in the B Complex, and (2) the liquid waste discharge of uranium-recovery process condensate from 1952 to 1957 at the 216-B-12 Crib (west of B Plant) (Figure 9-2). The uranium inventory associated with each of these releases was >10,000 kg (Appendix C of RPP-26744). The tank 241-BX-102 source impacted a thin perched horizon, as well as the thin unconfined aquifer at 3.1 m (10 ft) below the perched water aquifer. Uranium contamination is concentrated in the perched water aquifer, which is up to 3.7 m (12 ft) thick and acts as a source of groundwater contamination near and beneath the B and BX Tank Farms. The 200-DV-1 OU is addressing remedy selection for the perched water aquifer (Section 9.8.2). A 200-BP groundwater removal action is addressing the uranium in the unconfined aquifer beneath the perched water aquifer (Section 9.8.1). The 216-B-12 Crib is monitored by downgradient well 299-E28-30 and shows no contributions of uranium contamination to groundwater at this time. Sections 9.5.1 and 9.5.2 provide further discussion of the two uranium plumes.

9.5.1 B Complex

The uranium plume sourced by the 241-BX-102 tank release extends northwest and southeast of WMA B-BX-BY (Figure 9-17). Groundwater extraction reduced the uranium concentration by an average of 29% in 6 of the 12 wells monitored within the B Complex uranium plume in 2019 (Table 9-10). Figure 9-18 shows the 2015 through 2019 uranium trends for wells inside the 2019 DWS plume and a comparison of the 2015 and 2019 plume extents.

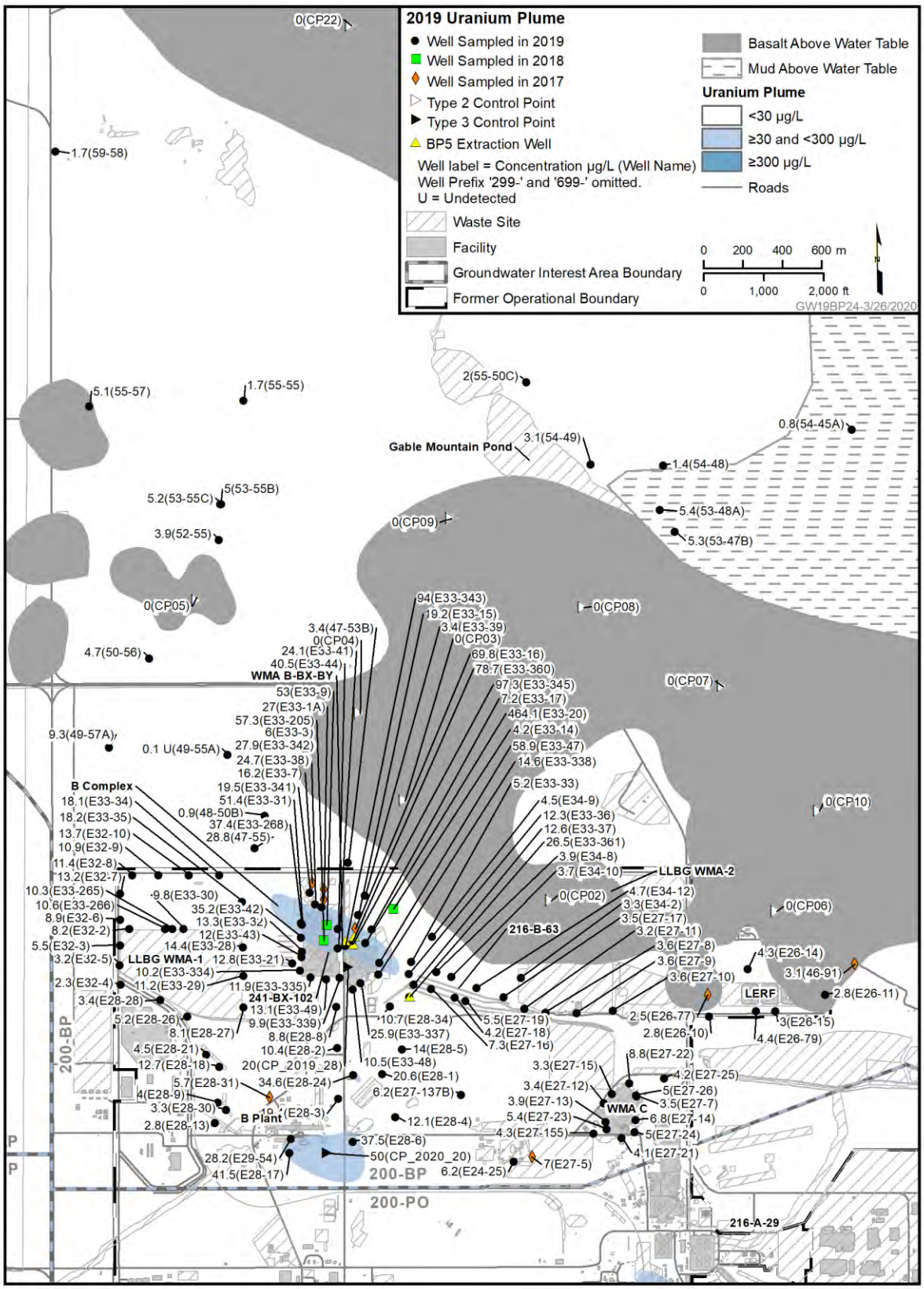


Figure 9-17. 200-BP Uranium Plume, 2019

Table 9-10. Change in Uranium Concentration at Selected B Complex Wells in 2019

Well	February 2019 Unfiltered Uranium Concentration (µg/L)	November 2019 Unfiltered Uranium Concentration (µg/L)	Percent Change
299-E33-20	641	303	-53
299-E33-31	65.5	38.5	-41
299-E33-42	39.7	23.6	-41
299-E33-44	42.0	42.0	0
299-E33-47	60.1	49.7	-17
299-E33-337	30.0	24.0	-20
		Average	**-29**

9.5.2 B Plant

The interpreted 2019 uranium extent exceeding the DWS beneath B Plant is defined by wells 299-E28-6 and 299-E28-17, with concentrations ranging between 37 and 42 µg/L (Figure 9-17). The source of this plume was the 216-B-12 Crib; however, uranium flux from soils beneath the 216-B-12 Crib appears to have ceased prior to installation of well 299-E28-30. Advection and dispersion appear to be responsible for current position of the B Plant uranium plume.

The 216-B-5 reverse well (Figure 9-2) was a former source of uranium. Uranium concentrations exceeded the DWS only in well 299-E28-24 in 2019 (32.6 to 38.1 µg/L) (Figure 9-17). Concentrations in nearby wells 299-E28-23 and 299-E28-7 remained below the DWS. Thus, the plume extent is relatively small and appears to be diminishing under natural groundwater flow conditions.

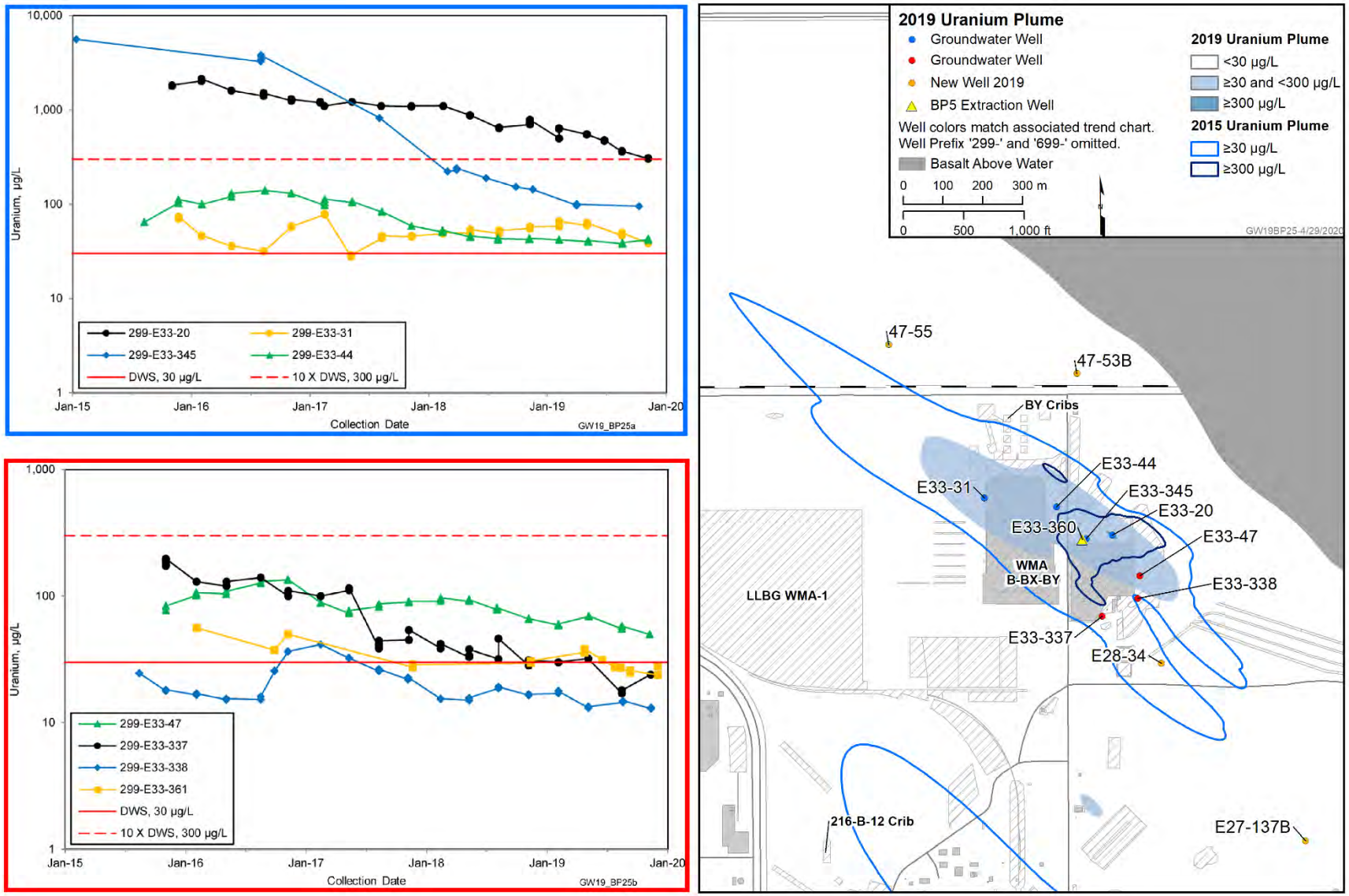


Figure 9-18. 200-BP Comparison of 2015 and 2019 Uranium Plumes

9.6 Strontium-90

Strontium-90 exceeds the 8 pCi/L DWS near the former Gable Mountain Pond (inactive and dry since the mid- to late 1980s) and near the 216-B-5 reverse well (Figure 9-19). About 179 Ci of strontium-90 was discharged to Gable Mountain Pond, with most of it associated with the 1964 PUREX Plant unplanned release (UPR-200-E-34). About 7.5 Ci of strontium-90 were injected into the 216-B-5 reverse well between 1945 and 1947. Because strontium-90 tends to bind to vadose zone sediments, it reached groundwater only at locations where the vadose zone is relatively thin (e.g., <12 m [39 ft] at Gable Mountain Pond) or where waste was injected into the aquifer (216-B-5 reverse well).

9.6.1 Former Gable Mountain Pond

The strontium-90 plume exceeding the DWS beneath the eastern half of the former Gable Mountain Pond is located within a thin narrow saturated channel of Hanford formation gravels bounded by the Ringold mud unit and Elephant Mountain basalt. Beneath the western half of the former Gable Mountain Pond, the saturated Hanford formation gravels thicken and widen while the Ringold mud unit is interpreted to pinch out. The strontium-90 plume beneath Gable Mountain Pond has yet to reach well 699-55-50C, indicating either very slow migration of the plume to the west-northwest or hydrologic conditions that divert groundwater migration in this direction.

Stronitum-90 concentration in the saturated Hanford formation gravels beneath Gable Mountain Pond diminish to the west as the Hanford formation gravel saturated aquifer thickens and widens. Well 699-53-47B, located near the east boundary of the pond and the transfer pipeline outfall to Gable Pond, is perforated across the 2 m (6.6 ft) thick Hanford formation gravel aquifer (bounded below by Elephant Mountain basalt). Well 699-53-47B has historically had the highest strontium-90 concentration and continued to have the highest concentration in 2019 (Figure 9-20). Strontium-90 at well 699-53-47B has ranged between 220 and 281 pCi/L since 2012, with an average concentration of 250 pCi/L. In 2019, the strontium-90 concentration at well 699-53-47B was 262 pCi/L. The stable strontium-90 concentrations at well 699-53-47B, indicating a continuing source of contamination, may be present from the vadose zone.

Farther west at well 699-54-49, located beneath the central portion of the former Gable Pond, the strontium-90 concentration has declined from 180 to 158 pCi/L between 2012 and 2019 (Figure 9-20). The decline in concentration is consistent with radioactive decay. The Hanford formation gravel aquifer thickness at this well is approximately 3.7 m (12 ft), or twice as thick as beneath the east end of Gable Mountain Pond.

Near the western end of the former Gable Mountain Pond at well 699-55-50C, the aquifer thickness is estimated at 12 m (39 ft), and strontium-90 concentration continues to be less than detection (Figure 9-20). Well 699-52-55, located 1.4 km (0.87 mi) west of Gable Mountain Pond, also has detectable strontium-90 (14 pCi/L in 2019). The source of contamination is not currently known.

9.6.2 216-B-5 Reverse Well

Five wells (299-E28-2, 299-E28-7, 299-E28-23, 299-E28-24, and 299-E28-25) define the strontium-90 plume near the former 216-B-5 reverse well. Wells 299-E28-2 and 299-E28-7 define the northwest and southeast portion of the plume, respectively. Well 299-E28-2 is currently upgradient of the 216-B-5 reverse well, but prior to 2011 it was downgradient. Well 299-E28-7 is currently downgradient of the 216-B-5 reverse well. Strontium-90 concentrations continue to decline at all five wells faster than the decay rate (Figure 9-21). The highest strontium-90 concentration in 2019 was at well 299-E28-24, located <4 m (13 ft) downgradient from the former 216-B-5 reverse well, with a concentration of 337 pCi/L. Strontium-90 concentrations at downgradient well 299-E28-4, located 290 m (950 ft) from well 299-E28-7, continue to be less than detection.

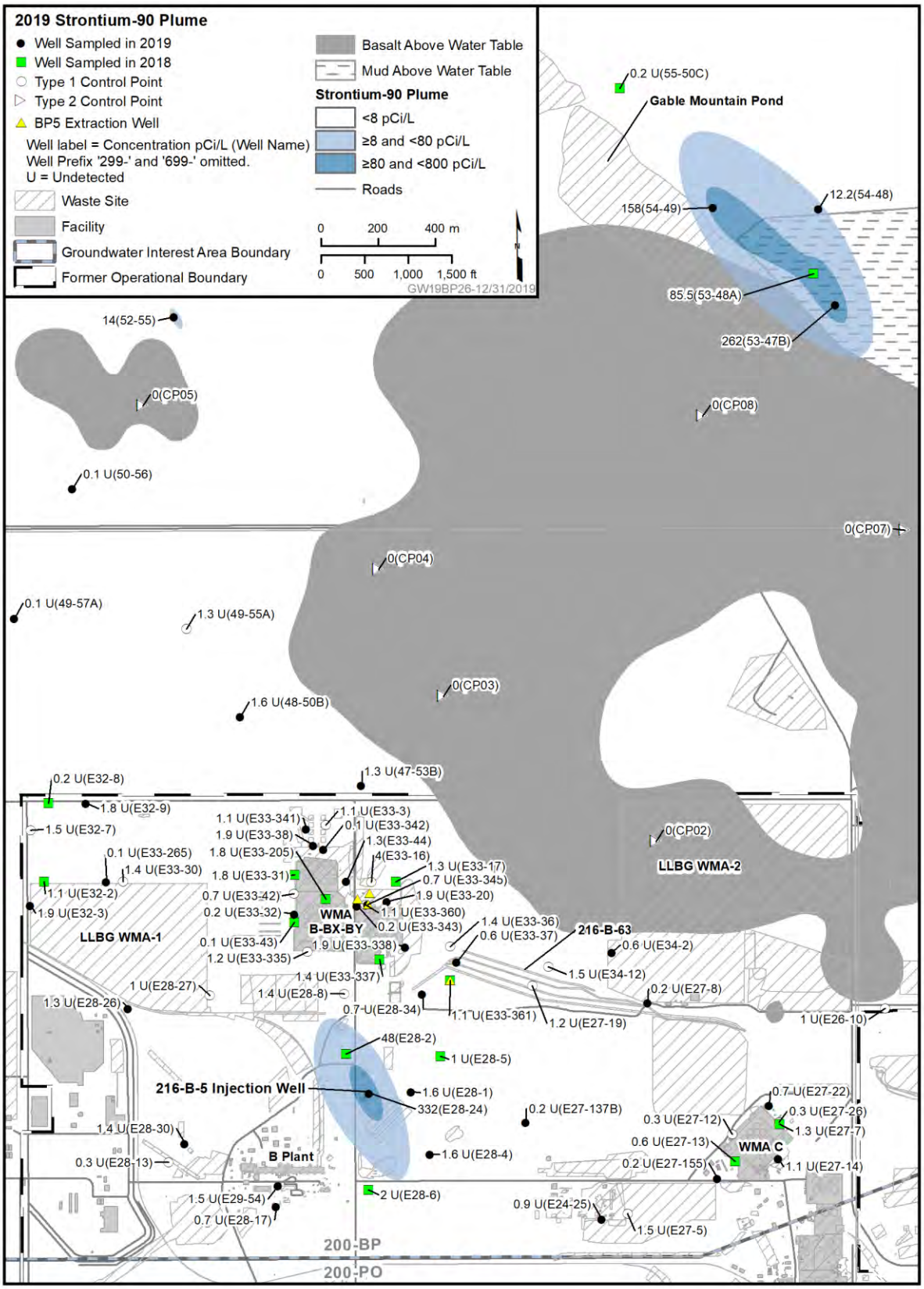


Figure 9-19. 200-BP Strontium-90 Plume, 2019

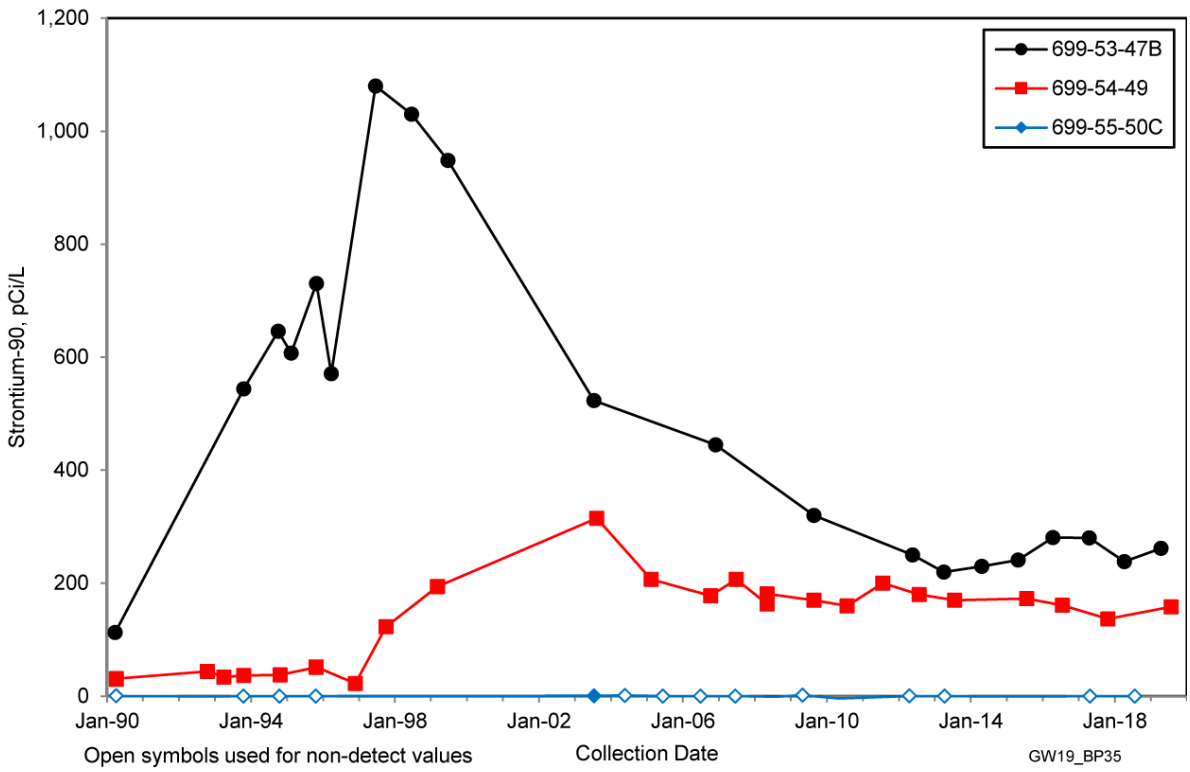


Figure 9-20. 200-BP Strontium-90 Data for Wells at the Former Gable Mountain Pond

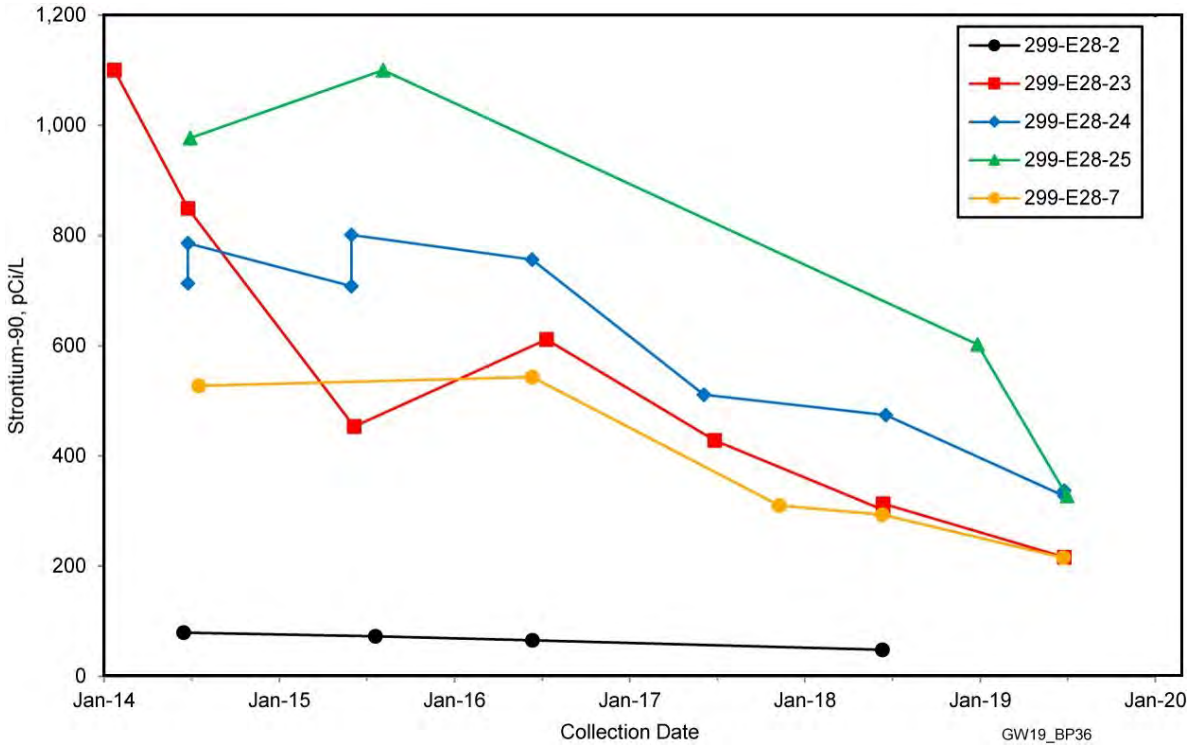


Figure 9-21. 200-BP Strontium-90 Data for Wells Near the Former 216-B-5 Reverse Well

9.7 Cyanide

Cyanide in 200-BP groundwater is primarily associated with past B Complex and C Tank Farm discharge sites and unplanned releases of liquid scavenged waste. The scavenging process was used in the 1950s to precipitate cesium-137 and strontium-90 from uranium-recovery and first-cycle decontamination liquid wastes before disposal to the soil column. The primary scavengers were sodium ferrocyanide and nickel sulfate. Since the 1950s, concentrations of total cyanide (e.g., primarily ferrocyanide) >200 µg/L have continued to migrate into the groundwater in B Complex area (Figure 9-22).

In EPA 815-B-16-012, *Cyanide Clarification of Free and Total Cyanide Analysis for Safe Drinking Water Act (SDWA) Compliance*, EPA clarifies that total cyanide methods are allowed for screening but cyanide is regulated as free cyanide, and the 200 µg/L DWS applies to free cyanide. Total cyanide concentrations in groundwater are much higher than free cyanide concentrations. Free cyanide has a MTCA (WAC 173-340) cleanup level of 4.8 µg/L.

In 2019, a total of 5 of 45 wells at the B Complex and C Tank Farm area detected free cyanide concentrations ≥4.8 µg/L (299-E27-137B, 299-E28-34, 299-E33-20, 299-E33-39, and 299-E33-44). Three of the wells (e.g., 299-E33-20, 299-E33-39, and 299-E33-44) are located near vadose zone source sites and have high continuous total cyanide groundwater concentrations (e.g., >400 µg/L). All three wells are within the capture zone of extraction well 299-E33-360. The other two wells had single detections above the 4.8 µg/L cleanup level in samples collected during drilling. Post-completion groundwater samples for wells 299-E27-137B and 299-E28-34 did not detect free cyanide.

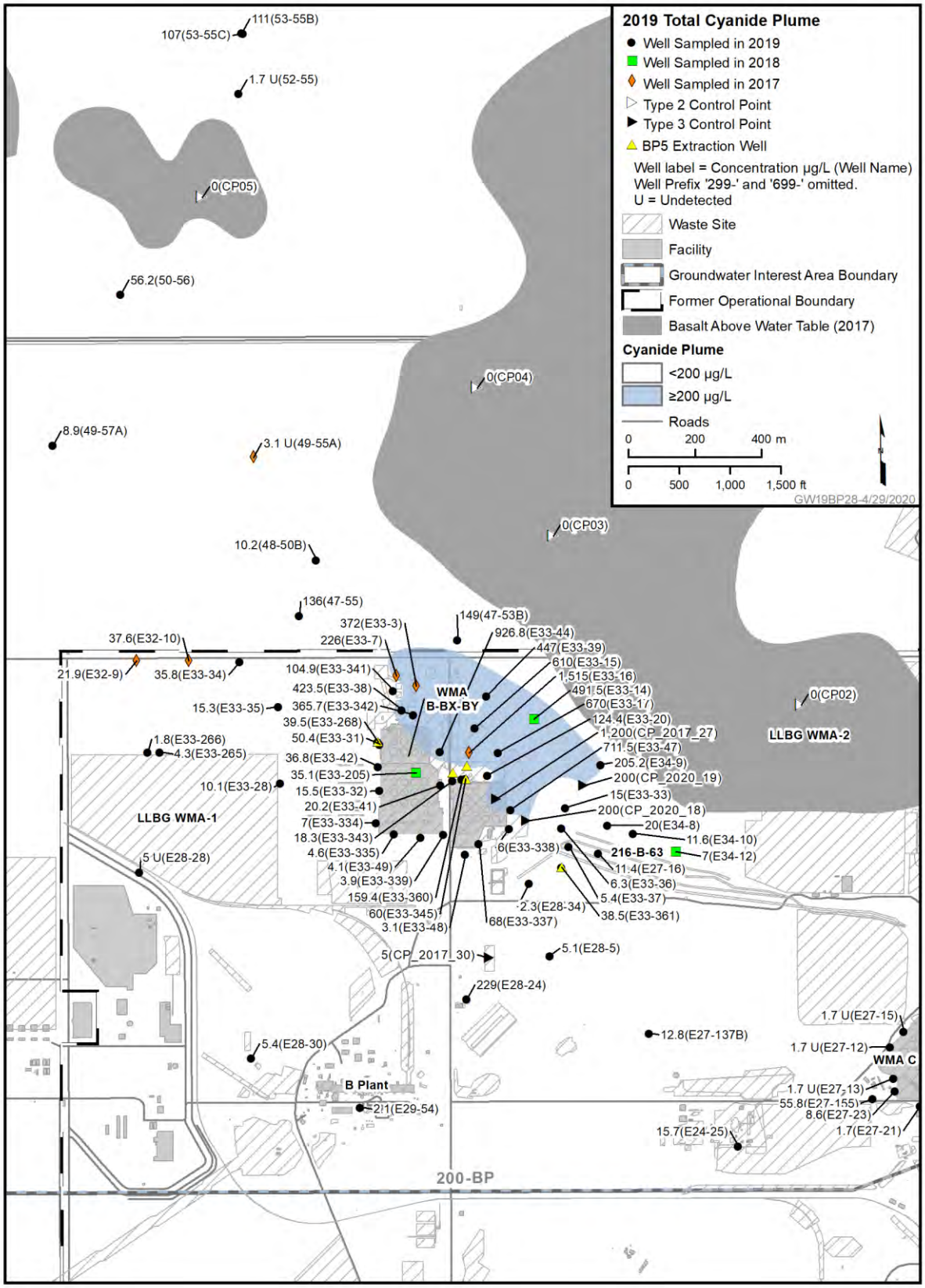


Figure 9-22. 200-BP Total Cyanide Plume, 2019

9.8 CERCLA Remediation and Monitoring

This section summarizes activities in the 200-BP-5 Groundwater OU and the 200-DV-1 Deep Vadose Zone OU.

9.8.1 200-BP-5 Operable Unit

In December 2019, DOE issued the 200-BP-5 FS report (DOE/RL-2018-30, *200-BP-5 and 200-PO-1 Groundwater Operable Units Feasibility Study for Interim Action*. In 2019, DOE also released DOE/RL-2018-58, Draft A, *Proposed Plan for Interim Action Remediation of the 200-BP-5 and 200-PO-1 Operable Units*. The Tri-Parties are pursuing an interim ROD for groundwater OUs to expedite the remediation of the technetium-99 and uranium groundwater plumes.

CERCLA groundwater monitoring in 2019 was conducted in accordance with DOE/RL-2014-33, *Sampling and Analysis Plan for the 200-BP-5 Groundwater Operable Unit*. Seven wells and one aquifer tube could not be sampled as planned (Appendix A). A revised SAP is being prepared to add new wells drilled in 2019 (Table 9-11) and remove the aquifer tube and wells no longer serviceable.

Table 9-11. Wells Drilled in 200-BP in 2019

Well Name	Well ID	Purpose*	Drill Depth		Construction Depth		Accepted Date
			ft	m	ft	m	
299-E27-137B	C9753	Monitoring	325.5	99.2	325.1	99.1	9/23/2019
299-E28-34	C9752	Monitoring	288.4	87.9	288.0	87.8	9/23/2019
699-47-53B	C9751	Monitoring	252.1	76.8	225.1	68.6	2/4/2020
699-47-55	C9750	Monitoring	255.0	77.7	226.5	69.0	2/4/2020

*Wells were installed to complete the B Complex removal action performance monitoring network in accordance with Appendix C of DOE/RL-2017-11, *Removal Action Work Plan for 200-BP-5 Operable Unit Groundwater Extraction*, as modified by TPA-CN-0846.

ID = identification

In 2019, groundwater extraction from wells 299-E33-360 and 299-E33-361 in the B Complex continued to remove uranium, technetium-99, and other contaminants from groundwater (Table 9-12; Figure 9-23). The extracted groundwater is treated at the 200 West P&T before reinjection in the 200 West Area. A December 2016 action memorandum (DOE/RL-2016-41) documented the decision to implement a non-time-critical removal action for the B Complex technetium-99 and uranium plumes exceeding 10 times the DWS. In February 2018, DOE issued DOE/RL-2017-11, *Removal Action Work Plan for 200-BP-5 Operable Unit Groundwater Extraction*, as modified by TPA-CN-0846.

Table 9-12. 200-BP Remediation Summary

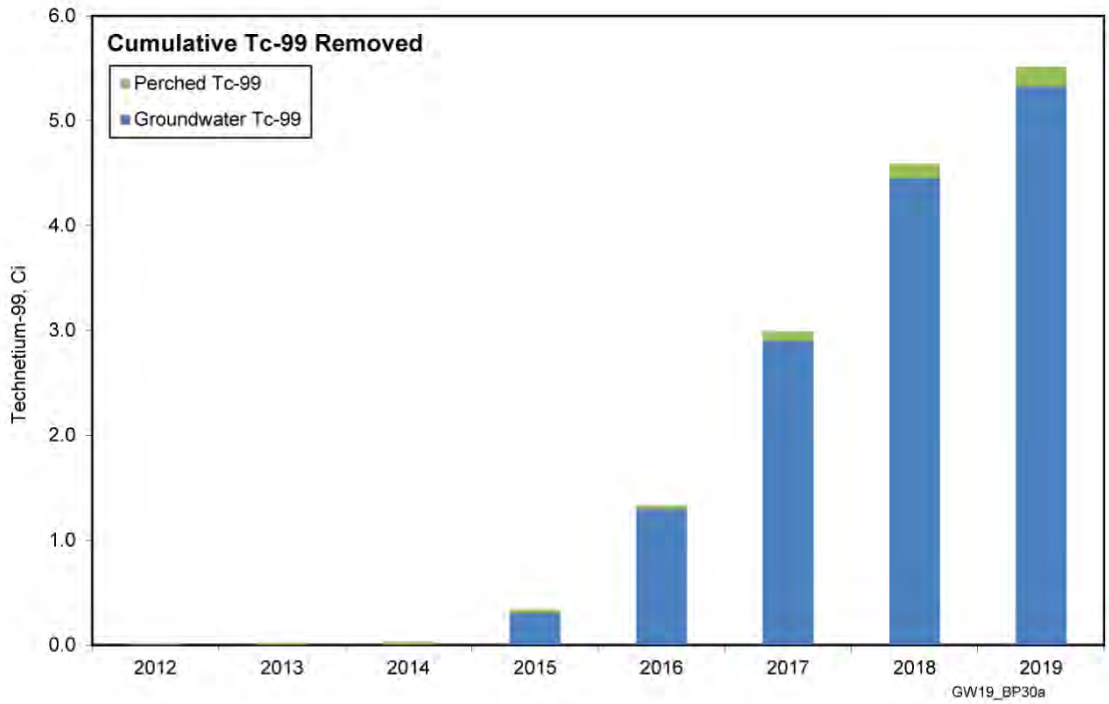
200-BP-5 Operable Unit Groundwater Extraction		
Contaminant	**Removed 2019**	**Removed Since 2015**
Cyanide (kg)	47	207
Iodine-129 (Ci)	2.56×10^{-4}	2.58×10^{-3}
Nitrate (kg)	63,411	285,774
Technetium-99 (g; Ci)	56.5; 0.96	313.5; 5.33
Tritium (Ci)	0.19	3.79
Uranium (kg)	22.4	187
Perched Water Extraction Removal Action		
Contaminant	**Removed 2019**	**Removed Since 2011**
Nitrate (kg)	1,280	5,364
Technetium-99 (g; Ci)	2.7; 4.6×10^{-2}	10.7; 18.1×10^{-2}
Uranium (kg)	63	294

Wells 699-47-53B and 699-47-55 were drilled in 2019 as part of DOE/RL-2017-11 to differentiate whether remnant plumes to the north of the B Complex may be contributing to the elevated concentrations at B Complex well 299-E33-39. Continued monitoring in 2020 at the two new wells and well 299-E33-39 should reveal if the BY Crib contaminant flux from the vadose zone into the groundwater is the primary reason for continued elevated technetium-99 concentrations at well 299-E33-39. DOE/RL-2019-67 provides additional information about the 200-BP-5 OU removal action in 2019.

9.8.2 200-DV-1 Operable Unit

The 200-DV-1 OU was created in 2010 to support remedy selection for waste sites with deep vadose zone contamination in the Central Plateau. In general, deep vadose zone contamination is considered to be contamination that poses a potential threat to groundwater and is challenging to remediate using standard surface-based remedies. The goal for the 200-DV-1 OU is to ensure long-term protection of groundwater from deep vadose zone contaminant sources in the Central Plateau. A total of 43 waste sites are assigned to the 200-DV-1 OU. In the 200 East Area, the 200-DV-1 OU waste sites are near WMA B-BX-BY. In the 200 West Area, the 200-DV-1 OU waste sites are near WMA T, WMA TX-TY, and WMA S-SX. However, the OU does not include the tank farms.

In August 2011, DOE began a treatability test at perched water well 299-E33-344 (DOE/RL-2011-40, *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*). The treatability test investigated the feasibility of removing contaminants by extracting water from the perched water horizon. Two additional perched water extraction wells (299-E33-350 and 299-E33-351) were added to the system in 2016, and the treatability test transitioned to a CERCLA removal action (DOE/RL-2014-34, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*, as modified by TPA-CN-0880). In 2019, contaminated perched water was conveyed to the 200 West P&T through the same cross-site pipeline used for the 200-BP-5 OU removal action. Table 9-12 provides the amounts of nitrate, technetium-99, and uranium removed during 2019 and since startup in August 2011. Chapter 5 in DOE/RL-2019-67 provides additional information about the 200-DV-1 OU perched water removal action in 2019.



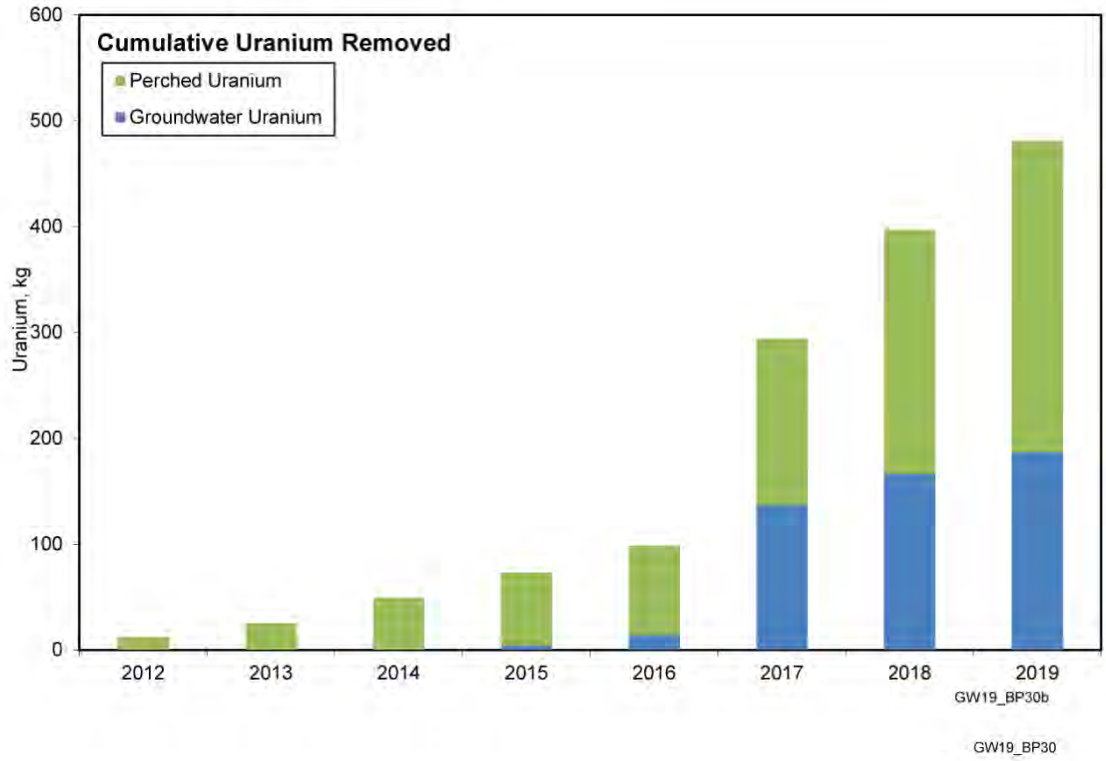


Figure 9-23. 200-BP Contamination Removed from Groundwater and Perched Water in the B Complex Area

9.9 RCRA Monitoring

DOE/RL-2019-65 presents the results of RCRA groundwater monitoring for the Hanford Site in 2019. This section repeats that information for the RCRA units in 200-BP. These units are monitored under RCRA requirements for dangerous waste/dangerous waste constituents and under AEA for source, special nuclear, and byproduct materials. Data from unit-specific monitoring are also integrated into CERCLA groundwater investigations. Dangerous constituents and radionuclides are occasionally discussed jointly in this section to provide comprehensive interpretations of groundwater contamination. Pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority. Therefore, the inclusion of information on radionuclides in such a context is for informational purposes only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

The 200-BP groundwater interest area contains six RCRA units with groundwater monitoring requirements: WMA B-BX-BY, WMA C, 216-B-63 Trench, LERF, LLBG WMA-1, and LLBG WMA-2 (Figure B-1 in Appendix B). The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for 2019. Groundwater data are available in the HEIS database. Appendix B provides additional information, including well and constituent lists, and statistical tables.

9.9.1 Waste Management Area B-BX-BY

WMA B-BX-BY is located in the northwestern 200 East Area (Figure B-1 in Appendix B; Figure 9-24). It was constructed in stages: B Tank Farm between 1943 and 1944, BX Tank Farm between 1946 and 1947, and BY Tank Farm between 1948 and 1949. All three tank farms provided interim storage for radioactive mixed waste, primarily from the bismuth phosphate and uranium extraction processes. All of the 24 SSTs in the B and BX Tank Farms were built to store up to 2.0 million L (530,000 gal) of liquid waste. In the B Tank Farm, four additional tanks each had a capacity of 208,000 L (55,000 gal). Each of the 12 SSTs in the BY Tank Farm had a 2.9 million L (770,000 gal) capacity. Ancillary equipment at WMA B-BX-BY includes diversion boxes, underground catch tanks, connecting underground pipelines, and the 244BXR waste transfer vault.

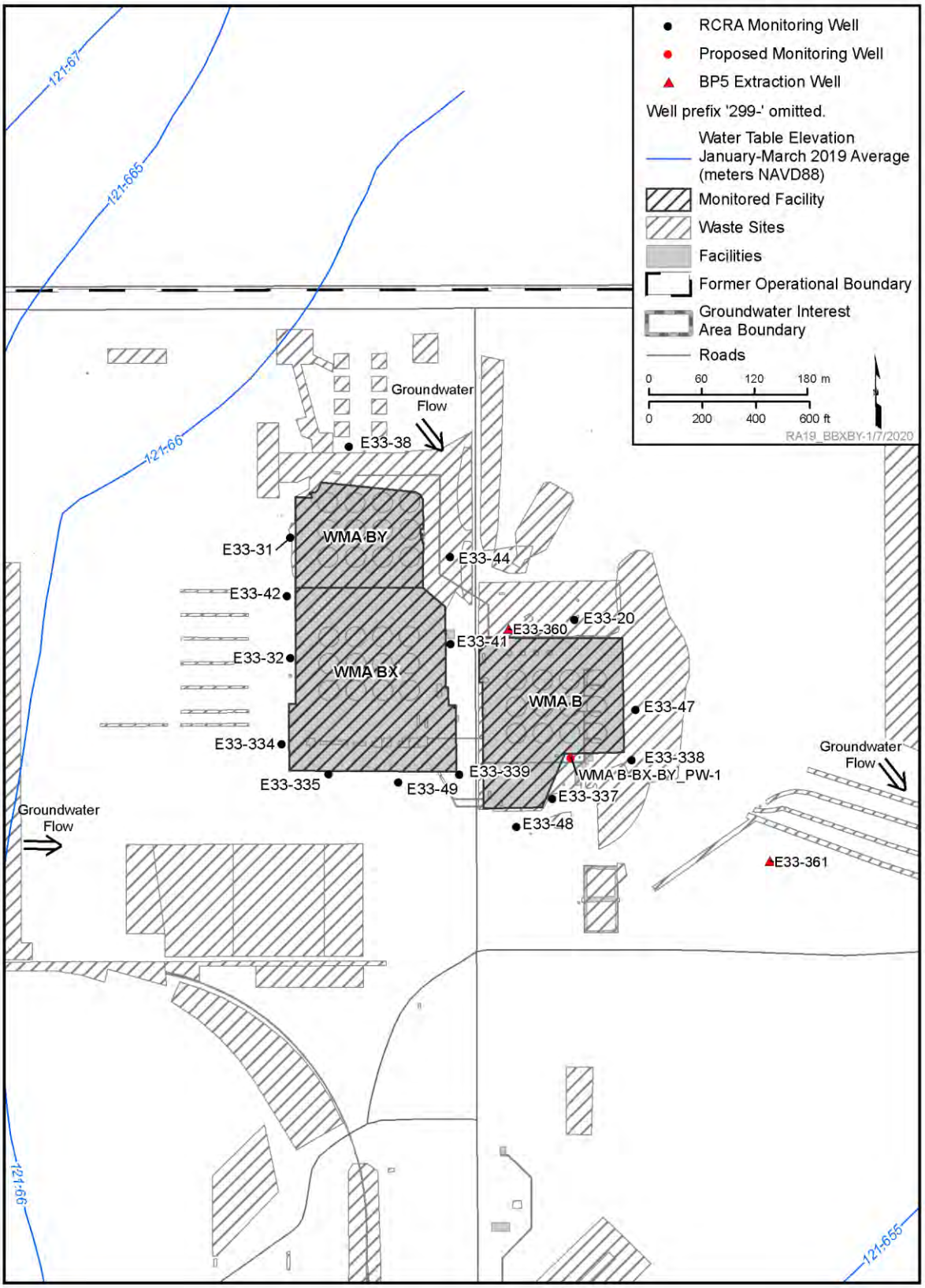


Figure 9-24. Waste Management Area B-BX-BY

Of the 40 SSTs in WMA B-BX-BY, 20 SSTs are assumed or confirmed to have leaked in the past (Table 4-1 in HNF-EP-0182, Rev. 359, *Waste Tank Summary Report for Month Ending November 30, 2017*).To minimize the probability and severity of future leaks, most of the drainable liquid in each tank has been removed and transferred to DSTs. Additional sources of unplanned releases within WMA B-BX-BY include tank overfills, waste loss from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases.

DOE monitors groundwater beneath WMA B-BX-BY under an interim status assessment program in accordance with 40 CFR 265.93(d)(4), as defined in DOE/RL-2012-53, Rev. 0, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY*. While developing DOE/RL-2012-53, Rev. 0, an assessment of historical process chemistry, leak assessment reports, and groundwater contaminants concluded that cyanide had affected groundwater quality beneath the B Tank Farm. The probable cyanide source and a conceptual model for transport were provided as part of the determination. Although other releases from WMA B-BX-BY have affected groundwater, there is currently no evidence of additional dangerous waste or dangerous waste constituents.

The revised assessment plan (DOE/RL-2012-53, Rev. 1, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY*), effective in May 2019, implements the monitoring network recommended in Section 7.4 of SGW-60578, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area U Groundwater Monitoring*, including one proposed new well. The flow direction in DOE/RL-2012-53, Rev. 1 was based on water-level measurements from 2013 through 2016 (p. 5-3 in SGW-60587), before the 2017 start of high-capacity pumping at extraction well 299-E33-360 (Figure 9-24). As discussed in Section 1 of DOE/RL-2012-53, Rev. 1, regular updates to the engineering evaluation report (SGW-60578) are planned as new data become available.

Table B-52 in Appendix B lists the WMA B-BX-BY monitoring well attributes. Most of the well screens extend across the entire unconfined aquifer to the underlying basalt surface. Water-level predictions indicate that all of the wells (except 299-E33-42) will have sufficient water for continued sampling through at least 2028 (SGW-63743, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity Within the Central Plateau, Hanford Site*). Well 299-E33-42 is predicted to be sample dry in 2027, but well life may be lengthened by use of a low-flow sampling pump.

The groundwater gradient magnitude and flow direction were extrapolated using the 200 East Area regional low-gradient monitoring network from January and March 2019. The 2019 gradient was estimated at 6.0×10^{-6} m/m, dipping to the southeast (Table B-2 in Appendix B), with an average flow rate of 0.43 m/d (1.4 ft/d). However, local flow directions are influenced by groundwater extraction wells 299-E33-360 and 299-E33-361, as described in DOE/RL-2017-11.

Assessment monitoring at WMA B-BX-BY focuses on cyanide, which is a dangerous waste constituent that was present in groundwater upgradient, beneath, and downgradient of WMA B-BX-BY in 2019. Four wells had total cyanide results >200 µg/L in 2019 (299-E33-20, 299-E33-38, 299-E33-44, and 299-E33-47). Well 299-E33-38 is upgradient of WMA B-BX-BY and had the highest concentrations by the end of 2019. Total cyanide concentrations at downgradient wells 299-E33-44 and 299-E33-47 ranged from 675 to 1,000 µg/L in 2019 and represent contaminant migration from WMA B-BX-BY. Free cyanide concentrations are lower than total cyanide, and only wells 299-E33-20 and 299-E33-44 had concentrations above the 4.8 µg/L MTCA (WAC 173-340) cleanup level for free cyanide in 2019. In addition, only well 299-E33-44 had concentrations above the secondary DWS for both filtered and unfiltered iron. Iron represents the primary cyanide complex present in the groundwater, which is not appreciably decomposed by strong acid. All four wells are within the capture zone of extraction well 299-E33-360.

Table B-53 in Appendix B summarizes groundwater quality parameters and other constituents required by DOE/RL-2012-53, Rev. 1. Nitrate concentrations were above the 45 mg/L DWS at all wells (except 299-E33-48) due to regional and local nitrate plumes. Nitrate concentrations continue to decrease at WMA B-BX-BY since implementing extraction well 299-E33-360.

Nickel and chromium data are analyzed as indicators of stainless-steel well corrosion. Nickel was near or below the quantitation limit in most cases. Sporadic detections at higher levels were observed in several wells (maximum 30.4 µg/L in an unfiltered sample from well 299-E33-48 in May 2019). Chromium was the highest in unfiltered samples from wells 299-E33-32 and 299-E33-337. Based on the 2019 nickel and chromium results, there are no well corrosion concerns in the WMA B-BX-BY well network.

Manganese, which is a constituent reviewed for well corrosion, was near or below the quantitation limit in 2019 except at well 299-E33-20. Concentrations were above the 50 µg/L secondary DWS in filtered and unfiltered samples from 2010 until early 2019. It is likely that the manganese was due to a galvanized carbon steel riser pipe for the pump. Until November 2015, there was no protection between the electrical plug and the landing plate, which appeared to create a electrochemical reaction that caused elevated iron, manganese, and zinc concentrations at this well. After a rubber grommet or compression fitting was used to alleviate the issue, zinc was no longer detected, and iron and manganese concentrations decreased in groundwater samples.

9.9.2 Waste Management Area C

WMA C is located in the east-central portion of the 200 East Area (Figure B-1 in Appendix B; Figure 9-25). Constructed in 1943 and 1944, WMA C provided interim storage for radioactive mixed waste, primarily from the bismuth phosphate and uranium extraction processes. High-level liquid waste from these processes was stored in 12 SSTs, each with a capacity of 2.01 million L (530,000 gal). Four additional SSTs, each with a capacity of 208,000 L (55,000 gal), were also used to store high-level liquid waste.

Ancillary equipment at WMA C includes diversion boxes, underground catch tanks, connecting underground pipelines, and the 244CR vault. Of the 16 underground SSTs in WMA C, 7 tanks were confirmed or assumed to have leaked in the past (DOE/RL-2009-77, Rev. 0, *Groundwater Quality Assessment Plan for the Single-Shell Waste Management Area C*), and retrieval processes since 1998 have removed the remaining liquid waste. Additional release sources include past waste losses from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases.

DOE monitors groundwater beneath WMA C under an interim status assessment program in accordance with 40 CFR 265.93(d)(4), as defined in the groundwater quality assessment plan. While developing DOE/RL-2009-77, Rev. 0, an assessment of historical process chemistry, leak assessment reports, and groundwater contaminant distribution concluded that cyanide had affected groundwater beneath the C Tank Farm. Although other tank waste constituents from WMA C have affected groundwater, there is currently no significant evidence of additional dangerous waste or dangerous waste constituents.

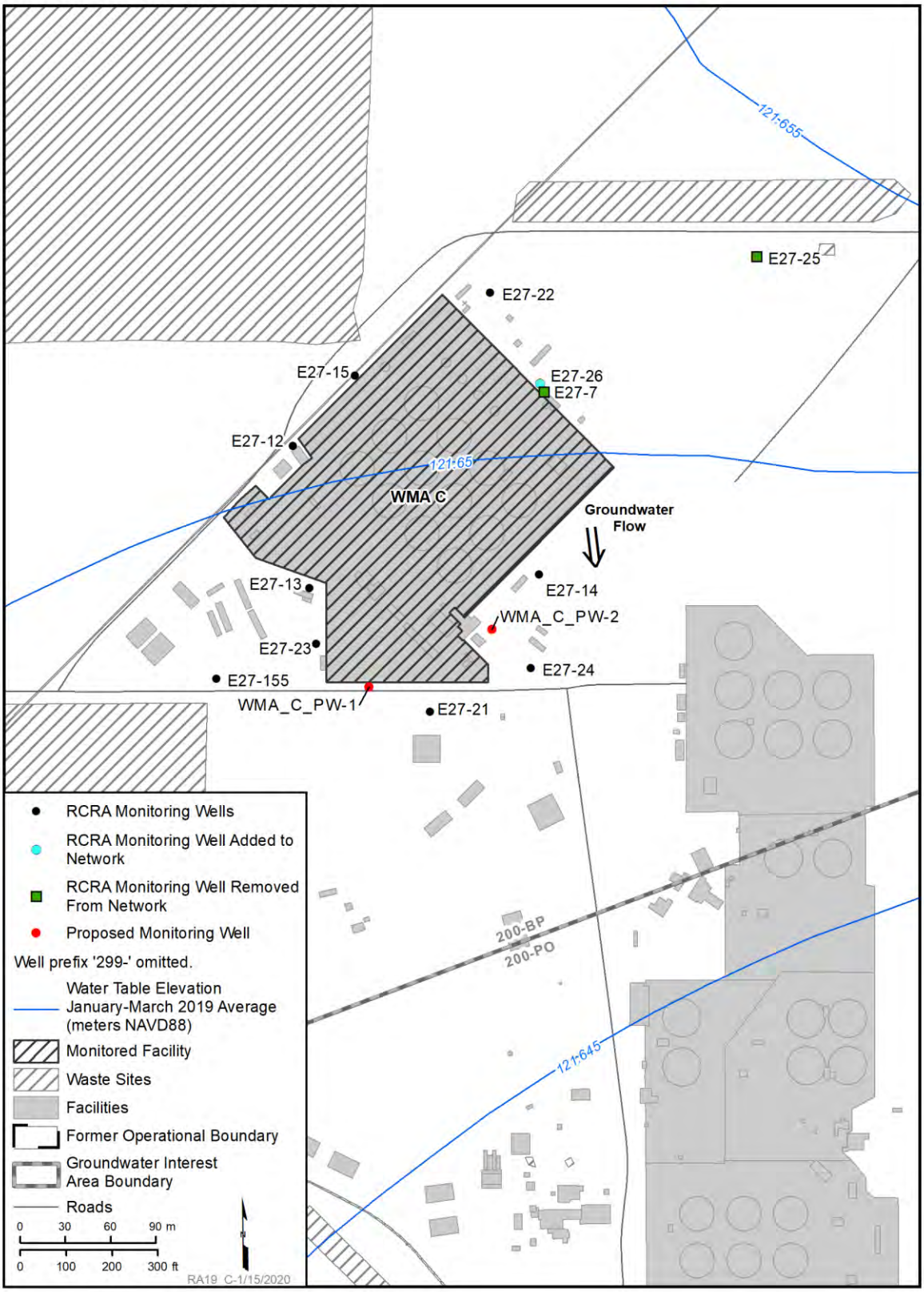


Figure 9-25. Waste Management Area C

A revised assessment plan (DOE/RL-2009-77, Rev. 1, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*), issued in June 2019, uses the same monitoring well network as Rev. 0, minus wells 299-E27-7 and 299-E27-25. Well 299-E27-7 (not compliant with WAC 173-160) was replaced by compliant well 299-E27-26, which provided results similar to well 299-E27-7. Well 299-E27-25 was no longer upgradient because of the groundwater flow direction change between 2009 and 2012 and was removed from the network. All of the wells were sampled as required during the reporting period (Table B-54 in Appendix B). Water-level predictions indicate that all of the wells (except 299-E27-13) will have sufficient water for continued sampling through at least 2028 (SGW-63743). Well 299-E27-13 is predicted to be sample dry in 2027, but well life may be lengthened by use of a low-flow sampling pump.

Groundwater gradient magnitude and flow direction were determined using a low-gradient monitoring network across the 200 East Area. The estimated average gradient was 2.2×10^{-5} m/m, dipping toward the south (Table B-2 in Appendix B). The estimated flow rate was 1.5 m/d (5.0 ft/d).

Assessment monitoring at WMA C focuses on cyanide, which is a dangerous waste constituent that was detected in 8 of the 12 WMA C groundwater wells in 2019. Cyanide concentrations along the west side of WMA C appear to be associated with an advancing plume from the B Complex area. A removal action initiated in 2016 at the B Complex is reducing the size of the advancing cyanide plume. Well 299-E27-155 had the highest total cyanide concentration at WMA C in 2019 (66.7 µg/L in March). Cyanide concentrations increased to 10.8 µg/L in well 299-E27-23, located 70 m (230 ft) east of well 299-E27-155. The coincident increase at well 299-E27-23 appears to mark the east edge of the southeast-migrating B Complex plume. The second highest total cyanide concentration at WMA C was at well 299-E27-24 (2019 high of 22 µg/L). Cyanide trends at well 299-E27-24 were similar to those at well 299-E27-14 (located 60 m [200 ft] to the north) until December 2017. Since December 2017, cyanide concentrations at well 299-E27-24 have remained fairly stable, while concentrations at well 299-E27-14 have declined. Cyanide at well 299-E27-14 represents contaminant migration from WMA C sources, while well 299-E27-24 may detect a mixture of sources (B Complex and WMA C). Wells 299-E27-24 and 299-E27-155 are screened in the lower part of the unconfined aquifer, and wells 299-E27-14 and 299-E27-23 are screened in the upper portion of the aquifer. The March 2019 free cyanide results showed all wells below the 4.8 µg/L MTCA (WAC 173-340) cleanup level. A planned CERCLA ROD for interim action includes installing an extraction system downgradient of WMA C.

Table B-55 in Appendix B summarizes the groundwater quality parameters and other constituents required by DOE/RL-2009-77, Rev. 1. Iron, nitrate, and sulfate were above comparison values in 2019, and a discussion of each follows:

- Iron was above the 300 µg/L secondary DWS in an unfiltered sample from well 299-E27-7, which is an older carbon steel well that has been replaced with well 299-E27-26 and is being evaluated for decommissioning. One sample from well 299-E27-13 was also above the DWS for iron, but it was inconsistent with a duplicate sample.

- Nitrate concentrations were above the 45 mg/L DWS at all but four of the WMA C wells in 2019 due to local and regional nitrate plumes. The highest nitrate concentrations were at wells 299-E27-155 and 299-E27-14. Nitrate concentrations increased at well 299-E27-14 throughout 2019, from 96.9 to 133 mg/L in September and 112 mg/L in December. The increase at well 299-E27-14 reflects contaminant flux from WMA C. Nitrate concentrations at well 299-E27-155 decreased throughout 2019, from 193 mg/L in March to 159 mg/L in December. The decreasing nitrate concentration at well 299-E27-155 is consistent with the decreasing cyanide concentrations and is considered part of the migrating B Complex plume. The increase of nitrate at well 299-E27-23 from 2018 through 2019

is attributed to the migrating B Complex plume; however, the migrating B Complex plume did not affect nitrate concentrations at well 299-E27-21. Regional nitrate increases north of WMA C are reflected in the increasing nitrate trend at upgradient well 299-E27-22.

- Sulfate concentrations were above the 250 mg/L secondary DWS in five WMA C wells in 2019 (Table B-55 in Appendix B) due to local and regional sulfate plumes. Regional sulfate increases north of WMA C are reflected in the increasing sulfate trend at upgradient well 299-E27-22, which also contributes to elevated levels at wells 299-E27-25 and 299-E27-26. However, elevated sulfate at wells 299-E27-14 and 299-E27-24 appears to be attributed to contaminant flux from WMA C.

In 2019, a review of nickel and chromium data (indicators of stainless-steel corrosion) identified one well with likely corrosion. Well 299-E27-15 had elevated levels of nickel and chromium in unfiltered samples (maximum of 55 µg/L nickel and 70 µg/L chromium), with concentrations increasing from 2018. Well 299-E27-15 was added to the well maintenance list for cleaning. Based on the 2019 nickel and chromium results, there are no other well corrosion concerns in the WMA C well network.

9.9.3 216-B-63 Trench

The 216-B-63 Trench is located in the north-central portion of the 200 East Area (Figure B-1 in Appendix B; Figure 9-26). Beginning in 1970, it was used as an emergency percolation trench for chemical sewer waste from B Plant (RHO-CD-798, *Current Status of the 200 Area Ponds*). Major contributors to this waste stream were the 2902B high tank (contained potable sanitary water), cooling water from B Plant and the 225B Waste Encapsulation and Separation Facility, some 221B steam condensate, and demineralizer effluent. Minor contributions may have included the chemical makeup overflow system (sodium hydroxide and sodium nitrite), air conditioning units, and space heaters (radiators).

Before November 1985, acidic effluent from anion exchanger regeneration and the basic effluent from cation exchanger regeneration were discharged without neutralization (WHC-EP-0287, *Waste Stream Characterization Report*, p. A.9-2). In March and April 1987, incidental corrosive liquid waste releases were discharged to the 216-B-63 Trench. The corrosive waste discharges were regulated under RCW 70.105, "Hazardous Waste Management," and its implementing requirements in WAC 173-303. Discharges to the 216-B-63 Trench ceased in 1992.

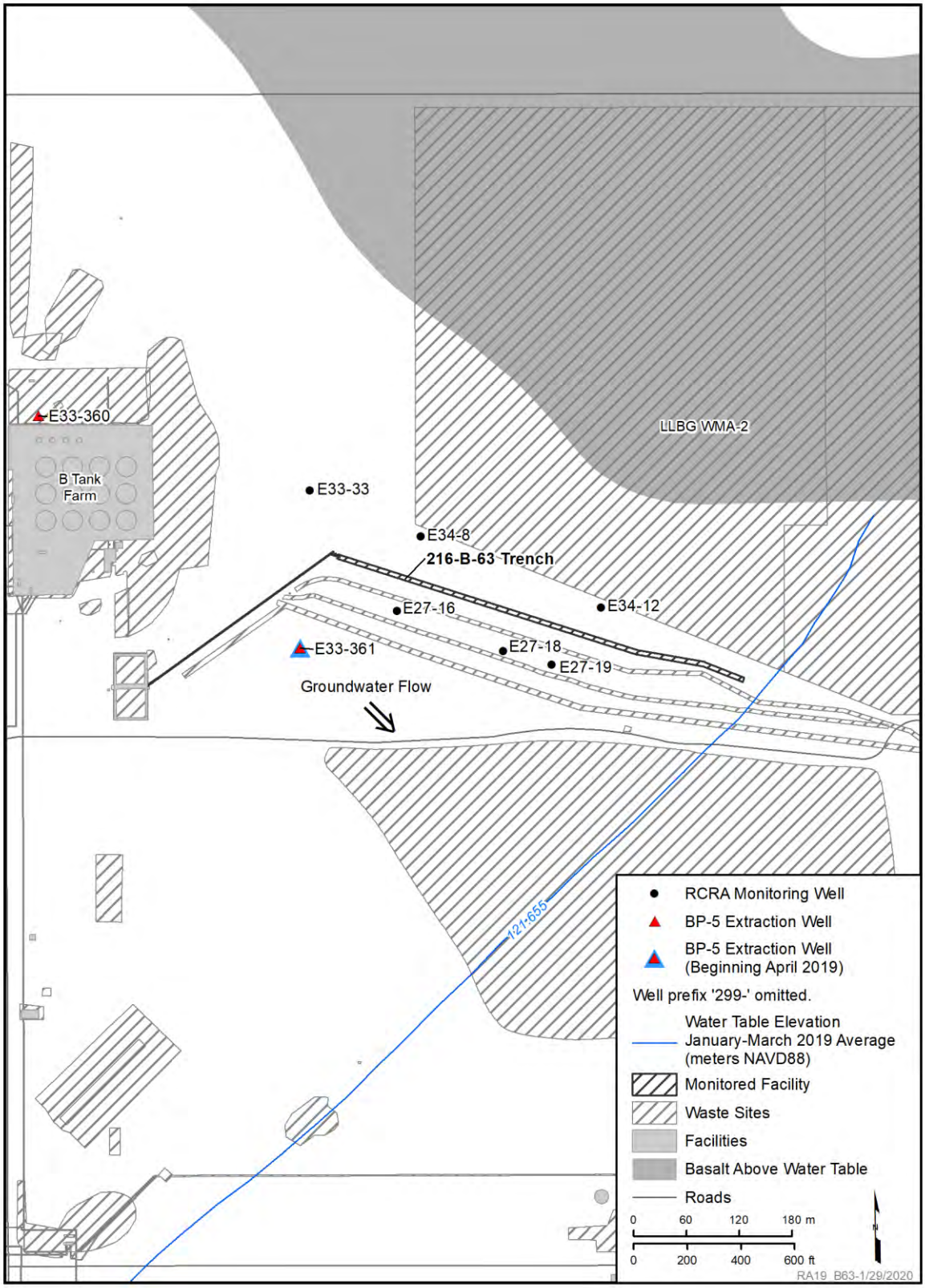


Figure 9-26. 216-B-63 Trench

DOE monitors groundwater at the 216-B-63 Trench under an interim status indicator evaluation program as defined in DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*. Table B-18 in Appendix B presents construction information and water levels for the 216-B-63 wells. The monitoring network defined in DOE/RL-2008-60 consists of three upgradient and three downgradient wells screened in the upper portion of the aquifer at the water table. However, in April 2019, well 299-E33-361 began extracting groundwater in accordance with DOE/RL-2017-11. Groundwater extraction at well 299-E33-361 likely changed the local flow direction. In accordance with Section 4.4 of DOE/RL-2008-60, "…an annual evaluation of the network to determine if it remains adequate to monitor the B-63 Trench…" is required and, "If flow changes are observed, the 216-B-63 Trench conceptual model and geochemical trends will be re-evaluated to determine network efficiency and any necessary modification requirements for the network." Based on the groundwater flow changes caused by well 299-E33-361, a revised interim status monitoring plan is planned for 2020.

Groundwater gradient magnitude and flow direction were inferred using a low-gradient monitoring network across the 200 East Area prior to initial pumping of extraction well 299-E33-361. The groundwater gradient calculated for the 216-B-63 Trench area was 6.2×10^{-6} m/m, dipping to the southeast, and the estimated groundwater flow rate was 0.44 m/d (1.4 ft/d) (Table B-2 in Appendix B). After April 2019, use of groundwater extraction at well 299-E33-361 likely caused a local deviation from the estimated groundwater flow direction and rate.

In 2019, the 216-B-63 Trench monitoring wells were sampled semiannually for indicator parameters as scheduled (Table B-19 in Appendix B). Specific conductance, pH, TOC, and total organic halides (TOX) did not exceed critical mean values, and the 216-B-63 Trench remains in indicator evaluation monitoring.

Table B-20 in Appendix B summarizes the 2019 results for groundwater quality parameters and additional constituents required by the monitoring plan (DOE/RL-2008-60). Nitrate was the only parameter with a concentration above a water quality standard. Nitrate reflects contaminant migration from sources northwest of the 216-B-63 Trench.

Iron, manganese, and other metals are analyzed as indicators of stainless-steel corrosion. Manganese concentrations were near or below the quantitation limit, and iron was below regional background levels.

9.9.4 Liquid Effluent Retention Facility

Located at the eastern boundary of the 200 East Area, the LERF consists of three lined surface impoundment basins (Figure B-1 in Appendix B; Figure 9-27). The LERF construction was completed in 1991 using a dual-confinement barrier concept (i.e., dual basin liners and pipe-in-a-pipe transfer piping system) to minimize human exposure and the potential for accidental releases to the environment. A leachate detection, collection, and removal system and the basin covers also reduce possible environmental or personnel exposure. The basins are located side by side, with 18 m (60 ft) of separation between each basin. Each basin (cell) is 100 by 82 m (330 by 270 ft), with a maximum fluid depth of 6.7 m (22 ft).

The LERF provides aqueous waste storage and treatment prior to final treatment at the 200 Area Effluent Treatment Facility. Treatment at the LERF consists of flow and pH equalization. Flow equalization allows for several smaller waste streams that are intermittently received at the LERF basins to accumulate for continuous higher volume campaign processing at the Effluent Treatment Facility. The LERF continues to receive liquid waste from a number of onsite facilities, with the largest volume from the 242A evaporator.

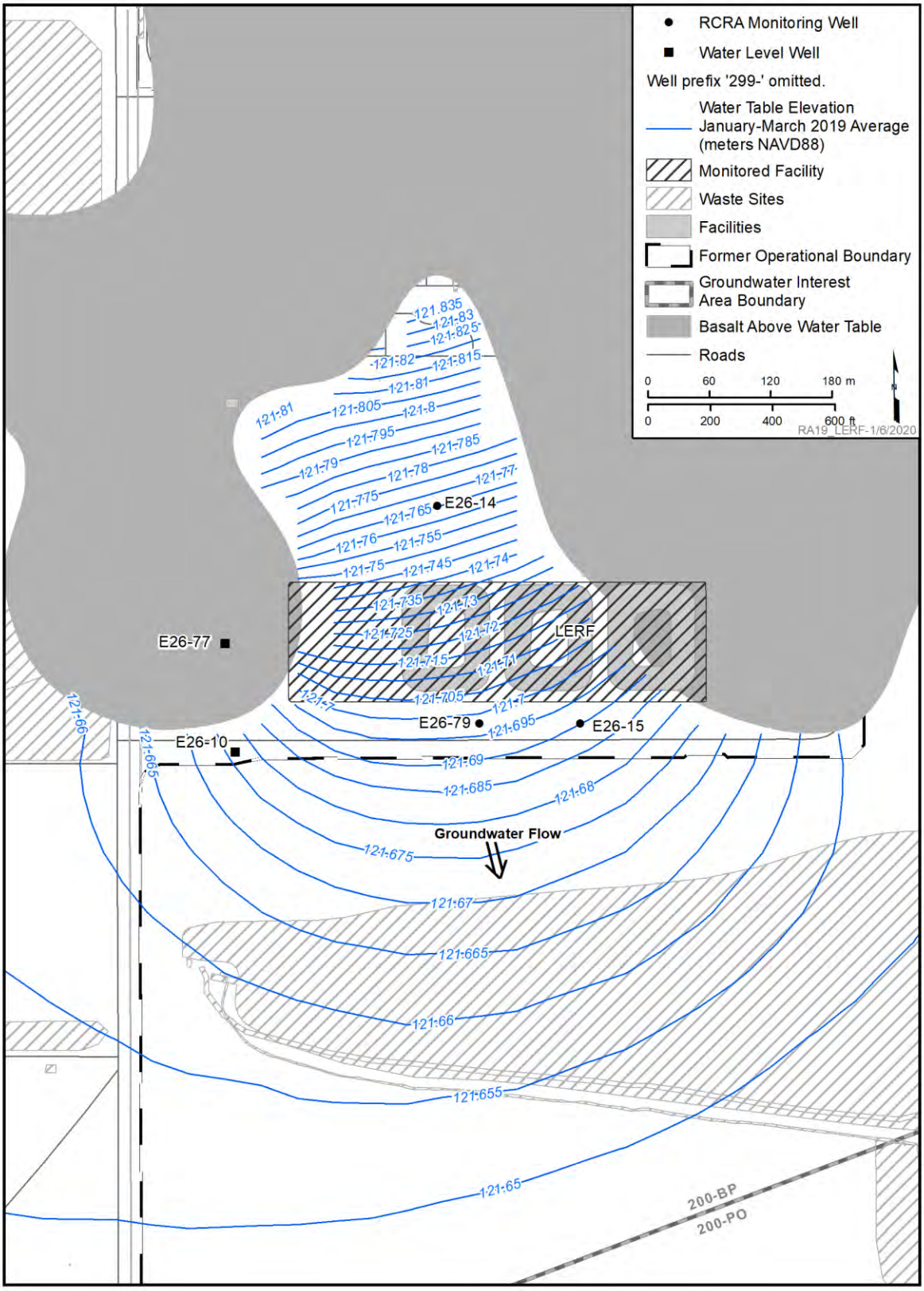


Figure 9-27. Liquid Effluent Retention Facility

Groundwater at the LERF is monitored under a final status detection monitoring program under the Hanford RCRA Permit (Part III, OUG-3, Addendum D, "Groundwater Monitoring Plan" [modification date of January 23, 2018]). The plan was revised in 2017 and a permit modification became effective November 26, 2017.

The uppermost aquifer suprabasalt sediments beneath the LERF range from possibly not present to >8 m (26 ft) in thickness. The sediments beneath and north of the LERF are interpreted as the Hanford formation, but groundwater gradient and hydraulic conductivity indicate that the sediments are characteristic of the Ringold Formation. South of the LERF, the hydraulic conductivity increases substantially, which is characteristic of Hanford sediments. Weathered and fractured Elephant Mountain basalt underlies the suprabasalt sediments. Basalt observations and geophysical investigations indicate that the upper 2 to 3 m (6 to 9 ft) of the fractured basalt can be hydraulically connected to the unconfined aquifer in much of the area beneath the LERF (Figures D-6 and D-11 in the LERF groundwater monitoring plan in the Hanford RCRA Permit (Part III, OUG-3, Addendum D]).

The current LERF monitoring network (Table B-31 in Appendix B) was evaluated in SGW-41072, *Liquid Effluent Retention Facility Engineering Evaluation and Characterization Report*. Four of the five well screens extend to the underlying basalt or within the basalt fracture zone. Well 299-E26-14 extends to within 0.9 m (3 ft) of the underlying basalt surface. All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743).

Based on the low-gradient water table elevations from March and October 2019, the magnitude of the hydraulic gradient beneath the LERF was calculated at 3.7×10^{-4} m/m (Table B-32 in Appendix B). The flow direction was generally south, and the estimated groundwater flow rate was 0.15 m/d (0.48 ft/d).

In 2019, the LERF monitoring well sampling frequency was quarterly to complete a 2-year baseline for regional plume characteristics, groundwater quality, and field parameters. In addition, indicator waste constituents were sampled, analyzed, and evaluated quarterly. In 2019, organic constituents were undetected, and Cr(VI) was below quantitation limits (Table B-33 in Appendix B).

Table B-34 in Appendix B summarizes the 2019 monitoring results for other constituents. Nitrate remained above the DWS in upgradient well 299-E26-14 and downgradient well 299-E26-79 due to a regional plume. Sulfate is elevated throughout the eastern part of the 200 East Area, and concentrations were above the 250 mg/L secondary DWS at LERF well 299-E26-15.

Several trace metals were reviewed as indicators of well corrosion in 2019. Nickel was below the quantitation limit at all wells, and chromium was near or below the quantitation limit except in unfiltered samples from well 299-E26-79 (with a maximum unfiltered result of 41.3 µg/L). Manganese was below quantitation limits in unfiltered samples, and iron was below regional background levels. Based on the 2019 nickel and chromium results, there are no well corrosion concerns in the LERF well network.

9.9.5 Low-Level Burial Grounds Waste Management Area 1

LLBG WMA-1 is located in the northwest corner of the 200 East Area and comprises the 218-E-10 Burial Ground with 14 soil covered unlined trenches (Figure B-1 in Appendix B; Figure 9-28). LLBG WMA-1 received low-level radiological waste from 1955 to 2000 and low-level mixed waste between 1987 and 1993. Portions of Trench 9 that received dangerous chemicals are referred to as "Green Islands," and are regulated under RCRA and its implementing requirements in 40 CFR 265, Subpart F.

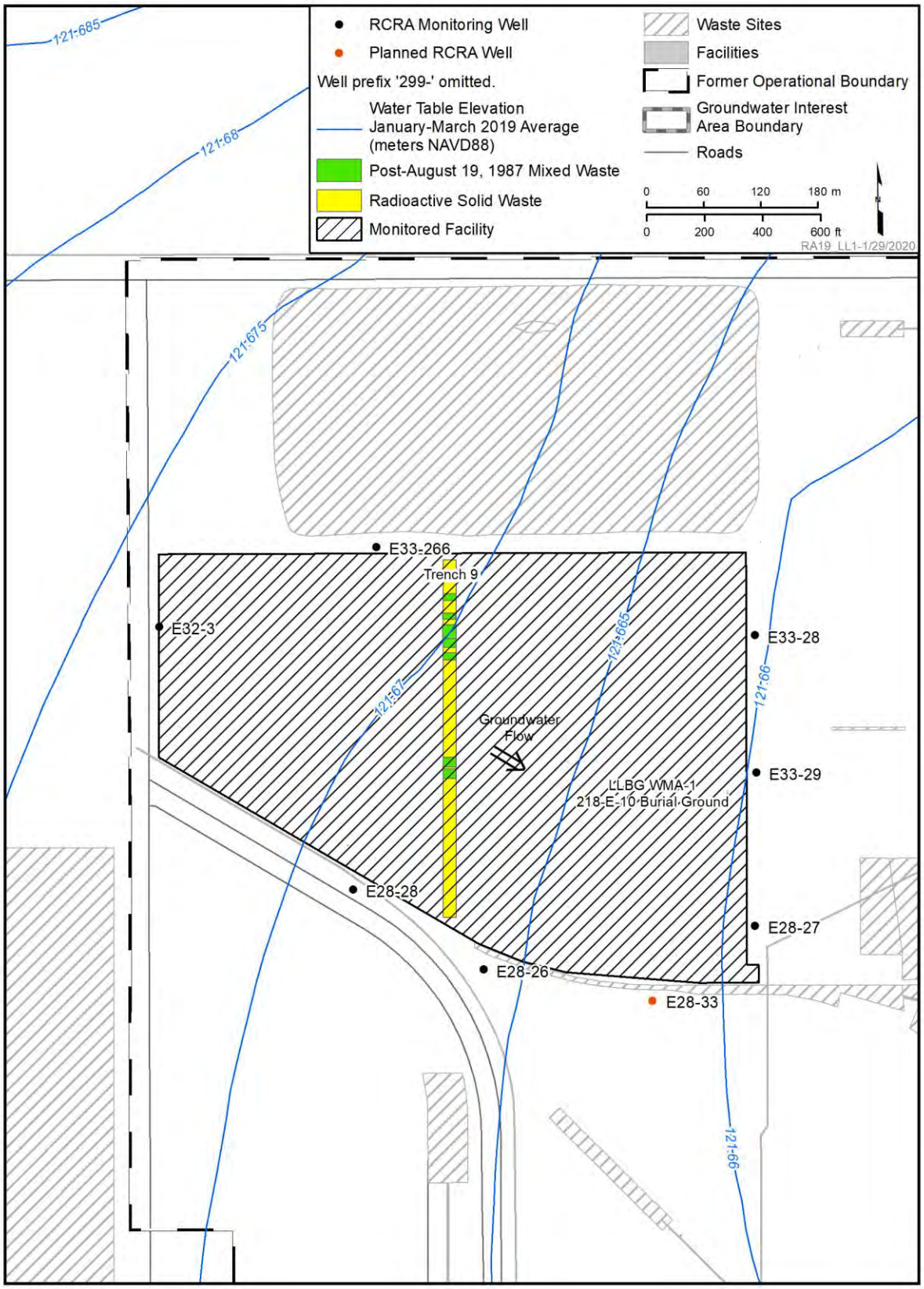


Figure 9-28. Low-Level Burial Grounds Waste Management Area 1

The LLBG WMA-1 monitoring network is designed to detect indicators of dangerous waste or dangerous waste constituents affecting groundwater from the 218-E-10 Burial Ground. The LLBG WMA-1 monitoring network encompasses the 218-E-10 Burial Ground boundary to provide coverage for potential groundwater flow direction changes. DOE monitors groundwater under an interim status indicator evaluation program as described in DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*.

The current LLBG WMA-1 monitoring network consists of seven wells screened in the upper portion of the aquifer at the water table (Table B-35 in Appendix B). The monitoring plan (DOE/RL-2009-75) proposed a new well near the southeast corner of LLBG WMA-1 (Figure 9-28). All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Section 7.4 in SGW-60590, *Engineering Evaluation Report for Low-Level Burial Grounds Waste Management Area-1 Green Islands Groundwater Monitoring*, recommended a modified network for monitoring the LLBG WMA-1 Green Islands under final status, including five of the current wells and three proposed new wells.

The average hydraulic gradient beneath LLBG WMA-1 was 3.3×10^{-5} m/m, sloping to the east-southeast (Table B-2 in Appendix B). The associated groundwater flow rate was 2.3 m/d (7.6 ft/d).

In 2019, LLBG WMA-1 monitoring wells were sampled semiannually for indicator parameters as scheduled (Table B-36 in Appendix B). The January sampling event for well 299-E33-29 did not include quadruplicate samples for specific conductance or pH as required. Statistical comparisons were performed using single results instead of averages. Specific conductance, pH, TOC, and TOX did not exceed critical mean values in any of the downgradient wells in 2019, and LLBG WMA-1 remains in indicator evaluation monitoring.

Table B-37 in Appendix B summarizes the groundwater quality parameters and other constituents for LLBG WMA-1. Nitrate concentrations were above the 45 mg/L DWS in two wells due to a regional nitrate plume. Manganese and iron (trace metals reviewed for well corrosion) were below the quantitation limits or regional background levels.

9.9.6 Low-Level Burial Grounds Waste Management Area 2

LLBG WMA-2 is located in the northeast corner of the 200 East Area and includes the 218-E-12B Burial Ground and Trench 94 (Figure B-1 in Appendix B; Figure 9-29). While LLBG WMA-2 received solid, low-level, radiological and transuranic waste from 1967 to 2004, it did not receive dangerous waste constituents. However, because Trench 94 continues to receive defueled U.S. Navy reactor compartments that use lead as a shielding material, Ecology considers the lead subject to regulation as a state-only dangerous waste (18-NWP-062, "Request for Removal of 218-E-12B Trench 94 from the Hanford Facility Resource Conservation and Recovery Act/ Dangerous Waste Permit Application Part A Form for the Low-Level Burial Grounds Operating Unit Group, letter 16-AMRP-0032, dated November 20, 2015"). Therefore, LLBG WMA-2 is monitored under an interim status indicator evaluation program (DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*).

Interpreted directions of groundwater flow beneath LLBG WMA-2 in 2019 ranged from southeast to southwest, with an average hydraulic gradient sloping to the south at 5.4×10^{-6} m/m. The average flow rate was 0.37 m/d (1.2 ft/d) (Table B-2 in Appendix B). Groundwater extraction well 299-E33-361 was brought online for the 200-BP-5 OU in April 2019, and will likely change flow directions beneath LLBG WMA-2.

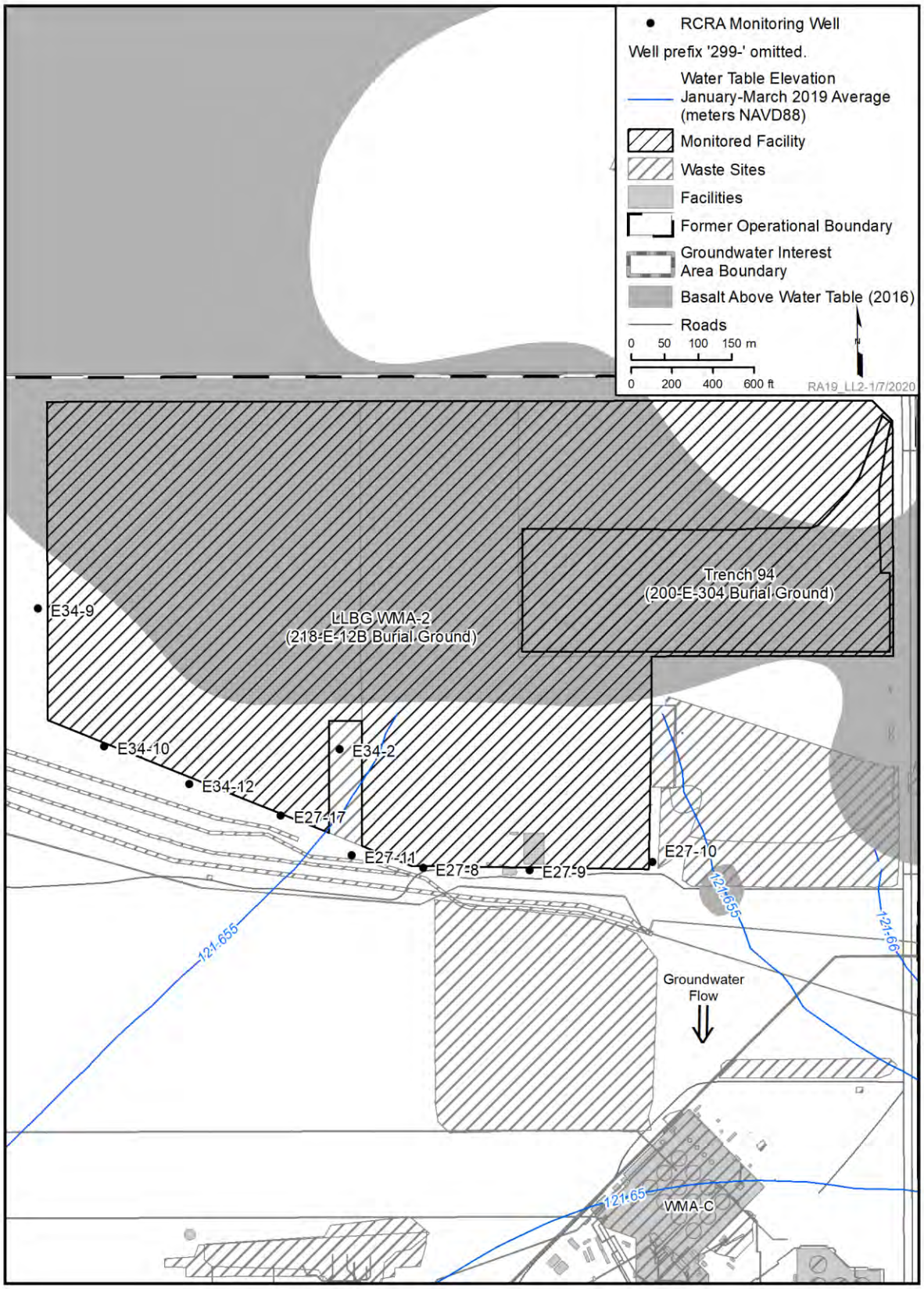


Figure 9-29. Low-Level Burial Grounds Waste Management Area 2

The monitoring network for LLBG WMA-2 (Table B-38 in Appendix B) is constrained by the presence of basalt above the water table in the northern portion of the unit (Figure 9-29). There is no unconfined aquifer in this region, so there is no upgradient well. In 2019, data from well 299-E34-2 were used to calculate critical mean values. A revision to the interim status monitoring plan is anticipated in 2020, and DOE is preparing an engineering evaluation report to investigate alternatives for monitoring Trench 94 under final status. Water-level predictions indicate that wells 299-E34-2, 299-E34-9, and 299-E34-12 may become sample dry within the next 10 years (SGW-63743). Well life may be extended by the use of low-flow sampling pumps.

In 2019, LLBG WMA-2 monitoring wells were sampled semiannually for indicator parameters as required, and no exceedances were verified (Table B-39 in Appendix B). During the May 2019 sampling event, the average pH result at well 299-E27-11 exceeded the critical mean. Split verification pH measurements from two field meters were collected on May 31, 2019. Both pH verification average split results were below the critical mean (Table B-39 in Appendix B). Only three of the four required quadruplicate verification measurements were made with each meter due to a paperwork error.

The TOX holding times for the May 2019 semiannual sampling event were exceeded for some samples, and the entire network was resampled for TOX between June 21 and June 24, 2019. All of the June 2019 TOX results were below the critical mean. During the June 2019 TOX resampling event, the pH results at well 299-E27-8 exceeded the critical mean. Split verification pH measurements from two field meters were collected on July 15, 2019. Both pH verification average split quadruplicate results were below the critical mean (Table B-39 in Appendix B).

Table B-40 in Appendix B summarizes the groundwater quality parameters and other constituents for LLBG WMA-2. Iron, nitrate, and sulfate concentrations were above DWSs but did not originate from the 218-E-12B Burial Ground, as explained below:

- Iron concentrations were above the 300 µg/L secondary DWS in one unfiltered sample from well 299-E27-17. Other metals associated with stainless-steel corrosion (chromium and nickel) are also monitored at this well and have declined in concentration over the past 5 years, indicating that cleaning of this well is not currently required.
- Nitrate concentrations were above the 45 mg/L DWS in five wells due to regional nitrate plumes. Nitrate concentrations in the west part of LLBG WMA-2 are associated with past migration of B Complex waste. An ongoing removal action at the B Complex has resulted in declining nitrate concentrations in the western LLBG WMA-2 wells. Remedial action is planned to the south of the eastern portion of LLBG WMA-2 (at WMA C) and should reduce nitrate concentrations at wells 299-E27-9 and 299-E27-10.
- Sulfate concentrations were above the secondary DWS in three wells due to regional sulfate plumes. Sulfate concentrations in the western part of LLBG WMA-2 are associated with past migration of B Complex waste. An ongoing removal action at the B Complex has resulted in declining sulfate concentrations in the west. The remedial action planned to the south of the east portion of LLBG WMA-2 (at WMA C) should also reduce sulfate concentrations.

Manganese (a trace metal monitored as an indicator of well corrosion) was below the quantitation limit except in well 299-E27-10, where concentrations temporarily increased after the well was cleaned in April 2019. This pattern is consistent with those observed in other WMA C wells after cleaning.

9.10 Atomic Energy Act Monitoring

AEA groundwater monitoring was conducted at 115 groundwater wells in 200-BP in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 200-BP are iodine-129, nitrate, technetium-99, strontium-90, uranium, and tritium. Historically, nitrate has been monitored through the AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Five wells were not sampled in accordance with SAP requirements in 2019. Minor exceptions to planned monitoring occurred due to laboratory tracer errors. Appendix C lists the sampling exceptions for 2019 AEA monitoring of the 200-BP groundwater wells.

Radionuclide concentrations detected in groundwater samples from 146 wells[11] 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 exceeded the 100 mrem/yr standard at three groundwater wells in 200-BP (Table 9-13). The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 82 locations in 200-BP. The DWSs for cumulative alpha emitters and the EPA net alpha activity standard were exceeded at one well. The 30 µg/L uranium DWS was exceeded at 19 locations. None 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 that restrict access to groundwater. CERCLA remedial action decisions will provide additional protection of the public and the environment.

9.10.1 Low Level Burial Grounds Waste Management Area 1

Additional monitoring is integrated into the AEA SAP (DOE/RL-2015-56) as part of existing performance assessment monitoring plans for LLBG WMA-1 and LLBG WMA-2, as described in DOE/RL-2000-72, *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds*. The COCs for the monitoring plans are iodine-129, technetium-99, tritium, and uranium. Trend plots of the indicator parameters did not indicate groundwater quality effects associated with the 218-E-10 or 218-E-12B Burial Grounds in 2019.

Iodine-129 concentrations exceeded the DWS in six LLBG WMA-1 wells during 2019. The concentration trends at wells with elevated iodine-129 vary from decreasing to variable. Technetium-99 concentrations exceeded the DWS in one LLBG WMA-1 well during 2019; however, the concentration trend is decreasing at this well. Tritium concentrations are <50% of the DWS and show trends that are either stable or continued to decrease during 2019. None of the LLBG WMA-1 uranium values exceeded the DWS in 2019. Uranium concentrations in LLBG WMA-1 wells decreased or remained stable for all wells. The 2019 groundwater data do not indicate a release associated with the 218-E-10 Burial Ground.

9.10.2 Low Level Burial Grounds Waste Management Area 2

Iodine-129 concentrations exceeded the DWS in three LLBG WMA-2 wells during 2019. The iodine-129 concentrations at these three wells are variable or decreasing. Technetium-99 exceeded the DWS at two LLBG WMA-2 wells during 2019. The elevated concentrations have a variable or decreasing trend. Tritium concentrations did not exceed the DWS in LLBG WMA-2 wells during 2019. None of the LLBG WMA-2 uranium values exceeded the DWS in 2019. Trend plots of the indicator parameters did not indicate groundwater quality effects associated with the 218-E-12B Burial Grounds in 2019.

[11] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Cumulative Alpha Emitter Activity ≥15 pCi/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E24-25	—	—	14.47	14.47	—	—	—	—	—	—
299-E27-7	—	—	25.06	25.06	—	—	—	—	—	—
299-E27-8	—	—	6.87	6.87	—	—	—	—	—	—
299-E27-9	—	—	5.98	6.54	—	—	—	—	—	—
299-E27-10	—	—	6.27	6.95	—	—	—	—	—	—
299-E27-12	—	—	20.00	20.00	—	—	—	—	—	—
299-E27-13	—	—	25.60	119.48	—	—	—	—	—	—
299-E27-14	—	—	17.091	39.14	—	—	—	—	—	—
299-E27-15	—	—	16.41	16.41	—	—	—	—	—	—
299-E27-16	—	—	12.15	14.68	—	—	—	—	—	—
299-E27-19	—	—	6.99	6.99	—	—	—	—	—	—
299-E27-21	—	—	76.00	134.30	—	—	—	—	—	—
299-E27-22	—	—	26.95	26.95	—	—	—	—	—	—
299-E27-23	—	—	51.11	122.68	—	—	—	—	—	—
299-E27-24	—	—	25.22	35.97	—	—	—	—	—	—
299-E27-26	—	—	28.68	28.68	—	—	—	—	—	—
299-E27-137B	—	—	14.11	30.56	40.80	40.80	—	—	—	—
299-E27-155	—	—	11.20	25.32	—	—	—	—	—	—
299-E28-4	—	—	4.45	4.45	—	—	—	—	—	—
299-E28-5	—	—	7.25	10.04	—	—	—	—	—	—

Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Cumulative Alpha Emitter Activity ≥15 pCi/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E28-6	—	—	—	—	38	38	—	—	—	—
299-E28-7	—	—	111.77	111.77	—	—	—	—	—	—
299-E28-17	—	—	—	—	41.9	41.9				
299-E28-23	—	—	118.22	118.22	—	—	20.9	20.9	22.31	22.31
299-E28-24	—	—	214.95	214.95	38.1	38.1	—	—	—	—
299-E28-25	—	—	164.27	164.27	—	—	—	—	—	—
299-E28-34	—	—	18.16	18.16	67.30	67.30	—	—	—	—
299-E32-8	—	—	8.26	8.65	—	—	—	—	—	—
299-E32-9	—	—	12.70	13.78	—	—	—	—	—	—
299-E32-10	—	—	17.36	18.51	—	—	—	—	—	—
299-E33-12	—	—	4.12	4.12	—	—	—	—	—	—
299-E33-15	—	—	74.10	74.10	—	—	—	—	—	—
299-E33-17	—	—	95.58	95.58	—	—	—	—	—	—
299-E33-20	—	—	20.33	45.02	309	641	—	—	—	—
299-E33-28	—	—	11.09	11.13	—	—	—	—	—	—
299-E33-30	—	—		7.38	—	—	—	—	—	—
299-E33-31	—	—	10.11	21.82	38.6	65.5	—	—	—	—
299-E33-32	—	—	14.58	14.58	—	—	—	—	—	—
299-E33-33	—	—	14.77	14.77	—	—	—	—	—	—
299-E33-34	—	—	15.93	19.89	—	—	—	—	—	—

Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Cumulative Alpha Emitter Activity ≥15 pCi/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E33-35	—	—	13.02	18.40	—	—	—	—	—	—
299-E33-36	—	—	8.61	18.57	—	—	—	—	—	—
299-E33-37	—	—	7.92	11.26	—	—	—	—	—	—
299-E33-38	—	—	35.14	156.53	—	—	—	—	—	—
299-E33-39	—	—	47.63	88.78	—	—	—	—	—	—
299-E33-41	—	—	16.11	29.31	—	—	—	—	—	—
299-E33-42	—	—	17.56	17.56	—	43.9	—	—	—	—
299-E33-44	—	—	92.91	102.49	41	43	—	—	—	—
299-E33-47	—	—	72.56	80.44	50.3	69.7	—	—	—	—
299-E33-49	—	—	6.32	6.32	—	—	—	—	—	—
299-E33-265	—	—	4.39	4.39	—	—	—	—	—	—
299-E33-268	—	—	18.62	22.03	34.8	39.5	—	—	—	—
299-E33-334	—	—	5.69	5.69	—	—	—	—	—	—
299-E33-337	—	—	7.57	16.57	32	32	—	—	—	—
299-E33-338	—	—	6.64	7.85	—	—	—	—	—	—
299-E33-339	—	—	5.08	5.08	—	—	—	—	—	—
299-E33-341	—	—	18.69	90.13	—	—	—	—	—	—
299-E33-342	—	—	43.23	54.87	—	—	—	—	—	—
299-E33-343	—	—	18.83	18.83	97.1	97.1	—	—	—	—
299-E33-344	3,899.40	4,576.56	120.42	162.87	38,734.04	47,800	—	—	—	—

Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Cumulative Alpha Emitter Activity ≥15 pCi/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E33-345	—	—	21.71	23.33	95.00	100.00	—	—	—	—
299-E33-350	4,539.92	7,986.43	127.69	367.20	46,000	108,000	—	—	—	—
299-E33-351	3,034.30	3,967.85	161.29	235.61	31,100	37,922.81	—	—	—	—
299-E33-360	—	—	23.25	73.83	73.40	91.40	—	—	—	—
299-E33-361	—	—	11.44	15.83	38.20	38.20	—	—	—	—
299-E34-8	—	—	8.87	12.57	—	—	—	—	—	—
299-E34-9	—	—	11.69	23.34	—	—	—	—	—	—
699-42-40A	—	—	9.57	9.57	—	—	—	—	—	—
699-43-41F	—	—	14.72	14.72	—	—	—	—	—	—
699-43-41G	—	—	6.60	6.60	—	—	—	—	—	—
699-45-42	—	—	15.59	15.59	—	—	—	—	—	—
699-47-53B	—	—	16.11	16.11	—	—	—	—	—	—
699-47-55	—	—	18.87	18.87	—	—	—	—	—	—
699-49-57A	—	—	9.047	9.04	—	—	—	—	—	—
699-50-56	—	—	5.00	5.00	—	—	—	—	—	—
699-50-59	—	—	7.84	7.84	—	—	—	—	—	—
699-52-55	—	—	7.08	7.08	—	—	—	—	—	—
699-53-47B	—	—	131	131	—	—	—	—	—	—
699-53-55B	—	—	9.61	9.61	—	—	—	—	—	—
699-53-55C	—	—	9.63	9.63	—	—	—	—	—	—

Table 9-13. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-BP in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Cumulative Alpha Emitter Activity ≥15 pCi/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
699-54-48	—	—	6.10	6.10	—	—	—	—	—	—
699-54-49	—	—	79.00	79.00	—	—	—	—	—	—
699-55-55	—	—	5.30	5.30	—	—	—	—	—	—
699-55-57	—	—	7.54	7.54	—	—	—	—	—	—

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford.*

Note: Blank cells (—) indicate no exceedances.

10 200-PO

This chapter presents information for the 200-PO groundwater interest area, which includes groundwater contaminant plumes sourced beneath the southern half of the 200 East Area and extends to the south-southeast throughout much of the 600 Area to the adjoining 300 Area, 400 Area, and Columbia River (Figures 1-1 and 10-1). Groundwater monitoring in 200-PO is performed to meet AEA, CERCLA, RCRA, and *Washington Administrative Code* requirements. The 200-PO groundwater interest area is informally divided into the near-field area (includes the former operational areas within and near the 200 East Area) and the far-field area (includes wells downgradient of the near-field area and aquifer tubes along the Columbia River, and generally comprises areas where site operations did not occur).

10.1 Overview

The 200-PO groundwater interest area includes the CERCLA 200-PO-1 OU and adjacent region; seven RCRA units (216-A-29 Ditch, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-3 Pond [B Pond], Nonradioactive Dangerous Waste Landfill [NRDWL], Integrated Disposal Facility [IDF], and WMA A-AX [SST]); one state-regulated landfill (the SWL); and the 400 Area. Currently, no groundwater remediation systems are implemented within 200-PO. Table 10-1 summarizes some key facts about 200-PO. Section 1.5 provides plume mapping details, including descriptions of terms (e.g., Type 1 control point) used in the figure legends.

Groundwater beneath 200-PO primarily occurs in an unconfined aquifer consisting of Hanford formation and Ringold Formation sands and gravels (Figure 1-6). However, due to the large extent and overall thickness of the aquifer (up to 215 m [705 ft]), it also includes localized semiconfined and confined intervals within deeper portions of the aquifer system. The base of the unconfined aquifer is the Ringold lower mud unit (hydrostratigraphic unit 8), which locally confines the underlying Ringold unit 9. Finer-grained strata within Ringold unit 9 confine underlying sediments locally. In one location immediately east of the 200 East Area, there are no saturated sediments above the Ringold lower mud unit, and the unconfined aquifer is absent. Detailed discussions of geology and hydrogeology within 200-PO are provided in Sections 3.4 and 3.6 of DOE/RL-2009-85, *Remedial Investigation Report* for the *200-PO-1 Groundwater Operable Unit*; Section 3.1 in DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*; and Chapters 3 and 4 in PNNL-12261.

Groundwater within 200-PO has been contaminated primarily by past releases from facilities associated with PUREX and B Plant operations. These include discharge to cribs, ponds, and trenches, as well as unplanned releases from SSTs. Groundwater sampling within 200-PO (Figure 10-1) is directed by SAPs, permits, Tri-Party Agreement change notices (Ecology et al., 1989b), and other documents that identify groundwater monitoring requirements. A 2018 addendum to the *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2009-85-ADD1) identified gross alpha, iodine-129, nitrate, strontium-90, sulfate, technetium-99, tritium, and uranium as final COPCs. Gross alpha is associated with uranium (Section 10.6). Sulfate concentrations were all below the 250 mg/L secondary DWS in 2019; therefore, sulfate is not discussed further in this chapter.

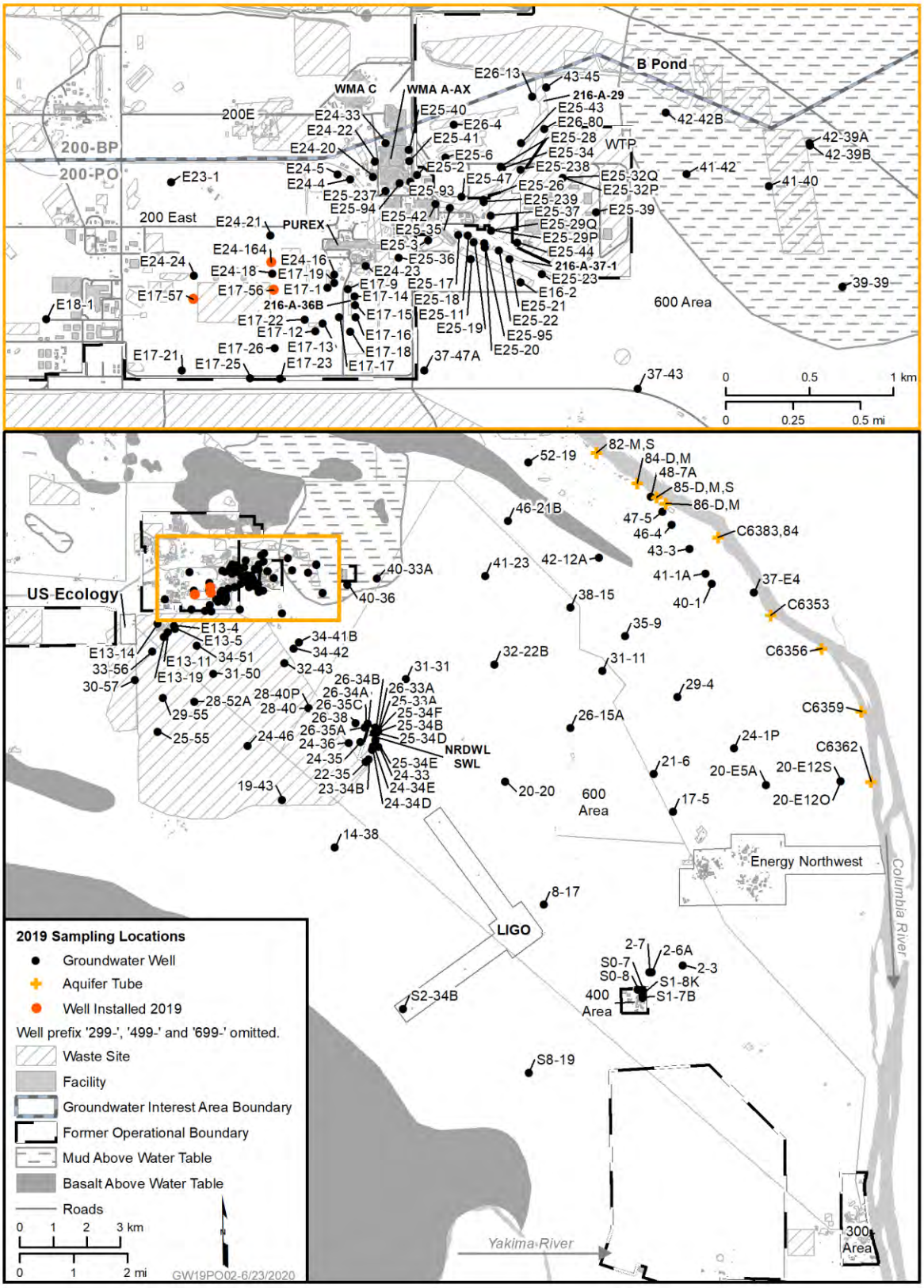


Figure 10-1. 200-PO Sampling Locations, 2019

Table 10-1. 200-PO at a Glance

PUREX Plant operations: 1956 to 1972 (plutonium separation); 1983 to 1989 (plutonium separation)			
Groundwater Monitoring			
Contaminant, Water Quality Standard	**Year**	**Maximum Concentration (Well)**	**Plume Area[a] (km^2)**
Tritium, 20,000 pCi/L	2019	4,240,000 (299-E17-9)	56.8
	2018	365,000 (299-E17-19)	61.8
Iodine-129, 1 pCi/L[b]	2019	12.2 (299-E26-13)	54.8
	2018	13.1 (699-43-45)	64.1
Nitrate, 45 mg/L	2019	133 (299-E17-19)	3.8[c]
	2018	159 (299-E17-20)	4.0[c]
Strontium-90, 8 pCi/L[b]	2019	11.9 (299-E17-14)	<0.01
	2018	14.8 (299-E17-14)	<0.01
Sulfate, 250 mg/L	2019	240 (299-E25-93, 299-E25-94, and 699-39-39	Not calculated
	2018	2670 (699-39-39)	Not calculated
Technetium-99, 900 pCi/L[b]	2019	6,300 (299-E24-22)	0.14
	2018	4,850 (299-E24-22)	0.12
Uranium, 30 µg/L	2019	68 (299-E25-36)	0.06
	2018	71 (299-E25-36)	0.07
Gross alpha, 15 pCi/L	2019	55.5 (299-E25-36)	Not calculated
	2018	25.4 (299-E25-36)	Not calculated

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

b. Single isotope equivalent drinking water standard. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr.

c. Excludes plume in the southern part of 200-PO that originates offsite.

PUREX = Plutonium-Uranium Extraction (Plant)

As shown in Figure 9-4, the unconfined groundwater gradient in the 200 East Area is extremely flat. More precise methods for water-level measurement and mapping were developed, as discussed in Section B5 of Appendix B. In the southeastern part of the 200 East Area, groundwater generally flows to the southeast. Groundwater continues to flow to the southeast from the 200 East Area to NRDWL, then turns to the east and northeast, and eventually discharges to the Columbia River (Figure 1-2). A paleochannel created by Pleistocene cataclysmic floods is filled with highly transmissive sands and gravels and influences the regional groundwater flow (Section 4.2.2 in PNNL-12261). Regional tritium and iodine-129 plume migration patterns follow the preferential groundwater flow path through this paleochannel southeast, away from the 200 East Area, and then east to the Columbia River.

Vertical gradients between the Ringold confined and unconfined aquifers are in the upward direction; therefore, contamination would tend to remain within the unconfined aquifer (Section 5.6 in DOE/RL-2007-31, *Remedial Investigation/Feasibility Study Work Plan for 200-PO-1 Groundwater Operable Unit*).

Figure 10-2 provides a graph of the calculated plume areas from 2003 through 2019 for tritium, iodine-129, nitrate, uranium, and technetium-99. These COPCs (except technetium-99) are primarily associated with PUREX Plant operations, which discharged liquid effluents to cribs and ditches in the southern part of the 200 East Area from 1956 to 1972 and from 1983 to 1988. Technetium-99 within 200-PO has been detected above the DWS near WMA A-AX.

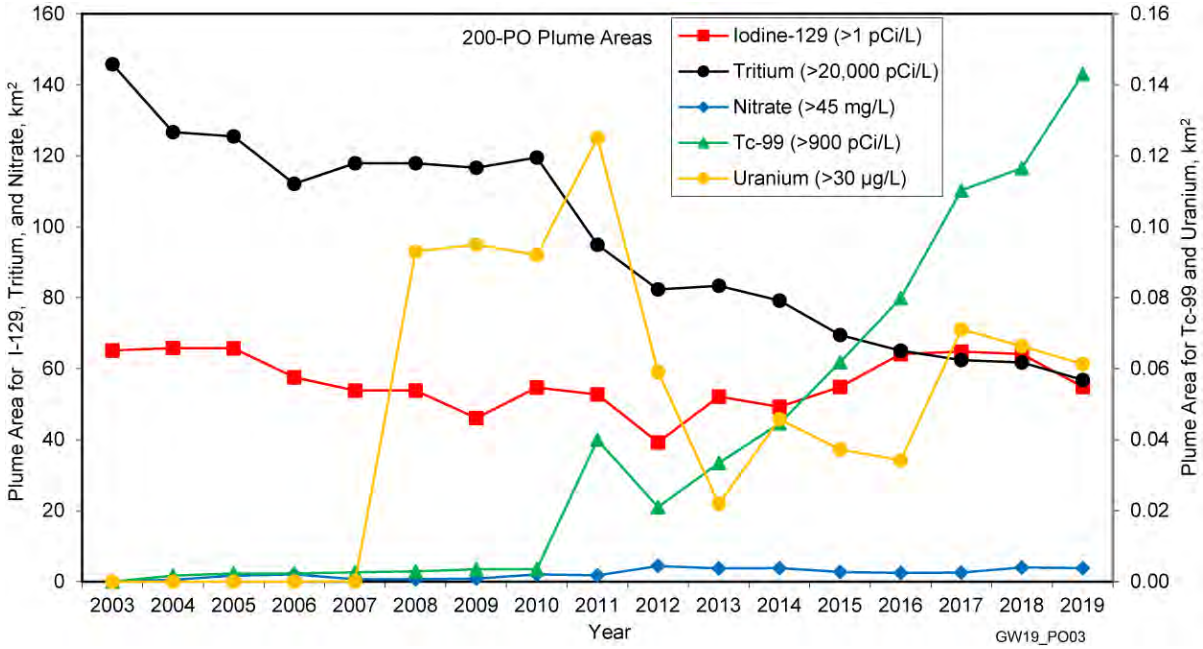


Figure 10-2. 200-PO Plume Areas

10.2 Tritium

The 200-PO near-field wells are sampled for tritium annually, and most far-field wells are sampled triennially (every 3 years). Triennial sampling events were conducted in 2010, 2013, 2016, and 2019. A subset of far-field area wells is sampled annually.

Due to radioactive decay and dispersion, the tritium plume bounded by the 20,000 pCi/L contour has decreased in size by 69% since 1980 (from 185 to 56.8 km^2 [71.4 to 21.9 mi^2]) (Figure 10-3). Since 2015, the far-field portion of the plume is no longer connected to the near-field portion. Figures 10-4 and 10-5 show the 2019 plume in greater detail.

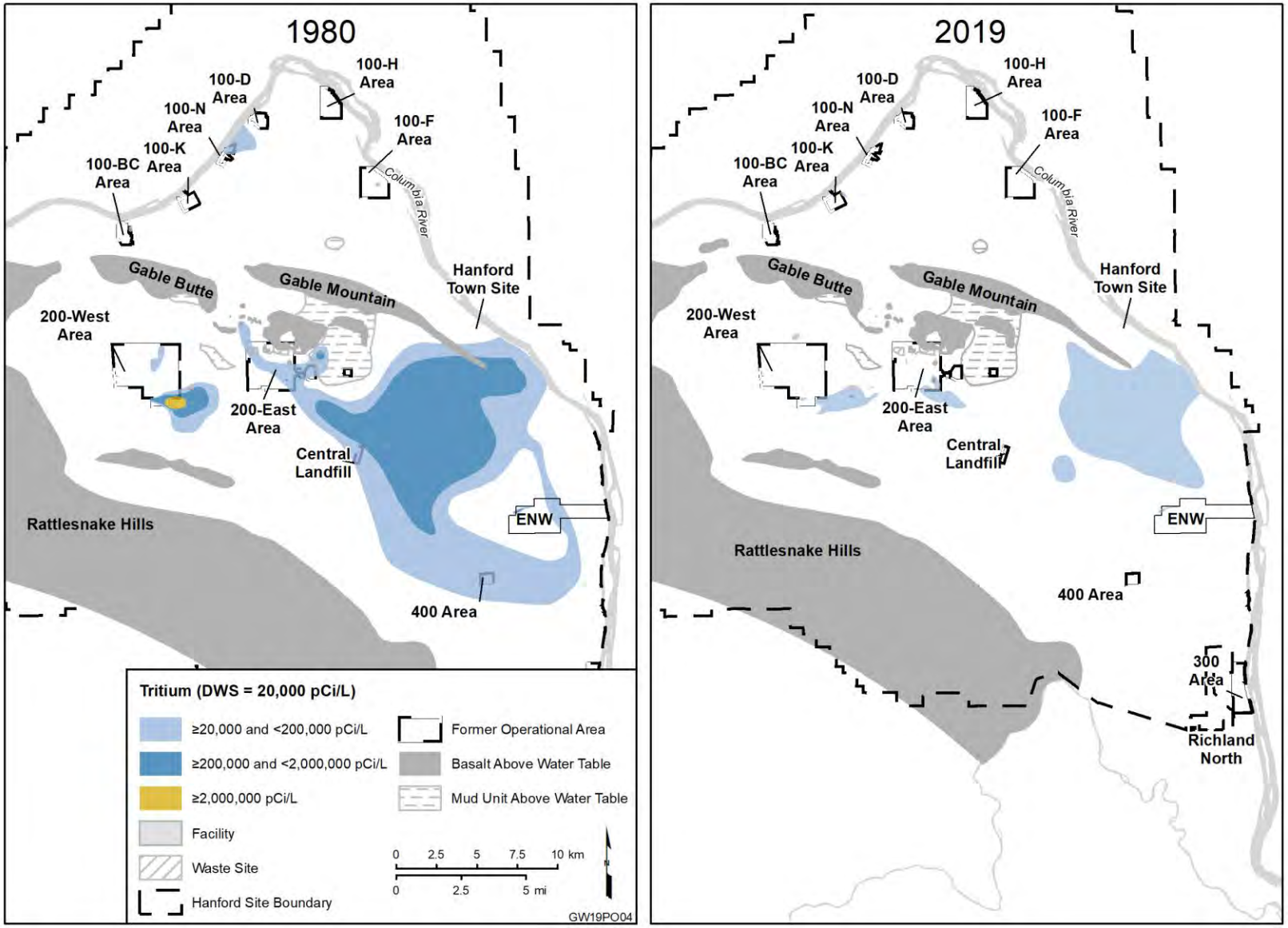


Figure 10-3. Hanford Site Tritium Plumes, 1980 and 2019

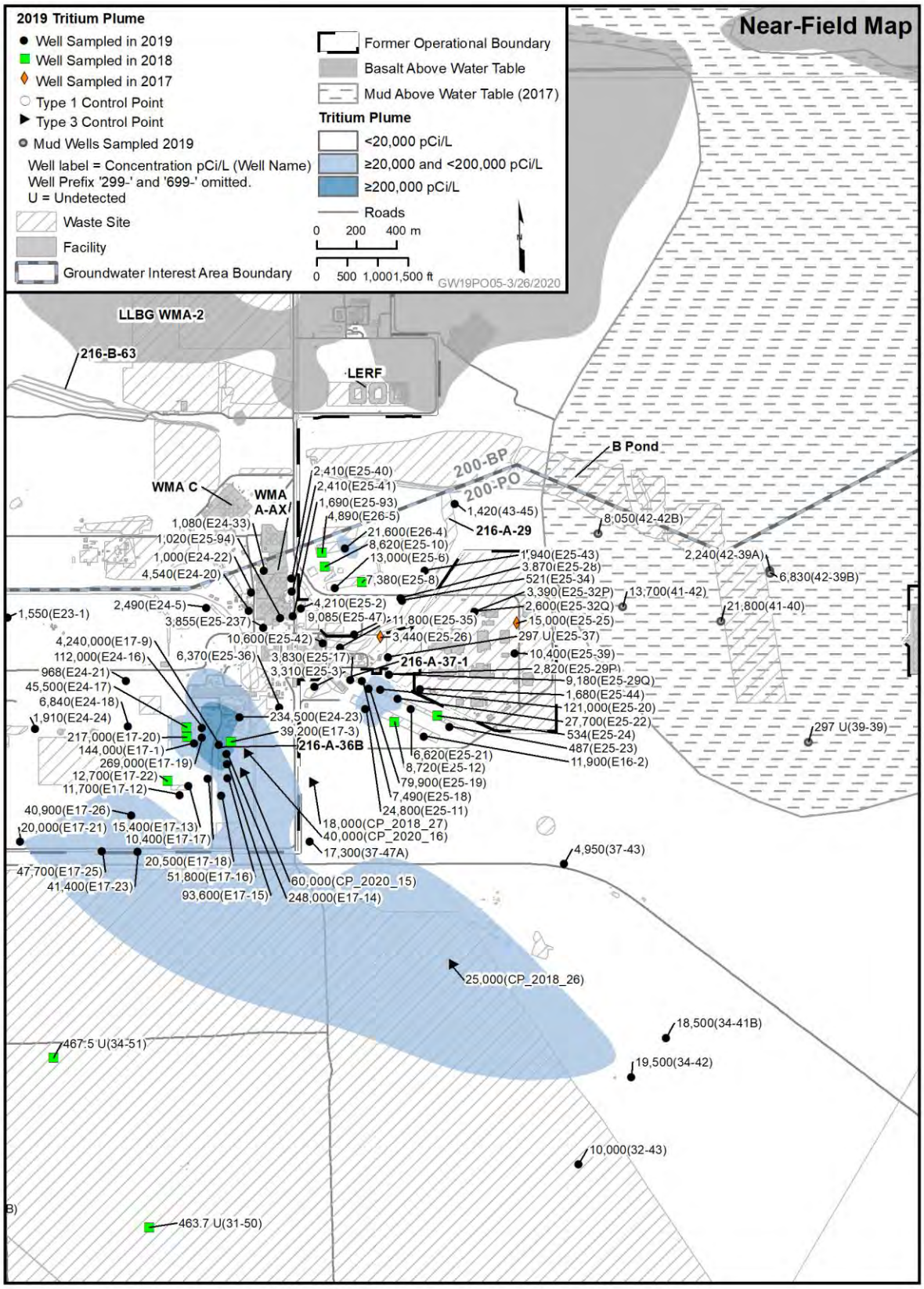


Figure 10-4. 200-PO Near-Field Tritium Plume, 2019

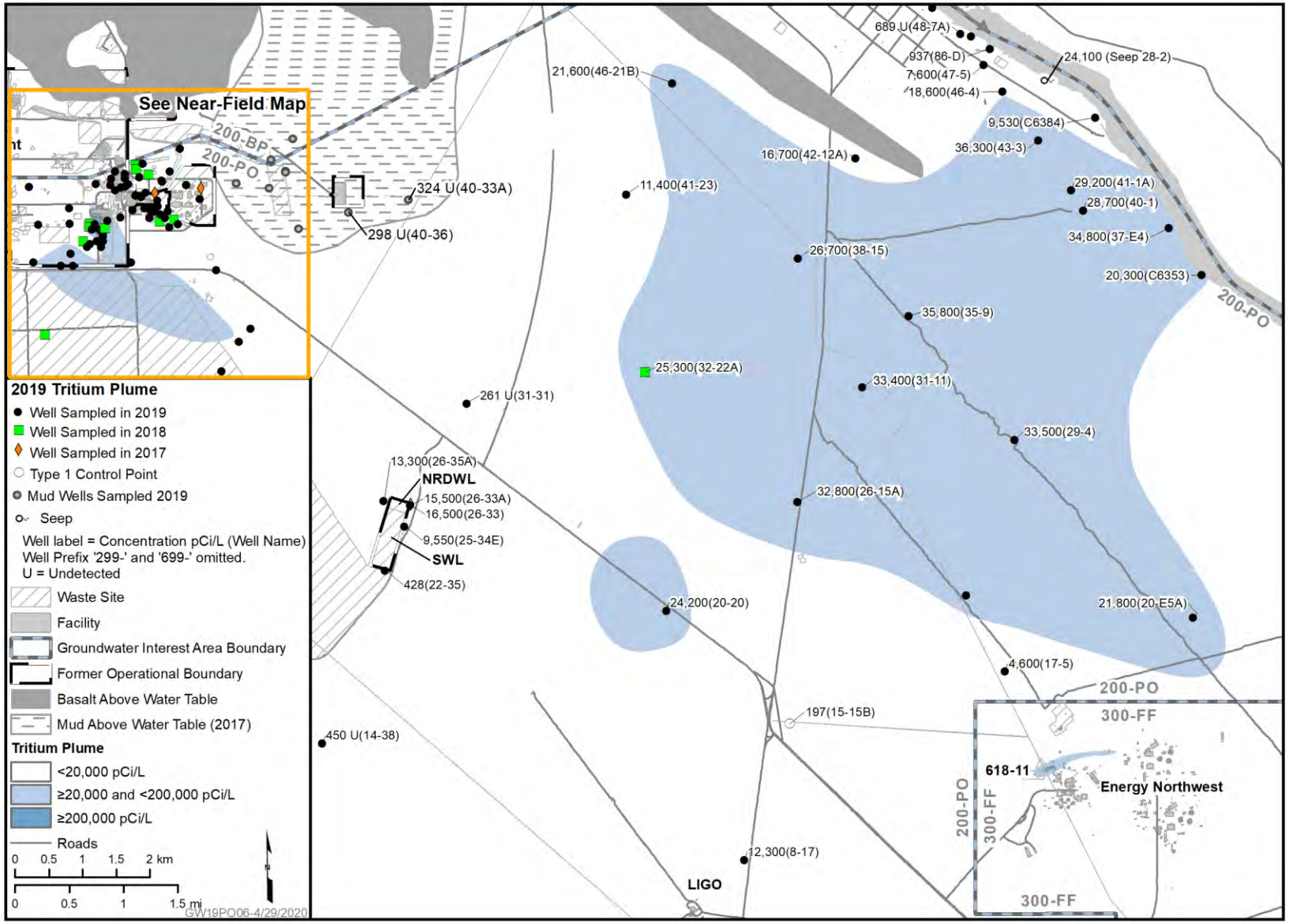


Figure 10-5. 200-PO Far-Field Tritium Plume, 2019

Comparing the 2019 plumes to the 2018 plume (Figures 10-5 and 10-6 in DOE/RL-2018-66) shows the following changes:

- A tritium plume based on concentrations >20,000 pCi/L DWS in wells 699-42-40A and 699-41-40 is not shown on the 2019 map (Figure 10-4) because they are screened in the semiconfined Ringold unit A aquifer and do not reflect unconfined aquifer conditions.
- The southeastern "tail" of the far-field tritium plume at well 699-20-20 split off from the main plume (Figure 10-5). Declining concentrations in wells 699-20-20 and 699-26-15A caused the contours to recede in this area.

The highest current and historical concentrations have been observed near the PUREX cribs and trenches, which were the major release points. Continuing sources from the vadose zone in this area may be present (Section 4.2 in DOE/RL-2009-85). Soil borings at the 216-A-36B Crib recorded tritium concentrations as high as 121 pCi/g in 2003 (Section 3.3.3.2 in DOE/RL-2004-25, Draft A, *Remedial Investigation Report for the 200-PW-2 Uranium-Rich Process Waste Group and the 200-PW-4 General Process Condensate Group Operable Units*).

In 2019, the highest tritium concentration in groundwater was 4,240,000 pCi/L in well 299-E17-9 (near the 216-A-36A Crib), an order of magnitude higher than nearby wells (Figure 10-6). Well 299-E17-9 had not been sampled since 2002, when the concentration was 5,570,000 pCi/L. The high concentrations may indicate a continuing source of tritium in the vadose zone near the well, which is perforated over the top 1 m (3 ft) of the aquifer. Concentrations are declining in other near-field wells, including 299-E17-1 and 299-E17-19 (near the 216-A-10 Crib) and 299-E17-14 (near the 216-A-36B Crib) (Figure 10-6).

A large, dispersed tritium plume remains in the far-field area, with a portion of the plume discharging into the Columbia River to the east (Figure 10-5). Many of the far-field wells are sampled every 3 years (most recently in 2019). Continuing declines in tritium concentration in far-field wells 699-26-33, 699-28-40, and 699-31-31 (Figure 10-7) correlate with the decrease in plume size. These trends are expected to continue as tritium in the groundwater decays. The far-field plume discharges to the Columbia River. The highest concentration in a 200-PO aquifer tube in 2019 was 20,300 pCi/L in C6353, where concentrations are declining. Seep 28-2 continued to have tritium concentration above the DWS in 2019 (24,100 pCi/L).

The highest concentration from far-field wells in 2019 was 209,000 pCi/L in well 699-13-3A at the 618-11 Burial Ground, where levels are declining. The groundwater contamination associated with the burial ground is part of the 300-FF-5 Groundwater OU (discussed in Chapter 7).

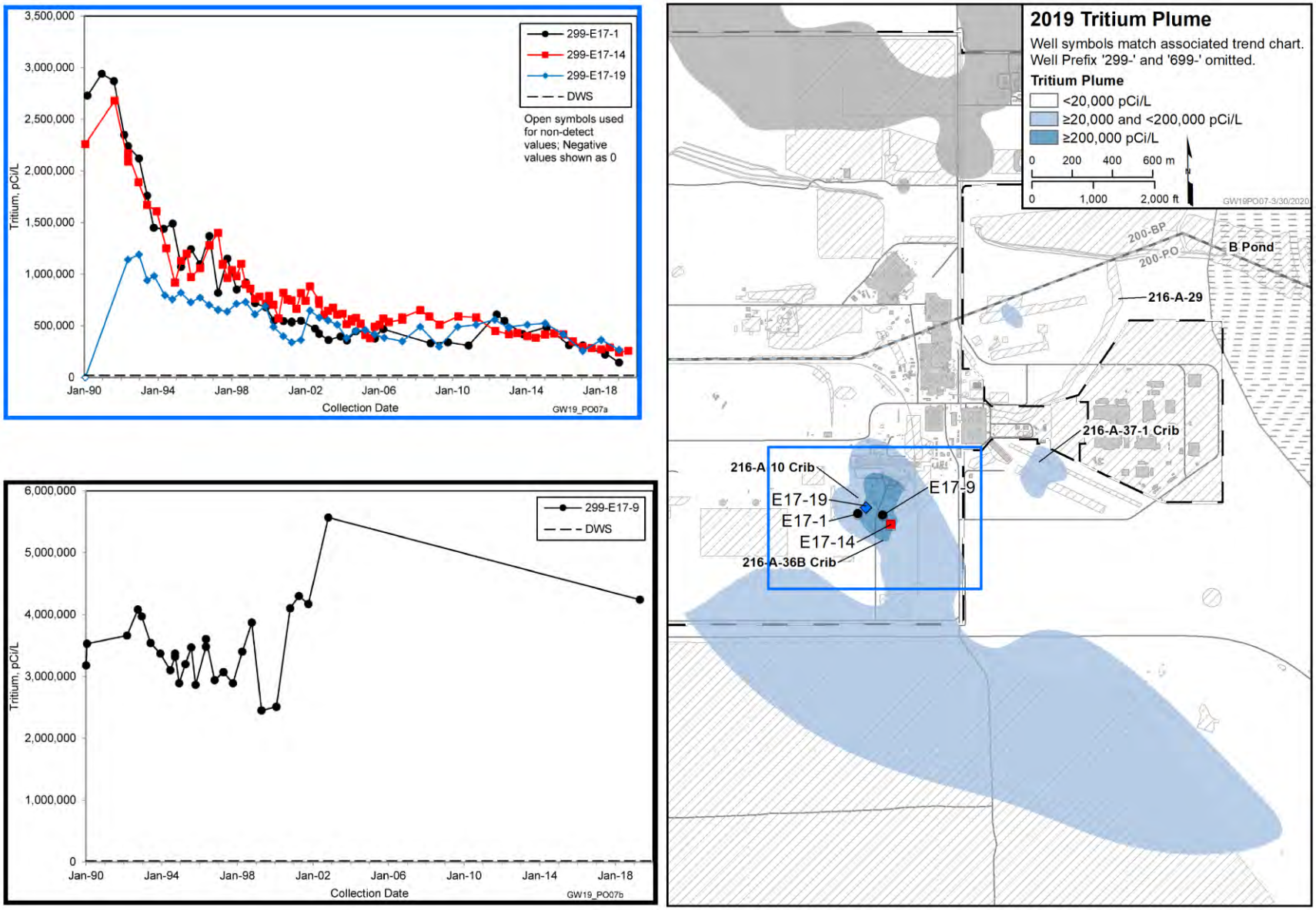


Figure 10-6. 200-PO Tritium Data for Selected Wells in the Near-Field Region

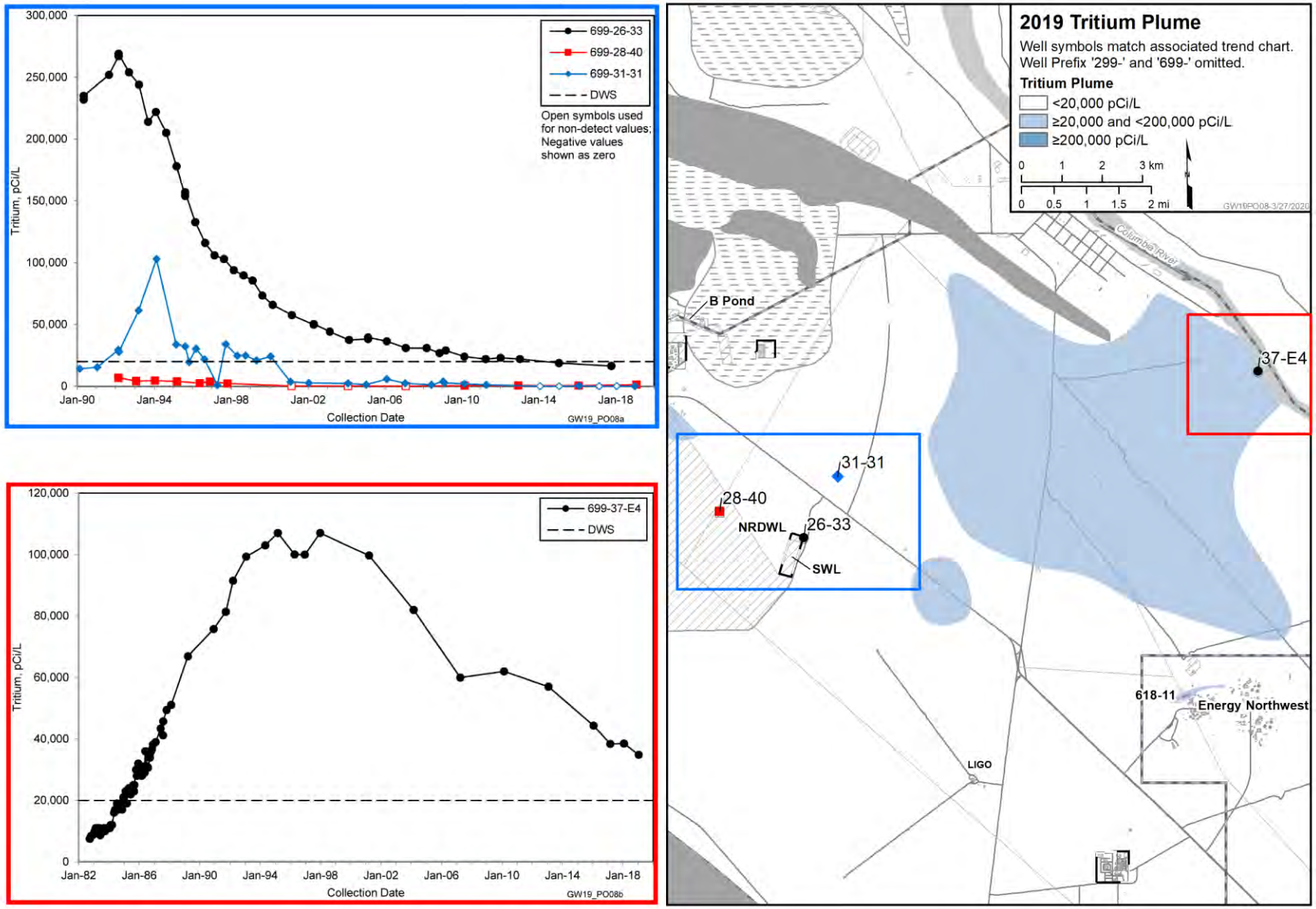


Figure 10-7. 200-PO Tritium Data for Selected Wells in the Far-Field Region

Although tritium contamination is the most widespread in the upper part of the aquifer, it is also detected within the limited monitoring networks for the deep unconfined, Ringold confined, and basalt confined aquifers.

In 2019, wells screened (or casings perforated) in the middle or lower portions of the unconfined aquifer had tritium results ranging from 2,600 pCi/L (299-E25-32Q) to 5,860 pCi/L (299-E25-29Q) in the near-field area. In the far-field area, concentrations ranged from 1,330 pCi/L in well 699-28-40 to 34,800 pCi/L in near-river well 699-37-E4 in 2019. Since 1997, tritium concentrations at well 699-37-E4 have decreased (Figure 10-7).

In 2019, tritium concentrations in wells near B Pond and screened in the Ringold confined aquifer beneath the Ringold lower mud unit ranged from below detection limits (699-39-39) to 28,700 pCi/L (699-42-40A). Since 2007, tritium levels have declined from 42,000 pCi/L at well 699-42-40A (Figure 10-8). Concentrations have also significantly decreased in nearby Ringold confined well 699-41-40, from 226,000 to 21,800 pCi/L in this same time period. Past discharges caused sufficient head beneath the B Pond to cause a downward gradient through the low-permeability Ringold lower mud unit into the semiconfined aquifer. Tritium will continue to attenuate in the Ringold confined aquifer due to radioactive decay.

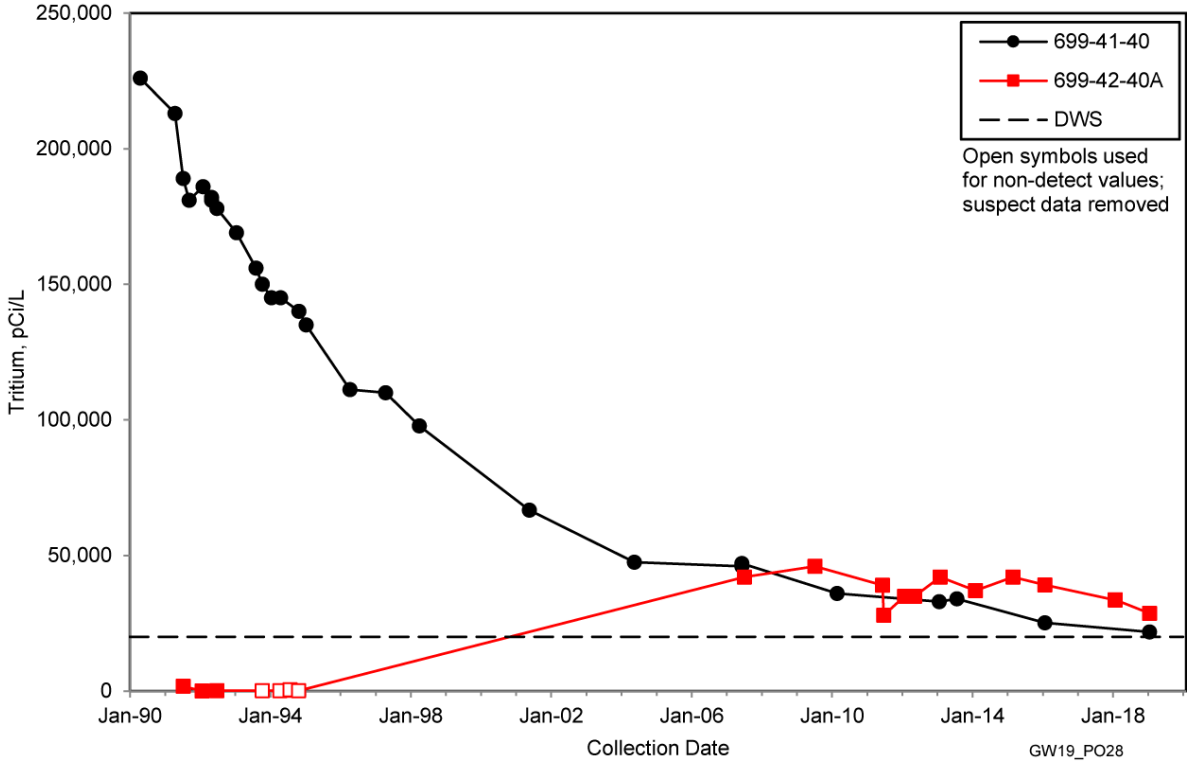


Figure 10-8. 200-PO Tritium Data in Ringold Semiconfined Wells

Seven wells screened in the basalt confined aquifer are sampled triennially under DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*. Tritium has been detected only intermittently at low concentrations in samples collected from these wells, except well 699-42-40C (located near the B Pond in 200-BP). Tritium in well 699-42-40C has been detected since 1982, up to a maximum of 8,320 pCi/L in 1993. The downward gradient from past B Pond discharges likely caused tritium to be present in well 699-42-40C. Since 1996, concentrations in well 699-42-40C have declined, and the last sample result (from 2018) was 2,710 pCi/L (Figure 10-9). Appendix D provides a well location map and additional information about the basalt confined aquifer.

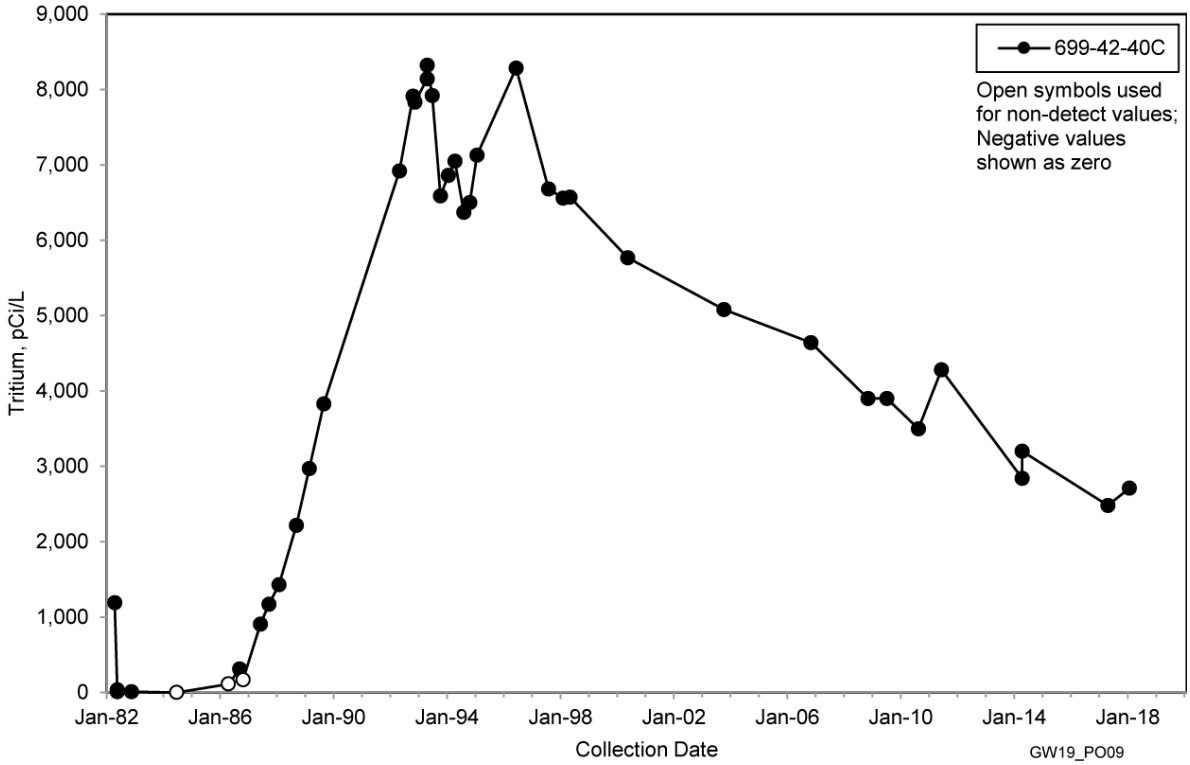


Figure 10-9. 200-PO Tritium Data for Basalt Confined Well 699-42-40C

10.3 Iodine-129

Iodine-129 concentrations greater than the 1 pCi/L DWS are found in a relatively dispersed plume that covers a large area within 200-PO (Figures 10-10 and 10-11). The highest historical and current concentrations were detected near the PUREX cribs and trenches. The majority of triennial far-field area well sampling was completed in 2019. The 2019 interpolated plume extent above the 1 pCi/L concentration in the far-field area remained about the same as in 2018.

Iodine-129 concentrations in near-field area wells in 2019 ranged from less than detection limits to 12.2 pCi/L. The highest concentrations in 2019 were detected near the 216-A-10 Crib, 216-A-29 Ditch, and WMA A-AX, where trends are variable (Figure 10-12). Iodine-129 concentrations at well 299-E17-14 (near the PUREX cribs) show a generally decreasing trend, while concentrations in well 699-43-45 (located near B Pond and the north end of the 216-A-29 Ditch) have increased.

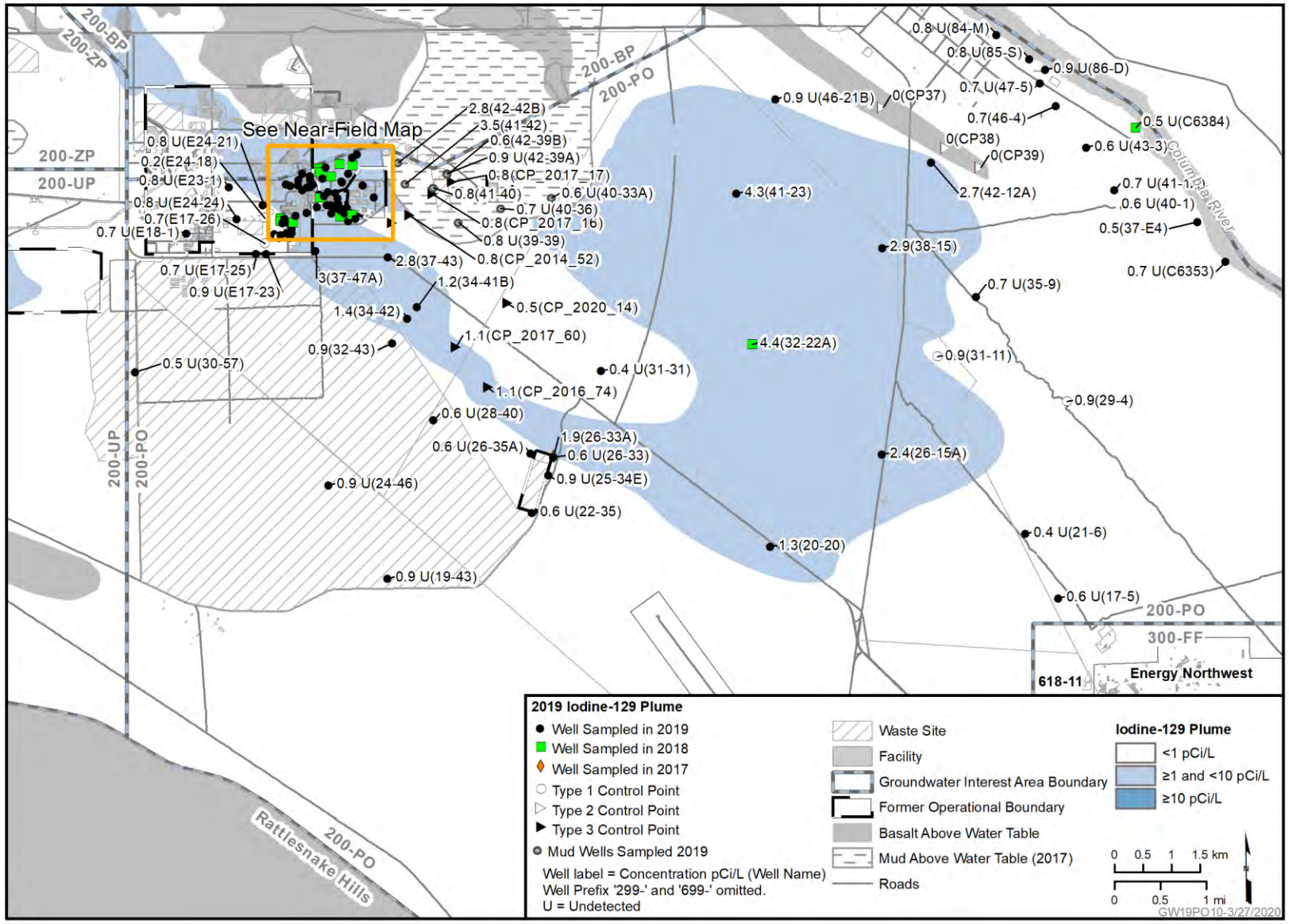


Figure 10-10. 200-PO Far-Field Iodine-129 Plume, 2019

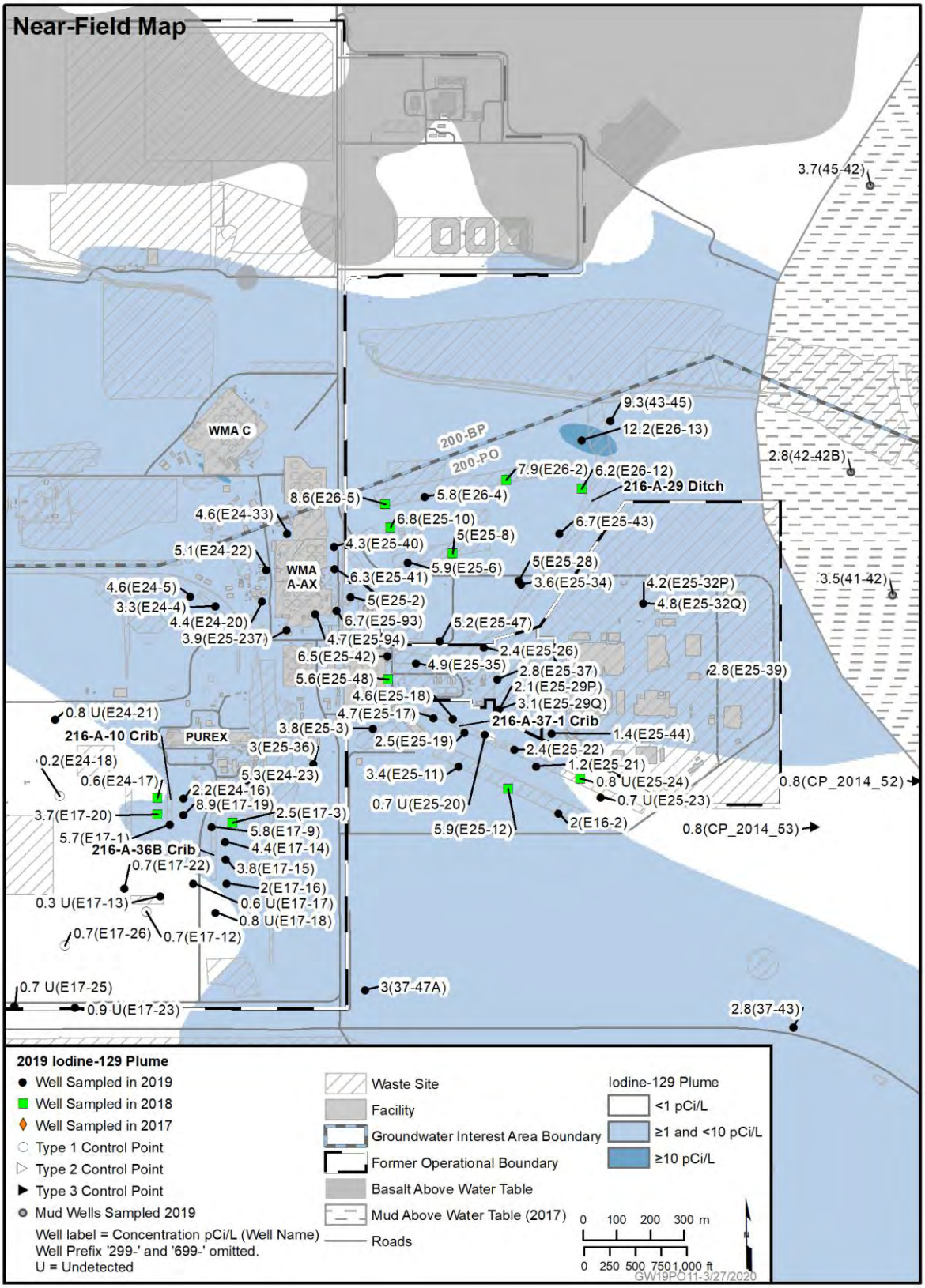


Figure 10-11. 200-PO Near-Field Iodine-129 Plume, 2019

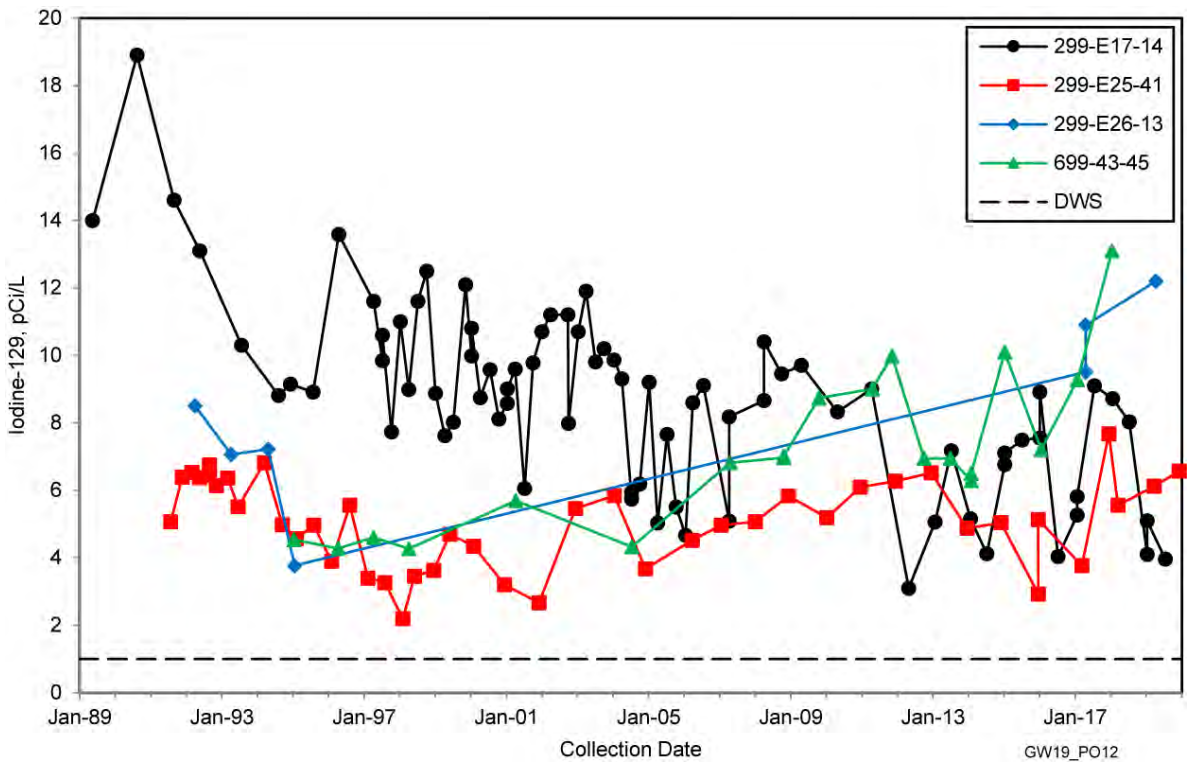
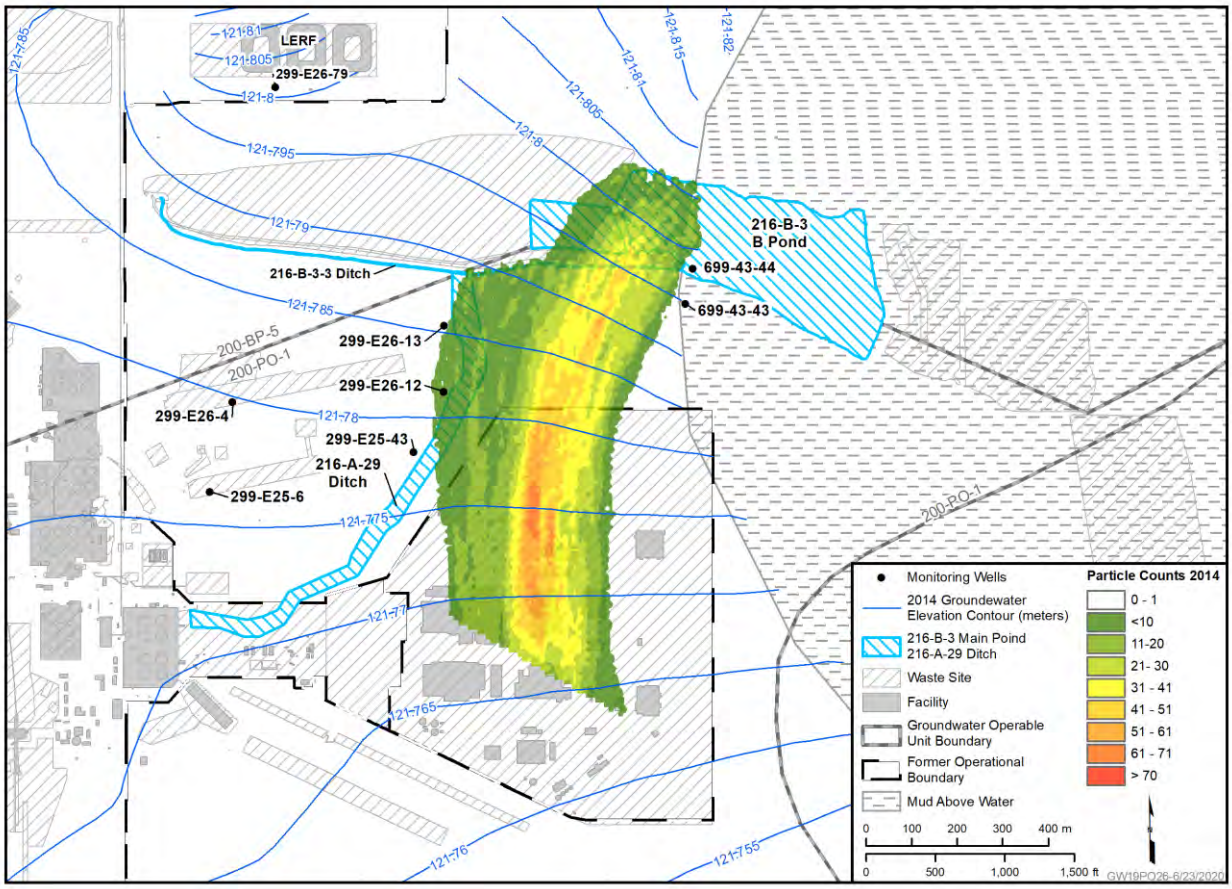


Figure 10-12. 200-PO Iodine-129 Data for Wells 299-E26-13, 299-E17-14, 299-E25-41, and 699-43-45

Although the plume extent has not changed, iodine-129 concentrations have increased in several wells, with well 299-E26-13 (downgradient of the 216-A-29 Ditch) showing the highest concentration in 2019 at 12.2 pCi/L (Figures 10-12). The increasing concentrations have raised concerns that the 216-A-29 Ditch may be a secondary source of contamination to the groundwater in its immediate vicinity. The Hanford Soil Inventory Model (RPP-26744) does not include iodine-129 inventory for the 216-A-29 Ditch, but this does not exclude the possibility that iodine-129 was discharged to the ditch. However, the 216-B-3-3 Ditch and 216-B-3 Pond (immediately upgradient to the north) are more likely sources of iodine-129 because the ditch and pond received 0.0032 Ci of iodine-129 between 1945 and 1997. Recent particle tracking and groundwater flow modeling showed that the wells with increasing iodine-129 concentrations could be receiving contamination from the direction of the 216-B-3-3 Ditch and 216-B-3 Pond (ECF-200E-18-0066, *Groundwater Flow and Migration Calculations to Assess Monitoring Networks in the 200 East Area Dangerous Waste Management Units*) (Figure 10-13).

Figure 10-10 illustrates the 2019 far-field iodine-129 plume. The highest concentration in the far-field area in 2019 occurred at well 699-41-23 (4.26 pCi/L). Concentrations in near-river monitoring wells remained below the DWS. Iodine-129 was not detected in any 200-PO aquifer tubes sampled in 2019.



Reference: SGW-60591, *Engineering Evaluation Report for the 216-B-3 Main Pond Groundwater Monitoring*.

Figure 10-13. Local Groundwater Flow Near the 216-B-3 Pond and 216-A-29 Ditch

Although iodine-129 contamination is the most widespread in the upper part of the aquifer, it is also detected in the limited monitoring networks for the Ringold confined and basalt confined aquifers:

- The Ringold confined aquifer is monitored near B Pond and the Treated Effluent Disposal Facility (TEDF) and contains iodine-129 contamination that is present because of the vertical hydraulic head gradients created by past B Pond discharges. In 2019, iodine-129 was detected at 5 and 3.23 pCi/L in wells 299-E25-28 and 699-42-42B, respectively. Concentrations are declining overall.

- Three wells (299-E16-1, 699-32-22B, and 699-42-40C) screened in the upper basalt confined aquifer within the 200-PO interest area are sampled triennially for iodine-129. Only well 699-32-22B was sampled in 2019, and iodine-129 was undetected. Concentrations of iodine-129 within the basalt confined aquifer wells have historically been near or below detection limits.

10.4 Nitrate

The highest historical concentrations in 200-PO were detected near the PUREX cribs and trenches. PUREX nitrate process waste discharged to the cribs included ammonia scrubber waste effluent and 242A evaporator process condensate. Both of these effluents contained nitrate in large amounts. The 216-A-36B Crib just south of the PUREX Plant received an estimated 1.5 million kg of nitrate at an average concentration of 4.1 mg/L (Appendix C of RPP-26744). The extent of nitrate at concentrations >45 mg/L is limited to the near-field area (Figure 10-14). Historically, the nitrate plume was larger, but concentrations within the far-field area have decreased to <45 mg/L, except near the 618-11 Burial Ground in the 300-FF-5 OU (Chapter 7).

A comparison of the 2019 plume (Figure 10-14) to the 2018 plume (Figure 10-13 in DOE/RL-2018-66) shows the following changes:

- The interpolated extent of the main plume at 45 mg/L expanded slightly in 2019 because additional data were available in 2019 for the area just south of WMA A-AX.
- The plume at the southeast corner of WMA A-AX expanded slightly because nitrate concentrations increased at well 299-E25-93 from 2018 to 2019.
- The plume at the 216-A-37-1 Crib was larger in 2019 because concentrations increased in wells 299-E25-17, 299-E25-19, 299-E25-20, and 299-E25-37. However, concentrations decreased at wells 299-E25-95 and 299-E25-18 in the southern part of this plume.
- The plume east of the 216-A-29 Ditch expanded because concentrations increased at wells 299-E25-32Q and 299-E25-32P.
- Nitrate levels in well 299-E24-22, along the western margin of WMA A-AX, increased as contamination from WMA C migrated toward the southeast.

Some of the highest nitrate concentrations in 200-PO are detected at wells monitoring the 216-A-10 Crib (e.g., 299-E17-19 and 299-E17-20) and the 216-A-36B Crib (e.g., 299-E17-14) (Figure 10-15). Concentrations in these wells are stable.

Nitrate concentrations continued to increase at some wells near the PUREX cribs, including wells 299-E24-16 (216-A-10), 299-E17-18 (216-A-36B), 299-E25-17, 299-E25-18, and 299-E25-20 (216-A-37-1). These wells have exhibited increasing nitrate concentrations since 2002.

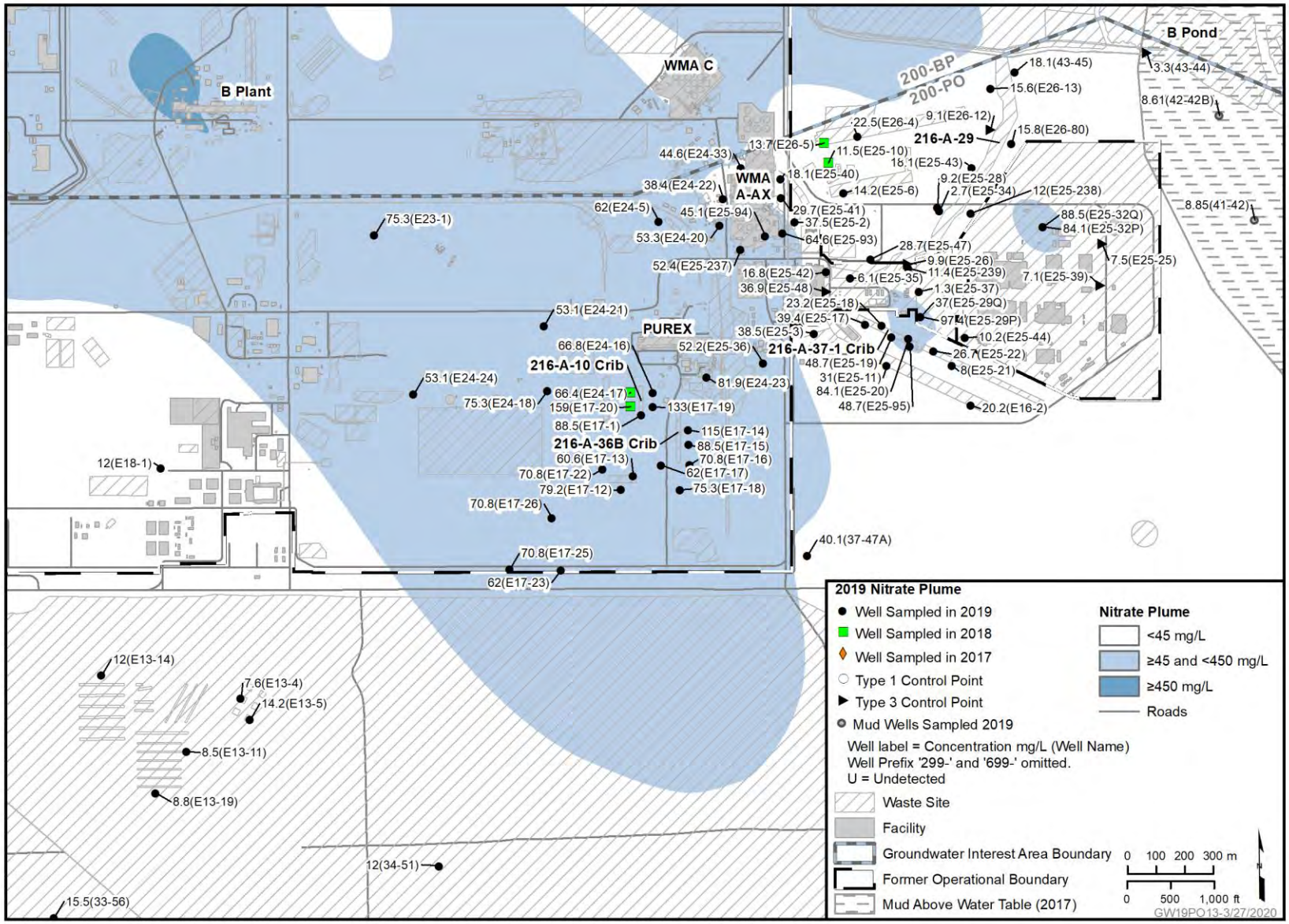


Figure 10-14. 200-PO Nitrate Plume, 2019

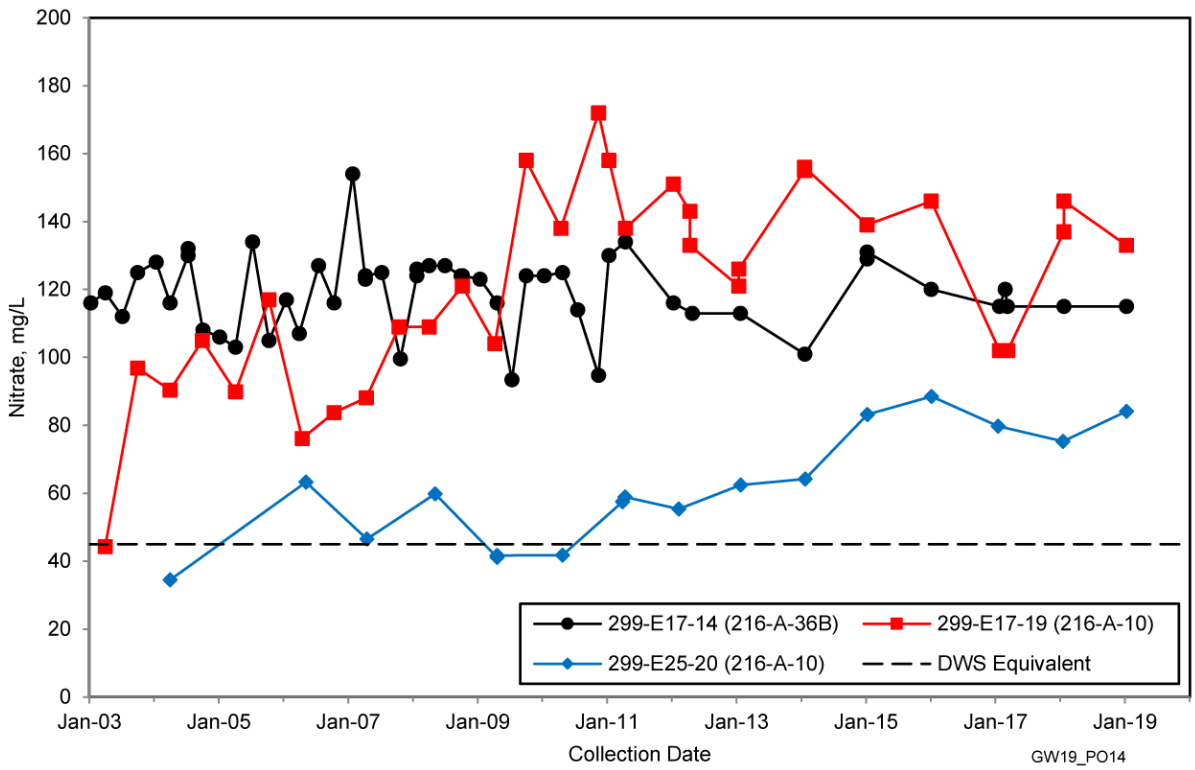


Figure 10-15. 200-PO Nitrate Data for Wells 299-E17-14, 299-E17-19, and 299-E17-20

Wells in the southeastern portion of the 200 East Area have had increasing nitrate concentrations since about 2002 (Figure 10-16). The increase in nitrate concentrations in this portion of the 200 East Area may be related to changes in gradient and groundwater flow direction, contaminant migration from the B Plant plume (Chapter 9), or from an unidentified source from multiple nearby waste sites.

The nitrate concentration in well 299-E25-32Q (monitoring the middle to lower portion of the unconfined aquifer) exceeded 45 mg/L in 2019. Concentrations have increased steadily from 4.4 mg/L in 2011 to 88.5 mg/L in 2019. None of the far-field wells screened into the deeper portion of the aquifer were sampled for nitrate in 2018.

In 2019, nitrate exceeded the 45 mg/L DWS within the Ringold confined aquifer near B Pond in well 699-39-39, with a concentration of 88.5 mg/L. Beginning in 1995, nitrate concentrations increased as the water table elevation in the area decreased (Figure 10-17). Contamination from the unconfined aquifer may have migrated down the borehole annulus in the past when the B Pond groundwater mound was present. The high head may have forced the contaminated groundwater a limited distance into the Ringold lower mud unit and thin silty or sandy lenses adjacent to the well. The saturated portion of the perforated interval of well 699-39-39 is now entirely within the Ringold lower mud unit because the water level has declined. None of the wells completed in sand intervals below the Ringold lower mud unit in this area show elevated nitrate concentrations. Wells open to Ringold unit A near B Pond are typically screened in gravelly sands and sandy gravels. Some wells (e.g., 699-40-39 and 699-40-40B) have sandy material overlying gravely material in the screened interval, while other wells are screened entirely within material described as sandy gravels (e.g., 699-40-40A and 699-41-42).

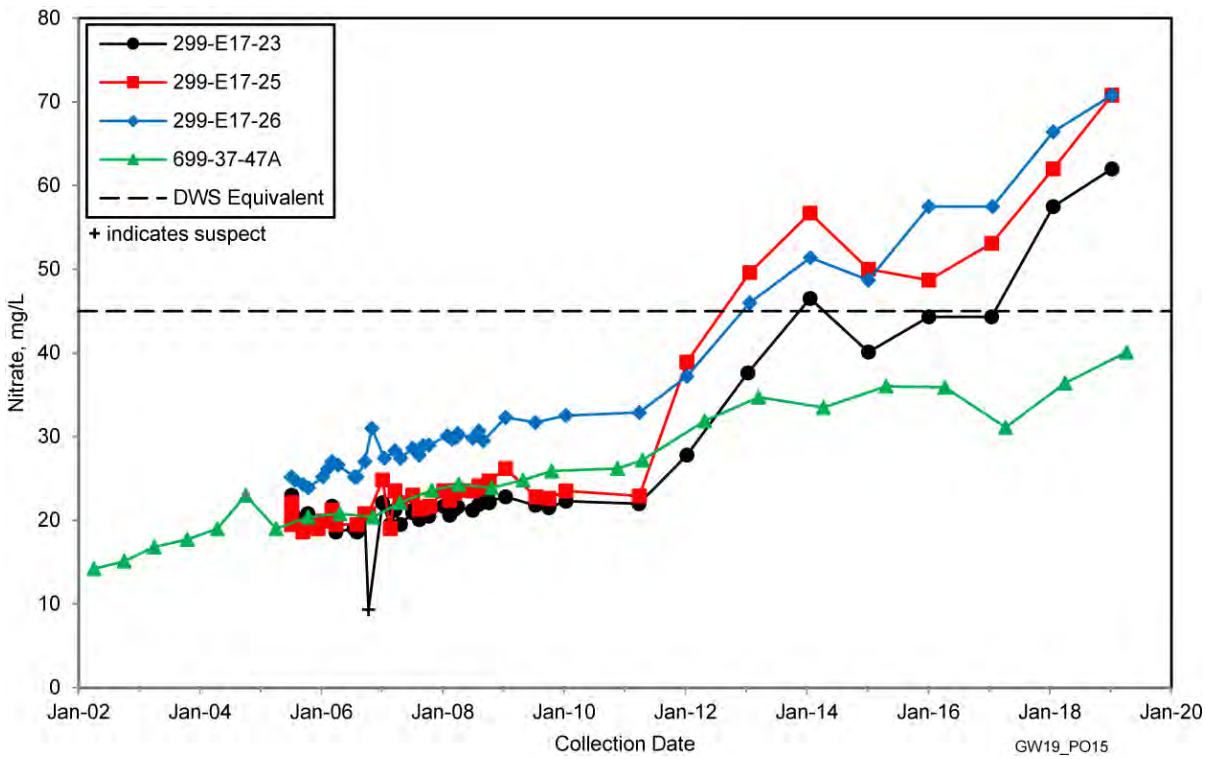


Figure 10-16. 200-PO Nitrate Data for Wells in Southeastern 200 East Area

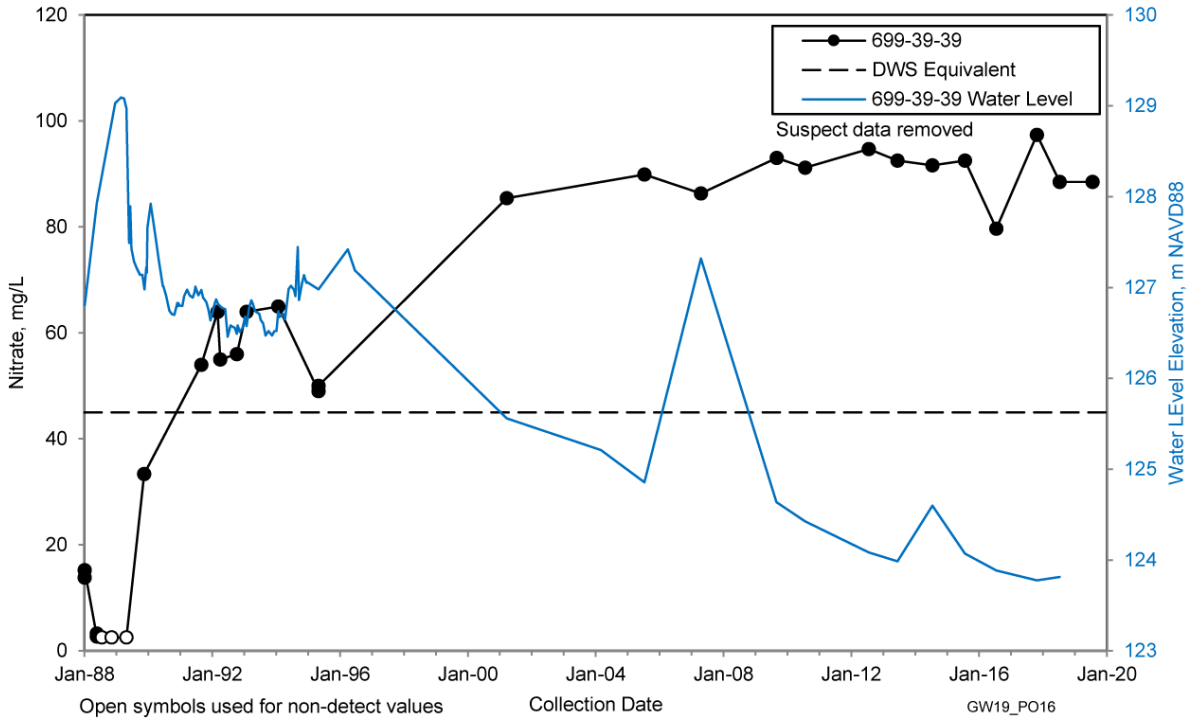


Figure 10-17. 200-PO Nitrate Data and Hydraulic Head in Ringold Confined Well 699-39-39

Nitrate concentrations in the basalt confined aquifer range from below detection limits to 0.292 mg/L, which is much lower than in the unconfined aquifer. The basalt confined aquifer is largely isolated from the unconfined aquifer in 200-PO.

10.5 Technetium-99

Technetium-99 has historically been detected in one relatively small area in the 200-PO near-field region around WMA A-AX (Figure 10-18). This plume appears to have continuing sources from both WMA C (in 200-BP) and WMA A-AX (in 200-PO). WMA A-AX is hydraulically downgradient of WMA C. The plume extent exceeding the 900 pCi/L DWS expanded slightly to the west between 2018 and 2019 with a concentration of 863 pCi/L at well 299-E24-4, which had not been sampled for technetium-99 since 2004.

Comparing trends in upgradient well 299-E24-22 to downgradient well 299-E25-93 (Figure 10-19) suggests that WMA A-AX may be a source of technetium-99 groundwater contamination. Until June 2013, the highest technetium-99 concentrations detected at WMA A-AX generally occurred in the downgradient well; this well demonstrated a decreasing concentration trend until that time. Concentrations in upgradient well 299-E24-22 increased between 2011 and 2019. From June 2013 until July 2015, concentrations in both wells were similar, with increasing trends. This suggests that the leading edge of the WMA C plume was being detected in both wells between June 2013 and July 2015, while the highest concentration portion of the WMA A-AX plume had migrated beyond the two wells. Detections above the 900 pCi/L DWS southeast and downgradient of WMA A-AX in well 299-E25-93 before June 2013 are inferred to be primarily associated with WMA A-AX, although there may have been some contribution from WMA C. This interpretation is also supported by different characteristics in the historical technetium-99 trends in other upgradient and downgradient wells. The increasing trend in the WMA A-AX upgradient wells is expected to continue as the WMA C plume continues migrating to the southeast toward WMA A-AX.

Outside the WMA A-AX plume, three wells have increasing technetium-99 concentrations at levels below the DWS (Figure 10-20), and the sources of these increases are unknown:

- In 2019, technetium-99 was reported at 882 pCi/L in well 699-37-47A, located near the southeastern corner of the 200 East Area (Figure 10-18). Concentrations have increased since annual sampling began in 2009.
- Concentrations increased sharply in 2018 and 2019 in wells 299-E17-22 and 299-24-18 near the IDF.

Technetium-99 was detected in 200-PO in only 5 of 13 aquifer tubes sampled during 2019. The maximum concentration was 97.6 pCi/L in C6353 (Figure 10-1), an increase from 75.3 pCi/L in 2018.

Wells monitoring the Ringold confined and basalt confined aquifers historically have had little or no detectable technetium-99 and are no longer monitored for this analyte.

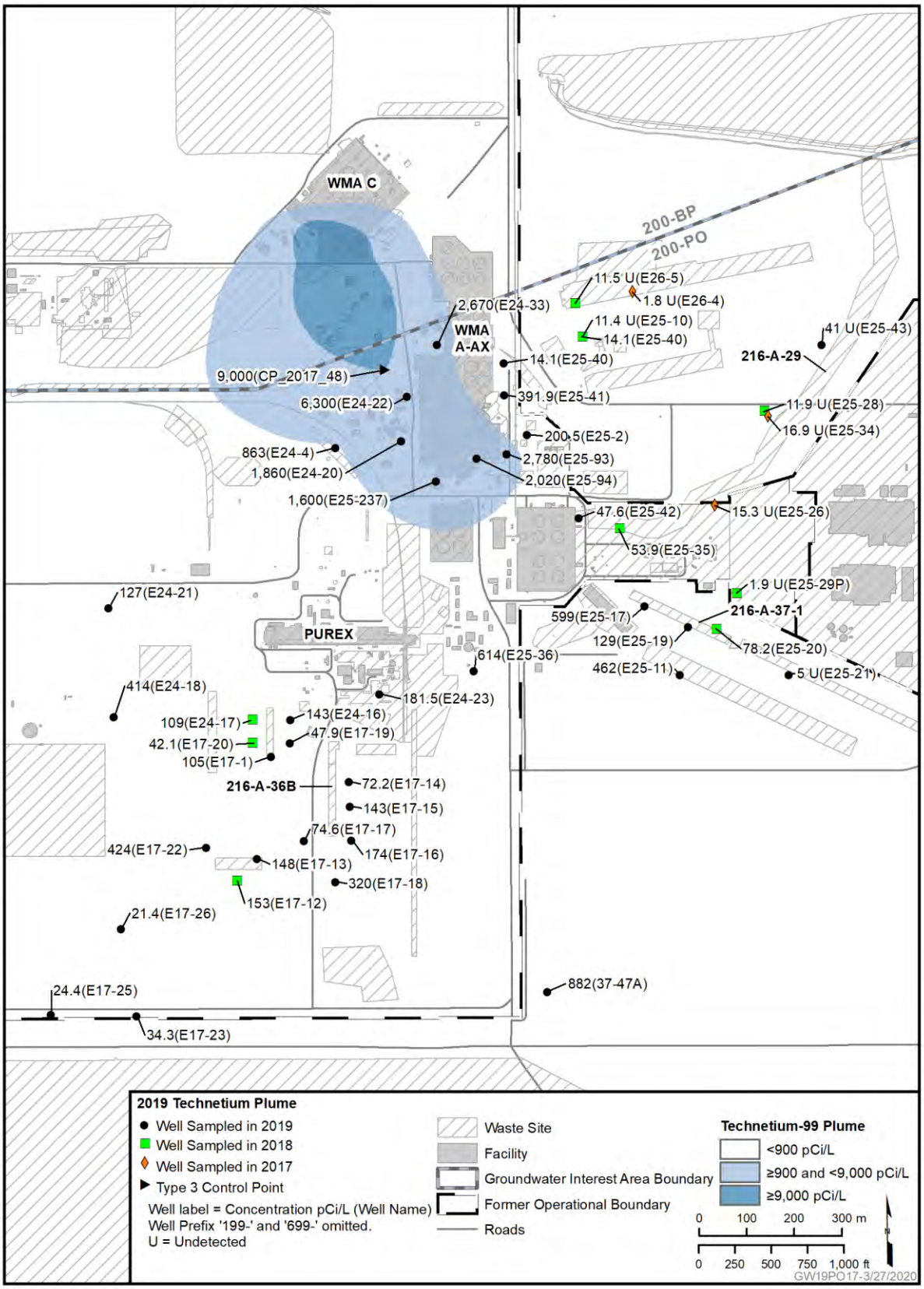


Figure 10-18. 200-PO Technetium-99 Plume, 2019

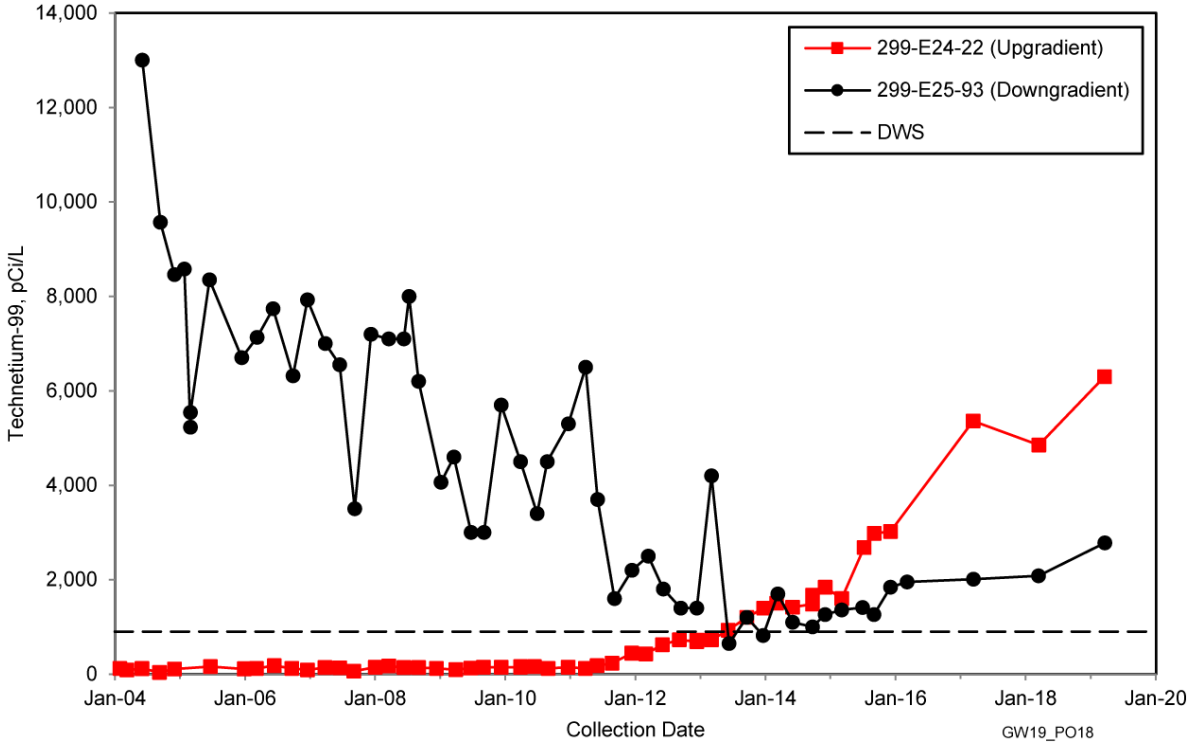


Figure 10-19. 200-PO Technetium-99 Data for WMA A-AX Upgradient and Downgradient Wells

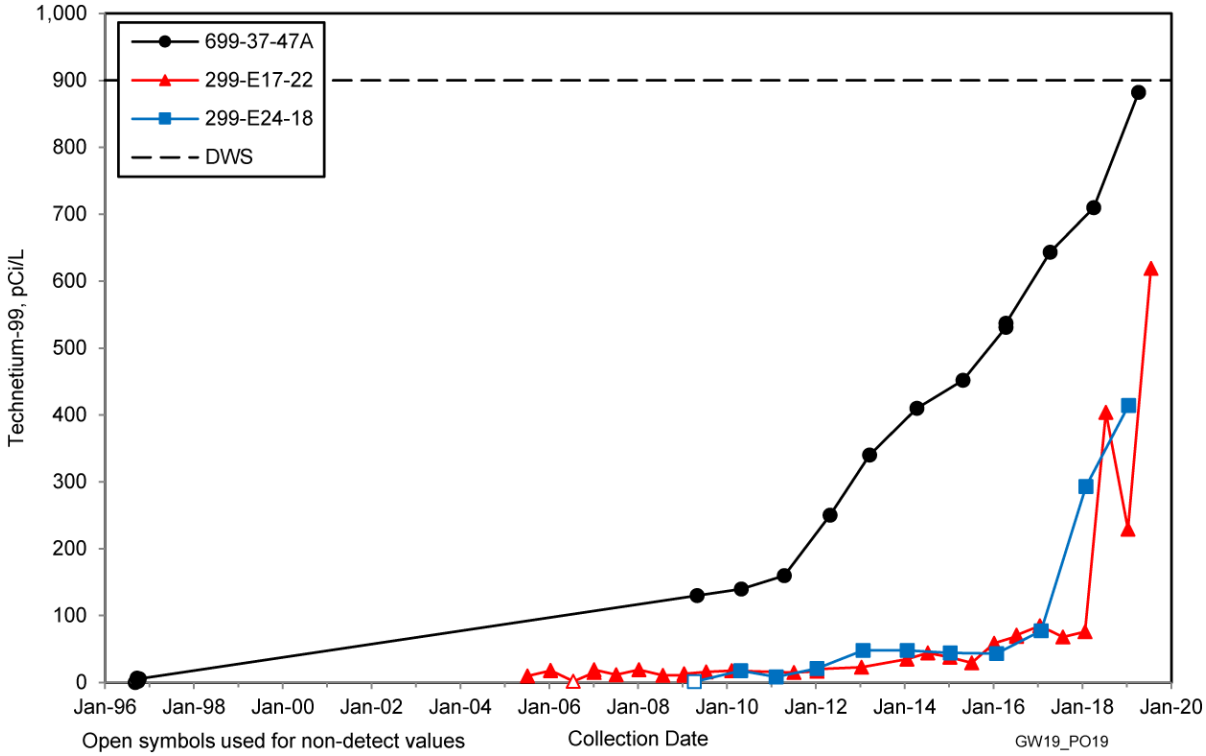


Figure 10-20. 200-PO Technetium-99 Data for Wells 699-37-47A, 299-E17-22, and 299-E24-18

10.6 Uranium

Uranium concentrations above the 30 µg/L DWS have been identified as a small plume near the PUREX cribs and trenches in the near-field area (Figure 10-21). The 216-A-3 and 216-A-4 Cribs, located near the PUREX Plant, received uranium waste (Table 4 in HNF-1744, *Radionuclide Inventories of Liquid Waste Disposal Sites on Hanford Site*) and are likely sources for this contamination. The concentration changes observed are consistent with continued slow dispersion of uranium away from source areas. The only 2019 concentration above the DWS was 68.0 µg/L in well 299-E25-36, a decrease from 2018 (Figure 10-22). Uranium concentrations at well 299-E17-14 (near the 216-A-36B Crib) and well 299-E24-16 (near the 216-A-10 Crib) remained below the 30 µg/L DWS in 2019 and are declining (Figure 10-22).

During 2019, uranium within far-field unconfined, Ringold confined, and basalt confined aquifers remained well below the DWS. Concentrations ranged from below detection limits to 9.5 µg/L in far-field wells.

10.7 Strontium-90

Strontium-90 has historically been detected at concentrations greater than the 8 pCi/L DWS near the 216-A-5, 216-A-10, and 216-A-36B Cribs. The only well in 200-PO with concentrations above the 8 pCi/L DWS in 2019 was well 299-E17-14 (near the 216-A-36B Crib) (Figure 10-1), with an annual average of 11.5 pCi/L. Concentrations have declined since April 2008 (Figure 10-23). A possible source of the strontium-90 contamination is PUREX process condensate that was discharged to the PUREX cribs (WHC-EP-0342, Addendum 15, *242-A Evaporator Process Condensate Stream-Specific Report*).

Concentrations of strontium-90 near the 216-A-10 Crib have historically exceeded the 8 pCi/L DWS in only one sampling event in one well (299-E24-16 at a concentration of 8.19 pCi/L in 2004). (Figure 10-23). Strontium-90 concentrations in far field wells were below detection limits in 2019.

Wells screened in the middle or deep unconfined aquifer are no longer monitored for strontium-90 because it was typically undetected.

10.8 Tetrachloroethene and Trichloroethene

TCE and PCE were identified as final COPCs for the 200-PO-1 OU but were ruled out as COCs in the baseline risk assessment performed for the RI addendum (DOE/RL-2009-85-ADD1). In 2019, the final COPCs were analyzed in wells that monitor the SWL, and concentrations were near or below detection limits. PCE was detected at a maximum concentration of 0.76 (J) µg/L in well 699-24-33, near the SWL (Figure 10-1), which is below the 5 µg/L DWS. The laboratory "J" flag indicates that the value is estimated, the detection is uncertain, and the value reported is less than the PQL but greater than or equal to the MDL. TCE was detected at a maximum level of 0.52 (J) µg/L in well 699-25-34F.

US Ecology, Inc., operates a commercial low-level radioactive waste disposal facility located south of the 200 East Area (Figure 10-1). This state-regulated disposal facility has been in operation since 1965. TCE is detected in several of the US Ecology monitoring wells at concentrations above the 5 µg/L DWS (Figure 10-24). The plume is not related to the larger TCE plume originating in the 200 West Area (Chapters 11 and 12).

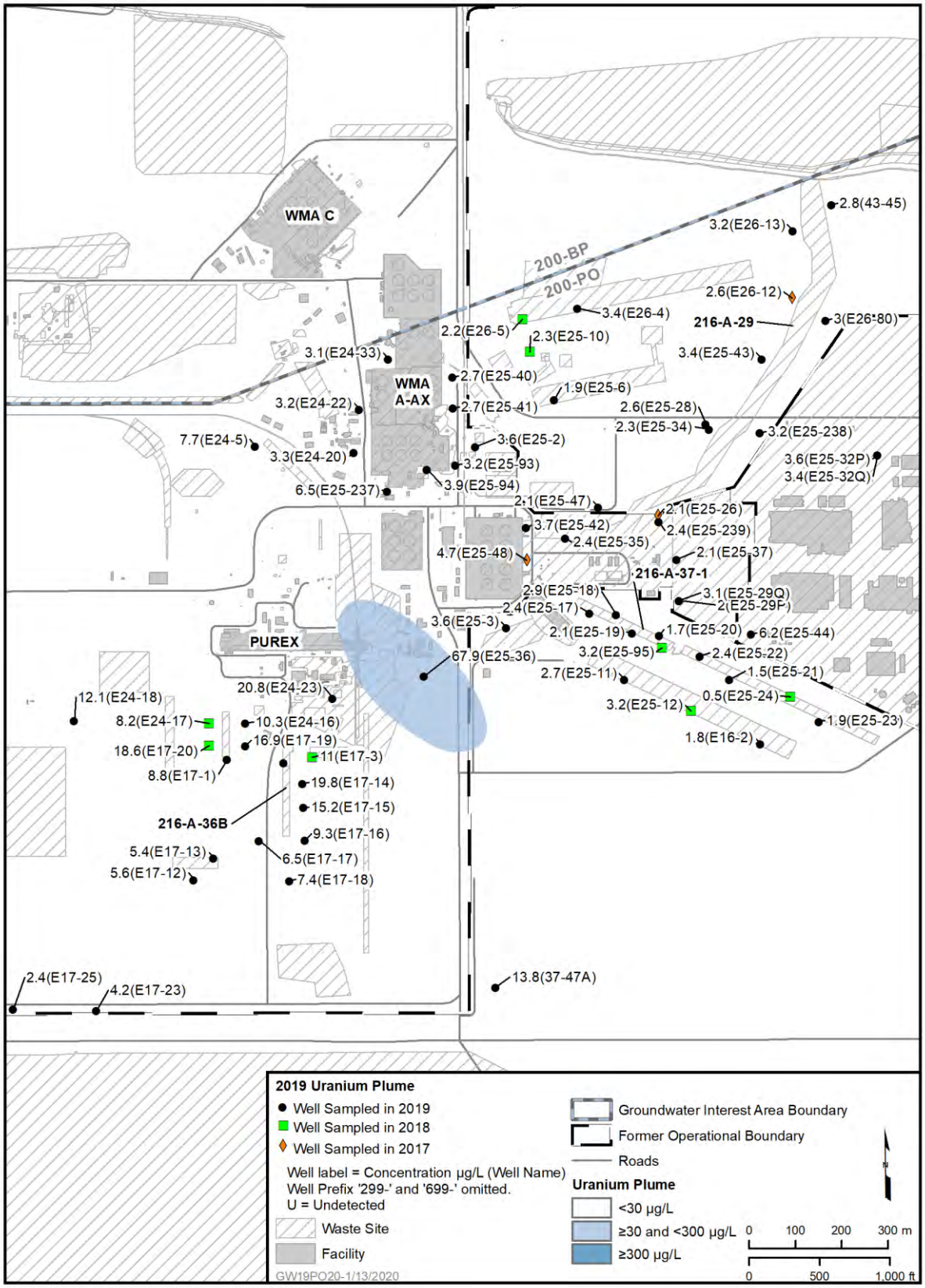


Figure 10-21. 200-PO Uranium Plume, 2019

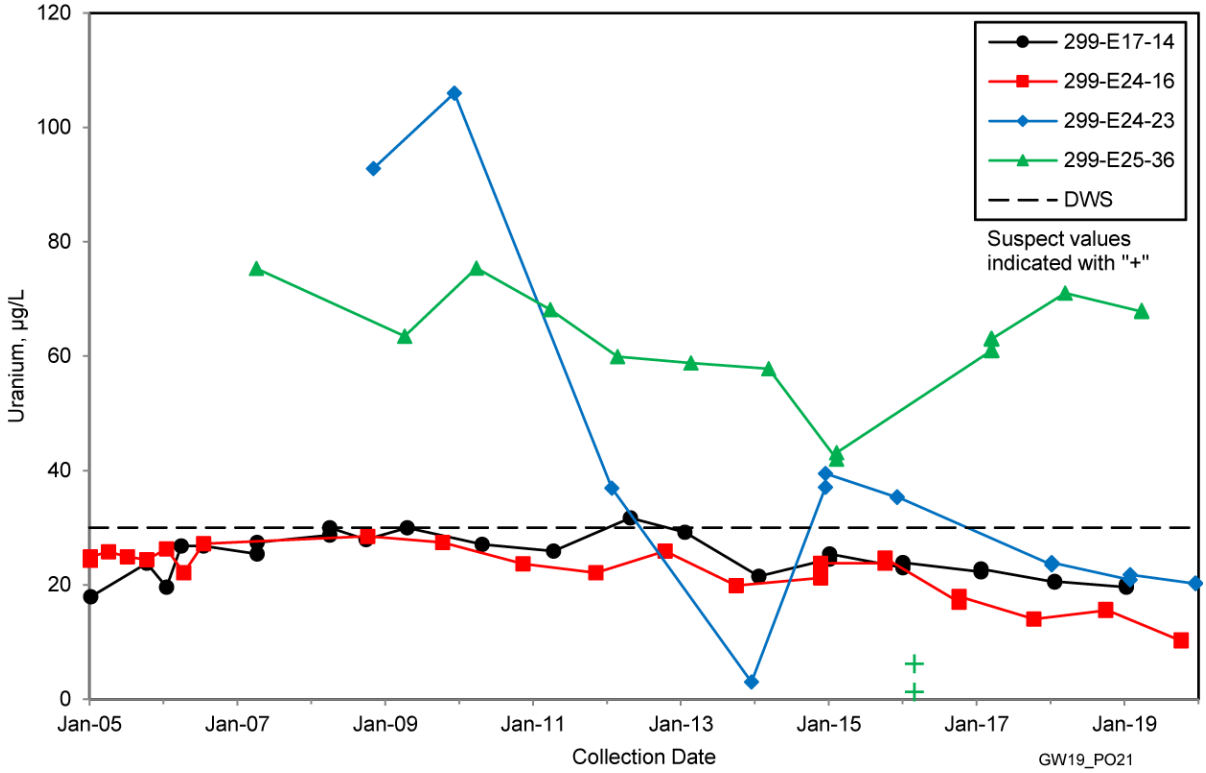


Figure 10-22. 200-PO Uranium Data for Wells 299-E17-14 (216-A-36B Crib), 299-E24-23 (216-A-4 Crib), 299-E24-16 (216-A-10 Crib), and 299-E25-36

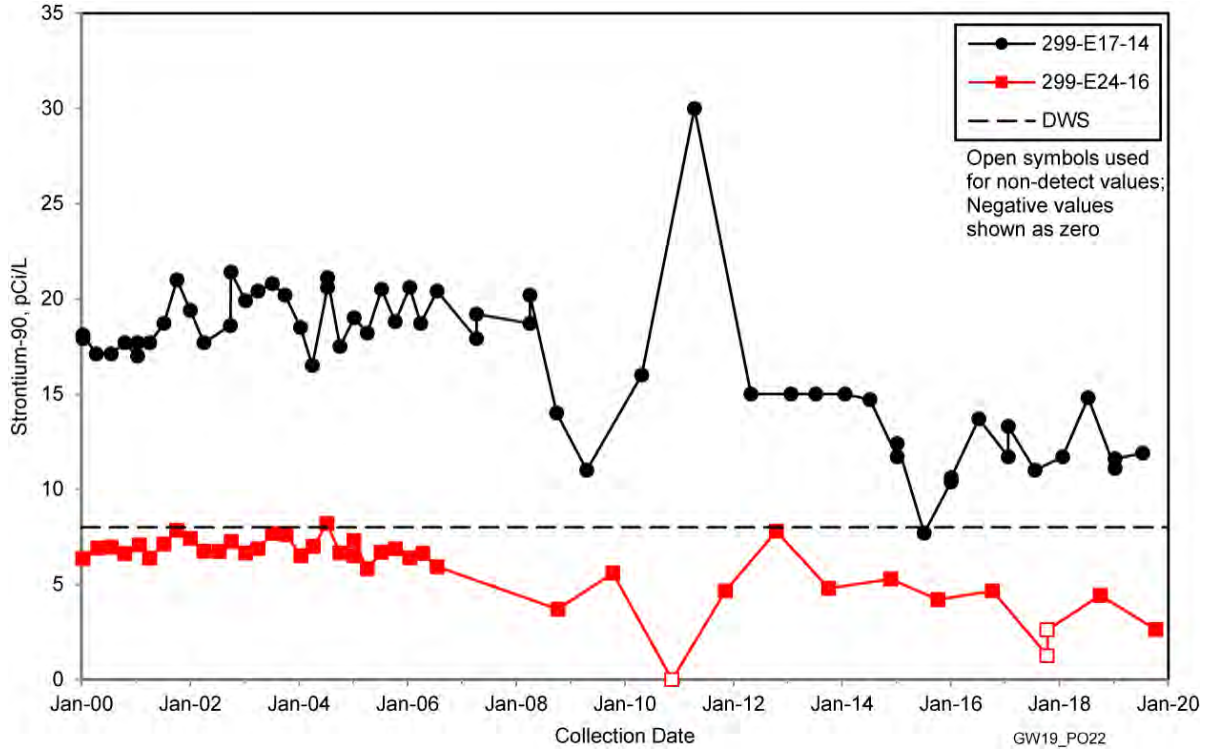


Figure 10-23. 200-PO Strontium-90 Data for Wells 299-E17-14 and 299-E24-16

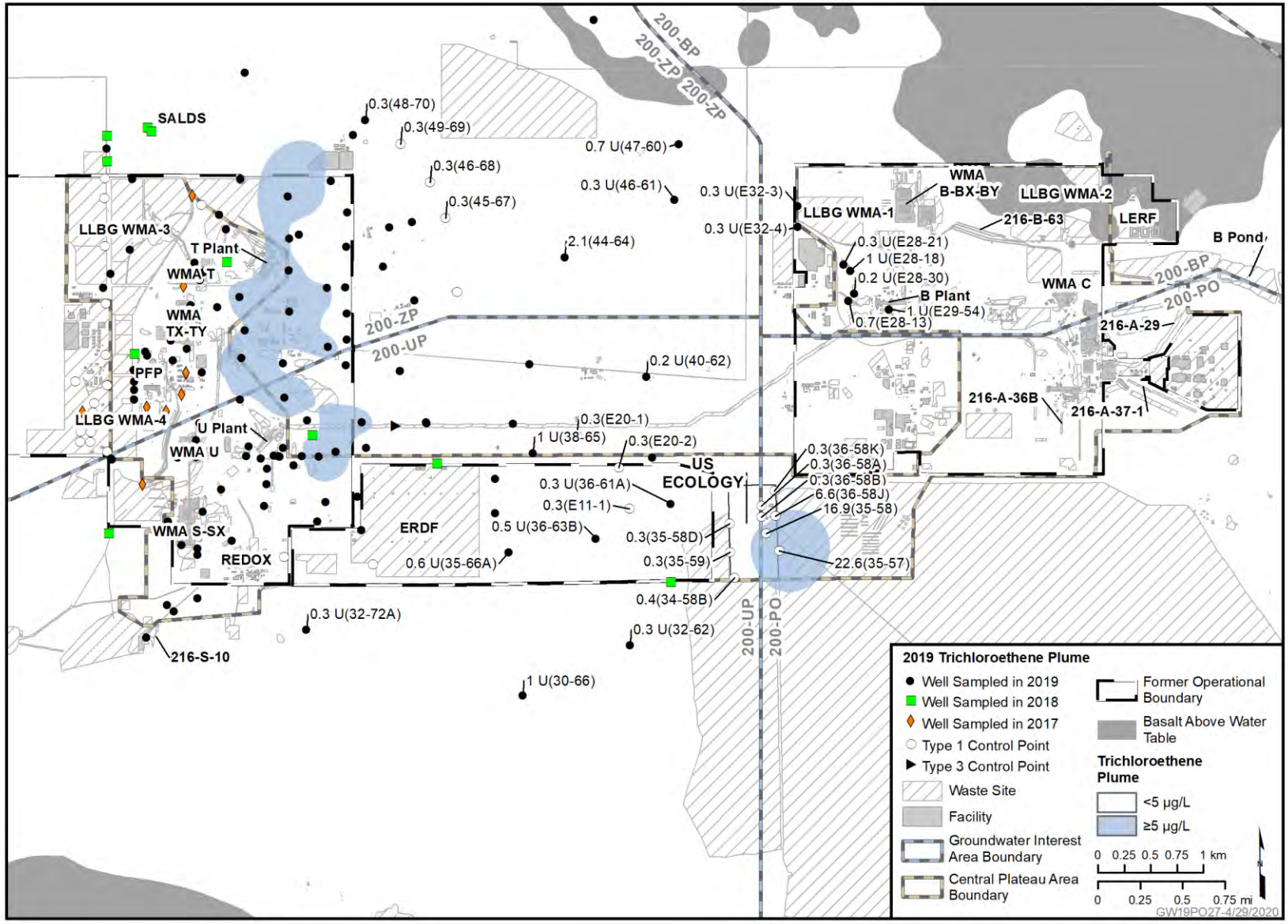


Figure 10-24. Central Plateau TCE Plume

10.9 CERCLA Monitoring

Groundwater monitoring in the 200-PO-1 OU under CERCLA is described in the SAP (DOE/RL-2003-04, as modified by TPA-CN-205). Groundwater is monitored within the unconfined aquifer, Ringold confined aquifer, and the basalt confined aquifer. Wells and aquifer tubes (Figure 10-1) are generally sampled annually or triennially. Additional aquifer tube sampling within 200-PO is also conducted as defined in the SAP for aquifer sampling tubes (DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, as modified by TPA-CN-353, TPA-CN-556, TPA-CN-612, TPA-CN-676, TPA-CN-0730, and TPA-CN-741). Table A-1 in Appendix A lists the monitoring exceptions for 2019.

In 2019, DOE released Rev. 0 of an FS for the 200-PO-1 and 200-BP-5 OUs (DOE/RL-2018-30) and DOE/RL-2018-58, Draft A, *Proposed Plan for the Interim Action Remediation of the 200-BP-5 and 200-PO-1 Operable Units*. The Tri-Parties are pursuing an interim ROD for groundwater OUs to expedite the remediation of certain groundwater plumes.

10.10 RCRA Monitoring

The following sections, taken from DOE/RL-2019-65, describe the results of monitoring at seven individual WMAs within 200-PO conducted in accordance with RCRA regulations: 216-A-29, 216-A-36B, 216-A-37-1, B Pond, IDF, NRDWL, and WMA A-AX. Interim status groundwater quality assessment monitoring was conducted at 216-A-29, NRDWL, and WMA A-AX (40 CFR 265.93(d), as referenced by WAC 173-303-400). Interim status detection monitoring for indicator parameter evaluation is conducted at 216-A-36B, 216-A-37-1, and B Pond (40 CFR 265.92, as referenced by WAC 173-303-400). The IDF, incorporated into the Hanford RCRA Permit, is not operational but is monitored to obtain baseline information. Three new IDF monitoring wells were installed in 2019 (Table 10-2).

Table 10-2. Wells Drilled in 200-PO in 2019

Well Name	Well ID	Purpose*	Drill Depth		Construction Depth		Accepted Date	Comments
			ft	m	ft	m		
299-E17-56	D0038	IDF downgradient well	364.8	111.2	344.2	104.9	9/23/2019	
299-E17-57	D0041	IDF upgradient well	355.6	108.4	350.2	106.7	8/7/2019	
299-E24-164	D0040	IDF downgradient well	350.0	106.7	347.3	105.9	9/30/2019	

*For future monitoring under DOE/RL-2019-29, *Groundwater Monitoring Plan for the Integrated Disposal Facility*.

ID = identification

IDF = Integrated Disposal Facility

10.10.1 Waste Management Area A-AX

WMA A-AX is located in the southeastern quarter of the 200 East Area (Figure B-1 in Appendix B; Figure 10-25) and consists of 10 underground storage tanks with an operating capacity of 3,785,000 L (1,000,000 gal), two of which are confirmed or assumed to have leaked in the past (HNF-EP-0182, Rev. 359). Leaks were reassessed in the 2014 revision of RPP-ENV-37956, *Hanford 241-A/AX Farm Leak Inventory Assessment Report*. To minimize the probability and severity of future leaks, most of the drainable liquid in each tank has been removed and transferred to double-shell tanks.

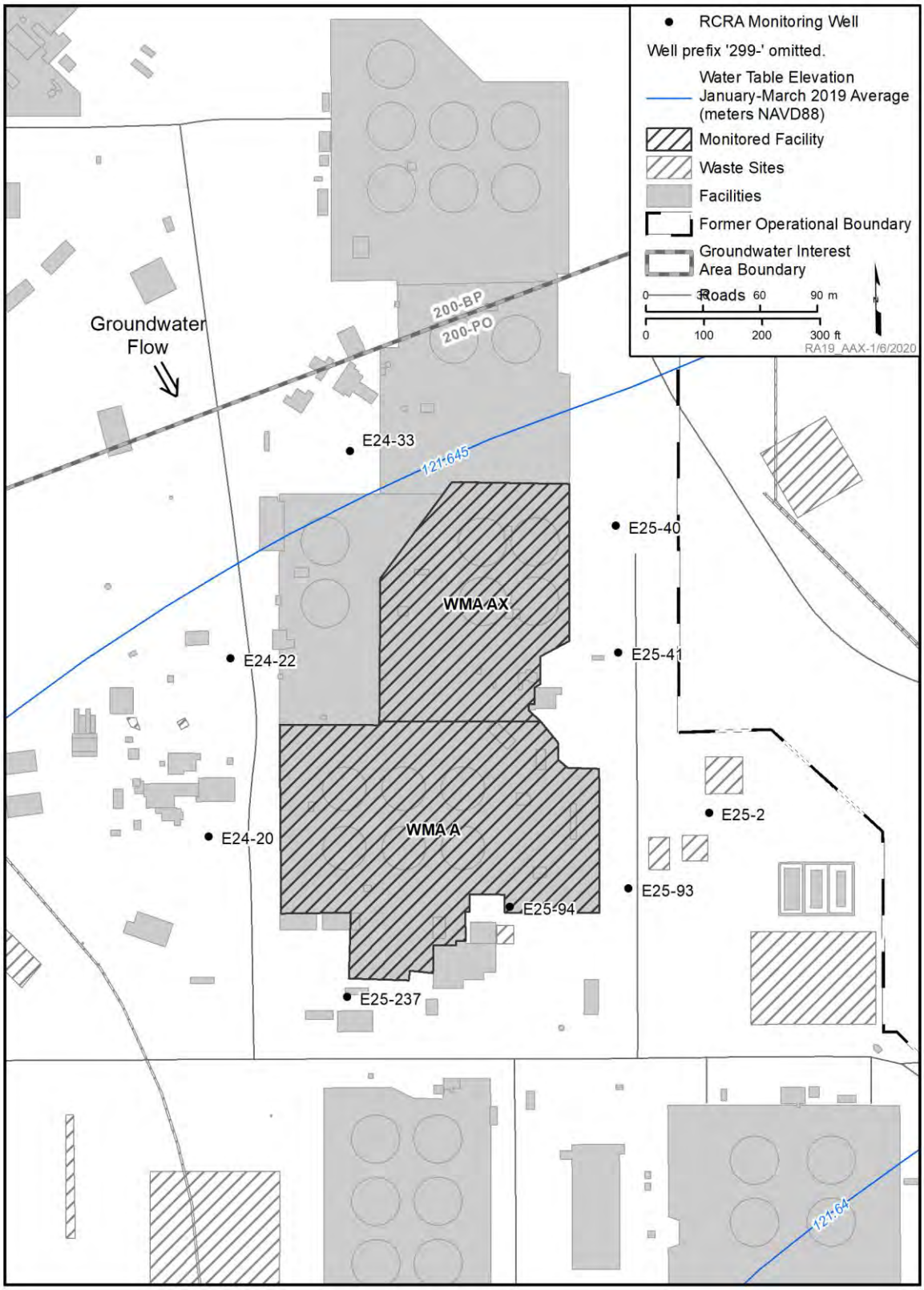
WMA A-AX was monitored under an interim status assessment program since 2005 when specific conductance exceeded the critical mean value. In 2019, monitoring continued under DOE/RL-2015-49, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*. Nine quarters of assessment monitoring data were evaluated for potentially dangerous waste constituents attributable to WMA A-AX. Results were published in a first determination report (DOE/RL-2019-21, *Groundwater Assessment First Determination Report for Waste Management Area A-AX*) and transmitted to Ecology in 2019 for review. The report concluded that no dangerous waste groundwater contamination is attributed to releases from WMA A-AX. It is anticipated that monitoring will be conducted under a new indicator evaluation monitoring plan being prepared in 2020.

The monitoring network includes three upgradient and six downgradient wells monitoring the upper portion of the unconfined aquifer (Table B-50 in Appendix B). The estimated thickness of the unconfined aquifer is from 24 to 31 m (79 to 102 ft) near WMA A-AX. Water-level predictions indicate that all of the wells (except 299-E25-41) will have sufficient water for continued sampling through at least 2028 (SGW-63743). Well 299-E25-41 is predicted to be sample dry in 2024, but well life may be extended by the use of a low-flow sampling pump. Section 7.4 in SGW-60586, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring*, recommended a modified network for monitoring under final status, including eight of the nine current wells and two proposed new wells.

Indications of corrosion were identified in well 299-E25-41 in 2016 and were confirmed with an inspection video log conducted in 2017. The corrosion was observed at 65.2 m (214 ft) below top of casing, about 17 m (56 ft) above the water table in a sandy gravel unit. This was above the Cold Creek silt unit, which is at a depth of 79 to 88 m (262 to 289 ft) bgs at WMA A-AX. Sampling of this well continued in 2019, with elevated unfiltered iron. Cleaning the well may improve sample quality until the well can be replaced.

In 2019, groundwater near WMA A-AX was interpreted to flow to the south-southeast (Table B-2 in Appendix B). Supporting evidence for the flow orientation included water-level measurements with slightly higher hydraulic heads to the northwest, as well as the distribution and migration of the nitrate plume in this area. This flow direction also corresponds to the orientation of a southeast-trending paleochannel in the area (Appendix E of DOE/RL-2011-118). In 2019, the estimated hydraulic gradient was 1.6×10^{-5} m/m, with an estimated groundwater flow rate of 1.2 m/d (3.8 ft/d).

Table B-51 in Appendix B summarizes the monitoring results for 2019. Nitrate concentrations were above the 45 mg/L DWS in several wells due to a regional plume.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-25. Waste Management Area A-AX

Low-level detections of several organic compounds were detected at levels near or below quantitation limits in 2019, as in previous years (Table B-51 in Appendix B). Higher concentrations of acetone detected in September (25.2 µg/L in well 299-E25-40 and 19 µg/L in well 299-E25-94) are likely laboratory contaminants.

The highest total cyanide concentration in a WMA A-AX well in 2019 was 5.2 µg/L in downgradient well 299-E25-40. Cyanide also was detected in upgradient well 299-E25-33 at a concentration of 5.1 µg/L. Cyanide is detected in WMA C monitoring wells (Section 9.9.2), located upgradient of WMA A-AX.

10.10.2 216-A-36B Crib

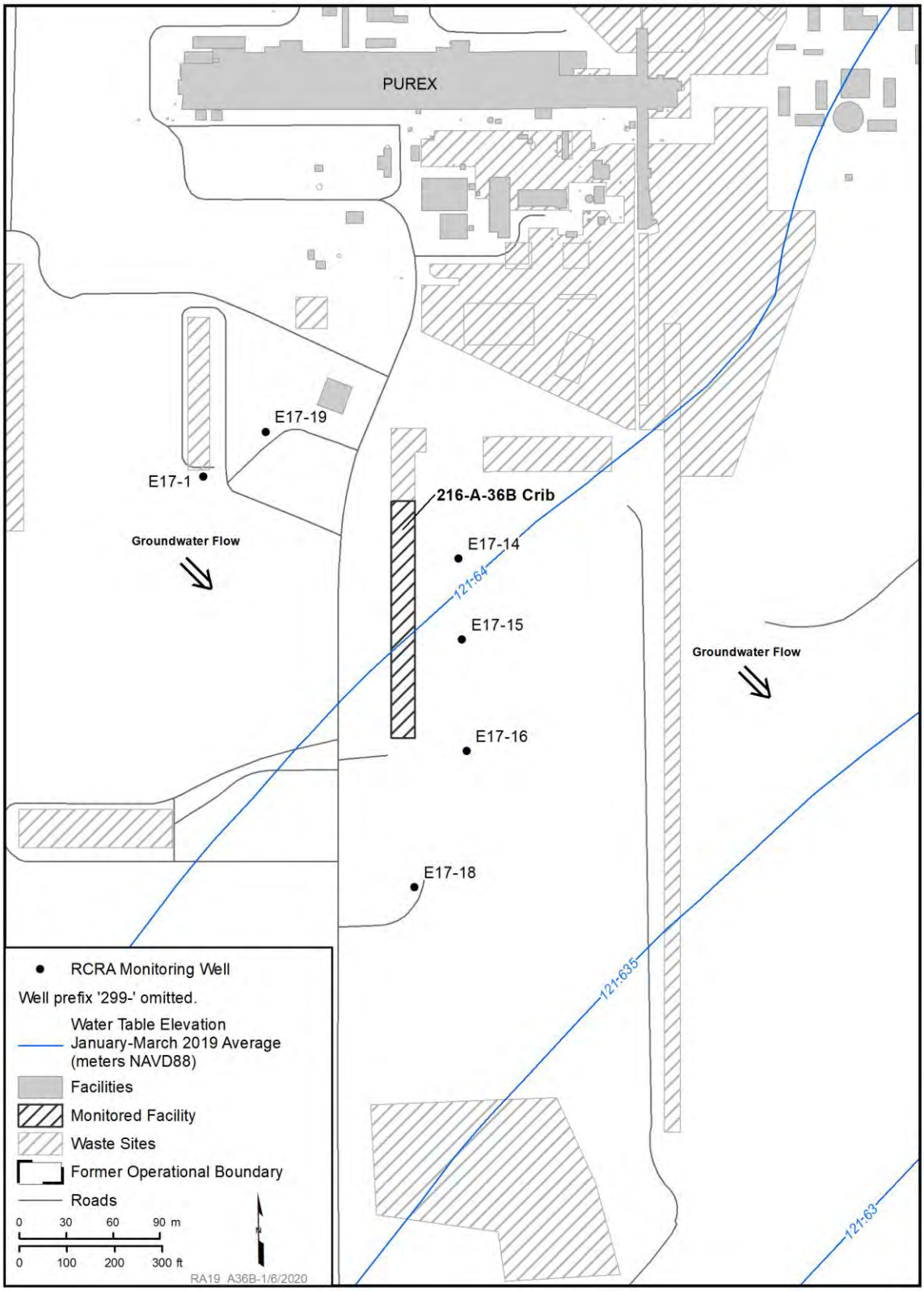
The 216-A-36B Crib is located in the southeastern portion of the 200 East Area (Figure B-1 in Appendix B; Figure 10-26). When in use, the crib was 7 m (23 ft) deep, 150 m (500 ft) long, and 2.3 to 3.4 m (7.5 to 11 ft) wide at the base; the sides sloped at 1:1.5 (drawing H-2-59129, *Crib 216-A-36B, Plan Profiles & Details*). The crib construction included 7 m (23 ft) of naturally revegetated clean backfill soil. The crib was originally part of the 180 m (590 ft) long 216-A-36 Crib, which received PUREX Plant effluent from September 1965 to March 1966. In March 1966, the northernmost 30 m (98 ft) of the crib was isolated with a grout barrier and was no longer used. The southern portion of the 216-A-36 Crib (now known as 216-A-36B) is the only portion regulated as a RCRA DWMU. The 216-A-36B Crib operated from March 1966 to October 1972 and was reactivated in November 1982 for the PUREX Plant restart. It received 290 million L (76.6 million gal) of PUREX ammonia scrubber distillate and was permanently removed from service in September 1987. In 2010, 15 cm (6 in.) of gravel was added to the surface of the entire 216-A-36 Crib.

The 216-A-36B Crib is monitored under an interim status indicator evaluation program (DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*). The monitoring network includes two upgradient wells and four downgradient wells (Table B-8 in Appendix B; Figure 10-26). Section 7.4 in SGW-60595, *Engineering Evaluation Report for the 216-A-36B Crib Groundwater Monitoring*, concluded that the current well network is adequate to monitor the 216-A-36B Crib. All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). However, well 299-E17-1 was installed in 1955, prior to the requirements of WAC 173-160 (Section 9.3 in SGW-60595).

The hydraulic gradient in 2019 sloped to the southeast with a magnitude of 1.1×10^{-5} m/m, and the estimated flow rate was 3.6×10^{-4} m/d (1.2×10^{-3} ft/d) (Table B-2 in Appendix B).

The 216-A-36B Crib groundwater wells were sampled twice in 2019 for RCRA indicator parameters (TOC, TOX, pH, and specific conductance) (Table B-9 in Appendix B). There were no exceedances of the 2019 critical mean values.

Groundwater quality parameters monitored for the site include chloride, iron, manganese, phenols, sodium, and sulfate (Table B-10 in Appendix B). Although not required by 40 CFR 265, Subpart F, site-specific constituents (alkalinity, fluoride, nitrate, nitrite, calcium, and potassium) were also analyzed. Samples for analyses of alkalinity, calcium, magnesium, and potassium are collected to support cation-anion balance calculations. In 2019, nitrate continued to be above the DWS in all of the network wells associated with a regional nitrate plume. Nitrate is a constituent of interest at the 216-A-36B Crib because it is a breakdown product of nitric acid, which was disposed to the 216-A-10 Crib (120 m [390 ft] to the west).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-26. 216-A-36B Crib

Iron concentrations were above the secondary DWS in unfiltered samples from well 299-E17-18 (Table B-10 in Appendix B). Elevated values of unfiltered chromium, nickel, and manganese were detected in proportions that may indicate stainless-steel corrosion. A downhole camera survey is planned.

Well 299-E17-1 was high in unfiltered iron but low in unfiltered chromium and nickel. This well has little water, was sampled by bailing, and had elevated turbidity.

Sampling for VOCs is required every 3 years (most recently in 2017) and was not required in 2019.

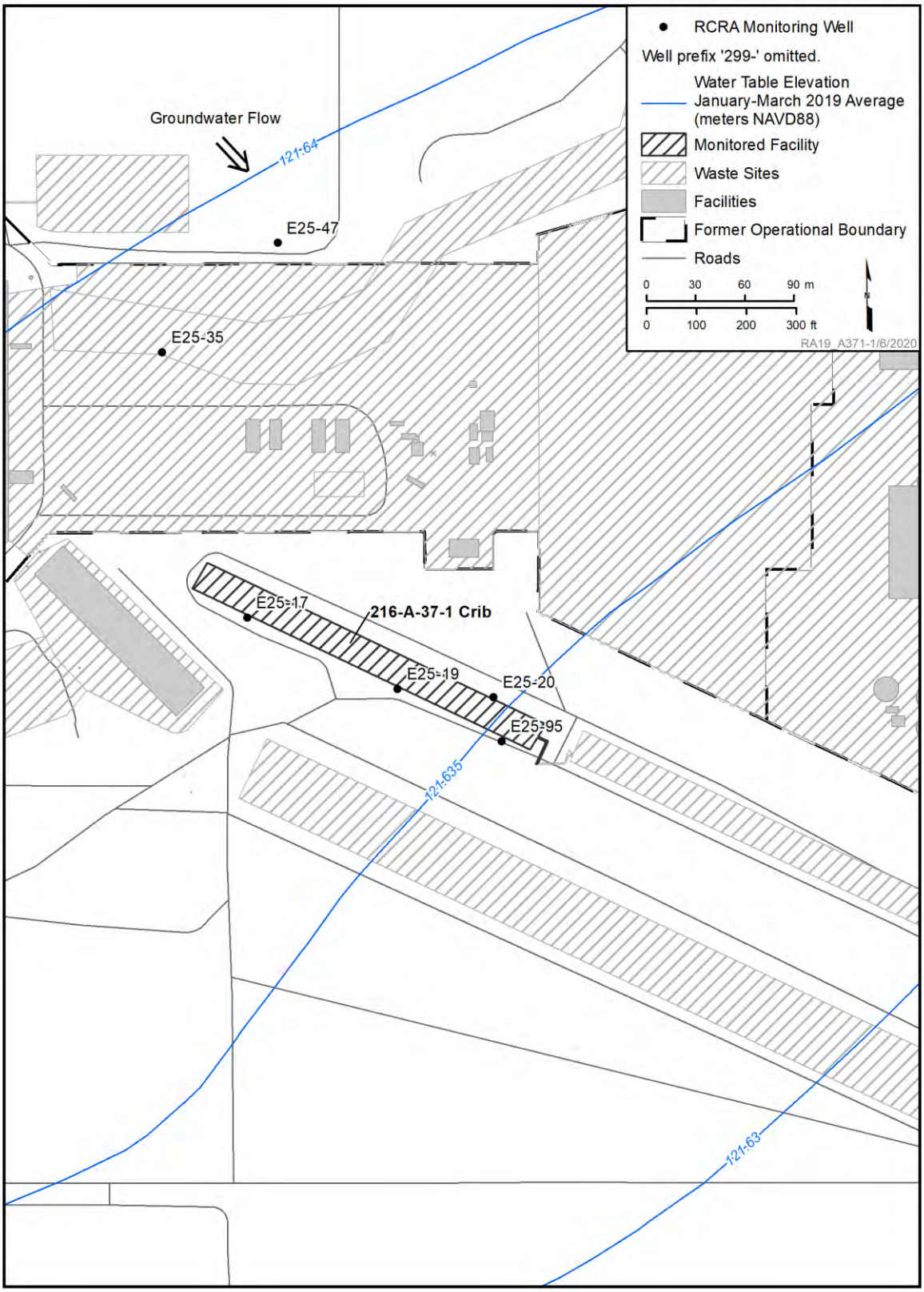
10.10.3 216-A-37-1 Crib

The 216-A-37-1 Crib is located east of the 200 East Area (Figure B-1 in Appendix B; Figure 10-27). During its active life, the crib was 5.2 m (17.1 ft) deep, 213 m (699 ft) long, and 33 m (108 ft) wide at the base, with sides sloped at 1:1. The crib operated from March 1977 through April 1989 and was used to percolate 242A evaporator process condensate to the soil column. It received spent halogenated and nonhalogenated solvents, as well as ammonia. During its operational life, this crib received 380 million L (98 million gal) of process condensate. In 1994, the bottom of the diversion box used to route effluent to the crib was filled with grout to prevent inadvertent discharges to the crib. In July 2000, vent risers from the crib were sealed to prevent potential passive radioactive emissions.

The 216-A-37-1 Crib is monitored under an interim status indicator evaluation program under DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib.* The monitoring network includes two upgradient wells and four downgradient wells (Table B-11 in Appendix B). All of the current monitoring wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Section 7.4 in SGW-60593, *Engineering Evaluation Report for the 216-A-37-1 Crib Groundwater Monitoring*, recommended a modified network for monitoring under final status, including four of the current wells, two new downgradient wells, and one new upgradient well.

Near the 216-A-37-1 Crib, the estimated groundwater flow in 2019 was toward the southeast. Flow directions are influenced by a northwest-southeast-trending paleochannel with high-permeability Hanford formation sediments near the crib, the Ringold lower mud unit at the water table east of the 200 East Area, and the higher water table elevations to the west and north. In 2019, the gradient magnitude was 1.5×10^{-5} m/m, and the estimated groundwater flow rate was 1.0 m/d (3.4 ft/d) (Table B-2 in Appendix B).

The 216-A-37-1 Crib network wells are monitored for RCRA indicator parameters (TOC, TOX, pH, and specific conductance) (Table B-12 in Appendix B), temperature, turbidity, water quality parameters, and other constituents (Table B-13 in Appendix B). The 216-A-37-1 Crib network wells were sampled semiannually as scheduled in 2019. Well 299-E25-20 had an average pH value below the lower critical mean value in July 2019, but this exceedance was not verified upon resampling. Analytical results for other RCRA indicator parameters did not exceed the 2019 critical mean values, so the site remains in interim status indicator evaluation monitoring.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-27. 216-A-37-1 Crib

Table B-13 in Appendix B summarizes the 2019 results for groundwater quality parameters (40 CFR 265.92(b)(2)) and additional constituents required by the monitoring plan (Table 3-1 in DOE/RL-2010-92). Nitrate, manganese, and iron were reported above the primary or secondary DWSs and are explained below:

- Nitrate concentrations were above the DWS in downgradient wells 299-E25-19, 299-E25-20, and 299-E25-95. Nitrate concentrations have been above the DWS in well 299-E25-95 since its initial sampling in October 2017. Nitrate concentrations at well 299-E25-20 have been above the DWS since March 2011. Nitrate was last observed above the DWS in 2011 in well 299-E25-19. The 216-A-37-1 Crib is likely a source of nitrate groundwater contamination (Section 2.5 in DOE/RL-2010-92).
- Unfiltered iron and filtered and unfiltered manganese remained above the secondary DWS at wells 299-E25-19 and 299-E25-20 in 2019 (Table B-13 in Appendix B). Elevated turbidity, unfiltered chromium, and nickel persisted in well 299-E25-19 during 2019, suggesting casing corrosion. A previous borehole video revealed debris from a damaged well pump within the sump that cannot be removed. The well will be considered for decommissioning and replacement. Corrosion indicator metals nickel and chromium were not elevated in well 299-E25-20; therefore, this well has not been scheduled for camera surveying.

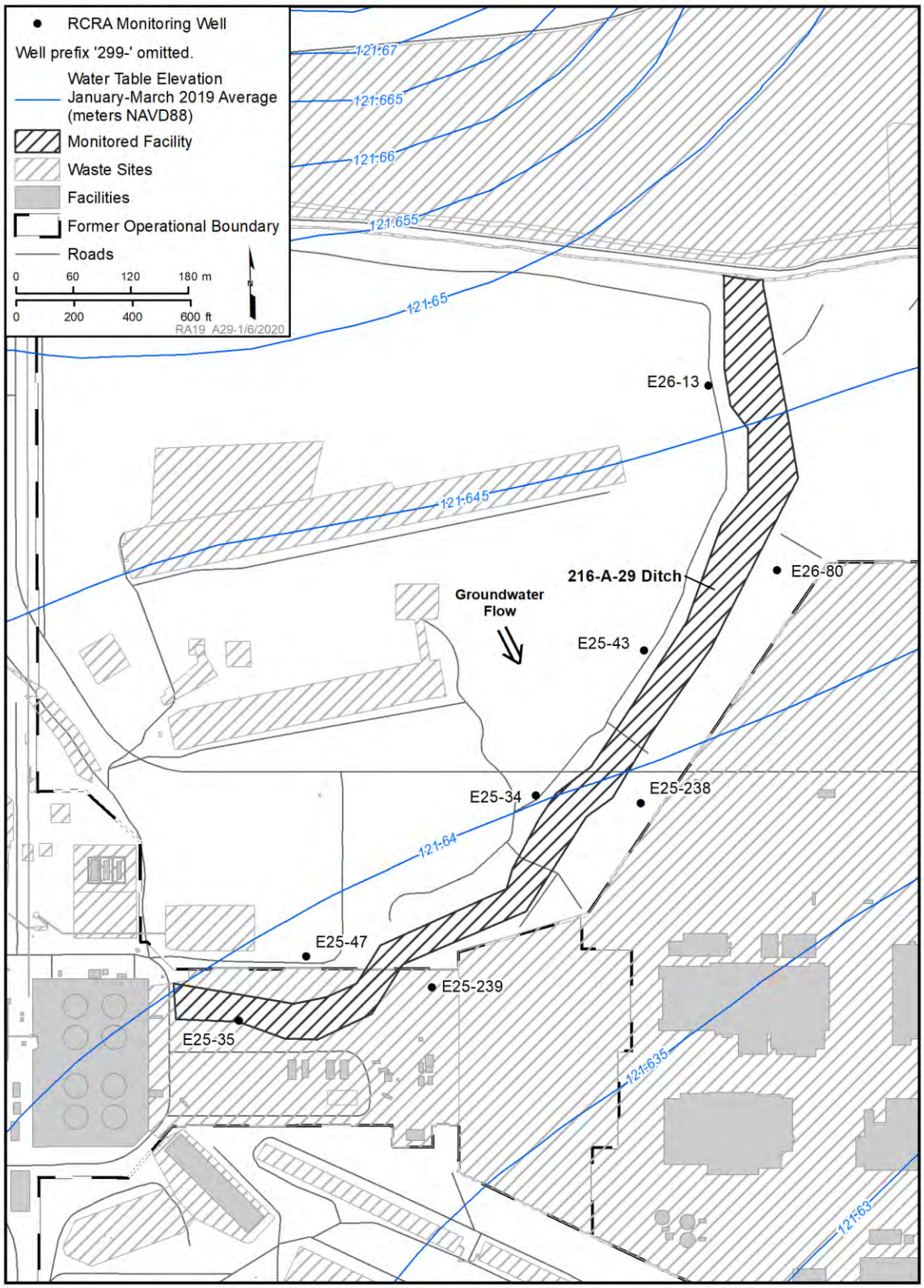
10.10.4 216-A-29 Ditch

The 216-A-29 Ditch is located just east of the 200 East Area fence line (Figure B-1 in Appendix B; Figure 10-28). The site is designated as a surface impoundment in accordance with WAC 173-303-040, "Definitions."

The 216-A-29 Ditch was placed into service in November 1955. It received continuous discharge of corrosive waste and potentially hazardous spilled chemical materials from the PUREX Plant. Discharges included acidic and caustic effluents from backwashing during demineralizer column regeneration. From 1955 to 1986, daily discharges of sodium hydroxide and sulfuric acid solutions occurred. Treatment of this waste involved the successive addition of acidic and caustic waste, which neutralized waste in the ditch. The ditch also received spills from the PUREX Plant chemical sewer (low-level contamination). Flow from the chemical sewer was continuous, with an average volume of 3,700 L/min (970 gal/min). After 1986, dangerous waste was no longer discharged to the chemical sewer. A complete estimated inventory of materials discharged to the 216-A-29 Ditch is provided in Appendix A of WHC-SD-EN-AP-045, *Ground Water Monitoring Plan for the 216-A-29 Ditch*.

The 216-A-29 Ditch was removed from service in 1991, partly backfilled with material from the ditch sides, and the portion of the ditch inside the 200 East Area security fence was brought to grade with clean fill material. The ditch outside of the 200 East Area security fence was topped with clean fill material in a series of 11 terraces progressing down the length of the ditch. Both areas were revegetated and posted as underground radioactive material areas.

In January 2016, the 216-A-29 Ditch was placed into a groundwater assessment program because specific conductance in wells 299-E25-32P, 299-E25-35, and 299-E25-48 exceeded the critical mean value in 2015. DOE/RL-2016-23, *216-A-29 Ditch Interim Status Groundwater Quality Assessment Monitoring Plan*, is the applicable groundwater quality assessment monitoring plan.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-28. 216-A-29 Ditch

In 2019, nine quarters of assessment monitoring data were evaluated for potentially dangerous waste constituents attributable to the 216-A-29 Ditch, and the results were published in a first determination report (DOE/RL-2019-27, *Groundwater Assessment First Determination Report for the 216-A-29 Ditch*), which was transmitted to Ecology for review. The report concluded that no dangerous waste groundwater contamination is attributed to releases from the 216-A-29 Ditch. It is anticipated that monitoring will be conducted under a new indicator evaluation monitoring plan being prepared in 2020.

Table B-6 in Appendix B lists the wells in the 216-A-29 Ditch monitoring network, as well as screened intervals and water levels. All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). SGW-60592, *Engineering Evaluation Report for the 216-A-29 Ditch Groundwater Monitoring*, recommended a modified network for final status monitoring, including all eight of the current wells and seven proposed new wells.

In 2019, the hydraulic gradient dipped to the south-southeast with a magnitude of 1.7×10^{-5} m/m, and the calculated average flow velocity was 1.2 m/d (4.1 ft/d) (Table B-2 in Appendix B).

Table B-7 in Appendix B summarizes the results for constituents required by the monitoring plan (DOE/RL-2016-23) and detected in 2019.

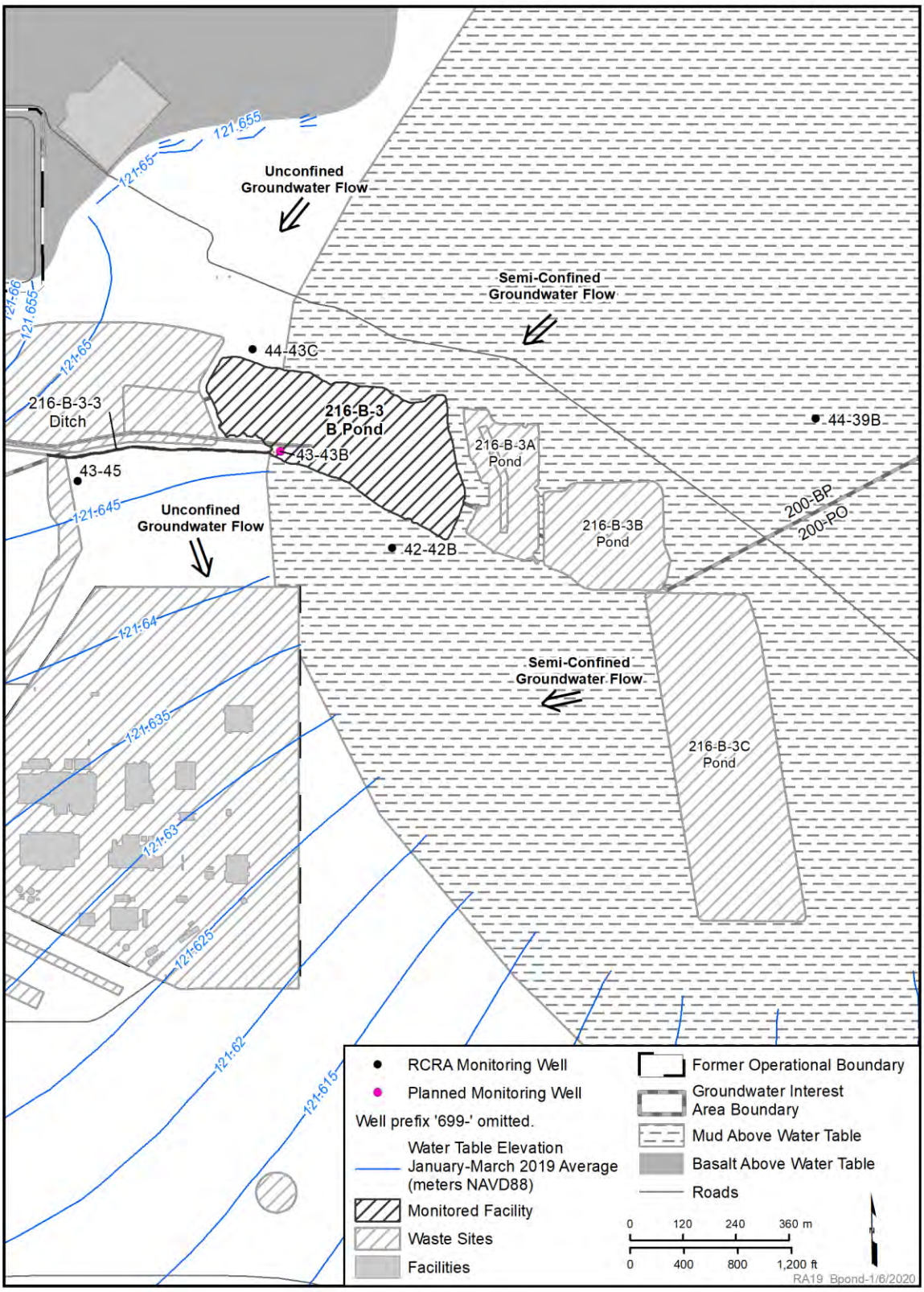
Unfiltered iron was above the secondary DWS in downgradient well 299-E25-35 in the July 2019 sample, but chromium, manganese, and nickel were all at low levels. These concentrations are not indicative of stainless-steel corrosion within the well.

The nitrate concentration was above the 45 mg/L DWS in well 299-E25-47 during the October 2019 sampling event. Nitrate values have been increasing at this location because of the encroachment of the regional nitrate groundwater plume from the 200-BP-5 OU to the northwest.

Arsenic concentrations were above the DWS in upgradient wells 299-E25-34, 299-E25-47, and 299-E26-13 and in downgradient well 299-E25-35. The maximum concentration was 11.5 µg/L in a January 2019 sample from well 299-E25-34, which is slightly lower than the Hanford Site background concentration of 11.8 µg/L (DOE/RL-96-61) at the 95th percent confidence interval.

10.10.5 216-B-3 Main Pond

The inactive 216-B-3 main pond and an adjoining portion of the 216-B-3-3 Ditch (collectively known as B Pond) were located east of the 200 East Area fence line (Figure B-1 in Appendix B; Figure 10-29). The main pond was in a natural topographic depression, diked on the eastern margin, and encompassed 14.2 ha (35 ac). During its operation (which began in 1945), B Pond received effluent from several 200 East Area facilities, including PUREX Plant, B Plant, A Tank Farm, 242A evaporator, 244AR vault, and 284E power plant. Dangerous waste was received from the 216-A-29 Ditch, conveyed to the eastern portion of the 216-B-3-3 Ditch, and then flowed eastward into the main pond. The last known reportable discharge of chemical waste (sodium nitrite) occurred in 1987. All discharges ceased in 1994, and B Pond was backfilled with coarse-grained material and then covered with fine-grained material. The total estimated discharge to B Pond since 1945 exceeded 1 trillion L (260 billion gal) (PNNL-15479, *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility*).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-29. 216-B-3 Main Pond (B Pond)

The 216-B-3 main pond is monitored under an interim status indicator evaluation program (DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*; as modified by RCRA-CN-01_DOE/RL-2008-59_R2, *RCRA Interim Status Change Number 1: Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*). DOE/RL-2008-59 provides a detailed description of the geology and hydrogeology at B Pond. In summary, because of the dipping beds of the Ringold Formation in this area and the erosional contact with the overlying Hanford formation, groundwater beneath B Pond can occur in both confined and unconfined aquifers, depending on the location. The uppermost aquifer is unconfined west, southwest, and northwest of the main pond where the Ringold Formation confining units 8 and 9B are absent. The aquifer is progressively more confined to the east and southeast of the main pond. Confinement of the Ringold unit 9 aquifers to the east is supported by the fact that hydrologic response to TEDF discharges was not observed in the wells completed in Ringold unit 9A (Section 2.4.3 in DOE/RL-2008-59). Figure 10-29 presents the approximate boundary of the Ringold mud unit above the water table near B Pond.

The B Pond groundwater monitoring network currently includes two upgradient wells, two downgradient wells, and an additional downgradient well planned for installation in 2020 (Table B-14 in Appendix B; Figure 10-29). The existing wells are screened across the top 1.4 to 6.4 m (4.5 to 21 ft) of the aquifer and are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Section 7.4 in SGW-60591, *Engineering Evaluation Report for the 216-B-3 Main Pond Groundwater Monitoring*, recommended installing four additional wells to support final status monitoring.

Groundwater flow in the unconfined aquifer of the Hanford formation (beneath western B Pond) was toward the south-southeast at an estimated rate of 1.1 m/d (3.6 ft/d) (Table B-15 in Appendix B; Figure 10-29). In the semiconfined Ringold Formation, flow was toward the southwest at 0.064 m/d (0.21 ft/d).

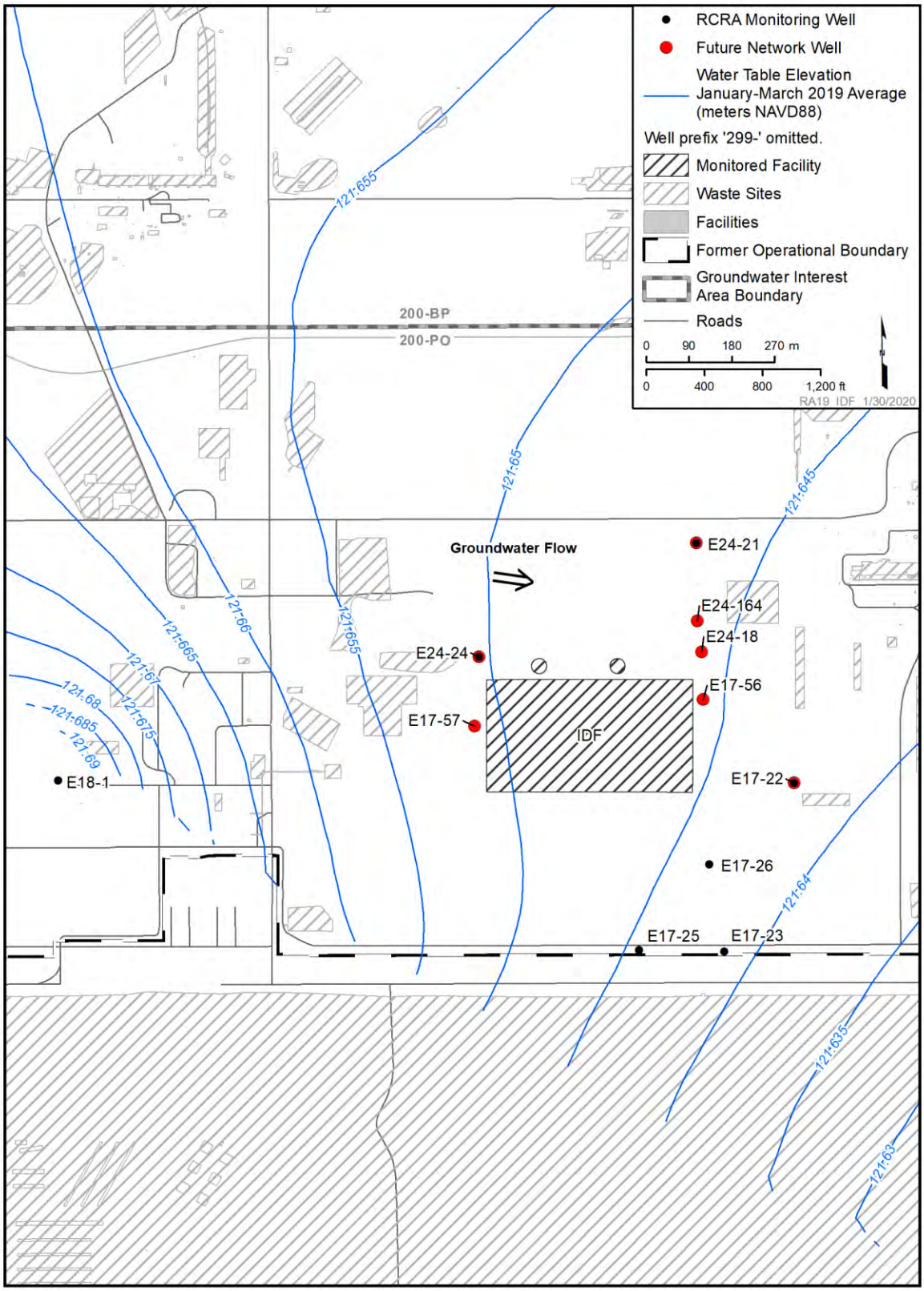
The B Pond network wells are monitored semiannually for RCRA indicator parameters (TOC, TOX, pH, and specific conductance) (Table B-16 in Appendix B). Indicator parameter results for the network during 2019 were below their critical mean values.

Table B-17 in Appendix B summarizes the 2019 results for groundwater quality constituents (40 CFR 265.92(b)(2)) and additional constituents required by Table 3-1 in the monitoring plan (DOE/RL-2008-59). Arsenic concentrations in wells 699-42-42B and 699-43-45 were above the primary DWS. The maximum concentrations (Table B-17 in Appendix B) were higher than the sitewide background value at the 95th confidence interval of 11.8 µg/L.

10.10.6 Integrated Disposal Facility

The IDF is an expandable, double-lined landfill in the 200 East Area (Figure B-1 in Appendix B; Figure 10-30) with 0.07 km^2 (0.027 mi^2) of liner. It includes two distinct cells: an east cell for low-level radioactive waste, and a west cell for mixed waste. The IDF is not yet in use.

Construction of the first phase for IDF was completed in April 2006. DOE submitted a Part B RCRA Permit application to Ecology, which was incorporated into the Hanford RCRA Permit on April 9, 2006. The anticipated start date for IDF operations is January 2021. In 2019, it was monitored under a pre-operational final status detection monitoring program under the Hanford RCRA Permit (Part III, OUG-11, Chapter 5.0, “Groundwater Monitoring” [modification date of June 30, 2010]).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-30. Integrated Disposal Facility

In 2019, DOE submitted a plan for a revised groundwater monitoring program to Ecology (DOE/RL-2019-29, *Groundwater Monitoring Plan for the Integrated Disposal Facility*). The revised monitoring program will be incorporated into the Hanford RCRA Permit in the future. Ecology approved DOE's request to begin baseline sampling under the revised monitoring program in 2020 (19-NWP-197, "Approval of Request for Integrated Disposal Facility Groundwater Sampling Activities"). Table B-28 in Appendix B and Figure 10-30 present the IDF monitoring networks in effect in 2019 and in the revised program.

Because the IDF is not yet operating, the current monitoring objective is to collect baseline groundwater information. The network wells were sampled as scheduled during 2019. All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Well 299-E18-1 was sampled with a bailer in 2019 due to low water and is not included in the revised monitoring network.

The groundwater flow direction in 2019 was slightly south of east, with an estimated gradient of 9.7×10^{-6} m/m and a flow rate of 0.48 m/d (1.6 ft/d) (Table B-2 in Appendix B). In recent years, the flow direction has varied from east-northeast (2008 to 2011) to southeast (2013 to 2014). Hydraulic conductivity is markedly different between the two unconfined aquifer units beneath the IDF. The water table is at an elevation of about 121.7 m (399 ft) in Hanford formation flood channel deposits, which have an estimated hydraulic conductivity of 17,000 m/d (56,000 ft/d). The top of Ringold unit E, with an estimated hydraulic conductivity of 3.26 m/d (10.7 ft/d), is at an elevation of about 104.5 m (343 ft) where it is thickest in the eastern portion of the IDF site. Hanford formation saturated thickness ranges from 15 to 20 m (49 to 66 ft) from east to west. The maximum saturated thickness of Ringold unit E is about 2 m (7 ft) in the eastern portion of the IDF site. Because the Hanford formation comprises a majority of the total saturated thickness, its associated hydraulic conductivity is considered the primary driver for overall groundwater flow velocity.

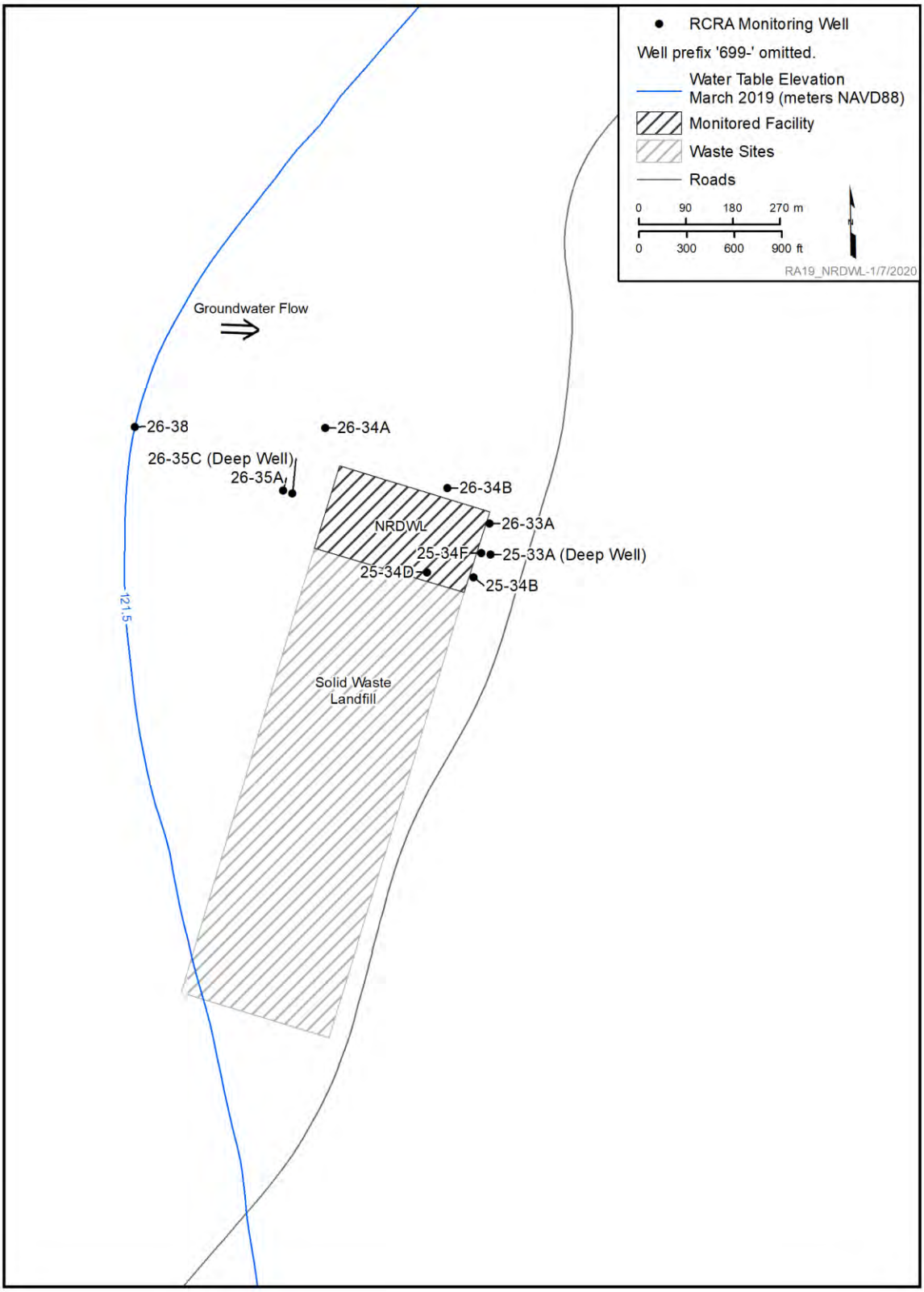
In 2019, the wells were sampled once as required for indicator parameters chromium (filtered), pH, specific conductance, TOC, and TOX (Table B-29 in Appendix B). In addition, monitoring includes the supplemental constituents alkalinity, anions, metals, and turbidity (Table B-30 in Appendix B). Upgradient/downgradient comparisons of indicator parameters are not required because the IDF is not in use.

Nitrate concentrations in 2019 were above the DWS in six IDF wells (Table B-30 in Appendix B). Wells monitoring the IDF are within the regional 200 East Area nitrate plume.

10.10.7 Nonradioactive Dangerous Waste Landfill

The NRDWL is located southeast of the 200 East Area, next to the SWL (Figure B-1 in Appendix B; Figure 10-31). The NRDWL encompasses an area of 0.045 km^2 (0.017 mi^2) and consists of 19 parallel unlined trenches, each about 122 m (400 ft) long, 4.9 m (16 ft) wide at the base, and 4.6 m (15 ft) deep. The landfill received chemical, asbestos, and nonhazardous waste from 1975 to 1985.

The NRDWL entered a groundwater quality assessment monitoring program in 2017, which continued in 2019 in accordance with DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site.* Quarterly assessment sampling began in April 2017. Table B-47 in Appendix B lists the current monitoring well network. SGW-60589, *Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring*, concluded that the existing monitoring network is adequate to detect a potential release from NRDWL. Wells were sampled as planned in 2019 and are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-31. Nonradioactive Dangerous Waste Landfill

Data compiled in 2019 and used for trend surface analysis indicate groundwater flow toward the east-southeast and a hydraulic gradient of 3.7×10^{-5} m/m (Table B-48 in Appendix B). A southeast flow direction is inferred from historical plume migration in this area and hydraulic head differences in the NRDWL/SWL area compared to the 200 East Area. The average groundwater flow rate was 0.02 m/d (0.07 ft/d).

Five quarters of assessment monitoring data were evaluated for potentially dangerous waste constituents attributable to the NRDWL. Results were published in a first determination report in 2019 (DOE/RL-2019-22, *Groundwater Assessment First Determination Report for the Nonradioactive Dangerous Waste Landfill*) and transmitted to Ecology for review. The report concluded that no dangerous waste groundwater contamination is attributed to releases from the NRDWL. It is anticipated that monitoring will be conducted under a new indicator evaluation monitoring plan being prepared in 2020.

In 2019, wells were sampled as required by the current assessment monitoring plan (DOE/RL-2017-19). Table B-49 in Appendix B summarizes the results.

The unfiltered iron concentration in well 699-25-33A was above the 300 µg/L secondary DWS in October 2019. The concentrations in filtered samples from the same well were <30 µg/L, except for the July 2019 sampling event with a concentration of 61.0 µg/L. The October concentration of unfiltered manganese was slightly higher than the previous sample value.

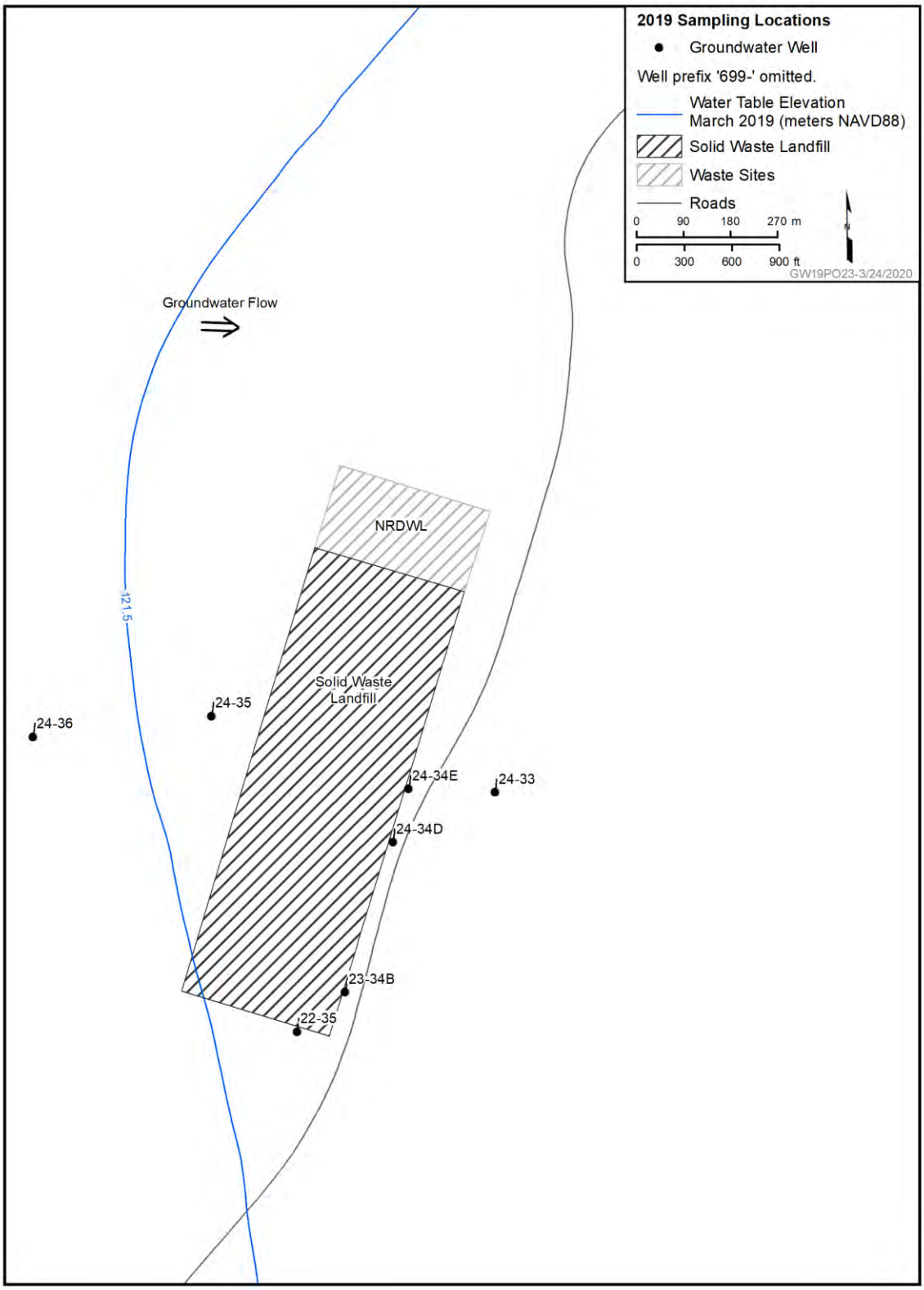
Low-level detections of several organic compounds were noted in 2019 (Table B-49 in Appendix B). Most results were below quantitation limits, except for acetone, butyl phthalate, dimethyl phthalate, di-n-butylphthalte, and methylene chloride. Acetone is a common laboratory contaminant that was above the quantitation limit in four samples. The maximum concentration of 9.34 µg/L was associated with a "J" laboratory qualifier, indicating that this value was less than the quantitation limit. The highest quantifiable value was 4.2 µg/L (quantitation limits vary among analytical laboratories). The other VOC detections were single isolated events. Phthalates are associated with plastics and are the result of residual contamination from sampling and/or laboratory equipment, and/or containers such as plastic tubing and sample bottles. Methylene chloride is common solvent and is associated with polyurethane foam; therefore, it is also likely a sampling or laboratory contaminant. Because no trends of detections exist with these contaminants, it is not likely that the contaminants originated from waste disposed at the NRDWL.

10.11 Washington Administrative Code Monitoring – Solid Waste Landfill

The SWL is located south of and adjacent to the NRDWL (Figure 10-32). The landfill is regulated by Ecology in accordance with WAC 173-350, which requires monitoring of leachate, soil gas, and groundwater. Annual reporting for the SWL is additionally presented by MSA in an annual monitoring report (e.g., DOE/RL-2015-21, Rev. 4, *Hanford Site Solid Waste Landfill Annual Monitoring Report October 2017 through September 2018*).

Sampling events for fiscal year 2019 were completed in October 2018 and April 2019 under the monitoring plan (DOE/RL-2015-33, *Groundwater Monitoring Plan for the Solid Waste Landfill*). Compliance is determined by comparing results from downgradient monitoring wells with statistically derived background threshold values (BTVs) from upgradient wells.

The results of the leachate, soil gas, and groundwater monitoring are reported annually in a separate report prepared by MSA. The following discussion provides a summary of the groundwater monitoring results.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 10-32. Solid Waste Landfill

The BTVs were calculated for applicable constituents under DOE/RL-2015-33 and are presented in ECF-200PO1-16-0144, *Calculation of Background Threshold Values (BTVs) for the Solid Waste Landfill (SWL) through CY 2016*. The SWL groundwater sampling data for fiscal year 2019 were compared to the BTVs, and exceedances are summarized below.

Wells 699-22-35, 699-24-33, 699-24-24E, 699-24-34D, and 699-25-24E exceeded the chloride BTV of 6.1 mg/L in all sampling events from October 2018 to October 2019. Well 699-23-34B exceeded the chloride BTV in the October 2018 sampling event.

The calcium BTV of 81 mg/L was exceeded in the October 2018 and April 2019 sampling events in wells 699-22-35, 699-23-34B, 699-24-33, and 699-24-34E. Well 699-24-34D exceeded the calcium BTV in October 2018. Well 699-25-34E exceeded the BTV in January and April 2019.

The magnesium BTV of 17.2 mg/L was exceeded in the October 2018 and April 2019 sampling events in wells 699-22-35, 699-23-34B, and 699-24-33.

The sodium BTV was exceeded in well 699-25-34E in the April 2019 sampling event.

The closure of the Test America Richland Laboratory (TARL) removed the availability for coliform analysis to be performed within the required 6-hour holding time. The closure of TARL affected only the second semiannual samples. This issue was communicated with DOE and the Washington State Department of Health and is documented in the operating record for the SWL. The CH2M HILL Plateau Remediation Company Soil and Groundwater Remediation Project continues to assess local laboratory capabilities for this analysis. Wells 699-24-34D and 699-24-34E both had coliform bacteria detected above the BTV of one colony/100 mL in the October 2018 sampling event.

The nitrate BTV of 14.6 mg/L was exceeded in wells 699-22-35, 699-23-34B, 699-24-33, and 699-25-34E in the October 2018 and April 2019 sampling events. The nitrate BTV was exceeded in well 699-24-34E in the October 2018 sampling event. The SWL is near the southwestern extent of the historical elevated nitrate concentrations that once emanated from 200 East Area sources into the 200-PO far-field area. Nitrate concentrations detected in the SWL have been consistent with the far-field interpretation of nitrate groundwater impacts.

Wells 699-23-35, 699-23-34B, 699-24-33, 699-24-34D, 699-25-34E, and 699-25-34E exceeded the specific conductance BTV of 576 µS/cm in the October 2018 and April 2019 sampling events. One downgradient well (699-22-35) in October 2018 and April 2019 had measurements above the 700 µS/cm limit of WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)." Specific conductance measurements in upgradient wells were below the BTV. Elevated specific conductance is principally caused by an increase of bicarbonate concentration in the groundwater at the SWL (Section 3.4 in DOE/RL-94-143, *Corrective Action Plan for the Hanford Site Solid Waste Landfill*). Since sampling began under the current sampling plan in 2001, specific conductance has exceeded the BTV intermittently in eight of the nine historical and current downgradient network wells and two upgradient wells (699-24-35 and 699-26-35A).

10.12 Atomic Energy Act Monitoring

AEA monitoring in 200-PO includes area-wide sampling, 400 Area water supply wells, and the IDF. Additional AEA monitoring at the IDF is described in RPP-PLAN-26534, *Integrated Disposal Facility Operational Monitoring Plan to Meet DOE Order 435.1*.

AEA groundwater monitoring was conducted at 87 groundwater wells and aquifer tubes in 200-PO in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 200-PO are tritium, iodine-129, nitrate, strontium-90, technetium-99, and uranium. Historically, nitrate has been monitored through AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Seven wells were not sampled in accordance with SAP requirements in 2019 (Appendix C). Minor exceptions to planned monitoring occurred because of well access issues and dry wells.

Radionuclide concentrations detected in groundwater samples from 137 wells[12] were used to estimate the cumulative TED and to compare the cumulative beta/photon emitters, alpha emitters, and uranium mass to DWSs (described in Section 1.2.4). The estimated TED exceeded the 100 mrem/yr standard at one location in 200-PO. None of the DWSs for cumulative alpha emitters were exceeded, but one location did exceed the EPA net alpha activity standard. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 79 locations in 200-PO (Table 10-3). One location exceeded the 30 µg/L uranium DWS. One of the locations that exceeded the beta/photon emitters (aquifer tube C6353) is 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 that restrict access to groundwater. CERCLA remedial actions provide longer-term protection of the public and environment.

Table 10-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-PO in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E16-2	—	—	10.26	10.26	—	—	—	—
299-E17-1	—	—	52.69	52.69	—	—		
299-E17-9	224.94	224.94	871.00	871.00	—	—	—	—
299-E17-14	—	—	73.49	75.35	—	—	—	—
299-E17-15	—	—	38.07	38.07	—	—	—	—
299-E17-16	—	—	20.36	20.36	—	—	—	—
299-E17-18	—	—	5.52	5.52	—	—	—	—
299-E17-19	—	—	90.57	90.57	—	—	—	—
299-E17-21	—	—	4.00	4.00	—	—	—	—
299-E17-22	—	—	5.27	5.27	—	—	—	—
299-E17-23	—	—	8.47	8.47	—	—	—	—
299-E17-25	—	—	17.22	17.22	—	—	—	—
299-E17-26	—	—	8.30	8.30	—	—	—	—
299-E24-4	—	—	16.88	16.88	—	—	—	—

[12] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 10-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-PO in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E24-5	—	—	18.90	18.90	—	—	—	—
299-E24-16	—	—	33.03	33.03	—	—	—	—
299-E24-20	—	—	26.81	26.81	—	—	—	—
299-E24-22	—	—	48.60	48.60	—	—	48.60*	48.60*
299-E24-23	—	—	63.94	73.55	—	—	—	—
299-E24-33	—	—	30.48	30.48	—	—	—	—
299-E25-2	—	—	21.45	22.34	—	—	—	—
299-E25-3	—	—	15.67	15.67	—	—	—	—
299-E25-6	—	—	26.08	26.08	—	—	—	—
299-E25-11	—	—	20.69	20.69	—	—	—	—
299-E25-17	—	—	22.19	22.19	—	—	—	—
299-E25-18	—	—	19.86	19.86	—	—	—	—
299-E25-19	—	—	26.47	26.47	—	—	—	—
299-E25-20	—	—	24.20	24.20	—	—	—	—
299-E25-21	—	—	6.28	6.28	—	—	—	—
299-E25-22	—	—	14.94	14.94	—	—	—	—
299-E25-26	—	—	9.4	9.4	—	—	—	—
299-E25-28	—	—	20.77	20.77	—	—	—	—
299-E25-29P	—	—	8.88	8.88	—	—	—	—
299-E25-29Q	—	—	15.30	15.30	—	—	—	—
299-E25-32P	—	—	17.40	17.40	—	—	—	—
299-E25-32Q	—	—	19.68	19.68	—	—	—	—
299-E25-34	—	—	14.46	14.46	—	—	—	—
299-E25-35	—	—	22.04	22.04	—	—	—	—
299-E25-36	—	—	15.92	15.92	68.41	68.41	—	—
299-E25-37	—	—	11.32	11.32	—	—	—	—
299-E25-39	—	—	13.32	13.32	—	—	—	—
299-E25-40	—	—	17.58	17.58	—	—	—	—
299-E25-41	—	—	26.48	28.25	—	—	—	—
299-E25-42	—	—	28.37	28.37	—	—	—	—

Table 10-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-PO in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
299-E25-43	—	—	26.81	30.74	—	—	—	—
299-E25-44	—	—	6.14	6.14	—	—	—	—
299-E25-47	—	—	24.46	24.46	—	—	—	—
299-E25-93	—	—	39.45	39.45	—	—	—	—
299-E25-94	—	—	27.86	27.86	—	—	—	—
299-E25-237	—	—	22.00	25.04	—	—	—	—
299-E26-4	—	—	27.56	27.56	—	—	—	—
299-E26-13	—	—	48.80	48.80	—	—	—	—
699-20-20	—	—	10.10	10.10	—	—	—	—
699-20-E5A	—	—	4.36	4.36	—	—	—	—
699-21-6	—	—	4.71	4.71	—	—	—	—
699-26-15A	—	—	16.52	16.52	—	—	—	—
699-26-33A	—	—	10.58	10.58	—	—	—	—
699-29-4	—	—	13.41	13.41	—	—	—	—
699-31-11	—	—	19.84	19.84	—	—	—	—
699-32-43	—	—	5.53	5.53	—	—	—	—
699-34-41B	—	—	8.75	8.75	—	—	—	—
699-34-42	—	—	9.30	9.30	—	—	—	—
699-35-9	—	—	7.52	7.52	—	—	—	—
699-37-43	—	—	12.31	12.31	—	—	—	—
699-37-47A	—	—	19.58	19.58	—	—	—	—
699-37-E4	—	—	9.34	9.34	—	—	—	—
699-38-15	—	—	17.14	17.14	—	—	—	—
699-40-1	—	—	6.14	6.14	—	—	—	—
699-41-1A	—	—	5.84	5.84	—	—	—	—
699-41-23	—	—	19.32	19.32	—	—	—	—
699-41-40	—	—	7.57	7.57	—	—	—	—
699-41-42	—	—	12.16	21.08	—	—	—	—
699-42-12A	—	—	14.34	14.34	—	—	—	—
699-42-42B	—	—	10.86	14.44	—	—	—	—

Table 10-3. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-PO in 2019

Monitoring Location/ Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L		Net Alpha-Emitter Activity ≥15 pCi/L	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
699-43-3	—	—	7.65	7.65	—	—	—	—
699-43-45	—	—	44.69	44.69	—	—	—	—
699-46-21B	—	—	4.32	4.32	—	—	—	—
699-46-4	—	—	6.56	6.56	—	—	—	—
C6353	—	—	4.49	4.49	—	—	—	—

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

None of the wells in 200-PO had total effective dose ≥100 mrem/yr or cumulative alpha activity ≥15 pCi/L.

Blank cells (—) indicate no exceedances.

*Under evaluation for potential error.

10.12.1 400 Area

The 400 Area is located 16.2 km (10.1 mi) southeast of the 200 East Area (Figure 10-1). The 400 Area includes the Fast Flux Test Facility, ancillary facilities, and waste sites. Monitoring is conducted to provide information on the potential impact of sitewide contamination (primarily tritium, nitrate, and iodine-129) on the water supply wells that provide drinking water and emergency supply water for the 400 Area (Chapter 7 in DOE/RL-2018-32, *Hanford Site Environmental Report for Calendar Year 2017*) One well in the 400 Area was not sampled in accordance with AEA SAP (DOE/RL-2015-56) due to a well maintenance issue in 2019 (Appendix C). Minor exceptions to planned monitoring occurred due to maintenance issues and well access issues.

Wells sampled in 2019 for AEA SAP (DOE/RL-2015-56) constituents in the 400 Area did not exceed DWSs. In well 499-S0-8, tritium was reported at 4,100 pCi/L in November 2019 showing a decreasing trend. All other radionuclides sampled in 2019 were either below detection limits or below 50% of the DWSs.

10.12.2 Integrated Disposal Facility

The IDF is a permitted RCRA facility (Section 10.10.6; Figure 10-30) that has additional groundwater sampling requirements under the AEA, as described in RPP-PLAN-26534. The plan describes sampling of the IDF groundwater monitoring network (described in Section 10.10.6) semiannually for gross alpha, gross beta, iodine-129, and technetium-99. The IDF is not yet in use.

Wells sampled in 2019 under the AEA and IDF monitoring plan (RPP-PLAN-26534) exceeded DWSs for nitrate, tritium, and gross beta at levels consistent with regional plumes. All of the IDF monitoring wells sampled for nitrate in 2019 exceeded the nitrate DWSs. Nitrate concentrations were stable to increasing for wells that exceeded DWSs in 2019.Tritium exceeded DWSs in four locations, but concentrations remained stable to decreasing in 2019. Gross beta concentrations exceeded the DWS at three locations. Gross beta concentrations generally exhibited increasing trends for 2019. Technetium-99 concentrations at well 299-E17-22 increased in July to 619 pCi/L, which was the highest reported technetium-99 value for IDF wells in 2019. Aside from well 299-E17-22, technetium-99 concentrations were variable to increasing for all IDF wells but remained less than the DWS. One well exceeded the DWS for iodine-129 for 2019. For the remainder of the IDF wells, iodine-129 results are below detection limits and stable.

11 200-UP

The 200-UP groundwater interest area includes the 200-UP-1 Groundwater OU in the southern portion of the 200 West Area and the surrounding vicinity (Figure 1-1). This chapter includes an overview of 200-UP; a discussion of CERCLA-, RCRA-, and AEA-related groundwater activities conducted in 2019; and a summary of the 2019 groundwater monitoring results.

11.1 Overview

The facilities and waste sites within 200-UP are associated with early operation of the REDOX Plant (plutonium and uranium separation) and U Plant (uranium recovery). There currently are no active liquid waste disposal sites within 200-UP. The only active solid waste disposal site is the Environmental Restoration Disposal Facility (ERDF), which receives waste from removal remedial actions at the Hanford Site. The SSTs in 200-UP have been interim stabilized (i.e., most of the drainable liquid from each tank has been transferred to double-shell tanks).

DOE is remediating groundwater in 200-UP under CERCLA (Section 11.10) and also monitors groundwater under RCRA (Section 11.11) and AEA (Section 11.12).

Groundwater COCs, as defined by the 200-UP-1 OU ROD (EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*), are uranium, technetium-99, chromium (Cr(VI) and total), nitrate, iodine-129, tritium, and carbon tetrachloride. Table 11-1 shows the cleanup levels and maximum concentrations observed in 2018 and 2019 for these COCs. The carbon tetrachloride in 200-UP groundwater originated from waste sites associated with the PFP in the 200-ZP groundwater interest area (Chapter 12). Some ditches from the PFP extended to the 216-U-10 Pond (Figure 11-1), which may also have been a carbon tetrachloride source. Additional groundwater COPCs (TCE, chloroform, PCE, strontium-90, and 1,4-dioxane) were identified in the ROD for monitoring in selected wells.

The contaminant plume maps presented in this chapter are generally based on all available well data collected from various aquifer depths. In some locations (particularly for carbon tetrachloride and chromium), the greatest concentrations occur near the bottom of the aquifer. If wells are paired (shallow/deep), the greater concentration is used for plume mapping. Plume mapping details, including descriptions of terms used in the figure legends, are provided in Section 1.5. Figure 11-1 shows the sample locations for 2019.

Within 200-UP, groundwater occurs in an unconfined aquifer within the lower portion of Ringold unit E and in confined aquifers beneath the Ringold lower mud unit (within Ringold unit A and permeable interflow zones in the underlying basalt). Figure 1-6 shows a generalized stratigraphic column for the Central Plateau. Geologic data indicate that the Ringold lower mud unit is continuous beneath 200-UP, except for a small area in the eastern 200 West Area, north of extraction well 299-W11-97 (Figure 6-7 in ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*; Figure 12-3 in this report). The interpreted absence of the Ringold lower mud unit north of well 299-W11-97 (where approximately 3.4 m [11 ft] of the mud unit was observed) is based on the absence of the mud unit at wells 299-W13-1 and 299-W14-22 within 200-ZP, which are the nearest wells north of well 299-W11-97 (Figure 12-4; Table A-2 in ECF-HANFORD-13-0029) The unconfined aquifer has been impacted by past waste disposal operations within 200-UP. Carbon tetrachloride is present in both the unconfined aquifer and in the confined aquifer beneath the Ringold lower mud unit in the northern portion of 200-UP.

Table 11-1. 200-UP at a Glance

Reduction-Oxidation Plant operations: 1952 to 1967 (plutonium separation) **U Plant operations:** 1952 to 1957 (uranium recovery)			
Groundwater Monitoring			
Contaminant, Cleanup Level[a]	**Year**	**Maximum Concentration (Well)**	**Plume Area[b] (km^2)**
Carbon tetrachloride, 3.4 µg/L	2019	408 (299-W14-71)	See 200-ZP
	2018	428 (299-W14-71)	
Chromium (hexavalent), 48 µg/L	2019	463 (299-W23-19)	11.7[c]
	2018	330 (299-W23-19)	11.2[c]
Chromium (total), 100 µg/L	2019	438 (299-W23-19 unfiltered)	3.9[c]
	2018	373 (299-W23-19 unfiltered)	4.2[c]
Nitrate, 45 mg/L	2019	211[d] (299-W20-1)	6.9
	2018	270 (299-W23-19)	6.0
Iodine-129, 1 pCi/L	2019	23.7 (299-W21-3)	4.1
	2018	23.0 (299-W21-3)	4.0
Technetium-99, 900 pCi/L	2019	15,200 (299-W23-19)	0.13
	2018	30,900 (299-W23-19)	0.15
Tritium, 20,000 pCi/L	2019	222,000 (699-36-65)	3.7
	2018	187,000 (699-36-66B)	3.8
Uranium, 30 µg/L	2019	2,100 (299-W19-36)	0.11
	2018	3,520 (299-W19-36)	0.12
Remediation			
U Plant interim actions: 1994 to present. **WMA S-SX interim action:** 2012 to present. **Iodine-129 plume hydraulic control:** 2015 to present. **Southeast chromium plume:** Future remedial action. The Record of Decision (EPA et al., 2012) was approved in September 2012.			

a. From Table 14 in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*.

b. Estimated area above the cleanup level.

c. Hexavalent and total chromium plume areas include the portion that extends into the 200-PO groundwater interest area

d. Maximum nitrate concentration of 211 mg/L was for a characterization sample collected during drilling of well 299-W20-1. For routine groundwater sampling in 200-UP, the maximum nitrate concentration was 186 mg/L at well 699-38-65, and the nitrate concentration at well 299-W20-1 was 155 mg/L.

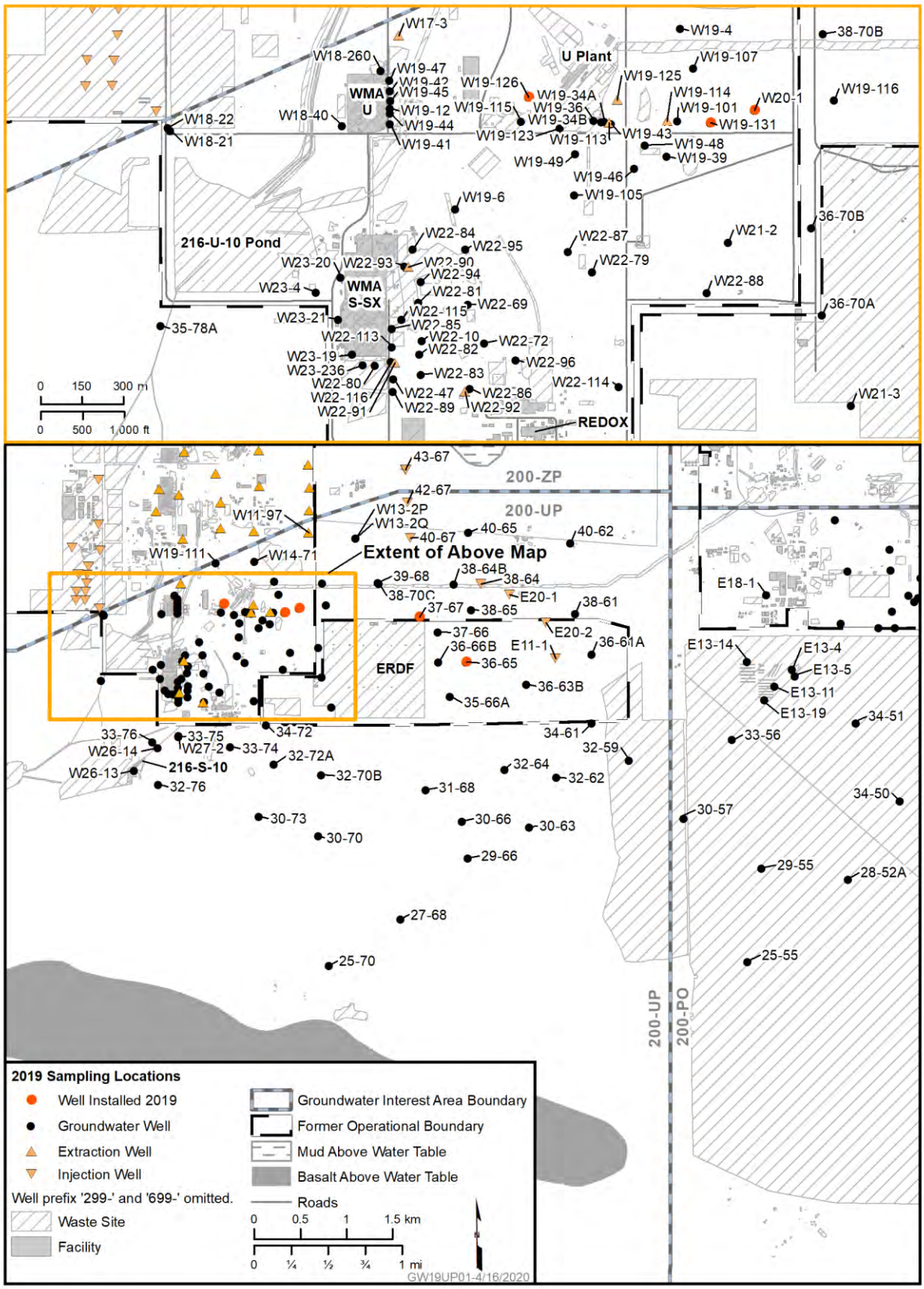


Figure 11-1. 200-UP Sampling Locations, 2019

Depths from land surface to the water table range from 66 to 104 m (215 to 341 ft), with the greatest depths occurring in the northeastern portion of 200-UP. The unconfined aquifer thickness varies from 100 m (330 ft) in the west to near zero north of the 200-UP boundary where the top of the Ringold lower mud unit has been interpreted to occur above the water table. The water table elevation and groundwater gradients in the 200 West Area have historically been affected by large-volume wastewater discharges (Chapter 2 in SGW-60338, *Historical Changes in Water Table Elevation and Groundwater Flow Direction at Hanford: 1944 to 2014*) and currently are affected by groundwater extraction and injection within the 200 West Area. Groundwater within the unconfined aquifer generally flows toward the east in the western portion of the OU, toward the east-northeast in the northeast portion of the OU, and toward the north in the north-central portion of the OU (Figures 11-2 and 11-3).

The plume areas above cleanup levels are shown in Figure 11-4 for the 200-UP COCs over time. Abrupt changes (e.g., changes in chromium and uranium plume areas in 2017) are caused by reinterpretation of plume extents as additional data have been obtained from new monitoring wells.

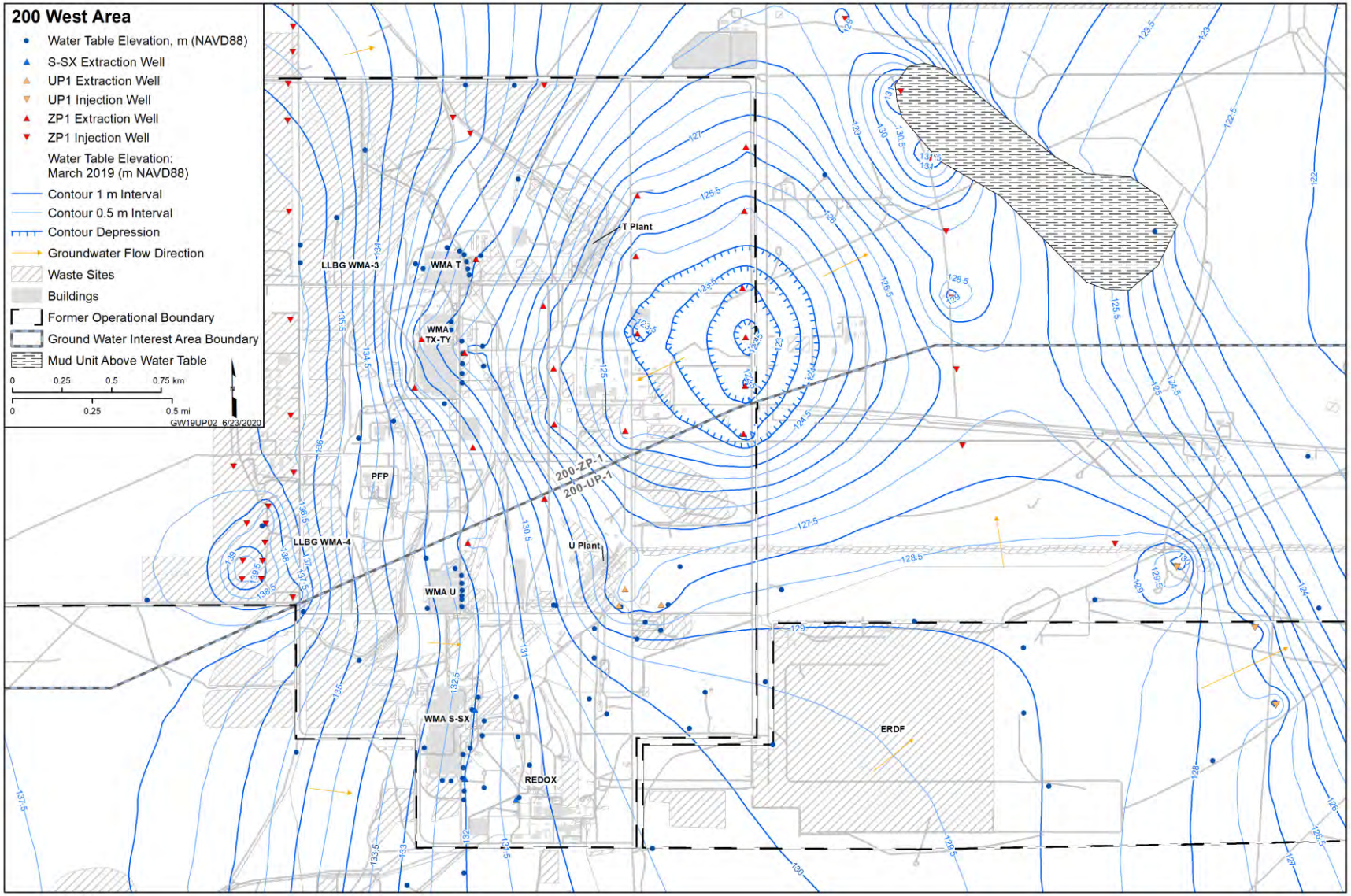
11.2 Uranium

Within 200-UP, uranium concentrations exceed the 30 µg/L cleanup level downgradient of the 216-U-1 and 216-U-2 Cribs, and in a small area near the 216-U-10 Pond (U Pond) (Figure 11-5).

11.2.1 216-U-1 and 216-U-2 Cribs Plume

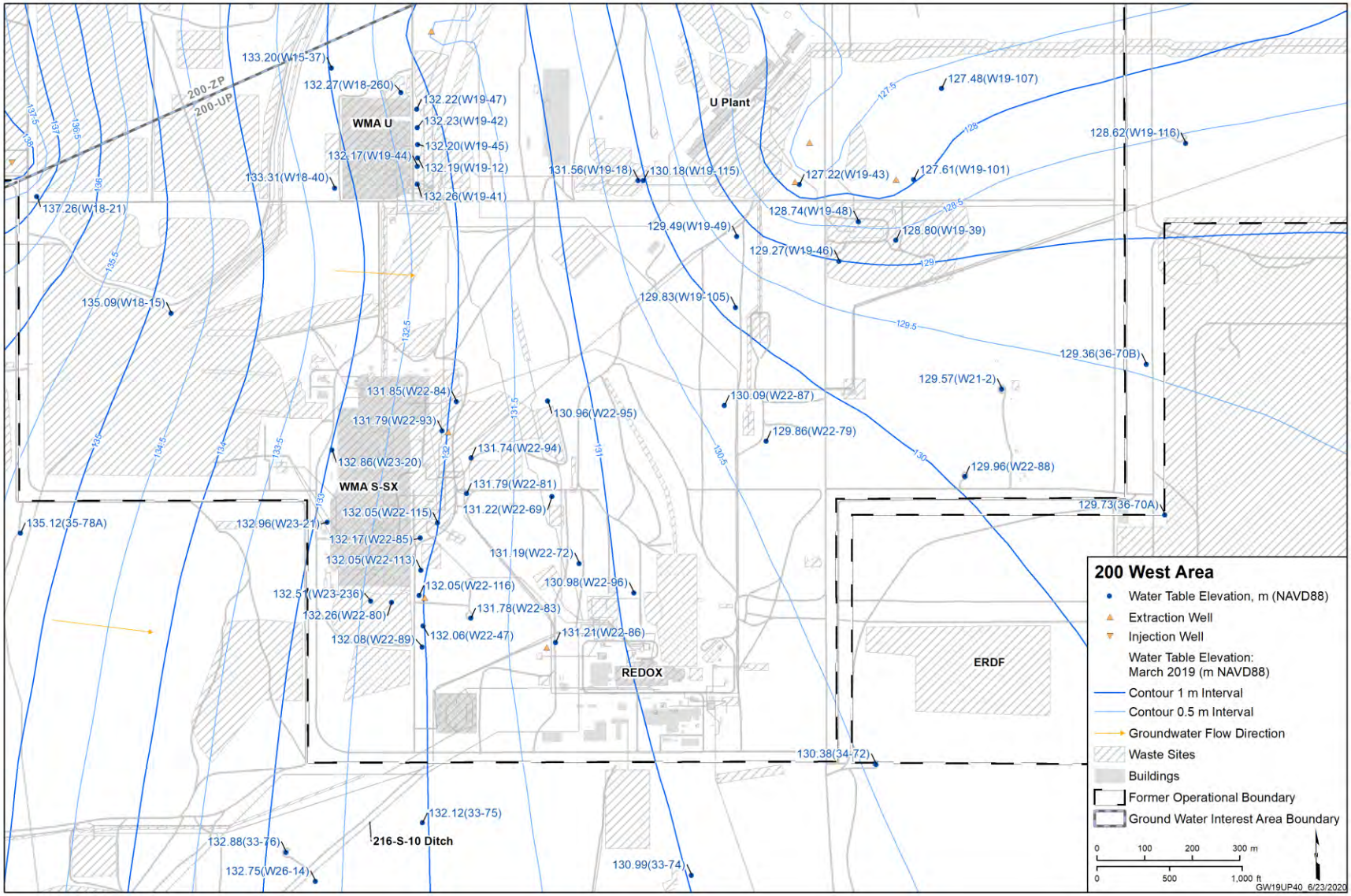
The 216-U-1 and 216-U-2 Cribs were the source of a uranium plume extending to the east near U Plant at levels above the 30 µg/L cleanup level (Figure 11-5). A groundwater extraction system for this area began operating in September 2015 using extraction wells 299-W19-113 and 299-W19-114; a third extraction well, 299-W19-125, was added in September 2017. The system was designed to remediate uranium, technetium-99, and the high-concentration portion of the nitrate plume in the U Plant area (Section 11.10.3).

Figure 11-6 includes uranium concentration charts for selected monitoring wells near U Plant. Uranium concentrations declined in most of these wells before and during operation of the current groundwater extraction system, except as follows. At well 299-W19-36, uranium concentrations began increasing in 2015, peaked at 5,000 µg/L in August 2017, and then declined through August 2019 to 1,700 µg/L (Figure 11-6); the previous increasing concentrations could be attributed to contaminated groundwater being drawn toward nearby extraction well 299-W19-113 (Figure 11-7) or potential continuing sources. Following installation of well 299-W19-123 in 2017, the post-development sample had a concentration of 69 µg/L, which subsequently increased to 153 µg/L during 2019. Reducing conditions caused by the drilling process may have suppressed the initial concentrations measured at this well.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-2. 200 West Water Table Map, March 2019



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-3. Water Table Map in Vicinity of 200-UP Groundwater Extraction Systems, March 2019

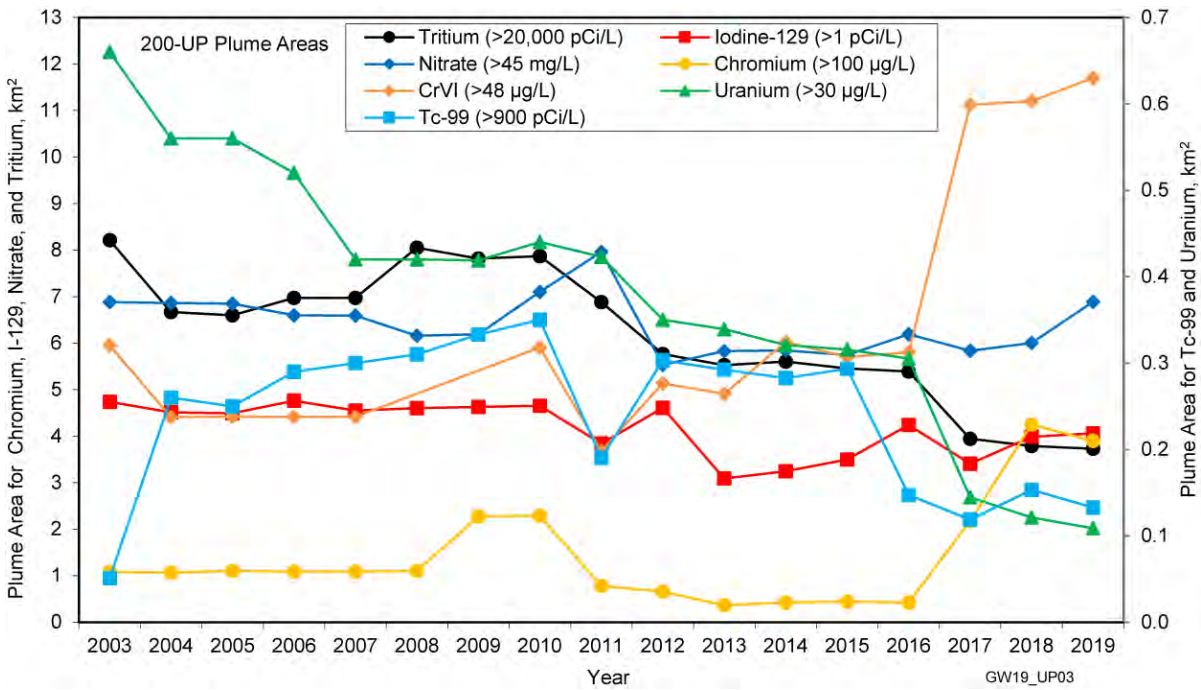


Figure 11-4. 200-UP Plume Areas

To better define the extent of the uranium plume, three new wells were installed in 2019: 299-W19-126, 299-W19-131, and 299-W20-1 (Figure 11-5). At well 299-W19-126 (west of U Plant), all characterization samples collected during drilling had concentrations below the 30 µg/L cleanup level, but the routine sample collected in December 2019 had a concentration of 31 µg/L. As such, the interpreted plume extent for 2019 was extended slightly to the north in this area. Well 299-W19-131 was installed 160 m (520 ft) east of well 299-W19-101 (the easternmost well within the interpreted 2018 plume boundary), and well 299-W20-1 was installed 350 m (1,100 ft) east of well 299-W19-101.
At well 299-W19-131, all characterization samples collected during drilling had uranium concentrations <22 µg/L, and the routine sample collected in December 2019 had a concentration of 13 µg/L.
At well 299-W20-1, the shallowest characterization sample collected during drilling had a uranium concentration of 46.7 µg/L, and the routine sample collected in December 2019 had a concentration of 32 µg/L. In addition, the uranium concentration at well 299-W19-48 decreased from 31.7 µg/L in 2018 to 20.7 µg/L in 2019. Based on these results, the 2019 plume interpretation shows the eastern plume extent as detached from the main uranium plume, and a small plume is shown farther to the east at well 299-W20-1 (Figures 11-5 and 11-6). Given that reducing conditions caused by the drilling process can suppress initial uranium concentrations measured in new wells, these wells will be sampled quarterly for at least one year. If concentrations increase, this will affect future interpretation of plume extent.

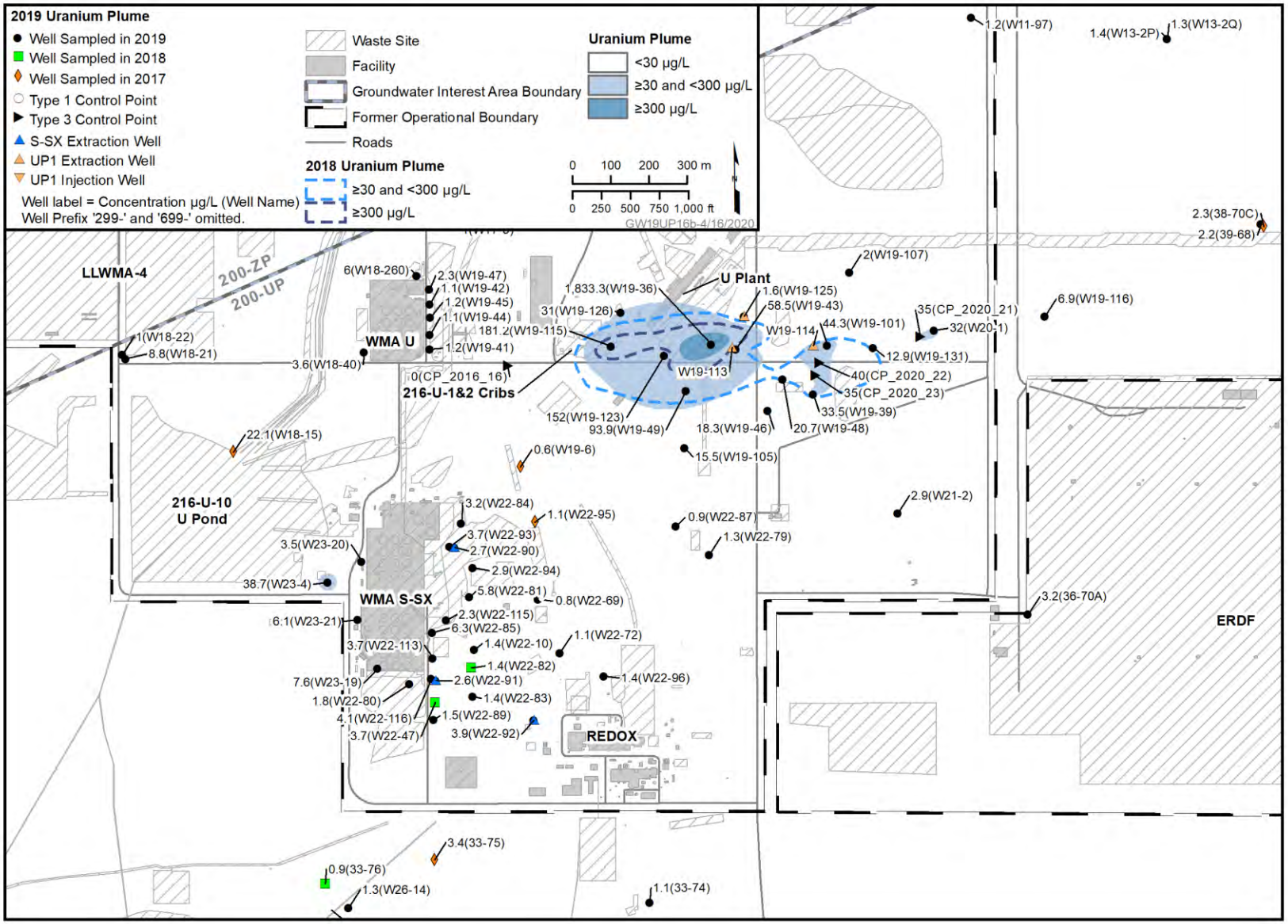


Figure 11-5. 200-UP Uranium Plume, 2019

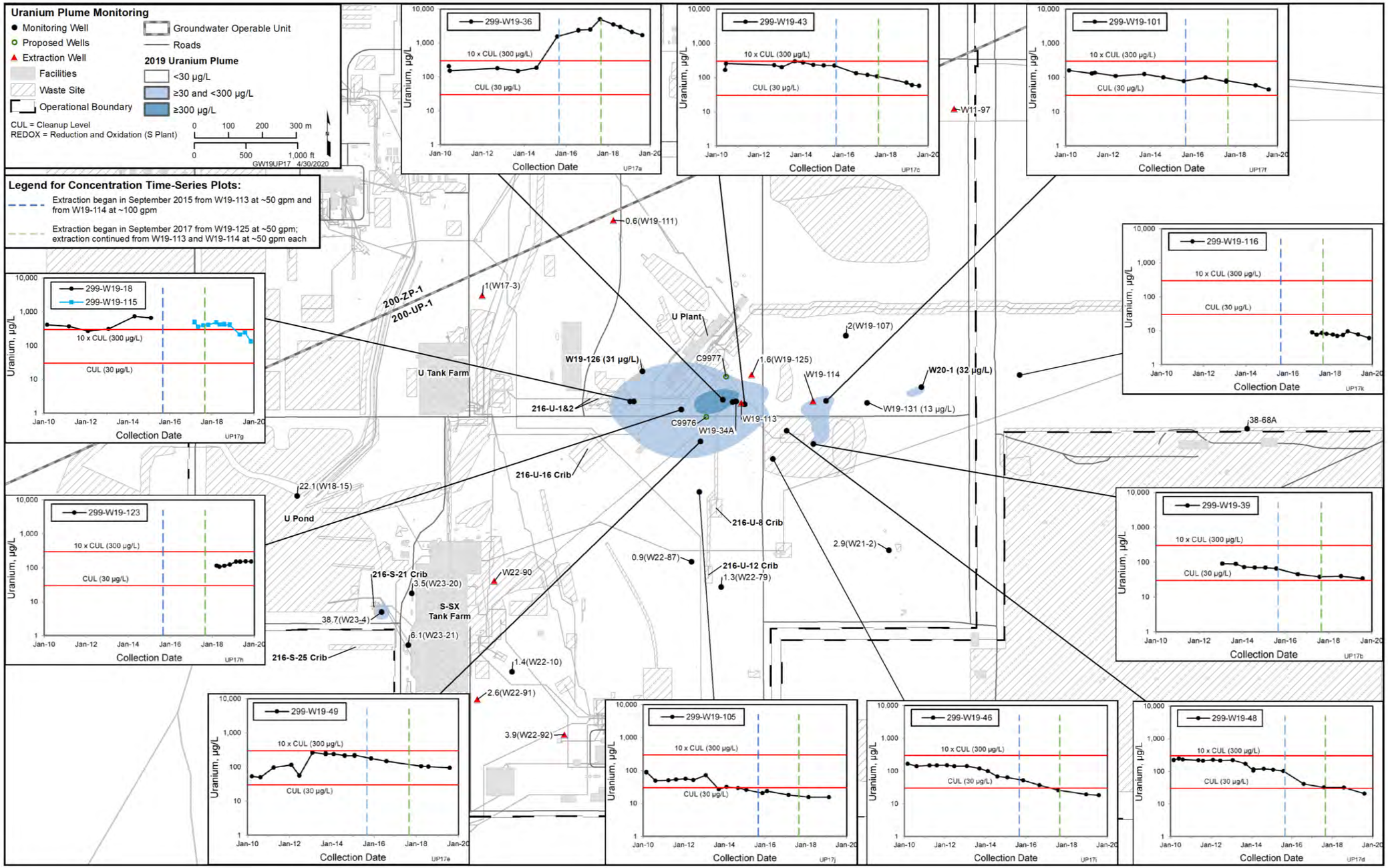


Figure 11-6. 200-UP Uranium Concentrations Near the U Plant Area Plume, 2010–2019

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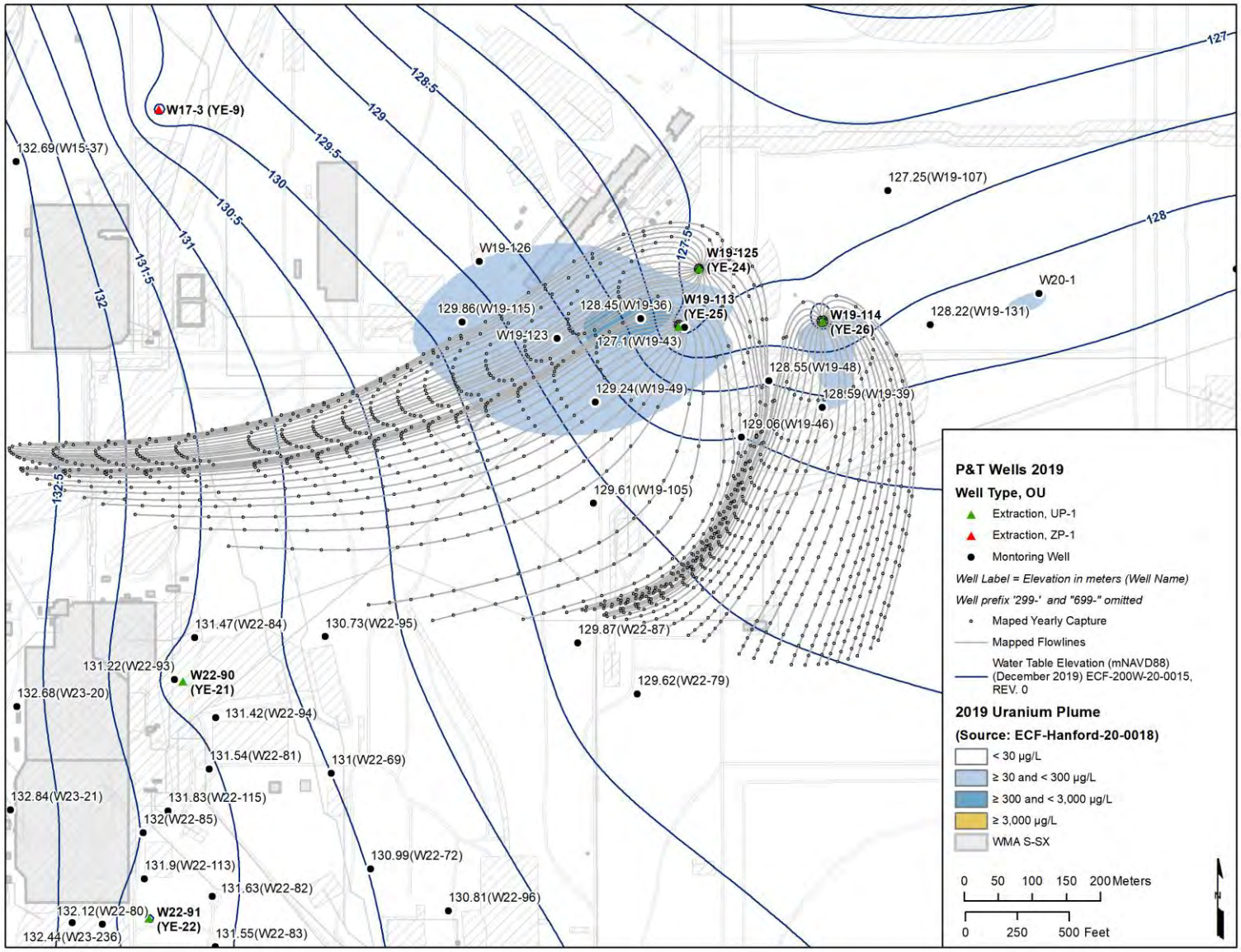

Figure 11-7. 200-UP Capture Zones for U Plant Area Extraction Wells

11.2.2 U Pond

Near U Pond (Figure 11-5), the uranium concentration continued to exceed the cleanup level in 2019 at one well (299-W23-4) with an average concentration of 37.7 µg/L. Uranium is interpreted to be leaching from the vadose zone beneath U Pond, which received an estimated 2,100 kg of uranium (Section 4.2.2 in DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*; Appendix C in RPP-26744).

11.3 Technetium-99

Within 200-UP, technetium-99 concentrations exceed the 900 pCi/L cleanup level downgradient of WMA S-SX, the 216-U-1 and 216-U-2 Cribs (near U Plant), and WMA U (Figure 11-8).

11.3.1 Waste Management Area S-SX

Within WMA S-SX, technetium-99 plumes occur downgradient of both the S and SX Tank Farms and are being remediated by extraction wells that began operating in July 2012. The plume from the SX Tank Farm is attributed primarily to a 190,000 L (51,000 gal) leak from tank SX-115 during 1965 (Section 4.3 in RPP-ENV-39658, *Hanford SX-Farm Leak Assessments Report*). As shown in Figure 11-9, technetium-99 concentrations have declined in several wells near WMA S-SX, particularly those within capture zones of the WMA S-SX extraction wells (Figure 11-10). Depth-discrete samples obtained during well installation indicate that the technetium-99 plume beneath and east of the SX Tank Farm is in the upper 20 m (66 ft) of the aquifer at concentrations above the cleanup level (Section 4.2.1 in DOE/RL-2009-122).

The highest technetium-99 concentration in 2019 was observed at well 299-W23-19, located next to tank SX-115 inside the SX Tank Farm fence. In June 2019, the concentration was 15,200 pCi/L, which was a decrease from 30,900 pCi/L in June 2018. Concentrations decreased further to 6,620 pCi/L (average of duplicate results) in December 2019 (Figure 11-11). Elevated technetium-99 concentrations also continue to be observed at well 299-W22-116, located to the east toward extraction well 299-W22-91 (Figures 11-9 and 11-10). The average 2019 concentration at well 299-W22-116 was 12,163 pCi/L. Wells 299-W23-19 and 299-W22-116 lie within the capture zone of extraction well 299-W22-91, and their elevated concentrations may indicate a continuing technetium-99 source from the SX Tank Farm. Groundwater contamination in this area is also attributed to the SX Tank Farm based on elevated concentrations of chromium and nitrate (RPP-ENV-39658) (Figures 11-11 and 11-12).

Outside the capture zones of the WMA S-SX extraction wells, technetium-99 concentrations have been increasing at wells 299-W22-96, 299-W22-115, 299-W22-10, and 299-W22-72 (Figures 11-9 and 11-10). At well 299-W22-96, the increasing technetium-99 concentrations were accompanied by increasing concentrations of co-contaminants nitrate and chromium (Figure 11-13), which are attributed to the SX Tank Farm. To the north at well 299-W22-115, the increasing technetium-99 concentrations were accompanied by increasing nitrate concentrations; however, chromium did not show a similar response (Figure 11-14). For groundwater in the vicinity of well 299-W22-115, a contaminant source other than the S or SX Tank Farms could be the 216-S-1&2 Cribs. The cribs are approximately 50 m (160 ft) southeast of well 299-W22-115, and they received about 2.6 Ci of technetium-99, 211,000 kg of nitrate, and no documented chromium (Appendix C of RPP-26744). At well 299-W22-10, located southeast of well 299-W22-115, the technetium-99 concentration first exceeded the 900 pCi/L cleanup level in 2018 at 1,700 pCi/L and was 1,660 pCi/L in 2019 (Figure 11-15). Similar to well 299-W22-115, nitrate was elevated and chromium was not. To the west at well 299-W22-72, technetium-99 concentrations remain below the cleanup level, but the increasing technetium-99 and nitrate concentrations will continue to be evaluated (Figures 11-9 and 11-16).

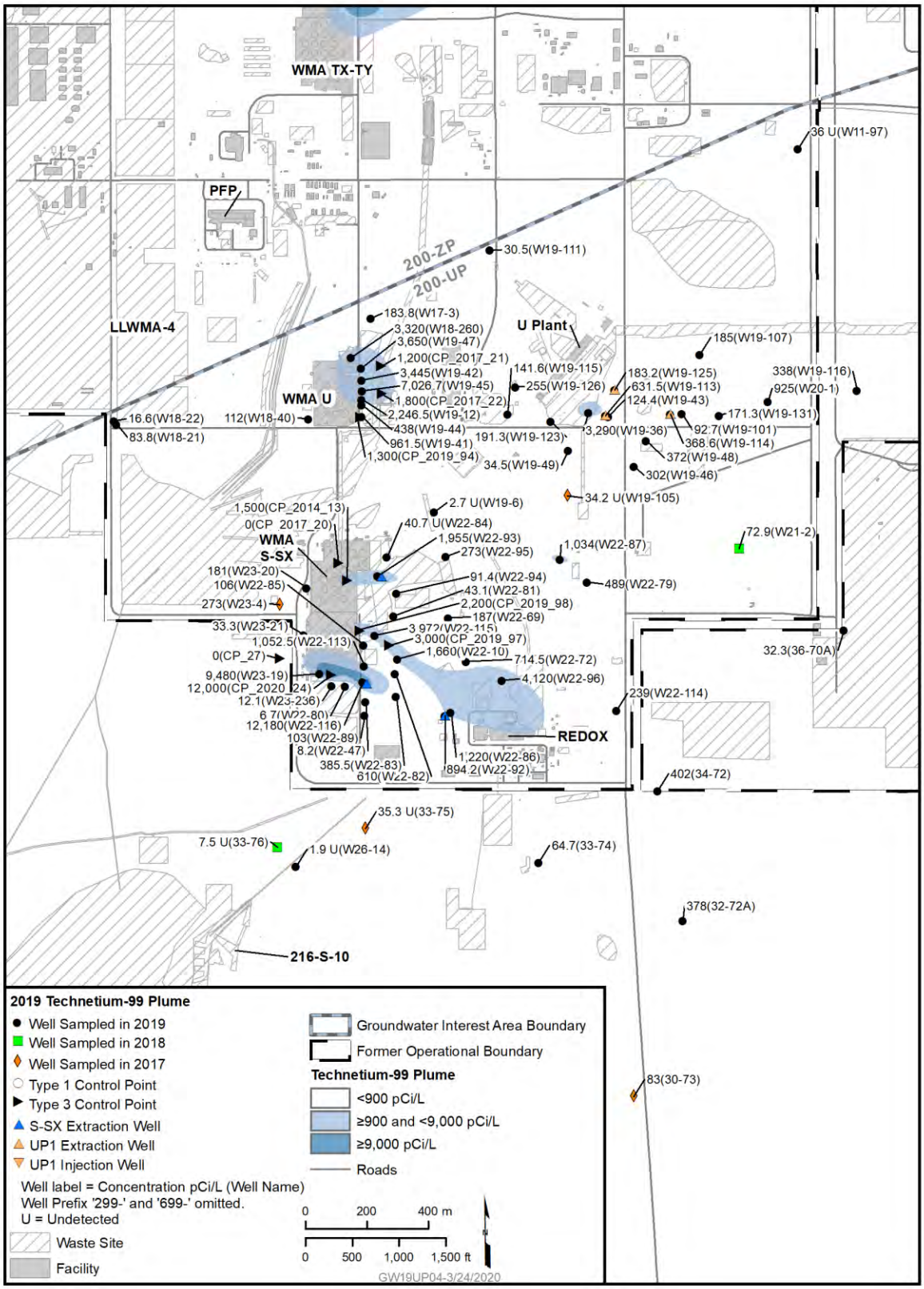

Figure 11-8. 200-UP Technetium-99 Plumes, 2019

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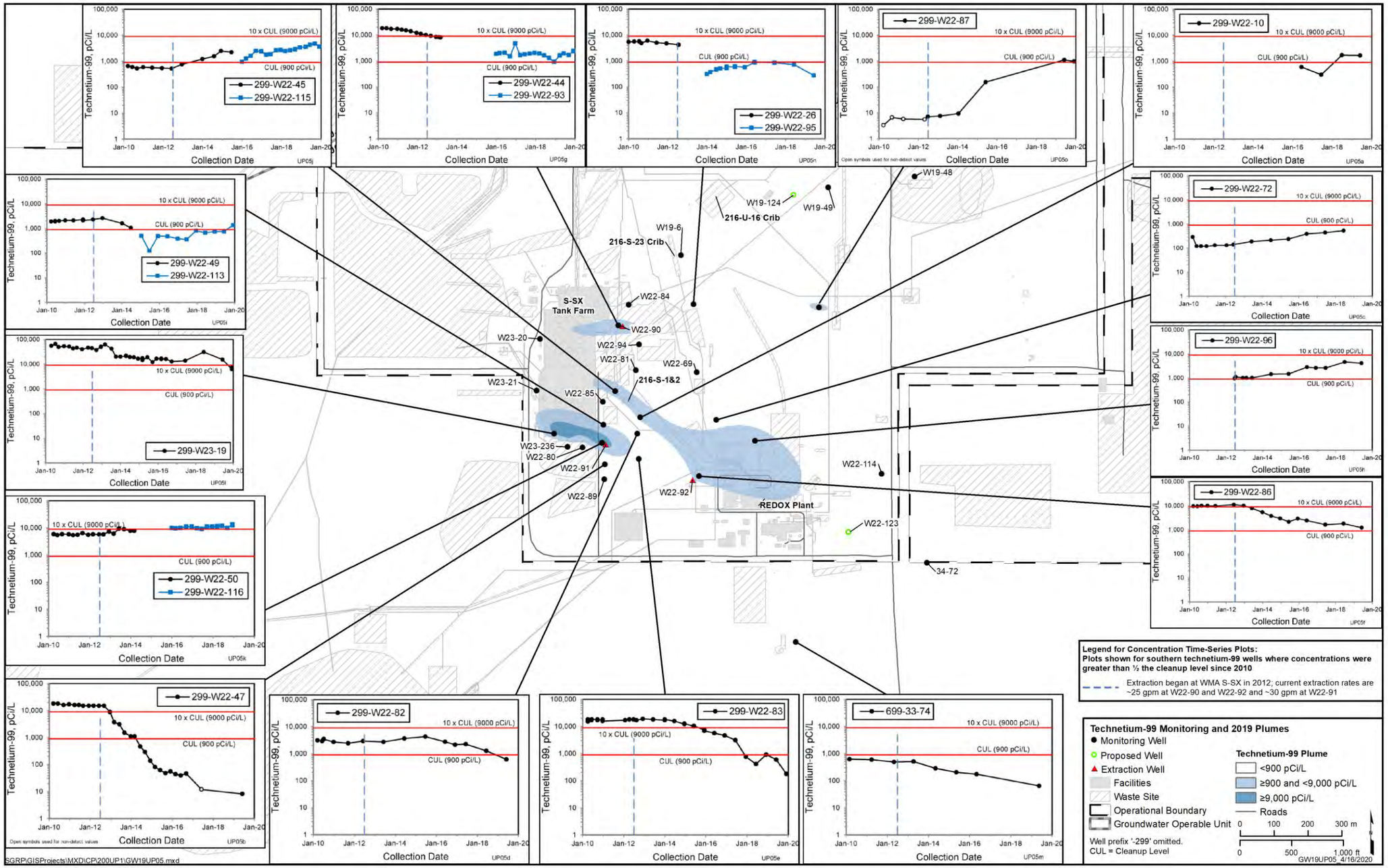

Figure 11-9. 200-UP Technetium-99 Concentrations in Selected Monitoring Wells Near WMA S-SX, 2010–2019

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Figure 11-10. 200-UP Capture Zones for WMA S-SX Extraction Wells with 2019 Technetium-99 Plumes

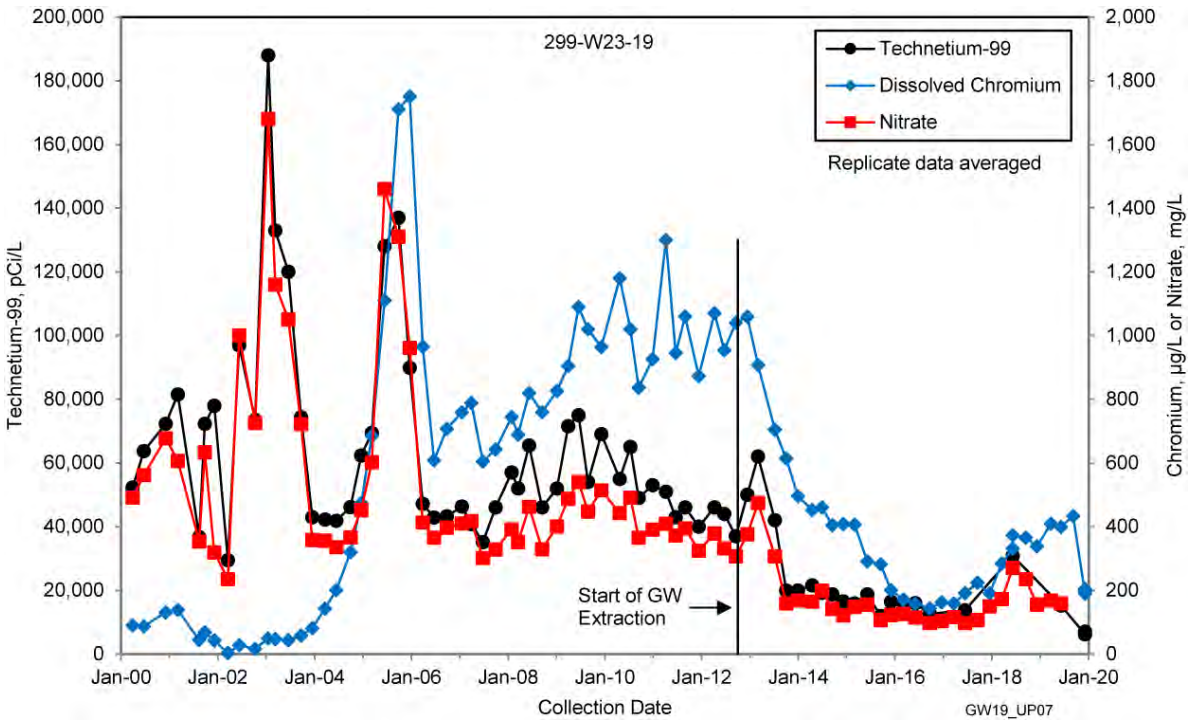

Figure 11-11. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W23-19

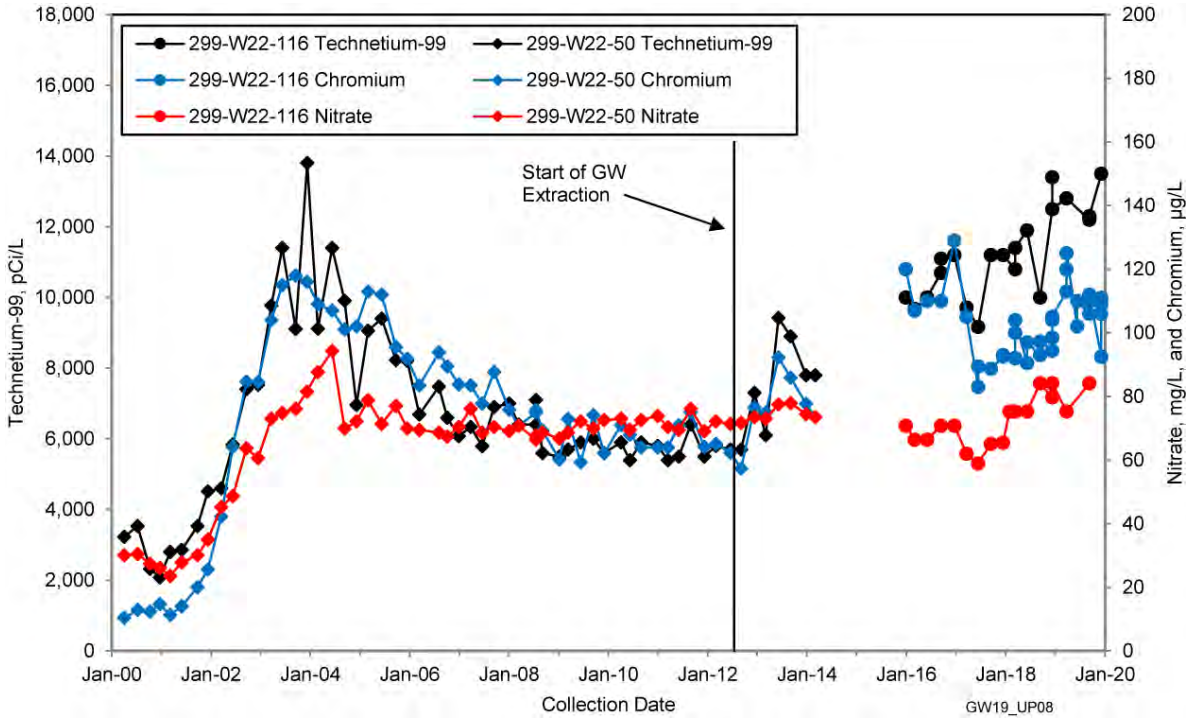

Figure 11-12. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-50 and Replacement Well 299-W22-116

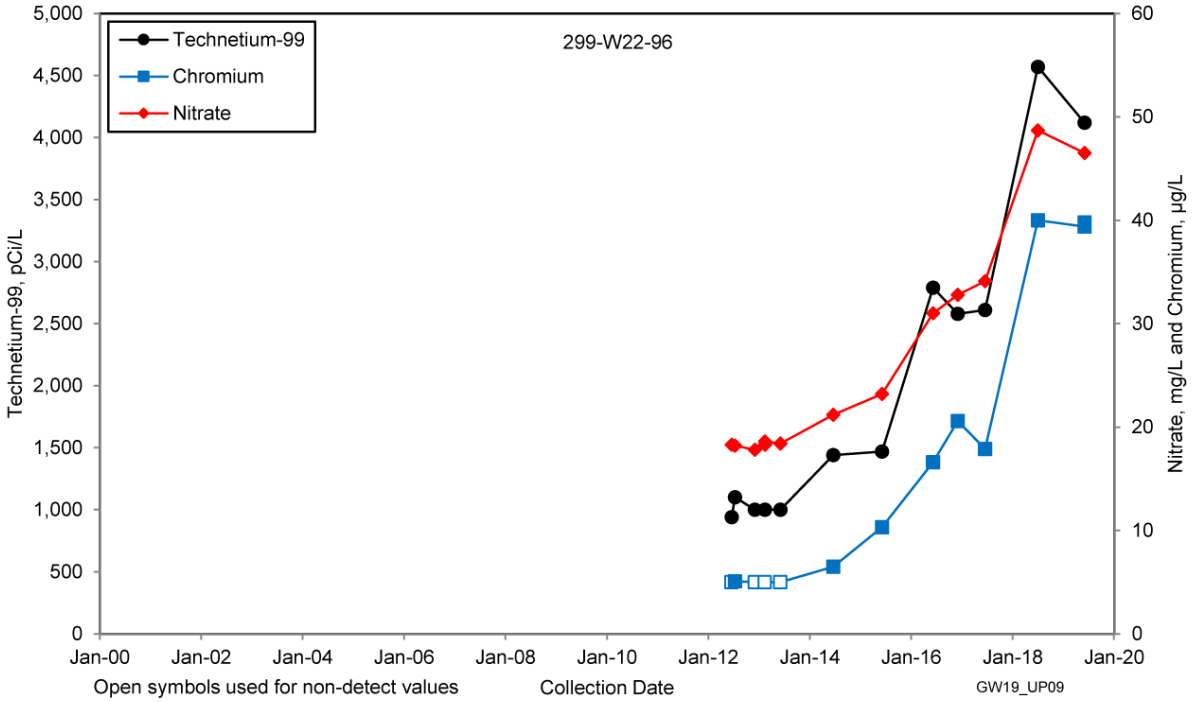

Figure 11-13. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-96

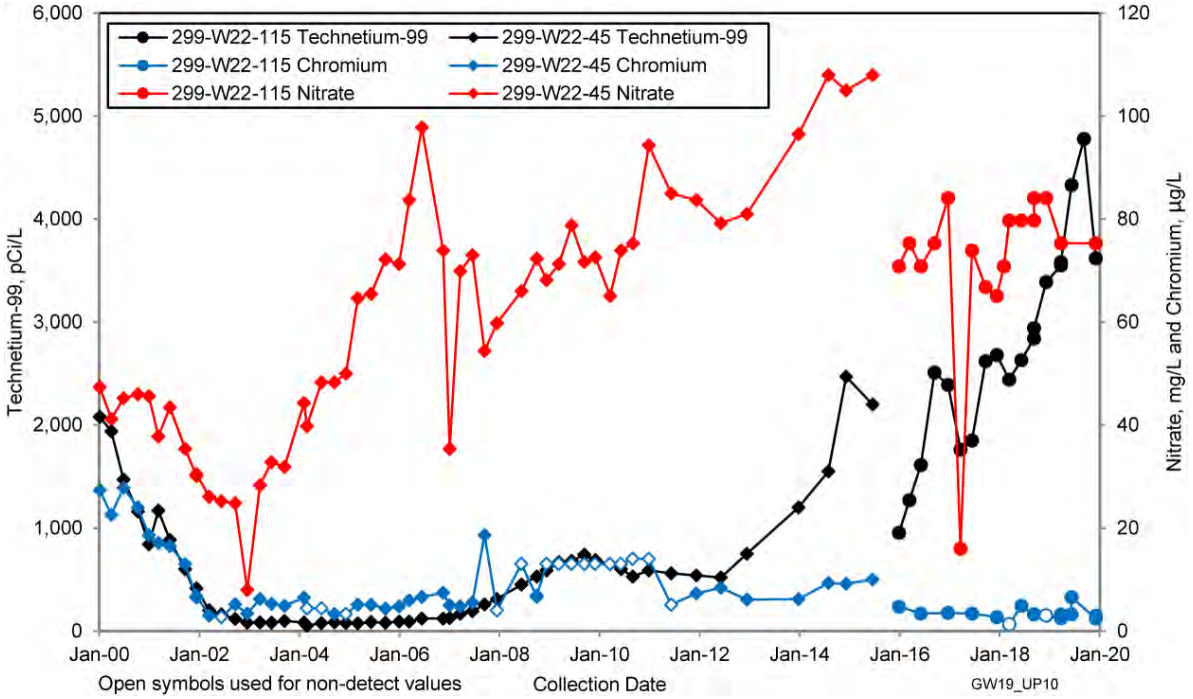

Figure 11-14. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-45 and Replacement Well 299-W22-115

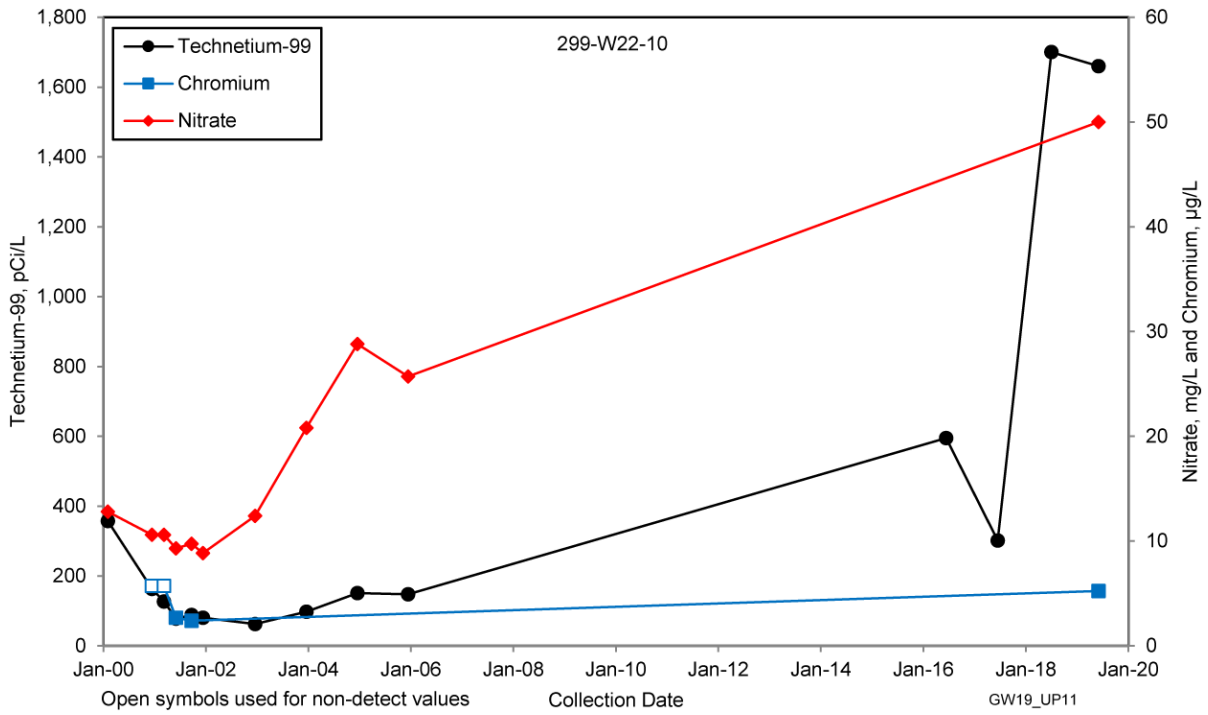

Figure 11-15. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-10

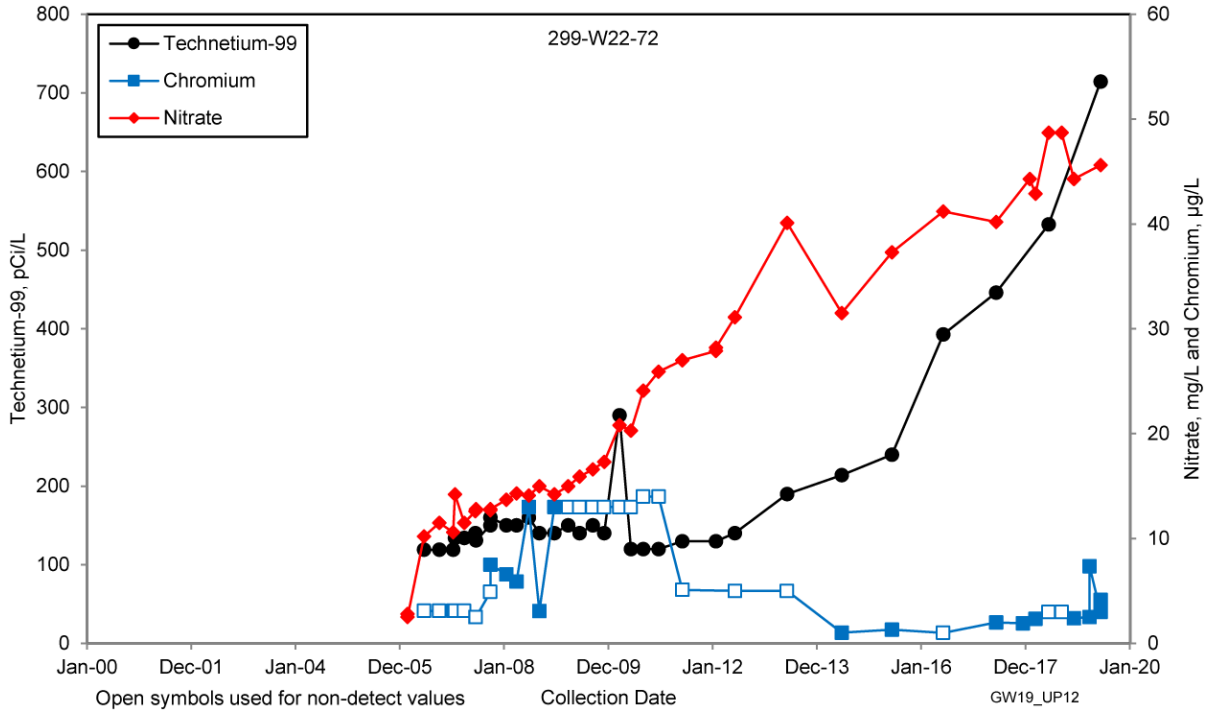

Figure 11-16. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-72

At the S Tank Farm between 1966 and 1970, an estimated 91,000 L (24,000 gal) of waste was released from tank S-104 in an overfill event. A geophysical survey conducted in 2005 indicated that technetium-99 in the vadose zone reached the groundwater (Sections 3.6, 3.7.2, and 4.6 in RPP-RPT-48589, *Hanford 241-S Farm Leak Assessment Report*) and is the source of the plume downgradient from the S Tank Farm (Figures 11-8 and 11-9). The technetium-99 plume in this area was formerly defined by wells 299-W22-44 and 299-W22-26, which are now sample dry and were replaced by wells 299-W22-93 and 299-W22-95, respectively (Figure 11-8). As shown in Figure 11-17, groundwater extraction, which began prior to installing the replacement wells, decreased technetium-99 concentrations in this area from over 9,000 pCi/L in 2012 to approximately 2,000 pCi/L in 2015 through 2017. At well 299-W22-93 (located near extraction well 299-W22-90), technetium-99 concentrations generally declined through 2018 and then increased to 2,410 pCi/L (average of duplicate results) in December 2019 (Figure 11-17). Figure 11-17 shows that the observed changes in technetium-99 concentrations have generally been associated with similar changes in nitrate and chromium concentrations.

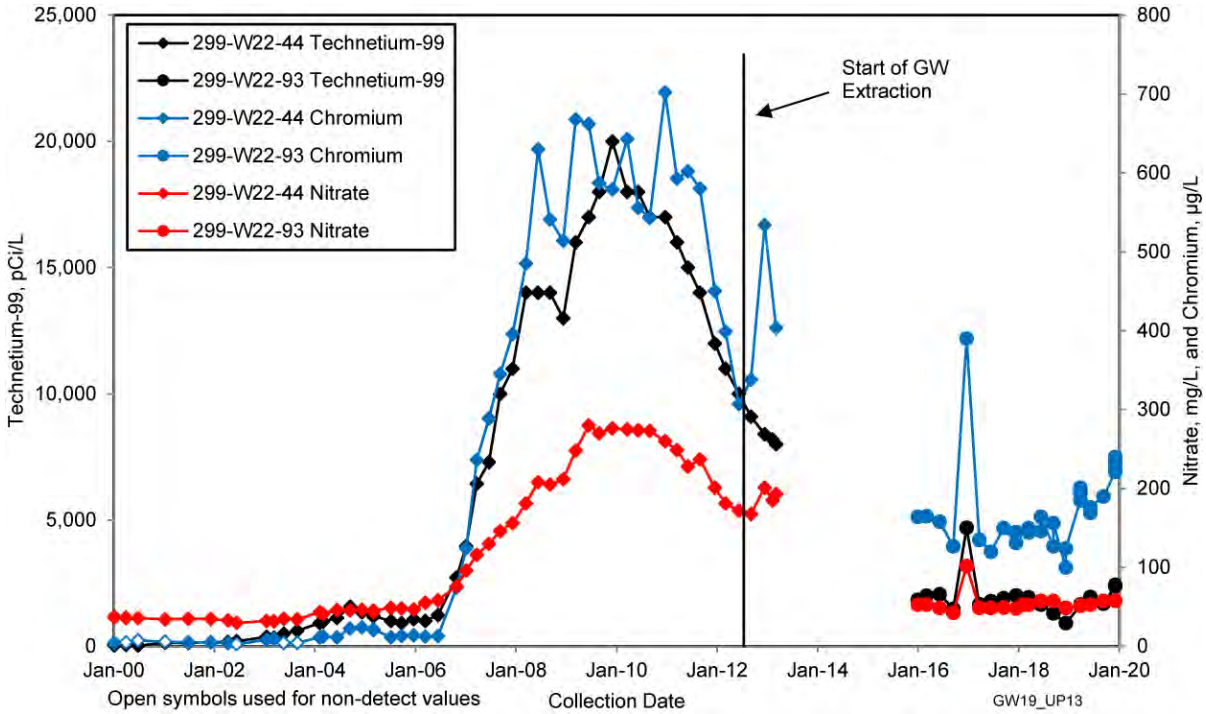

Figure 11-17. 200-UP Technetium-99, Nitrate, and Chromium Concentrations for Well 299-W22-44 and Replacement Well 299-W22-93

Extraction well 299-W22-90 was installed with the primary intent of capturing the technetium-99 plume associated with the S Tank Farm (Figure 11-10). Depth-discrete samples obtained during drilling of this extraction well indicated that the technetium-99 plume at concentrations above the cleanup level extends to a depth of approximately 10 m (33 ft) below the water table (Section 3.3 in DOE/RL-2011-118).

For the 2019 plume interpretations, a small technetium-99 plume is shown downgradient and east of the S Tank Farm (Figures 11-8 and 11-10). This plume is associated with well 299-W22-87, where technetium-99 concentrations were above the 900 pCi/L cleanup level at 1,100 pCi/L in June 2019 and 968 pCi/L in December 2019. Well 299-W22-87 had not been sampled for technetium-99 since 2015 when the concentration was 154 pCi/L (Figure 11-18). Emergence of this plume appears to be associated with previous concentration changes at upgradient well 299-W22-95, where technetium-99 concentrations

(along with chromium and nitrate concentrations) increased from 2014 through 2016 and then decreased through 2019 (Figure 11-18). It appears a contaminant plume that previously migrated past well 299-W22-93 now is present near well 299-W22-87, which is generally consistent with the modeling predictions in ECF-200W-17-0045, *Capture-Zone and Particle-Tracking Analysis for the WMA S-SX Pump and Treat System using a sub model from the 2017 Updated Central Plateau Model*.

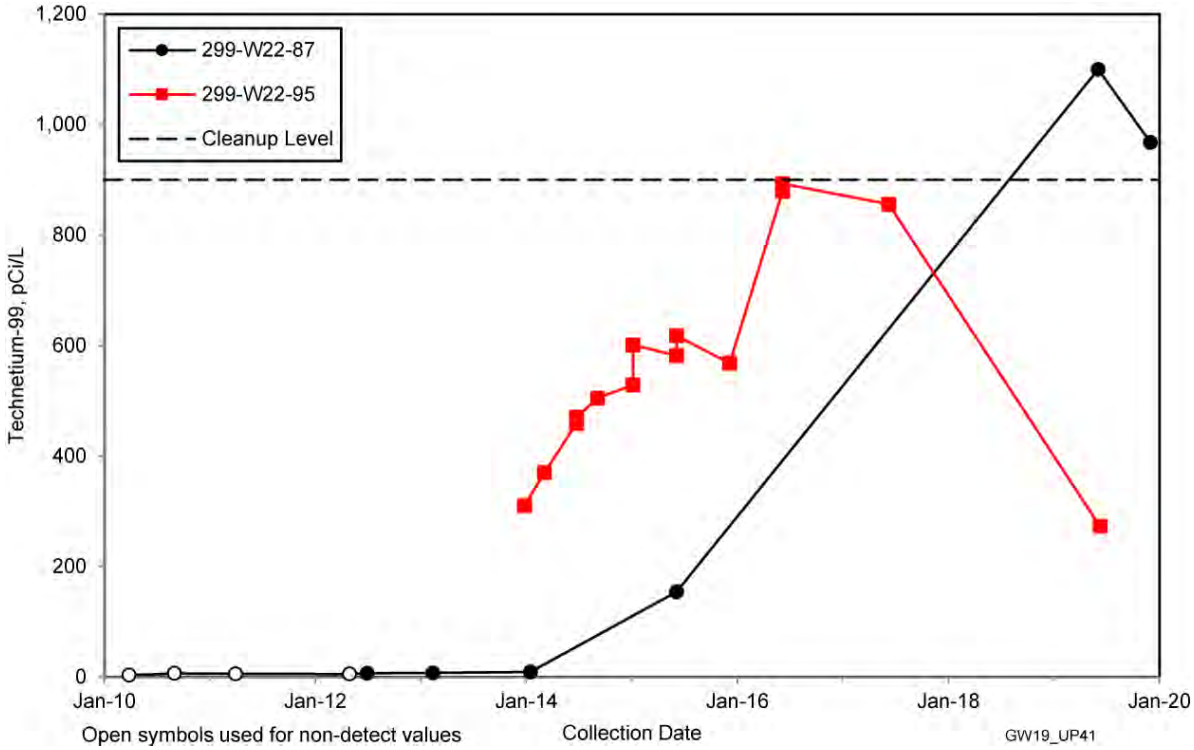

Figure 11-18. 200-UP Technetium-99 Concentrations for Well 299-W22-87 and Upgradient Well 299-W22-95

Updated fate and transport modeling for technetium-99 has been proposed for the areas discussed above where concentrations are increasing or are substantially above the cleanup level and outside extraction well capture zones.

11.3.2 216-U-1 and 216-U-2 Cribs

The technetium-99 plume near U Plant originated from the 216-U-1 and 216-U-2 Cribs, which were active in the 1950s and 1960s. The current groundwater extraction system for this area began operating in September 2015 with extraction wells 299-W19-113 and 299-W19-114; a third extraction well, 299-W19-125, began operating in September 2017 (Figure 11-19). The extraction system was designed to remediate uranium, technetium-99, and the high-concentration portion of the nitrate plume within the U Plant area (Section 11.10.3). Technetium-99 concentrations near U Plant have generally declined during operation of the current groundwater extraction system. In 2019, concentrations exceeded the 900 pCi/L cleanup level at two wells in this area: well 299-W19-36 with a concentration of 3,290 pCi/L (average of three results), and well 299-W20-1 with a concentration of 925 pCi/L (routine sample collected from this new well in 2019).

11.3.3 Waste Management Area U

WMA U (which encompasses the U Tank Farm) is also a source of technetium-99 contamination to groundwater (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*). As shown in Figure 11-19, technetium-99 concentrations exceeded the 900 pCi/L cleanup level in 2019 at all but one monitoring well downgradient of the U Tank Farm, and concentrations are increasing in the majority of these wells. For this area in 2019, well 299-W19-45 had the highest technetium-99 concentration of 7,027 pCi/L (average of three results). Groundwater contamination at WMA U is believed to result from multiple sources in the WMA (HNF-EP-0182, Rev. 297, *Waste Tank Summary Report for Month Ending December 31, 2012*). Two additional wells are planned to further delineate the technetium-99 plume downgradient of the U Tank Farm (Figure 11-19).

11.4 Chromium

Although Cr(VI) and total chromium are listed in the 200-UP-1 OU ROD (EPA et al., 2012) as separate COCs, dissolved chromium in Hanford Site groundwater is almost entirely Cr(VI) (Chapter 7 in WHC-SD-EN-TI-302; Appendix C in DOE/RL-2008-01), so filtered total chromium data effectively represent Cr(VI) concentrations. Total chromium and Cr(VI) have different cleanup levels specified in the 200-UP-1 OU ROD (100 and 48 µg/L, respectively). In this chapter, sample results for total dissolved chromium and Cr(VI) typically will be referred to simply as chromium.

In 200-UP, chromium plumes with concentrations above the Cr(VI) cleanup level are observed near WMA S-SX, downgradient of the REDOX Plant and the 216-S-20 Crib, and at the 216-S-10 and 216-S-11 Ponds (Figure 11-20). In addition, the large southeast chromium plume is present southeast of the 200 West Area and extends to the east beyond 200-UP into 200-PO (Figure 11-21).

11.4.1 Waste Management Area S-SX

The highest chromium concentrations within 200-UP are associated with a 190,000 L (51,000 gal) leak from tank SX-115 during 1965 (Section 4.3 in RPP-ENV-39658), which also released technetium-99 and nitrate to groundwater (Sections 11.3 and 11.5). The WMA S-SX groundwater extraction system has reduced chromium concentrations in nearby monitoring wells (Figure 11-22). In 2019, the highest chromium concentrations in 200-UP continued to be observed at well 299-W23-19, with an average concentration of 299.8 µg/L (Figure 11-22).

To the north, within the S Tank Farm, another chromium plume is associated with an overfill event at tank S-104 between 1966 and 1970. In this area, elevated chromium concentrations have been observed at wells 299-W22-44 (now dry) and its replacement well 299-W22-93 (Figure 11-22). The overall decline in chromium concentrations for this dry well and its replacement is also attributed to WMA S-SX groundwater extraction system operation.

11.4.2 216-S-10 Pond, 216-S-11 Pond, and 216-S-20 Crib

Near the 216-S-10 and 216-S-11 Ponds, chromium concentrations at well 299-W26-13 exceeded the Cr(VI) cleanup level since 2009, increased to near 150 µg/L through 2015, and averaged 150 µg/L in 2019 (Figures 11-20 and 11-23).

Downgradient of the 216-S-20 Crib, chromium was previously measured at concentrations near 400 µg/L at well 299-W22-20 (Figure 11-20) before this well was sample dry in 2006. Replacement well 299-W22-123 is planned for drilling to assess the current concentrations of chromium and other contaminants in this area.

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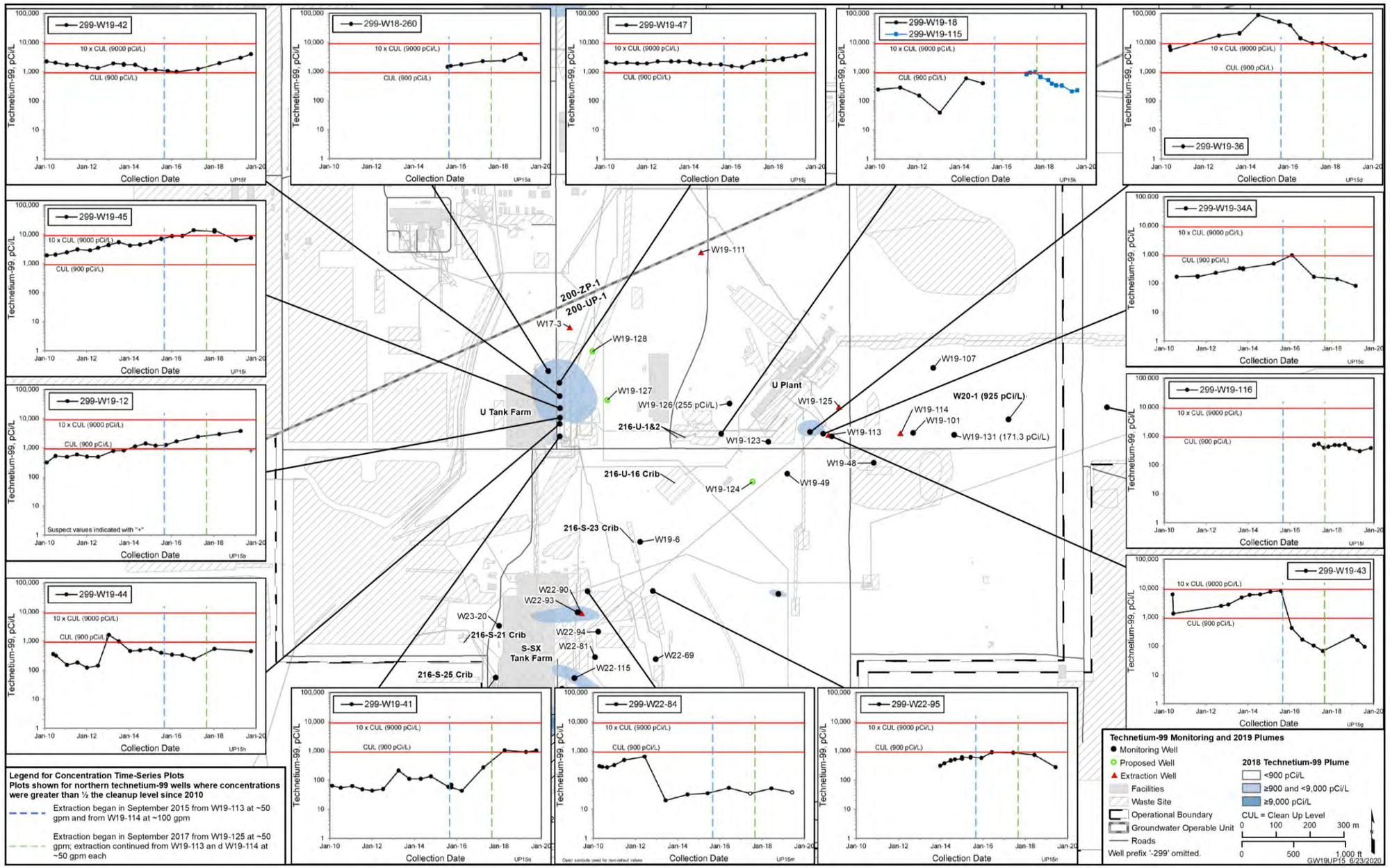

Figure 11-19. 200-UP Technetium-99 Concentrations in Selected Monitoring Wells Near the U Tank Farm and U Plant, 2010–2019

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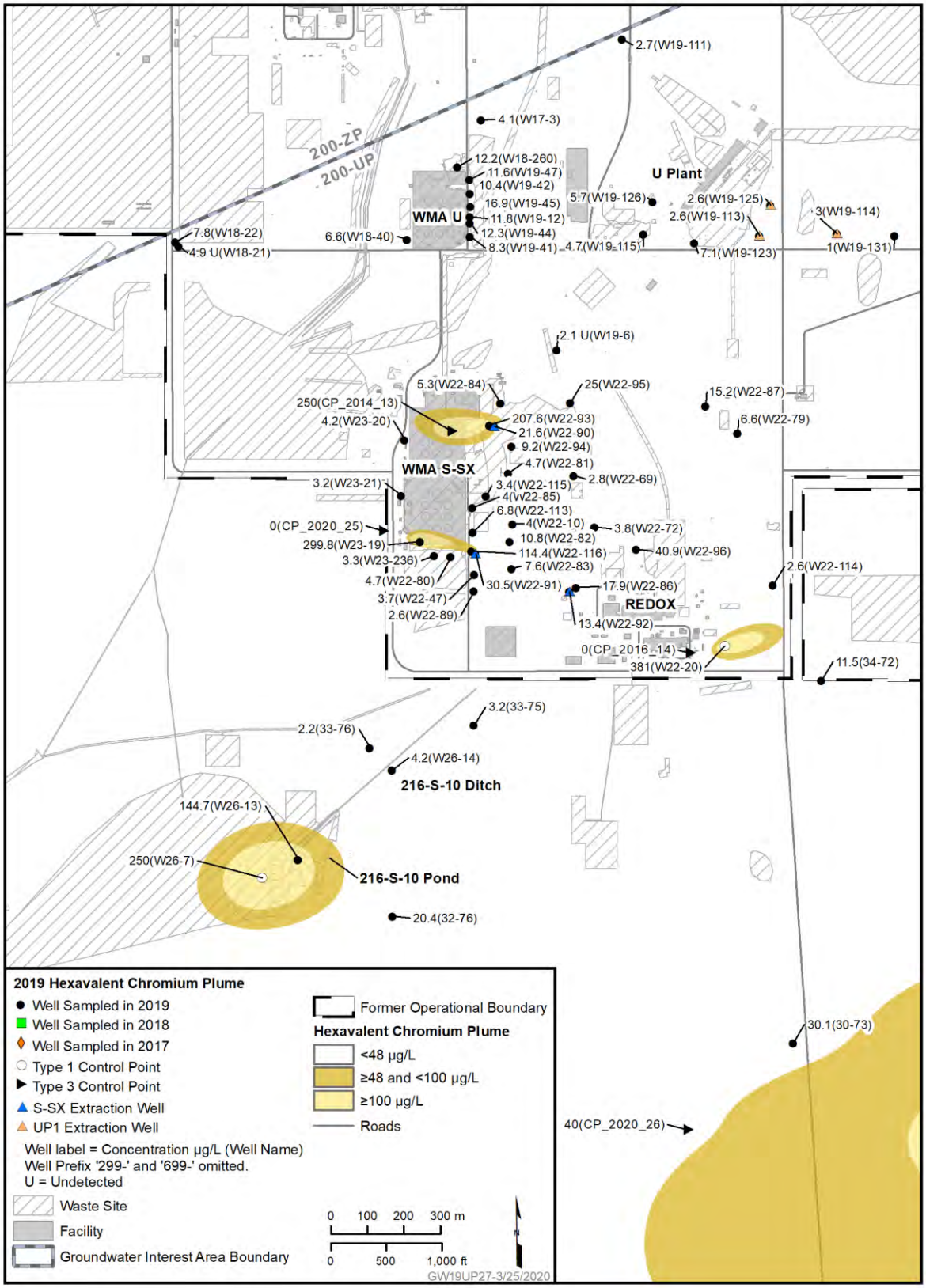


Figure 11-20. 200-UP Chromium Plumes Near WMA S-SX, REDOX Plant, and 216-S-10 Pond, 2019

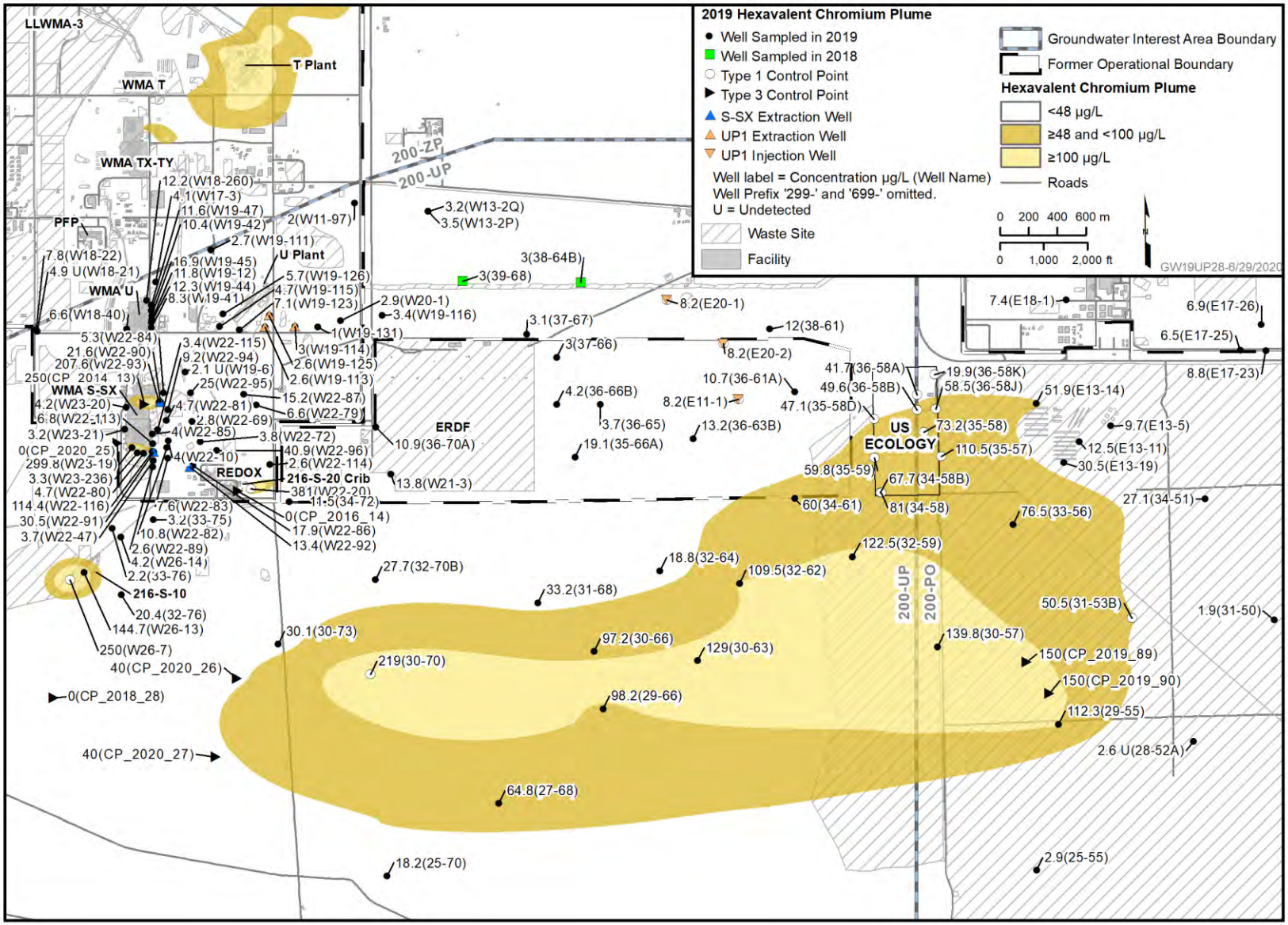


Figure 11-21. 200-UP Southeast Chromium Plume, 2019

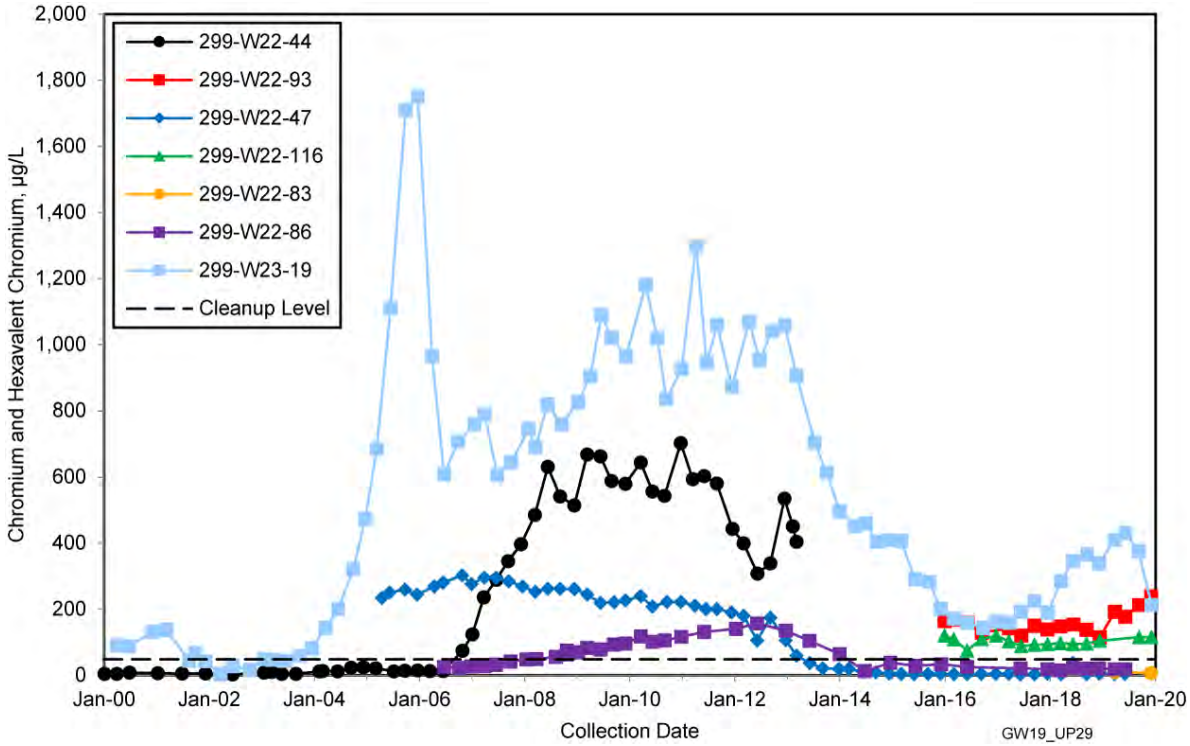


Figure 11-22. 200-UP Chromium Concentrations at Select WMA S-SX Wells

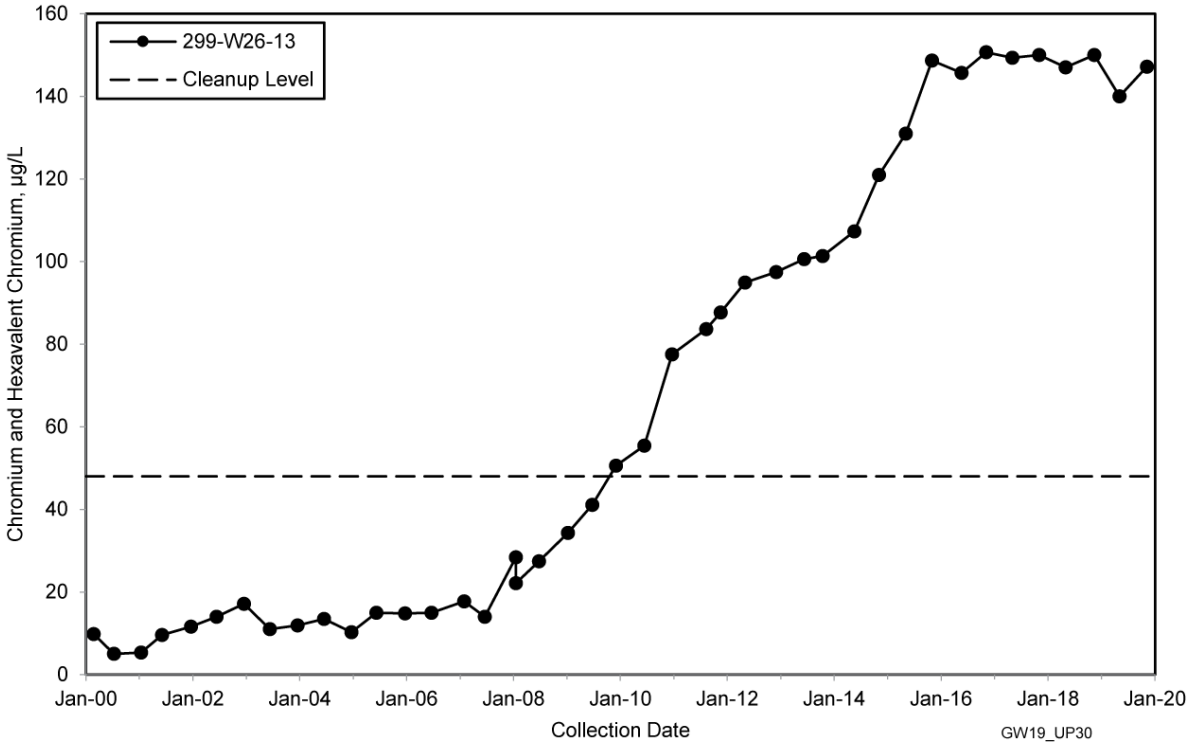


Figure 11-23. 200-UP Chromium Concentrations at Well 299-W26-13

11.4.3 Southeast Chromium Plume

The southeast chromium plume (Figure 11-21) originated primarily from effluent disposed to the 216-S-20 Crib during the 1950s, although the REDOX Plant ponds and ditches south of the 200 West Area were also sources (Section 4.2.4 in DOE/RL-2009-122). An estimated 5,900 kg of chromium were disposed to the 216-S-20 Crib, and an estimated 3,000 kg were disposed to 216-S-10 Pond and Ditch (Appendix C in RPP-26744). As shown in Figure 11-21, concentrations that currently exceed the 48 µg/L Cr(VI) cleanup level within the southeast chromium plume are detached from the source areas.

DOE/RL-2017-60, *Remedial Design Investigation Report for the 200-UP-1 Operable Unit Southeast Chromium Plume*, was issued in October 2019 to update the conceptual site model and evaluate remedial options for the southeast chromium plume.

The highest chromium concentrations generally occur within the center of the southeast chromium plume (Figure 11-21). In 2019, the highest average concentrations were 129 µg/L at well 699-30-63 and 140 µg/L at well 699-30-57, where concentrations have increased since routine sampling began in December 2016 (Figure 11-24). Chromium is also elevated at well 699-30-66 (Figure 11-24), which is completed deep in the aquifer just above the Ringold lower mud unit. These data indicate that chromium is present throughout the aquifer thickness of approximately 43 m (141 ft) in this region (see cross section in Figure 4-3 of DOE/RL-2017-60). The extent of the southeast chromium plume above the 48 µg/L Cr(VI) cleanup level in 2019 is shown somewhat farther east than in 2018 based on a concentration increase at well 699-31-53B to slightly above the cleanup level in January 2020[13] (Figure 11-21). However, in 2016 and 2017, the cleanup level was also slightly exceeded at this well (Figure 11-24).

[13] Sampling at well 699-31-53B was unsuccessful in 2019, and the January 2020 result is shown in Figures 11-21 and 11-24.

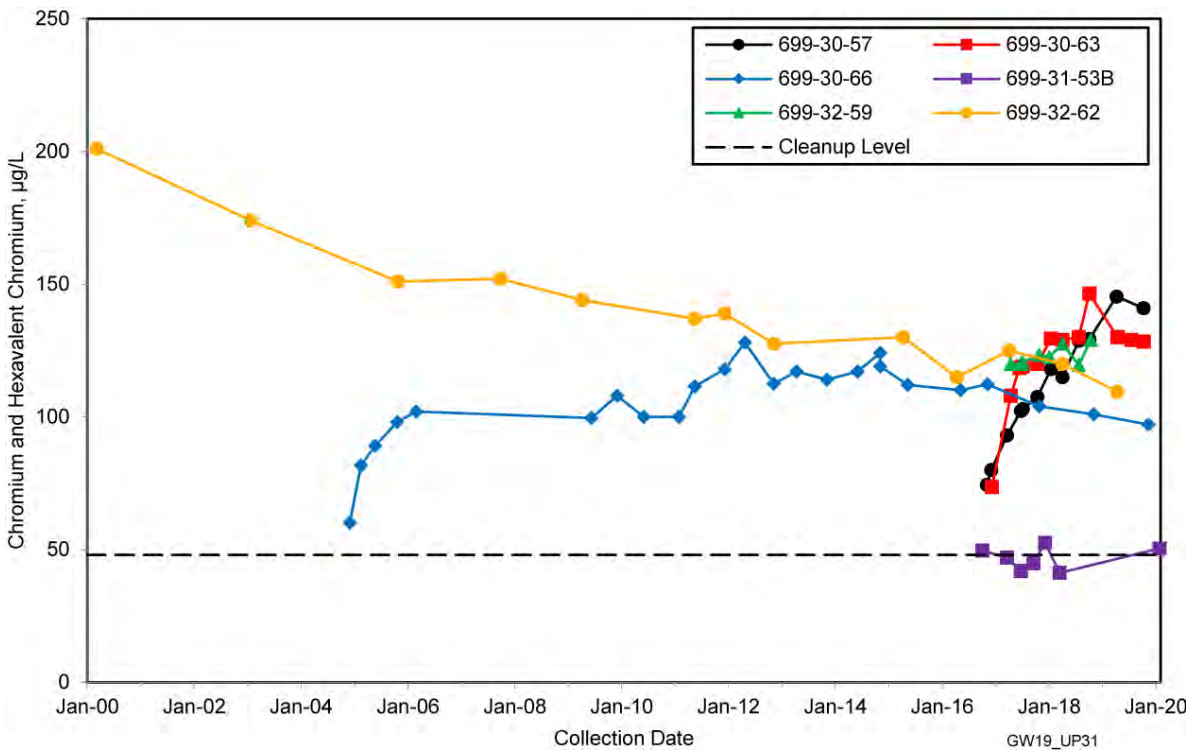


Figure 11-24. 200-UP Chromium Concentrations at Selected Southeast Chromium Plume Wells

11.5 Nitrate

Nitrate plumes in 200-UP originated from WMA S-SX, WMA U, and disposal facilities associated with the U Plant and REDOX Plant (Figure 11-25); the U Plant sources were the most substantial (Appendix C in RPP-26744). The cleanup level for nitrate is 45 mg/L.

In 2019, DOE initiated an optimization study (DOE/RL-2019-38, *200-ZP-1 Operable Unit Optimization Study Plan*) to increase the treatment capacity for carbon tetrachloride, as discussed in Section 12.2. One aspect of the optimization study involves suspending biological treatment for nitrate. Updated fate and transport modeling performed in support of the optimization study indicates that sufficient nitrate may already have been removed from the aquifer so nitrate treatment could be suspended and still meet the remedial objectives for nitrate within the timeframe stated in EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington* (hereinafter referred to as the 200-ZP-1 OU ROD). Biological treatment was suspended in October 2019, and effluent from the 200 West Area groundwater treatment facility subsequently had nitrate concentrations above the cleanup level. The effluent had an average nitrate concentration of 104 mg/L during the fourth quarter of 2019, which was an increase from 28 mg/L in 2018. For 2019, control points representing the P&T injection wells were assigned concentrations of 104 mg/L, which increased the extent of the nitrate plume eastward to injection wells 299-E20-1, 299-E20-2, and 299-E11-1 (Figure 11-25).

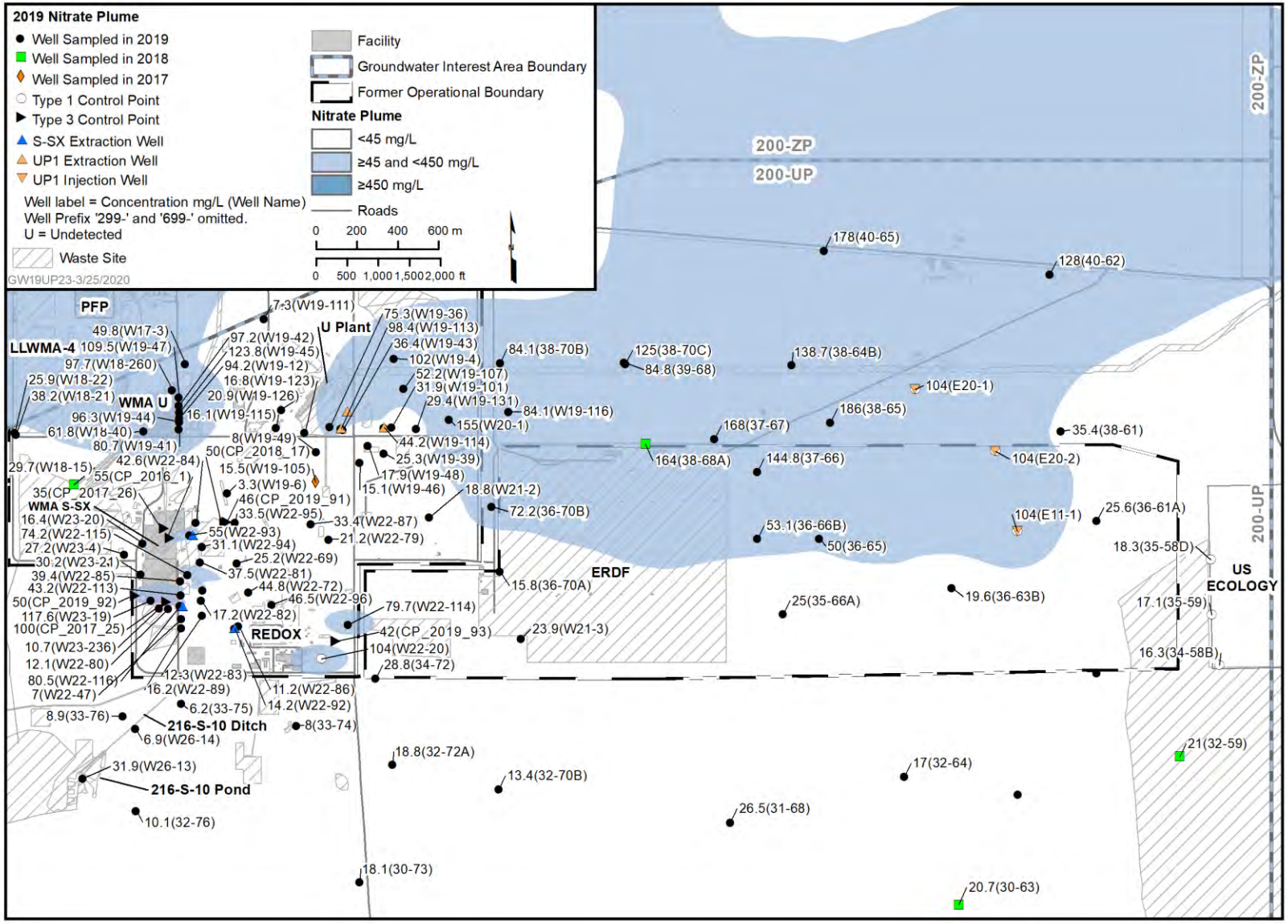


Figure 11-25. 200-UP Nitrate Plume, 2019

In 2019, the highest nitrate concentrations in 200-UP were found within the main body of the plume at wells 699-38-65, 699-40-65, and 699-37-67, and east of U Plant at new well 299-W20-1 (Figure 11-25). Within the immediate U Plant area, the highest nitrate concentrations have been observed at monitoring wells 299-W19-43 and 299-W19-36 and extraction well 299-W19-113. Following extraction at well 299-W19-113, which began in September 2015, nitrate concentrations in all three of these wells decreased by at least 90% through 2019 (Figure 11-26). The maximum 2019 concentration in the U Plant area was 91.6 mg/L at well 299-W19-113.

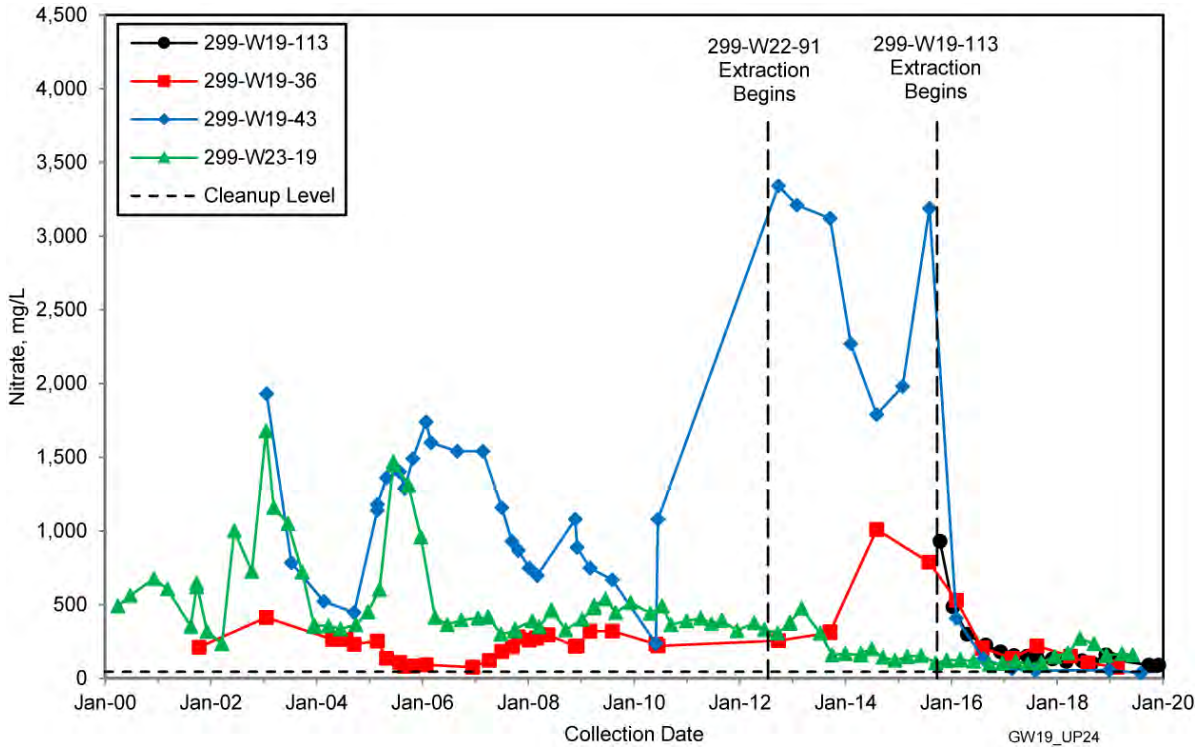


Figure 11-26. 200-UP Wells with Nitrate Concentrations >10 Times the Cleanup Level (>450 mg/L) Since 2000

For the SX Tank Farm, the highest nitrate concentrations continue to be observed at well 299-W23-19 in the SX Tank Farm, although concentrations decreased to <100 mg/L in December 2019 (Figure 11-26). As with the technetium-99 plume in this area (Section 11.3.1), the nitrate plume from the SX Tank Farm primarily formed from a 190,000 L (51,000 gal) leak from tank SX-115 during 1965 (Section 4.3 in RPP-ENV-39658). The recently reduced nitrate (and technetium-99) concentrations at well 299-W23-19 can be attributed to groundwater extraction from well 299-W22-91 that began in September 2012 (Figures 11-11 and 11-26).

Another nitrate source area for 200-UP lies within the WMA U vicinity, where 2019 nitrate concentrations exceeded the cleanup level in all nine wells (Figures 11-25 and 11-27). In this area, the primary nitrate source was water injected into wells upgradient of WMA U from the former 200-ZP-1 interim action P&T system. The injected water was treated for VOCs but still contained nitrate (Section 3.3.5 in DOE/RL-2011-118). Because concentrations at some wells downgradient of WMA U are higher than at the upgradient wells, it is likely that WMA U is also a nitrate source. In the WMA U vicinity, the maximum 2019 nitrate concentration was 136.5 mg/L at well 299-W19-45, and concentrations generally are increasing at most wells in this area (Figure 11-27).

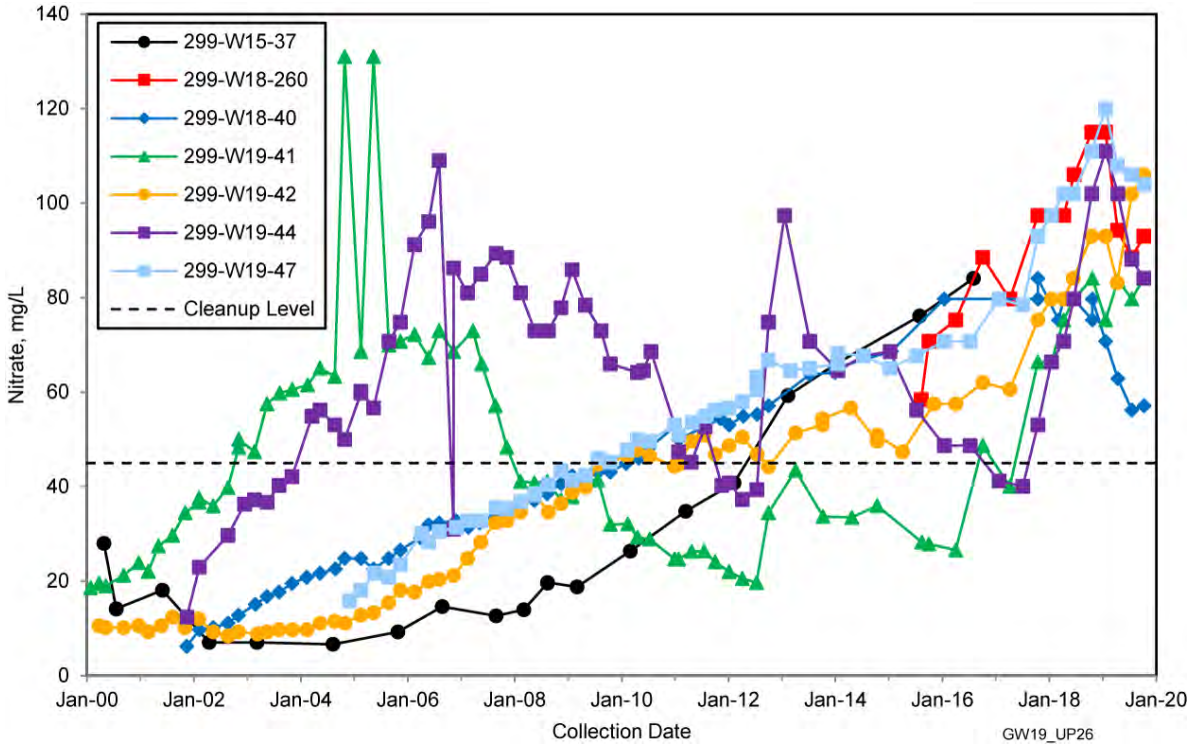


Figure 11-27. 200-UP Nitrate Concentrations at WMA U Wells

As shown in Figure 11-25, 200-UP also has five smaller nitrate plumes with concentrations above the 45 mg/L cleanup level. The wells associated with these plumes, their locations, and their maximum 2019 nitrate concentrations are as follows:

- 299-W22-93 (downgradient of the S Tank Farm): 58.0 mg/L
- 299-W22-115 (downgradient of the northern SX Tank Farm): 75.3 mg/L
- 299-W22-114 (downgradient of REDOX Plant facilities): 79.7 mg/L
- 299-W22-96 (between the SX Tank Farm and REDOX Plant facilities): 46.5 mg/L

Additionally, well 299-W22-20, which is dry and downgradient of the REDOX Plant facilities, had a nitrate concentration of 104 mg/L in 2007 and that concentration is retained as a control point on the 2019 plume map. The nitrate concentration in this area will be reassessed following installation of replacement well 299-W22-123.

11.6 Iodine-129

Iodine-129 plumes in 200-UP originated from the 216-U-1 and 216-U-2 Cribs near the U Plant and REDOX Plant waste sites; the latter were the primary sources (Figure 11-28). To the east of the 200 West Area, these plumes merge and become indistinguishable.

The main iodine-129 plume with concentrations greater than the 1 pCi/L cleanup level extends 3.5 km (2.2 mi) east from the REDOX Plant waste sites (Figure 11-28). For 200-UP in 2019, well 299-W21-3 had the highest average concentration of 21.4 pCi/L; a similar mean concentration of 20.7 pCi/L was observed in 2018.

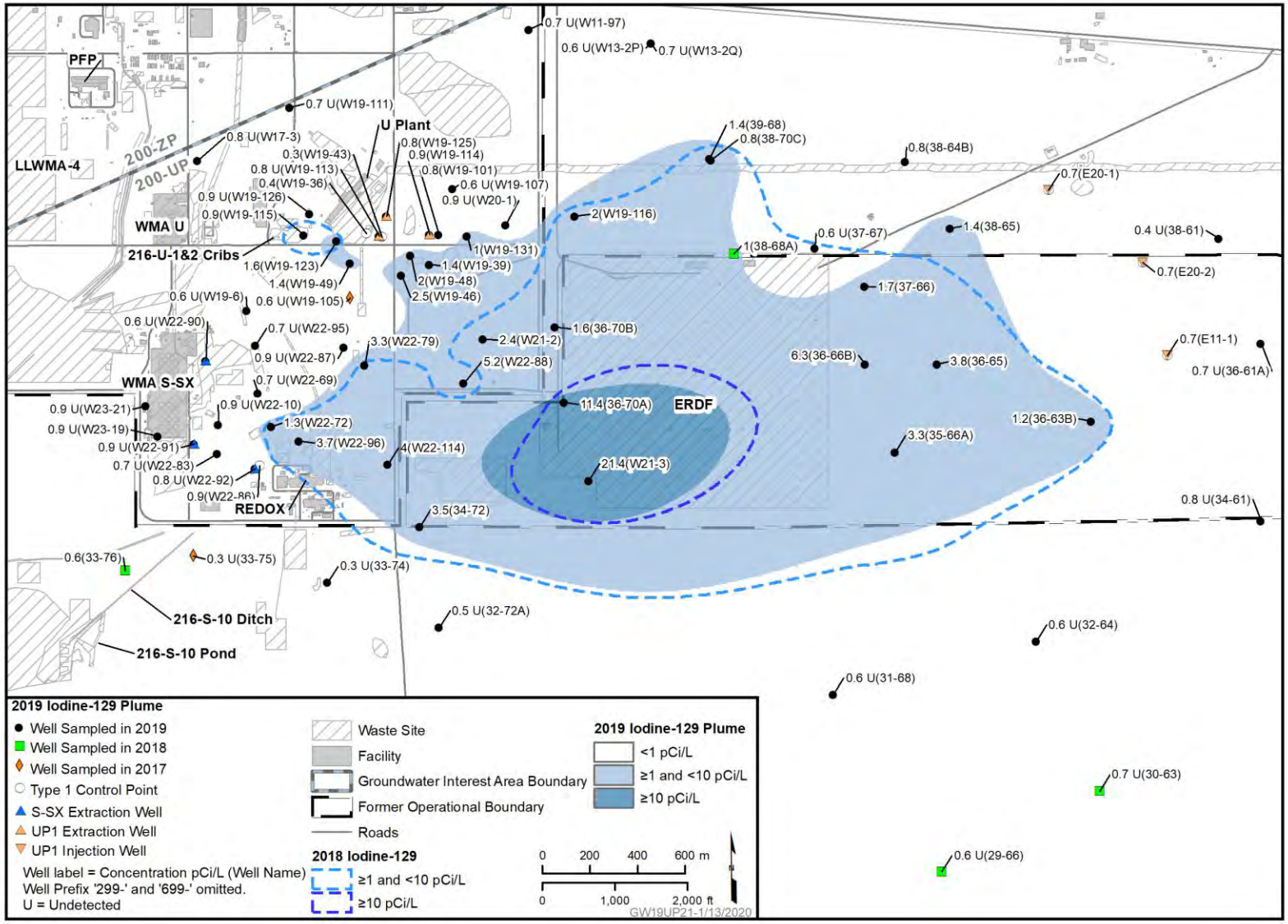


Figure 11-28. 200-UP Iodine-129 Plume, 2019

As shown in Figure 11-28, the interpreted extent of iodine-129 (where concentrations exceed the cleanup level) changed from 2018 to 2019 based on the following results:

- At well 699-38-65, the 2019 concentration was 1.45 pCi/L. This well was not sampled for iodine-129 in 2018, and iodine-129 was not detected in 2017, which resulted in an extension of the plume boundary to the northeast in 2019. However, in 2016 the mean iodine-129 concentration was 1.3 pCi/L at well 699-38-65, so the plume previously extended to this well.
- The plume also extends farther to the northwest based on increased concentrations at five wells that had not been sampled since 2015 or 2016 when concentrations were below the cleanup level. In this area, the plume extent also includes new well 299-W19-131, where the average concentration was 1.0 pCi/L.
- Another new well, 699-37-67, was drilled in 2019 northeast of ERDF, and iodine-129 was below the 0.62 pCi/L MDA in December 2019. As such, the plume extent was refined to show concentrations below the cleanup level in this area.
- Near the 216-U-1 and 216-U-2 Cribs, the iodine-129 concentrations decreased to below the cleanup level at well 299-W19-115 and increased to above the cleanup level at well 299-W19-49. As such, this smaller plume is shown to have shifted to the southeast. The assumed separation between this smaller plume and the main plume is based on low concentrations at wells to the north and south.

Interpretation of the 1 pCi/L plume boundary for iodine-129 is subject to the high analytical error relative to the 1 pCi/L cleanup level and the MDA that is typically near the cleanup level. For example, the 1.45 pCi/L result at well 699-38-65 had an analytical error of ± 0.978 pCi/L and an MDA of 0.805 pCi/L.

Among wells with iodine-129 concentrations >5 pCi/L, the concentrations have generally been stable in recent years (Figure 11-29). One exception to this is observed at well 699-36-70A located north-northwest of 299-W21-3, where concentrations are highest (Figures 11-28 and 11-29). At well 699-36-70A (where the second highest concentrations occur), the iodine-129 concentrations have generally increased since 2015.

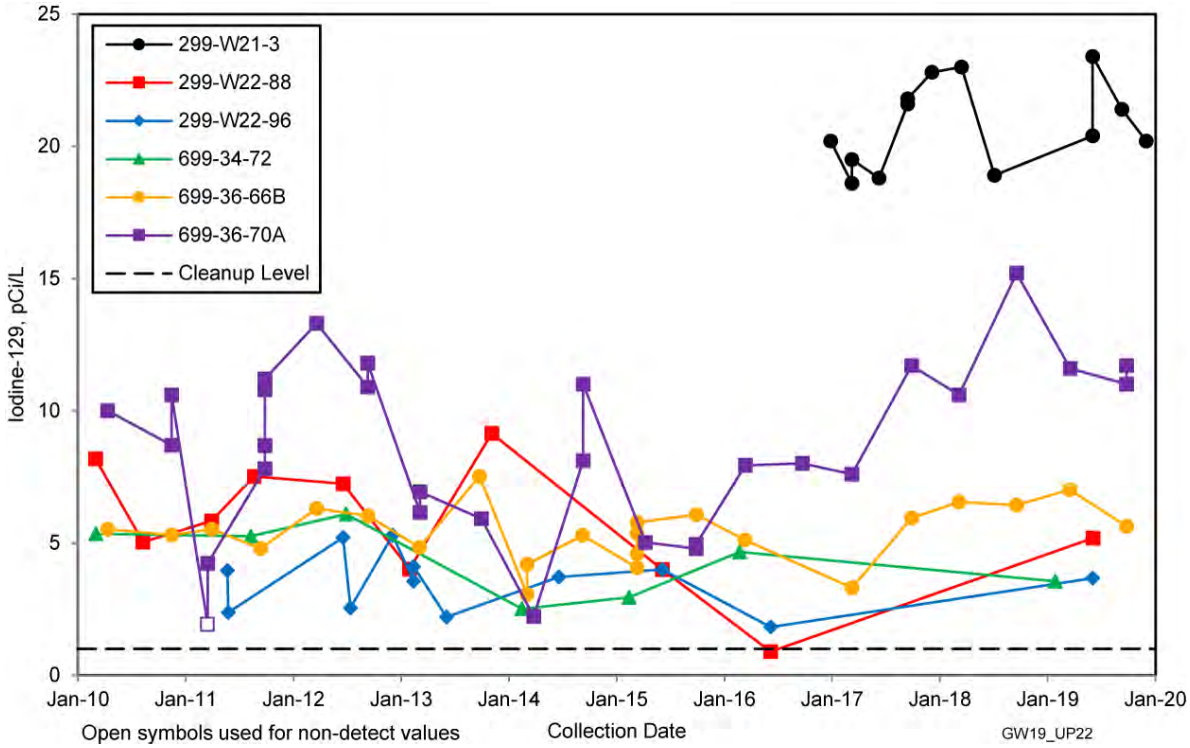


Figure 11-29. 200-UP Iodine-129 Concentrations for Wells with Recent Concentrations >4 pCi/L

11.7 Tritium

Disposal facilities associated with the REDOX Plant, which operated from 1952 until 1967, were the primary sources of tritium in 200-UP. The extent of tritium plumes in 200-UP where concentrations exceed the 20,000 pCi/L cleanup level are shown in Figure 11-30. The main tritium plume from the REDOX Plant cribs extends 4 km (2.5 mi) to the east and northeast at concentrations above the 20,000 pCi/L cleanup level (Figure 11-30). Smaller plumes are present near the 216-S-21 and 216-S-25 Cribs.

11.7.1 Main Tritium Plume

The main tritium plume is defined by 13 monitoring wells where concentrations exceeded the cleanup level in 2019 (Figure 11-30). Concentrations are decreasing at the majority of these wells, consistent with attenuation by dispersion and radiological decay, and concentrations generally are stable at the other wells. The highest tritium concentration in 2019 of 222,000 pCi/L was observed at new well 699-36-65. Previously, nearby well 699-36-66B had the highest tritium concentrations, where concentrations decreased from 350,000 pCi/L in 2012 to 193,000 pCi/L in 2019. South of the main plume at well 699-31-68, the tritium concentrations decreased from an average of 20,175 pCi/L in 2018 to 17,700 pCi/L in 2019. As such, the 2019 plume extent no longer includes well 699-31-68 (Figure 11-30).

A detached tritium plume is interpreted near well 699-38-61, which lies northeast of the main tritium plume (Figure 11-30). This interpretation takes into account the low tritium concentrations in treated water from the 200 West P&T at injection wells 299-E11-1 and 299-E20-2. Tritium concentrations at well 699-38-61 decreased from 41,200 pCi/L in 2018 to 29,100 pCi/L in 2019.

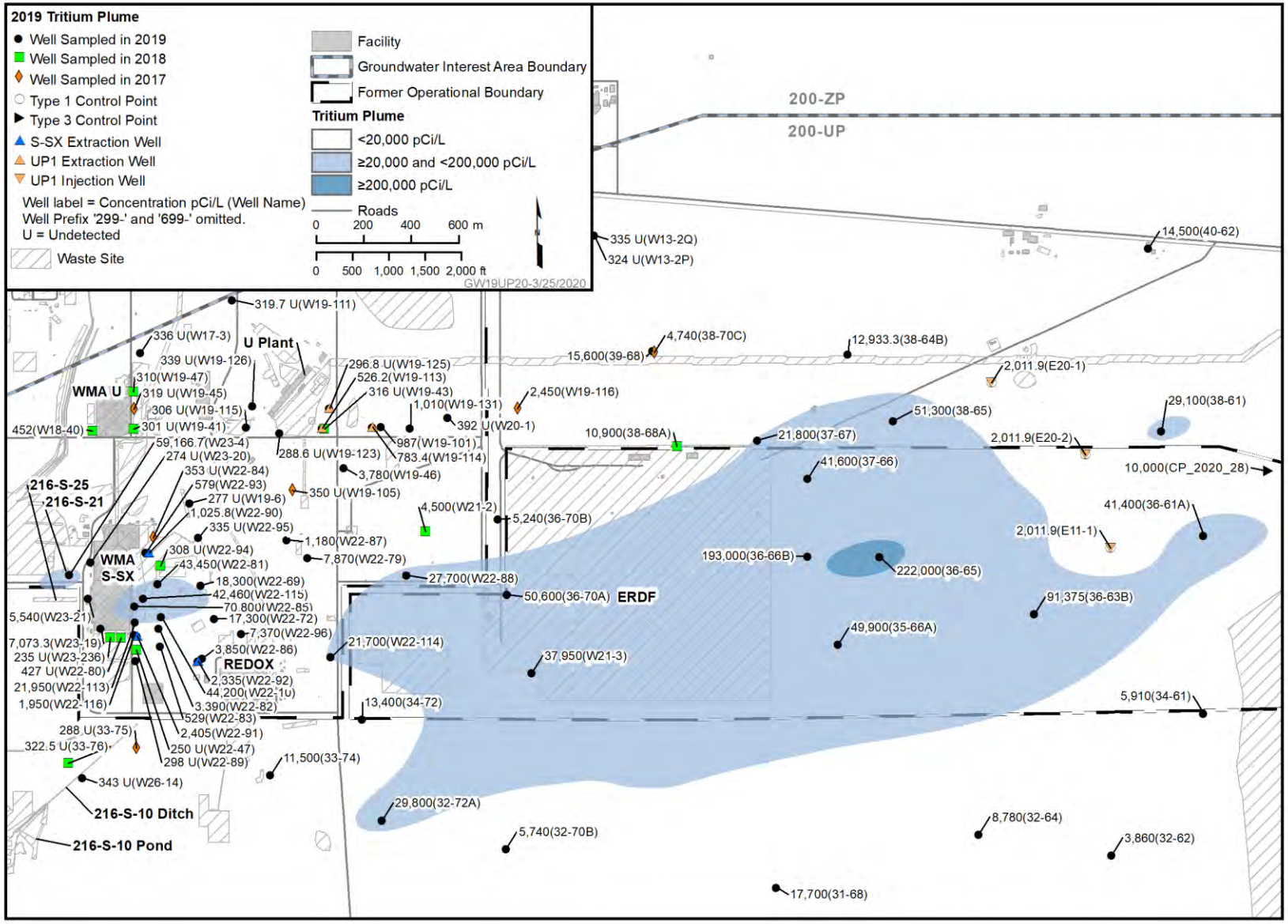


Figure 11-30. 200-UP Tritium Plume, 2019

11.7.2 216-S-21 Crib

West of WMA S-SX, a small tritium plume is located near the 216-S-21 Crib (Figure 11-30), which received an estimated 2,500 Ci of tritium between 1954 and 1969 (Appendix C in RPP-26744). The tritium concentration at nearby well 299-W23-4 increased from <1,000 pCi/L in 2001 to a mean concentration of 84,250 pCi/L in 2018 and then decreased to an average concentration of 59,167 pCi/L in 2019.

11.7.3 216-S-25 Crib

Another tritium plume is located beneath and east of the SX Tank Farm, downgradient of the 216-S-25 Crib (Figure 11-30). Tritium was discharged to the 216-S-25 Crib from 1973 through 1980, and in 1985 and the crib received an estimated 3,620 Ci of tritium (Appendix C in RPP-26744). The highest tritium concentrations within this plume are observed at well 299-W22-85, where concentrations increased <10,000 pCi/L in 2002 to 96,500 pCi/L in 2016 and then decreased to 70,800 pCi/L in 2019.

11.8 Carbon Tetrachloride

Carbon tetrachloride concentrations above the 3.4 µg/L cleanup level are widespread in 200-UP groundwater (Figure 11-31). The plume originated from PFP waste disposal sites in 200-ZP. Some of the ditches from PFP extended to U Pond, which may also have been a carbon tetrachloride source. Among the 62 wells in 200-UP that were sampled for carbon tetrachloride in 2019, 41 wells had concentrations greater than the cleanup level and 28 wells had concentrations >10 times the cleanup level. Consistent with previous results, the highest carbon tetrachloride concentration was observed at well 299-W14-71, where the 2019 concentration was 408 µg/L. This well is located north of U Plant near the 200-ZP boundary (Figure 11-31) and is screened near the base of the unconfined aquifer. Chapter 12 provides additional information regarding carbon tetrachloride in the 200 West Area.

11.9 Contaminants of Potential Concern

The 200-UP-1 OU ROD (EPA et al., 2012) also requires monitoring of final COPCs: TCE, chloroform, PCE, strontium-90, and 1,4-dioxane.

11.9.1 Trichloroethene

TCE in groundwater is found in the northern portion of 200-UP (Figure 10-24). Similar to carbon tetrachloride, depth-discrete sampling during well drilling indicated that TCE concentrations tend to increase with depth. Among 64 wells in 200-UP that were sampled for TCE in 2019, 4 wells had concentrations greater than the 5 µg/L DWS and 21 wells had concentrations greater than the 200-ZP cleanup level of 1 µg/L. In 2019, the highest TCE concentration in 200-UP was 33.1 µg/L in a characterization sample collected during drilling of new well 299-W19-131; among routine samples, the highest concentration was 11.9 µg/L at well 299-W14-71. As shown in Figure 10-24, TCE also exceeded 5 µg/L at three wells near the eastern edge of 200-UP where US Ecology, Inc. operates a commercial, low-level radioactive waste disposal facility; however, all three of these wells are located slightly east of 200-UP within 200-PO.

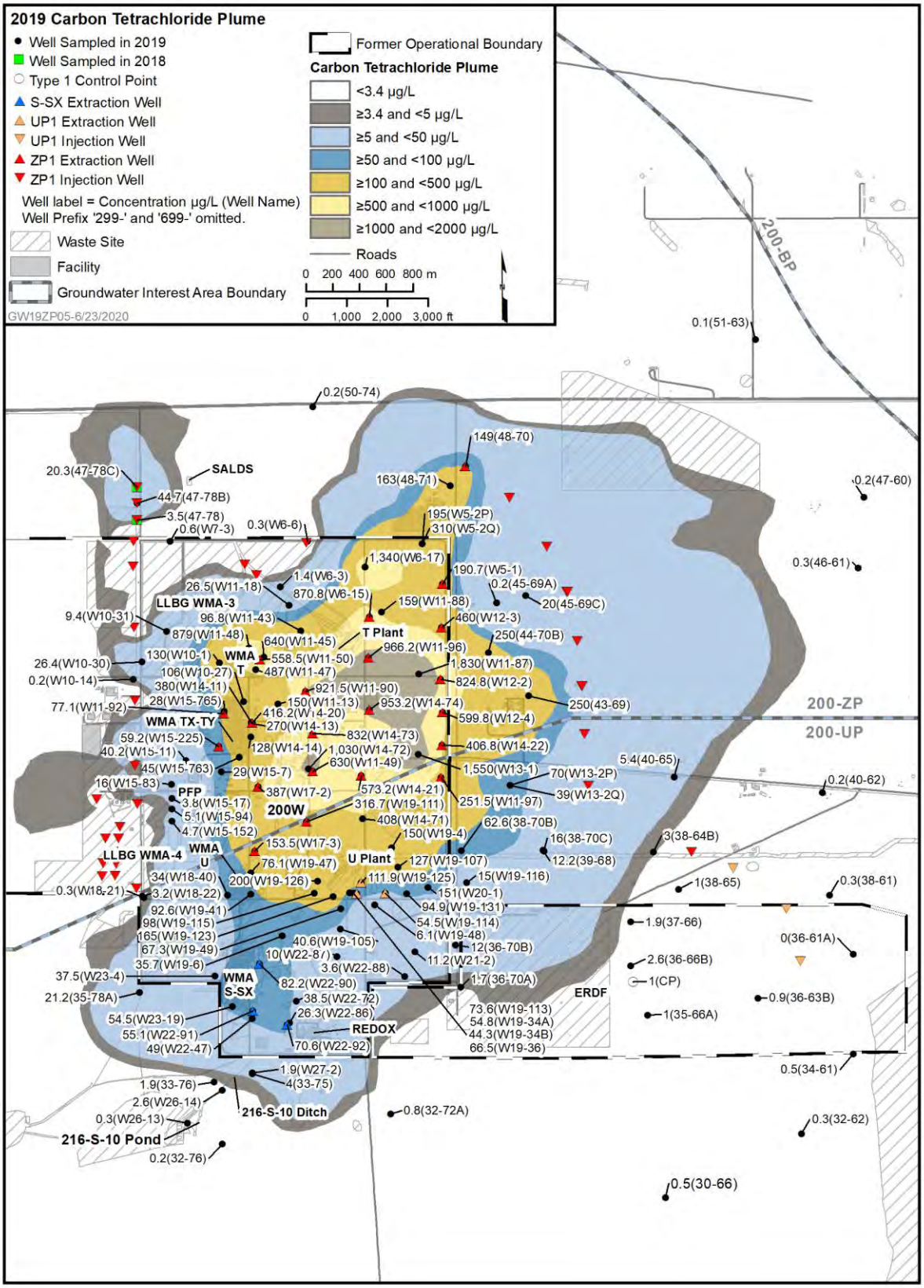


Figure 11-31. Carbon Tetrachloride Plume, 2019

11.9.2 Chloroform

Chloroform is a degradation product of carbon tetrachloride and TCE, and it tends to be found in the same wells. This suggests that natural degradation of carbon tetrachloride or TCE may be occurring, although chloroform was also introduced to the aquifer from the 2607-Z Tile Field (Section 12.2.8 in DOE/RL-2011-01). During 2019, chloroform concentrations did not exceed the DWS (80 µg/L for total trihalomethanes) in 200-UP. The maximum concentration was 21.6 µg/L in well 299-W14-71. Depth-discrete sampling during well drilling indicated that chloroform concentrations tend to increase with depth, similar to carbon tetrachloride.

11.9.3 Tetrachloroethene

PCE is detected sporadically in some 200-UP monitoring wells at concentrations below the 5 µg/L risk-based comparison level. Since 2000, the maximum detected concentrations were 3.8 µg/L at well 299-W19-107 in 2008, 3.4 µg/L at well 299-W14-71 in 2009, and 1.01 µg/L at well 699-36-70A in 2005. In 2019, PCE was detected at one well (299-W14-71 at 0.42 µg/L).

11.9.4 Strontium-90

The strontium-90 DWS of 8 pCi/L has been regularly exceeded at one well within 200-UP, 299-W22-10, where the 2019 concentration was 37.1 pCi/L. Well 299-W22-10 is located east of the SX Tank Farm and near the 216-S-1 and 216-S-2 Cribs, which received highly acidic waste from the REDOX Plant between 1952 and 1956. The waste is believed to have corroded the casing of nearby well 299-W22-3 in 1955, which allowed the effluent to bypass the soil column and flow down the well, directly to groundwater (Section 2.3.3.1 in DOE/RL-91-60, *S Plant Aggregate Area Management Study Report*).

As discussed in Section 11.9.4 of DOE/RL-2018-66, well 299-W22-93 had a strontium-90 concentration reported above the DWS at 189 pCi/L in March 2018. Given the 2017 result of <0.56 pCi/L in June 2017, four nondetect results in 2019 at <0.28 pCi/L, and one detection at 0.18 pCi/L in 2019, the reported concentration of 189 pCi/L for March 2018 is considered erroneous.

11.9.5 1,4-Dioxane

In 2019, 1,4-dioxane was detected only at well 299-W22-114, with a concentration of 2.2 µg/L. Since 2000, 1,4-dioxane has been detected in three 200-UP wells, with maximum concentrations of 160 µg/L at well 299-W22-20 in 2003, 5.8 µg/L at well 699-34-72 in 2012, and 2.1 µg/L at well 299-W22-114 in 2018. Well 299-W22-20 is now dry, but the last sample collected in 2009 had a concentration of 39 µg/L. In DOE/RL-2009-122, the action level identified for 1,4-dioxane is 4 µg/L. The 216-S-20 Crib is the likely source of the 1,4-dioxane contamination in these wells. From 1952 through 1972, the crib received waste from laboratory hoods and decontamination sinks in the 222S Building, as well as laboratory waste from the 300 Area.

11.10 CERCLA Remediation and Monitoring

During 2019, CERCLA remediation activities at 200-UP consisted of groundwater extraction and treatment for WMA S-SX and the U Plant area, hydraulic containment of the iodine-129 plume, and MNA. Groundwater monitoring results related to these remediation activities are summarized in Sections 11.2 through 11.8 for the 200-UP-1 COCs. The focus of this section is to summarize remediation activities as specified in CERCLA decision documents and plans. ERDF monitoring is also summarized as specified under a CERCLA ROD (EPA/ROD/R10-95/100, *Declaration of the Record of Decision, USDOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*).

Other activities conducted during 2019 included drilling five wells in 200-UP, as summarized in Table 11-2. Figure 11-1 shows the new well locations. Wells 299-W19-131 and 299-W20-1 were installed to address uncertainty regarding the eastern extent of the uranium plume in the U Plant area. Well 299-W19-126 was installed to assess the northern extent of the uranium plume in the U Plant area and was constructed for possible future use as an extraction well. Well 699-36-65 was installed for ERDF monitoring and to accommodate its future expansion. Well 699-37-67 was installed for ERDF monitoring and to replace a non-WAC compliant well (699-35-66A) that is going dry. The drilling, soil and groundwater sampling, logging, and construction of these wells are documented in SGW-64055, *Borehole Summary Report for the Installation of One Dual-Purpose Well and Two Monitoring Wells in the 200-UP-1 Operable Unit, FY2019*; and SGW-63813, *Borehole Summary Report for the Installation of Six M-24 Wells in the 200-PO-1, 200-UP-1 and 300-FF-5 Operable Units, FY2019*.

11.10.1 CERCLA Decision Documents and Plans

A ROD for interim remedial action for the 200-UP-1 OU was issued in September 2012 (EPA et al., 2012), an RD/RAWP was issued in September 2013 (DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*), and the performance monitoring plan was released in August 2015 (DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*, as modified by TPA-CN-0802. The selected remedy in the ROD consists of the following components:

- Groundwater extraction and treatment with MNA for all COCs (except iodine-129 and tritium)
- MNA for the entire tritium plume and parts of the nitrate and carbon tetrachloride plumes not captured by the groundwater extraction remedies
- Hydraulic containment for iodine-129 while treatment technologies are investigated
- Remedy performance monitoring
- Institutional controls

The RD/RAWP (DOE/RL-2013-07) describes implementation of the ROD and addresses the following:

- Design approach for the P&T system near U Plant, a P&T system for the chromium plume southeast of the 200 West Area, and an injection well system for hydraulic containment of the iodine-129 plume while treatment technologies are investigated
- Continued operation of the groundwater extraction system at WMA S-SX
- Modifications to the 200 West P&T in the 200-ZP groundwater interest area to accommodate the additional water and treatment needs to support the 200-UP-1 remedies

Table 11-2. Wells and Boreholes Installed in 200-UP in 2019

Well Name	Well ID	Purpose	Construction Depth (m bgs)	Construction Depth (ft bgs)	Drilled Depth (m bgs)	Drilled Depth (ft bgs)	Acceptance or Decommission Date	Comment
299-W19-126	C9604	200-UP-1 dual-purpose monitoring-extraction[a]	133.2	436.9	138.9	455.8	9/24/2019	Currently used as monitoring well
299-W19-131	C9954	200-UP-1 monitoring[b]	90.0	295.2	130.9	429.5	8/20/2019	
299-W20-1	C9955	200-UP-1 monitoring[b]	94.8	310.9	132.0	433.0	8/20/2019	
699-36-65	C9871	ERDF monitoring[c]	104.0	341.1	105.8	347.2	9/30/2019	
699-37-67	C9953	ERDF monitoring[c]	105.1	344.9	106.2	348.5	9/30/2019	

a. DOE/RL-2014-27, *Sampling and Analysis Plan for Remediation Wells in the 200-UP-1 Operable Unit*, as modified by TPA-CN-0793 and TPA-CN-0850.

b. TPA-CN-0850 for DOE/RL-2014-27.

c. SGW-62784, *FY2019 M-24-00 Well Installation Work Instruction for the Environmental Restoration Disposal Facility and 324 Building*.

bgs = below ground surface

ERDF = Environmental Restoration Disposal Facility

ID = identification

Implementation of the RD/RAWP (DOE/RL-2013-07) began in 2014, and the following activities were continued during 2019:

- Operation of the WMA S-SX groundwater extraction system (primarily for technetium-99 removal)
- Operation of the U Plant area groundwater extraction system (primarily for uranium and technetium-99 removal)
- Operation of the iodine-129 plume hydraulic containment system
- Monitoring of the southeast chromium plume area
- Iodine-129 treatment technology evaluation, conceptual model refinement, and evaluation of iodine species attenuation and transport characteristics

11.10.2 S-SX Groundwater Extraction

The WMA S-SX groundwater extraction system was primarily designed to capture the high-concentration portions of the technetium-99 plume. In 2017, the performance of the WMA S-SX groundwater extraction system was assessed, and the remedy was found to be performing as expected (ECF-200UP1-17-0094, *Fate and Transport Analysis for WMA S-SX Groundwater Plumes in the 200-UP-1 Operable Unit*). This system began operating in July 2012 using extraction wells 299-W22-90, 299-W22-91, and 299-W22-92, and extracted groundwater is pumped to the 200 West P&T. Figure 11-10 shows the locations and capture zones for the extraction wells and Table 11-3 summarizes the volume of extracted groundwater and mass of contaminants removed through 2019.

Table 11-3. 200-UP-1 Remedy Summary

Iodine-129 Plume Hydraulic Containment (2015–2019)		
Injection wells		3
Average flow rate in 2019, L/min (gal/min)		853 (225)
Monitored Natural Attenuation (2015–2019)		
Dispersion of all contaminants of concern		
Radioactive decay of tritium		
Current P&T Systems		
P&T System	**U Plant Area, 2019**	**WMA S-SX, 2019**
Design capacity, L/min (gal/min)	568 (150)	303 (80)
Extraction wells	3	3
Volume extracted, million L (million gal)	293 (77.3)	157 (41.4)
Mass of uranium removed, kg	14.9	N/A
Mass (activity) of technetium-99 removed, g (Ci)	8.2 (0.14)	16.5 (0.28)
Mass of nitrate removed, kg	19,754	3,725
Mass of carbon tetrachloride removed, kg	26.1	10.6
Mass of chromium removed, kg	1.1	3.6

Table 11-3. 200-UP-1 Remedy Summary

All 200-UP-1 P&T Systems, 1994–2019	
Mass of uranium removed, kg	968
Mass (activity) of technetium-99 removed, g (Ci)	403 (6.85)
Mass of nitrate removed, kg	225,757
Mass of carbon tetrachloride removed, kg	232
Mass of chromium removed, kg	54.9

N/A = not applicable
P&T = pump and treat
WMA = waste management area

Additional details regarding performance of the WMA S-SX groundwater extraction system are provided in the 2019 annual P&T system report (DOE/RL-2019-68).

11.10.3 U Plant Area Groundwater Extraction

The U Plant area groundwater extraction system was primarily designed to address uranium, technetium-99, and nitrate contamination near U Plant. This system consists of three extraction wells: 299-W19-113, 299-W19-114, and 299-W19-125. Extraction from wells 299-W19-113 and 299-W19-114 began in September 2015, and extraction from well 299-W19-125 began in September 2017. The locations and capture zones for these wells are shown in Figure 11-7. Table 11-3 summarizes the volume of extracted groundwater and mass of contaminants removed through 2019.

The performance of the current U Plant area groundwater extraction system was assessed in ECF-200UP1-17-0093, *Fate and Transport Analysis for U Plant Groundwater Plumes in the 200-UP-1 Operable Unit*; and ECF-200UP1-18-0018, *200-UP-1 U Plant 2017 Uranium Plume Pump and Treat System Analysis.* As described in these documents, it is not anticipated that the current system will successfully remediate the uranium plume in this area. Once the plume extent has been better characterized following evaluation of data from new monitoring wells 299-W19-131 and 299-W20-1, the extraction system will be redesigned.

Additional details regarding performance of the U Plant area groundwater extraction system are provided in the 2019 annual P&T system report (DOE/RL-2019-68).

11.10.4 Iodine-129 Plume Hydraulic Containment

The 200-UP-1 OU ROD (EPA et al., 2012) requires hydraulic containment of the iodine-129 plume while treatment technologies are evaluated. This remedy was implemented in 2015 by locating three injection wells for the 200 West P&T (299-E11-1, 299-E20-1, and 299-E20-2) on the eastern (downgradient) side of the plume (Figure 11-32). The locations and flow rates for these wells were determined by groundwater flow modeling, and the resulting design called for a minimum flow rate of 190 L/min (50 gal/min) and a maximum rate of 380 L/min (100 gal/min) per well to slow eastward plume migration. The injection wells began operating on October 28, 2015. Figure 11-32 shows the effect of the operating injection wells on the water table.

During 2019, flow rates in the injection wells met the design objective for most of the year. Each of the three injection wells operated at an average flow rate of 190 L/min (50 gal/min) or greater, thus meeting the design objective for hydraulic containment.

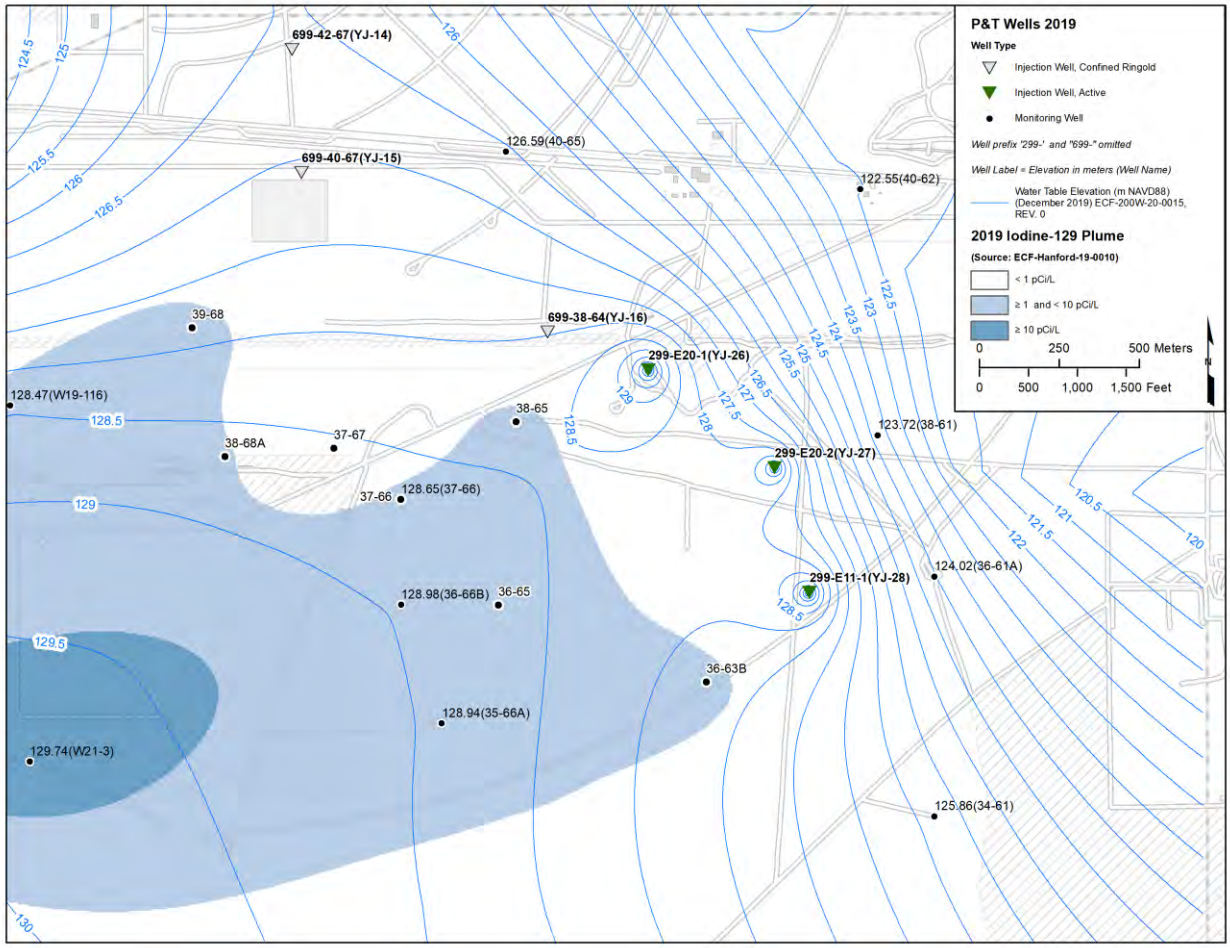


Figure 11-32. 200-UP Iodine-129 Plume Hydraulic Control Remedy Effect on Water Table

An iodine-129 treatment technology evaluation plan (DOE/RL-2015-69, *UP-1 Evaluation Plan for Iodine*) identified iodine-129 fate and transport processes and provided an overview of possible groundwater remediation options. From 2017 through 2019, PNNL evaluated potential treatment options for iodine-129 (PNNL-29148, *Assessment of Technologies for I-129 Remediation in the 200-UP-1 Operable Unit*). The conclusion of these evaluations was that none of the candidate remediation technologies for the iodine-129 plume are practicable. As such, a technical impracticability waiver will be pursued under 40 CFR 300.430(f)(l)(ii)(c).

11.10.5 Monitored Natural Attenuation

MNA is specified in the interim action ROD (EPA et al., 2012) to be used in conjunction with active remedies (or as a standalone remedy, in the case of tritium) to achieve RAOs. Two primary MNA mechanisms have been identified for the 200-UP-1 OU: dispersion for all COCs, and radiological decay for tritium. These mechanisms are supported by the fate and transport modeling performed for the FS (Chapter 9 in DOE/RL-2009-122), which indicated that the portion of the plumes not affected by the planned active remedies will disperse (or decay) naturally to below cleanup levels.

MNA is evaluated statistically by calculating the one-sided 95% UCL on the mean of the plume concentrations, as specified in Section 2.3 of the RD/RAWP (DOE/RL-2013-07). The initial set of wells used for these calculations is specified in the performance monitoring plan (Chapter 3 in DOE/RL-2015-14). Methods and results of these calculations are reported in DOE/RL-2019-68.

11.10.6 Environmental Restoration Disposal Facility Monitoring

ERDF is a low-level radioactive mixed waste facility used to dispose solid waste from remedial actions on the Hanford Site. The facility consists of 10 disposal cells, and each cell was constructed with a double-liner system to collect leachate from natural precipitation and water added as a dust suppressant. The collected leachate is sent to the 200 West P&T.

Groundwater monitoring at ERDF is regulated under a CERCLA ROD (EPA/ROD/R10-95/100), which states that groundwater monitoring will be conducted in accordance with RCRA regulations. The site was designed to meet RCRA standards, although it is not actually permitted as a RCRA facility. Detailed discussion of leachate and groundwater sampling are provided in annual summary reports (e.g., ERDF-00075, *Groundwater, Leachate, Lysimeter Monitoring and Sampling at the Environmental Restoration Disposal Facility, Calendar Year 2017*).

11.10.6.1 Leachate Monitoring

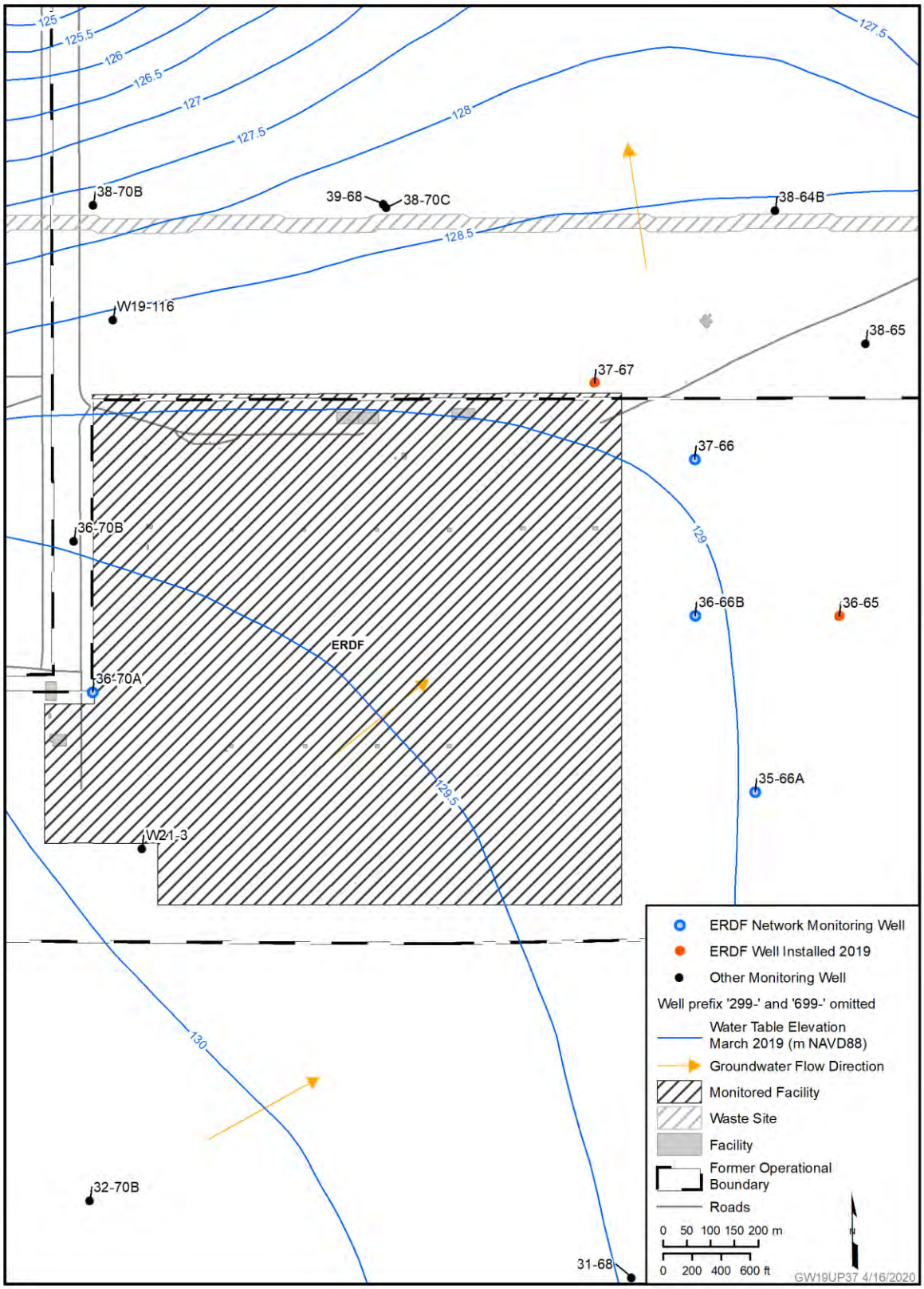
The ERDF leachate was delisted as a hazardous waste in 1999, allowing the leachate to be managed as a nonhazardous waste for transfer to the 200 West P&T for treatment, which began in 2012. Periodic sampling and analyses of ERDF leachate is performed to ensure that the leachate maintains its delisting status and meets treatment acceptance criteria, and to assess whether additional analytes should be added to the routine monitoring program. Details of the sampling and analysis program for the leachate are provided in WCH-173, *Environmental Restoration Disposal Facility Leachate Sampling and Analysis Plan*. Results of leachate sampling during 2019 indicated that no analytes need to be added to the groundwater monitoring program.

11.10.6.2 Groundwater Sampling

Groundwater monitoring at ERDF is performed in accordance with CP-60092, *Groundwater Protection Plan for the Environmental Restoration Disposal Facility, formerly WCH-198 Rev. 1*. The groundwater flow direction is toward the east-northeast (Figure 11-33). One upgradient well (699-36-70A) and three downgradient wells (699-37-66, 699-36-66B, and 699-35-66A) are sampled semiannually and were sampled in March and September 2019. To detect potential impacts to groundwater quality, sample results are compared to baseline conditions established when monitoring began in 1996 using a tolerance interval approach (Appendix B in CP-60092). All monitoring wells were sampled successfully during 2019.

As discussed in Section 11.10 and shown in Figure 11-33, two additional ERDF wells were installed in 2019: well 699-36-65 to accommodate future ERDF expansion, and well 699-37-67 to replace a non-WAC compliant well 699-35-66A, which is going dry. In 2020, these new wells will be added to groundwater monitoring program for ERDF.

The results of ERDF groundwater monitoring continue to indicate that the facility has not affected groundwater quality. Several constituents (tritium, iodine-129, nitrate, and carbon tetrachloride) are present in groundwater near or above the 200-UP-1 OU cleanup levels, but these constituents are elevated in both upgradient and downgradient wells. The plumes originated in the 200 West Area and have migrated toward and beneath ERDF.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-33. 200-UP ERDF Monitoring Well Locations and Groundwater Gradients

11.11 RCRA Monitoring

DOE/RL-2019-65 presents the results of RCRA monitoring for the Hanford Site in 2019. The following sections describe the results of monitoring in accordance with RCRA regulations at three individual WMAs within 200-UP: WMA S-SX, WMA U, and the 216-S-10 Pond and Ditch. Interim status groundwater quality assessment monitoring is conducted at WMA S-SX and WMA U (40 CFR 265.93(d), as referenced by WAC 173-303-400). Interim status detection monitoring for indicator parameter evaluation is conducted at the 216-S-10 Pond and Ditch (40 CFR 265.92 and 40 CFR 265.93(b), as referenced by WAC 173-303-400).

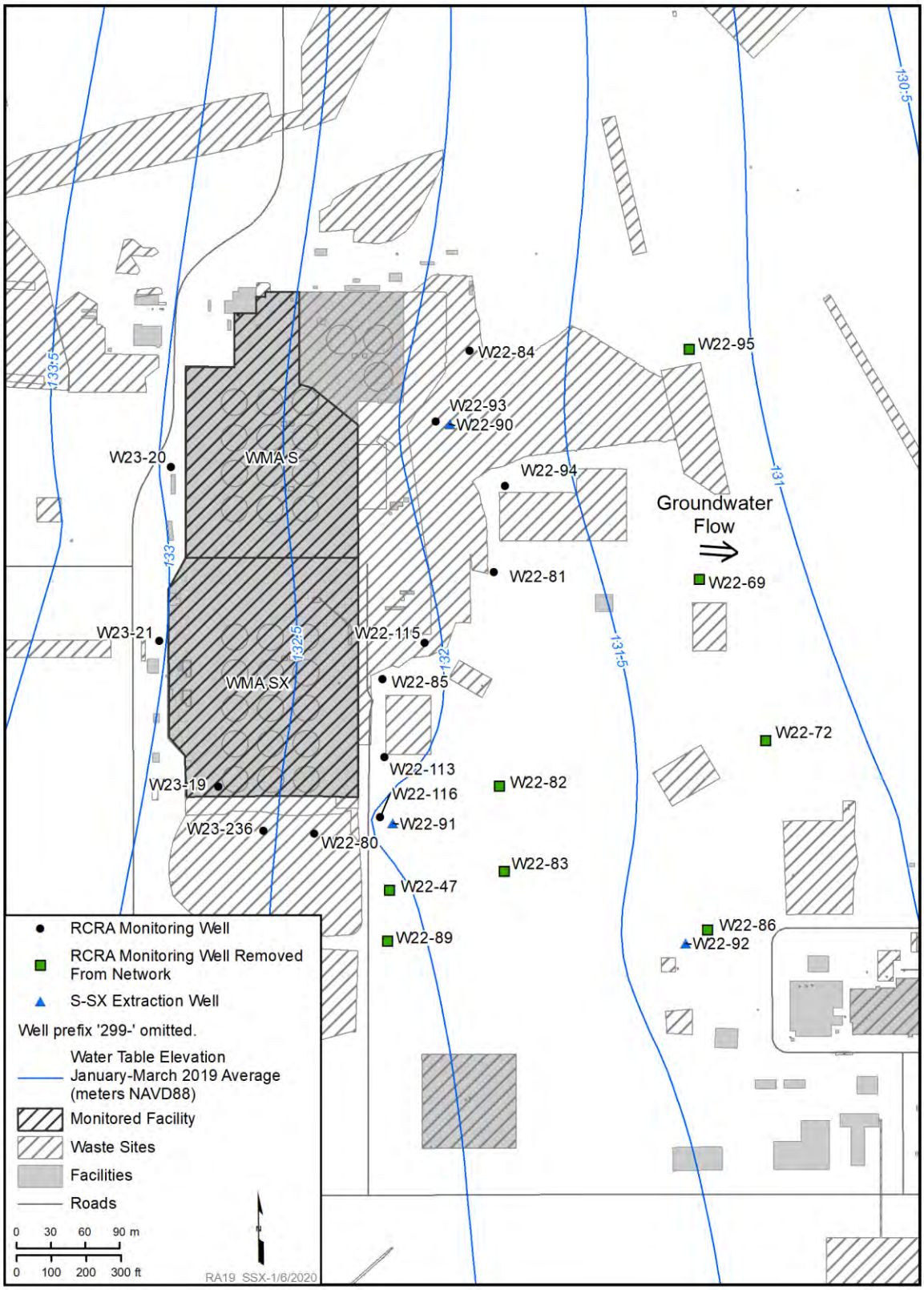
Groundwater data are available in the HEIS database, which is available at https://ehs.hanford.gov/eda. Appendix B includes additional information (including well and constituent lists, groundwater flow rates, and statistical tables).

11.11.1 Waste Management Area S-SX

WMA S-SX (Figure 11-34) is located in the 200 West Area and consists of the S and the SX Tank Farms. The S Tank Farm contains 12 SSTs, each with a capacity of 2.9 million L (758,000 gal). The SX Tank Farm contains 15 SSTs, each with a capacity of 3.8 million L (1,000,000 gal) (Section 1.2 in RPP-7884, *Field Investigation Report for Waste Management Area S-SX*). The WMA also includes the following ancillary equipment: three catch tanks; one receiver tank; six diversion boxes; and associated piping, valve pits, and pumps (Section 1.2 in RPP-7884). Both tank farms received waste from the REDOX Plant in the 1950s and 1960s. To minimize the probability and severity of future leaks, most of the drainable liquid in each tank has been removed and transferred to DSTs.

In 1996, at the direction of Ecology, WMA S-SX was placed into assessment status due to elevated specific conductance in downgradient monitoring wells. The first determination assessment found that multiple sources within the WMA had affected groundwater quality with elevated chromium (Chapter 5 in PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*). In 2019, the WMA S-SX assessment plan was revised to update the well network (DOE/RL-2009-73, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX*). The objective of RCRA monitoring at WMA S-SX is to assess the rate and extent of migration and the concentration of the dangerous waste constituent chromium in the groundwater. Cr(VI) is monitored as a supporting constituent. Dissolved chromium in Hanford Site groundwater is nearly all hexavalent, so filtered total chromium and Cr(VI) concentrations are similar.

Table B-56 in Appendix B lists the monitoring wells for WMA S-SX. The revised assessment plan (DOE/RL-2009-73) implemented the monitoring network recommended in SGW-60577, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area S-SX Groundwater Monitoring*. All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-34. Waste Management Area S-SX

In 2019, the hydraulic gradient was estimated to be 4.5×10^{-3} m/m toward the east, with an estimated groundwater flow rate of 0.15 m/d (0.49 ft/d) (Table B-2 in Appendix B).

Table B-57 in Appendix B summarizes the assessment data. Groundwater beneath WMA S-SX is contaminated with chromium at levels above the DWS. The chromium is attributed to a 91,000 L (24,000 gal) overfill event from tank S-104 in the S Tank Farm (Sections 3.7.2 and 4.6 in RPP-RPT-48589) and a 190,000 L (51,000 gal) leak from tank SX-115 during 1965 in the SX Tank Farm (Section 4.3 and Table ES-1 in RPP-ENV-39658). The Cr(VI) concentrations are about the same as total chromium. Because dissolved chromium is highly mobile in the aquifer, it migrates to the east at the same average flow rate as groundwater. Depth-discrete sampling while drilling well 299-W22-47 in 2004 and 2005 indicated that chromium was present within the upper 20 m (65 ft) of the aquifer.

The maximum filtered chromium concentration at WMA S-SX in 2019 was 433 µg/L in September at well 299-W23-19, inside the SX Tank Farm (Figure 11-35). The increasing concentrations in this well between 2017 and 2019 indicate that chromium is migrating downward from the vadose zone.

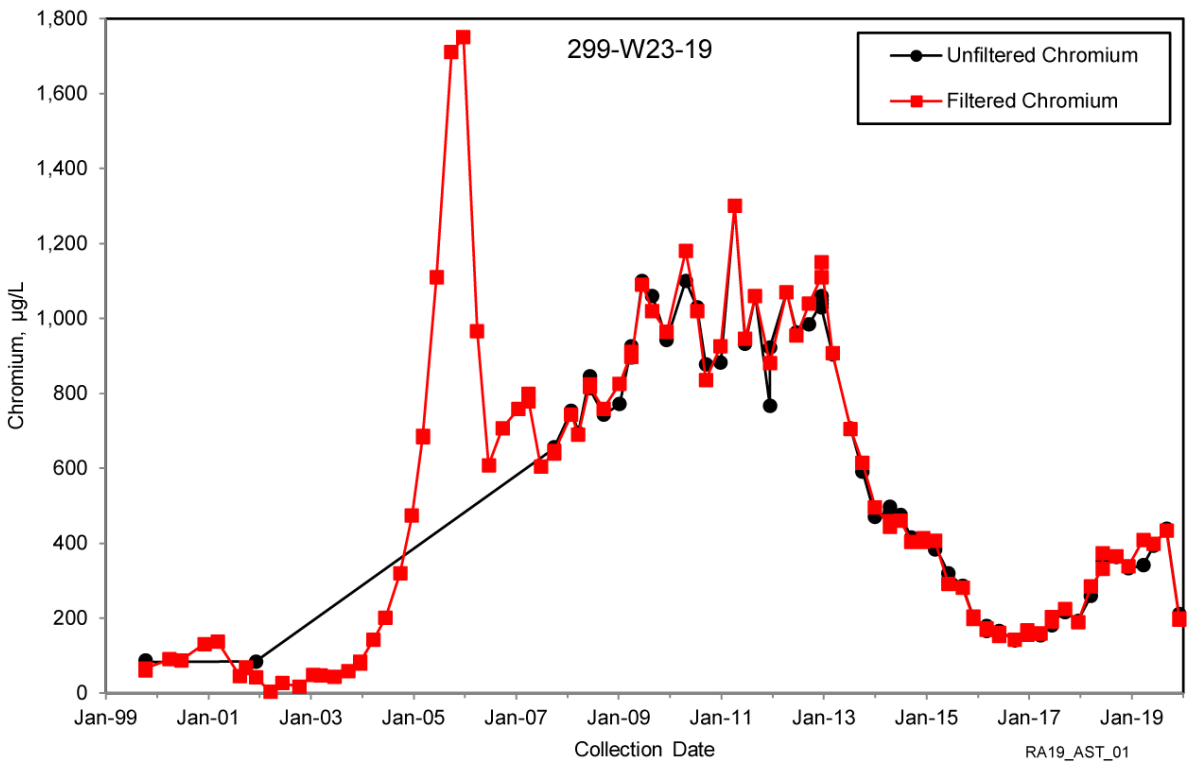


Figure 11-35. Chromium Concentration in Well 299-W23-19 in WMA S-SX

Four wells had nitrate concentrations above the 45 mg/L DWS due to a regional contaminant plume (Table B-57 in Appendix B).

Iron, manganese, and nickel are analyzed as indicators of stainless-steel well corrosion. Sample turbidity and unfiltered metals continued to be elevated in well 299-W22-81 in 2019, and the well will be evaluated for well corrosion.

11.11.2 Waste Management Area U

WMA U (Figure 11-36) contains 16 underground SSTs constructed between 1943 and 1944. Twelve SSTs have 2 million L (535,000 gal) capacities, and four SSTs have 210,000 L (55,000 gal) capacities (Section 1.2 in RPP-35485, *Field Investigation Report for Waste Management Area U*). The WMA also has a variety of ancillary equipment, including six diversion boxes; the 271UR control house; the 244UR process vault; the 244U double-contained receiver tank; and waste transfer lines, pits, and junction boxes.

WMA U received waste from the bismuth phosphate process between 1946 and 1948 and from the REDOX process between 1954 and 1957 (WHC-MR-0132, *A History of the 200 Area Tank Farms*). In 1952, some waste was retrieved and pumped to the 242T evaporator, and between 1952 and 1957, the metal waste stored in nine of the 2 million L (535,000 gal) capacity tanks was transferred to U Plant for uranium recovery. To minimize the probability and severity of future leaks, most of the drainable liquid in each tank has been removed and transferred to double-shell tanks.

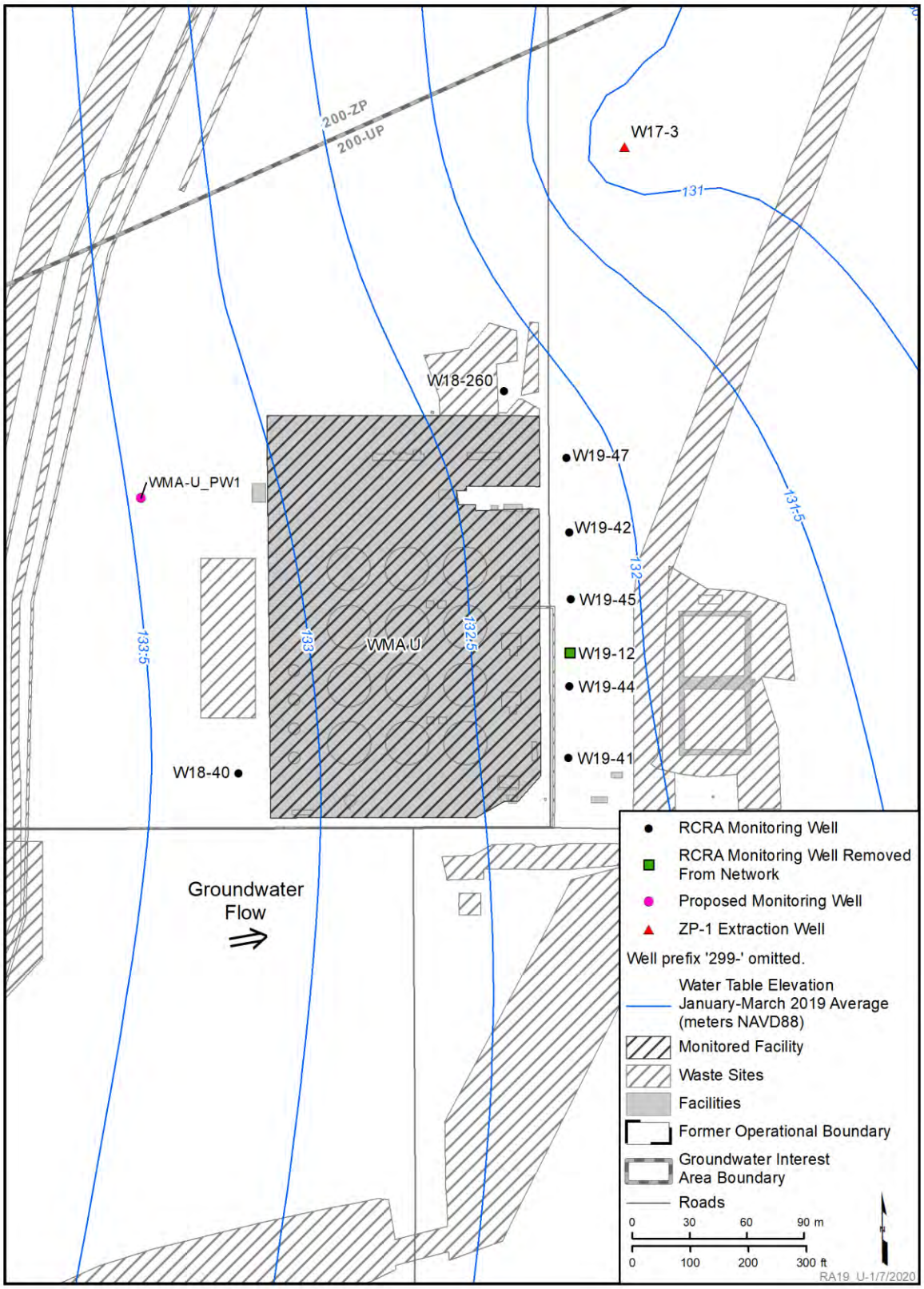
WMA U was placed into assessment status in 2000 when specific conductance in downgradient monitoring wells exceeded upgradient levels. An assessment of that finding in 2000 determined that the WMA had affected groundwater quality based on elevated nitrate and possibly chromium in downgradient wells (Chapter 6.0 in PNNL-13282). However, these contaminants were below their respective DWSs, and the affected area was limited to the southeastern corner of the WMA.

Revision 2 of the groundwater quality assessment plan (DOE/RL-2009-74, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*) was released in 2019. The revised plan implemented the monitoring network recommended in SGW-60578, including a proposed new well (Table B-62 in Appendix B). All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743).

Groundwater flow beneath WMA U is affected by the 200 West P&T. In 2019, the hydraulic gradient sloped to the east with a magnitude of 6.1×10^{-3} m/m, and the estimated flow rate was 0.20 m/d (0.66 ft/d) (Table B-2 in Appendix B).

All required sampling was performed successfully during 2019. Table B-63 in Appendix B summarizes the sampling results.

WMA U is the source of groundwater contamination with dissolved chromium on the downgradient (east) side of the tank farm (Chapter 6.0 in PNNL-13282). In 2019, the concentration of filtered total chromium was 20.4 µg/L in downgradient well 299-W19-44 compared to 7.5 µg/L in upgradient well 299-W18-40.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-36. Waste Management Area U

Where total chromium concentrations in unfiltered samples are higher than in filtered samples, it may indicate stainless-steel well corrosion. The highest chromium concentration in an unfiltered sample was 133 µg/L in well 299-W19-12 in January 2019, before this well was removed from the monitoring plan. The filtered chromium result from this well in January was 12.5 µg/L. Many of the network wells have elevated concentrations of iron, manganese, and nickel, which (along with chromium) are the primary components of 304 stainless steel used to construct the network wells. In particular, nickel is an indicator of stainless-steel corrosion because its natural concentration in Hanford Site groundwater is very low (90th percentile background is 1.56 µg/L [DOE/RL-96-61]). In wells 299-W19-45 and 299-W19-47, nickel is not routinely detected, while the chromium concentrations in 2019 ranged from 13.4 to 20.0 µg/L in well 299-W19-45 and from 10.4 to 12.2 µg/L in well 299-W19-47. The lack of nickel in these wells indicates that the chromium is from groundwater contamination and not well corrosion.

While dissolved chromium is highly mobile in the aquifer, it can migrate more slowly than the movement of moisture in the vadose zone beneath the tank farms (at least initially) following release from a tank. This has been attributed to a reduction process where tank fluids dissolve divalent iron minerals in the sediment. The iron then reacts with the soluble Cr(VI), reducing it to trivalent chromium, which precipitates as an insoluble iron chromium hydroxide (Zachara et al., 2007, "Geochemical Processes Controlling Migration of Tank Wastes in Hanford's Vadose Zone"). This reaction may explain the relatively low concentrations of chromium in the filtered groundwater samples. In the aquifer, dissolved chromium migrates to the east at the estimated groundwater flow rate of 0.20 m/d (0.66 ft/d).

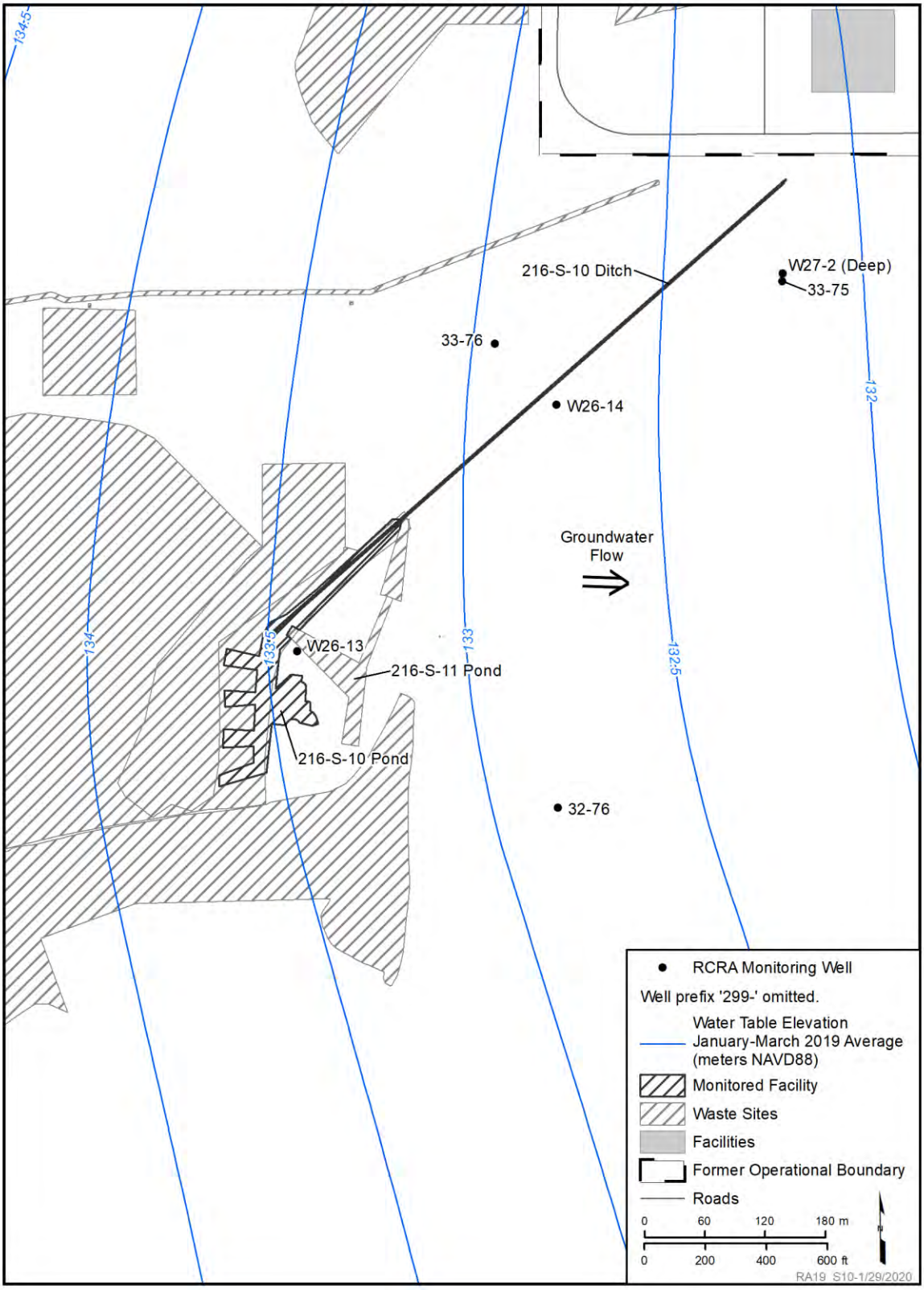
Concentrations of the nondangerous constituent nitrate exceed the 45 mg/L DWS and are steadily increasing in network wells, including the upgradient well. The upgradient nitrate source is treated water injected into wells formerly used for the 200-ZP-1 OU interim action P&T system. The injected water was treated for VOCs but still contained nitrate (Section 3.3.5 in DOE/RL-2011-118). Because nitrate in some downgradient wells is higher than the upgradient well, it is likely that WMA U is also a source of nitrate to the groundwater.

11.11.3 216-S-10 Pond and Ditch

The 216-S-10 Pond and Ditch, located outside the southwestern corner of the 200 West Area, comprised an unlined ditch, 1.2 m (3.9 ft) wide at its base and 686 m (2,250 ft) long, connected to a pond. The ditch was also connected to the 216-S-11 Pond between 1954 and 1965, which was an overflow pond to accommodate excess discharges. The 216-S-10 Pond and Ditch and the 216-S-11 Pond received 6.6 billion L (1.7 billion gal) of effluent from the REDOX Plant chemical sewer between 1951 and 1991. Figure 11-37 shows the major site features and monitoring well locations.

The groundwater beneath the 216-S-10 Pond and Ditch is monitored under an interim status indicator evaluation program to determine whether dangerous waste constituents have affected groundwater (DOE/RL-2008-61, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*). The monitoring network consists of an upgradient well, four downgradient wells screened in the upper portion of the aquifer at the water table, and a downgradient well screened 50 m (164 ft) below the water table (Table B-21 in Appendix B).

In 2019, groundwater flow was calculated to be toward the east with a gradient of 2.6×10^{-3} m/m, and the velocity was estimated at 0.09 m/d (0.30 ft/d) (Table B-2 in Appendix B). All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Section 7.4 in SGW-60585 recommended a modified network for monitoring under final status, including five wells from the existing network and four new wells.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 11-37. 216-S-10 Pond and Ditch

All of the network wells were sampled as planned in 2019 for RCRA contamination indicator parameters (pH, specific conductance, TOC, and TOX) (Table B-22 in Appendix B), groundwater quality parameters, and site-specific analytes (Table B-23 in Appendix B). No indicator parameter critical mean exceedances occurred in 2019.

In 2019, total chromium concentrations in well 299-W26-13 remained above the 100 µg/L DWS, and Cr(VI) concentrations were above the 48 µg/L MTCA standard (WAC 173-340) (Table B-23 in Appendix B). The 216-S-10 Pond and Ditch system was the most substantial source of chromium in this area (Appendix C in RPP-26744), but other sources of chromium also exist (e.g., 216-S-5 Crib, 216-S-6 Crib, 216-S-11 Pond, 216-S-16 Pond, 216-S-17 Pond, and associated ditches). In particular, the 216-S-11 overflow pond received waste similar to the 216-S-10 Pond but is not part of the RCRA unit.

Concentrations of stainless-steel corrosion products (chromium, iron, and nickel) continue to be elevated in unfiltered samples from deep well 299-W27-2. A downhole video of the well screen in 2017 confirmed corrosion in this well. The results for filtered total chromium and Cr(VI) were near or below the detection limits. Well maintenance has been scheduled.

11.12 Atomic Energy Act Monitoring

The AEA groundwater monitoring was conducted at 64 groundwater wells in 200-UP in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 200-UP are iodine-129, nitrate, technetium-99, tritium, and uranium. Historically, nitrate has been monitored through AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. All wells were sampled in accordance with SAP requirements in 2019. Minor exceptions to planned monitoring occurred due to well access issues and scheduling constraints.

Radionuclide concentrations detected in groundwater samples from 94 wells[14] were used to estimate the cumulative TED and to compare to cumulative beta/photon emitters, alpha emitters, and uranium mass to DWSs, as described in Section 1.2.4. The estimated TED exceeded the 100 mrem/yr standard at one groundwater well in 200-UP (Table 11-4). The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 55 locations in this interest area. No locations exceeded the DWSs for cumulative or net alpha emitters. The 30 µg/L uranium DWS was exceeded at 11 locations. None 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 that restrict access to groundwater and through remedial action measures (e.g., P&T) to control the migration of contaminated groundwater to exposure points.

The AEA groundwater monitoring is integrated with existing performance assessment monitoring for ERDF. Iodine-129, tritium, and nitrate concentrations exceeded DWSs in 2019. Tritium concentrations continued to decline for all wells except 699-36-70A, where values continue to increase in 2019. Iodine-129 concentrations were variable to increasing. Nitrate exceeded DWSs at one well, and concentrations trends were generally stable for 2019. Tritium concentrations continued to decrease or remain stable for most ERDF wells.

[14] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 11-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-UP in 2019

Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
299-W18-260	—	—	11.73	17.78	—	—
299-W19-12	—	—	16.53	16.53	—	—
299-W19-36	183.12	219.87	12.80	15.60	1,720.47	2,100
299-W19-39	—	—	5.6	5.6	33.50	33.50
299-W19-41	—	—	4.01	4.53	—	—
299-W19-42	—	—	13.07	17.56	—	—
299-W19-43	—	—	—	—	59.36	60
299-W19-45	—	—	27.56	33.24	—	—
299-W19-46	—	—	12.67	12.67	—	—
299-W19-47	—	—	14.89	17.56	—	—
299-W19-48	—	—	9.85	9.85	—	—
299-W19-49	—	—	5.67	5.67	93.90	93.90
299-W19-101	—	—	—	—	44.30	44.30
299-W19-113	—	—	—	—	115.00	134.00
299-W19-114	—	—	—	5.89	—	—
299-W19-115	—	—	4.09	4.60	136.00	243.00
299-W19-116	—	—	9.24	9.57	—	—
299-W19-123	—	—	5.99	9.84	151.00	155.00
299-W19-125	—	—	4.89	4.89	—	—
299-W19-126	—	—	—	—	31.00	31.00
299-W19-131	—	—	6.14	6.14	—	—
299-W20-1	—	—	7.92	7.92	46.70	46.70
299-W21-2	—	—	9.64	9.64	—	—
299-W21-3	—	—	86.92	103.68	—	—
299-W22-10	—	—	34.77	34.77	—	—
299-W22-69	—	—	4.56	4.56	—	—
299-W22-72	—	—	13.49	13.49	—	—
299-W22-79	—	—	16.91	16.91	—	—
299-W22-81	—	—	8.95	8.95	—	—

Table 11-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-UP in 2019

Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
299-W22-85	—	—	14.63	14.63	—	—
299-W22-86	—	—	6.19	6.19	—	—
299-W22-87	—	—	4.55	5.11	—	—
299-W22-88	—	—	26.30	26.30	—	—
299-W22-91	—	—	15.72	17.46	—	—
299-W22-92	—	—	4.74	4.74	—	—
299-W22-93	—	—	8.04	10.94	—	—
299-W22-96	—	—	34.47	34.47	—	—
299-W22-113	—	—	7.62	10.52	—	—
299-W22-114	—	—	21.52	21.52	—	—
299-W22-115	—	—	23.29	29.18	—	—
299-W22-116	—	—	45.28	60.00	—	—
299-W23-4	—	—	11.54	12.24	34.60	41.00
299-W23-19	—	—	32.62	69.34	—	—
699-32-72A	—	—	7.64	7.64	—	—
699-34-72	—	—	18.67	18.67	—	—
699-35-66A	—	—	11.60	26.26	—	—
699-36-61A	—	—	8.28	8.28	—	—
699-36-63B	—	—	23.12	24.02	—	—
699-36-65	—	—	59.48	59.48	—	—
699-36-66B	—	—	22.88	66.95	—	—
699-36-70A	—	—	10.68	55.57	—	—
699-36-70B	—	—	7.41	7.41	—	—
699-37-66	—	—	6.11	19.72	—	—
699-37-67	—	—	4.89	4.89	—	—
699-38-61	—	—	5.82	5.82	—	—
699-38-64B	—	—	5.34	6.252	—	—
699-38-65	—	—	16.06	16.06	—	—

Table 11-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-UP in 2019

Well Name	Cumulative Total Effective Dose ≥100 mrem/yr		Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Cumulative Uranium Mass ≥30 µg/L	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
699-38-70C	—	—	6.34	6.34	—	—
699-39-68	—	—	7.92	12.39	—	—

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

Blank cells (—) indicate no exceedances.

None of the wells in 200-UP had cumulative alpha activity ≥15 pCi/L.

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12 200-ZP

This chapter presents information for the 200-ZP groundwater interest area, including an overview; a discussion of CERCLA-, RCRA-, and AEA-related groundwater activities conducted in 2019; and a summary of the 2019 groundwater monitoring results.

12.1 Overview

The 200-ZP groundwater interest area is located in the northern and central portions of the 200 West Area and the surrounding region (Figure 1-1). It includes the 200-ZP-1 Groundwater OU, where activities focus on groundwater remediation, monitoring, and reporting. Figure 12-1 shows key facility areas and wells. Groundwater COCs include carbon tetrachloride, chromium (total and Cr(VI)), iodine-129, nitrate, technetium-99, TCE, and tritium (EPA et al., 2008). Table 12-1 lists some key facts about 200-ZP. Section 1.5 provides plume mapping details, including descriptions of terms (e.g., Type 1 control point) used in the figure legends.

Carbon tetrachloride is the major COC in groundwater, forming a plume with an area >20 km^2 (7.7 mi^2) that extends north, south, and east from the source areas. The primary sources were discharges of liquid waste from the PFP plutonium-finishing processes to the 216-Z-1A, 216-Z-9, and 216-Z-18 Cribs and Trenches (Section 1.2.2 in DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*). Except for nitrate and tritium, the remaining contaminant plumes within 200-ZP are within the horizontal extent of the carbon tetrachloride plume. The 200 West P&T is currently remediating groundwater in the 200 West Area (Section 12.10.2). Figure 12-2 illustrates changes in plume areas from 2003 to 2019.

Within 200-ZP, groundwater occurs in an unconfined aquifer (within Ringold unit E) and in confined aquifers beneath the Ringold lower mud unit and in basalt interbeds (Figure 1-6). The base of the unconfined aquifer is the fine-grained lower mud (where present) or the top of basalt (where the lower mud is absent). The lower mud is absent where the Ringold Formation sediments were eroded by Ice Age floods and subsequently filled with Hanford formation sediments (Figure 12-3). Depths to the water table in 200-ZP range from 66.4 to 106.6 m (218 to 350 ft), with the greatest depths in the eastern portion of the groundwater interest area. The thickness of the unconfined aquifer ranges from 0 m where the mud is above the water table east of the 200 West Area to >70 m (230 ft) in the northwest. Carbon tetrachloride migrated into Ringold unit A in areas where the lower mud is absent, and this contaminated groundwater then flowed beneath the lower mud where the Ringold unit A is confined.

Groundwater in the 200 West Area generally flows east but is influenced by the 200 West P&T (Figure 11-2). The water table declined after wastewater discharged to various cribs, ponds, and ditches ceased during the 1980s and 1990s. Section 3.2 in DOE/RL-2011-118 provides detailed discussions of 200-ZP geology and hydrogeology.

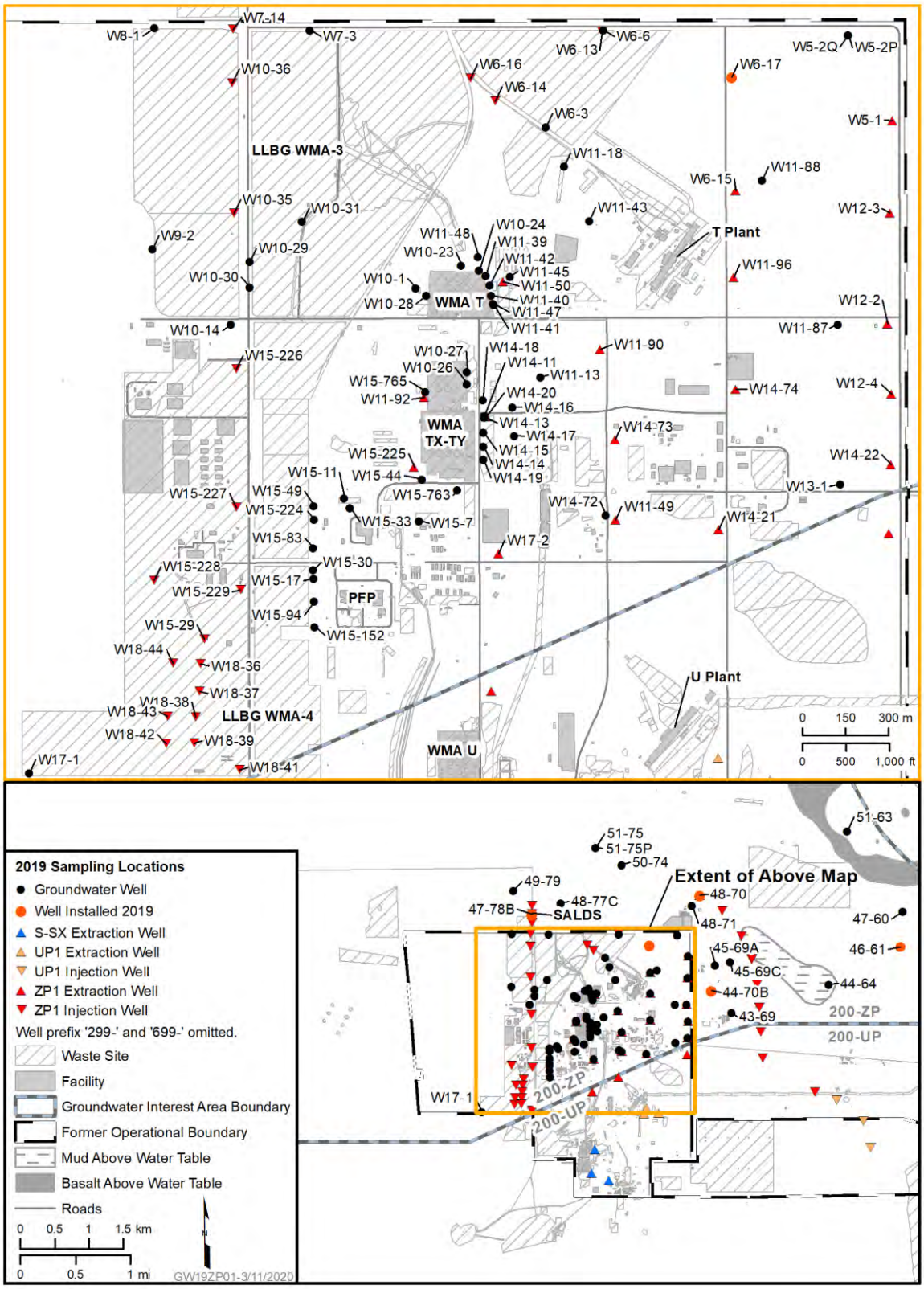


Figure 12-1. 200-ZP Sampling Locations, 2019

Table 12-1. 200-ZP at a Glance

T Plant operations: 1944 to 1956 (plutonium separation) **Plutonium Finishing Plant operations:** 1949 to 1989			
Groundwater Monitoring			
Contaminant, Cleanup Level[a]	**Year**	**Maximum Concentration**	**Plume Area (km^2)**
Carbon tetrachloride, 3.4 µg/L	2019	1,830 (299-W11-87)	20.1[b]
	2018	1,750 (299-W11-87)	20.3[b]
Hexavalent chromium, 48 µg/L	2019	175 (299-W6-17)	1.1
	2018	140 (299-W14-16 and 299-W6-15)	0.70
Chromium (total), 100 µg/L	2019	576 (299-W11-13 unfiltered)	0.27
	2018	257 (299-W14-16 unfiltered)	0.14
Iodine-129, 1 pCi/L	2019	2.15 (299-W14-11)	0.13
	2018	1.87 (299-W5-2Q)	0.30
Nitrate, 45 mg/L	2019	553 (299-W14-18)	10.2
	2018	664 (299-W5-2Q and 299-W5-2P)	7.3
Technetium-99, 900 pCi/L	2019	25,200 (299-W11-42)	0.13
	2018	13,800 (299-W14-13)	0.05
Trichloroethene, 1 µg/L	2019	27.0 (299-W6-17)	5.8[c]
	2018	12.0 (299-W14-72)	5.0[c]
Tritium, 20,000 pCi/L	2019	58,100 (699-48-77C)	0.14
	2018	56,000 (699-48-77C and 699-48-77D)	0.13
Remediation			
Soil vapor extraction: 1992 to 2012. **200-ZP-1 interim action P&T:** 1994 to 2012. **200 West P&T:** 2012 to present.			

a. From Table 11 of EPA et al., 2008 *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*.

b. Area of full plume footprint (includes area within 200-UP and 200-ZP combined), all depths in unconfined aquifer, at >3.4 µg/L.

c. Area of full plume footprint (includes area within 200-UP and 200-ZP combined), all depths in unconfined aquifer, at >1.0 µg/L.

P&T = pump and treat

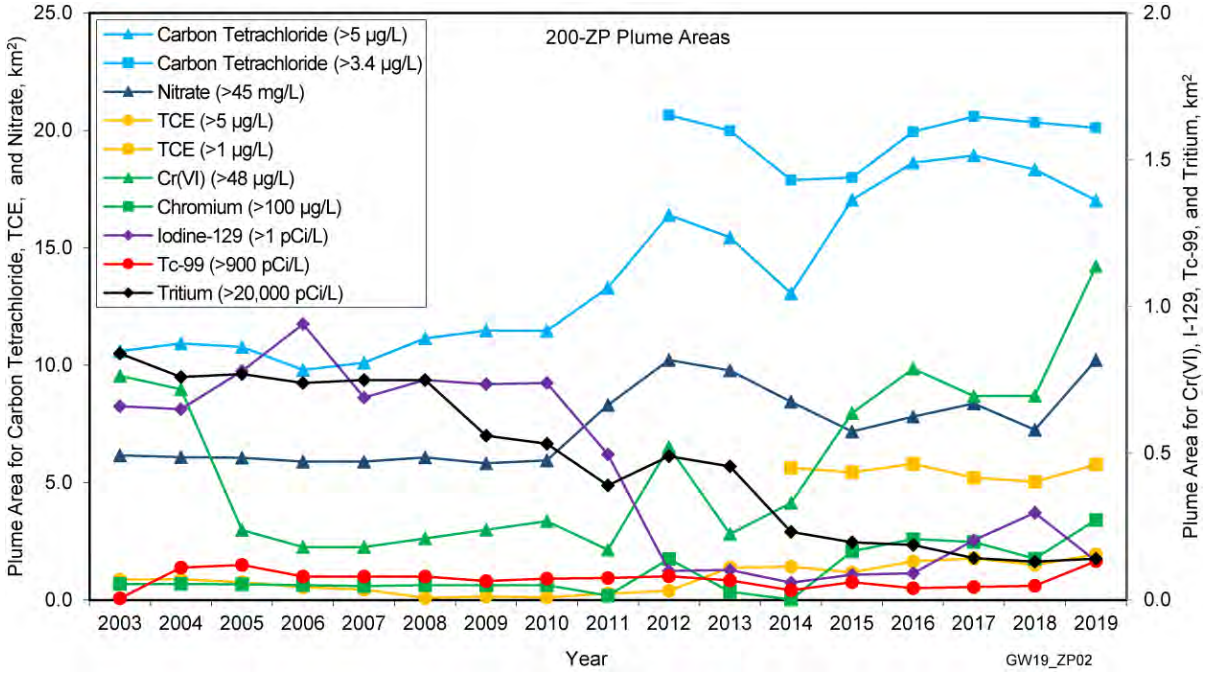
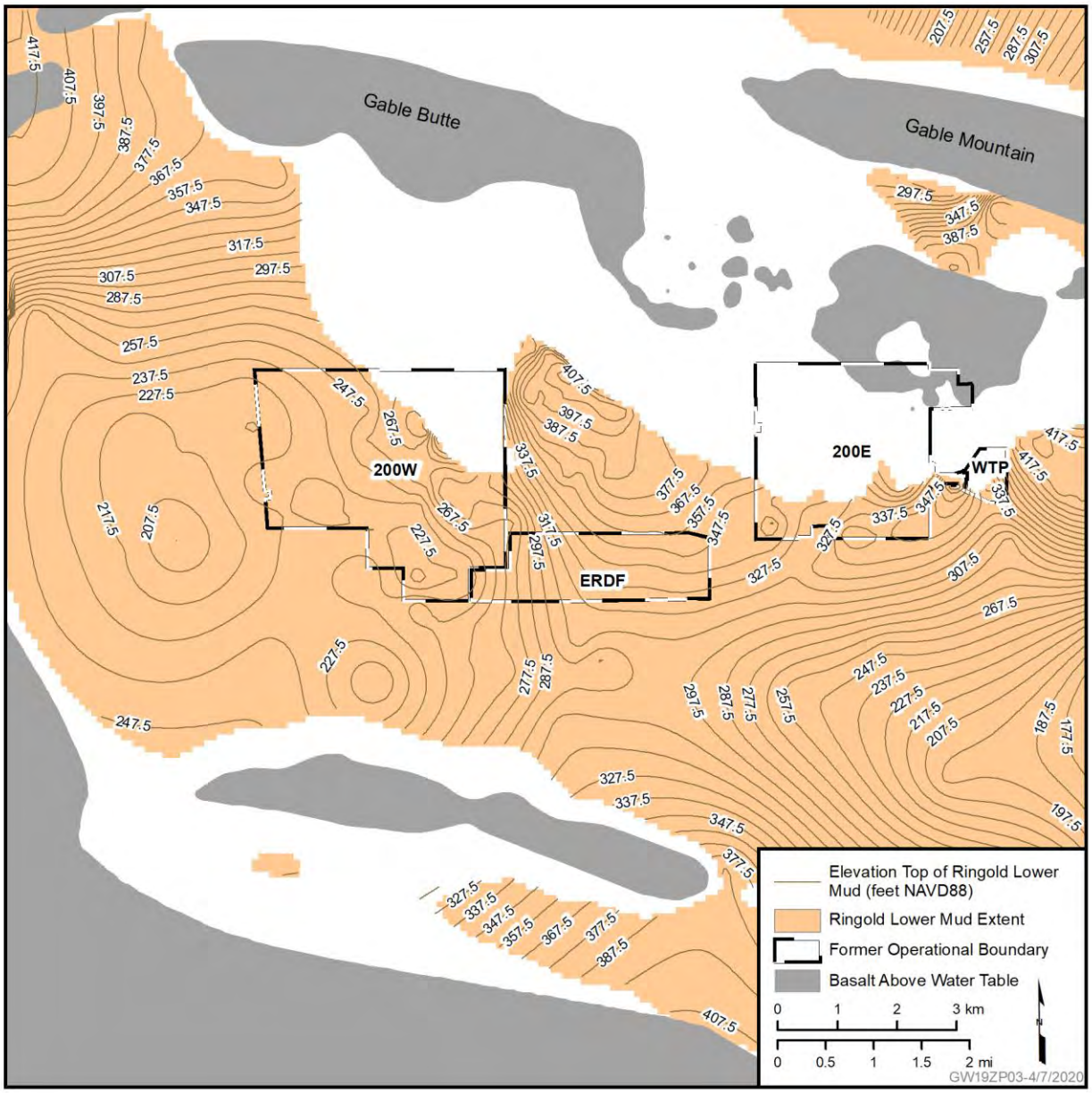


Figure 12-2. 200-ZP Plume Areas

Groundwater in the 200-ZP-1 OU is monitored under CERCLA to assess the performance of the final remedy, as documented in the 200-ZP-1 OU ROD (EPA et al., 2008); under RCRA at WMA T, WMA TX-TY, LLBG WMA-3, and LLBG WMA-4; and under the *Washington Administrative Code* at the SALDS. Radionuclide monitoring is performed in accordance with the AEA and CERCLA. Figure 12-1 shows the wells sampled in 2019.

In some locations, the greatest concentrations of 200-ZP COCs occur near the bottom of the aquifer. The plume maps presented in this chapter are generally based on data from all wells, not only those screened in the upper part of the aquifer. If wells are paired (shallow/deep), the higher concentration is used for plume mapping. Plume mapping details are provided in ECF-HANFORD-20-0018, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2019 Hanford Site Groundwater Monitoring Report*.



Source: Geologic interpretations based on data from boreholes as documented in ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*.

Figure 12-3. Extent of the Ringold Formation Lower Mud Unit

12.2 Carbon Tetrachloride

Carbon tetrachloride exceeds the final cleanup level (3.4 µg/L) and the DWS (5 µg/L) under most of the 200 West Area (Figure 12-4). Investigations during well drilling revealed that, in many locations, carbon tetrachloride contamination is present throughout the entire thickness of the unconfined and Ringold confined aquifers. The plume interpretation considers all depths and is based on 2019 sampling data, sample data collected during well drilling in previous years, and a computer model (ECF-200W-20-0047, *Description of Groundwater Calculations and Assessments for the Calendar Year 2019 (CY 2019) 200 Areas Pump and Treat Report*). Initially, carbon tetrachloride concentrations

exceeded 2,000 µg/L beneath PFP, but the high-concentration portion of the plume has responded to remediation by the 200 West P&T system (Section 12.10.2). The remedial action alternative for the portion of the plume beyond the influence of extraction wells is MNA. Figure 12-5 depicts a cut-away view of the three-dimensional plume simulation based on ECF-200W-20-0052, *Updates to the 200-West Three-Dimensional Groundwater Concentration Plumes for Calendar Year 2015 for use as Initial Conditions in the Plateau to River (P2R) Groundwater Model*. Figure 12-6 shows the 2012 plume footprint (start of the final action P&T system) compared to the 2019 plume footprint.

As shown on the plume map (Figure 12-4), carbon tetrachloride extends to the east from the PFP source areas. Prior to startup of 200-ZP-1 OU interim actions in 1996, carbon tetrachloride concentrations were >2,000 µg/L in 40 wells and >4,000 µg/L in 20 wells. During 2019, none of the concentration exceeded 2,000 µg/L. In 2019, four wells (new well 299-W6-17 and wells 299-W11-87, 299-W13-1, and 299-W14-72) had carbon tetrachloride concentrations >1,000 µg/L (Figure 12-7).

Carbon tetrachloride routine sample concentrations are declining in monitoring wells, where the highest concentrations formerly were observed near PFP and west of WMA T and WMA TX-TY (Figure 12-4) as a result of capture by extraction wells and natural attenuation (dispersion). For example, concentrations in well 299-W15-765 declined from 2,800 µg/L in 2011 to 28 µg/L in 2019. The significant decline in the maximum carbon tetrachloride concentration (from 8,700 µg/L in 1990 to 1,830 µg/L in 2019) and the number of wells exceeding 2,000 µg/L (from 40 wells in 1990 to zero in 2019) demonstrates that the P&T systems have reduced carbon tetrachloride concentrations and mass (Section 12.10.2) in the aquifer.

Despite the initial success of P&T, data and information obtained following issuance of the 200-ZP-1 OU ROD (EPA et al., 2008) suggest that conditions are less favorable for attaining the carbon tetrachloride cleanup level with the current P&T configuration in the timeframe specified in the ROD. The new data and information include the following:

- The site-specific abiotic degradation rate of carbon tetrachloride, as presented in PNNL-22062, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report*, has been determined to be about an order of magnitude slower than the degradation rate assumed in DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*. As a result of the slower natural degradation rate, more intensive P&T efforts and/or a longer cleanup duration is needed to achieve the carbon tetrachloride cleanup levels specified in the 200-ZP-1 OU ROD (EPA et al., 2008).

- Data compiled since the startup of the current P&T system in 2012 show that more carbon tetrachloride contamination is present in Ringold unit E than was identified in the 200-ZP-1 OU FS (Section 2.4 in DOE/RL-2007-28). Current estimates indicate that over one-third more carbon tetrachloride mass resides within Ringold unit E than assumed in the 200-ZP-1 OU FS.

- Data compiled since the startup of the current P&T system in 2012 show that more carbon tetrachloride contamination is present in Ringold unit A than was identified in the 200-ZP-1 OU FS (Section 2.4 in DOE/RL-2007-28). The data also indicate lower hydraulic conductivity in Ringold unit A compared to Ringold unit E. Ringold unit A is being characterized further in accordance with DOE/RL-2019-23, *200-ZP-1 Operable Unit Ringold Formation Unit A Characterization Sampling and Analysis Plan*, which is scheduled to be implemented in 2020.

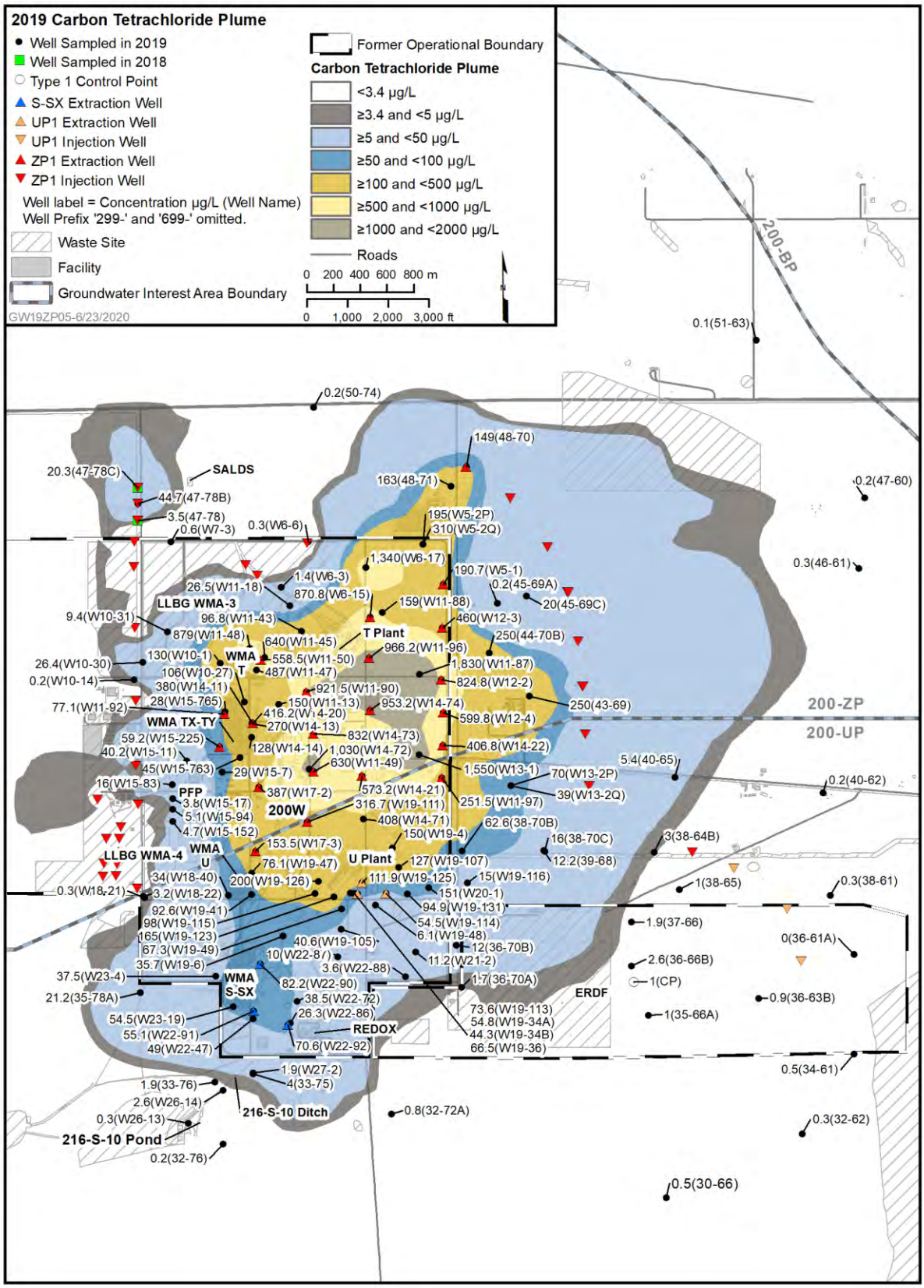


Figure 12-4. 200-ZP Carbon Tetrachloride Plume, 2019

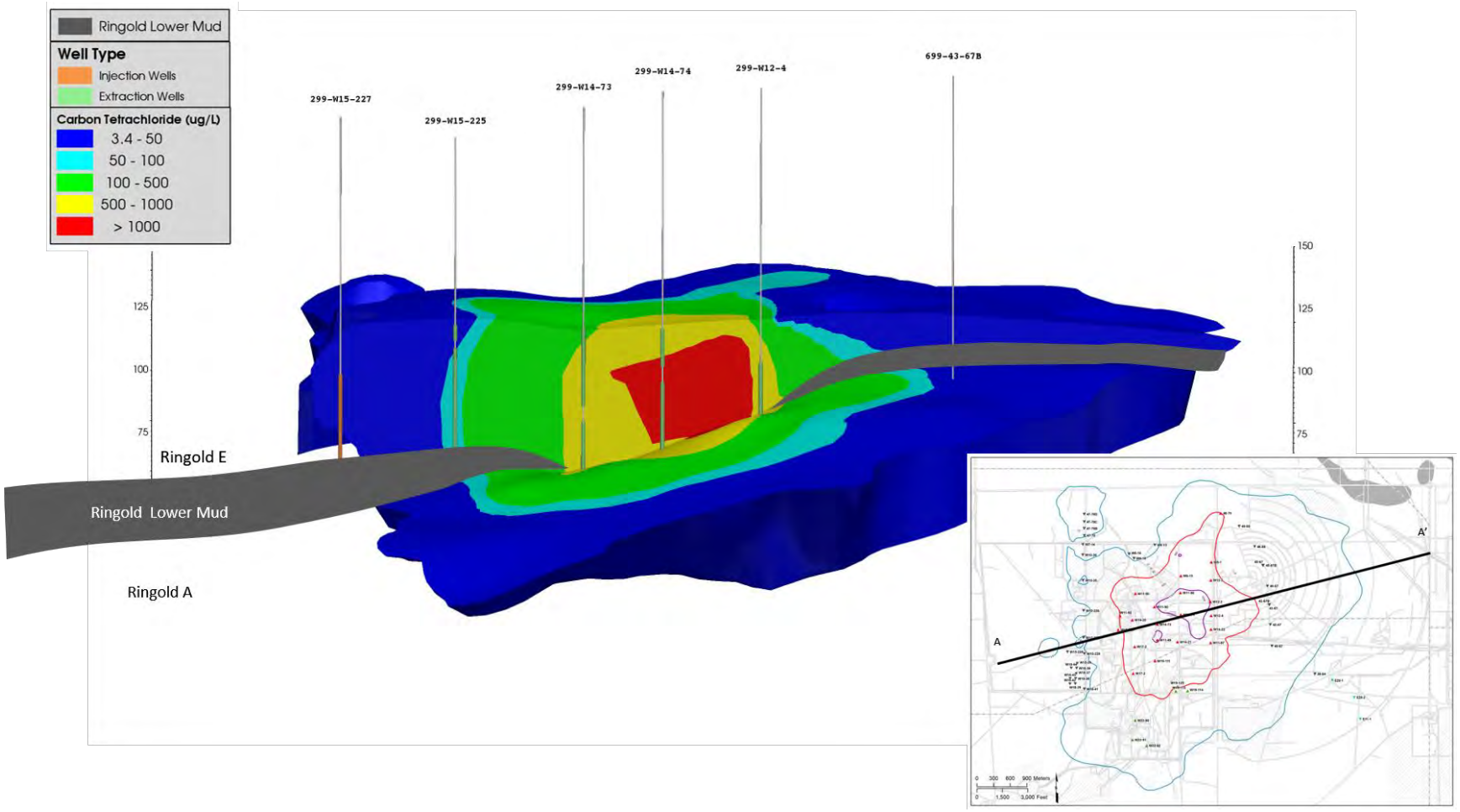


Figure 12-5. 200-ZP Cut-Away View of the Three-Dimensional Carbon Tetrachloride Plume Simulation, 2019

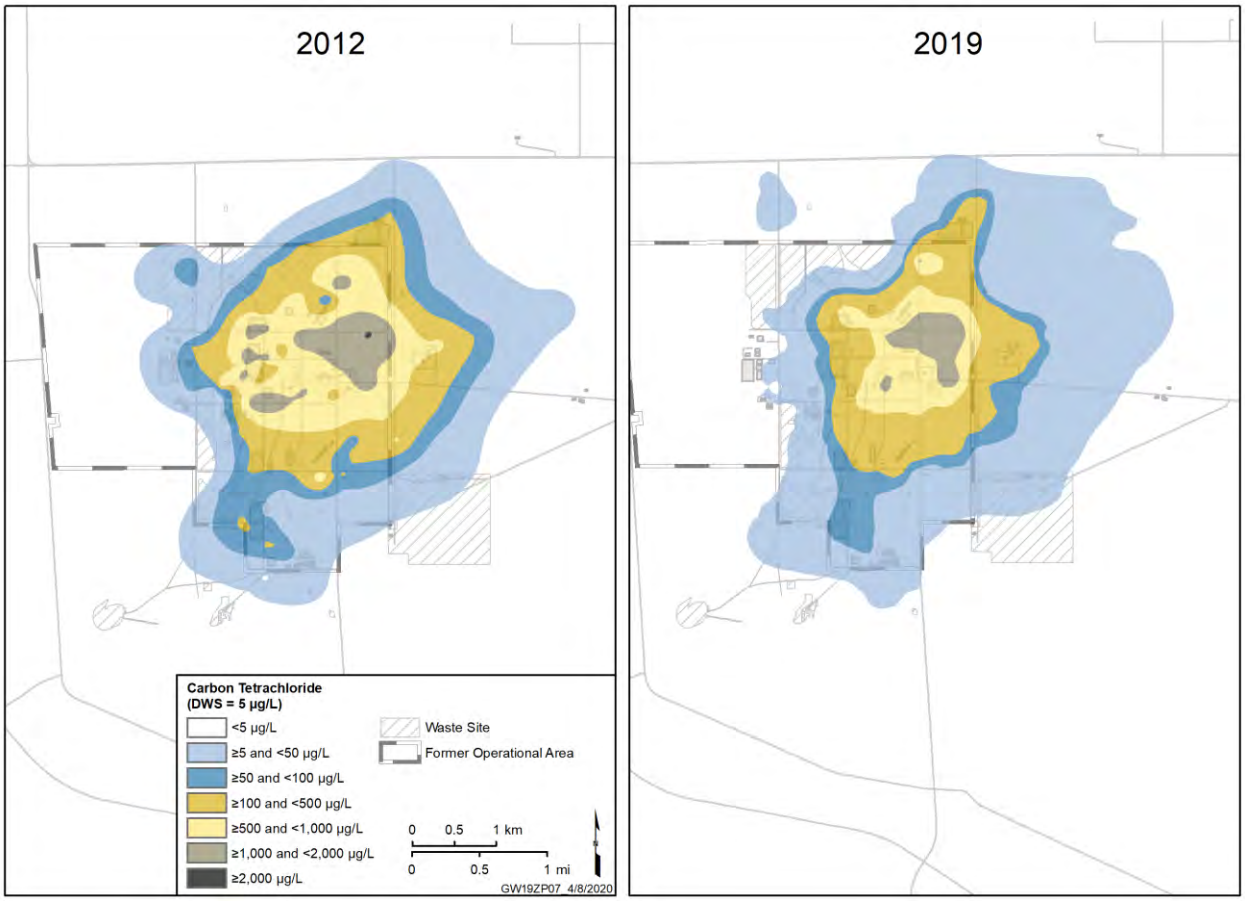


Figure 12-6. 200 West Carbon Tetrachloride Plume in 2012 (Start of Final Action P&T) and 2019

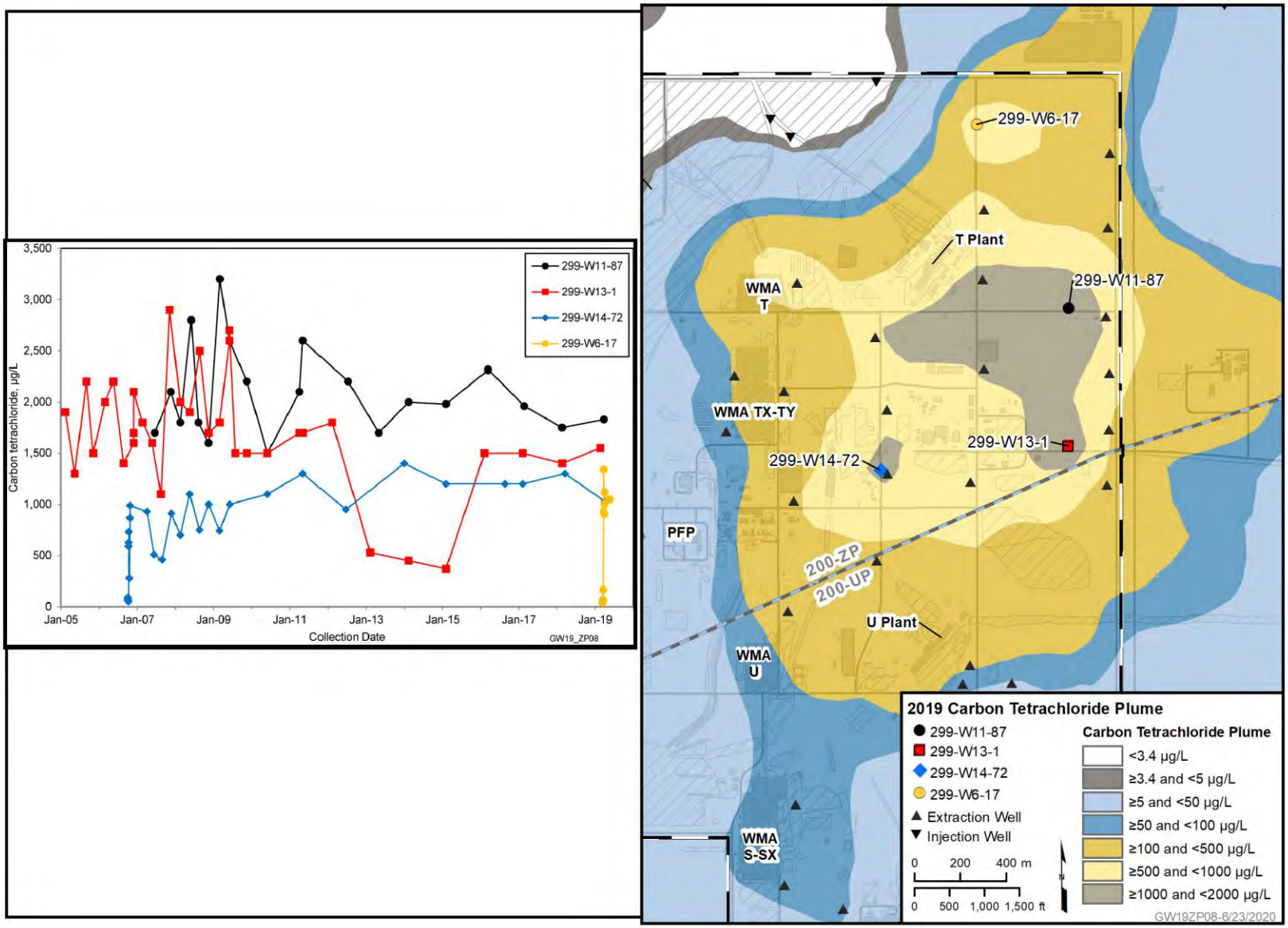


Figure 12-7. 200-ZP Carbon Tetrachloride Data for Wells 299-W6-17, 299-W11-87, 299-W13-1, and 299-W14-72

12.3 Chromium

Although Cr(VI) and total chromium are listed in the 200-ZP-1 OU ROD (EPA et al., 2008) as separate COCs, dissolved chromium in Hanford Site groundwater is nearly all Cr(VI) (Chapter 7 in WHC-SD-EN-TI-302; Appendix C in DOE/RL-2008-01). Cr(VI) exceeds the final cleanup level (48 µg/L) downgradient of the SSTs at WMA T and WMA TX-TY (Figure 12-8). The highest Cr(VI) concentration in 2019 was 175 µg/L in an unfiltered post-development sample from new monitoring well 299-W6-17.

Groundwater extraction from well 299-W11-50 near WMA T has caused chromium concentrations to decline below the cleanup level in nearby monitoring wells (Figure 12-9). However, concentrations farther east (at T Plant) have increased in wells 299-W6-15, 299-W11-96, and 299-W14-74 (Figure 12-10).

Groundwater extraction near monitoring wells 299-W10-26 and 299-W14-16 (downgradient of the WMA TX-TY) has resulted in concentrations increasing to near or above the cleanup level due to the plume migration toward the extraction well (299-W14-20) (Figure 12-11). Chromium sources include past leaks from SSTs.

The Cr(VI) plume to the northeast of T Plant (Figure 12-8) is defined by wells 299-W5-1 (an extraction well), 299-W6-17 (a new 2019 monitoring well), 299-W5-2P, 299-W5-2Q, 699-48-70 (a new 2019 extraction well), and 699-48-71. In 2019, the highest concentration was in new well 299-W6-17 at 175 µg/L. Concentrations in wells 299-W5-1 and 699-48-71 have been stable since 2015.

Vertical distribution data for Cr(VI) collected during drilling of wells near WMA T, WMA TX-TY, and adjacent cribs and trenches indicate that the highest concentrations are within the lower portion of the unconfined aquifer. Vertical characterization data for Cr(VI) in the aquifer near WMA T and WMA TX-TY have been collected primarily during drilling and special studies. In the northeast plume, samples collected during the drilling of wells 299-W6-17 and 699-48-70 in 2019 indicated both deep and shallow concentrations above the cleanup level. Well 299-W6-17 had concentrations of 87.2 and 123 µg/L at about 33.3 and 39.4 m (109.4 and 129.3 ft), respectively, below the water table. Well 699-48-70 had concentrations of 49.1 µg/L, 51.0 µg/L, and 77.5 µg/L at about 4.6 m, 10.7 m, and 16.8 m (15.2 ft, 35.0 ft, and 55.2 ft) respectively, below the water table. The amount of time between vertical characterization sampling in different wells makes it difficult to correlate interpretations between wells due to the P&T remedial action that is currently operating near these wells.

Several wells exceeded the 100 µg/L cleanup level for total chromium in 2019. Total chromium concentrations are similar to Cr(VI) concentrations in 200-ZP groundwater, except in the few unfiltered samples that contain particulate matter from corrosion of well screens or casing.

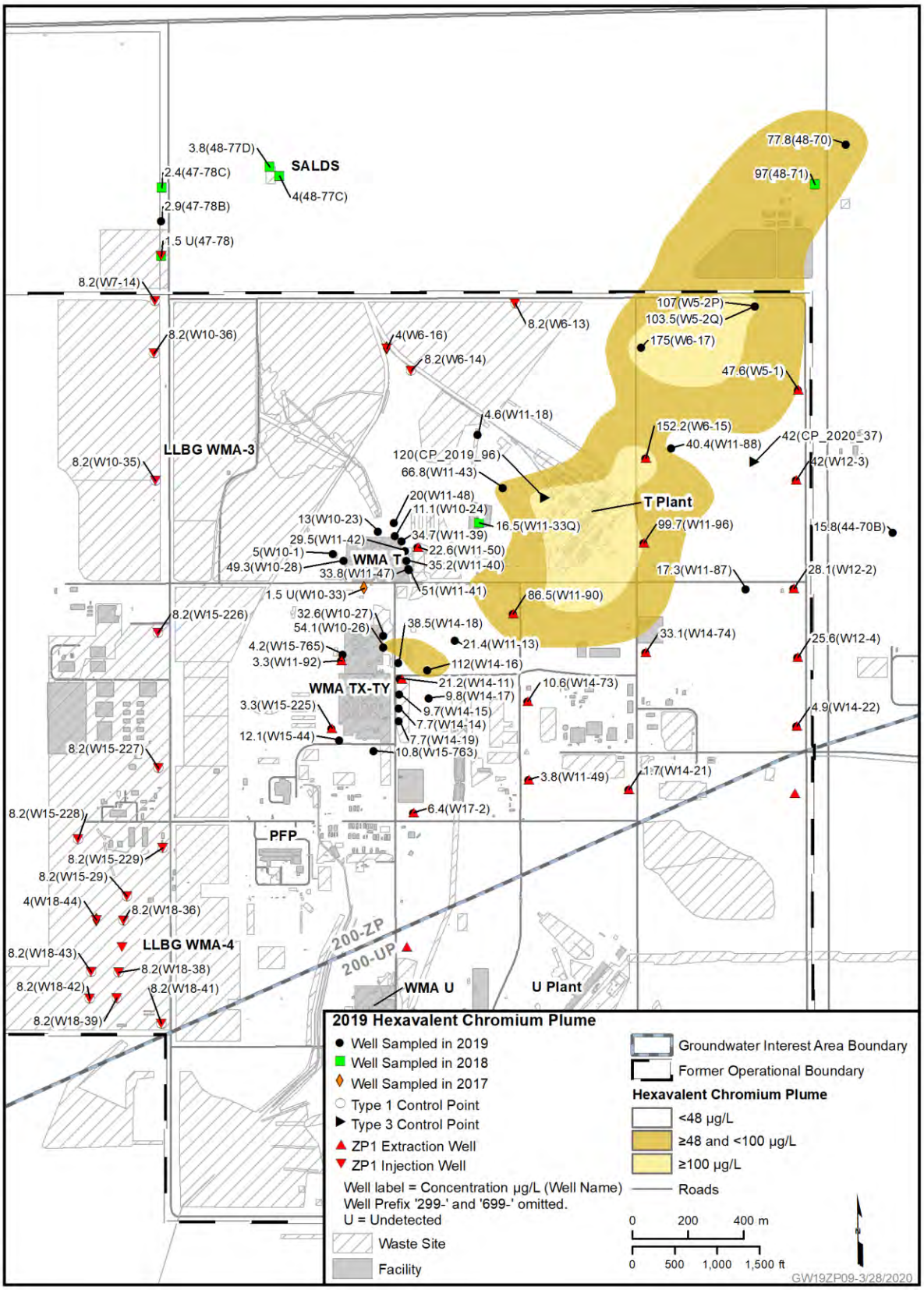


Figure 12-8. 200-ZP Cr(VI) Plume, 2019

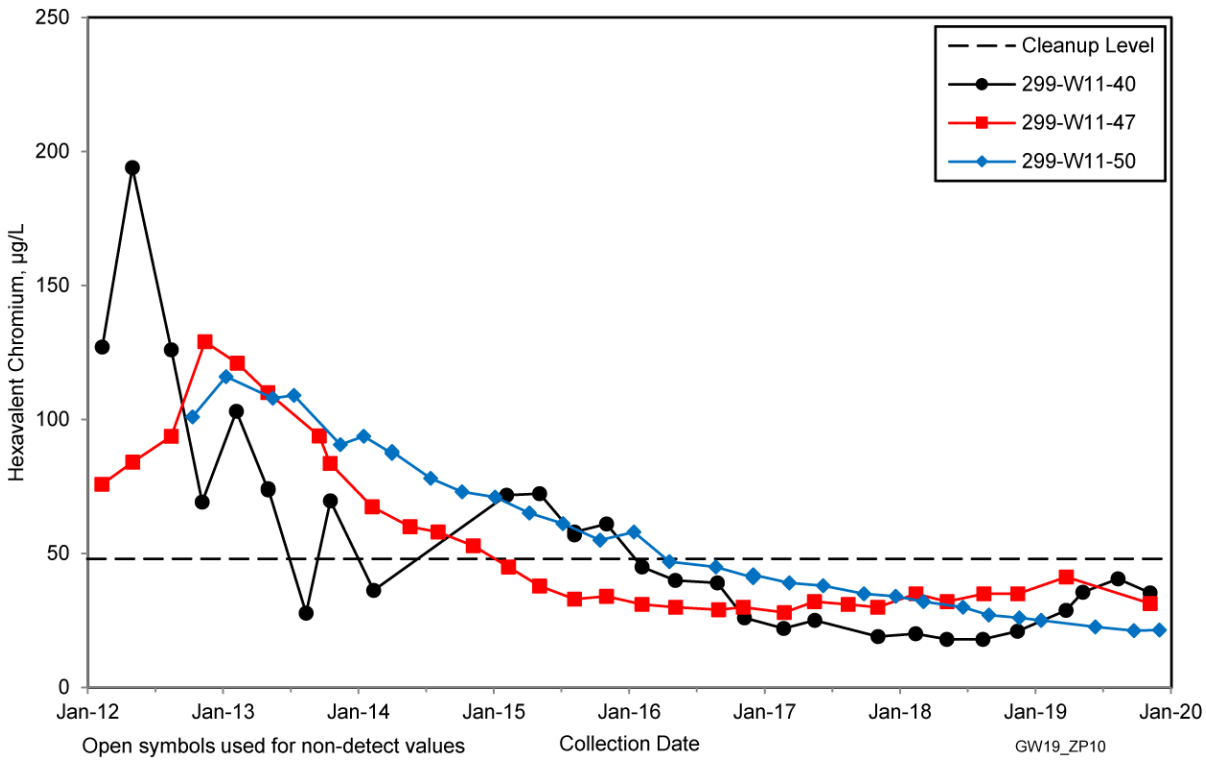


Figure 12-9. 200-ZP Cr(VI) Concentrations in Wells at WMA T

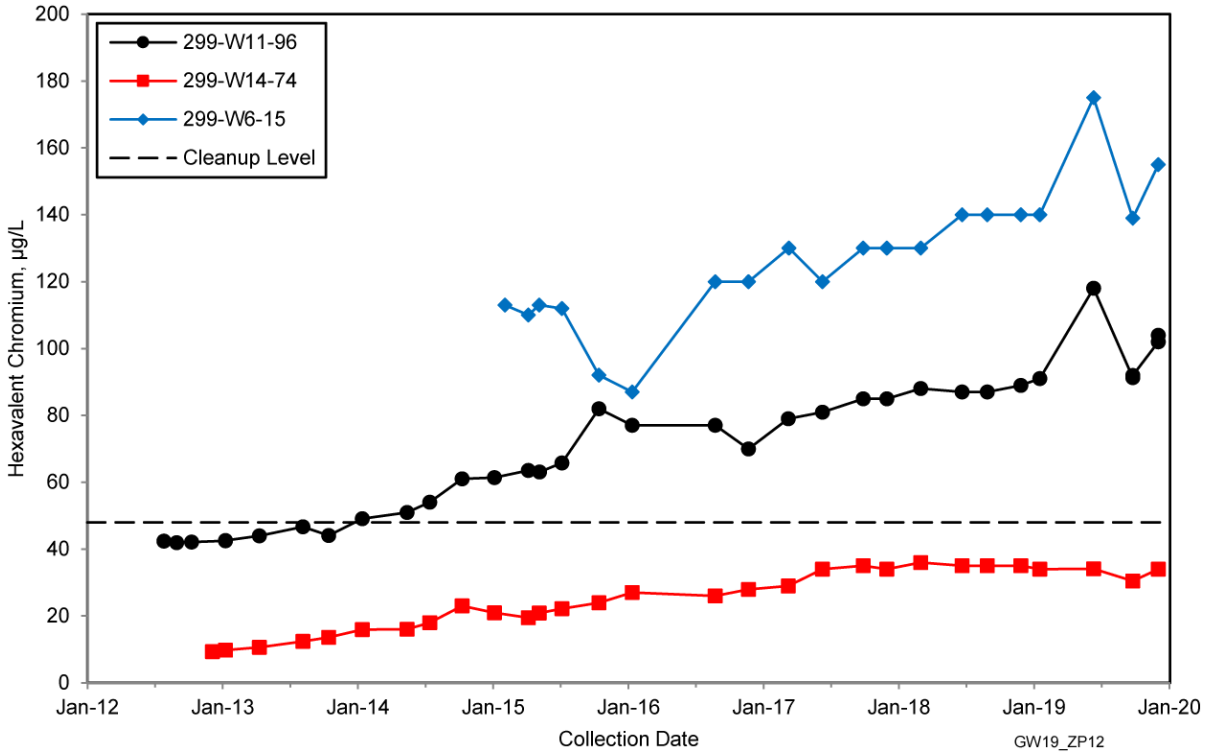


Figure 12-10. 200-ZP Cr(VI) Concentrations in Wells on the East Side of the WMA T Plume

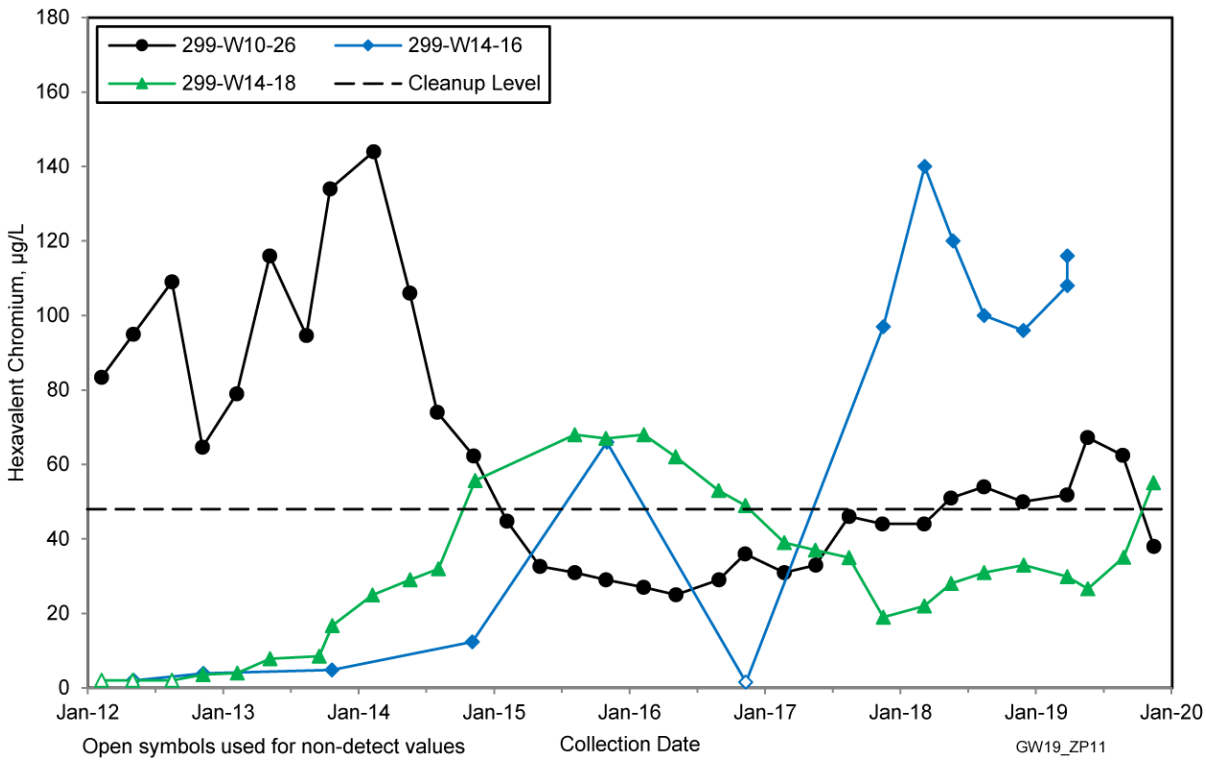


Figure 12-11. 200-ZP Cr(VI) Concentrations in Wells at WMA TX-TY

12.4 Iodine-129

Two wells in 200-ZP had iodine-129 concentrations exceeding the 1 pCi/L cleanup level in at least one sample in 2019 (Figure 12-12): well 299-W14-11, located east of WMA TX-TY (maximum of 2.2 pCi/L), and new extraction well 299-W6-17 located in northeastern 200 West Area (1.6 pCi/L maximum concentration during drilling in April 2019). Iodine-129 sources include past leaks from SSTs (containing metal and liquid waste) and chemical processing at T Plant. The MDA for iodine-129 varies from about 0.3 to 1.2 pCi/L.

Iodine-129 concentrations were much higher in some 200-ZP monitoring wells in the past. For example, in monitoring well 299-W14-13, iodine-129 declined from 50 pCi/L in 2000 to less than the MDA in 2019. Well 299-W14-13 is located near an extraction well.

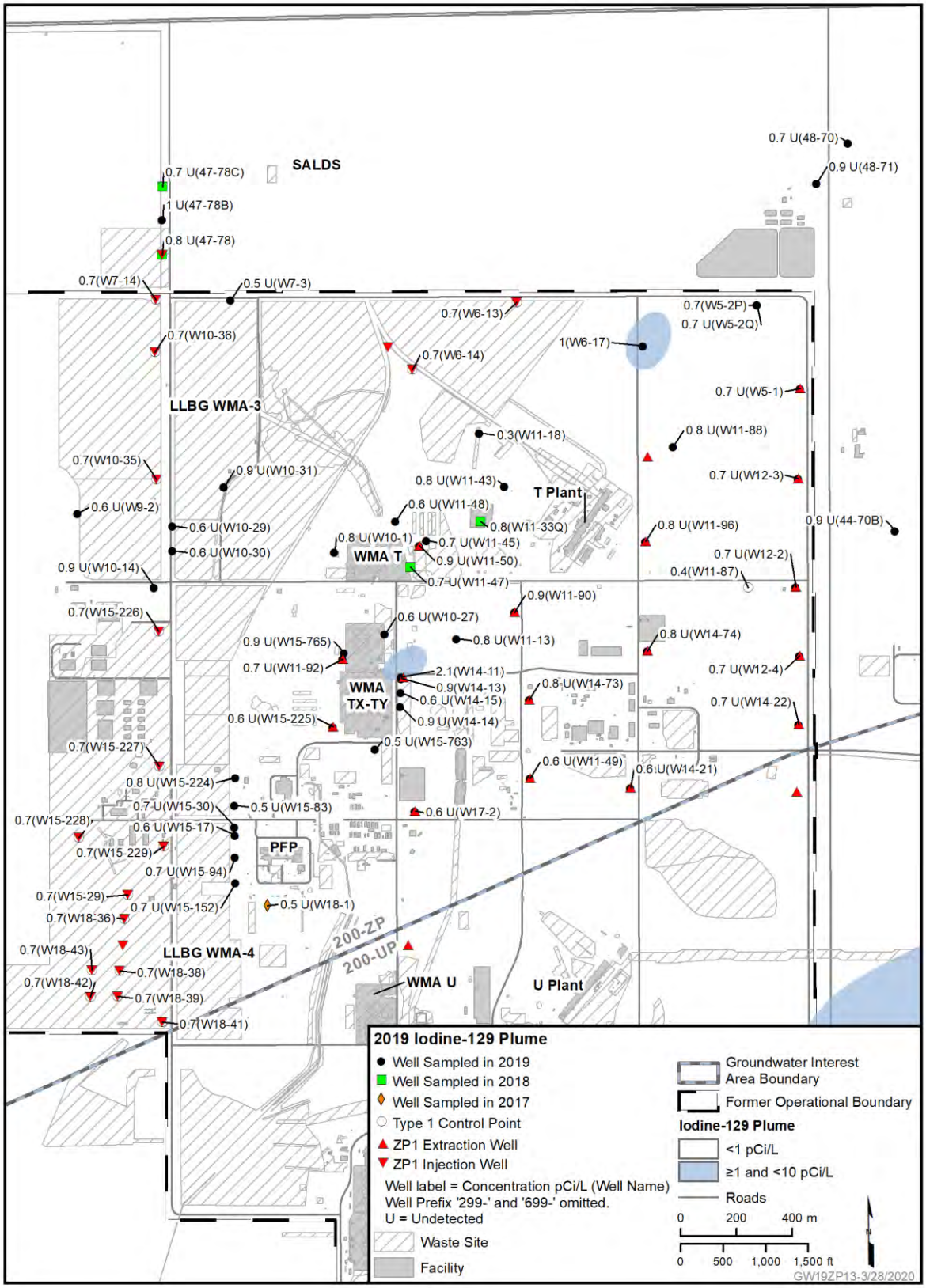


Figure 12-12. 200-ZP Iodine-129 Plume, 2019

12.5 Nitrate

Nitrate concentrations greater than the final cleanup level (45 mg/L as nitrate) are present beneath much of 200-ZP (Figure 12-13). Nitrate sources included liquid waste from PFP processes that was disposed to the cribs near WMA T and the 216-Z Cribs and Trenches.

In 2019, DOE initiated an optimization study (DOE/RL-2019-38) for the 200-ZP-1 OU to increase the treatment capacity for carbon tetrachloride (Section 12.10.2). One aspect of the optimization study involves suspending biological treatment for nitrate. Updated fate and transport modeling performed in support of the optimization study indicates that sufficient nitrate may already have been removed from the aquifer so nitrate treatment could be suspended and still meet the remedial objectives for nitrate within the timeframe stated in the 200-ZP-1 OU ROD (EPA et al., 2008). Biological treatment was suspended in October 2019, and effluent from the 200 West P&T subsequently had nitrate concentrations above the cleanup level. The effluent had an average nitrate concentration of 104 mg/L during the fourth quarter of 2019, which was an increase from 28 mg/L in 2018. For the 2019 nitrate plume map, control points representing the P&T injection wells were assigned concentrations of 104 mg/L. Considering current nitrate concentration trends and assuming there is no continuing source of nitrate, sufficient nitrate may have already been removed from the aquifer (2,186,276 kg as of December 2019) to enable a transition to the MNA phase of the 200-ZP-1 OU remedy for nitrate.

The 2019 nitrate plume (Figure 12-13) extends farther west than the 2018 plume (Figure 12-14 in DOE/RL-2018-66) because the control points used to represent the P&T injection wells had concentrations of 104 mg/L in 2019 compared to 28 mg/L in 2018. The nitrate concentration in the injected effluent averaged 104 mg/L in the fourth quarter of 2019 after treatment was suspended.

Within the nitrate plume, three discrete areas have concentrations >450 mg/L: (1) an area east of WMA T and WMA TX-TY, (2) an area in northeastern 200 West Area, and (3) an area near the 216-Z Cribs and Trenches. These plumes merge at the 45 mg/L contour, extending from the 216-Z Cribs and Trenches to beyond the 200 West Area boundary to the northeast (Figure 12-13). This combined plume is distributed throughout the entire thickness of the aquifer.

The high-concentration areas of the nitrate plume east of WMA T and WMA TX-TY are within the capture zones of 200 West P&T extraction wells. Figure 12-14 shows the nitrate trends in well 299-W10-28 (upgradient of WMA T) and wells 299-W14-16 and 299-W14-18 (downgradient of WMA TX-TY).

In the northeastern 200 West Area, nitrate is present throughout the entire aquifer thickness, with the highest concentrations near the bottom of the aquifer. Characterization samples from well 299-W5-2 in 2015 and well 299-W6-17 in 2019 had maximum nitrate concentrations of 753 and 435 mg/L, respectively. The screened intervals of wells 299-W5-2Q and 299-W6-17 were selected to monitor this deep interval, and concentrations in routine samples in 2019 were 531 and 434 mg/L, respectively. Nearby well 699-48-71 (screened at the top of the aquifer) had a concentration of 328 mg/L in 2019, which has been declining since 2013. The presence of nitrate in this region is likely due to the shifting regional nitrate plume and changes in groundwater flow. Injection wells to the east slow migration of the high-concentration portion of the nitrate plume.

The third area with nitrate concentrations >450 mg/L is monitored by well 299-W18-16, near the 216-Z Cribs and Trenches (Figure 12-15). The well was not sampled in 2019 because of temporary PFP boundary restrictions.

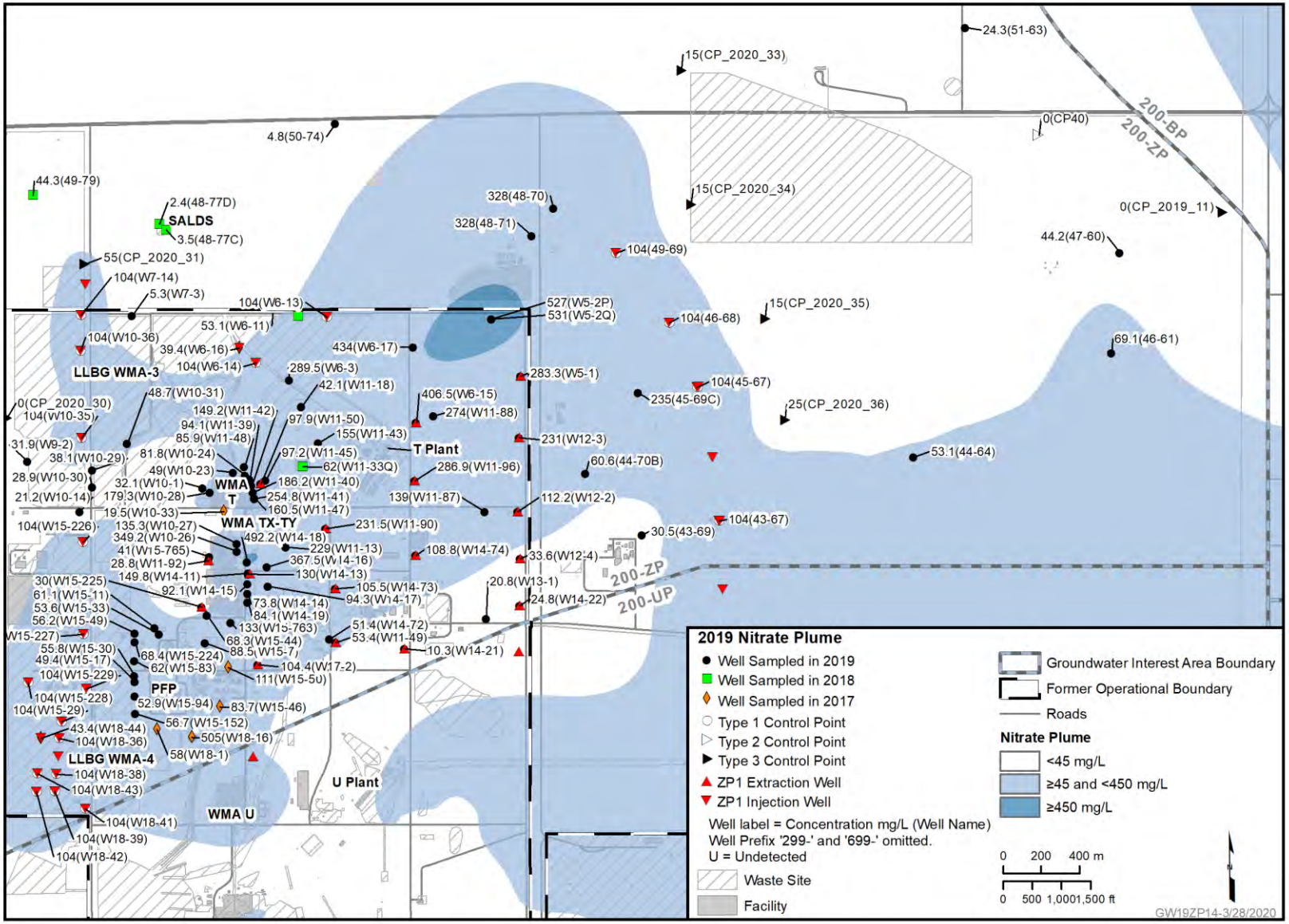


Figure 12-13. 200-ZP Nitrate Plume, 2019

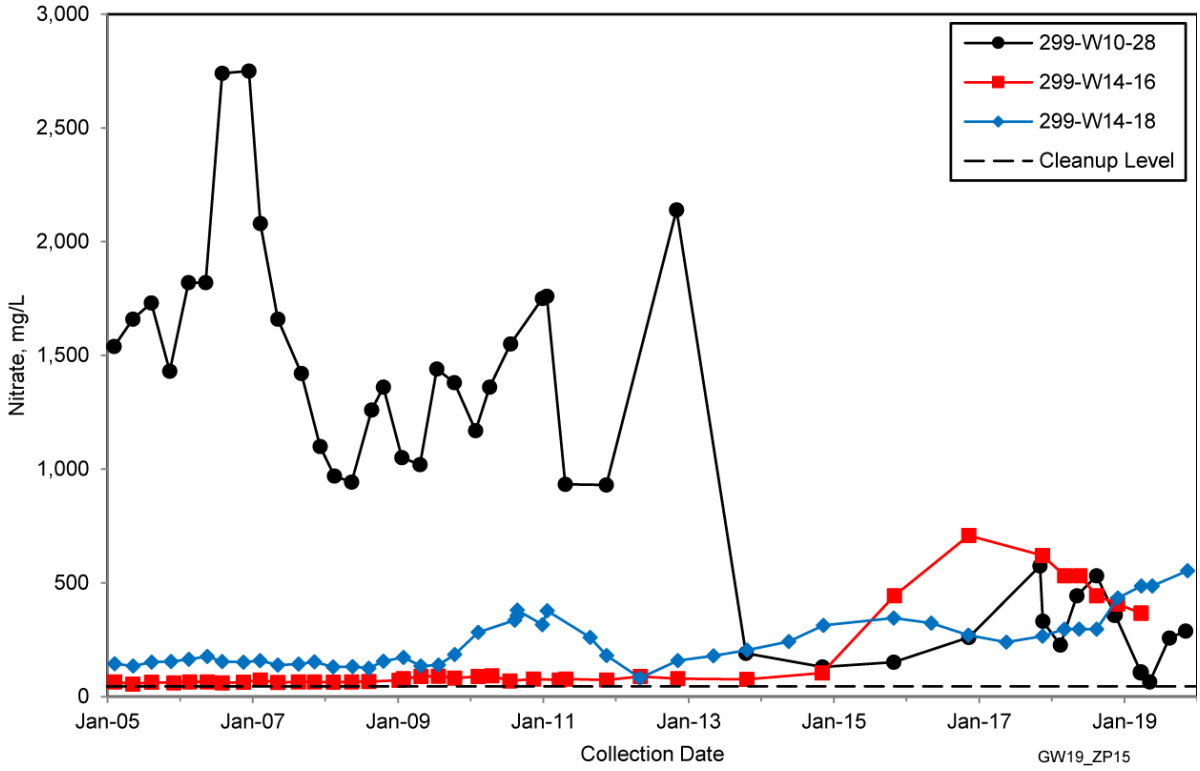


Figure 12-14. 200-ZP Nitrate Data in Wells 299-W10-28, 299-W14-16, and 299-W14-18

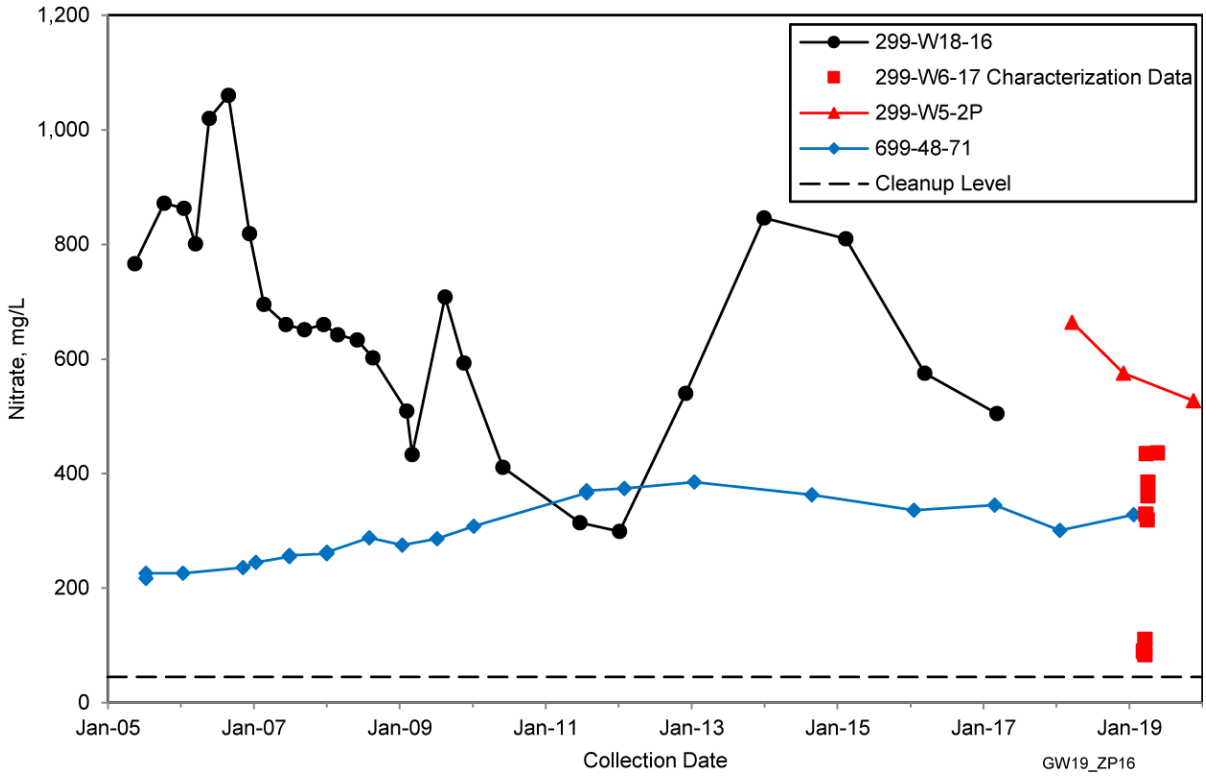


Figure 12-15. 200-ZP Nitrate Data in Wells 299-W5-2P, 299-W18-16, and 699-48-71

12.6 Technetium-99

Technetium-99 exceeded the 900 pCi/L final cleanup level in two distinct plumes east of WMA T and WMA TX-TY (Figure 12-16). Technetium-99 sources in 200-ZP were leaks from tanks and pipelines, and liquid waste disposal from plutonium-processing operations to cribs and trenches adjacent to the WMAs. Technetium-99 is found primarily in the upper 15 m (50 ft) of the unconfined aquifer (Section 2.8 in DOE/RL-2008-01). Technetium-99 exceeded the 900 pCi/L cleanup standard at four monitoring wells in the 200-ZP-1 OU in 2019, similar to 2018. The biggest increase in concentration was at monitoring well 299-W11-13 at 1,630 pCi/L in 2019 compared to 445.5 pCi/L in 2018, which increased the plume extent to near downgradient extraction well 299-W11-90.

After groundwater remediation at WMA T began in 2007, the technetium-99 plume moved toward the extraction wells, and concentrations increased in some monitoring wells and declined in other wells (Figure 12-17). The maximum concentration in the WMA T plume in 2019 was 25,200 pCi/L in monitoring well 299-W11-42, more than doubling since the last time the well was sampled in 2016. Well 299-W11-40 had a concentration of 11,100 pCi/L the last time the well was sampled in 2017. Since 2007, concentrations in well 299-W11-45 have declined from >20,000 pCi/L to below the cleanup level.

Groundwater extraction has occurred near WMA TX-TY since 2005. Concentrations in monitoring wells 299-W14-11 and 299-W14-13 (east of the WMA) have declined from their 2014 and 2015 peak values to below 5,000 pCi/L in 2019 (Figure 12-17). At well 299-W14-18, concentrations increased from 968 pCi/L in 2016 to 24,300 pCi/L in 2019, likely due to a continuing source. At well 299-W10-26, concentrations increased to 11,300 pCi/L in 2018 (not sampled for technetium-99 in 2019) compared to 1,520 pCi/L in 2012. Nearby extraction well 299-W14-20 (downgradient of WMA TX-TY) is screened across most of the aquifer thickness and has much lower concentrations. The extraction well draws in water from all directions and depths, so less-contaminated water is mixed with water from the plume. The extraction well data were not used to create the plume map provided in Figure 12-16. The plume extent at WMA TX-TY is defined to the north and south by wells 299-W10-27 and 299-W14-15, respectively, where concentrations consistently have been near or below the 900 pCi/L cleanup level.

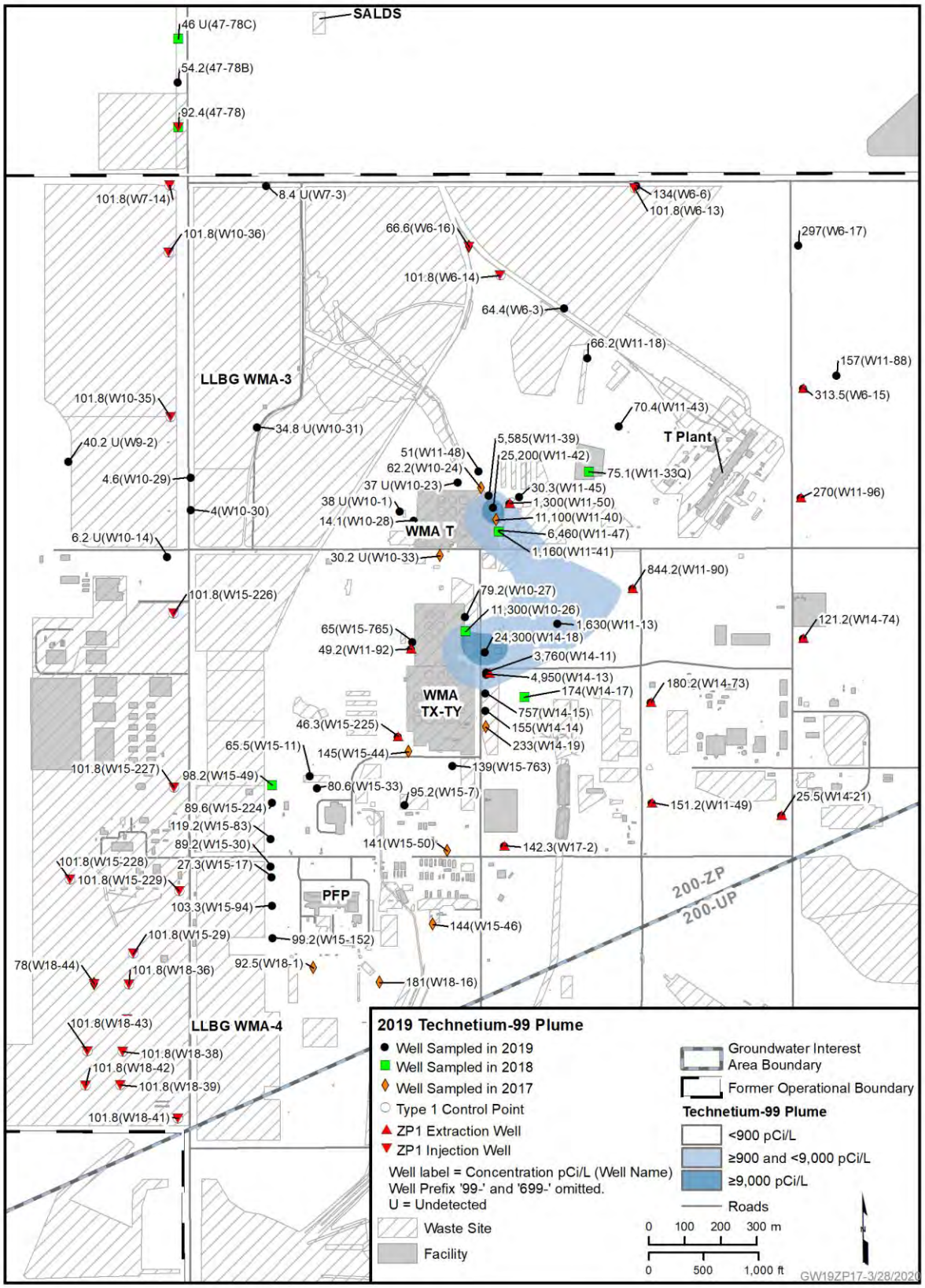


Figure 12-16. 200-ZP Technetium-99 Plume, 2019

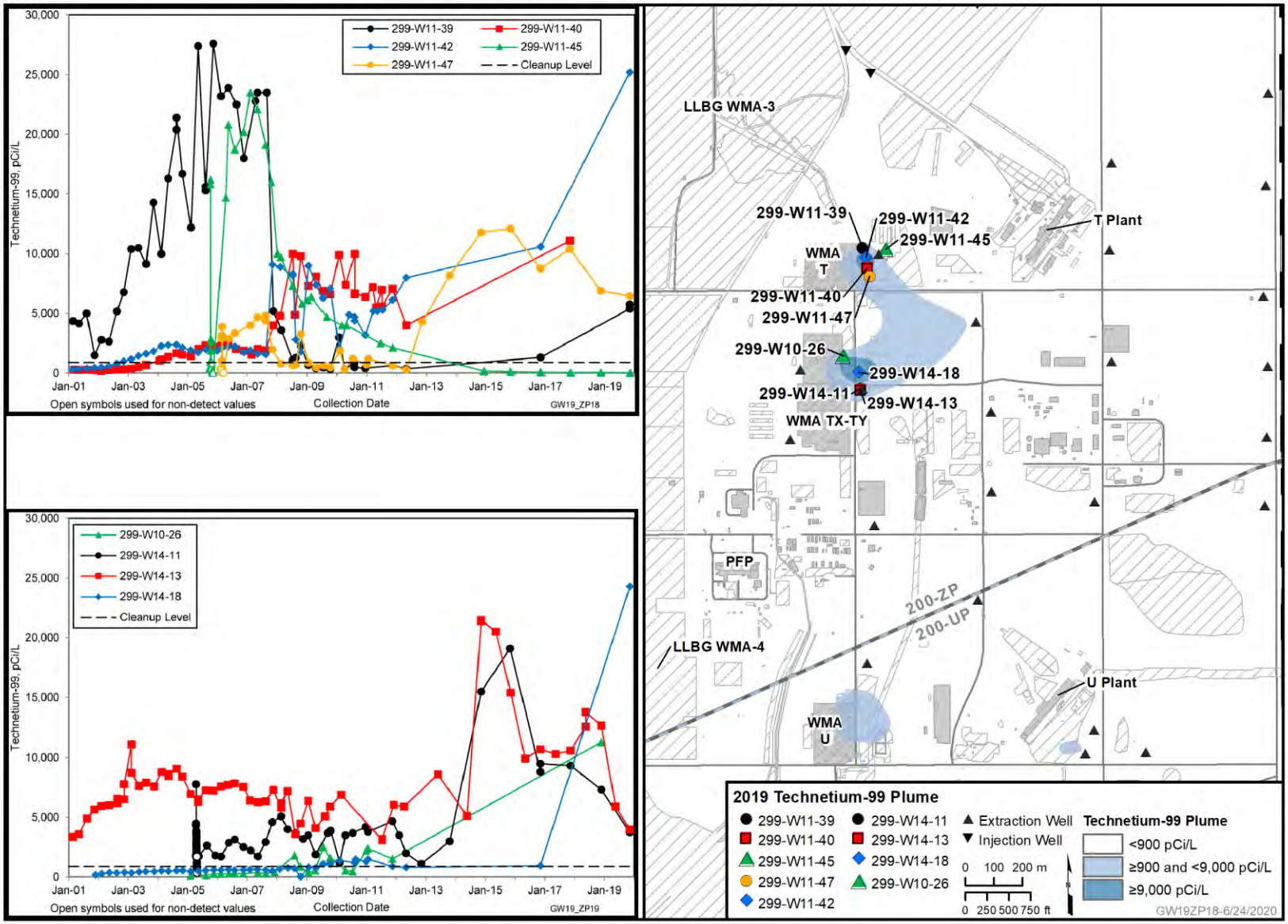


Figure 12-17. 200-ZP Technetium-99 Data in Wells East of WMA T and WMA TX-TY

12.7 Trichloroethene

TCE exceeds the 5 µg/L DWS beneath a portion of the 200 West Area (Figure 12-18). The 200-ZP-1 OU ROD (Table 11 in EPA et al., 2008) defines the final cleanup level as 1 µg/L.[15] The TCE plume is collocated with the carbon tetrachloride plume and is detected from the water table to the bottom of the aquifer. The interpreted plume size in 2019 was similar to 2018. The reported laboratory MDL for TCE was 0.25 to 0.33 µg/L in 2019.

The maximum TCE concentration in 2019 was 27.0 µg/L in a depth-discrete sample from monitoring well 299-W6-17, constructed in the northeastern 200 West Area in 2019. Concentrations declined in most wells, except those located near extraction wells. Extraction wells draw contaminated groundwater from the surrounding areas, effectively capturing contamination and temporarily increasing concentrations in nearby monitoring wells.

12.8 Tritium

Tritium concentrations in groundwater have declined below the 20,000 pCi/L cleanup level in most of 200-ZP due to radioactive decay, dispersion, and mixing from groundwater extraction and injection. The only results above the cleanup level in 2018 or 2019 were at two wells adjacent to the SALDS (Figure 12-19). Active permitted discharges at the SALDS are an ongoing source of tritium to groundwater in 200-ZP (Section 12.12).

Inactive tritium sources in 200-ZP were LWDFs associated with plutonium processing (including the 216-T-25 Trench) and past leaks from tanks and pipelines adjacent to WMA TX-TY. Outside of the SALDS plume, the highest concentration in 2019 was 15,300 pCi/L in monitoring well 299-W6-17 depth-discrete sampling during drilling (in the northeastern 200 West Area).

[15] DOE will clean up COCs for the 200-ZP-1 OU subject to MTCA (WAC 173-340) (carbon tetrachloride and TCE) so the excess lifetime cancer risk does not exceed 1×10^{-5} at the conclusion of the remedy.

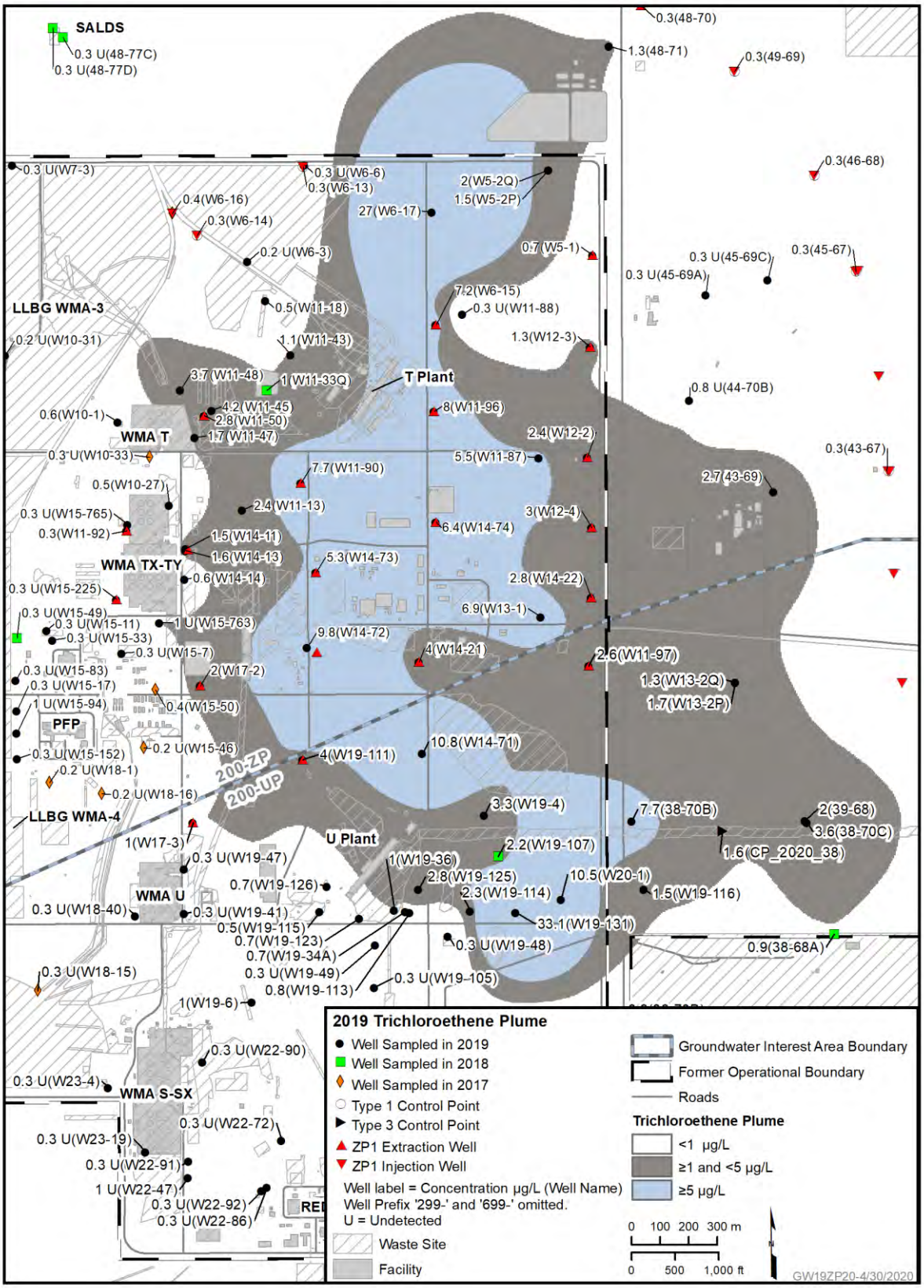


Figure 12-18. 200-ZP TCE Plume, 2019

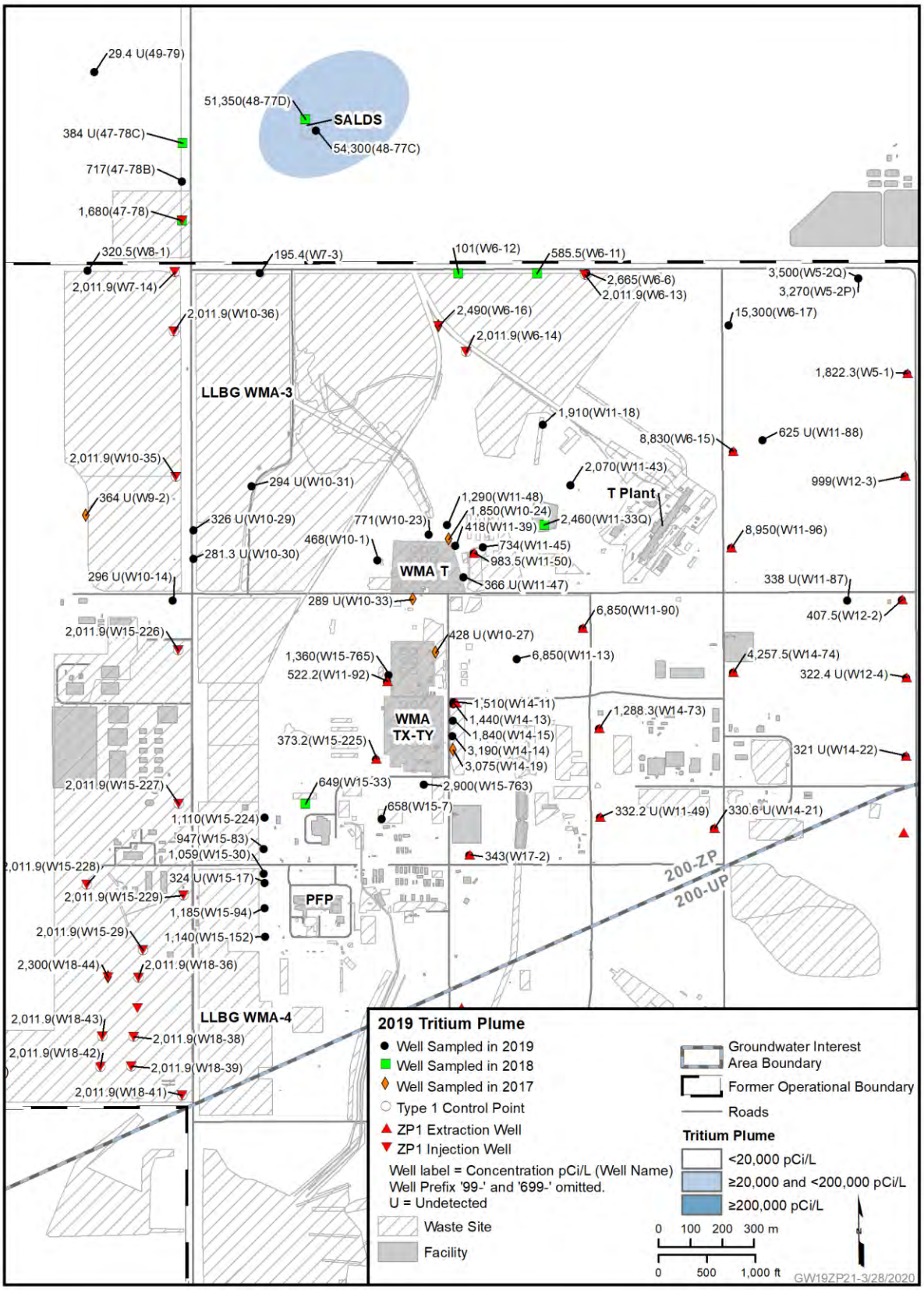


Figure 12-19. 200-ZP Tritium Plume, 2019

12.9 Cyanide

Cyanide is not a COC for the 200-ZP-1 OU, but cyanide contamination has been observed downgradient of WMA T and WMA TX-TY since 2003. Ferrocyanide was used to form precipitates to bind with (scavenge) cesium-137 in underground storage tanks. Once the chemicals were added to the tanks, settling was allowed to occur for 7 to 10 days, and then the supernatant was decanted and discharged to the ground via cribs and trenches. Tanks T-107, TX-118, TY-101, TY-103, and TY-104 were used for the scavenging process in WMA T and WMA TX-TY.

In 2019, WMA TX-TY wells 299-W10-26 and 299-W14-18 had total cyanide concentrations exceeding the 200 µg/L DWS for free cyanide[16]. These wells were sampled monthly for total and free cyanide and, as shown in Figure 12-20, free cyanide concentrations were much lower than total cyanide. Well 299-W14-11 is no longer sampled monthly since total cyanide concentrations have dropped below the 200 µg/L free cyanide DWS. Wells 299-W10-27 and 299-W14-13 were also sampled for total and free cyanide in 2019. The highest free cyanide concentration was 24.5 µg/L in well 299-W10-26 (greater than the 4.8 µg/L MTCA standard [WAC 173 340]). Section 12.11.2 includes additional discussion of cyanide at WMA TX-TY.

12.10 CERCLA Remediation and Monitoring

This section summarizes CERCLA activities for 200-ZP OU in 2019.

12.10.1 CERCLA Decision Documents and Plans

Groundwater contaminants are being remediated under a CERCLA ROD (EPA et al., 2008). The selected remedy in the ROD consists of a combination of MNA, institutional controls, flow-path control, and P&T.

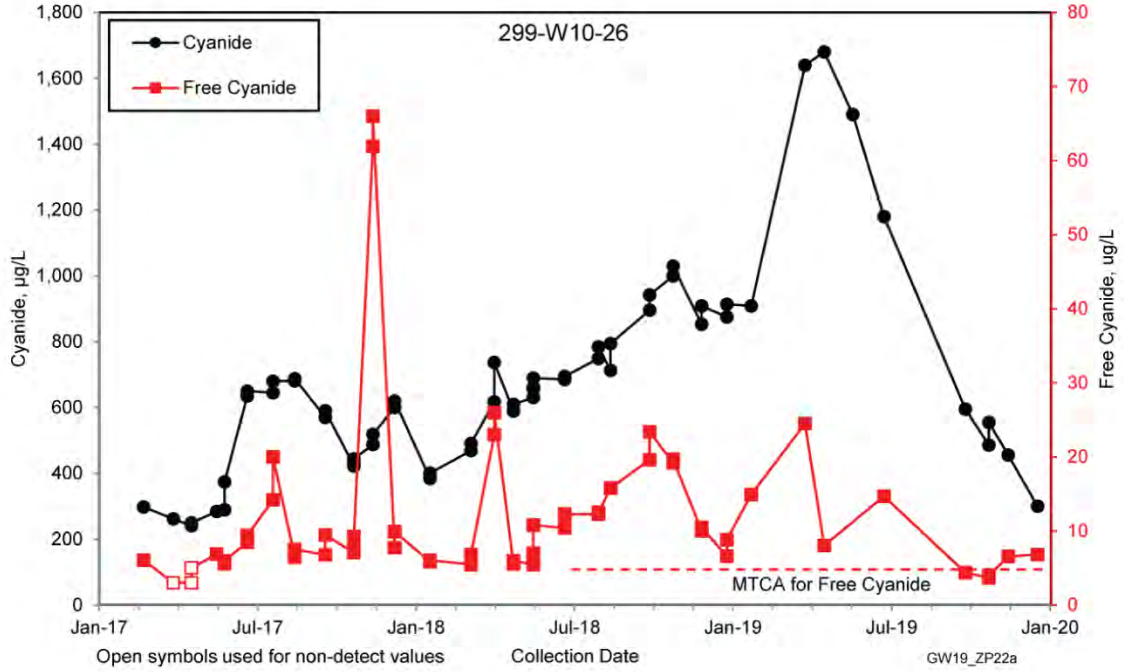
DOE/RL-2008-78, *200-ZP-1 OU Remedial Design/Remedial Action Work Plan*, outlines the remediation targets and goals necessary to achieve the selected remedy of P&T, flow-path control, MNA, and institutional controls as specified in the 200-ZP-1 OU ROD (EPA et al., 2008). The 200-ZP performance monitoring plan (DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*) requires groundwater monitoring activities associated with the 200-ZP-1 OU remedial action. Table A-1 in Appendix A lists the 2019 groundwater sampling exceptions. The operations and maintenance plan (DOE/RL-2009-124, *200 West Pump and Treat Operations and Maintenance Plan*) outlines the activities necessary to operate, maintain, and monitor performance of the 200 West P&T, from startup of operations through decommissioning of the system.

12.10.2 Pump and Treat

The 200 West P&T (Figure 12-21) began operating in 2012 and operated continuously during 2019. DOE/RL-2019-68 provides additional information about the 200 West P&T.

As of December 2019, the final remedy P&T, the former interim remedy P&T, and vapor extraction systems have removed 111,058 kg of carbon tetrachloride from the subsurface. Remediation also removes other contaminants including chromium, nitrate, TCE, and technetium-99 (Table 12-2).

[16] Total cyanide methods are allowed for screening but cyanide is regulated as free cyanide, and the 200 µg/L DWS applies to free cyanide. Total cyanide concentrations in groundwater are much higher than free cyanide concentrations. Section 9.7 provides additional information.



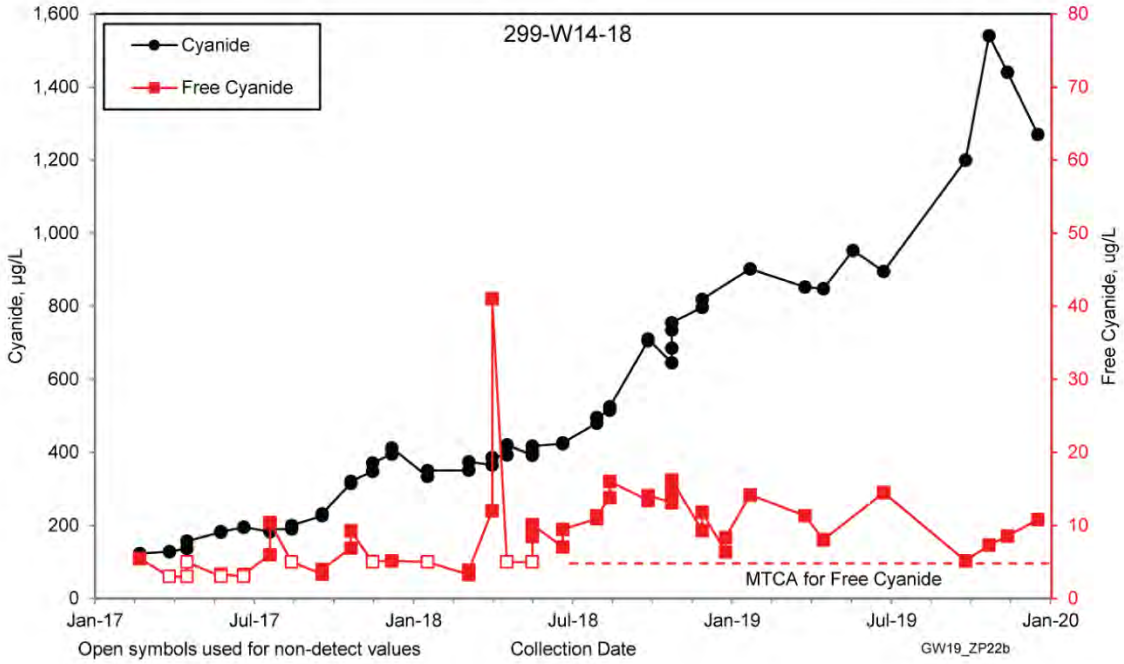


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Figure 12-20. Total and Free Cyanide in WMA TX-TY Wells 299-W10-26 and 299-W14-18

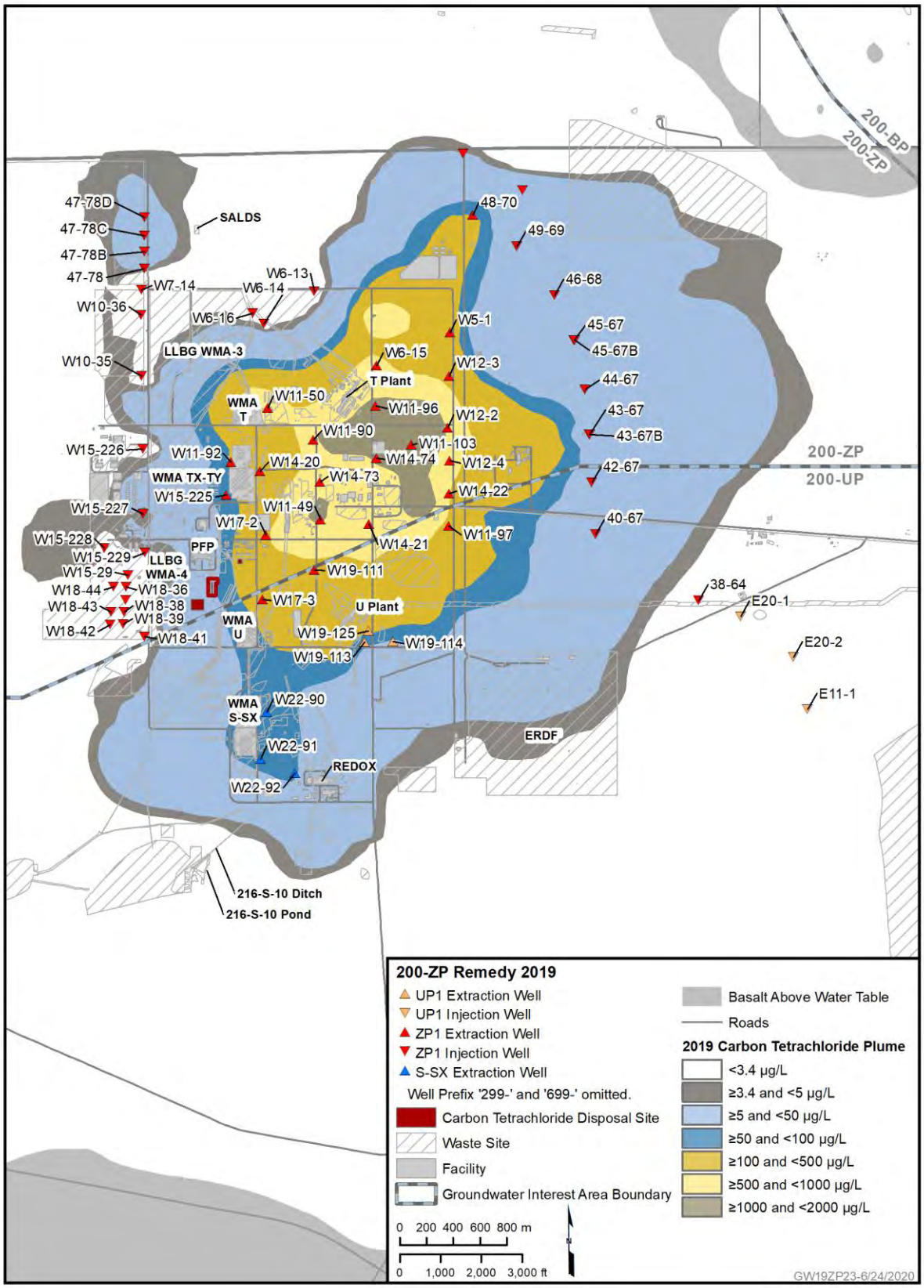


Figure 12-21. 200 West Extraction and Injection Well Network

Table 12-2. 200-ZP-1 Remedy Summary

Monitored Natural Attenuation (2012–2019)				
Dispersion of all COCs				
Radioactive decay of tritium				
Current 200 West P&T				
		2019		**2012–2019**
Extraction wells		33		—
Injection wells		31		—
Volume processed, million L (million gal)		4,237.8 (1,118.7)		25,642.7 (6,769.7)
Contaminant	**Average 2019 Influent Concentration**	**Average 2019 Effluent Concentration**	**Mass Removed in 2019**	**Cumulative Mass Removed, 2012–2019**
Carbon tetrachloride	377 µg/L	<0.37 µg/L	1,917 kg	17,040 kg
Chromium	28.5 µg/L	7.7 µg/L	68.52 kg	505.77 kg
Iodine-129	1.5 pCi/L	<7.1 pCi/L	Footnote a	N/A
Nitrate as NO_3	125.2 mg/L	49.7 mg/L[b]	245,982 kg	2,186,276 kg
Technetium-99	1,442 pCi/L	102 pCi/L	1.85 Ci / 108.8 g	13.2 Ci / 774.1 g
Trichloroethene	2.76 µg/L	<0.3 µg/L	10.5 kg	76.0 kg
Tritium	2,165 pCi/L	2,012 pCi/L[b]	Footnote b	N/A
Uranium[c]	169 µg/L	1.0 µg/L	102.98 kg	630.62 kg
Former 200-ZP-1 P&T Systems, 1994–2012				
Carbon tetrachloride mass removed, kg			13,911	
Former Soil Vapor Extraction, 1992–2012				
Carbon tetrachloride mass removed, kg			80,107	

a. No treatment for iodine-129 or tritium; mass removal not calculated.

b. Biological treatment for nitrate was suspended in October 2019. The average effluent concentration in 2019 while biological treatment was operating was 31.5 mg/L and increased to an average of 104 mg/L after shutdown.

c. Uranium is not a 200-ZP-1 OU COC. It is included for groundwater treated for the 200-UP-1, 200-DV-1, and 200-BP-5 OUs.

COC = contaminant of concern
N/A = not applicable
OU = operable unit
P&T = pump and treat

Currently, the 200 West P&T has a maximum 9,500 L/min (2,500 gal/min) flow capacity and a sustained operating capacity of approximately 7,600 L/min (2,000 gal/min), and it is designed to capture and treat contaminated groundwater and reduce the mass of COCs. Future maximum design capacity will be upgraded to 14,200 L/min (3,750 gal/min) for air stripping and granular activated carbon. The P&T system removes COCs from groundwater using ion exchange, anoxic and aerobic bioreactors (biological treatment was suspended in October, 2019), and air stripping. The remedial action is designed to include MNA as part of the remedy for portions of the plumes outside the P&T capture zone and when the P&T system is shut off.

In 2019, DOE began implementing an optimization study for the 200-ZP-1 OU after assessing the 200 West P&T system configuration performance of the first 6 years of operation (DOE/RL-2019-38). Implementing the study will increase the likelihood of achieving cleanup of carbon tetrachloride in the timeframe specified in the 200-ZP-1 OU ROD (EPA et. al, 2008). Computer simulations evaluated alternative P&T configurations to accelerate remediation of the carbon tetrachloride plume in Ringold unit E. Optimization efforts will continue to investigate different configurations. One aspect of the optimization study increases P&T operating capacity by suspending biological treatment for nitrate (see discussion in Sections 12.2 and 12.5) and using MNA as the future treatment for nitrate. The P&T encountered difficulties in maintaining injection well capacity due to organic and inorganic materials from the biotreatment process fouling the wells, which necessitated frequent well cleaning and numerous treatment facility infrastructure and operational changes. For the duration of the optimization study (5 to 7 years), nitrate will be reinjected into the aquifer at concentrations up to three times the cleanup level. Other aspects of the optimization study involve adding a third air stripper and additional optimized extraction and injection wells for a maximum design capacity of 14,200 L/min (3,750 gal/min). Implementation of these changes are necessary to accommodate greater total overall operating capacity for the 200 West P&T.

The 200 West P&T (Figure 12-21) is designed to capture contamination within the 200-ZP-1 OU (see Figure 12-5 for Ringold lower mud cross section for reference). The extraction wells are 20 cm (8 in.) in diameter with screens more than 30 m (98 ft) long, placed within 3 m (10 ft) of the bottom of each well. Aquifer testing was used to ensure that well spacing would be sufficient to capture contamination throughout the aquifer (Section 2.2 in DOE/RL-2010-13). The estimated hydraulic capture is based on particle tracking (Figure 12-22), as discussed in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*.

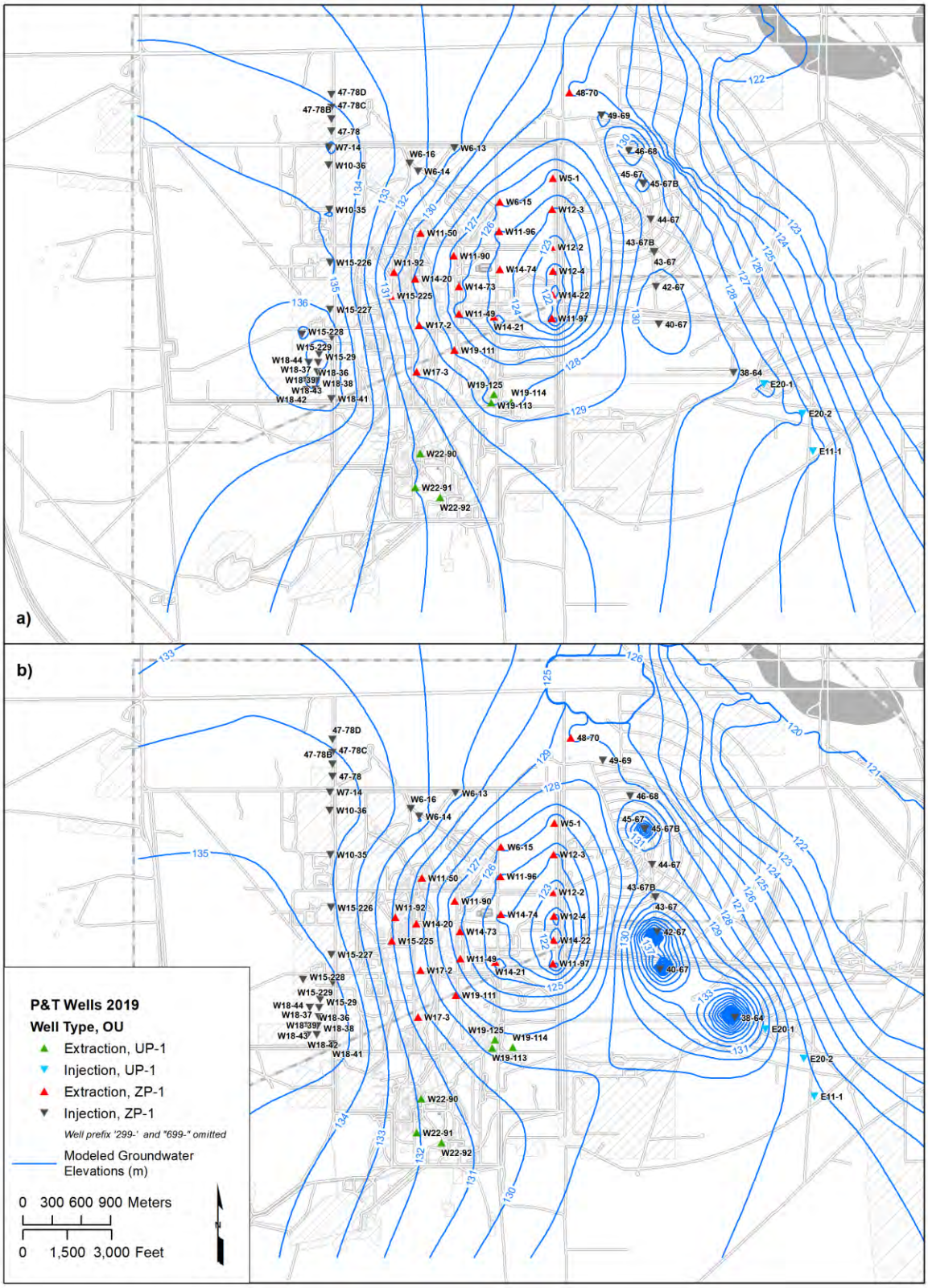


Figure 12-22. 200-ZP Groundwater Elevation Contours: (a) Above the Lower Mud at the End of 2019; (b) Below the Lower Mud at the End of 2019

DOE began analyzing 200 West Area effluent for total cyanide in 2015 and free cyanide in 2017 because perched water from the 200-DV-1 OU and groundwater from the 200-BP-5 OU (which contains cyanide [Section 9.7]) began to be treated in the 200 West P&T. Most results for 200 West Area effluent were below or near detection limits, with a maximum total cyanide concentration of 5 µg/L. The DWS and MTCA Method B (WAC 173-340) standard for free cyanide are 200 µg/L and 4.8 µg/L, respectively.

Except for nitrate, residual COC concentrations in the treated water were at or below cleanup levels. The treated water was returned to the aquifer via the injection well network. One additional injection well and one additional extraction well were installed in 2019 (Table 12-3) and were not yet connected to the system in 2019.

12.11 RCRA Monitoring

DOE/RL-2019-65 presents the results of RCRA monitoring on the Hanford Site in 2019. This section repeats that information for RCRA units in 200-ZP, including the SST farms. Some of these units are monitored under RCRA requirements for dangerous waste constituents and under AEA for source, special nuclear, and byproduct materials.

The 200-ZP interest area contains four RCRA sites with groundwater monitoring requirements: WMA T, WMA TX-TY, LLBG WMA-3, and LLBG WMA-4. Interim status groundwater quality assessment monitoring was conducted at WMA T and WMA TX-TY (40 CFR 265.93(d), as referenced by WAC 173-303-400). Interim status indicator parameter evaluation monitoring was conducted at LLBG WMA-3 and LLBG WMA-4 (40 CFR 265.92 and 40 CFR 265.93(b), as referenced by WAC 173-303-400). The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for the reporting period. LLBG WMA-3 and LLBG WMA-4 also have AEA monitoring conducted under a performance assessment monitoring plan (DOE/RL-2000-72), as discussed in Section 12.13.

Groundwater data are available in the HEIS database at https://ehs.hanford.gov/eda/. Appendix B includes well and constituent lists, flow rates, and statistical tables.

12.11.1 Waste Management Area T

WMA T (Figure 12-23), which includes the T Tank Farm, is located in the northern portion of the 200 West Area. WMA T contains 16 underground SSTs constructed in 1943 and 1944. Tanks T-101 through T-112 have capacities of 2,000,000 L (528,000 gal), and tanks T-201 through T-204 have capacities of 208,000 L (55,000 gal). WMA T also includes diversion boxes, ancillary pumps, valves, and pipes.

The tanks in WMA T began receiving waste in 1944 and were in almost continual use until 1980, when all of the tanks in the WMA were removed from service. The SSTs received transuranic, high-level metal, and first-cycle waste from chemical processing of uranium-bearing, irradiated reactor fuel rods. Lesser amounts of other waste also were stored in the WMA T tanks. WHC-MR-0132; WRPS-55779-FP, *Hanford Tank Waste to WIPP – Maximizing the Value of our National Repository Asset – 14230*; and RPP-7218, *Preliminary Inventory Estimates for Single-Shell Tank Leaks in T, TX, and TY Tank Farms*, provide more detailed information on WMA T waste inventory. Most of the drainable liquid in each tank has been removed, and the tanks have been interim stabilized. As an interim corrective action, berms were constructed around the tank farms in 2001 to stop run-on of natural precipitation, and all known water lines were tested or cut off. In 2008, interim surface barriers were placed over the tanks in WMA T to inhibit precipitation infiltration.

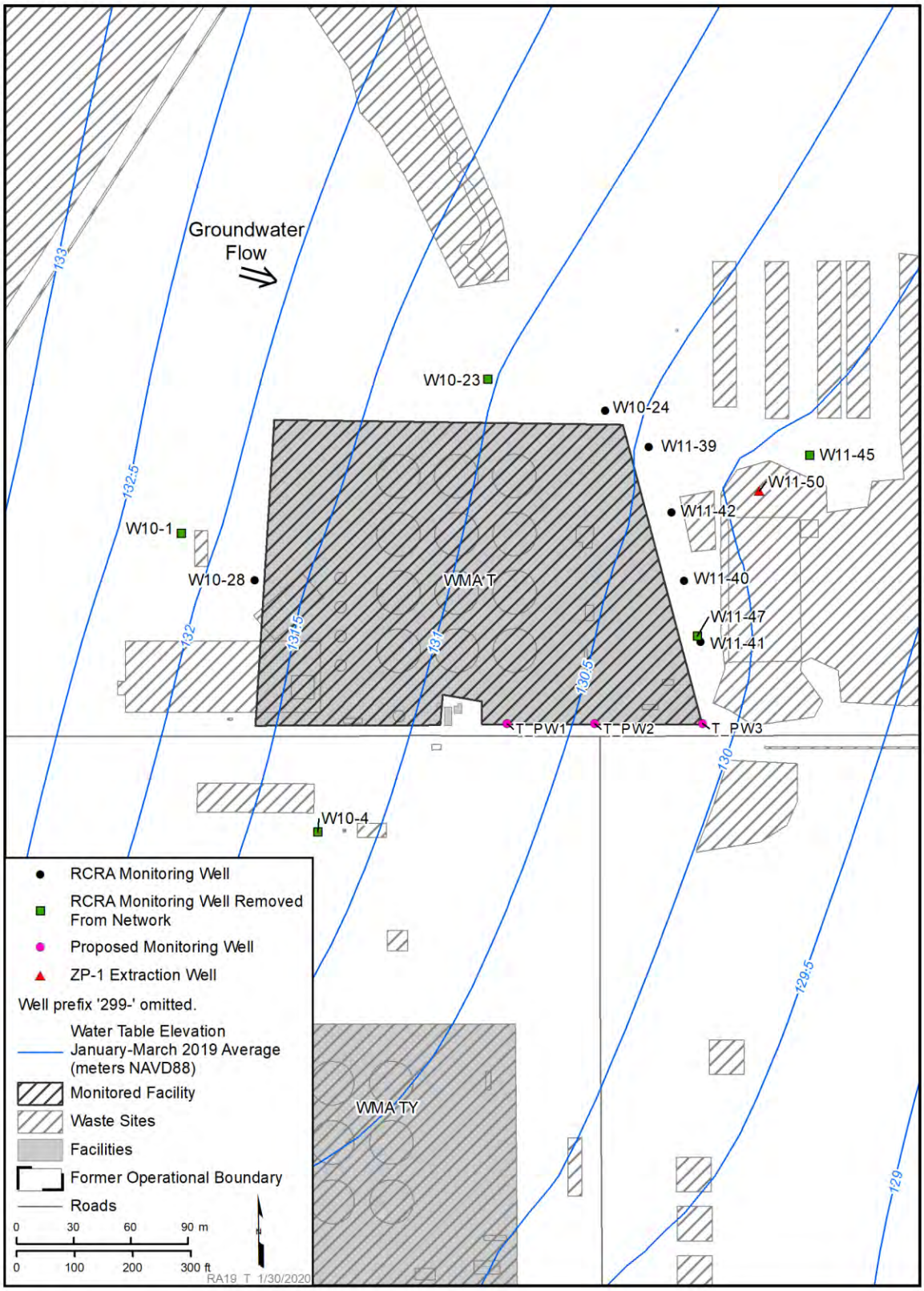
Table 12-3. Wells Installed in 200-ZP in 2019

Well Name	Well ID	Well Purpose*	Drill Depth (ft bgs)	Drill Depth (m bgs)	Construction Depth (ft bgs)	Construction Depth (m bgs)	Accepted Date	Comment
299-W6-17	C9738	Monitoring	489.0	149.0	442.8	135.0	7/11/2019	
699-44-70B	C9740	Monitoring	510.7	155.7	423.3	129.0	7/11/2019	
699-46-61	C9936	Monitoring	356.0	108.5	317.2	96.7	5/6/2019	
699-47-78B	C9879	Injection	480.7	146.5	405.4	123.6	9/30/2019	Well is pending operation for 2021
699-48-70	C9988	Extraction	401.8	122.5	370.5	112.9	9/30/2019	Well is pending operation for 2020

*From DOE/RL-2010-72, *Sampling and Analysis Plan for Remediation Wells in the 200-ZP-1 Operable Unit*, as modified by TPA-CN-641, TPA-CN-0758, TPA-CN-0794, TPA-CN-0818, TPA-CN-0833, and TPA-CN-0876.

bgs = below ground surface

ID = identification



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 12-23. Waste Management Area T

WMA T was placed in assessment in 1993 due to elevated specific conductance. Chromium is a dangerous waste constituent monitored under the RCRA assessment program. Past leaks from SSTs and waste pipelines within the WMA are the sources of chromium contamination, described in DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T*.

Revision 2 of the assessment plan (DOE/RL-2009-66), issued in 2019, implemented the monitoring network recommended in SGW-60575, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area T Groundwater Monitoring*, including three proposed new wells (Table B-58 in Appendix B). Water-level predictions indicate that all of the wells will have sufficient water for continued sampling through at least 2028 (SGW-63743). In 2019, the wells were sampled as planned (Table B-58 in Appendix B).

Extraction wells east of the WMA affect local groundwater flow (Figure 12-23). Groundwater generally flows to the east-southeast with a gradient of 6.8×10^{-3} m/m. The estimated groundwater and contaminant flow rate beneath WMA T is 0.23 m/d (0.75 ft/d) (Table B-2 in Appendix B). The direction of groundwater flow is not expected to change with continued operation of the 200 West P&T.

Table B-59 in Appendix B summarizes the monitoring results for 2019. Concentrations of the dangerous waste constituent chromium were below the 100 µg/L DWS in all filtered samples. Concentrations of chromium and Cr(VI) were above the 48 µg/L MTCA standard (WAC 173-340) for Cr(VI) in wells 299-W10-28 and 299-W11-41.

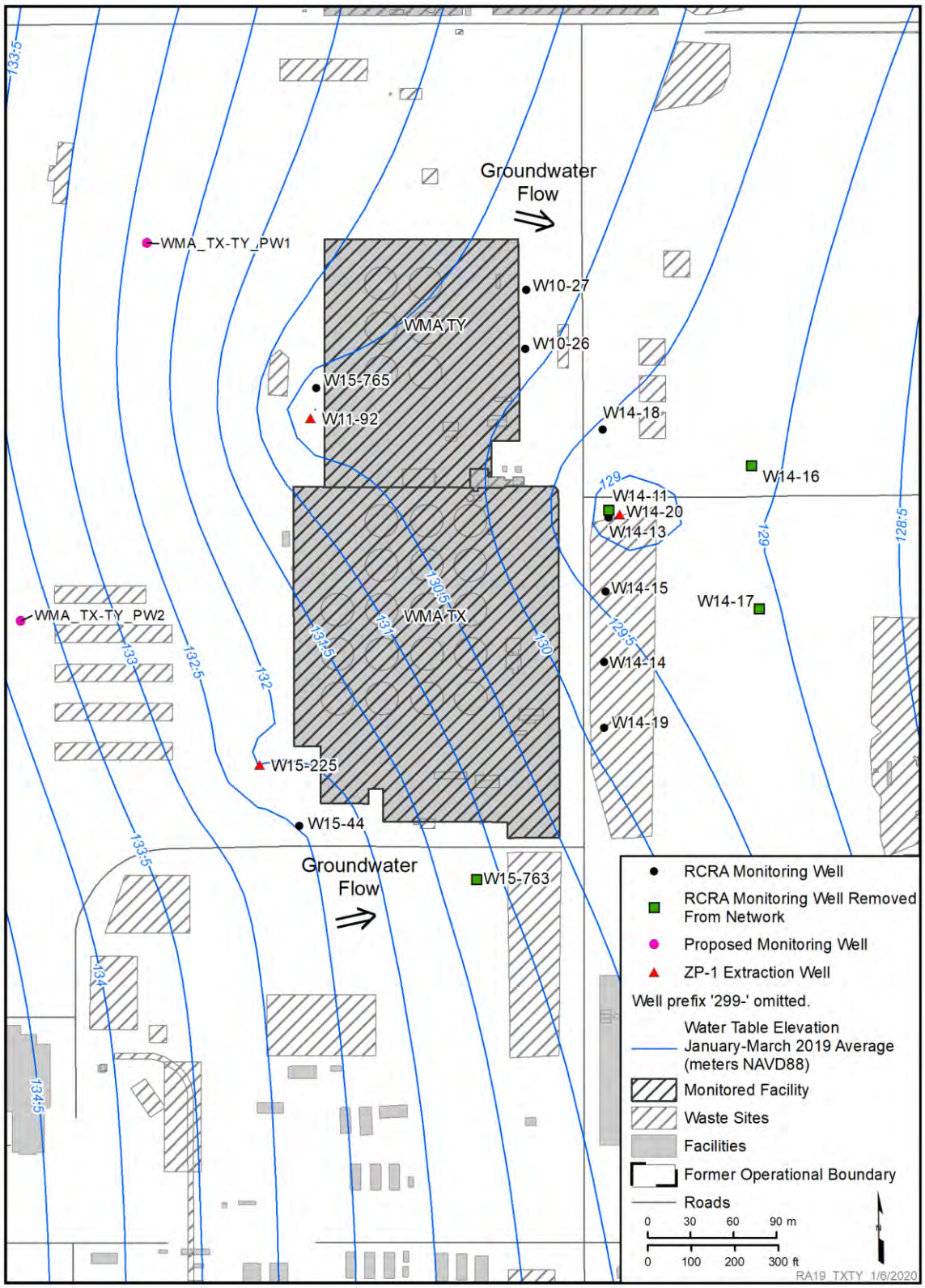
Nitrate is also found in groundwater beneath the WMA and is from the same source as the Cr(VI). The nitrate plume beneath WMA T is within a regional nitrate plume and did not change substantially between 2018 and 2019; however, the maximum concentrations for the network overall decreased. The highest nitrate concentrations in 2019 were in upgradient well 299-W10-28 (288 mg/L in November 2019) and downgradient well 299-W11-41 (292 mg/L in March 2019). While WMA T is a source of nitrate, other upgradient sources are larger contributors.

In 2019, fluoride concentrations were above the primary DWS (4 mg/L) in wells 299-W10-24 and 299-W11-39, which is consistent with previous results.

Iron concentrations were above the secondary DWS in unfiltered samples from several wells (Table B-59 in Appendix B).

12.11.2 Waste Management Area TX-TY

WMA TX-TY (Figure 12-24), which includes the TX and TY Tank Farms, is located in the northern portion of the 200 West Area. The WMA contains 24 underground SSTs constructed in 1947 and 1948 for the TX Tank Farm and in 1951 and 1952 for the TY Tank Farm. Each tank has a capacity of 2.84 million L (750,000 gal). In addition to the tanks, six diversion boxes and ancillary pumps, valves, and pipes are included in the Hanford RCRA Permit Part A Form for the SSTs in the TX-TY Tank Farms system.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 12-24. Waste Management Area TX-TY

The tanks in WMA TX-TY began receiving waste in 1949, with the tanks in both farms used to support the bismuth phosphate process and the uranium recovery program. Some of the tanks also received waste from REDOX and PUREX Plant operations. Detailed information for WMA TX-TY is provided in DOE/RL-2009-67, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY*. Most of the drainable liquid in the tanks has been removed, and the tanks have been interim stabilized. As an interim corrective action, berms were constructed around the tank farms in 2001 to stop the run-on of natural precipitation, water lines were pressure tested and repaired, and lines no longer needed were cut and capped. Interim surface barriers were placed over tanks in the TY Tank Farm in 2011 to inhibit precipitation infiltration.

WMA TX-TY is regulated under RCRA, and its implementing requirements were revised in 2019 (DOE/RL-2009-67). WMA TX-TY is monitored under an interim status assessment program due to elevated specific conductance in two downgradient wells in 1993. The dangerous waste constituent chromium was monitored under the WMA TX-TY RCRA assessment program during the reporting period.

The revised assessment plan (DOE/RL-2009-67) implements the monitoring network recommended in SGW-60576, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area TX-TY Groundwater Monitoring* (Table B-60 in Appendix B). Two new upgradient wells are proposed for installation in 2021, and existing wells 299-W15-44 and 299-W15-765 are being monitored until the new wells are installed. Water-level predictions indicate that all of the wells (except 299-W14-13) will have sufficient water for continued sampling through at least 2028 (SGW-63743). Well 299-W14-13 is predicted to be sample dry in 2028, but its use could be extended by sampling with a low-flow pump.

The 200 West P&T extraction wells on the east, west, and south sides of the WMA alter the groundwater flow direction and hydraulic gradients (Figure 12-24). Based on 2019 water-level data, the overall flow direction is toward the east-southeast, but local directions vary from southeast to east-northeast. The hydraulic gradient averaged 9.2×10^{-3} m/m, and the groundwater and contaminant flow rate was estimated at 0.31 m/d (1.0 ft/d) (Table B-2 in Appendix B).

Quarterly sampling continued in 2019. All of the WMA TX-TY wells scheduled for sampling in February were sampled in March 2019 due to PFP radiological controlled area restrictions. Table B-61 in Appendix B summarizes the monitoring results for 2019.

Total chromium concentrations were below the 100 µg/L DWS in all filtered samples in 2019. Total chromium and Cr(VI) were above the 48 µg/L MTCA standard (WAC 173-340) for Cr(VI) in wells 299-W10-26, 299-W14-16, and 299-W14-18. The 2019 maximum Cr(VI) concentration was 116 µg/L in well 299-W14-16 in March 2019, which was lower than the 2018 maximum of 140 µg/L. The source of dissolved chromium was past leaks from tanks and pipelines at WMA TX-TY (Section 2.1 in SGW-60576).

The maximum total chromium concentration in an unfiltered sample in 2019 was 167 µg/L in well 299-W14-16. This was higher than the Cr(VI) concentration, indicating the presence of undissolved trivalent chromium, possibly due to stainless-steel corrosion. Aluminum was elevated in unfiltered samples from many of the wells, likely due to particulate matter from aquifer sediments.

During 2019, nitrate concentrations remained above the 45 mg/L DWS in all network wells except 299-W15-765. Maximum concentrations declined from 3,600 mg/L at well 299-W14-11 in 2005 to 553 mg/L at well 299-W14-18 in 2019. Most of the nitrate contamination is attributed to PFP operations, as well as past-practice disposal to cribs and trenches in the area.

Although not required under DOE/RL-2009-67, total and free cyanide continued to be analyzed at many of the WMA TX-TY wells in 2019. Total cyanide concentrations were >200 µg/L in wells 299-W10-26 and 299-W14-18 (Figure 12-20). The highest free cyanide concentration was 24.5 µg/L in well 299-W10-26 (greater than the 4.8 µg/L MTCA standard [WAC 173-340]).

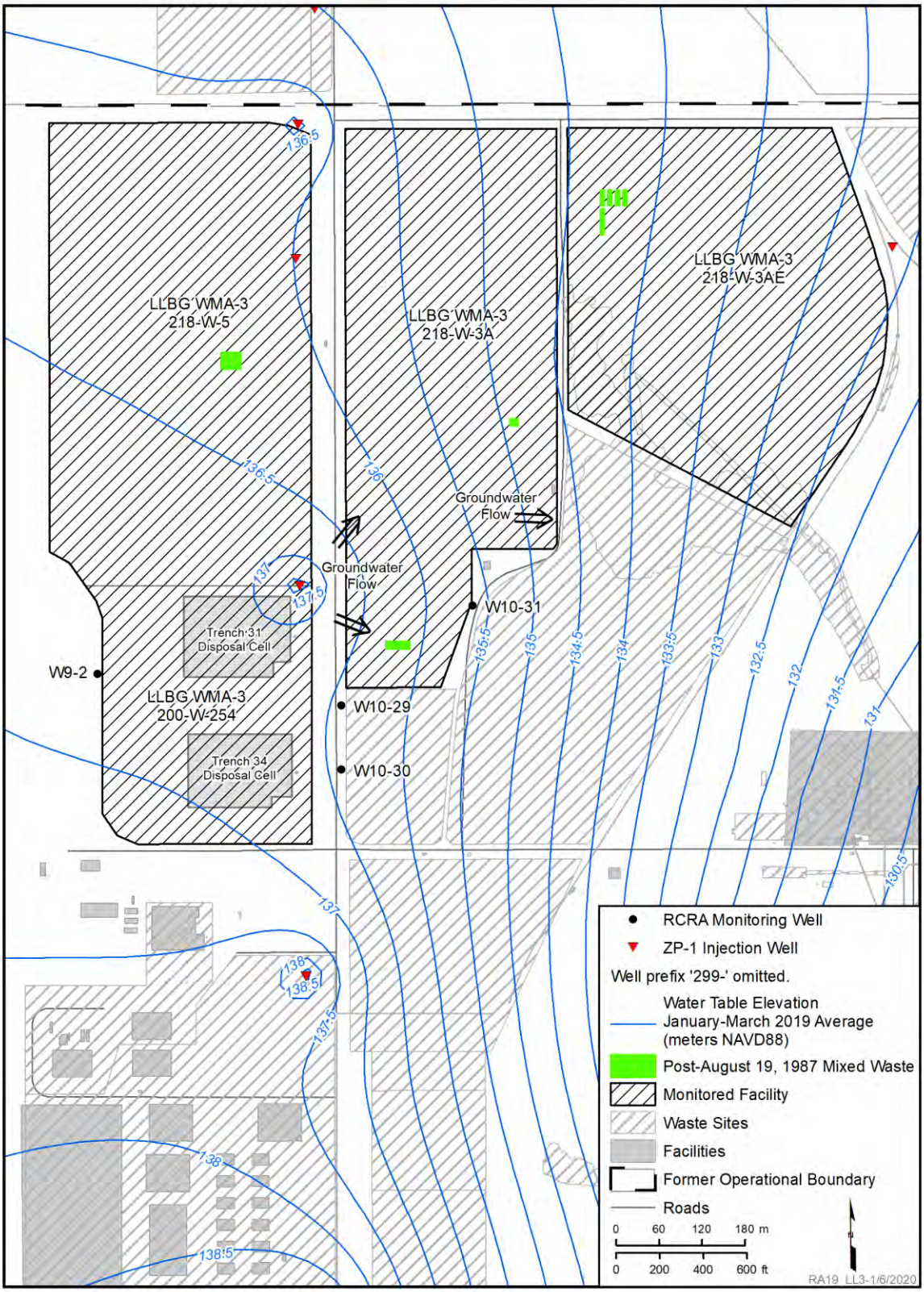
12.11.3 Low-Level Burial Grounds Waste Management Area 3

LLBG WMA-3 (Figure 12-25) is located in the northwest quadrant of the 200 West Area and has four burial grounds (218-W-3A, 218-W-3AE, 218-W-5, and 200-W-254) within its boundary. The 218-W-3A Burial Ground (0.204 km^2 [0.079 mi^2]) has 57 unlined trenches and operated between 1970 and 1998. The 218-W-3AE Burial Ground (0.200 km^2 [0.077 mi^2]) has eight unlined trenches and operated between 1981 and July 2004. The 218-W-5 Burial Ground (0.27 km^2 [0.103 mi^2]) has 10 unlined trenches and began operating in 1986. The 200-W-254 Burial Ground (0.105 km^2 [0.041 mi^2] was originally within the 218-W-5 Burial Ground boundary.

In 2014, a new waste site code (200-W-254) was placed in the Hanford Site Waste Information Data System database to specifically identify the active areas of the 218-W-5 Burial Ground containing Trenches 31 and 34 and associated waste treatment and storage pads. Constructed with double polyethylene liners, the trenches and pads are unique within LLBG WMA-3 and direct all surface runoff to a leachate collection and removal system. The 200-W-254 Burial Ground began operating in 1999 and continues to receive waste. Trenches 31 and 34 and their associated waste treatment and storage pads are considered to be four separate DWMUs. LLBG WMA-3 received primarily nondangerous low-level radiological waste, but there are discrete areas within the LLBG, referred to as "Green Islands" (Figure 12-25), where regulated mixed waste (waste with both a radioactive and dangerous waste component) was disposed in unlined trenches.

In 2019, LLBG WMA-3 was monitored under an interim status indicator evaluation program as described in DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*. The monitoring network consisted of one upgradient well and three downgradient wells (Table B-41 in Appendix B). All of the wells are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). Two engineering evaluation reports have been published for portions of LLBG WMA-3 to support final status monitoring in the future: SGW-59564, *Engineering Evaluation of the 200 West Pump and Treat Influence on Groundwater Monitoring for the Low-Level Burial Ground Trenches 31 and 34*; and SGW-60583, *Engineering Evaluation Report for Low-Level Burial Grounds Waste Management Area-3 Green Islands Groundwater Monitoring*. These engineering evaluation reports propose additional monitoring wells.

Treated water from the 200 West P&T is injected into wells within and adjacent to LLBG WMA-3, creating groundwater mounds (Figure 12-25). The general direction of groundwater flow beneath LLBG WMA-3 is eastward with a gradient of 4.3×10^{-3} m/m and an estimated velocity of 0.14 m/d (0.46 ft/d) (Table B-2 in Appendix B). Beneath Trenches 31 and 34, the average gradient is 3.3×10^{-3} m/m toward the east-southeast, and the estimated velocity is 0.11 m/d (0.36 ft/d).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 12-25. Low-Level Burial Grounds Waste Management Area 3

Wells in the LLBG WMA-3 monitoring network were sampled in 2019 for indicator parameters (specific conductance, pH, TOC, and TOX) (Table B-42 in Appendix B), water quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate), and other parameters (Table B-43 in Appendix B). Critical mean exceedances occurred in two wells in 2019, and DOE notified Ecology. Details of the 2019 exceedances (Table B-42 in Appendix B) are as follows:

- The average specific conductance in downgradient well 299-W10-31 exceeded the critical mean value in March and September, and verification sampling confirmed the exceedances. The 2019 results were consistent with previous data, and the elevated specific conductance is presumed to be associated with the regional nitrate plume. In 2019, the highest nitrate concentration in an LLBG WMA-3 well (299-W10-31) was 48.7 mg/L, which is above the 45 mg/L DWS and an increase from 40.5 mg/L in 2018 (Figure 12-14 in DOE/RL-2018-66).
- The average TOX concentrations in well 299-W10-30 exceeded the critical mean value in March and September, and verification sampling confirmed the exceedances. The TOX concentrations are consistent with observed levels of carbon tetrachloride in the well (27.0 µg/L in 2019, an increase from 23.6 µg/L in 2018). Well 299-W10-30 is within the regional carbon tetrachloride plume (Figure 12-5 in DOE/RL-2018-66).

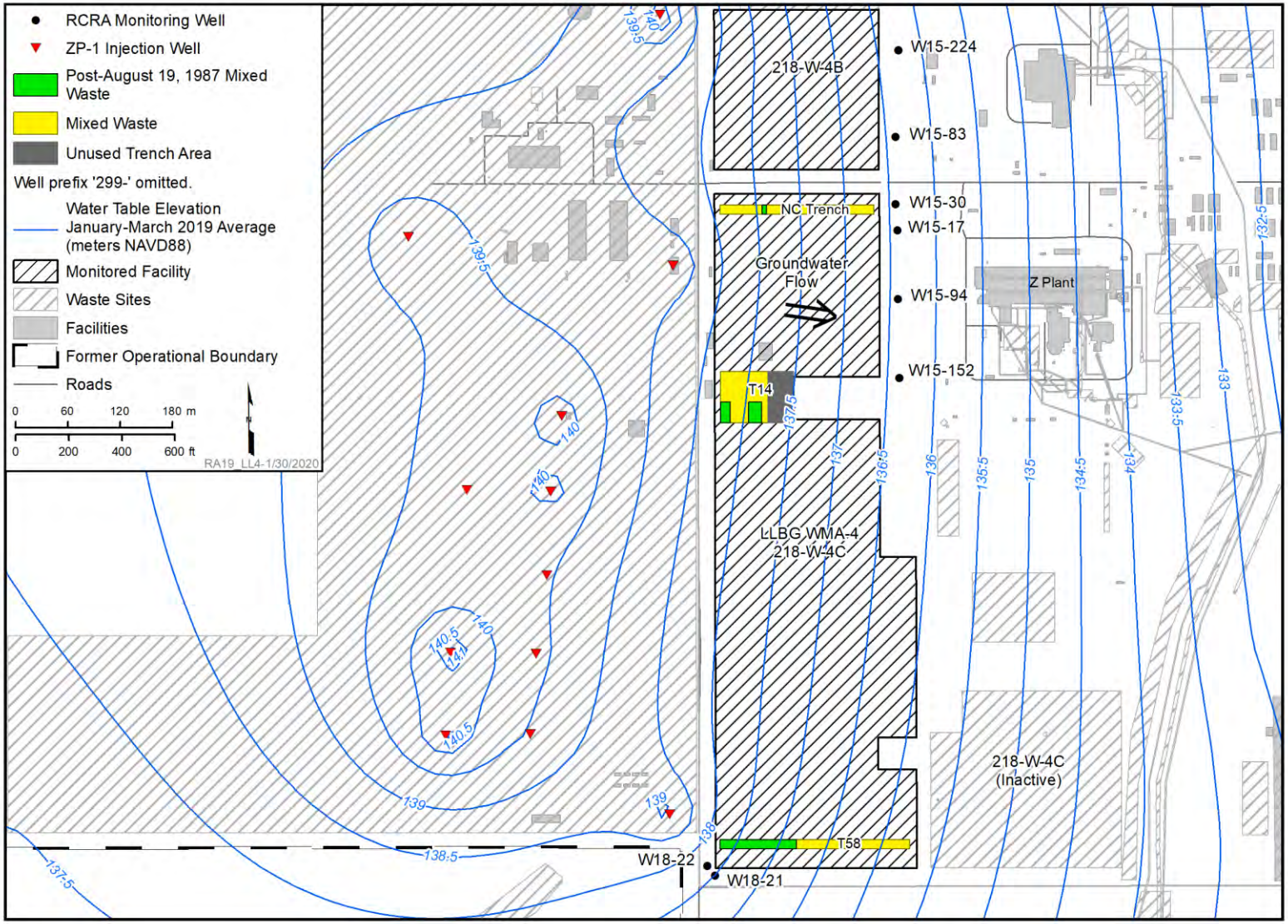
Due to the 2019 critical mean exceedances of specific conductance and TOX at wells 299-W10-31 and 299-W10-30, DOE prepared an interim status groundwater assessment plan (DOE/RL-2019-32, *Interim Status Groundwater Quality Assessment Plan for the Low-Level Burial Grounds Waste Management Area-3*). The plan replaces the previous indicator evaluation groundwater monitoring plan (DOE/RL-2009-68, Rev. 2) and will be implemented in 2020.

12.11.4 Low-Level Burial Grounds Waste Management Area 4

LLBG WMA-4 (Figure 12-26) is located in the 200 West Area and includes the 218-W-4B and 218-W-4C Burial Grounds, which collectively contain 28 unlined trenches used to dispose low-level radioactive waste and low-level mixed waste. After August 19, 1987, mixed waste was not disposed to the 218-W-4B Burial Ground, and it was closed in 1990. The 218-W-4C Burial Ground contains post-August 19, 1987, mixed waste in select areas of Trenches NC, 14, and 58; these areas are referred to as "Green Islands." The 281-W-4B Burial Ground was closed in 2004. RCRA monitoring is conducted under DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, as modified by TPA-CN-718.

Table B-44 lists the wells monitored for LLBG WMA-4 in 2019. The water level in upgradient well 299-W18-21 (screened at the top of the aquifer) varies in response to changes in operation of nearby injection wells. The well was sampled with a bailer in 2019 because it typically does not contain sufficient water to sample with a pump. Other wells in the monitoring network are expected to have sufficient water for continued sampling through at least 2028 (SGW-63743). An engineering evaluation report published in 2018 in support of final status monitoring recommended a modified network that includes several new wells (SGW-60584, *Engineering Evaluation Report for Low-Level Burial Grounds Waste Management Area-4 Green Islands Groundwater Monitoring*).

Operation of P&T injection wells upgradient of LLBG WMA-4 (Figure 12-26) has caused the water table to rise in the area and increased the hydraulic gradient since injection began in 2012. The general direction of groundwater flow is east, the gradient magnitude in 2019 was 8.8×10^{-3} m/m, and the estimated flow rate was 0.29 m/d (0.95 ft/d) beneath LLBG WMA-4 (Table B-2 in Appendix B).



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 12-26. Low-Level Burial Grounds Waste Management Area 4

The well network was sampled in 2019 for indicator parameters pH, specific conductance, TOC, and TOX; no critical mean values were exceeded (Table B-45 in Appendix B). Due to the PFP radiological controlled area restrictions in 2019, the scheduled January 2019 samples were collected in April, and the scheduled July 2019 samples were collected in August. Wells 299-W15-83, 299-W15-224, and 299-W18-21 were resampled in June 2019 (Table B-45 in Appendix B) due to TOX holding-time exceedances for the April 2019 sample event.

Nitrate concentrations were above the 45 mg/L DWS in five wells (Table B-46 in Appendix B) as a result of a regional nitrate plume. Concentrations of iron (in wells 299-W15-83 and 299-W18-21) and manganese (in well 299-W15-152) exceeded their respective secondary DWSs in unfiltered samples.

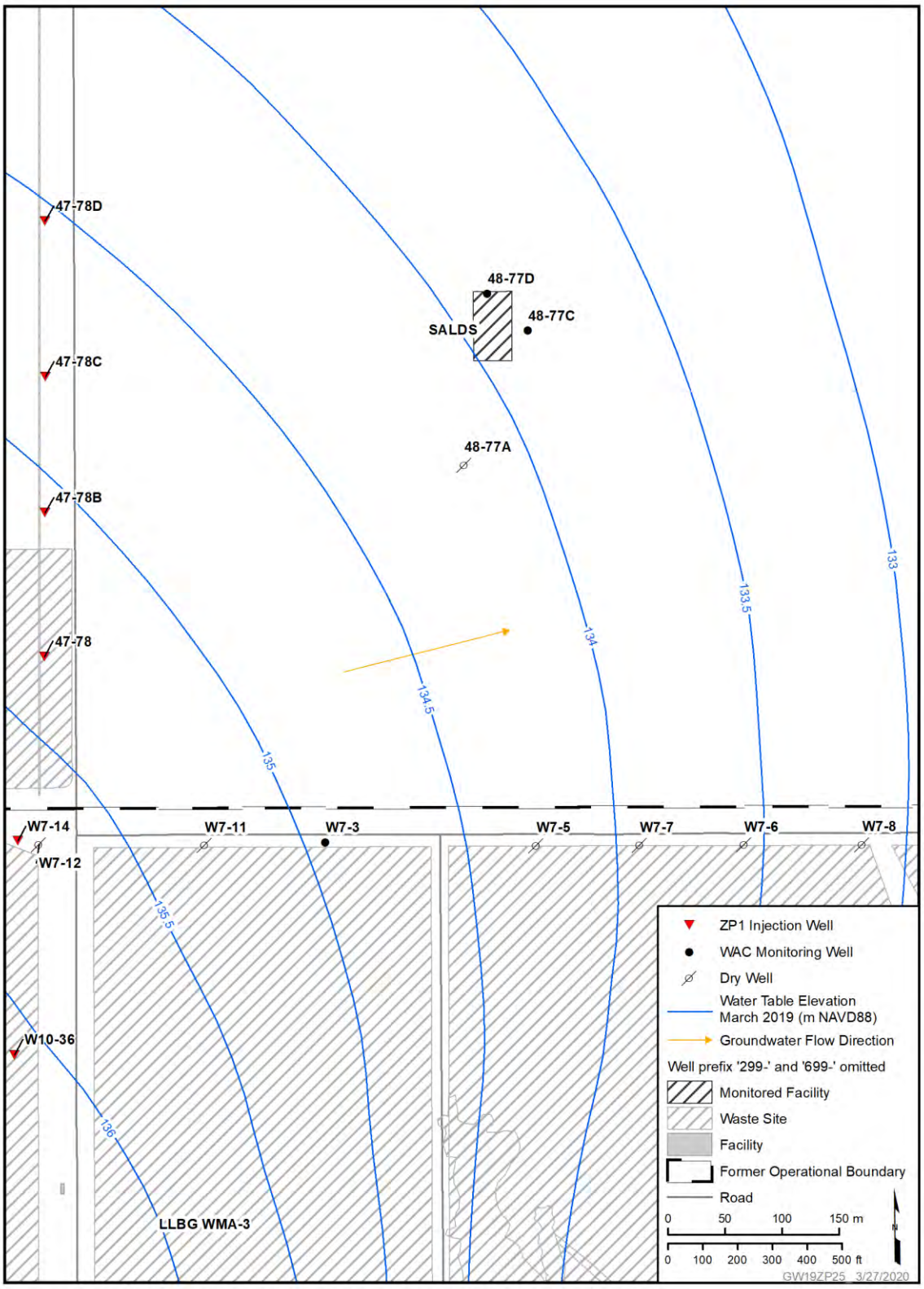
12.12 Washington Administrative Code Monitoring at the State-Approved Land Disposal Site

The ETF, which is regulated under WAC 173-216, processes aqueous wastes from various Hanford Site facilities. Treated water from the ETF is discharged to the SALDS (Figure 12-27), which is authorized to receive the effluent by Ecology, 2000, *State Waste Discharge Permit Number ST 4500*. The permit was issued in June 1995, and the site began operating in December 1995. The SALDS is located 400 m (1,300 ft) outside the northern boundary of the 200 West Area and consists of a 35 m by 61 m (115 ft by 200 ft) drain field. DOE has taken the position that monitoring groundwater and providing data to Ecology is a matter of intergovernmental comity and cooperation, and that the permit has no jurisdiction over radionuclides. Radionuclides are regulated by DOE under AEA authority, in the same way that permits for wastewater discharge to surface waters issued by the EPA under Section 402 of *Federal Water Pollution Control Act*, "National Pollutant Discharge Elimination System," of the *Clean Water Act of 1977* are preempted by the AEA from regulating radionuclides (40 CFR 122.2, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System," "Definitions"; *Train v. Colorado Public Interest Research Group, Inc.*(426 U.S. 1, No. 74-1270).

Under a 2015 permit renewal, sampling for comparison to groundwater concentration limits is performed at the ETF verification tank prior to discharge to the SALDS. If concentrations in the discharged water are below permit limits, then so are concentrations in the groundwater. The only analyte listed for groundwater sampling in the 2015 permit is tritium. However, sampling of other analytes will continue until Ecology approves the revised monitoring plan (RPP-ENV-59215, *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site*). The revised version of the plan was submitted in December 2017 and removes discussion of required groundwater analytes and refers to RPP-PLAN-60544, *Sampling and Analysis Plan for the 200 Area State-Approved Land Disposal Site*, for the list of required analytes. Modification to the permit was not completed in 2019.

During fiscal year 2019, 14.9 million L (3.94 million gal) of water containing 6.65 Ci of tritium were discharged to SALDS, an increase from 0.06 Ci of tritium discharged to the site in fiscal year 2018. Releases of tritium from the SALDS have resulted in a tritium plume in groundwater beneath the facility (Figure 12-19).

DOE monitors groundwater in the SALDS vicinity to track tritium plume migration and to compare concentrations of other constituents to permit limits (prior to the revision of the permit). Groundwater monitoring requirements are described in RPP-ENV-59215. Quarterly sampling is required for two wells proximal to the SALDS, and both annual and semiannual sampling are required for a set of tritium-tracking wells located farther away. Several wells are no longer sampled because they are dry.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 12-27. State-Approved Land Disposal Site

Monitoring results for the SALDS are reported in fiscal year annual reports, most recently in RPP-RPT-61913, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2019.* The permit also specifies that periodic numerical modeling of the tritium plume be performed to predict future plume migration. The model was most recently updated during 2018 (Chapter 4 in RPP-RPT-61178, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2018*).

Discharges to the SALDS previously formed a small groundwater mound, causing a localized area of radial flow beneath the facility. This mound is no longer evident on the regional water table map (Figure 11-2), and the regional groundwater flow direction in the SALDS vicinity is currently toward the east-northeast. The water table beneath the SALDS responds to discharges from the facility, but it also responds to operation of the nearby 200 West P&T and the long-term regional decline of the water table. The long-term decline in the regional water table has caused many of the 19 tritium-tracking wells listed in the monitoring plan (RPP-ENV-59215) to become sample dry. One of the proximal wells (699-48-77A) became sample dry in 2017. This issue also affected proximal well 699-48-77D in 2019 when it did not produce sufficient water for sampling, although the well was successfully sampled four times in 2017 and 2018. The third proximal well, 699-48-77C, is completed deeper in the unconfined aquifer and is not in danger of becoming sample dry.

During 2019, proximal wells 699-48-77C and 699-48-77D were sampled for constituents and parameters listed in the monitoring plan (Table 5.2 in RPP-ENV-59215), and the results are listed in Table 3-2 in RPP-RPT-61913, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2019*. Tritium concentrations in the proximal wells correlate with the activity of tritium released, although the concentration response in deeper well 699-48-77C exhibits a time lag of several years. Recent trends in the proximal wells indicate declining tritium concentrations (Figure 12-28). The highest tritium concentration during 2019 was 58,100 pCi/L in well 699-48-77C.

To date, tritium from the SALDS has not been detected in any of the tritium-tracking wells (Section 3.2 in RPP-RPT-61913). The low levels of tritium observed in wells 299-W6-6, 299-W6-11, 299-W6-12, 299-W8-1, and 699-48-71 (Figure 12-19) are interpreted to have originated from past wastewater releases from other 200 West Area sources and from the 200 West P&T. Water extracted in the 200-ZP-1 OU contains tritium, but as with the ETF, the 200 West P&T does not remove tritium from the water. Thus, the water reinjected into the aquifer at injection wells contains tritium that is being detected in nearby monitoring wells.

12.13 Atomic Energy Act Monitoring

The AEA groundwater monitoring was conducted at 39 groundwater wells in 200-ZP in accordance with the AEA SAP (DOE/RL-2015-56). The primary AEA constituents for 200-ZP are iodine-129, nitrate, technetium-99, radium-226, and tritium. Historically, nitrate has been monitored through AEA as an indicator of contaminant migration and continues to be monitored in the current AEA SAP. Eight wells were not sampled in accordance with SAP requirements in 2019, as explained in Appendix C.

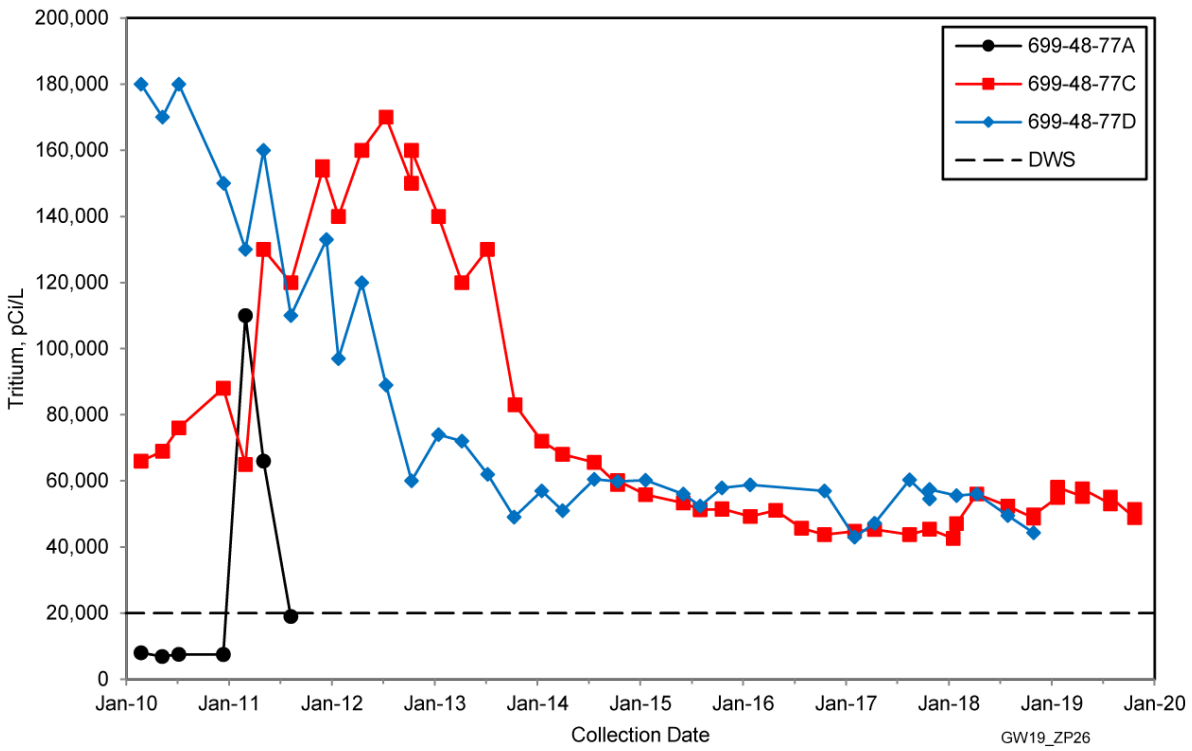


Figure 12-28. 200-ZP Tritium Data for Wells Monitoring the SALDS

Radionuclide concentrations detected in groundwater samples from 78 wells[17] 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 200-ZP (Table 12-4). None of the DWSs for cumulative alpha emitters were exceeded, and the 30 µg/L uranium DWS was not exceeded. The net alpha dose exceeded the 15 mrem/yr at one location in 200-ZP. The cumulative drinking water dose from beta/photon emitters exceeded the 4 mrem/yr standard at 15 locations in 200-ZP. None 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 that restrict access to groundwater and through remedial action measures (e.g., P&T) to control the migration of contaminated groundwater to exposure points.

[17] The AEA calculations used data from wells sampled only for CERCLA, as well as those sampled specifically for the AEA.

Table 12-4. Cumulative TEDs and Groundwater Concentrations that Exceeded Standards at Groundwater Monitoring Locations in 200-ZP in 2019

Monitoring Location/ Well Name	Cumulative Drinking Water Dose (Beta/Photon) ≥4 mrem/yr		Net Alpha-Emitter Activity ≥15 pCi/L	
	Minimum	Maximum	Minimum	Maximum
299-W5-2P	5.42	5.42	—	—
299-W6-15	8.18	8.18	—	—
299-W6-17	9.54	9.54	—	—
299-W11-13	8.61	8.61	—	—
299-W11-39	25.75	25.75	—	—
299-W11-42	112.00	112.00	—	—
299-W11-47	28.71	28.71	—	—
299-W11-50	5.02	7.01	—	—
299-W11-90	7.67	9.64	—	—
299-W14-11	25.61	25.61	—	—
299-W14-13	21.68	29.88	48.70*	48.70*
299-W14-18	108.00	108.00	—	—
299-W14-20	5.24	7.13	—	—
699-48-77C	10.28	11.62	—	—
699-49-100C	22.00	22.00	—	—

Reference: ECF-HANFORD-20-0031, *Calculation of Radiological Dose Based on Calendar Year 2019 Atomic Energy Act Groundwater Monitoring at Hanford*.

Notes:

None of the wells in 200-ZP had a total effective dose ≥100 mrem/yr or cumulative uranium mass ≥30 µg/L.

Blank cells (—) indicate no exceedances.

*The net alpha-emitter activity for well 299-W14-13 is not representative because of a gross alpha outlier.

12.13.1 State-Approved Land Disposal Site

Additional monitoring is integrated into the AEA SAP (DOE/RL-2015-56) as part of existing performance assessment monitoring plans for the SALDS. The primary COC is tritium, which exceeded the DWS at one AEA well (699-48-77C at 58,100 pCi/L). Tritium concentrations at this well continued to remain stable during 2019 (Section 12.12). All other radionuclide concentrations were either not detected or were <50% of the respective DWSs. Nitrate concentrations were below the DWS (45 mg/L) at well 299-W6-6 with a concentration of 34.5 mg/L in 2019, a decrease from 40.3 mg/L in 2018. However, nitrate concentrations for well 299-W6-6 increased to 110 mg/L in January 2020. This increase can likely be attributed to higher nitrate concentrations injected into nearby well 299-W6-13 because nitrate treatment was suspended in the 200 West P&T (Section 12.10).

12.13.2 Low-Level Burial Ground Waste Management Areas 3 and 4

Additional monitoring is integrated into the AEA SAP (DOE/RL-2015-56) as part of existing performance assessment monitoring plan for LLBG WMA-3 and LLBG WMA-4, as described in DOE/RL-2000-72. The COCs for this monitoring plan are technetium-99, iodine-129, and uranium. All COCs for LLBG WMA-3 were below detection limits or were <50% of the respective DWSs. Uranium concentrations for LLBG WMA-3 were consistently <2 µg/L.

Iodine-129 and technetium-99 concentrations in LLBG WMA-3 wells were near or below detection limits. The 2019 groundwater data do not indicate a release associated with the 218-W-5 Trenches 31 and 34.

For LLBG WMA-4, technetium-99 concentrations remained well below 50% of the DWS, but two wells exhibited slightly increased concentrations and trends from 2018 to 2019. Two of these wells were upgradient and one well was downgradient. Uranium concentrations in upgradient well 299-W18-21 continued to decrease and are below the 30 µg/L DWS. Three wells downgradient of Trenches NC and 14 exhibited increased uranium concentrations but remain well below 50% of the DWS. The 2019 groundwater data do not indicate a release associated with the Trenches NC, 14, and 58 (Figure 12-26).

13 References

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Subpart I, "Control of Lead and Copper."

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265.92, "Sampling and Analysis."

265.93, "Preparation, Evaluation, and Response."

Subpart F, "Ground-Water Monitoring."

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=9b3377c5f3d66f36e3fd4b46f3d8cf1f&mc=true&node=ap40.30.300_11105.b&rgn=div9.

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Appendix A

Supporting Information for CERCLA Operable Units

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Contents

A1 Supporting Information for CERCLA Operable Units A-1

A2 References A-4

Table

Table A-1. CERCLA Well Sampling Exceptions, 2019 ..... A-1

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A1 Supporting Information for CERCLA Operable Units

Table A-1 lists deviations from *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* sampling requirements for 2019. Exceptions for sampling beyond the requirements listed in sampling and analysis plans may not be noted in Table A-1.

Table A-1. CERCLA Well Sampling Exceptions, 2019

Well(s)	Comment
100-BC-5 Groundwater OU (DOE/RL-2003-38, as modified by TPA-CN-0734	
Aquifer tubes	Sampling of some aquifer tubes began in late August rather than September as specified in the SAP. Met the intent of the requirement because the river stage was low.
Hyporheic sampling points C8860 and C8861 and aquifer tubes AT-B-5-D and AT-B-7-M	Sampling delayed from September to early October.
Aquifer tube C6230	Label was missing on two of the three tubes in the cluster. Sampled the only labeled tube (C6231). Substitutions are allowed under the SAP.
Aquifer tube C6234	No longer produces representative samples. Sampled another tube in the cluster (C6235), as allowed under the SAP.
Hyporheic sampling point C8861; nearby aquifer tubes and sampling points	Additional sampling in April and July 2019 to investigate the 2018 increase in hexavalent chromium in C8861.
699-65-72	Manual water level not measured in March 2019 because well was not on the well access list. Successfully measured in June and September.
100-FR-3 Groundwater OU (DOE/RL-2014-44-ADD2, as modified by TPA-CN-708, TPA-CN-0736, TPA-CN-0814, and TPA-CN-0874)	
Aquifer tube C6306	Aquifer tube could not be located; may have broken off. If repair is not possible, this tube will be removed from the SAP.
Seep 187-1	Seep was not present in 2019.
100-HR-3 Groundwater OU (DOE/RL-2013-30, as modified by TPA-CN-0743, TPA-CN-0798, and TPA-CN-0825)	
199-D4-83, 199-D4-84, 199-D4-101, 199-D5-20, 199-D5-130, 199-D5-154, 199-D7-6, 199-D8-55, 199-D8-73, 199-H1-4, 199-H1-32, 199-H1-33, 199-H1-34, 199-H1-36, 199-H1-37, 199-H1-38, 199-H1-39, 199-H1-40, 199-H1-46, 199-H1-48, 199-H3-21, 199-H3-26, 199-H4-4, 199-H4-74, 199-H4-76, 199-H4-83, and 199-H4-86	Missed or canceled one or more quarterly, semiannual, or triannual samples. Low river stage resulted in the inability to collect a sample from P&T wells.
199-D4-97, 199-H3-9, 199-H3-25, and 199-H5-16	Quarterly samples canceled due to P&T configuration.
199-D4-97, 199-D5-39, 199-D8-69, 199-D8-88, 199-D8-98, 199-H1-47, 199-H3-9, and 199-H3-25	Quarterly samples canceled due to weather issues.

Table A-1. CERCLA Well Sampling Exceptions, 2019

Well(s)	Comment
199-H1-5 and 199-H4-82	Quarterly samples missed due to conversion to injection.
C6278, C6293, C6301, and 51-D	Aquifer tube samples missed because tubes were broken.
100-KR-4 Groundwater OU (DOE/RL-2013-29, as modified by TPA-CN-0797, TPA-CN-0831, and TPA-CN-0857)	
199-K-141	May sample event was missed. Well was realigned from an extraction well to a monitoring well, but this detail was not communicated to sampling group until the August sample event.
199-K-225	May sampling event was canceled. This extraction well was not operating during sampling event.
19-D and AT-K-4-D	Fall sampling events were canceled. These aquifer tubes are broken and cannot be repaired. The SAP will be revised.
DK-04-3	Fall sampling event was canceled. The aquifer tube did not sustain flows for sampling. This aquifer tube appears more sensitive to river stage than others along the 100-K shoreline.
SK-063-2	The seep could not be located during low river stage.
100-NR-2 Groundwater OU (DOE/RL-2001-27, as modified by TPA-CN-0747, TPA-CN-0751, and TPA-CN-0791)	
199-N-147	Low river stage sample not collected in September because water was below the screen. Well sampled on January 13, 2020, for low river period.
199-N-172	High river stage (June) sample not collected. Well screen split, causing filter pack material to fall into well above water level. Repairs will be attempted.
199-N-75	Low river stage sample not collected in September due to pump issues. Issues were corrected and well was sampled on January 2, 2020, for low river period.
N116mArray-8A and N116mArray-10A	These aquifer tubes were not sampled in 2019 because they are broken and cannot be repaired. Will be removed from the SAP when it is revised.
300-FF-5 Groundwater OU (DOE/RL-2014-42, as modified by TPA-CN-0762, TPA-CN-0820, TPA-CN-0827, and TPA-CN-0867; and DOE/RL-2014-42-ADD1, as modified by TPA-CN-0828, TPA-CN-0835, and TPA-CN-0868)	
399-1-2, 399-1-12, 399-1-16A, 399-1-17A, 399-1-7, 399-1-23, 399-1-55, 399-1-62, 399-1-72, 399-1-73, 399-1-155, 399-1-156, 399-1-157, 399-1-158, 399-1-159, 399-1-160, 399-1-161, 399-1-162, 399-1-164, 399-1-165, 399-1-166, and 399-2-2	Missed monthly samples in February; wells not accessible because of snow accumulation.
399-6-5	Missed December sample because of electrical issue. Maintenance requested.

Table A-1. CERCLA Well Sampling Exceptions, 2019

Well(s)	Comment
200-BP-5 Groundwater Operable Unit (DOE/RL-2014-33)	
13-S	Aquifer tube could not be located. A SAP modification was drafted to remove this aquifer tube.
299-E33-10	Inner casing collapsed and groundwater access is blocked. Will be removed from the SAP.
299-E33-14	Well became sample dry due to continued water-level declines. Will be removed from the SAP.
299-E33-3, 299-E33-7, and 299-E33-16	A subsidence zone was posted around these wells, and groundwater sampling is not accessible. A SAP modification was drafted to remove these wells.
299-E33-9 and 299-E33-205	Wells could not be sampled because purge water truck was contaminated with rodent droppings.
200-PO-1 Groundwater OU (DOE/RL-2003-04, as modified by TPA-CN-205)	
299-E13-11	The 2018 sampling event was delayed until March 31, 2019. Sampled in July for 2019.
499-S1-8J	Missed annual sample because of an obstruction within well.
84-S and 86-S	Aquifer tubes did not produce water.
200-UP-1 Groundwater OU (DOE/RL-2015-14, as modified by TPA-CN-0802)	
299-W15-37	Missed annual sample; overhead piping blocked access to the well. The last successful sample was collected on August 2, 2016.
299-W18-15	Missed annual sample; no water to surface. Pump replaced in 2020.
699-31-53B	Missed annual sample; bees nest prevented access. Successfully sample on January 28, 2020, and results for that sample are used in this report.
699-38-68A	Missed annual sample; no water to surface. Successfully sampled on February 5, 2020.
200-ZP-1 Groundwater OU (DOE/RL-2009-115)	
299-W10-33, 299-W11-13, 699-44-64, and 699-48-77D	Missed annual sample because the wells did not produce sufficient groundwater and are dry or nearly dry.

Note: The references cited in this table are included in the References section of this appendix.

OU = operable unit

P&T = pump and treat

SAP = sampling and analysis plan

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Appendix B

Supporting Information for RCRA Units

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Contents

B1 Supporting Information for RCRA Units B-1

B2 RCRA Groundwater Monitoring Programs B-2

B3 RCRA Interim Status Reporting Requirements B-6

B4 RCRA Final Status Reporting Requirements B-6

B5 Water Table B-6

B6 Specific Conductance B-11

B7 RCRA Inspections B-11

B8 Supporting Tables B-12

B9 References B-94

Figures

Figure B-1. Hanford Site RCRA Units B-2

Figure B-2. 200 East Area Water Table, January Through March 2019 ..... B-8

Figure B-3. 200 West Area Water Table, January Through March 2019 ..... B-9

Tables

Table B-1. RCRA Monitoring Status, 2019 ..... B-3

Table B-2. Average Hydraulic Gradient and Average Linear Velocity, January Through March 2019 ..... B-10

Table B-3. 183-H Groundwater Monitoring Network B-13

Table B-4. 183-H Solar Evaporation Basins Sampling Results, 2019 ..... B-14

Table B-5. Statistical Evaluation of 183-H Solar Evaporation Basins Dangerous Waste Constituents, 2019 ..... B-16

Table B-6. 216-A-29 Groundwater Monitoring Network B-17

Table B-7. 216-A-29 Sampling Summary: Constituents Detected in 2019 ..... B-18

Table B-8. 216-A-36B Groundwater Monitoring Network B-21

Table B-9. 216-A-36B Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-22

Table B-10. 216-A-36B Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-23

Table B-11. 216-A-37-1 Groundwater Monitoring Network B-25

Table B-12. 216-A-37-1 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-26

Table B-13. 216-A-37-1 Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019 ..... B-27

Table B-14. 216-B-3 Main Pond Groundwater Monitoring Network B-29

Table B-15. Groundwater Velocity at 216-B-3 Main Pond B-30
Table B-16. 216-B-3 Main Pond Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-31
Table B-17. 216-B-3 Main Pond Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019 ..... B-32
Table B-18. 216-B-63 Groundwater Monitoring Network B-34
Table B-19. 216-B-63 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-35
Table B-20. 216-B-63 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-36
Table B-21. 216-S-10 Groundwater Monitoring Network B-37
Table B-22. 216-S-10 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-38
Table B-23. 216-S-10 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-39
Table B-24. 300 Area Process Trenches Groundwater Monitoring Network B-41
Table B-25. Groundwater Velocity at 300 Area Process Trenches B-42
Table B-26. 300 Area Process Trenches RCRA Sampling Results, 2019 ..... B-42
Table B-27. Statistical Evaluation of 300 Area Process Trenches Dangerous Waste Constituents, 2019 ..... B-44
Table B-28. IDF Groundwater Monitoring Network B-45
Table B-29. IDF Contamination Indicator Parameters, 2019 ..... B-47
Table B-30. IDF Sampling Summary for Supplemental Constituents, 2019 ..... B-48
Table B-31. LERF Groundwater Monitoring Network B-49
Table B-32. Groundwater Velocity at the LERF B-50
Table B-33. LERF Sampling Summary for Waste Constituents, 2019 ..... B-50
Table B-34. LERF Sampling Summary for Other Constituents, 2019 ..... B-51
Table B-35. LLBG WMA-1 Groundwater Monitoring Network B-52
Table B-36. LLBG WMA-1 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-53
Table B-37. LLBG WMA-1 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-54
Table B-38. LLBG WMA-2 Groundwater Monitoring Network B-55
Table B-39. LLBG WMA-2 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-56
Table B-40. LLBG WMA-2 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-59
Table B-41. LLBG WMA-3 Groundwater Monitoring Network B-60
Table B-42. LLBG WMA-3 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-61
Table B-43. LLBG WMA-3 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-63
Table B-44. LLBG WMA-4 Groundwater Monitoring Network B-64
Table B-45. LLBG WMA-4 Sampling Summary for Contamination Indicator Parameters, 2019 ..... B-65
Table B-46. LLBG WMA-4 Sampling Summary for Water Quality Parameters and Other Constituents, 2019 ..... B-67

Table B-47. NRDWL Groundwater Monitoring Network B-68
Table B-48. NRDWL Groundwater Velocity B-69
Table B-49. NRDWL Sampling Summary: Constituents Detected in 2019 ..... B-69
Table B-50. WMA A-AX Groundwater Monitoring Network B-72
Table B-51. WMA A-AX Sampling Summary: Constituents Detected in 2019 ..... B-73
Table B-52. WMA B-BX-BY Groundwater Monitoring Network B-75
Table B-53. WMA B-BX-BY Sampling Summary for 2019 ..... B-76
Table B-54. WMA C Groundwater Monitoring Network B-78
Table B-55. WMA C Sampling Summary for 2019 ..... B-80
Table B-56. WMA S-SX Groundwater Monitoring Network B-82
Table B-57. WMA S-SX Sampling Summary for 2019 ..... B-84
Table B-58. WMA T Groundwater Monitoring Network B-86
Table B-59. WMA T Sampling Summary for 2019 ..... B-87
Table B-60. WMA TX-TY Groundwater Monitoring Network B-89
Table B-61. WMA TX-TY Sampling Summary for 2019 ..... B-90
Table B-62. WMA U Groundwater Monitoring Network B-92
Table B-63. WMA U Sampling Summary for 2019 ..... B-93

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Terms

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
IDF	Integrated Disposal Facility
LERF	Liquid Effluent Retention Facility
LOQ	limit of quantitation
P&T	pump and treat
RCRA	*Resource Conservation and Recovery Act of 1976*
Tri-Parties	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington Department of Ecology
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TOC	total organic carbon
TOX	total organic halides

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B1 Supporting Information for RCRA Units

This appendix includes supporting tables for 22 dangerous waste management units (DWMUs) at the Hanford Site (Figure B-1). These units are regulated under Washington State dangerous waste regulations with authorization from the *Resource Conservation and Recovery Act of 1976* (RCRA). RCRA regulates the management of solid waste, hazardous waste, and certain underground storage tanks. It applies to active or recently active DWMUs. Groundwater monitoring is required at land disposal units (including surface impoundments, landfills, or land treatment facilities) to determine if these units are affecting water quality in the uppermost aquifer.

Groundwater monitoring requirements for Hanford Site RCRA DWMUs fall into two broad categories: final status or interim status. Final status units have been incorporated into WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended (hereinafter referred to as the Hanford RCRA Permit). A permitted RCRA unit requires final status monitoring under WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring under WAC 173-303-400, "Interim Status Facility Standards," as implemented by 40 CFR 265, Subpart F, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground Water Monitoring."

In 1989, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (hereinafter referred to as the Tri-Parties) signed Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). The Tri-Party Agreement implemented remediation of the Hanford Site under federal facility provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), Section 120, "Federal Facilities," and brought the Hanford Site into compliance with environmental requirements under RCRA, including groundwater monitoring. In the early 1990s, certain DWMUs had ceased operations and were scheduled for closure. These units included ponds, ditches, trenches, cribs, and retention basins. Tri-Party Agreement milestones were agreed upon for the submission of closure plans, and individual closure plans were submitted for regulatory approval and eventual implementation. While awaiting approval and implementation of these closure plans, DOE developed interim status groundwater monitoring plans to monitor the effects of these units on groundwater until closures could be implemented. Until these closures have been implemented or the units are included in the Hanford RCRA Permit, interim status groundwater monitoring will continue.

This appendix includes summary tables for the 2019 monitoring results from RCRA sampling campaigns. Only the well networks, constituents, and sampling events identified in the current RCRA monitoring plans are used (1) to determine statistically significant changes for interim status units; (2) to assess unit impacts to groundwater, if any; and (3) for final status statistical evaluations. In certain situations, other data may be used to help evaluate flagged RCRA results.

Some of the data summary tables in this appendix include comparison values such as the federal primary drinking water standards (DWSs), secondary DWSs, and Model Toxics Control Act cleanup levels (WAC 173-340, "Model Toxics Control Act—Cleanup"), which are provided for information only. These comparison values are not used to determine RCRA or *Washington Administrative Code* groundwater monitoring exceedances, nor to satisfy any RCRA or *Washington Administrative Code* groundwater monitoring requirements at the 22 DWMUs at the Hanford Site.

The RCRA sections of the main text of this report and the information in this appendix were previously published in DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*.

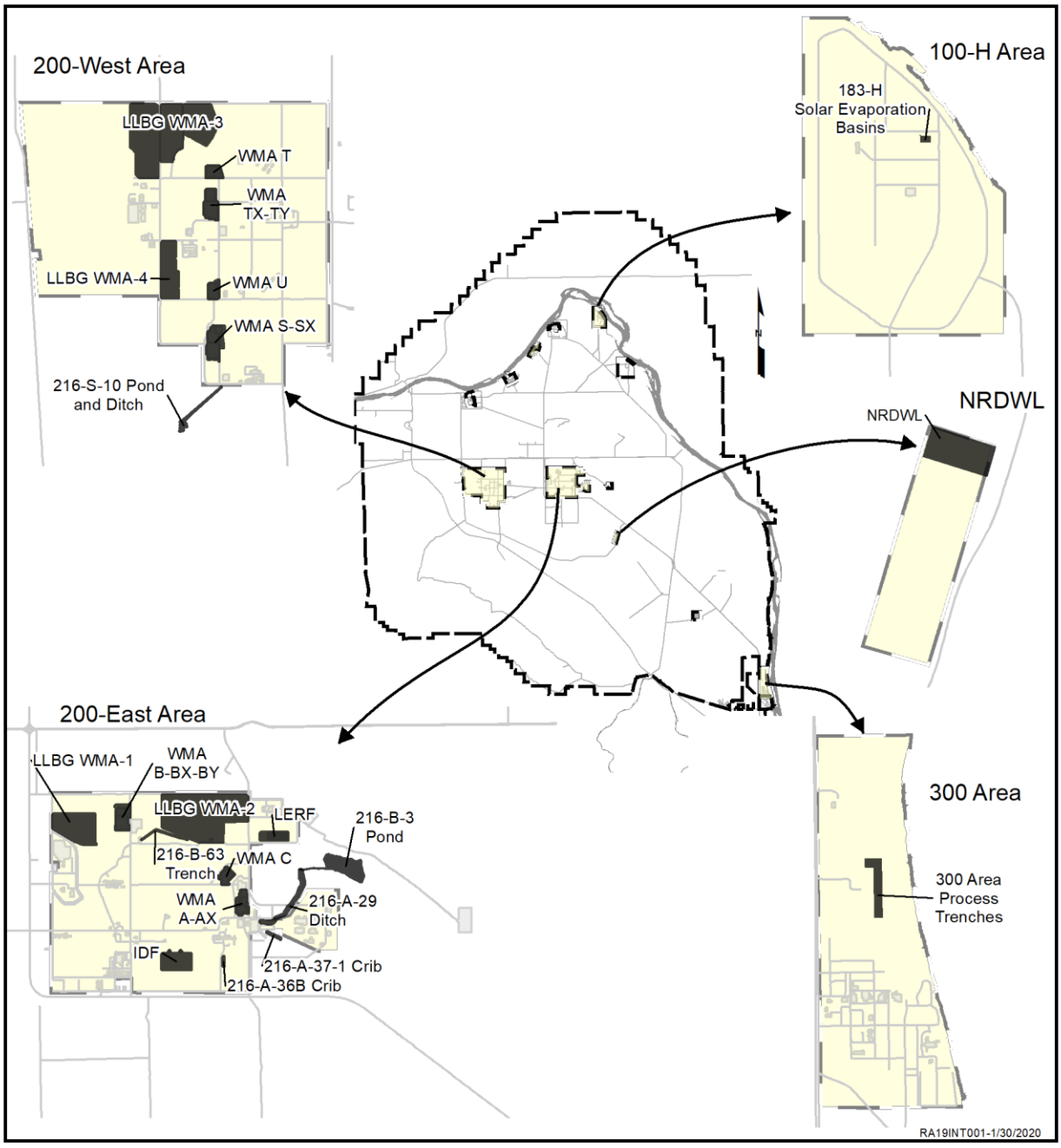


Figure B-1. Hanford Site RCRA Units

B2 RCRA Groundwater Monitoring Programs

DOE conducts RCRA groundwater monitoring under four types of programs:

- Interim status indicator evaluation
- Interim status groundwater quality assessment
- Final status detection
- Final status corrective action

Table B-1 lists the Hanford Site RCRA units and their 2019 monitoring status. Natural or anthropogenic changes in groundwater flow and water quality (e.g., those imposed by pump and treat [P&T] systems) may affect the adequacy of RCRA groundwater monitoring networks. DOE is working with Ecology to review the monitoring networks and is evaluating the need for additional wells through the Hanford RCRA Permit working group. In anticipation of final status permitting, DOE is preparing RCRA engineering evaluation reports (Table B-1) and related final status monitoring plans, which are expected to be added to the Hanford RCRA Permit. Some of the recommendations from the engineering evaluation reports were applied to revised interim status monitoring plans. Additional wells proposed for installation at the Hanford Site are negotiated annually by the Tri-Parties under Tri-Party Agreement Milestone M-24-00 (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*).

Table B-1. RCRA Monitoring Status, 2019

RCRA Unit	Section in Main Text	Status	Engineering Evaluation[a]
183-H Solar Evaporation Basins	4.10	Continued final status corrective action monitoring program during CERCLA remedial action.	Not applicable
216-A-29 Ditch	10.10	Interim status assessment; prepared first determination report (DOE/RL-2019-27).	SGW-60592 (2019)
216-A-36B Crib	10.10	Continued interim status indicator evaluation monitoring.[b]	SGW-60595 (2019)
216-A-37-1 Crib	10.10	Continued interim status indicator evaluation monitoring.[b]	SGW-60593 (2019)
216-B-3 Main Pond	10.10	Continued interim status indicator evaluation monitoring.[b]	SGW-60591 (2019)
216-B-63 Trench	9.9	Continued interim status indicator evaluation monitoring.[b]	SGW-60594 (2019)
216-S-10 Pond and Ditch	11.11	Continued interim status indicator evaluation monitoring.[b]	SGW-60585 (2018)
300 Area Process Trenches	7.7	Continued final status corrective action monitoring program during CERCLA remedial action.	Not applicable
IDF	10.10	Not yet in use; monitoring results added to baseline data set for detection program.	SGW-62007 (2019)
LERF	9.9	Continued final status detection monitoring.[b]	SGW-41072 (2017)
LLBG WMA-1	9.9	Continued interim status indicator evaluation monitoring.[b]	SGW-60590 (Green Islands) (2019)
LLBG WMA-2	9.9	Continued interim status indicator evaluation monitoring.[b]	Planned for 2020 (Trench 94)

Table B-1. RCRA Monitoring Status, 2019

RCRA Unit	Section in Main Text	Status	Engineering Evaluation[a]
LLBG WMA-3	12.11	Interim status indicator evaluation monitoring in 2019. Critical mean for specific conductance exceeded; interim status assessment plan prepared (DOE/RL-2019-32).	SGW-59564 (Trenches 31 and 34; 2016) and SGW-60583 (Green Islands; 2018)
LLBG WMA-4	12.11	Continued interim status indicator evaluation monitoring.[b]	SGW-60584 (2018)
NRDWL	10.10	Interim status assessment; prepared first determination report (DOE/RL-2019-22).	SGW-60589 (2019)
SST WMA A-AX	10.10	Interim status assessment; prepared first determination report (DOE/RL-2019-21).	SGW-60586 (2019)
SST WMA B-BX-BY	9.9	Continued interim status assessment monitoring (cyanide[c]).	SGW-60587 (2019)
SST WMA C	9.9	Continued interim status assessment monitoring (cyanide[c]).	SGW-60588 (2019)
SST WMA S-SX	11.11	Continued interim status assessment monitoring (chromium[c]).	SGW-60577 (2018)
SST WMA T	12.11	Continued interim status assessment monitoring (chromium[c]).	SGW-60575 (2018)
SST WMA TX-TY	12.11	Continued interim status assessment monitoring (chromium[c]).	SGW-60576 (2018)
SST WMA U	11.11	Continued interim status assessment monitoring (chromium[c]).	SGW-60578 (2018)

Note: The references cited in this table are provided in Section B8.

a. Engineering evaluations are used to determine the need for new or replacement monitoring wells for these units in anticipation of final status permitting.

b. Analysis of RCRA interim status indicator parameters and final status monitored constituents provided no evidence of groundwater contamination with dangerous waste or dangerous waste constituents from the unit.

c. Primary RCRA constituent at this unit.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
IDF = Integrated Disposal Facility
LERF = Liquid Effluent Retention Facility
LLBG = low-level burial grounds
NRDWL = Nonradioactive Dangerous Waste Landfill
RCRA = *Resource Conservation and Recovery Act of 1976*
SST = single-shell tank
WMA = waste management area

Interim status indicator evaluation programs monitor specific conductance, pH, total organic carbon (TOC), and total organic halides[1] (TOX) (collectively referred to as indicator parameters; 40 CFR 265.92(b)(3), "Sampling and Analysis") to determine if the RCRA unit has impacted groundwater in the uppermost aquifer. A statistically significant change is determined by comparing concentrations of the indicator parameters in downgradient wells to a statistical comparison value

[1] Total organic halides (TOX) are synonymous with total organic halogens, which is the term used in 40 CFR 265.92.

(referred to as a critical mean at the Hanford Site) that is derived from background measurements (usually from upgradient wells). If a downgradient well exceeds a critical mean value for any of the indicator parameters, the well is resampled. If the results of the second sampling event confirm the exceedance, the indicator evaluation program changes to a groundwater quality assessment program. The critical mean values for the indicator parameters represent 99% prediction limits, calculated using groundwater sample data from upgradient wells. The methodology used to calculate the critical mean value is the Student's t-test in accordance with 40 CFR 265.93(b), "Preparation, Evaluation, and Response."

Critical mean values are recalculated annually, or whenever the number of analyses changes (e.g., due to adding or removing wells). ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*, describes the 2019 critical mean calculations. The tables presented in this appendix provide the 2019 critical mean values and the results of statistical comparisons. Annual recalculation accounts for additional monitoring data and changing hydrologic conditions due to natural or manmade causes (e.g., P&T systems). If changes occur in a monitoring well network, critical mean values are recalculated for subsequent sampling events using the new well network. In 2019, when a critical mean for TOC or TOX could not be calculated using a parametric statistical test because >50% of data from the upgradient well(s) were below detection limits, the limit of quantitation (LOQ) was used as the upper reporting limit.

The LOQs for TOC and TOX may vary from laboratory to laboratory and from quarter to quarter. An indicator parameter exceedance is not declared unless the downgradient concentration exceeds both the critical mean and the applicable LOQ. In 2019, the LOQs were the practical quantitation limit reported by the analytical laboratories (i.e., the concentration of the least-concentrated standard used for instrument calibration). The indicator parameter tables in this appendix list the applicable LOQs.

If an exceeded critical mean is verified in a downgradient well, an interim status groundwater quality assessment plan is implemented (40 CFR 265.93(d)). The objective of the assessment program is to determine the rate and extent of migration, as well as the groundwater concentration of the dangerous waste from the unit (if any).

Interim status groundwater quality assessments may also consider and test for alternative explanations for critical mean exceedances. For example, specific conductance exceedances may be caused by nondangerous waste constituents such as sulfate (Section B.6). Because of changes in the direction of groundwater flow and the presence of multiple past-practice CERCLA release sites, some assessments require determining if the cause of an indicator parameter exceedance originated from other sources. These assessments can take time to evaluate before a first determination is made, and some DWMUs in assessment can be returned to indicator evaluation monitoring in accordance with 40 CFR 265.93(d)(6).

For final status detection monitoring (WAC 173-303-645(9)), appropriate indicator parameters, waste constituents, or reaction products are specified in the Hanford RCRA Permit for groundwater monitoring. If statistically significant evidence of contamination is determined at the point of compliance, DOE must notify Ecology and resample the well(s). The results of these analyses form the basis for a final status compliance monitoring program, which is established through a permit modification.

For final status compliance monitoring (WAC 173-303-645(10)), if contaminant concentrations in groundwater have exceeded a permit concentration limit, a corrective action program must be established. Corrective action groundwater monitoring under WAC 173-303-645(11) would then be initiated to determine if the corrective action is effective. Currently, none of the units at the Hanford Site are monitored under final status compliance monitoring programs.

B3 RCRA Interim Status Reporting Requirements

40 CFR 265.94, "Recordkeeping and Reporting," includes reporting requirements for interim status groundwater monitoring programs. For indicator evaluation programs, the owner/operator must report the following information no later than March 1 each year (40 CFR 265.94(a)(2)(ii)):

- Concentrations of the contamination indicator parameters for each groundwater monitoring well, along with the required evaluations for these parameters (i.e., comparison to critical mean values)
- Any significant differences from initial background found in the upgradient wells
- Results of evaluations of groundwater surface elevations and a description of the response to that evaluation, where applicable

For groundwater quality assessments, the owner/operator must submit an annual report with the results of the groundwater quality assessment program no later than March 1 of the following year (40 CFR 265.94(b)(2)). The report must include the calculated (or measured) rate of migration of dangerous waste constituents in groundwater during the reporting period.

DOE submitted DOE/RL-2019-65 to Ecology in February 2020 to meet interim status reporting requirements.

B4 RCRA Final Status Reporting Requirements

Under the final status requirements of WAC 173-303-645(8)(j), reporting requirements are specified in the Hanford RCRA Permit. The following requirements apply to final status units on the Hanford Site:

- The Liquid Effluent Retention Facility (LERF) is monitored under a final status detection program, with data reported annually by March 1 of the following year. DOE submitted DOE/RL-2019-65 to Ecology in February 2020 to meet the reporting requirement for LERF.
- For the Integrated Disposal Facility (IDF), the Hanford RCRA Permit (Part III, Operating Unit Group 11 [OUG-11], Section 5.5.4.3.3, "Reporting") requires the following: "The results of the statistical evaluation and associated information will be submitted to Ecology quarterly in Hanford Site groundwater monitoring reports." Because the IDF is not in use, this statistical evaluation has not been prepared to date.
- The 183-H Solar Evaporation Basins and 300 Area Process Trenches are monitored under corrective action, which is reported in semiannual and annual reports (DOE/RL-2019-65).

B5 Water Table

Groundwater flow directions are inferred from water table maps. These maps are based on water-level measurements from wells in the RCRA monitoring networks and other nearby monitoring wells and, in some cases, are guided by computer models.

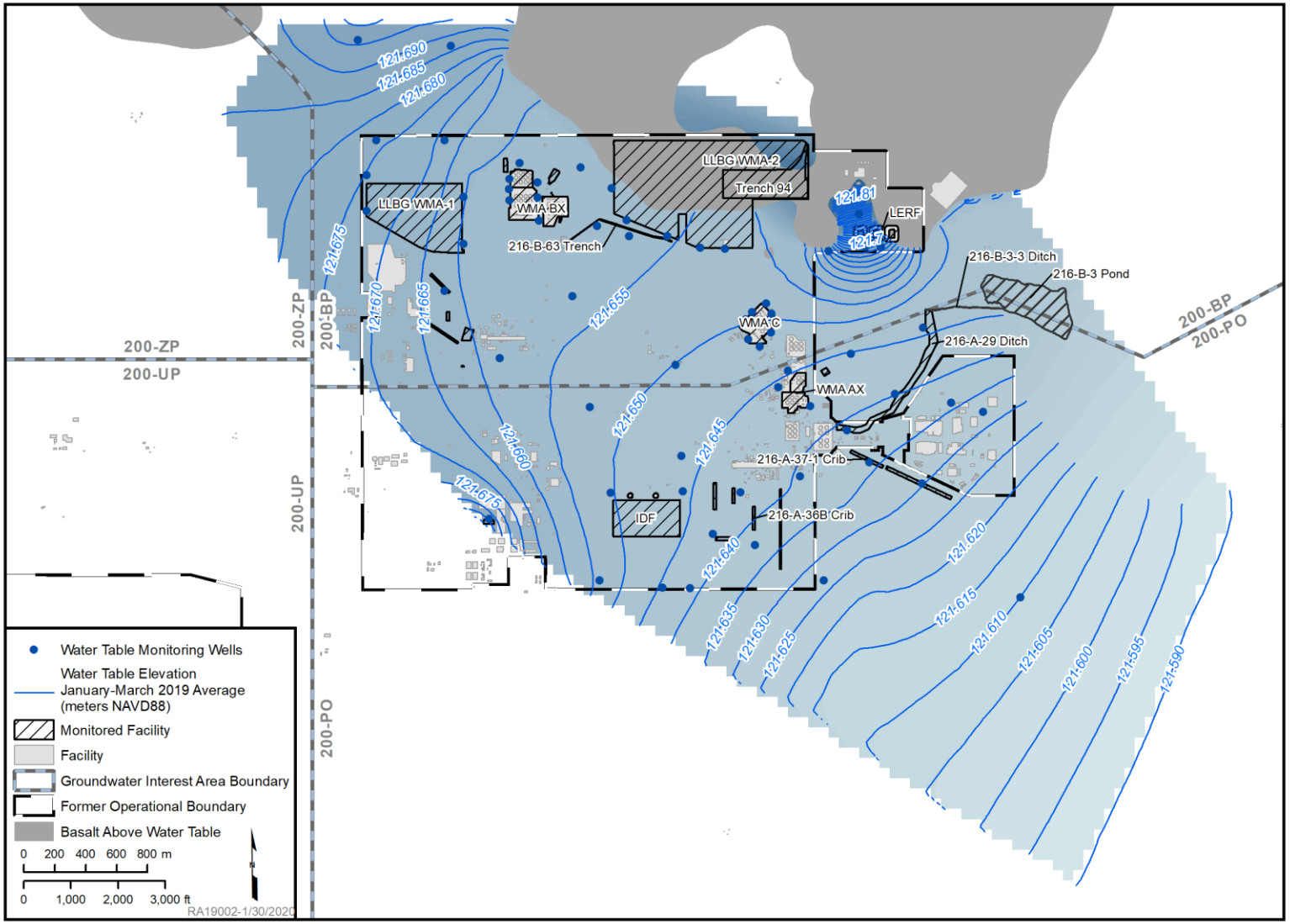
In the 200 East Area where the water table is very flat, a regularized inverse interpolation technique was applied to develop the water table map (Figure B-2). The Tikhonov regularized inverse method uses a formal mathematical method that seeks a trade-off between the complexity of the method or model that is used to interpret measured data versus the "fit" to those measured data. ECF-200E-19-0081, *Groundwater Elevation Mapping for 200 East Area – Quarter 1 Calendar Year 2019*, describes the

method of constructing the January through March Tikhonov regularized inverse method map for the 200 East Area (Figure B-2).

Groundwater flow directions in the 200 West Area are affected by groundwater extraction and injection from P&T systems (Figure B-3). A regression-based technique is used to interpret the measured water-level data and prepare depictions of hydraulic gradients and likely flow directions (ECF-200W-19-0082, *Groundwater Elevation Mapping for 200 West Area – Quarter 1 Calendar Year 2019*).

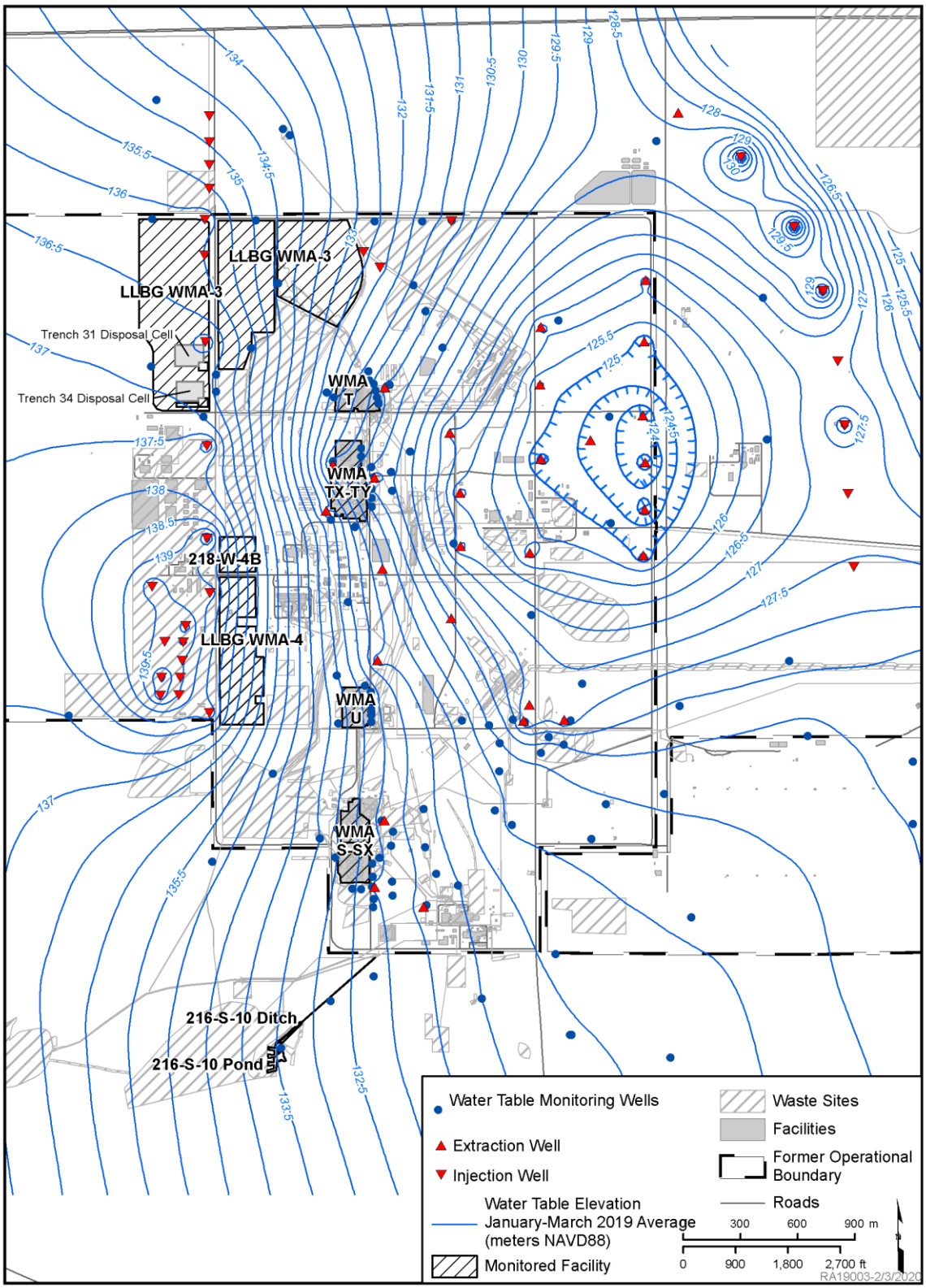
Grids of groundwater elevations based on the 200 East Area and 200 West Area water table maps were used as the basis for particle tracking at each RCRA unit (ECF-HANFORD-19-0091, *Hydraulic Gradient and Average Linear Velocity Calculations – Quarter 1 Calendar Year 2019*). Table B-2 lists the results. Estimates of gradient and velocity for RCRA units that are not listed in Table B-2 are provided in applicable tables of this appendix.

The water table beneath the Central Plateau continued to decline in recent years. The impact of these declines on groundwater monitoring wells is provided in SGW-63743, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the Central Plateau*. That document, published in 2019, compared predicted water-level elevations for 2019 through 2028 to the elevation of the bottom of monitoring well screens. Those elevations are used in the tables for the monitoring networks discussed in Chapters 2 and 3 of DOE/RL-2019-65. In some cases, the screen bottom elevations used in SGW-63743 may not have accounted for reference point differences between land surface and top of casing, resulting in estimates of water column that are smaller than actual.



Source: ECF-200E-19-0081, *Groundwater Elevation Mapping for 200 East Area – Quarter 1 Calendar Year 2019.*

Figure B-2. 200 East Area Water Table, January Through March 2019



Source: ECF-200W-19-0082, *Groundwater Elevation Mapping for 200 West Area – Quarter 1 Calendar Year 2019*.

Figure B-3. 200 West Area Water Table, January Through March 2019

Table B-2. Average Hydraulic Gradient and Average Linear Velocity, January Through March 2019

RCRA Unit	Gradient Magnitude (m/m or ft/ft)	Gradient Direction (Degrees East of North)	Average Linear Velocity, (m/d [ft/d])
200 East Area			
216-A-29 Ditch	1.7E-05	153 (south-southeast)	1.2 (4.1)
216-A-36B Crib	1.1E-05	135 (southeast)	3.6E-04 (1.2E-03)
216-A-37-1 Crib	1.5E-05	133 (southeast)	1.0 (3.4)
216-B-63 Trench	6.2E-06	135 (southeast)	0.44 (1.4)
Integrated Disposal Facility	9.7E-06	98 (east)	0.48 (1.6)
LLBG WMA-1	3.3E-05	121 (east-southeast)	2.3 (7.6)
LLBG WMA-2	5.4E-06	181 (south)	0.37 (1.2)
WMA A-AX	1.6E-05	150 (south-southeast)	1.2 (3.8)
WMA B-BX-BY	6.0E-06	142 (southeast)	0.43 (1.4)
WMA C	2.2E-05	173 (south)	1.5 (5.0)
200 West Area			
216-S-10 Pond and Ditch	2.6E-03	88 (east)	0.09 (0.30)
Trenches 31 and 34*	3.3E-03	112 (east-southeast)	0.11 (0.36)
LLBG WMA-3	4.3E-03	92 (east)	0.14 (0.46)
LLBG WMA-4	8.8E-03	98 (east)	0.29 (0.95)
WMA S-SX	4.5E-03	94 (east)	0.15 (0.49)
WMA T	6.8E-03	105 (east-southeast)	0.23 (0.75)
WMA TX-TY	9.2E-03	103 (east-southeast)	0.31 (1.0)
WMA U	6.1E-03	80 (east)	0.20 (0.66)

Notes: Information in this table is from Tables 7-1 and 7-2 in ECF-HANFORD-19-0091, *Hydraulic Gradient and Average Linear Velocity Calculations – Quarter 1 Calendar Year 2019*.

Hydraulic conductivity for the Hanford formation is 17,000 m/d (55,800 ft/d), for the Cold Creek unit gravel is 18,200 m/d (59,700 ft/d), and for Ringold unit E is 5 m/d (16 ft/d). Effective porosity for the Hanford formation is 0.25 and for Ringold unit E is 0.15.

*Located in LLBG WMA-3.

LLBG = low-level burial grounds

RCRA = *Resource Conservation and Recovery Act of 1976*

WMA = waste management area

B6 Specific Conductance

Specific conductance (one of the interim status contamination indicator parameters) is a measure of the ability of water to pass an electrical current, and it is affected by the presence of dissolved solids. The primary contributors to specific conductance in Hanford Site groundwater are bicarbonate, chloride, nitrate, sulfate, calcium, potassium, magnesium, and sodium. Many of these ions are present from natural sources, and others (notably nitrate and sulfate) were introduced from Hanford Site waste disposal. Contaminants such as nitrate are commonly detected in concentrations of tens of mg/L and have a large effect on specific conductance. Specific conductance is not a reliable indicator of contaminants such as chromium that are present in concentrations of tens of µg/L (three orders of magnitude less).

Regional nitrate and sulfate plumes influence the contamination indicator parameter specific conductance. These plumes originated at past-practice waste sites and some RCRA units. Many of the RCRA units in the 200 East and 200 West Areas are located within regional nitrate or sulfate plumes. Interactive groundwater monitoring report tools[2] allow users to view nitrate plumes as they migrated from 1993 to 2019.

B7 RCRA Inspections

During 2019, Ecology conducted three inspections of Hanford Site RCRA units and documented the results in the following letters:

- 19-NWP-127, "Dangerous Waste Compliance Inspection on May 9, 2019 at the Single Shell Tank (SST) System, Resource Conservation Recovery Act (RCRA) Site ID: WA7890008967, NWP Compliance Index No.: 19.662"

  This inspection cited two concerns and no areas of noncompliance. Neither of the concerns was related to groundwater monitoring.

- 19-NWP-172, "Dangerous Waste Compliance Inspection on June 20, 2019, at the 216-A-29 Ditch, 216-A-37-1 Crib, 216-A-36B Crib, 216-B-63 Trench, 216-S-10 Pond and Ditch, and 216-B-3 Main Pond RCRA Site ID: WA7890008967, Nuclear Waste Program Compliance Index Nos.: 19.665 to 19.670"

  This inspection identified no concerns and one noncompliance. During the third quarter of 2018, a required analysis for ammonia in well 299-E26-13 (at the 216-A-29 Ditch) was not performed because of a sample preservation error. DOE notified Ecology of the omission in October 2018, and it was also reported in Section 3.8 of DOE/RL-2018-65, *Hanford Site RCRA Groundwater Monitoring Report for 2018*. The inspection report indicated that no further action was required.

- 19-NWP-208, "Dangerous Waste Compliance Inspection on June 20, 2019, at 183-H, 300-APT, LLBG Green Islands WMA-4, and NRDWL RCRA Site ID: WA7890008967, Nuclear Waste Program Compliance Index Nos.: 19.671 thru 19.674"

  This inspection identified no areas of noncompliance and one area of concern. No pre-trip inspection was performed before a sampling event at well 199-H4-8 at the 183-H Solar Evaporation Basins in February 2018.

[2] The interactive groundwater monitoring report tools are available online at https://higrv.hanford.gov/Hanford_Reports_2017/Hanford_GW_Report/.

B8 Supporting Tables

Tables B-3 through B-63 contain supporting information originally published in DOE/RL-2019-65.

Table B-3. 183-H Groundwater Monitoring Network

Well Name	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments; Sampling Exceptions
			m	ft	m	ft	m	ft	m	ft		
199-H4-8	1986 (C)	7/11/2019	114.94	377.10	117.0	383.9	114.0	373.9	1.0	3.2	S	No fall 2019 sample
199-H4-84	2011 (C)	8/5/2019	114.76	376.51	117.2	384.4	114.1	374.4	0.6	2.1	S	No fall 2019 sample
199-H4-85	2013 (C)	8/6/2019	115.02	377.36	119.7	392.6	113.6	372.7	1.4	4.6	S	
199-H4-88	2016 (C)	8/5/2019	114.78	376.56	119.3	391.5	113.2	371.5	1.5	5.0	Q/S	November and December samples collected using bailer
199-H4-89	2016 (C)	8/5/2019	114.83	376.73	118.6	389.2	114.1	374.2	0.8	2.5	Q/S	December sample collected with a bailer; insufficient water available to conduct all required analyses (see Table B-4)

Note: Requirements are from the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c [modification date of May 24, 2017], Part VI, Post-Closure Unit 2 (PCU-2), Chapter 3.0, "Groundwater Monitoring Plan").

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

Q/S = quarterly for first 2 years from the third quarter of 2017 through the second quarter of 2019; semiannually thereafter

RCRA = *Resource Conservation and Recovery Act of 1976*

S = semiannually

Table B-4. 183-H Solar Evaporation Basins Sampling Results, 2019

Well	Sample Date	Program	Chromium (Filtered) (µg/L)	Nitrate (mg/L)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (µS/cm)	Temperature (ºC)	Turbidity (NTU)
Permit Concentration Limit			**48**	**45**	**—**	**—**	**—**	**—**	**—**
199-H4-8[a]	5/1/2019	RCRA, CERCLA	5.5	11.5 D	4.7	7.40	530	25.1 Y	5.2
199-H4-84[a]	5/1/2019	RCRA, CERCLA	30.0	55.8 D	7.0	7.45	767	21.7	8.7
199-H4-85	3/7/2019	CERCLA	—	7.5	9.7	7.77	227	17.8	1.3
	5/1/2019	RCRA, CERCLA	5.0 N	5.3 D	8.5	7.43	194	15.4 Y	2.7
	8/6/2019	CERCLA	—	3.5	9.4	7.60	191	19.3	3.6
	12/30/2019	RCRA, CERCLA	5.74 B	1.7	9.4	7.74	177	15.5	4.9
199-H4-88[a]	3/7/2019	RCRA, CERCLA	12.0	53.1 D	7.3	7.42	731	18.5	4.6
	5/1/2019	RCRA, CERCLA	10.2 N	47.8 D	6.2	7.48	743	22.8	4.8
			10.1 N	47.8 D					
	8/5/2019	RCRA, CERCLA	7.8 B	45.2 DXH	6.2	7.48	759	24.9	4.7
	11/8/2019	RCRA, CERCLA	10.0	66.4 H	10	7.57	756	14.8	36.3
	12/30/2019	RCRA, CERCLA	8.8 B	70.9 D	8.5	7.25	934	17.0	2.3
199-H4-89[a]	3/7/2019	RCRA, CERCLA	4.3 BD	19.9 D	6.1	7.22	586	17.7	4.5
	5/2/2019	RCRA, CERCLA	4.4 BD	21.3	6.2	7.02	659	19.3	2.8
	8/5/2019	RCRA, CERCLA	4.9 B	37.6 D	6.4	7.14	678	22.7	3.0
	12/30/2019	RCRA, CERCLA	—[a]	—[a]	6.2	7.16	737	17.6	>1,000[b]

Table B-4. 183-H Solar Evaporation Basins Sampling Results, 2019

Well	Sample Date	Program	Chromium (Filtered) (µg/L)	Nitrate (mg/L)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (µS/cm)	Temperature (ºC)	Turbidity (NTU)

Notes: This table contains sample results collected specifically for this RCRA unit, as well as CERCLA data used for statistical calculations in well 199-H4-85 (see text discussion). Appendix A of DOE/RL-2019-65 presents the full data set for 2019.

Yellow-highlighted cells indicate concentrations greater than the concentration limit identified in the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part VI, Post-Closure Unit 2 (PCU-2), Chapter 3.0, "Groundwater Monitoring Plan").

a. Well 199-H4-88 was the only well successfully sampled as scheduled in November because others were dry. Sampling of all of the wells was attempted again in December, but only wells 199-H4-85 and 199-H8-88 had sufficient water to produce samples.

b. Turbidity off-scale; bailed sample.

— = not applicable

B = result is below the quantitation limit

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

D = reported at a secondary dilution factor

H = recommended holding time exceeded (review flag)

N = spike and/or spike duplicate sampling recover was outside control limits

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

X = recommended holding time exceeded (laboratory flag)

Y = suspected error

Table B-5. Statistical Evaluation of 183-H Solar Evaporation Basins Dangerous Waste Constituents, 2019

Well	Semiannual Period	Chromium (Filtered) (Permit Concentration Limit 48 µg/L)	Nitrate (Permit Concentration Limit 45 mg/L)
		95% UCL	95% UCL
199-H4-8	January – June	N/A[a]	N/A[a]
	July – December	N/A[a]	N/A[a]
199-H4-84	January – June	N/A[a,b]	104.9[b]
	July – December	46.91	71.9
199-H4-85	January – June	N/A[a,b]	N/A[a,b]
	July – December	N/A[a,b]	N/A[a,b]
199-H4-88	January – June	N/A[a,b]	78.7[b]
	July – December	N/A[a]	74.9
199-H4-89	January – June	N/A[a,c]	37.6[b]
	July – December	N/A[a]	41.16

Sources:

SGW-63832, *Post-Closure Corrective Action Groundwater Monitoring Report for the 183-H Solar Evaporation Basins: January – June 2019*.

SGW-64454, *Post-Closure Corrective Action Groundwater Monitoring Report for the 183-H Solar Evaporation Basins: July – December 2019*.

Note: Yellow-highlighted cells indicate that the UCL exceeded a concentration limit identified in the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part VI, Post-Closure Unit 2 (PCU-2), Chapter 3.0, "Groundwater Monitoring").

a. None of the results in the data set exceeded the concentration limit; therefore, no UCL was calculated.

b. Samples collected for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* monitoring.

N/A = not applicable

RCRA = *Resource Conservation and Recovery Act of 1976*

UCL = upper confidence limit

Table B-6. 216-A-29 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-E25-238	DG	2017 (C)	10/8/2019	121.60	398.94	122.3	401.3	113.2	371.3	8.4	27.6	Q	1, 4, 7, 10
299-E25-239	DG	2017 (C)	10/8/2019	121.58	398.88	122.8	402.7	113.6	372.7	8.0	26.1	Q	1, 4, 7, 10
299-E25-34[a]	UG	1988 (C)	10/8/2019	121.63	399.04	125.8	412.6	119.7	392.6	2.0	6.5	Q	1, 4, 7, 10
299-E25-35[a]	DG	1988 (C)	10/4/2019	121.60	398.94	126.2	414.0	119.9	393.5	1.6	5.4	Q	1, 4, 7, 10
299-E25-43	UG	1991 (C)	10/7/2019	121.58	398.89	125.5	411.6	119.1	390.6	2.5	8.3	Q	1,[b] 4,[c] 5, 7, 10
299-E25-47	UG	1992 (C)	10/4/2019	121.59	398.91	125.2	410.7	119.0	390.4	2.5	8.4	Q	1, 4, 7, 10
299-E26-13[a]	UG	1991 (C)	9/27/2019	121.63	399.05	126.0	413.2	119.7	392.6	2.0	6.4	Q	1, 4, 7, 10
299-E26-80	DG	2017 (C)	10/7/2019	121.61	398.97	122.5	402.0	113.4	372.0	8.2	27.0	Q	1, 4, 7, 10

Note: Requirements are from Table 3-2 in DOE/RL-2016-23, *216-A-29 Ditch Interim Status Groundwater Quality Assessment Monitoring Plan*.

a. Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

b. No quadruplicate field readings recorded.

c. Total organic halides samples in April 2019 exceeded holding time; well resampled in May.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

Q = quarterly

UG = upgradient

Table B-7. 216-A-29 Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Alkalinity (total and bicarbonate)	mg/L	82.5	120	—	
Ammonia	µg/L	20.7 U	235	—	
Calcium, unfiltered	µg/L	25,100	68,500	—	
Calcium, filtered	µg/L	24,200	69,500	—	
Chloride	mg/L	4.96	30.0	250[b]	
Chromium, unfiltered	µg/L	0.89 B	27.0	100[c]	
Chromium, filtered	µg/L	0.71 B	7.5 B	100[c]	
Iron, unfiltered	µg/L	22 U	360	300[b]	299-E25-35
Iron, filtered	µg/L	22 U	50.3	300[b]	
Magnesium, unfiltered	µg/L	7,350	19,200	—	
Magnesium, filtered	µg/L	7,170	18,400	—	
Manganese, unfiltered	µg/L	0.31 U	6.1	50[b]	
Manganese, filtered	µg/L	0.31 U	5.0	50[b]	
Nickel, unfiltered	µg/L	0.6 U	13 B	—	
Nickel, filtered	µg/L	0.49 B	4.9 B	—	
Nitrate	mg/L	2.58	60.6	45[d]	299-E25-47
pH measurement	unitless	7.85	8.48	6.5 – 8.5[b]	
Phenols[e]	µg/L	0.08 U	8.4 U	2,400[f]	
Potassium, unfiltered	µg/L	4,480	8,500	—	
Potassium, filtered	µg/L	4,600	8,300	—	
Sodium, unfiltered	µg/L	8,800	30,800	—	
Sodium, filtered	µg/L	8,800	31,200	—	
Specific conductance	µS/cm	239	573	—	
Sulfate	mg/L	18.9	150	250[b]	
Temperature	°C	15.4	19.4	—	
TOC	µg/L	330 U	609 B	—	
TOX	µg/L	3.33 U	11.3 B	—	
Turbidity	NTU	0.11	3.8	—	

Table B-7. 216-A-29 Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Detected Dangerous Waste Constituents[g]					
Acetone	µg/L	1.1 J	7.56 J	—	
Antimony, unfiltered	µg/L	0.15 B	0.45 B	6[c]	All <PQL
Antimony, filtered	µg/L	0.18 B	3.6	6[c]	
Arsenic, unfiltered	µg/L	4.2	11.5	10[c]	299-E25-34, 299-E25-35, 299-E25-47, 299-E26-13
Arsenic, filtered	µg/L	4.2	11.2	10[c]	299-E25-34, 299-E25-35, 299-E25-47, 299-E26-13
Barium, unfiltered	µg/L	18.1	47.3	2,000[c]	
Barium, filtered	µg/L	18	47.7	2,000[c]	
Beryllium, filtered	µg/L	—	0.43 B	4[c]	Single detection; <PQL
Bis(2-ethylhexyl) phthalate	µg/L	N/A	0.597 J	6[c]	All <PQL
Cadmium, filtered	µg/L	—	0.30 B	5[c]	Single detection; <PQL
Carbon disulfide	µg/L	—	0.49 J	—	All <PQL
Cobalt, unfiltered	µg/L	0.057 B	0.26 B	—	All <PQL
Cobalt, filtered	µg/L	0.080 B	1.2 B	—	All <PQL
Copper, unfiltered	µg/L	0.326	7.61 B	1,000[b]	
Copper, filtered	µg/L	0.300	1.00 B	1,000[b]	All <PQL
Di-n-butylphthalate	µg/L	0.641 B	2.33 J	—	All <PQL
Lead, unfiltered	µg/L	0.10	0.1 B	15[h]	All <PQL
Lead, filtered	µg/L	—	0.3 B	15[h]	Single detection; <PQL
Mercury, filtered	µg/L	—	0.068 B	2[c]	All <PQL
Selenium, unfiltered	µg/L	1.4 B	7.37	50[b]	
Selenium, filtered	µg/L	1.6 B	7.19	50[b]	
Silver, unfiltered	µg/L	—	0.04 B	100[b]	Single detection; <PQL
Silver, filtered	µg/L	0.04 B	0.05 B	100[b]	All <PQL
Thallium, unfiltered	µg/L	—	1.4 B	2[c]	Single detection; <PQL
Thallium, filtered	µg/L	—	0.34 B	2[c]	Single detection; <PQL
Tin, unfiltered	µg/L	0.14 B	1.43 B	—	All <PQL
Tin, filtered	µg/L	0.17 B	1.38 B	—	All <PQL
Vanadium, unfiltered	µg/L	13.4	42.9 B	—	

Table B-7. 216-A-29 Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Vanadium, filtered	µg/L	16.0	39.8 B	—	
Zinc, unfiltered	µg/L	1.5 B	10.9	5,000[b]	
Zinc, filtered	µg/L	3.4 B	17 B	5,000[b]	All <PQL

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

g. Samples were analyzed for all dangerous waste constituents listed in Table 3-1 of DOE/RL-2016-23, *216-A-29 Ditch Interim Status Groundwater Quality Assessment Monitoring Plan*. Only detected constituents and ranges are listed in this table.

h. Action level (40 CFR 141, Subpart I, "Control of Lead and Copper").

—	=	no comparison value	PQL	=	practical quantitation limit
B or J	=	result is below the quantitation limit	RCRA	=	*Resource Conservation and Recovery Act of 1976*
NTU	=	nephelometric turbidity unit	U	=	result is below the detection limit

Table B-8. 216-A-36B Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E17-1	UG	1955 (P)	7/16/2019	121.50	398.63	127.2	417.4	120.2	394.4	1.3	4.1	S	Sampled with bailer
299-E17-14	DG	1988 (C)	7/16/2019	121.62	399.00	126.0	413.2	119.2	391.2	2.4	7.8	S	
299-E17-15	DG	1988 (C)	7/16/2019	121.34	398.10	125.5	411.8	119.6	392.3	1.8	5.8	S	
299-E17-16	DG	1988 (C)	7/16/2019	121.54	398.75	125.4	411.4	119.3	391.4	2.2	7.3	S	
299-E17-18*	DG	1988 (C)	7/16/2019	121.61	398.98	125.8	412.6	118.8	389.8	2.8	9.2	S	
299-E17-19	UG	1988 (C)	7/16/2019	121.42	398.35	126.8	416.0	119.9	393.4	1.5	4.9	S	

Note: Requirements are from Table 3-1 in DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*.

*Hydraulic head data for this well corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

S = semiannual

UG = upgradient

Table B-9. 216-A-36B Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean*		6.70	8.98	938		1,300			17.7				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
299-E17-1	1/11/2019	8.02	0.04	587	9	330 U	0	1,000	3.4 B	0.1	10	GEL	
	7/16/2019	7.94	0.01	593	15	460 B	19	1,000	3.3 U	0.0	10	GEL	
299-E17-14	1/11/2019	7.95	0.00	711	14	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/16/2019	7.76	0.00	716	0	370 B	15	1,000	7.8	4.8	10	GEL	
299-E17-15	1/11/2019	8.10	0.00	636	8	330 U	0	1,000	3.5 B	0.2	10	GEL	
	7/16/2019	7.90	0.00	632	1	330 U	0	1,000	4.5 B	1.3	10	GEL	
299-E17-16	1/11/2019	7.98	0.01	608	0	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/16/2019	7.81	0.00	608	0	330 U	0	1,000	4.1 B	1.3	10	GEL	
299-E17-18	1/11/2019	7.95	0.00	598	5	330 U	0	1,000	4.7 B	1.2	10	GEL	
	7/16/2019	7.78	0.00	618	0	330 U	0	1,000	3.3 U	0.0	10	GEL	
299-E17-19	1/11/2019	7.87	0.00	734	9	330 U	0	1,000	5.4 B	2.3	10	GEL	
	7/16/2019	7.78	0.00	711	4	330 U	0	1,000	3.3 U	0.0	10	GEL	

*Critical mean values from Table 10 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
SD = standard deviation of replicates
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-10. 216-A-36B Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	121	131	—	
Calcium (unfiltered)	µg/L	57,100	77,300	—	
Calcium (filtered)	µg/L	57,600	76,300	—	
Chloride	mg/L	16.0	18.0	250[c]	
Dissolved oxygen	mg/L	6.8	9.1	—	
Fluoride	mg/L	0.27	0.38	4[d]	
Iron (unfiltered)	µg/L	42 B	3,340	300[c]	299-E17-1, 299-E17-18
Iron (filtered)	µg/L	22 U	86.4	300[c]	
Magnesium (unfiltered)	µg/L	19,000	22,800	—	
Magnesium (filtered)	µg/L	19,000	23,000	—	
Manganese (unfiltered)	µg/L	0.93 B	71.5	50[c]	299-E17-1
Manganese (filtered)	µg/L	0.31 U	40.6	50[c]	
Nitrate	mg/L	70.8	133	45[e]	All
Nitrite	mg/L	0.125 U	0.125 U	3.3[e]	No detections
Phenols[f]	µg/L	0.24 U	19 U	2,400[g]	No detections
Potassium (unfiltered)	µg/L	6,900	8,370	—	
Potassium (filtered)	µg/L	6,900	8,480	—	
Sodium (unfiltered)	µg/L	24,000	30,100	—	
Sodium (filtered)	µg/L	24,000	30,100	—	
Sulfate	mg/L	80.0	110	250[c]	
Temperature	°C	17.3	24.7	—	
Turbidity	NTU	0.58	16.3	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in January 2019. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

Table B-10. 216-A-36B Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

f. Analysis for phenols included 17 compounds, which were all below detection limits. The minimum and maximum detection limits are listed in this table.

g. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value
B = result is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-11. 216-A-37-1 Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E25-17	DG	1976 (P)	7/11/2019	121.98	400.20	123.5	405.1	118.2	387.8	3.7	12.3	S	
299-E25-19*	DG	1976 (P)	7/11/2019	122.64	402.36	124.5	408.6	116.9	383.6	5.7	18.8	S	
299-E25-20	DG	1976 (P)	7/11/2019	122.52	401.97	124.5	408.6	118.6	389.1	3.9	12.9	S	
299-E25-35*	UG	1988 (C)	7/11/2019	121.62	399.02	126.2	414.0	119.9	393.5	1.7	5.5	S	
299-E25-47	UG	1992 (C)	7/11/2019	121.62	399.00	125.2	410.7	119.0	390.5	2.6	8.5	S	
299-E25-95	DG	2017 (C)	7/11/2019	121.61	398.99	122.3	401.2	113.1	371.2	8.5	27.8	S	

Note: Requirements are from DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*.

*Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

S = semiannually

UG = upgradient

Table B-12. 216-A-37-1 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean*		7.58	9.01	714		705			13.1				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
299-E25-17	1/10/2019	7.88	0.00	565	1	330 U	0	1,000	3.4 B	0.1	10	GEL	
	7/11/2019	7.70	0.00	566	1	401 B	6	1,000	3.3 B	0.0	10	GEL	
299-E25-19	1/10/2019	7.92	0.00	438	0	330 U	0	1,000	3.3 B	0.0	10	GEL	
	7/11/2019	7.96	0.00	430	0	468 B	9	1,000	3.3 U	0.0	10	GEL	
299-E25-20	1/10/2019	7.68	0.00	476	1	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/11/2019	7.55	0.00	477	0	343 B	11	1,000	4.4 B	1.9	10	GEL	Average pH below critical range
	9/9/2019	7.71	0.04	477	1	N/A	N/A	1,000	N/A	N/A	10	N/A	pH verification; not confirmed
		7.72	0.04										
299-E25-35	1/11/2019	8.19	0.00	517	1	330 B	0	1,000	3.5 B	0.4	10	GEL	
	7/11/2019	8.07	0.00	532	2	333 B	2	1,000	3.3 U	0.0	10	GEL	
299-E25-47	1/11/2019	8.41	0.04	439	5	330 U	0	1,000	3.9 B	0.7	10	GEL	
	7/11/2019	8.26	0.01	511	2	378 B	13	1,000	4.0 B	1.2	10	GEL	
299-E25-95	1/10/2019	7.97	0.00	514	2	351 B	22	1,000	4.0 B	1.1	10	GEL	
	7/11/2019	7.84	0.00	530	1	417 B	8	1,000	3.3 U	0.0	10	GEL	

Note: Yellow-highlighted cell indicates exceedance of a critical mean.

*Critical mean values are from Table 11 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
N/A = not applicable
SD = standard deviation of replicates
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-13. 216-A-37-1 Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	88	94	—	
Calcium (unfiltered)	µg/L	38,000	59,000	—	
Calcium (filtered)	µg/L	39,000	59,000	—	
Chloride	mg/L	7.5	19.0	250[c]	
Chromium (unfiltered)	µg/L	1.3 B	31.2	100[d]	
Chromium (filtered)	µg/L	1.2 B	4.4	100[d]	
Fluoride	mg/L	0.22	0.38	4.0[d]	
Hexavalent chromium	µg/L	1.5 U	1.5 U	48[e]	
Iron (unfiltered)	µg/L	30 U	1,130	300[c]	299-E25-19, 299-E25-20
Iron (filtered)	µg/L	30 U	237	300[c]	
Magnesium (unfiltered)	µg/L	12,000	17,000	—	
Magnesium (filtered)	µg/L	12,300	17,000	—	
Manganese (unfiltered)	µg/L	0.36 U	117	50[c]	299-E25-19, 299-E25-20
Manganese (filtered)	µg/L	0.36 U	113	50[c]	299-E25-19, 299-E25-20
Nickel (unfiltered)	µg/L	0.92 U	18.6	—	
Nickel (filtered)	µg/L	0.92 U	9.8	—	
Nitrate	mg/L	5.75	84.1	45[f]	299-E25-19, 299-E25-20, 299-E25-95
Nitrite	mg/L	0.125	0.174 B	3.3[f]	
Phenols[g]	µg/L	0.24 U	19 U	2,400[e]	
Potassium (unfiltered)	µg/L	6,200	8,020	—	
Potassium (filtered)	µg/L	6,200	8,040	—	
Sodium (unfiltered)	µg/L	15,000	25,000	—	
Sodium (filtered)	µg/L	15,000	25,000	—	
Sulfate	mg/L	56.0	150	250[c]	
Temperature	°C	15.4	22.9	—	
Turbidity	NTU	0.25	25.4	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in January 2019. Appendix A of DOE/RL-2019-65 , *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

Table B-13. 216-A-37-1 Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

f. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

g. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

— = no comparison value

B = result is below the quantitation limit

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

U = result is below the detection limit

Table B-14. 216-B-3 Main Pond Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
699-42-42B	DG	1988 (C)	7/1/2019	122.08	400.52	121.8	399.6	115.7	379.6	6.4	21.0	S	
699-43-45	DG	1989 (C)	3/29/2019	121.64	399.08	126.5	414.9	120.3	394.6	1.4	4.5	S	July water level erroneous
699-44-39B	UG	1992 (C)	7/1/2019	123.26	404.38	126.2	414.1	120.1	394.1	3.1	10.2	S	
699-44-43C	UG	2017 (C)	7/1/2019	122.67	402.46	124.1	407.0	116.4	382.0	6.2	20.4	S	
699-43-43B	DG	Proposed	—	—	—	—	—	—	—	—	—	Q/S	Not yet installed

Note: Requirements are from Table 3-1 in DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*, as modified by RCRA-CN-01_DOE/RL-2008-59_R2, *RCRA Interim Status Change Number 1: Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*.

— = no information (well not yet installed)

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

Q/S = quarterly first year; semiannually thereafter

S = semiannually

UG = upgradient

Table B-15. Groundwater Velocity at 216-B-3 Main Pond

Flow Direction	Ringold semiconfined: 227 degrees (southwest) Hanford unconfined: 160 degrees (south-southeast)
Flow Rate (m/d)	Ringold semiconfined: 0.064 Hanford unconfined: 1.1
Hydraulic Conductivity (m/d) (Source)	Ringold Formation: 5.0 (CP-57037) Hanford formation: 17,000 m/d (ECF-HANFORD-19-0091)
Effective Porosity	Ringold Formation: 0.1 (CP-57037) Hanford formation: 0.25 (ECF-HANFORD-19-0091)
Gradient (m/m)	Ringold semiconfined: 1.3×10^{-3} Hanford unconfined: 1.5×10^{-5}
Comments	Ringold Formation gradient based on three-point analysis of data collected in March 2019. Hanford formation gradient based on ECF-HANFORD-19-0091.

References:

CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*.

ECF-HANFORD-19-0091, *Hydraulic Gradient and Average Linear Velocity Calculations – Quarter 1 Calendar Year 2019*.

Table B-16. 216-B-3 Main Pond Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean*		7.38	8.69	453		953			8.0				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
699-42-42B	1/7/2019	—	—	—	—	—	—	—	—	—	—	—	Incomplete January sampling; sampling completed in March
	3/27/2019	8.0	0.0	311	0	330 U	0	1,000	4.8 B	2.6	10	GEL	
	7/1/2019	8.0	0.0	309	0	330 U	0	1,000	5.2	3.0	10	GEL	
699-43-45	1/7/2019	8.2	0.0	293	0	330 U	0	1,000	3.8 B	0.8	10	GEL	
	7/1/2019	8.3	0.0	299	0	330 U	0	1,000	3.6 B	0.5	10	GEL	
699-44-39B	1/7/2019	8.2	0.0	259	0	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/1/2019	8.2	0.0	261	1	330 U	0	1,000	6.3	3.7	10	GEL	
699-44-43C	1/7/2019	8.0	0.0	276	0	339 B	8	1,000	5.4 B	2.6	10	GEL	
	7/1/2019	8.2	0.0	279	1	416 B	23	1,000	4.2 B	1.3	10	GEL	

*Critical mean values are from Table 12 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
SD = standard deviation of replicates
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-17. 216-B-3 Main Pond Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	96	109	—	
Arsenic (unfiltered)	µg/L	4.0 B	14.6	10[b]	699-42-42B, 699-43-45
Arsenic (filtered)	µg/L	4.0 B	17.6	10[b]	699-42-42B
Cadmium (unfiltered)	µg/L	0.2 U	1.0 U	5[b]	
Cadmium (filtered)	µg/L	0.2 U	1.0 U	5[b]	
Calcium (unfiltered)	µg/L	24,000	32,300	—	
Calcium (filtered)	µg/L	24,100	32,200	—	
Chloride	mg/L	4.5	5.9	250[c]	
Dissolved oxygen	mg/L	8.01	13.52	—	
Iron (unfiltered)	µg/L	30 U	82 B	300[c]	
Iron (filtered)	µg/L	30 U	31.9 B	300[c]	
Magnesium (unfiltered)	µg/L	8,630	11,000	—	
Magnesium (filtered)	µg/L	8,490	10,400	—	
Manganese (unfiltered)	µg/L	1.0	12.2	50[c]	
Manganese (filtered)	µg/L	1.0	9.4	50[c]	
Nitrate	mg/L	3.36	18.6	45[d]	
Phenols[e]	µg/L	0.43 U	8.4 U	2,400[f]	
Potassium (unfiltered)	µg/L	4,150	5,220	—	
Potassium (filtered)	µg/L	4,160	5,200	—	
Sodium (unfiltered)	µg/L	10,700	20,300	—	
Sodium (filtered)	µg/L	10,800	20,700	—	
Sulfate	mg/L	20.0	30.0	250[c]	
Temperature	°C	15.9	22.6	—	
Turbidity	NTU	0.45	4.94	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in January 2019 (March 2019 for well 699-42-42B). Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

Table B-17. 216-B-3 Main Pond Sampling Summary for Groundwater Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

d. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value

B = result is below the quantitation limit

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

U = result is below the detection limit

Table B-18. 216-B-63 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E27-16	DG	1990 (C)	11/5/2019	121.54	398.76	126.2	414.1	119.8	393.1	1.7	5.7	S	
299-E27-18*	DG	1992 (C)	11/5/2019	121.61	399.00	124.7	409.1	118.6	389.0	3.1	10.0	S	
299-E27-19	DG	1992 (C)	11/5/2019	121.52	398.68	124.7	409.1	118.6	389.1	2.9	9.6	S	
299-E33-33	UG	1989 (C)	11/5/2019	121.85	399.76	126.0	413.4	119.6	392.4	2.2	7.3	S	
299-E34-12	UG	1992 (C)	11/6/2019	121.51	398.64	126.6	415.3	120.4	395.0	1.1	3.7	S	
299-E34-8	UG	1990 (C)	11/5/2019	121.64	399.08	126.0	413.2	119.4	391.7	2.2	7.3	S	

Note: Requirements are from Table 3-1 in DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*.

*Hydraulic head data for this well were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

S = semiannually

UG = upgradient

Table B-19. 216-B-63 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		Total Organic Carbon (µg/L)				Total Organic Halides (µg/L)				
2019 Critical Mean*		7.7	8.55	907		690				5.45				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Lab	Avg	SD	LOQ	Lab	Comment
299-E27-16	5/1/2019	8.21	0.00	551	1	178 B	21	1,000	TADN	5.8 B	2.4	10	GEL	
	11/5/2019	8.12	0.01	553	1	345 U	0	1,000	TADN	3.3 U	0.0	10	GEL	
299-E27-18	5/1/2019	8.27	0.03	633	8	195 B	3	1,000	TADN	5.1 B	2.3	10	GEL	
	11/5/2019	8.01	0.01	528	2	377 B	47	1,000	GEL	3.6 B	0.4	10	GEL	
299-E27-19	5/1/2019	8.29	0.02	669	2	208 B	11	1,000	TADN	4.0 B	1.1	10	GEL	
	11/5/2019	8.04	0.01	637	1	345 U	0	1,000	TADN	3.3 U	0.0	10	GEL	
299-E33-33	5/1/2019	8.14	0.01	608	2	211 B	13	1,000	TADN	4.5 B	0.4	10	GEL	
	11/5/2019	8.02	0.01	583	1	345 U	0	1,000	TADN	3.4 B	0.1	10	GEL	
299-E34-12	5/2/2019	8.01	0.01	622	1	188 B	18	1,000	TADN	7.7 U	0.0	30	TADN	
	11/6/2019	7.99	0.01	478	1	330 B	0	1,000	GEL	3.8 B	0.8	10	GEL	
299-E34-8	5/2/2019	8.19	0.05	669	1	220 B	11	1,000	TADN	7.7 U	0.0	30	TADN	
	11/5/2019	7.96	0.01	645	1	330 U	0	1,000	GEL	3.4 B	0.1	10	GEL	

*Critical mean values from Table 13 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
SD = standard deviation of replicates
TADN = TestAmerica – Denver
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-20. 216-B-63 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	103	120	—	
Calcium (unfiltered)	µg/L	53,500	74,600	—	
Chloride	mg/L	13.0	25.0	250[b]	
Dissolved oxygen	mg/L	7.84	10.46	—	
Fluoride	mg/L	0.16 B	0.47	4.0[c]	
Iron (unfiltered)	µg/L	33.8 B	190	300[b]	
Magnesium (unfiltered)	µg/L	13,700	20,400	—	
Manganese (unfiltered)	µg/L	1.04 B	4.2	50[b]	
Nitrate	mg/L	53.1	133	45[d]	All
Nitrite	mg/L	0.046 U	0.755	3.3[d]	
Phenols[e]	µg/L	0.24 U	19 U	2,400[f]	
Potassium (unfiltered)	µg/L	7,630	9,170	—	
Sodium (unfiltered)	µg/L	21,000	28,600	—	
Sulfate	mg/L	66.0	101	250[b]	
Temperature	°C	17.7	19.4	—	
Turbidity	NTU	0.64	6.47	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in November. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value

B = result is below the quantitation limit

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

U = result is below the detection limit

Table B-21. 216-S-10 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-W26-13	DG	1999 (C)	11/8/2019	133.32	437.39	137.4	450.8	126.7	415.7	6.6	21.7	S	
299-W26-14	DG	2003 (C)	11/8/2019	132.63	435.13	136.6	448.1	125.9	413.1	6.7	22.0	S	
299-W27-2	DG/deep	1992 (C)	5/6/2019	132.11	433.44	82.7	271.4	79.6	261.2	52.5	172.3	A	
699-32-76	DG	2008 (C)	11/8/2019	132.33	434.16	134.8	442.2	124.1	407.2	8.2	27.0	S	
699-33-75	DG	2008 (C)	11/8/2019	132.05	433.23	135.0	442.8	124.3	407.8	7.7	25.4	S	
699-33-76	UG	2008 (C)	11/8/2019	132.94	436.15	135.5	444.7	124.9	409.7	8.1	26.5	S	

Note: Requirements are from Table 3-1 in DOE/RL-2008-61, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*.

A = annually

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

S = semiannually

UG = upgradient

Table B-22. 216-S-10 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		Total Organic Carbon (µg/L)				Total Organic Halides (µg/L)				
2019 Critical Mean*		6.63	8.39	392		645				34.6				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Lab	Avg	SD	LOQ	Lab	Comment
299-W26-13	5/6/2019	7.80	0.00	316	0	155 U	0	1,000	TADN	4.1 B	1.4	10	GEL	
	11/8/2019	7.82	0.01	335	0	330 U	0	1,000	GEL	3.3 U	0.0	10	GEL	
299-W26-14	5/6/2019	7.73	0.01	282	0	170 B	17	1,000	TADN	3.7 B	0.7	10	GEL	
	11/8/2019	7.75	0.00	298	0	345 U	0	1,000	TADN	3.3 B	0.0	10	GEL	
299-W27-2	5/6/2019	7.70	N/A	368	N/A	155 U	N/A	1,000	TADN	6.9 B	N/A	10	GEL	Deep well; no quads or statistics required
699-32-76	5/6/2019	7.71	0.00	309	1	155 U	0	1,000	TADN	3.3 U	0.0	10	GEL	
	11/8/2019	7.80	0.00	328	1	345 U	0	1,000	TADN	3.3 U	0.0	10	GEL	
699-33-75	5/6/2019	7.76	0.00	284	0	155 U	0	1,000	TADN	5.3 B	1.6	10	GEL	
	11/8/2019	7.67	0.02	297	0	330 U	0	1,000	GEL	3.5 B	0.2	10	GEL	
699-33-76	5/6/2019	7.74	0.00	305	0	155 U	0	1,000	TADN	4.2 B	0.6	10	GEL	
	11/8/2019	7.76	0.01	324	0	345 U	0	1,000	TADN	3.3 U	0.0	10	GEL	

*Critical mean values from Table 15 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
N/A = not applicable
SD = standard deviation of replicates
TADN = TestAmerica – Denver
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-23. 216-S-10 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	101	123	—	
Calcium (unfiltered)	µg/L	24,700	37,200	—	
Calcium (filtered)	µg/L	24,800	37,800	—	
Carbon tetrachloride	µg/L	0.19 U	3.97	5[b]	
Chloride	mg/L	6.22	20.3	250[c]	
Chromium (unfiltered)	µg/L	1.38 B	160	100[b]	299-W26-13, 699-33-76 (suspect data)
Chromium (filtered)	µg/L	1.33 B	150	100[b]	299-W26-13
Hexavalent chromium	µg/L	2.18 B	153	48[d]	299-W26-13
Iron (unfiltered)	µg/L	22 U	416	300[c]	299-W27-2
Iron (filtered)	µg/L	22 U	38 B	300[c]	Maximum value excludes two outliers
Magnesium (unfiltered)	µg/L	8,180	13,800	—	
Magnesium (filtered)	µg/L	8,010	13,800	—	
Manganese (unfiltered)	µg/L	0.43 B	7.9 B	50[c]	
Manganese (filtered)	µg/L	0.35 B	6.2	50[c]	
Nickel (unfiltered)	µg/L	0.92 U	26.1 B	—	
Nickel (filtered)	µg/L	0.92 U	18.3 B	—	
Nitrate	mg/L	6.2	32.4	45[e]	
Phenols[f]	µg/L	2.8 U	5.05 U	2,400[d]	
Potassium (unfiltered)	µg/L	3,080	3,990	—	
Potassium (filtered)	µg/L	2,840	4,030	—	
Sodium (unfiltered)	µg/L	12,800	23,000	—	
Sodium (filtered)	µg/L	12,500	23,400	—	
Sulfate	mg/L	17.0	22.5	250[c]	
Temperature	°C	17.9	21.3	—	
Turbidity	NTU	0.3	7.84	—	

Note: Minimum and maximum are based on sample results collected specifically for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

Table B-23. 216-S-10 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

e. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

f. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

— = no comparison value

B = result is below the quantitation limit

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

U = result is below the detection limit

Table B-24. 300 Area Process Trenches Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
399-1-10A	DG	1986 (C)	9/19/2019	104.77	343.72	106.9	350.8	102.3	335.8	2.4	8.0	S	
399-1-10B	DG deep	1991 (C)	9/19/2019	104.74	343.62	82.7	271.3	79.6	261.3	25.1	82.3	S	
399-1-16A	DG	1986 (C)	9/20/2019	104.72	343.56	107.0	351.0	102.4	336.0	2.3	7.5	S	
399-1-16B	DG deep	1987 (C)	9/20/2019	104.73	343.61	84.8	278.4	81.8	268.4	22.9	75.2	S	
399-1-17A	DG	1986 (C)	9/20/2019	104.77	343.75	107.7	353.5	103.2	338.5	1.6	5.3	S	
399-1-17B	DG deep	1986 (C)	9/20/2019	104.80	343.84	85.0	278.8	81.9	268.8	22.9	75.0	S	
399-1-18A	UG	1986 (C)	9/19/2019	105.19	345.12	107.3	352.1	102.8	337.1	2.4	8.0	S	
399-1-18B	UG deep	1987 (C)	9/19/2019	105.22	345.22	86.0	282.1	82.9	272.1	22.3	73.1	S	

Note: Requirements are from the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part VI, Post-Closure Unit 1 (PCU-1), Chapter 3.0, "Groundwater Monitoring Plan").

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

RCRA = *Resource Conservation and Recovery Act of 1976*

S = semiannually

UG = upgradient

Table B-25. Groundwater Velocity at 300 Area Process Trenches

Flow Direction	Southeast
Flow Rate (m/d)	22
Hydraulic Conductivity (m/d) (Source)	9,000 (ECF-300FF5-11-0151)
Effective Porosity	0.17
Gradient (m/m)	4.2×10^{-4}
Comments	Gradient and direction determined by trend surface analysis using March 2019 data. Velocity calculated using the Darcy equation.

Reference: ECF-300FF5-11-0151, *Groundwater Flow and Uranium Transport Modeling in Support of the 300 Area FF-5 RI/FS.*

Table B-26. 300 Area Process Trenches RCRA Sampling Results, 2019

Well Name	RCRA Sample Date	*cis*-1,2-DCE (µg/L)	TCE (µg/L)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)
Permit Concentration Limit		**16**	**4.0**	—	—	—	—
399-1-10A	6/17/2019	0.3 U	0.3 U	7.78	439	17.8	0.18
399-1-10A	9/19/2019	0.3 U	0.3 U	7.81	482	17.4	0.35
399-1-10B	6/17/2019	0.2 U	0.3 U	7.36	304	16.8	0.49
399-1-10B	9/19/2019	0.3 U	0.5 U	7.66	312	15.7	1.72
399-1-16A	6/18/2019	0.2 U	0.3 U	7.79	448	18.4	2.19
399-1-16A	9/20/2019	0.2 U	0.3 U	7.49	497	17.1	0.35
399-1-16B	6/18/2019	169 DXH	1.6 J	8.18	318	16.9	2.85
399-1-16B	9/20/2019	147 D	1.4 J	8.02	311	16.3	0.80

Table B-26. 300 Area Process Trenches RCRA Sampling Results, 2019

Well Name	RCRA Sample Date	*cis*-1,2-DCE (µg/L)	TCE (µg/L)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)
399-1-17A	6/18/2019	0.3 U	0.5 U	7.76	536	17.9	1.72
399-1-17A	9/20/2019	0.3 U	0.3 U	7.60	513	18.9	0.41
399-1-17B	6/17/2019	0.2 U	0.3 U	7.74	356	17.5	0.71
399-1-17B	9/20/2019	0.69 J	0.5 U	7.63	342	18.8	0.63
399-1-18A	6/17/2019	0.3 U	0.3 U	8.04	485	18.0	1.05
399-1-18A	9/19/2019	0.2 U	0.2 U	8.11	486	17.1	1.67
399-1-18B	6/17/2019	0.3 U	0.3 U	7.59	368	17.6	1.09
399-1-18B	9/19/2019	0.3 U	0.3 U	7.65	371	17.3	0.69

Notes: Sample results collected for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

Yellow-highlighted cells indicate exceedances of the concentration limit defined in the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part VI, Post-Closure Unit 1 (PCU-1), Chapter 3.0, "Groundwater Monitoring Plan").

cis-1,2 DCE = *cis*-1,2-dichloroethene
D = analyte was reported at a secondary dilution factor
H = recommended holding time exceeded (data review qualifier)
J = estimated value; result is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
TCE = trichloroethene
U = result is below the detection limit
X = recommended holding time exceeded (laboratory qualifier)

Table B-27. Statistical Evaluation of 300 Area Process Trenches Dangerous Waste Constituents, 2019

Well	Semiannual Period	*cis*-1,2 DCE (Permit Concentration Limit = 16 µg/L)	TCE (Permit Concentration Limit = 4 µg/L)
		95% UCL	95% UCL
399-1-10A	January – June	N/A*	N/A*
399-1-10A	July – December	N/A*	N/A*
399-1-10B	January – June	N/A*	N/A*
399-1-10B	July – December	N/A*	N/A*
399-1-16A	January – June	N/A*	N/A*
399-1-16A	July – December	N/A*	N/A*
399-1-16B	January – June	175.1	N/A*
399-1-16B	July – December	173.1	N/A*
399-1-17A	January – June	N/A*	N/A*
399-1-17A	July – December	N/A*	N/A*
399-1-17B	January – June	N/A*	N/A*
399-1-17B	July – December	N/A*	N/A*

Sources:

SGW-63850, *Post-Closure Corrective Action Groundwater Monitoring Report for the 300 Area Process Trenches: January – June 2019*.

SGW-64410, *Post-Closure Corrective Action Groundwater Monitoring Report for the 300 Area Process Trenches: July – December 2019*.

Note: Yellow-highlighted cells indicate that the 95% UCL exceeded concentration limits defined in Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part VI, Post-Closure Unit 1 (PCU-1), Chapter 3.0, "Groundwater Monitoring Plan").

*None of the results in the data set exceeded the concentration limit; therefore, the UCL was not calculated.

cis-1,2 DCE = *cis*-1,2-dichloroethene
N/A = not applicable
RCRA = *Resource Conservation and Recovery Act of 1976*
TCE = trichloroethene
UCL = upper confidence limit

Table B-28. IDF Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		2019 Sample Frequency[a]	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E17-22	DG	2002 (C)	1/30/2019	121.65	399.12	122.6	402.1	111.9	367.0	9.8	32.1	A	In current and revised plans
299-E17-23	DG	2002 (C)	1/10/2019	121.62	399.01	122.3	401.4	111.9	367.3	9.7	31.7	A	Not in revised plan[b]
299-E17-25	DG	2002 (C)	1/10/2019	121.63	399.05	122.4	401.7	111.8	366.7	9.9	32.4	A	Not in revised plan[b]
299-E17-26[c]	DG	2005 (C)	1/10/2019	121.68	399.21	121.4	398.2	110.7	363.2	11.0	36.0	A	Not in revised plan[b]
299-E17-56	DG	2019 (C)	9/7/2019	121.68[d]	399.22[d]	122.1	400.6	116.0	380.6	5.7	18.6	—	Added in revised plan[b]
299-E17-57	UG	2019 (C)	6/26/2019	121.23[d]	397.74[d]	121.1	397.3	115.0	377.2	6.2	20.5	—	Added in revised plan[b]
299-E18-1	UG	1988 (C)	1/11/2019	121.69	399.24	125.5	411.6	118.4	388.6	3.2	10.6	A	Sampled with a bailer in 2019; not in revised plan[b]
299-E24-21	UG/DG[e]	2001 (C)	1/10/2019	121.63	399.06	122.7	402.5	116.6	382.5	5.0	16.5	A	In current and revised plans
299-E24-24[f]	UG	2005 (C)	1/10/2019	121.63	399.06	122.5	402.0	111.9	367.0	9.8	32.1	A	In current and revised plans
299-E24-164	DG	2019	9/5/2019	121.74[d]	399.39[d]	121.8	399.5	114.1	374.4	7.6	25.0	—	Added in revised plan[b]
299-E24-18[d]	DG	1988 (C)	1/15/2019	121.65	399.12	126.0	413.4	119.0	390.4	2.6	8.7	—	Added in revised plan[b]

Table B-28. IDF Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		2019 Sample Frequency[a]	Comments
				m	ft	m	ft	m	ft	m	ft		

Note: Requirements are from the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c [modification date of June 30, 2010], Part III, Operating Unit Group 11 (OUG-11), Chapter 5.0, "Groundwater Monitoring").

a. The IDF is not yet in use. In accordance with the Hanford RCRA Permit, OUG-11, Unit-Specific Condition III.11.E.1.b, groundwater sampling under the permit will continue annually during the pre-active life of the IDF.

b. A revised monitoring plan (DOE/RL-2019-29, *Groundwater Monitoring Plan for the Integrated Disposal Facility*) will be incorporated into the Hanford RCRA Permit in the future. Ecology approved DOE's request to begin baseline sampling under the revised monitoring program in 2020 (19-NWP-197, "Approval of Request for Integrated Disposal Facility Groundwater Sample Activities").

c. Listed in Part III, OUG-11, Chapter 5.0 of the Hanford RCRA Permit as "New Downgradient Well #1."

d. Approximate water level measured during well construction.

e. Well 299-E24-21 is designated as upgradient in Part III, OUG-11, Chapter 5.0 of the Hanford RCRA Permit, and as downgradient in the revised plan (DOE/RL-2019-29).

f. Listed in Part III, OUG-11, Chapter 5.0 of the Hanford RCRA Permit as "New Upgradient Well."

A = annually

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

IDF = Integrated Disposal Facility

OUG = operating unit group

RCRA = *Resource Conservation and Recovery Act of 1976*

UG = upgradient

Table B-29. IDF Contamination Indicator Parameters, 2019

Well Name	Sample Date	Chromium (Filtered) (µg/L)	pH (unitless)	Specific Conductance (µS/cm)	Total Organic Carbon (µg/L)	Total Organic Halides (µg/L)
299-E17-22	1/11/2019	3.4 BQ	7.86	562	330 U	4.5 B
299-E17-23	1/10/2019	8.75 BQ	7.79	501	330 U	3.34 B
299-E17-25	1/10/2019	6.5 Q	7.74	512	330 U	5.28 B
299-E17-26	1/10/2019	6.9 BQ	7.7	526	330 U	3.33 U
299-E18-1	1/11/2019	7.4 BQ	8.58	410	330 U	3.33 U
299-E24-21	1/10/2019	2.64 BQ	7.86	591	721 B	3.33 U
299-E24-24	1/10/2019	2.4 U	7.75	522	330 U	4.54 B

B = result is below the quantitation limit
Q = associated field quality control sample is out of limits
U = result is below the detection limit

Table B-30. IDF Sampling Summary for Supplemental Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	69	142	—	
Calcium (unfiltered)	µg/L	21,000	57,100	—	
Calcium (filtered)	µg/L	21,000	58,800	—	
Chloride	mg/L	6.2	18.0	250[b]	
Magnesium (unfiltered)	µg/L	13,000	19,000	—	
Magnesium (filtered)	µg/L	12,000	19,000	—	
Nitrate	mg/L	12	70.8	45[c]	299-E17-22, 299-E17-23, 299-E17-25, 299-E17-26, 299-E24-21, 299-E24-24
Potassium (unfiltered)	µg/L	6,150	7,400	—	
Potassium (filtered)	µg/L	6,200	7,300	—	
Sodium (unfiltered)	µg/L	19,000	29,000	—	
Sodium (filtered)	µg/L	19,000	29,000	—	
Sulfate	mg/L	44.0	100	250[b]	
Turbidity	NTU	0.23	12.7	—	

Notes: Minimum and maximum are based on sample results collected specifically for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

Table 5.2 in the groundwater monitoring plan (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Part III, Operating Unit Group 11 (OUG-11), Chapter 5.0, "Groundwater Monitoring") calls for alkalinity, anions, metals, and turbidity to provide supplemental data on general groundwater chemistry. The plan does not list specific metals or anions. This table lists the constituents typically needed to characterize general groundwater chemistry.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels"). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

Table B-31. LERF Groundwater Monitoring Network

Well Name	Purpose	Year Installed	Head Date	Hydraulic Head*		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E26-10	Water level	1990 (C)	10/25/2019	121.64	399.08	125.4	411.6	120.7	396.0	0.9	3.1	—	Used for quarterly water levels only
299-E26-14	BG	2011 (C)	10/28/2019	121.71	399.31	122.8	402.8	116.7	382.8	5.0	16.5	Q/S	
299-E26-15	POC	2015 (C)	10/28/2019	121.64	399.07	124.2	407.3	119.5	392.0	2.1	7.0	Q/S	
299-E26-77	Water level	2008 (C)	10/28/2019	121.68	399.22	122.8	402.8	115.2	378.0	6.4	21.1	—	Used for quarterly water levels only
299-E26-79	POC	2008 (C)	10/28/2019	121.65	399.10	122.9	403.1	115.2	378.0	6.4	21.0	Q/S	

Note: Requirements are from Table D-7 in the Hanford RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c [modification date of January 23, 2018], Part III, Operating Unit Group 3 (OUG-3), Addendum D, "Groundwater Monitoring Plan").

*Hydraulic head has been corrected for borehole deviation from vertical in all wells in this network.

— = no sampling required

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

BG = background

POC = point of compliance

Q/S = quarterly for first 2 years beginning January 2018; semiannually thereafter

RCRA = *Resource Conservation and Recovery Act of 1976*

Table B-32. Groundwater Velocity at the LERF

Flow Direction	171 degrees (south)
Flow Rate (m/d)	0.15
Hydraulic Conductivity (m/d) (Source)	39.5 (Hanford RCRA Permit [WA7890008967, Part III, Operating Unit Group 3, Addendum D, "Groundwater Monitoring Plan"])
Effective Porosity	0.1 (WA7890008967)
Gradient (m/m)	3.7×10^{-4}
Comments	Gradient and direction determined by trend surface analysis using March and October 2019 data. Velocity calculated using the Darcy equation.

Reference:

WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended.

RCRA = *Resource Conservation and Recovery Act of 1976*

Table B-33. LERF Sampling Summary for Waste Constituents, 2019

Well Name	Sample Date	1-Butanol (µg/L)	Carbon Tetrachloride (µg/L)	Hexavalent Chromium (µg/L)	n-Nitrosodi-methylamine (µg/L)
299-E26-14	1/3/2019	U	U	1.5 U	U
	4/9/2019	U	U	1.63 BQ	U
	7/16/2019	U	U	2.2 BXH	U
	10/10/2019	U	U	1.3 U	U
299-E26-15	1/3/2019	U	U	1.5 U	U
	4/9/2019	U	U	1.3 U	U
	7/11/2019	U	U	1.61 B	U
	10/10/2019	U	U	1.3 U	U
299-E26-79	1/3/2019	U	U	1.5 U	U
	4/9/2019	U	U	1.45 BX	U
	7/11/2019	U	U	2.06 B	U
		U	U	2.08 B	U
	10/10/2019	U	U	1.3 U	U

B = result is below the quantitation limit

H = recommended holding time exceeded (review qualifier)

Q = associated with out of limit field blank

U = result is below the detection limit

X = recommended holding time exceeded (laboratory qualifier)

Table B-34. LERF Sampling Summary for Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	79.1	96	—	Range excludes outlier
Calcium (unfiltered)	µg/L	74,800	123,000	—	
Calcium (filtered)	µg/L	74,000	121,000	—	
Chromium (unfiltered)	µg/L	1.5 B	41.3	100[b]	
Chromium (filtered)	µg/L	1.02 B	8.3 B	100[b]	
Dissolved oxygen	mg/L	6.4	8.9	—	Range excludes outlier
Iron (unfiltered)	µg/L	30 U	180	300[c]	
Iron (filtered)	µg/L	22 U	60 U	300[c]	
Magnesium (unfiltered)	µg/L	24,100	35,900	—	
Magnesium (filtered)	µg/L	23,400	35,800	—	
Manganese (unfiltered)	µg/L	1.2 B	8.0 U	50[c]	
Manganese (filtered)	µg/L	1.0 U	8.0 U	50[c]	Range excludes outlier
Nickel (unfiltered)	µg/L	5.9	21.4 B	—	
Nickel (filtered)	µg/L	3.0 B	21.0 B	—	
Nitrate	mg/L	36.3	102	45[d]	299-E26-14, 299-E26-79
Oxidation-reduction potential	mV	161	463	—	
pH measurement	unitless	7.74	8.26	6.5 – 8.5[c]	
Potassium (unfiltered)	µg/L	9,640	11,900	—	
Potassium (filtered)	µg/L	8,660	11,700	—	
Sodium (unfiltered)	µg/L	26,200	48,000	—	
Sodium (filtered)	µg/L	25,500	48,000	—	
Sulfate	mg/L	159	290	250[c]	299-E26-15
Temperature	°C	18	20.6	—	
Turbidity	NTU	0.66	4.32	—	

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L as NO_3.

— = no comparison value
B = result is below the quantitation limit
NTU = nephelometric turbidity units
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-35. LLBG WMA-1 Groundwater Monitoring Network

Well Name	Location	Year Installed	Hydraulic Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E28-26	DG	1987 (C)	7/9/2019	121.64	399.07	124.9	409.6	118.7	389.5	2.9	9.4	S	
299-E28-27[a]	DG	1987 (C)	7/8/2019	121.64	399.07	125.6	411.9	119.5	392.0	2.2	7.1	S	
299-E28-28	DG	1990 (C)	7/9/2019	121.60	398.95	125.6	412.1	119.5	392.2	2.1	6.7	S	
299-E32-3	UG	1987 (C)	7/8/2019	121.63	399.05	125.8	412.7	119.7	392.8	1.9	6.3	S	
299-E33-266	UG	2010 (C)	7/9/2019	121.51	398.65	123.4	404.8	117.3	384.8	4.2	13.9	S	
299-E33-28[a]	DG	1987 (C)	7/8/2019	121.64	399.07	125.2	410.6	119.1	390.6	2.6	8.5	S	
299-E33-29	DG	1987 (C)	7/8/2019	121.60	398.95	125.7	412.2	119.5	392.1	2.1	7.0	S	
299-E28-33[b]	DG	Proposed	—	—	—	—	—	—	—	—	—	Q/S	Not yet installed

Note: Requirements are from Table 3-1 in DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*.

a. Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

b. Listed as "Proposed Well" in Table 3-1 of DOE/RL-2009-75.

— = no information (well not yet installed)

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

Q/S = quarterly for first year; semiannually thereafter

S = semiannually

UG = upgradient

Table B-36. LLBG WMA-1 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean*		7.29	8.59	538		1,260			14.6				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
299-E28-26	1/3/2019	7.94	0.00	475	1	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/9/2019	7.88	0.00	489	1	330 U	0	1,000	4.1 B	1.3	10	GEL	
299-E28-27	1/7/2019	8.05	0.00	437	1	330 U	0	1,000	3.3 U	0.0	10	GEL	
	7/8/2019	7.89	0.00	418	0	330 U	0	1,000	4.0 B	1.1	10	GEL	
299-E28-28	1/3/2019	8.17	0.00	445	1	330 U	0	1,000	3.5 B	0.3	10	GEL	
	7/9/2019	8.09	0.01	433	0	330 U	0	1,000	3.6 B	0.4	10	GEL	
299-E32-3	1/3/2019	8.05	0.00	396	0	330 U	0	1,000	5.5 B	2.3	10	GEL	
	7/8/2019	7.89	0.00	411	0	330 U	0	1,000	3.7 B	0.4	10	GEL	
299-E33-266	1/3/2019	8.02	0.01	431	0	391 B	16	1,000	3.3 U	0.0	10	GEL	
	7/9/2019	7.99	0.00	433	0	392 B	60	1,000	3.5 B	0.4	10	GEL	
299-E33-28	1/7/2019	8.07	0.00	531	0	330 U	0	1,000	3.3 B	0.0	10	GEL	
	7/8/2019	7.85	0.00	499	0	330 U	0	1,000	5.3 B	1.9	10	GEL	
299-E33-29	1/7/2019	8.10	N/A	446	N/A	330 U	0	1,000	3.3 U	0.0	10	GEL	No quad pH or specific conductance
	7/8/2019	7.95	0.01	418	1	330 U	0	1,000	3.7 B	0.7	10	GEL	

*Critical mean values from Table 16 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
N/A = not applicable
SD = standard deviation of replicates
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-37. LLBG WMA-1 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Calcium (unfiltered)	µg/L	40,000	51,100	—	
Calcium (filtered)	µg/L	39,800	50,500	—	
Chloride	mg/L	11.0	14.0	250[b]	
Dissolved oxygen	mg/L	8.2	9.7	—	
Fluoride	mg/L	0.40	0.50	4.0[c]	
Iron (unfiltered)	µg/L	22 U	144	300[b]	
Iron (filtered)	µg/L	22 U	33 B	300[b]	
Magnesium (unfiltered)	µg/L	11,700	14,700	—	
Magnesium (filtered)	µg/L	11,600	15,000	—	
Manganese (unfiltered)	µg/L	0.4 B	4.0	50[b]	
Manganese (filtered)	µg/L	1.2	4.0	50[b]	
Nitrate	mg/L	38.1	62.0	45[d]	299-E28-26, 299-E33-28
Nitrite	mg/L	0.13 U	0.13 U	3.3[d]	
Phenols[e]	µg/L	0.24 U	19 U	2,400[f]	
Potassium (unfiltered)	µg/L	5,570	6,730	—	
Potassium (filtered)	µg/L	5,480	6,840	—	
Sodium (unfiltered)	µg/L	21,400	26,600	—	
Sodium (filtered)	µg/L	21,500	27,100	—	
Sulfate	mg/L	37.0	69.0	250[b]	
Temperature	°C	15.7	19.7	—	
Turbidity	NTU	0.22	4.74	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in January 2019. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value
B = value is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = value is below the detection limit

Table B-38. LLBG WMA-2 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-E27-10	CG	1987 (C)	11/7/2019	121.60	398.95	126.2	413.9	119.8	393.0	1.8	5.9	S	
299-E27-11	DG	1989 (C)	11/7/2019	121.35	398.13	126.0	413.5	119.6	392.5	1.7	5.6	S	
299-E27-17[a]	DG	1991 (C)	11/7/2019	121.59	398.93	125.5	411.9	119.1	390.9	2.5	8.0	S	
299-E27-8[a]	DG	1987 (C)	11/7/2019	121.60	398.95	125.8	412.7	119.5	392.1	2.1	6.8	S	
299-E27-9[a]	DG	1987 (C)	11/7/2019	121.60	398.94	125.3	411.1	119.4	391.8	2.2	7.2	S	
299-E34-10[a]	DG	1991 (C)	11/6/2019	121.62	399.00	126.5	415.0	120.1	394.0	1.5	5.0	S	
299-E34-12	DG	1992 (C)	11/6/2019	121.51	398.64	126.6	415.3	120.4	395.0	1.1	3.7	S	
299-E34-2	DG[b]	1987 (C)	11/6/2019	121.59	398.92	125.2	410.9	119.9	393.4	1.7	5.4	S	
299-E34-9[a]	DG	1991 (C)	11/6/2019	121.60	398.95	127.0	416.7	120.7	395.9	0.9	3.0	S	

Note: Requirements are from Table 3-1 in DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*. Planned wells 299-E34-13 through 299-E34-16 were cancelled during negotiations of Tri-Party Agreement Milestone M-24-00 (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*).

a. Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

b. Although designated as a downgradient well in DOE/RL-2009-76, well 299-E34-2 provided the data used to calculate critical mean values for 2019.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

CG = cross-gradient

DG = downgradient

S = semiannually

UG = upgradient

Table B-39. LLBG WMA-2 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)				TOX (µg/L)				
Critical Mean[a]		7.47	8.12	1,630		1,960				36.8				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Lab	Avg	SD	LOQ	Lab	Comment
299-E27-10	5/9/2019	7.73	0.00	1,420	4	1,253	13	1,000	TADN	8.8	4.4	10	GEL	TOX exceeded holding time
	6/24/2019	7.67	0.01	1,447	0	N/A	N/A	N/A	N/A	3.3 B	0.0	10	GEL	Resampled for TOX
	11/7/2019	8.02	0.02	1,460	3	1,333	24	1,000	TADN	5.7 B	1.4	10	GEL	
299-E27-11	5/8/2019	8.13	0.01	490	1	180 B	5	1,000	TADN	4.0 B	0.8	10	GEL	pH exceeded critical mean; TOX exceeded holding time
	5/31/2019	8.11	0.04	477	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	pH exceedance not confirmed [b]
		7.90	0.02											
	6/24/2019	8.09	0.04	484	2	N/A	N/A	N/A	N/A	7.5	4.5	10	GEL	Resampled for TOX
	11/7/2019	8.08	0.00	640	7	330 U	0	1,000	GEL	6.5 B	1.5	10	GEL	
299-E27-17	5/7/2019	8.00	0.00	533	0	202 B	12	1,000	TADN	4.5 B	2.0	10	GEL	TOX exceeded holding time
	6/23/2019	7.99	0.00	518	0	N/A	N/A	N/A	N/A	10.8	1.6	10	GEL	Resampled for TOX
	11/7/2019	7.94	0.01	525	1	400 B	47	1,000	GEL	3.9 B	0.9	10	GEL	

Table B-39. LLBG WMA-2 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)				TOX (µg/L)				
Critical Mean[a]		7.47	8.12	1,630		1,960				36.8				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Lab	Avg	SD	LOQ	Lab	Comment
299-E27-8	5/8/2019	8.04	0.00	513	1	363 B	32	1,000	TADN	4.9 B	2.3	10	GEL	TOX exceeded holding time
	6/23/2019	8.19	0.00	495	0	N/A	N/A	1,000	N/A	9.1	2.2	10	GEL	Resampled for TOX; pH exceedance
	7/15/2019	8.01	0.00	494	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	pH exceedance not confirmed
		7.97	0.00											
	11/7/2019	8.00	0.00	499	1	331 B	2	1,000	GEL	3.3 B	0.0	10	GEL	
299-E27-9	5/8/2019	8.03	0.01	1,115	0	794 B	23	1,000	TADN	6.6	2.3	10	GEL	TOX exceeded holding time
	6/24/2019	7.89	0.01	1,109	6	N/A	N/A	N/A	N/A	3.7 B	0.3	10	GEL	Resampled for TOX
	11/7/2019	7.94	0.00	1,216	5	931 B	33	1,000	TADN	5.1 B	1.4	10	GEL	
299-E34-10	5/7/2019	8.00	0.00	727	1	270 B	15	1,000	TADN	3.5 B	0.2	10	GEL	TOX exceeded holding time
	6/21/2019	7.97	0.01	703	1	N/A	N/A	N/A	N/A	4.2 B	1.5	10	GEL	Resampled for TOX
	11/6/2019	7.90	0.00	683	0	345 B	6	1,000	GEL	3.3 U	0.0	10	GEL	
299-E34-12	5/2/2019	8.01	0.01	622	1	188 B	18	1,000	TADN	7.7 U	0.0	30	TADN	
	6/21/2019	8.08	0.02	576	2	N/A	N/A	N/A	N/A	3.3 U	0.0	10	GEL	Resampled for TOX
	11/6/2019	7.99	0.01	478	1	330 B	0	1,000	GEL	3.8 B	0.8	10	GEL	

Table B-39. LLBG WMA-2 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)				TOX (µg/L)				
Critical Mean[a]		7.47	8.12	1,630		1,960				36.8				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Lab	Avg	SD	LOQ	Lab	Comment
299-E34-2	5/8/2019	7.96	0.00	598	1	260 B	14	1,000	TADN	4.6 B	N/A	10	GEL	TOX exceeded holding time; single result
	6/21/2019	8.06	0.00	609	1	N/A	N/A	N/A	N/A	3.5 B	0.4	10	GEL	Resampled for TOX
	11/6/2019	7.88	0.00	587	1	345 U	0	1,000	TADN	3.6 B	0.4	10	GEL	
299-E34-9	5/7/2019	7.83	0.00	1,438	1	639 B	10	1,000	TADN	4.3 B	0.9	10	GEL	TOX exceeded holding time
	6/23/2019	7.88	0.00	1,374	1	N/A	N/A	N/A	N/A	4.3 B	1.6	10	GEL	Resampled for TOX
	11/6/2019	7.77	0.00	1,082	4	526 B	27	1,000	GEL	4.6 B	1.1	10	GEL	

Note: Yellow-highlighted cells indicate exceedance of a critical mean.

a. Critical mean values from Table 17 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

b. Two pH meters were used for verification sampling. Due to a paperwork error, only three measurements from each meter were measured rather than the required four.

Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
N/A = not applicable
SD = standard deviation of replicates
TADN = TestAmerica – Denver
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-40. LLBG WMA-2 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	58	110	—	
Calcium (unfiltered)	µg/L	50,500	205,000	—	
Calcium (filtered)	µg/L	53,000	204,000	—	
Chloride	mg/L	13.0	123	250[b]	
Chromium (unfiltered)	µg/L	8.0	75.2	—	
Chromium (filtered)	µg/L	2.6	28.7	—	
Dissolved oxygen	mg/L	7.6	10.4	—	
Fluoride	mg/L	0.25	0.53	4.0[c]	
Iron (unfiltered)	µg/L	34 B	340	300[b]	299-E27-17
Iron (filtered)	µg/L	28 B	109	300[b]	
Manganese (unfiltered)	µg/L	0.7 B	47.9	50[b]	
Manganese (filtered)	µg/L	0.6 B	44.9	50[b]	
Nitrate	mg/L	14.3	227	45[d]	299-E27-10, 299-E27-9, 299-E34-10, 299-E34-12, 299-E34-9
Nitrite	mg/L	0.046 U	0.108 U	3.3[d]	Range excludes outliers
Phenols[e]	µg/L	0.24 U	19 U	2,400[f]	
Potassium (unfiltered)	µg/L	7,510	13,600	—	
Potassium (filtered)	µg/L	7,330	13,600	—	
Sodium (unfiltered)	µg/L	16,000	47,200	—	
Sodium (filtered)	µg/L	16,800	45,700	—	
Sulfate	mg/L	66.0	478	250[b]	299-E27-10, 299-E27-9, 299-E34-9
Temperature	°C	16	24	—	
Turbidity	NTU	0.7	5.0	—	

Note: Minimum and maximum are based on sample results collected specifically for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value
B = all values were below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = all values were below the detection limit

Table B-41. LLBG WMA-3 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-W10-29	DG	2006 (C)	9/6/2019	136.50	447.83	136.9	449.3	126.3	414.3	10.2	33.5	S	
299-W10-30	DG	2006 (C)	9/6/2019	136.54	447.97	137.1	449.8	126.3	414.4	10.2	33.5	S	
299-W10-31	DG	2006 (C)	9/6/2019	135.85	445.70	136.5	447.9	125.8	412.9	10.0	32.8	S	
299-W9-2	UG	2011 (C)	9/6/2019	136.76	448.69	135.9	445.8	125.3	411.1	11.4	37.5	S	

Note: Requirements are from Table 3-1 in DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

S = semiannually

UG = upgradient

Table B-42. LLBG WMA-3 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean[a]		7.45	8.67	459		668			11.2				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
299-W10-29	3/13/2019	8.03	0.01	414	0	330 U	0	1,000	4.9 B	2.0	10	GEL	
	7/25/2019	8.00	0.03	404	2	330 U	0	1,000	6.6	0.9	10	GEL	Extra sampling[b]
						345 U	0	1,000	8.6 B	1.6	30	TADN	
	9/6/2019	7.90	0.00	404	0	330 U	0	1,000	3.6 B	0.4	10	GEL	
	10/16/2019	8.04	0.01	387	0	355 B	16	1,000	5.4 B	0.4	10	GEL	
						345 U	0	1,000	—	—	—	TADN	Extra sampling[b]
299-W10-30	3/13/2019	8.00	0.00	393	1	341 B	18	1,000	18.7	3.6	10	GEL	TOX exceedance
	7/25/2019	7.97	0.04	381	1	330 U	0	1,000	15.1	1.3	10	GEL	TOX verification sampling[b]
						345 U	0	1,000	17.9 B	2.5	30	TADN	
	9/6/2019	7.85	0.00	380	0	330 U	0	1,000	21.5	3.1	10	GEL	TOX exceedance
	10/16/2019	8.05	0.01	374	0	369 B	10	1,000	12.8	0.6	10	GEL	TOX verification sampling[b]; split samples analyzed outside holding time
						345 U	0	1,000	25.9	22.7	30	TADN	
299-W10-31	3/13/2019	7.91	0.02	483	0	330 U	0	1,000	10.1	1.3	10	GEL	Specific conductance exceedance
	7/25/2019	7.96	0.04	492	1	330 U	0	1,000	7.1 B	0.7	10	GEL	Verification sampling[b]
				488	0	345 U	0	1,000	8.8 B	1.1	30	TADN	
	9/6/2019	7.83	0.00	493	0	397 B	116	1,000	8.9	2.7	10	GEL	Specific conductance exceedance
	10/16/2019	8.00	0.01	481	1	416 B	14	1,000	5.4 B	1.1	10	GEL	Verification sampling[b, c]
						345 U	0	1,000	—	—	—	TADN	

Table B-42. LLBG WMA-3 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)			Lab (TOC and TOX)	Comment
Critical Mean[a]		7.45	8.67	459		668			11.2				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ		
299-W9-2	3/13/2019	8.12	0.00	403	0	330 U	0	1,000	5.3	3.0	10	GEL	
	7/25/2019	7.99	0.05	397	3	330 U	0	1,000	3.3 U	0.0	10	GEL	Extra sampling[b]
						345 U	0	1,000	10.8 B	4.7	30	TADN	
	9/6/2019	7.93	0.01	393	0	384 B	33	1,000	5.4 B	2.0	10	GEL	
	10/16/2019	8.14	0.00	379	0	332 B	2	1,000	3.3 U	0.0	10	GEL	
						345 U	0	1,000	—	—	—	TADN	Extra sampling[b]

Note: Yellow-highlighted cells indicate exceedances of a critical mean.

a. Critical mean values from Table 20 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring.*

b. March and September sample results exceeded the critical mean for specific conductance in one well and TOX in one well. All of the wells were resampled in July and October, although verification sampling was only required in the two affected wells.

— = no result
Avg = average of replicates
B = all values were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
SD = standard deviation of replicates
TADN = TestAmerica – Denver
TOC = total organic carbon
TOX = total organic halides
U = all values were below the detection limit

Table B-43. LLBG WMA-3 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	112	122	—	
Calcium (unfiltered)	µg/L	43,200	52,300	—	
Chloride	mg/L	16.0	26.0	250[b]	
Chromium (unfiltered)	µg/L	2.18 B	3.92 B	100[c]	
Dissolved oxygen	mg/L	7.68	10.89	—	
Fluoride	mg/L	0.18 B	0.321 B	4[c]	
Iron (unfiltered)	µg/L	30 U	141	300[b]	
Magnesium (unfiltered)	µg/L	13,600	16,600	—	
Manganese (unfiltered)	µg/L	2.0 U	4.58 B	50[b]	
Nitrate	mg/L	28.8	48.7	45[d]	299-W10-31
Nitrite	mg/L	0.046 U	0.108 U	3.3[d]	
Oxidation-reduction potential	mV	217.4	496.1	—	
Phenols[e]	µg/L	2.86 U	9.4 U	2,400[f]	
Potassium (unfiltered)	µg/L	3,820 B	4,640	—	
Sodium (unfiltered)	µg/L	10,100	11,000	—	
Sulfate	mg/L	36.0	52.0	250[b]	
Temperature	°C	17.3	21.5	—	
Turbidity	NTU	0.18	5.11	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in April 2019. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/ Feasibility Study Reports*.

— = no comparison value
B = result is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-44. LLBG WMA-4 Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Comments
				m	ft	m	ft	m	ft	m	ft		
299-W15-152	DG	2005 (C)	8/4/2019	135.21	443.60	137.5	451.1	126.8	416.1	8.4	27.5	S	
299-W15-17	DG Deep	1987 (C)	8/4/2019	135.30	443.91	80.6	264.5	77.4	253.9	57.9	189.9	S	Deep well
299-W15-224	DG	2006 (C)	8/4/2019	135.31	443.93	136.5	447.9	125.9	412.9	9.4	31.0	S	
299-W15-30	DG	1995 (C)	8/4/2019	135.44	444.36	142.8	468.6	130.6	428.6	4.8	15.8	S	
299-W15-83	DG	2005 (C)	8/4/2019	135.35	444.05	137.3	450.5	126.7	415.5	8.7	28.5	S	
299-W15-94	DG	2005 (C)	8/4/2019	135.27	443.80	137.5	451.0	126.8	416.0	8.5	27.8	S	
299-W18-21	UG	1987 (C)	8/9/2019	137.13	449.90	144.7	474.6	135.5	444.6	1.6	5.3	S	Sampled with a bailer
299-W18-22	UG Deep	1987 (C)	8/6/2019	136.29	447.14	77.5	254.1	67.9	222.8	68.4	224.5	S	Deep well

Note: Requirements are from Table 3-1 in DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, as modified by TPA-CN-718, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-69, Interim Status Groundwater Monitoring Plan for the LLBG WMA-4, Revision 2*.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

S = semiannually

UG = upgradient

Table B-45. LLBG WMA-4 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)				
Critical Mean*		7.03	9.15	704		649			44.1				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ	Lab	Comment
299-W15-152	4/14/2019	7.76	0.00	518	1	330 U	0	1,000	7.7	0.5	10	GEL	Only three TOX results
	8/4/2019	7.85	0.00	589	0	350 B	8	1,000	6.2 B	1.2	10	GEL	
299-W15-17	4/14/2019	7.99	N/A	382	N/A	330 U	N/A	1,000	7.3 B	N/A	10	GEL	Sampled for information only; no quads or statistics required
	8/4/2019	8.03	N/A	394	N/A	330 U	N/A	1,000	5.0 B	N/A	10	GEL	
299-W15-224	4/14/2019	7.82	0.00	539	0	330 U	0	1,000	14.8	3.3	10	GEL	TOX exceeded holding time; resampled in June
	6/23/2019	7.99	0.00	561	0	N/A	N/A	1,000	22.0	4.4	10	GEL	
	8/4/2019	7.89	0.00	567	0	336 B	10	1,000	17.0	5.4	10	GEL	
299-W15-30	4/14/2019	8.03	0.06	513	16	330 U	0	1,000	13.0 B	1.8	10	GEL	Only three TOX results
	8/4/2019	8.09	0.00	557	1	334 B	5	1,000	7.2 B	1.2	10	GEL	
299-W15-83	4/17/2019	7.83	0.00	569	0	330 U	0	1,000	16.5	5.3	10	GEL	TOX exceeded holding time; resampled in June
	6/25/2019	7.78	0.00	570	0	N/A	N/A	1,000	14.5	2.3	10	GEL	
	8/4/2019	7.90	0.00	577	0	330 U	0	1,000	14.2	4.4	10	GEL	
299-W15-94	4/14/2019	7.77	0.00	553	0	330 U	0	1,000	9.9 B	1.5	10	GEL	
	8/4/2019	7.85	0.00	590	1	330 U	0	1,000	5.5 B	2.3	10	GEL	
299-W18-21	4/15/2019	8.22	0.02	644	6	330 U	0	1,000	N/A	N/A	10	GEL	No TOX reported; resampled in June
	6/23/2019	8.11	0.09	629	1	N/A	N/A	1,000	5.3 B	1.7	10	GEL	
	8/8/2019	8.30	0.02	565	5	481 B	18	1,000	6.0 B	1.9	10	GEL	

Table B-45. LLBG WMA-4 Sampling Summary for Contamination Indicator Parameters, 2019

Indicator Parameter		pH		Specific Conductance (µS/cm)		TOC (µg/L)			TOX (µg/L)				
Critical Mean*		7.03	9.15	704		649			44.1				
Well	Sample Date	Avg	SD	Avg	SD	Avg	SD	LOQ	Avg	SD	LOQ	Lab	Comment
299-W18-22	4/15/2019	7.82	0.00	435	1	330 U	0	1,000	3.4 B	0.1	10	GEL	Sampled for information only; no statistics required
	6/23/2019	8.15	0.00	433	1	N/A	N/A	1,000	4.4 B	1.9	10	GEL	
	8/6/2019	8.00	0.00	444	1	330 U	0	1,000	3.5 B	0.29	10	GEL	

*Critical mean values from Table 22 in ECF-HANFORD-18-0079, *Calculation of Critical Means for Calendar Year 2019 RCRA Groundwater Monitoring*.

Avg = average of replicates
B = all results were below the quantitation limit
GEL = GEL Laboratories
LOQ = limit of quantitation
N/A = not applicable
SD = standard deviation of replicates
TOC = total organic carbon
TOX = total organic halides
U = all results were below the detection limit

Table B-46. LLBG WMA-4 Sampling Summary for Water Quality Parameters and Other Constituents, 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity	mg/L	113	140	—	
Calcium (unfiltered)	µg/L	40,800	67,800	—	
Chloride	mg/L	15.0	41.0	250[b]	
Chromium (unfiltered)	µg/L	5.0 B	23.5	100[c]	
Dissolved oxygen	mg/L	3.31	9.18	—	
Fluoride	mg/L	0.21	0.554	4[c]	
Iron (unfiltered)	µg/L	30 U	614	300[b]	299-W15-83, 299-W18-21
Magnesium (unfiltered)	µg/L	13,600	22,800	—	
Manganese (unfiltered)	µg/L	1.9	16	50[b]	299-W15-152
Nitrate	mg/L	23.5	75.3	45[d]	299-W15-152, 299-W15-224, 299-W15-30, 299-W15-83, 299-W15-94
Nitrite	mg/L	0.046 U	1.08	3.3[d]	
Phenols[e]	µg/L	0.24 U	21 U	2,400[f]	
Potassium (unfiltered)	µg/L	4,420	5,950	—	
Sodium (unfiltered)	µg/L	14,000	30,100	—	
Sulfate	mg/L	28.0	84.0	250[b]	
Temperature	°C	17.6	21.5	—	
Turbidity	NTU	0.31	358	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Constituents required annually were collected in April 2019. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

e. Analysis for phenols included 17 compounds, all below detection limits. The minimum and maximum detection limits are listed in this table.

f. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

— = no comparison value
B = value is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = value is below the detection limit

Table B-47. NRDWL Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
699-25-33A*	DG deep	1987 (C)	10/3/2019	121.47	398.51	103.4	339.1	100.3	329.1	21.2	69.4	Q	1, 4, 7, 10
699-25-34B	DG	1986 (C)	10/3/2019	121.46	398.50	125.7	412.4	119.6	392.4	1.9	6.1	Q	1, 4, 7, 10
699-25-34D	CG/DG	1992 (C)	10/3/2019	121.47	398.51	125.3	411.0	114.7	376.5	6.7	22.1	Q	1, 4, 7, 10
699-25-34F	DG	2015 (C)	10/3/2019	121.47	398.54	122.6	402.2	113.4	372.2	8.0	26.3	Q	1, 4, 7, 10
699-26-33A	DG	2015 (C)	10/3/2019	121.47	398.53	122.7	402.6	113.6	372.6	7.9	25.9	Q	1, 4, 7, 10
699-26-34A	UG	1986 (C)	10/2/2019	121.48	398.54	125.7	412.5	119.6	392.5	1.8	6.1	Q	1, 4, 7, 10
699-26-34B	CG/DG	1992 (C)	10/2/2019	121.47	398.53	125.4	411.4	114.7	376.5	6.7	22.1	Q	1, 4, 7, 10
699-26-35A	UG	1986 (C)	10/2/2019	121.48	398.54	125.9	413.2	119.8	393.2	1.6	5.4	Q	1, 4, 7, 10
699-26-35C*	UG deep	1987 (C)	10/2/2019	121.45	398.46	103.9	341.0	100.9	331.0	20.6	67.5	Q	1, 4, 7, 10
699-26-38	UG	2014 (C)	10/2/2019	121.48	398.56	123.1	403.9	114.0	373.9	7.5	24.7	Q	1, 4, 7, 10

Note: Requirements are from Table 3-2 in DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*.

*Hydraulic head data for these wells were not corrected for borehole deviation from vertical, which may cause reported head to be less than actual head.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

CG = cross-gradient

DG = downgradient

Q = quarterly

UG = upgradient

Table B-48. NRDWL Groundwater Velocity

Flow Direction	105 degrees (east-southeast)
Flow Rate (m/d)	0.020
Hydraulic Conductivity (m/d) (Source)	109 (CP-57037)
Effective Porosity	0.2 (CP-57037)
Gradient (m/m)	3.7×10^{-5}
Comments	Gradient and direction determined by trend surface analysis using March 2019 data. Velocity calculated using the Darcy equation.

Reference: CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*.

Table B-49. NRDWL Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Alkalinity	mg/L	130	250	—	
Calcium, unfiltered	µg/L	34,000	74,600	—	
Calcium, filtered	µg/L	34,000	73,800	—	
Chloride	mg/L	6.1	13.9	250[b]	
Chromium, unfiltered	µg/L	3.8 B	37.0	100[a]	
Chromium, filtered	µg/L	3.5 B	13.3	100[a]	
Iron, unfiltered	µg/L	22 U	510	300[b]	699-25-33A
Iron, filtered	µg/L	22 U	117	300[b]	
Magnesium, unfiltered	µg/L	9,400	18,600	—	
Magnesium, filtered	µg/L	9,500	18,700	—	
Manganese, unfiltered	µg/L	0.42 B	31.6	50[b]	
Manganese, filtered	µg/L	0.36 U	25.6	50[b]	
Nickel, unfiltered	µg/L	0.33 B	53.9	—	
Nickel, filtered	µg/L	0.30 U	5.0	—	
Nitrate	mg/L	6.15	35.3	45[d]	
pH measurement	unitless	7.25	8.26	6.5 – 8.5[b]	
Potassium, unfiltered	µg/L	4,700	8,550	—	
Potassium, filtered	µg/L	4,700	8,390	—	
Sodium, unfiltered	µg/L	15,000	29,700	—	
Sodium, filtered	µg/L	15,000	29,300	—	
Specific conductance	µS/cm	303	648	—	

Table B-49. NRDWL Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Sulfate	mg/L	25.0	70.8	250[b]	
Temperature	°C	17.4	22.8	—	
TOC	µg/L	330 U	1,790	—	Maximum value is an outlier
TOX	µg/L	3.33 U	8.18 B	—	
Turbidity	NTU	0.27	4.96	—	
Dangerous Waste Constituents[e]					
1,1,1-Trichloroethane	µg/L	—	0.17 J	200[c]	Single detection; <PQL
Acetone	µg/L	1.6 J	9.34 J	—	
Antimony (unfiltered)	µg/L	0.16 B	0.82 B	6[c]	All <PQL
Antimony (filtered)	µg/L	0.13 B	0.76 B	6[c]	All <PQL
Arsenic (unfiltered)	µg/L	1.9 B	5.5 B	10[c]	
Arsenic (filtered)	µg/L	1.7 B	5.42	10[c]	
Barium (unfiltered)	µg/L	32	81.7	2,000[c]	
Barium (filtered)	µg/L	31	78.7	2,000[c]	
Benzo(a)anthracene	µg/L	—	0.32 J	—	Single detection; <PQL
Beryllium (filtered)	µg/L	—	0.19 B	4[c]	Single detection; <PQL
Bis(2-ethylhexyl) phthalate	µg/L	—	0.484 J	6[c]	Single detection;<PQL
Butylbenzylphthalate	µg/L	—	12	—	Single detection
Chloroform	µg/L	0.30 J	0.42 J	70[c]	All <PQL
Cobalt (unfiltered)	µg/L	0.51 B	3.4	—	
Cobalt (filtered)	µg/L	0.22 B	1.6 B	—	
Copper (unfiltered)	µg/L	0.34 B	4.59	1,000[b]	
Copper (filtered)	µg/L	0.32 B	4.23	1,000[b]	
Dimethyl phthalate	µg/L	—	19	—	Single detection
Di-n-butylphthalate	µg/L	—	0.328 J	—	Single detection; <PQL
Heptachlorodibenzo-p-dioxins	µg/L	8.0E-07 J	4.0E-06 J	—	All <PQL
Hexachlorodibenzo-p-dioxin	µg/L	5.8E-07 J	3.1E-06 J	—	All <PQL
Lead (unfiltered)	µg/L	—	0.25 B	15[f]	Single detection; <PQL
Lead (filtered)	µg/L	—	0.11 B	15[f]	Single detection; <PQL
Mercury (unfiltered)	µg/L	—	0.357	2[c]	Single detection flagged as suspect
Mercury (filtered)	µg/L	—	0.072 B	2[c]	Single detection flagged as suspect

Table B-49. NRDWL Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum Detection	Comparison Value[a]	Wells Above Comparison; Comments
Methylene chloride	µg/L	—	5.69	5[c]	699-25-34D; single detection is an outlier
Octachlorodibenzo-p-dioxin	µg/L	5.0E-07 J	1.6E-05 J	—	All <PQL
Pentachlorodibenzo-p-dioxins	µg/L	1.1E-06 J	2.5E-06 J	—	All <PQL
Selenium (unfiltered)	µg/L	1.2 B	4.1 B	50[c]	All <PQL
Selenium (filtered)	µg/L	1.1 B	4.7 B	50[c]	All <PQL
Silver (unfiltered)	µg/L	0.030 B	0.07 B	100[b]	All <PQL
Silver (unfiltered)	µg/L	0.038 B	0.09 B	100[b]	All <PQL
Tetrachlorodibenzo-p-dioxins	µg/L	6.1E-07 J	7.5E-07 J	—	All <PQL
Tetrachloroethene	µg/L	0.31 J	0.62 J	5[c]	All <PQL
Tin (unfiltered)	µg/L	0.47 B	1.32 B	—	All <PQL
Tin (filtered)	µg/L	0.41 B	1.3 B	—	All <PQL
Trichloroethene	µg/L	0.32	0.36 J	5[c]	All <PQL (excluding rejected data)
Trichloromonofluoromethane	µg/L	0.33	0.47 J	—	All <PQL
Vanadium (unfiltered)	µg/L	6.10	21.3 B	—	
Vanadium (filtered)	µg/L	6.86	24.5 B	—	
Zinc (unfiltered)	µg/L	2.7 B	24.7	5,000[b]	
Zinc (unfiltered)	µg/L	2.3 B	11.7 B	5,000[b]	All <PQL

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standards for nitrate is 10 mg/L, expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

e. Samples were analyzed for all constituents listed in Tables 3-1 of DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*. Only detected constituents and ranges are listed in this table.

f. Action level (40 CFR 141, Subpart I, "Control of Lead and Copper").

— = no comparison value
B or J = result is below the quantitation limit
NTU = nephelometric turbidity unit
PQL = practical quantitation limit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-50. WMA A-AX Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-E24-20	UG	1991 (C)	9/18/2019	121.63	399.04	125.0	410.2	118.9	390.0	2.8	9.1	Q	3, 6, 9, 12
299-E24-22*	UG	2003 (C)	9/20/2019	121.62	399.01	122.3	401.3	111.6	366.2	10.0	32.8	Q	3, 6, 9, 12
299-E24-33*	UG	2004 (C)	9/18/2019	121.60	398.94	121.3	397.9	111.5	365.9	10.1	33.1	Q	3, 6, 9, 12
299-E25-2	DG	1955 (P)	9/19/2019	121.59	398.93	122.1	400.6	109.9	360.6	11.7	38.3	Q	3, 6, 9, 12
299-E25-237	DG	2015 (C)	9/19/2019	121.54	398.75	123.2	404.1	112.5	369.1	9.0	29.6	Q	3, 6, 9, 12
299-E25-40	DG	1989 (C)	9/20/2019	121.59	398.93	126.3	414.4	119.9	393.4	1.7	5.6	Q	3, 6, 9, 12
299-E25-41	DG	1989 (C)	9/20/2019	121.61	398.98	126.9	416.4	120.5	395.4	1.1	3.6	Q	3, 6, 9, 12
299-E25-93*	DG	2003 (C)	9/19/2019	121.61	398.98	122.5	401.8	111.8	366.7	9.8	32.3	Q	3, 6, 9, 12
299-E25-94*	DG	2004 (C)	9/19/2019	121.66	399.15	121.4	398.2	110.7	363.2	11.0	36.0	Q	3, 6, 9, 12

Note: Requirements are from Table 3-2 in DOE/RL-2015-49, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*.

*Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause the reported head to be less than actual head.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

Q = quarterly

UG = upgradient

Table B-51. WMA A-AX Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value; Comments
Alkalinity	mg/L	84.0	137	—	
Calcium (unfiltered)	µg/L	59,500	108,000	—	
Calcium (filtered)	µg/L	59,900	105,000	—	
Chloride	mg/L	12.7	38.0	250[b]	
Chromium (unfiltered)	µg/L	3.0 U	33.0	100[c]	
Chromium (filtered)	µg/L	2.1 B	10.7	100[c]	Suspect data excluded
Iron (unfiltered)	µg/L	22 U	193	300[b]	
Iron (filtered)	µg/L	22 U	93.0	300[b]	
Magnesium (unfiltered)	µg/L	16,600	31,000	—	
Magnesium (filtered)	µg/L	16,500	30,700	—	
Manganese (unfiltered)	µg/L	0.31 U	5.9	50[b]	
Manganese (filtered)	µg/L	0.36 B	8.3	50[b]	
Nickel (unfiltered)	µg/L	0.44 B	22.0	—	
Nickel (filtered)	µg/L	0.37 B	18.1	—	
Nitrate	mg/L	9.74	70.8	45[d]	299-E24-20, 299-E24-33, 299-E25-237, 299-E25-93, 299-E25-94
pH measurement	unitless	7.75	8.33	—	
Potassium (unfiltered)	µg/L	6,800	9,510	—	
Potassium (filtered)	µg/L	6,900	9,410	—	
Sodium (unfiltered)	µg/L	18,200	30,500	—	
Sodium (filtered)	µg/L	18,100	30,300	—	
Specific conductance	µS/cm	550	876	—	
Sulfate	mg/L	104	240	250[b]	
Temperature	ºC	14.4	20.8	—	
Turbidity	NTU	0.11	4.86	—	
Detected Dangerous Waste Constituents[e]					
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	U	0.13 J	70[c]	Single detection; <PQL
Acetone	µg/L	2.2	25.2	—	Common laboratory contaminant
Antimony (unfiltered)	µg/L	0.13 B	0.20 B	6[c]	All <PQL
Antimony (filtered)	µg/L	0.14 B	0.40 B	6[c]	All <PQL
Aroclor 1260	µg/L	U	0.0629 J	—	Single detection; <PQL
Arsenic (unfiltered)	µg/L	5.3 B	9.6	10[c]	

Table B-51. WMA A-AX Sampling Summary: Constituents Detected in 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value; Comments
Arsenic (filtered)	µg/L	5.2 B	9.5	10[c]	
Barium (unfiltered)	µg/L	37.7	114	2,000[c]	
Barium (filtered)	µg/L	38.0	110	2,000[c]	
Bis(2-ethylhexyl) phthalate	µg/L	0.393 J	0.395 J	6[c]	All <PQL
Chloroform	µg/L	0.27 J	0.34 J	80[c]	All <PQL
Cobalt (unfiltered)	µg/L	0.054 U	0.390 B	—	All <PQL
Cobalt (filtered)	µg/L	0.14 B	0.753 B	—	All <PQL
Copper (unfiltered)	µg/L	0.30 B	3.10 B	1,000[b]	
Copper (filtered)	µg/L	0.33 B	4.40	1,000[b]	
Cyanide	µg/L	1.67 B	5.2	—	
Dioxins[f]	µg/L	1.79E-07 J	9.29E-06 J	—	All <PQL
Lead (unfiltered)	µg/L	0.079 B	0.20 B	15[g]	All <PQL
Lead (filtered)	µg/L	0.079 B	0.21 B	15[g]	All <PQL
Mercury (unfiltered)	µg/L	0.067 B	0.226	2[c]	
Mercury (filtered)	µg/L	0.060 B	0.225	2[c]	
Selenium (unfiltered)	µg/L	2.9 B	14.3	50[c]	
Selenium (filtered)	µg/L	3.3 B	14.0	50[c]	
Silver (unfiltered)	µg/L	0.029 U	0.26 B	100[b]	All <PQL
Tin (unfiltered)	µg/L	0.31 B	1.1 B	—	All <PQL
Tin (filtered)	µg/L	0.14 B	1.8 B	—	All <PQL
Vanadium (unfiltered)	µg/L	16.4	26.3	—	
Vanadium (filtered)	µg/L	14.8 B	26.4	—	
Zinc (unfiltered)	µg/L	1.6 B	8.28 B	5,000[b]	All <PQL
Zinc (filtered)	µg/L	2.2 B	8.25 B	5,000[b]	All <PQL

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

c. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

d. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

e. Samples were analyzed for all dangerous waste constituents listed in Table 3-1 of DOE/RL-2015-49, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*. Only detected constituents and ranges are listed in this table.

f. Analyzed for 19 polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran compounds.

g. Action level (40 CFR 141, Subpart I, "Control of Lead and Copper").

—	=	no comparison value	PQL	=	practical quantitation limit
B, J	=	result is below the quantitation limit	RCRA	=	*Resource Conservation and Recovery Act of 1976*
NTU	=	nephelometric turbidity unit	U	=	result is below the detection limit

Table B-52. WMA B-BX-BY Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-E33-20*	DG	1956 (P)	11/8/2019	121.60	398.94	125.9	413.1	118.7	389.5	2.5	8.2	Q	2, 5, 8, 11
299-E33-31	UG	1989 (C)	11/8/2019	121.61	398.99	125.8	412.8	119.4	391.8	2.2	7.2	Q	2, 5, 8, 11
299-E33-32	UG	1989 (C)	11/8/2019	121.61	398.98	126.1	413.8	119.8	393.0	1.9	6.1	Q	2, 5, 8, 11
299-E33-334	UG	2000 (C)	11/11/2019	121.60	398.94	124.7	409.3	117.1	384.3	4.5	14.7	Q	2, 5, 8, 11
299-E33-335*	DG	2000 (C)	11/11/2019	121.57	398.86	124.2	407.4	118.1	387.4	3.5	11.5	Q	2, 5, 8, 11
299-E33-337	DG	2001 (C)	11/11/2019	121.59	398.93	124.1	407.3	116.5	382.3	5.1	16.6	Q	2, 5, 8, 11
299-E33-338	DG	2001 (C)	11/12/2019	121.62	399.02	123.8	406.1	117.7	386.1	3.9	12.9	Q	2, 5, 8, 11
299-E33-339	DG	2001 (C)	11/12/2019	121.62	399.01	123.2	404.3	117.2	384.4	4.4	14.6	Q	2, 5, 8, 11
299-E33-38	UG	1991 (C)	11/8/2019	121.60	398.96	126.4	414.7	120.0	393.7	1.6	5.3	Q	2, 5, 8, 11
299-E33-41	DG	1991 (C)	11/13/2019	121.61	398.97	124.9	409.9	119.7	392.8	1.9	6.1	Q	2, 5, 8, 11
299-E33-42	UG	1991 (C)	11/12/2019	121.60	398.93	126.7	415.7	120.4	395.0	1.2	4.0	Q	2, 5, 8, 11
299-E33-44	DG	1998 (C)	11/8/2019	121.61	398.97	123.5	405.1	118.9	390.1	2.7	8.8	Q	2, 5, 8, 11
299-E33-47	DG	2004 (C)	11/8/2019	121.61	398.99	123.3	404.7	117.3	384.7	4.4	14.3	Q	2, 5, 8, 11
299-E33-48	DG	2004 (C)	11/11/2019	121.60	398.96	123.3	404.5	115.7	379.5	5.9	19.5	Q	2, 5, 8, 11
299-E33-49	DG	2004 (C)	11/11/2019	121.60	398.96	122.9	403.3	116.8	383.3	4.8	15.7	Q	2, 5, 8, 11
WMA_B-BX-BY_PW-1 (D0062)	DG	Proposed	—	—	—	—	—	—	—	—	—	Q	Not yet installed

Note: Requirements are from DOE/RL-2012-53, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY* (Table 3-1 in Rev. 0 and Table 2-1 in Rev. 1).

*Hydraulic head data for these wells were not corrected for borehole deviation from vertical, which may cause reported head to be less than actual head.

— = no information (well decommissioned)

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

Q = quarterly

UG = upgradient

WMA =waste management area

Table B-53. WMA B-BX-BY Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	95.2	130	—	
Calcium (unfiltered)	µg/L	35,900	211,000	—	
Calcium (filtered)	µg/L	38,100	208,000	—	
Chloride	mg/L	11.2	43.8	250[c]	
Chromium (filtered)	µg/L	3.1	64	100[d]	
Chromium (unfiltered)	µg/L	3.0	32.9	100[d]	
Cyanide (total)	µg/L	2.03	1,000	—	
Cyanide (free)[e]	µg/L	1.0 U	8.41	200/4.8[f]	299-E33-20, 200-E33-44
Iron (unfiltered)	µg/L	22 U	430	300[c]	299-E33-339, 299-E33-38, 299-E33-44
Iron (filtered)	µg/L	22 U	374	300[c]	299-E33-38, 299-E33-44
Magnesium (unfiltered)	µg/L	11,200	57,100	—	
Magnesium (filtered)	µg/L	11,000	54,600	—	
Manganese (unfiltered)	µg/L	0.34 B	62.7	50[c]	299-E33-20
Manganese (filtered)	µg/L	0.31 U	58.7	50[c]	299-E33-20
Nickel (unfiltered)	µg/L	0.60 U	30.4	—	
Nickel (filtered)	µg/L	0.59 B	23.0	—	
Nitrate	mg/L	37.2	1,090	45[g]	All except 299-E33-48
pH measurement	unitless	7.39	8.27	—	
Potassium (unfiltered)	µg/L	6,100	19,000	—	
Potassium (filtered)	µg/L	6,140	19,000	—	
Sodium (unfiltered)	µg/L	22,400	188,000	—	
Sodium (filtered)	µg/L	21,600	183,000	—	
Specific conductance	µS/cm	433	2,217	—	
Sulfate	mg/L	42.0	240	250[c]	
Total organic carbon	µg/L	330 U	2,800	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. Free cyanide is not required under DOE/RL-2012-53, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY*, but was analyzed in 2019.

Table B-53. WMA B-BX-BY Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

f. The following comparison values apply to free cyanide:

- 200 µg/L (40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels")
- 4.8 µg/L (WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B")

g. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value
B = result is below the quantitation limit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-54. WMA C Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-E27-7[a,b]	—[a]	1982 (P)	9/10/2019	121.62	399.01	120.8	396.2	108.9	357.3	12.7	41.6	—	3; not in Rev. 1[a]
299-E27-12[b]	UG	1989 (C)	9/20/2019	121.63	399.03	126.4	414.7	120.0	393.6	1.6	5.4	Q	3, 6, 9, 12
299-E27-13	DG	1989 (C)	9/20/2019	121.58	398.87	126.8	416.0	120.4	394.9	1.2	4.0	Q	3, 6, 9, 12
299-E27-14[b]	DG	1989 (C)	9/17/2019	121.60	398.95	125.9	413.1	119.5	392.1	2.1	6.8	Q	3, 6, 9, 12
299-E27-15[b]	UG	1989 (C)	9/17/2019	121.61	398.97	126.6	415.4	120.2	394.4	1.4	4.6	Q	3, 6, 9, 12
299-E27-155	DG (deep)	2007 (C)	9/17/2019	121.49	398.59	116.1	380.9	105.4	345.9	16.1	52.7	Q	3, 6, 9, 12
299-E27-21[b]	DG	2003 (C)	9/17/2019	121.59	398.92	122.3	401.1	111.6	366.1	10.0	32.8	Q	3, 6, 9, 12
299-E27-22[b]	UG	2003 (C)	9/18/2019	121.63	399.06	123.1	403.8	110.9	363.9	10.7	35.2	Q	3, 6, 9, 12
299-E27-23[b]	DG	2003 (C)	9/18/2019	121.60	398.94	122.3	401.2	111.6	366.2	10.0	32.7	Q	3, 6, 9, 12
299-E27-24[c]	DG (deep)	2010 (C)	9/17/2019	121.55	398.80	113.0	370.9	107.0	350.9	14.6	47.9	Q	3, 6, 9, 12
299-E27-25[a,c]	—[a]	2010 (C)	3/22/2019	121.51	398.65	125.0	410.2	117.2	384.5	4.4	14.3	—	3; not in Rev. 1[a]
299-E27-26[d]	UG	2016 (C)	9/18/2019	121.05	397.13	122.9	403.2	110.7	363.2	10.3	34.0	Q	3, 6, 9, 12
WMA_C_PW-1 (D0044)	DG	Proposed	—	—	—	—	—	—	—	—	—	—	Not yet installed
WMA_C_PW-2 (D0045)	DG	Proposed	—	—	—	—	—	—	—	—	—	—	Not yet installed

Note: Requirements are from Table 3-1 in DOE/RL-2009-77, Rev. 0, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*; and Table 2-1 in DOE/RL-2009-77, Rev. 1, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*.

a. Wells included in DOE/RL-2009-77, Rev. 0 but not in Rev. 1.

b. Hydraulic head data for these wells were corrected for borehole deviation from vertical. Corrections are not available for other wells in this network, which may cause reported head to be less than actual head.

c. Wells 299-E27-24 and 299-E27-25 were listed as "Proposed Well South of 299-E27-14" and "Proposed Upgradient Well," respectively, in Table 3-1 of DOE/RL-2009-77, Rev. 0. Well 299-E27-25 is not included in the network under Rev. 1.

d. Head in well 299-E27-26 is consistently much lower than other wells in the network, suggesting that the well is deviated from vertical.

Table B-54. WMA C Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

Q = quarterly

S = semiannually

UG = upgradient

WMA = waste management area

Table B-55. WMA C Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	77.2	130	—	
Calcium (unfiltered)	µg/L	45,700	137,000	—	
Calcium (filtered)	µg/L	46,400	136,000	—	
Chloride	mg/L	13.0	77.0	250[c]	Minimum excludes suspect value
Chromium (unfiltered)	µg/L	4.0 U	70.0	100[d]	
Chromium (filtered)	µg/L	3.0 U	24.1	100[d]	
Cyanide (total)	µg/L	1.67 U	66.7	—	
Cyanide (free)[e]	µg/L	1.0 U	3.07	200/4.8[f]	
Iron (unfiltered)	µg/L	30 U	530	300[c]	299-E27-7, 299-E27-13
Iron (filtered)	µg/L	22 U	161	300[c]	
Magnesium (unfiltered)	µg/L	13,600	39,600	—	
Magnesium (filtered)	µg/L	13,500	39,200	—	
Manganese (unfiltered)	µg/L	0.36 U	8.8	50[c]	
Manganese (filtered)	µg/L	0.31 U	7.0	50[c]	
Nickel (unfiltered)	µg/L	0.92 U	55	—	
Nickel (filtered)	µg/L	0.92 U	29	—	
Nitrate	mg/L	12.0	193	45[g]	299-E27-14, 299-E27-155, 299-E27-21, 299-E27-22, 299-E27-23, 299-E27-24, 299-E27-25, 299-E27-26; minimum excludes suspect value
Nitrite	mg/L	0.05 U	0.69	3.3[g]	
pH measurement	unitless	7.48	8.65	—	
Potassium (unfiltered)	µg/L	6,550	11,700	—	
Potassium (filtered)	µg/L	6,660	11,500	—	
Sodium (unfiltered)	µg/L	12,300	31,200	—	
Sodium (filtered)	µg/L	12,800	29,800	—	
Specific conductance	µS/cm	398	1,209	—	
Sulfate	mg/L	60.0	357	250[b]	299-E27-14, 299-E27-22, 299-E27-24, 299-E27-25, 299-E27-26; minimum excludes suspect value

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. This analysis is not required under the groundwater monitoring plan but was performed in 2019.

Table B-55. WMA C Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

f. These comparison values apply to free cyanide:

- 200 µg/L (40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels")
- Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*

g. The federal drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L expressed as nitrogen (40 CFR 141, Subpart G). These equate to 45 mg/L and 3.3 mg/L when expressed as NO_3 and NO_2.

— = no comparison value
B = result is below the quantitation limit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-56. WMA S-SX Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-W22-113	DG	2014 (C)	9/30/2019	131.88	432.67	132.7	435.5	123.6	405.4	8.3	27.2	Q	3, 6, 9, 12
299-W22-115	DG	2015 (C)	9/30/2019	131.80	432.43	133.3	437.2	122.6	402.1	9.2	30.3	Q	3, 6, 9, 12
299-W22-116	DG	2015 (C)	9/30/2019	131.87	432.65	132.5	434.8	121.9	399.8	10.0	32.8	Q	3, 6, 9, 12
299-W22-47	—[a]	2005 (C)	9/30/2019	131.88	432.68	135.8	445.6	125.2	410.6	6.7	22.1	—	3; not in Rev. 1[a]
299-W22-69	—[a]	2006 (C)	9/30/2019	131.00	429.78	134.7	442.0	124.0	406.9	7.0	22.9	—	3; not in Rev. 1[a]
299-W22-72	—[a]	2006 (C)	9/30/2019	130.72	428.87	135.1	443.3	124.4	408.3	6.3	20.6	—	3; not in Rev. 1[a]
299-W22-80	DG	2000 (C)	9/30/2019	132.10	433.39	137.5	451.1	126.8	416.0	5.3	17.4	Q	3, 6, 9, 12
299-W22-81	DG	2001 (C)	9/30/2019	131.54	431.55	136.8	448.8	126.1	413.9	5.4	17.7	Q	3, 6, 9, 12
299-W22-82	—[a]	2001 (C)	9/30/2019	131.63	431.84	137.2	450.2	126.5	415.1	5.1	16.8	—	3; not in Rev. 1[a]
299-W22-83	—[a]	2001 (C)	6/5/2019	131.74	432.21	137.4	450.7	126.7	415.7	5.0	16.5	—	3; not in Rev. 1[a]
299-W22-84	DG	2001 (C)	9/30/2019	131.51	431.45	137.1	449.7	126.4	414.7	5.1	16.7	Q	3, 6, 9, 12
299-W22-85	DG	2001 (C)	9/30/2019	131.99	433.03	137.5	451.1	126.9	416.2	5.1	16.8	Q	3, 6, 9, 12
299-W22-86	—[a]	2006 (C)	9/30/2019	131.04	429.91	135.2	443.5	124.5	408.4	6.6	21.5	—	3; not in Rev. 1[a]
299-W22-89	—[a]	2006 (C)	9/30/2019	131.88	432.69	135.1	443.3	124.4	408.2	7.5	24.5	—	3; not in Rev. 1[a]
299-W22-93	DG	2015 (C)	9/11/2019	131.35	430.94	132.3	434.1	121.6	399.1	9.7	31.9	Q	3, 6, 9, 12
299-W22-94	DG	2013 (C)	9/30/2019	131.40	431.11	133.2	436.9	122.5	401.9	8.9	29.2	Q	3, 6, 9, 12
299-W22-95	—[a]	2013 (C)	9/30/2019	130.73	428.91	132.1	433.3	119.9	393.3	10.9	35.6	—	3; not in Rev. 1[a]
299-W23-19	DG	1999 (C)	9/30/2019	132.56[b]	434.91[b]	138.3	453.6	128.9	423.0	3.6	11.9	Q	3, 6, 9, 12
299-W23-20	UG	2000 (C)	9/30/2019	132.64	435.17	138.3	453.8	126.7	415.8	5.9	19.3	Q	3, 6, 9, 12
299-W23-21	UG	2000 (C)	9/30/2019	132.78	435.62	137.8	452.0	126.5	414.9	6.3	20.7	Q	3, 6, 9, 12

Table B-56. WMA S-SX Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		

Note: Requirements are from DOE/RL-2009-73, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX* (Table 3-2 in Rev. 0 and Table 2-1 in Rev. 1).

a. Wells included in DOE/RL-2009-73, Rev. 0 and not in Rev. 1.

b. Water-level measurements are not possible from well 299-W23-19 because it is located within the tank farm fence line and is sampled remotely from outside the fence. The water level was estimated as 0.2 m higher than at nearby well 299-W23-236.

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

Q = quarterly

UG = upgradient

Table B-57. WMA S-SX Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	90.8	118	—	
Calcium (unfiltered)	µg/L	20,300	58,400	—	
Calcium (filtered)	µg/L	19,600	63,400	—	
Chloride	mg/L	5.59	23.0	250[c]	
Chromium (unfiltered)	µg/L	1.29 B	438	100[d]	299-W22-116, 299-W22-81, 299-W22-93, 299-W22-94, 299-W23-19
Chromium (filtered)	µg/L	1.43 B	433	100[d]	299-W22-116, 299-W22-93, 299-W23-19
Chromium (hexavalent) (filtered)	µg/L	1.75 B	463	48[e]	299-W22-116, 299-W22-93, 299-W23-19
Iron (unfiltered)	µg/L	22 U	2,900	300[c]	299-W22-80, 299-W22-81, 299-W22-94
Iron (filtered)	µg/L	22 U	198	300[c]	
Magnesium (unfiltered)	µg/L	7,100	18,000	—	
Magnesium (filtered)	µg/L	7,100	20,000	—	
Manganese (unfiltered)	µg/L	0.46 B	93.1	50[c]	299-W22-81
Manganese (filtered)	µg/L	0.31 U	32.1	50[c]	
Nickel (unfiltered)	µg/L	0.3 U	97.6	—	
Nickel (filtered)	µg/L	0.33 B	44.7	—	
Nitrate	mg/L	6.95	168	45[f]	299-W22-115, 299-W22-116, 299-W22-93, 299-W23-19
pH measurement	unitless	7.29	8.3	6.5 – 8.5[c]	
Potassium (unfiltered)	µg/L	2,600	4,700	—	
Potassium (filtered)	µg/L	2,600	4,700	—	
Sodium (unfiltered)	µg/L	14,600	31,000	—	
Sodium (filtered)	µg/L	14,200	31,000	—	
Specific conductance	µS/cm	254	574	—	Minimum excludes suspect data
Sulfate	mg/L	16.0	34.6	250[c]	
Temperature	ºC	15.9	23.8	—	
Turbidity	NTU	0.13	92.1	—	

Table B-57. WMA S-SX Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

f. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value
B = result is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-58. WMA T Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-W10-1	—*	1947 (P)	11/7/2019	132.27	433.97	148.6	487.6	124.2	407.6	8.0	26.3	—	3; not in Rev. 2*
299-W10-4	—	1952 (P)	—	—	—	—	—	—	—	—	—	—	Dry since 2014; not in Rev. 2*
299-W10-23	—*	1998 (C)	5/8/2019	131.10	430.12	137.8	452.1	127.1	417.1	3.9	12.9	—	3; not in Rev. 2*
299-W10-24	DG	1998 (C)	11/6/2019	130.67	428.71	138.0	452.6	127.3	417.6	3.4	11.1	Q	3, 5, 8, 11
299-W10-28	UG	2001 (C)	11/5/2019	131.51	431.48	137.5	451.2	126.8	416.0	4.7	15.5	Q	3, 5, 8, 11
299-W11-39	DG	2000 (C)	11/6/2019	130.50	428.13	137.0	449.6	126.5	415.0	4.0	13.2	Q	3, 5, 8, 11
299-W11-40	DG	2000 (C)	11/7/2019	130.33	427.59	137.2	450.0	126.5	415.0	3.9	12.7	Q	3, 5, 8, 11
299-W11-41	DG	2000 (C)	11/6/2019	130.13	426.92	137.4	450.9	126.8	415.9	3.4	11.0	Q	3, 5, 8, 11
299-W11-42	DG	2000 (C)	11/6/2019	130.48	428.07	137.9	452.6	127.3	417.7	3.1	10.3	Q	3, 5, 8, 11
299-W11-45	—*	2006 (C)	11/11/2019	130.24	427.28	127.2	417.4	122.7	402.4	7.5	24.7	—	3; not in Rev. 2*
299-W11-47	—*	2006 (C)	11/7/2019	130.14	426.95	126.1	413.8	116.8	383.2	13.4	43.9	—	3; not in Rev. 2*
T_PW1 (D0017)	DG	Proposed	—	—	—	—	—	—	—	—	—	Q	Not yet installed
T_PW2 (D0018)	DG	Proposed	—	—	—	—	—	—	—	—	—	Q	Not yet installed
T_PW3 (D0019)	DG	Proposed	—	—	—	—	—	—	—	—	—	Q	Not yet installed

Note: Requirements are from DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T* (Table 3-2 in Rev. 1 and Table 2-1 in Rev. 2).

*Wells included in DOE/RL-2009-66, Rev. 1 but not in Rev. 2.

— = no information or not applicable

A = annually

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

Q = quarterly

UG = upgradient

Table B-59. WMA T Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	106	140	—	
Calcium (unfiltered)	µg/L	4,560	93,300	—	
Calcium (filtered)	µg/L	4,350	94,400	—	
Chloride	mg/L	15.5	34	250[c]	
Chromium (unfiltered)	µg/L	8.57 B	220	100[d]	299-W11-39
Chromium (filtered)	µg/L	8.96 B	75.5	100[d]	
Dissolved oxygen	mg/L	7.33	9.88	—	
Fluoride	mg/L	0.24	4.93	4[d]	299-W10-24, 299-W11-39
Hexavalent chromium	µg/L	6.0 B	75.1	48[e]	299-W11-41, 299-W10-28
Iron (unfiltered)	µg/L	30 U	2,560	300[c]	299-W10-28, 299-W11-39, 299-W11-41, 299-W11-42
Iron (filtered)[c]	µg/L	30 U	130	300[c]	Maximum value excludes result flagged as associated with laboratory blank contamination
Magnesium (unfiltered)	µg/L	1,400	31,100	—	
Magnesium (filtered)	µg/L	1,370	32,400	—	
Manganese (unfiltered)	µg/L	1.2 B	41.9	50[c]	
Manganese (filtered)	µg/L	0.55 B	7.8	50[c]	
Nickel (unfiltered)	µg/L	0.55 B	79	—	
Nickel (filtered)	µg/L	0.60 U	33	—	
Nitrate	mg/L	35	292	45[f]	All except 299-W10-1
pH measurement	unitless	7.68	8.85	8.5[c]	299-W10-24, 299-W11-39
Potassium (unfiltered)	µg/L	2,020	6,300	—	
Potassium (filtered)	µg/L	1,990	6,200	—	
Sodium (unfiltered)	µg/L	10,600	164,000	—	
Sodium (filtered)	µg/L	18,600	148,000	—	
Specific conductance	µS/cm	440	961	—	
Sulfate	mg/L	35.0	59.0	250[c]	
Temperature	ºC	14.7	220	—	
Turbidity	NTU	0.83	222	—	

Table B-59. WMA T Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

Note: Minimum and maximum are based on the required samples for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/ Feasibility Study Reports*.

f. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value

B = result is below the quantitation limit

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

U = result is below the detection limit

Table B-60. WMA TX-TY Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-W10-26	DG	1998 (C)	11/15/2019	129.71	425.55	138.5	454.5	127.9	419.5	1.9	6.2	Q	3, 5, 8, 11
299-W10-27	DG	2001 (C)	11/15/2019	129.80	425.85	137.5	451.2	126.9	416.2	2.9	9.6	Q	3, 5, 8, 11
299-W14-11	—*	2005 (C)	11/13/2019	127.44	418.12	124.5	408.5	121.6	399.0	5.9	19.3	—	3; not in Rev. 2*
299-W14-13	DG	1998 (C)	11/13/2019	128.09	420.24	138.2	453.4	127.6	418.6	0.5	1.5	Q	3, 5, 8, 11
299-W14-14	DG	1998 (C)	11/14/2019	129.39	424.51	138.5	454.3	127.8	419.3	1.6	5.2	Q	3, 5, 8, 11
299-W14-15	DG	2000 (C)	11/18/2019	129.01	423.26	137.5	451.2	127.0	416.7	2.0	6.7	Q	3, 5, 8, 11
299-W14-16	—*	2000 (C)	11/17/2019	128.76	422.45	137.4	450.8	126.7	415.8	2.0	6.6	—	3; not in Rev. 2*
299-W14-17	—*	2000 (C)	4/1/2019	129.10	423.54	137.4	450.8	126.7	415.8	2.3	7.7	—	3; not in Rev. 2*
299-W14-18	DG	2000 (C)	11/14/2019	128.85	422.73	137.8	452.2	127.1	417.2	1.7	5.6	Q	3, 5, 8, 11
299-W14-19	DG	2002 (C)	11/18/2019	129.45	424.71	136.6	448.2	126.1	413.7	3.3	11.0	Q	3, 5, 8, 11
299-W15-44	UG	2002 (C)	11/15/2019	131.38	431.05	138.3	453.8	127.6	418.6	3.8	12.5	Q	3, 5, 8, 11
299-W15-763	—*	2001 (C)	11/15/2019	130.68	428.73	137.6	451.3	126.9	416.3	3.7	12.2	—	3; not in Rev. 2*
299-W15-765	UG	2001 (C)	11/15/2019	129.97	426.41	137.4	450.9	126.8	415.9	3.2	10.5	Q	3, 5, 8, 11
WMA_TX-TY_PW1 (D0020)	UG	Proposed	—	—	—	—	—	—	—	—	—	Q	None
WMA_TX-TY_PW2 (D0021)	UG	Proposed	—	—	—	—	—	—	—	—	—	Q	None

Note: Requirements are from DOE/RL-2009-67, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY* (Table 3-2 in Rev. 1 and Table 2-1 in Rev. 2).

*Wells included in DOE/RL-2009-67, Rev. 1 but not in Rev. 2.

— = no information or not applicable

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

Q = quarterly

UG = upgradient

WMA = waste management area

Table B-61. WMA TX-TY Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	101	140	—	
Aluminum (unfiltered)	µg/L	12.9 B	2,440	50[c]	All wells but 299-W14-11 and 299-W15-763
Aluminum (filtered)	µg/L	9.2 U	20 U	50[c]	
Calcium (unfiltered)	µg/L	42,500	132,000	—	
Calcium (filtered)	µg/L	43,400	128,000	—	
Chloride	mg/L	17.2	42.0	250[c]	
Chromium (unfiltered)	µg/L	3.96 B	167	100[d]	299-W14-16, 299-W15-44
Chromium (filtered)	µg/L	3.7 B	65.1	100[d]	
Cyanide (total)[e]	µg/L	1.67 U	1,680	—	
Cyanide (free)[e]	µg/L	1.0 U	24.5	200/4.8[f]	
Dissolved oxygen	mg/L	5.4	10.0	—	
Fluoride	mg/L	0.09 B	1.91	4[d]	
Hexavalent chromium	µg/L	2.6 B	116	48[g]	299-W10-26, 299-W14-16, 299-W14-18
Iron (unfiltered)	µg/L	26.1 B	4,800	300[c]	299-W10-26, 299-W10-27, 299-W14-13, 299-W14-18, 299-W14-19
Iron (filtered)	µg/L	22 U	733	300[c]	299-W10-26, 299-W14-18
Magnesium (unfiltered)	µg/L	13,000	47,600	—	
Magnesium (filtered)	µg/L	12,800	46,300	—	
Manganese (unfiltered)	µg/L	0.31 U	112	50[c]	299-W10-27, 299-W14-13
Manganese (filtered)	µg/L	0.52 B	5.0	50[c]	
Nickel (unfiltered)	µg/L	0.30 B	19	—	
Nickel (filtered)	µg/L	0.43 B	4.0 B	—	
Nitrate	mg/L	38.2	553	45[h]	All wells but 299-W15-765
pH measurement	unitless	7.58	8.26	—	
Potassium (unfiltered)	µg/L	3,940	8,190	—	
Potassium (filtered)	µg/L	4,230	7,950	—	
Sodium (unfiltered)	µg/L	11,900	149,000	—	
Sodium (filtered)	µg/L	12,400	148,000	—	
Specific conductance	µS/cm	500	1,382	—	

Table B-61. WMA TX-TY Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Sulfate	mg/L	34.1	69.7	250[c]	
Temperature	°C	13.5	22.6	—	
Turbidity	NTU	0.38	88.6	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

e. Total and free cyanide are not required under DOE/RL-2009-67, Rev. 2, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY*, but were analyzed in 2019.

f. The following comparison values apply to free cyanide:

- 200 µg/L (40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels")
- 4.8 µg/L (WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B")

g. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports.*

h. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value
B = result is below the quantitation limit
NTU = nephelometric turbidity unit
RCRA = *Resource Conservation and Recovery Act of 1976*
U = result is below the detection limit

Table B-62. WMA U Groundwater Monitoring Network

Well Name	Location	Year Installed	Head Date	Hydraulic Head		Elevation Screen Top		Elevation Screen Bottom		Water Column		Sample Frequency	Sampled Months; Comments
				m	ft	m	ft	m	ft	m	ft		
299-W18-260	DG	2014 (C)	10/10/2019	131.73	432.19	132.0	432.9	122.8	402.9	8.9	29.2	Q	1, 4, 7, 10
299-W18-40	UG	2001 (C)	10/10/2019	132.84	435.84	136.2	446.8	125.5	411.8	7.3	24.0	Q	1, 4, 7, 10
299-W19-12	—*	1983 (P)	10/9/2019	131.72	432.14	141.7	464.8	129.5	424.8	2.2	7.3	—	1, 4; not in Rev. 2*
299-W19-41	DG	1998 (C)	10/9/2019	131.80	432.42	138.7	455.0	128.0	420.0	3.8	12.4	Q	1, 4, 7, 10
299-W19-42	DG	1998 (C)	10/9/2019	131.77	432.31	138.4	453.9	127.7	418.8	4.1	13.5	Q	1, 4, 7, 10
299-W19-44	DG	2001 (C)	10/9/2019	131.73	432.17	136.4	447.7	125.8	412.7	5.9	19.5	Q	1, 4, 7, 10
299-W19-45	DG	2001 (C)	10/9/2019	131.74	432.21	137.4	450.6	126.7	415.7	5.0	16.5	Q	1, 4, 7, 10
299-W19-47	DG	2004 (C)	10/10/2019	131.75	432.26	136.3	447.3	125.7	412.4	6.1	19.9	Q	1, 4, 7, 10
WMA-U_PW1 (D0016)	UG	Proposed	—	—	—	—	—	—	—	—	—	Q	Not yet installed

Note: Requirements are from DOE/RL-2009-74, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U* (Table 3-2 in Rev. 1 and Table 2-1 in Rev. 2). Well 299-W18-30 was also listed in Rev. 1 but it went dry in 2013 and was replaced by 299-W18-260.

*Well included in DOE/RL-2009-74, Rev. 1 but not in Rev. 2.

— = no information or not applicable

C = constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

DG = downgradient

P = constructed prior to *Washington Administrative Code* requirements

Q = quarterly

UG = upgradient

WMA = waste management area

Table B-63. WMA U Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value
Alkalinity[b]	mg/L	74	109	—	
Calcium (unfiltered)	µg/L	35,700	50,400	—	
Calcium (filtered)	µg/L	36,300	51,000	—	
Chloride	mg/L	12.7	36.0	250[c]	
Chromium (unfiltered)	µg/L	6.3 B	133	100[d]	299-W9-12
Chromium (filtered)	µg/L	5.4 B	20.4	100[d]	
Hexavalent chromium (filtered)	µg/L	6.13	18.5	48[e]	
Iron (unfiltered)	µg/L	34.1	1100	300[c]	299-W19-44
Iron (filtered)	µg/L	30 U	30 U	300[c]	
Magnesium (unfiltered)	µg/L	12,900	17,000	—	
Magnesium (filtered)	µg/L	12,600	17,000	—	
Manganese (unfiltered)	µg/L	1.49 B	29.0	50[c]	
Manganese (filtered)	µg/L	0.36 B	4.0 U	50[c]	
Nickel (unfiltered)	µg/L	0.60 U	17.1	—	
Nickel (filtered)	µg/L	0.60 U	10.0 U	—	
Nitrate	mg/L	56.2	137	45[f]	All
pH measurement	unitless	7.71	8.98	6.5 – 8.5[c]	299-W19-41, 299-W19-44
Potassium (unfiltered)	µg/L	3,890	5,700	—	
Potassium (filtered)	µg/L	3,810	5,500	—	
Sodium (unfiltered)	µg/L	20,000	27,200	—	
Sodium (filtered)	µg/L	19,000	26,000	—	
Specific conductance	µS/cm	410	520	—	
Sulfate	mg/L	25.2	42.3	250[c]	
Temperature	ºC	14.1	20.6	—	
Turbidity	NTU	0.95	26.2	—	

Note: Minimum and maximum are based on the required sample results for this RCRA unit. Appendix A of DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019*, presents the full data set for 2019.

a. Comparison values are provided for information only and are not used to determine RCRA groundwater monitoring exceedances.

b. Minimum and maximum reflect total and bicarbonate alkalinity.

c. 40 CFR 143.3, "National Secondary Drinking Water Regulations," "Secondary Maximum Contaminant Levels."

d. 40 CFR 141, Subpart G, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels and Maximum Residual Disinfectant Levels."

Table B-63. WMA U Sampling Summary for 2019

Constituent	Units	Minimum	Maximum	Comparison Value[a]	Wells Above Comparison Value

e. Individual risk-based concentration levels as derived from WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," as calculated in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

f. The federal drinking water standard for nitrate is 10 mg/L expressed as nitrogen (40 CFR 141, Subpart G). This equates to 45 mg/L when expressed as NO_3.

— = no comparison value

NTU = nephelometric turbidity unit

RCRA = *Resource Conservation and Recovery Act of 1976*

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Appendix C

Supporting Information for Atomic Energy Act Monitoring

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Contents

C1 Supporting Information for Atomic Energy Act Monitoring C-1

C2 References C-4

Table

Table C-1. AEA Well Sampling Exceptions, 2019 ..... C-2

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C1 Supporting Information for Atomic Energy Act Monitoring

DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Monitoring Plan*, defines the requirements for *Atomic Energy Act of 1954* (AEA) groundwater monitoring at the Hanford Site. Sample collection from the monitoring locations identified in the plan was distributed over 3 years to start; not all wells were intended to be sampled during the first year of the monitoring program. The AEA groundwater sampling and analysis plan (SAP) is reviewed annually and revised if needed.

The AEA groundwater monitoring is integrated with other groundwater monitoring programs at the Hanford Site as part of an overall strategy to meet the requirements of the AEA groundwater monitoring plan. To implement program integration, a comprehensive groundwater sampling and analysis schedule is developed each year by incorporating the sampling and analysis needs established in individual SAPs. Integrating the AEA monitoring program into the comprehensive groundwater monitoring schedule includes scheduling AEA sampling events in conjunction with other programs (where possible) to avoid duplicative sampling events. Schedule integration may also result in situations where AEA monitoring data are collected on a slightly different schedule than established in the AEA SAP (DOE/RL-2015-56). It may also be the case that schedule integration with multiple projects for a well may not be feasible; therefore, sampling events may be delayed to be consolidated with a later sampling event.

Sample collection and analysis in accordance with the AEA SAP (DOE/RL-2015-56) focuses on radiological analytes and nitrate. The AEA groundwater monitoring program relies on existing *Resource Conservation and Recovery Act of 1976*; *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; and *Washington Administrative Code* monitoring activities for collecting and analyzing groundwater samples for nonradiological constituents of interest to meet the requirements of DOE O 458.1, *Radiation Protection of the Public and the Environment*, for human health and protection. The AEA groundwater monitoring program evaluates radiological data collected under the other programs to support AEA surveillance reporting activities.

Table C-1 lists sampling deviations and omissions for 2019 based on DOE/RL-2015-56 groundwater monitoring requirements. Wells not listed in Table C-1 were sampled according to monitoring requirements of the AEA SAP (DOE/RL-2015-56). In some cases, wells were sampled beyond the requirements listed in the SAP (e.g., wells were sampled more frequently or for additional constituents), and those exceptions are not noted in Table C-1.

Table C-1. AEA Well Sampling Exceptions, 2019

Well Name(s)	Sampling Exceptions and Explanation
100-BC Groundwater Interest Area	
—	No sampling exceptions.
100-FR Groundwater Interest Area	
199-F5-43B	Unsuccessful sampling due to wasp nest in the well. Well concern report has been submitted.
100-HR Groundwater Interest Area	
C6278	Unsuccessful sampling; broken at ground level. Maintenance has been requested.
199-D4-101	Missed sampling event. Pump and treat system was not running.
199-H4-8, 199-H4-84, 199-H4-89	Unsuccessful sampling event. Not enough water in these wells due to low water table.
100-KR Groundwater Interest Area	
19-D	Unsuccessful sampling event due to no flow.
100-NR Groundwater Interest Area	
199-N-172	Unsuccessful sampling. Well is dry; screen has separated. Will be removed from the AEA SAP (DOE/RL-2015-56).
199-N-147, 199-N-75	September 2019 samples unsuccessful due to running out of water (199-N-147) or pump would not remain running (199-N-75). Sampling was successful in January 2020.
1100-EM Groundwater Interest Area	
—	No sampling exceptions.
Richland North Groundwater Interest Area	
—	No sampling exceptions.
300-FF Groundwater Interest Area	
699-11-E5A	Well access issue; Energy Northwest well. Working on facilitating data sharing with Energy Northwest.
399-1-63	Unsuccessful. Well produced no water
AT-3-5-S	Unsuccessful sampling. All traces of aquifer tube have vanished at this location. Will remove from the AEA SAP (DOE/RL-2015-56).
399-6-5	Missed sampling event due to the pump tripping the breaker. Maintenance has been requested.

Table C-1. AEA Well Sampling Exceptions, 2019

Well Name(s)	Sampling Exceptions and Explanation
200-BP Groundwater Interest Area	
299-E33-14	Unsuccessful sampling due to pump issues. No water was produced after 15 minutes. Maintenance has been requested.
299-E33-1A	Well access issue. Well is located in subsidence area. Will remove from the AEA SAP (DOE/RL-2015-56).
299-E33-205, 299-E33-9	Well access issues. Wells are inside the BX-BY Tank Farms and need Washington River Protection Solutions resources.
299-E28-13, 299-E32-3	Technetium-99 not reported from the laboratory due to tracer error.
299-E27-25	Unsuccessful; pump rod snapped. Well concern report was submitted, maintenance was notified, and the pump was removed for access.
200-PO Groundwater Interest Area	
699-10-54A	Well access issue. A new road is needed.
499-S1-8J	Canceled sampling; well maintenance issue. Will replace well in AEA SAP (DOE/RL-2015-56).
699-8-25	Unsuccessful sampling due to no access. New access road will be requested.
699-33-42	Unsuccessful sampling since well is dry. Well was removed from AEA SAP (DOE/RL-2015-56).
299-E13-11	Unsuccessful sampling due to no access. New access road will be requested.
299-E13-18	Unsuccessful sampling due to no access since the well is in a subsidence zone. Well should be removed from AEA SAP (DOE/RL-2015-56).
699-49-13E	Unsuccessful sampling due to diesel tractor motor that prohibits sampling. Will request maintenance to look at well. If well cannot be updated, it will be removed from AEA SAP (DOE/RL-2015-56).
699-S2-34B	Well access issue. Working on coordinating with LIGO Hanford Observatory to sample.
200-UP Groundwater Interest Area	
699-35-59	Unsuccessful. It is a US Ecology, Inc. well. Will attempt to coordinate access with US Ecology.
299-W15-37	Unsuccessful; access limitations. This well should be replaced in AEA SAP (DOE/RL-2015-56).
699-17-70	Unsuccessful. Well is located in Arid Lands Ecology Reserve and there is no road access. Will request road access or remove from AEA SAP (DOE/RL-2015-56).

Table C-1. AEA Well Sampling Exceptions, 2019

Well Name(s)	Sampling Exceptions and Explanation
200-ZP Groundwater Interest Area	
299-W18-7, 299-W15-34, 299-W15-43, 299-W15-45, 299-W18-6	Missed sampling event due to scheduling constraints associated with Plutonium Finishing Plant demolition zone.
699-48-77D	Unsuccessful sampling due to no water to surface.
699-49-100C	Anions not analyzed due to an error in the sample request.
299-W11-33Q	Unsuccessful sampling due to no water to surface.

Reference: DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan*.

AEA = *Atomic Energy Act of 1954*

LIGO = Laser Interferometer Gravitational-Wave Observatory

SAP = sampling and analysis plan

C2 References

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Appendix D

Confined Aquifers

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Contents

D1 Confined Aquifers D-1

D2 Ringold Confined Aquifers D-1

D2.1 Groundwater Flow in Ringold Confined Aquifers D-1

D2.2 Groundwater Quality in Ringold Confined Aquifers D-4

D3 Upper Basalt Confined Aquifer D-7

D3.1 Groundwater Flow in Upper Basalt Confined Aquifer D-7

D3.2 Groundwater Quality in Upper Basalt Confined Aquifer D-10

D4 References D-12

Figures

Figure D-1. Ringold Confined Aquifer Monitoring Wells D-2

Figure D-2. Potentiometric Surface for Ringold Unit A, March 2019 ..... D-3

Figure D-3. Upper Basalt Confined Aquifer Monitoring Wells D-8

Figure D-4. Potentiometric Surface for Upper Basalt Confined Aquifer, March 2019 ..... D-9

Tables

Table D-1. Groundwater Quality in Ringold Confined Aquifers D-5

Table D-2. Groundwater Quality in Upper Basalt Confined Aquifer D-11

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D1 Confined Aquifers

This appendix describes groundwater flow and groundwater quality in confined and semiconfined aquifers within the Ringold Formation and the upper portion of the Columbia River Basalt Group. The U.S. Department of Energy monitors groundwater quality in the confined aquifer systems because of the potential for downward contaminant migration from the overlying unconfined aquifer in areas where confining units are absent or fractured. Groundwater monitoring of the confined aquifer system is conducted in accordance with DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan* (hereinafter referred to as the *Atomic Energy Act of 1954* [AEA] sampling and analysis plan [SAP]), as well as some of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* SAPs that also have requirements for confined aquifer wells.

D2 Ringold Confined Aquifers

Numerous wells at the Hanford Site monitor the confined water-bearing units in the Ringold Formation (Figure D-1). The most widespread Ringold confined aquifer is where the Ringold lower mud unit confines the underlying sediment of Ringold unit A (Figure 1-6 in the main text). Approximately 40 wells are screened in Ringold unit A, although not all of the wells have been sampled in recent years. Most of the wells are located in or near the Central Plateau; other wells are located in the southern Hanford Site (including the 300 Area), and one well is in the 100 Area.

Local water-bearing units in or beneath the Ringold upper mud unit (RUM) exist in the northern Hanford Site (Figure 1-4 in the main text). Hydrogeologic testing in the 100-H Area shows that some of these units are interconnected locally, but they are not believed to form a regional confined aquifer. Twenty-eight wells in the 100 Area are screened in water-bearing units within or beneath this unit.

D2.1 Groundwater Flow in Ringold Confined Aquifers

This section describes groundwater flow in the confined aquifer of Ringold unit A near the 200 Areas and farther south. A potentiometric map for the RUM aquifer was recently developed in the 100-HR groundwater interest area and is presented in Chapter 4 of the main text.

The elevation of the top of the Ringold confined aquifer varies from 34 m (111.5 ft) (NAVD88, *North American Vertical Datum of 1988*) northwest of the 200 West Area to >127 m (417 ft) southeast of the 200 East Area (ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*). Insufficient data are available from Ringold unit A in the northern part of the Hanford Site to interpret groundwater flow directions.

Figure D-2 presents the March 2019 potentiometric surface for a portion of the confined aquifer in Ringold unit A based on water-level measurements from 30 monitoring wells. The map is subject to uncertainty due to the paucity of data in some areas. However, generalized flow patterns can be inferred from available data when the hydrogeologic framework (i.e., the extent of the confined unit, presence of basalt subcrops, and influence of the May Junction fault) is considered.

Groundwater flow in the Ringold confined aquifer is generally west to east near the 200 West Area and west to east along the southern boundary of the aquifer near the Rattlesnake Hills. This flow pattern indicates that recharge occurs west of the 200 West Area in upgradient areas within the Cold Creek Valley, as well as in Dry Creek Valley and possibly the Rattlesnake Hills. East of the 200 West Area, a bend in the 128 m (420 ft) contour and the closed 130 m (427 ft) contour shown in Figure D-2 illustrate the impact of pump and treat injection wells screened in Ringold unit A.

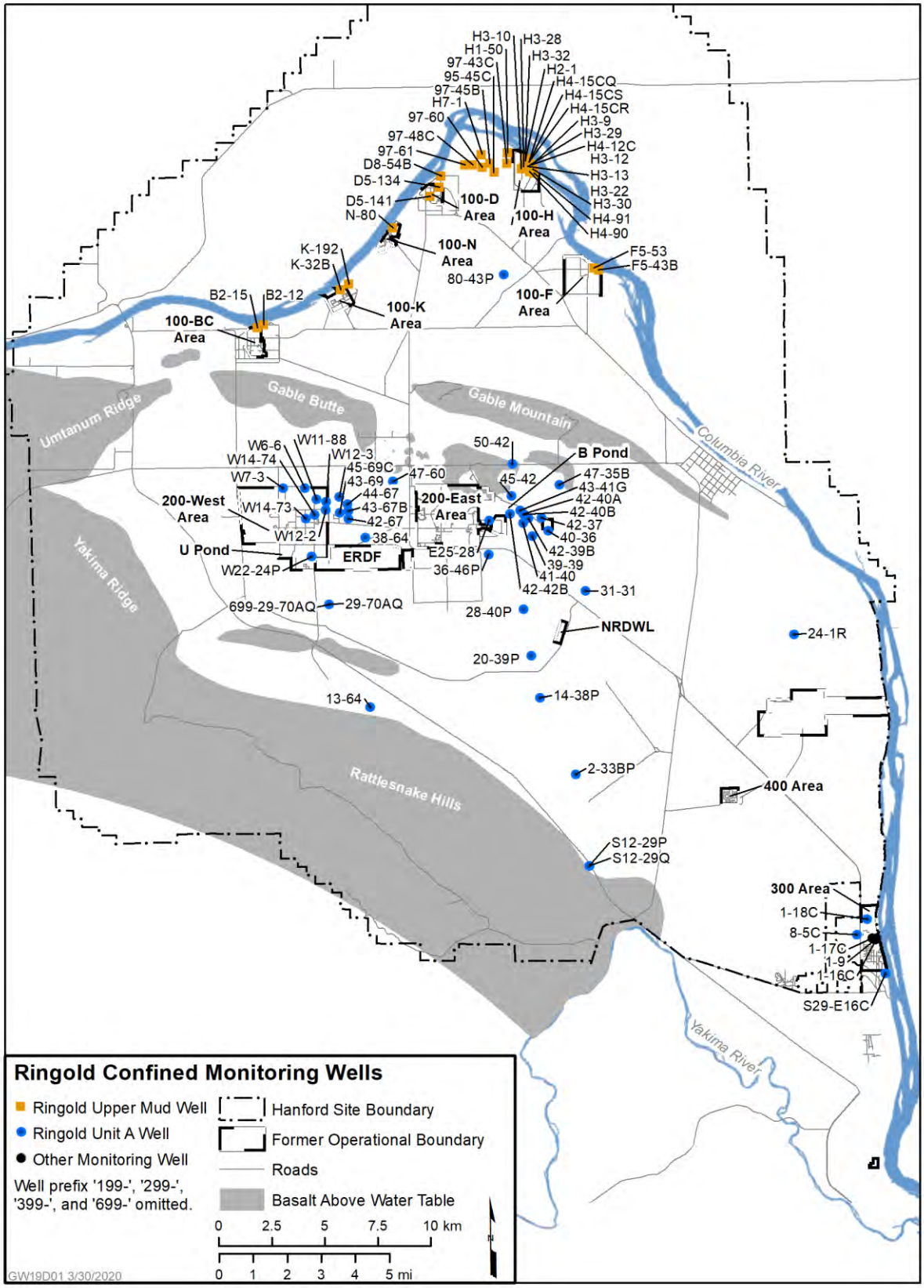
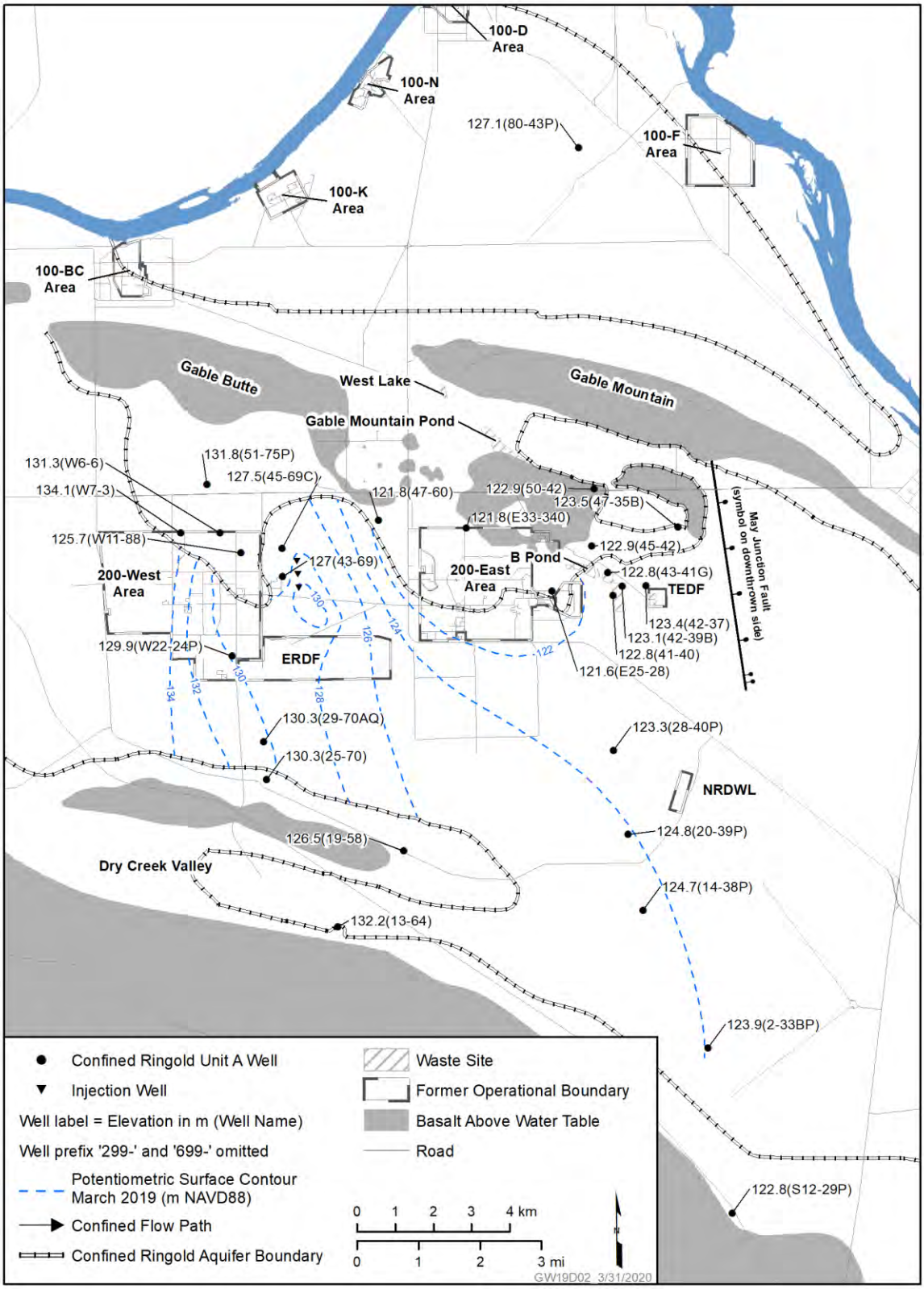


Figure D-1. Ringold Confined Aquifer Monitoring Wells



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure D-2. Potentiometric Surface for Ringold Unit A, March 2019

The head in confined wells in the 200 West Area declined as much as 0.81 m (2.7 ft) in well 299-W7-3 between 2018 and 2019 in response to declining head in the overlying unconfined aquifer. Increases in head of 0.25 and 0.38 m (0.82 and 1.2 ft) were noted in wells 699-43-69 and 699-45-69C, located east of the 200 West Area near confined aquifer injection wells.

Near the 200 East Area, flow in the Ringold confined aquifer converges from the west, south, and east before discharging to the unconfined aquifer where the Ringold lower mud unit is absent (Section 4.2.3 in PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*). There are higher heads in the region under B Pond and the Treated Effluent Disposal Facility. The head in confined wells near the 200 East Area decreased as much as 0.21 m (0.7 ft) in well 699-42-37 between 2018 and 2019. The rate of decline in head in this well has slowed in recent years.

Eastward flow away from the region of elevated water levels west of the May Junction fault does not occur due to the north-south-trending fault, located east of the B Pond area (Section 2.4.3 in DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*). Hydraulic head and water chemistry differences across this fault indicate that it is a barrier-to-groundwater flow in the confined aquifers (Sections 4.2.3 and 4.3.2 in PNNL-12261). While impermeable units have been juxtaposed against permeable units along part of the fault, the mud units may also have smeared along the fault zone and sealed it (Plates 8 and 9 in PNNL-12261). South of the B Pond area, the water flow divides, with some flow moving northwest toward the 200 East Area and some flow moving east or southeast. The exact location of the flow divide is not known because of a lack of water-level data in this area and uncertainty regarding the southward extent of the May Junction fault.

The potentiometric contours for the Ringold confined aquifer (Figure D-2) are similar to the potentiometric surface contours for the upper basalt confined aquifer system, indicating that flow patterns in the central portion of the Hanford Site are similar in both aquifers. Basalt bedrock from the topographic low area at Gable Gap near the 200 East Area was eroded significantly by late Pleistocene catastrophic flooding (Section 7.0 in PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*), which facilitates intercommunication between the unconfined and confined aquifers. The 200 East Area is a discharge area for both of the confined aquifers, which explains the similar flow patterns.

D2.2 Groundwater Quality in Ringold Confined Aquifers

Wells monitoring Ringold confined aquifers are sampled in accordance with the objectives of the AEA SAP (DOE/RL-2015-56) and the groundwater operable units in which they are located. The main text of this report discusses the monitoring results, and highlights of the monitoring are summarized in the following discussion.

Aquifer tests for selected Ringold confined wells in 2016 indicate that the RUM aquifer is a leaky confined aquifer with variable vertical hydraulic conductivity across the 100-H Area (SGW-60571, *Aquifer Testing of the First Water-Bearing Unit in the RUM at 100-H*). The RUM confined aquifer is hydraulically connected to the Columbia River. These factors are important for determining future movement of contaminants in the RUM and the overlying unconfined aquifer.

Twenty-eight of the 30 wells screened in the RUM aquifer (Table D-1) were sampled at least once between 2018 and 2019. Hexavalent chromium (Cr(VI)) concentrations are greater than the 48 µg/L WAC 173-340, "Model Toxics Control Act—Cleanup," standard in some RUM wells in the 100-HR-H groundwater interest area. Figure 4-5 in the main text shows the extent of Cr(VI) contamination in the RUM aquifer. One RUM aquifer well in 100-HR-H (199-H3-29) also exceeded the drinking water

standard (DWS) for nitrate. Nitrate concentrations were generally decreasing in 2019 for this well but remained above the DWS at 85.4 mg/L during the final 2019 sampling event.

The RUM aquitard separates the semiconfined and unconfined aquifer and is thicker and more competent in the 100-D Area. Farther east, the confining unit thins and tends to consist of more sand and gravel. It is theorized that the less competent nature of the material in the eastern part of 100-HR allowed contaminants to move downward into the lower aquifer during the operational period of the pump and treat system, when there was high hydraulic head in the unconfined aquifer. Groundwater in the RUM semiconfined aquifer in 100-HR is being remediated (Section 4.9 in the main text).

Table D-1. Groundwater Quality in Ringold Confined Aquifers

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a] (DWS)
Wells Screened in Ringold Upper Mud Unit		
100-BC	199-B2-12	None
100-FR	199-F5-43B	None
100-HR-D	199-D5-134, 199-D5-141, 199-D8-54B, 699-97-48C, and 699-97-61	Hexavalent chromium (48 µg/L): up to 153 µg/L
100-HR-H	199-H2-1, 199-H3-2C, 199-H3-9, 199-H3-10, 199-H3-12, 199-H3-13, 199-H3-22, 199-H3-28, 199-H3-29, 199-H3-30, 199-H3-32, 199-H4-12C, 199-H4-15CQ, 199-H4-15CS, 199-H4-90, 199-H4-91, 199-H7-1, 699-97-45B, 699-95-45C, and 699-97-60	Hexavalent chromium (48 µg/L): up to 544 µg/L Nitrate (45 mg/L): up to 298 mg/L
100-KR-4	199-K-32B and 199-K-192	None
100-NR	199-N-80	Hexavalent chromium (48 µg/L): up to 118 µg/L
Well Screened in Ringold Unit B		
100-HR-H	199-H4-15CR	None
Wells Screened in Ringold Unit A		
100-HR-H	199-H4-15CQ	None
300-FF	399-1-16C, 399-1-17C, 399-1-18C, 399-1-9, 399-8-5C, and 699-S29-E16C	None
200-BP	699-42-40A, 699-43-41G, and 699-45-42	Iodine-129 (1 pCi/L): up to 3.41 pCi/L Tritium (20,000 pCi/L): up to 28,700 pCi/L
200-PO	299-E25-28, 699-28-40P, 699-31-31, 699-39-39, 699-41-40, 699-42-39B, and 699-42-42B	Iodine-129 (1 pCi/L): up to 5.0 pCi/L Nitrate (45 mg/L): up to 88.5 mg/L
200-UP	299-W22-24P[b, d]	Iodine-129 (1 pCi/L): up to 4.7 pCi/L[d]
200-ZP[c]	699-43-69, 699-45-69C,699-47-60, and 299-W11-88	Carbon tetrachloride (5 µg/L): up to 250 µg/L Nitrate (45 mg/L): up to 235 mg/L Hexavalent chromium (48 µg/L): up to 38 µg/L

Table D-1. Groundwater Quality in Ringold Confined Aquifers

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a] (DWS)

a. Evaluation based on data from 2018 through 2019 unless otherwise noted. Listed contaminants are present at levels one-half of the DWS or greater.

b. The 2017 reported values were used when 2019 data were not available and exceedances were recorded in 2017.

c. Other wells in the 200-ZP groundwater interest area are screened in Ringold unit A where the lower mud is not present: 299-W6-6, 299-W7-3, 299-W11-88, 299-W12-2, 299-W12-3, 299-W14-73, and 299-W14-74. The aquifer is not confined at these locations, and the results are not reported here.

d. Data from piezometer 299-W22-24P are being evaluated as suspect and are believed to be unrepresentative of the basalt confined aquifer.

DWS = drinking water standard

In the 100-N Area, tritium and Cr(VI) concentrations are elevated in Ringold mud unit well 199-N-80, although tritium levels are below the DWS and remain stable. The Cr(VI) levels remain >48 µg/L (about 118 µg/L) but are stable. This is the only well in 100-NR that is screened in the RUM. Attempts to install another well in a similar water-bearing zone in 2011 were unsuccessful; no water-bearing zone was encountered during drilling.

Twenty-two wells screened in Ringold unit A were sampled at least once between 2018 and 2019 (Table D-1). The region just east of the 200 West Area (200-UP and 200-ZP) is contaminated with carbon tetrachloride, Cr(VI), and nitrate. These contaminants apparently reached Ringold unit A in a region of the 200 West Area where the lower mud is absent. As the groundwater continues to flow toward the east where the lower mud is present, it becomes confined. Carbon tetrachloride exceeded the 5 µg/L DWS in wells 699-43-69 and 699-45-69C in 2019. Nitrate exceeded the 45 mg/L DWS at well 699-45-69C at 235 mg/L. Chapter 12 (200-ZP chapter in the main text) discusses contaminant distribution with depth in the 200 West Area.

Six additional wells screened in Ringold unit A exceeded DWSs for carbon tetrachloride, iodine-129, and nitrate, but these wells are not included in the evaluations herein because the aquifer is not confined at these locations: 299-W6-6, 299-W11-88, 299-W12-2, 299-W12-3, 299-W14-73, and 299-W14-74.

The Ringold confined aquifer (unit A) is the uppermost aquifer in a region east of the 200 East Area (200-BP and 200-PO). The regional contaminants nitrate, iodine-129, and tritium are detected in wells monitoring this aquifer (Table D-1). Contamination has not been observed in wells located downgradient of the contaminated wells, indicating that it is of limited extent.

Iodine-129 contamination of Ringold confined wells in the 200 East Area exceeded the DWS at wells 299-E25-28, 699-42-42B, and 699-45-42 in 2019. The highest contamination level was 5.0 pCi/L at well 299-E25-28, which was the highest concentration for iodine-129 in Ringold confined wells in 2019. Well 699-39-39 exceeded the DWS for nitrate at 88.5 mg/L, which is the same as the concentration in 2018. Tritium concentrations at well 699-42-40A exceeded the DWS at 28,700 pCi/L which is a decrease from the concentration in 2018.

D3 Upper Basalt Confined Aquifer

The upper basalt confined aquifer occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey interbed, which is present only in the southern portion of the Hanford Site. A small interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt and may be significant to the lateral transmission of water. The upper basalt confined aquifer system is confined by the dense, low-permeability interior portions of the overlying basalt flows and in some places by silt and clay units of the lower Ringold Formation that overlie the basalt. Approximately 40 wells screened in the upper basalt confined aquifer have been sampled or had water levels measured in recent years (Figure D-3).

An area of intercommunication between the unconfined and upper basalt confined aquifers exists near the 200 East Area where the confining layers are eroded away or fractured. Several basalt confined wells have shown evidence of intercommunication with the overlying unconfined aquifer (Section 3.0 in PNL-10817, *Hydrochemistry and Hydrogeologic Conditions within the Hanford Site Upper Basalt Confined Aquifer System*).

D3.1 Groundwater Flow in Upper Basalt Confined Aquifer

Figure D-4 presents the interpreted 2019 potentiometric surface for the upper basalt confined aquifer south of Gable Butte and Gable Mountain based on the water-level measurements from 36 monitoring wells. The region to the north of Gable Butte and Gable Mountain was not contoured due to an insufficient number of wells in this area. Plate 1 in PNL-8869, *Preliminary Potentiometric Map and Flow Dynamic Characteristics for the Upper-Basalt Confined Aquifer System*, provides a generalized potentiometric surface map of this area. The upper basalt confined aquifer system does not exist in the Cold Creek Valley and along the west portion of the Gable Mountain and Gable Butte structural area due to the absence of the Rattlesnake Ridge interbed.

Recharge to the upper basalt confined aquifer system likely occurs from upland areas along the margins of the Pasco Basin and results from infiltrating precipitation and surface water where the basalt and interbeds are exposed at or near ground surface. Recharge may also occur from the overlying aquifers (i.e., the unconfined aquifer or confined aquifer in the Ringold Formation) in areas where the hydraulic gradient is downward and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge to this aquifer system. The Columbia River represents a discharge area for this aquifer system in the southeastern portion of the Hanford Site where the river has a lower head than the upper basalt confined aquifer, but not for the northern portion of the Hanford Site where the river head is higher (Section 3.2 in PNL-8869). Discharge also occurs to the overlying aquifers in areas where the hydraulic gradient is upward. Discharge to the overlying unconfined aquifer near the Gable Butte and Gable Mountain structural area is believed to occur through windows eroded in the basalt.

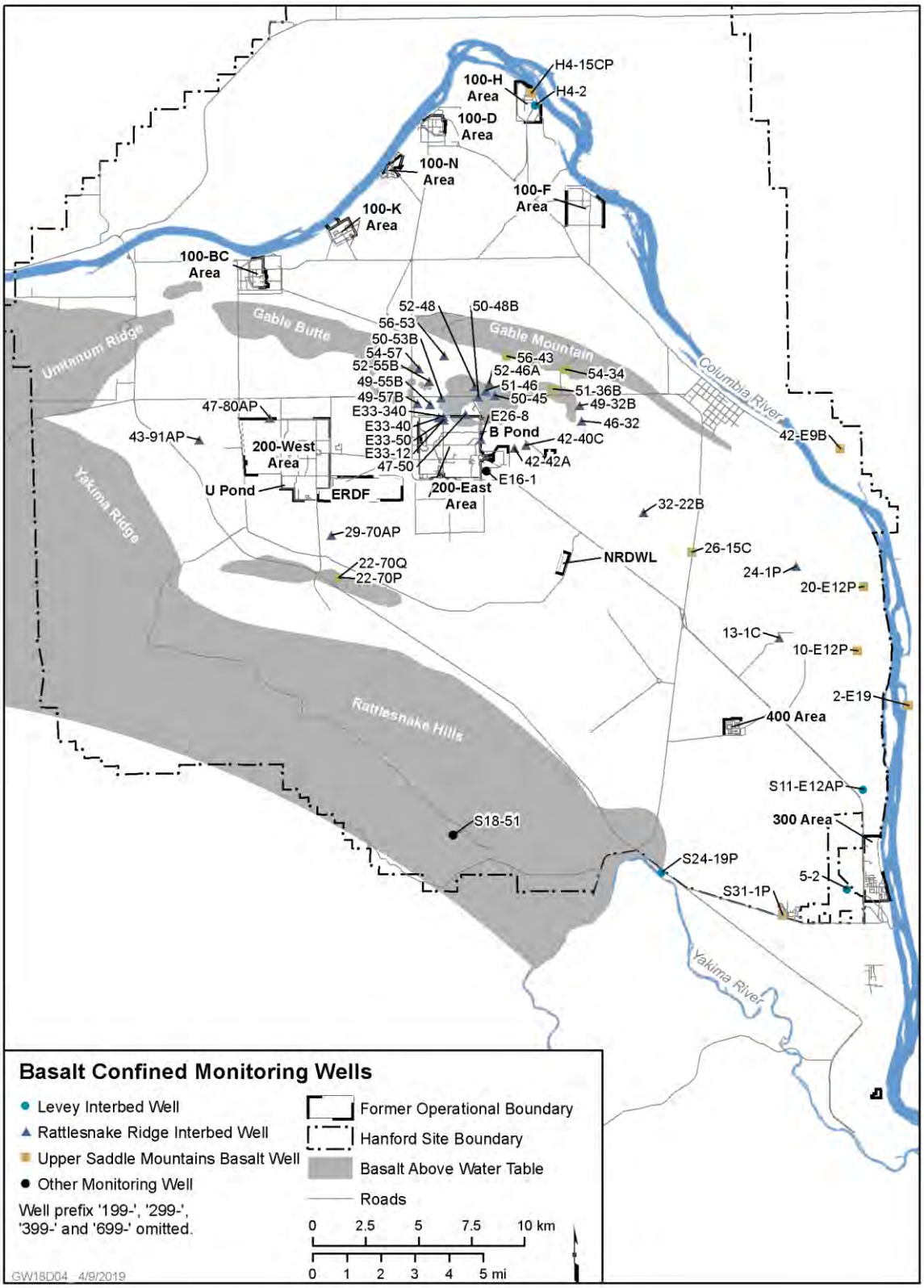
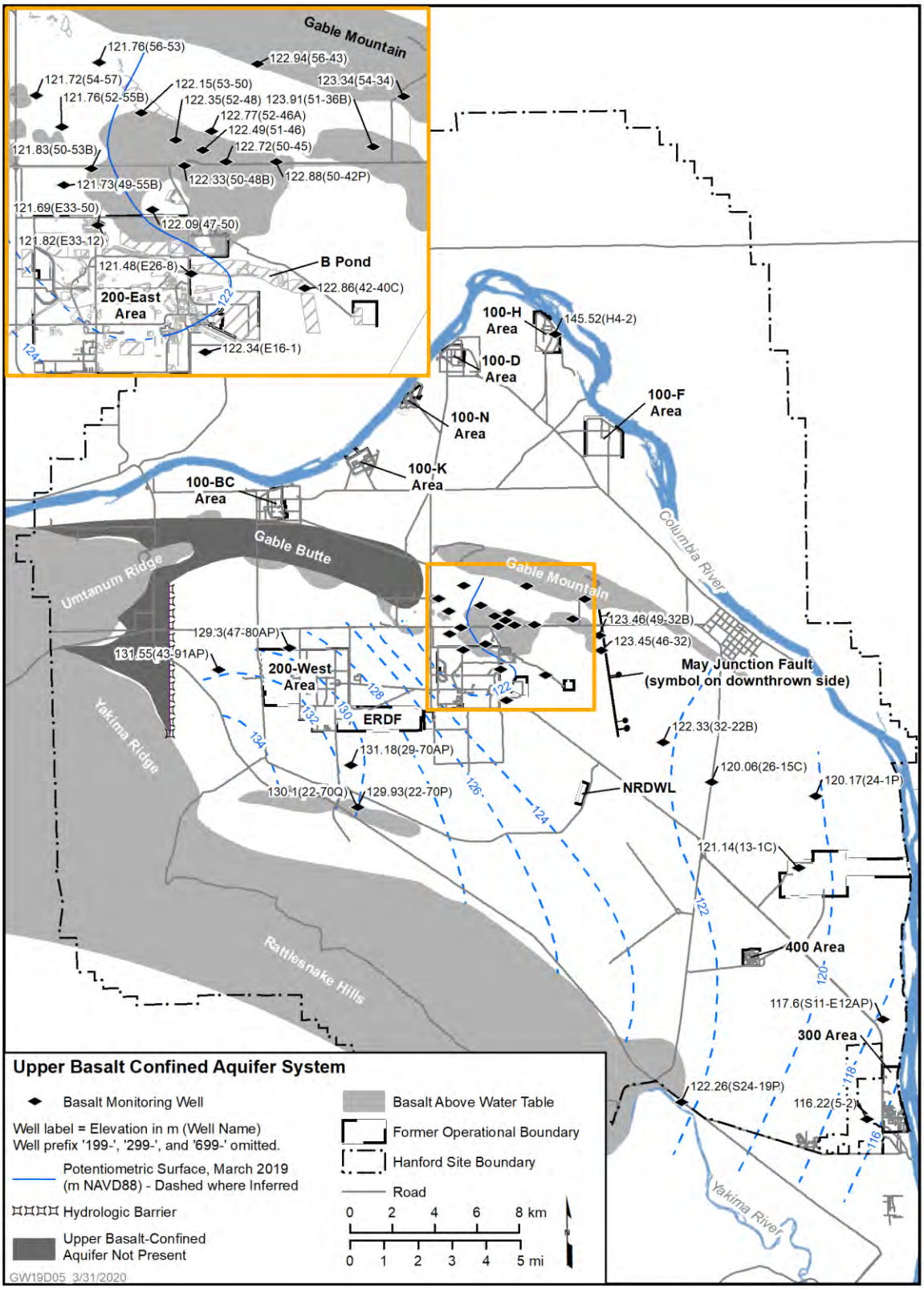


Figure D-3. Upper Basalt Confined Aquifer Monitoring Wells



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure D-4. Potentiometric Surface for Upper Basalt Confined Aquifer, March 2019

South of Gable Butte and Gable Mountain, groundwater in the upper basalt confined aquifer system generally flows from west to east across the Hanford Site, toward the Columbia River. The north-south-trending May Junction fault, located east of B Pond, acts as a barrier to groundwater flow in the unconfined aquifer and the confined aquifer within the Ringold Formation (Section 2.4.3 in DOE/RL-2008-59). It may also impede the movement of water in the upper basalt confined aquifer system by juxtaposing permeable units opposite impermeable units. As with the Ringold confined aquifer, a flow divide is interpreted to exist southeast of the 200 East Area and B Pond in the upper basalt confined aquifer system, but the exact location of this divide is uncertain because of a lack of wells in the area.

Groundwater flow rates within the Rattlesnake Ridge interbed have been estimated between 0.7 and 2 m/yr (2.3 and 6.6 ft/yr) (Section 4.2 in PNL-10817), which is a considerably lower flow rate than most estimates for the overlying unconfined aquifer system. The sediment comprising the interbed consists mostly of sandstone (with silts and clays) and is much less permeable than the sediment in the unconfined aquifer. In addition, the magnitude of the hydraulic gradient is generally lower than in the unconfined aquifer.

The vertical hydraulic gradient between the upper basalt confined aquifer system and the overlying aquifer varies spatially, as shown by comparison of observed heads depicted for 2014 in Figure D-4 of DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*. An upward gradient exists beneath most of the Hanford Site. A downward gradient exists in the western portion of the Hanford Site and near the B Pond recharge mound, as well as in regions north and east of the Columbia River. Near B Pond, the vertical head gradient between the unconfined aquifer system and the upper basalt confined aquifer system has diminished in recent years but remains downward. An area of upward gradient beneath a portion of the 200 West Area is caused by groundwater extraction, which reduced heads in the unconfined aquifer.

In the 200 East Area, the potentiometric surface (Figure D-4) is similar to the potentiometric surface for the Ringold confined aquifer (Figure D-2). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication (Section 7.0 in PNNL-19702). In the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt confined aquifer system and the overlying aquifer is upward. It is likely that the upper basalt confined aquifer system currently discharges to the overlying aquifer in this region.

Water levels have been declining in most of the basalt confined wells in the 200 East and 200 West Areas in response to reduced loading of the confined aquifer (i.e., a reduction in external stress) caused by water-level declines in the overlying unconfined aquifer and Ringold confined aquifer. The largest decline near the 200 West and 200 East Areas between 2018 and 2019 was 0.18 m (0.6 ft) in piezometer 699-29-70AP. The largest decline in hydraulic head is 0.6 m (2 ft) shown in well 699-S11-E12AP, which is located offsite.

D3.2 Groundwater Quality in Upper Basalt Confined Aquifer

The upper basalt confined aquifer system is not affected by contamination as much as the unconfined aquifer. Contamination in the upper basalt confined aquifer system is most likely to occur in areas where the confining units have been eroded away or were never deposited, and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. Researchers have identified areas of intercommunication between the contaminated unconfined aquifer and the upper basalt confined aquifer by geochemical signatures and the presence of nitrate and tritium in groundwater in some basalt confined wells near the 200 East Area (Chapter 3.0 in PNL-10817). However, groundwater monitoring data do not indicate that contamination has migrated into the upper basalt confined aquifer. Due to poor seals in wells

constructed prior to implementation of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," intercommunication between aquifers has permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer in the past, increasing the potential to spread contamination (e.g., at well 299-E33-12, as discussed below). Section 2.14.2 in DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*, further discusses communication between the upper basalt confined aquifer system and the overlying aquifers.

Thirteen wells screened in the upper basalt confined aquifer were sampled between 2018 and 2019. Contaminant concentrations are far below DWSs in the basalt confined aquifer (Table D-2), with two exceptions. Previous drilling practices and well construction at well 299-E33-12 (northwestern 200 East Area) allowed migration of groundwater from the overlying unconfined aquifer. This well was drilled in 1953 and was completed as an open hole from just above the bottom of the unconfined aquifer through the Rattlesnake Ridge interbed. Contamination is believed to have migrated from the unconfined aquifer, down the open borehole, and into the Rattlesnake Ridge interbed (Section 2.14.2 in DOE/RL-2008-01). The well was sealed from the unconfined aquifer in 1979, with an additional seal placed in the well in 1990 to shorten the open interval. Technetium-99 concentrations continued to be elevated in samples from this well and possibly in a small area of the confined aquifer. In 2017, iodine-129 was detected in well 299-E33-50 above the DWS (3.11 pCi/L). Iodine-129 monitoring was conducted at this well since 2007 with no previous detections ≥50% of the DWS. The 2017 iodine-129 result was flagged as suspect, and the well will be sampled again in 2020. Other confined wells in this region showed no contamination. The hydraulic gradient is upward in this region.

The strong, downward hydraulic gradient formerly present in this region and partial erosion of the basalt confining unit allowed communication between the unconfined and basalt confined aquifers (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*). The hydraulic gradient in this region remains downward.

Groundwater in basalt confined wells in other regions of the Hanford Site is uncontaminated based on data from a small number of available wells that were sampled in recent years (Table D-2).

Table D-2. Groundwater Quality in Upper Basalt Confined Aquifer

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a]
100-H	199-H4-15CP	None
200-BP	299-E26-8, 299-E33-12, 299-E33-340, 299-E33-40, 299-E33-50, 699-42-40C, 699-49-55B, 699-49-57B, 699-52-55B	Technetium: up to 927 pCi/L[b] Iodine-129: up to 3.11 pCi/L[b, c]
200-PO	299-E16-1 and 699-S24-19P	None
300-FF	699-13-1C	None

a. Evaluation based on data from 2018 through 2019. Listed contaminants are present at levels one-half of the drinking water standard or greater.

b. Not representative of the basalt confined aquifer. Migrated down wellbore from unconfined aquifer (see text discussion).

c. This is the 2017 sample concentration value for well 299-E33-50, which was flagged as a suspected error. Sampling for iodine-129 was not conducted in 2018 or 2019 for well 299-E33-50.

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Appendix E

Groundwater Monitoring Data Usability Assessment

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Contents

E1 Groundwater Monitoring Data Usability Assessment E-1

E2 Scope E-1

E2.1 Data Verification E-2
E2.2 Data Validation E-2
E2.3 Data Usability E-2

E3 Groundwater Monitoring Program Analytical Data Quality Requirements E-2

E3.1 Analyte Reporting Conventions E-7
E3.2 Field Quality Control Sample Types E-7
E3.3 Laboratory Quality Control Sample Types E-10
E3.4 Qualification Flags E-12
E3.5 Laboratory Information and Analytical Methods E-13
E3.5.1 Laboratory Information E-14
E3.5.2 Analytical Methods E-14

E4 Data Verification E-17

E4.1 Completeness E-17
E4.1.1 Percentage of Successful Sampling Events E-17
E4.1.2 Percentage of Field Quality Control Samples Collected E-18
E4.1.3 Percentage of Data with Quality Issues E-19
E4.1.4 Sample Preservation and Holding Times E-19
E4.2 Field Quality Control E-24
E4.2.1 Field Blanks E-24
E4.2.2 Field Duplicate Samples E-26
E4.2.3 Field Split Samples E-28
E4.2.4 Quadruplicate Total Organic Carbon and Total Organic Halides Samples E-30
E4.3 Laboratory Quality Control E-31
E4.3.1 Laboratory Method Blanks E-31
E4.3.2 Laboratory Control Samples and Laboratory Control Sample Duplicates E-34
E4.3.3 Matrix Spikes and Matrix Spike Duplicates E-35
E4.3.4 Laboratory Sample Duplicates E-37
E4.3.5 Surrogates E-37

E5 Laboratory Performance Evaluation E-39

E5.1 Quarterly Blind Standard Evaluations E-39
E5.2 Laboratory Performance Evaluation Programs E-41

E6 Data Usability Conclusions E-41

E6.1 Data Verification Considerations E-41

E6.1.1 Data Verification: Precision E-41
E6.1.2 Data Verification: Accuracy E-41
E6.1.3 Data Verification: Representativeness E-41
E6.1.4 Data Verification: Completeness E-43
E6.1.5 Data Verification: Sensitivity E-43
E6.2 Data Validation Considerations E-43
E7 Summary E-43
E8 References E-44

Tables

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria E-3
Table E-2. Laboratory Qualifier Data Quality Flags E-12
Table E-3. Review Qualifier Data Quality Flags E-13
Table E-4. Laboratory Analytical Methods E-15
Table E-5. Field QC Samples E-18
Table E-6. Data Quality Issues Summarized by Analyte Class E-20
Table E-7. Groundwater Sample Container, Preservative, and Holding-Time Requirements E-21
Table E-8. Field Blank Numbers by Blank Type E-25
Table E-9. Field Blank Summary Statistics by Analyte Class E-25
Table E-10. Field Duplicate Summary Statistics by Analyte Class E-27
Table E-11. Field Split Summary Statistics by Analyte Class E-29
Table E-12. Field Quads Summary Statistics E-30
Table E-13. Laboratory QC Results by Analyte Class E-32
Table E-14. Groundwater Blind Standard Recovery and Precision Requirements E-39
Table E-15. Groundwater Blind Standard Recovery and Precision Requirements E-40
Table E-16. Summary of Field QC Precision Metrics E-42
Table E-17. Summary of Laboratory Precision Metrics E-42
Table E-18. Summary of Laboratory Accuracy Metrics E-42

Terms

ALS	ALS Laboratory
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DQA	data quality assessment
DUA	data usability assessment
EB	equipment blank
EPA	U.S. Environmental Protection Agency
EQL	estimated quantitation limit
ERA	Environmental Resources Associates
FB	field blank
FTB	full trip blank
FXR	field transfer blank
GC/MS	gas chromatography/mass spectrometry
GEL	GEL Laboratory
HEIS	Hanford Environmental Information System
ICP	inductively coupled plasma
ICP/MS	inductively coupled plasma/mass spectrometry
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
MDC	minimum detectable concentration
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RPD	relative percent difference

RSD	relative standard deviation
S&GRP	Soil and Groundwater Remediation Project
SVOC	semivolatile organic compound
SWRI	Southwest Research Institute
TADN	Test America–Denver
TAKN	Test America–Knoxville
TARL	Test America–Richland
TASL	Test America–St. Louis
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbons
VOC	volatile organic carbon

E1 Groundwater Monitoring Data Usability Assessment

This data usability assessment (DUA) evaluates laboratory data generated from routine groundwater samples collected during 2019 as part of the Hanford Site groundwater monitoring program. The purpose of this DUA is to determine if the data are the right type and of sufficient quality and quantity to meet the data quality requirements specified in CHPRC-00189, *Environmental Quality Assurance Program Plan*, Rev. 16, which was the revision in effect for 2019.

Because nonstatistical sampling designs were used for collecting routine groundwater samples, the data quality assessment (DQA) process presented in EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide* (EPA QA/G-9R), is not appropriate for assessing routine groundwater data. Instead, routine groundwater data were evaluated using the data quality indicators of precision, accuracy, representativeness, comparability, completeness, and sensitivity/bias.

For the 2019 routine groundwater monitoring program, a total of 1,262 wells, aquifer tubes, and springs were sampled during 2,515 sampling trips over the extent of the Hanford Site.[1] These sampling events generated 3,080 field samples and 13,574 laboratory samples, for a total of 16,654 samples. From these 16,654 samples, Field Sampling Operations generated 16,168 field measurements, and eight analytical laboratories reported 189,112 laboratory results, for a total of 205,280 measurements. These sampling events only cover routine groundwater monitoring and do not include groundwater sampling events for special projects (e.g., 300-FF-5 Operable Unit uranium sequestration). The sampling events included are those that generated data in the Hanford Environmental Information System (HEIS) database as of February 12, 2020. Any 2019 routine groundwater monitoring data entered into the HEIS database after that date are not included in this assessment.

The purpose of this DUA is to determine whether the data generated for the 2019 groundwater monitoring effort meet the data quality requirements specified in CHPRC-00189. Meeting the specified data quality requirements provides assurance that the data collected are the right type and of sufficient quantity and quality for the groundwater monitoring program.

E2 Scope

The 2019 routine groundwater monitoring data are evaluated to determine whether they meet the analytical criteria outlined in CHPRC-00189. The methodology includes data verification and data usability evaluations.

This assessment focuses on the laboratory chemical and radiochemical data collected for routine groundwater monitoring during 2019 and evaluates these data to determine if they are the right type and of sufficient quality and quantity to meet the data quality requirements specified in CHPRC-00189. The DUA process is not intended to be a definitive analysis of a project or problem. Rather, it provides an initial assessment of the reasonableness of the data based solely on the quality control (QC) information associated with the data and not on the technical interpretations of the data.

Statistical analysis of the data was not performed as part of this DUA because the collection of routine groundwater monitoring samples are not selected by statistical design. If a statistical sampling design had been used during field sampling activities, then a DQA would have been performed following guidance provided in EPA/240/B-06/002. Because routine groundwater monitoring sampling does not follow a statistical design, data usability is assessed using the data quality indicators of precision, accuracy,

[1] The numbers in this paragraph refer to routine groundwater sample events for laboratory analysis and do not include in-process samples for pump-and-treat systems.

representativeness, comparability, completeness, and sensitivity/bias in accordance with EPA QA/G-5i, *Guidance on Data Quality Indicators*.

E2.1 Data Verification

Data verification is the process of evaluating the completeness, correctness, conformance, and compliance of a specific data set against the method, procedural, or contractual requirements. The verification process includes confirmation that the specified sampling and analytical requirements have been completed as specified in CHPRC-00189. Section E4 documents this evaluation. In addition, verification is performed for field QC samples (Section E4.2) and laboratory QC samples (Section E4.3).

E2.2 Data Validation

Data validation is an analyte- and sample-specific process that extends the evaluation of data beyond method or contractual compliance (data verification) to determine the analytical quality of a specific data set, typically data in single analytical batches. Data validation is an independent assessment to establish the reliability of data and is typically performed by an independent third party. Analytical data validation provides a level of assurance based on technical evaluation that an analyte is either present or absent. Validation might include verifying required deliverables (e.g., the minimum detection limits), verifying instrument calibrations, evaluating analytical results based on method blanks, recovering various internal standards, determining correctness of uncertainty calculations, identifying and quantifying analytes, and determining the effect of quality deficiencies on the analytical sample data.

Third-party validation was not performed on 2019 routine groundwater monitoring data.

E2.3 Data Usability

A DUA is a determination of the adequacy of the entire data set to support groundwater monitoring program requirements based upon the verification results. Data usability was assessed using the data quality indicators of precision, accuracy, representativeness, comparability, and completeness in accordance with EPA/240/R-02/004, *Guidance on Environmental Data Verification and Data Validation* (EPA QA/G-8), as interpreted through the requirements of CHPRC-00189. Section E6 summarizes this assessment.

E3 Groundwater Monitoring Program Analytical Data Quality Requirements

Table E-1 presents the groundwater monitoring program data requirements from CHPRC-00189. The QC results for groundwater monitoring samples were evaluated against these requirements as part of this DUA (Sections E4.2 and E4.3). The QC samples governed by the QC requirements may be divided into field and laboratory components. Sections E3.2 and E3.3 describe these two types of QC samples.

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria

Constituent	QC Element	Acceptance Criteria[a]	Corrective Action
General Chemical Parameters			
Alkalinity Coliform[b] Oil and grease Total dissolved solids Total organic carbon Total organic halides	Method blank	<MDL or <5% sample concentration	Flag with "C"
	LCS	80% to 120% recovery	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	75% to 125% recovery	Flag with "N"
	FB	<MDL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Ammonia and Anions			
Ammonia IC anions Total cyanide Free cyanide Sulfide	Method blank	<MDL or <5% sample concentration	Flag with "C"
	LCS	80% to 120% recovery	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	75% to 125% recovery	Flag with "N"
	FB	<MDL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Metals			
Hexavalent chromium ICP/AES metals ICP/MS metals Mercury Uranium	Method blank	<MDL or <5% sample concentration	Flag with "C"
	LCS	80% to 120% recovery	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	75% to 125% recovery	Flag with "N"
	FB	<MDL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Volatile Organic Compounds			
TPH-gasoline by GC	Method blank	<MDL or <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[e]
	MS/MSD[e]	70% to 130% recovery	Flag with "N"
	Surrogate	60% to 140% recovery	Review data[f]
	FB	<MDL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria

Constituent	QC Element	Acceptance Criteria[a]	Corrective Action
Volatiles by GC/MS	Method blank	<MDL[h] or <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	70% to 130% recovery	Flag with "T"
	Surrogate	70% to 130% recovery	Review data[f]
	FB	<MDL[h] or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Semivolatile Organic Compounds			
Extractable petroleum hydrocarbons by GC (aliphatic and aromatic hydrocarbon fractions) TPH-diesel or TPH-kerosene by GC	Method blank	<MDL or <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	70% to 130% recovery	Flag with "N"
	Surrogate	60% to 140% recovery	Review data[f]
	FB	<MDL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Herbicides by GC PAHs by GC/MS PCBs by GC Pesticides by GC Semivolatiles by GC/MS	Method blank	<MDL[h] or <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d] or MS/MSD[e]	≤20% RPD	Review data[f]
	MS/MSD[e]	% Recovery statistically derived[g]	Flag with "N" or "T"
	Surrogate	% Recovery statistically derived[g]	Review data[f]
	FB	<MDL[h] or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Dioxins/furans, total, and/or congeners by HRGC/HRMS	Method blank	<PQL or <5% sample concentration	Flag with "B"
	LCS	% Recovery statistically derived[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	Surrogate	60% to 140% recovery	Review data[f]
	FB	<PQL or <5% sample concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria

Constituent	QC Element	Acceptance Criteria[a]	Corrective Action
Radiological Parameters			
Alpha energy analysis: Americium/curium Neptunium Plutonium Thorium Uranium (isotopic)	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	Tracer	30% to 105% recovery	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Carbon-14	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	MS	75% to 125% recovery	Flag with "N"
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Chlorine-36 Radium-226 by Lucas cell Radium-228 by gas-flow proportional counting Strontium-90	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	Tracer	30% to 105% recovery	Review data[f]
	Carrier	40% to 110% recovery	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Gamma energy analysis	Method blank	<MDC or <5% sample activity	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Gross alpha Gross beta	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria

Constituent	QC Element	Acceptance Criteria[a]	Corrective Action
Iodine-129	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	Carrier	40% to 110% recovery	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Selenium-79	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	Duplicate[d]	≤20% RPD	Review data[f]
	Carrier	40% to 110% recovery	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Plutonium-241	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	Tracer	30% to 105% recovery	Review data[f]
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"
Technetium-99 Tritium	Method blank	<MDC or <5% sample activity concentration	Flag with "B"
	LCS	80% to 120% recovery or statistically derived limits[g]	Flag with "o"[c]
	Duplicate[d]	≤20% RPD	Review data[f]
	MS	75% to 125% recovery	Flag with "N"
	FB	<MDC or <5% sample activity concentration	Flag with "Q"
	Field duplicate/split[d]	≤20% RPD	Flag with "Q"

Source: CHPRC-00189, *Environmental Quality Assurance Program Plan*.

a. For the laboratory duplicate type "LCS duplicate," the RPD limit of 20% was used.

b. Passing QC: method blank = no colonies detected; LCS = appropriate colonies detected; DUP = colonies detected/undetected are consistent with sample.

c. The reporting laboratory applies the "o" flag with Sample Management and Reporting concurrence.

d. The RPD for batch sample duplicates and field duplicates is calculated only if at least one of the results is greater than the PQL or 0.5 times the MDC. The RPD for field splits is calculated only if at least one of the results is ≥5 times the larger MDL or MDC of the two analyzing laboratories.

e. Either a sample duplicate or a MSD is to be analyzed to determine measurement precision. If there is insufficient sample volume, an LCS duplicate is analyzed with the acceptance criteria defaulting to the DUP/MSD criteria.

f. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the associated groundwater monitoring data as suspect ("Y" flag) or rejected ("R" flag).

g. Laboratory-determined, statistically derived control limits based on historical data are used here. Control limits are reported with the data.

h. For the common laboratory contaminants 2-butanone, acetone, methylene chloride, toluene, and phthalate esters, the acceptance criterion is <5 times the MDL.

Table E-1. Groundwater Field and Laboratory QC Elements and Acceptance Criteria

Constituent	QC Element	Acceptance Criteria[a]	Corrective Action

GC = gas chromatography
GC/MS = gas chromatography/mass spectrometry
FB = field blank (includes equipment blank, full trip blank, and field transfer blank samples)
HRGC = high-resolution gas chromatography
HRMS = high-resolution mass spectrometry
IC = ion chromatography
ICP/AES = inductively coupled plasma/atomic emission spectroscopy
ICP/MS = inductively coupled plasma/mass spectrometry
LCS = laboratory control sample
MDC = minimum detectable concentration
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
PAH = polynuclear aromatic hydrocarbons
PCB = polychlorinated biphenyl
PQL = practical quantitation limit
QC = quality control
RPD = relative percent difference
TPH = total petroleum hydrocarbons

Data flags:
B, C = possible laboratory contamination (analyte was detected in the associated method blank)
N = result may be biased (associated MS result was outside of the acceptance limits)
o = result may be biased (associated LCS result was outside of the acceptance limits)
Q = problem with associated field QC sample (FB, field duplicate, and/or field split results were out of limits; used for all methods except GC/MS)
T = result may be biased (associated MS result was outside of the acceptance limits; used with GC/MS methods only)

E3.1 Analyte Reporting Conventions

To conform to the analyte reporting conventions used in the annual report and to provide comparability of analytical results among the reporting laboratories, the following analyte reporting conventions are used in this assessment:

- **Ammonium:** Ammonia, nitrogen-in-ammonia, and nitrogen-in-ammonium results are converted to and evaluated as ammonium ion.
- **Nitrate:** Nitrogen-in-nitrate results are converted to and evaluated as nitrate.
- **Nitrite:** Nitrogen-in-nitrite results are converted to and evaluated as nitrite.
- **Nitrate + nitrite:** Nitrogen-in-nitrite and nitrate results are converted to and evaluated as nitrate.
- **Phosphate:** Phosphorus-in-phosphate results are converted to and evaluated as phosphate.
- **Strontium-90:** Total-beta-radiostrontium results are evaluated as strontium-90.

E3.2 Field Quality Control Sample Types

Field QC samples are used to assess the precision, repeatability, and potential contamination related to sampling and laboratory activities. Field QC samples include three types of field blanks (FBs) (equipment blanks [EBs], full trip blanks [FTBs], and field transfer blanks [FXRs]), field duplicates, field split samples, and field matrix spike (MS) samples (blind standards). Table E-5 (provided later in this appendix) summarizes the various field QC sample types, the required collection frequencies, and the actual collection frequencies. For groundwater samples, preservative reagents specific for the analytes to be determined are added to the field QC sample bottles prior to collecting the QC samples. All field QC

samples are delivered to the laboratory without any differentiation between the field QC samples and actual groundwater samples.

- **FTB:** Samples that contain high-purity deionized water and any required preservatives. FTBs are used to check for potential contamination in sample bottles, preservative agents, and laboratory sample preparation. The FTB is analyzed for all constituents of interest and is collected in the same types of sample bottles used to collect groundwater samples. FTBs are prepared prior to travelling to the field and are not opened in the field.

- **FXR:** Analyzed for volatile organic compounds (VOCs) and used to check for VOC contamination associated with sampling activities. At the time of sample collection, the FXR is filled at the sampling site by pouring high-purity deionized water from a clean glass container into VOC sample vials pre-loaded with acid preservative. After collection, the FXR is treated in the same manner as the other samples collected during the sampling event. Typically, one FXR is collected each day that groundwater samples are collected for VOCs. If the VOC samples collected on a given day will be shipped to multiple laboratories, then an FXR is collected for each laboratory for that day.

- **EB:** Samples of high-purity deionized water that was pumped or washed through nondedicated sampling equipment. EBs are used to monitor the effectiveness of equipment decontamination procedures and to monitor for contamination associated with field sampling equipment. EBs are not usually required for dedicated sampling equipment or disposable sampling equipment. The EB is analyzed for all constituents of interest and is collected in the same type of sample bottles used to collect groundwater samples.

- **Field duplicate sample:** Replicate samples sequentially collected to determine the precision of sampling and the laboratory analytical measurement processes by comparing results with an identical sample collected at the same time and location. Matching field duplicates are collected and stored in separate containers and are analyzed as separate samples at the same laboratory.

- **Split sample:** Replicate samples are sequentially collected from the same location in the same sampling event and analyzed at different laboratories. Split samples are used to evaluate interlaboratory precision and comparability. Only those field split result pairs with at least one result greater than five times the method detection limit (MDL) or minimum detectable concentration (MDC) are evaluated. Field split sample results must agree within 20% as measured by the RPD to be acceptable.

- **Field MS:** The groundwater monitoring program issues field MSs (blind standards) to the contracted analytical laboratories to provide a measure of intralaboratory and interlaboratory precision and accuracy. These standards help Soil and Groundwater Remediation Project (S&GRP) troubleshoot analytical problems identified through data reviews and QC evaluations. The blind standards may also be used to confirm the adequacy of corrective actions to resolve analytical problems. Blind standards are required to be submitted to the participating laboratories on a quarterly basis (CHPRC-00189). The 2019 blind standards were prepared by Pacific Northwest National Laboratory personnel. Blind standards are generally prepared in triplicate to check laboratory analytical accuracy and precision. For most constituents, the blind standards are prepared in a groundwater matrix from an appropriate background well to simulate actual groundwater samples. Multi-metal blind standards for analysis by inductively coupled plasma (ICP) techniques are prepared in deionized water using commercially prepared metal standards. The blind standards are submitted to the laboratories as routine groundwater samples.

The FB (i.e., FTB, FXR, and EB) results are evaluated by comparison with the MDL or MDC of the performing laboratory. If a FB result for a given analyte exceeds that analyte's MDL or MDC and also exceeds 5% of the analyte's value in an associated field sample, then the analyte's result in the associated field sample is flagged as "Q." Associated field samples are those samples collected on the same day for the same purpose (i.e., associated with the same sample authorization form) and are analyzed by the same method as the corresponding FB. The results of FBs are not flagged as "Q."

Field duplicate sample results are evaluated only if at least one result is five times the laboratory MDL or MDC. Split sample results are evaluated only if at least one result is five times the larger of the laboratory MDL or MDC of the two analyzing laboratories. Field duplicate and field split samples that qualify are evaluated using the relative percent difference (RPD) between the duplicate or split sample pair. The RPD is a measure of precision and is calculated as shown in Equation E-1:

$$RPD = \left| \frac{C_1 - C_2}{(C_1 + C_2) / 2} \right| \times 100 \qquad \text{(Equation E-1)}$$

where:

C_1 = parent sample analyte concentration or activity

C_2 = duplicate sample analyte concentration or activity.

A perfect match between the parent sample and its duplicate yields an RPD of 0%. Results for field duplicate samples that exceed the RPD limit of 20% are flagged as "Q." Only the two samples of the duplicate pair or split pair are considered to be associated samples.

Total organic carbon (TOC) and total organic halides (TOX) are *Resource Conservation and Recovery Act of 1976* (RCRA) indicator analytes; samples for these analytes are usually obtained in quadruplicate (40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis"). For the purposes of this DUA, field quadruplicate sample results are evaluated for precision only if at least one result is at least five times the laboratory MDL. Field quadruplicate results that qualify are evaluated using the percent relative standard deviation (RSD) within the quadruplicate sample set. The percent RSD is a measure of precision and is calculated as shown in Equation E-2:

$$\%RSD = \frac{\sqrt{\frac{\sum_{i=1}^{n} (C_i - \bar{C})^2}{(n - 1)}}}{\bar{C}} \times 100 \qquad \text{(Equation E-2)}$$

where:

$\%RSD$ = percent relative standard deviation

C_i = i^{th} sample concentration

$\bar{C}$ = average sample concentration

n = number of results (usually four).

A perfect match of results within a quadruplicate sample set yields an RSD of 0%. For any results in a qualifying quadruplicate data set that were less than the laboratory MDL, MDLs were used to compute the percent RSD. Quadruplicate split sample results are evaluated only if at least one quadruplicate average is greater than or equal to five times the larger of the laboratory MDLs of the two analyzing laboratories. To determine the precision of a set of split quadruplicate samples, the RPD of the two averages for the quadruplicate split samples is determined and compared to 20%. Results for field

quadruplicate samples that exceed an RSD of 20% or quadruplicate split samples that exceed an RPD of 20% are not assigned a review qualifier.

Blind standard results reported from the laboratories are compared with the spiked concentrations to determine laboratory accuracy and precision for the blind standard analytes. Laboratory precision is determined as percent RSD (Equation E-2). Laboratory accuracy is determined using percent recovery as shown in Equation E-3:

$$Percent\ recovery = \frac{C_m}{C_a} \times 100 \qquad \text{(Equation E-3)}$$

where:

C_m = measured analyte concentration or activity

C_a = actual, known analyte concentration or activity .

Perfect recovery of the measured analyte concentration or activity yields a recovery of 100%.

E3.3 Laboratory Quality Control Sample Types

Laboratory quality assurance (QA)/QC requirements govern nearly all aspects of analytical laboratory operation, including instrument procurement, maintenance, calibration, and operation. Laboratory requirements for internal QC checks are performed as appropriate for the analytical method at a rate of one QC check per sample batch[2] (CHPRC-00189). Laboratory internal QC checks usually include at least one check for laboratory contamination (method blank), a measure of analytical accuracy (e.g., laboratory control sample [LCS], MS, or surrogates), and a measure of analytical precision (e.g., duplicate sample, laboratory control sample duplicate [LCSD], or matrix spike duplicate [MSD]). These laboratory QC samples are included in sample preparation and analytical batches along with customer samples.
An analytical batch typically consists of a maximum of 20 customer samples. The numbers and types of QC samples included in sample batches are dictated by the analytical method being used. Analytical methods usually use only a subset of the available types of QC samples. At a minimum, most sample preparation and analytical methods include a method blank, one of the duplicate types (e.g., sample duplicate), and one of the standard types (e.g., LCS). These types of laboratory QC samples and how they are evaluated are described as follows:

- **Laboratory contamination:** Each analytical batch contains a laboratory method blank (material of composition similar to that of the samples with known/minimal contamination of the analytes of interest) carried through the complete analytical process. The method blank is used to evaluate potential false-positive results in samples caused by contamination during laboratory handling.
- **Analytical accuracy:** LCSs, MSs, and surrogates contain known amounts of analytes and provide a measure of analytical process accuracy. Percent recovery (Equation E-3) is the metric used to determine analytical accuracy. Percent recoveries consistently less than or greater than 100% may indicate a bias in the analytical process. At least one of these standards is carried through the sample preparation and analysis process.

[2] An analytical batch is usually defined in the statements of work for the environmental laboratory contracts as 20 client samples.

- **LCS:** Contains a known amount of the analyte(s) of interest and closely matches the matrix of the field samples. The LCS may be prepared from an independent standard or from the same standard used for instrument calibration at a concentration within the calibration range. The LCS is taken through all of the preparation and analysis steps used in the method. Depending on how it is introduced into the analysis, the LCS is sometimes referred to as a blank spike sample.
- **MS:** A known quantity of representative analytes of interest added to a separate aliquot of a sample from the analytical batch. The known amount added is compared to the actual measured amount to calculate the percent recovery. The MS percent recovery (Equation E-3) is used to evaluate analytical accuracy and to determine any extent of matrix interferences.
- **Surrogate:** In addition to MS recovery, surrogate compounds are used to evaluate accuracy in volatile and semivolatile organic analyses. Surrogate compounds are organic compounds not typically found in environmental samples but behave chemically similar to organic analytes of interest during sample preparation and analysis. Surrogate compounds are added to all of the field samples and batch QC samples, and the recovery is evaluated.

- **Analytical precision:** A laboratory sample duplicate, LCSD, MSD, or surrogate duplicate provides a measure of the reproducibility of the analytical process. The RPD (Equation E-1) is the metric used to determine reproducibility. At least one of these samples is carried through the sample preparation and analysis process.
  - **Laboratory sample duplicate:** A separate aliquot of a client sample is analyzed for each analytical batch. The RPD is calculated between the original sample result and the duplicate sample result to assess analytical precision. The RPD is usually determined between a sample and its duplicate only if at least one result of the pair is greater than the practical quantitation limit or at least five times the laboratory MDC.
  - **MSD:** May be used for assessing the precision of metals and organic parameters. For an MSD, a separate aliquot of the same client sample used to prepare the MS is spiked in the same manner as the MS. The concentrations from the MS/MSD are used to calculate a RPD and to assess precision.
  - **LCSD:** May be used to assess method precision if too little sample volume is available for a sample duplicate or MSD.
  - **Surrogate duplicates:** Duplicates that occur when sample/sample duplicate, MS/MSD, or LCS/LCSD pairs occur for organic analyses. The RPD is calculated between the concentrations of the surrogate/surrogate duplicate pair to measure analytical precision.

In addition to these laboratory QC samples, radioanalytical methods often incorporate two additional QC types:

- **Tracer:** A known quantity of radioactive isotope that is different from the target isotope but is expected to be chemically similar to the target isotope. The tracer is generally added to an aliquot of sample prior to the sample preparation step. Ideally, the tracer does not chemically interfere with the target radioisotope during radiochemical preparation, separation, and counting. Sample results are generally corrected based on tracer recovery. Tracers are added to all of the field samples and batch QC samples, and the recovery is evaluated.

- **Carriers:** Carriers are typically nonradioactive (e.g., natural strontium, barium, or yttrium) elements. Carriers are chemically similar to the target radionuclide during sample processing and are added to samples to determine the overall chemical yield during analytical preparation steps. The yield of the carrier can be determined gravimetrically or by means of one of the ICP methods. Carrier compounds are added to all of the field samples and batch QC samples, and the recovery is evaluated.

E3.4 Qualification Flags

When generating and evaluating environmental analytical data, any of several qualification flags may be assigned to an individual result. The HEIS database carries qualification flags applied from three sources: the laboratory (laboratory qualifier), a data reviewer (review qualifier), or a third-party data validator (validation qualifier). Table E-2 presents the laboratory qualifier flags and Table E-3 outlines the review qualifier flags. For the 2019 routine groundwater monitoring data set, third-party validation was not performed, and validation qualifiers were not applied to the data set.

Table E-2. Laboratory Qualifier Data Quality Flags

Flag	Definition
>	**Wetchem:** Result greater than quantifiable range or greater than upper limit of the analysis range.
*	**Inorganics:** Duplicate analysis not within control limits.
B	**Inorganics and Wetchem[a]:** The analyte was detected at a value greater than or equal to the MDL but less than the PQL. **Organics:** The analyte was detected in both the associated method blank and in the sample. **Radionuclides:** The associated method blank has a result ≥2 times the MDC and, after corrections, the result is greater than or equal to the MDC for this sample.
C	**Inorganics and Wetchem[a]:** The analyte was detected in both the sample and the associated method blank, and the blank concentration was at least 5% of the sample concentration.
D	**All:** Analyte was determined using a secondary dilution factor greater than one. The primary preparation required dilution either to bring the analyte within the calibration range or to minimize interference.
E	**Inorganics:** Reported value is estimated because of interference. See any comments that may be in the laboratory report case narrative. **Organics:** Concentration exceeds the calibration range of the GC/MS.
J	**Organics:** The analyte was detected at a value greater than or equal to the MDL but less than the PQL.
M	**Inorganics:** Duplicate precision criteria was not met.
N	**All (except GC/MS methods):** The MS recovery is outside control limits. The associated sample data may be biased. **ORGANICS (GC/MS only):** Presumptive evidence of the compound based on mass spectral library search.
o,	**All:** The laboratory control sample recovery is outside control limits.
P	**ORGANICS (PCB only):** Aroclor target analyte with >25% difference between column analyses.
Q	**ORGANICS (dioxins and PCB-congeners only):** Estimated maximum concentration. Used if one of the qualitative identification criteria is not met (e.g., Cl isotopic ratios outside theoretical range).
T	**Organics (GC/MS methods only):** The MS recovery is outside control limits. The associated sample data may be biased.
U	**All:** The constituent was analyzed for but was not detected.

Table E-2. Laboratory Qualifier Data Quality Flags

Flag	Definition
X, Y, Z	**All:** Indicates a result-specific comment is provided in the data report and/or case narrative.

[a]Wetchem is a miscellaneous group of analytical methods such as the colorimetric determination of hexavalent chromium, the titrimetric determination of alkalinity, or the distillation and titrimetric determination of sulfide.

GC/MS = gas chromatography/mass spectrometry
MDC = minimum detectable concentration
MDL = method detection limit
MS = matrix spike
PCB = polychlorinated biphenyl
PQL = practical quantitation limit

Table E-3. Review Qualifier Data Quality Flags

Flag	Definition
A	Indicates an issue with the chain of custody that could affect data integrity.
F*	Result is undergoing further review. This review qualifier is assigned when a request for data review is first processed.
G*	Result has been reviewed through the request for data review process and determined to be correct, or the laboratory has supplied a corrected result after reviewing the original result or after reanalyzing the sample.
H	Sample holding time was exceeded before the sample was extracted or analyzed.
P*	Potential problem. Collection/analysis circumstances make the result questionable.
Q	An associated field QC sample is out of limits; the associated sample number is listed in the "Result Comment" field for the "Q"-flagged result. (See Section E3.2 for the definition of associated samples.)
R*	Do not use. Further review indicates the result is not valid. This review qualifier is used only when documented evidence exists that the result is not valid. Generally, results that are "R"-qualified will be excluded from statistical evaluations, maps, and other interpretations.
Y*	Result is suspect; request for data review generated insufficient evidence to show result valid or invalid.
Z*	Miscellaneous circumstance exists. Additional information for this record may be found in the "Result Comment" field in the HEIS database RESULT table and/or in the "Sample Comment" field in the HEIS SAMPLE table.

*These flags are applied as part of the request for data review process. "F" flags are typically resolved to "G," "P," "R," or "Y" during the request for data review process.

HEIS = Hanford Environmental Information System
QC = quality control

The "Q" flag review qualifier is applied to the analytical results of those samples associated with field QC samples having analytical results that did not meet the QC criteria identified in CHPRC-00189 and outlined in Table E-1. Section E3.2 defines the associated samples.

E3.5 Laboratory Information and Analytical Methods

Samples collected for the groundwater monitoring program were sent to the eight laboratories (described in Section E3.5.1) for analysis. Each sample is tracked by a unique HEIS number. Analytical requests for chemical and radiochemical services to be completed by the laboratories were documented on sample

chain-of-custody forms. Analytical results provided by the laboratories were documented by sample delivery group in data packages. The analytical results were electronically uploaded and stored in the HEIS database.

E3.5.1 Laboratory Information

The samples collected for routine groundwater monitoring were analyzed at the following eight laboratories:

- ALS Laboratories (ALS) (Fort Collins, Colorado) provided sample analysis for chemical and radiochemical constituents. ALS generated 16.3% of the analytical laboratory results.
- GEL Laboratories, LLC (GEL) (Charleston, South Carolina) provided sample analysis for chemical and radiochemical constituents. GEL generated 52.7% of the analytical laboratory results.
- RJ Lee Group, Inc. (Pasco, Washington) provided sample analysis for chemical constituents. This laboratory generated 0.005% of the analytical laboratory results.
- Southwest Research Institute (SWRI) (San Antonio, Texas) provided sample analysis for chemical and radiochemical constituents. SWRI generated 0.6% of the analytical laboratory results.
- TestAmerica–Denver (TADN) (Denver, Colorado) provided sample analysis for chemical constituents. TADN generated 8.1% of the analytical laboratory results.
- TestAmerica–Knoxville (TAKN) (Knoxville, Tennessee) provided sample analysis for polychlorodibenzo-p-dioxins and polychlorodibenzofurans. TAKN generated 0.5% of the analytical laboratory results.
- TestAmerica–Richland (TARL) (Richland, Washington) provided sample analysis for chemical and radiochemical constituents. TARL generated 1.8% of the analytical laboratory results.
- TestAmerica–St. Louis (TASL) (St. Louis, Missouri) provided sample analysis for chemical and some radiochemical constituents. TASL generated 20.1% of the analytical laboratory results.

Sections E4.2 and E4.3 discuss the analytical data provided by these laboratories.

E3.5.2 Analytical Methods

For the analysis of chemical constituents, the analyzing laboratories used standard methods from the U.S. Environmental Protection Agency (EPA), ASTM International (formerly American Society for Testing and Materials), and the American Public Health Association. For radiological constituents, the analyzing laboratories used methods that are recognized as acceptable within the radiochemical industry.

Samples were analyzed using the methods listed in Table E-4. Both single- and multiple-component EPA analytical methods were used (SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, current update). Single-component analytical methods such as EPA Method 9012 for cyanide or EPA Method 7470 for mercury yield a single analytical result per analysis. Multi-component analytical methods (e.g., EPA Method 6020 for inductively coupled plasma/mass spectrometry [ICP/MS] metals or EPA Method 8260 for gas chromatography/mass spectrometry [GC/MS] for VOCs) yield results for multiple analytes per analysis. Multi-component methods may generate results for both target and nontarget analytes.

Table E-4. Laboratory Analytical Methods

Parameter	Laboratory Analytical Method[a]	Source
General Chemical Parameters		
Alkalinity	Standard Method 2320	Standard methods[b]
Alkalinity	EPA Method 310.1	EPA[c]
Coliform	Standard Method 9223	Standard methods[b]
Oil and grease	EPA Method 1664A	EPA[d]
Total dissolved solids	Standard Method 2540C	Standard methods[b]
Total organic carbon	EPA Method 9060	EPA[e]
Total organic halides	EPA Method 9020	EPA[e]
Ammonia and Anions		
Ammonium by colorimetry	EPA Method 350.1	EPA[c]
Anions by IC	EPA Method 300.0	EPA[f]
Anions by IC	EPA Method 9056	EPA[e]
Cyanide	EPA Method 9012	EPA[e]
Cyanide (free)	EPA Method 9014	EPA[e]
Sulfide	Standard Method 4500D	Standard methods[b]
Sulfide	EPA Method 9034	EPA [e]
Metals		
Hexavalent chromium	EPA Method 7196	EPA[e]
Mercury	EPA Method 7470	EPA[e]
Metals by ICP/AES	EPA Method 6010	EPA[e]
Metals by ICP/MS	EPA Method 6020	EPA[e]
Volatile Organic Compounds		
Total petroleum hydrocarbons–gasoline	NWTPH-Gx	Ecology[g]
Volatile organic compounds by GC/MS	EPA Method 8260	EPA[e]
Semivolatile Organic Compounds		
Chlorinated herbicides by GC	EPA Method 8151	EPA[e]
Dioxins by GC/MS	EPA Method 8290	EPA[e]
Extractable petroleum hydrocarbon	WEPH-GC	Ecology[g]
Organochlorine pesticides by GC	EPA Method 8081	EPA[e]
Polychlorinated biphenyls by GC	EPA Method 8082	EPA[e]
Semivolatile organic compounds by GC/MS	EPA Method 8270	EPA[e]
Total petroleum hydrocarbons–diesel, –kerosene, –motor oil (high boiling)	NWTPH-Dx	Ecology[g]

Table E-4. Laboratory Analytical Methods

Parameter	Laboratory Analytical Method[a]	Source
Radiological Parameters		
Americium-curium isotopes	AEA	Laboratory-specific
Carbon-14	LSC	Laboratory-specific
Chlorine-36	GPC	Laboratory-specific
Gamma-emitting isotopes	Gamma energy analysis	Laboratory-specific
Gross alpha/beta by GPC	EPA Method 9310	Laboratory-specific
Gross alpha	GPC	Laboratory-specific
Gross beta	GPC	Laboratory-specific
Iodine-129	LEPS-GS	Laboratory-specific
Iodine-129	LSC	Laboratory-specific
Neptunium-237	AEA	Laboratory-specific
Plutonium isotopes	AEA	Laboratory-specific
Plutonium-241	LSC	Laboratory-specific
Radium-226	Lucas cell	EPA Method 903.1[h]
Radium isotopes	GPC	Laboratory-specific
Selenium-79	LSC	Laboratory-specific
Strontium-90	LSC	Laboratory-specific
Strontium-90 (total beta radiostrontium)	GPC	Laboratory-specific
Technetium-99	LSC	Laboratory-specific
Thorium isotopes	AEA	Laboratory-specific
Tritium	LSC	Laboratory-specific
Uranium isotopes	AEA	Laboratory-specific

a. Does not include field methods used during sampling.

b. APHA/AWWA/WEF, 2012, *Standard Methods For the Examination of Water and Wastewater*.

c. EPA/600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*.

d. EPA-821-R-98-002, *Method 1664, Revision A: N-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated N-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry*.

e. SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, current update.

f. EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*.

g. Ecology Publication No. ECY 97-602, *Analytical Methods for Petroleum Hydrocarbons*.

h. EPA/600/R-17/356, *Selected Analytical Methods for Environmental Remediation and Recovery (SAM)*.

Table E-4. Laboratory Analytical Methods

Parameter			Laboratory Analytical Method[a]			Source
AEA	=	alpha energy analysis	IC	=	ion chromatography	
Ecology	=	Washington State Department of Ecology	ICP/AES	=	inductively coupled plasma/atomic emission spectroscopy	
EPA	=	U.S. Environmental Protection Agency	ICP/MS	=	inductively coupled plasma/mass spectrometry	
GC	=	gas chromatography				
GC/MS	=	gas chromatography/mass spectrometry	LEPS	=	low-energy photon spectroscopy	
GPC	=	gas proportional counting	LSC	=	liquid scintillation counting	
GS	=	gamma spectroscopy	NWTPH	=	Northwest total petroleum hydrocarbons	

E4 Data Verification

As noted in Section E2.1, data verification is the process of evaluating the completeness, correctness, conformance, and compliance of a specific data set against the method, procedural, or contractual requirements as specified in CHPRC-00189. The evaluation is documented in this section and further summarized in Section E6.1. Verification is performed for field QC samples (Section E4.2) and laboratory QC samples (Section E4.3).

E4.1 Completeness

Data completeness is a measure of how much of the data set is judged to meet the quality criteria and, therefore, is usable for the groundwater monitoring program. The completeness goal is determined as a percentage of data judged "good" versus all data collected for the program and is set at a minimum of 85.0%[3] (DOE/RL-91-50, *Hanford Site Environmental Monitoring Plan*). Completeness statistics are calculated and presented for the following:

- Percentage of successful sampling events during 2019 versus the number of scheduled sampling events
- Percentage of field QC samples collected versus the number of QC samples required
- Percentage of the data set that meets quality criteria

E4.1.1 Percentage of Successful Sampling Events

During 2019, a total of 3,091 groundwater sampling events were planned; 3,011 of these sampling events were successfully executed, for an overall sampling event completion rate of 97.3%. An additional nine sample events originally scheduled for 2018 were performed in 2019, for a total of 3,020 successful well trips during 2019 to support groundwater data collection needs. The 3,020 successful well trips included all groundwater sampling events (not just routine groundwater monitoring sampling). The 2,515 well trips listed in Table E-5 are a subset of the 3,020 well trips and reflect only the 2019 sampling events that resulted in routine groundwater monitoring field and laboratory data appearing in the HEIS "RESULT" table as of February 12, 2020, when the data were obtained from the HEIS database. Sources sampled included wells, aquifer tubes, and springs.

[3] DOE/RL-91-50 defines this completeness goal on a quarterly basis. For this DUA, the completeness goal is applied over the entire year.

Completeness is evaluated for the specific requirements of individual sampling and analysis plans for CERCLA groundwater operable units, RCRA dangerous waste management units, and other programs. Describing deviations from sampling requirements in 2019 is outside the scope of this DUA and covered in Chapters 2 through 12 and in Appendices A, B, and C of this annual report.

E4.1.2 Percentage of Field Quality Control Samples Collected

The types and collection frequencies of field QC samples for the groundwater monitoring program are provided in CHPRC-00189; the collection of quadruplicate samples at RCRA sites for TOC and TOX is mandated by 40 CFR 265.92. Section E4.2 provides a more complete discussion of field QC samples. Table E-5 summarizes the QC types, the required collection frequencies, and the actual collection frequencies. The table indicates that the requirements for the minimum collection frequencies for groundwater monitoring field QC samples were met during 2019.

Table E-5. Field QC Samples

Field QC Sample Type	Number of Sampling Trips[a]	Number of QC Sample Sets Collected[b]	Frequency	
			Required[c]	Actual[d]
Full trip blanks	2,515	248	5%	9.8%
Field transfer blanks	316[e]	320	100%	101%
Equipment blanks	102[f]	71	10%[g]	69.6%
Field duplicates	2,515	140[h]	5%	5.6%
Field split samples	2,515	20[i]	As needed	0.8%
TOC quadruplicates	174[j]	181[k]	N/R	104%
TOX quadruplicates	182[j]	186[k]	N/R	102%

a. Sampling trips include trips to wells, aquifer tubes, and springs. Sampling trips are counted only if they are associated with routine groundwater monitoring results in the Hanford Environmental Information System database RESULT table. The number of sampling trips listed is applicable to the field QC sample type and are explained in the following footnotes.

b. Values listed include only field blanks, field duplicates, and field split sample sets collected for routine groundwater monitoring sampling events. A QC sample set consists of all the QC samples of a particular QC sample type (e.g., full trip blanks or field duplicates) for a given well trip and may contain multiple sample numbers.

c. Required frequency is from CHPRC-00189, *Environmental Quality Assurance Program Plan*.

d. Actual frequency = 100 × number of QC sample sets ÷ number of sampling trips.

e. For each day that VOC samples are collected, one field transfer blank is required for each laboratory receiving that day's VOC samples. Multiple field transfer blanks may be required each day that VOC samples are collected if these samples are to be shipped to more than one laboratory for analysis.

f. Number of sampling events for which nondedicated sampling equipment was used.

g. The 10% frequency is for routinely used, nondedicated sampling equipment. For new types of nondedicated sampling equipment, the equipment blank frequency is 100% until the decontamination procedure for the new equipment is shown to produce acceptable equipment blank results.

h. Number of pairs of field duplicate sample sets collected.

i. Number of pairs of field split sample sets collected.

j. Number of sampling trips for which TOC or TOX samples were collected.

k. Number of sets of quadruplicate samples collected.

N/R = not required
QC = quality control
TOC = total organic carbon
TOX = total organic halides
VOC = volatile organic compound

To determine the collection frequency for EBs, the only nondedicated sampling equipment currently tracked in the HEIS database are bailer samplers, Kabis™ samplers, and portable Grundfos® pumps. Nondedicated sampling manifolds are also used to collect some groundwater samples but are not tracked in the HEIS database. Consequently, the number of well trips for EBs reported in Table E-5 underestimates the actual number of well trips that use nondedicated sampling equipment. Until the use of nondedicated sampling manifolds is tracked, a more accurate estimate of the actual sampling frequency for EBs is not available.

E4.1.3 Percentage of Data with Quality Issues

This section provides an overview of data with potential quality issues. Subsequent sections provide detailed information regarding data compliance with quality requirements.

For routine groundwater monitoring samples collected during 2019, Table E-6 summarizes the percentage of groundwater monitoring data with potential quality issues. Overall, 95.7% of the results have no identified quality issues. This percentage is well above the data completeness goal of 85.0% specified in DOE/RL-91-50 and indicates that most of the data collected for the groundwater monitoring program do not have identified quality issues.

E4.1.4 Sample Preservation and Holding Times

Sample preservation and holding times are designed to ensure that the analytical results generated from a sample are representative of the sample source. Sample preservation is any method used to ensure that the analyte of interest is not altered between the time the sample is acquired and the time the sample is analyzed. Sample preservation includes selecting the correct sample container material (e.g., plastic or glass) and may include cooling the sample to ≤6°C (43°F), adjusting the sample pH with acids or bases, or adding other chemicals (e.g., sodium bisulfite) to prevent oxidation of the analytes of interest. Typically, any preservation chemicals are added to the sample container during container preparation, prior to taking the container to the sample site.

Holding times are defined as the time from sample collection or sample extraction to sample analysis. An extraction holding time is the time from sample collection to sample extraction. Holding times are calculated from the date of sample collection as recorded on the sample chain of custody. Analytes that may change quickly over time (e.g., coliform or hexavalent chromium [Cr(VI)]) have short holding times, while other analytes such as acid-preserved metals and radionuclides have much longer holding times.

Table E-7 lists the sample preservation and holding-time requirements for the groundwater monitoring program. Upon receipt of a groundwater sample set, the analyzing laboratory inspects the contents of the sample set container (usually an ice chest) to ensure that the samples received reflect those listed on the accompanying chain-of-custody forms. During the receipt inspection, the samples are usually checked for any anomalies (e.g., missing samples, broken sample bottles, or absent tamper tape). The as-received sample temperature is also usually checked. Samples that are received immediately from the field will not have had time to cool to a preservation temperature ≤6°C (43°F); in this instance, the as-received condition of the samples is noted, and normal processing of the samples for analysis proceeds.

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Table E-6. Data Quality Issues Summarized by Analyte Class

Analyte Class	Total Results [b]	Results Flagged	Percent Flagged	Results in Review (F) [c]	Suspect Results (Y) [c]	Rejected Results (R) [c]	Field QC Flags (Q) [c]	Missed Holding Time (H) [c]	Method Blank Qualifiers (BC) [d]
General chemistry parameters[a]	21,589	928	4.8	2	36	44	60	157	729
NH_3/anions	11,865	1,159	9.8	4	28	17	90	988	83
Metals	82,389	5,672	6.9	18	239	101	2,206	876	3,028
Volatile organic compounds	32,028	133	0.42	0	10	57	71	3	9
Semivolatile organic compounds	27,074	476	1.8	0	0	0	39	320	130
Radiochemical parameters	30,329	361	1.2	7	47	104	187	0	47
Total	**205,280**	**8,729**	**4.3**	**31**	**360**	**326**	**2,653**	**2,329**	**3,946**

a. Includes both laboratory generated general chemistry results and field sampling parameter results.

b. Groundwater monitoring results were pulled from the Hanford Environmental Information System database on February 12, 2020, and include both field and laboratory results.

c. Review qualifiers “F,” “Y,” “R,” “Q,” and “H” are defined in Table E-3.

d. Laboratory qualifiers “B” and “C” are defined in Table E-2.

QC = quality control

Table E-7. Groundwater Sample Container, Preservative, and Holding-Time Requirements

Parameter	Container	Preservative	Holding Time	Source
General Chemical Parameters				
Alkalinity	G/P	Cool to ≤6°C	14 days	40 CFR 136, Table II
Coliform	G/P	Cool to ≤10°C; 0.0008% $Na_2S_2O_3$	6 hours	40 CFR 136, Table II
Oil and grease/hexane extractable material	G	Cool to ≤6 °C; HCl or H_2SO_4 to pH <2	28 days	SW-846, Table 3-2
Total dissolved solids	G/P	Cool to ≤6°C	7 days	APHA/AWWA/WEF (2012), Standard Method 2540c
Total organic carbon	aG	Cool to ≤6°C; HCl or $H_2SO_4$to pH <2	28 days	40 CFR 136, Table II; SW-846, Table 3-2
Total organic halides	aG	Cool to ≤6°C; H_2SO_4 to pH <2	28 days	SW-846, Method 9020B
Ammonia and Anions				
Ammonia	G/P	Cool to ≤6°C; H_2SO_4 to pH <2	28 days	40 CFR 136, Table II
Cyanide	G/P	Cool to ≤6°C; NaOH to pH>12	14 days	SW-846, Table 3-2
Bromide, chloride, fluoride, and sulfate	G/P	Cool to ≤6°C	28 days	40 CFR 136, Table II; SW-846, Tables 2-40(B) and 3-2
Nitrate, nitrite, phosphate	G/P	Cool to ≤6°C	48 hours	40 CFR 136, Table II; SW-846, Tables 2-40(B) and 3-2
Sulfide	G/P	Cool to ≤6°C; zinc acetate and NaOH to pH >9	7 days	40 CFR 136, Table II; SW-846, Tables 2-40(B) and 3-2
Metals				
Hexavalent chromium	G/P	Cool to ≤6 °C	24 hours	SW-846, Tables 2-40(B) and 3-2
Mercury	G/P	HNO_3 to pH<2	28 days	SW-846, Tables 2-40(B) and 3-2
All other metals	G/P	HNO_3 to pH<2	6 months	SW-846, Tables 2-40(B) and 3-2
Volatile Organic Compounds				
Total petroleum hydrocarbons-gasoline	aG	Cool to ≤6°C; HCl to pH<2	14 days preserved 7 days unpreserved	Ecology Publication No. ECY97-602
Volatile organic compounds	aGs	Cool to ≤6 °C; HCl or H_2SO_4 to pH <2	14 days preserved 7 days unpreserved	SW-846, Table 4-1
Semivolatile Organic Compounds				
Extractable aliphatic and aromatic petroleum hydrocarbons	aG	Cool to ≤6°C; HCl to pH<2	14 days before extraction, 40 days after extraction	Ecology Publication No. ECY97-602

Table E-7. Groundwater Sample Container, Preservative, and Holding-Time Requirements

Parameter	Container	Preservative	Holding Time	Source
Semivolatile organic compounds	aG/PTFE-lined cap	Cool to ≤6°C	7 days before extraction, 40 days after extraction	40 CFR 136, Table II
Organochlorine pesticides, and herbicides	aG/PTFE-lined cap	Cool to ≤6°C	7 days before extraction, 40 days after extraction	40 CFR 136, Table II; SW-846, Table 4-1
Polychlorinated biphenyls	aG/PTFE-lined cap	Cool to ≤6°C	1 year before extraction, 40 days after extraction	40 CFR 136, Table II; SW-846, Method 8082A
Polychlorodibenzo-p-dioxins, polychlorodibenzo-furans	aG/PTFE-lined cap	Cool to ≤6°C	30 days before extraction, 45 days after extraction	SW-846, Method 8290
Total petroleum hydrocarbons-diesel, -kerosene, -motor oil (high boiling)	aGs	Cool to ≤6°C; HCl to pH<2	14 days before extraction, 40 days after extraction	Ecology Publication No. ECY97-602*
Radiological Parameters				
Americium isotopics, gamma spectroscopy radionuclides, plutonium isotopics, radium isotopics, strontium-90, and uranium isotopics	G/P	HNO_3 to pH<2	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure
Carbon-14, tritium	G	None	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure
Chlorine-36	G/P	None	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure
Gross alpha, gross beta	G/P	HNO_3 to pH<2	6 months	SW-846, Table 2-40(B)
Iodine-129	G/P	None	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure
Selenium-79	G/P	HNO_3 to pH<2	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure
Technetium-99	G/P	HNO_3 to pH<2	6 months	DOE/RL-96-68, Vol. 2, Appendix A; laboratory procedure

Table E-7. Groundwater Sample Container, Preservative, and Holding-Time Requirements

Parameter	Container	Preservative	Holding Time	Source

Sources:

40 CFR 136, "Guidelines Establishing Test Procedures for the Analysis of Pollutants."

APHA/AWWA/WEF, 2012, *Standard Methods For the Examination of Water and Wastewater*.

DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document, Volume 2, Sampling Technical Requirements.*

Ecology Publication No. ECY 97-602, *Analytical Methods for Petroleum Hydrocarbons*.

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, current update.

*By analogy with semivolatile organic compounds (SW-846, Table-4-1; CHPRC-00189, Table B-4).

aG = amber glass
aGs = amber glass with septum cap
G = glass
P = plastic
PTFE = polytetrafluorinatedethylene

Either at the time of receipt or immediately before sample preparation and analysis, the pH of samples that require pH adjustment is checked to ensure that the sample was properly preserved. If the pH is not correct for the sample type (e.g., pH is >2 for ICP metals or is <12 for cyanide samples), then the laboratory notes the anomaly and may adjust the sample pH. Any anomalies noted during sample receipt or with sample preservation are reported to S&GRP via sample issue resolution requests. If S&GRP does not deem that the anomaly will affect the sample results, the laboratory is instructed to proceed with the analysis. S&GRP may decide that the anomaly (e.g., a cyanide sample with pH <12) could jeopardize the integrity of the sample results; in this instance, the laboratory will be instructed to cancel the sample analysis.

E4.1.4.1 Sample Preservation

Of the 13,574 routine groundwater monitoring laboratory samples acquired during 2019, a total of 36 samples (0.3%) were associated with sample preservation issues. Of the 36 samples with sample preservation issues, one analysis was cancelled. This indicates that incorrect sample preservation is not a major issue for the groundwater monitoring program.

E4.1.4.2 Holding Times

Of the 205,280 groundwater monitoring laboratory results reported during 2019, a total of 2,329 analytical results (1.1%) were affected by missed holding times. Most of the samples with missed holding times were analyzed within two times the holding time. With the exception of three results, S&GRP scientists and project coordinators deemed that these results are acceptable for the groundwater monitoring program.

For the short holding-time analytes Cr(VI) and the IC anions nitrate, nitrite, and phosphate, S&GRP personnel instructed GEL and TASL in 2014 to submit sample issue resolution forms for those analytes only when they were analyzed outside two times of the holding-time requirement. Consequently, not all results with missed holding times are documented via the sample issue resolution process. All missed holding times were still to be noted in the case narratives of the laboratory analytical reports. All sample results associated with missed holding times are qualified with an "H" flag.

In February 2019, the local laboratory supporting groundwater analysis closed. Subsequently, samples requiring analyses with short holding times (<48 hours) were required to be shipped longer distances. The laboratories agreed to give first priority to the short hold-time analyses, but due to the shipping times involved, it was anticipated and observed that more holding times would be missed for Cr(VI) (24-hour

hold time) and nitrate/nitrite (48-hour hold time). Cr(VI), which has the shortest holding time and the greatest number of exceedances, has been observed to be stable in Hanford Site groundwater over an extended period (up to 6 months in one study); therefore, the missed holding time is not expected to have a significant impact on the results. For nitrate/nitrite, the concern is conversion of nitrite to nitrate. It should be noted that the holding time for the combined nitrate/nitrite analysis is 28 days. Given the relatively small nitrite concentrations compared to the nitrate values in most Hanford Site groundwater samples and the relatively few missed holding times for anions, the data impacts from these missed holding times are minimal. Efforts are underway to establish local capability for these two analytical methods so the need to ship these samples can be reduced or eliminated.

Examples of the holding-time issues include the following:

- **Late sample delivery:** This issue covers delivery of a sample with insufficient or no time left to complete the analysis before the holding time expired.
- **Laboratory failure to observe holding time:** This issue covers missed holding times caused by the laboratory failing to observe the analyte holding time before analyzing the sample.
- **Instrument failure/diverted to other laboratory:** This issue covers missed holding times caused by an instrument malfunction with subsequent diversion of the affected samples to another laboratory.
- **Instrument failure:** This issue covers missed holding times caused by an instrument malfunction.

E4.2 Field Quality Control

This section discusses the 2019 groundwater monitoring field QC data that did not meet the QC acceptance criteria listed in Table E-1. Section E3.2 discusses the types of field QC samples that are evaluated in this section.

E4.2.1 Field Blanks

The FBs are used to assess potential contamination associated with sampling and laboratory activities. Analytical results for the FBs are assessed against the acceptance limits listed in Table E-1. Overall, the percentage of acceptable FB results evaluated during this reporting period was 94.4%. This percentage indicates minimal problems with contamination during sampling and analysis.

The FB results greater than the acceptance criterion of the MDL or MDC are identified as suspected contamination. For the common laboratory contaminants 2-butanone, acetone, methylene chloride, toluene, and phthalate esters, the limit is five times the MDL. If an FB exhibits suspected contamination for an analyte and the FB result is at least 5% of an associated sample's analyte result, then the associated sample result is flagged as "Q" in the HEIS database to indicate a potential contamination issue. Section E3.2 defines the associated samples for FBs. Table E-8 summarizes the numbers of FBs acquired during 2019. Table E-9 provides a statistical summary by analyte class for the 2019 FB results. The remainder of the FB discussion in this section provides additional context for the information presented in Tables E-8 and E-9.

Table E-8. Field Blank Numbers by Blank Type

Field Blank Type	Number of Blank Sets	Number of Blank Samples	Number of Blank Results
Equipment blank	71	271	3,662
Full trip blank	248	854	13,183
Field transfer blank	315	320	6,448
Total	**570**	**1,445**	**23,293**

Table E-9. Field Blank Summary Statistics by Analyte Class

Analyte Class	Number of Blank Results	Number of Blank Results Out	Percent of Blank Results Out
General chemical parameters	698	154	22.1
NH_3/anions	1,028	65	6.3
Metals	7,601	588	7.7
Volatile organic compounds	8,437	439	5.2
Semivolatile organic compounds	3,314	25	0.8
Radiochemical parameters	2,168	38	1.8
Total	**23,246**	**1,309**	**5.6**

Additional information for the 2019 groundwater field blanks by analyte class is as follows:

- **General chemical parameters:** The 698 general chemical parameter FB results yielded 154 results (22.1%) that were outside QC limits, mostly for TOX and alkalinity.
- **Ammonia/anions:** Of the 1,028 ammonia/anion FB results, 65 results (6.3%) were outside QC limits. All of out-of-limits results were for the IC anions: 29 results for chloride, 6 results for nitrite, 19 results for nitrate, 5 results for phosphate, and 6 results for sulfate.
- **Metals:** Of the 7,601 FB metals results for 2019, 588 results (7.7%) were outside QC limits. Most of the exceedances were for the ICP/atomic emission spectrometry (AES) and ICP/MS metals: zinc (80 results), sodium (77 results), tin (60 results), potassium (58 results), chromium (39 results), copper (31 results), uranium (22 results), silver (20 results), and vanadium (20 results). The remaining 181 out-of-limit results were scattered among 20 other metals.
- **VOCs:** The 2019 groundwater monitoring FBs yielded 8,437 VOC results. Of these, 439 results (5.2%) exceeded limits and included 274 methylene chloride detections that ranged from 0.36 to 55.3 µg/L. During 2012, a study of VOC contamination in groundwater FBs determined that the deionized water used to generate the FBs is the most likely source of the methylene chloride and, to a lesser extent, carbon tetrachloride and chloroform found in the FBs (SGW-52194, *Volatile Organic Compound Contamination in Groundwater Samples and Field Blanks*). The same study also concluded that the appearance of acetone, bromomethane, carbon disulfide, chloromethane, tetrachloroethene, and toluene in laboratory method blanks indicates that these volatile organic analytes may be introduced as contaminants during laboratory sample preparation and analysis and may appear as spurious analytes in groundwater samples. Installing additional charcoal filtering to the

deionized water supply to decrease the occurrence of spurious organic compounds in groundwater monitoring FBs was completed during 2016. Continued monitoring since this corrective action was implemented indicates that charcoal filtering is ineffective at reducing the presence of organic compounds in the FBs. No additional corrective actions are planned at this time.

The remaining VOC analytes with 5 or more out-of-limits results were 2-propanol (30 results; 12 to 270 µg/L), acetone (90 results; 0.94 to 34.5 µg/L), 2-butanone (7 results; 1.3 to 5.6 µg/L), trichloroethene (5 results, 1.18 µg/L to 48.1 µg/L), and carbon disulfide (5 results; 0.27 to 0.93 µg/L). The continuing appearance of 2-propanol in the FBs and groundwater samples was identified as a likely field contamination issue during blank preparation and field collection (Appendix E of DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*).

Octamethylcyclotetrasiloxane, hexamethylcyclotrisiloxane, and trimethylsilanol were reported as tentatively identified compounds in FBs during 2019. These three VOCs are decomposition products of the capillary columns used to perform analyte separations during GC/MS. Because these decomposition products are not native to the FBs or groundwater samples, the 12 reported results for these compounds were not included in the FB results.

- **Semivolatile organic compounds (SVOCs):** Of the 3,314 SVOC FB results, a total of 25 (0.8%) were outside QC limits. Fifteen of the out-of-limits results were for polychlorodibenzodioxins and polychlorodibenzofurans. The remaining out-of-limit results were distributed among 5 other SVOCs.
- **Radiochemical parameters:** Of the 2,168 radiochemical parameter results, 38 results (1.8%) were outside QC limits. The out-of-limit radiochemical parameters included uranium-233/234, uranium-238, potassium-40, strontium-90, tritium, gross alpha, and gross beta. All out-of-limit potassium-40 results are considered false positive results based on large peak widths.

E4.2.2 Field Duplicate Samples

Field duplicate samples are replicate groundwater samples sent to the same laboratory and are used to assess field sampling and laboratory measurement precision. In accordance with Table E-1, the results of field duplicates must have a precision ≤20%, as measured by the RPD (Equation E-1). Field duplicates with at least one result greater than five times the MDL or MDC were evaluated. Field duplicate results with an RPD >20% are flagged as "Q" in the HEIS database RESULT table to indicate potential precision issues. Field duplicate values flagged as "Y" were included in the assessment of duplicate precision.

For 2019, 140 field duplicate sets were collected. For these 140 field duplicate sets, 804 sample duplicate pairs were acquired. The 804 sample pairs yielded 20,073 pairs of results, of which 7,901 result pairs (39.4%) met the evaluation criterion and for which RPDs were calculated. Of the 7,901 calculated RPDs, a total of 7,294 (92.3%) met the RPD criterion, indicating reasonable field sampling and intralaboratory precision. The 20,073 result pairs also produced 12,172 nondetect results pairs (60.6%) (i.e., both results in the pair were less than the MDL). While the nondetect results cannot be evaluated in the same manner as the detected results, nondetect result pairs indicate agreement between the two results. Table E-10 presents the summary statistics by analyte class for the 2019 field duplicates.

Table E-10. Field Duplicate Summary Statistics by Analyte Class

Analyte Class	Number Duplicate Result Pairs	Number of Nondetects[a]	Percent of Nondetects	Number of RPDs Calculated[b]	Percent Calculated	Number of RPDs Out of Limits[c, d]	Percent of RPDs Out of Limits
General chemical parameters	448	189	42.2	259	57.8	0	0.0
NH_3/anions	1,350	292	21.6	1,058	78.4	26	2.5
Metals	8,397	3,145	37.5	5,252	62.5	446	8.5
Volatile organic compounds	3,366	3,200	95.1	166	4.9	11	6.6
Semivolatile organic compounds	2,848	2,793	98.1	55	1.9	16	29.1
Radiochemical parameters	3,664	2,553	69.7	1,111	30.3	108	9.7
Total	**20,073**	**12,172**	**60.6**	**7,901**	**39.4**	**607**	**7.7**

a. Number of pairs of results where both results were less than the MDL or MDC.

b. Duplicates with at least one result >5 times the MDL or MDC were evaluated.

c. Duplicate control limit is a relative percent difference ≤20%.

d. In cases where a nondetected result was compared with a measured value, the MDL or MDC was used for the nondetected result.

MDC = minimum detectable concentration

MDL = method detection limit

RPD = relative percent difference

Additional information for the 2019 groundwater field duplicates by analyte class is as follows:

- **General chemical parameters:** The general chemical parameters had 448 field duplicate result pairs, of which 189 (42.2%) pairs were nondetects and 259 (58.0%) pairs met the evaluation criterion. None of the field duplicate result pairs had an out-of-limit RPD.

- **Ammonia/anions:** Ammonia and anions had 1,350 field duplicate result pairs, of which 292 (21.6%) pairs were nondetects and 1,058 (78.4%) pairs met the evaluation criterion. Of these duplicate pairs, 26 (2.5%) exceeded the RPD criterion. The constituents with out-of-limit RPD results were bromide (2 result pairs), chloride (2 result pairs), fluoride (6 results pairs), free cyanide (6 result pairs), nitrogen in nitrate (6 result pairs), nitrogen in nitrite (2 result pairs), and sulfate (2 result pairs).

- **Metals:** Metals had 8,397 field duplicate result pairs, of which 3,145 (37.5%) pairs were nondetects and 5,252 (62.5%) pairs met the evaluation criterion. Of the 5,252 data pairs, 446 (8.5%) data pairs exceeded the RPD criterion. The out-of-limit RPD results were scattered over the ICP and ICP/MS metals, including aluminum (14 results), antimony (6 results), arsenic (14 results), barium (10 results), beryllium (4 results), boron, (4 results), chromium (66 results), cobalt (18 results), copper (38 results), iron (22 result pairs), lead (20 results), manganese (36 result pairs), molybdenum (12 results), nickel (20 results), potassium (18 results), selenium (2 results), silver (4 results),

sodium (4 results), strontium (2 results), thallium (2 results), thorium (6 results), tin (26 results), uranium (8 results), vanadium (38 results), and zinc (36 results), as well as 16 results for Cr(VI) analyses.

Historically, many of the out-of-limit duplicates for metals have been attributed to unfiltered samples in which heterogeneous distribution of suspended solids in the samples tends to cause discrepancies between result pairs. For 2019, 60.5% of the duplicate result failures for metals occurred in unfiltered samples; these failures may reflect the effect of suspended solids on the metals results. Failures among the filtered samples may indicate possible sample swaps either in the field or laboratory, a sample contamination event that affected only one of the duplicate pairs, a dilution error during sample preparation, or natural variability between duplicate samples.

- **VOCs:** The VOCs had 3,366 field duplicate result pairs, of which 3,200 (95.1%) pairs were nondetects and 166 (4.9%) pairs met the evaluation criterion. Of the 166 pairs, 11 (6.6%) failed to meet the RPD criterion. The out-of-limit analytes were acetone (4 results), carbon tetrachloride (2 results), chloroform (2 results), methylene chloride (2 results), and total petroleum hydrocarbons (TPH)-gasoline (1 result). Two of the acetone results were tentatively identified compounds, and both results were associated with out-of-limit field blank sample B3RTL5.
- **SVOCs:** The SVOCs had 2,848 field duplicate result pairs, of which 2,793 pairs (98.1%) were nondetects and 55 pairs (1.9%) met the evaluation criterion. Of the 55 pairs, 16 (29.1%) exceeded the RPD criterion. The 16 out-of-limit RPD result pairs were scattered over 6 different SVOC constituents which include aliphatic petroleum hydrocarbons (4 results), di-n-butylphthalate (2 results), hexachlorodibenzo-p-dioxin (2 results), octachlorodibenzofuran (2 results), octachlorodibenzo-p-dioxin (4 results), and phenanthrene (2 results).
- **Radiochemical parameters:** For the radiochemical parameters, 3,664 field duplicate result pairs yielded 2,553 (69.7%) nondetect pairs and 1,111 (30.3%) result pairs that met the evaluation criterion. Of these duplicate pairs, 108 (9.7%) exceeded the RPD criterion. The 108 out-of-limit RPD results were scattered among eight different radiochemical parameters and included gross beta (4 results), iodine-129 (8 results), strontium-90 (14 results), technetium-99 (32 results), tritium (18 results), uranium-233/234 (24 results), uranium-235 (6 results), and uranium-238 (2 results).

E4.2.3 Field Split Samples

Field split samples are duplicate samples that are sent to two different laboratories to allow interlaboratory comparisons of analytical results. These comparisons are used to evaluate laboratory performance, to determine the extent of any analytical problems, and to confirm out-of-trend results. In accordance with Table E-1, the results of field splits must have a precision ≤20%, as measured by the RPD (Equation E-1). The field split results pairs with at least one result greater than five times the MDLs or MDCs of both laboratories were evaluated. If the laboratory reported an estimated quantitation limit[4] (EQL) or equivalent instead of an MDL, the evaluation criterion was one times the EQL instead of five times the MDL. Field split results that have an RPD >20% are flagged as "Q" in the HEIS database RESULT table to indicate potential precision issues. Field split values flagged as "Y" were included in the assessment of duplicate precision.

For TOC and TOX split samples, a matching set of quadruplicate samples was submitted to each of the two laboratories. To evaluate the interlaboratory reproducibility for TOC and TOX, an average result was first calculated for each laboratory's quadruplicate sample set, and then the average values from the two

[4] The estimated quantitation limit is the lowest concentration of an analyte that can reported with a known uncertainty.

laboratories were used to calculate the RPD. The TOC and TOX field splits with average results that generate a RPD >20% are not flagged as "Q."

For 2019, 20 field split sample sets were collected. For these 20 field split sets, 75 split samples pairs yielded 190 pairs of field split results. Of the 190 result pairs, 84 pairs (44.2%) met the evaluation criterion to generate calculated RPDs. Of the 84 RPDs, 84 (100%) RPDs met the 20% RPD criterion. A total of 106 (55.8%) result pairs agreed as nondetects. Table E-11 presents the summary statistics by analyte class for the 2019 field splits.

Table E-11. Field Split Summary Statistics by Analyte Class

Analyte Class	Number Split Result Pairs	Number of Nondetects[a]	Percent of Nondetects	Number of RPDs Calculated[b]	Percent Calculated	Number of RPDs Out of Limits[c, d]	Percent of RPDs Out of Limits
General chemistry parameters	174	106	60.9	68	39.1	0	0.0
NH_3/anions	0	0	0	0	0	0	0
Metals	16	0	0.0	16	100	—	—
Volatile organic compounds	0	0	0	0	0	0	0
Semivolatile organic compounds	0	0	0	0	0	0	0
Radiochemical parameters	0	0	0	0	0	0	0
Total	**190**	**106**	**55.8**	**84**	**44.2**	—	—

a. Number of pairs of results where both results were less than the MDL or MDC.

b. Splits with at least one result five times greater than the MDL or MDC were evaluated.

c. Split control limit is a relative percent difference ≤20%.

d. In cases where a nondetected result was compared with a measured value, the MDL or MDC was used for the nondetected result.

MDC = minimum detectable concentration

MDL = method detection limit

RPD = relative percent difference

Additional information for the 2019 groundwater field splits by analyte class is as follows:

- **General chemistry parameters:** For the general chemical parameters, 68 of 174 (39.1%) split results passed the evaluation criterion with no split RPD failures. A total of 106 of 174 (60.9%) split pairs were nondetects.

- **Ammonia/anions:** There were no split pairs for ammonia and anions in 2019.
- **Metals:** The metals analyses had 16 field split result pairs, of which 16 (100%) pairs met the evaluation criterion with no split RPD failures. For the 16 split pairs discussed, none of the laboratories flagged the results as having analyte contamination in the associated method blank (flagged as "C"). In previous years, "C"-qualified results indicated possible contamination of one of the sample/split pair and may have contributed to sample/split RPD failures.
- **VOCs:** There were no VOC split pairs in 2019.
- **SVOCs:** There were no SVOC split pairs in 2019.
- **Radiochemical parameters:** There were no radiochemical split pairs in 2019.

E4.2.4 Quadruplicate Total Organic Carbon and Total Organic Halides Samples

TOC and TOX are classified as RCRA indicator analytes, and the samples for these analytes are usually taken in quadruplicate (40 CFR 265.92). For these analytes, the percent RSD (Equation E-2) of the quadruplicate results was determined and compared to a precision limit of 20%. Field quadruplicate sample results were evaluated only if at least one result of the quadruplicate was at least five times the laboratory MDL.

During 2019, a total of 181 quadruplicate sample sets was taken for TOC. Of the 181 sample sets, 2 sample sets (1.1%) met the evaluation criterion; of these, neither exceeded the precision criterion.

For TOX, a total of 186 quadruplicate sample sets was taken. Of the 186 sample sets, 19 (10.2%) met the evaluation criterion. Of these, 8 sets (42.1%) exceeded the precision criterion, with a range of percent RSDs from 22.7% to 87.9%. One possible explanation for these failures may be inconsistent rinsing of inorganic chloride from the sample prior to the determination of organic halides in the sample. If inorganic chloride is not consistently and completely removed from the sample before determining organic halides, the apparent concentration of organic halides is likely to vary across a set of quadruplicate samples. A second source of error, particularly for gas-pressured systems, is the loss of volatile organic halogens from the sample into the sample headspace during elution of the sample through the charcoal columns. Table E-12 presents summary statistics for the TOC and TOX quadruplicate sample sets.

Table E-12. Field Quads Summary Statistics

Constituent	Total Number of Quads	Number of Quads Evaluated	Percent of Quads Evaluated	Number Within QC Limit	Number Exceeding QC Limit	Percent Within QC Limit	Percent Exceeding QC Limit
Total organic carbon	181	2	1.1	0	0	100	0.0
Total organic halides	186	19	10.2	11	8	57.9	42.1

QC = quality control

E4.3 Laboratory Quality Control

This section discusses the 2019 groundwater monitoring laboratory batch QC data that exceeded the QC acceptance criteria listed in Table E-1. The types of laboratory QC samples that are evaluated in this section are further discussed in Section E3.3. Table E-13 summarizes the laboratory QC data by analyte class. Overall, the laboratory QC data indicate that laboratory analytical measurements for the groundwater monitoring program are produced within the QC limits identified in Table E-1. Of the 142,276 laboratory batch QC measurements reported with groundwater monitoring results, 94.7% of the measurements met the groundwater monitoring QC requirements. When the laboratories detect failures in batch QC samples, they usually apply a QC laboratory qualifier to the data (Table E-2).

E4.3.1 Laboratory Method Blanks

Laboratory method blanks are used to assess potential contamination associated with laboratory sample preparation and analysis. Of the 43,359 laboratory method blank results evaluated for 2019, 97.1% met the QC criteria outlined in Table E-1, indicating few problems with laboratory contamination.

For the common laboratory VOC contaminants 2-butanone, acetone, methylene chloride, phthalate esters, and toluene, the QC limit is five times the MDL. The laboratories flag results associated with out-of-limit blank results in the laboratory qualifier field in the HEIS database (as described in Table E-3). For inorganic analytes (including the indicator analytes TOC and TOX), results associated with an out-of-limit method blank are flagged as “C.” For organic analytes and radioanalytes, results associated with an out-of-limit method blank are flagged as “B.” The laboratory may not flag a given groundwater sample result if the analyte concentration in the associated method blank is <5% of the concentration of the analyte in the given groundwater sample. Table E-13 presents summary statistics for the 2019 out-of-limit method blank results.

- **General chemical parameters:** By analyte category, general chemical parameters had a method blank success rate at 95.7%, with 29 out-of-limit method blank results of the 670 method blank results. The general chemical parameter analytes with blank failures were TOX (207 results/ 23 failures), TOC (109 results/3 failures), and total dissolved solids (14 results/3 failures).

- **Ammonia/anions:** After metals, ammonia and anions had the next lowest method blank success rate at 96.8%, with 94 method blank failures out of 2,914 method blank results. All method blank failures were for IC anion analyses. The analytes with method blank failures were phosphate (7 results/17 failures), ammonia (14 results/6 failures), nitrate (512 results/28 failures), chloride (513 results/20 failures), sulfate (513 results/15 failures), fluoride (513 results/5 failures), and nitrate (513 results/3 failures).

- **Metals:** Metals had the poorest method blank success rate at 91.7%, with 941 method blank failures of 11,374 method blank results. The most common blank failures were aluminum (332 results/39 failures), antimony (392 results/21 failures), chromium (579 results/34 failures), cobalt (393 results/21 failures), copper (390 results/44 failures), lead (330 results/30 failures), molybdenum (377 results/50 failures), phosphorous (40 results/11 failures), potassium (413 results/138 failures), sodium (413 results/189 failures), tin (330 results/131 failures), uranium (477 results/23 failures), and zinc (392 results/117 failures). The remaining metals had fewer than 20 and <5% out-of-limit method blank results.

Table E-13. Laboratory QC Results by Analyte Class

QC Parameter		General Chemical Parameters	Ammonia/ Anions	Metals	Volatile Organic Compounds	Semivolatile Organic Compounds	Radiochemical Parameters	Total
Laboratory QC results	Total	2,092	9,519	5,0767	56,365	28,912	8,204	155,858
	Out	53	178	1,017	794	690	211	2,943
	Percent out	2.6	1.9	2.0	1.4	2.4	2.6	1.9
Method blanks	Total	670	2,914	11,374	16,485	7,875	4,041	43,359
	Out	29	94	941	27	159	21	1,271
	Percent out	4.3	3.2	8.3	0.2	2.0	0.5	2.9
Laboratory control samples/laboratory control sample duplicate recoveries	Total	689	2,917	11,374	15,340	5,313	2,919	38,552
	Out low	0	0	0	3	40	1	44
	Out high	0	0	0	58	4	0	61
	Percent out	0.0	0.0	0.0	0.4	0.8	0.03	0.3
Laboratory control sample duplicate RPDs	Total	62	514	195	3,614	420	209	5,014
	Out	0	0	0	4	3	1	8
	Percent out	0.0	0.0	0.0	0.1	0.7	0.5	0.2
Matrix spike/matrix spike duplicate recoveries	Total	355	2,083	18,556	7,734	6,640	439	35,804
	Out low	7	12	47	109	137	14	326
	Out high	6	62	22	17	24	27	158
	Percent out	3.7	3.6	0.4	1.7	2.4	9.3	1.4
Matrix spike duplicate RPDs	Total	44	22	9,161	3,861	3,286	126	16,500
	Out	2	0	4	65	202	4	277
	Percent out	4.5	0.0	0.04	1.7	6.1	3.2	1.7
Sample duplicates	Total	272	1,069	107	0	0	470	1,918
	Out	9	10	3	0	0	143	165
	Percent out	3.3	0.9	2.8	0.0	0.0	30.4	8.6

Table E-13. Laboratory QC Results by Analyte Class

QC Parameter		General Chemical Parameters	Ammonia/ Anions	Metals	Volatile Organic Compounds	Semivolatile Organic Compounds	Radiochemical Parameters	Total
Surrogates	Total	—	—	—	8,822	5,320	—	14,142
	Out low	—	—	—	2	53	—	55
	Out high	—	—	—	0	12	—	12
	Percent out	—	—	—	0.02	1.2	—	0.5
Surrogate duplicates	Total	—	—	—	509	57	—	566
	Out	—	—	—	0	0	—	0
	Percent out	—	—	—	0.0	0.0	—	0.0

QC = quality control
RPD = relative percent difference

- **VOCs:** VOCs had a method blank success rate of 99.8% (27 failures in 16,485 results) and will not be discussed in detail, other than to note that the appearance of 2-propanol was not reported in any VOC method blank.
- **SVOCs:** The SVOCs had a method blank success rate of 98.0% (159 failures of 7,875 results). A total of 113 of the failures were for a number of polychlorodibenzodioxins and polychlorodibenzofurans. Other failures were for polynuclear aromatic hydrocarbons (PAHs) (21 failures), aliphatic petroleum hydrocarbons nC8-nC10 (5 results/3 failures), aliphatic petroleum hydrocarbons >nC21-nC34 (5 results/3 failures), di-n-butylphthalate (40 results/8 failures), and bis(2-ethylhexyl)phthalate (62 results/5 failures). The remaining SVOC out-of-limit method blanks had two or fewer failures each.
- **Radiochemical parameters:** The radiological analyte method blank results met the QC criterion at a success rate of 99.5%, with 21 of 4,041 method blank results not meeting the QC criterion. The failed method blanks were for uranium-238 (134 results/5 failures), europium-152 (170 results/ 3 failures), gross beta (177 results/3 failures), plutonium-241 (103 results/3 failures), cesium-134 (125 results/2 failures), uranium-235 (134 results/2 failures), iodine-129 (192 results/1 failure), potassium-40 (125 results/1 failure), and strontium-90 (373 results/1 failure).

E4.3.2 Laboratory Control Samples and Laboratory Control Sample Duplicates

The LCS recoveries provide a measure of the accuracy of an analytical result, and the LCS duplicate RPD provides a measure of the repeatability of the analytical result. Laboratories may apply a qualifier of "o" or "X" and an accompanying explanatory note when LCS recoveries or LCSD RPDs are outside of the QC limits. For 2019, LCS and LCSD results were available across all analyte categories. In this section, "LCS" includes both LCSs and LCSDs when percent recoveries are discussed.

Overall for 2019, 99.7% of the percent recoveries for the 38,552 reported LCS results and 99.8% of the RPDs for the 5,014 reported LCSD results met the QC criteria listed in Table E-1. These success rates provide assurance that the analytical measurement processes are in reasonable control and are producing results with sufficient accuracy and precision to meet the needs of the groundwater monitoring program.

- **General chemical parameters:** For 2019, general chemical parameters had an LCS recovery rate of 100% for 689 LCS recoveries and no RPD failures for 62 LCSD RPDs.
- **Ammonia/anions:** Ammonia and anions had an LCS recovery success rate of 100% for 2,917 LCS recoveries. A total of 514 LCSD RPD results were reported, and all met the RPD criterion.
- **Metals:** Metals had an LCS recovery success rate of 100% for 11,374 LCS results. A total of 195 LCSD RPD results were reported for metals, and none exceeded the RPD criterion.
- **VOCs:** VOCs had an LCS recovery success rate of 99.7% (61 failures of 15,340 results) and a LCSD RPD success rate of 99.9% (3,614 results/4 failures). Of the LCS recovery failures, 3 were out low and 58 were out high. The EPA Method 8260 analytes with the most LCS recovery failures were 2-butanone (557 results/20 failures/0 failures low/20 failures high), dichlorodifluoromethane (144 results/16 failures/1 failure low/15 failures high), carbon disulfide (557 results/7 failures/0 failures low/7 failures high), bromomethane (144 results/5 failures/1 failure low/4 failures high), and 1,2-dibromo-3-chloropropane (114 results/5 failures/0 failures low/5 failures high). The remaining VOCs with recovery failures had fewer than five failures. The four RPD failures were for three VOCs (1-butanol, isobutyl alcohol, and vinyl acetate).

- **SVOCs:** The SVOCs had a LCS recovery success rate of 99.2% (5,313 recoveries with 40 failures low and 3 high), with an LCSD RPD success rate of 99.3% (420 RPDs with 3 failures). This indicates a possible tendency for low recoveries in actual groundwater samples. The LCS and LCSD RPD performances of the SVOCs were as follows:
  - EPA Method 8081 pesticides had an LCS recovery success rate of 99.2% for 757 total LCS recoveries, with 5 low and 1 high. Overall LCSD RPD performance for this method was 97.5%, with three RPDs out of limits for 120 LCSDs.
  - EPA Method 8270 SVOCs and PAHs had a success rate of 99.4% for 3,567 reported LCS recoveries, with 17 LCS failures low and 3 failures high. The EPA Method 8270 analytes with the majority of the LCS recovery failures were 4-nitrophenol (56 results/6 failures low/0 failures high), 2,6-dichlorophenol (55 results/0 recoveries low/3 recoveries high), and naphthalene (58 results/2 failures low/0 failures high). Overall LCSD RPD performance for this method was 100% (no RPDs out of limits) for 265 LCSDs.
  - TPH (diesel, kerosene, and motor oil) had a success rate of 79.5%; of 88 reported LCS recoveries, with all 18 failures low. The 18 LCS recovery failures were for TPH-kerosene range (7 results/ 7 failures low) and TPH-diesel range (46 results/11 failures low). Overall, LCSD RPD performance was 100%, with no RPDs out of limits for 7 LCSDs.

  The remaining SVOC methods had LCS recovery rates of 96% or better.

- **Radiochemical parameters:** The radiological analyte LCS recoveries met the QC criteria at a success rate of more than 99.9% for 2,919 LCS recoveries, with 1 failing low. For the LCSD RPDs, only 1 of 209 RPDs did not meet the RPD criterion, for a success rate of 99.5%. The failed LCS recovery was for iodine-129 (192 results/1 failure/1 failure low/0 failures high).

E4.3.3 Matrix Spikes and Matrix Spike Duplicates

The MSs provide a measure of the accuracy of an analytical result and are used to determine if sample matrix effects may have affected analytical results. The MSDs give a measure of the repeatability of the analytical result. Only those MS samples that were spiked at a level at least one-fourth of the parent sample concentration were evaluated. For MS recovery failures, the laboratories apply a laboratory qualifier of “N” for non-GC/MS methods or a qualifier of “T” for GC/MS methods. For 2019, MS/MSD results were available across all the analyte categories. In this discussion, the set of MS recoveries also includes MSD recoveries.

Of the 35,804 MS results reported for 2019, 35,321 (98.3%) met the evaluation criterion (see previous paragraph). Of the 35,321 evaluated MS results, 98.6% met the percent recovery QC criteria cited in Table E-1. These success rates for percent recoveries and RPDs are similar to those for the LCS and LCSD QC and provide additional assurance that the laboratories are producing data with sufficient accuracy and precision to meet the needs of the groundwater monitoring program. Of the 16,621 MS/MSD pairs reported, 16,500 (99.3%) met the evaluation criterion. Of the 16,500 MS/MSD pairs evaluated, 98.3% met the RPD QC criteria listed in Table E-1.

- **General chemical parameters:** A total of 355 MS or MSD recoveries reported met the evaluation criteria; 7 MS or MSD recoveries failed low and 6 failed high for an acceptance rate of 96.3%. Two of 44 MS/MSD RPDs were greater than the RPD limit for an acceptance rate of 95.5%. The general chemical parameter analytes with out-of-limit recoveries were TOX (184 MS or MSD results; 5 low and 6 high) and oil and grease (19 MS results; 3 low and 0 high).

- **Ammonia/anions:** A total of 2,083 MS or MSD results reported met the evaluation criteria; 12 MS/MSD recoveries failed low and 62 failed high for an acceptance rate of 96.4%. All 22 MS/MSD RPDs met the RPD limit. The out-of-limit MS/MSD recoveries were for nitrite (375 results/5 recoveries low/ 52 recoveries high), sulfate (377 results/1 recoveries low/0 recoveries high), nitrate (377 results/ 2 recoveries low/2 recoveries high), phosphate (55 recoveries/1 recovery low/6 recoveries high), fluoride (379 results/1 recovery low/0 recoveries high), cyanide (70 results/ 1 recovery low/ 0 recoveries high), free cyanide (1 result/0 recoveries low/1 recovery high), and phosphorus (55 results/2 recoveries low/7 recoveries high). The IC anions and sulfide tend to exhibit a positive bias in their MS/MSD recoveries.

- **Metals:** Of the 18,556 MS/MSD results that met the evaluation criteria, 47 MS/MSD recoveries were low and 22 were high for an acceptance rate of 99.6%. Of 9,161 MS/MSD RPDs, 4 exceeded the RPD limit, for a success rate of 99.9%. The out-of-limit results were scattered over 19 different metals. Metals with five or more MS/MSD recovery failures were calcium (670 results/7 recoveries low/1 recovery high), chromium (902 results/2 recoveries low/3 recoveries high), magnesium (680 results/19 recoveries low/2 recoveries high), sodium (671 results/6 recoveries low/1 recovery high), strontium (550 results/1 recovery low/6 recoveries high), and beryllium (551 results/ 0 recoveries low/5 recoveries high).

- **VOCs:** 7,734 MS/MSD recoveries that met the evaluation criteria; 109 MS/MSD recoveries were low and 17 were high, for an overall success rate of 98.3%. Of 3,861 MS/MSD RPDs, 65 exceeded the RPD limit, for a success rate of 98.3%. The out-of-limits MS and MSD RPD results were scattered over 34 different VOC analytes. The analytes with at least 10 MS/MSD recovery failures were acetone (268 results/35 recoveries low/2 recoveries high) and 2-butanone (270 results/21 recoveries low/0 recoveries high). For these analytes, most of the out-of-limit MS/MSD recoveries were low.

- **SVOCs:** 6,640 MS/MSD recoveries met the evaluation criteria; 137 MS/MSD recoveries were low and 24 were high, for an overall success rate of 97.6%. Of the 3,286 evaluated MS/MSD RPDs, 202 were greater than the RPD limit, for a success rate of 93.9%. The SVOC methods with out-of-limit MS/MSD recoveries were as follows:

  - Method 8081 pesticides (1,178 results/2 recoveries low/13 recoveries high; 593 MS/MSD RPDs with 40 failures), Method 8151 herbicides (454 results/2 recoveries low/3 recoveries high; and 227 MS/MSD RPDs with 13 failures).

  - Method 8270 SVOCs and PAHs (4,569 results/115 recoveries low/6 recoveries high; 2,217 MS/MSD RPDs with 134 failures), extractible petroleum hydrocarbons (24 results/2 recoveries low/2 recoveries high; 10 MS/MSD RPDs with 1 failure), and TPH SVOCs (85 results/16 recoveries low/0 recoveries high; 39 MS/MSD RPDs with 10 failures).

  - The EPA Method 8082 PCBs and Method 8290 dioxins had no MS recovery failures; polychlorinated biphenyls (PCBs) reported 53 MS RPDs, with 4 RPDs greater than the QC limit.

- **Radioanalytes:** 439 MS/MSD recoveries met the evaluation criteria, with 14 recoveries low and 27 recoveries high for an overall success rate of 98.6%. Only four of 126 MS/MSD RPDs exceeded the RPD limit, for a success rate of 96.8%. Analytes with out-of-limit MS/MSD recoveries include carbon-14 (82 results/1 recovery low/1 recovery high; 13 MS/MSD RPDs/3 failures), gross alpha, (122 results/4 recoveries low/15 recoveries high; 50 MS/MSD RPDs/1 failure), gross beta (121 results/3 recoveries low/6 recoveries high), iodine-129 (38 results/1 recovery low/0 recoveries high), and tritium (108 results/5 recoveries low/5 recoveries high).

E4.3.4 Laboratory Sample Duplicates

Laboratory sample duplicates give a measure of the repeatability of an analytical result. Only the sample results with values five times greater than the MDL or the MDC, or one times the EQL, were evaluated. The RPDs for sample duplicates that met the evaluation criteria were compared to a maximum of 20%. When laboratory sample duplicate RPDs are outside of QC limits, laboratories may assign a laboratory qualifier of "X" and an accompanying explanatory note.

The laboratories reported 5,075 laboratory sample duplicates for 2019. A total of 1,918 (37.8%) sample duplicates met the evaluation criterion; of these, 165 RPDs exceeded the precision criteria for an overall acceptance rate of 91.4%. This acceptance rate is slightly lower than those for LCSDs (99.8%) and MS/MSDs (98.2%) (discussed in previous sections) but still demonstrates reasonable analytical reproducibility. By analyte class, laboratory sample duplicate data were reported for general chemical parameters, ammonia and anions, metals, SVOCs, and radioanalytes. For the radioanalytes, the laboratory sample duplicate is the primary measure of analytical precision.

- **General chemical parameters:** The general chemical parameters had 272 duplicates that met the evaluation criterion, of which 9 exceeded the QC limit. The RPD failures were for TOX (20 results/ 9 failures).
- **Ammonia/anions:** Ammonia and anions had 1,069 duplicates meet the evaluation criterion, of which 10 exceeded the QC limit. The IC anions had a number of RPDs that exceeded the QC limit: bromide (2 results/1 exceedance), chloride (304 results/1 exceedance), fluoride (121 results/1 exceedance), ammonia (2 results/1 exceedance), nitrate (289 results/ exceedance), and free cyanide (35 results/ 5 failures).
- **Metals:** Metals had 107 duplicates that met the evaluation criterion with 3 RPD failures. The RPD failures were for Method 7196 Cr(VI) (106 results/3 failures). The other duplicate that met evaluation criterion was for mercury (1 result/0 failures).
- **VOCs:** No sample duplicates for the VOCs met the evaluation requirement.
- **SVOCs:** No sample duplicates for the SVOCs met the evaluation requirement.
- **Radiochemical parameters:** For the radioanalytes, 470 sample duplicates met the evaluation criterion; 143 of these exceeded the QC RPD criterion. The out-of-limit RPDs were distributed over the following: carbon-14 (19 results/6 failures), cesium-134 (1 result/1 failure), cesium-137 (3 results/1 failure), cobalt-60 (4 results/2 failures), europium-152 (1 result/1 failure), europium-154 (3 results/2 failures), gross alpha (35 results/19 failures), gross beta (68 results/12 failures), iodine-129 (38 results/11 failures), potassium-40 (1 result/1 failure), radium-226 (3 results/3 failures), selenium-79 (2 results/2 failures), strontium-90 (12 results/3 failures), technetium-99 (40 results/ 4 failures), thorium-228 (1 result/1 failure), tritium (67 results/6 failures), uranium-233/234 (71 results/22 failures), uranium-235 (27 results/14 failures), and uranium-238 (72 results/ 32 failures).

E4.3.5 Surrogates

Surrogates are used to monitor percent recovery during sample analysis for VOCs and SVOCs. Surrogates are typically deuterated, fluorinated, or brominated organic compounds with chemical properties similar to those of the analytes of interest in a sample but are not normally found in environmental samples. Known amounts of the surrogates are added to the sample prior to sample preparation and analysis to monitor the recovery of organic compounds during sample preparation and analysis.

Table E-1 indicates that percent recoveries for surrogates are to be compared either to the Table E-1 acceptance criteria or to statistically derived, laboratory-specific process control limits. The recovery limits specified in Table E-1 may be stricter than laboratory process control limits for those same analytes. Consequently, the Table E-1 criteria may generate more surrogate recovery failures than the laboratory process control limits. When laboratory surrogate percent recoveries are outside of laboratory QC limits, the laboratories may assign a laboratory qualifier of "X" and an accompanying explanatory note in the data report or case narrative.

Surrogate data were reported for VOCs and SVOCs. Table E-13 indicates that for the 14,142 surrogate recoveries reported in 2019, 55 recoveries were less than the lower QC control limit and 12 exceeded the upper QC control limit, for an overall success rate of 99.5%. For the same reporting period, the laboratories reported a total of 566 surrogate duplicates, with no RPDs exceeding the QC RPD criterion for an overall success rate of 100%. These success rates, along with those for the other measures of laboratory accuracy and precision, continue to provide assurance that the laboratories are producing VOC and SVOC data with sufficient accuracy and precision to meet the needs of the groundwater monitoring program.

- **VOCs:** The laboratories reported 8,822 surrogate recoveries, with 2 recoveries less than the lower recovery limit and no recoveries greater than the recovery limit, for a success rate of 99.9%; Of the 509 surrogate duplicates reported, none were greater than the surrogate RPD limit for a 100% success rate.
  - **EPA Method 8260 VOCs:** All 8,643 surrogate results were within QC limits, for a 100% success rate. In addition, all 500 surrogate duplicates met the QC RPD limit.
  - **TPH-gasoline range:** Of 179 surrogate recoveries, 2 recoveries were lower than the QC limits. Neither of the surrogate duplicates exceeded the QC RPD limit.
- **SVOCs:** The laboratories reported 5,320 SVOCs surrogate recoveries, with 53 recoveries less than the lower QC limit and 12 greater than the upper QC limit, for a success rate of 98.8%. The laboratories also reported 57 surrogate duplicates, with none that exceeded the RPD criterion, for a success rate of 100%. For the SVOC analytes, the laboratories reported the following:
  - **EPA Method 8081 pesticides:** Of 456 surrogate recoveries, 3 recoveries were low and 3 were high.
  - **EPA Method 8082 PCBs:** Of 537 surrogate results, all recoveries were within QC limits. Each of the 24 surrogate duplicates met QC RPD criterion.
  - **EPA Method 8151 herbicides:** Of 198 surrogate results, 5 recoveries were low and 4 were high. All three surrogate duplicates met QC RPD criterion.
  - **EPA Method 8270 SVOCs:** Of 3,766 surrogate recoveries, 30 recoveries were low and 5 were high. All 12 of the surrogate duplicates met the QC RPD criterion.
  - **Extractable petroleum hydrocarbons:** None of the 66 surrogate result recoveries were outside of the QC limits.
  - **TPH-diesel range:** Of 297 surrogate results, 15 recoveries were out low and none were out high. Of 30 surrogate duplicates, 1 exceeded the QC RPD limit.

E5 Laboratory Performance Evaluation

During 2019, laboratory performance was tracked using two methods: the groundwater quarterly blind standards program, and laboratory performance evaluation programs. Section E5.1 discusses the results of the blind standards program, and Section E5.2 discusses the laboratory performance evaluation programs.

E5.1 Quarterly Blind Standard Evaluations

The groundwater monitoring program issues blind standards to the supporting laboratories to provide a measure of intralaboratory and interlaboratory precision and accuracy. These standards help S&GRP troubleshoot analytical problems identified through data reviews and QC evaluations. The blind standards may also be used to confirm the adequacy of corrective actions to resolve analytical problems. Blind standards are required to be submitted to the participating laboratories on a quarterly basis (CHPRC-00189). For 2018, the fourth quarter blind standard results were not provided in time to be included in the 2018 DUA and are included in the 2019 DUA.

The quality requirements and control limits for the groundwater monitoring blind standards are provided in CHPRC-00189 and are listed in Table E-14. A success rate is calculated using Equation E-4 for the results returned by each supporting laboratory:

$$Success\ rate = \frac{Number\ of\ results\ meeting\ QC\ recovery\ criteria}{Total\ number\ of\ results\ reported} \times 100 \qquad \text{(Equation E-4)}$$

The acceptance criterion for the success rate is 80% (CHPRC-00189).

Table E-14. Groundwater Blind Standard Recovery and Precision Requirements

Analyte Class	Recovery Limits (% Recovery)	Precision Limit[a] (% RSD)
General chemical parameters	75–125	≤25
Ammonia and anions	75–125	≤25
Metals	80–120	≤20
Volatile organic compounds	75–125	≤25
Semivolatile organic compounds[b]	N/R	N/R
Radiological parameters	70–130	≤20

Source: CHPRC-00189, *Environmental Quality Assurance Program Plan*.

Note: Blind standards are required to be submitted to participating laboratories on a quarterly basis. The identity of the analytes and their concentrations vary from quarter to quarter.

a. If the results are <5 times the required detection limit, then the criterion is that the maximum difference of the results of the replicates is less than the required detection limit.

b. The blind standards program does not require semivolatile organic compound standards.

N/R = not required

RSD = relative standard deviation

During 2019, the groundwater monitoring program sent blind standards to ALS, GEL, SWRI, TADN, and TASL. Of the blind standard results for all laboratories during 2019 and the fourth quarter of 2018, 85.9% were acceptable. GEL and TASL did not meet the 80% acceptance criterion for one or more quarters in 2019. Table E-15 presents the success rates for each laboratory by quarter during this reporting period.

Table E-15. Groundwater Blind Standard Recovery and Precision Requirements

Laboratory	Success Rate (Percent) by Quarter[a]				
	2018 4th Quarter[b]	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
ALS	95.5	100	93.8	85.7	95.7
GEL	85.7	70.0	96.4	83.3	88.6
SWRI	100	N/A	100	N/A	100
TADN	79.2	91.3	88.2	88.9	83.3
TARL	88.9	N/A	N/A	N/A	N/A
TASL	79.2	60.9	94.4	73.9	87.5
Overall	87.1	79.1	93.8	82.6	88.8

a. Success rate = 100 × number of results within quality control recovery criteria/total number of results submitted. The minimum acceptable success rate is 80% (CHPRC-00189, *Environmental Quality Assurance Program Plan*). Success rates less than the 80% criterion are denoted by yellow-shaded cells.

b. These results were not available in time for the 2018 annual groundwater report.

ALS = ALS Laboratory
GEL = GEL Laboratory
N/A = not available
SWRI = Southwest Research Institute
TADN = TestAmerica–Denver
TARL = TestAmerica–Richland
TASL = TestAmerica–St. Louis

Pacific Northwest National Laboratory personnel prepared the blind standards for 2019. Blind standards were generally prepared in triplicate to check laboratory analytical accuracy and precision. For most constituents, the blind standards were prepared in a groundwater matrix from an appropriate background well to simulate actual groundwater samples. Multi-metal blind standards for analysis by ICP techniques were prepared in deionized water using commercially prepared metal standards. The blind standards were submitted to the laboratories as routine groundwater samples.

After the laboratories reported the blind standard results, the results were compared with the spiked concentrations to generate percent recoveries and percent RSDs. The percent recoveries and percent RSDs were compared to the control limits to determine whether the data met the QC criteria.[5] Out-of-limit results were reviewed for errors. In situations where several results for the same method were unacceptable, a request for data review may be generated to reanalyze the blind samples (if within holding times) or to recheck the results. Chronic out-of-limit results were discussed with the laboratory, potential problems were investigated, and corrective actions were requested when appropriate. Occasionally, several laboratories reported very similar out-of-limit results; in those cases, a blind standard makeup error was suspected to have occurred. At the discretion of the S&GRP blind standards scientist, the out-of-limit results were removed from the laboratories' submitted results and were not counted.

[5] If the blind standard concentration is less than five times the RDL for the analyte, the secondary precision criterion is used: the difference between the maximum and minimum values reported must be less than the RDL (DOE/RL-91-50).

E5.2 Laboratory Performance Evaluation Programs

During 2019, Environmental Resources Associates (ERA) and U.S. Department of Energy (DOE) conducted national studies to evaluate laboratory performance for chemical and radiological constituents. ALS, GEL, SWRI, TADN, and TASL participated in the EPA-sanctioned water pollution/water supply performance evaluation studies conducted by ERA. The laboratories also participated in the DOE Mixed Analyte Performance Evaluation Program, and three of the laboratories participated in the ERA InterLaB RadCheM Proficiency Testing Program.

Furthermore, each contract environmental laboratory was required to participate in the DOE Consolidated Audit Program–Accreditation Body program and be accredited by an accreditation body in order to receive Hanford Site environmental samples. All seven laboratories maintained their accreditation through this program.

E6 Data Usability Conclusions

For 2019, the overall groundwater monitoring data set met the requirements of CHPRC-00189 with no major deficiencies. The data usability conclusions are summarized in the following sections.

E6.1 Data Verification Considerations

Data verification is summarized here using the data quality indicators: precision, accuracy, representativeness, comparability, completeness, and sensitivity.

E6.1.1 Data Verification: Precision

Overall precision in the data set was determined using a number of precision metrics. Table E-16 summarizes the field QC metrics for field sample duplicates and field sample splits. Table E-17 presents a summary of the laboratory QC metrics for laboratory sample duplicates, LCSD, MSD, and surrogate duplicates. All measures of precision met the Table E-1 requirements with better than a 91% success rate.

E6.1.2 Data Verification: Accuracy

Overall accuracy in the data set was determined using several laboratory accuracy metrics. Table E-18 summarizes the laboratory QC metrics for LCSs, MSs, and surrogates. All three measures of analytical accuracy met the Table E-1 requirements for laboratory accuracy with better than a 98% success rate.

E6.1.3 Data Verification: Representativeness

Field sampling and laboratory analytical methods based on industry-recognized standards and the observance of proper sample preservation and holding times help ensure that the final analytical results are as representative of Hanford Site groundwater, as practicable. Field Sampling Operations acquired groundwater monitoring field samples and generated field blanks in accordance with approved procedures that follow EPA guidelines and industry standards for performing groundwater sampling. The eight laboratories that generated data for the groundwater monitoring program performed sample preparation and analysis using methods based on recognized standard methods (Table E-4). Correct sample preservation and the observance of sample holding times also ensures that the values reported for field samples are representative of the sampled source. For 2019, 99.7% of samples were properly preserved prior to analysis, and the holding times were met for 98.9% of the analytes reported.

Table E-16. Summary of Field QC Precision Metrics

Field QC Duplicate Type	Number Duplicates	Number of Duplicate Nondetects	Percent of Duplicate Nondetects	Number of Duplicates Evaluated	Percent of Duplicates Evaluated	Number of Duplicates Out	Percent of Duplicates Good	Percent of Duplicates Out
Field QC sample duplicates	20,073	12,172	60.6	7,901	39.4	607	93.7	7.7
Field QC sample splits	190	106	55.8	84	44.2	0	100	0.0

QC = quality control

Table E-17. Summary of Laboratory Precision Metrics

Laboratory Duplicate Type	Number of Duplicates	Number of Duplicates Evaluated	Percent of Duplicates Evaluated	Number of Duplicates Out	Percent of Duplicates Good	Percent of Duplicates Out
Laboratory sample duplicates	5,075	1,918	37.8	165	91.4	8.6
Laboratory control sample duplicates	5,014	5,014	100	8	99.8	0.2
Laboratory matrix spike duplicates	16,621	16,500	99.3	277	98.3	1.7
Laboratory surrogate duplicates	566	566	100	0	100	0

N/A = not applicable

Table E-18. Summary of Laboratory Accuracy Metrics

Laboratory Standard Type	Number of Standards	Number of Standards Evaluated	Percent of Standards Evaluated	Number of Standards Out	Percent of Standards Good	Percent of Standards Out
Laboratory control samples	38,552	38,552	100	105	99.7	0.3
Laboratory matrix spikes	36,134	35,804	99.1	484	98.6	1.4
Laboratory surrogates	14,142	14,142	100	67	99.5	0.5

Due to the closure of a local laboratory supporting groundwater analysis, holding times were missed for several samples requiring analyses with short holding times (<48 hours). Cr(VI), which has the shortest holding time and the greatest number of holding time exceedances, has been observed to be stable in Hanford Site groundwater over an extended period (up to 6 months in one study); therefore, the missed holding times are not expected to have a significant impact on the results. For nitrate/nitrite, the relatively small nitrite concentrations compared to the nitrate values in most Hanford Site groundwater samples combined with the relatively few missed holding times for anions, the data impacts from these missed holding times are minimal. Efforts are underway to establish local capability for these two analytical methods so that the need to ship these samples can be reduced or eliminated.

E6.1.4 Data Verification: Completeness

Section E4.1 discusses four aspects of data completeness for the 2019 groundwater monitoring program, which are summarized as follows:

- **Percentage of successful sampling events:** 97.3% of planned groundwater samples for 2019 were collected.
- **Percentage of field QC samples collected:** For 2019, the number of field QC samples collected met or exceeded groundwater monitoring program requirements.
- **Percentage of data with no potential QC issues:** For 2019, the estimated percentage of data without potential QC issues is 95.7%, which is well above the completeness goal of 85%.
- **Sample preservation and holding times:** 98.8% of groundwater samples were properly preserved at the time of analysis, and 98.9% of samples were analyzed within the required holding times.

E6.1.5 Data Verification: Sensitivity

Sensitivity was not specifically investigated for this DUA.

E6.2 Data Validation Considerations

Third-party data validation was not performed for the 2019 routine groundwater monitoring data set.

E7 Summary

The QC data for the 2019 groundwater monitoring data set indicate that the data set may be used for its intended purposes.

The overall percentage of data quality issues increased from 3.4% in 2018 (Table E-6 in DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*) to 4.3% in 2019 (Table E-6). The number of rejected results (qualified “R”), missed holding times (qualified “H”), and method blank contamination issues (qualified “B” or “C”, depending on analyte class) increased for several analyte classes. These increases were partially offset by decreases in data quality problems between 2018 and 2019 for other analyte classes.

The increase in missed holding times for anions, general chemistry parameters, and metals (specifically Cr(VI)) is attributed to closure of the local laboratory supporting analysis of samples with short holding times (<48 hours). This precluded delivery of samples to a laboratory within a few hours of collection. First priority was given to the short hold-time analyses, but due to the shipping times involved, more holding times were missed for Cr(VI) (24-hour hold time) and nitrate/nitrite (48-hour holding time) in 2019. Cr(VI) has been observed to be stable in Hanford Site groundwater for up to 6 months

(Section 4.3.7.2 in DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*); therefore, the missed holding times are not expected to have a significant impact on the results. For nitrate/nitrite, the concern is conversion of nitrite to nitrate. Given the relatively small nitrite concentrations compared to the nitrate values in most Hanford Site groundwater samples, the data impacts from these missed holding times are minimal. Efforts are underway to establish local capability for analytical methods with short holding times to allow for fewer missed holding times in the future. It should be noted that there was a significant decrease in holding-time exceedances for volatile organic analyses (from 310 analyses in 2018 to only 3 analyses in 2019).

The number of samples affected by method blank contamination increased for general chemistry parameters, ammonia/anions, and metals results between 2018 and 2019. Results for these three analyte classes were qualified "C" when an analyte was detected in both the sample and associated method blank, and the blank concentration was ≥5% of the concentration reported for the groundwater sample. The largest increase in the number of results qualified "C" was for general chemistry parameters, which increased from 218 to 729. The number of results qualified "C" for ammonia/anions (from 65 to 83) and metals (from 2,483 to 3,028) also showed large increases in 2019 compared to 2018. The number of results for VOCs, SVOCs, and radiochemical parameters qualified based on potential influence of contamination during preparation and/or analysis either decreased (VOCs from 49 to 9) or remained approximately the same (SVOCs from 123 to 130; radiochemical parameters 53 to 47) in 2019 compared to 2018.

There was a notable increase in rejected results (qualified "R") for general chemistry parameters (from 1 to 44), ammonia/anions (from 5 to 17), metals (from 5 to 101), VOCs (from 1 to 57), and radiochemical parameters (from 11 to 104) in 2018 compared to 2019. More than half the general chemistry parameters qualified "R" were field parameters (dissolved oxygen, pH, oxidation-reduction potential, specific conductance, temperature, and turbidity). The increase in ammonia/anions and metals results qualified "R" is linked, in part, to the increase in gross exceedance (more than two times) of holding times. Radiochemical parameters qualified as "R" were primarily noted as considered to be false-positive results based on low abundance, high peak width, no valid peak, or high counting uncertainty associated with the reported result.

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