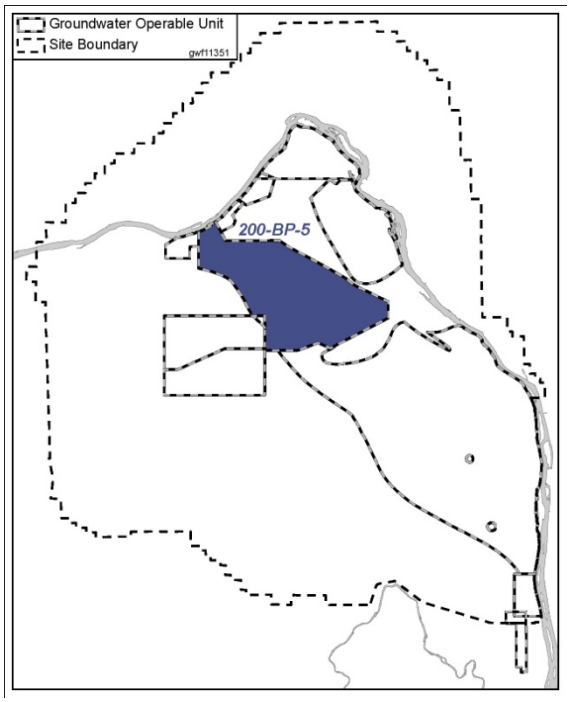
3.4 200-BP-5

G.S. Thomas



This section describes the groundwater flow and contaminant distribution in 200-BP-5, which includes the north portion of the 200 East Area and adjacent 600 Area. The 200-BP-5 area within the adjacent 600 Area extends eastward to the east end of Gable Mountain, then northwest to the Columbia River between interest areas of 100-BC and 100-K. Finally, the 200-BP-5 area is closed by a line extending back to the 200 East Area through the Gable Butte/Gable Mountain Gap (Gable Gap). Figures 3.4-1 and 3.4-2 identify the waste sites, waste management units, and wells in the 200 East Area and 600 Area portions of the interest area. Currently, there are84 routinely sampled wells located south of the Gable Gap (near major sources of groundwater contamination) considered near-field 200-BP-5 wells. Eight additional routinely sampled wells located north of Gable Gap are considered far-field wells.

DOE monitors groundwater in 200-BP-5 to track local and regional contaminant plumes associated with past-practice sites in accordance with CERCLA and the AEA. The current monitoring is in association with the RI/FS process until final cleanup decisions are made. A ROD has not yet been prepared. Ninety-two wells are routinely monitored for CERCLA in accordance with *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49). An additional 15 wells were added in accordance with the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18). The main CERCLA sites that have contributed or are currently contributing to groundwater contamination in 200-BP-5 include:

- 216-A-25 Pond (Gable Mountain Pond)
- 216-B-2-2 Ditch
- 216-B-5 Injection Well
- 216-B-12 Crib
- BY Cribs and other proximal waste sites (216-B-7A&B and 216-B-8 Cribs)

In addition, the monitoring network is supplemented by 76 wells associated with sites that are monitored in accordance with RCRA Plans. Forty-six of the 76 RCRA wells are sampled for both CERCLA and RCRA requirements. The RCRA sites in 200-BP-5 include:

- Single-shell tank farms at WMA B-BX-BY and WMA C
- 216-B-63 Trench
- LERF
- LLWMAs-1 and 2

Two of these sites, WMA B-BX-BY and WMA C, have impacted groundwater quality and are in assessment monitoring. Twenty-six wells are also monitored for AEA requirements at LLWMA-1 and

2 in accordance with DOE/RL-2000-72. All 26 of the AEA wells are also sampled for RCRA requirements and 20 are also sampled for CERCLA requirements.

200-BP-5 at a Glance

B Plant Operations:	**1945–1952 (Plutonium separation)** **1967–1985 (Strontium and Cesium recovery)**		
2011 Groundwater Monitoring			
Contaminant	**Drinking Water Standard**	**Maximum Concentration[a]**	**Plume Area[b] (km^2)**
Nitrate	45 mg/L	1,700 mg/L	7.2
Iodine-129	1 pCi/L	6.8 pCi/L	6.4
Technetium-99	900 pCi/L	36,500 pCi/L	2.4
Uranium	30 µg/L	2,420 µg/L	0.85
Strontium-90	8 pCi/L	4,400 pCi/L	0.27
Cyanide	200 µg/L	1,500 µg/L	0.24
Tritium	20,000 pCi/L	39,000 pCi/L	0.21
Remediation			
B Complex perched aquifer pump-and-treat (treatability test): • Being performed by the 200-DV-1 Operable Unit • Test successful; ~90,000 liters pumped in 2011 Final action 200-BP-5 record of decision scheduled for 2016			

a. Maximum concentration within the regional unconfined aquifer (i.e., excludes the perched aquifer beneath the B Complex).

b. Estimated area above listed drinking water standard.

A detailed discussion of the geology and hydrogeology within the 200-BP-5 Operable Unit is provided in DOE/RL-2007-18. The following summarizes key characteristics of the aquifer and flow characteristics.

The geology within 200-BP-5 consists of sediments of the Hanford formation and Ringold Formation overlying the Saddle Mountains Basalt. The uppermost basalt member of the Saddle Mountains Basalt is generally the Elephant Mountain Member. This member defines the base of the unconfined aquifer, with the exception of the Gable Gap and area further north. In the Gable Gap area, portions of the Elephant Mountain, Pomona, Esquatzel, and Asotin members of the Saddle Mountains Basalt were removed by erosion, exposing and interconnecting the lower permeability Rattlesnake Ridge and Selah interbed hydraulic units to the unconfined aquifer. An excellent cross section of this area is provided in Figure E-5 and E-10 in Appendix E. Groundwater elevations in the interbeds are higher than the overlying unconfined aquifer water table, indicating an upward hydraulic gradient and flow regime. Therefore, groundwater contamination migrating north of the 200 East Area is constrained to the unconfined aquifer within the highly permeable Hanford formation. North of Gable Gap, a high-angle reverse fault shifted basalt upward across the Ringold Formation lower mud, which defines the base of the unconfined aquifer north of the fault.

The unconfined aquifer is mainly contained within moderate to low-permeability Ringold Unit A (hydraulically subdivided into units 9A, 9B, and 9C as explained in Appendix E) sediments along the southwestern boundary of the Operable Unit. The Ringold sediments extend from the southerly portion of the LLWMA-1, east of B Plant near well 299-E28-6, and into the 200-PO-1 OU as defined in PNNL-12261 (plate maps 3, 4, and 5). Two 200-BP-5 RI wells were drilled through the Ringold Formation to basalt near B Plant in CY 2010. Based on these wells, the aquifer thickness in this area is ~18.3 meters and it lies entirely within the Ringold Formation.

North and east of this area, cataclysmic flooding eroded some to all of the Ringold Formation sediments and deposited sediments of the Hanford formation. As a result of past folding of the underlying basalts, the aquifer thins to the north-northeast. Along the northern boundary of the 200 East Area, the aquifer becomes very thin or is absent. East of the 200 East Area, the Ringold sediments are again present throughout the aquifer. Most of the sediments east of the 200 East Area are comprised of the Ringold lower mud unit. This unit creates a semiconfined aquifer where it overlies the silty, sandy, gravelly Ringold Unit A and the Elephant Mountain Basalt. The Ringold lower mud unit is mainly the only saturated unit that extends north to Gable Mountain, and groundwater contaminants are generally west of

this unit. An exception is beneath both the Gable Mountain Pond and B Pond, where a few contaminants still reside.

The saturated glaciofluvial Hanford formation and/or Cold Creek units are deposited in an eroded channel between the Ringold Formation sediments discussed above (i.e., to the east and west). Some remnant Ringold Formation sediments are present within paleochannels north of the 200 East Area, as discussed in PNNL-19702. The saturated Hanford sediments are thickest within the southerly portion of the operable unit and thin as the sediments extend to the northwest toward Gable Gap. Previous folding of the underlying basalts causes the aquifer to thin to apparently a couple meters or less between the 200 East Area and Gable Gap. The saturated Hanford sediment extending northwest of the 200 East Area is the primary groundwater flow path from the northwest portion of the 200 East Area to Gable Gap. It is worth noting that the more permeable Hanford sediments are juxtaposed with the remnant Ringold Formation paleochannel sediments. Groundwater contaminants migrate primarily within the more permeable Hanford sediments as opposed to the Ringold sediments. The thinnest part of the saturated Hanford sediments is thought to be northwest of well 699-49-57A (Figure 3.4-2). A cross section of this area is provided on Figure A.5 of PNNL-19702; the primary flow path is shown between wells 699-50-59 and 699-50-56 on Figure A.5. Geophysical methods have been used in this area, but the aquifer thickness remains uncertain.

In the 200 East Area, groundwater flows into 200-BP-5 from the southwest (Figure 3.4-3). A groundwater divide is assumed to be located near the boundary between 200-BP-5 and 200-PO-1. Flow entering north of the divide flows north and northwest towards the Gable Gap, while south of the divide groundwater flows northeast-east. Flow in the northeast part of the 200 East Area also appears divided, with groundwater near the west part of the LLWMA-2 flowing west and northwest towards WMA B-BX-BY. Near the east part of LLWMA-2, flow appears to be south. Occasionally, this flow regime is disrupted by high Columbia River spring stages. The first disruption occurred in 2008-2009 when a flow reversal was observed in the northwest corner of the 200 East Area (DOE/RL-2008-66). Another disruption in the northwest corner of the 200 East Area occurred in 2011. Flow began to change from northwest to south-southeast in June 2011. By August 2011, a statistically significant gradient to the south-southeast was measured (Figure 3.4-4). The south-southeast flow direction was maintained through the remainder of the year. This reversal was also visible by the change in groundwater contaminant concentrations beneath the WMA B-BX-BY and BY Cribs, discussed further in Sections 3.4.1.1, 3.4.3.1, 3.4.4.1, and 3.4.6. Gradient declines were observed in December, initiating a probable return to prior flow conditions.

In 2011, the groundwater gradient measurements in the north part of 200 East Area were corrected for barometric responses to normalize the data to a constant pressure. This action was included with the highly accurate casing elevation surveys and borehole deviation surveys previously completed at fourteen wells across this area. The drivers for this action are the RCRA regulations requiring understanding of the groundwater flow direction for upgradient/downgradient well comparisons during detection monitoring and rate of hazardous waste constituent movement for sites in assessment. Locally, this information is derived for LLWMA-1 and WMA B-BX-BY. In addition, 11 wells near LLWMA-2 with previous corrections as stated above were also corrected for barometric response. Because of the flat nature of the water table and a possible divide near the 216-B-63 Trench and LLWMA-2, the gradient was not measurable. It is recommended that a regional approach be investigated to determine the gradient in this area. The regional approach would entail evaluating existing wells across the east portion of the 200 East Area for spatial continuity, correcting for deviation and barometric response, and resurveying to a common datum.

Other important concepts associated with 200-BP-5 include the following:

- Principal sources of groundwater contamination include cribs, ponds, ditches, injection wells, and single-shell tanks that formerly leaked. These facilities are currently inactive. In addition,

the pumpable liquids within the single-shell tanks have been removed. However, residual liquid waste within the vadose zone has not yet been remediated and remains a source of present and future contamination to the groundwater.

- Nitrate, iodine-129, technetium-99, and uranium are the principal groundwater contaminants of concern because of either their widespread distribution or concentrated levels associated with ongoing drainage from the vadose zone.
- Smaller plumes of cesium-137, cyanide, plutonium-239/240, strontium-90, sulfate, and tritium also exceed their respective drinking water standards. These plumes are generally limited to wells beneath the contributing waste site. Cesium-137, plutonium-239/240, strontium-90, and tritium are either stable or decreasing in concentrations because of decay. Cyanide is also decreasing in concentration at the two locations where elevated concentrations occur. Sulfate, while increasing slowly, is at levels just exceeding the secondary drinking water standard.
- All of the near field monitoring wells screened in the unconfined aquifer are screened across the upper part of the aquifer except wells 299-E27-24 and 299-E27-155 near the 241-C Tank Farm and wells 699-53-55A&B west of Gable Mountain Pond.

The ten contaminants of concern identified in DOE/RL-2001-49 are the main constituents discussed in Sections 3.4.1 through 3.4.11. The sections are discussed in descending order of the size of the plume. Additional contaminants exceeding the secondary drinking water standard are also discussed. The additional contaminants and associated sections are as follows: sulfate (Section 3.4.10), iron (Section 3.4.6), arsenic (Section 3.4.11), and fluoride (Section 3.4.11). Manganese also exceeded the secondary drinking water standard in five wells this year, but appears to be associated with well degradation based on visual findings in two representative wells, 299-E33-337 and 299-E33-339. Thus, manganese is not discussed further. In addition, iron is only discussed for wells associated with the ferrocyanide waste disposed at the BY Cribs. Other elevated iron concentrations are generally unfiltered results and are considered to be associated with well degradation, and therefore not discussed further.

Section 3.4.12 summarizes the CERLCA activities completed in 2011, including monitoring, document preparation, treatability test preparation for the unconfined aquifer near WMA B-BX-BY, and treatability test in the perched water horizon near the 241-B Tank Farm.

Section 3.4.13 discusses monitoring results associated with the six RCRA sites. Three of the sites (LLWMA-1, LLWMA-2, and 216-B-63 Trench) are in interim status detection monitoring programs, two (WMA B-BX-BY and WMA C) are in interim status assessment monitoring programs, and one (LERF) has been issued a permit. Summaries in this section discuss indicator parameters, groundwater quality parameters, assessment results, and determinations.

Groundwater data are available in the HEIS database and in the data files accompanying this report. Appendix B provides additional information (including well and constituent lists, maps, and statistical tables) for RCRA monitoring.

One new well was partially drilled in 2011, and no wells were decommissioned. Four wells with high chrome, iron, manganese, and nickel concentrations were internally surveyed using a television camera; and evidence of stainless steel degradation was observed. The degradation appears widespread based on two other television surveys in other areas of 200 East. The degradation appears to be associated with the corrosive nature of the aquifer, local presence of iron rich clay materials, and bacteria. Further discussion on the iron-rich clay materials can be found in *Geochemical Processes Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site* (PNNL-16663). Based on visual observation, the casing conditions were not significant; therefore, no maintenance has been requested at this time.

3.4.1 Nitrate

Nitrate contamination in 200-BP-5 groundwater is primarily due to waste sites that received liquid effluent with high nitrate concentrations. For example, the 216-B-46 and 216-B-49 Cribs received liquid waste with nitrate concentrations near 198,600 mg/L (Appendix C of RPP-26744). The other six cribs associated with the BY Cribs received similar concentrated waste. Dilution of these wastes with groundwater has resulted in concentrations ranging from 841 to 1,700 mg/L in wells beneath the BY Cribs. Other sites that contribute to nitrate contamination at the B Complex include the 216-B-7A&B Cribs, 216-B-8 Crib, and the 241-BX-102 unplanned release (Section 9.1 of PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*). Other waste sites, such as Gable Mountain Pond and B Pond, received effluent with lower concentrations of nitrate according to RPP-26744. In some cases, the nitrate concentration data in RPP-26744 is not consistent with the monitoring results. One example is Gable Mountain Pond where groundwater concentrations should not exceed one mg/L; however, concentrations exceed the drinking water standard of 45 mg/L. In addition, unplanned releases may not have been included for some sites where nitrate plumes exist, such as the 216-B-2 Ditch. Additional inventory information is provided in each subsection.

The 200-BP-5 nitrate plume has expanded in several areas since 2007. Total area of the plume has grown by ~30 percent.

Figure 3.4-5 illustrates the 2011 nitrate plume in 200-BP-5. The plume area has increased in recent years (Figure 3.4-6). Comparing the 2011 plume to that of 2007 (Figures 2.10-10 and 2.10-11 of DOE/RL-2008-01) provides seven significant changes:

1. Nitrate concentrations in wells 299-E32-8, 299-E33-28, 299-E33-29, and 299-E33-30, located beneath the central part of LLWMA-1, now exceed the drinking water standard. The concentration increases in these wells indicate nitrate migration from the B Complex located to the east and from the 216-B-12 Crib to the south.
2. Residual waste drainage from the deep vadose zone beneath the BY Cribs and the predominant historical northwest groundwater flow has caused increased nitrate concentrations to the northwest and expansion of the 450 mg/L nitrate contour toward Gable Gap.
3. Interpretation of basalt above the water table has changed because of recent well installations.
4. The nitrate plume from well 699-53-55C was expanded upgradient towards well 699-50-53A, located to the southeast, because of the new top of basalt interpretation and the past nitrate plume at well 699-50-53A.
5. The Gable Mountain Pond plume has expanded to the west.
6. The plume located east of the 216-B-2 Ditches has expanded to the south.
7. A new plume has formed beneath WMA C.

The distribution of nitrate above the drinking water standard (45 mg/L) in 200-BP-5 is widespread and split into the following eight regions for presentation of the 2011 results:

- B Complex (BY Cribs, 216-B-7A&B Cribs, 216-B-8 Crib, and 241-BX-102 unplanned release)
- Grouped wells 699-53-55A, B, and C near Gable Gap
- Gable Mountain Pond

- 216-B-12 Crib and north to LLWMA-1
- B Plant
- 216-B-5 Injection Well
- 216-B-2 Ditches
- WMA C

The following sections provide additional details on these nitrate plumes and their related sources.

3.4.1.1 Nitrate Near B Complex

The highest nitrate concentrations in 200-BP-5 continued to be reported in wells monitoring the BY Cribs.

Significant nitrate inventories, received at the BY Cribs in the past, have drained through approximately 70 meters of vadose zone to the groundwater. The highest nitrate concentrations in 200-BP-5 in 2011 continued to be reported in wells monitoring the BY Cribs. The highest result (1,700 mg/L) was at well 299-E33-7 in August 2011 (Figure 3.4-7). The value is equal to the highest value reported, November 2009. The nitrate concentration declined significantly in November because of the groundwater flow change to the south-southwest. The decrease at well 299-E33-38 was less than in the other wells beneath the BY Cribs in November because of its south location to the cribs.

The next highest average nitrate concentrations were beneath the 216-B-8 Crib. In 2011, well 299-E33-16 recorded concentrations of 753 mg/L in both January and August (Figure 3.4-8). These concentrations are consistent with the discharge associated with the 216-B-8 Crib. Concentrations increased significantly in December, to 961 mg/L, as a result of the flow change and nitrate migration from the BY Cribs.

Nitrate concentrations to the southeast of the 216-B-8 Crib were between 558 and 584 mg/L in well 299-E33-20 in March and August, respectively (Figure 3.4-8). The concentrations beneath the perched water horizon in wells 299-E33-18, 299-E33-343, and 299-E33-345 were lower by comparison (Figure 3.4-8). In December, concentrations at 299-E33-345 increased from 302 to 382 mg/L. However, this increase may not be representative of groundwater conditions because of problems during well construction (Section 3.4.4.1). In nearby well 299-E33-18, concentrations increased significantly during the same time frame, rising from 392 to 620 mg/L. The increase is primarily due to migration from the 216-B-8 Cribs, but may also be associated with increases within the perched water horizon.

Nitrate concentrations at 299-E33-344, within the perched water horizon, increased from 401 to 810 mg/L between September and December 2011.

Nitrate concentrations at 299-E33-344, within the perched water horizon, increased from 401 to 810 mg/L between September and December. The increase at this well was due to the perched water pumping test in accordance with *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test* (DOE/RL-2011-40). The source of the increase is consistent with early discharge concentrations of nitrate to the 216-B-7A&B Crib versus the 241-BX-102 unplanned release. The early 216-B-7A&B Crib discharges were eight times more concentrated with nitrate than the 241-BX-102 unplanned release. This observation is supported by the lower nitrate groundwater concentrations identified close to the 241-BX-102 unplanned release (for example, wells 299-E33-41 and 299-E33-343)

versus wells located near the 216-B-7A&B Cribs (for example, wells 299-E33-18, 299-E33-20, and 299-E33-345) (Figure 3.4-8). Note the comparison is prior to the flow reversal when infiltration from the perched water horizon was the main source of the elevated nitrate.

The contaminated perched water horizon was considered to be contributing to nitrate increases at well 299-E33-18 in December through the short circuit between the perched horizon and perforations across the perched water zone. However, a recent television survey within well 299-E33-18 showed no moisture within the inner casing. In addition, nitrate increase comparisons for wells 299-E33-343 and 299-E33-18 between August and late November/early December are nearly identical (Figure 3.4-8). Figure 3.4-8 provides the trend in upgradient wells 299-E33-16 and 299-E33-44 for comparison with increases at wells 299-E33-18 and 299-E33-343 associated with migration after the reversal. This indicates the nitrate increases at well 299-E33-18 are primarily associated with migration of higher contaminated plumes to the north.

Nitrate concentrations continue to increase at wells 299-E33-47 and are most likely associated with releases associated with the 216-B-7A&B Crib.

Continuing to the south along the east boundary of the 241-B Tank Farm, nitrate concentrations increased from 300 and 452 mg/L from March to August at well 299-E33-47. Elevated concentrations in March and June indicate residual contaminant drainage near this well. The groundwater flow during that time was towards the northwest, and no significant source is located to the south to southeast (Figure 3.4-9). Because of the limited volume or concentration associated with other waste sites and unplanned releases in the area, the source is believed to be associated with the 216-B-7A&B Cribs.

Nitrate concentrations increased in well 299-E33-337 through July, prior to the flow reversal (Figure 3.4-10). The increase was consistent with technetium-99 increases. The increase was local as no significant increases were seen in adjacent wells 299-E33-48 or 299-E33-338 prior to the flow reversal. The source of the increase is indeterminate.

The nitrate plume from B Complex extends northwest beyond the 200 East Area boundary (Figure 3.4-5). The pathway of migration in this area was discussed in Section 9.1.1.1 of DOE/RL-2011-01. Nitrate concentrations at well 699-49-57A increased from 269 mg/L in 2010 to 322 mg/L in April of 2011, prior to the flow reversal. Farther northwest at wells 699-60-60 and 699-61-62 nitrate concentrations only increased approximately 1.5 mg/L. Concentrations at these wells range between 27 and 35 mg/L. As a result of past tritium and iodine-129 migration between well 699-49-57A and these wells, the 45 mg/L nitrate plume contour is drawn between these wells (Figure 3.4-5). The plume was expanded to the northwest because of the significant increase at well 699-49-57A. The sample was collected in April, before the flow reversal.

3.4.1.2 Nitrate Near Gable Gap

Nitrate infiltration from the BY Cribs into the unconfined aquifer prior to the 1990s migrated north. The center of mass is now 2.2 kilometers to the north near well 699-53-55C. Based on 2011 results compared to 2010, nitrate is continuing to migrate to the northwest into the Gable Gap, as modeled in DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*. Six wells (699-52-55, 699-53-55A, 699-53-55B, 699-53-55C, 699-55-57, and 699-57-59) to the north of the BY Cribs are the primary wells used to define past nitrate migration and the current extent near well 699-53-55C (Figure 3.4-5). In 2011, the plume's orientation extends to the northwest from well 699-53-55C and includes well 699-55-57, where concentrations increased slightly from 2010 (83.2 to 85.9 mg/L). This indicates continued migration to the northwest. Bounding the plume to the northwest is well 699-57-59, where concentrations did not change significantly.

3.4.1.3 Nitrate in Gable Mountain Pond Area

The former Gable Mountain Pond received low nitrate containing discharges (less than 0.6 mg/L) (RPP-26744). However, there are nitrate concentrations exceeding the drinking water standard within the aquifer beneath this site.

Nitrate concentrations in the upgradient well (east) of the former pond (e.g., 699-54-45A) averaged less than 2 mg/L. This is significantly lower than wells 699-53-48A and 699-54-49 adjacent to the inactive pond, which returned 141 mg/L and 48.3 mg/L, respectively. Note the result for well 699-53-48A is from 2010. Concentrations at well 699-54-49 increased slightly compared to 2010 (48.3 mg/L versus 46.9 mg/L). Over the previous 5 years, concentrations at this well have increased approximately 6 mg/L. The nearest downgradient well (699-55-55), located about 1 kilometer west of the waste site, has nitrate concentrations significantly lower than the drinking water standard. Based on current analytical results, the plume size is increasing slowly to the west.

3.4.1.4 Nitrate near 216-B-12 Crib and Low-Level Waste Management Area 1

The 216-B-12 releases from the 1950s ranged in concentration from 7,650 to 8,300 mg/L, enough to source the 800 mg/L found at depth during the drilling of well 299-E28-30.

Nitrate levels at well 299-E28-18 declined from 190 to 100 mg/L between 2009 and 2011. The source of nitrate contamination at 299-E28-18 is the 216-B-12 Crib. This is based on waste discharge information provided in Appendix C of RPP-26744 and depth-discrete groundwater data collected near the crib. The 216-B-12 liquid waste releases from the 1950s ranged in concentration from 7,650 to 8,300 mg/L, enough to source the 800 mg/L found at depth during drilling of well 299-E28-30. Continued groundwater flow to the north causes elevated nitrate levels at well 299-E28-18. The estimated extent of the 450 mg/L nitrate plume was provided in Section 9.1.1.2 of DOE/RL-2011-01. The methodology used to create the plume configuration is provided in an environmental calculation brief (ECF-200BP5-11-0160, *450 mg/L Nitrate Contour Map at Depth for 2010 Annual Report*). The primary data for the interpretation was based on depth-discrete data during drilling from wells 299-E28-30 and 299-E29-54. Both these wells show lower results in 2011 because they were completed with screens across the upper part of the aquifer, not extending to the depth of the high nitrate levels. Wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan to better define the extent and movement of this deep plume. The draft Sampling and Analysis Plan will be completed in 2012.

The prevailing groundwater flow direction near LLWMA-1 has been to the north-northwest over the past two decades. A change in the flow direction in 2011 may have contributed to concentration declines in 2011 results. Most of the wells had concentrations that declined 10 to 20 mg/L. Results at two wells (299-E28-28 and 299-E32-4) were unchanged. The larger declines occurred in the wells closer to the 216-B-12 Crib.

3.4.1.5 Nitrate in the B Plant Area

B Plant is located near the southern boundary of 200-BP-5. The contaminants in this region appear to have originated at the 216-B-12 Crib, with a nitrate inventory of 2.9 million kilograms. Eight other waste sites in the area have a combined total of 2,934 kilograms of nitrate (Appendix C in RPP-26744). The only other waste site in the area with significant inventory was the 216-B-6 Injection Well, located just south of B Plant, with an inventory of 58,373 kilograms of nitrate. In addition, vadose zone sample results near the 216-B-6 Injection Well indicated little to no nitrate in the deep vadose zone, greater than 61 meters below ground surface. Depth to groundwater in the area is approximately 93 meters.

Nitrate concentrations decrease to the east as seen in the following well comparisons. Nitrate concentration in well 299-E28-17 was 67.7 mg/L compared with 58.9 mg/L at well 299-E28-6, which is located approximately 325 meters to the east of well 299-E28-17. The well construction in both of these wells is similar with 6.1 and 9.1 meters of perforations across the upper unconfined aquifer, respectively. Dilution appears to be the reason for the decrease to the east. Note that a flow divide may exist between these wells.

3.4.1.6 Nitrate near 216-B-5 Injection Well

The two highest nitrate concentrations near the 216-B-5 Injection Well came from wells located to the southwest and west (well 299-E28-3 [67.7 mg/L] and well 299-E29-54 [65.1 mg/L], respectively). According to the conceptual model for flow and the evidence of a deep nitrate plume beneath the B Plant area, nitrate at the 216-B-5 Injection Well (ranging between 56.2 and 59.3 mg/L) appears to migrate from this area. The deep plume beneath sites to the west are discussed in Section 3.4.1.4. Nitrate concentrations drop significantly east of the 216-B-5 Injection Well at well 299-E28-1 (28.2 mg/L). Based on regional iodine-129 results discussed in Section 3.4.2, groundwater at well 299-E28-1 appears to be influenced by sources to the east. Thus, the convergence of flow from the southwest and east appears to occur near the 216-B-5 Injection Well. The groundwater divide is considered to be south-southeast of this location.

Nitrate at the 216-B-5 Injection Well appears to migrate from B Plant.

3.4.1.7 Nitrate near 216-B-2 Ditches

Nitrate concentrations have been increasing since 1994 beneath the 216-B-2 Ditches, primarily due to the unplanned release UPR-200-E-138. This unplanned release was associated with the strontium-90 Product Storage Tank (8-1) located inside the 221-B Building. At the time of the release, strontium-90 was part of a waste fractionization campaign (Section 3.2.2 of DOE/RL-98-28). The process used significant amounts of nitrate in order to dissolve the original precipitates, and additional nitrate was added with calcium for strontium-90 separation. In addition, nitrate contributions may be associated with drainage from fractured basalts to the north. Further discussion on the conceptual transport is discussed in Section 9.1.10.3 of DOE/RL-2011-01.

Nitrate concentrations have been increasing since 1994 beneath the 216-B-2 Ditches, primarily due to the unplanned release UPR-200-E-138.

The nitrate concentrations near the eastern portion of the 216-B-2 Ditches in well 299-E27-10 have continued to record the highest nitrate concentrations in this area since well 299-E34-7 went dry in 2005. There was one exception in fall 2011, when concentrations declined and higher concentrations were at well 299-E27-9, which is located to the west (Figure 3.4-11). Figure 3.4-11 shows nitrate progressively increasing in wells to the southwest to west over the past decade. These increases either infer slow southwest to westward migration at a maximum of 0.1 meter per day or increased extent of residual liquid waste drainage from the vadose zone.

Nitrate increases were also observed in wells 299-E27-22 and 299-E27-25 located to the south and southeast of well 299-E27-10 (Figure 3.4-11), respectively. Because the average nitrate concentrations in well 299-E27-25 increased relative to well 299-E27-22, the plume extent in Figure 3.4-5 was expanded towards well 299-E27-25 compared to 2010.

3.4.1.8 Nitrate at Waste Management Area C

Only two of the ten WMA C wells adjacent the 241-C Tank Farm exceeded the drinking water standard in 2011. The two wells are 299-E27-14 and 299-E27-24. The elevated nitrate concentration in

well 299-E27-14 (southeast side of WMA C) is clearly associated with 241-C Tank Farm releases. However, no known nitrate releases are capable of causing nitrate concentrations of this magnitude (Appendix C of RPP-26744). Nitrate concentrations in well 299-E27-14 are nearly twice as high as upgradient wells along the north part of WMA C. The highest released nitrate inventory is 5,806 kilograms from UPR-200-E-81. These inventories are not significant compared to other sites where groundwater nitrate concentrations have been linked to a vadose zone source such as the 241-BX-102 unplanned release. In addition, past vadose zone investigations at the 241-C Tank Farm have not encountered significant nitrate at depth. Thus, the source of nitrate for the 241-C Tank Farm remains uncertain.

Nitrate concentrations at well 299-E27-14 averaged 91 mg/L, which was only 2 mg/L higher than 2010. The next highest average nitrate concentration, 70 mg/L, was collected at well 299-E27-24, located ~61 meters south of well 299-E27-14. Note that well 299-E27-14 is screened across the upper 2.6 meters of the aquifer, while well 299-E27-24 is screened across the lower 6.1 meters of the aquifer, with the top of the screen ~9 meters below the water table. Approximately 215 meters south, well 299-E24-33 has elevated nitrate concentrations, although below the drinking water standard. Therefore, the orientation of the plume was expanded to the southeast toward this well (Figure 3.4-5).

3.4.2 Iodine-129

Figure 3.4-12 shows iodine-129 distribution in 200-BP-5. Three sources in the southeastern 200 East Area (216-A-10 Crib vicinity, 216-A-29 Ditch, and 216-B-3 Pond) were contributors to the widespread distribution of iodine-129 within the 200 East Area and Gable Gap. Historical review of the contaminant data indicates groundwater migration from the southern portion of the 200 East Area to WMA B-BX-BY and into the Gable Gap. Contaminant contributions of iodine-129 from these waste sites ceased to contribute to the 200-BP-5 plume because the flow divide moved north of these sites as the water table continued to decline. Other likely contributors of iodine-129 to groundwater include the BY Cribs, 241-BX-102 unplanned release, 216-B-8 Cribs, and the 216-B-2 Ditches. All these sites received significant inventories of iodine-129. For example, the average iodine-129 concentrations in waste discharges to the 216-B-49 Crib were ~4,870 pCi/L (Appendix C of RPP-26744). The other BY Cribs and the 216-B-8 Crib received similar concentrations. The 241-BX-102 unplanned release was ~2,900 pCi/L of iodine-129. Water samples from a perched water horizon, approximately 3 meters above the aquifer, have shown average iodine-129 levels exceeding 2.5 pCi/L. Iodine-129 levels at wells 299-E33-343 and 299-E33-345, within the unconfined aquifer beneath this perched zone, are consistently higher than surrounding wells, reflecting drainage from this perched zone.

Three sources in the southeastern 200 East Area (216-A-10 Crib vicinity, 216-A-29 Ditch, and 216-B-3 Pond), now inactive, were contributors to the widespread distribution of iodine-129 within the 200 East Area and Gable Gap.

Other waste sites received effluent with lower concentrations of iodine-129 and/or did not have significant liquid volumes according to RPP-26744. For example, iodine-129 concentrations associated with the 241-B-107 release were 155,358 pCi/L; however, the liquid volume was approximately 53,000 liters, indicating little impact, if any, on the unconfined aquifer. Alternatively, although the iodine-129 concentration for the former 216-B-3 Pond was inconsequential, less than 0.03 pCi/L, according to Appendix C of RPP-26744, there are levels in the groundwater below exceeding the drinking water standard (1 pCi/L). Thus, the information in Appendix C of RPP-26744 for this waste site is not complete.

The 200-BP-5 iodine-129 plume has expanded in several areas since 2007. Total area of the plume has grown by ~10 percent.

Figure 3.4-12 illustrates the 2011 iodine-129 plume in 200-BP-5. The plume area has increased in recent years (Figure 3.4-6). Comparing the 2011 plume to that of 2006 (Figures 2.10-10 and 2.10-11 of PNNL-16346) and 2007 (Figure 2.10-12 of DOE/RL-2008-01) provides five significant changes/observations:

1. The 1 pCi/L iodine-129 contour beneath B Pond has shifted southward and expanded including the former 216-B-3B and C Lobes.
2. Concentrations more than doubled in well 699-43-45 downgradient of 216-B-3 Pond.
3. Concentrations along the south and east side of the 241-B Tank Farm more than doubled.
4. The 200 East Area and Gable Gap plume were connected.
5. The Gable Gap plume expanded to the northwest.

The distribution of iodine-129 above the 1 pCi/L drinking water standard is widespread and split into six regions for 2011 result discussions:

1. B Pond
2. WMA C
3. LLWMA-2
4. 216-B-5 Injection Well
5. 216-B-2 Ditches
6. B Complex and extending northwest beyond well 699-49-57A.

3.4.2.1 Iodine-129 near B Pond

Levels as high as 9 pCi/L were detected in well 699-43-45 downgradient of B Pond. Elevated iodine-129 was also located at well 699-45-42, 2.74 pCi/L, located northeast of 216-B-3. One other well, 699-43-41G (1.81 pCi/L), exceeded the drinking water standard. This well is located north of the 216-B-3B Lobe and east of the 216-B-3A Lobe. These results indicate the iodine-129 inventory for the 216-B-3 Pond, published in Appendix C of RPP-26744, is not representative.

Iodine-129 levels as high as 9 pCi/L were detected in well 699-43-45 downgradient of B Pond.

3.4.2.2 Iodine-129 near Waste Management Area C

All of the wells at WMA C had iodine-129 levels exceeding the drinking water standard (Figure 3.4-12). The levels have fluctuated, but not much decrease has been noted over the past two decades. The source of the iodine-129 was from the southeast, where higher concentrations were present when the flow direction was west-northwest.

3.4.2.3 Iodine-129 near Low-Level Waste Management Area 2

Elevated iodine-129 has been detected in the wells along the south side of LLWMA-2 since monitoring began in the early 1990s. The highest level was in well 299-E27-10 when sampling began, but

have since declined below 2 pCi/L. Iodine-129 concentrations in wells west of well 299-E27-11 have primarily been lower than 1 pCi/L since the mid-1990s when monitoring for iodine-129 began. This indicates the northern and western extent of iodine-129 in this area.

3.4.2.4 Iodine-129 near the 216-B-5 Injection Well

The spatial distribution of iodine-129 at wells near the 216-B-5 Injection Well continue to demonstrate elevated levels of iodine-129 is from the east and the 1 pCi/L drinking water standard contour extends south of this former waste site and to the northwest (Figure 3.4-12). The groundwater flow for transport of iodine-129 from east to west is different from the flow direction of nitrate in this area which indicated southwest to northeast. Thus, the 216-B-5 Injection Well may be near a convergence of flow from the east and southwest.

3.4.2.5 Iodine-129 near 216-B-2 Ditches

Elevated iodine-129 levels were detected in wells beneath the 216-B-2 Ditches as early as the 1990s (Figure 3.4-13). Levels were highest in well 299-E33-36 located just north of the head end of the ditches. The correlation of elevated iodine-129 levels at the 216-B-3 Pond, wells beneath the 216-B-2 Ditches, and wells to the northwest along the south side of WMA B-BX-BY may indicate past contributions from the 216-B-2 Ditches. Because of the recent increases along the south side of WMA B-BX-BY, well 299-E33-36 will be included in the revised 200-BP-5 Sampling and Analysis Plan to better define iodine-129 changes. Alternatively, the iodine-129 increases may be associated with continued migration from sources to the east-southeast, as described in Section 3.4.2.

3.4.2.6 Iodine-129 near B Complex

Elevated iodine-129 in wells along the south side of the 241-B Tank Farm indicates a preferential west-northwest pathway from past sources. Well 299-E33-338 had one of the highest levels of iodine-129, 4.14 pCi/L, in May 2011, before the groundwater flow direction changed. Well 299-E28-8, located approximately 270 meters southwest of well 299-E33-338, also showed elevated levels of iodine-129 (3.45 pCi/L). Contributions from other sources in the vicinity (216-B-63 Trench and 241-B-107 tank release) were ruled out for one or more of the following reasons: limited liquid discharges, location, stratigraphic dip of vadose zone sediments, and low concentrations in groundwater. Note that wells 299-E34-8, 299-E34-10, and 299-E34-12, all located beneath the 216-B-63 Trench, have much lower iodine-129 levels, indicating no contributions from this waste site.

Elevated iodine-129 in wells along the south side of the 241-B Tank Farm indicates a preferential west-northwest pathway from past sources within 200-PO-1 and possibly the 216-B-2 Ditches.

The highest iodine-129 activity in WMA B-BX-BY was at well 299-E33-343 (5.38 pCi/L in May 2011), located adjacent the northwest corner of 241-B Tank Farm and northeast of the 241-BX-102 tank release. Based on inventory levels associated with RPP-26744, the stratigraphic dip of vadose zone sediment, and the iodine-129 levels in the perched water horizon, contributions of iodine-129 from the 241-BX-102 unplanned release at well 299-E33-343 are evident.

Because of the wide swath of elevated iodine-129 from well 299-E28-8 to the BY Cribs, past sources to the southeast appear to have contributed in this area. Iodine-129 from these sources has extended to the northwest beyond the 200 East Area. The 1 pCi/L (drinking water standard) leading contour is shown between wells 699-57-59, 699-59-58, and 699-61-62 (Figure 3.4-12). Because of the increase in iodine-129 levels in these wells, the plume configuration in this area was expanded from 2010.

3.4.3 Technetium-99

Technetium-99 in 200-BP-5 groundwater is primarily because of large disposal inventories to the BY Cribs. Six of the seven cribs received between approximately 14 to 25.5 Ci of technetium-99 (Appendix C of RPP-26744). Other waste sites either received less than 1 Ci of technetium-99 or had relatively small release volumes. Two other sources that impacted the groundwater are associated with the 241-BX and 241-C Tank Farms.

The 241-BX-102 unplanned release was slightly more than 2.27 Ci and is currently the only documented source impacting groundwater from the 241-BX Tank Farm. The 241-C Tank Farm source has not been identified, but inventories exceeding 1 Ci are only associated with the UPR-200-E-82 and UPR-200-E-86 sites (Appendix C of RPP-26744). Recent vadose zone investigations associated with these sites found limited technetium-99 at depth, resulting in conclusions of low potential for groundwater impact. In 2011, an updated leak assessment (RPP-ENV-33418, *Hanford C-Farm Leak Assessments Report*) was released, increasing the technetium-99 inventory for the 241-C-105 and 241-C-110 Tanks to 0.8 and 1.6 Ci, respectively.

The interpretation of the technetium-99 plume (Figure 3.4-14) has changed since 2006 because of new wells installed during the 200-BP-5 remedial investigation and reinterpretation of the top of basalt surface. The most prominent change was redirecting the plume from north to northwest of well 699-49-57A. For comparison, see Figure 2.10-9 of PNNL-16346. The change was based on the 2007 Remedial Investigation results at wells 699-50-56 and 699-52-55. The other change occurred in 2010 when top of basalt reinterpretations found evidence for a paleochannel extending into the basalt southeast of well 699-53-55C. Based on this interpretation, the elevated technetium-99 at well 699-53-55C was extended towards well 699-50-53A, where a significant technetium-99 plume existed in the 1990s. Overall, the size of the technetium-99 plume has not changed significantly since at least 2003 (Figure 3.4-6).

The distribution of technetium-99 above the 900 pCi/L drinking water standard was limited to three isolated regions in 200-BP-5 during 2011 (Figure 3.4-14):

- B Complex and extending northwest beyond well 699-49-57A
- Grouped wells 699-53-55A, B, and C near Gable Gap
- WMA C

3.4.3.1 Technetium-99 near B Complex

Technetium-99 at the BY Cribs was present in liquid effluent in the form of pertechnetate, a negatively charged oxyanion. This form is highly mobile, which contributed to migration of a significant inventory through approximately 70 meters of Hanford vadose zone sediments to the groundwater. The calculated technetium-99 mass in the aquifer continued to increase from 2000 to 2009 (Section 5.3 of PNNL-19277), while the technetium-99 levels rose to historical highs (Figure 3.4-15). By 2009, approximately 6.06 Ci were calculated as being in the groundwater (Table 5-2 of PNNL-19277). The 241-BX-102 unplanned release is also responsible for elevated technetium-99 in the groundwater near wells 299-E33-18, 299-E33-343, and 299-E33-345. These two sources are the primary technetium-99 sources in the B Complex.

The highest technetium-99 activity in 200-BP-5 continued to be reported in wells monitoring the BY Cribs.

The highest technetium-99 sample results in 200-BP-5 continued to be reported in wells monitoring the BY Cribs. The highest result in the unconfined aquifer (36,500 pCi/L) was at well 299-E33-38 in

August 2011 (Figure 3.4-15). This value was 1,500 pCi/L lower than the maximum value in 2010; however, it is one of the highest ever reported at this well. The increase was coincident with a groundwater flow direction change to the south-southwest. The flow change is the reason for the increase at 299-E33-38 because larger inventories of technetium-99 were disposed to Cribs 216-B-44, 216-B-45, 216-B-46, 216-B-48, and 216-B-49, located north of this well.

Adjacent to the north side of the 241-B Tank Farm, technetium-99 concentrations increased in the groundwater during 2011. The highest result was at well 299-E33-18 with a maximum of 30,800 pCi/L in December 2011 (Figure 3.4-15). This result is the highest result reported at this well. The 2011 increase indicates continued infiltration from the perched water horizon. Concentrations in the perched water horizon rose from 5,640 pCi/L in September 2011 to 45,100 pCi/L by December 2011. The increase at the perched water well, 299-E33-344, was because of the perched water pumping test performed in accordance with DOE/RL-2011-40. The source of the increase appears to be consistent with discharge concentrations of technetium-99 to the 241-BX-102 unplanned release versus the 216-B-7A&B Crib. The 241-BX-102 unplanned release was at least three orders of magnitude more concentrated than the 216-B-7A&B Crib discharges.

Technetium-99 also increased significantly in well 299-E33-337 along the south boundary of the 241-B Tank Farm. The increase, ~3,000 pCi/L, occurred over a 7-month period (128 pCi/L in December 2010 to 3,210 pCi/L in July 2011). The increase appears local as no significant increases were seen in adjacent wells 299-E33-48 or 299-E33-338. Near the end of 2011, a significant increase was seen in well 299-E33-338, where concentrations increased from 89.1 pCi/L to 1,100 pCi/L. The increase is a result of contaminant migration associated with the groundwater flow direction change. A smaller increase was seen in well 299-E33-48, indicating a preferential east to southeast flow direction in this area. The source of the increase is indeterminate but may be associated with the 241-BX-102 unplanned release.

Contaminant migration into the upper basalt-confined aquifer, the Rattlesnake Ridge interbed, at well 299-E33-12 is linked to past migration of waste received by the BY Cribs and poor well construction during early Hanford Site operations. Technetium-99 is currently the only contaminant that still exceeds the drinking water standard. The 2011 result was 200 pCi/L lower than the 1,200 pCi/L from 2010. Two new 200-BP-5 RI wells, 299-E33-50 and 299-E33-340, installed to the north and south of well 299-E33-12 were also found to have low levels of technetium-99. Both wells are screen across the upper 4.6 meters of the confined aquifer. Technetium-99 activity in well 299-E33-340 ranged between non-detect and 10 pCi/L in 2011. Technetium-99 in well 299-E33-50 was 47.3 pCi/L.

The technetium-99 plume from B Complex extends northwest beyond the 200 East Area boundary and the trend correlations are the same as those discussed in Section 3.4.1.1 for nitrate. Because of the technetium-99 concentration increases, the 900 pCi/L technetium-99 plume contour is drawn just beyond well 699-49-57A (Figure 3.4-14).

3.4.3.2 Technetium-99 Near Gable Gap

By the early 1990s, the center of mass of the technetium-99 plume, associated with the BY Cribs, had migrated approximately one kilometer to the north, creating an elevated region of technetium-99 around well 699-50-53A, as shown on Figure 4-12 of *Hydrogeologic Model for the 200 East Groundwater Aggregate Area* (WHC-SD-EN-TI-019). Continued migration northward over the last two decades has created the current plume conditions near well 699-53-55C. The plumes current orientation extends to the northwest and includes well 699-55-57. Low levels of technetium-99 contamination extend all the way to wells near the Columbia River between 100-BC-5 and 100-KR-4.

The continued decline in technetium-99 concentrations at well 699-53-55C indicates the center of mass from the south may have migrated past this well. In addition, the continued decrease in other wells to the northwest may indicate this plume is attenuating.

Technetium-99 results were 200 pCi/L lower at well 699-53-55C in 2011 than in 2010 (2,600 pCi/L versus 2,800 pCi/L). The technetium-99 decline at well 699-53-55C has continued since 2008 and indicates the center of mass from the south has migrated past this well as modeled in DOE/RL-95-59. In addition, the continued decrease in wells to the northwest (e.g., 699-55-57 and 699-57-59) indicates the plume is being diluted because of the increased thickness of the aquifer in this area versus well 699-50-53A.

3.4.3.3 Technetium-99 Near Waste Management Area C

The source of elevated technetium-99 found beneath WMA C is more elusive than at the B Complex. Based on current inventory calculations, the unplanned release, UPR-200-E-86, has by far the most technetium-99 inventory (4.92 Ci) (Appendix C of RPP-26744). However, recent investigation using thirteen direct-push holes surrounding the release site found little technetium-99 in the vadose zone. Pushes varied from 30 to 61 meters below ground surface. Based on the direct push investigation, an updated leak assessment concluded the initial leak loss estimate was high (Section 5.4.1 of RPP-ENV-33418). Another unplanned release, UPR-200-E-82, with approximately 1.4 Ci of technetium-99 inventory (RPP-26744), also found limited technetium-99 in the vadose zone. Based on the investigation at UPR-200-E-82, the prominent conclusion was "*the leak was of low volume and not a source of groundwater contamination for the waste management area.*" Another possibility provided was "*actions taken to control exposure to the spill resulted in it being diluted and/or flushed into the underlying groundwater*" (Section 5.4.1 of RPP-ENV-33418). Another release of 1.6 Ci of technetium-99 was associated with the 241-C-110 tank (Section 4.0 of RPP-ENV-33418). Although this site has not been investigated, a recent assessment update concluded the tank is sound with a maximum port overflow of only 7,570 liters (Section 4.3 of RPP-ENV-33418). The last known source with sizeable technetium-99 inventory is the 241-C-105 release (0.8 Ci) (Section 4.0 of RPP-ENV-33418). After site characterization of this area, technetium-99 was limited to a depth of 48.8 meters below ground surface. Depth to groundwater is approximately 70 meters.

Wells located along the west to southwest and south-southeast sides of the 241-C Tank Farm have technetium-99 concentrations above the drinking water standard (Figure 3.4-14). All these wells are considered downgradient of the 241-C Tank Farm.

Small decreases in Technetium-99 were seen in well 299-E27-23 until December 2011, when levels rose to a new high of 25,000 pCi/L.

Steeply increasing trends over the past 4 to 6 years are unique to wells 299-E27-13 and 299-E27-23 (Figure 3.4-16). However, technetium-99 began to decline at well 299-E27-13 in 2011. Small decreases were also seen in well 299-E27-23 until December 2011, when activity rose to a new high of 25,000 pCi/L. Currently, no other wells at WMA C return a quarter of the technetium-99 activity as well 299-E27-23. This indicates that the residual liquid drainage from the vadose zone is near this well. Further information regarding depth discrete sampling at WMA C can be found in the 2010 report (DOE/RL-2011-01). Well information is provided in DOE/RL-2009-77, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C.*

3.4.4 Uranium

Uranium found in 200-BP-5 groundwater is primarily because of large disposal inventories to the 216-B-12 Crib and the 241-BX-102 unplanned release. The uranium inventory disposed to these sites exceeded 10,000 kilograms, which is at least an order of magnitude greater than other waste sites overlying 200-BP-5. The 216-B-3 Pond and Gable Mountain Pond both received inventories of this magnitude; however, the liquid discharge volumes were so significant that historical concentrations beneath these sites did not exceed the drinking water standard. One final site to impact the groundwater was the 216-B-5 Injection Well. This site only received 10.5 kilograms (Appendix C of RPP-26744); however, the injection well extended into the aquifer allowing the entire inventory to reach the aquifer.

Additional wells will be proposed in the revised 200-BP-5 Sampling and Analysis Plan to better define the deep uranium plume and associated movement.

The plume configurations within 200-BP-5 have not changed significantly over the past five years (Figure 3.4-17). A minor change associated with the uranium plume in the B Complex area was the expansion of contamination within the south part of the 241-BX Tank Farm. Another area of change, although not shown on Figure 3.4-17, was the identification of a deep uranium plume (greater than 6.2 meters below the water table) beneath the 216-B-12 Crib. Evidence of this plume was discovered in the 2010 drilling of the 200-BP-5 RI well 299-E28-30. A discussion of the data was provided in the 2010 Annual Groundwater Monitoring report (Section 9.1.4.2 of DOE/RL-2011-01). Data are not yet available to define the extent and movement of this plume. Wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan (DOE/RL-2001-49) to better define the plume and movement.

The distribution of uranium above the 30 µg/L drinking water standard was limited to four regions during 2011 (Figure 3.4-17):

- B Complex and northwest beyond the 200 East Area
- 216-B-12 Crib and north to LLWMA-1
- 216-B-5 Injection Well
- B Plant

The following sections provide additional details about the uranium distribution and related sources.

3.4.4.1 Uranium near B Complex and Northwest Beyond the 200 East Area

The uranium isotopic signatures from samples within the vadose zone, including boreholes 299-E33-45 and 299-E33-343, and within the groundwater, demonstrate the 241-BX-102 tank release as the primary source of uranium in groundwater at WMA B-BX-BY (Section 5.7 of PNNL-19277). The uranium inventory associated with this release was established at 10,100 kilograms (Appendix C of RPP-26744). Rough order of magnitude calculations indicated that 1,050 kilograms of water-extractable uranium may reside in the Cold Creek unit silt zone approximately 3 meters above the aquifer. This estimate was based on three wells in an east-west orientation within the perched water zone. Continued liquid waste drainage of uranium laden pore water from 2000 to 2009 caused the mass within the aquifer to increase from 3.4 to 22.3 kilograms (Table 5.4 of PNNL-19277).

Because of the groundwater impact associated with infiltration from the perching horizon, a perched water pumping test was initiated in 2011. The perched water contained the highest uranium concentrations detected at the Hanford Site in 2011.

To address the groundwater impact associated with infiltration from the perching horizon, DOE initiated a perched water pumping test in 2011 (DOE/RL-2011-40). Well 299-E33-344 was used for perched water extraction during the test. Pumping began in August and continued until early December when extracted perched water results received from the lab rose significantly and required a different waste disposal path before continued testing. Pumping resumed in April 2012. The uranium results showed an increase from 4,500 µg/L in September to 63,600 µg/L in October. The increase in concentration was confirmed in December with a result of 71,500 µg/L. These were the highest uranium concentrations detected at the Hanford Site in 2011. Approximately 90,000 liters of contaminated water were removed through the 4-month test. The actual drawdown may be several centimeters; however, because of uncertain baseline conditions, it is not possible to quantify the perched water level decline.

Well 299-E33-343 (adjacent to the northwest corner of B Tank Farm) continued to record the highest average groundwater uranium results in 200-BP-5 in 2011. This well is approximately 39 meters west of well 299-E33-344, but is screened in the unconfined aquifer. The maximum uranium result in 2011 was 2,420 µg/L in February; however, concentrations continued to steeply decline from the 5,550 µg/L result in June 2009 until December 2011, when concentrations rose to 1,750 µg/L. The trend indicates liquid waste drainage of uranium from the vadose zone is declining near this well.

Elsewhere in the unconfined aquifer, near well 299-E33-18, which is located approximately 4 meters west of well 299-E33-344, uranium concentrations increased this year. Uranium concentrations increased from 605 µg/L in December 2010 to 1,830 µg/L in December 2011. The concentration increases before the flow reversal imply increased liquid waste drainage of uranium from the vadose zone, while increases after the flow reversal (August through December 2011) are mostly because of southeast migration of a highly contaminated local plume due to the flow reversal. It is believed that the later elevated uranium concentrations are associated with the same plume that was present near well 299-E33-343 in 2009. Conceptually, this plume migrated slowly northward from 2009 to June, 2011 and then to the southeast from July, 2011 (e.g., towards 299-E33-18). It is believed concentrations will continue to increase, possibly meeting or exceeding the 5,500 µg/L seen earlier at well 299-E33-343. Well 299-E33-345, located about 3 meters north of well 299-E33-18, does not appear to be representative of the uranium plume because of construction issues during well completion. The permanent casing was smashed near the ground surface during well construction, causing the well and completion materials, including the bentonite seal across the perching horizon, to be drilled out. It appears that during drilling out this material, bentonite may have been smeared across the aquifer sediments. This is supported by the observation that the well water production is low, as compared to other wells in the B Complex. Therefore, this well will not be included in sampling plans for uranium in the future.

The high uranium concentrations in wells 299-E33-38 and 299-E33-342 beneath the south side of the BY Cribs suggest a historical north-northwest flow path from well 299-E33-343. The northwest flow path extends further to the northwest through wells 299-E33-26 and 299-E33-34, and is bounded to the south by well 299-E33-35. Westward flow during the past 2 to 4 years is seen along the north boundary of LLWMA-1, from well 299-E33-34 to well 299-E32-9. The westward flow between these two wells may be due to declining groundwater levels and possibly remnant Ringold sediments reaching farther south than as defined in PNNL-19702. Alternatively, folds in the underlying basalt may also divert groundwater westward in this area. Groundwater, then, appears to migrate northwest from well 299-E32-9 towards well 699-49-57A because the uranium concentrations at 699-49-57A are higher than at well 299-E32-8. Because of the flow direction change in mid-2011, uranium concentrations decreased at many of the wells

along this flow path and increased at wells to the south. For example, well 299-E33-38, located along the northerly flow path, decreased from 997 µg/L in May 2011, before the flow change, to 331 µg/L by December 2011. Also, well 299-E33-41, located south of the flow path, increased from 82.7 µg/L in May 2011 to 567 µg/L by December 2011.

Uranium increases in May along the south boundary of the 241-BX Tank Farm (299-E33-334) indicate another possible point of infiltration from the vadose zone.

Uranium increases in May along the southwest boundary of the 241-BX Tank Farm (299-E33-334) indicate another possible point of residual liquid waste drainage from the vadose zone. The increase was before the south groundwater flow direction change. Of the sources in this area, only the 241-BX-102 unplanned release appears to be a viable option. Another possible source may be the 216-B-12 Crib; however, the extent of this plume is poorly understood, and elevated uranium would have been expected in well 299-E33-335 before well 299-E33-334, which did not occur.

3.4.4.2 Uranium near 216-B-12 Crib and Low-Level Waste Management Area 1

Over the past 10 years, uranium has been detected at levels near the 30 µg/L drinking water standard in well 299-E28-18, which monitors the 216-B-62 Crib located northwest of B Plant (Figure 3.4-17). Uranium concentrations exceeded 200 µg/L in the mid-1980s, but decreased by the late 1980s to levels similar to those reported during 2011 (33.9 µg/L).

Well 299-E28-21 also monitors the 216-B-62 Crib and is located northwest of well 299-E28-18. Uranium concentrations have been decreasing at this well since maximum values were observed in the mid-1980s. The 2011 uranium concentration in well 299-E28-21 was 10.4 µg/L.

Evidence for the 216-B-12 Crib as the source of elevated uranium in the aquifer is provided by the elevated analytical results from depth-discrete samples collected during drilling near this crib in 2010.

The source of uranium for these wells (299-E28-18 and 299-E28-21) was initially linked to the 216-B-62 Crib; however, the only waste site with significant uranium inventory is the 216-B-12 Crib located southeast of the 216-B-62 Crib (Appendix C in RPP-26744). Supporting evidence for the 216-B-12 Crib as the source of elevated uranium in the aquifer is provided by the elevated analytical results from depth-discrete samples collected during drilling near this crib in 2010. Approximately 35 µg/L of uranium was reported for a sample collected 7.6 meters below the water table. Elevated uranium is interpreted to extend to the northwest, north, and northeast from the 216-B-12 Crib at depth within the unconfined aquifer. Additional wells are needed to better define the extent and movement of this deep plume.

The prevailing groundwater flow direction near LLWMA-1 has been to the north-northwest for more than two decades. Previous uranium groundwater concentrations were observed to migrate from near wells 299-E28-18 and 299-E28-21 to the north-northwest. The elevated uranium concentrations along the western side of LLWMA-1 show the northwest extent of the migration. In 2011, uranium concentrations in wells along the western boundary of LLWMA-1 ranged from less than 3 µg/L to 18.6 µg/L, and the highest concentration was in well 299-E32-7. Higher concentrations are also found in well 299-E28-27 (southeast corner of LLWMA-1), where the June 2011 value was 35.9 µg/L. Based on the historical flow direction in this area and at WMA B-BX-BY, it appears that deep uranium from beneath the 216-B-12 Crib is responsible for the increased concentrations beneath the 216-B-62 Crib, the south to southeast corner of LLWMA-1, and along the west side of LLWMA-1.

3.4.4.3 Uranium near 216-B-5 Injection Well

The 216-B-5 Injection Well was located northeast of B Plant (Figure 3.4-17). A small uranium plume has been reported since 1981 when groundwater monitoring began at the injection well. Since 2007, concentrations in all the 216-B-5 Injection Well monitoring network wells have been below the drinking water standard so no contours are provided in this area (Figure 3.4-18). Previously, the highest uranium concentrations were associated with well 299-E28-23 located approximately one meter from the 216-B-5 Injection Well. Since 2001, uranium concentrations at well 299-E28-23 have continued to decrease while concentrations have increased in well 299-E28-25, located about 7 meters northwest of the 216-B-5 Injection Well. The highest 2011 uranium concentration from the three wells was 28 µg/L at well 299-E28-25. Based on the history of uranium concentrations, flow is continuing to the northwest from the 216-B-5 Injection Well.

3.4.4.4 Uranium near B Plant

Elevated uranium concentrations were present in three wells south and southeast of B Plant during 2011. The uranium concentration at well 299-E29-54, located just south of B Plant, was 30.9 µg/L. Farther south in well 299-E28-17, the uranium concentration was 33.9 µg/L. Finally, in well 299-E28-6, the concentration was 40.2 µg/L. Historically, concentrations have been higher in well 299-E28-6 since sampling began in the early 1990s. Other than the 216-B-12 Crib, there does not appear to be a significant inventory in this area to source this plume. Additional wells are needed to better define the apparent deep plume in this area as discussed further in Section 3.4.4.2.

3.4.5 Strontium-90

Strontium-90 found in 200-BP-5 groundwater is primarily due to high concentrations in waste disposed into areas with a limited vadose zone thickness (<12 meters) at the Gable Mountain Pond and at the 216-B-5 Injection Well. The strontium-90 inventory disposed to these sites was approximately 183 and 7.5 Ci, respectively. The injection of strontium-90 at the 216-B-5 Injection Well occurred during the years 1945 through 1947. The majority of the Gable Mountain Pond discharge was associated with the 1964 unplanned release (UPR-200-E-34). This release was estimated at approximately 178.9 Ci of strontium-90.

Strontium-90 has relatively low mobility in the subsurface and does not migrate significant distances, as observed by concentrations at wells adjacent to these sites. Based on historical activity comparisons for these plumes, decay with little attenuation appears to be the dominant reason for the strontium-90 decline, as modeled and concluded in Sections 5.4.2 and 5.4.3 of DOE/RL-95-59. The area of the plume has decreased since 2006 (Figure 3.4-6). Comparison of the 8 and 80 pCi/L contours for 2010 and 2011 show no change.

Four of the five strontium-90 results above the drinking water standard were from wells near the 216-B-5 Injection Well (Figure 3.4-19). The high concentrations seen at this location are because of the strontium-90 inventory received by the injection well and the depth of the injection well, perforated within the upper part of the unconfined aquifer. The highest strontium-90 concentration (4,400 pCi/L) was from well 299-E28-23, ~1 meter from the 216-B-5 Injection Well. The concentrations within this well have fluctuated between 3,290 to 4,900 pCi/L since 2005. Higher concentrations of strontium-90 are present in well 299-E28-25 (~7 meters to the northwest) than well 299-E28-24 (~5 meters to the southeast) because of the dominant northwest flow direction over the past 25 years since discharges to Gable Mountain Pond were terminated. Concentrations in well 299-E28-25 have ranged between 1,500 and 2,420 pCi/L since 1997, and are currently at 2,200 pCi/L. Farther north in well 299-E28-2 (~170 meters to the north), strontium-90 has fluctuated between 180 and 190 pCi/L and are currently 180 pCi/L, which is no change from 2010. Strontium-90 concentrations farther north have been suspected to be false positives. Concentrations in well 299-E28-24 remained the same as 2010 at 350 pCi/L.

Strontium-90 activity has been steadily decreasing at Gable Mountain Pond, and the highest activity reported was 310 pCi/L in wells monitoring this area.

The highest historical strontium-90 activity reported at Gable Mountain Pond has been at well 699-53-47 (beneath the southeastern portion of the once active pond). In 2010, strontium-90 at this well was 310 pCi/L. The activity at this well has steadily decreased from 1,320 pCi/L over the last 13 years. This well was not sampled in 2011 because of schedule constraints, but is planned to be sampled in 2012.

Another well not sampled in 2011 was 699-54-48, located approximately 330 meters north of well 699-53-47A. Strontium-90 concentrations at this well have been approximately 30 pCi/L. This well is also scheduled for sampling in 2012. Farther west beneath the central portion of Gable Mountain Pond at well 699-54-49, the strontium-90 activity increased from 160 pCi/L in 2010 to 200 pCi/L in 2011. Regionally, concentrations decrease to the west indicating the majority of strontium-90 drainage into the aquifer occurred near the outlet pipe to the former Gable Mountain Pond.

Well 699-55-55, located approximately 1.2 kilometers west of the pond, was also sampled in 2011. The result from this well was 4.4 pCi/L; however, based on several false positive results for strontium-90 in 2011 (Appendix D), it is uncertain whether this result is another false positive or not. The result has been flagged and the well is scheduled to be sampled again in 2012. Based on the results in 2012, a determination will be made on the 2011 result.

3.4.6 Cyanide and Iron

Cyanide and elevated iron found in 200-BP-5 groundwater probably originated from disposal of wastes associated with scavenging cesium-137 and strontium-90. After scavenging was completed, the ferrocyanide complex was discharged to the BY Cribs. Migration of a significant inventory of cyanide and iron was able to drain through approximately 70 meters of Hanford vadose zone soils to the groundwater because of the initial discharge volume and the negatively charged ferrocyanide complex. In the late 1990s, cyanide concentrations began to increase beneath the BY Cribs. Cyanide and iron trend plots are nearly identical in most of the wells beneath the BY Cribs, confirming the complex nature (Figure 3.4-20).

The distribution of cyanide above the 200 µg/L drinking water standard originates beneath the BY Cribs and extends predominantly to the northwest beyond the 200 East Area boundary (Figure 3.4-21). The plume configuration has expanded over the past 5 years because of the continued residual liquid drainage from the BY Cribs and groundwater flow to the northwest (Figure 3.4-3). In the summer of 2011, concentrations beneath the BY Cribs began to decrease significantly coincident with the flow reversal, causing the plume to contract from the west and north.

The maximum cyanide concentration in 200-BP-5 in 2011 was located beneath the BY Cribs in well 299-E33-7 (1,500 µg/L), but this was 90 µg/L less than the value reported in 2010.

The maximum cyanide concentration in 200-BP-5 during 2011 was beneath the BY Cribs in well 299-E33-7 (1,500 µg/L), but was 90 µg/L less than the value reported in 2010. Because of the groundwater flow direction change, cyanide concentrations exceeded the drinking water standard in November 2011 at wells 299-E33-16, 299-E33-39, and 299-E33-44 located to the south-southeast. However, the yearly average concentrations in these wells were still below the drinking water standard. The cyanide 200 µg/L (drinking water standard) contour continues to extend predominantly to the

west-northwest beyond the 200 East Area boundary between wells 299-E33-34 and 699-49-57A (Figure 3.4-21).

The maximum filtered iron concentration in 200-BP-5 groundwater was also located beneath the BY Cribs at well 299-E33-7 (748 µg/L). Besides wells located beneath the BY Cribs, only one other well, 299-E33-34 (317 µg/L), exceeded the secondary drinking water standard. Well 299-E33-15 exceeded the standard in November 2011 because of the flow reversal, but the average concentration was lower than the drinking water standard.

Elevated cyanide concentrations are also associated with well 699-53-55C, where concentrations have continued to decrease since the peak value in April 2009 (195 µg/L). The June 2011 concentration was 135 µg/L compared with 158 µg/L in July 2010 and 170 µg/L in January 2010. As stated for technetium-99, it appears the center of mass has passed by this well. Thus, there are no plume contours associated with well 699-53-55C in 2011.

3.4.7 Tritium

The tritium distribution within the unconfined aquifer from the 216-B-12 Crib is poorly understood; however, the levels found at depth during the RI are within the realm of decay associated with the 1950 releases.

Tritium found in 200-BP-5 groundwater primarily originated from large inventories disposed to the 216-B-50 and 216-B-57 Cribs in the mid- to late 1960s to the early to mid-1970s. Also contributing were cribs in the north part of 200-PO-1, which received large tritium waste inventories that migrated to groundwater and to the northwest within the aquifer in the late 1980s, after liquid disposal was discontinued to the Gable Mountain Pond. The discontinuation of discharges to Gable Mountain Pond resulted in a significant flow change in the 200 East Area towards the northwest and the Gable Gap. In addition, a large inventory of tritium was disposed to the 216-B-12 Crib in the 1950s. The tritium distribution within the unconfined aquifer from the 216-B-12 releases is poorly understood; however, the levels found at depth during the RI are within the realm of decay associated with the 1950 releases. Finally, significant inventories of tritium were discharged to the 216-B-3 Pond in the mid-1960s to mid-1970s and mid-1980s to mid-1990s, causing elevated levels of tritium in the past and currently at wells beneath and downgradient this site.

The distribution of tritium above the 20,000 pCi/L drinking water standard was limited to two isolated regions during 2011 (Figure 3.4-22):

- Wells at the B Complex and northwest beyond the 200 East Area
- Wells near the 216-B-3 Pond

Both of these plumes are detected in the upper portion of the unconfined aquifer. Although not shown on Figure 3.4-22, a plume deeper in the aquifer appears to exist beneath the 216-B-12 Crib and B Plant. This plume appears to be associated with the elevated tritium levels to the north along the southern and western portion of LLWMA-1. Section 3.4.7.2 provides additional information about this site.

The size of the plume exceeding the drinking water standard in the upper part of the unconfined aquifer within 200-BP-5 has decreased significantly over the past 8 years (Figure 3.4-6). The plume formerly extended through Gable Gap to wells and aquifer tubes near the Columbia River between 100-BC-5 and 100-KR-4. Concentrations declined because of radioactive decay and other natural processes.

3.4.7.1 Tritium Near B Complex and Northwest Beyond the 200 East Area

A small tritium plume with concentrations above the drinking water standard is located in the thin unconfined aquifer at the B Complex.

A small tritium plume is located in the thin unconfined aquifer at the B Complex. Wells 299-E33-7, 299-E33-13, 299-E33-26, and 299-E33-38 are located in the north part of the B Complex beneath or adjacent to the 216-B-50 and 216-B-57 Cribs. Elevated tritium at this location is not surprising as these two cribs received over 100 Ci of tritium (Appendix C of RPP-26744). The 216-B-50 Crib received approximately 126.3 Ci and 216-B-57 Crib received approximately 194.6 Ci. Except for the 216-B-49 Crib, this is 100 Ci more than any of the other BY Crib inventories. Overall, the groundwater tritium levels in this area are declining. Although some samples from wells 299-E33-7, 299-E33-13, and 299-E33-38 exceeded the drinking water standard, the yearly average results were below it. The increases in these wells from August to December of 2011 were associated with a flow reversal and the southeast position of the wells to the source sites. In addition, wells located to the northwest (299-E33-26, 299-E33-34, and 299-E32-10) continued to show declining levels even before the flow reversal. For example, well 299-E33-34 declined from an average of 18,000 pCi/L in 2010 to an average of 14,000 pCi/L in 2011. The continued declines indicate subsiding tritium-laden pore water drainage from the vadose zone beneath these source sites. As a result, the plume size in Figure 3.4-22 was reduced compared to 2010.

Farther north and within the Gable Gap, elevated tritium levels continue to decrease. The initial source of elevated tritium in this area can be traced back to 200 Area plumes from the 1970s and 1990s. Over the past 10 years, maximum levels have declined from 32,000 to 16,000 pCi/L at well 699-60-60. The decline is slightly faster than the decay rate, indicating some dilution. The decrease in this well is consistent with the decrease in other wells in the area.

As a result of residual tritium laden liquid waste drainage from the perched horizon, three unconfined aquifer wells had activities exceeding 10,000 pCi/L.

One additional well at the B Complex that exceeded the drinking water standard in 2011 was well 299-E33-344, located in a perched water horizon above the unconfined aquifer. Specifically, this well is located in the perched water horizon approximately 3 meters above the aquifer. Tritium levels increased significantly from September 2011 to October 2011 (1,400 to 41,300 pCi/L). A verification sample, collected December 5, 2011, confirmed the increase with 43,500 pCi/L. The tritium increase was observed after initiating a pumping test at this well. The source of the increase appears to be consistent with the 241-BX-102 unplanned release versus the 216-B-7A&B Crib. The 241-BX-102 unplanned release was at least three orders of magnitude more concentrated than the 216-B-7A&B Crib discharges (Appendix C of PNNL-19277). As a result of drainage from the perched horizon, three unconfined aquifer wells (299-E33-16, 299-E33-18, and 299-E33-44) had activities exceeding 10,000 pCi/L. Tritium levels in the unconfined aquifer decrease away from these wells, indicating attenuation of the contaminant levels.

It is worth noting that elevated tritium concentrations near 10,000 pCi/L were also located along the south boundary of the 241-B and 241-BX Tank Farms. The elevated tritium levels may be associated with the 241-BX-102 unplanned release. This is based on the elevated uranium also observed in this area. Alternatively, the increases may be associated with an apparent deep plume observed beneath the 216-B-12 Crib and B Plant (Section 3.4.7.2).

3.4.7.2 Tritium Near 216-B-62 Crib and Low-Level Waste Management Area 1

The highest tritium concentrations in 200-BP-5 in 2010 were in new RI Wells located near the 216-B-12 Crib and B Plant in the deeper part of the aquifer.

The two groundwater wells with the highest tritium concentrations in 2010 were the two new Remedial Investigation wells, 299-E28-30 and 299-E29-54, located near the 216-B-12 Crib and B Plant, respectively. The highest tritium activity, 150,000 pCi/L, was reported during sample collection while drilling at well 299-E29-54. The elevated result was encountered at ~18.3 meters below the water table, the deepest sample collected. There was no duplicate sample to confirm the result; however, the sample was run twice with different dilution factors and provided consistent results. Shallower samples had tritium concentrations ranging from 4,300 to 18,000 pCi/L. During drilling of well 299-E28-30, a tritium concentration of 93,500 pCi/L was encountered at ~7.62 meters below the water table, near the middle of the aquifer. This result was an average of two samples, 93,000 pCi/L and a duplicate of 94,000 pCi/L. The results are consistent with the significant tritium inventory associated with the 216-B-12 Crib (2,340 curies) versus the less than one curie for the other combined waste sites in this area (Appendix C of RPP-26744). Samples from other depths had tritium results ranging from 4,000 to 11,000 pCi/L.

Additional wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan to better define the tritium plume and movement.

The high tritium level in well 299-E28-30 coincides with the Ringold Formation unit 9A (Plate 5 of PNNL-12261). The top of the Ringold unit 9A is interpreted to extend from just above the water table through most of the saturated thickness, overlying a thin layer of unit 9B and ~6.1 meters of unit 9C. North of this well, Ringold unit 9A is truncated by the glaciofluvial Hanford sediments, which overlie the Ringold unit 9C. The change in hydraulic conductivity between these two formations ranges from an order of magnitude to several orders of magnitude (Table 3.1 of PNNL-12261). It is believed that tritium migrates north within these Ringold units, causing elevated activities to the north, beneath the 216-B-62 Crib. The elevated tritium at depth, beneath the 216-B-12 Crib, is also interpreted as the source of elevated tritium to the north along the southeast and west side of LLWMA-1. A tritium contour is not provided around well 299-E28-30 because the results are based on vertical data obtained during drilling; therefore, the tritium contour is not shown on Figure 3.4-22. Additional wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan (DOE/RL-2001-49) to better define the plume and movement.

3.4.7.3 Tritium in 216-B-3 Pond Area

In 2010, the tritium distribution was overestimated at the 216-B-3 Pond because of the elevated concentrations at well 699-45-42. Based on the result at well 699-43-41G and evaluation of the historical levels between wells 699-45-42, 699-44-43B, and 699-44-42, the north part of the 20,000 pCi/L contour has been contracted to the confines of the southern part of the 216-B-3 Pond and the A, B, and C lobes.

One well, 699-42-40A (near B Pond), had tritium concentrations exceeding the drinking water standard in 200-BP-5 in 2011. Well 699-42-40A is screened over 9.45 meters of Ringold lower mud and unit A (Ringold confined aquifer). The lower mud adjacent to the upper two meters of the screen is described as silt and clay with cobbles. The upper 3 meters of unit A is described as cemented gravels. The pump intake is located just below the cemented gravels within silty sandy gravels. The tritium levels in this well increased to a peak of 46,000 pCi/L in 2009. Levels appear to be in flux as considerable variation was seen in samples collected on June 8th and 22nd of 2011. The analytical results were

39,000 pCi/L and 28,000 pCi/L, respectively. It appears the recent increase in tritium at this well may correlate to the elevated tritium-to-liquid ratio from 1986 to 1997.

The southern extent of the 20,000 pCi/L contour is defined by wells 299-E25-25 and 299-E25-39 which had concentrations of 22,000 and 23,000 pCi/L in 2008. The wells have not been sampled since. The concentration in these wells increased significantly between the late 1990s and 2008 because of the elevated concentrations beneath B Pond. The concentrations in these wells are considered to be increasing.

3.4.8 Plutonium

Plutonium-239 is found in the groundwater at the 216-B-5 Injection Well because the waste was injected into the aquifer. Approximately 39.68 Ci of the plutonium isotopes 239 and 240 were released to the 216-B-5 Injection Well in the mid to late-1940s (Appendix C of RPP-26744).

In 2011, only three wells, 299-E28-23, 299-E28-24, and 299-E28-25 (all at the 216-B-5 Injection Well), had detectable plutonium-239/240. Detectable activities in these wells have been continuous since monitoring began in 1986. The concentrations reported for 2011 ranged between 0.56 pCi/L and 52 pCi/L; comparable with the 2010 range of 0.21 and 42.6 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 Injection Well, had the highest activity at 52 pCi/L. Plutonium-239/240 has limited mobility, as reflected by the low stable results in wells 299-E28-24 (0.56 pCi/L) and 299-E28-25 (1.2 pCi/L), which are located ~5 to 7 meters from the 216-B-5 Injection Well, respectively. Concentrations in well 299-E28-25, located to the northwest, are slightly higher because it is in the predominant direction of historical groundwater flow.

Historically, plutonium has been detected at locations other than at the 216-B-5 Injection Well; however, the results were below 1 pCi/L. All but four of the historical results from the late 1980s and early 1990s were less than 0.1 pCi/L. The majority of the plutonium detections were located northwest of the 216-B-5 Injection Well; the prominent flow direction at that time. Some of the results are suspect because of the location, such as within the Rattlesnake Ridge interbed (basalt confined aquifer).

Between 2007 and 2011, a total of 123 samples have been collected with 9 detectable results, omitting the 3 wells near the 216-B-5 Injection Well. The positive results were associated with the new Remedial Investigation wells and were generally single occurrences measured shortly after drilling. All the results were less than 0.1 pCi/L. Because of the number of samples collected at each of these Remedial Investigation wells since drilling, the results have become statistically inconsistent or are approaching this level.

Migration of colloidal particles of plutonium have been of interest to some (Kaplan et al., 2006, “Eleven-year Field Study of Pu Migration from Pu III, IV, and VI Sources”), but based on data collected at the Hanford Site, the levels are so low that it is impractical to track potential particles. Thus, future sampling will be focused at wells near the 216-B-5 Injection Well.

3.4.9 Cesium-137

Cesium-137 is found in the groundwater at the 216-B-5 Injection Well because the well was completed in the unconfined aquifer. Approximately 8.67 Ci of cesium-137 was released to the 216-B-5 Injection Well in the mid to late-1940s (Appendix C of RPP-26744).

Only three wells (all near the 216-B-5 injection well) had detectable cesium-137 within 200-BP-5.

Consistent with past results, only three wells (all near the 216-B-5 Injection Well) had detectable cesium-137 within 200-BP-5. The values ranged from 34.5 to 2,140 pCi/L. The levels were slightly lower

than 2010 when the results ranged from 35.4 to 2,180 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 Injection Well, had the highest activity at 2,140 pCi/L. The reported activity is above the 200 pCi/L drinking water standard and is less than the DOE-derived concentration standard of 3,000 pCi/L.

Cesium-137 has relatively low mobility in the subsurface and does not migrate significant distances, as observed by the much lower concentration (62 pCi/L) at well 299-E28-24, located ~5 meters to the southeast of the 216-B-5 Injection Well. An even lower concentration (34.5 pCi/L) is found ~7 meters to the northwest in well 299-E28-25. Based on historical activity comparisons, this plume is decaying with little migration, as modeled and concluded in Section 5.4.2 of DOE/RL-95-59.

3.4.10 Sulfate

Sulfate within 200-BP-5 groundwater is primarily because of large inventories to liquid disposal sites with sufficient fluid to migrate through more than 70 meters of vadose zone. For example, the 216-B-46 and 216-B-49 Cribs received past liquid waste inventories of sulfate near 11,750 mg/L (Appendix C of RPP-26744). Another waste site in the same area, 216-B-8 Crib, received much lower sulfate concentrations; however, levels in the groundwater are higher beneath this site than under the BY Cribs. Other sites, such as Gable Mountain Pond and B Pond, which had sufficiently large inventories of sulfate, had even more liquid discharges, thus reducing the concentrations to little consequence. Note that although Gable Mountain Pond had low concentrations in the effluent according to RPP-26744, there are sulfate concentrations that exceed the secondary drinking water standard within the aquifer beneath this site. When the inventory of sulfate for the Gable Mountain Pond site was reviewed in RPP-26744 on a year-by-year basis, the average concentration were less than 18 mg/L. Thus, RPP-26744 does not represent accurate sulfate records for the former Gable Mountain Pond and 216-B-8 Crib waste sites.

Some unplanned releases may not have been included for certain sites such as the UPR-200-E-138, which was not included in RPP-26744 for the 216-B-3 Pond. The unplanned release was associated with the strontium-90 Product Storage Tank (8-1) inside the 221-B Building. At the time of the release, strontium-90 was part of a waste fractionization campaign (Section 3.2.2 in DOE/RL-98-28). It is believed the fractionization process was similar to the process described in "*In-Farm Scavenging" Operating Procedure and Control Data* (HW-38955). This process used nickel sulfate for the separation of strontium. Large quantities of sulfate are believed to have been associated with this process because of the elevated sulfate beneath the 216-B-2 Ditch. Further information regarding the conceptual model transport mechanism associated with the 216-B-2 Ditch was presented in the 2010 Annual Groundwater Monitoring Report, (Section 9.1.10.3 of DOE/RL-2011-01). The fractionation process was also used at WMA C, however, large sulfate release inventories are not provided for WMA C releases in RPP-26744.

The distribution of sulfate above the secondary drinking water standard (250 mg/L) was limited to four locations within 200-BP-5 (Figure 3.4-23):

- B Complex
- WMA C
- 216-B-2 Ditches
- Gable Mountain Pond

In comparing the sulfate plume from 2007 (Figure 2.10-19 of DOE/RL-2008-01) with 2011 contours, three changes are noticed, as follows:

1. The extent of the 250 mg/L contour has increased at the B Complex. In 2007, only two wells had concentrations at or exceeding the secondary drinking water standard at the B Complex. These wells were located beneath the 216-B-8 Crib and the BY Cribs. In 2011, the plume stretches to the northeast corner of LLWMA-1 from the BY Cribs and from the 216-B-8 Crib to the BY Cribs.

2. The extent of the 250 mg/L contour has increased beneath the 216-B-2 Ditch. Only a small region east of LLWMA-2 and south of Trench 94 had sulfate concentrations exceeding 250 mg/L in 2007. In 2011 the 250 mg/L contour extends south to southeast beyond well 299-E27-25 located east of WMA C. The change in distance of the contour is 375 meters. Because there are no wells located between wells 299-E27-10 and 299-E27-25, correlating the flow rate and direction from the expansion of the interpreted contour line is not advised. This is because the infiltration of sulfate-laden pore water from the vadose zone may also extend towards well 299-E27-25.
3. The plume along the southeast side of WMA C has been extended to the south-southeast. The concentration along the southeast side of WMA C in well 299-E27-14 has increased from about 250 to 300 mg/L. Likewise, the sulfate concentration in well 299-E24-33, located to the south-southeast of well 299-E27-14, has increased from approximately 108 mg/L to 150 mg/L.

3.4.10.1 Sulfate near B Complex

Sulfate concentration increases were seen beneath the BY Cribs and the 216-B-8 Crib in August 2011, coincidental with a midyear flow direction change. The concentration decreased in November, indicating increased flow rates to the south. Concurrently, wells south of these waste sites saw increased concentrations in November.

3.4.10.2 Sulfate near Waste Management Area C

The elevated sulfate concentration reported in well 299-E27-14 (on the southeast side of WMA C) is clearly associated with WMA C.

The elevated sulfate concentration reported in well 299-E27-14 (southeast side of WMA C) is clearly associated with WMA C. This is based on the lower sulfate concentrations upgradient along the north part of the tank farm. No known sulfate releases are capable of the concentrations in the groundwater based on RPP-26744 (discussed further in Sections 3.4.1.8 and 3.4.3.3). The orientation of the plume has been expanded to the south towards well 299-E24-33 because of the increasing sulfate trend at this well. Lower sulfate concentrations to the west bound the 250 mg/L contour. Lack of a bounding well to the east requires an estimation of the elevated sulfate extent in this direction.

3.4.10.3 Sulfate near the 216-B-2 Ditches

The sulfate concentration beneath the east end of the 216-B-2 Ditches in well 299-E27-10 has continued to be the highest sulfate concentrations in this area since well 299-E34-7 went dry in 2005. Like the discussion for nitrate (Section 3.4.1.7), sulfate concentrations have shown increases to the west and south over the past decade. The increases infer radial spreading or increased lateral extent from the vadose zone drainage in the area.

3.4.10.4 Sulfate near Gable Mountain Pond

Historically, sulfate concentrations beneath the former Gable Mountain Pond exceeded the secondary drinking water standard in only one well, 699-53-48A. This well was not sampled in 2011, but is scheduled to be sampled in 2012. Concentrations to the east near the former outlet are historically less although the aquifer is thinner. Farther west, concentrations decrease as the aquifer thickness increases.

3.4.11 Other Constituents

Elevated arsenic was found at one well, 299-E33-16, located beneath the 216-B-8 Crib. Review of historical chemicals used at the site during the active discharges to this crib revealed no arsenic or arsenic compounds. The 216-B-8 Crib did receive acetic and/or hydrochloric acid. However, it is unclear how or why arsenic in the dissolved state has migrated into the groundwater at concentrations near ten times

background levels (at a maximum of 104 µg/L). Based on lower than background levels at the eight surrounding monitoring wells, arsenic preferentially adsorbs to the sediments near the point of drainage.

Cobalt-60 concentrations were elevated in 200-BP-5 groundwater in the past, but contaminant levels continued to decline in 2011. Levels have not exceeded the drinking water standard since 2008. The elevated levels were only at one well, 299-E33-4, which went sample dry in 2008.

Fluoride concentrations exceeded the drinking water standard in well 299-E33-344. This well is screened within a perched water horizon ~3 meters above the unconfined aquifer near the 216-B-7A&B Cribs. The elevated fluoride concentrations are associated with the elevated concentrations of fluoride laden liquid waste received by the 216-B-7A&B Cribs. The fluoride concentration declined in this well during 2011 because of mixing with the 241-BX-102 unplanned release. Concentrations declined from a maximum of 97 mg/L in December 2010 to 9.4 mg/L in December 2011. Fluoride-laden pore water drainage from the perched water zone into the underlying unconfined aquifer is not significant as concentrations are ten times less than the drinking water standard of 4 mg/L.

3.4.12 CERCLA Groundwater Activities

The following paragraphs provide information about the CERCLA groundwater activities for 2011, which included routine groundwater monitoring, report writing, and preparation of a treatability test (DOE/RL-2011-40) to address technetium-99 and uranium contamination, and preparation and startup.

Routine CERCLA groundwater monitoring requirements are described in DOE/RL-2001-49. Appendix A of this report provides information about the monitoring network, constituent lists, and sampling frequency. The CERCLA monitoring data are used to define the extent of groundwater contamination. Each year, contours are revised for each contaminant of concern identified in DOE/RL-2001-49. The certainty of the plume interpretation is also assessed to determine the effectiveness of the CERCLA and AEA monitoring program. The assessment determines if the selected analytical methods, sampling frequencies, and well locations are appropriate. In addition, the new contours are compared each year with previous contours to interpret groundwater flow and track concentration trends near contaminant sources. DOE/RL-2001-49 also provides the direction for the integrated use of RCRA analytical data.

DOE/RL-2001-49 is in the process of being revised and should be completed in 2012. Data from the new Remedial Investigation wells and the existing monitoring network are being used to determine data gaps. Also, new AEA requirements at various RCRA facilities that were included since completion of revision 1.0 in 2004 are being added for an all-inclusive document.

The 2011 contaminant concentrations near source sites were lower than 2010 for most areas. Reduced residual liquid waste drainage may be one reason, for example, technetium-99 levels beneath the BY Cribs continued to see declines (Section 3.4.3.1). Concentrations of cyanide, sulfate, and tritium decreased beneath the BY Cribs (Sections 3.4.6, 3.4.10.1, and 3.4.7.1, respectively). Most of these same constituents also decreased at well 699-53-55C (Sections 3.4.6, 3.4.1.2, and 3.4.3.2 for notable contaminants). Contaminant levels beneath the 216-B-2 Ditches also began to decrease towards the end of the year (Sections 3.4.1.7 and 3.4.10.3). Contaminant levels at Gable Mountain Pond also saw decreases in 2011.

The 2011 contaminant concentrations near source sites were lower than 2010 for most areas.

In 2011, eight of the 200-BP-5 required wells were not sampled in accordance with DOE/RL-2001-49. The main reason for the wells not sampled was schedule constraints; however, some wells were mistakenly not scheduled or maintenance was required. Besides the wells not sampled, several

required contaminants were not sampled. The majority of contaminants not sampled were associated with cesium-137, plutonium-239/240, and strontium-90. Appendix A provides a list of the required 200-BP-5 wells to be sampled. This appendix also provides the contaminants and supporting constituents to be sampled and those not sampled. Note, because of significant knowledge obtained over the past decade (e.g., geologic environment, source sites, flow regime, and contaminant nature and extent) and the changes to well network (for example, dry, decommissioned, and new wells) the 200-BP-5 Groundwater SAP (DOE/RL-2001-49) needs updated. Thus, the Sampling and Analysis Plan is being revised and will be used to derive the FY 2013 groundwater sampling requirements. In addition, new well installations will be proposed to define deep plume extent and movement. Finally, additional wells will be proposed to track migrating plumes for the probable near term flow direction change.

Two major reports saw activity in 2011. The draft *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit* (DOE/RL-2009-127) was completed and submitted to DOE in 2011. The draft Feasibility Study/Proposed Plan are due June 30, 2015 in accordance with the Tri-Party Agreement (Ecology et al., 1989) Milestone M-15-21A. The other major report, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74), is associated with the pumping tests near the 241-B and BY Tank Farms. Minor reports completed in 2011 associated with the treatability test included a small project functional design report and work packages for drilling two wells near the 241-BY Tank Farm.

The treatability test for 200-BP-5 is designed to evaluate the practicality of performing a groundwater pump-and-treat system for the extraction of uranium and technetium-99 contaminant plumes near WMA B-BX-BY. The well site selection was discussed in the 2010 report (Section 9.2.3 of DOE/RL-2011-01). Field activities beginning in 2011included the following:

- Preparation of the drill site west of the 241-BY Tank Farm
- Initial drilling of the extraction well 299-E33-268, located west of the 241-BY Tank Farm (i.e, started in 2011 and completed in 2012)
- Initial construction of an aboveground pipeline from both extraction wells, 299-E33-268 (to be located west of the 241-BY Tank Farm and 299-E33-343 (located along the northwest corner of the 241-B Tank Farm), to the tie with the cross-site line to the Effluent Treatment Facility, including road crossings
- Construction of a utility distribution rack
- Barometric response measurements in existing monitoring wells associated with the pump test at wells 299-E33-268 and 299-E33-343

The barometric response activity was tied with the completion of the Treatability Test for the completion of Milestone M-15-82B.

The barometric response activity was tied with the completion of the treatability test for the completion of Milestone M-15-82B.

In addition to the 200-BP-5 CERCLA activities, two deep vadose zone CERCLA activities were completed associated with the perched water horizon near the 241-BX-102 unplanned release and the 216-B-7A&B Cribs. The first was issuance of DOE/RL-2011-40, which focuses on a perched water zone. The test plan includes the parameters for evaluating perched water pumping/pore water extraction as a potential remedy for uranium extraction. In addition, information needed to conduct fate and transport modeling will be collected so numerical models can be used to estimate the effectiveness of the treatment for protection of groundwater. The second activity was startup of perched water pumping from

well 299-E33-344. Pumping began in August 2011 and continued until early December 2011, when contaminant concentrations increased significantly and required a different waste disposal path before continued testing. Approximately 90,000 liters of contaminated water were removed before pumping was halted. The uranium results associated with the test showed an increase from 4,500 µg/L on September 7, 2011, to 63,600 µg/L on October 4, 2011. Another sample, collected December 5, 2011, confirmed the uranium increase at well 299-E33-344 with a result of 71,500 µg/L. The increase in uranium indicates a lateral radius influence to the west where more concentrated levels of uranium were found in depth-discrete samples collected across the perched horizon during drilling at well 299-E33-343. Thus, the retrievable liquid volumes and the radius of influence associated with the 299-E33-344 are evidence of the effectiveness of perched water pumping.

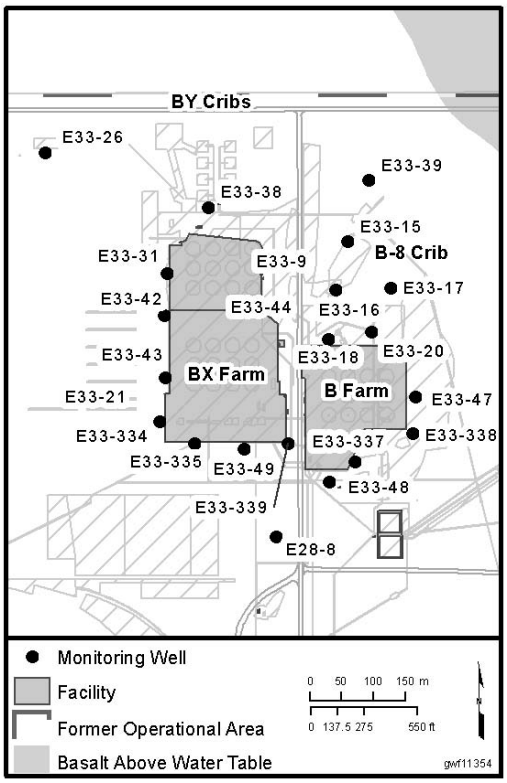
3.4.13 RCRA and Other Facility Monitoring

This section describes the results of monitoring at individual units such as treatment, storage, and disposal units. 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. As previously discussed and 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, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

The 200-BP-5 Operable Unit contains six RCRA sites with groundwater monitoring requirements: WMA B-BX-BY, WMA C, 216-B-63 Trench LERF, LLWMA-1, and LLWMA-2. The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for this reporting period. Groundwater data are available in the HEIS database and in the data files accompanying this report. Appendix B provides additional information (including well and constituent lists, maps, and statistical tables).

3.4.13.1 Waste Management Area B-BX-BY

The WMA B-BX-BY is located in the north-northwest part of the 200 East Area. It includes the 241-B-BX-BY Tank Farms, which consists of 36 underground storage tanks ranging from 1,892,500-liter to 2,869,000-liter capacity. There are four additional 208,000-liter underground storage tanks in the 241-B-Tank Farm. Twenty-one of the forty underground tanks are confirmed or assumed to have leaked. Additional sources of unplanned releases include waste loss from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases. Currently, only one of these releases, the 241-BX-102 unplanned release, has been confirmed as impacting the groundwater. No dangerous waste/dangerous waste constituents have been identified with this release.



In June 1996, the specific conductance indicator parameter exceeded the critical mean at well 299-E33-32 initiating an assessment of the 241-B-BX-BY Tank Farms. During the course of the initial assessment contaminants exceeding the drinking water standard were identified at

well 299-E33-41. A subsequent assessment to identify the source was planned (PNNL-13022, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site*). Field investigations (RPP-10098, *Field Investigation Report For Waste Management Area B-BX-BY*; DOE/RL-2007-18) provided significant vadose zone samples to fingerprint the source of contamination. Based on these investigations, a determination was made identifying the source as the 241-BX-102 unplanned release (Section 5.7 of PNNL-19277). The various contaminants associated with this release are discussed in Sections 3.4.1.1, 3.4.2.6, 3.4.3.1, 3.4.4.1, and 3.4.9.1. Another objective of monitoring identified in PNNL-13022 was to determine the contaminant levels and the extent/rate of migration on a quarterly basis, discussed below.

During the 200-BP-5 remedial investigation, the unplanned release from tank 241-BX-102 was identified as the source of groundwater contamination beneath WMA B-BX-BY.

In accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400), the WMA B-BX-BY well network was sampled quarterly in order to make continued determinations of the concentration and extent of dangerous waste/dangerous waste constituents in the groundwater. All of the WMA B-BX-BY monitoring wells defined in PNNL-13022—except 299-E33-7, 299-E33-9, 299-E33-16, and 299-E33-26—were sampled as required during the reporting period. Appendix B Table B-35 includes a list of WMA B-BX-BY wells, constituents monitored, and whether the wells were sampled as scheduled.

The flow direction and rate have been reported as indeterminate to nearly stagnant over the past 5 years. This was because of variability in the regional groundwater monitoring measurements from a network of fourteen wells located near B Plant, 216-B-5 Injection Well, WMA B-BX-BY, LLWMA-1, and north of the 200 East Area. The use of this regionally corrected groundwater measurement network (survey to single bench mark, deviation and barometrically corrected) has helped to define the variability of uncorrected measurements and determined flow direction and rate occasionally over the past five years. Based on the water level measurements from this monitoring network, the groundwater flow direction was north-northwest over the first five months of 2011. However, high Columbia River spring stages caused a flow direction to change to the south-southwest in August 2011. Because of the flow change, the overall groundwater flow direction and rate are defined as indeterminate this year (Table B-1, Appendix B).

The network well screens range from 0.90 to 11.67 meters into the aquifer. All the wells have adequate water columns in the screened interval for sampling except possibly well 299-E33-26. This well is being investigated because water was not able to be retrieved during the November 2011 sampling event. The next shortest water column is 1.63 meters in well 299-E33-39, which should be sufficient for the next decade or more.

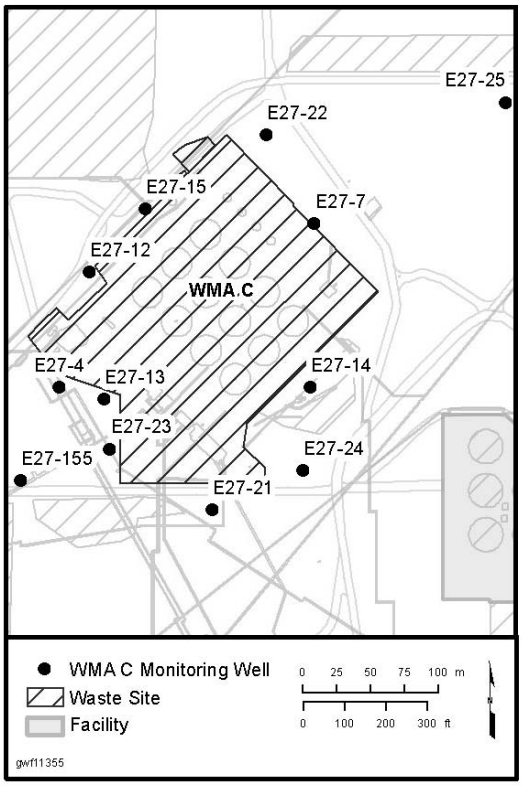
During 2011, no dangerous wastes/dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY. However, as explained in the other sections of this report, groundwater continues to be impacted by non-RCRA constituents from the 241-BX-102 unplanned release. Because no dangerous waste/dangerous waste constituent has been determined to impact groundwater, the extent of WMA B-BX-BY monitoring network is confined to the boundary of WMA. Other non-RCRA contaminants are monitored by the 200-BP-5 Operable Unit.

During 2011, no dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY.

Although no dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY, the presence of non-RCRA contaminants associated with the 241-BX-102 unplanned release in the groundwater indicates the WMA is affecting the groundwater quality. Thus, the site will remain in assessment monitoring as allowed in 40 CFR 265.93(d)(6). Because of the findings in recent investigations in this area and the addition of new monitoring wells, the assessment plan will be revised in 2012 and submitted to Ecology for review.

3.4.13.2 Waste Management Area C

The WMA C is located in the east central part of the 200 East Area. It includes the 241-C Tank Farm, which consists of twelve underground storage tanks with an approximate capacity of 1.9 million liters. There are four additional underground storage tanks with an approximate capacity of 208,000 liters. Seven of the sixteen underground tanks are confirmed or assumed to have leaked. Additional sources of unplanned releases include waste loss from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases. Significant uncertainty is associated with the extent of contaminant migration from both the underground storage tanks and unplanned releases.



In July 2009, the specific conductance indicator parameter exceeded the critical mean at well 299-E27-14 initiating an assessment of the 241-C Tank Farm. Furthermore, the dangerous waste constituent cyanide was detected in the groundwater. Based on these findings, with no upgradient source the 241-C Tank Farm entered into assessment monitoring in accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400).

In accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400), the well network was sampled quarterly in order to make continued determinations of the concentration and extent of cyanide in the groundwater (DOE/RL-2009-77, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*). All of the wells were sampled quarterly, as required, during 2011. Appendix B Tables B-36 and B-37 includes a list of WMA-C wells, constituents monitored, and indicates if the wells were sampled as scheduled. Flow direction and rate were indeterminate based on lack of corrected groundwater level measurements as discussed in the following text and in Table B-1 of Appendix B.

The monitoring network as defined in DOE/RL-2009-77 consists of three upgradient, seven downgradient, and three cross-gradient wells. The definition of upgradient and downgradient is based on a southwest flow direction. Currently, the flow direction and flow rate is indeterminate by water table measurements because the measurement error exceeds the gradient. Use of regionally corrected measurements (survey to single bench mark, deviation and barometrically corrected) in the northwest corner of the 200 East Area have helped to define the variability of uncorrected measurements and occasionally determine flow direction and rate. Regional corrections near WMA C may also help define the flow direction and rate. Until corrections are made, the flow direction continues to be generally defined as southward (from southwest to southeast). Regional nitrate and sulfate contaminants have recently shown a possible southeast flow direction north of WMA C (Sections 3.4.1.7 and 3.4.10.3). However, distribution of certain contaminants indicates a southwest flow direction (Section 3.4.3.3). Based the lack of a definitive gradient measurement in this area, flow direction and rate are indeterminate.

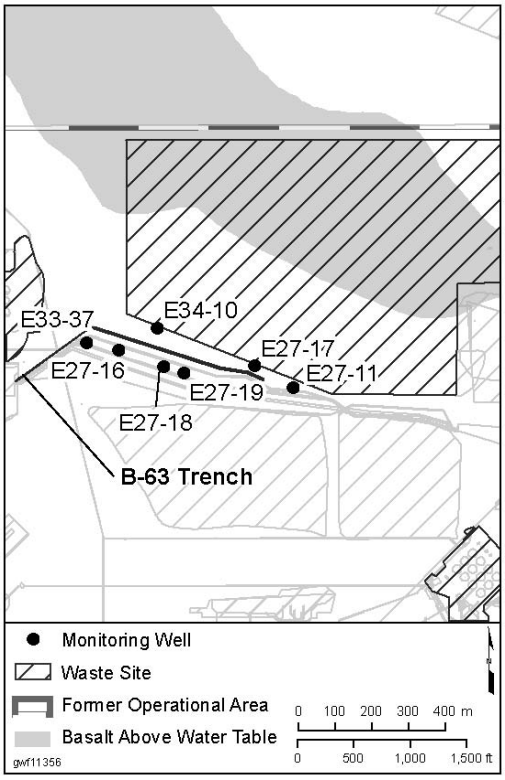
The network well screens range from 1.61 to 13.47 meters into the aquifer. These wells all have adequate water columns in the screened interval for sampling through the next decade or more.

During 2011, the only dangerous waste/dangerous waste constituent impacting groundwater at WMA C was cyanide.

During 2011, the only dangerous waste/dangerous waste constituent impacting groundwater was cyanide. The concentrations were significantly below the 200 µg/L drinking water standard with a yearly high of 21.7 µg/L at well 299-E27-14. Note that cyanide was reported as high as 37.4 µg/L at well 299-E27-7, but the value was flagged because cyanide was also found in the associated quality control blank. Four other possible dangerous wastes/dangerous waste constituents that continued to be evaluated from 2010 are discussed as follows:

- Carbon tetrachloride was not detected in any WMA C monitoring well in 2011 and therefore the one detection in 2010 was determined to be false positive. This constituent is excluded from further review.
- Chloroform was continuously detected in well 299-E27-12, but excluded because this well is an upgradient well (see SGW-51057, *WMA C April through June 2011 Quarterly Groundwater Monitoring Summary Report*, for further explanation).
- Nickel, like manganese (discussed in Section 3.4), was determined to be associated with well screen degradation based on the investigation associated with similar findings at wells 299-E33-337 and 299-E33-339.
- Elevated vanadium was determined to be associated with an upgradient source because of the levels in wells north of WMA C.

The presence of the dangerous waste constituent cyanide implies the 241-C Tank Farm is continuing to impact the groundwater. The current monitoring network is sufficient to determine the extent of contamination, as shown on Figure 3.4-24. Because of the lack of a measurable groundwater gradient, as described above, the rate of migration is indeterminate. Existing wells in the region will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.



3.4.13.3 216-B-63 Trench

The 216-B-63 Trench is located in the north central portion of the 200 East Area. The trench was constructed by 1970 as an emergency percolation trench for radioactively contaminated cooling water from B Plant. Through 1985, acidic and caustic treatments were completed to neutralize the waste. The actual corrosive portion from the demineralizers was less than 1,890 liters per day, while the remainder of the 378,000 to 1,408,000 liters per day was a combination of chemical sewer and cooling water. The corrosive waste

discharges were regulated under RCRA and its implementing requirements WAC 173-303-400. Discharges to this trench ceased in 1992.

In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semiannually for contaminant indicator parameters and supporting constituents (DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*). All of the wells were sampled semiannually, as required, during 2011. Appendix B Table B-16 includes a list of 216-B-63 Trench wells, the constituents monitored, and indicates if the wells were sampled as scheduled. Because of the midyear flow direction change as noted in the introduction of Section 3.4, the flow direction and rate were indeterminate. Appendix B Tables B-2 and B-17 provides the indicator parameter comparison values for 2011 and 2012, respectively.

The monitoring network for the 216-B-63 Trench consists of two upgradient and five downgradient wells.

The monitoring network, as defined in DOE/RL-2008-60, consists of two upgradient and five downgradient wells. The definition of upgradient and downgradient is based on a west-southwest flow direction. Currently, the flow direction is undefined because of the flat nature of the water table. Barometric response corrections were included for the 216-B-63 Trench network in 2011; however, the variability in the measurements compared to the water table change was too great to return a statistically significant flow direction determination. Because of the local variability, taking a more regional approach may provide sufficient data to determine a gradient in this area. A regional approach for evaluating existing wells will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.

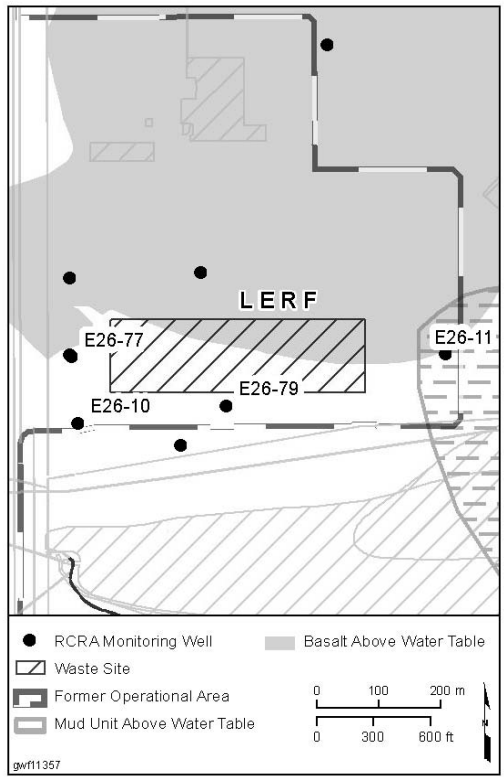
Regional contaminant evaluations provide additional information on groundwater flow directions. These evaluations indicate flow to the west-northwest from the west end of the 216-B-63 Trench (wells 299-E27-16, 299-E33-33, 299-E33-36, 299-E33-37, 299-E33-337, 299-E33-338, and 299-E34-8). Some of the wells are not associated with the RCRA monitoring network. Sections 3.4.2.5 and 3.4.2.6 discuss historical contaminant migration observations in this area. Based on these observations, the dominant flow direction appears to be west-northwest along the west end of the trench. However, a midyear groundwater flow change deters stating a prominent flow direction in 2011. The regional contamination discussed above is assumed to be associated with the 216-B-2 Ditches and other past sources to the east-southeast.

The network well screens range from 2.09 to 4.69 meters into the aquifer. These water table wells all have adequate water columns in the screened interval for sampling through the next decade and beyond.

During 2011, the indicator parameter measurements for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the 216-B-63 Trench wells ranged from 7.91 to 8.28, which is within the lower and upper bound of the critical mean (7.42 to 8.67, respectively). The highest specific conductance level was 470 µS/cm, which is below the critical mean (1,030 µS/cm). The highest average total organic carbon level was 517 µg/L, which is below the critical mean (1,000 µg/L). The highest average total organic halide concentration was 10.18 µg/L, which is below the critical mean (10.9 µg/L). In addition, the annual groundwater phenol results were all reported as non-detects for the April 2011 sampling event. Thus, this site remained in interim status indicator evaluation monitoring.

3.4.13.4 Liquid Effluent Retention Facility

Located on the eastern boundary of the 200 East Area, the LERF consists of three lined surface impoundment basins. Construction of the complex was completed in 1991. The basins are arranged side by side, with an 18.2 meter separation between each basin. The dimensions of each basin (cell) are 100.5 meters by 82.2 meters, with a maximum fluid depth of 6.7 meters.



Groundwater at LERF continued to be monitored under RCRA final status permit conditions. The LERF is a RCRA-regulated unit under RCW 70.105 ("Hazardous Waste Management") and is subject to groundwater monitoring requirements pursuant to WAC 173-303-645. All of the wells were sampled semiannually, as required, for RCRA indicator and site-specific parameters (PNNL-11620, *Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan*) during 2011.

The uppermost aquifer directly beneath the LERF consists of thin aquifer(s) in the Hanford formation and Elephant Mountain Member flow top. The aquifer in the Hanford formation is unconfined; however, recent analysis of water-level data for barometric pressure responses indicates that the aquifer near well 299-E26-11 is semiconfined.

A new well (299-E26-14) was installed on the north side of the LERF in 2011 to acquire more hydrologic data because of the complexity of the basalt-Hanford formation contact and the flow top lithology on the top of the basalt. The well will be sampled in 2012 along with the other LERF wells and a characterization report will be issued with a recommendation as to whether the well should be added to the existing network.

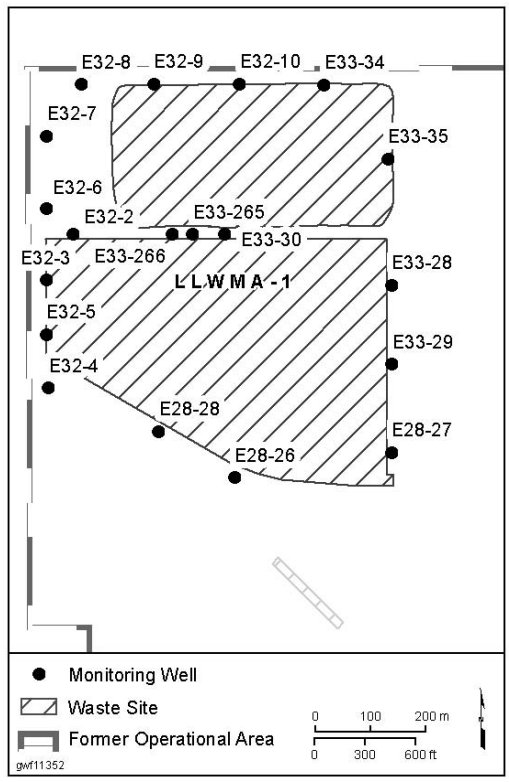
The current groundwater monitoring network consists of one upgradient well and three downgradient wells, which are sampled semiannually (Appendix B Table B-22). All monitoring wells are compliant with WAC 173-160.

Work began in fiscal year 2008 to better understand the groundwater flow direction beneath the LERF. Vertical elevation surveys and gyroscopic surveys were performed at three wells (299-E26-10, 299-E26-77, and 299-E26-79) in 2009as a result of the flatness of the water table. Trend-surface analyses were applied in 2011 to the measurements to determine gradient magnitudes and flow directions on two data sets: one data set without barometric corrections, and the second data set with barometric corrections. The two sets are very similar, so only the corrected set will be discussed. Since well 299-E26-11 is considered to be in the semiconfined aquifer and possibly not in direct hydraulic communication with the other three wells, it shows ~0.8 meter higher head than the remainder of the wells and was excluded from the analyses. The semiconfined aquifer is in communication with the unconfined aquifer; however, it is a different hydrostratigraphic unit with different properties. Trend-surface analysis was performed for the three remaining wells in the network (exclusive of well 299-E26-11), and the data set corrected for barometric effects showed average groundwater flow direction to be south-southwest at 199 (±28) degrees) and the average gradient magnitude was 2.6×10^{-4} ($\pm 5.8 \times 10^{-4}$) meter per meter, with a calculated groundwater flow of ~0.02 meter per day (Table B-1, Appendix B). This analysis is similar to the 2009 groundwater flow direction of 199 degrees. The gradient magnitude increased from the 2009 value of 1.3×10^{-4} meter per meter.

The uppermost aquifer beneath the LERF is being evaluated as part of a groundwater evaluation plan. This plan will be part of a revision of the LERF operating permit that will form the basis for future groundwater monitoring at the unit. The results from drilling new wells suggest that the fractured basalt flow top makes up the basal portion of the unconfined aquifer. New well 299-E26-14 on the north side of the LERF is screened in the Hanford formation and contains sufficient water to further delineate groundwater flow direction.

The dangerous waste constituents and groundwater quality parameters currently monitored according to the permit are alkalinity, ammonium, anions, metals, phenols, and volatile organics. The contaminants of concern are nitrate, total organic halogen, and total organic carbon.

Analyses of samples collected during the reporting period indicate that all constituents in the permit were either undetected or below drinking water standards, except for nitrate. Sulfate concentrations slightly increased in well 299-E26-10. Nitrate continued to exceed the drinking water standard in wells 299-E26-10 and 299-E26-77, with maximum concentrations of 51.4 and 50 mg/L, respectively. Nitrate stabilized in well 299-E26-10, but has increased since 2003 and in wells south and east of the LERF. The regional increase of anions and cations is evident in wells located in the central and eastern portions of the 200 East Area. Wells installed prior to LERF operations showed increasing nitrate from a regional plume.



3.4.13.5 Low-Level Waste Management Area 1

The LLWMA-1 is located in the northwest corner of the 200 East Area. It includes the 218-E-10 Burial Ground, which consists of 14 unlined trenches. The LLWMA-1 received low-level radiological waste and low-level mixed wastes beginning in 1955. The dangerous chemicals in the low-level mixed waste portions of LLWMA-1 are regulated under RCRA and its implementing requirements WAC 173-303-400, as defined in DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*. DOE monitors the LLWMAs for radionuclides under the requirements of the AEA, as described in DOE/RL-2000-72.

In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semiannually for RCRA contaminant indicator parameters and supporting constituents. All of the wells were sampled semiannually, as required, during the reporting period. Appendix B Table B-23 includes a list of LLWMA-1 wells, constituents monitored, and indicates if the wells were sampled as scheduled. Because of the midyear flow direction change as noted in the introduction of Section 3.4, the flow direction and rate were indeterminate (Table B-1, Appendix B). Appendix B Tables B-2 and B-24 provide the indicator parameter comparison values for 2011 and 2012, respectively.

The monitoring network for LLWMA-1 consists of six upgradient and eleven downgradient wells.

The monitoring network as defined in DOE/RL-2009-75 consists of six upgradient and eleven downgradient wells. The definition of upgradient and downgradient is based on a northwest flow

direction. Occasionally the flow direction changes as a result of high Columbia River spring stages. This occurred in 2011 and previously in June 2008. The previous reversal back to the north was not statistically realized until the summer of 2009. Fortunately, wells are located on all sides of the burial ground and indicator parameters are collected at all wells semiannually.

The network well screens range from 1.72 to 3.36 meters into the aquifer. These groundwater wells all have adequate water columns in the screened interval available for sampling, possibly for several decades.

In 2011, the indicator parameter measurements for pH, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the LLWMA-1 wells ranged from 7.53 to 8.20, which is within the lower and upper bound of the critical mean (7.43 to 8.57, respectively). The highest total organic carbon level was 1,009 µg/L, which is below the critical mean (1,330 µg/L). Note that the average total organic carbon level was even lower. The highest total organic halide concentration was 10.32 µg/L, which is below the critical mean (11.1 µg/L). Also, note that the average total organic halide concentration was even lower. In addition, the annual groundwater phenol results were all reported as non-detects for the January 2011 sampling event.

The indicator parameter specific conductance was reported below the critical mean of 1,100 µS/cm for all wells except 299-E32-10 and 299-E33-34. DOE initially reported the exceedance of specific conductance in well 299-E33-34 to Ecology in 1999. The elevated specific conductance levels are influenced by the migration of BY Cribs plumes. Thus, the elevated specific conductance in wells 299-E32-10 and 299-E33-34 is not a cause for a change to the interim status indicator evaluation monitoring.

Performance assessment monitoring of radionuclides at LLWMA-1 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium specifically for performance assessment. Based on observations at the LLWMA-1 wells and other 200-BP-5 monitoring wells, the LLWMA-1 did not impact the groundwater. The paragraphs that follow provide summaries of the performance assessment monitoring results and source interpretations for each of the contaminants of concern.

Technetium-99 concentrations exceed the drinking water standards in wells monitoring the northeast portion of the WMA. The technetium-99 groundwater concentrations in the northeast wells (299-E32-10 and 299-E33-34) is primarily associated with the technetium-99 plume migrating from the BY Cribs. Technetium-99 detected in wells 299-E32-8, 299-E32-9, 299-E33-28, 299-E33-29, 299-E33-30, and 299-E33-35 is associated with either the 241-BX-102 unplanned release or a combination of the 241-BX-102 unplanned release and the BY Cribs. Technetium-99 from the B Complex is discussed further in Section 3.4.3.1.

Elevated iodine-129 activities found predominantly in the northeast portion of the WMA is from sources to the east-southeast, as discussed in Section 3.4.2. The highest level was in well 299-E33-35 (4.93 pCi/L). Levels decrease across the WMA to the southwest.

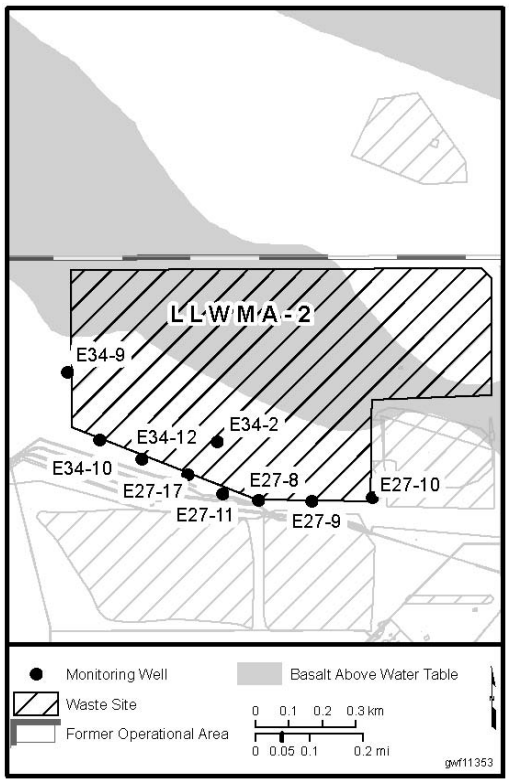
Uranium concentrations exceed the drinking water standards in wells monitoring the northwest corner of the WMA. The elevated concentrations are associated with the 241-BX-102 unplanned release. The highest concentrations was in well 299-E33-34 at 159 µg/L. Uranium concentrations also exceed the drinking water standard at well 299-E28-27 (southeast corner of WMA). The source is the 216-B-12 Crib, as discussed in Section 3.4.4.2.

Tritium was not reported above the drinking water standard in any LLWMA-1 monitoring well in 2011. The highest activity continued to be in well 299-E33-34, which is the result of migration from the 216-B-57 and 216-B-50 Cribs (Section 3.4.7.1).

3.4.13.6 Low-Level Waste Management Area 2

The LLWMA-2 is located in the northeast corner of the 200 East Area. It includes the 218-E-12 Burial Ground, which consists of 40 unlined trenches. The LLWMA-2 received low-level radiological waste and low-level mixed wastes beginning in 1967. The dangerous chemicals in the low-level mixed waste portions of LLWMA-2 are regulated under RCRA and its implementing requirements WAC 173-303-400. DOE monitors the LLWMAs for radionuclides under the requirements of the AEA, as described in DOE/RL-2000-72.

In accordance with 40 CFR 265.93(b), as referenced by WAC 173-303-400, the well network was sampled semiannually for contaminant indicator parameters and supporting constituents (DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*). All of the wells were sampled semiannually, as required, during the reporting period. Appendix B Table B-25 includes a list of LLWMA-2 wells, constituents monitored, and indicates if the wells were sampled as scheduled. Flow direction and rate were indeterminate as a result of the flat nature of the water table, as discussed in the following paragraphs and shown in Table B-1, Appendix B. Appendix B Tables B-2 and B-26 provide the indicator parameter comparison values for 2011 and 2012, respectively.



The monitoring network, as defined in DOE/RL-2009-76, consists of one cross-gradient and eight downgradient wells. Previously, when the water table was higher, there were seven additional LLWMA-2 monitoring wells. The upgradient well, 299-E35-1, went sample dry in 1999. An additional well is proposed to replace this well, and installation is scheduled for 2013. The location is provided on Figure 2-5 of DOE/RL-2009-76. More specifically, the well will be positioned adjacent to well 299-E35-1.

The flow direction beneath LLWMA-2 is undefined because of the variability associated with the water table measurements, possibly related to minor measurement errors.

The initial definition of upgradient and downgradient was based on a west-southwest flow direction shown in Figure 3.2 of *Revised Ground-Water Monitoring Plan for the 200 Areas Low-Level Burial Grounds* (WHC-SD-EN-AP-015). Currently, the flow direction is undefined because of the flat nature of the water table. Barometric response corrections were included for the LLWMA-2 network in 2011; however, the variability in the measurements compared to the water table change was too great to return a statistically significant flow direction determination. Because of the local variability, taking a more regional approach may provide sufficient data to determine a gradient in this area. A regional approach for evaluating existing wells will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.

Groundwater quality parameter evaluations have helped to define the direction of groundwater flow near LLWMA-2 in the past. The 2011 data evaluations indicate groundwater movement to the west-southwest at LLWMA-2 wells (299-E27-8, 299-E27-9, 299-E27-10, and 299-E27-11). There is also evidence of south-southeast movement based on nitrate and sulfate increases at wells 299-E27-22 and 299-E27-25 (as discussed in Sections 3.4.1.7 and 3.4.10.3). These observations indicate a varying flow direction based on location along the south boundary of the WMA.

The network well screens range from 1.24 to 2.78 meters into the aquifer. These water table wells all have adequate water columns in the screened interval available for sampling, possibly for the next decade or more.

During 2011, the indicator parameter measurements for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the LLWMA-2 wells ranged from 7.64 to 8.21, which is within the lower and upper bound of the critical mean (6.72 to 8.89, respectively). The highest specific conductance level was 1,112 µS/cm which is below the critical mean (1,460 µS/cm). The highest average total organic carbon level was 988 µg/L, which is below the critical mean (2,220 µg/L). The highest average total organic halide concentration was 13 µg/L, which is below the critical mean (37.1 µg/L). In addition, the annual groundwater phenol results were all reported as non-detects for the April 2011 sampling event. Thus, this site remained in interim status indicator evaluation monitoring.

Performance assessment monitoring of radionuclides at LLWMA-2 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides that are not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium. Based on observations at the LLWMA-2 wells and other 200-BP-5 monitoring wells, the LLWMA-2 did not impact the groundwater. The following paragraphs provide summaries of the performance assessment monitoring results and source interpretations for contaminants of concern if applicable.

The highest average technetium-99 concentrations were at well 299-E27-10 (76 pCi/L) during 2011. The concentration was 5 pCi/L lower than in 2010. The low technetium-99 is assumed to be associated with the elevated nitrate and sulfate from the 216-B-2 Ditches. Alternatively, contributions may be associated with drainage from fractured basalts to the north.

Iodine-129 concentration was most prominent in well 299-E27-8 at 2.43 pCi/L in April 2011. Levels of iodine-129 exceeding the drinking water standards are limited to wells east of well 299-E27-17. The iodine-129 is associated with past migration from sources to the south-southeast, as discussed in Section 3.4.2.

Tritium concentrations have also decreased over the past two decades, with maximum concentrations currently below 500 pCi/L (396 pCi/L at well 299-E27-9 in November 2011). The tritium is associated with past migration from sources to the south-southeast, as discussed in Section 3.4.7.

Uranium concentrations at LLWMA-2 were less than 5 µg/L, which is below background levels (DOE/RL-96-61).

Figure 3.4-1. Facilities and Groundwater Monitoring Wells in the 200 East Area Portion of the 200-BP-5 Operable Unit

Figure 3.4-2. Facilities and Groundwater Monitoring Wells in the 600 Area Portion of the 200-BP-5 Operable Unit

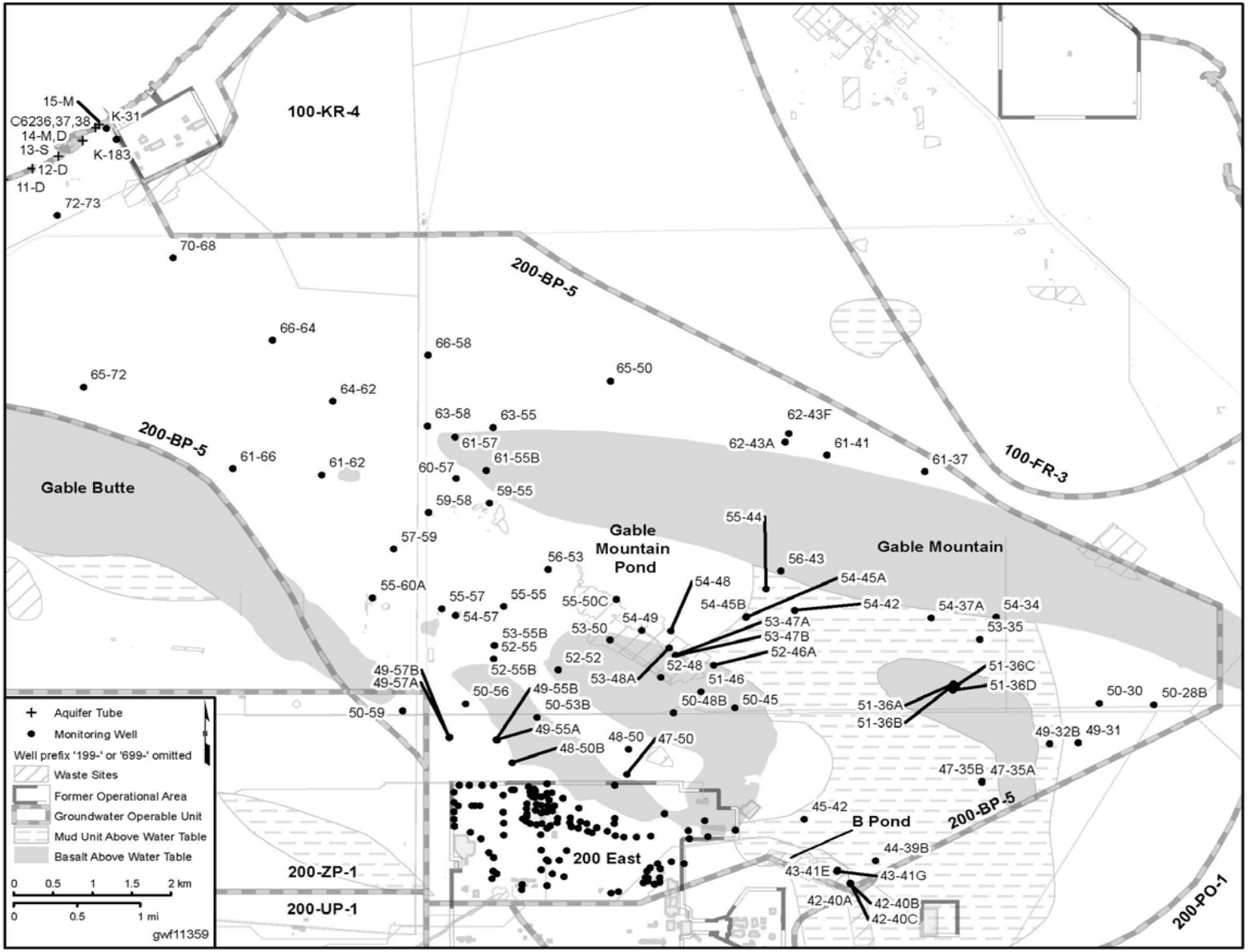


Figure 3.4-3. 200 East Groundwater Table Map, March 2011

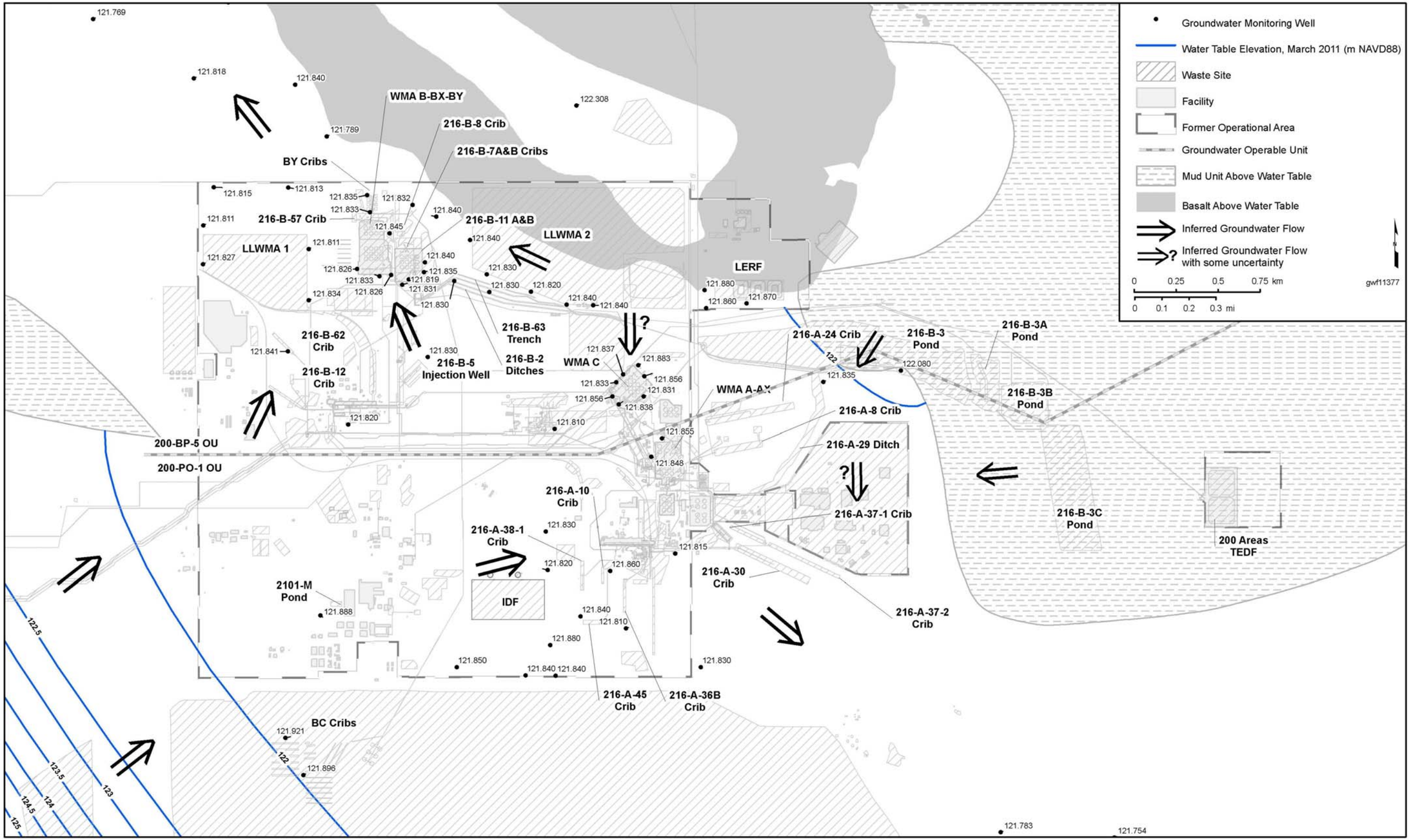


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Figure 3.4-4. Northwest Corner of 200 East Groundwater Table Map, August 2011

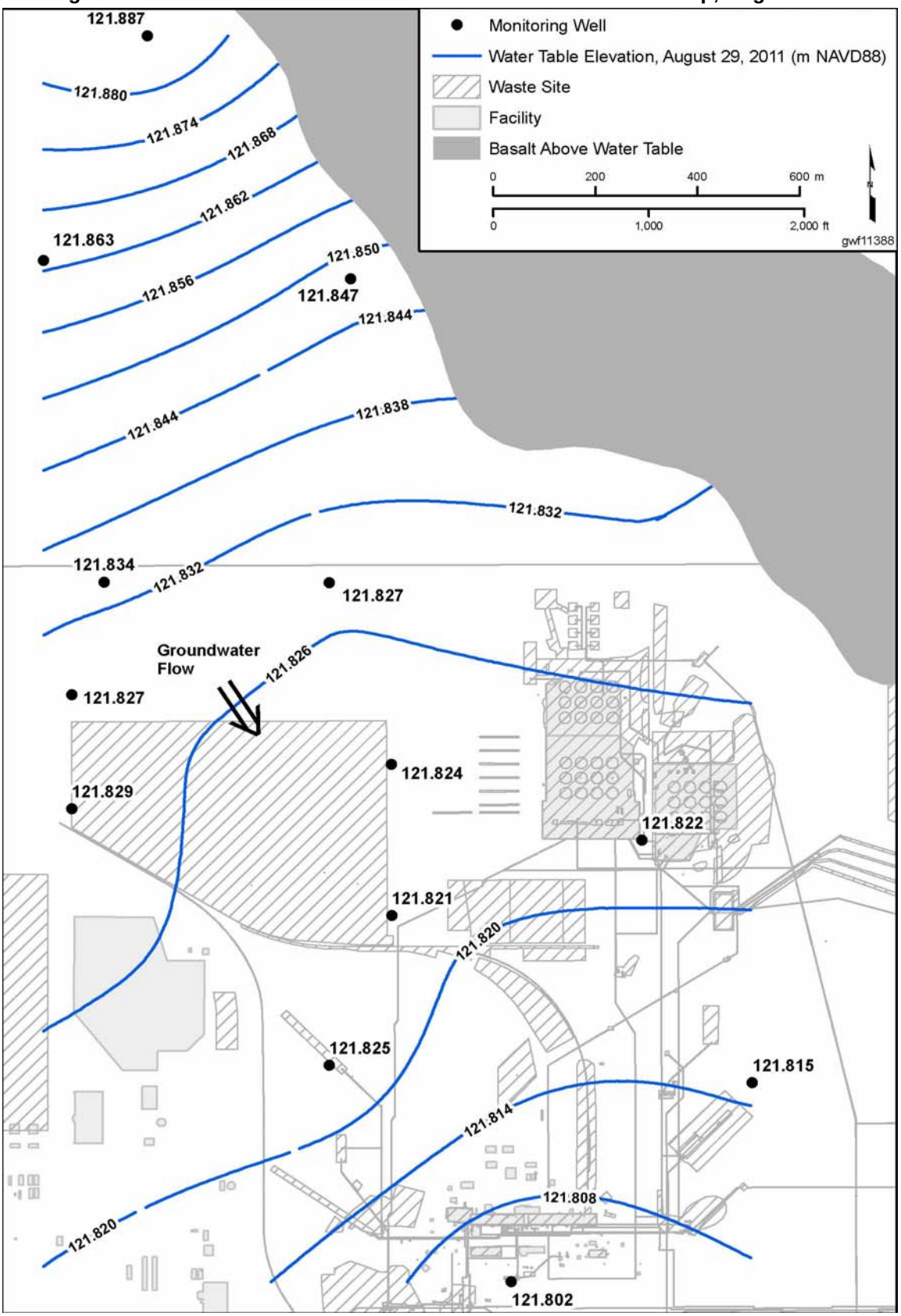

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Figure 3.4-5. Average Groundwater Nitrate Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

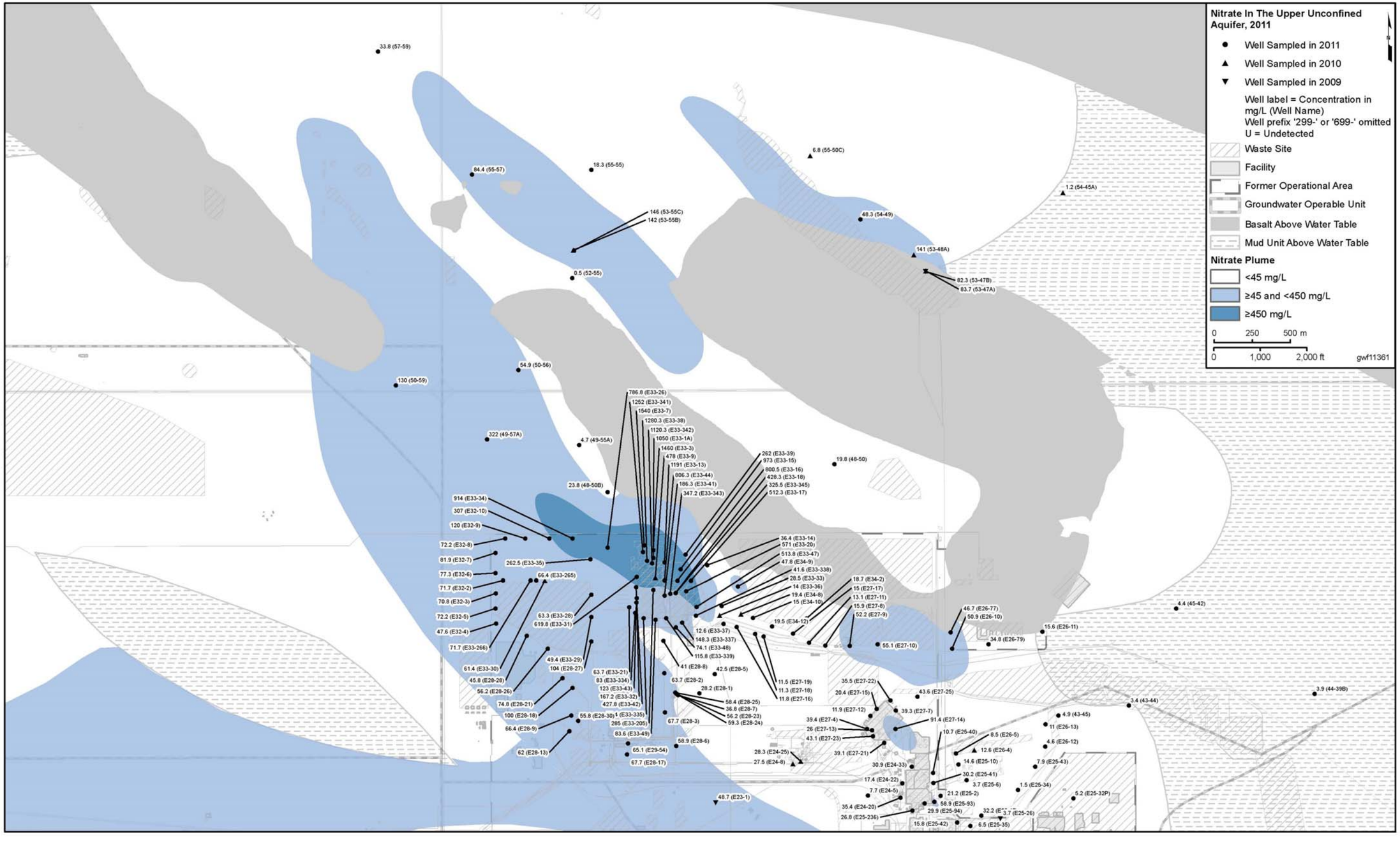

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Figure 3.4-6. Changes in 200-BP-5 Plume Areas

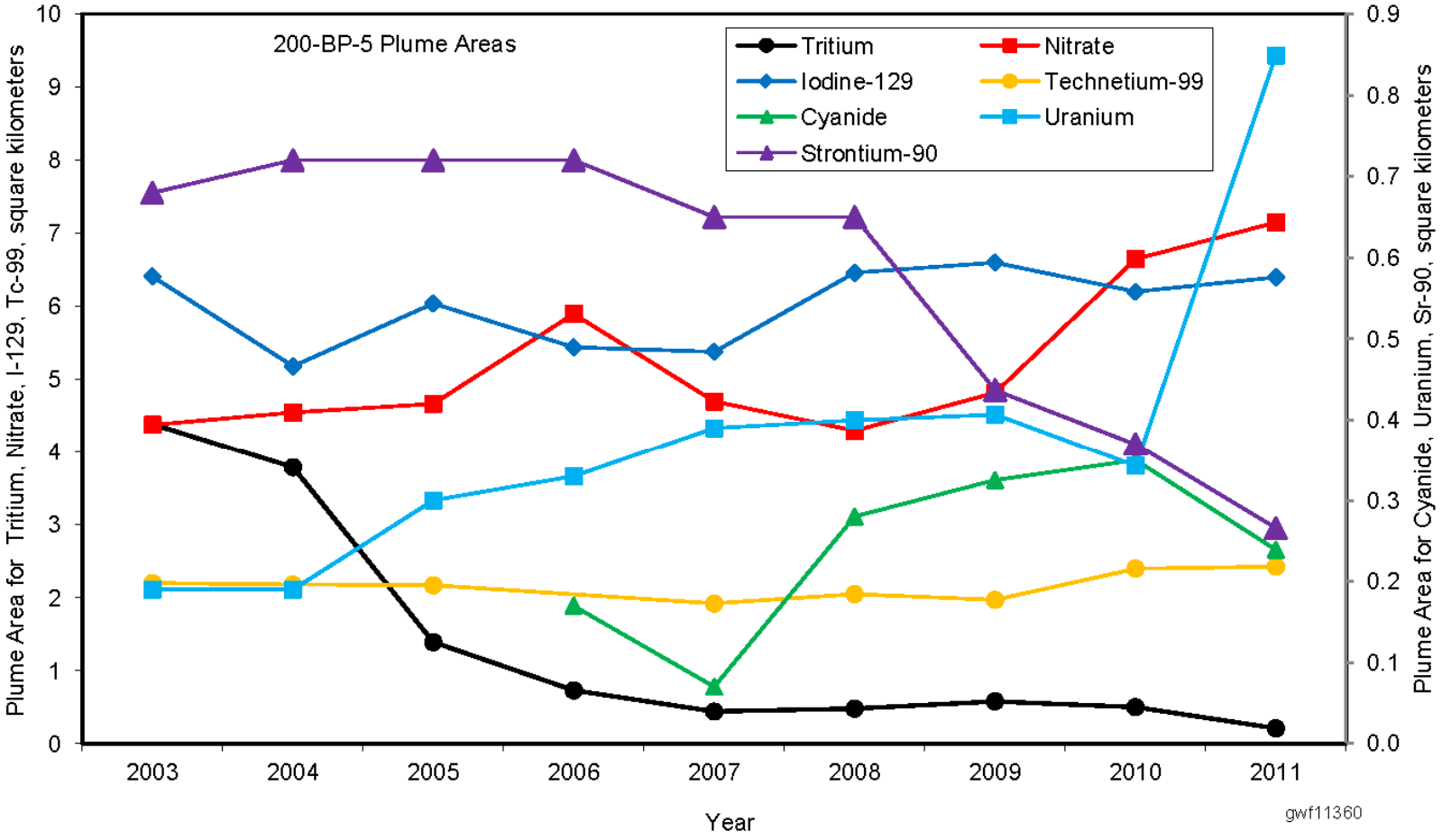

Figure 3.4-7. Nitrate Trend Plot of Wells Located beneath the BY Cribs

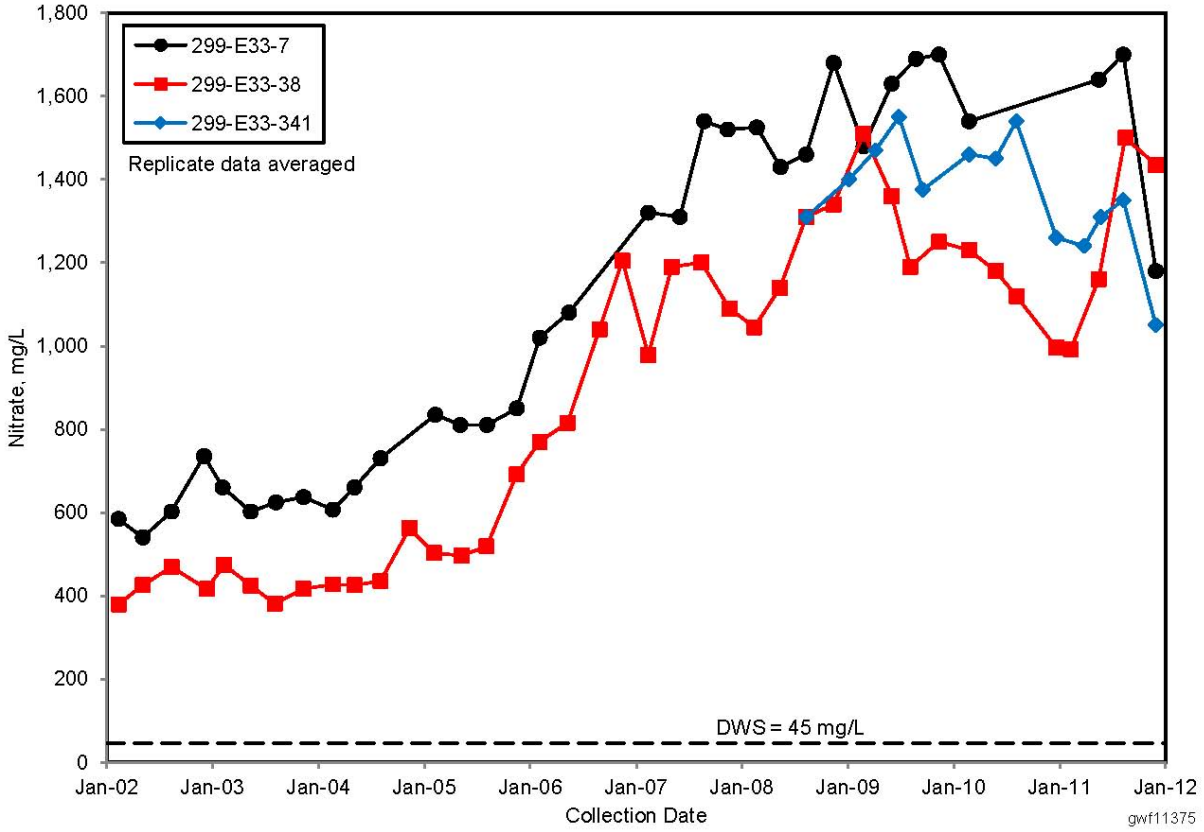

Figure 3.4-8. Nitrate Trend Plot in the Central Portion of the B Complex

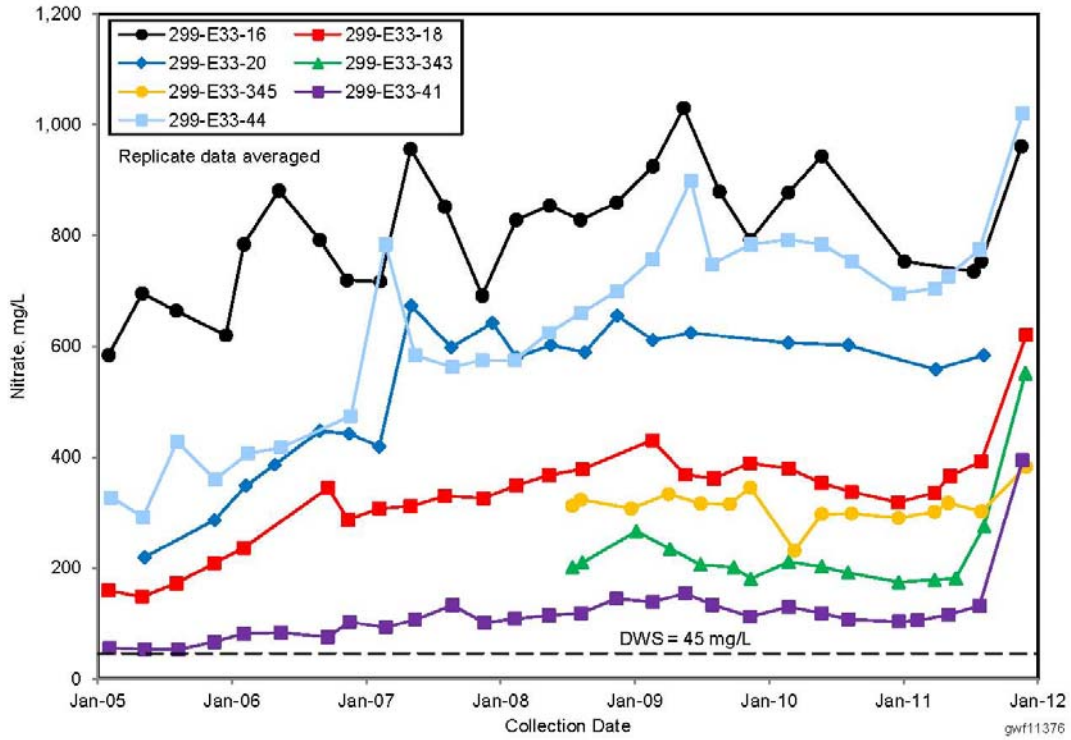

Figure 3.4-9. Nitrate Trend Plot for the East Side of the 241-B Tank Farm

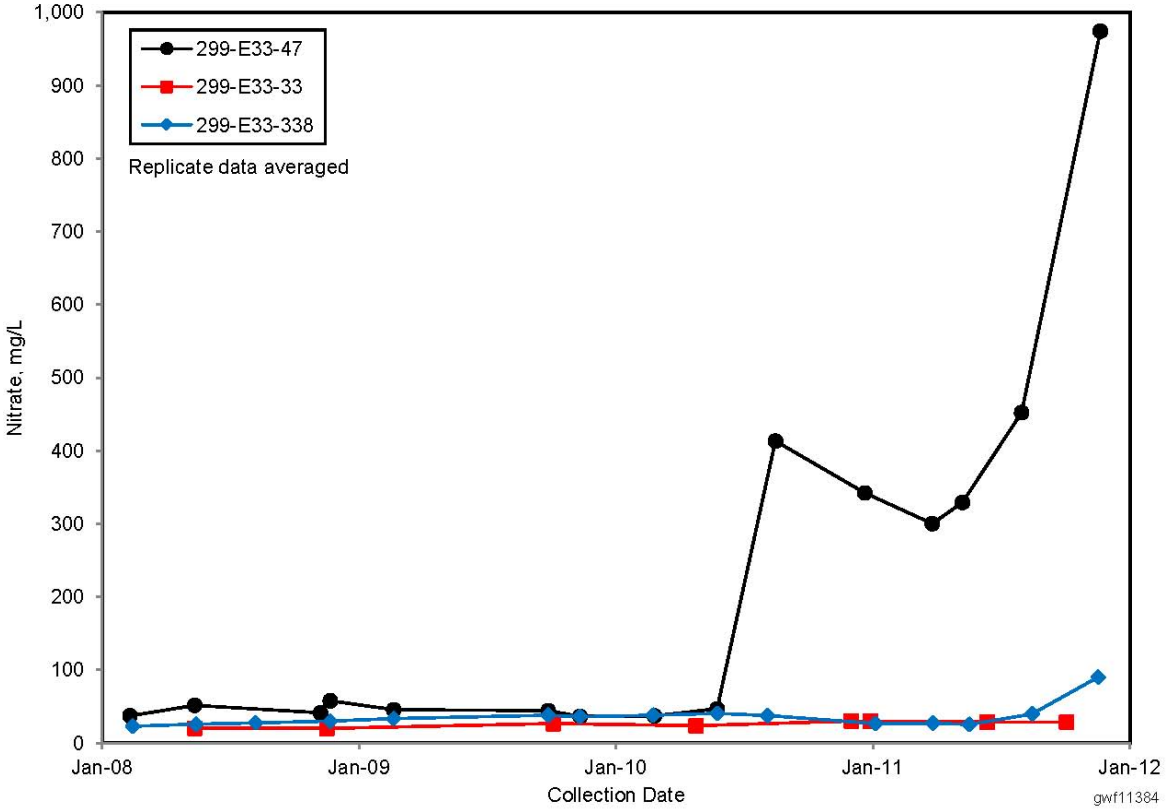

Figure 3.4-10. Nitrate Trend Plot for the South Side of the 241-B Tank Farm

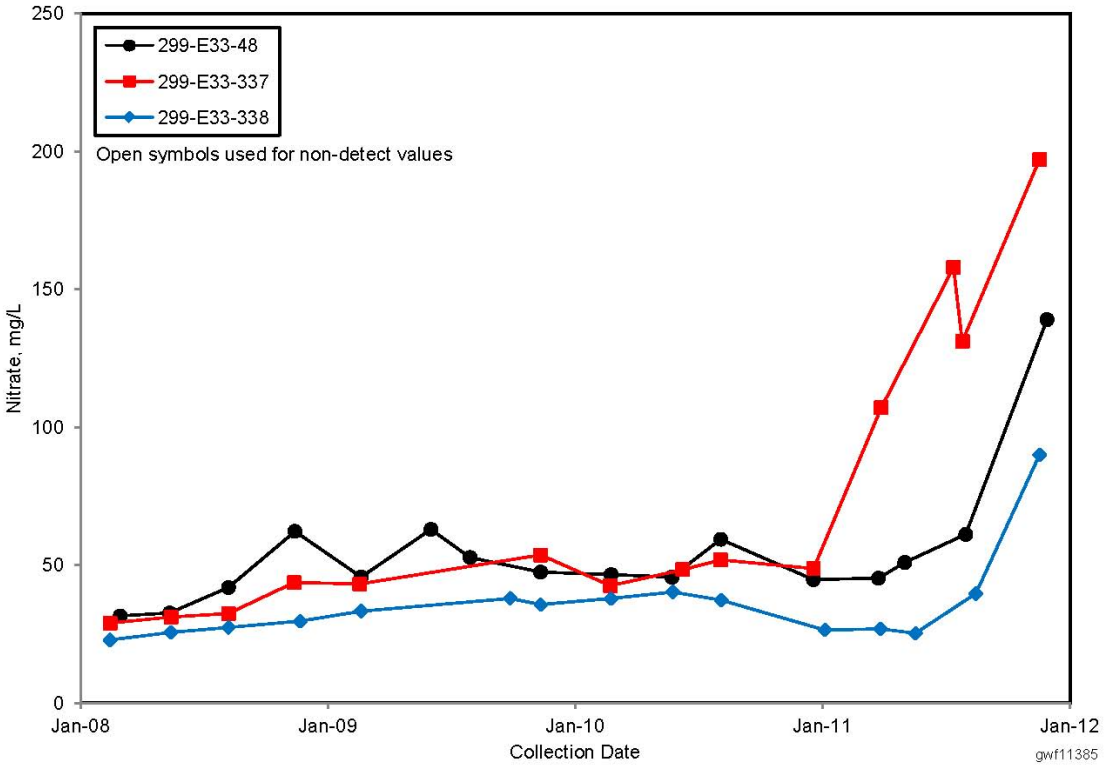

Figure 3.4-11. Nitrate Trend Plot near the East Extent of the 216-B-2 Ditches

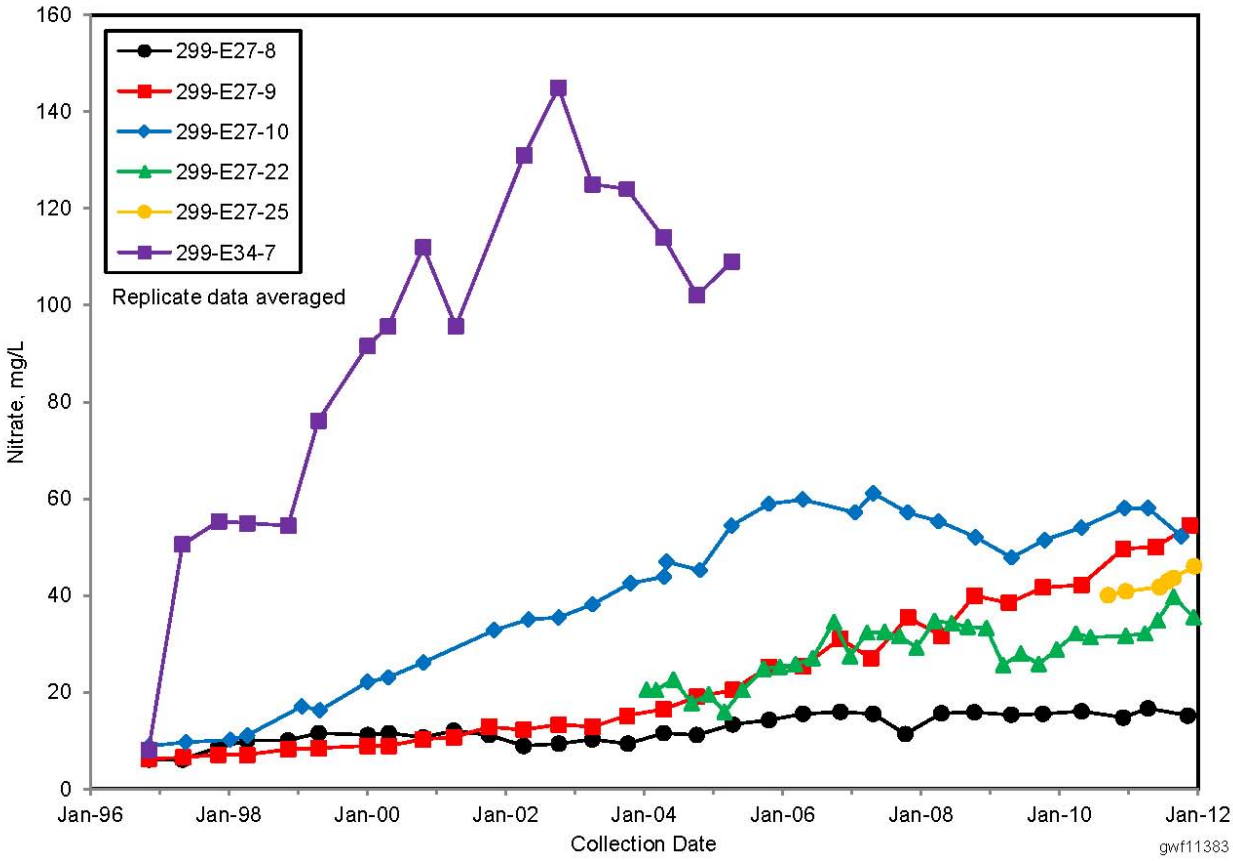

Figure 3.4-12. Average Groundwater Iodine-129 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

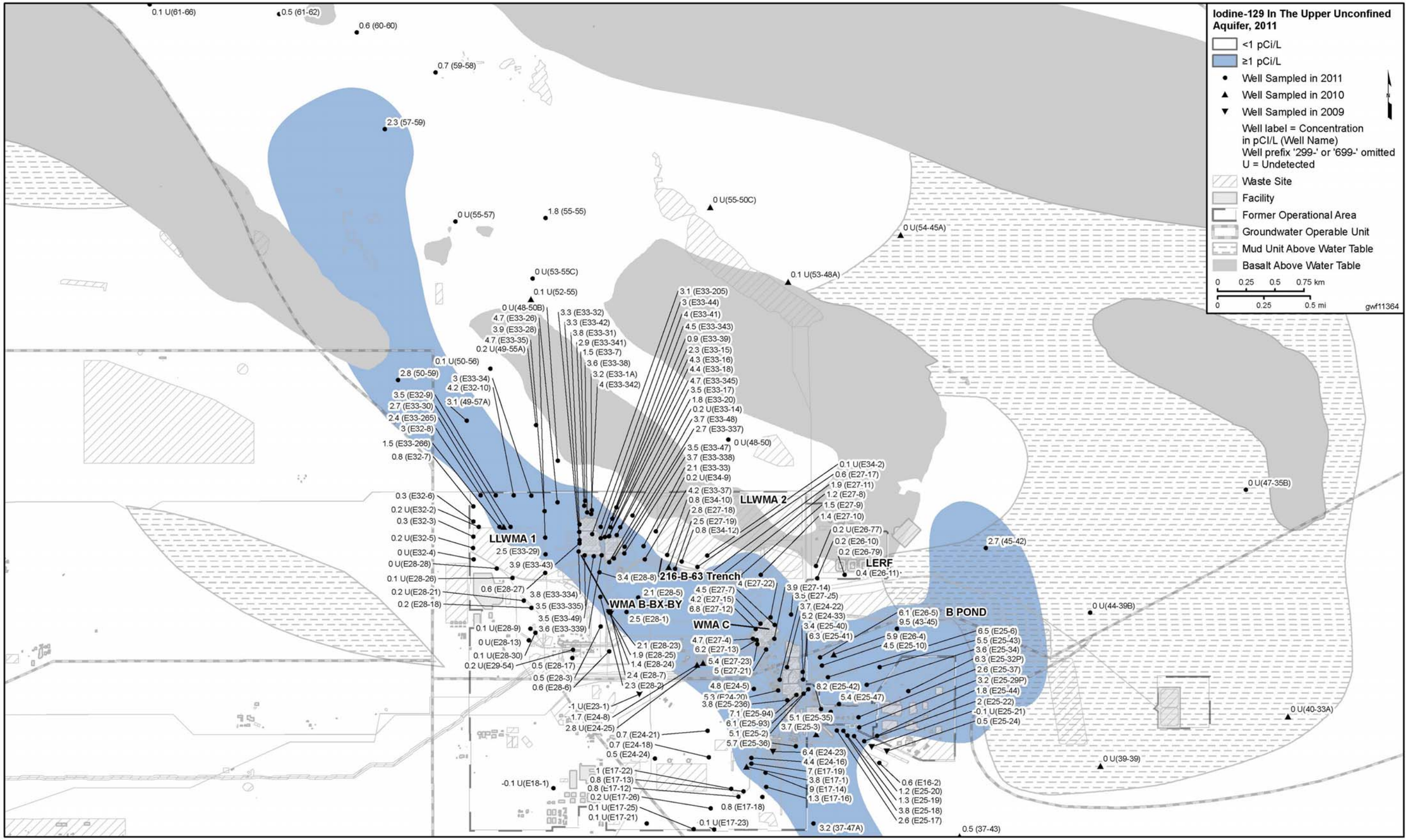

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Figure 3.4-13. Iodine-129 Trend Plots beneath the 216-B-2 Ditches and South-Southeast Side of the 241-B Tank Farm

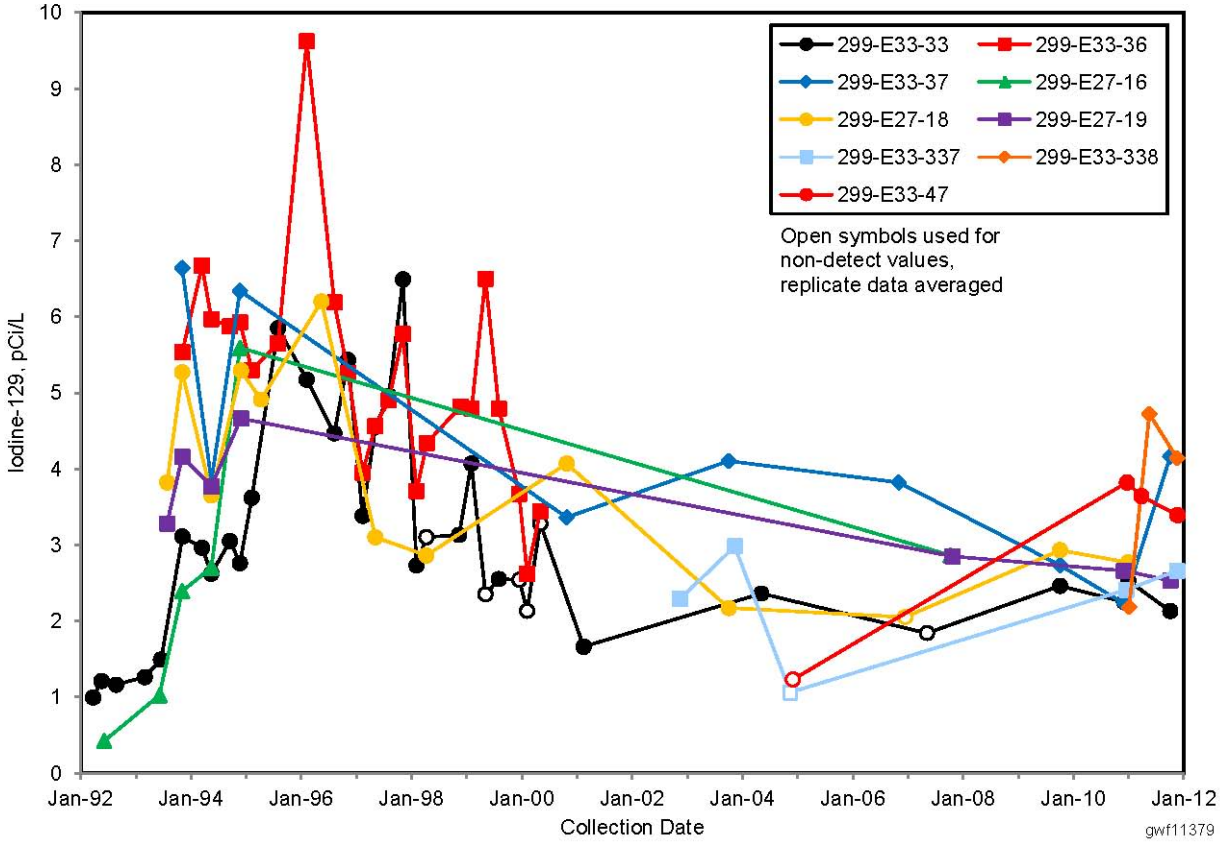

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Figure 3.4-14. Average Groundwater Technetium-99 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

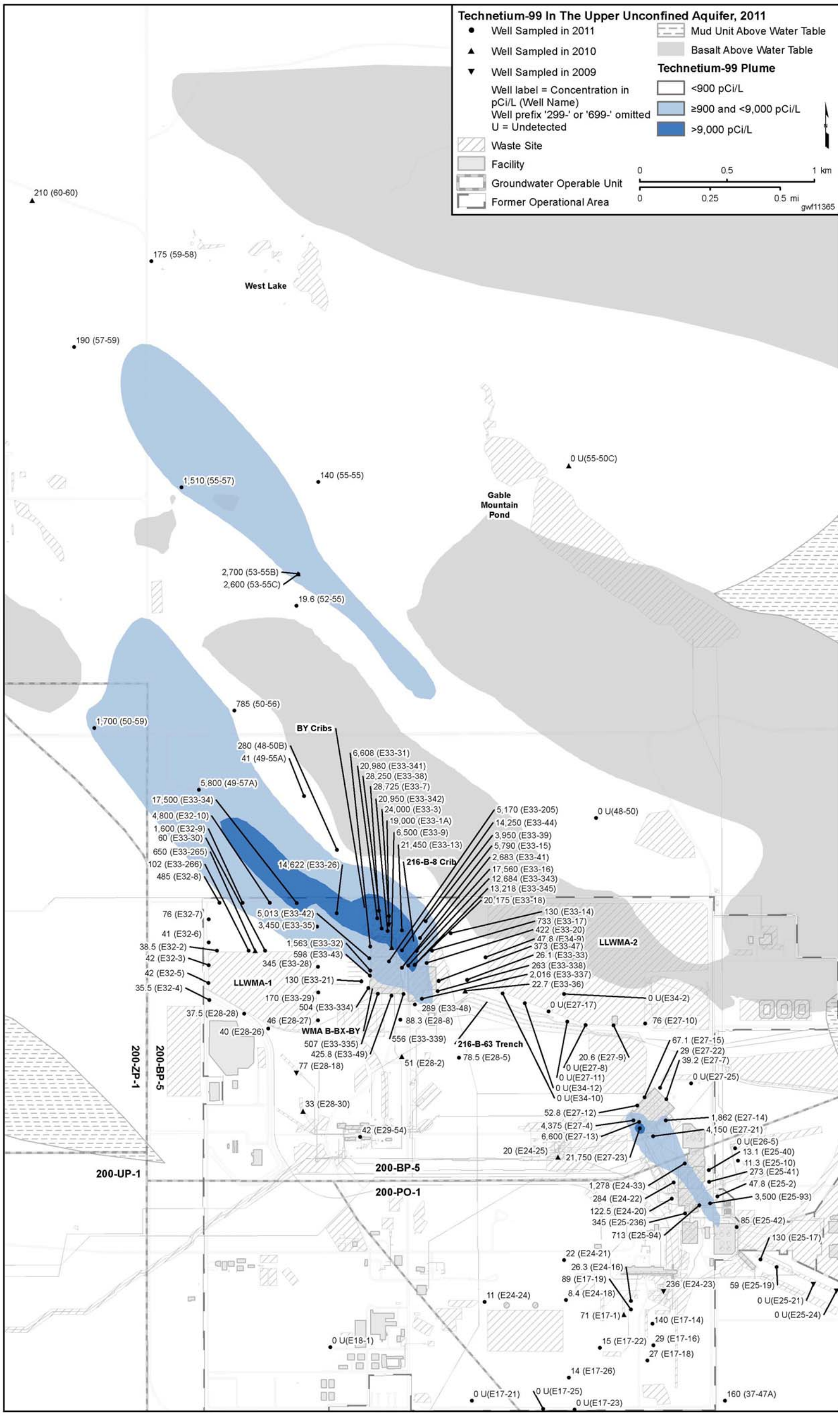

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Figure 3.4-15. Technetium-99 Trend Plot of Wells Located beneath the BY Cribs

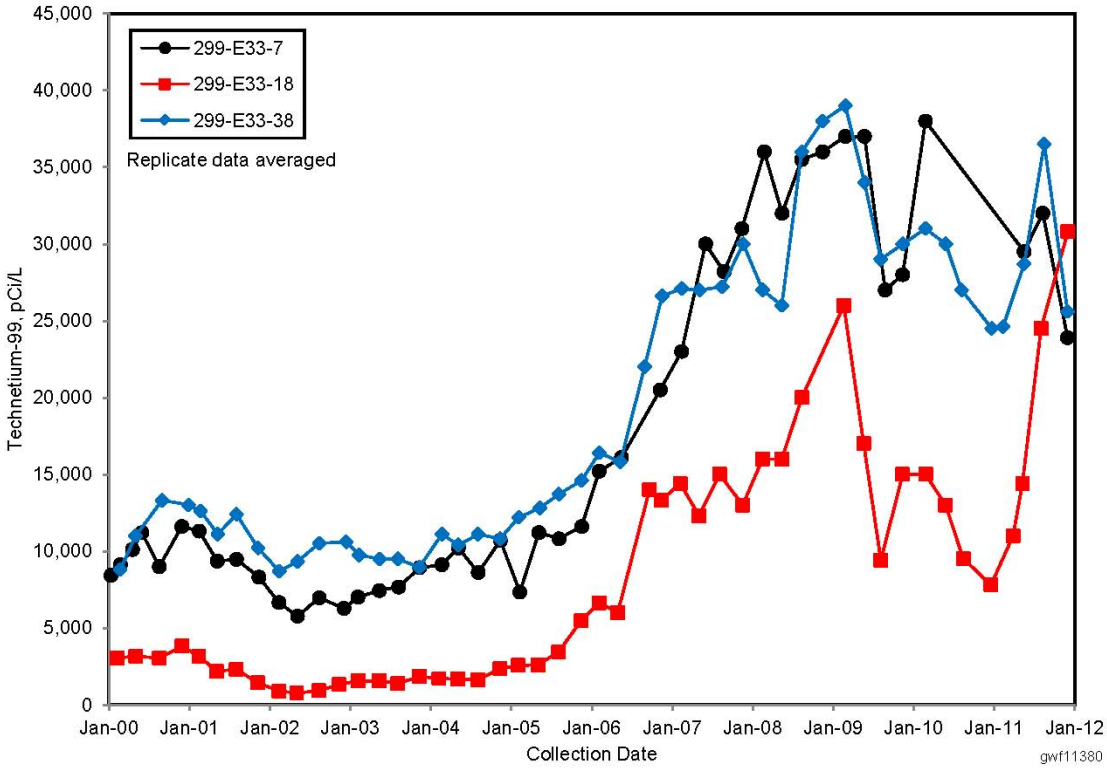

Figure 3.4-16. Technetium-99 Trend Plot for Wells 299-E27-13, 299-E27-23, and 299-E27-4 at WMA C

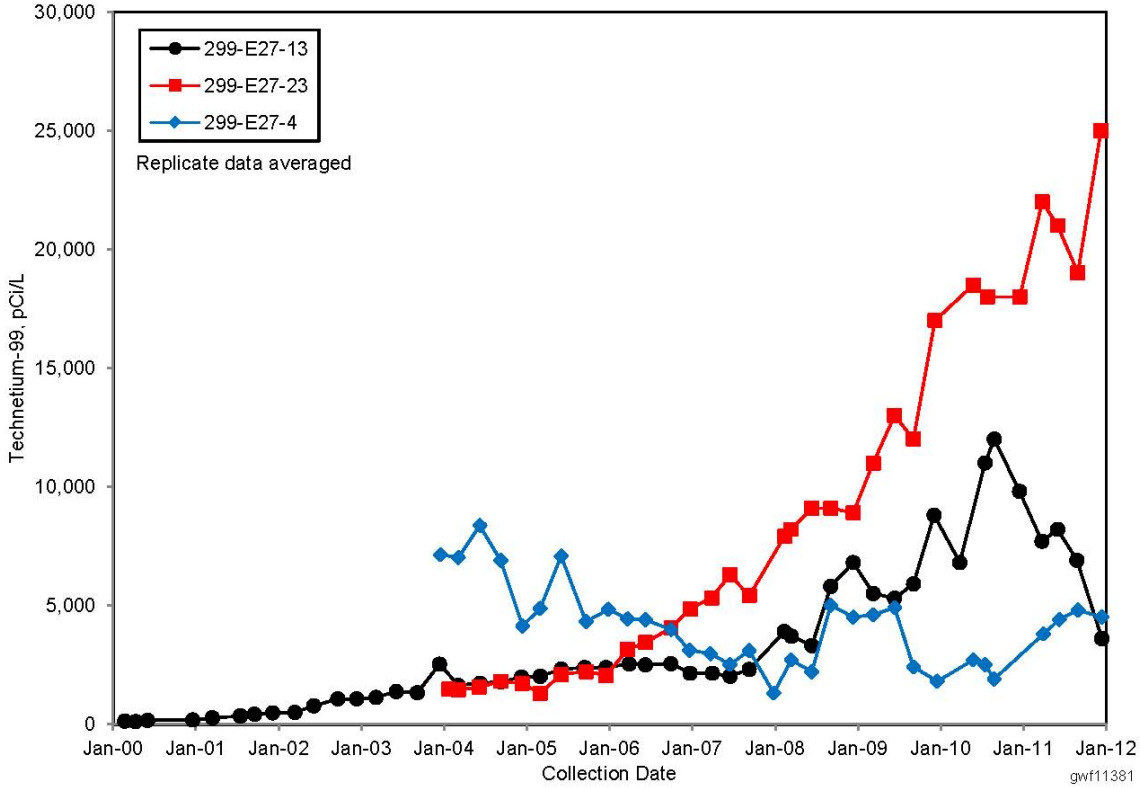

Figure 3.4-17. Average Groundwater Uranium Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

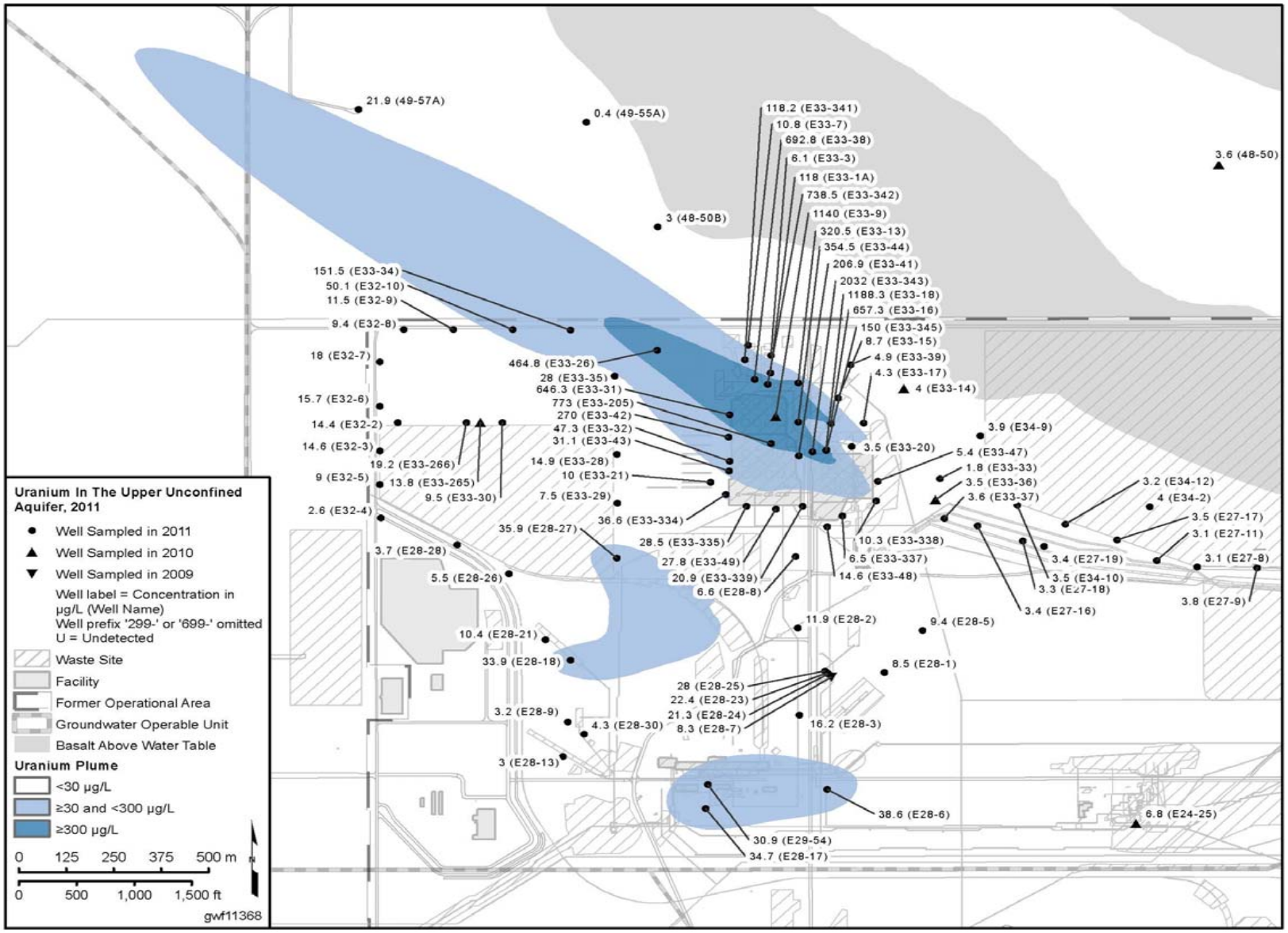

Figure 3.4-18. Uranium Concentrations near the 216-B-5 Injection Well

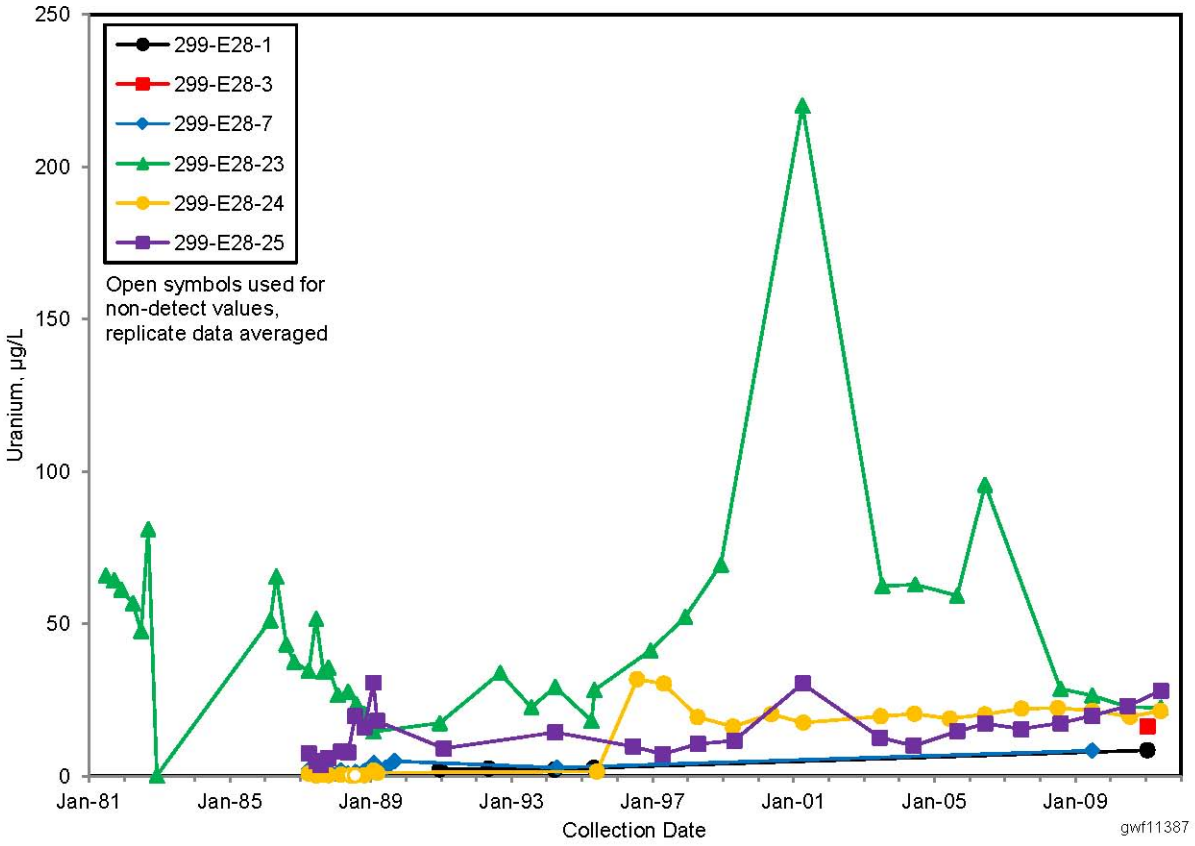

Figure 3.4-19. Average Groundwater Strontium-90 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

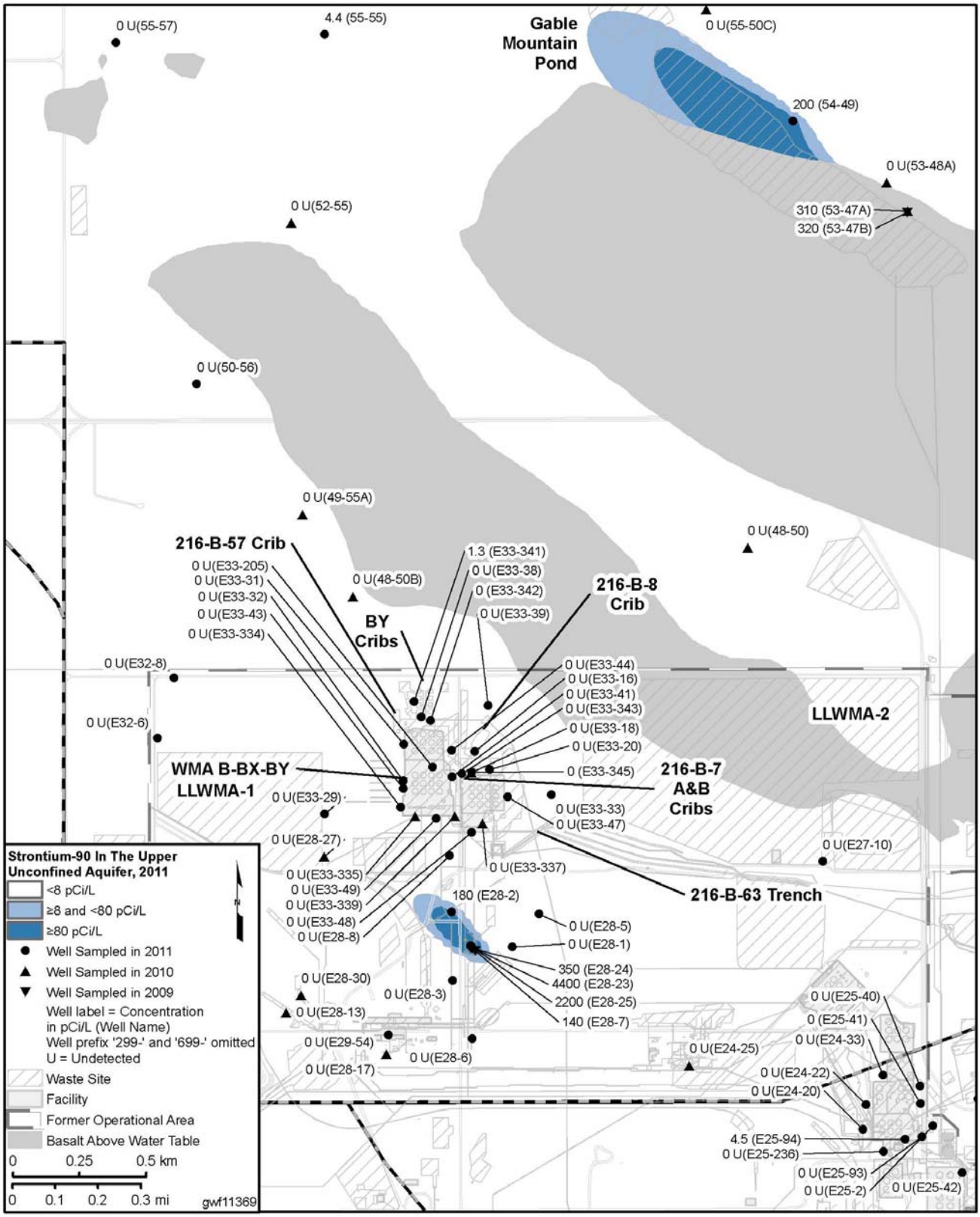

Figure 3.4-20. Cyanide and Iron Trend Plot for the BY Cribs

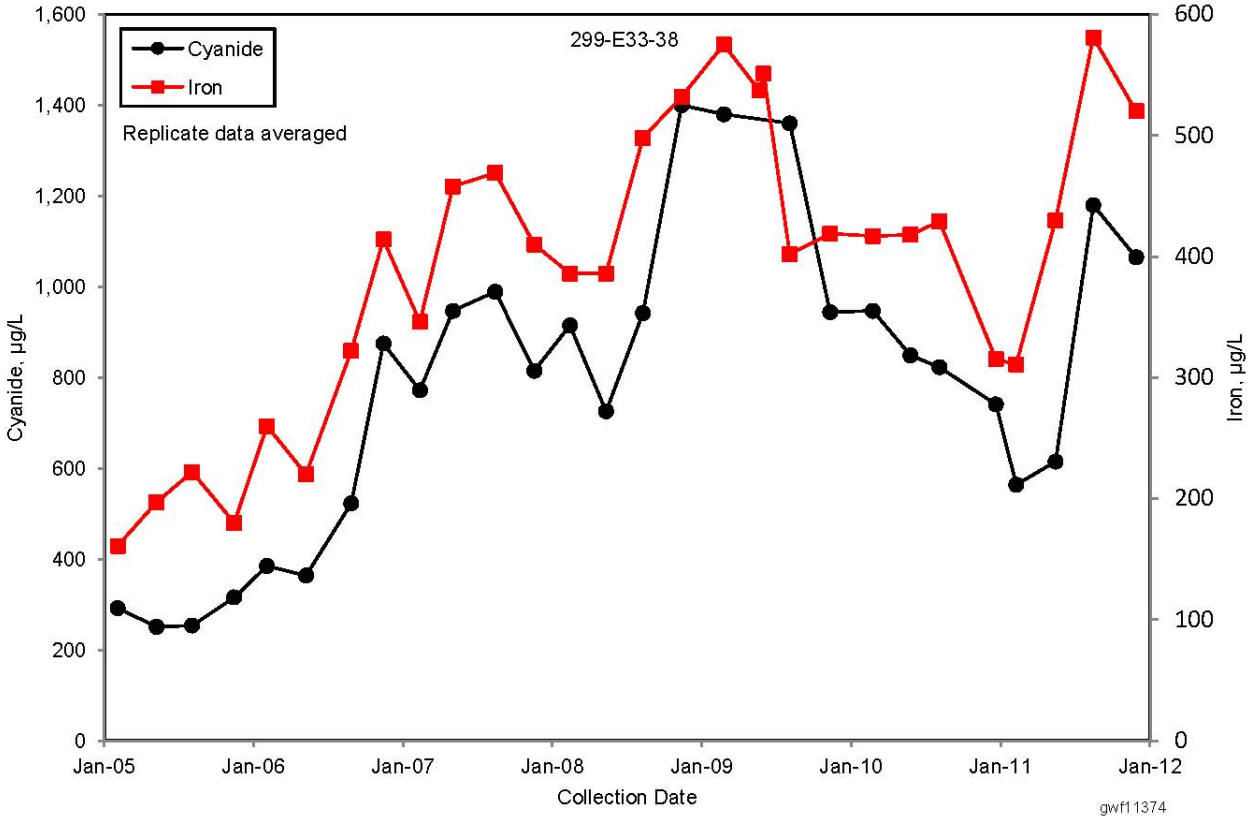

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Figure 3.4-21. Average Groundwater Cyanide Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

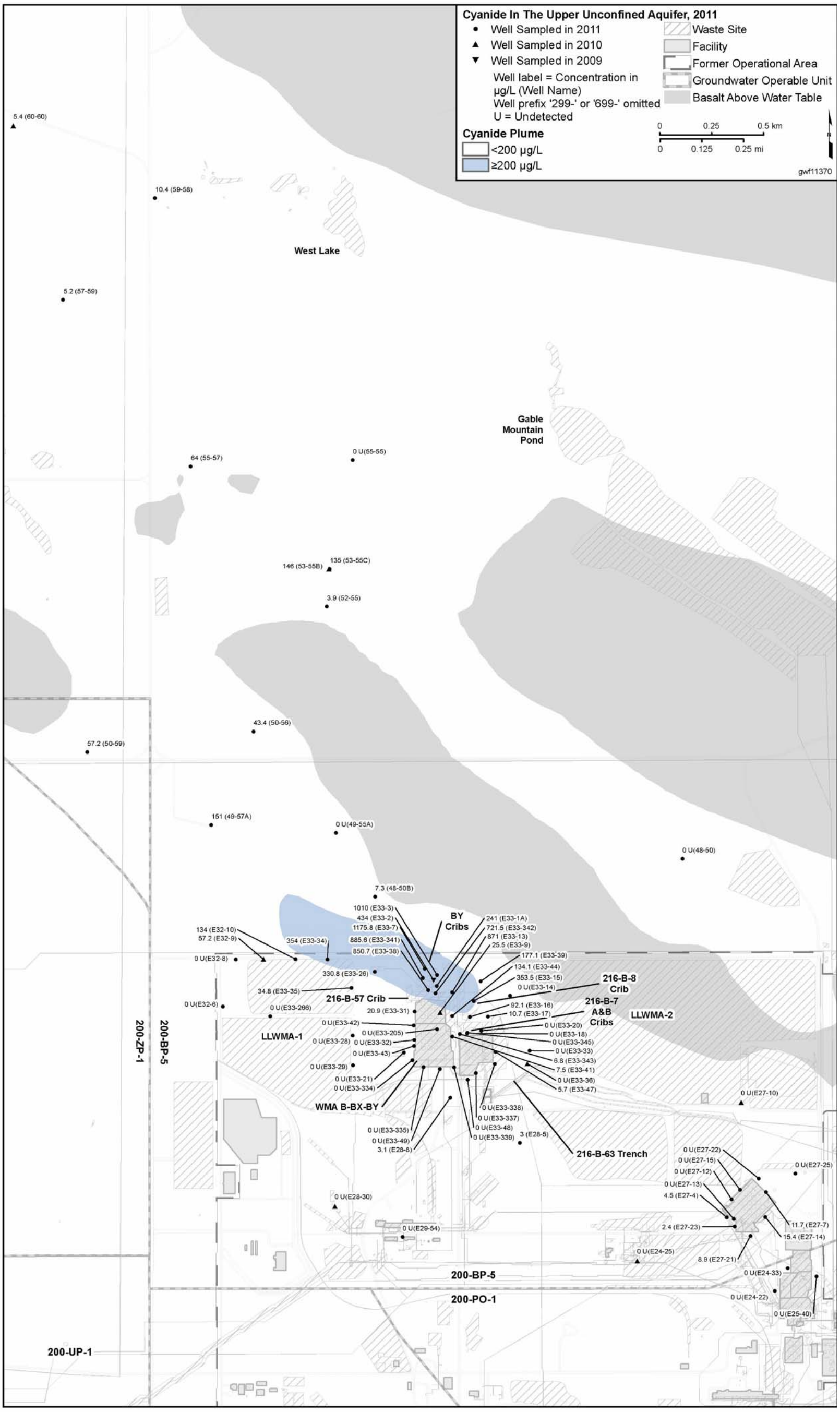

Figure 3.4-22. Average Groundwater Tritium Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

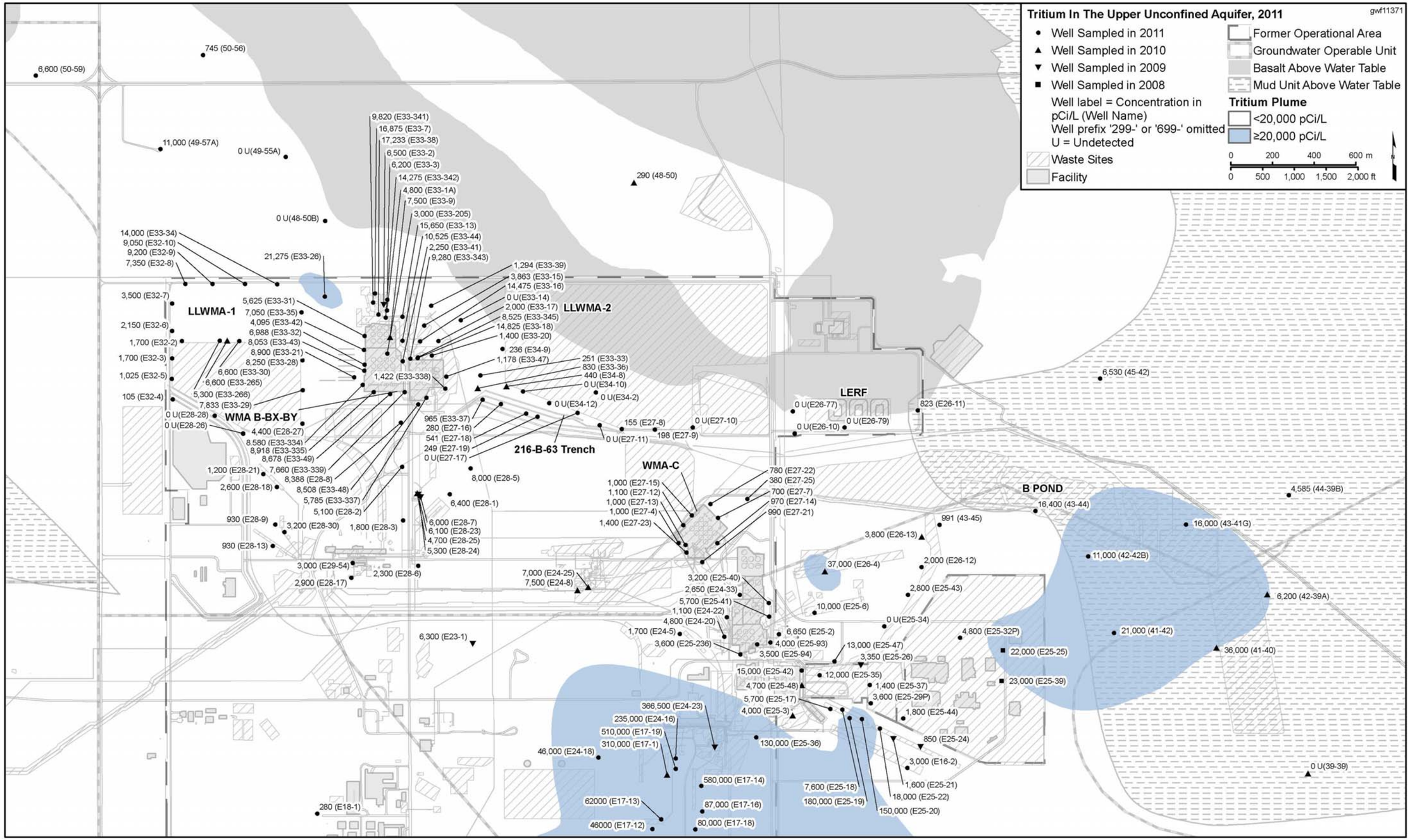

Figure 3.4-23. Average Groundwater Sulfate Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

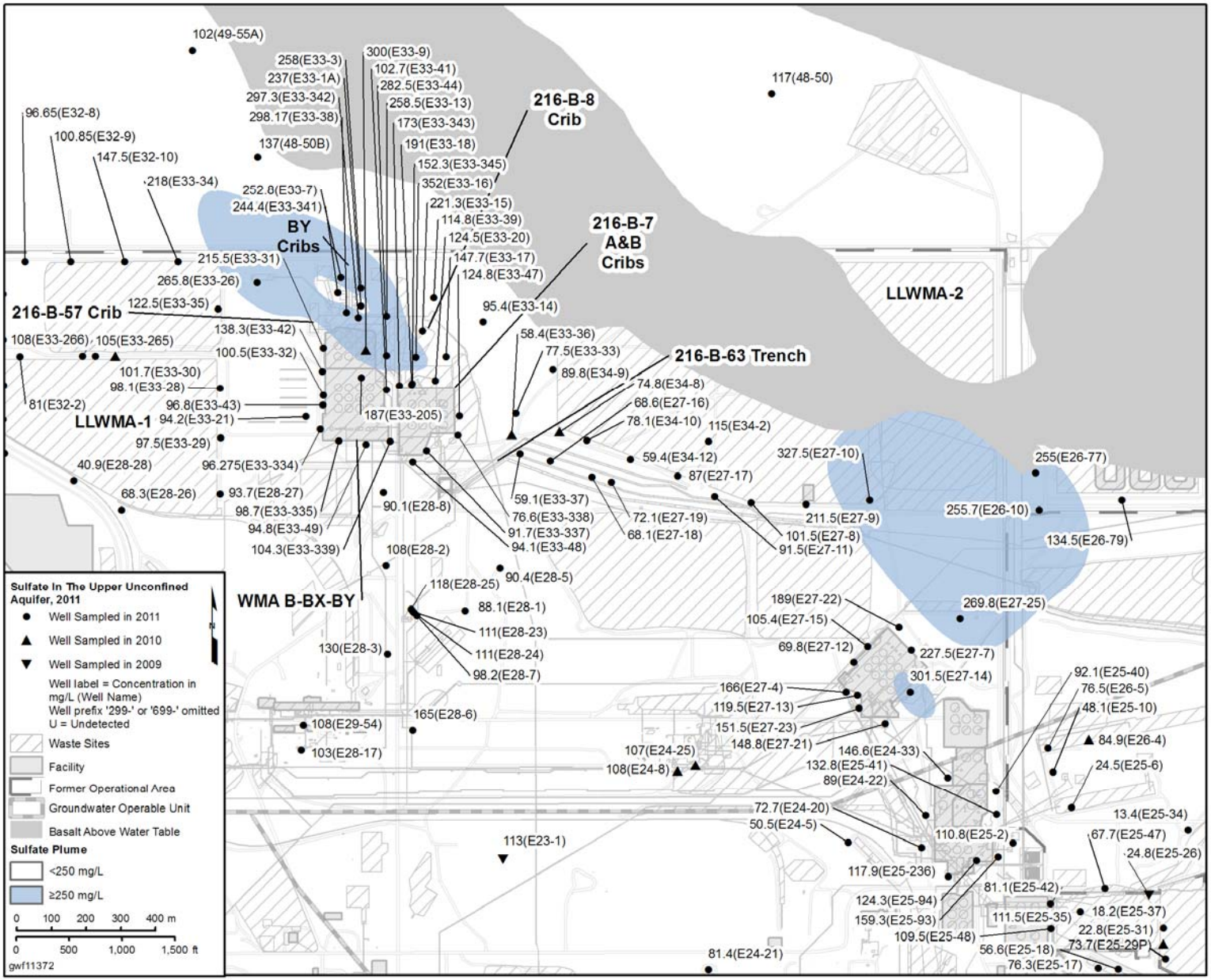
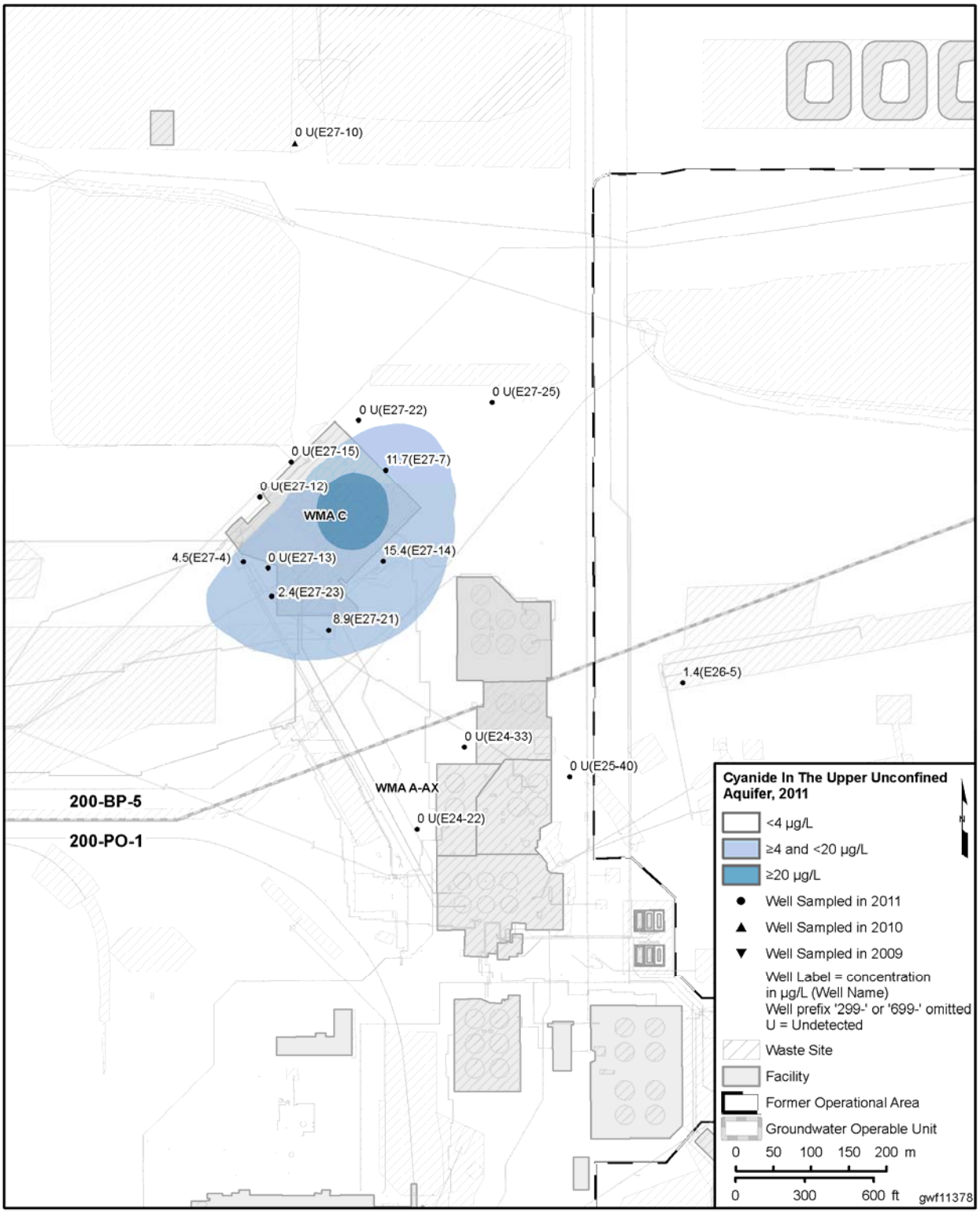
Figure 3.4-24. Average Cyanide Concentrations at WMA C, Upper Part of Unconfined Aquifer, 2011