14.0 100-KR-4 Operable Unit

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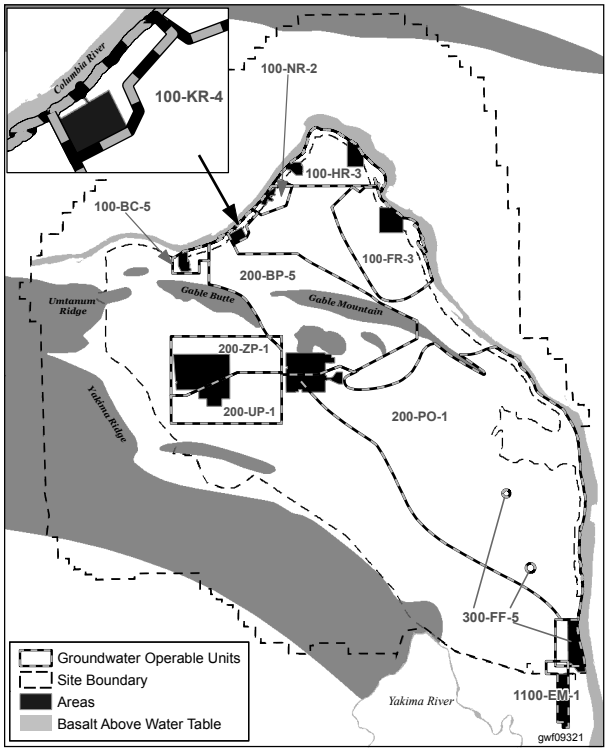

The 100-KR-4 Groundwater Operable Unit (OU) includes groundwater affected by contaminant releases from facilities and waste sites within the 100-K Area. The OU boundaries extend from the reactor area northeast beneath the footprint of the former 116-K-2 Trench, into the southwestern portion of the 100-NR-2 Groundwater OU, to the N Reactor fence line. Most of the facilities within the 100-KR-4 OU are associated with past operation of the KE and KW Reactors and their support facilities. The OU lies within the larger 100-K Area, as defined in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (DOE/RL-2008-46-ADD2). Figure 14-1 shows the facilities, groundwater wells (with uses defined as of December 31, 2009), river shoreline monitoring sites, and key waste sites.

Three *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) interim action ion-exchange pump-and-treat systems operated during calendar year (CY) 2009 in the 100-KR-4 OU. The original KR4 treatment system around the 116-K-2 Trench began operations in 1997. The new KX system, which began operations in February 2009, is treating groundwater contaminated by the 116-K-2 Trench that has migrated to the N Reactor fence line. The KW system began remediating hexavalent chromium in the KW Reactor area in January 2007. The systems are operated to prevent hexavalent chromium from reaching the Columbia River at concentrations greater than the 10 µg/L aquatic water quality criterion. For near-shore and compliance wells, the alternate compliance point criterion to 20 µg/L using a 1:1 dilution factor for hexavalent chromium.

This chapter discusses the groundwater contaminant plumes and pump-and-treat operations for the 12-month period from January 1 through December 31, 2009 (CY 2009). The *Calendar Year 2008 Annual Summary Report for the 100-HR-3, 100-KR-4 and 100-NR-2 Operable Unit Pump-and-Treat Operation* (DOE/RL-2009-15, Rev. 1) discusses the CY 2008 plumes and treatment system operations.

The cost information for the 100-KR-4 pump-and-treat system covers the 15-month reporting period (from October 1, 2008, to December 31, 2009) and is presented in Appendix B.

14.1 Conceptual Site Model

The conceptual site model summarizes the path that the contaminants associated with the 100-KR-4 OU have taken to reach the groundwater, where treatment is now required. A detailed conceptual site model is presented in DOE/RL-2008-46-ADD2.

Hexavalent chromium entered the environment as part of the cooling water that passed through the KE and KW Reactors. It was added as sodium dichromate and helped to prevent corrosion in the reactors. Most of the chromium reached groundwater

during reactor operations (1955 through 1971) at waste site 116-K-2 (also known as the Mile-Long Trench). To a lesser degree, discharges to the 116-K-1 Trench and over-ground flow from leaks at the 107-KE and -KW retention basins may have percolated to the aquifer beneath the waste sites. Other contaminants such as tritium, strontium-90, and carbon-14 have reached groundwater from discharges to other liquid waste sites associated with reactor operations.

Data also suggest that hexavalent chromium likely reached the groundwater at the sodium dichromate unloading stations associated with the 183-KE and -KW headhouses and sedimentation basins. Leaks and spills at the chemical unloading and handling areas may have moved to the groundwater. These sites may continue as source areas in the future.

The 116-K-2 Trench is estimated to have received 18,930 to 37,900 liters per minute of radioactively contaminated cooling water over 16 years of operation, or 160 to 320 billion liters. The 116-K-1 Trench received an estimated 40 million liters of water over 16 months of operation. It was removed from service following an embankment failure and was not used again.

The vadose zone is up to 32 meters thick in locations near the southern edge of the reactor area and is made up of Hanford and Ringold Unit 5 sediments. The unconfined aquifer in the 100-KR-4 OU is generally found in the sands and/or gravels of Ringold Unit 5 (see Chapter 3.0 for details on site geology). At a few wells northeast of the 116-K-2 Trench, the aquifer may extend into the coarser-grained Hanford formation. The Ringold upper mud unit (a sandy silt) underlies the unconfined aquifer and is relatively impermeable to downward migration of groundwater. Discontinuous sand stringers and lenses within the Ringold upper mud unit are water-bearing. One well within the 100-K Area system, 199-K-32B, penetrates into the Ringold upper mud unit and is screened in a sand lens. Analyses from this well indicate low (5 to 10 µg/L) but detectable levels of hexavalent chromium. An upward hydraulic gradient is indicated in the 100-KR-4 OU based on hydraulic head data from well 199-K-32A (screened in the unconfined upper aquifer) and well 199-K-32B (~31 meters deeper than well 199-K-32A).

Considerable topography is observed on the contact between the Ringold upper mud unit and Ringold Unit 5, and between Ringold Unit 5 and Hanford units, indicating erosion during deposition of the overlying units. Aquifer thickness at the 100-KR-4 OU ranges from 5.8 to 7.6 meters at wells 199-K-129 and 199-K-146 to 32 meters at well 199-K-162 (at the head end of the 116-K-2 Trench). The aquifer thickness beneath the reactor area appears to be more uniform at 21 to 25 meters. No obvious channels for preferential contaminant movement have been identified.

Groundwater beneath the 100-K Area generally flows to the northwest (downgradient) to the Columbia River (Figure 14-2). Locally, groundwater flow is affected by extraction and injection wells at the three pump-and-treat systems. Water levels in the Columbia River are controlled by upstream hydroelectric dams. Seasonal high water levels in the spring and summer effectively dam plume migration to the Columbia River by creating a higher inland gradient along the river than the riverward gradient from the center of the Hanford Site. As a result, chromium concentrations typically decline in near-river wells during the spring and summer, then rise in the fall. The daily and seasonal water-level increases are thought to contribute a subtle flow component that parallels the river in near-shore groundwater and contaminant plumes, and which may have contributed in part to the chromium plume in the 100-NR-2 OU. Occasional hexavalent chromium exceedances at aquifer tubes

downriver from hexavalent chromium plumes meeting the Columbia River may be attributable to this effect.

14.2 Contaminant Monitoring

R. F. Raidl

This section summarizes the CERCLA analytical results from sampling groundwater monitoring wells supporting the 100-KR-4 OU, the three pump-and-treat well systems, and wells in other areas of the OU.

Plume areas (square kilometers) in the 100-KR-4 Operable Unit:

Carbon-14, 2,000 pCi/L — 0.08
Chromium, 100 µg/L — 0.10
Chromium, 20 µg/L — 1.81
Nitrate, 45 mg/L — 0.166
Strontium-90, 8 pCi/L — 0.054
Trichloroethene, 5 µg/L — 0.02
Tritium, 20,000 pCi/L — 0.158

The following documents define the sampling protocols that were implemented for CY 2009:

- DOE/RL-96-84, Rev. 0, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*
- DOE/RL-96-90, Rev. 0, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*
- DOE/RL-2006-52, Rev. 2, *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*
- DOE-RL-2006-75, Rev. 1, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System*.

The results presented in this section represent fall 2009 results, unless otherwise specified. This discussion includes the chromium plumes and the information for tritium, strontium-90, carbon-14, nitrate, trichloroethene, and other target analytes.

Hexavalent chromium plume maps used in this section represent the hexavalent chromium distribution in the upper 7.6 to 15.2 meters of the unconfined aquifer. The data used are from laboratory analyses taken in specific timeframes. For the fall of 2009, groundwater wells were sampled in mid-October, while aquifer tubes were sampled in November. If a well was offline in October, laboratory data were used for the next closest month in CY 2009. Where a laboratory sample was not available in October, monthly or weekly results from field analyses taken closest to the laboratory sample period were used. Non-detect values were given values of zero; duplicate sample results were averaged.

Plume maps for the other analytes are based upon results at each well, averaged for all of CY 2009, but that otherwise follow the computational conventions described above (see Chapter 1.0 for more details).

14.2.1 Chromium Monitoring Results

The hexavalent chromium groundwater plume in the 100-K Area (Figure 14-3) includes four separate plumes based on the likely principal sources. This figure depicts chromium concentrations in the spring and fall of 2009 and shows the impact of low and high river stage on near-river contaminant distribution.

Groundwater in the deeper unconfined aquifer is generally interrogated by fully penetrating wells screened across most or all of the unconfined aquifer. Although wells drilled in the initial stages of pump-and-treat operations were partially penetrating, virtually all of the wells drilled recently in the 100-KR-4 OU have fully penetrated

the aquifer and have then been screened according to the analytical results obtained during drilling. A few prominent locations lack good vertical coverage. The wells originally drilled for the KR4 and KW systems were partially penetrating. Most of the recent wells have been drilled into the Ringold upper mud unit and then screened based on elevated chromium concentrations detected in the aquifer. Thus, each system has been supplemented with newer wells designed with much greater, if not complete, penetration. Specific areas of concern remain at the downgradient extent of the KW treatment system well field, near wells 199-K-132 and 199-K-138, where the wells penetrate approximately one-quarter of the aquifer. A new well planned in CY 2010 will address the lack of deep well control and will be used to determine the presence or absence of deeper contamination. The two-dimensional model used in this annual report does not address the extent of well penetration; future calculations using a three-dimensional model (remedial investigation/feasibility study) will address the degree of well penetration.

Hexavalent chromium concentrations detected by near-river extraction and compliance wells, plus near-river aquifer tubes, are shown in Figure 14-4. Although aquifer tubes are not accepted compliance points, the tubes provide an opportunity to assess contaminant migration toward the Columbia River; thus, these results are used as guidance for plume depictions. Some of the aquifer tubes could not be sampled in CY 2009. Chromium concentrations at extraction/compliance wells are treated by the three systems. The aquatic standard for hexavalent chromium in the riverbed is 10 µg/L. The federal drinking water standard (DWS) for hexavalent chromium in groundwater is 100 µg/L; Washington State has a voluntary cleanup level of 48 µg/L (*Washington Administrative Code* [WAC] 173-340, "Model Toxics Control Act - Cleanup").

Two of the largest plumes are associated with the 116-K-2 Mile-Long Trench. The original plume has been divided at the center of the 116-K-2 Trench by the KR4 system's 12+ years of groundwater extraction and injection.

The third hexavalent chromium plume is located downgradient of the KE Reactor and is currently centered around wells 199-K-141 and 199-K-178. This plume was thought to extend upgradient to the KE Reactor headhouse area and well 199-K-36; however, leakage from the active KE sedimentation basin may have obscured past connections to the current plume. The source of the plume is assumed to be from leakage or spills at water treatment facilities supporting the KE Reactor. This plume is being remediated by extraction at well 199-K-141 and by treatment at the KX pump-and-treat system. Well 199-K-178 will be added to the extraction system in CY 2010.

The fourth hexavalent chromium plume is located near the KW Reactor. High baseline hexavalent chromium concentrations in wells 199-K-137 and 199-K-165 (located upgradient of the KW Reactor) suggest that the plume may be attributed to an upgradient leak or spill of concentrated sodium dichromate solution likely near the 183-KW headhouse. This plume is being remediated by the KW pump-and-treat system.

The major differences between the hexavalent chromium plume maps for the 100-K Area in the fall of 2008 and the fall of 2009 (DOE/RL-2009-15) (Figure 14-3) are as follows:

- The northeast plume was extended further inland based on initial analytical results from new well 199-K-182 (74.8 µg/L hexavalent chromium). The inland extent of the plume is currently unknown and needs to be bounded.

- The KE Reactor plume was extended downgradient to new well 199-K-178.
- The KW Reactor plume does not extend to the Columbia River shoreline.

Data gaps exist in well control that prevent full definition of the 20 µg/L hexavalent chromium plume contour. Significant gaps are found upgradient of wells 199-K-171 and 199-K-182.

14.2.1.1 116-K-2 Trench

Two hexavalent chromium plumes, split by the original KR4 system treatment actions, are associated with the former 116-K-2 Trench. The larger plume is located near the northeast end of the trench and the smaller plume is located near the southwest end of the trench. The northeast plume is being remediated by the KR4 and KX pump-and-treat systems, and the southwest plume is being remediated by the KR4 pump-and-treat system. Table 14-1 compares the fall 2009 hexavalent and total chromium concentrations to the baseline results, as available. The criteria for selecting baseline samples for each well are discussed in Chapter 16.0.

A summary of the results for hexavalent and total chromium sampling in the area of the 116-K-2 Trench is as follows:

- The maximum fall 2009 hexavalent chromium concentration in the southwestern 116-K-2 Trench area was 192 µg/L at well 199-K-18. This represents an increase of 380% in hexavalent chromium since sampling in December 1996 (40 µg/L hexavalent chromium) prior to startup of the KR4 system. The hexavalent and total chromium concentrations have been steadily increasing in this well since the onset of pump-and-treat operations, but a potential upgradient source other than the 116-K-2 Trench has not been identified. The most recent hexavalent chromium concentration in this well is above the expected maximum in reactor coolant water based on a mixture of 500 µg/L sodium dichromate (i.e., ~170 µg/L hexavalent chromium) used during later reactor operations.
- The maximum fall 2009 hexavalent chromium concentration in the northeastern 116-K-2 Trench area was 120 µg/L at well 199-K-22. The November 1996 baseline hexavalent chromium concentration at this well was 130 µg/L; therefore, the hexavalent chromium concentration in this well has not changed significantly since startup of operations in 1997. Well 199-K-115A, an extraction well downgradient from well 199-K-22, had a fall 2009 hexavalent chromium concentration of 84.4 µg/L, which is a decrease of 33% since the startup of operations.
- Hexavalent chromium concentrations in the wells located between the northeast and southwest plume have stabilized at less than 20 µg/L. As a result, wells 199-K-119A and 199-K-125A were removed from the KR4 extraction well network. These wells will be converted to compliance or monitoring wells.
- Compliance well 199-K-117A was characterized by mostly non-detect hexavalent chromium concentrations during CY 2009. None of the other data points exceeded 4 µg/L. The baseline 1996 hexavalent chromium concentration in this well was 200 µg/L.
- Four wells in the 100-NR-2 OU area were monitored to ensure that the KX treatment system is preventing hexavalent chromium from reaching beneath the N Reactor area (Figure 14-3). Hexavalent chromium in wells 199-N-16, 199-N-71, 199-N-72, and 199-N-165 was either not detected or was at very low concentrations just above detection.

- Of the fourteen aquifer tubes located downgradient of the 116-K-2 Trench sampled in fall 2009, five aquifer tubes were characterized by hexavalent chromium concentrations greater than 20 µg/L. Aquifer tube C6253, located downriver of the well 199-K-18 plume (C6253) increased from 18 µg/L in 2008 to 53.4 µg/L in 2009.
- Chromium trends in tubes near the 116-K-2 Trench indicate that the pump-and-treat system may have decreased contamination at some segments of the shoreline. In aquifer tubes 22-D and 23-D (near the northeast end of the 116-K-2 Trench), chromium concentrations decreased from greater than 50 µg/L in the late 1990s to less than 10 µg/L from 2007 through 2009. Trend graphs are discussed in Section 14.3.5.2.
- Hexavalent chromium at aquifer tube site 26 has declined to below 20 µg/L. This well is downgradient of extraction well 199-K-150 and injection wells 199-K-159 and 199-K-160. The concentrations at tube site 26 decreased in 2008 and 2009 to 5.5 µg/L from a high of 63.6 µg/L in November 2007. The changing concentrations may reflect capture of the chromium plume or the injection of clean water. This portion of the chromium plume is the target of the KX pump-and-treat system.
- Hexavalent chromium was undetected (2 µg/L) in seven aquifer tubes sampled in November 2009 along the 116-K-2 Trench shoreline.

14.2.1.2 KW Reactor Area

The KW Reactor area hexavalent chromium plume has been monitored since the early 1990s when many of the CERCLA monitoring wells were installed. After elevated hexavalent chromium concentrations were detected in aquifer tube AT-K-1, the KW pump-and-treat system was constructed and became operational in January 2007. The system originally consisted of four extraction wells and two injection wells, plus a treatment system with a capacity of 379 liters per minute. The system was expanded in CY 2009 to seven extraction wells and four injection wells. Table 14-2 compares the fall 2009 hexavalent and total chromium concentrations in KW Reactor area wells to baseline concentrations.

A summary of the sampling results for the KW Reactor is provided in Table 14-2 and is as follows:

- The highest fall 2009 hexavalent chromium concentrations in wells located in the KW Reactor area were 232 µg/L in extraction well 199-K-165 and 211 µg/L in extraction well 199-K-137. These concentrations represent decreases of ~90% in both wells compared to the baseline concentrations (2,850 µg/L and 1,940 µg/L, respectively).
- Hexavalent chromium concentrations in the other four extraction wells ranged from a maximum of 130 µg/L in well 199-K-168 to 38 µg/L in well 199-K-138.
- Well 199-K-140 was converted from an extraction well to a monitoring well after hexavalent chromium declined from a baseline concentration of 161 µg/L to less than the 20 µg/L alternate compliance point. The well remained connected to the KW treatment system for ease of sampling and field analysis for the duration of 2009. The fall 2009 hexavalent chromium concentration in this well was 13 µg/L.
- Aquifer tubes 17-D and AT-K-1, located downgradient of KW extraction wells, had hexavalent chromium concentrations of 7.1 µg/L and 7.8 µg/L, respectively, in the fall of 2009.

- Three monitoring wells located near the former KW Reactor have shown a significant decrease in hexavalent chromium concentration since baseline sampling, ranging from 80.4% in well 199-K-106A to 97.4% in well 199-K-108A. The fall 2009 hexavalent chromium concentration in well 199-K-107A remained above the alternate compliance point criterion at 29.3 µg/L. Prior to startup of KW treatment system operations, hexavalent chromium concentrations ranged from 375 to 600 µg/L.
- Hexavalent and total chromium concentrations have increased in well 199-K-35 (located in the former 183-KW headhouse area) to 190 µg/L at the end of CY 2009. This injection well was shut down when remediation of the 183.2 sedimentation basin impacted pipeline routing. Weekly sampling began in late December 2009. A decline in mounding at well 199-K-35 caused by cessation of injection at this well may have mobilized hexavalent chromium present in the vadose zone that resulted from spilled or leaked sodium dichromate in the 183-KW headhouse area.

14.2.1.3 KE Reactor Area

The KE Reactor hexavalent chromium plume has been monitored since the early 1990s when many of the CERCLA monitoring wells were installed. Table 14-3 compares hexavalent chromium and total chromium concentrations for the fall 2009 samples collected from aquifer tubes and wells to the baseline results. The source of the hexavalent chromium plume may be a combination of localized spills and leaks associated with the KE Reactor water treatment facilities, possibly combined with the residual of the large plume created by mounding around the 116-K-2 Trench. None of the groundwater samples collected in the KE Reactor area since 2001 have had high hexavalent chromium concentrations that could be attributed to spilled sodium dichromate solution. Following startup of the KR4 treatment system, the baseline sample from well 199-K-36 (located at the 183-KE headhouse) was characterized by an unfiltered total chromium concentration of 1,120 µg/L; however, the filtered total chromium concentration was 501 µg/L.

A summary of the results presented in Table 14-3 for the KE Reactor area is as follows:

- The maximum fall 2009 hexavalent chromium concentrations in the KE Reactor area plume wells were 117 µg/L in extraction well 199-K-178 and 209 µg/L in extraction well 199-K-141. The trend at well 199-K-141 rapidly declined from this value following restart of extraction. The high chromium concentration at well 199-K-141 was 459 µg/L in January 2009.
- Monitoring well 199-K-36 (near the former 183-KE headhouse) had a fall 2009 hexavalent chromium concentration of 19.9 µg/L. Monitoring well 199-K-111A (downgradient of the 118-K-1 Burial Ground) had a concentration of 30 µg/L.
- All other KE Reactor area wells had hexavalent chromium concentrations less than 20 µg/L or registered as non-detects for hexavalent chromium.
- Aquifer sampling tubes located along the Columbia River shoreline in the KE Reactor area yielded hexavalent chromium concentrations near the detection limit.
- The KE Reactor area hexavalent chromium plume is being remediated by the KX pump-and-treat system.

14.2.2 Tritium Monitoring Results

Tritium plumes in groundwater are usually associated with drainage around the 116-KW-1 and 116-KE-1 gas condensate cribs and the 118-K-1 Burial Ground

(Figure 14-5). The fall 2009 results are compared to baseline pre-pump-and-treat results collected mainly in 1996, or where available.

14.2.2.1 116-K-2 Trench

Twenty-two wells and twelve aquifer tubes were sampled in fall 2009. A summary of the tritium results for the 116-K-2 Trench is presented below. The tritium source is thought to be a series of silos along the northwestern border of the 118-K-1 Burial Ground. The burial ground and silos are scheduled for remediation by FY 2011. The DWS for tritium is 20,000 pCi/L.

- Three well samples exceeded the DWS: 199-K-157 (290,000 pCi/L), 199-K-18 (43,000 pCi/L), and 199-K-144 (140,000 pCi/L). Tritium concentrations have decreased more than 50% in wells 199-K-144 and 199-K-157 since the May 2008 baseline sampling events; however, tritium concentrations have increased in well 199-K-18 nearly 75% since the July 1996 baseline sampling.
- The maximum tritium concentration in an aquifer tube was 5,400 pCi/L in AT-K-3-D.
- Tritium concentrations increased to 300 pCi/L (from 147 pCi/L [non-detect]) in well 199-N-16, located along the boundary between the 100-KR-4 and 100-NR-2 OUs. However, tritium also decreased significantly, from 8,800 to 1,150 pCi/L in well 199-N-71 (located northeast of KX injection well 199-K-164). These wells are monitoring the effect of the pump-and-treat system expansion on water chemistry along the boundary of the two OUs.
- Although tritium concentrations have increased dramatically in wells 199-K-147 and 199-K-20 when considering percentage increases, the actual fall 2009 concentrations (2,100 pCi/L in well 199-K-147, and 6,100 pCi/L in well 199-K-20) are well below the DWS.

14.2.2.2 KW Reactor Area

A summary of the tritium results for thirteen wells and one aquifer tube sampled in the fall of 2009 at the KW Reactor area is presented below. The source for this plume is believed to be the former 116-KW-1 gas condensate system crib on the eastern side of the KW Reactor.

- The maximum tritium concentration was 8,200 pCi/L in well 199-K-132. A high value of 11,000 pCi/L was reported for well 199-K-138 but upon review was found to actually be 1,100 pCi/L. The 2009 results represent increases of ~2,000% in well 199-K-138 and ~800% in well 199-K-132. Tritium concentrations in wells upgradient from extraction wells 199-K-132 and 199-K-138 are significantly lower; therefore, it is likely that tritium concentrations in wells 199-K-132 and 199-K-138 will decrease in the future.
- The tritium concentration in aquifer tube AT-K-1-D was 100 pCi/L (non-detect), similar to the baseline concentration of 198 pCi/L (non-detect).

14.2.2.3 KE Reactor Area

A summary of the tritium results for ten wells and three aquifer tubes sampled in fall 2009 around the KE Reactor area is presented below. The tritium source is believed to be the former 116-KE-2 gas condensate crib located on the eastern side of the KE Reactor.

- The maximum tritium concentrations were 140,000 pCi/L in well 199-K-30 and 7,515 pCi/L in well 199-K-111A. The 2009 results represent a decrease of ~50% in well 199-K-30 and an increase of ~2,600% in well 199-K-111A.

- Tritium concentrations were monitored at several wells within the 100-NR-2 OU to ensure that treated water injected near the N Reactor fence line will not create a plume from KX operations. Tritium concentrations at well 199-N-165 ranged between 380 to 620 pCi/L, and averaged 1,050 pCi/L at well 199-N-71.
- Wells 199-K-29 and 199-K-30 are scheduled for decommissioning in CY 2010 to support demolition activities at the 117-KE filter building. These wells cannot be replaced until demolition is completed. Monitoring well 199-K-142 will provide partial coverage; however, the well is not directly downgradient of the two wells and it will not detect peak releases from the waste site. The maximum tritium concentration reported at well 199-K-30 was 3.2 million pCi/L in 1993, while well 199-K-29 reached a maximum of 98,300 pCi/L in 2002. Both wells will need to be replaced at the conclusion of demolition activities. A second well should be placed downgradient of well 199-K-30 and outside of the demolition control area to monitor tritium (and carbon-14; see Section 14.2.4.3) plume movement during demolition activities.
- The maximum tritium concentration in a fall 2009 aquifer tube sample was 2,100 pCi/L in tube C6244.

14.2.3 Strontium-90 Monitoring Results

Strontium-90 in groundwater is associated with discharges to the 116-KE-3 and 116-KW-2 Cribs both during and after reactor operations (Figure 14-6). Water leaking from the KE and KW Reactor fuel rod storage sub-basin was conveyed to the crib by a pipeline. A well constructed through each crib is thought to have accelerated radionuclide migration to the groundwater. Significant amounts of radionuclides have been encountered during remediation beneath the KE Basin and crib. The contaminants may have been driven deeper into the vadose zone and possibly to groundwater by the use of dust-suppression water. Several significant spikes in strontium-90 have been observed at the nearby KE Reactor downgradient monitoring well 199-K-109A, as well as elevated levels at well 199-K-34 (near KW Basin). The fall 2009 results are compared to baseline pre-pump-and-treat results collected mainly in 1996, or where available. The DWS for strontium-90 is 8 pCi/L.

14.2.3.1 116-K-2 Trench

A summary of the strontium-90 results for the 23 wells and 8 aquifer tubes sampled during the fall of 2009 around the 116-K-2 Trench is presented below. The 116-K-2 Trench is assumed to be the source of the strontium-90.

- Three wells were characterized by strontium-90 concentrations above the DWS: 199-K-21 (22 pCi/L), 199-K-161 (14.8 pCi/L), and 199-K-114A (8.7 pCi/L).
- Strontium-90 concentrations are decreasing in the three wells above the DWS.
- None of the aquifer tubes sampled in fall 2009 had detectable levels of strontium-90.

14.2.3.2 KW Reactor Area

A summary of the strontium-90 results for the fourteen wells sampled during fall 2009 around the KW Reactor Area is presented below. The suspected source of the strontium-90 that has reached well 199-K-34 is the former KW Basin's 116-KW-2 Crib.

- Two wells (199-K-34 at 16 pCi/L, and 199-K-107A at 13 pCi/L) were characterized by strontium-90 concentrations above the DWS.

- Strontium-90 concentrations have decreased nearly 70% in well 199-K-107A and nearly 33% in well 199-K-34 since the 1997 baseline sampling.

14.2.3.3 KE Reactor Area

A summary of the strontium-90 results for the ten wells and two aquifer tubes sampled during fall 2009 around the KE Reactor area are presented below. The suspected source of the strontium-90 in wells 199-K-109A and 199-K-32A is the 116-KE-3 Crib.

- Strontium-90 concentrations at well 199-K-32A were initially reported at 16 pCi/L. The sample was re-analyzed and a concentration of 3.8 pCi/L was reported.
- Well 199-K-109A was last sampled in March 2008, and the strontium-90 concentration was 1,120 pCi/L, representing a decrease of nearly 65% from baseline sampling in 1996. Peak strontium-90 concentrations in this well reached 18,600 pCi/L in 1997. This well was decommissioned in April 2008 and should be replaced in the near future following completion of waste site remediation activities.

14.2.4 Carbon-14 Monitoring Results

Carbon-14 is found in groundwater and originates from two waste sites (116-KE-1 and 116-KW-2) associated with the 115-KE and 115-KW gas condensate facilities (Figure 14-7). A liquid condensate stream containing both carbon-14 and tritium was discharged to the two cribs during reactor operations. The contaminants appear to remain in the soil column in significant quantities and slowly drain into the aquifer. The DWS for carbon-14 is 2,000 pCi/L.

14.2.4.1 116-K-2 Trench

Twenty-five wells and ten aquifer tubes were sampled during the fall of 2009 around the 116-K-2 Trench. The suspected carbon-14 source is the 118-K-1 Burial Ground.

- The maximum carbon-14 concentration was 54.3 pCi/L in well 199-K-157, which is a decrease of nearly 68% since the May 2008 baseline sampling. The maximum carbon-14 concentrations in aquifer tubes were 22.6 pCi/L in aquifer tube 18-S and 21.2 pCi/L in aquifer tube AT-K-3-D.
- Carbon-14 was not detected in 25 of 35 samples collected from wells and aquifer tubes in the fall of 2009.

14.2.4.2 KW Reactor Area

Fourteen wells and one aquifer tube were sampled during fall 2009 around the KW Reactor area. A summary of the carbon-14 results for the KW Reactor area is presented below:

- The maximum carbon-14 concentration was 3,970 pCi/L in well 199-K-106A, which is a decrease of almost 78% since the December 1996 baseline sampling. This well is located downgradient of the 116-KW-1 condensate crib (the likely carbon-14 source).
- The only other well in which carbon-14 was detected above the DWS was 199-K-132 at 2,320 pCi/L, which is a decrease of ~26% since the October 2005 baseline sampling. Carbon-14 concentrations at aquifer tube AT-K-1-D averaged 35 µg/L and 221 µg/L at AT-17-D.
- The carbon-14 concentrations in other wells near the Columbia River were 285 pCi/L in well 199-K-138 and 565 pCi/L in well 199-K-31. The carbon-14

concentrations have increased significantly in these two wells but are not approaching the DWS.

14.2.4.3 KE Reactor Area

Ten wells and six aquifer tubes were sampled during the fall of 2009 around the KE Reactor area, The probable carbon-14 source is the 116-KE-1 gas condensate crib

- The maximum carbon-14 concentration was 5,830 pCi/L in well 199-K-30, which is a decrease of ~53% since baseline sampling in 1996. This is the only well or aquifer tube with a carbon-14 concentration above the DWS.
- Well 199-K-30 is located downgradient of the 116-KE-1 condensate crib (the likely carbon-14 source). This well is scheduled for demolition during CY 2010 as part of demolition of the 117-KE filter building and needs to be replaced. The peak carbon-14 concentration at this well was 23,000 pCi/L in 1993.
- The maximum carbon-14 concentration in an aquifer tube was 295 pCi/L in C6247. An April 2009 value of 398 µg/L was reported at this tube.
- The carbon-14 concentration in extraction well 199-K-178 was 200 pCi/L and 331 µg/L at well 199-K-181.

14.2.5 Nitrate Monitoring Results

Nitrate is present in most of the groundwater wells within the 100-KR-4 OU at below-DWS concentrations (45 mg/L). The nitrate may be associated with Hanford Site reactor or water plant operations, decontamination activities, septic systems, or pre-Hanford agricultural activities.

14.2.5.1 116-K-2 Trench

A summary of the nitrate results for 27 wells and 7 aquifer tubes sampled in fall 2009 around the 116-K-2 Trench are presented below:

- The maximum nitrate concentration was 73 mg/L in compliance well 199-K-18. This was also the only well or aquifer tube with a nitrate concentration exceeding the 45 mg/L DWS.
- The maximum nitrate concentration in an aquifer tube was 8.85 mg/L in aquifer tube AT-K-5-D.
- At the 100-N Area monitoring wells tracked by the KX treatment system, the maximum increase in nitrate concentration since baseline sampling was 798.6% (to 12.4 mg/L) in performance well 199-N-71.
- The maximum decrease in nitrate concentration since baseline sampling was 49.4% (to 88.1 mg/L) in KX extraction well 199-K-130.

14.2.5.2 KW Reactor Area

A summary of the nitrate results for fifteen wells and one aquifer tube around the KW Reactor area is presented below:

- Three wells had nitrate concentrations above the 45 mg/L DWS: 199-K-106A (96 mg/L), 199-K-108A (61.3 mg/L), and 199-K-34 (50 mg/L).
- The maximum increase in nitrate concentration since baseline sampling was 270% (to 32 mg/L) in well 199-K-35.
- The maximum decrease in nitrate concentration since baseline sampling was 77.3% (to 2.13 mg/L) in well 199-K-138.
- The fall 2009 nitrate concentration in aquifer tube AT-K-1-D was 2.4 mg/L, which is a decrease of 66% since baseline sampling in 2005.

14.2.5.3 KE Reactor Area

A summary of the nitrate results for ten wells and five aquifer tubes in the KE Reactor area is presented below:

- The maximum concentration was 49.1 mg/L in well 199-K-11. This was the only sample collected with a nitrate concentration above the DWS.
- The maximum increase in nitrate concentration since baseline sampling was more than 3,000% (to 9.9 mg/L) in aquifer tube AT-K-2-M.
- The maximum decrease in nitrate concentration since baseline sampling was 99% (to 0.55 mg/L in aquifer tube C6241).
- The maximum near-river nitrate concentration was 13.4 mg/L in aquifer tube 18-S.

14.2.6 Trichloroethene Monitoring Results

Trichloroethene is a minor contaminant found at wells in the KW Reactor area. In CY 2009, most of the KW Reactor area wells, plus selected wells inside the K Reactor area and downgradient of the 116-K-2 Trench, were analyzed for trichloroethene. Trichloroethene was not detected at the wells near the 116-K-2 Trench. Wells associated with the KE Reactor area had detections of trichloroethene at concentrations below the 5.0 µg/L DWS.

The highest concentrations were 9.2 and 9.0 µg/L, reported at well 199-K-132 in a May 2009 sample, but concentrations declined to 6.2 µg/L in October 2009. Wells on the west side of the KW Reactor area's hexavalent chromium plume/pump-and treat system reported the next highest concentrations of trichloroethene (199-K-140 at 5.9 µg/L, and 199-K-138 at to 6.2 µg/L). Wells on the east side of the plume/pump-and-treat system reported lower concentrations ranging from 1.0 µg/L (non-detect at 199-K-34),to 3.3 µg/L (estimated value at 199-K-106A), and 4.1 µg/L (estimated value at 199-K-108A). Upgradient wells 199-K-173, 199-K-174, and 199-K-175 reported trichloroethene concentrations of 3.8 µg/L, 3.9 µg/L, and 3.0 µg/L, respectively (all estimated values). This distribution suggests a plume source upgradient and possibly west of the KW Reactor area.

14.2.7 Other Target Analytes

14.2.7.1 Technetium-99

Technetium-99 is tracked in the KW Reactor treatment system area because it occurs in wells but at concentrations far below the 900 pCi/L DWS. The highest concentration reported in CY 2009 was 56 pCi/L at well 199-K-168. Other wells within the KW monitoring system have ranged between non-detects at wells 199-K-106A and 199-K-108A, 51 pCi/L at upgradient monitoring well 199-K-173, and 47 pCi/L at new KW Reactor injection well 199-K-175. Well 199-K-157 (near the head end of the 116-K-2 Trench) also reported technetium-99 concentrations of 56 pCi/L.

14.2.7.2 Total Petroleum Hydrocarbons

Total petroleum hydrocarbons were detected at several KW Reactor area wells during drilling in August and September 2008. Well 199-K-167 was started near the 166-KW fuel storage bunker and was abandoned after diesel-saturated soils were encountered at a depth of 8.5 to 9.1 meters in the vadose zone. Replacement well 199-K-173 was drilled ~1.8 meters southwest of well 199-K-167 and also encountered diesel in the soil. A review of analytical data indicated that during drilling, 130 µg/L of total petroleum hydrocarbon-diesel (at the groundwater table) in

well 199-K-165 was detected in groundwater. Similarly, 300 µg/L of total petroleum hydrocarbon-diesel and 210 µg/L of total petroleum hydrocarbon-kerosene were detected at the groundwater table at well 199-K-168, which is located downgradient (northwest) of the KW Reactor.

Total petroleum hydrocarbon analyses were performed on groundwater samples collected in October 2009, but none of the three total petroleum hydrocarbon categories (diesel, gasoline, or kerosene) were detected at any of the wells upgradient or downgradient of the 166-KW fuel bunker. Visual inspections of process filters in the operations building have not shown buildup of total petroleum hydrocarbon material. Annual sampling for this analyte suite will be continued at selected KW Reactor wells and will be added at several similarly located KE Reactor wells.

14.3 CERCLA Groundwater Activities

All remediation work performed at the 100-KR-4 Groundwater OU is conducted in accordance with CERCLA requirements.

The remedial action objectives for the 100-KR-4 Operable Unit (EPA/ROD/R10-96/134) are as follows.

- ***Protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.***
- ***Protect human health by preventing exposure to contaminants in the groundwater.***
- ***Provide information that will lead to the final remedy.***

The contaminant of concern is hexavalent chromium. The record of decision specifies 20 µg/L as the concentration at compliance wells that is protective of aquatic organisms in the river environment.

14.3.1 CERCLA Decision Documents

A number of decision documents direct the activities at the 100-KR-4 OU. Key documents include the following:

- ***DOE/RL-96-84, Rev. 0 and Rev. 0A, Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action.*** The work plan describes the design and operational requirements for the original KR4 pump-and-treat system.
- ***DOE/RL-96-90, Rev. 0, Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units.*** This document established the initial operational, monitoring, and sampling requirements for the 100-KR-4 Groundwater OU to demonstrate satisfactory system operations and control of the plume by the treatment system.
- ***DOE/RL-2006-20, Rev. 1, The Second CERCLA Five-Year Review Report for the Hanford Site.*** See discussion in Section 14.3.2.
- ***DOE/RL-2006-52, Rev. 1, The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Operable Unit Interim Action.*** This document established the initial operational, monitoring, and sampling requirement for the KW pump-and-treat system.
- ***DOE/RL-2006-75, Rev. 1 Reissue, Supplement to the 100-HR-3 and 100-KR-4 Remedial Design and Remedial Action Work Plan for the Expansion of the 100-KR-4 Pump-and-Treat System.*** This document established the operational, monitoring, and sampling requirements for the new KX pump-and-treat system.

Several decision documents were generated for the 100-KR-4 OU in CY 2009, including the following:

- ***DOE/RL-2006-52, Rev. 2, The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Operable Unit Interim Action.*** This document describes modifications to the KW pump-and-treat

system, including additions to increase treatment capacity and the addition of new extraction and injection wells.

- ***DOE/RL-2008-46, Rev. 0, Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan; and DOE/RL-2008-46-ADD2, Rev. 0, Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units.*** These documents provide the basis for vadose zone and groundwater characterization needed to support preparation of a remedial investigation/feasibility study and proposed plan and in order to reach a final Record of Decision for the 100-K Area.
- ***DOE/RL-2009-41, Rev. 0, Sampling and Analysis Plan for the 100-K Area Remedial Investigation/Feasibility Study.*** This document provides specific sampling and analytical requirements for testing at thirteen groundwater wells and two boreholes planned for the 100-KR-4 OU.
- ***DOE/RL-2009-59, Interim Action Monitoring Plan for the 100-KR-4 Operable Unit (decisional draft for review; in preparation).*** This document provides the guidance and rationale for sampling groundwater at existing and future wells used in support of the three pump-and-treat systems at the 100-KR-4 OU. Revisions to DOE/RL-2009-59 will be necessary to coordinate changes to the treatment system configurations and additions of new treatment technologies, and to address emerging groundwater contaminant conditions. The document was transmitted to the U.S. Department of Energy in November 2009 for review.
- Tri-Party Agreement Change Notice 273, *DOE/RL-2006-75, Rev 1, Supplement to the 100-HR-3 and 100-KR-4 Remedial Design and Remedial Action Work Plan for the Expansion of the 100-KR-4 Pump and Treat System*. This change notice addressed a number of changes required to improve operations at the KR4 and KX pump-and-treat systems. The changes are as follows:
  - Realign wells between the two systems to contain the impact of a tritium plume potentially impacting groundwater quality at KX injection wells
  - Standardize sampling of extraction, compliance and injection wells at the KR4 and KX systems
  - Identify five new wells with locations for KR4 and KX systems, plus the sampling requirements, proposed uses, and general well design
  - Delete requirement to prepare a semiannual report to provide status of the pump-and-treat systems.

14.3.2 Status of Five – Year Review Action Items

The second *CERCLA Five Year Review Report for the Hanford Site* (DOE/RL-2006-20) listed three issues and recommended four actions:

- ***Issue 3.*** The southeastern (inland) extent of the chromium groundwater plume from the 116-K-2 Trench, northeast of the current injection wells, has not been delineated.

  Action 3-1. Install three additional wells to further delineate the southeastern (inland) extent of the chromium groundwater plume from the 116-K-2 Trench, northeast of the current injection wells. Wells installed as part of the pump-and-treat system expansion or injection well relocation may count toward this effort if appropriately located. Complete by September 2009.

  Wells 199-K-153, 199-K-154, and 199-K-163 were drilled in November 2008. This completed the required action.

- ***Issue 4.*** The small chromium plume at KW Reactor site has reached the Columbia River, as evidenced by near-shore aquifer tubes. There is currently no active remediation system in place for the small chromium plume at the KE/KW Reactor site.

  Action 4-1. Implement the existing remedial action decision (pump-and-treat) at this location. Complete by March 2007.

  An ion-exchange pump-and-treat system (capacity of 379 liters per minute) was constructed at the KW Reactor and began operations in January 2007. This completed the required action. (Note that the KW system was expanded to a treatment capacity of 757 liters per minute in 2008 and 2009, and the system became operational in April 2009.)

- ***Issue 5.*** Groundwater monitoring indicates that the expansion of the 100-K Area pump-and-treat extraction system has not yet achieved the remedial action objective.

  Action 5-1. Expand the 100-K Area pump-and-treat system by 378.5 liters per minute to enhance remediation of the chromium plume between the 116-K-2 Trench and the N Reactor perimeter fence. Complete by September 2009.

  The KX ion-exchange pump-and-treat system (capacity of 2,271 liters per minute) began operation in February 2009 and reached full operating capacity by May 2009. This completed the required action.

  Action 5-2. Add wells between the 116-K-2 Trench and the N Reactor perimeter fence for groundwater extraction, and connect the additional wells to the pump-and-treat system.

  Wells 199-K-148, 199-K-149, and 199-K-150 were drilled in late 2007 and early 2008. Along with existing wells 199-K-130 and 199-K-131, the five wells were converted to extraction wells and were connected to the KX treatment system. This completed the required action.

14.3.3 Remedial Process Optimization Activities

Remedial process optimization was implemented at the 100-KR-4 OU in CY 2009. This process is intended to improve treatment system performance to meet the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989) milestones described below. The goal of the milestones is to improve remediation of the hexavalent chromium plume and other plumes that have been determined to impact groundwater and the Columbia River. The key proposed milestones are as follows:

- **Milestone M-016-110-TO1**: Take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area OUs so ambient water quality standards are achieved in the hyporheic zone and river water column (December 31, 2012).
- **Milestone M-016-110-TO2**: Take actions necessary to remediate hexavalent chromium groundwater plumes so hexavalent chromium will meet DWSs (December 31, 2020).
- **Milestone M-016-110-TO4**: Implement remedial actions selected in all 100 Area groundwater Records of Decision so no contamination above DWSs or ambient water quality standards enters the Columbia River unless otherwise specified in a CERCLA decision (December 31, 2016).

The remedial process optimization approach has involved modeling groundwater flow and determining where the hexavalent chromium plume will reach the Columbia River without any intervention, and then revising the current treatment system well configuration to prevent plume intrusion into the Columbia River. Additional modeling is then used to determine where longer term threats exist so more elaborate system changes away from the river (including alternate treatment technologies) can be applied. This work is proceeding in five phases:

- Phase 1 addressed well realignments to the KR4/KX treatment systems to address tritium issues (completed in 2009).
- Phase 2 addressed the drilling of five additional wells for use at the KR4 and KX treatment systems (to be completed in early 2010).
- Phase 3 will install four new wells for plume control: two extraction wells and one monitoring well at the KR4 treatment system, and one extraction well at the KW treatment system (to be completed in 2010).
- Phases 4 and 5 will address the more complex changes required to implement alternate technologies and/or expand existing treatment systems.

The approach for Phases 4 and 5 will be described in an upcoming technical memorandum for the conceptual design.[1] The conceptual design proposes modifications to the three existing treatment systems that are essential to meet the Tri-Party Agreement milestones dated for the years 2016 and 2020.

14.3.4 Remedial Investigation/Feasibility Study Work Plan Activities

The characterization activities for the 100-KR-4 OU are described in DOE/RL-2008-46 and DOE/RL-2008-46-ADD2, which were prepared during CY 2009 and issued in January 2010. The sampling and analysis plan (DOE/RL-2009-41) was issued in October 2009. These documents provide the rationale and direction for vadose zone and groundwater characterization needed to support preparation of a remedial investigation/feasibility study and proposed plan, which will lead to a final Record of Decision for the 100-K Area. The documents provide specific sampling and analytical requirements for testing at thirteen groundwater wells, two boreholes, and one three-tube aquifer tube location planned for the 100-KR-4 OU.

14.3.5 116-K-2 Pump-and-Treat Systems (KR4, KX, and KW Systems)

M. E. Caron

The 100-KR-4 OU includes the groundwater underlying the 100-KR-1 and 100-KR-2 Source OUs and extends into the 100-NR-2 Groundwater OU (Figure 14-3) to the N Reactor fence line. This figure shows the spring and fall 2009 hexavalent chromium plumes, plus the wells and aquifer tube locations in the 100-K Area. The OU contains three treatment systems and respective injection/extraction well fields:

- Original 100-KR-4 treatment system (KR4) (capacity of 1,136 liters per minute)
- KX pump-and-treat system (capacity of 2,271 liters per minute)

1 Conceptual Design of Process Enhancements, 100-KR-4 Groundwater Operable Unit, Remedial Process Optimization, draft technical memorandum dated September 30, 2009, CH2M HILL, Denver, Colorado.

- KW Reactor pump-and-treat system (capacity of 757 liters per minute).

The 100-KR-4 OU interim action is similar to the 100-HR-3 OU interim action in that the primary contaminant of concern is hexavalent chromium. Interim action co-contaminants for the 100-KR-4 OU include tritium and strontium-90. Carbon-14, technetium-99, and nitrate are considered target analytes because they are present above their respective DWS, or are detected at some wells. In either case, target analytes are regarded as possibly impacting the final Record of Decision and are trended to better understand their behavior in the aquifer.

14.3.5.1 KR4 Pump-and-Treat System

The 12-year-old 100-KR-4 OU pump-and-treat system (now KR4) treats the hexavalent chromium plume associated with the 116-K-2 Trench. Over time, the central portion of the plume has been remediated to concentrations below 20 µg/L, but the plumes at either end of the trench require continuing treatment. The new KX system was originally designed to address the remnant plume segments associated with 116-K-2 Trench operations by using overlapping extraction well fields at the ends of the trench. However, the presence of a tritium plume at the proximal end (head end) of the trench required revising extraction well connections to prevent discharging tritium to areas close to N Reactor.

As a result of action items identified in the second CERCLA 5-year review (DOE/RL-2006-20), several new wells were constructed or reconfigured in CY 2009 to support plume remediation and delineation. Figure 14-8 presents the wells completed through CY 2009 and the wells proposed for installation during CY 2010 in support of the CERCLA 5-year review. The figure also presents hexavalent chromium trend plots of extraction and monitoring wells aligned with the KR4 treatment system and aquifer tube trends. To improve KR4 pump-and-treat system efficiency, flow rates for select extraction and injection wells were adjusted to prevent over-pumping and associated system shutdown during freezing conditions, which resulted in greater scheduled system availability. Figure 14-9 depicts the current KR4 pump-and-treat system. A summary of operational parameters and total system performance for CY 2009 is provided in Table 14-4.

Changes in Calendar Year 2009

The KR4 system has been realigned to receive contaminated groundwater from three wells (199-K-144, 199-K-145, and 199-K-162) originally connected to the KX system. This change was made to control the tritium plume believed to be associated with the 118-K-1 Burial Ground and projected to move downgradient to these extraction wells.. If the wells had remained connected to the KX treatment system, tritium at potentially elevated concentrations would have been reinjected over a broad area, including near the 100-NR-2 Groundwater OU. As now aligned, the injection/extraction well system will create a partial recirculation system that should help to contain and localize tritium within a smaller area.

In addition to new extraction well connections, two existing extraction wells were disconnected based on the long-term trends of hexavalent chromium concentrations below the alternate compliance point criterion. Wells 199-K-119A and 199-K-125A have trended below 20 µg/L for 27 to 39 months and have been removed from service. Well 199-K-120A concentrations decreased to below 20 µg/L during the summer of 2009. Injection well 199-K-124A will be removed from service in 2010. These wells are sampled semiannually for hexavalent chromium, tritium, carbon-14, strontium-90, nitrate, and technetium-99.

New injection well 199-K-179 was drilled for the KR4 system in late September 2009. Well 199-K-179 was designed for use as an injection well and is located within the injection well arc upgradient of the 116-K-2 Trench. The well will be connected to the KR4 system in early 2010.

Treatment System Performance

Key operational and system highlights for the KR4 pump-and-treat system for CY 2009 are presented below:

- 317.5 million liters of groundwater were treated, and ~7.8 kilograms of hexavalent chromium were removed.
- The mass removal efficiency for CY 2009 was 86.9%, which is somewhat lower than that reported for CY 2008 (Figure 14-10). Mass removal efficiency tends to decrease in ion-exchange systems when influent concentrations are very low.
- The average 100-KR-4 influent hexavalent chromium concentration of 24.6 µg/L in CY 2009 was 26% lower than the CY 2008 average of 33.2 µg/L. In CY 2009, influent concentrations ranged between 14 µg/L (high river stage) to 58 µg/L (low river stage). Two extraction wells (199-K-119A and 199-K-125) were taken offline in July and August 2009 due to historic hexavalent chromium trends less than 20 µg/L.
- The average effluent hexavalent chromium concentration of 3.9 µg/L for CY 2009 was slightly higher than the 3.8 µg/L reported in CY 2008. Trend plots of influent and effluent concentrations are presented in Figure 14-11. No exceedances above 20 µg/L for hexavalent chromium were detected in treated effluent.
- The total system availability for CY 2009 was 87.0%, which is lower than the 96.4% reported in CY 2008. The scheduled system availability was 87.5%, which is also lower than the online availability of 98.5% reported for CY 2008. Figure 14-12 and Table 14-5 present the monthly online percentages and method used to calculate the availability and online percentage for the reporting period. Major unplanned outages/shutdowns were from April 29 through May 20 for pressure-relief valve testing and replacement, from August 10 through August 24 due to damage from a range fire, and from September 17 through September 23 to allow for removal of construction material.

The pumping flow rates and total run-time (total flow hours ÷ total possible run-time) for extraction wells currently in use at the KR4 pump-and-treat system are presented in Table 14-6. The recommended flow rates were based on initial estimated extraction rates from short-term pumping tests conducted as the wells were developed. Additional wells were added after 1997 to support the first CERCLA 5-year review design modification. To maximize mass removal, extraction wells with greater chromium concentrations have generally been pumped at higher rates than less productive wells. The yearly average flow rates are calculated from total volumes divided by the hours in a year.

A comparison of the extraction rates in Table 14-6 shows that wells 199-K-115A, 199-K-120A, and 199-K-125A were pumped at greater flow rates than initially recommended. These wells were able to sustain higher yields during the reporting period and were therefore used to offset lower rates from the other extraction wells (199-K-113A, 199-K-114A, 199-K-116A, 199-K-119A, 199-K-127, and 199-K-129). The addition of wells 199-K-144, 199-K-145 and 199-K-162 will make up for the loss of extraction rates and throughput of hexavalent chromium resulting from the low-concentration extraction wells.

The flow rates at wells 199-K-113A, 199-K-114A, 199-K-116A, 199-K-119A, 199-K-127, and 199-K-129 are lower than initially recommended. This may be attributed to a locally thin aquifer and fluctuations in Columbia River levels throughout the year, which frequently limited the available drawdown in these wells. Actual flow rates reflect the long-term extraction capacities of the wells and also the operational adjustments made to maximize mass removal. During CY 2009, all wells were subject to downtime because of unplanned pump and equipment failures and system outages (e.g., local range fire), as well as planned maintenance and system upgrades.

The KR4 treatment system was designed to receive and process up to 1,136 liters per minute. During CY 2009, the pump-and-treat system processed groundwater at an average annual rate of 694.1 liters per minute. The less-than-design rate is due to outages associated with the extraction well system realignment, plus unplanned outages due to the range fire and to replacement of pressure relief valves on the KR4 system's ion-exchange vessels.

Compliance Monitoring

The KR4 system's control over the hexavalent chromium plume is demonstrated by the sampling results of several compliance wells, plus active extraction/compliance wells presented in DOE/RL-2006-75, Rev. 1. The KR4 system compliance wells are 199-K-18, 199-K-20 and 199-K-117A and extraction/compliance wells 199-K-114A, and 199-K-129. The current compliance well system will need to be revised because well 199-K-18 is currently upgradient of extraction well 199-K-162. The trends for the compliance wells are shown in Figure 14-8.

Well 199-K-18 continues to show high concentrations of hexavalent chromium that appear to be intercepted by extraction wells 199-K-145 and 199-K-162, and to a lesser degree by well 199-K-120A. Trends at compliance well 199-K-20 show chromium remaining below 20 µg/L for all of CY 2009, with an occasional exceedance in CY 2008. Concentration trends at extraction/compliance wells 199-K-114A and 199-K-129 are either consistently or cyclically (at low river stage) above 20 µg/L. Trends at well 199-K-117A have consistently been below 20 µg/L since October 2002.

Although not official compliance points for treatment system performance, aquifer tubes are helpful for locating areas where hexavalent chromium is present near the Columbia River at levels above 20 µg/L, and several locations were observed in CY 2009. One location in the KR4 treatment system well field is near the proximal end (head end) of the 116-K-2 Trench. Hexavalent chromium concentrations in this area are elevated at well 199-K-18 and at downgradient extraction wells 199-K-145 and 199-K-162. As shown in Figure 14-8, trends at the several tubes of the aquifer tube clusters are above 20 µg/L. Extraction wells 199-K-162 and 199-K-145, and aquifer tubes AT-K-3-D and K-3-S, had similar trends.

The 53.4 µg/L chromium detection at new aquifer tube C6253 (installed in 2008) is also included in the plume, although it may represent residual chromium not accessible to capture by upgradient extraction wells. Indirect evidence for a connection to the southwest plume may result from review of the chromium trend at extraction well 199-K-125A. The last time this well was consistently above 50 µg/L was in 2003. Aquifer tubes C6251 and C6252 (in the same cluster as C6253) at 4.0 to 2.3 µg/L, respectively, were well below 20 µg/L.

Aquifer tube exceedances at AT-K-3 and C6253 may, in part, reflect the downtime of extraction wells 199-K-145 and 199-K-162 due to well realignments and range

fire damage. These wells became operational with the startup of the KX treatment system but were taken offline after 2 months, following recognition of tritium contamination. The wells were realigned to the KR4 system and were restarted in February 2010. Several Phase 3 wells (which will be constructed for remedial process optimization) will be installed downgradient of wells 199-K-145 and 199-K-162 to better control near-river plume migration.

A second aquifer tube exceedance was observed further downriver at the new cluster (tubes C6254 through C6256), where hexavalent chromium was detected in deep tube C6256 at 36.0 and 30.1 µg/L. This tube location aligns with a plume lobe associated with the distal end of the 116-K-2 Trench, represented by the October 2009 values of hexavalent chromium at extraction well 199-K-115A (84 µg/L) and monitoring well 199-K-22 (122 µg/L) (Figure 14-8). (It is important to note that KX system extraction well 199-K-161 also treats a portion of the plume.) Hexavalent chromium trends at extraction wells 199-K-113A, 199-K-114A, 199-K-115A, and 199-K-116A are similar to, but lower than, the concentrations for well 199-K-161. Adjacent aquifer tubes around C6256 were either below 20 µg/L or could not be sampled during CY 2009; this exceedance may indicate a gap in the extraction well coverage. Additional analytical data are needed to determine if there is an increasing trend at aquifer tube C6256.

14.3.5.2 KX Pump-and-Treat System

The KX pump-and-treat system's operation and sampling activities for CY 2009 are discussed in this section. Information is included on system configuration, system availability, mass of contaminants removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and contaminant trends.

Changes in Calendar Year 2009

The KX pump-and-treat system began partial operation in November 2008 and became fully operational on February 3, 2009. This system was designed to treat the hexavalent chromium plume located between the 116-K-2 Trench and fence line at the N Reactor (Figure 14-13). The extraction well system was realigned to treat contaminated groundwater associated with the KE Reactor plume at well 199-K-141. The schematic for the KX pump-and-treat system is presented in Figure 14-14. In total, eleven extraction wells and eight injection wells were active at the end of CY 2009. At the end of CY 2009, three additional extraction wells (199-K-153, 199-K-171, and 199-K-178) and one injection well (199-K-180) were being readied for use in CY 2010. A six-train, four-vessel-per-train, ion-exchange treatment system, similar in design to that used for the 100-KR-4 and 100-HR-3 OUs has a treatment capacity of 2,271 liters per minute. Operational parameters from the startup of operations through the end of December 2009 are presented in Table 14-7.

Wells 199-K-144, 199-K-145, and 199-K-162 were identified for realignment when tritium trends at upgradient well 199-K-157 ranged between 320,000 and 620,000 pCi/L. Since the three proposed extraction wells either were directly downgradient of this well or were already showing increasing levels of tritium (well 199-K-144 at 200,000 to 286,000 pCi/L), a decision was made to limit tritium exposure to only the KR4 system. Five wells were proposed in support of Phase 2 expansions at the KR4 and KX pump-and-treat systems, but only four wells were completed in CY 2009. Four of these wells were intended to support the KX treatment system. All of the wells were drilled to the top of the Ringold upper mud unit and were constructed using 15.2-centimeter casing.

Wells 199-K-178 and 199-K-181 were drilled downgradient of KX system extraction well 199-K-141, to the top of the Ringold upper mud unit, and were intended for use as extraction wells. Elevated hexavalent chromium at well 199-K-178 was detected in the upper portion of the aquifer but rapidly diminished with depth. The well was drilled to the top of the Ringold upper mud unit and constructed to a multi-purpose design for use as an extraction, injection, or monitoring well. This well will be connected to the KX system as an extraction well.

Soil samples were taken at 1.5-meter intervals during the course of vadose zone drilling and were examined for cations, anions, and radionuclides. The radionuclides of interest included cobalt-60, strontium-90, cesium-137, europium-152/154, uranium-233/234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. Both cesium-137 and uranium-234 were detected at background concentrations. Cobalt-60, europium-152, uranium-233/234, uranium-235, and uranium-238 concentrations were less than detect. Plutonium-239/240 and strontium-90 were found above detection limits at low concentrations at several intervals within the vadose zone. The maximum plutonium-239/240 concentration was 0.19 pCi/L at a depth of 5.5 to 6.1 meters below ground surface. The maximum strontium-90 concentration was 0.8 pCi/L at a depth of 4.0 to 4.6 meters below ground surface.

Hexavalent chromium concentrations in well 199-K-181 were too low to initially warrant using the well for extraction. Chromium results did not exceed 13 µg/L during sampling while drilling. The well was constructed for multiple purposes (monitoring, injection, or extraction) and is currently being used as a monitoring well. It will be converted to an extraction well in CY 2010.

The remaining KX well, 199-K-182, was drilled in December 2009 and was completed in early 2010. The well was drilled upgradient of well 199-K-151 and will monitor groundwater for at least one year. Well 199-K-182 was screened across the unconfined aquifer and into the vadose zone. Development samples at this well detected hexavalent chromium concentrations of 73.9 and 75.4 µg/L, expanding the extent of the plume in this area.

The fifth well, 199-K-180, was planned as an injection well near well 199-K-143 but was moved ~305 meters upgradient to resolve cultural resource conflicts. This well was completed in January 2010.

A gravel pit located upgradient and northeast of the 116-K-2 Trench will be expanded over the next 10 to 15 years to provide clean backfill for Hanford Site contractors performing remediation activities in the 100 Areas. Pit expansion will be to the southwest and will interfere with continued use of extraction wells 199-K-153, 199-K-154, and 199-K-163.

Treatment System Performance

Key operational and system highlights for the KX pump-and-treat system for CY 2009 are as follows:

- 718.9 million liters of groundwater were treated and ~39.7 kilograms of hexavalent chromium were removed in CY 2009. This includes 62.1 million liters treated in January 2009 and the removal of 2.2 kilograms of hexavalent chromium.
- A review of project-specific database records during acceptance and operational testing determined that 66.7 million liters of groundwater were treated and 3.9 kilograms of hexavalent chromium were removed in November and December 2008.

- Through CY 2009, a total of 785.6 million liters of contaminated groundwater have been treated, with total hexavalent chromium mass removal of 43.6 kilograms.
- The mass removal efficiency for CY 2009 was 96.3% (Figure 14-15).
- The average influent hexavalent chromium concentration for CY 2009 was 55.3 µg/L and ranged between 42 and 84 µg/L.
- The average hexavalent concentration in the effluent during CY 2009 was 2.1 µg/L. Trend plots of influent and effluent concentrations are presented in Figure 14-16.
- The maximum effluent concentration reported in CY 2009 was 12 µg/L. The minimum concentration reported was non-detected.
- The total system availability for CY 2009 was 94.5%, and the scheduled system availability was 98.1%. Figure 14-17 and Table 14-8 present the monthly online percentages and method used to calculate availability and online percentage for the reporting period. No long periods of unplanned downtime occurred during the year. Several short periods of downtime occurred in June, August, and September, which were related to high pH levels in the effluent tank.
- During CY 2009, 24.9 cubic meters of new resin was installed, and 24.9 cubic meters of resin were regenerated during the period.

Table 14-9 presents the pumping flow rates and total run-time (total flow hours ÷ total possible run-time) for extraction wells currently at use in the KX pump-and-treat system. The recommended flow rates are based on the initial estimated extraction rates from short-term pumping tests conducted after the wells were drilled. A comparison of the extraction rates shows that several wells (including wells 199-K-130, 199-K-131, 199-K-148, 199-K-149, 199-K-150, and 199-K-161) were pumped at rates lower than the initial estimated extraction rates.

The KX system has design capacity to treat at a rate up to 2,271 liters per minute. During CY 2009, the pump-and-treat system processed groundwater at an average annual rate of 1,546.5 liters per minute.

Compliance Monitoring

Of the KX system extraction wells, 199-K-130, 199-K-131, 199-K-146, 199-K-147, 199-K-148, 199-K-149, 199-K-150 and 199-K-161 are considered to be both compliance and extraction wells. At the northeast end of the KX well field, concentrations at wells 199-K-150 and 199-K-149 have declined below 20 µg/L under the combined influence of treatment and reinjection of treated water at wells 199-K-159, 199-K-160, and possibly 199-K-164 (Figure 14-13). A rebound study should be conducted to determine if residual hexavalent chromium remains accessible in the aquifer, If concentrations remain low, wells 199-K-150 and 199-K-149 should be converted to injection wells to better control this lobe of the plume.

The hexavalent chromium trend at well 199-K-131 has declined but remains well above 20 µg/L, averaging 58 µg/L in December 2009. Aquifer tubes at sites AT-26 and AT-K-6, downgradient of these wells, were not sampled in CY 2009. Historically, hexavalent chromium at these tubes has been above 20 µg/L.

Extraction/compliance wells 199-K-148 and 199-K-130 trended well above 20 µg/L (Figure 14-13). At aquifer tubes AT-K-5-D and AT-K-5-M, data points of 45.7 and 34 µg/L, respectively, from November 2009 sampling agree with chromium trend for well 199-K-130 (45 µg/L), indicating that limited progress is being made

in capturing parts of the plume downgradient of the well's capture zone. Hexavalent chromium in aquifer tube AT-25-S was 13.4 µg/L. Hexavalent chromium at extraction well 199-K-148 remains elevated but was not detected above 20 µg/L at aquifer tube DK-04-2. Aquifer tube DK-04-3 was not sampled.

Extraction wells 199-K-147, 199-K-146, and 199-K-161 successfully captured moderate to elevated concentrations of hexavalent chromium in CY 2009 (Figure 14-13). Analyses of samples from downgradient aquifer tubes yielded non-detect to very low levels of hexavalent chromium. Since this area overlaps with long-standing extraction by KR4 wells, the lower concentrations at both wells and aquifer tubes ensure improved control of the local chromium plume.

New well 199-K-181, in conjunction with well 199-K-32A, is planned as a compliance well in the vicinity of the KE Reactor plume, around wells 199-K-141 and 199-K-178 (Figure 14-13). The trend plot for well 199-K-178 depicts analytical results while drilling and also presents two values from sampling after drilling. One pair of values at 106 µg/L (well development samples) and a second set at 118 µg/L (baseline sampling results) reflect the elevated concentrations first noticed in the upper portion of the aquifer. The plume has not spread laterally to impact wells 199-K-32A or 199-K-181; it is also not reflected in any of the aquifer tubes sampled in the fall of 2009. The values at aquifer tube C6244 are typical for tube set C6242 through C6244 and AT-K-2-D.

14.3.5.3 KW Pump-and-Treat System

The CY 2009 operational and sampling activities for the KW pump-and-treat system are discussed in this section. Based on recommendations in the second 5-year CERCLA review, the KW treatment facility was built and became operational on January 29, 2007. Four new wells drilled in 2008 indicated the presence of a larger and more concentrated hexavalent chromium plume, with concentrations up to 2,850 µg/L.

Changes in Calendar Year 2009

The KW pump-and-treat system was expanded to a treatment capacity of 757 liters per minute with the addition of a second, four-vessel, 379-liter-per-minute capacity treatment train at the KW processing building. Three of four new wells drilled in August and September 2008 (199-K-165, 199-K-166, and 199-K-168) joined 199-K-137 to serve as extraction wells. The fourth well, 199-K-173, monitors plume movement in the area downgradient of former injection well 199-K-35. New injection wells 199-K-174 and 199-K-175 were drilled in February 2009 at locations designed to help control plume movement toward the extraction wells while disposing of treated water. The injection well locations were based on the results of groundwater modeling, which showed plume control for 10 years (DOE/RL-2006-52, Rev. 2). Injection of treated water at well 199-K-35 was halted due to demolition of the nearby 183.2 sedimentation basin in the fall of 2009. The well remained active into 2010 as groundwater sampling continued in an attempt to monitor vadose zone response to demolition activities.

The expanded treatment system began operation on April 20, 2009, following downtime to disconnect existing well 199-K-139 and to connect the four new wells. Due to low chromium concentrations, well 199-K-140 was not used for extraction after the April 20 restart, but the well was turned on monthly to permit sampling, for field and laboratory analysis. Well 199-K-139 will be reconnected to the system in place of well 199-K-140 in CY 2010.

The KW system currently consists of seven extraction wells and three injection wells (Figure 14-18). The system schematic drawing for the KW pump-and-treat system is shown in Figure 14-19. The operational parameters from startup of operations through the end of December 2009 are presented in Table 14-10.

Treatment System Performance

Key operational and system highlights for the KW pump-and-treat system for CY 2009 are as follows:

- 297.6 million liters of groundwater were treated and ~49.3 kilograms of hexavalent chromium were removed. The mass removal efficiency for CY 2009 was 95.8%, which is slightly lower than the 98.8% reported for CY 2008 (Figure 14-20).
- The average influent hexavalent chromium concentration for CY 2009 was 165.4 µg/L, which is more than twice the average influent concentration of 65.6 µg/L reported for CY 2008. Prior to restart, influent concentrations ranged between 26 and 58 µg/L. Following restart on April 20, 2009, hexavalent chromium influent concentrations increased to a peak of 451 µg/L but then declined to between 110 and 130 µg/L by the end of CY 2009.
- The average hexavalent concentration in the effluent during CY 2009 was 4.2 µg/L, which is greater than the average effluent concentration of 0.84 µg/L reported for CY 2008. Trend plots of influent and effluent concentrations are presented in Figure 14-21. The maximum recorded effluent concentrations reported in CY 2009 was 14 µg/L.
- A problem with resin changeout at one train in August 2009 resulted in brief effluent discharges of up to 70 µg/L hexavalent chromium. The exceedance was reported to the regulatory agencies, and the system was restarted within a week after the exceedance was detected.
- The total system availability for CY 2009 was 95.6%, which is slightly lower than the 99.4% availability reported for CY 2008. The scheduled availability was 98.6%, which was slightly lower than the system availability of 99.4% reported in CY 2008. Figure 14-22 and Table 14-11 show the monthly online percentages and method used to calculate availability and online percentage for the reporting period. Although no long periods of unplanned downtime occurred during the year, limited downtime occurred in April due to a leaking check valve and issues with pressure-relief valves on ion-exchange vessels and compressors.
- New resin installed during CY 2009 consisted of 97.4 cubic meters, and ~61.2 cubic meters of resin were regenerated during the period.
- Table 14-12 presents the pumping flow rates and total run-time (total flow hours ÷ total possible run-time) for extraction wells currently in use at the KW pump-and-treat system. The recommended flow rates were initially based on estimated extraction rates from short-term pumping tests conducted after the wells were drilled. The flow rates were revised (DOE/RL-2006-52, Rev. 2) based on groundwater modeling results designed to meet requirements of preventing hexavalent chromium from reaching the Columbia River at concentrations above 20 µg/L. Pumping rates may be limited by excessive drawdown or by pump performance.
- The KW pump-and-treat system was originally designed to receive and process up to 378.5 liters per minute but was expanded in CY 2008/CY 2009 with the addition of a second treatment train (capacity of 378.5 liters per minute).

During CY 2009, the pump-and-treat system processed groundwater at an average annual rate of 565.4 liters per minute.

KW Compliance Monitoring

Wells 199-K-132 and 199-K-138, the farthest downgradient, are extraction/compliance wells at the KW treatment system. Chromium concentrations at the two wells, although above 20 µg/L, continued to decline, averaging 28 µg/L at well 199-K-132 and 30 µg/L at well 199-K-138 for December 2009 (Figure 14-18). These trends have decreased significantly from the January 2007 averages of 136 and 63 µg/L, respectively. The impact of high river stage on chromium concentrations in the spring and summer are not observed at the two extraction wells, suggesting limited hydraulic connectivity between the wells and the Columbia River.

Aquifer tube data for CY 2009 indicate that hexavalent chromium is not approaching the Columbia River at levels above 20 µg/L. Hexavalent chromium at downgradient aquifer tubes AT-K-1-D, 17-D, and 17-M remained below 10 µg/L in CY 2009 sampling. Previous aquifer tube exceedances in this area have been as high as 44 µg/L at aquifer tube AT-K-1-D in 2005 and 24.3 µg/L at aquifer tube 17-D in 2007.

14.3.6 Hydraulic Capture

M. J. Tonkin

This section describes groundwater flow in the 100 Areas and the extent of capture estimated at the 100-K Area pump-and-treat system during CY 2009. Groundwater levels are measured throughout the 100 Areas continuously at some wells using pressure transducers with data loggers and on a regular basis at other wells using manual (depth-to-water) measurements. Groundwater elevations indicate that flow is generally toward the Columbia River, but the rates and directions of flow are affected by the pump-and-treat remedies. Consistent with the recommendations in *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems, Final Project Report* (EPA 600/R-08/003), multiple lines of evidence are used to estimate capture. The two methods used to estimate the extent of hydraulic capture developed by pump-and-treat remedies during CY 2009 are water-level mapping and groundwater modeling, which are discussed below.

14.3.6.1 Water-Level Mapping and Capture Zone Estimation Method

Flow rates and directions are affected by pumping related to remedial activities. As a result, water-level maps and estimates of the extent of capture are prepared using a method that incorporates drawdown (or mounding) in response to extraction (or injection) at wells. This technique is an alternative to the use of a numerical model for interpreting capture using measured water levels and pumping rates. The technique is detailed in *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater P&T Remedy Performance* (SGW-42305). Estimating capture using water-level mapping follows the three-step process described below. Derivations for the equations presented, and additional equations that describe expected changes in water levels near rivers and ponds are presented in "Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift" (Tonkin and Larson 2002); "A Simple Approach to Account for Radial Flow and Boundary Conditions When Kriging Hydraulic Head Fields for Confined Aquifers" (Brochu and Marcotte 2003); and SGW-42305. The *Conceptual Framework and Numerical Implementation of 100 Area Groundwater Flow and Transport Model* (SGW-46279) also discusses the model.

First, water-level maps are prepared using universal kriging (*Geostatistics: Modeling Spatial Uncertainty* [Chiles and Delfiner 1999]; "On the Use of a Main Trend for the Kriging Technique in Hydrology" [Volpi and Gambolati 1978]), which allows a trend to be incorporated in the map. The form of the trend is defined by the analyst, and the trend coefficients are estimated automatically through kriging. For example, where planar groundwater flow exists, a linear trend is appropriate, leading to the following estimate of the water level, H, at any location (x,y) (Equation 14-1):

$$H(x,y) = A + Bx + Cy + \varepsilon(x,y) \qquad \textbf{(Equation 14-1)}$$

where A, B, and C are regression coefficients, and $\varepsilon(x,y)$ is the residual from the linear trend. Because the objective is to estimate the extent of capture, the trend must also reflect the expected response of water levels to pumping at wells. This is accomplished using a term that can be derived from the Thiem equation or the Cooper-Jacob equation. These equations state that under quasi-steady conditions, water-level changes due to pumping are centered on the pumped well and are proportional to the logarithm of the radial distance (r) from the pumped well, the pumping rate (Q), and the aquifer transmissivity. If superposition is used to sum the effects of multiple pumped wells, these pumping effects can be combined with the linear trend to provide the following water-level estimator (Equation 14-2):

$$H(x,y) = A + Bx + Cy + D\sum_{1}^{n} Q_i \log_{10}(r_i) + \varepsilon(x,y) \qquad \textbf{(Equation 14-2)}$$

where n is the number of pumped well, $Q_i \log_{10}(r_i)$ describes the effect of pumping at well i, and D is the regression coefficient corresponding to the pumping effects.

Particle tracking is then used to estimate flow directions and the extent of capture using the mapped water levels. Particle tracking on a single water-level map provides an instantaneous depiction of capture corresponding to the water levels and pumping rates used to prepare that map. Because data loggers provide essentially continuous water-level data with corresponding pumping rates, maps depicting water levels and capture can be produced on any frequency. However, determining a best estimate of capture on the basis of numerous maps can be difficult. This is accomplished in the third step of the analysis.

In the third analysis step, a capture frequency map is used to depict the capture estimated on the basis of numerous water-level maps. A capture frequency map depicts the frequency with which each released particle terminates at a pumped well, calculated over all water-level maps. A frequency of 1.0 indicates that the particle is captured on every map, a frequency of 0.0 (zero) indicates that a particle is not captured on any map, and intermediate frequencies indicate that the particle is captured using some maps and not on others. Since each individual water-level map is instantaneous, there is no explicit consideration for the time taken for contaminants to be recovered. Thus, a capture frequency map is most appropriately interpreted as an ensemble estimate for the monitoring period. Causes for frequencies below 1.0 include changing pumping rates and occasional violations of the underlying assumptions. Because low capture frequencies can be misleading, only frequencies of 0.5 and higher are depicted in figures.

When interpreting the results of this analysis, the following should be considered:

- A capture frequency map typically provides a reasonable estimate of remedy-wide capture within the footprint of the measured data, but distinguishing the capture zones of individual wells within a multi-well remedy can be prone to error. Therefore, inferences based on a capture frequency map should focus on area-wide capture and the relative distribution of low and high frequencies.

- Results presented on the basis of water-level mapping assume that vertical flow is negligible compared to horizontal flow, which is usually a reasonable assumption at some distance from the pumping wells.

14.3.6.2 Groundwater Flow Modeling and Capture Zone Estimation Method

The 100 Areas groundwater model encompasses the 100-D, 100-H, 100-K, and 100-N Areas. The model simulates two-dimensional groundwater flow using the MODFLOW-2000 program (*MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process* [Harbaugh et al. 2000]) and simulates the advective transport of contaminants using the particle-tracking program MODPATH (*User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S Geological Survey Finite-Difference Ground-Water Flow Model* [Pollock 1994]). The model simulates monthly stress periods, with monthly average river stage and pumping rate values for each stress period. Although a single depiction of capture can be calculated using particle tracking when a model simulates quasi-steady-state conditions, the approximate extent of hydraulic capture is calculated using the transient model using an approach similar to that described in "The Capture Efficiency Map: The Capture Zone Under Time-Varying Flow" (Festger and Walter 2002) and "Sources of Water to Wells for Transient Cyclic Systems" (Reilly and Pollock 1996), focusing on the evaluation of the temporal variation in capture due to changing flow patterns and hydraulic gradients:

- Releasing particles at the commencement of each of the twelve monthly stress periods and simulating their migration using a very low effective porosity, ensuring that particle travel times are essentially instantaneous
- Recording the instantaneous fate of each particle during each stress period
- Calculating a capture zone for each stress period based on the "snapshot" of aquifer conditions at the time of the particle release, in this case producing twelve instantaneous "snapshots" of the extent of capture
- Constructing a capture efficiency map by counting the number of times a particle originating from a location was captured by a well, and dividing this count by the total number of releases (i.e., twelve).

As for the capture frequency map prepared using the mapping technique, inferences from the capture efficiency map prepared using the groundwater model should focus on the relative extents and distribution of the low and high efficiencies.

14.3.6.3 100-K Area Approximate Flow Patterns and Extents of Capture

Pumping rates at the three 100-KR-4 OU groundwater pump-and-treat systems (KR4, KX, and KW) are shown in Figures 14-23, 14-24, and 14-25, respectively. Figures 14-23 and 14-24 clearly indicate two distinct periods of operation for the combined KR4/KX system. During Period 1 (from February to early August), wells 199-K-119A, 199-K-120A, 199-K-125A, 199-K-127, 199-K-145, and 199-K-162 were operational; however, during Period 2 (from late August to December), the wells were not operational and were either awaiting realignment to the KR4 system or were shut down due to low chromium concentrations. Other wells in the system operated at reasonably constant rates from February through December, although individual wells experienced intermittent periods of reduced pumping or complete shutdown lasting from weeks to months.

For the KW system (Figure 14-25), wells 199-K-165, 199-K-166, 199-K-168, 199-K-174, and 199-K-175 did not begin operating until mid-April. From April through December, all wells (except 199-K-139 and 199-K-140) were operational at reasonably consistent rates, although some wells experienced intermittent periods of reduced pumping rates or shutdown lasting weeks to months.

The water-level contours for each period identified for the KR4/KX system are shown in Figure 14-26(a and b), prepared using the water-level mapping method. In both panels of this figure, the KW system wells are active. Multiple maps analogous to those presented in this figure, constructed using weekly averaged water levels obtained throughout CY 2009 with transducers and corresponding pumping rates, were used to develop an ensemble estimate of the extent of capture developed by the KR4, KX, and KW pump-and-treat systems. These maps were used to estimate the extents of hydraulic capture for the combined KR4/KX system for Periods 1 and 2, and the extents of hydraulic capture for the KW system for the period in which all wells were operational (mid-April to December). The estimates of hydraulic capture for the KR4, KX, and KW systems obtained using the mapping technique are supplemented by estimates of capture calculated using the 100 Areas groundwater model.

The extent of hydraulic capture developed by the KR4/KX systems using a capture efficiency map, calculated using the groundwater model, is depicted in the three panels of Figure 14-27(a, b, and c). Figure 14-27(a) represents the combination of twelve instantaneous capture zone estimates calculated using the groundwater model, simulating monthly averaged river stages and pumping rates. Figure 14-27(b) depicts the extent of hydraulic capture developed by the KR4/KX system for Period 1 using a capture frequency map calculated and the mapping approach. Figure 14-27(b) represents the combination of 26 water-level and capture maps, generated using weekly averaged water levels and pumping rates. Figure 14-27(c) depicts the extent of hydraulic capture for the KR4/KX system for Period 2, using a capture frequency map and calculated using the mapping approach. This figure represents the combination of nineteen water-level and capture maps, generated using weekly averaged water levels and pumping rates. The three panels of Figure 14-28(a, b, and c) depict the same estimated extents of hydraulic capture developed by the KR4/KX system as shown in Figure 14-27(a, b, and c) but are overlaid with plume concentration contours that illustrate the extent of hexavalent chromium in groundwater during the spring of 2009.

The extent of hydraulic capture developed by the KW system using a capture efficiency map, calculated using the groundwater model, is depicted in Figure 14-29(a). This figure represents the combination of twelve instantaneous capture zone estimates, calculated using the groundwater model, simulating monthly averaged river stages and pumping rates. Figure 14-29(b) depicts the extent of hydraulic capture developed by the KW system, using a capture frequency map and calculated using the mapping approach, which represents the combination of 37 water-level and capture maps, generated using weekly averaged water levels and pumping rates from mid-April to December 2009. The 37 selected events represent periods when most of the wells in the KW system were operating at typical rates. Figure 14-30(a and b) depicts the same estimated extents of hydraulic capture developed by the KW system as shown in Figure 14-29(a and b) but is overlaid with contours that illustrate the extent of hexavalent chromium in groundwater during the spring of 2009.

14.3.6.4 Summary

The three panels in Figure 14-27(a, b, and c) suggest that the approximate extents of capture calculated using the mapping method and the groundwater model for

the combined KR4/KX system are broadly similar in appearance. The overlays of these capture efficiency and capture frequency maps with the contoured extents of hexavalent chromium identify areas where capture is satisfactory and where capture is unsatisfactory. Figure 14-28(a, b, and c) identifies areas of satisfactory and unsatisfactory capture. Noting that the capture efficiency map calculated using the model (Figure 14-27[a] and Figure 14-28[a]) depicts capture throughout CY 2009, while the capture frequency maps calculated using the mapping method represent Period 1 (Figure 14-27[b] and Figure 14-28[b]) and Period 2 (Figure 14-27[c] and Figure 14-28[c]) independently, the following is evident:

- The capture efficiency and capture frequency maps provide for a consistent interpretation of the extent of capture developed by the KR4/KX systems, throughout the contoured extent of hexavalent chromium, when the systems are operational.
- When the KR4/KX systems are operating, the high capture frequencies calculated by the mapping method, and the high capture efficiencies calculated using the model, encompass the majority of the contoured extent of hexavalent chromium.
- When wells 199-K-119A, 199-K-120A, 199-K-125A, 199-K-127, 199-K-145, and 199-K-162 are not operating, the capture frequency map (Period 2, shown in Figures 14-27[c] and 14-28[c]) indicates that there is effectively no chromium capture zone at the western end of the trench. The modeled capture efficiency map (Figures 14-27[a] and 14-28[a]) indicates diminished efficiencies since the model includes both periods when these wells are operating and periods when they are not operational.

Figure 14-29(a and b) suggests that the approximate extents of capture calculated using the mapping method and the groundwater model for the KW pump-and-treat system are similar in appearance. The overlays of these capture efficiency and capture frequency maps with the contoured extents of hexavalent chromium (Figure 14-30[a and b]) suggest that capture is typically satisfactory. The possible exception to this conclusion is the relatively low capture efficiencies and frequencies (Figure 14-30[a and b]) on the downgradient area of the KW treatment system near well 199-K-132.

None of the depictions of hydraulic capture encompass the chromium contamination that is depicted near well 199-K-141.

14.3.7 Calcium Polysulfide Treatability Test

A test was conducted during the summer of 2005 to evaluate the practicality of treating hexavalent chromium in the aquifer by injecting calcium polysulfide. The study concluded that hexavalent chromium concentrations in groundwater in the treated area were significantly reduced after the test, demonstrating that this method could be an effective alternative to pump-and-treat systems (DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*).

During the test, groundwater from a central extraction well was mixed with calcium polysulfide and injected into four wells in an array 30 meters from the extraction well. Calcium polysulfide and an emulsified vegetable oil circulated through the aquifer, reducing hexavalent chromium and the aquifer materials and creating a persistent zone of chemical reduction.

All five wells were sampled quarterly in 2009. The data show that hexavalent chromium in the injection wells remained at detection limits (~2 µg/L), indicating that the zone of reduction has persisted for over 4 years. Hexavalent chromium in

the extraction well began to increase to ~40 µg/L (about one-half the concentration in groundwater outside the treated area) one year after the test was completed and remained at that level in 2009. Dissolved oxygen also remained low in 2009, which is another indication that reducing conditions continue to persist in the aquifer.

14.4 Groundwater Monitoring at KE and KW Basins

Groundwater monitoring at the KE and KW Basins has occurred since the late 1970s; however, the monitoring frequency has been decreased as fuel has been removed from the basins. The basins received and stored irradiated fuel from N Reactor, as well as other miscellaneous fuel recovered during remedial actions at other reactor basins. Each basin held ~4.9 million liters of shielding water that was highly contaminated with long-lived radionuclides, some of which are mobile in the environment (e.g., tritium and strontium-90). Leaks at or around the KE Basin affected groundwater at well 199-K-109A, and the vadose zone beneath the basin has also become contaminated. Based on groundwater monitoring at downgradient wells, there is no indication that the KW Basin has leaked.

The fuel rods in the KE Basin were removed by 2008, and the sludge was pumped to the KW Basin through CY 2009. Demolition of the KE Basin and substructure was completed in CY 2009, and remediation is currently underway to remove the soil beneath the basin. Prior to the demolition, wells 199-K-109A and 199-K-27 were decommissioned. The 116-KE-3 Crib, which received overflow water from the KE Basin, is also being remediated. The KW Basin has been emptied of fuel rods but remains a depository for sludge from the KE and KW Basins. The KW Basin and the 116-KW-2 Crib will be removed after 2015.

Based on reported contamination in the basin shielding water, the contaminants of concern at the monitoring wells include tritium, carbon-14, technetium-99, and other less mobile radionuclides such as strontium-90 and cesium-137. Tritium is considered to be the primary indicator of water loss from the fuel rod basin/crib system. Strontium-90 and cesium-137 are not expected to move far in the groundwater, but the extensive use of dust-suppression water at the KE Basin and crib sites may mobilize contaminants in the vadose zone.

The previous KE and KW Basins sampling and analysis schedule complemented other 100-KR-4 OU groundwater sampling schedules. The KE and KW Basins monitoring plan (PNNL-14033, *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*) focused on the following objectives:

- Characterizing groundwater conditions between the KE and KW Basins and the Columbia River and providing a status of current conditions and attenuation of plumes
- Distinguishing between groundwater contamination associated with KE and KW Basins and the contamination from other past-practice sources to help guide operational and remedial action decisions
- Maintaining a strategy for the potential expansion of monitoring capabilities to respond to future basin-related issues.

The monitoring plan (PNNL-14033) specified at least an annual sampling frequency for radionuclides, anions, and groundwater field parameters at all KE Basin and KW Basin monitoring wells and downgradient aquifer tubes. A few monitoring wells were designated for quarterly analysis for tritium and radionuclide screening tests (gross alpha and gross beta). Although the basins are no longer filled with

shielding water, a continuing sampling program should be maintained. Previous leakage at the KE Basin and the use of dust-suppression water during basin and vadose zone remediation warrant continued monitoring at downgradient wells for the foreseeable future. A new well will be drilled to the east and downgradient of the 116-KE-3 Crib as part of the 100-K Area remedial investigation/feasibility study work plan (DOE/RL-2008-46) and will replace well 199-K-27. This well will improve contaminant monitoring in the area downgradient of the KE fuel rod basin site.

14.4.1 KE Basin

The key monitoring wells downgradient of the KE Basin (199-K-109A and 199-K-27) were removed in March 2008 to access the KE Basin and crib for decommissioning. These wells were replaced by 199-K-141 and 199-K-142, which are located 120 meters downgradient from the basin and crib. Due to high chromium concentrations in well 199-K-141, the well was converted to an extraction well. Tritium was routinely monitored at well 199-K-109A, reaching 420,000 pCi/L in October 1997 and then decreasing to 13,000 pCi/L in March 2008 (Figure 14-31). Tritium at wells 199-K-141 and 199-K-142 has remained below 5,000 pCi/L and 1,500 pCi/L, respectively, suggesting no significant plume movement since the wells were drilled.

Strontium-90 was routinely detected at well 199-K-109A at concentrations up to 18,600 pCi/L since monitoring began in 1994, which is well above the 8 pCi/L DWS. When the well was removed from service, strontium-90 concentrations of 900 to 1,100 pCi/L were detected (Figure 14-32). At wells 199-K-141 and 199-K-142, strontium-90 has not been detected in most samples and, if detected, has not exceeded 0.5 pCi/L.

14.4.2 KW Basin

The key downgradient monitoring wells around the KW Basin (199-K-34 and 199-K-107A) currently remain intact. Wells 199-K-139 and 199-K-168, both extraction wells for the KW treatment system, are also included because both are located near the basin. Tritium trends (Figure 14-33) at the two monitoring wells are elevated, suggesting past discharge to the 116-KW-2 Crib. Spikes in concentration similar to the KE Reactor area wells (suggesting releases from the basin) have not been observed at the KW Reactor area. Extraction wells 199-K-132 and 199-K-138 show more elevated tritium trends, but this may be the result of discharges to the 116-KW-1 gas condensate crib.

Strontium-90 is present above the 8 pCi/L DWS at monitoring wells 199-K-34 and 199-K-107A but has not exceeded 70 pCi/L since 1994. As noted in Figure 14-34, the trends have fluctuated between 20 and 45 pCi/L. Extraction well 199-K-139 has regularly detected strontium-90 but at concentrations below the DWS.

14.5 Conclusions

14.5.1 Groundwater Monitoring

The following conclusions are presented for the 100-KR-4 Groundwater OU:

- The hexavalent groundwater plumes are generally well defined around the 116-K-2 Trench and the KE and KW Reactors. However, recently drilled wells 199-K-171 and 199-K-182 indicate that the plume extends further inland of the trench than was previously known, particularly in areas east and northeast of the trench. Additional monitoring wells proposed for the 100-KR-4 OU

are expected to fill in a number of gaps in plume coverage. Cultural resource restrictions regarding well placement may locally affect a more complete understanding of the 116-K-2 plume configuration.

- The pump-and-treat network has removed significant chromium mass (more than 460 kilograms) from the aquifer and has reduced the portion of the 100-KR-4 OU shoreline where hexavalent chromium is present above 20 µg/L to several small strips. These strips are found along the shoreline at either end of the 116-K-2 Trench, as well as at downgradient locations at the southwest end of the trench (aquifer tube AT-K-3 series, C6249/C6250, C6253 and C6256) and along the northeastern reach of the KX treatment system's extraction well field (at aquifer tube AT-K-5). Hexavalent chromium concentrations in well 199-K-18 (downgradient of the southwest end of the 116-K-2 Trench) have been increasing steadily since the start of treatment operations in 1997, and concentrations in downgradient aquifer tube AT-K-3 have been as high as 85 µg/L. The recirculation cell that developed between the injection and extraction wells at the center of the 116-K-2 Trench has not affected the narrow plume downgradient of well 199-K-18. Not all tubes were sampled, and there may be a greater extent of shoreline with hexavalent chromium levels above 20 µg/L.
- The nature and source of hexavalent chromium contamination in well 199-K-18 at the southwestern end of the 116-K-2 Trench is not well understood. Trends at this well have increased since the start of treatment and have increased past the theoretical limit of 170 µg/L for dilutions of 500 µg/L sodium dichromate added to the cooling water. Chromic acid and nitric acid used for reactor decontamination and disposed in the 116-K-2 Trench may also have added to the hexavalent chromium detected in well 199-K-18, as well as the continuing high nitrate concentration that has declined to ~70,000 µg/L after 12+ years of treatment operations.
- The nature of spills and releases at the 183-KE/KW headhouses has been identified as a potential threat to groundwater based on local staining of surface sediments, but the extent of contamination is not well known. The potential for and amount of losses within the sodium dichromate-handling system between headhouses and the reactors was not documented and has not been defined during remedial actions.
- Tritium at concentrations below 20,000 pCi/L is widespread across the 100-KR-4 OU. Concentrations above the DWS are mainly associated with wells near and downgradient of the 118-K-1 Burial Ground, and to a lesser extent at the 116-KE/KW Cribs that received reactor gas system condensates. The greater concentrations downgradient of the burial ground have required well realignments to prevent spreading of the plume over a broader area of the 100-KR-4 OU. The burial ground, including silos, will be remediated by the end of FY 2011.
- The extent of carbon-14 at the reactors has not been completely defined. This isotope may become a significant contributor to overall risk when considered in the final Record of Decision. Carbon-14 has been observed in groundwater downgradient of the former 116-KE-1 and 116-KW-1 gas condensate cribs adjacent to the reactor areas, and residual carbon-14 may remain in vadose zone sediment pore spaces. Although the waste sites have been remediated, the vadose zone sediments were not addressed beyond 7.6 meters below ground surface.

Several key monitoring wells (199-K-29 and 199-K-30) at the KE Reactor waste site are being removed due to facility demolition activities and will eliminate two control-points monitoring the carbon-14 plume.

- Strontium-90 was present in coolant water that leaked from each reactor's fuel rod storage basins. Downgradient monitoring wells have detected significant spikes of strontium-90 in the past at the KE Reactor site and moderate levels above the 8 pCi/L DWS at the KW Reactor site. A key monitoring well at the KE Reactor (199-K-109A, which was decommissioned in CY 2008) was partially offset by construction of two replacement monitoring wells to the northwest (downgradient). Although strontium-90 has not been observed at the two wells near the DWS (8 pCi/L), the use of dust-suppression water during removal of the KE Basin and crib site may result in undetected migration. A proposed remedial investigation/feasibility study well will replace one of the KE Reactor monitoring wells and will improve monitoring of mobile (tritium) and less mobile (strontium-90) contaminants. A replacement for well 199-K-109A should be constructed at the completion of waste site remediation around the KE basin area.
- Total petroleum hydrocarbons (diesel, gasoline, and kerosene) are known to exist in the soil column around fuel storage bunkers. Total petroleum hydrocarbons have been found in vadose zone sediments, with occasional detections of diesel- and kerosene-grade total petroleum hydrocarbons in groundwater. No characterization or remediation efforts are currently underway for this contaminant suite. The leaks and spills at both reactor sites pose a potential threat to groundwater.

14.5.2 Hexavalent Chromium Treatment

The following conclusions pertain to the interim response measure remedial action objectives:

- ***Remedial action objective #1.*** Protect aquatic receptors in the river bottom substrate from contamination in the groundwater entering the Columbia River.

  The alternate compliance point cleanup criterion for compliance wells is 20 µg/L based on the 10 µg/L ambient water quality criterion recently revised in WAC 173-201A, "Water Quality Standards for Surface Water of the State of Washington." None of the compliance wells in the three treatment systems show contaminant trends for CY 2009 exceeding 20 µg/L. Many of the extraction/compliance wells aligned closest to the Columbia River are capturing elevated hexavalent chromium concentration above the 20 µg/L criterion. The informal data from aquifer tubes suggest chromium is reaching the river in fewer locations than observed in CY 2008 at the three locations described above.

  – Two measures of a water treatment system's performance are the volume treated and contaminant mass removed from the plumes. In CY 2009, the three 100-KR-4 OU treatment systems removed 94.6 kilograms of hexavalent chromium from 1.14 billion liters of water treated. Since startup of operations, the three systems have removed 468.3 kilograms of hexavalent chromium from 6.63 billion liters of water treated.

  – Additional monitoring details for the each of the three treatment systems that aid in evaluating pump-and-treat system performance are discussed below.

  <u>KR4 pump-and-treat system</u>

  The KR4 system has remediated the core of the original hexavalent chromium

plume over the past 12+ years. A number of monitoring and extraction wells had very low detections of chromium during CY 2009. Compliance wells 199-K-20 and 199-K-117A and monitoring well 199-K-21 did not exceed 14 µg/L, and concentrations in extraction wells 199-K-119A, 199-K-125, and 199-K-127 were below 20 µg/L for CY 2009.

- This system removed ~7.8 kilograms of hexavalent chromium from 317.5 million liters of water in CY 2009 and a total of 347.5 kilograms in 5.31 billion liters of water since startup of operations.
- Hexavalent chromium concentrations at well 199-K-18 continued to trend upward in CY 2009, reaching a peak value of 203 µg/L in July 2009. This portion of the plume is currently captured by extraction wells 199-K-145 and 199-K-162, located downgradient of well 199-K-18. Although well 199-K-18 only penetrates into the upper 4.6 meters of the aquifer, it is located in an area where the Ringold Unit 5 is unusually deep (32.5 meters).
- Aquifer tube data indicate that above-criterion concentrations of hexavalent chromium are reaching the Columbia River, at and between aquifer tubes AT-K-3-D and C6253. The plume is believed to have migrated downriver after passing extraction wells 199-K-145, 199-K-162, and 199-K-120A. The concentrations at these and intervening aquifer tubes ranged from 21.8 to 64.1 µg/L in CY 2009. Two new extraction wells midway between the river and wells 199-K-145, 199-K-162, and 199-K-120A will be installed in CY 2010 to better control the plume.
- The hexavalent chromium plume at the northeastern end of the 116-K-2 Trench is the largest plume in the 100-KR-4 OU. The plume is treated by extraction wells from both the KR4 and the KX systems and is characterized by a large area encompassed within the 50 µg/L contour line, with some well concentrations approaching 100 µg/L. This plume decreased in size during CY 2009. Results from aquifer tubes downgradient of this plume indicate that a portion of the chromium plume is reaching the Columbia River.
- Aquifer tube C6256 is located between extraction wells 199-K-115A and 199-K-116A, and the hexavalent chromium concentration in this tube reached 36 µg/L. Analytical results from shallower tubes C6254 and C6255, and adjacent aquifer tubes did not exceed hexavalent chromium concentrations of 8 µg/L in the fall of 2009.
- The decline (48%) in mass removed in CY 2009 compared to CY 2008 is due not only to the 35% reduction in pumping volumes, but is also the result of depletion of the available hexavalent chromium plume. System operation was optimized to extract from the wells with the greatest hexavalent chromium concentrations. New extraction wells replacing existing wells that were removed during realignment in late 2009 and 2010 should improve performance of the KR4 system.

KX pump-and-treat system

With official system startup on February 3, 2009, the KX pump-and treat system (capacity of 2,271 liters per minute) is extracting from a chromium plume associated with the KE Reactor and the northeastern extent of the plume beyond the 116-K-2 Trench. Process startup in November and December 2008 yielded 6.12 kilograms of hexavalent chromium from 66.7 million liters of groundwater treated. An additional 62.1 million liters of groundwater were treated in January 2009, yielding an additional 2.23 kilograms of chromium. For

February through December, the values for the KX system were 37.5 kilograms of chromium removed from 666.8 million liters of water treated. In total, 765 million liters of treated water yielded 43.6 kilograms of chromium.

– The groundwater plume is successfully captured at most of the wells in the KX extraction/compliance well system. Aquifer tubes AT-K-5-D and AT-K-5-M had chromium concentrations of 45.7 and 34 µg/L. respectively. These tubes are downgradient of extraction well 199-K-130.

– The KE Reactor plume at well 199-K-141 has expanded, following the detection of chromium concentrations greater than 100 µg/L at new downgradient extraction well 199-K-178. The source of the chromium is not clear. This is a relatively narrow plume, as it is not detected at new monitoring well 199-K-181 or at existing monitoring wells 199-K-32A or 199-K-142. Hexavalent chromium did not exceed 20 µg/L at downgradient aquifer tubes.

KW pump-and-treat system

The KW treatment system's treatment capacity was increased from 379 to 758 liters per minute in April 2009. For the year, 49.3 kilograms of hexavalent chromium were removed from 269.9 million liters of treated groundwater. Since startup of operations in January 2007, 83.3 kilograms of chromium have been removed from nearly 667 million liters of groundwater. None of the aquifer tubes downgradient of the plume exceeded the 20 µg/L alternate compliance point criterion in CY 2009.

– Significant hexavalent chromium declines following restart have been observed at wells 199-K-165 and 199-K-137. Prior to the April 2009 restart, the November 2008 analytical results at these wells reported hexavalent chromium concentrations of 2,220 µg/L and 1,110 µg/L, respectively. Hexavalent chromium concentrations declined to 150 µg/L (July 2009) and 193 µg/L (November 2009), respectively, before beginning a slow increase that continued into CY 2010.

– In late December 2009, elevated chromium concentrations were found at well 199-K-35, a former injection well removed from service in November 2009. Concentrations increased from 193 µg/L to 726 µg/L in late January 2010. This is the first substantial evidence that chromium lost to the ground at the 183-KW headhouse has reached groundwater; however, this does not rule out other vadose zone sources beneath the KW Reactor structures.

– Other contaminants of concern (tritium and strontium-90) are discussed in DOE/RL-96-84. Target analytes (carbon-14, technetium-99, trichloroethene, and nitrate) are also considered due to potential risk assessment impact for the final Record of Decision:

- Strontium-90 is generally considered to be a less mobile contaminant. It is present at a few wells downgradient of the 116-K-2 Trench and the 116-KW-1 and 116-KE-3 Cribs, which are associated with the KW and KE Basins. Most of the plumes are slightly above the 8 pCi/L DWS and may become mobilized through the use of dust-suppression water while decommissioning the KE Basin and its substructure. In addition, remediation of contaminated soil beneath the structures' footprints continues. A proposed remedial investigation/feasibility study well will be installed near the original location of well 199-K-27 to provide backup for contamination previously observed near the KE fuel rod basin. Data from this well will be used to determine if radionuclides are being mobilized toward extraction well 199-K-141.

- Tritium plumes above the DWS (20,000 pCi/L) are found at downgradient monitoring wells associated with the 116-KE-1 and 116-KW-1 gas condensate system cribs at the KE and KW Reactors, and also downgradient of the 118-K-1 Burial Ground (around the southwestern end of the 116-K-2 Trench).
- Carbon-14 plumes above the DWS (2,000 pCi/L) are found at downgradient monitoring wells associated with the 116-KE-1 and 116-KW-1 gas condensate system cribs at the KE and KW Reactors.
- Nitrate is widespread in Hanford Site groundwater. Nitrate concentrations above the DWS (45 mg/L) are associated with the southwestern end of the 116-K-2 Trench, at three wells on the northeast side of the KW Reactor, and at a monitoring well between the two reactors.
- ***Remedial action objective #2.*** Protect human health by preventing exposure to contaminants in groundwater.

  The *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units* (EPA/ROD/R10-96/134) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period, including the following:

  – Access control and visitor escorting
  – Signage providing visual identification and warning of hazards or sensitive areas
  – Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  – Regulatory agency notification of any trespassing incidents.

  The effectiveness of institutional controls was presented in the *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions* (DOE/RL-2004-56). The findings of this report indicate that institutional controls were maintained to prevent public access, as required.
- ***Remedial action objective #3.*** Provide information that will lead to a final remedy.
  – The pump-and-treat system concept of developing a recirculation network that extracts from the plume area and returns treated water to control plume migration toward the extraction well has been validated at the KR4 pump-and-treat system at the 116-K-2 Trench. The same design concept was used for the KW and KX pump-and-treat systems.
  – New wells drilled in CY 2009 have provided geologic and hydrologic data to improve the conceptual site model for the 100-KR-4 OU. The data allow more accurate numerical modeling to predict contaminant flow and response of treatment options.
  – The startup of the new KX treatment system and expansion of the existing KW treatment system, as well as well realignments at the KR4 and KX treatment systems, have begun to capture all known hexavalent chromium plumes in the 100-KR-4 OU.

14.6 Recommendations

The recommendations for groundwater monitoring and hexavalent chromium treatment discussed in this section are proposed for implementation within the next 3 to 5 years.

14.6.1 Groundwater Monitoring

The following general recommendations are made for the 100-KR-4 Groundwater OU:

- Data gaps in the extent of the hexavalent chromium plume in the 100-KR-4 OU have been detected at several well locations. Wells 199-K-171 and 199-K-182 each reported hexavalent chromium values exceeding 70 µg/L. Characterization planned as part of the remedial investigation/feasibility study work plan is designed to fill the data gaps. If the results indicate concentrations above 30 µg/L, additional wells should be considered to bound the extent of the chromium plumes.
- The hexavalent chromium source areas at the 183-KE/KW headhouses would benefit from additional characterization to support planned bioremediation activities. The lateral and vertical extent of contamination will not be fully identified with the planned remedial investigation/feasibility study characterization wells and the multiple potential sources at which sodium chromate could be lost. Additional wells should be considered to better understand the contaminant distribution, geology, and hydrogeology at each source area.
- Monitoring wells 199-K-29 and 199-K-30 track contaminant migration in the groundwater from the 116-KE-1 Crib; however, both wells will be decommissioned in CY 2010 to permit demolition of the 117-KE filter building. Additional wells are needed around the 116-KE-1 and 116-KW-1 gas condensate system cribs to better define the carbon-14 (5,830 pCi/L) and tritium (140,000 pCi/L) plumes detected at well 199-K-30. Replacement wells near these locations cannot be drilled until decommissioning is completed. Wells located further downgradient can be drilled more quickly and would help to define carbon-14 and tritium migration. These more-downgradient wells would not provide adequate detection if significant releases from remedial activities (i.e., dust-suppression water) occur. Multiple wells at the 116-KW-2 Crib are also recommended.
- The sampling frequency for some aquifer tubes should be increased to ensure that all areas where chromium may be reaching the river are well defined.

14.6.2 Hexavalent Chromium Treatment

The following recommendation is made for all treatment systems:

- Modeled remedial process optimization extraction rates need to be incorporated into routine pump-and treat operations for the three systems to ensure that the 2012 Tri-Party Agreement milestone is met for preventing greater than 20 µg/L hexavalent chromium groundwater from reaching the Columbia River.
- The 100-KR-4 OU interim action monitoring plan (DOE/RL-2009-59) should be revised to provide more robust monitoring of the three pump-and-treat systems. As treatment options and plume control measures are implemented, guiding documents should present sampling requirements, which will then be incorporated into regular document revisions. Document updates may also be required to address system reconfigurations and changing groundwater conditions.
- The three pump-and-treat systems' operations may need to be revised to address

river-stage impact and requirements to prevent hexavalent chromium from reaching the Columbia River. Required flow rates at wells near the river that prevent plume migration to the river may impact extraction rates near the core of a plume where more mass can be removed. A flexible approach should be developed to determine the most beneficial use of treatment capacity.

- Well construction should be examined to ensure that hexavalent chromium plumes are being intercepted across the vertical extent of the aquifer in areas where the plumes may be passing beneath partially penetrating wells. Where significant gaps exist, new wells may improve the contaminant removal.

The following recommendations are made for the individual treatment systems:

- **KR4 pump-and-treat system**:
  - Two of the three new Phase 3 wells proposed at the southwestern end of the 116-K-2 Trench will operate as extraction wells. Future well realignments should consider converting the third well from a monitoring well to an extraction well if downgradient aquifer tubes continue to show the presence of hexavalent chromium above 30 µg/L.
  - A new extraction well between wells 199-K-115A and 199-K-116A may be useful in capturing hexavalent chromium now approaching the Columbia River near aquifer tube C6256.
- **KX pump-and-treat system**:
  - Chromium trends at wells 199-K-150 and 199-K-149 are declining to levels below 20 µg/L, and these wells should be considered for conversion to injection wells. The pump should be turned off and used only for sampling as part of a short-term rebound study. The rebound will indicate whether residual chromium upgradient of the wells has been removed. Rebound studies at all extraction wells should be conducted following at least 6 months of hexavalent chromium values below 20 µg/L, including the months of low river stage in September and October. This will assist in determining whether to convert the wells to injection wells.
  - New injection wells upgradient of the northeastern chromium plume should be considered to help drive contamination to the extraction wells. When locating these wells, expansion of the gravel pit around wells 199-K-151 and 199-K-152 should be evaluated. Long-term pit expansion (10 to 15 years) will approach and consume extraction wells 199-K-153, 199-K-154, and 199-K-163, and it may approach injection well 199-K-143. Because pit expansion would also interfere with proposed bioremediation plans at the northeastern end of the 116-K-2 Trench, resolution of competing land uses in this area must be resolved.
  - To better define a hexavalent chromium plume associated with the KE Reactor and its facilities, additional wells are needed. Plume boundaries around the reactor and the water treatment system are not well defined, and the impact of leaks or spills at the 183.2-KE sedimentation basin are not identified. The wells identified in the remedial investigation/feasibility study work plan will improve understanding at key areas. Additional wells will help monitor migration of contaminants resulting from future facility decommissioning activities planned during the next 3 to 4 years and should be designed as multi-purpose wells in the event that treatment is needed.
- **KW pump-and-treat system**:

- Following the conclusion of decommissioning activities around the water treatment system, opportunities to locate groundwater monitoring or treatment wells should be investigated. The post-demolition site may provide opportunities to characterize the chromium plume between the headhouse source area and the current treatment well field.
- The 20 µg/L hexavalent chromium contour is unbounded along the southwestern side of the KW Reactor plume, upgradient of well 199-K-140. A well located west or southwest of extraction well 199-K-166 may provide a data point to close this contour.

Table 14-1. Changes in Hexavalent Chromium and Total Chromium from Baseline Through 2009 for Wells and Aquifer Tubes Monitoring the 116-K-2 Trench and North to the 100 N Area.

Well or Aquifer Tube Name	Current Well Use- and Pump-and-Treat System	Baseline Sample					Fall 2009 Sample					Percent Change in Conc. Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Hexavalent Chromium		Total Chromium					
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered. (µg/L)	Hexavalent Chromium (µg/L)	Total Chromium	
													Unfiltered	Filtered
199-K-18	C	12/16/1996	40	12/16/1996	40	40.1	10/22/2009	192	10/22/2009	184	174	380	360	333.9
199-K-19	P	12/16/1996	40	12/16/1996	84.8	85.8	10/18/2009	13.7	10/18/2009	13 U	13 U	-65.8	-84.7	-84.8
199-K-20	C	2/25/1997	129	11/15/1996	148	--	10/28/2009	2.3 (B)	10/28/2009	13 U	13 U	-98.2	-91.2	
199-K-21	P	11/18/1996	120	11/18/1996	122	111	10/18/2009	6 (N)	10/18/2009	32.7 B	13 U	-95	-73.2	-88.3
199-K-22	P	11/25/1996	130	11/25/1996	165	153	10/22/2009	120	10/22/2009	117	122	-7.7	-29.1	-20.3
199-K-37	P	11/25/1996	80	11/25/1996	103	97.9	10/22/2009	56.7	10/22/2009	64.9 (B)	54.5 (B)	-29.1	-37	-44.3
199-K-113A	E/C-KR4	11/12/1996	100	--	--	--	10/21/2009	58	10/21/2009	55.5 (B)	50.5 (B)	-42	--	--
199-K-114A	E/C-KR4	2/26/1997	62.3	--	--	--	10/21/2009	62.9	10/21/2009	59.2 (B)	62.9 (B)	1	--	--
199-K-115A	E/C-KR4	9/12/1997	126	--	--	--	10/21/2009	84.4	10/21/2009	81.7	85.5	-33	--	--
199-K-116A	E/C-KR4	11/20/1996	190	--	--	--	10/21/2009	25.3	10/21/2009	28.2 (B)	24.2 (B)	-86.7	--	--
199-K-117A	C	11/21/1996	200	5/27/1998	--	81.9	10/22/2009	2 (U)	10/22/2009	13 (U)	13 (U)	--	--	--
199-K-119A	E/C-KR4	11/21/1996	120	--	--	--	--	--	--	--	--	--	--	--
199-K-120A	E/C-KR4	11/26/1996	90	--	--	--	--	--	--	--	--	--	--	--
199-K-125A	C	11/10/1998	161	--	--	--	--	--	--	--	--	--	--	--
199-K-126	M	7/26/1999	75.6	3/14/2005	58.9	--	10/21/2009	36.6	10/21/2009	47.9 (B)	44 (B)	-51.6	-18.7	--
199-K-127	E/C-KR4	5/14/2002	76	--	--	--	--	--	--	--	--	--	--	--
199-K-129/ K-112A	E/C-KR4	11/12/1996	120	6/13/2006	20.6	--	10/21/2009	45.2	10/21/2009	46 (B)	44.5 (B)	-62.3	123.3	--
199-K-130	E/C-KX	3/26/2003	50	3/7/2006	79.2	--	10/20/2009	49.7	10/20/2009	49 (B)	51.4 (B)	-0.6	-38.1	--
199-K-131	E/C-KX	10/20/2004	63	--	--	--	10/20/2009	58	10/20/2009	56.4 (B)	60.6 (B)	-7.9	--	--
699-78-62	M	--	--	3/2/1988	106	--	--	--	--	--	--	--	--	--
199-K-121A	I-KR4	11/13/1996	150	--	--	--	--	--	--	--	--	--	--	--
199-K-122A	I-KR4	11/13/1996	90	--	--	--	--	--	--	--	--	--	--	--
199-K-123A	I-KR4	11/14/1996	71.3	--	--	--	--	--	--	--	--	--	--	--
199-K-124A	I-KR4	11/14/1996	50	--	--	--	--	--	--	--	--	--	--	--
199-K-128	I-KR4	--	--	--	--	--	--	--	--	--	--	--	--	--
199-K-143	I-KR4	2/23/2007	22.2	2/23/2007	23.3	20.2	--	--	--	--	--	--	--	--

Table 14-1. (Cont.)

Well or Aquifer Tube Name	Current Well Use- and Pump-and-Treat System	Baseline Sample					Fall 2009 Sample					Percent Change in Conc. Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Hexavalent Chromium		Total Chromium					
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered. (µg/L)	Hexavalent Chromium (µg/L)	Total Chromium	
													Unfiltered	Filtered
199-K-144	E/C-KR4	4/7/2008	38	--	--	--	--	--	--	--	--	--	--	--
199-K-145	E/C-KR4	4/15/2008	25 (N)	--	--	--	12/7/2009	59	--	--	--	136	--	--
199-K-146	E/C-KX	1/4/2008	110	--	--	--	10/20/2009	44.8	10/20/2009	43.9 (B)	42.5 (B)	-59.3	--	--
199-K-147	E/C-KX	11/15/2007	38	--	--	--	10/20/2009	37.9	10/20/2009	35.9 (B)	33 (B)	-0.3	--	--
199-K-148	E/C-KX	11/14/2007	74	--	--	--	10/20/2009	85.3	10/20/2009	78.4	85.9	15.3	--	--
199-K-149	E/C-KX	11/14/2007	64	--	--	--	10/20/2009	27.2	10/20/2009	24.2 (B)	28.3	-57.5	--	--
199-K-150	E/C-KX	4/23/2008	54	--	--	--	10/20/2009	8.8	10/20/2009	9.1 (B)	9.1 (B)	-83.7	--	--
199-K-151	P	12/14/2007	44	--	--	--	10/22/2009	26.4	10/22/2009	30.6 (B)	22.2 (B)	-40	--	--
199-K-152	P	2/1/2008	69	--	--	--	10/22/2009	69.9	10/22/2009	73.1	70.2	1.3	--	--
199-K-153	M	1/3/2008	37	--	--	--	--	--	--	--	--	--	--	--
199-K-154	E-KX	11/20/2007	99	--	--	--	10/12/2009	94	--	--	--	-5.1	--	--
199-K-156	I-KX	2/12/2008	7	--	--	--	--	--	--	--	--	--	--	--
199-K-157	P	1/30/2008	28	--	--	--	10/29/2009	51.5	10/29/2009	56 (B)	54.4 (B)	83.9	--	--
199-K-159	I-KX	11/12/2007	7	--	--	--	--	--	--	--	--	--	--	--
199-K-160	I-KX	11/13/2007	10	--	--	--	--	--	--	--	--	--	--	--
199-K-161	E/C-KX	1/4/2008	44	--	--	--	10/21/2009	85.9	10/21/2009	87.4	88.2	95.2	--	--
199-K-162	E/C-KR4	4/4/2008	88	--	--	--	--	--	--	--	--	--	--	--
199-K-163	E/C-KX	11/16/2007	129	--	--	--	10/12/2009	96	--	--	--	-25.6	--	--
199-K-164	I-KX	4/11/2008	2 (U)	--	--	--	--	--	--	--	--	--	--	--
199-K-169	I-KX	7/31/2008	4 (B)	--	--	--	--	--	--	--	--	--	--	--
199-K-170	I-KX	8/1/2008	4	--	--	--	--	--	--	--	--	--	--	--
199-K-171	E-KX	8/18/2008	77	--	--	--	--	--	--	--	--	--	--	--
199-K-172	I-KX	8/26/2008	18	--	--	--	--	--	--	--	--	--	--	--
199-K-179	I-KX	10/23/2009	2.4 (B)	--	--	--	--	--	11/5/2009	13 (U)	13 (U)	--	--	--
199-K-180	I-KX	--	--	--	--	--	--	--	--	--	--	--	--	--
199-K-182	P	12/28/2009	74.6	--	--	--	--	--	--	--	--	--	--	--
199-N-16	P	--	--	9/25/1996	--	4.4 U	--	--	--	--	--	--	--	--

Table 14-1. (Cont.)

Well or Aquifer Tube Name	Current Well Use- and Pump-and-Treat System	Baseline Sample					Fall 2009 Sample					Percent Change in Conc. Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Hexavalent Chromium		Total Chromium					
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered. (µg/L)	Hexavalent Chromium (µg/L)	Total Chromium	
													Unfiltered	Filtered
199-N-71	P	--	--	3/26/1996	52.2	4.4 U	--	--	--	--	--	--	--	--
199-N-72	P	--	--	3/21/1996	--	3.7 U	--	--	--	--	--	--	--	--
Aquifer Tubes														
19-D	AT	12/2/1997	5 (U)	--	--	--	11/17/2009	2 (U)	11/17/2009	13 (U)	13 (U)	--	--	--
21-M	AT	11/24/1997	41	--	--	--	11/18/2009	2 (U)	--	--	--	-95.1	--	--
22-M/D	AT	12/2/1997	59	--	--	--	11/21/2009	7	--	--	--	-88.1	--	--
23-D	AT	12/2/1997	81	--	--	--	11/23/2009	2 (U)	--	--	--	-97.5	--	--
26-D	AT	11/19/1997	5 (U)	--	--	--	--	--	--	--	--	--	--	--
C6246	AT	9/30/2008	14	--	--	--	11/16/2009	16	--	--	--	--	--	--
C6250	AT	--	--	--	--	--	11/17/2009	24.5	--	--	--	--	--	--
C6253	AT	11/6/2008	18	--	--	--	11/21/2009	49.4	--	--	--	--	--	--
C6256	AT	11/5/2008	13 (N)	--	--	--	11/21/2009	30.1	--	--	--	--	--	--
C6259	AT	11/10/2008	2 (U)	--	--	--	11/21/2009	2 (U)	--	--	--	--	--	--
C6260	AT	11/10/2008	8	--	--	--	11/23/2009	2 (U)	--	--	--	--	--	--
DK-04-2	AT	12/4/1997	25	--	--	--	11/21/2009	2 (U)	--	--	--	-92	--	--
AT-K-3-D	AT	3/2/2004	37	--	--	--	11/1/2009	62.8	11/1/2009	58.4 (B)	66.4	69.7	--	--
AT-K-4-M	AT	3/29/2006	1 (U)	--	--	--	11/23/2009	2 (U)	--	--	--	--	--	--
AT-K-5-D	AT	3/2/2004	58.7	--	--	--	11/23/2009	45.6	--	--	--	-22.3	--	--
AT-K-6-M	AT	3/2/2004	34.2	--	--	--	--	--	--	--	--	--	--	--

Notes:
1. Well use: C = compliance, E = extraction, I = injection, M = monitoring; X = 100-KR-4 expansion well (use to be determined); AT = aquifer tube.
2. Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, S = shallowest.
3. Change in hexavalent chromium concentration at site #22 included sample results from both the middle and deep tube in cluster because all tubes not sampled each year.
4. Change in hexavalent chromium concentration is not calculated when "U" (undetected) values are used in calculation. Where both values have a "U" qualifier, the values are assumed not to have changed significantly.
5. The 2007 results for injection wells are treated effluent hexavalent chromium concentrations.
6. Laboratory qualifiers: U = undetected (shown with detection limit in parentheses); B = detected above instrument or method detection limit, but below contract-required detection; D = sample diluted.
7. Hexavalent chromium results from well 199-K-126 have been influenced by the calcium polysulfide treatability test that changed the color of the groundwater and so strongly influence the colorimetric EPA Method 7196 results.
High out-of-trend results from this well have been rejected because of the lingering calcium polysulfide influence.
8. Blank cells ("—") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

Table 14-2. Changes in Hexavalent Chromium and Total Chromium from Baseline Through 2009 for Wells and Aquifer Tubes Monitoring the KW Reactor Area.

Well Name	Use	Baseline Sample					Fall 2009 Sample					Percent Change in Concentration Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Chromium		Total Chromium				Total Chromium	
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Unfiltered Hexavalent Chromium (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Hexavalent Chromium	Unfiltered	Filtered
199-K-34	M	1/22/2007	22	11/15/1996	12.9	8.4 (C)	10/22/2009	36.8	10/22/2009	42.8 (B)	42.8 (B)	67.3	231.8	409.5
199-K-35	M	--	--	12/4/1996	34.6	8.7 (B)	12/22/2009	188	10/22/2009	184	179	--	431.8	1,957.50
199-K-106A	M	1/18/2007	10.7	12/5/1996	4.4 (U)	4.4 (U)	10/22/2009	2.1 (B)	10/22/2009	13 (U)	13 (U)	-80.4	--	--
199-K-107A	M	3/20/1997	168	12/5/1996	197	190	10/22/2009	29.3	10/18/2009	31.4	27.7	-82.6	-84.1	-85.4
199-K-108A	M	3/20/1997	197	12/9/1996	160	154	10/22/2009	5.2	10/22/2009	13 (U)	13 (U)	-97.4	-91.9	-91.6
199-K-31	M	--	--	12/2/1996	14.4	9 (B)	10/22/2009	5.6	10/22/2009	13 (U)	13 (U)	--	-9.7	--
199-K-132	E	10/12/2006	180	1/5/2005	--	123	10/20/2009	20	10/20/2009	27.4 (B)	23 (B)	-88.9	--	-81.3
199-K-137	M	10/24/2006	1,942	10/24/2006	2,130	2,170	10/26/2009	211	10/20/2009	201	196	-89.1	-90.6	-91
199-K-138	E	10/12/2006	68	10/12/2006	63	59.3	10/12/2009	38	10/20/2009	31.7 (B)	26.9 (B)	-44.1	-49.7	-54.6
199-K-139	E	10/31/2006	293.5	10/31/2006	284	284	11/10/2009	117	11/10/2009	125	128	-60.1	-56	-54.9
199-K-140	E	10/31/2006	161	10/31/2006	149	148	10/20/2009	13	10/20/2009	13 (U)	16.9 (B)	-91.9	-91.3	-88.6
199-K-165	E	8/28/2008	2,850 (D)	--	--	--	10/20/2009	232	--	--	--	-91.9	--	--
199-K-166	E	9/11/2008	186	--	--	--	10/20/2009	56.1	--	--	--	-69.8	--	--
199-K-167	--	--	--	--	--	--	--	--	--	--	--	--	--	--
199-K-168	E	8/7/2008	10	--	--	--	10/20/2009	130	--	--	--	1200	--	--
199-K-173	M	9/20/2008	183	9/20/2008	145	--	10/21/2009	104	10/21/2009	107		-43.2	-26.2	
199-K-174	I	3/16/2009	2 (U)	3/16/2009	13 U	--	--	--	--	--	--	--	--	--
199-K-175	I	3/10/2009	5.4	3/10/2009	6.47	--	--	--	--	--	--	--	--	--
17-D	AT	12/1/1997	6	10/28/1998		10.5	11/15/2009	7.1	11/15/2009	13 (U)	13 (U)	18.3	--	--
C6236	AT	4/8/2009	2.1 (B)	--	--	--	11/15/2009	11	--	--	--	423.8	--	--
C6237	AT	9/30/2008	7.6	--	--	--	11/15/2009	7.1	--	--	--	-6.6	--	--
C6238	AT	9/30/2008	6.3	--	--	--	11/15/2009	5.8	--	--	--	-7.9	--	--

Table 14-2. (Cont.)

Well Name	Use	Baseline Sample					Fall 2009 Sample					Percent Change in Concentration Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Chromium		Total Chromium				Total Chromium	
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Unfiltered Hexavalent Chromium (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Hexavalent Chromium	Unfiltered	Filtered
C6239	AT	9/30/2008	11.4	--	--	--	11/15/2009	4.6 (B)	--	--	--	-59.6	--	--
C6240	AT	4/9/2009	2 (U)	--	--	--	11/15/2009	2 (U)	--	--	--	--	--	--
C6241	AT	4/9/2009	3.9 (U)	--	--	--	11/15/2009	8.4	--	--	--	--	--	--
AT-K-1-D/M	AT	3/2/2004	2	3/2/2004	--	4.4 (U)	11/1/2009	7.8	11/1/2009	13 (U)	13 (U)	290	--	--

Notes:
1. Laboratory qualifiers: B = detected above instrument or method detection limit, but below contract-required detection limit; D = sample diluted; C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration; U = analyte undetected and the detection limit is included within parentheses.
2. Well use: C = compliance, E = extraction, I= injection, M = monitoring, AT = aquifer tube.
3. Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, S = shallowest.
4. Change in hexavalent chromium concentration at site AT-K-1 included sample results from both the middle and deep tube in cluster because all tubes not sampled each year.
5. Hexavalent chromium detection limit is used when “U” (undetected) values are included in comparison of baseline versus 2009 results. Where both values have “U” qualifier, the values are assumed not to have changed significantly.
6. Blank cells (“—“) indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.

Table 14-3. Changes in Hexavalent Chromium and Total Chromium from Baseline Through 2009 for Wells and Aquifer Tubes Monitoring the KE Reactor Area.

Well or Aquifer Tube Name	Current Well Use and Pump-and-Treat System	Baseline Sample					Fall 2009 Sample					Percent Change in Concentration Since Baseline Sampling (Negative = Decrease)		
		Filtered and Unfiltered Hexavalent Chromium		Total Chromium			Unfiltered Hexavalent Chromium		Total Chromium				Total Chromium	
		Date Collected	Concentration (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Date Collected	Unfiltered Hexavalent Chromium (µg/L)	Date Collected	Unfiltered (µg/L)	Filtered (µg/L)	Hexavalent Chromium	Unfiltered	Filtered
199-K-32A	P	--	--	12/9/1996	25.3	21.7	10/22/2009	11.8	10/22/2009	18.4 (B)	14.4 (B)	--	-27.3	-33.6
199-K-32B	M	--	--	12/9/1996	27.6	8.6	10/18/2009	5.1	10/18/2009	20.7	13 (U)	--	-25.0	--
199-K-30	M	--	--	11/26/1996	6.2 (B)	5.6 (B)	10/18/2009	2.1 (B)	10/18/2009	13 (U)	13 (U)	--	--	--
199-K-29	M	--	--	4/27/1999	--	4.8 (U)	--	--	--	--	--	--	--	--
199-K-27	Decom.	--	--	--	3.5 (U)	3.5 (U)	--	--	--	--	--	--	--	--
199-K-23	M	--	--	12/6/1996	219	38.3	--	--	--	--	--	--	--	--
199-K-11	M	--	--	12/4/1996	12.4	8.9 (B)	10/28/2009	2 (U)	10/28/2009	13 (U)	13 (U)	--	--	--
199-K-110A	M	--	--	1/19/1996	37.3	4.4 (U)	10/18/2009	2 (U)	10/18/2009	135.0	13 (U)	--	-40.8	--
199-K-111A	P	3/7/2006	33	11/15/1996	25.4	8.4	10/21/2009	30.0	10/21/2009	30.6	26.8	-9.1	2.8	244.0
199-K-36	M	10/27/1997	17.5	12/4/1996	1,120	501	10/22/2009	20.0	10/22/2009	69.6	50.2	14.3	--	--
199-K-141	E-KX	6/29/2007	226	4/27/2007	245	--	11/23/2009	91	--	--	--	-59.7	--	--
199-K-142	M	6/29/2007	17.5 (G)	4/27/2007	7.8	--	10/22/2009	3.3 (B)	10/22/2009	13 (U)	13 (U)	-81.1	--	--
199-K-178	E-KX	--	--	--	--	--	11/5/2009	117	--	--	--	--	--	--
199-K-181	C	8/10/2009	2 (U)	8/10/2009	13 (U)	--	11/5/2009	8.6	--	--	--	--	--	--
C6242	AT	4/9/2009	8.7	--	--	--	11/18/2009	2 (U)	--	--	--	--	--	--
C6243	AT	4/9/2009	2.2 (B)	--	--	--	11/18/2009	4.8 (B)	--	--	--	118.2		--
C6244	AT	9/30/2008	14.8	--	--	--	11/18/2009	5.2	--	--	--	-64.9	--	--
C6245	AT	9/30/2008	16.6	--	--	--	11/16/2009	14.8	--	--	--	-10.8	--	--
C6246	AT	9/30/2008	14	--	--	--	11/16/2009	16	--	--	--	14.3	--	--
C6247	AT	9/30/2008	12.7	--	--	--	11/16/2009	15.7	--	--	--	23.6	--	--
18-S	AT	12/1/1997	5 (U)	10/28/1998	--	5.6	--	--	11/18/2009	13 (U)	13 (U)	--	--	--
19-D	AT	12/2/1997	5 (U)	4/26/2005	--	3.8 (B)	11/17/2009	2 (U)	11/17/2009	13 (U)	13 (U)	--	--	--
AT-K-2-D	AT	3/2/2004	5.3	--	--	--	11/1/2009	3.4 (B)	11/1/2009	13 (U)	13 (U)	--	--	--

Notes:
1. Well 199-K-32B is screened within the Ringold Upper Mud Unit, and well 199-K-32A is screened within the Ringold Unit E.
2. Well and aquifer tube use: M = monitoring, AT = aquifer tube, P= performance, C=compliance.
3. Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, S = shallowest.
4. F = filtered, UF = unfiltered.
5. Laboratory qualifiers: U = undetected (shown with detection limit in parentheses); B = detected above instrument or method detection limit but below contract-required detection limit; C = analyte detected in both the sample and the associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration.
6. Change in hexavalent chromium concentration is not calculated when "U" (undetected) values are involved in calculation. Where both values have a "U" qualifier, the values are assumed not to have changed significantly.
7. Blank cells ("—") indicate that the sample was not collected, the analysis was not performed, or the change in concentration was not calculated.
8. Decom = well decommissioned because of reactor decontamination and demolition activities.

Table 14-4. KR4 System Operational Parameters and System Performance for Calendar Year 2009.

Total processed groundwater	CY 2008	CY 2009
Total amount of groundwater treated (since October 1997 startup) (billion L)	4.99	5.31
Total amount of groundwater treated during CY (million L)	488.0	317.5
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since October 1997 startup (kg)	339.7	347.5
Total amount of hexavalent chromium removed in CY (kg)	14.98	7.78
Summary of operational parameters		
Removal efficiency (% by mass)	99.8%	86.9
Waste generation (m^3)	0	???
Regenerated resin installed (m^3)	54.4	29.4
New resin installed (m^3)	0	0
Number of resin vessel changeouts	24	--
Summary of system availability		
Total possible run-time (hours)	8,784	8,760
Scheduled downtime (hours)	159.5	53.6
Planned operations (hours)	8,624.5	8,706.4
Unscheduled downtime (hours)	126.7	1,089.8
Total time online (hours)	8,497.8	7,616.6
Total availability (%)	96.4%	87.0%
Scheduled system availability (%)	98.5%	87.5%

Notes:
CY = calendar year

Table 14-5 located on page 14.0-67.

Table 14-6. KR4 Pump-and-Treat Well Pumping Rates and Total Run-Time for Calendar Year 2009.

Well	Recommended Flow Rate,[b] L/min (gpm)	Yearly Avg. Flow Rate, L/min (gpm)	Total Flow Hours in CY 2009	Total RunTime (%)[c]	Purpose
199-K-129[a]	94.6 (25.0)	31.4 (8.3)	6,289.8	71.8%	Extraction
199-K-113A	56.8 (15.0)	41.3 (10.9)	7,211.4	82.3%	Extraction
199-K-114A[d]	94.6 (25.0)	82.9 (21.9)	7,135.0	81.4%	Extraction
199-K-115A	94.6 (25.0)	105.2 (27.8)	7,191.9	82.1%	Extraction
199-K-116A	151.4 (40.0)	145.0 (38.3)	6,472.8	73.9%	Extraction
199-K-119A	113.6 (30.0)	101.7 (26.9)[e]	4,056.4	46.3%	Extraction
199-K-120A	113.6 (30.0)	168.0 (44.4)[f]	4,642.8	53.0%	Extraction
199-K-125A	113.6 (30.0)	149.6 (39.5)[g]	4,023.4	45.9%	Extraction
199-K-127	151.4 (40.0)	150.4 (39.7)[f]	4,661.4	53.2%	Extraction
199-K-121A	NA	129.7 (34.3)	5,099.0	58.2%	Injection
199-K-122A	NA	272.0 (71.9)	7,585.4	86.6%	Injection
199-K-123A	NA	57.3 (15.1)	4,433.2	50.6%	Injection
199-K-124A	NA	85.0 (22.4)[h]	4,661.4	53.2%	Injection
199-K-128	NA	267.4 (70.6)	6,626.5	75.6%	Injection

Notes:
a. Extraction well 199-K-112A was replaced with well 199-K-129, which began operating as an extraction well on July 10, 2003.
b. Recommended flow rate based upon drawdown analysis.
c. Total flow hours in CY 2009 ÷ total hours in CY 2009 x 100%.
d. Monitoring well converted to an extraction well and began operation in November 2004.
e. Well taken out of service on July 15, 2009, due to hexavalent chromium concentrations <20 µg/L.
f. Well taken out of service on August 11, 2009, due to hexavalent chromium concentrations <20 µg/L.
g. Well taken out of service on July 15, 2009, due to hexavalent chromium concentrations <20 µg/L.
h. Well taken out of service on August 11, 2009.

CY = calendar year
gpm = gallons per minute
NA = not available

Table 14-7. KX System Operational Parameters from Startup Through December 2009.

Total processed groundwater	CY 2008	CY 2009
Total amount of groundwater treated since startup (million L)	66.7	785.6
Total amount of groundwater treated in CY (million L)	66.7	718.9
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since startup (kg)	3.9	43.6
Total amount of hexavalent chromium removed in CY (kg)	3.9	39.7
Summary of operational parameters		
Removal efficiency (% by mass)	N/A	96.3
Waste generation (m^3)	N/A	--
Regenerated resin installed (m^3)	N/A	61.2
New resin installed (m^3)	N/A	97.4
Number of resin vessel changeouts	N/A	--
Summary of system availability		
Total possible run-time (hours)	N/A	7,968.0
Scheduled downtime (hours)	N/A	152.2
Planned operations (hours)	N/A	7,815.8
Unscheduled downtime (hours)	N/A	288.1
Total time online (hours)	N/A	7,527.7
Total availability (%)	N/A	98.1%
Scheduled system availability (%)	N/A	94.5%

Notes:
CY = calendar year
N/A = not applicable

Table 14-8 located on page 14.0-73.

Table 14-9. KX System Pumping Flow Rates and Total Run-Time for Calendar Year 2009.

Well	Recommended Flow Rate,[b] L/min (gpm)	Yearly Avg. Flow Rate, L/min (gpm)	Total Flow Hours in CY 2009	Total RunTime (%)[c]	Purpose
199-K-130	227 (60)	173.4 (45.8)[c]	7,373.0	92.5%	Extraction
199-K-131	227 (60)	195.3 (51.6)[c]	7,400.0	92.9%	Extraction
199-K-141	TBD	182.5 (48.2)[d]	2,058.0	25.8%	Extraction
199-K-144	284 (75)	0 (0)[e]	0	0%	Extraction
199-K-145	TBD	203.3 (53.7)[f]	3,786.0	47.5%	Extraction
199-K-146	38 (10)	37.5 (9.9)[c]	7,111.0	89.2%	Extraction
199-K-147	76 (20)	76.1 (20.1)[c]	7,135.0	89.5%	Extraction
199-K-148	189 (50)	147.3 (38.9)[c]	6,900.0	86.6%	Extraction
199-K-149	189 (50)	150.3 (39.7)[c]	7,135.0	89.5%	Extraction
199-K-150	189 (50)	115.8 (30.6)[c]	7,086.0	88.9%	Extraction
199-K-154	TBD	255.9 (67.6)[g]	3,734.0	46.9%	Extraction
199-K-161	114 (30)	86.7 (22.9)[c]	7,408.0	93.0%	Extraction
199-K-162	TBD	204.8 (54.1)[h]	3,730.0	46.8%	Extraction
199-K-163	TBD	255.9 (67.6)[g]	3,729.0	46.8%	Extraction
199-K-143	NA	142.7 (37.7)[i]	7,151.4	89.8%	Extraction
199-K-156	NA	176.0 (46.5)[c]	7,086,1	88.9%	Injection
199-K-159	NA	196.5 (51.9)[c]	7,233.3	90.8%	Injection
199-K-160	NA	194.2 (51.3)[c]	7,226.9	90.7%	Injection
199-K-164	NA	131.0 (34.6)[j]	6,348.2	79.7%	Injection
199-K-169	NA	196.1 (51.8)[c]	7,215.2	90.6%	Injection
199-K-170	NA	252.5 (66.7)[c]	7,512.8	94.3%	Injection
199-K-171	NA	0 (0)[k]	0	0%	Injection
199-K-172	NA	227.5 (60.1)[c]	7,503.1	94.2%	Injection

Notes:
a. Recommended flow rate based upon drawdown analysis.
b. Total flow hours in CY 2009 ÷ total hours in CY 2009 x 100%.
c. Well put in service on February 3, 2009.
d. Well put in service on May 29, 2009.
e. Well not in service during CY 2009; it has been realigned to connect with the KR4 system.
f. Well put in service on February 3, 2009, and was taken out of service on August 11, 2009, for realignment with the KR4 system.
g. Well put in service on May 28, 2009.
h. Well put in service on February 3, 2009, and was taken out of service on August 7, 2009, for realignment with the KR4 system.
i. Well put in service on February 6, 2009.
j. Well put in service on March 24, 2009.
k. Well not in service during CY 2009.

CY = calendar year
gpm = gallons per minute
NA = not available
TBD = to be determined

Table 14-10. KW System Operational Parameters from Startup Through December 2009.

Total processed groundwater	CY 2008	CY 2009
Total amount of groundwater treated since January 2007 startup (million L)	369.36	666.99
Total amount of groundwater treated in CY (million L)	196.87	297.63
Mass of hexavalent chromium removed		
Total amount of hexavalent chromium removed since January 2007 startup (kg)	34.03	83.28
Total amount of hexavalent chromium removed in CY (kg)	13.0	49.25
Summary of operational parameters		
Removal efficiency (% by mass)	98.8%	95.8
Waste generation (m^3)	--	--
Regenerated resin installed (m^3)	--	24.9
New resin installed (m^3)	--	24.9
Number of resin vessel changeouts	--	--
Summary of system availability		
Total possible run-time (hours)	8,784	8,760
Scheduled downtime (hours)	50.0	268.8
Planned operations (hours)	8,734	8,491.2
Unscheduled downtime (hours)	0.0	118.0
Total time online (hours)	8,734	8,372.2
Total availability (%)	99.4%	95.6%
Scheduled system availability (%)	99.4%	98.6%

Notes:
CY = calendar year

Table 14-11 located on page 14.0-79.

Table 14-12. KW System Pumping Flow Rates and Total Run-Time for Calendar Year 2009.

Well	Recommended Flow Rate,[a] L/min (gpm)	Yearly Avg. Flow Rate, L/min (gpm)	Total Flow Hours in CY 2009	Total RunTime (%)[b]	Purpose
199-K-132	95 (25)	73.0 (19.3)	8,144.5	92.8%	Extraction
199-K-137	170 (45)	143.8 (38.0)[c]	5,847.5	66.7%	Extraction
199-K-138	114 (30)	79.7 (31.4)	8,132.0	92.7%	Extraction
199-K-139	38 (10)	105.5 (27.1)[d]	1,635.0	18.6%	Extraction
199-K-140	TBD	60.9 (16.1)[e]	3,033.2	34.6%	Extraction
199-K-165	189 (50)	181.1 (47.9)[c]	5,948.1	67.8%	Extraction
199-K-166	38 (10)	59.3 (15.7)[c]	5,922.5	67.5%	Extraction
199-K-168	151 (40)	145.0 (40.7)[c]	4,964.5	56.6%	Extraction
199-K-158	NA	305.4 (80.7)	7,935.1	90.4%	Injection
199-K-174	NA	251.5 (66.4)[c]	5,890.0	67.1%	Injection
199-K-175	NA	113.6 (30.0)[c]	5,890.5	67.1%	Injection
199-K-35	NA	56.9 (15.0)[f]	5,811.1	66.2%	Injection

Notes:
a. Recommended flow rate based upon drawdown analysis.
b. Total flow hours in CY 2009 ÷ total hours in CY 2009 x 100%.
c. Well put in service on April 20 2009.
d. Well out of service from March 9, 2009, to December 31, 2009, except for April 2, 2009 (when the well was pumped).
e. Well out of service after May 22, 2009 (except for short intervals of pumping to sample well).
f. Well removed from service on November 24, 2009.

CY = calendar year
gpm = gallons per minute
NA = not available
TBD = to be determined

Figure 14-1. 100-KR-4 Operable Unit Wells and Aquifer Sampling Tubes.

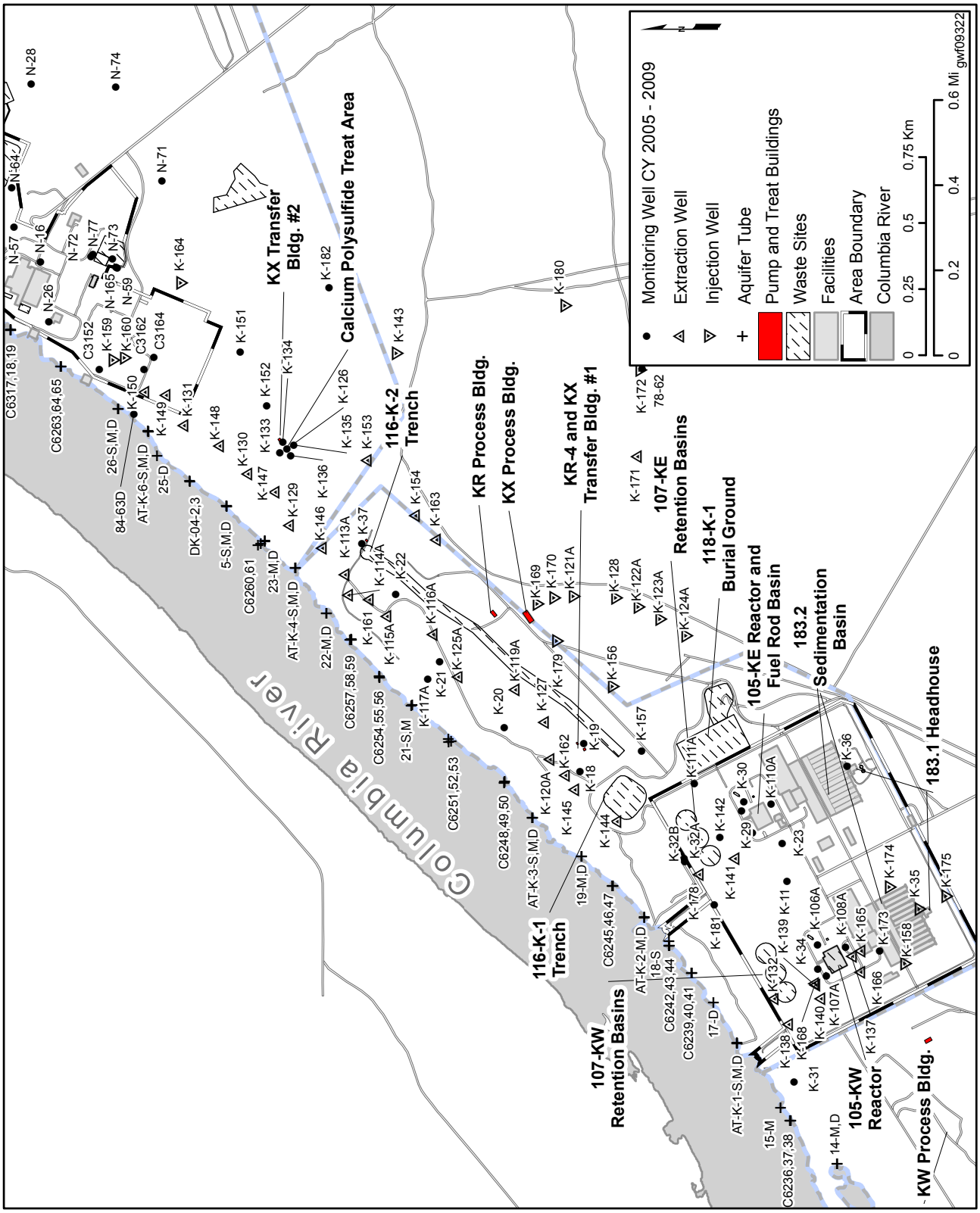

Figure 14-2. 100-KR-4 Operable Unit Water Table Map.

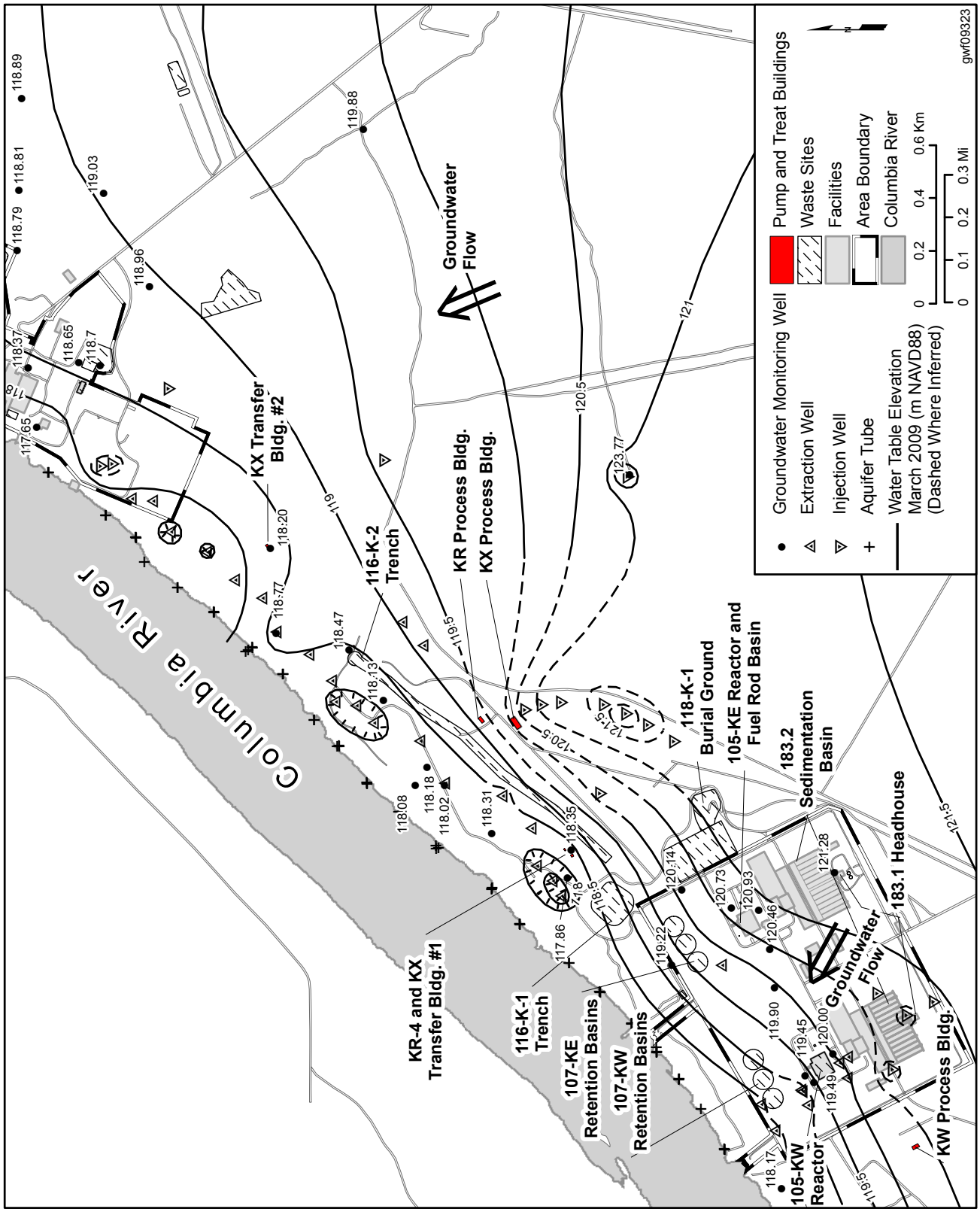

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Figure 14-3. 100-KR-4 Operable Unit Hexavalent Chromium Plume, Spring and Fall 2009.

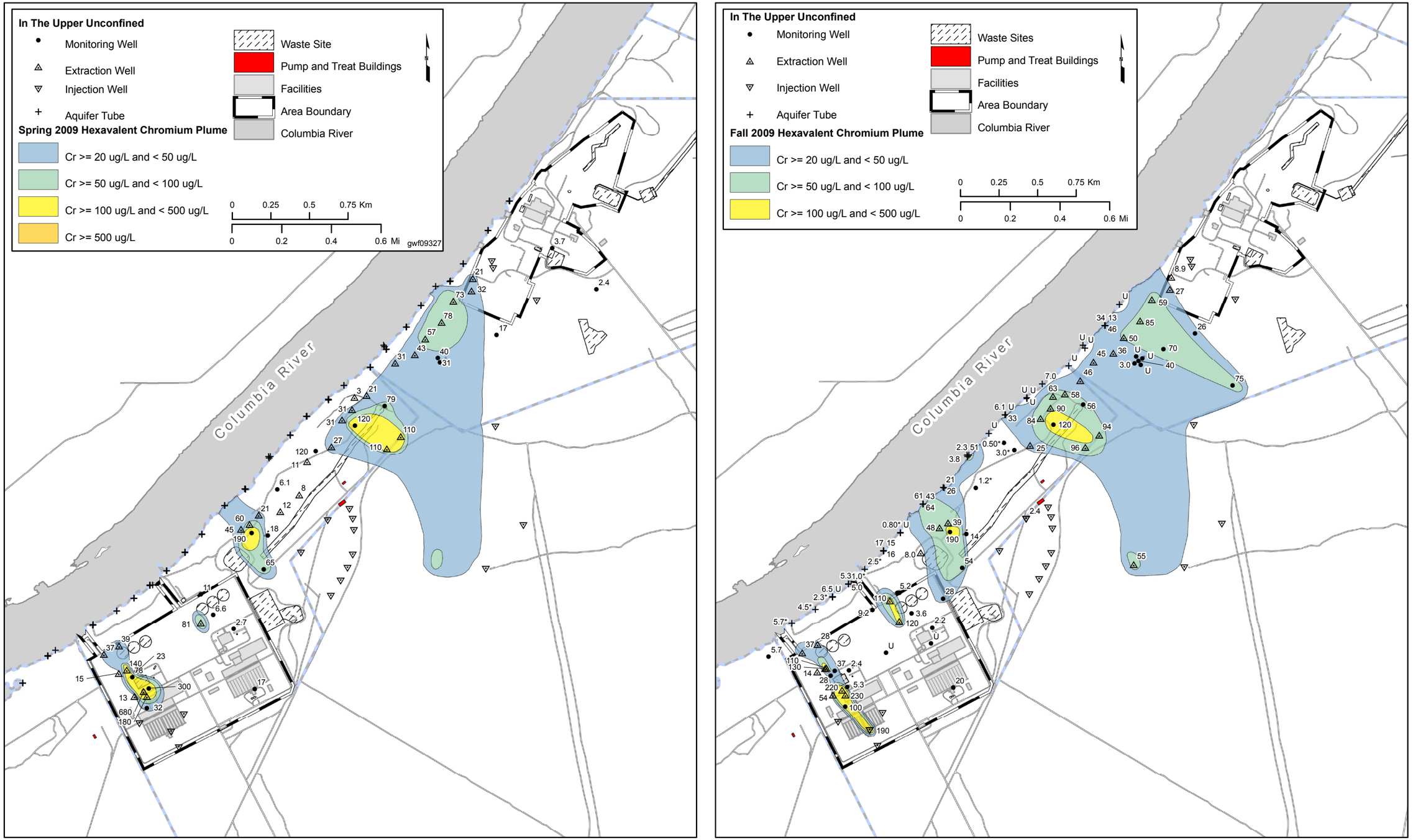

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Figure 14-4. 100-KR-4 Operable Unit, Hexavalent Chromium Concentrations in Wells and Aquifer Tubes Along the Columbia River.

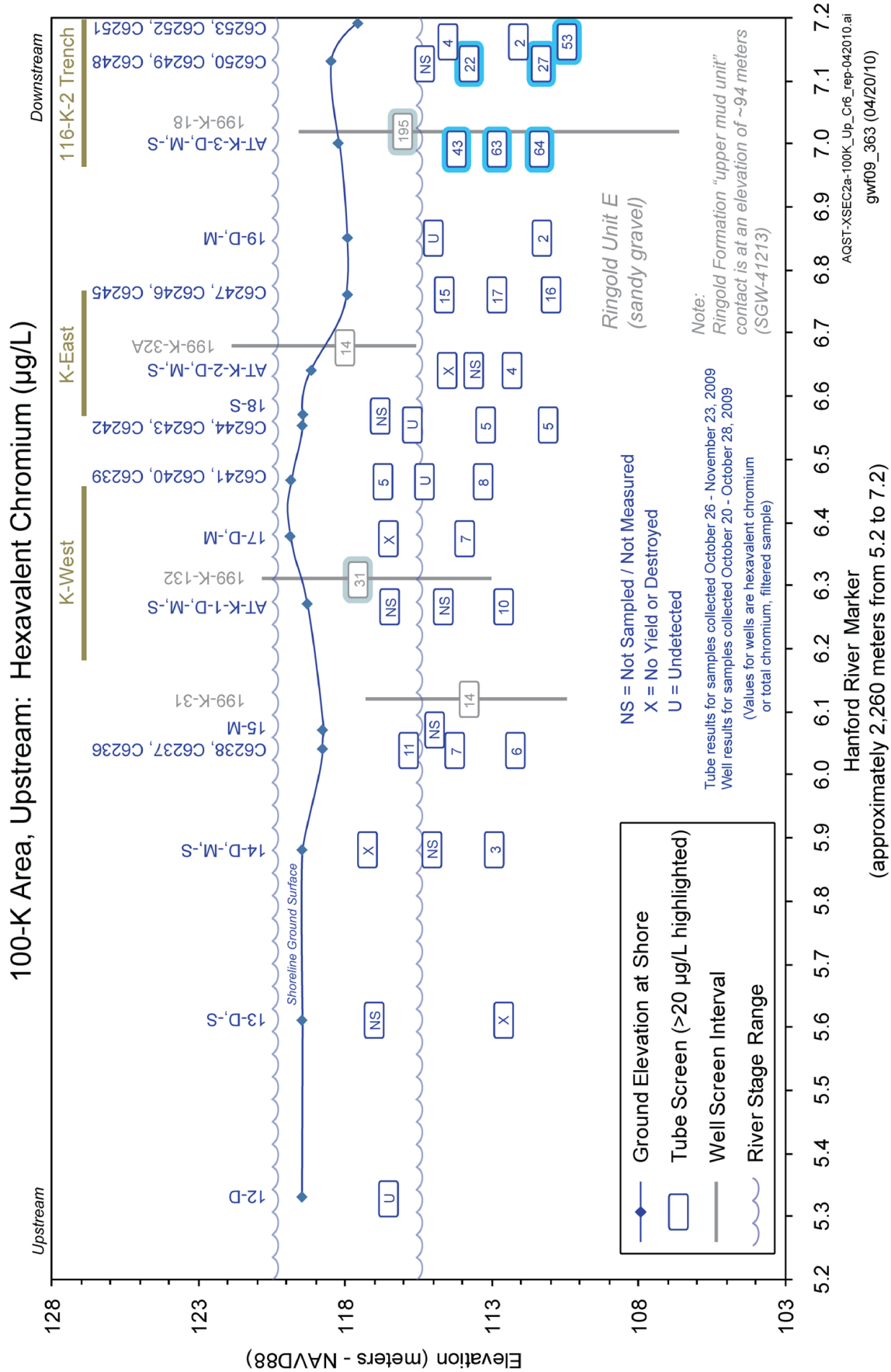

Figure 14-4. (Cont.)

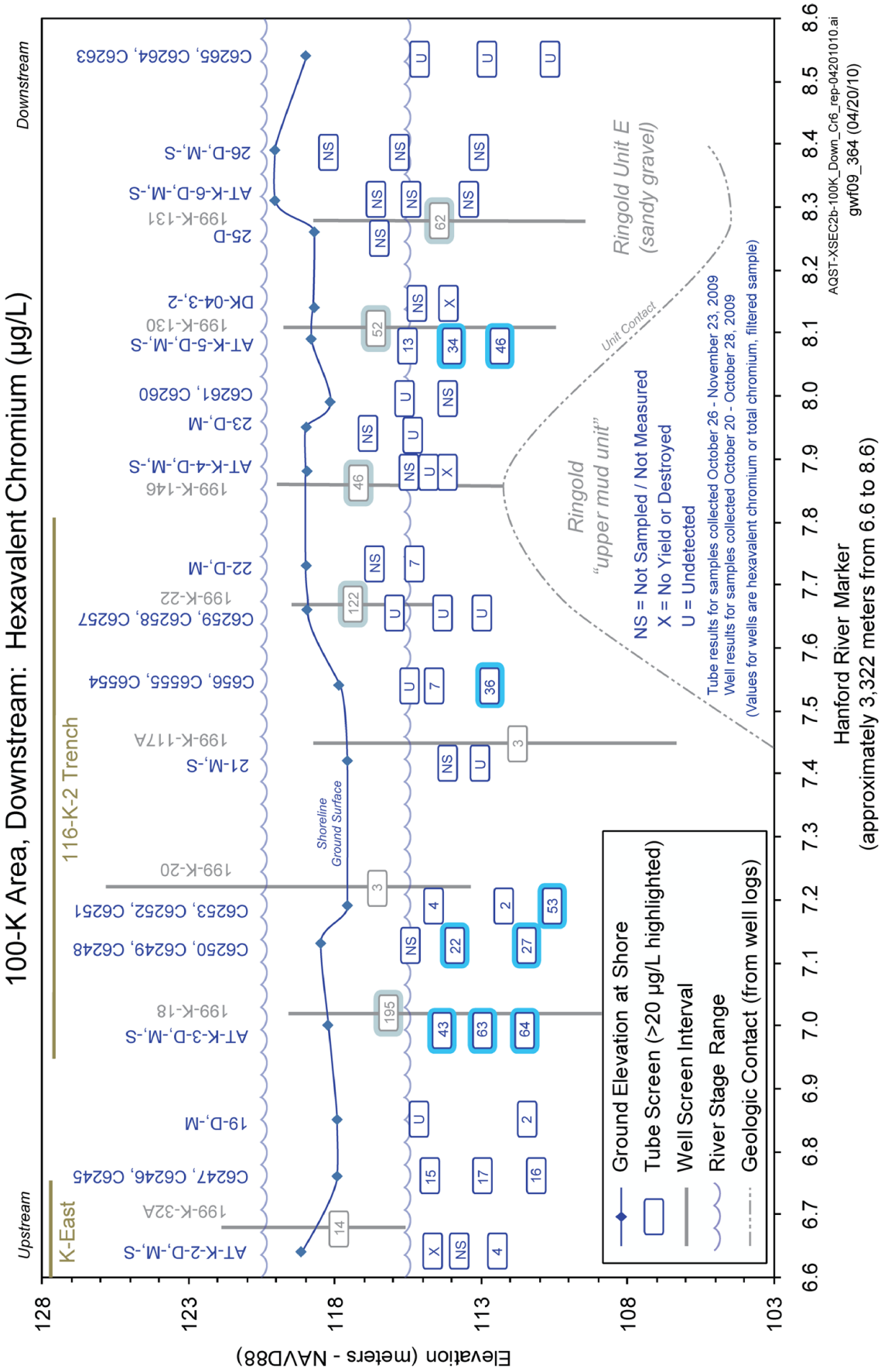

Figure 14-5. 100-KR-4 Operable Unit, Tritium Groundwater Plumes.

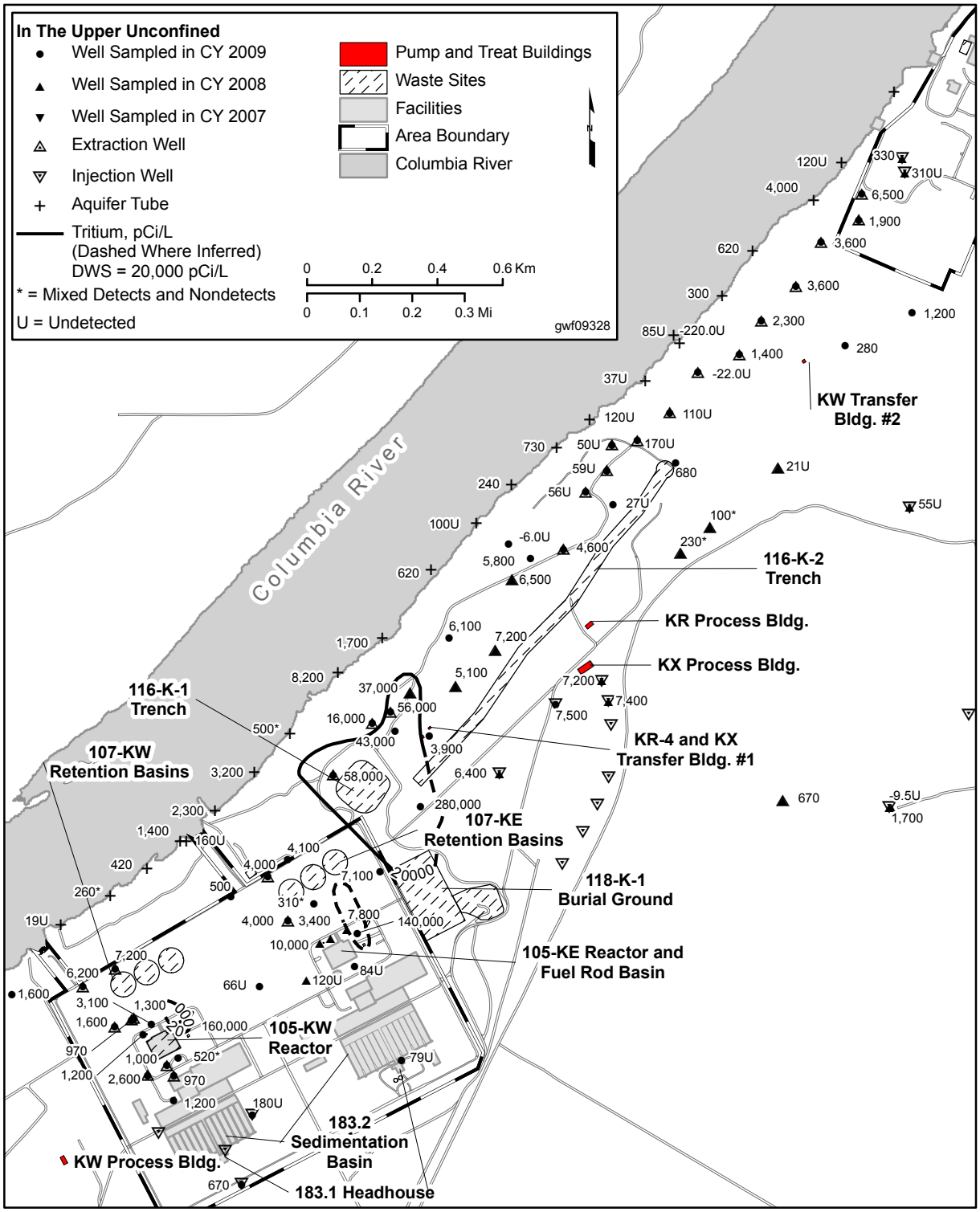

Figure 14-6. 100-KR-4 Operable Unit, Strontium-90 Plumes.

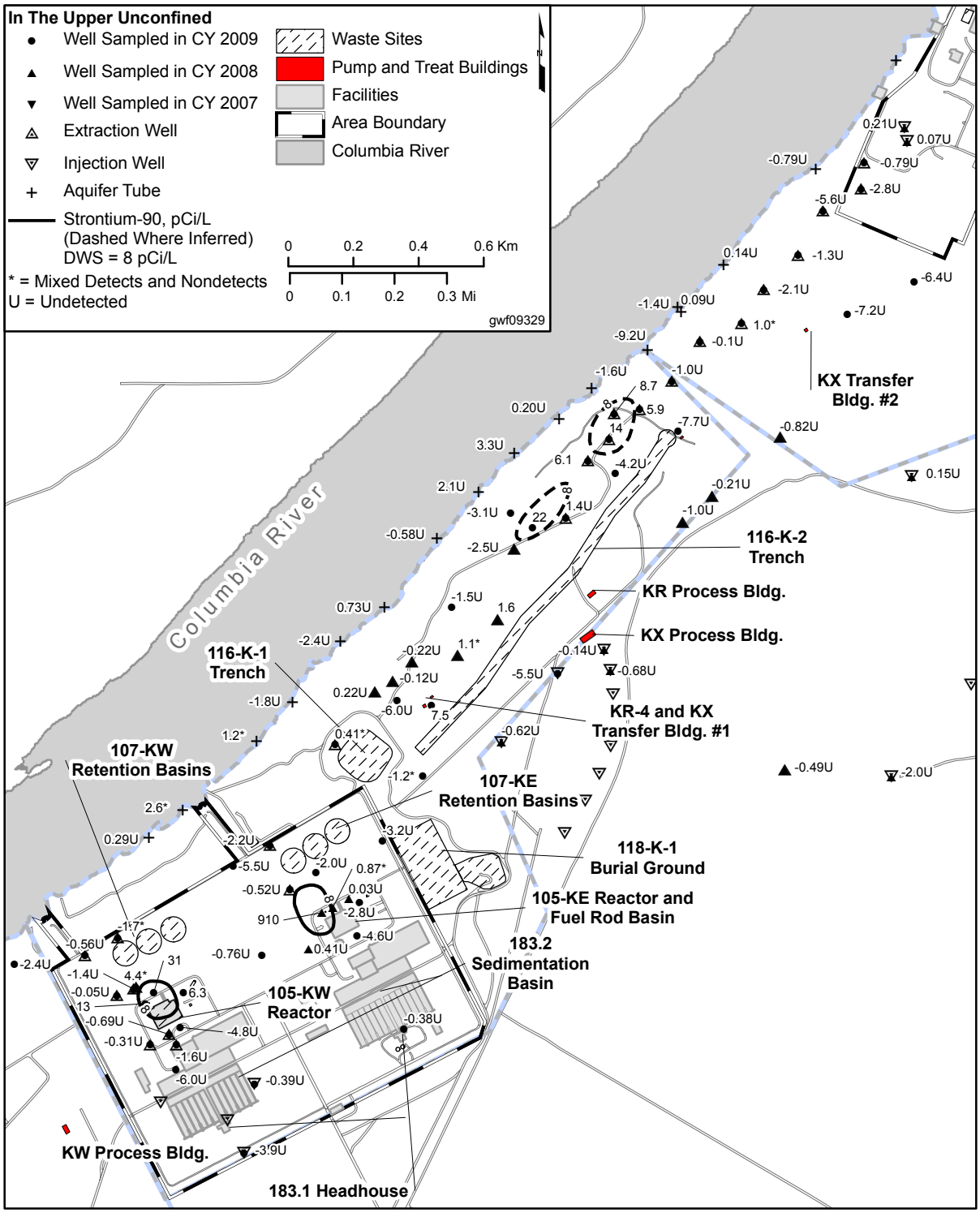

Figure 14-7. 100-KR-4 Operable Unit, Carbon-14 Plumes.

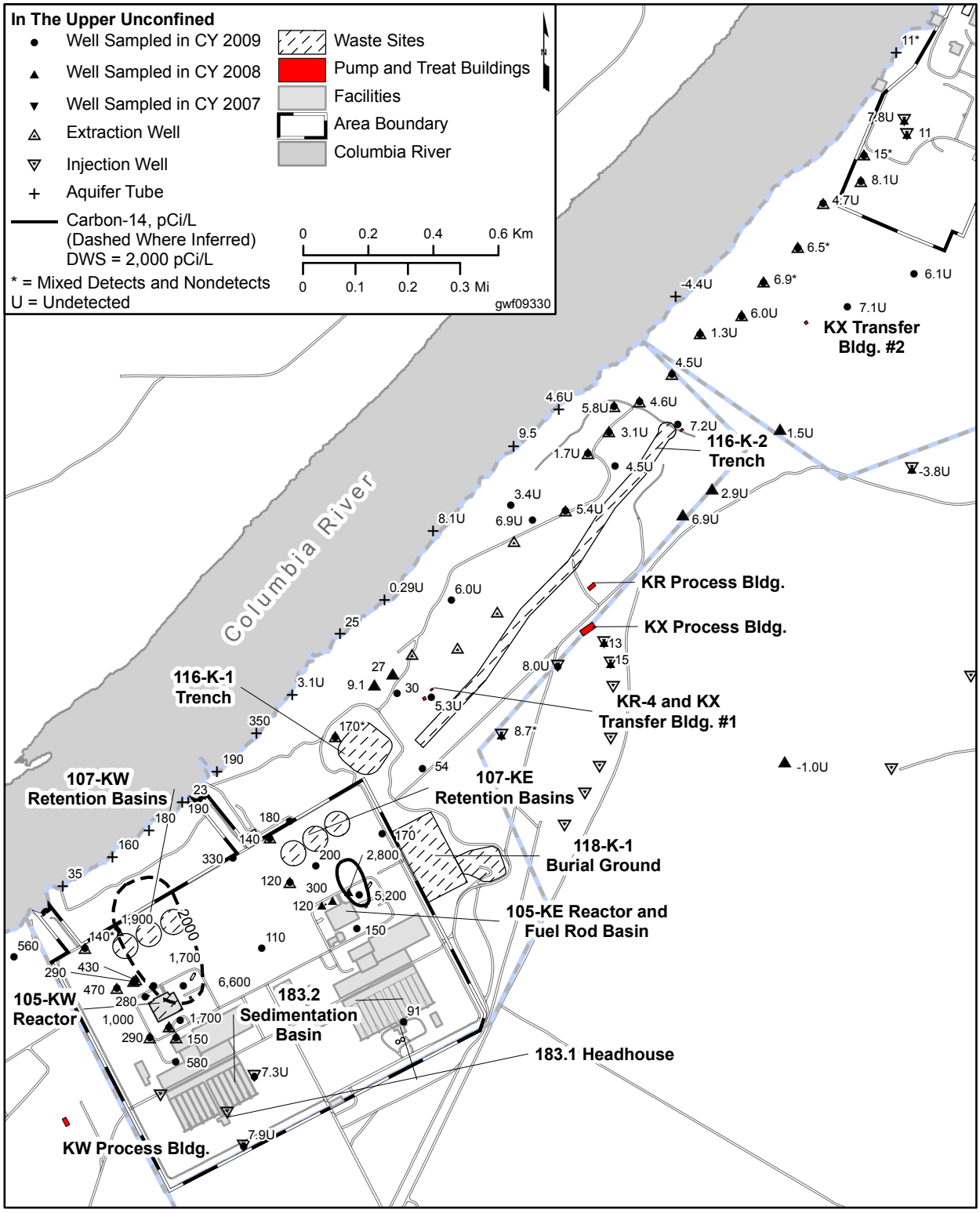

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Figure 14-8. 100-KR-4 Operable Unit, KR4 Hexavalent Chromium Plume, Wells, Aquifer Tubes and Representative Hexavalent Chromium Trends.

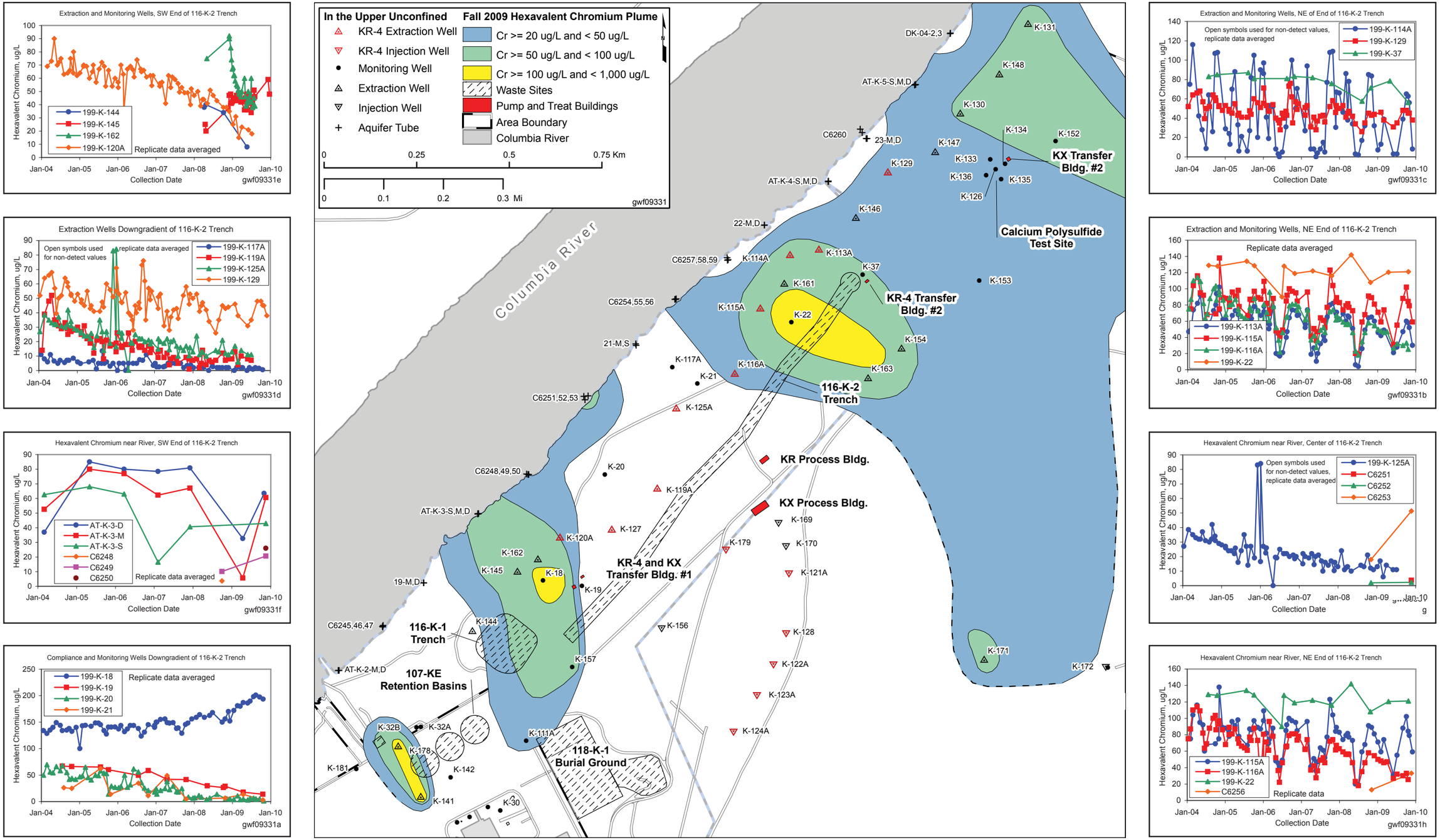

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Figure 14-9. 100-KR-4 Operable Unit, KR4 Pump-and-Treat System Schematic.

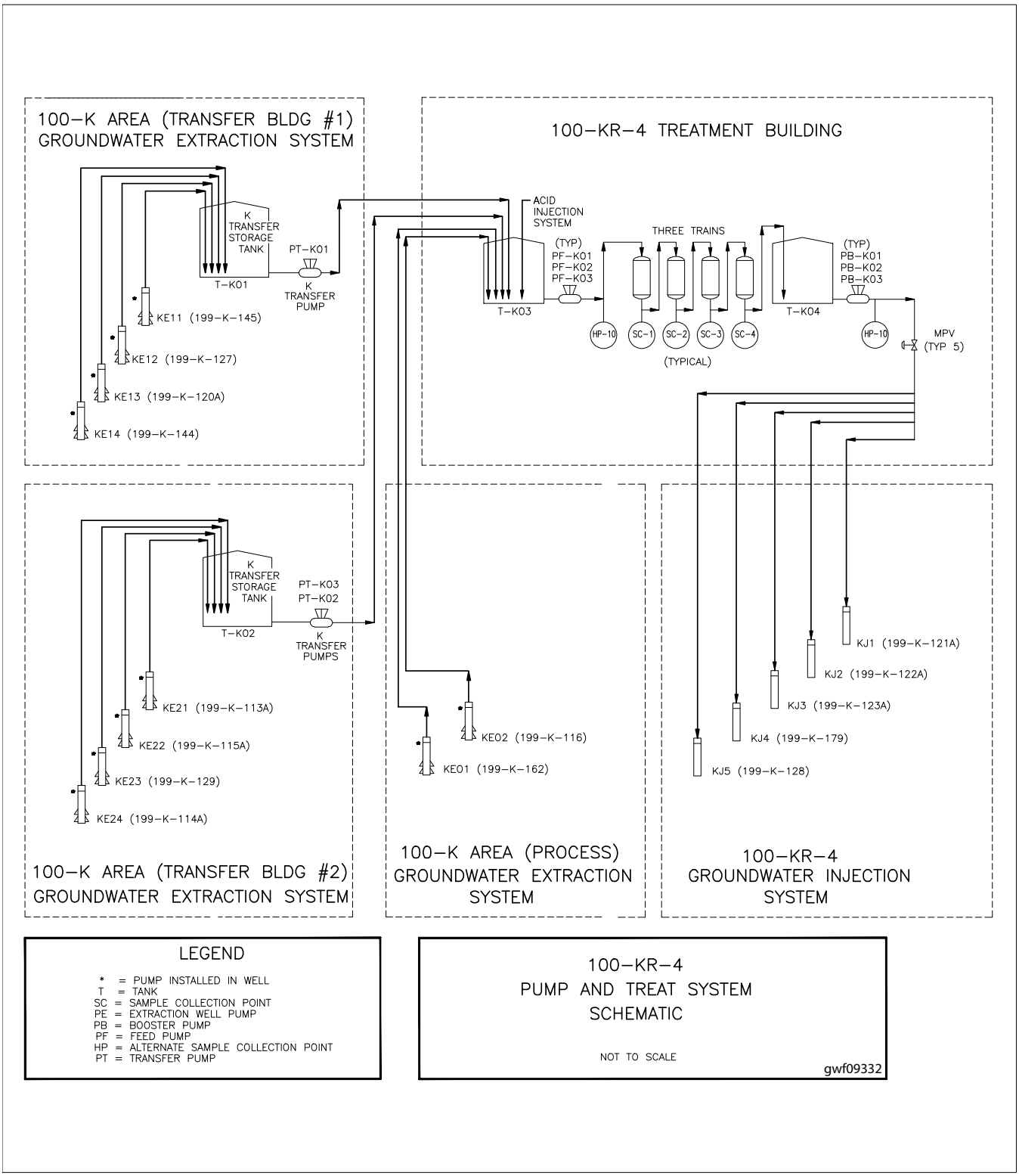

Figure 14-10. 100-KR-4 Operable Unit, KR4 Pump-and-Treat System Average Removal Efficiencies.

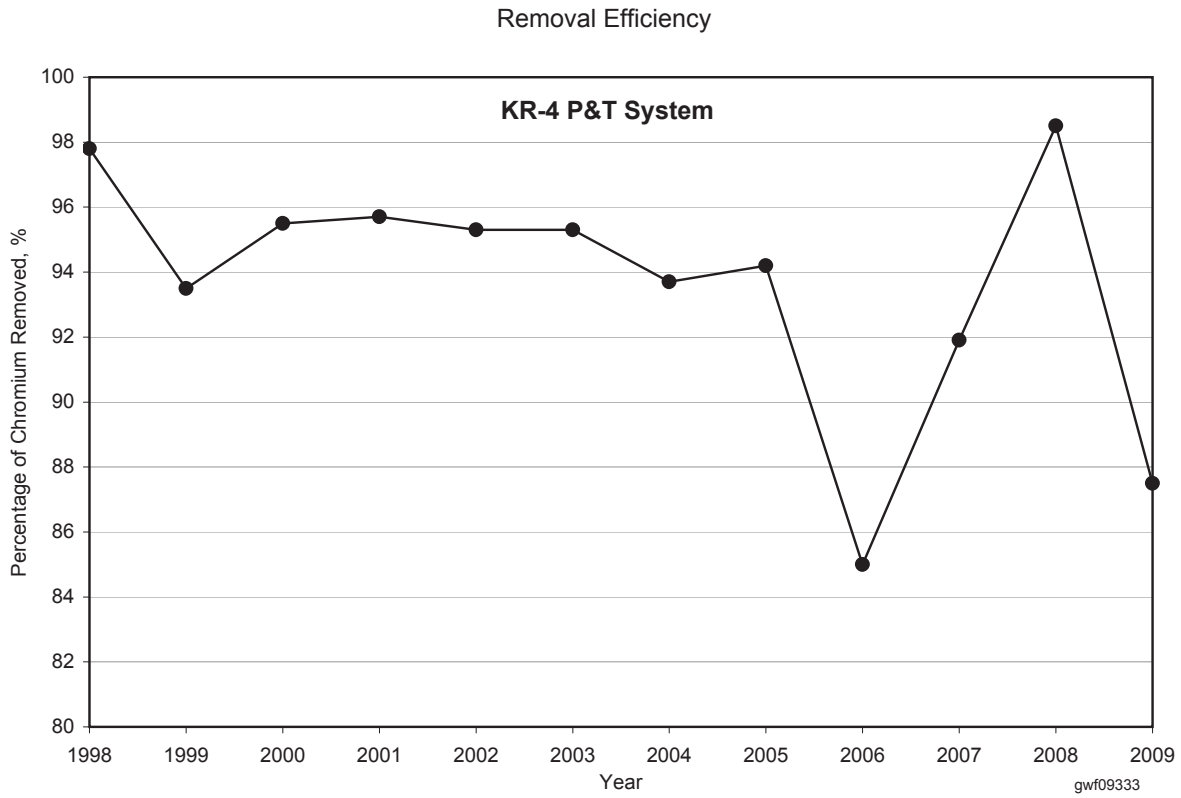

Figure 14-11. 100-KR-4 Operable Unit, KR4 Pump-and-Treat System Trends of Influent and Effluent, Hexavalent Chromium Concentrations, Calendar Year 2009.

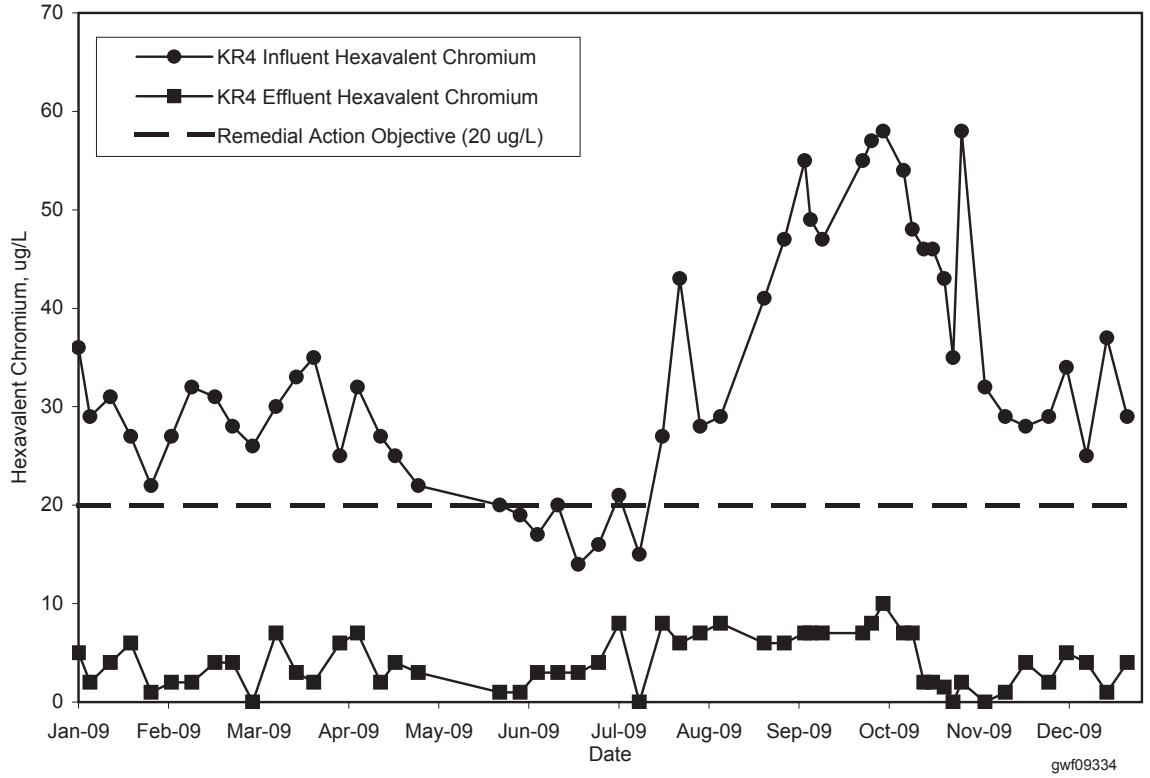

Figure 14-12. 100-KR-4 Operable Unit, KR4 Pump-and-Treat System Availability and Online Percentages for Calendar Year 2009.

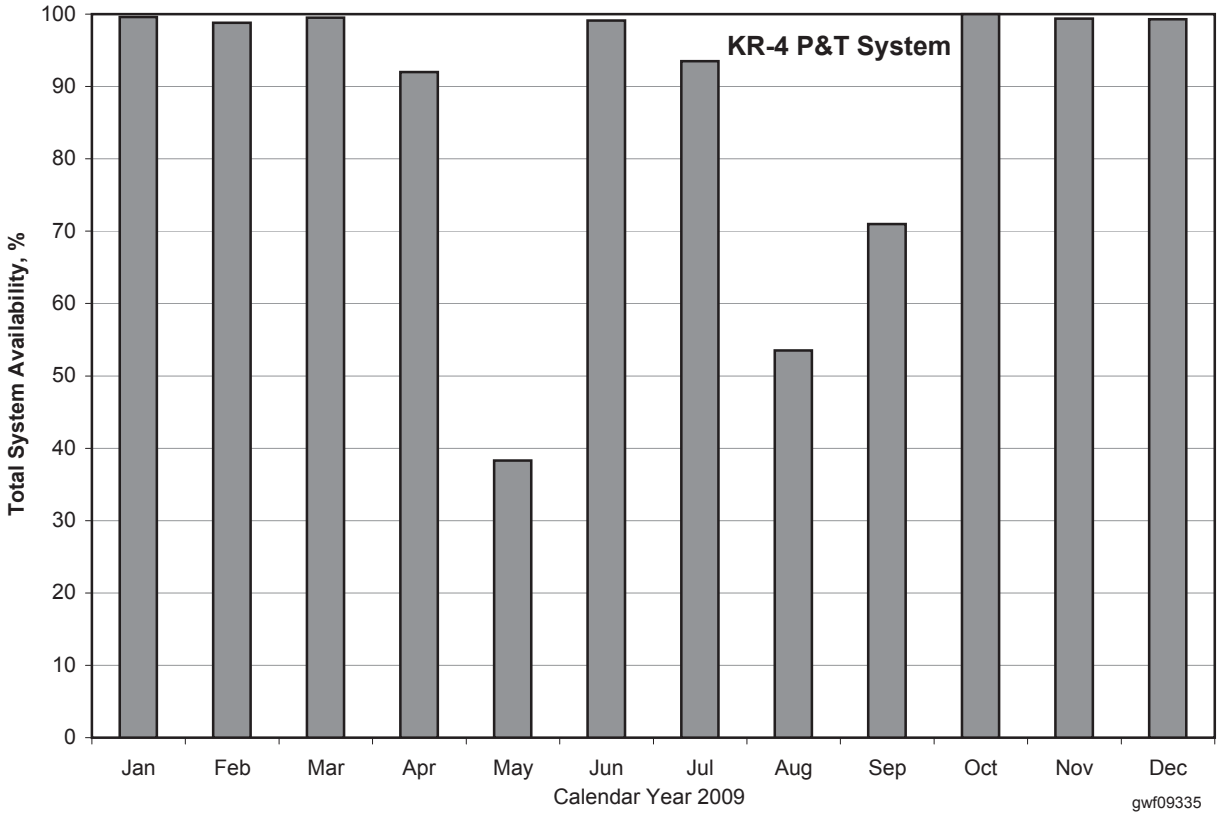

Table 14-5. KR4 Pump-and-Treat System Availability for Calendar Year 2009.

Total possible run-time (hours)	8,760
Scheduled downtime (hours)	53.6
Planned operations (hours)	8,706.4
Unscheduled downtime (hours)	1,089.8
Total time on-line (hours)	7,616.6
Total availability (%)[a]	87.0%
Scheduled system availability (%)[b]	87.5%

Notes:
a. Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible runtime].
b. Scheduled system availability [(total possible run-time – scheduled downtime) / total possible run-time].

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Figure 14-13. 100-KR-4 Operable Unit, KX Pump-and-Treat System, Hexavalent Chromium Plume, Wells, Aquifer Tubes and Representative Hexavalent Chromium Trends.

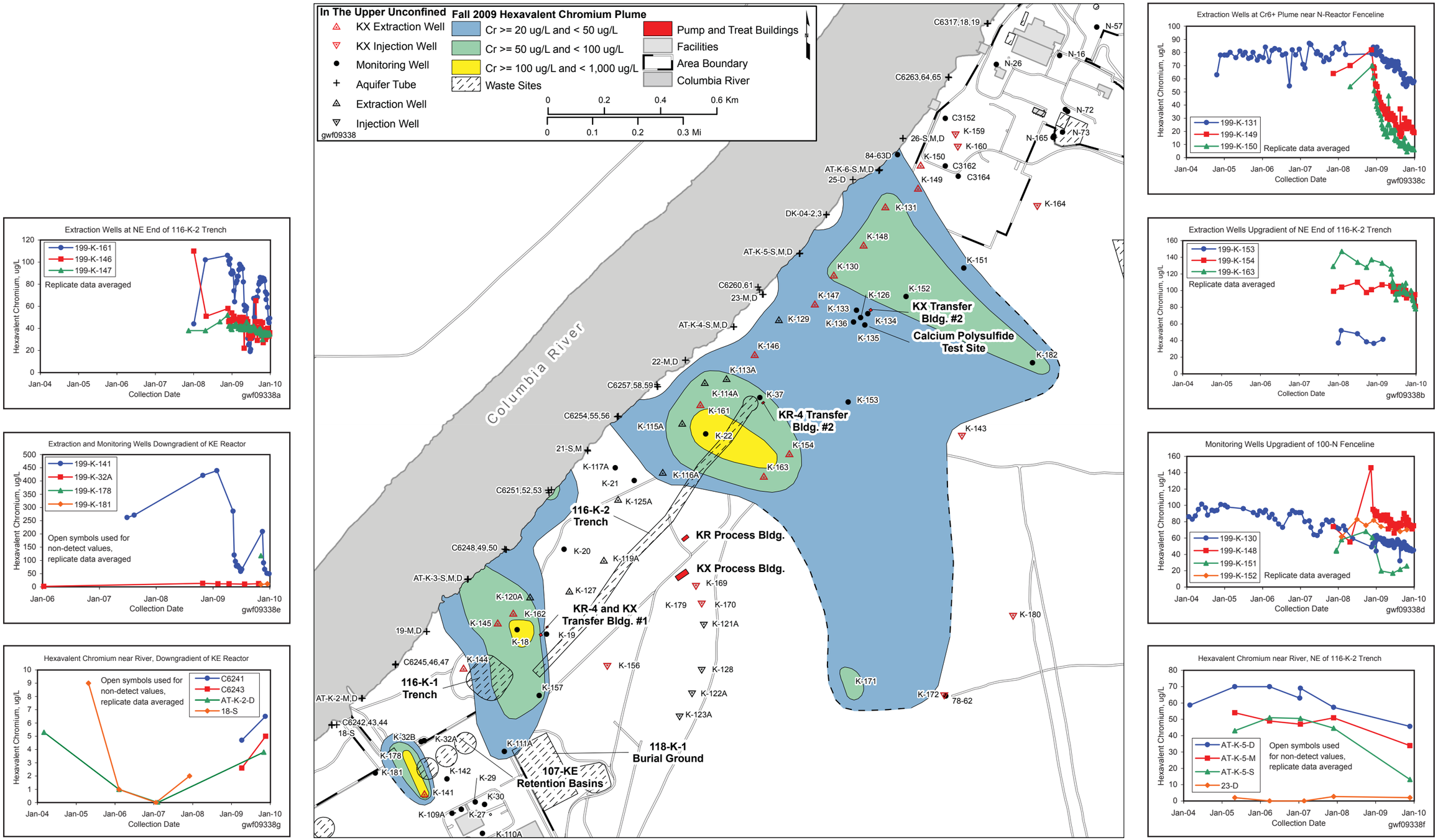

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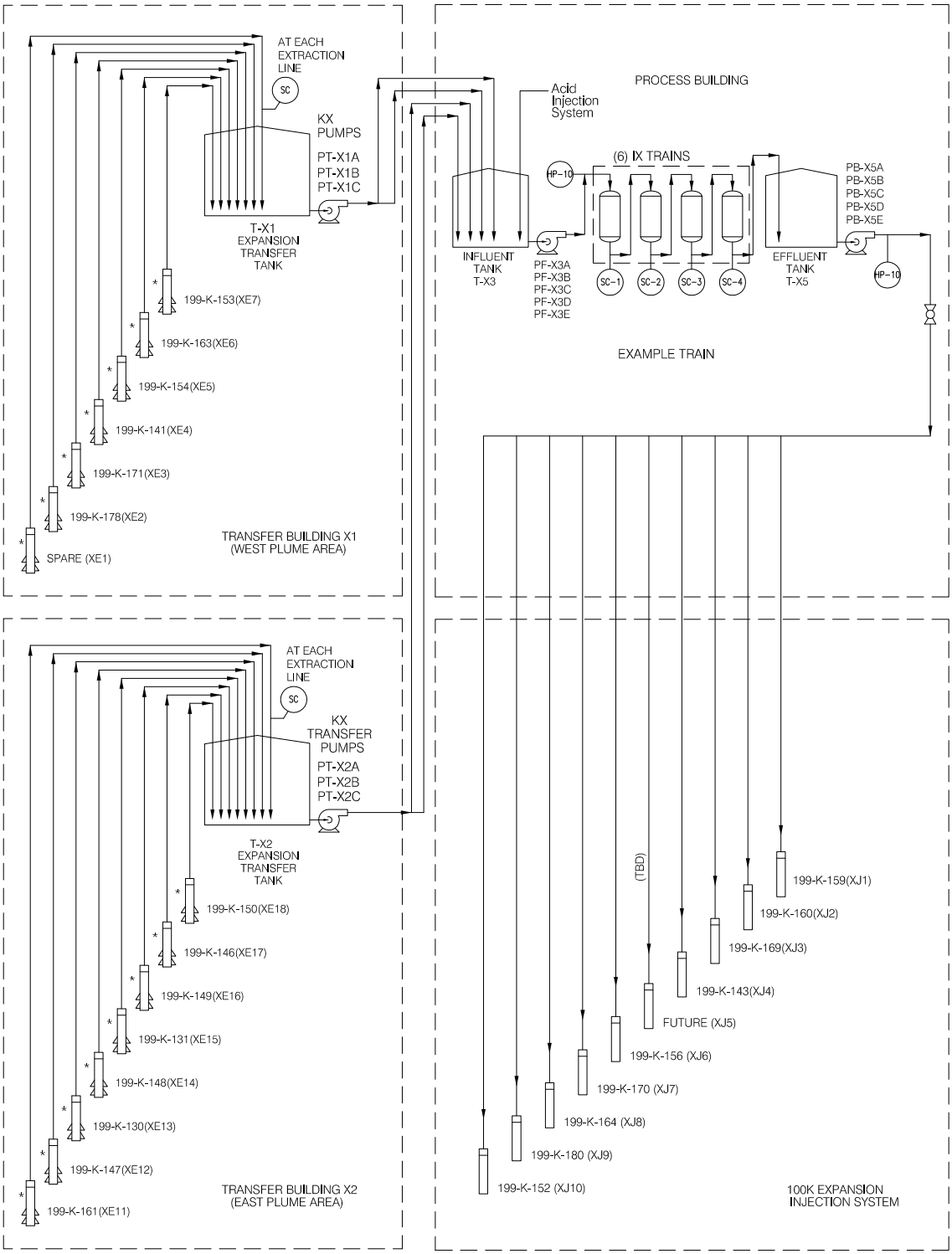
Figure 14-14. 100-KR-4 Operable Unit, KX Pump-and-Treat System Schematic.



100K EXPANSION
Pump and Treat System
Schematic

Not to Scale

Figure 14-15. 100-KR-4 Operable Unit, KX Pump-and-Treat System, Average Removal Efficiencies.

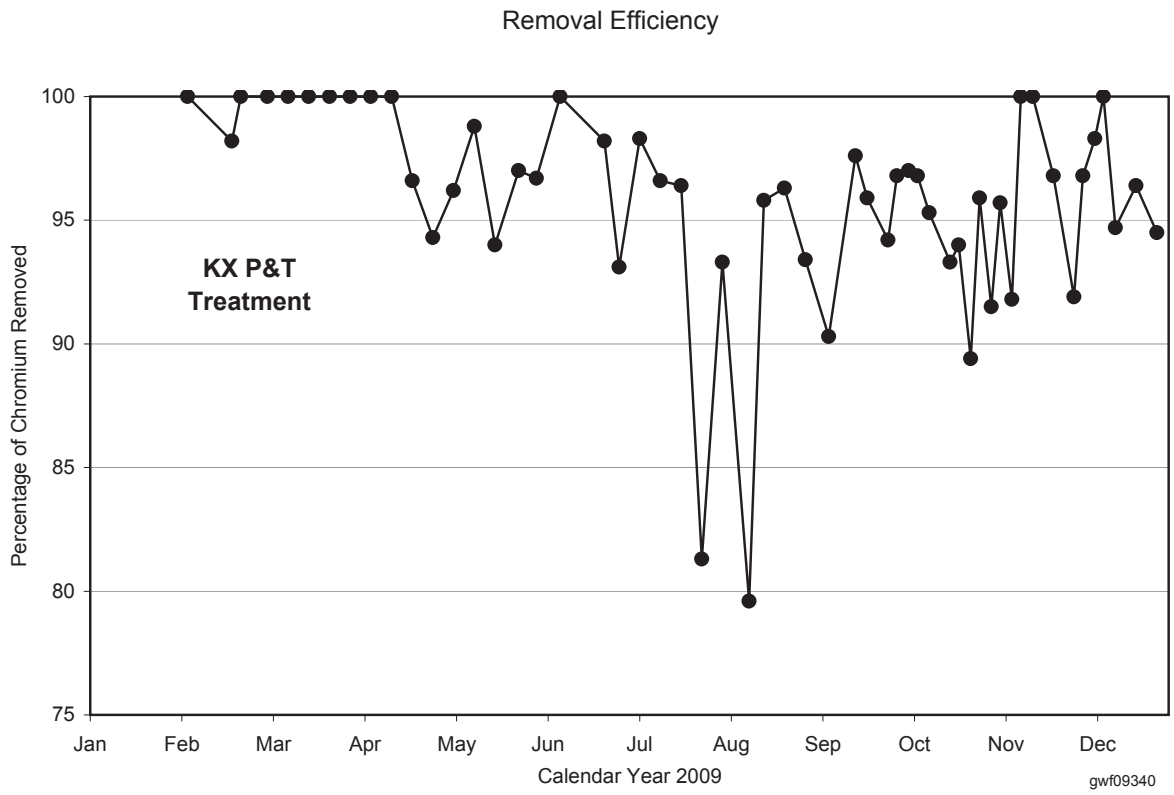


Figure 14-16. 100-KR-4 Operable Unit, KX Pump-and-Treat System, Influent and Effluent Trends for Hexavalent Chromium Concentrations, Calendar Year 2009.

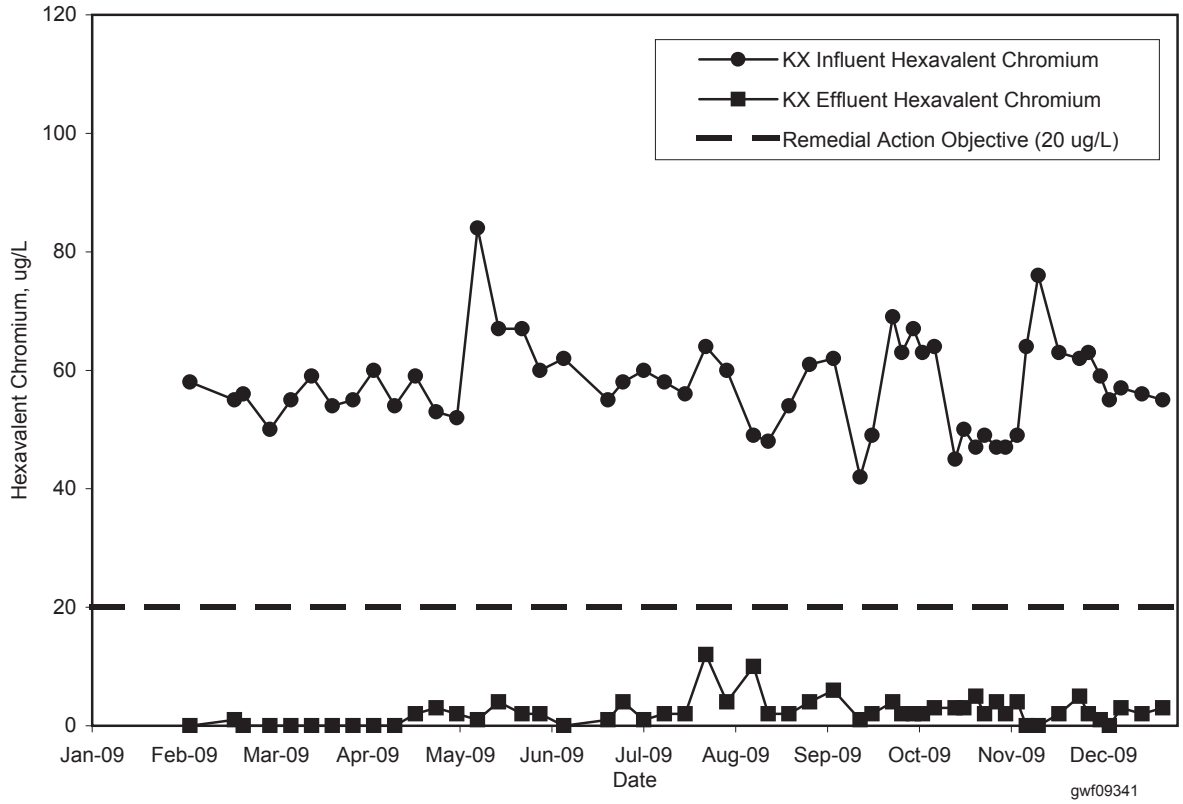


Figure 14-17. 100-KR-4 Operable Unit, KX Pump-and-Treat System Availability and Online Percentages for Calendar Year 2009.

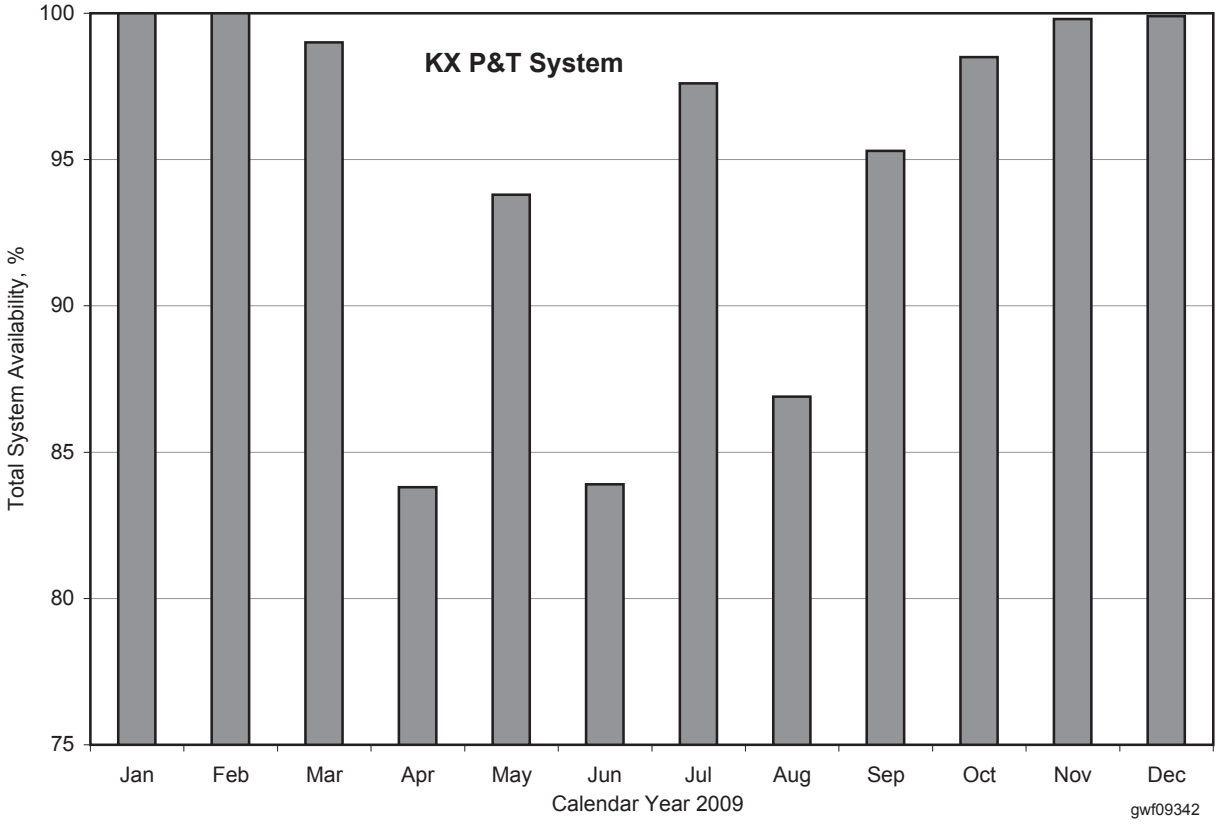


Table 14-8. KX Pump-and-Treat System Availability for Calendar Year 2009.

Total possible run-time (hours)	7,968.0
Scheduled downtime (hours)	152.2
Planned operations (hours)	7,815.8
Unscheduled downtime (hours)	288.1
Total time on-line (hours)	7,527.7
Total availability (%)[a]	98.1%
Scheduled system availability (%)[b]	94.5%

Notes:
a. Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible runtime].
b. Scheduled system availability [(total possible run-time – scheduled downtime) / total possible run-time].

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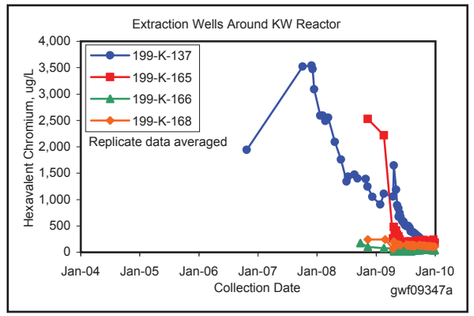
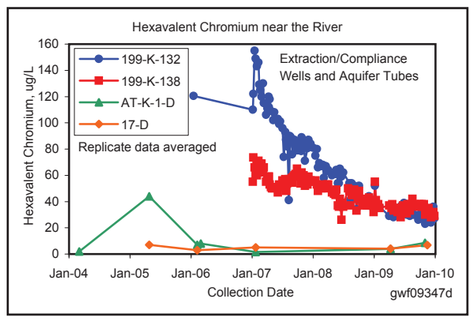
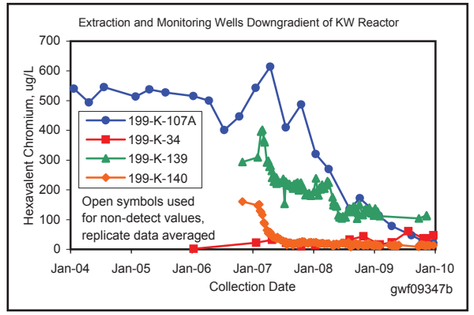
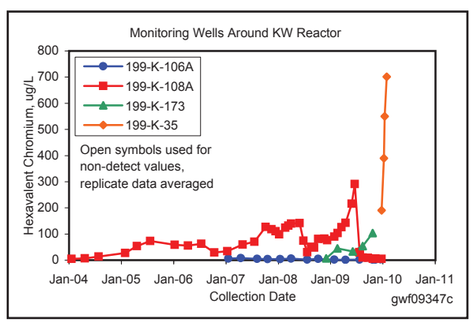
Figure 14-18. 100-KR-4 Operable Unit, KW Pump-and-Treat System Hexavalent Chromium Plume, Wells, Aquifer Tubes, and Representative Hexavalent Chromium Trends.









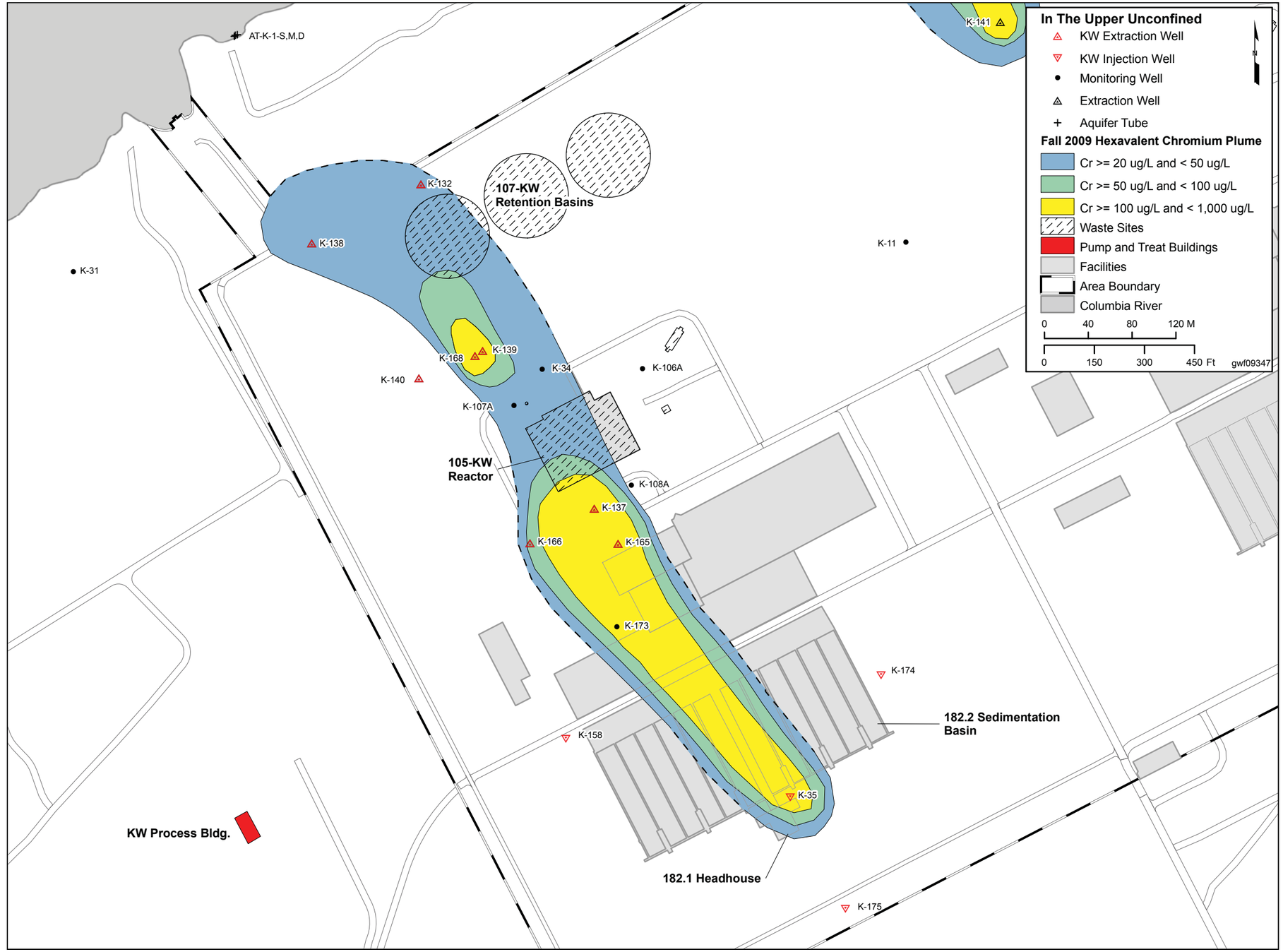


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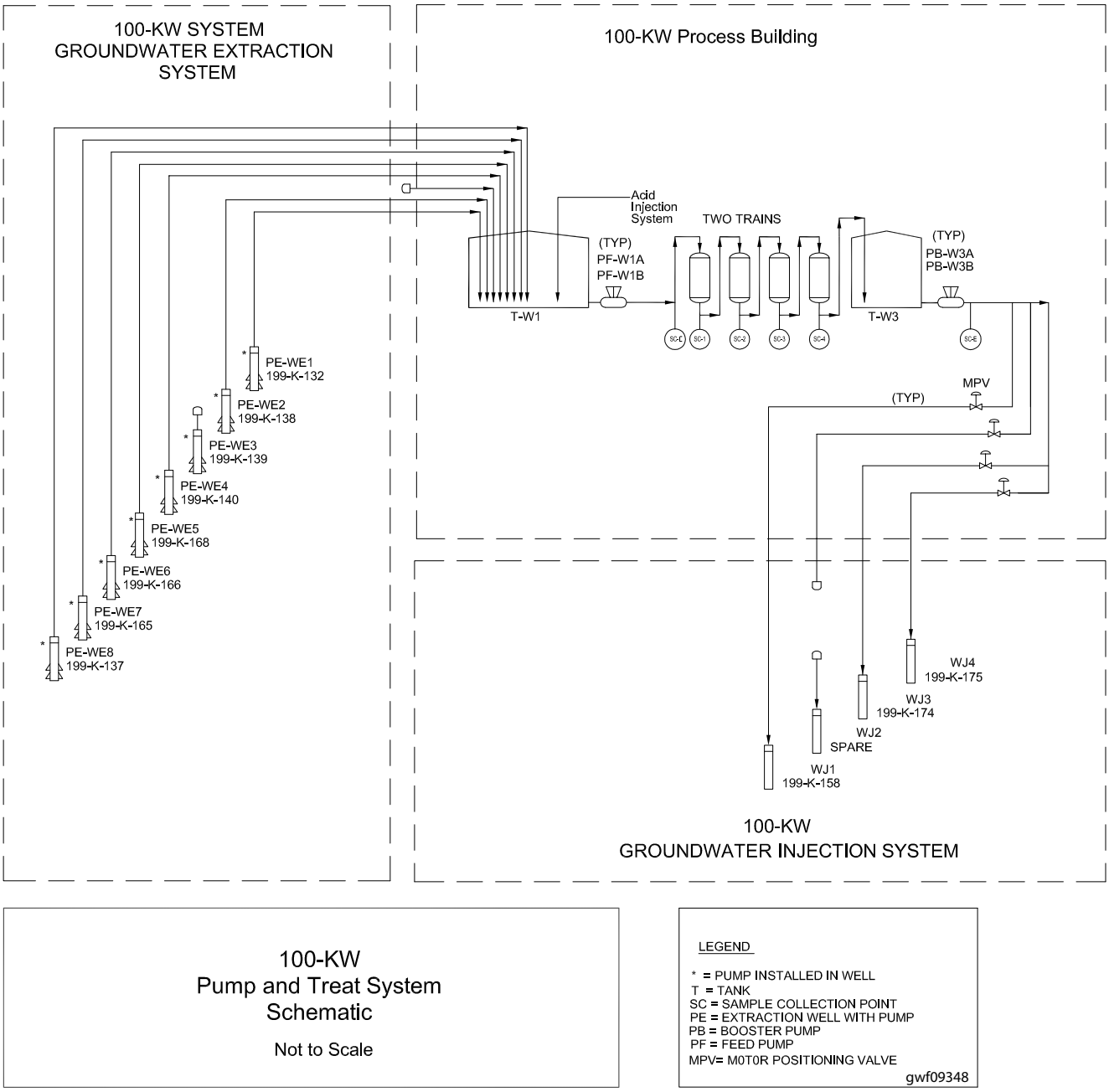
Figure 14-19. 100-KR-4 Operable Unit, KW Pump-and-Treat System Schematic.



100-KW
Pump and Treat System
Schematic

Not to Scale

LEGEND

* = PUMP INSTALLED IN WELL
T = TANK
SC = SAMPLE COLLECTION POINT
PE = EXTRACTION WELL WITH PUMP
PB = BOOSTER PUMP
PF = FEED PUMP
MPV= M0T0R POSITIONING VALVE

gwf09348

Figure 14-20. 100-KR-4 Operable Unit, KW Pump-and-Treat System Average Removal Efficiencies.

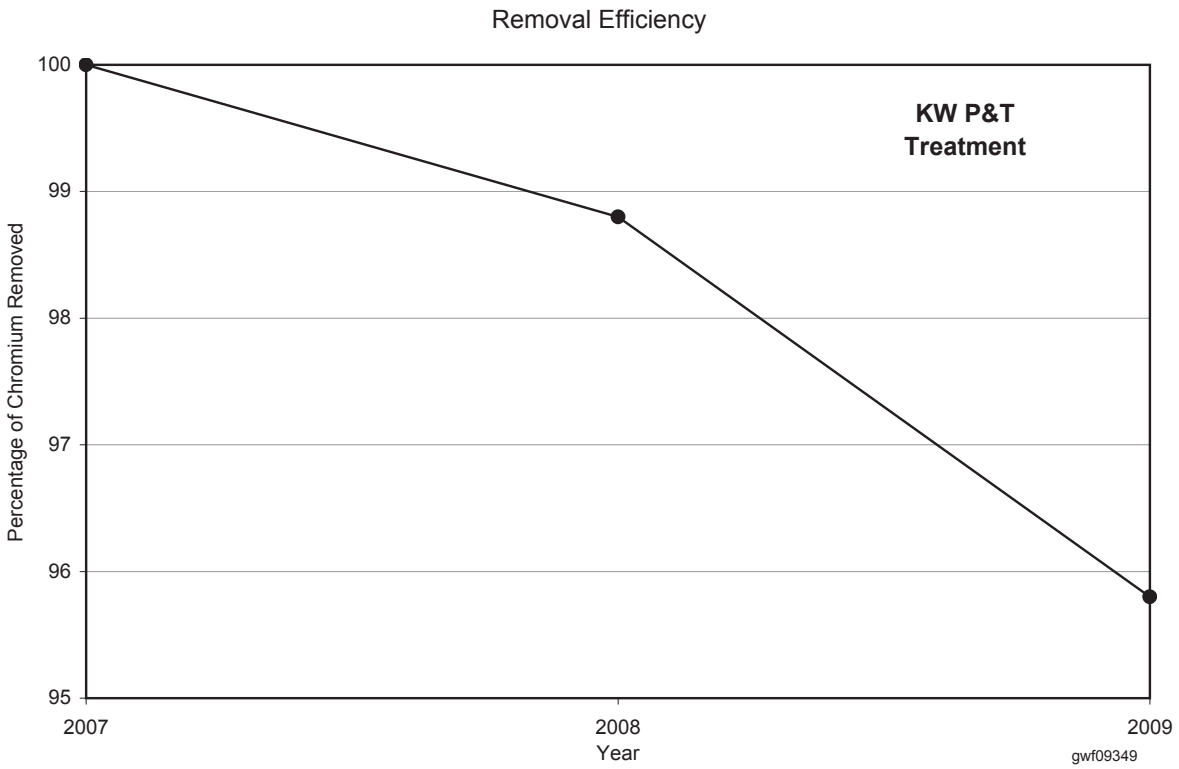


Figure 14-21. 100-KR-4 Operable Unit, KW Pump-and-Treat System, Influent and Effluents Trends for Hexavalent Chromium Concentrations, Calendar Year 2009.

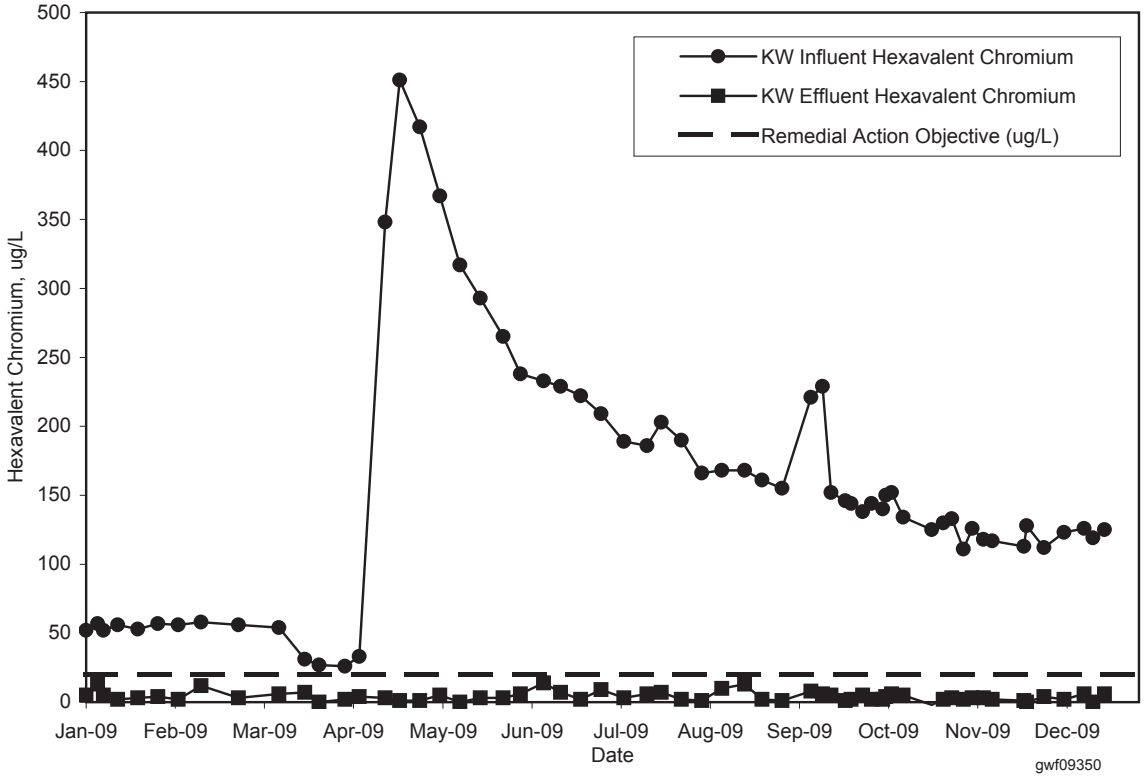


Figure 14-22. 100-KR-4 Operable Unit, KW Pump-and-Treat System Availability and Online Percentages for Calendar Year 2009.

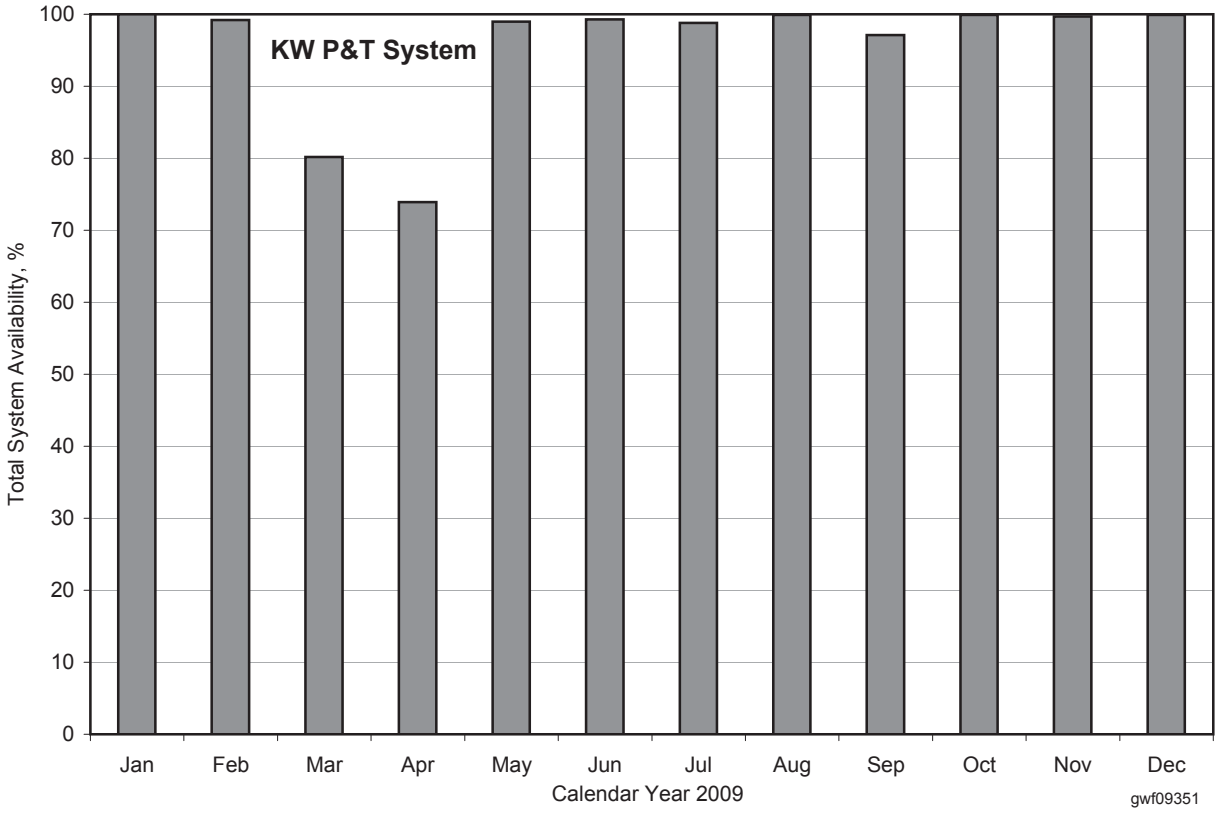


Table 14-11. KW4 Pump-and-Treat System Availability for Calendar Year 2009.

Total possible run-time (hours)	8,760
Scheduled downtime (hours)	268.8
Planned operations (hours)	8,491.2
Unscheduled downtime (hours)	118.0
Total time online (hours)	8,773.2
Total availability (%)[a]	95.6%
Scheduled system availability (%)[b]	98.6%

Notes:
a. Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible run-time] .
b. Scheduled system availability [(total possible run-time – scheduled downtime) / total possible run-time].

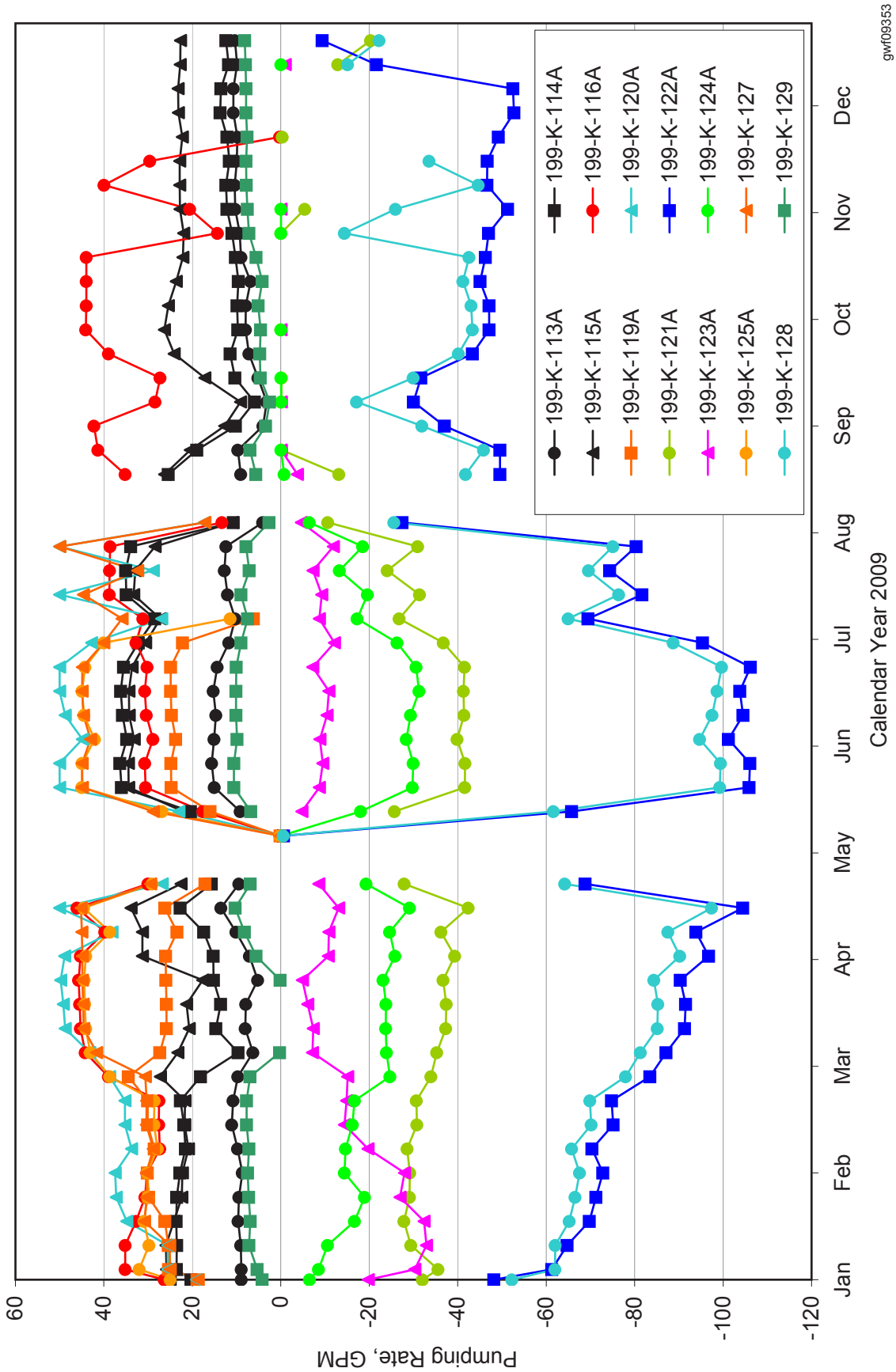


Figure 14-23. Pumping Rates for the KR4 Treatment System.

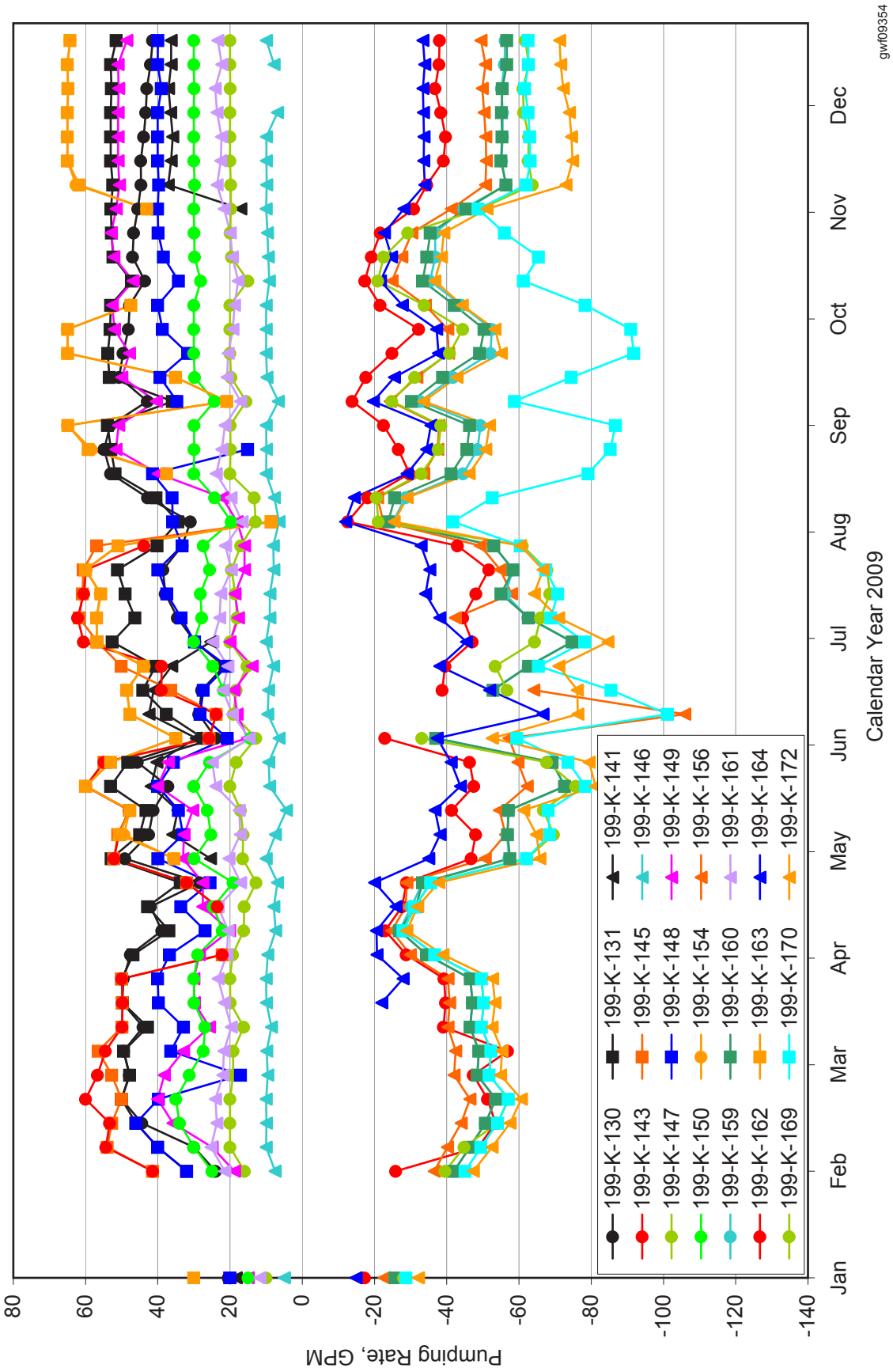


Figure 14-24. Pumping Rates for the KX Treatment System.

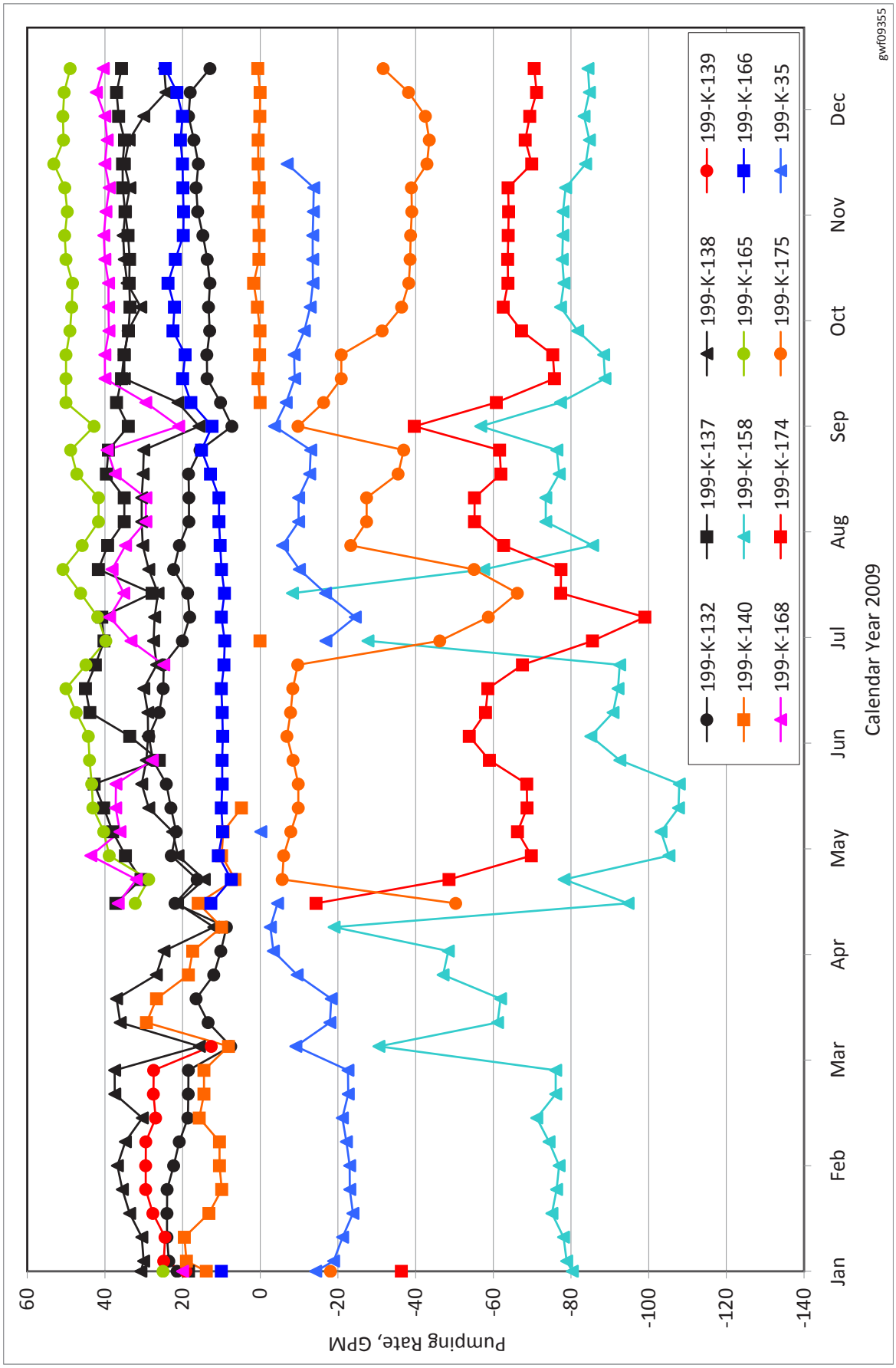
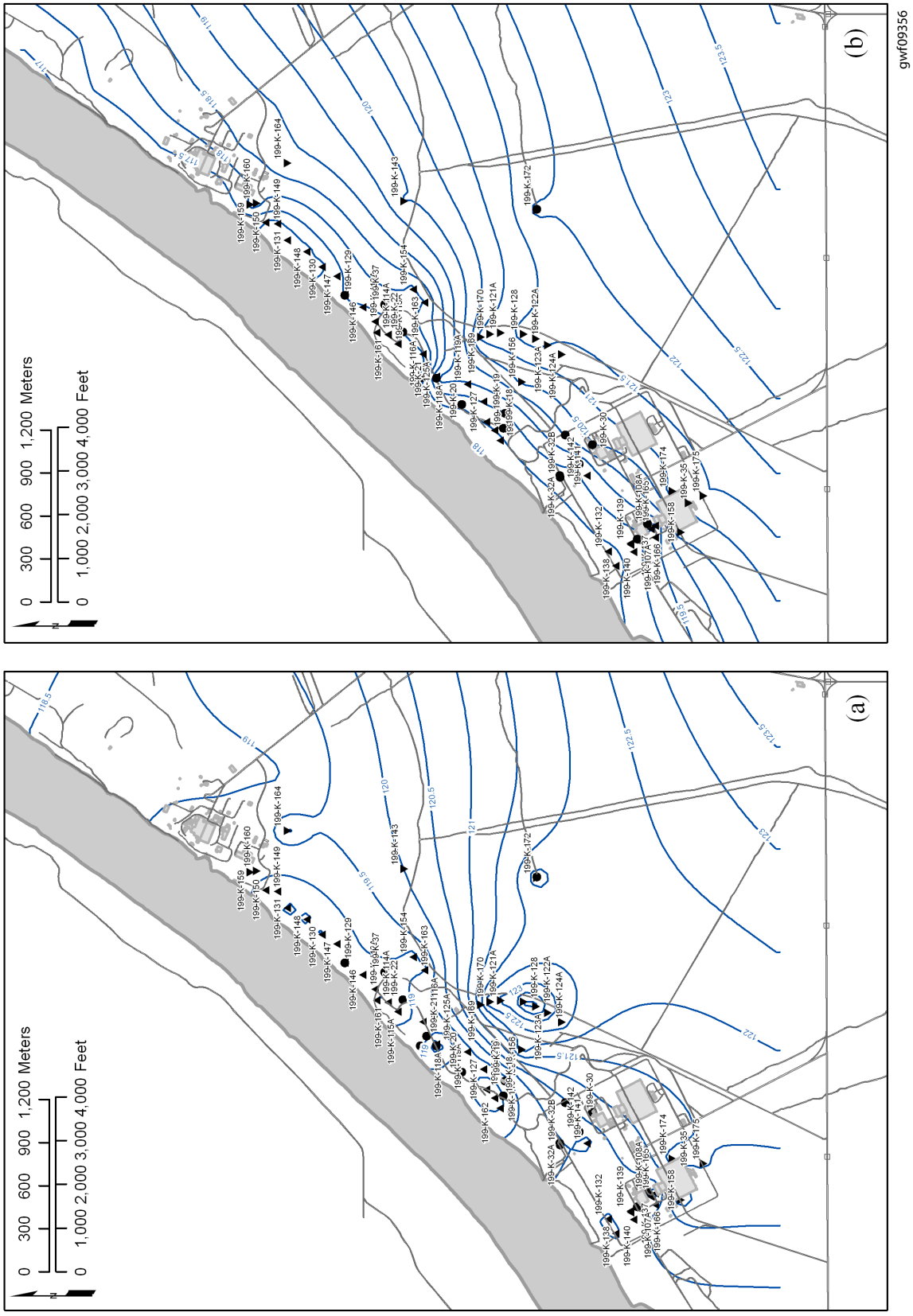


Figure 14-25. Pumping Rates for the KW Treatment System.

Figure 14-26. Example Groundwater Elevation Contours Throughout the 100-K Area for (a) Period 1 and (b) Period 2.



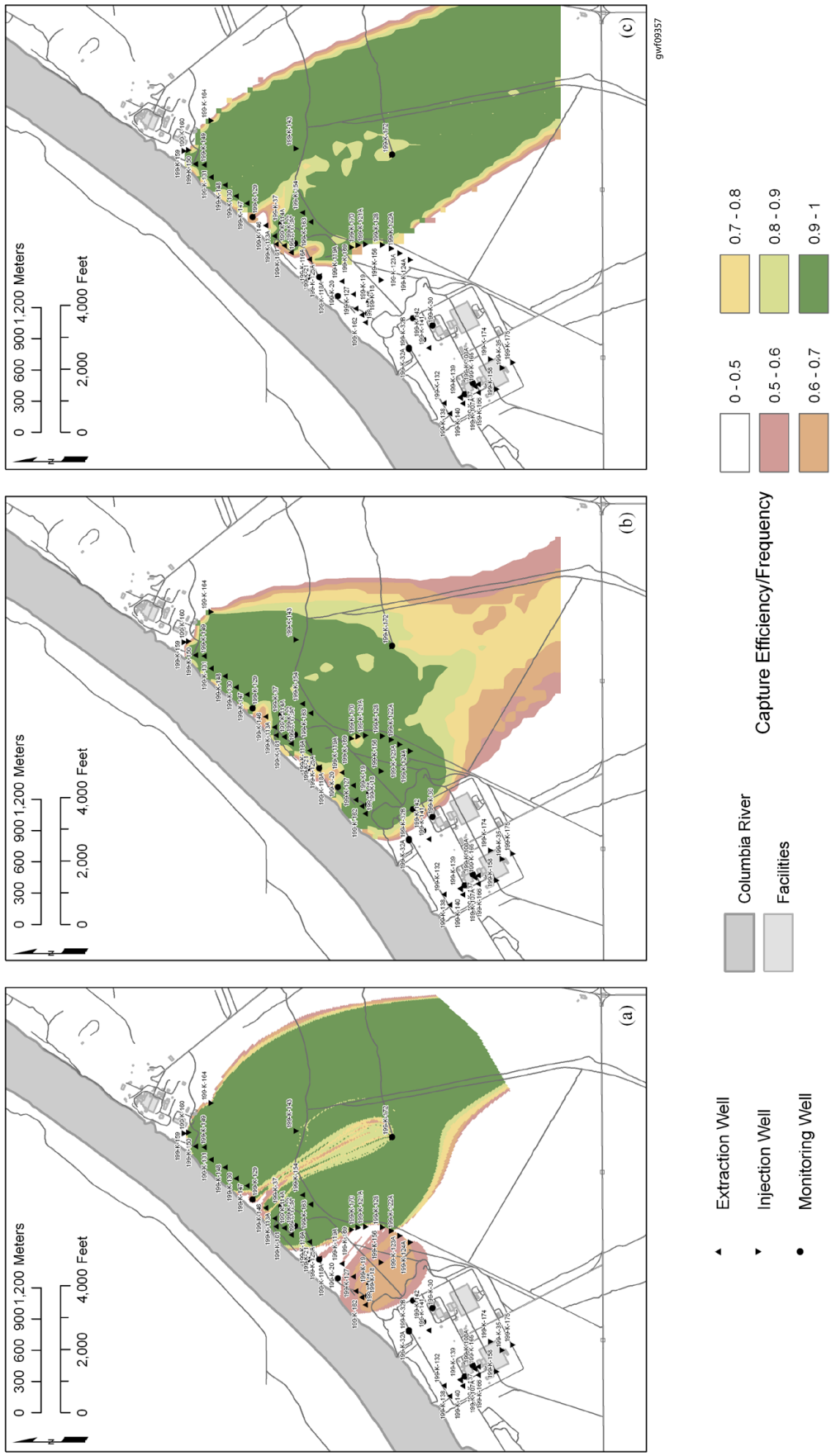


Figure 14-27. Approximate Extent of Capture for KR4 and KX Systems Calculated Using (a) Modeling Method; (b) Mapping Method, Period 1; and (c) Mapping Method, Period 2.

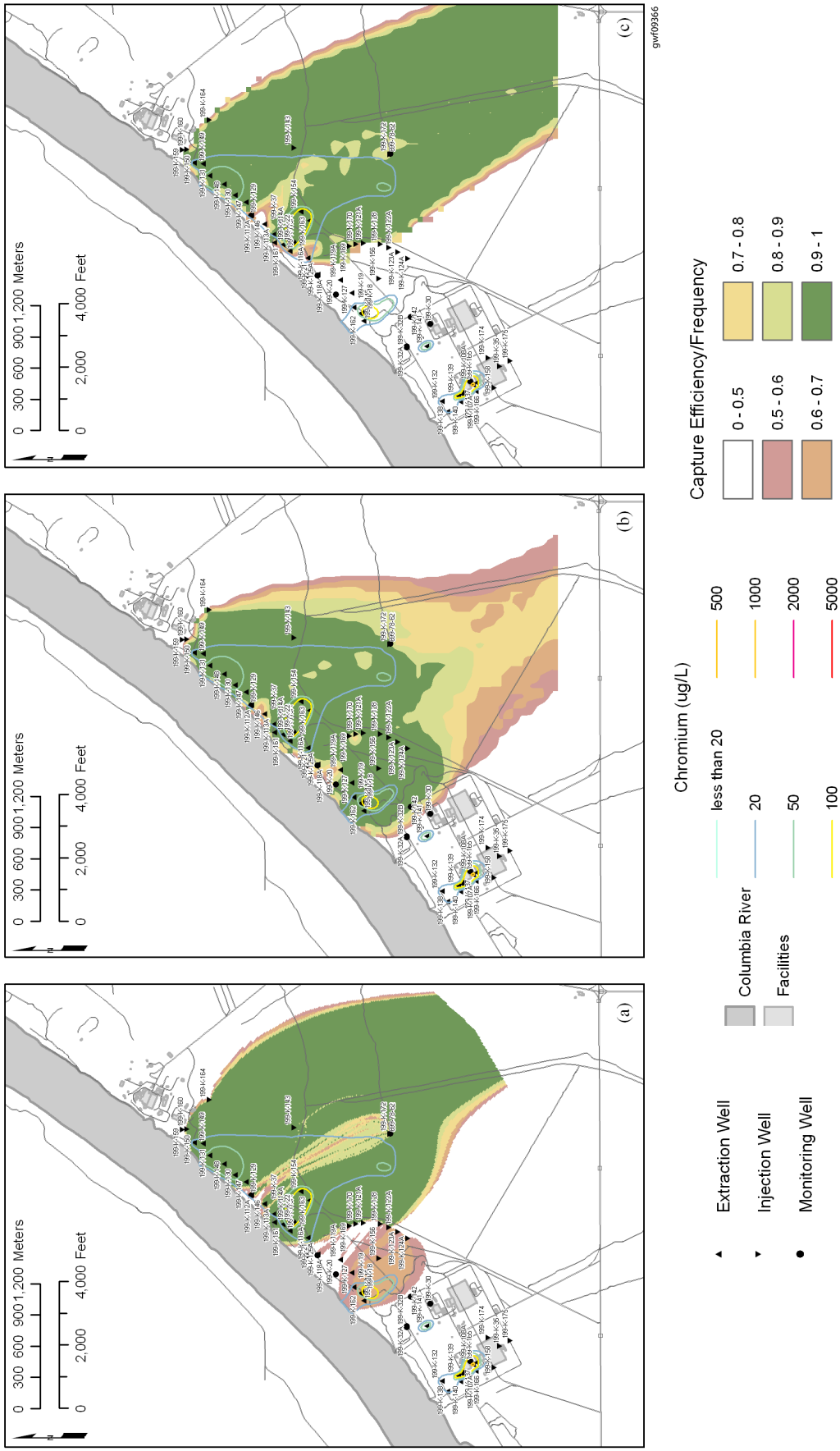
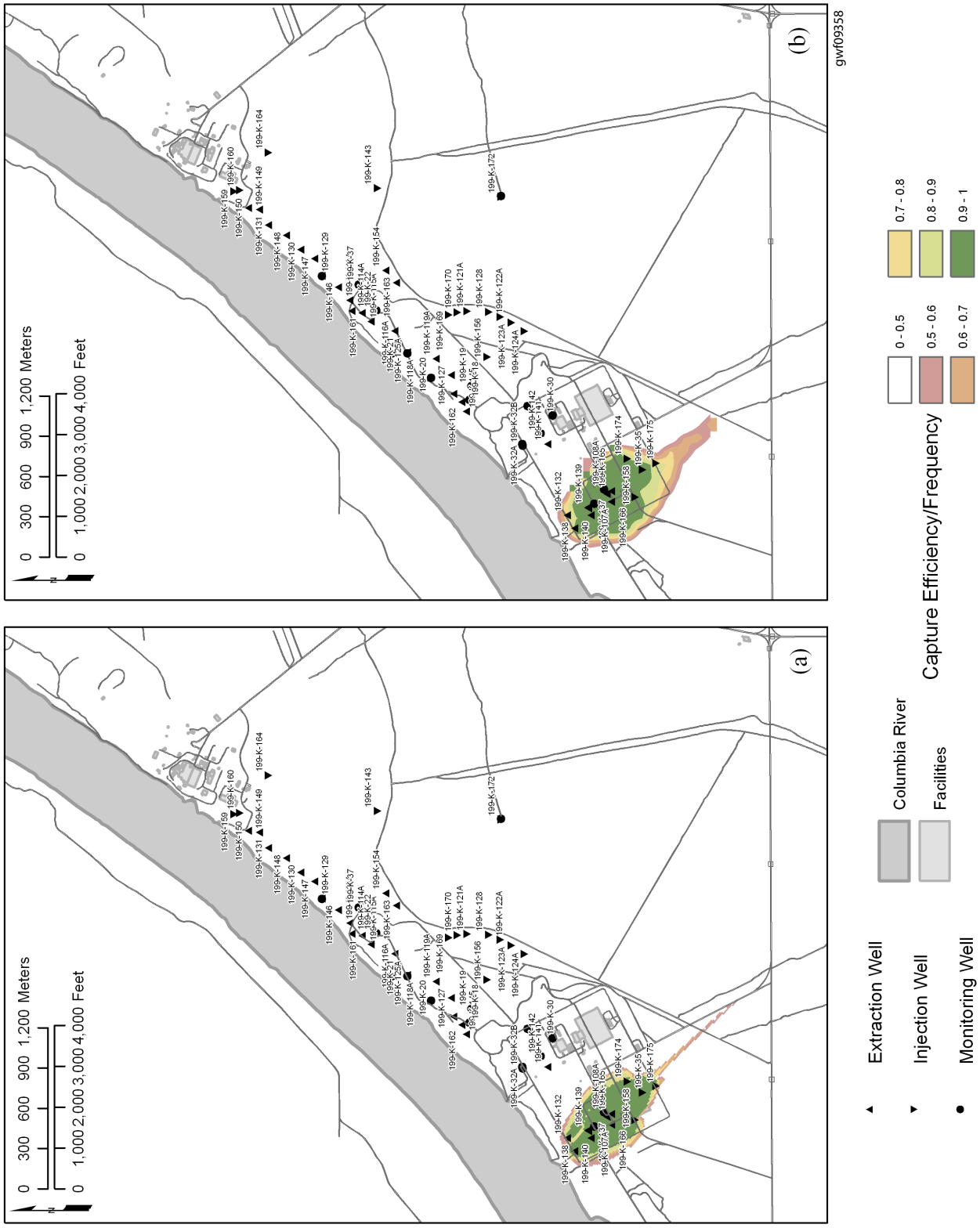


Figure 14-28. Approximate extent of Capture for KR4 and KX Systems Calculated Using (a) Modeling Method; (b) Mapping Method, Period 1; and (c) Mapping Method, Period 2 (Overlaid with Contoured Extent of Hexavalent Chromium in Spring 2009).

Figure 14-29. Approximate Extent of Capture for KW System Calculated Using (a) Modeling Method and (b) Mapping Method.



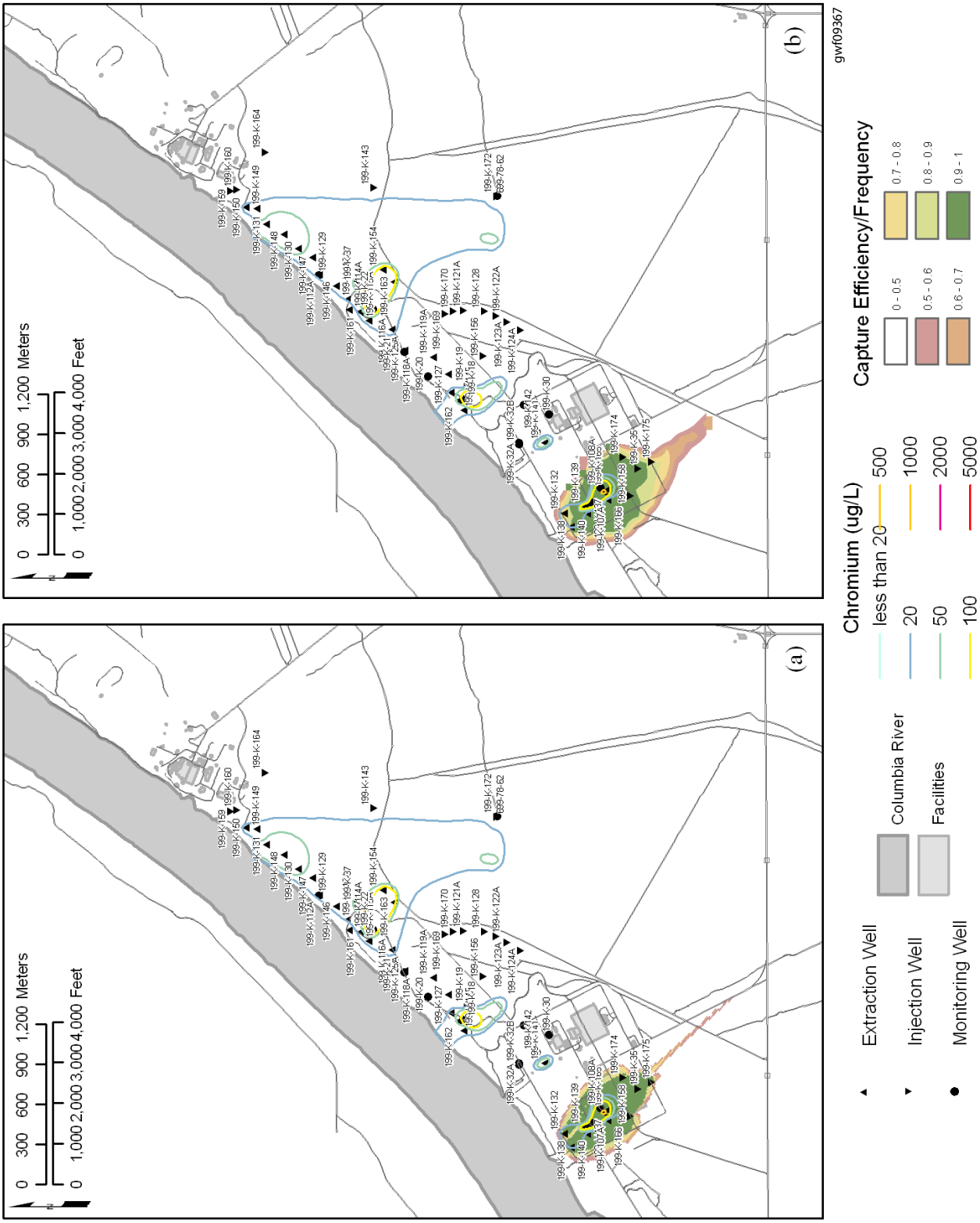


Figure 14-30. Approximate Extent of Capture for KW System Calculated Using (a) Modeling Method and (b) Mapping Method, Overlaid with the Contoured Extent of Hexavalent Chromium in Spring 2009.

Figure 14-31. 100-KR-4 Operable Unit, Tritium Trends at KE Basin Monitoring Wells.

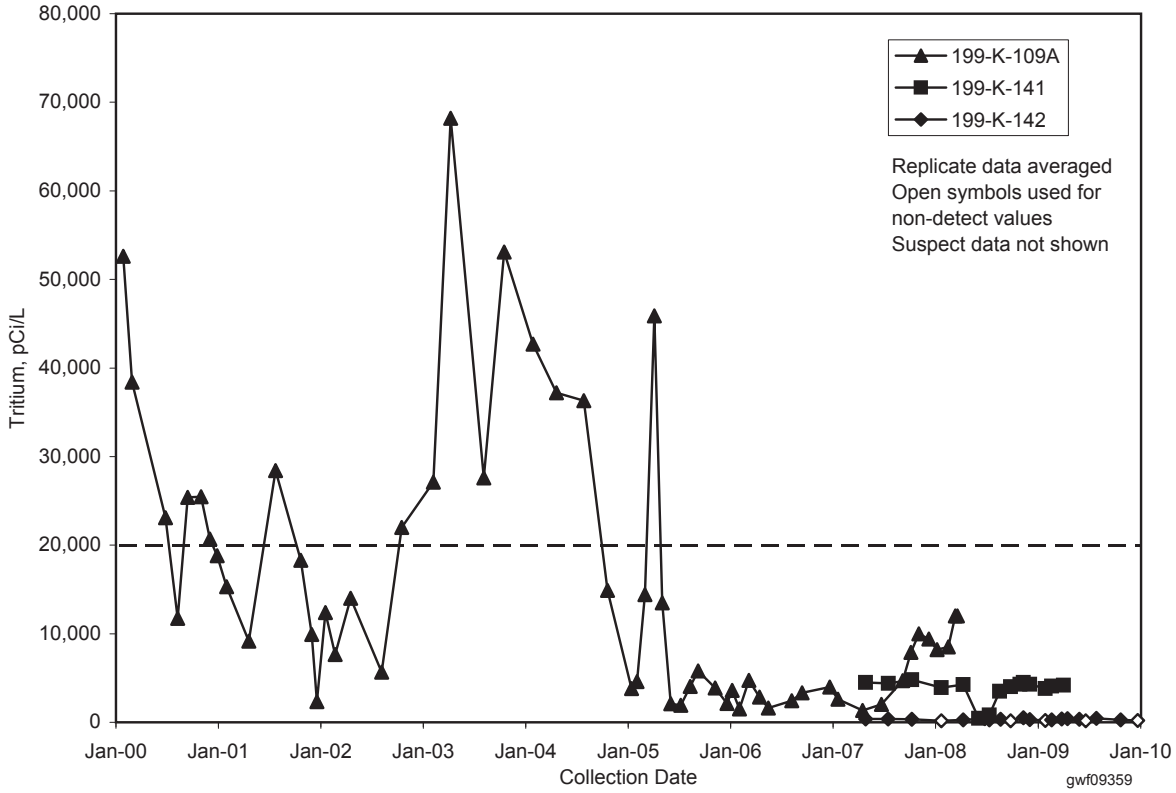


Figure 14-32. 100-KR-4 Operable Unit, Strontium-90 Trends at KE Basin Monitoring Wells.

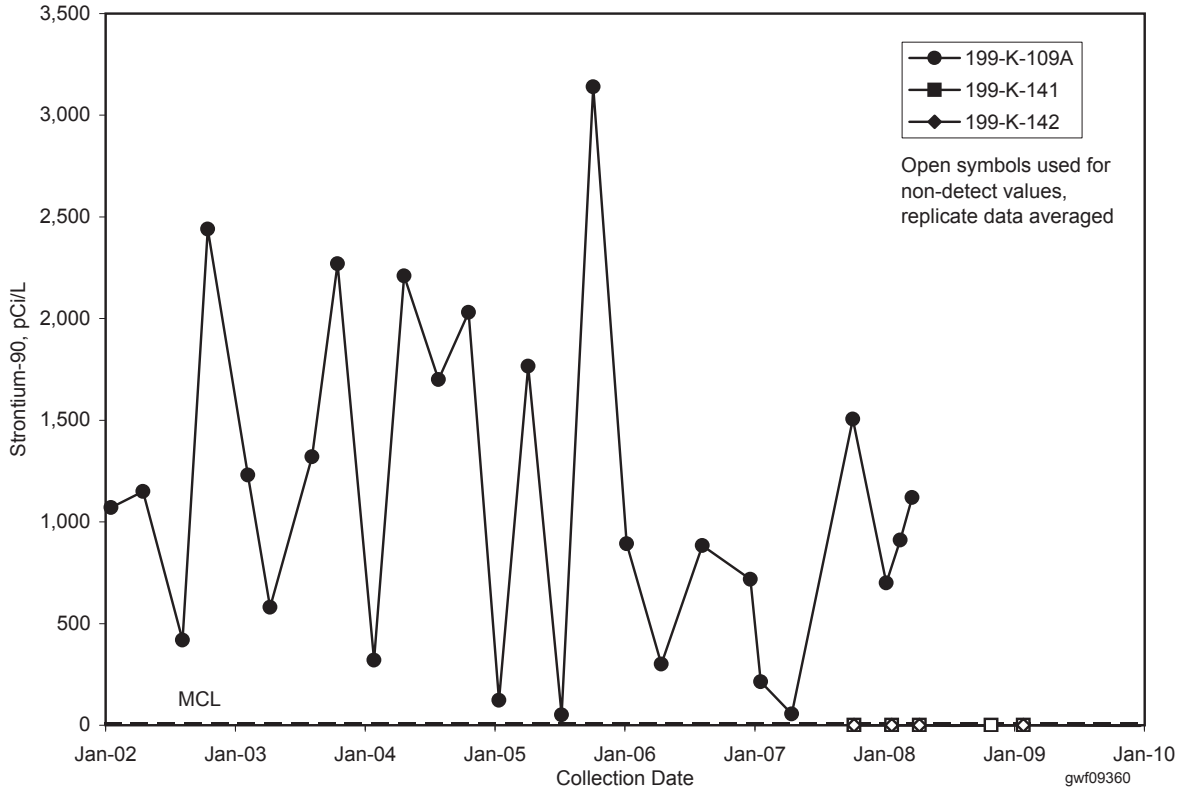


Figure 14-33. 100-KR-4 Operable Unit, Tritium Trends at KW Basin Monitoring Wells.

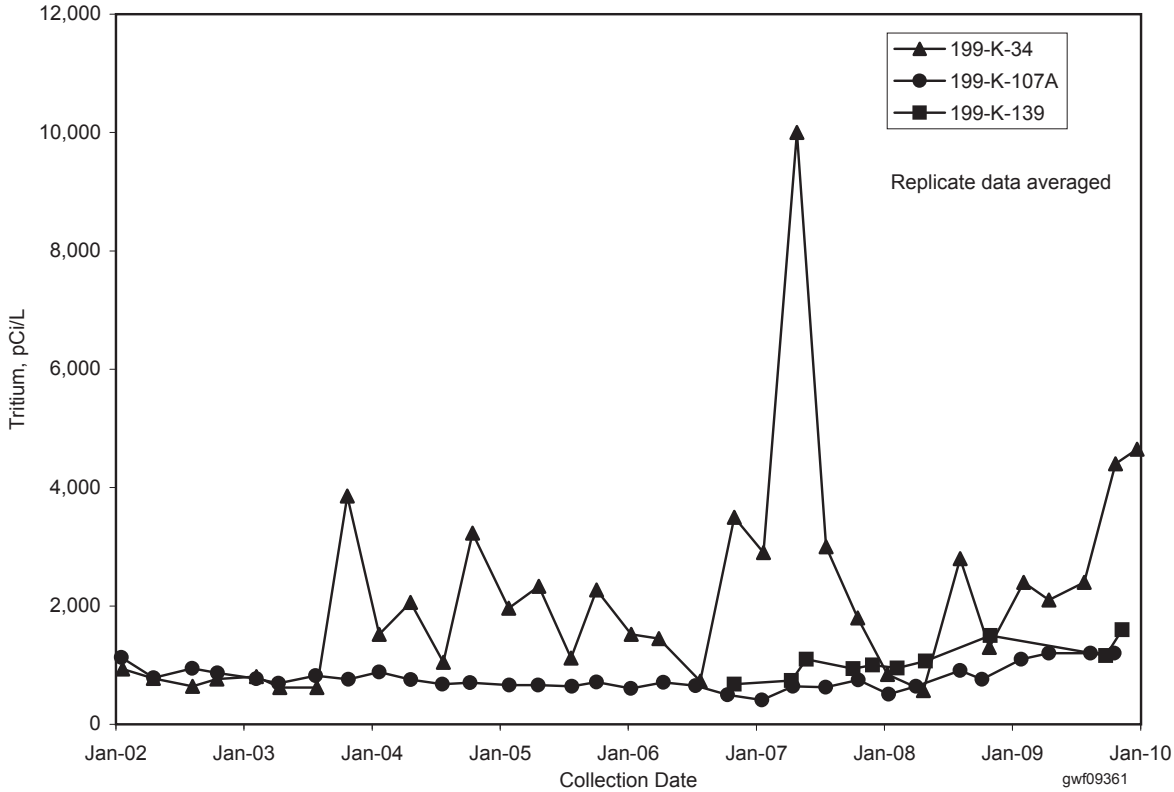
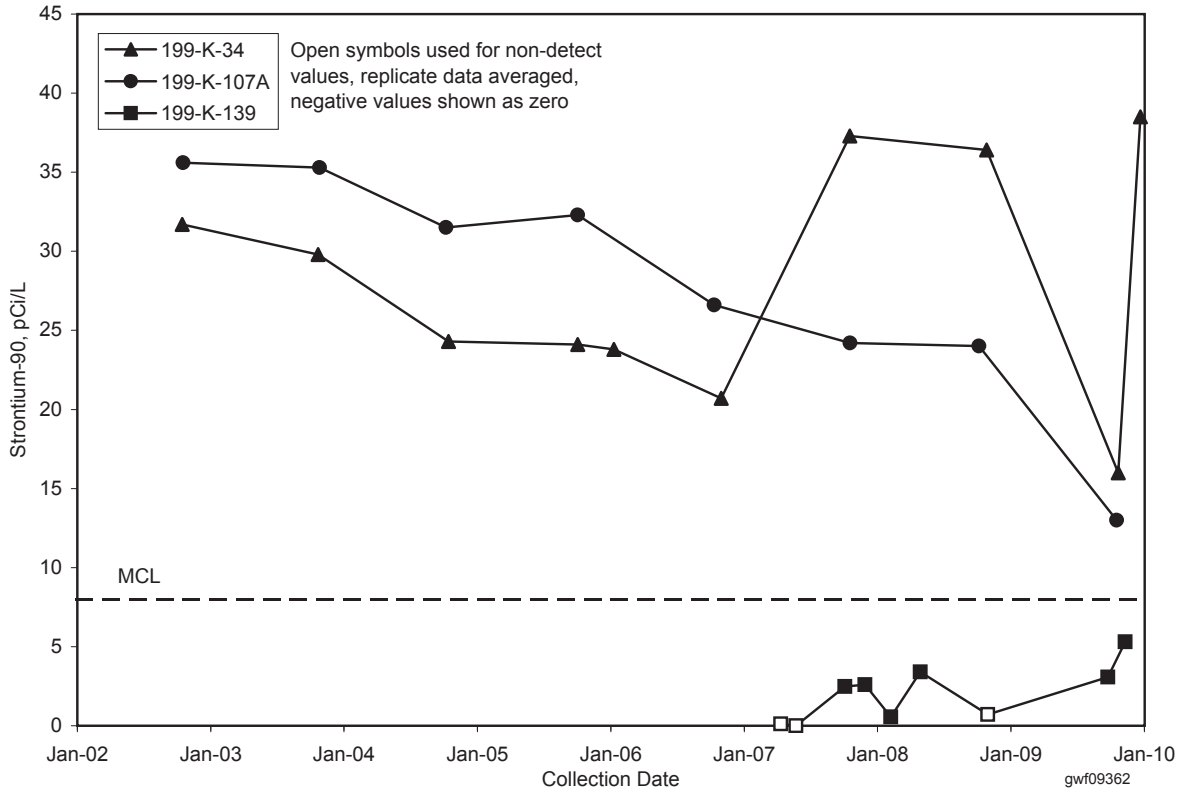


Figure 14-34. 100-KR-4 Operable Unit, Strontium-90 Trends at KW Basin Monitoring Wells.



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