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Hanford Site Groundwater Monitoring for Fiscal Year 2004

Editors
M. J. Hartman
L. F. Morasch
W. D. Webber

March 2005

Prepared for the U.S. Department of Energy
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Abstract

This report presents the results of groundwater and vadose zone monitoring and remediation for fiscal year 2004 on the U.S. Department of Energy's Hanford Site, Washington.

The most extensive contaminant plumes in groundwater are tritium, iodine-129, and nitrate, which all had multiple sources and are very mobile in groundwater. The largest portions of these plumes are migrating from the central Hanford Site to the southeast, toward the Columbia River. Concentrations of tritium, nitrate, and some other contaminants continued to exceed drinking water standards in groundwater discharging to the river in some locations. However, contaminant concentrations in river water remained low and were far below standards.

Carbon tetrachloride and associated organic constituents form a relatively large plume beneath the central part of the Hanford Site. Hexavalent chromium is present in smaller plumes beneath the reactor areas along the river and beneath the central part of the site. Strontium-90 exceeds standards beneath all but one of the reactor areas, and technetium-99 and uranium are present in the 200 Areas. Minor contaminant plumes with concentrations greater than standards include carbon-14, cesium-137, cis-1,2-dichloroethene, cyanide, fluoride, plutonium, and trichloroethene.

Monitoring for the *Comprehensive Environmental Response, Compensation, and Liability Act* is conducted in 11 groundwater operable units. The purpose of this monitoring is to define and track plumes and to monitor the effectiveness of interim remedial actions. Interim groundwater remediation in the 100 Areas continued with the goal of reducing the amount of chromium (100-K, 100-D, and 100-H) and strontium-90 (100-N) reaching the Columbia River. The objective of two interim remediation systems in the 200 West Area is to prevent the spread of carbon tetrachloride and technetium-99/uranium plumes.

Resource Conservation and Recovery Act groundwater monitoring continued at 24 waste management areas during fiscal year 2004:

- fifteen under interim or final status detection programs and data indicate that they are not adversely affecting groundwater
- seven under interim status groundwater quality assessment programs to assess contamination
- two under final status corrective-action programs.

During calendar year 2004, drillers completed 6 new RCRA monitoring wells and 19 wells for CERCLA. A total of 108 new aquifer tubes were installed along the Columbia River shoreline.

Vadose zone monitoring, characterization, and remediation continued in fiscal year 2004. Remediation and associated monitoring continued at a soil-vapor extraction system in the 200 West Area, which removes gaseous carbon tetrachloride from the vadose zone. DOE uses geophysical methods to monitor potential movement of contamination beneath single-shell tank farms. A study of premature casing corrosion in two groundwater monitoring wells indicated that the corrosion was apparently caused by chloride in the annular seal of the well and a wet sediment layer in the vadose zone.

The System Assessment Capability is a set of computer modules simulating movement of contaminants from waste sites through the vadose zone and groundwater. In fiscal year 2004, it was used to begin the Composite Analysis, which is designed to calculate the combined impacts of all radiological waste that will be left on the Hanford Site at the time of site closure.

This report is available on the Internet through the Hanford Groundwater Performance Assessment Project's web site: http://groundwater.pnl.gov/. Inquiries regarding this report may be directed to Ms. Mary J. Hartman, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 or by electronic mail to mary.hartman@pnl.gov.

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This report represents the efforts of dozens of individuals who contribute to the Groundwater Performance Assessment Project: planners, schedulers, samplers, laboratory technicians, data management staff, site scientists, editors, text processors, and staff in graphics and duplicating.

John Fruchter and Stuart Luttrell manage the Groundwater Performance Assessment Project and the Groundwater Monitoring Task, respectively. Dot Stewart manages the monumental tasks of sampling and analysis, quality control, and data management.

Most of the graphics for this report were generated by Mickie Chamness and Chris Newbill, who put in many hours to meet our tight schedule. John McDonald and Elaine Schneider also assisted with graphics. JoAnne Rieger retrieved and formatted data for maps and tables.

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Mary Hartman
Launa Morasch
Bill Webber

Report Contributors

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Summary

Introduction

The Hanford Site, a facility in the U.S. Department of Energy (DOE) nuclear weapons complex, encompasses ~1,517 square kilometers northwest of the city of Richland along the Columbia River in southeast Washington State. The federal government acquired the site in 1943, and until the 1980s, it was dedicated primarily to the production of plutonium for national defense and the management of resulting waste. Beginning in the 1990s, DOE has focused on cleaning up the site.

DOE is committed to protecting the Columbia River from contaminated groundwater resulting from past, present, and future operations and protecting and remediating groundwater. The Hanford Site Groundwater Strategy focuses on three key areas: groundwater protection, groundwater monitoring, and remediation of contaminated groundwater.

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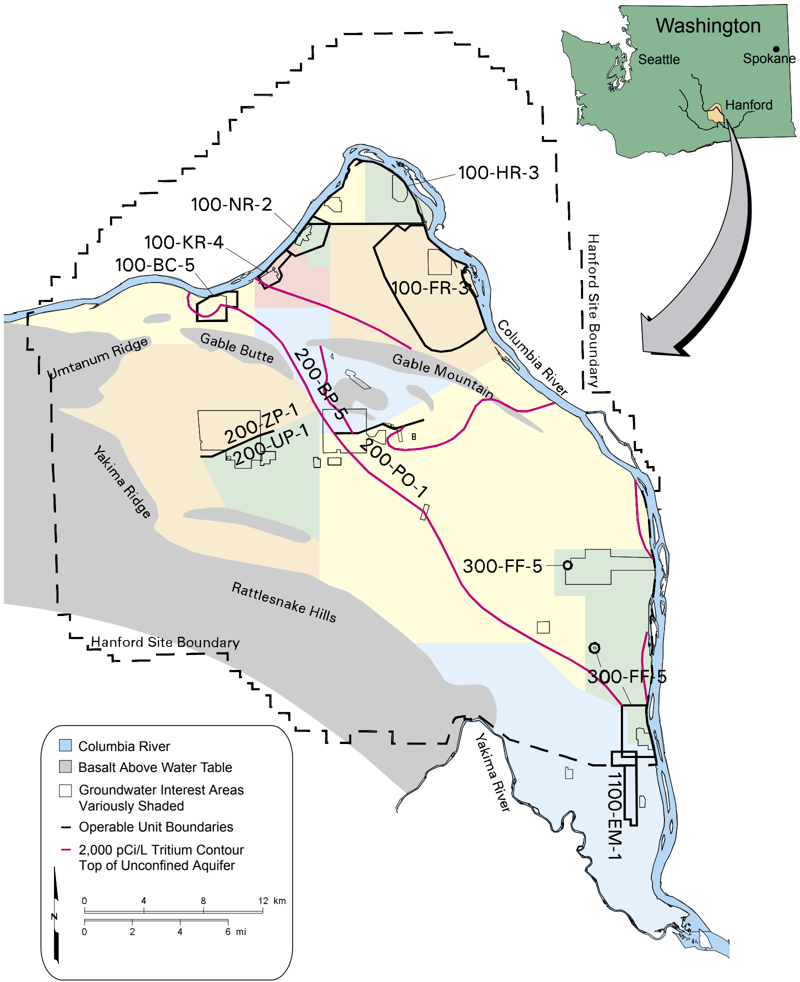
DOE monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the *Atomic Energy Act of 1954* (AEA), the *Resource Conservation and Recovery Act* (RCRA), the *Comprehensive Environmental Response, Compensation, and Liability*



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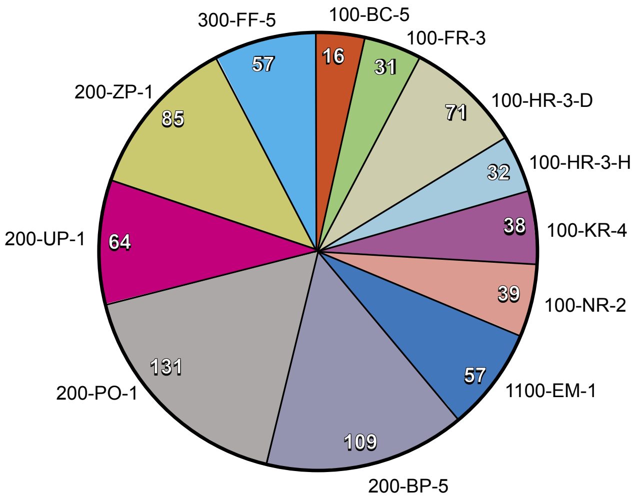
Hanford Site groundwater monitoring is organized by areas of interest, which are informally named after the groundwater operable units. The areas of interest are useful for planning and scheduling groundwater monitoring and interpreting data.

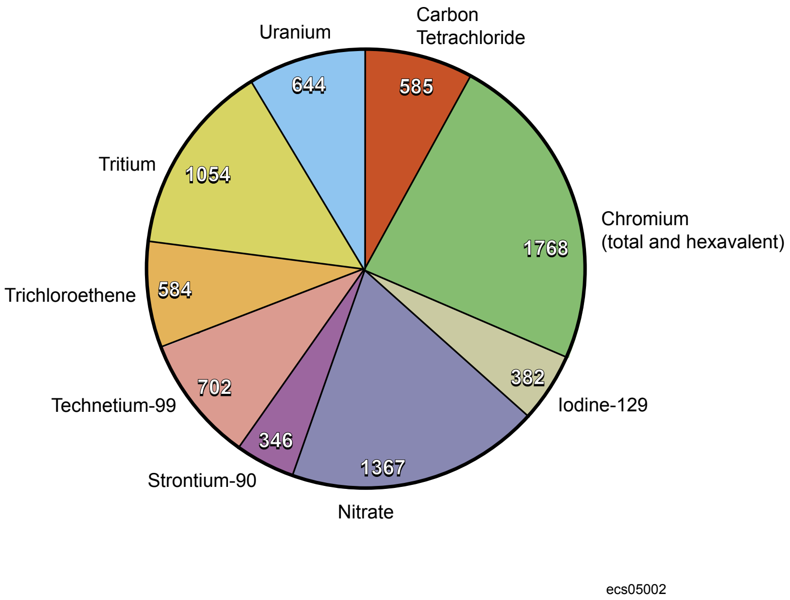
Act (CERCLA), and Washington Administrative Code (WAC). DOE manages most of these activities through the Groundwater Performance Assessment Project (groundwater project).

Some contamination reached the Columbia River by moving downward from waste sites through the vadose zone, into the groundwater, and then into the river. The analysis of groundwater samples helps determine the potential effects that contaminants could have on human health and the environment. DOE works with regulatory agencies such as the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) to make cleanup decisions based on sound technical information and the technical capabilities available.

DOE sampled 730 wells during FY 2004. Iodine-129, nitrate, and tritium are the most widespread contaminants.



This chart shows the number of wells sampled in each groundwater interest area in FY 2004.



The groundwater project requests specific laboratory analyses based on the well's location, historical contaminant trends, and regulatory requirements. This graph shows the number of analyses for the most common constituents during FY 2004.

In fiscal year (FY) 2004, workers sampled 730 monitoring wells and 139 shoreline aquifer tubes to determine the distribution and movement of contaminants. Many of the wells were sampled multiple times during the year for a total of 2,026 sampling trips. A total of 1,768 samples of Hanford groundwater were analyzed for chromium, 1,367 for nitrate, and 1,054 for tritium. Other constituents frequently analyzed include technetium-99 (702), carbon tetrachloride (585), and uranium (644).

Emerging Issues

Tritium at KE Basin. Tritium levels began to rise in January 2003 in a well downgradient of the KE Basin, exceeding 100,000 pCi/L in October 2003 and subsequently declining to ~40,000 pCi/L in October 2004. Because there are multiple sources of tritium in the area, no mobile co-contaminants such as technetium-99 are found with the tritium, and there is no evidence of measurable water losses from the KE Basin, scientists cannot conclude with certainty that the recent rise in tritium is a result of current loss of shielding water to the ground. Other potential sources of tritium include remobilization of tritium in the soil from a 1993 basin leak and remobilization of tritium in the soil from the remediation of condensate cribs. Cracks have been found in the concrete basins that still contain sludge and shielding water contaminated with tritium and other radionuclides. The extent of the cracking and possible impacts on groundwater are being investigated. The frequency of groundwater sample collection downgradient of the KE Basin has been increased to help evaluate the source of the tritium.

DOE is investigating recent changes in tritium concentrations downgradient of KE Basin in the 100-K Area and increases in technetium-99 concentrations east of Waste Management Area T.

Technetium-99 at Waste Management Area T. Concentrations continued to increase in wells on the east side (downgradient) of the tank farm in FY 2004. Well 299-W11-39, near the northeast corner of the waste management area, had a concentration of 21,400 pCi/L at the end of FY 2004, more than double the FY 2003 concentration of 9,140 pCi/L. Preliminary data from a new well installed in early FY 2005 east of Waste Management Area T showed a technetium-99 concentration of 182,000 pCi/L at ~10 meters below the water table. DOE will work with the regulatory agencies to develop actions in response to the technetium-99 increases.

100-N Pump-and-Treat Alternatives. Because pump-and-treat technology is not an effective way to clean up strontium-90 contamination, DOE is considering alternative technologies. DOE has developed a treatability test plan to evaluate the effectiveness of one technology, sequestration, where chemicals injected into the aquifer immobilize strontium-90 so it does not flow with the groundwater into the Columbia River. The plan includes a contingency provision for a permeable reactive barrier installed with compressed air to meet the same objective if sequestration fails. The test will also evaluate phytoremediation (plants) to enhance strontium-90 recovery along the shoreline. DOE has recommended temporarily suspending operation of the pump-and-treat system while they collect data to evaluate the alternative technologies. Sampling frequency was increased in anticipation of suspending the pump-and-treat operations. DOE also recommends monitored natural attenuation for that portion of the plume that is not expected to reach the Columbia River.

100-D Chromium Remediation. DOE began operating a new small-scale pump-and-treat system in the central 100-D Area, where hexavalent chromium was bypassing two existing remediation systems. If the new system is successful and cost-effective, it may be expanded.

Proposed Pump-and-Treat Cessation at 200-UP-1 Operable Unit. Technetium-99 and uranium concentrations were below interim action goals in FY 2004. DOE and Ecology have agreed to perform a rebound study to verify the effectiveness of the pump-and-treat actions at removing uranium and technetium-99 contamination in the groundwater. The pump-and-treat system will be turned off for 1 year, and DOE will sample and analyze groundwater monthly to determine how uranium and technetium-99 concentrations change when the aquifer is not stressed by continuous pumping.

Hanford groundwater flows into the Columbia River, which is used for recreation, drinking water, agriculture, and wildlife habitat. Therefore, DOE is focusing their remediation efforts on protecting the Columbia River.

Well Spacing at the Low-Level Burial Grounds. DOE and Ecology have been holding workshops regarding some aspects of groundwater monitoring at these sites. One of the issues to be resolved is the horizontal spacing and number of groundwater monitoring wells to be installed to meet RCRA groundwater monitoring requirements.

Alternative Statistics at RCRA Sites. DOE completed data collection and evaluation of an alternative statistical method for groundwater monitoring data. This method, using control charts, has been proposed to Ecology for use in RCRA groundwater monitoring. Discussions with Ecology in the next year are hoped to resolve the applicability of this method.

Well Decommissioning. DOE has accelerated the rate at which "at-risk" and unused wells are being decommissioned. This activity will continue to be a high priority for DOE to stop and/or prevent the risk of contaminants moving through these wells.

Feasibility Studies. DOE began a focused feasibility study of the 300-FF-5 Operable Unit, which will lead to final cleanup decisions. Similar studies are scheduled to being in the 100-BC-5 and 100-FR-3 operable units in FY 2005 and 2006.

Groundwater Flow

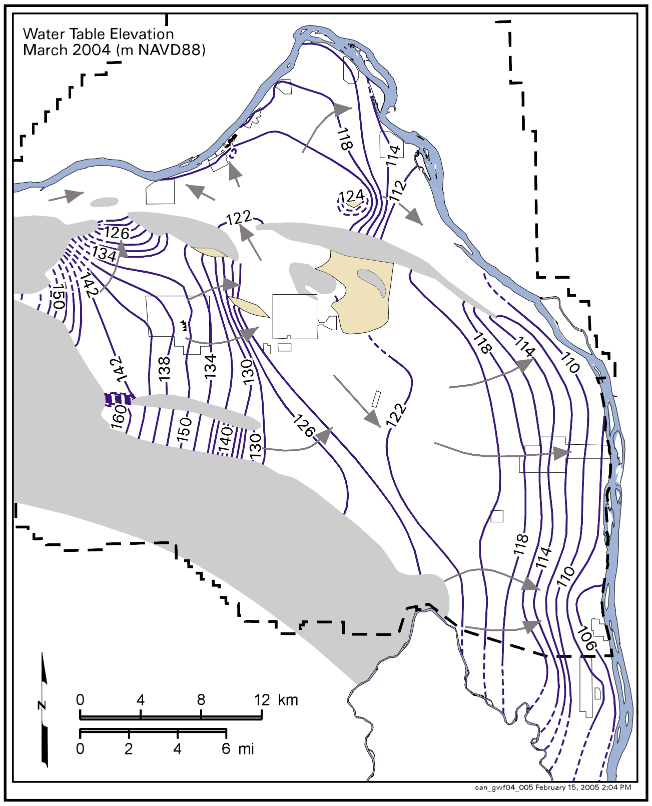
Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site to discharge areas along the Columbia River. The direction of groundwater flow is inferred from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants.

General directions of groundwater flow are illustrated on the map for March 2004. Groundwater enters the Hanford Site from recharge areas to the west and eventually discharges to the Columbia River. In the part of the site north of Gable Mountain and Gable Butte, groundwater flows generally northeast or east, except beneath the reactor areas on the west side of the horn where groundwater flows north and northwest toward the river. South of Gable Mountain and Gable Butte, groundwater flows toward the east and southeast. The water table in the central part of the site (beneath the 200 East Area) is relatively flat because of the presence of highly permeable sediment of the Hanford formation at the water table. In the south part of the Hanford Site, groundwater converges on the 300 Area from the northwest, west, and southwest.

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by the formation of mounds in the water table. The mounds were created by the discharge of large volumes of wastewater to the ground and were present in each reactor area and beneath the 200 Areas. Since effluent disposal decreased significantly in the 1990s, these mounds are disappearing.

Groundwater flow is currently altered where extraction or injection wells are used for pump-and-treat systems or where wastewater is discharged to the land surface.

East of the 200 East Area, a fine-grained confining unit creates a barrier to movement in the surrounding unconfined aquifer. Beneath this confining unit, the uppermost aquifer is a permeable unit in the Ringold Formation. Groundwater flow in this confined aquifer still is influenced by a residual recharge mound.



This map shows the water table and inferred flow directions in March 2004. Areas shaded in gray or tan show where the unconfined aquifer is absent.

Groundwater Monitoring and Remediation

DOE has developed a plan to accelerate cleanup of Hanford's groundwater, which will return it to its beneficial use where practicable or will at least prevent further degradation. Under the accelerated plan DOE will (a) remediate high-risk waste sites, (b) shrink the contaminated area, (c) reduce recharge, (d) remediate groundwater, and (e) monitor groundwater. The maps on the following pages show the distribution of nine principal groundwater contaminant plumes.

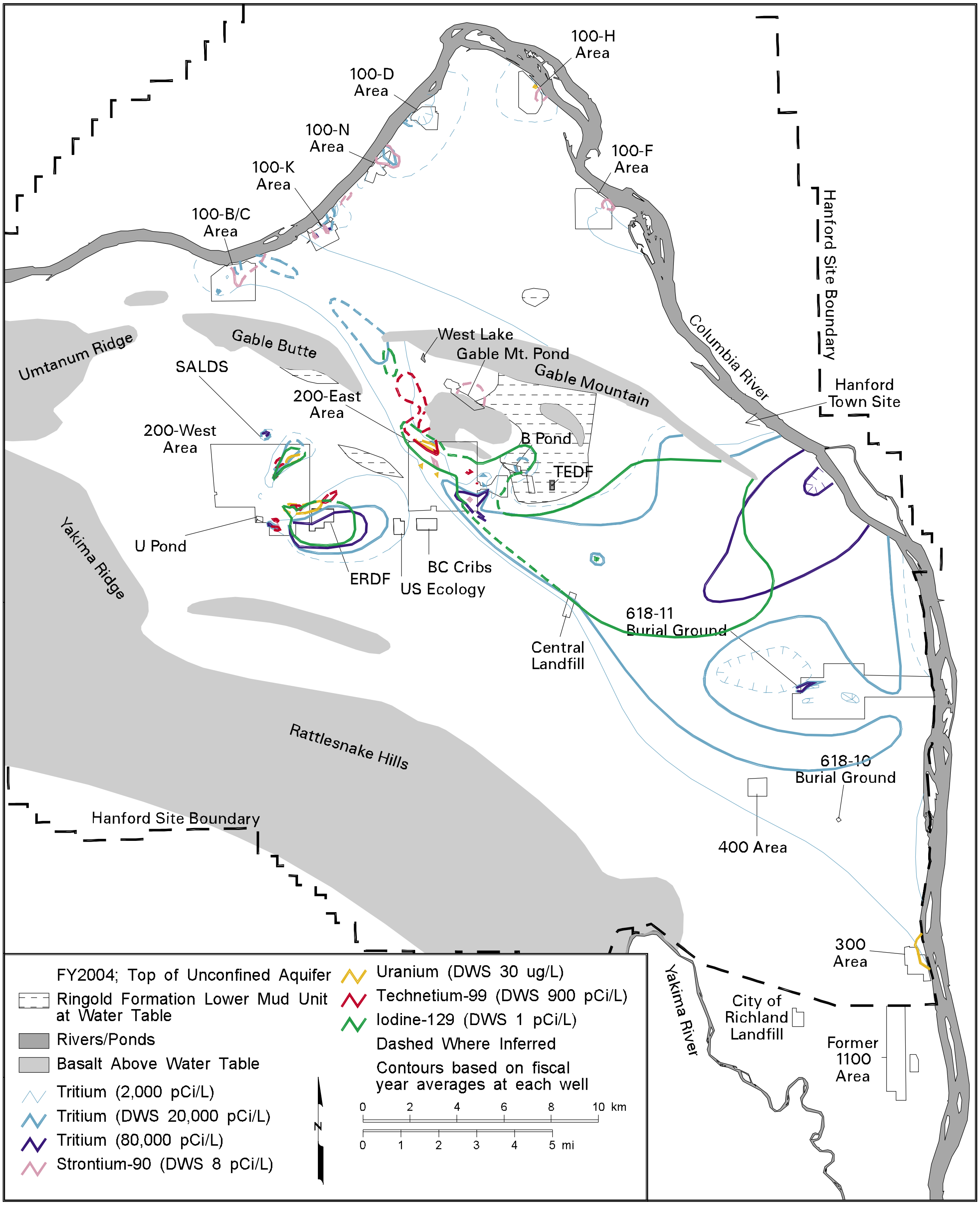
DOE's accelerated cleanup plan includes the following elements: (a) remediate high-risk waste sites, (b) shrink the contaminated area, (c) reduce recharge, (d) remediate groundwater, and (e) monitor groundwater.

Of the radionuclide plumes, tritium and iodine-129 have the largest areas where concentrations exceed drinking water standards. The dominant plumes had sources in the 200 East Area and extend toward the east and southeast. Extensive tritium and iodine-129 plumes are also present in 200 West Area. Technetium-99 exceeds standards in plumes within both the 200 East and 200 West Areas. One technetium-99 plume has moved northward from the 200 East Area. Uranium is less mobile than tritium, iodine-129, or technetium-99; plumes are found in the 200 East, 200 West, and 300 Areas. Strontium-90 is not very mobile in groundwater, but it exceeds standards in each of the 100 Areas and forms an extensive plume in 100-N Area. Other radionuclides, including cesium-137, cobalt-60, and plutonium, are even less mobile in the subsurface and exceed drinking water standards in very few wells.

Nitrate is a widespread chemical contaminant in Hanford Site groundwater; plumes originate from the 100 and 200 Areas and from offsite industry and agriculture. Carbon tetrachloride, the most widespread organic contaminant on the Hanford Site, forms a large plume beneath the 200 West Area. Other organic contaminants include chloroform, found in 200 West Area, and trichloroethene. The largest trichloroethene plume is found in 200 West Area with smaller plumes in the 100-K and 100-F Areas. Chromium contamination underlies portions of the 100-K, 100-D, and 100-H Areas. Local plumes of chromium contamination also are present in the 200 Areas, particularly the north part of 200 West Area.

Groundwater Remediation

Remedial Action Site	Startup Date	Progress From Startup to September 2004
100-K Area – 100-KR-4 Pump-and-Treat	1997	Decreases chromium to river; 244 kilograms removed.
100-N Area – 100-NR-2 Pump-and-Treat	1995	Diverts strontium-90 from river; 1.6 curies removed; ~12 curies decayed naturally.
100-D Area – 100-HR-3 Pump-and-Treat	1997	Decreases chromium to river; 199 kilograms removed.
100-D Area – 100-HR-3 In Situ Redox	1999	Decreases chromium concentrations downgradient of barrier.
100-H Area – 100-HR-3 Pump-and-Treat	1997	Decreases chromium to river; 37 kilograms removed.
200 West Area – 200-ZP-1 Pump-and-Treat	1994	Prevents high-concentration portion of carbon tetrachloride plume from spreading; 8,508 kilograms removed.
200 West Area – Soil-Vapor Extraction	1992	Prevents carbon tetrachloride movement to groundwater; 78,300 kilograms removed.
200 West Area – 200-UP-1 Pump-and-Treat	1994	Decreases migration of contaminants; 114 grams technetium-99 (2.39 curies) and 203 kilograms uranium removed.
Waste Management Area S-SX – Well 299-W23-19 Pump-and-Treat	2003	0.11 grams (0.0019 curies) of technetium-99 removed.
300 Area – 300-FF-5 Natural Attenuation	Not applicable	Average trichloroethene concentrations below target level; uranium concentrations above target level.
1100-EM-1 – Natural Attenuation	Not applicable	Average trichloroethene concentrations below 5 μg/L since 2001.



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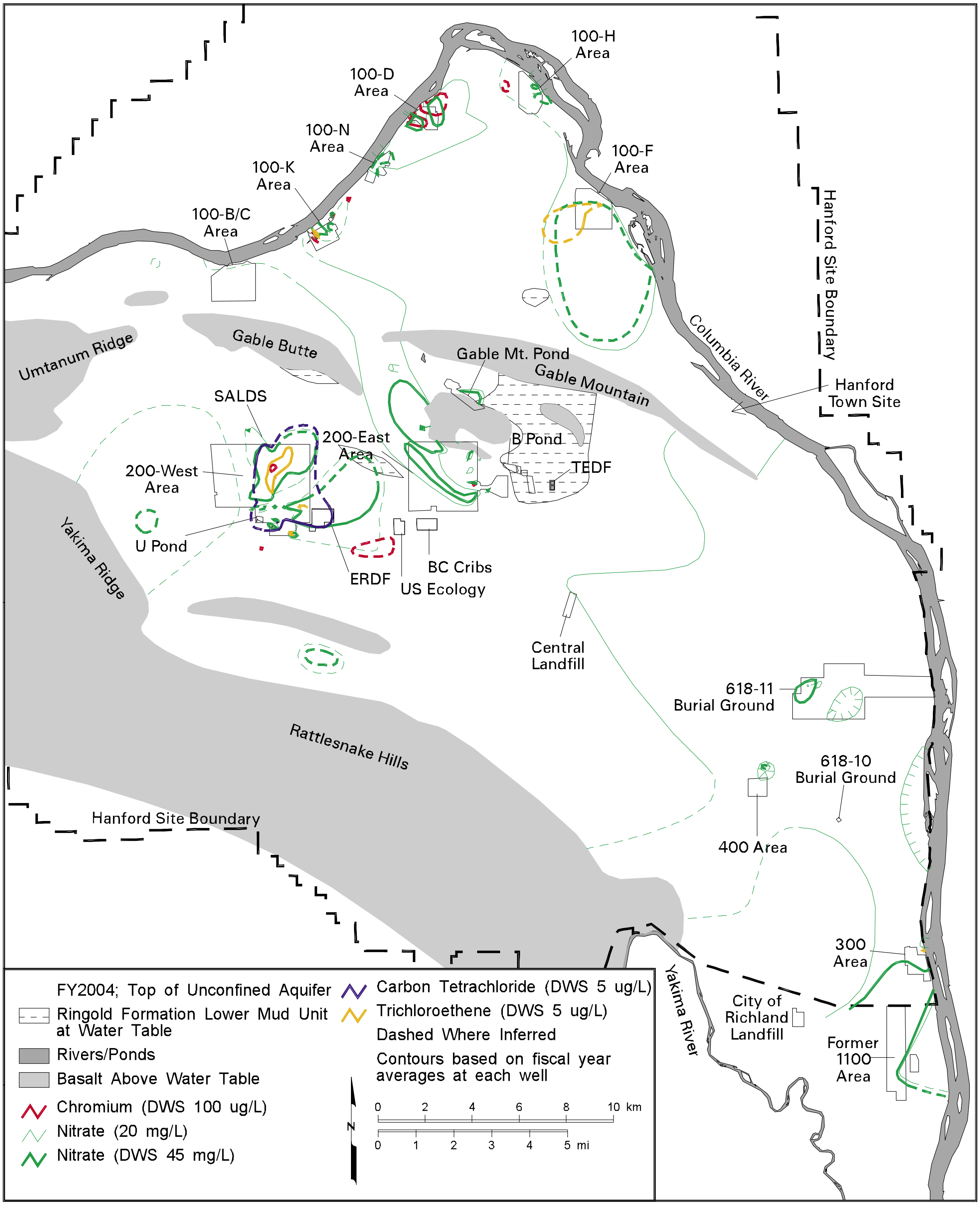
This map shows the distribution of radionuclides in groundwater at concentrations above drinking water standards during FY 2004 at the top of the unconfined aquifer.



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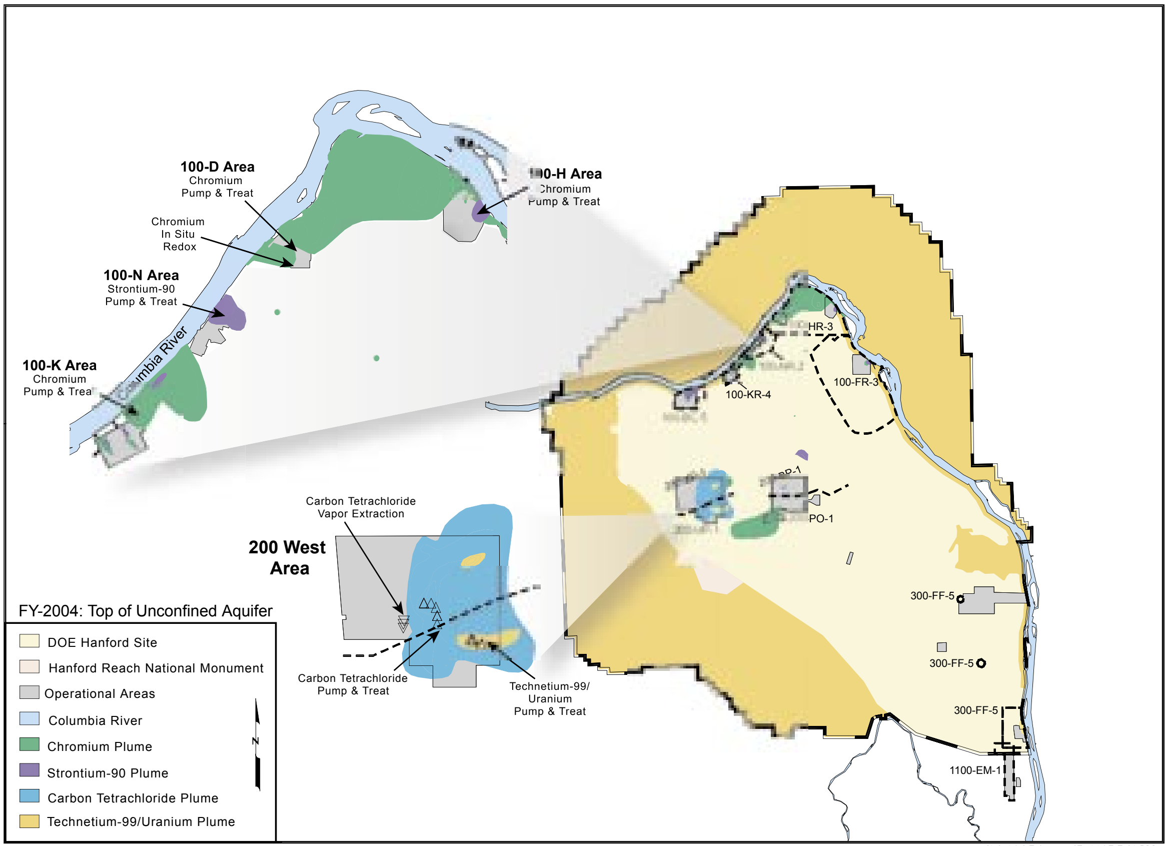
This map shows the distribution of hazardous chemicals in groundwater at concentrations above drinking water standards during FY 2004 at the top of the unconfined aquifer.



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DOE operates six pump-and-treat systems, one in situ remediation system, and one soil-gas extraction system to remove contaminants and limit their movement in groundwater and the vadose zone.

Area of Contaminant Plumes at Levels Above Drinking Water Standards (square kilometers)[a]

Constituent (drinking water standard)	Fiscal Year 2000	Fiscal Year 2001	Fiscal Year 2002	Fiscal Year 2003	Fiscal Year 2004
Carbon tetrachloride (5 μg/L)	9.8	9.9	10.0	10.6	10.9
Chromium (100 μg/L)	2.8	2.8	2.6	2.6	2.3
Iodine-129 (1 pCi/L)	89.7	79.5[b]	79.4	75.5	74.4
Nitrate (45 mg/L)	36.3	38.4	35.7	36.3	42.2[b]
Strontium-90 (8 pCi/L)	2.8	2.7	2.7	2.6	2.6
Technetium-99 (900 pCi/L)	2.3	2.4	2.3	2.3	2.4
Trichloroethene (5 μg/L)	4.2	4.3	3.4[b]	3.4	3.3
Tritium (20,000 pCi/L)	176	175	166	160	138
Uranium (20/30 μg/L)[c]	2.0	1.6	1.5	1.4	1.3
Combined Plumes	232	232	220	214	171

(a) An error in the algorithm used to compute the areas of some site plumes was discovered during preparation of this report. Area estimates in this table were corrected from those in previous annual reports where necessary.

(b) These large changes in estimates of plume area are caused by changing interpretations of the data and changes to the monitoring network. Changes in actual plume size are usually more gradual.

(c) Area of uranium plume based on 20 mg/L standard in 2000 and 30 mg/L standard in subsequent years.

The following text discusses groundwater contamination, monitoring, and remediation for each of the 11 groundwater operable units and in the confined aquifers.

100-BC-5 Operable Unit

A complete discussion of the 100-BC-5 Operable Unit can be found in Section 2.2. This operable unit includes the groundwater beneath the 100-B/C Area, located in the northwest Hanford Site. Most of the groundwater contamination is found in the north portion of the area, beneath former waste trenches and retention basins. Tritium and strontium-90 exceeded drinking water standards in several wells. Nitrate and chromium were somewhat elevated, but have been below drinking water standards in recent years.

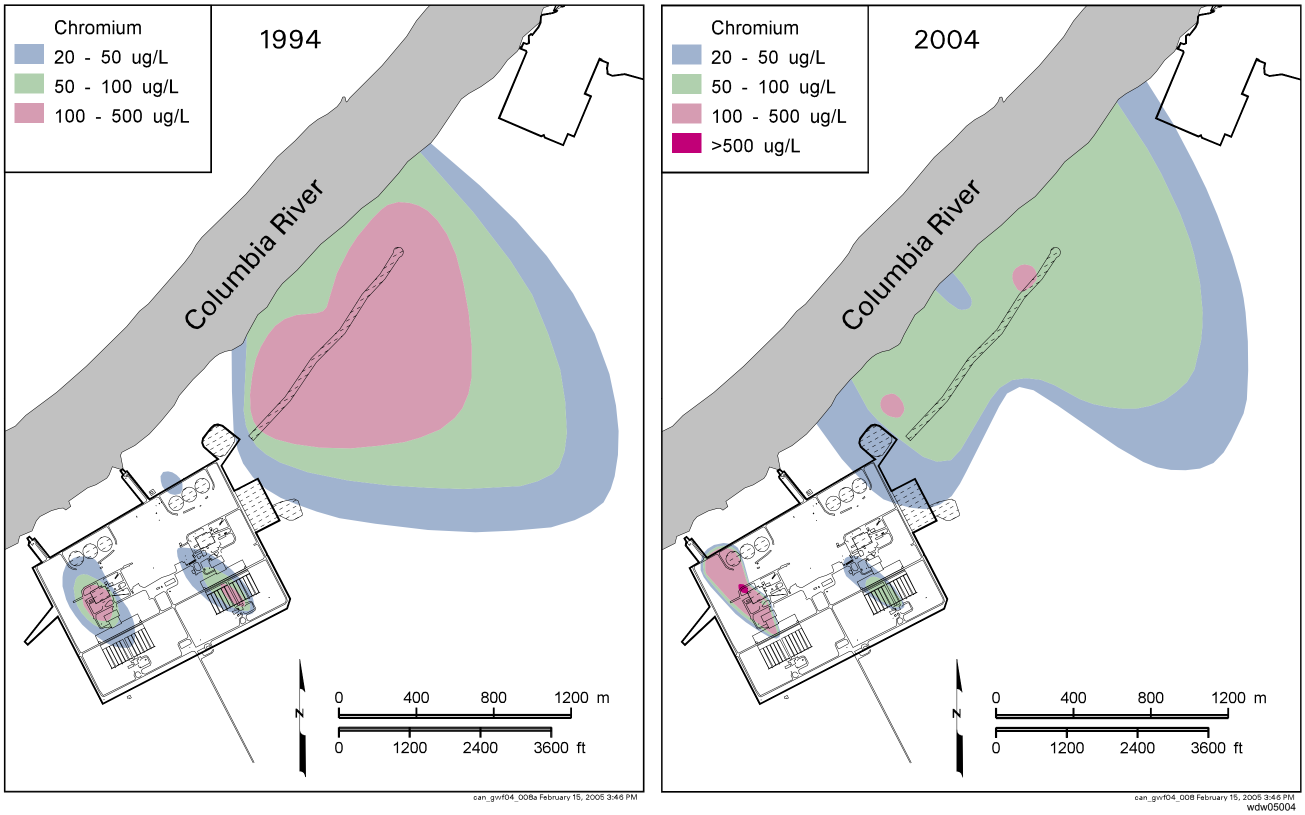
New aquifer tubes were installed in FY 2004 to improve monitoring coverage at the Columbia River shoreline. The sampling and analysis plan was revised for use in FY 2005, slightly altering the monitoring network based on data collected or interpreted after implementation of the previous plan.

A record of decision has not yet been developed for the 100-BC-5 Operable Unit, and no active remediation of groundwater is underway. Monitoring contaminant conditions has continued since the initial remedial investigation and while waste site remedial actions are conducted. A pilot-scale test ecological risk investigation was started in FY 2004, which will serve as a prototype for the other reactor areas. A focused feasibility study, which looks at remedial action alternatives for groundwater, will start in FY 2005.

DOE is planning feasibility studies in the 100-BC-5, 100-FR-3, and 300-FF-5 Operable Units to support final cleanup decisions.

100-KR-4 Operable Unit

A complete discussion of the 100-KR-4 Operable Unit can be found in Section 2.3. The principal groundwater issues in this operable unit include (a) remediation of groundwater



These maps show chromium at the top of the unconfined aquifer in the 100-K Area. A pump-and-treat system reduces the amount of chromium entering the Columbia River. Concentrations decreased in most areas since 1994.

beneath a large liquid-waste disposal trench; (b) tracking plumes from other past-practices sites; and (c) monitoring groundwater near the KE and KW Basins. Interim remedial action involves a pump-and-treat system that removes chromium from groundwater beneath the trench. Leakage detection monitoring is underway for the two basins, which are currently undergoing decontamination and decommissioning activities. New monitoring capabilities were added during FY 2004 in the form of additional aquifer tube sites along the 100-K Area shoreline. Two new groundwater wells were installed in calendar year 2004 to support the interim remedial action.

Interim Remedial Action Progress. A pump-and-treat system is being used to remove hexavalent chromium from the aquifer beneath the large infiltration trench. Approximately 244 kilograms of chromium have been removed since startup in 1997, a quantity that represents a significant proportion of the mapped plume. Although the mapped extent of contamination has remained fairly constant during the past 10 years, the area of highest concentrations has decreased markedly. The concentration goal for the interim remedial action is 22 µg/L in groundwater near the Columbia River.

Monitoring Past-Practices Waste Sites. Other contaminants of potential concern in the operable unit are tritium, carbon-14, nitrate, strontium-90, trichloroethene, and tritium. These contaminants are associated with waste disposal and facility operations that occurred during the reactor years (1955 to 1971). While levels remain above drinking water standards, risks to the river ecosystem are deemed low; decisions regarding remedial actions have been deferred until source remedial actions are complete. Some recent variability in contaminant concentrations is believed to be caused by remobilization of contaminants held in the vadose zone, because of infiltrating water from the ground surface, or possibly because of activities associated with remedial actions (e.g., excavation) of waste sites.

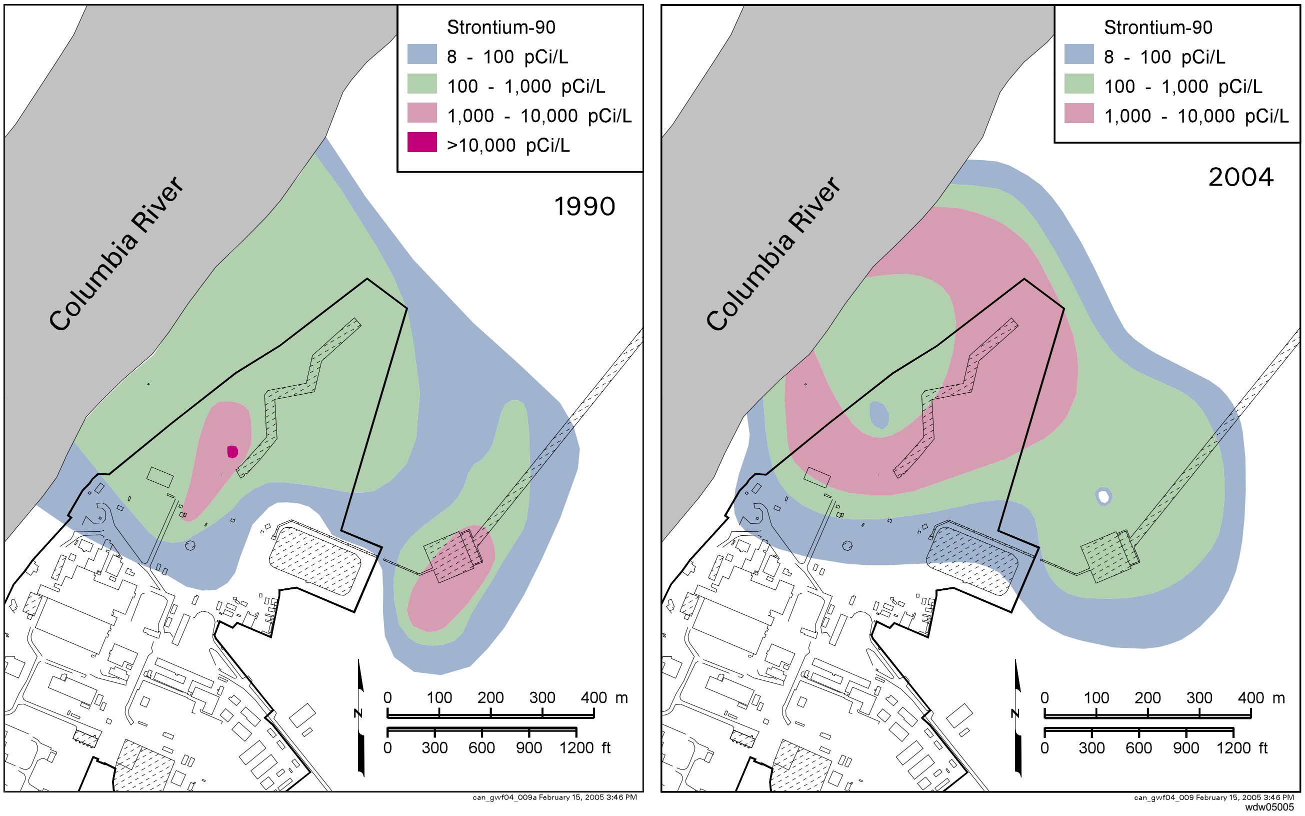
K Basins. The KE and KW Basins are integral parts of each reactor building. Since the late 1970s, they have been used to store irradiated fuel from the last run of N Reactor, as well as miscellaneous fuel fragments recovered from cleanup at other reactor areas. The Spent Nuclear Fuels Project completed removal, repackaging, and transport of all fuel from the basins to Central Plateau storage in fall 2004 and is now engaged in removing the highly contaminated sludge from the basin floors. Groundwater monitoring is conducted to help detect and evaluate any potential loss of water from the basins to the ground, because the remaining shielding water is also highly contaminated with radionuclides. The last well-documented leakage of shielding water occurred in 1993 from a construction joint associated with the KE Basin. There has been no documented leakage from KW Basin.

Pump-and-treat technology is not an effective way to clean up strontium-90 contamination. DOE, regulatory agencies, and stakeholders are investigating alternative methods.

100-NR-2 Operable Unit

A complete discussion of the 100-NR-2 Operable Unit can be found in Section 2.4. The primary groundwater contaminant in the 100-N Area is strontium-90, which originated at two liquid waste disposal cribs. The extent of the plume has changed little in over 12 years; however, concentrations increased during the 1990s because of changing water levels caused by fluctuating Columbia River levels. Tritium also was present in waste discharged to the 100-N Area cribs. Tritium concentrations in groundwater are declining, and the plume is shrinking. Nitrate, sulfate, and petroleum hydrocarbons also are present in 100-N Area groundwater.

Interim Remedial Action. A pump-and-treat system in the 100-N Area operates as a CERCLA interim action to reduce the movement of strontium-90 toward the Columbia River. Since strontium-90 binds to sediment grains, pump-and-treat technology is not an effective way to clean up the aquifer. Concentrations remained far above the drinking water standard in FY 2004. The system creates a hydraulic barrier to flow, thereby decreasing groundwater flow into the Columbia River. DOE is investigating alternative methods for remediation of the strontium-90 plume: phytoremediation (plants) and a permeable reactive barrier in the aquifer. In anticipation of applying the new methods, DOE increased sampling



Concentrations of strontium-90 in some parts of the 100-N Area increased after 1990, but the overall shape of the plume at the top of the aquifer remained about the same in 2004.

frequency beginning in FY 2004 and installed three new monitoring wells and new aquifer tubes along the 100-N Area shoreline to collect baseline data.

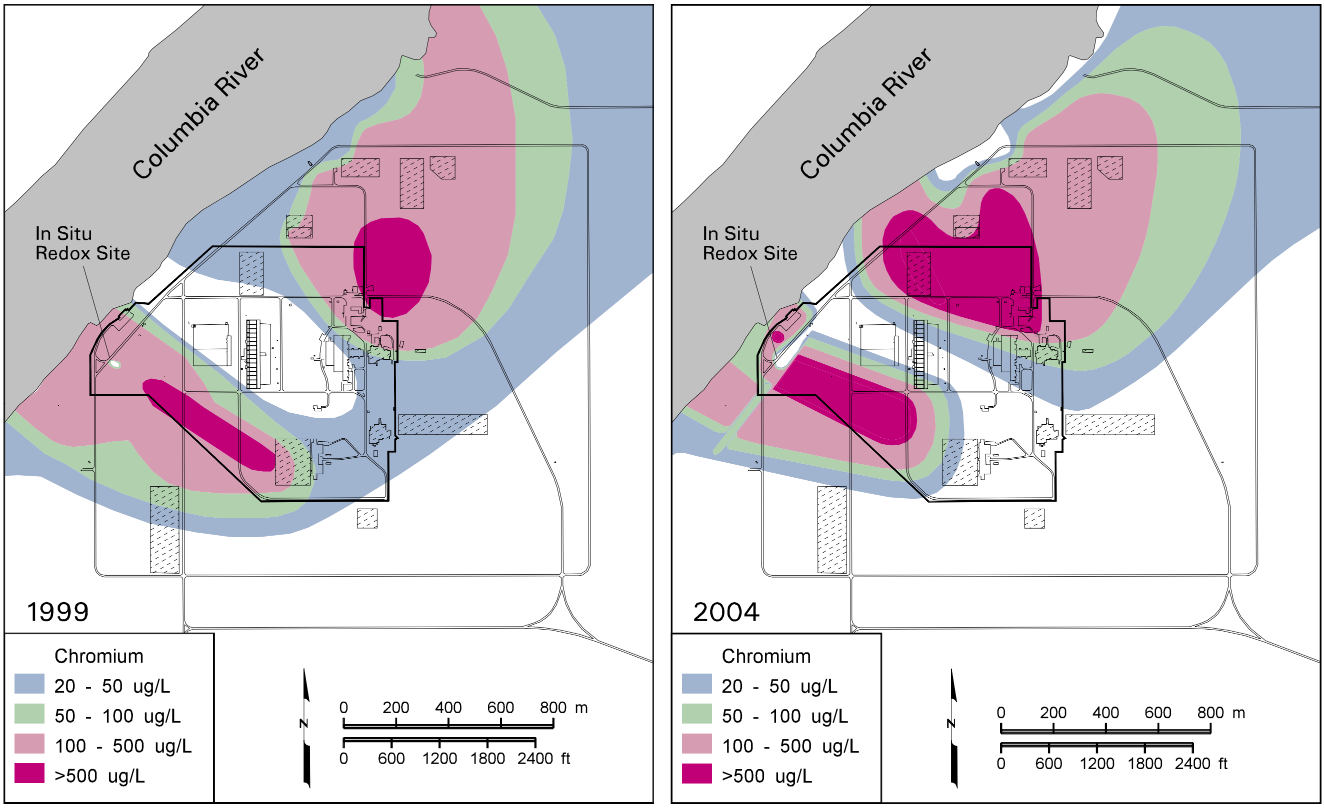
116-N-1, 116-N-3, 120-N-1, and 120-N-2 (1301-N, 1325-N, 1324-N/NA) Facilities. Four RCRA units are located in the 100-N Area. During FY 2004, the sites remained in detection monitoring programs. AEA monitoring continued to track strontium-90 and tritium plumes from the 116-N-1 and 116-N-3 facilities and sulfate from the 120-N-1 pond.

100-HR-3-D Operable Unit

The 100-HR-3 Operable Unit underlies the 100-D and 100-H Areas and the region between. Hexavalent chromium is the primary contaminant of concern in the 100-D Area (100-HR-3-D), which comprises the west part of the operable unit. A complete discussion of the 100-HR-3-D Operable Unit can be found in Section 2.5. The source of this contaminant was sodium dichromate added to reactor cooling water to inhibit corrosion, which was discharged to cribs and ditches. Chromium is distributed in two plumes. Other contaminant plumes include tritium, nitrate, and sulfate.

Interim Remedial Actions. The north chromium plume is the target of a pump-and-treat system, which is designed to reduce the amount of chromium entering the Columbia River. In FY 2004, concentrations remained above the remediation goal (22 µg/L) in compliance wells. DOE installed a second pump-and-treat system in FY 2004 to intercept groundwater in the central 100-D Area near the shoreline, where chromium concentrations had increased in recent years. The southwest chromium plume is being remediated with an in situ system that immobilizes chromium in the aquifer. Chromium concentrations downgradient of the remediation system have declined in some wells and aquifer tubes, but levels remained above

Chromium concentrations increased in the central 100-D Area in recent years, so DOE installed a new pump-and-treat system in FY 2004 to cover the central region.



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These maps show chromium plumes at the top of the aquifer in the 100-D Area. To decrease the amount of chromium entering the Columbia River, DOE operates two pump-and-treat systems in the north and an in situ treatment system in the south. One of the pump-and-treat systems was added in FY 2004.

the remediation goal (20 µg/L). Three new wells and new aquifer tubes were installed in 2004 to support the interim remedial actions.

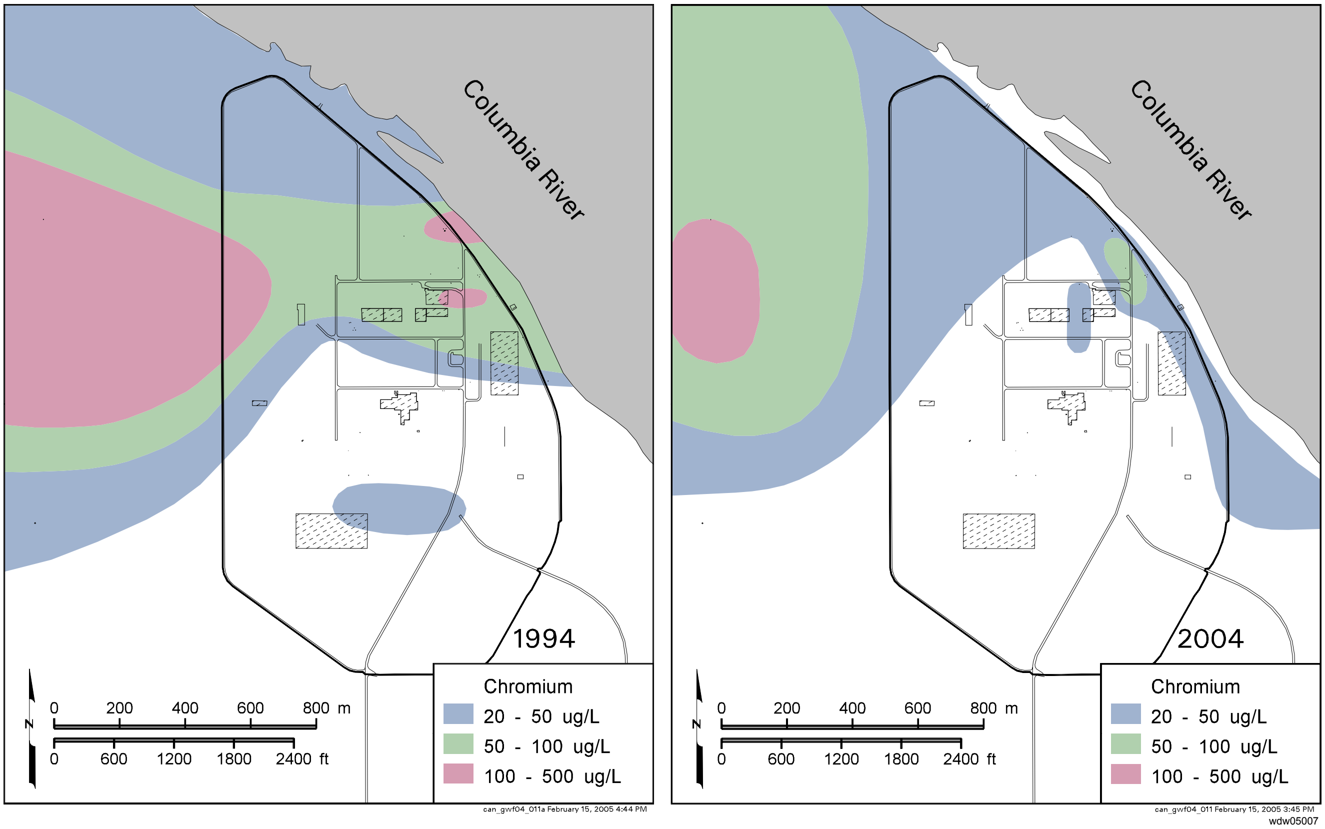
Chromium Sensor. DOE deployed a chromium sensor on the 100-D Area shoreline in FY 2004. The purpose of the deployment was to demonstrate the efficacy of such a system in the field. The system can measure chromium concentrations in monitoring wells and aquifer tubes at more frequent intervals than is practical using manual sampling techniques, and can record and report results immediately. Results of the limited deployment showed that sensors are suitable for shoreline monitoring at the Hanford Site.

100-HR-3-H Operable Unit

The east part of the 100-HR-3 Operable Unit (100-HR-3-H) underlies the 100-H Area. A complete discussion of the 100-HR-3-H Operable Unit can be found in Section 2.6. Hexavalent chromium is the primary constituent of concern, but the plume is smaller and concentrations are lower than in the 100-D Area. Nitrate also is elevated, but concentrations have declined from their peak levels. Strontium-90 exceeds the drinking water standard beneath former retention basins. Technetium-99 and uranium are elevated in a small area.

Chromium concentrations in 100-H Area have declined due to remediation and natural processes.

Interim Remedial Action. The chromium plume is the target of a pump-and-treat system. Chromium concentrations have decreased in recent years due to remediation and natural processes. However, concentrations in some compliance wells remained above the remediation goal (22 µg/L). New aquifer tubes were installed in 2004 to improve monitoring coverage along the 100-H Area shoreline.



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A pump-and-treat system in the 100-H Area reduces the amount of chromium entering the Columbia River. Between 1994 and 2004, concentrations at the top of the aquifer decreased through most of the plume. The decrease is the result of remediation and natural processes.

116-H-6 (183-H) Evaporation Basins. These former basins comprise the only RCRA site in the 100-H Area. Leakage from the basins contaminated groundwater with chromium, nitrate, and the non-RCRA regulated constituents, technetium-99 and uranium. The site is monitored during the post-closure period to track contaminant trends during the operation of the CERCLA interim action for chromium.

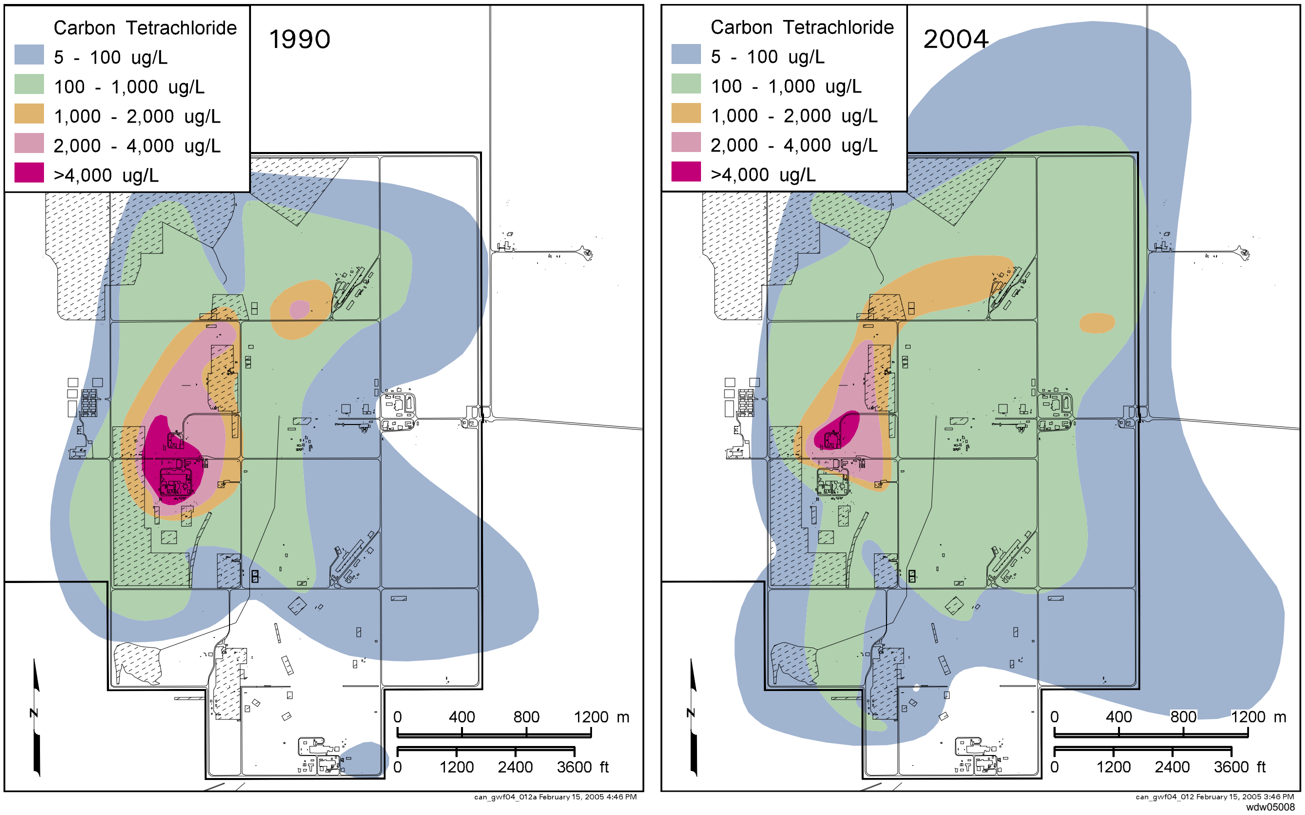
Bioremediation Research. DOE conducted field tests near the 100-H Area in FY 2003 and 2004 to demonstrate the feasibility of a remediation technology to immobilize hexavalent chromium in the aquifer. Researchers identified several types of bacteria in the sediment, including species that are known to reduce or sorb hexavalent chromium. The natural microbial population is likely insufficient for direct chromium reduction, but the population was successfully stimulated during the field tests.

100-FR-3 Operable Unit

A complete discussion of the 100-FR-3 Operable Unit can be found in Section 2.7. Nitrate exceeds the drinking water standard beneath much of the 100-F Area and the downgradient region. Other groundwater contaminants include strontium-90 and trichloroethene.

New aquifer tubes were installed in FY 2004 to improve monitoring coverage at the Columbia River shoreline. The sampling and analysis plan was revised for use in FY 2005, slightly altering the monitoring network based on data collected or interpreted after implementation of the previous plan.

A record of decision has not yet been developed for the 100-FR-3 Operable Unit, and no active remediation of groundwater is underway. Monitoring contaminant conditions



These maps show the carbon tetrachloride plume beneath the 200 West Area at the top of the unconfined aquifer. The edges of the plume spread between 1990 and 2004. Since 1996, a pump-and-treat system in the 200-ZP-1 Operable Unit is helping prevent further spreading of the core of the plume, shown here in pink and red. The system is being expanded to capture the portion of the plume shown in yellow that has appeared north of the existing system.

has continued since the initial remedial investigation and while waste site remedial actions are conducted. A focused feasibility study, which looks at remedial action alternatives for groundwater, will start in FY 2005.

200-ZP-1 Operable Unit

A complete discussion of the 200-ZP-1 Operable Unit can be found in Section 2.8. This operable unit encompasses the north portion of the 200 West Area. The primary contaminant of concern is carbon tetrachloride, which forms the largest plume of chlorinated hydrocarbons on the Hanford Site. The carbon tetrachloride contamination had sources associated with waste disposal from the Plutonium Finishing Plant, where organic chemicals were used to process plutonium. Trichloroethene and chloroform also are associated with this plume. Other contaminants in the 200-ZP-1 Operable Unit include tritium, nitrate, chromium, fluoride, iodine-129, technetium-99, and uranium.

Carbon tetrachloride has migrated vertically and laterally farther than expected. The distribution of carbon tetrachloride is complex because it may travel as a dense, non-aqueous phase liquid, in the gaseous state, and dissolved in water. Most wells in the 200 West Area are completed at the top of the aquifer, but in recent years, DOE has begun to study carbon tetrachloride deeper in the aquifer. In FY 2004, depth-discrete data collected during drilling of a well in east-central 200 West Area showed carbon tetrachloride concentrations of 32 μg/L near the water table and 1,300 μg/L at the bottom of the unconfined aquifer. Samples collected from the Ringold confined aquifer had lower concentrations, declining to 132 μg/L

A pump-and-treat system prevents the spread of the high-concentration portion of the carbon tetrachloride plume beneath the 200-ZP-1 Operable Unit.

at the top of basalt. Similar distribution with depth has been observed in other wells, but not ubiquitously. DOE will continue to study the nature and extent of carbon tetrachloride contamination.

The 200-ZP-1 Operable Unit contains one CERCLA interim action for groundwater, one remediation system for the vadose zone, four facilities monitored under RCRA and AEA, and one state-permitted unit.

Interim Remedial Action. Since 1994, DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride from spreading. More recently, carbon tetrachloride concentrations have been detected above the remedial action goal north of the original target area. Because of these changes, plans are now underway to expand the pump-and-treat system by adding additional extraction wells. Also, concentrations near the remedial action goal have been found in the east-central 200 West Area at various depths, suggesting that additional characterization of the deeper aquifer should be performed. Four new wells were installed in 2004 to support the interim remedial action.

Soil-Vapor Extraction. Soil vapor is extracted from the vadose zone and treated to remove carbon tetrachloride. As of October 2004, ~78,300 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991.

Low-Level Burial Grounds Waste Management Areas 3 and 4. RCRA groundwater monitoring continued under interim status requirements in FY 2004. Monitoring networks for both of these waste management areas contain fewer than the optimal number of wells for groundwater monitoring because many wells have gone dry. DOE is working with Ecology to correct the deficiencies.

In June 2002, DOE submitted an application to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit. As part of the application, new groundwater monitoring wells, constituents, and statistical evaluations were proposed. Workshops with Ecology to address Ecology comments (i.e., Notice of Deficiency) on this application began in FY 2003 and continued through 2004.

Waste Management Area T. Results of RCRA assessment and AEA monitoring indicate that the waste management area probably has introduced technetium-99 and other tank waste contaminants to the uppermost aquifer in the area. Additional contamination that is likely from other facilities is present in groundwater beneath the waste management area.

Waste Management Area TX-TY. Results of RCRA assessment and AEA monitoring continued to indicate that sources in the waste management area have contaminated groundwater with chromium and other tank waste constituents. Other nearby sources of

In FY 2004, depth-discrete data collected during drilling of a well in east-central 200 West Area showed carbon tetrachloride concentrations were much higher at the bottom of the unconfined aquifer than at the top. High concentrations were not expected in that region, which is not near the contaminant sources.

Dry Monitoring Wells

Some wells that were formerly sampled for the groundwater project have gone dry as the water table declined. Most of the wells are in the 200 West Area.

Fiscal Year	200 West	200 East	Other Areas	Total
1998	2	1	2	5
1999	9	0	1	10
2000	12	2	1	15
2001	7	0	1	8
2002	12	1	1	14
2003	6	2	3	11
2004	7	1	4	12
Total	**55**	**7**	**13**	**75**

Number of Wells for RCRA Statistical Comparisons, End of FY 2004

Some RCRA sites have insufficient monitoring networks because wells have gone dry. DOE is working with regulatory agencies to determine priorities for installing new wells for RCRA and CERCLA.

Site	Downgradient	Upgradient	Comments
Liquid Effluent Retention Facility	1	1	Unconfined aquifer too thin to monitor.
Low-Level Waste Management Area 2	7	2	No unconfined aquifer in north part of waste management area.
Low-Level Waste Management Area 3	4	2	Upgradient wells to be redesignated in FY 2005.
Low-Level Waste Management Area 4	0	3	
216-S-10 Pond and Ditch	2	0	
216-U-12 Crib	2	0	In assessment.

contamination make source determinations uncertain for some contaminants. Technetium-99, iodine-129, nitrate, and tritium are elevated in groundwater beneath the area.

State-Approved Land Disposal Site. This active disposal facility is regulated under a state waste discharge permit. Groundwater is monitored for tritium and 15 other constituents. Concentrations did not exceed permit enforcement limits during FY 2004.

200-UP-1 Operable Unit

A complete discussion of the 200-UP-1 Operable Unit can be found in Section 2.9. This operable unit underlies the south portion of 200 West Area. The primary contaminants of concern are technetium-99 and uranium. Tritium, iodine-129, and nitrate plumes also have sources in this operable unit. Sources of carbon tetrachloride were within the 200-ZP-1 Operable Unit, but the contamination underlies the 200-UP-1 Operable Unit as well.

There are four facilities monitored under RCRA and AEA, one CERCLA interim action, and a CERCLA disposal site in the 200-UP-1 Operable Unit. Monitoring activities are summarized below.

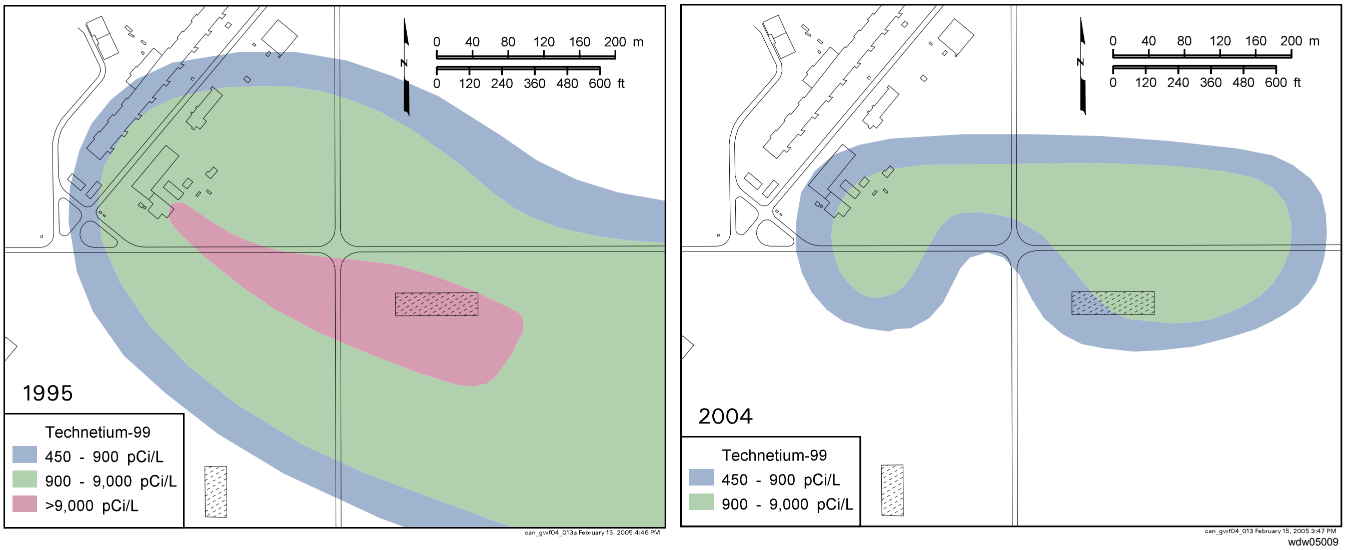
A groundwater pump-and-treat system is operating near U Plant to contain the technetium-99 and uranium plumes there. The high concentration portions of the plumes were hydraulically contained.

Interim Remedial Action. A groundwater pump-and-treat system is operating near U Plant to contain the technetium-99 and uranium plumes there. In FY 2004, concentrations in all the extraction and monitoring wells were below the remediation goals. However, many of the wells monitoring this area have gone dry, so the sizes of the current plumes are uncertain. Seven new wells were installed in the 200-UP-1 Operable Unit in calendar year 2004.

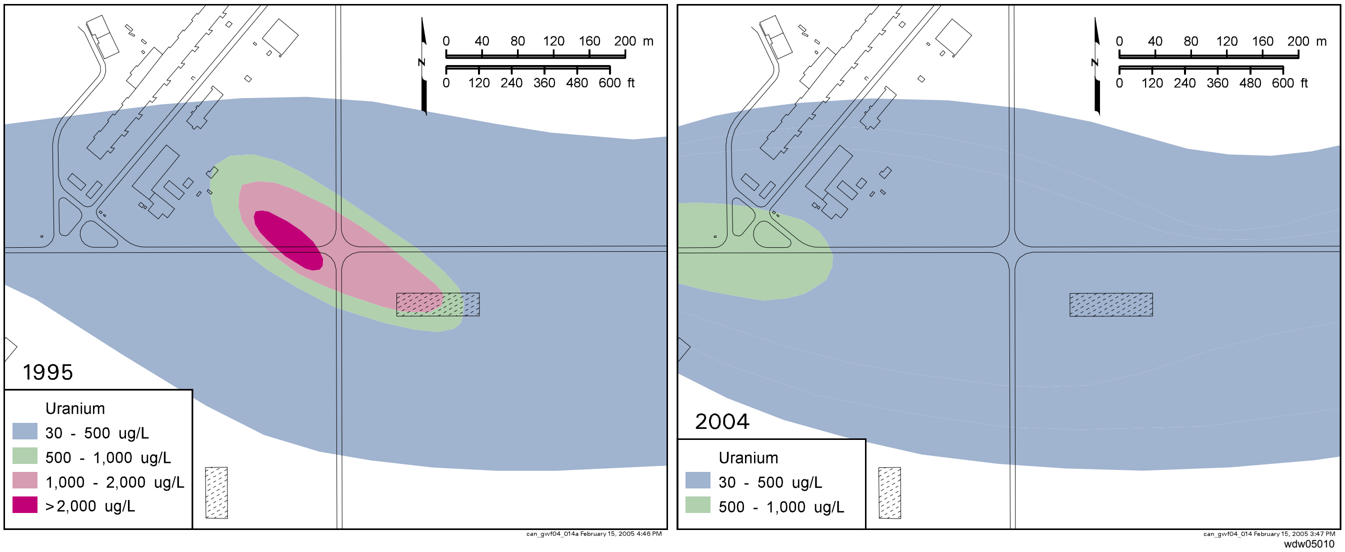
Waste Management Area S-SX. RCRA assessment and AEA monitoring continued in FY 2004. Groundwater beneath this waste management area is contaminated with nitrate, hexavalent chromium, and technetium-99 attributed to two general source areas within the waste management area. One well with very high technetium-99 concentrations continued to be purged at least 3,785 liters after each quarterly sampling event, as Ecology requested in FY 2003.

Waste Management Area U. RCRA assessment and AEA monitoring continued in FY 2004. The waste management area has been identified as the source for a small contaminant plume that is limited to the downgradient (east) side of the site. Plume constituents of interest include chromium, nitrate, and technetium-99. One new well was installed at this waste management area in 2004.

216-U-12 Crib. RCRA assessment and AEA monitoring continued in FY 2004. The crib is one of several sources that have contributed to nitrate and technetium-99 plumes in the area. Closure of the crib will be coordinated between RCRA and CERCLA. The monitoring network contains just two useable downgradient wells and no upgradient wells because other wells have gone dry.



A pump-and-treat system at the 200-UP-1 Operable Unit (200 West Area) has decreased the size of the technetium-99 plume at the top of the aquifer. The system began to operate in fall 1995. DOE plans to conduct a rebound study in FY 2005.



Uranium contamination in the 200-UP-1 Operable Unit (200 West Area), although now below the remedial action goal, did not respond to the pump-and-treat system as quickly as the technetium-99. Unlike technetium-99, uranium interacts with sediment grains, slowing its movement and response to remediation.

216-S-10 Pond and Ditch. The 216-S-10 facility continued to be monitored under a RCRA interim status detection program in FY 2004. The current RCRA monitoring network consists of only two downgradient wells because other wells have gone dry.

Environmental Restoration Disposal Facility. This facility is a low-level, mixed waste facility where waste from surface remedial actions on the Hanford Site is disposed. The site is designed to meet RCRA standards, although it is not permitted as a RCRA unit. Results of groundwater monitoring continued to indicate that the facility has not adversely impacted groundwater quality. Concentrations of gross beta and unfiltered chromium in groundwater declined from those observed in FY 2003.

200-BP-5 Operable Unit

A complete discussion of the 200-BP-5 Operable Unit can be found in Section 2.10. This operable unit includes groundwater beneath the north 200 East Area. Technetium-99 and tritium plumes extend northward between Gable Mountain and Gable Butte. Other contaminants include cesium-137, cobalt-60, cyanide, iodine-129, nitrate, plutonium, strontium-90, and uranium.

Groundwater monitoring under CERCLA continued in FY 2004. The sampling and analysis plan was revised to integrate AEA monitoring with CERCLA monitoring for FY 2005 monitoring. There is no active groundwater remediation in this operable unit and final remediation decisions are yet to be made.

There are five facilities in the 200-BP-5 Operable Unit that are monitored under RCRA and the AEA. Monitoring activities are summarized below.

Waste Management Area B-BX-BY. RCRA assessment and AEA monitoring continued at this site in FY 2004. Uranium, technetium-99, nitrate, sulfate, and nitrite contamination observed in downgradient wells is believed to be due to vertical movement of residual waste left in the soil under the tank farms. Three new wells were installed at this waste management area in calendar year 2004.

A plume containing tritium, nitrate, and technetium-99 extends from the 200 East Area to the north, as far as the Columbia River.

Waste Management Area C. This site continued to be monitored under AEA and an interim status RCRA detection program in FY 2004. RCRA indicator parameters did not exceed critical mean values. However, technetium-99 and nitrate are elevated in groundwater beneath the waste management area and may have originated in the tank farm.

216-B-63 Trench. This site continued to be monitored under an interim status RCRA detection monitoring program. The average value for total organic carbon in one downgradient well was higher in April 2004 than in previous samples. However, the value was below the limit of quantitation (1,520 µg/L), so the results did not trigger assessment monitoring. The well was sampled in October 2004 and no total organic carbon was detected (<390 µg/L).

Low-Level Waste Management Areas 1 and 2. These sites continued to be monitored under RCRA interim status requirements and AEA. Specific conductance continued to exceed its critical mean value at Low-Level Waste Management Area 1, and total organic carbon continued to exceed its critical mean value in an upgradient well at Low-Level Waste Management Area 2. However, both exceedances were reported previously and neither appears to indicate contamination from the burial grounds. Most wells in the north part of Low-Level Waste Management Area 2 are dry, and the water table has dropped below the top of basalt.

In June 2002, DOE submitted an application to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit. As part of the application, new groundwater monitoring wells, constituents, and statistical evaluations are proposed. Workshops with Ecology to address comments (i.e., Notice of Deficiency) on this application began in FY 2003 and continued through 2004.

Liquid Effluent Retention Facility. A 2001 letter from Ecology directed DOE to discontinue statistical evaluation of groundwater sample results because all but two wells have gone dry and a 1999 variance to allow DOE to operate the remaining network expired. DOE has continued to sample the two remaining wells but is not conducting statistical analyses of the results. DOE and Ecology are pursuing an agreement for permit conditions for environmental monitoring.

200-PO-1 Operable Unit

A complete discussion of the 200-PO-1 Operable Unit can be found in Section 2.11. This operable unit encompasses the south portion of the 200 East Area and a large portion of the Hanford Site extending to the east and southeast that is contaminated with plumes of tritium, nitrate, and iodine-129. Concentrations of tritium continued to decline as the plume attenuates naturally due to radioactive decay and dispersion. Other contaminants include strontium-90 and technetium-99, but these are limited to very small areas.

CERCLA groundwater monitoring continued in FY 2004. There is no active groundwater remediation in this operable unit and final remediation decisions are yet to be made.

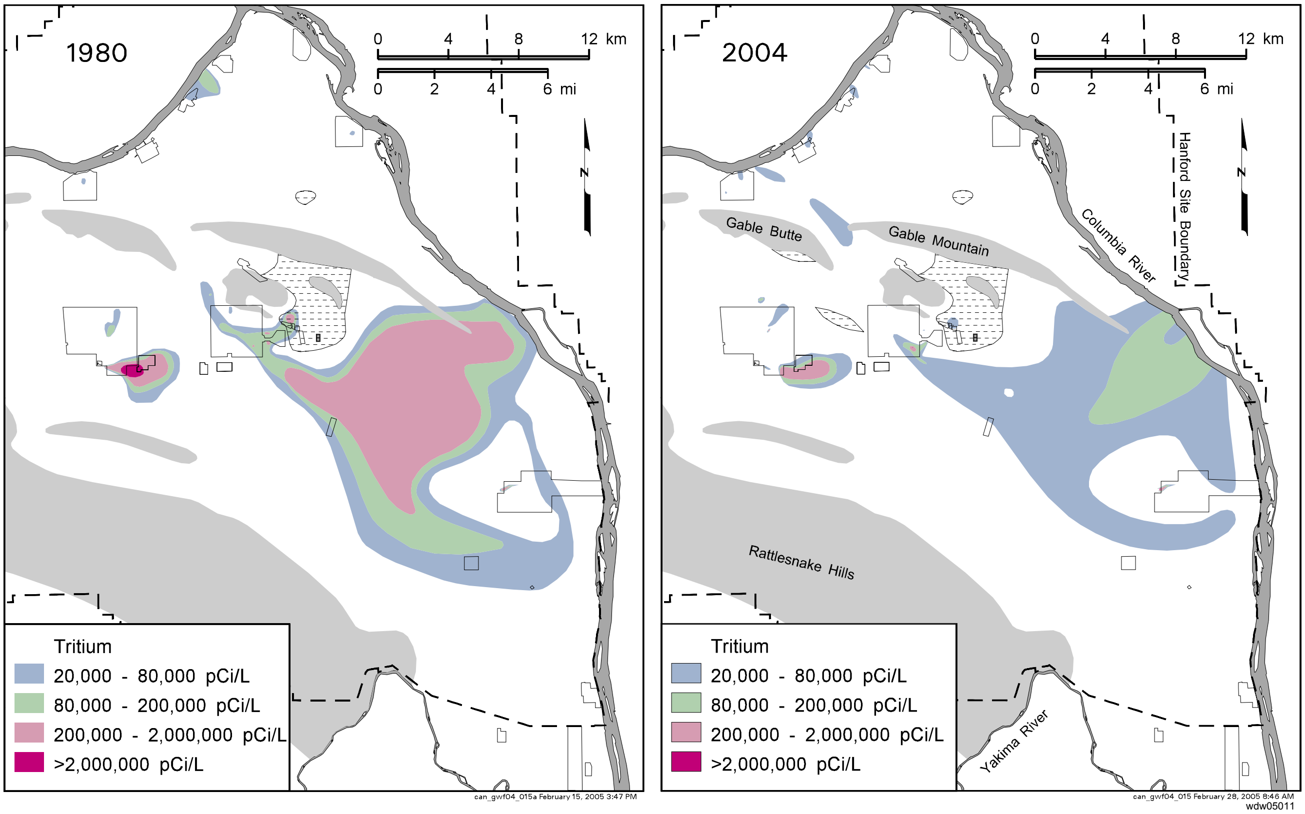
There are eight regulated units in the 200-PO-1 Operable Unit. Water supply wells in the 400 Area, which falls within the footprint of the 200-PO-1 Operable Unit, also are monitored.

Tritium concentrations generally are decreasing southeast of the 200 East Area.

Integrated Disposal Facility. This planned facility will be an expandable, lined, RCRA-compliant landfill. The groundwater monitoring network will consist of three upgradient wells and five downgradient wells. Three wells remain to be installed; two will be installed in FY 2005; the third will be installed at a future date when required by facility expansion.

PUREX Cribs. Three cribs (216-A-10, 216-A-36B, and 216-A-37-1) are monitored jointly under a RCRA interim status assessment program and AEA. The cribs have contributed to widespread contaminant plumes in the area, including nitrate, tritium and iodine-129. The nitrate and tritium plumes are generally attenuating throughout most of their area. However, in recent years the concentration of nitrate in near-field wells at the PUREX cribs has either held steady or increased.

Waste Management Area A-AX. This site continued to be monitored under a RCRA interim status indicator evaluation program and AEA in FY 2004. In FY 2004, one additional upgradient well and a replacement downgradient well were installed. Two downgradient wells formerly monitored for this site were decommissioned after it was confirmed with a borehole



These maps show site-wide tritium plumes at the top of the unconfined aquifer in 1980 and 2004. Concentrations in the core of the plume have decreased over the years; the south margin has ceased its southward migration.

video survey that each well suffered from extensive corrosion of the casing. FY 2004 data from a downgradient well installed in FY 2003 showed elevated nitrate and technetium-99. DOE is conducting additional studies to determine if the cause of the contamination is the waste management area.

Two wells at Waste Management Area A-AX were taken out of use because the casings were corroded.

216-A-29 Ditch. The groundwater beneath this site continued to be monitored as required by RCRA interim status detection regulations. Except for specific conductance, RCRA indicator parameters in downgradient wells did not exceed critical mean values in FY 2004. Specific conductance exceeded its critical mean value in three downgradient wells as groundwater quality returns to ambient conditions in response to the cessation of effluent disposal at B Pond. Groundwater quality beneath the ditch closely resembles regional patterns.

216-B-3 Pond. Monitoring for this site returned to a conventional RCRA interim status detection monitoring program in FY 2004. This change marked the end of a trial period for an alternate approach to groundwater monitoring and statistical analysis at the site.

200 Area Treated Effluent Disposal Facility. A state waste discharge permit governs groundwater sampling and analysis in the three monitoring wells at this facility. No permit criteria for constituents in groundwater were exceeded in FY 2004. The groundwater monitoring network continues to show that effluent from the facility is not taking a direct route to the uppermost aquifer, which is confined.

Nonradioactive Dangerous Waste Landfill. This RCRA site is located in the 600 Area, within the footprint of the 200-PO-1 regional plume. Interim status detection monitoring continued FY 2004.

Solid Waste Landfill. This facility is adjacent to the Nonradioactive Dangerous Waste Landfill and is regulated under state solid waste regulations. In FY 2004, temperature, specific conductance, pH, total organic carbon, chemical oxygen demand, chloride, sulfate, and coliform bacteria exceeded their background threshold levels in one or more samples.

400 Area Water Supply Wells. Three water supply wells provide drinking water and emergency supply water for the 400 Area. Because the 400 Area lies in the path of the site-wide tritium plume, the wells are routinely monitored for tritium. The main water supply well is completed deep in the unconfined aquifer and has low tritium values. Two backup wells are shallower and have higher tritium levels, but tritium concentrations in all samples were below the drinking water standard in FY 2004.

300-FF-5 Operable Unit

Uranium beneath the 300 Area has persisted above drinking water standards longer than expected. DOE is supporting detailed investigations of plume behavior and remedial action alternatives.

A complete discussion of the 300-FF-5 Operable Unit can be found in Section 2.12. This operable unit includes three geographic subdivisions: the 300 Area, the 618-11 burial ground region, and the 316-4 cribs/618-10 burial ground region (the latter two regions are referred to as "300-FF-5 North"). The operable unit is currently regulated under a record of decision that calls for continued monitoring of groundwater conditions and institutional controls on the use of groundwater as an interim action, until source remedial actions are complete. The operable unit includes groundwater associated with a former liquid waste disposal site; that groundwater is also regulated under a RCRA final status, corrective action monitoring program.

Status of Interim Remedial Actions. Contaminants of concern in 300 Area groundwater are uranium, trichloroethene, and cis-1,2-dichloroethene. Monitoring and plume characterization activities indicate relatively constant or gradually decreasing levels for these contaminants. Uranium is the primary contaminant of concern and remains above the drinking water standard beneath approximately half of the 300 Area. The decrease in concentrations predicted by modeling during the initial remedial investigation has not occurred as expected, so DOE has supported additional investigation of natural processes that lead to reduced concentrations, as well as more detailed groundwater modeling. An update to the focused feasibility study for remedial action alternatives for uranium is also underway. The new information developed by these activities will be used to guide future remedial action decisions.

Groundwater downgradient of the 618-11 burial ground is contaminated by a high-concentration tritium plume, whose origin is believed to be irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased since maximum values in 2000, but are still the highest observed on the Hanford Site. Continued characterization and modeling are underway to predict the future movement of the narrow plume, which extends ~1 kilometer to the east of the waste site.

At the 316-4 cribs/618-10 burial ground waste sites, uranium and tributyl phosphate are contaminants of potential concern; both are associated with the 316-4 cribs, which were removed during fall 2004. Current concentrations of uranium in the area are generally below the drinking water standard, although there is some suggestion that excavation activities may have remobilized vadose zone contamination. Tributyl phosphate has been undetected in recent samples. There is no evidence for impacts to groundwater caused by releases from the 618-10 burial ground.

316-5 Process Trenches. This liquid waste disposal site was the last in the 300 Area to receive uranium-bearing effluent, with discharges ending in the early 1990s. The trenches have undergone two phases of remedial action (1991 and 1995), which included removal of contaminated soil and operational structures, and backfilling with clean soil. Uranium currently exceeds the drinking water standard in wells downgradient from the waste site, although concentrations appear to be decreasing with time. Cis-1,2,dichloroethene exceeds the standard at only one downgradient well.

In some areas, DOE and the regulatory agencies agree that natural processes will clean up groundwater contamination. This approach is being applied in the 1100-EM-1 Operable Unit, and trichloroethene concentrations continued to be below the cleanup level.

1100-EM-1 Operable Unit

A complete discussion of the 1100-EM-1 Operable Unit can be found in Section 2.13. This operable unit is in the south part of the Hanford Site. Trichloroethene is the primary contaminant of concern. Contaminants also flow into the area from offsite sources (e.g., nitrate from agriculture and industry).

Selected Remedial Action. The final remedy selected for 1100-EM-1 Operable Unit groundwater is monitored natural attenuation of volatile organic compounds. Average concentrations of trichloroethene have remained below the drinking water standard since FY 2001.

Wells in the city of Richland well field are monitored frequently to detect any changes in Hanford contaminants near these wells. The tritium plume from the 200 East Area has not been detected in these wells. Low levels of tritium, similar to Columbia River water, continued to be detected.

Confined Aquifers

A complete discussion of the confined aquifers can be found in Section 2.14. Although most of Hanford's groundwater contamination is in the unconfined aquifer, DOE monitors wells in deeper aquifers because of the potential for downward migration of contamination and the potential migration of contamination offsite through the basalt-confined aquifer.

The Ringold Formation confined aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of the Ringold Formation. It is confined below by basalt and above by the lower mud unit. Groundwater in this aquifer flows generally west to east in the vicinity of the 200 West Area. In the central portion of the aquifer, flow converges on the 200 East Area from the west, south, and east. Groundwater discharges from the confined aquifer into the overlying unconfined aquifer near the 200 East Area.

While effluent disposal was occurring at the B Pond system, groundwater mounding forced groundwater and any associated contamination a limited distance into the Ringold

Cyanide, nitrate, and technetium-99 were elevated in only one basalt-confined well. Contaminant migration during well construction is suspected.

Formation confined aquifer. Groundwater analyses for FY 2004 at the 200 Area Treated Effluent Disposal Facility continued to demonstrate isolation of the confined aquifer from disposal activities.

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds. Groundwater in the upper basalt-confined aquifer generally flows from west to east across the Hanford Site, up through fractures or other pathways in the confining layers, into the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Downward gradients are measured west of the 200 East Area, near B Pond, and north and east of the Columbia River.

Results of sampling basalt-confined groundwater show that tritium was detected in some wells at very low levels, while iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected. Cyanide, nitrate, and technetium-99 were elevated in one well in the north part of the 200 East Area, but contaminant migration during well construction is suspected. Contaminants on the Hanford Site have not migrated through the upper basalt-confined aquifer system to offsite sample locations south and southeast of the Hanford Site.

Well Installation, Maintenance, and Decommissioning

During FY 2004, 278 wells received maintenance and 98 were decommissioned.

A complete discussion of the well installation, maintenance, and decommissioning can be found in Chapter 5. DOE installs new wells when needed for monitoring or characterization, maintains wells to prevent or repair problems, and decommissions wells that are no longer needed. Ecology, EPA, and DOE worked together to develop a prioritized list of new wells needed to meet requirements of various groundwater monitoring regulations. During calendar year 2004, as approved via Tri-Party Agreement milestone M-24-57D, a total of 25 new wells were installed at the Hanford Site, which included 6 RCRA wells and 19 CERCLA wells. Fifty-one vadose characterization holes were installed in the 200 Areas to support remediation and decommissioned after soil sampling was complete. A total of 278 wells received maintenance, and 98 were decommissioned (filled with grout) because they are no longer needed, were in poor condition, or were in the way of remediation sites. In FY 2004, a total of 108 new aquifer tubes were installed along the shoreline of the 100 and 300 Areas.

Wells and Aquifer Tubes Installed in 2004

Site or Purpose	Number of New Wells Calendar Year 2004	Number of New Aquifer Tubes Fiscal Year 2004
100-BC-5	0	15
100-KR-4	2	18
100-NR-2	3	8
100-HR-3-D	3	14
100-HR-3-H	0	8
100-FR-3	0	12
200-ZP-1	4	0
200-UP-1	7	0
300-FF-5	0	33
Waste Management Area A-AX	2	0
Waste Management Area B-BX-BY	3	0
Waste Management Area U	1	0
Total	**25**	**108**

Modeling

Computer simulations of groundwater flow and contaminant movement help predict future conditions and assess the effects of remediation systems. A site-wide numerical model has been developed and is being improved and refined. A complete discussion of FY 2004 groundwater modeling can be found in Chapter 4. During FY 2004, the pattern of geologic facies-zones within the Hanford formation and Ringold Formation gravel units of the model has evolved in a continuing effort to improve the calibration of the model. The calibration involves adjusting the facies-zonation configuration, the hydraulic conductivities associated with the facies-zones, and the amounts of recharge to the system in an effort to match historical changes in water-table elevation and the historical movement of tritium. Changes were also made to the configuration of hydrogeologic units in the model based on new well data and reinterpretation of geological contacts at some locations.

Computer models of groundwater help predict movement of contaminants in groundwater and future groundwater conditions. This information is important in planning waste management and cleanup activities at the Hanford Site.

DOE applied the site-wide groundwater model to specific waste-site assessments in FY 2004:

- Modeling the movement of tritium disposed to the State-Approved Land Disposal Site north of 200 West Area.
- Site-wide groundwater flow and transport calculations supporting the performance assessment for the Integrated Disposal Facility and the preliminary performance assessment for closure of single-shell tank farms.
- Site-wide modeling of dissolved carbon tetrachloride migration from 200 West Area through the groundwater considering different source conditions and various degrees of sorption and natural degradation.

The System Assessment Capability is an integrated assessment tool that includes several linked computer models designed to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors. It also incorporates modules that calculate the risks to human health and the environment. During FY 2004, the System Assessment Capability was used to begin the 2004 Composite Analysis. The Composite Analysis is designed to calculate the combined impacts of all radiological waste that will be left on the Hanford Site at the time of site closure.

Local-scale simulations of the movement of dense, non-aqueous liquid (carbon tetrachloride) at the 216-Z-9 trench in the 200 West Area were performed in FY 2004. The purpose of this work was to enhance understanding of carbon tetrachloride in the subsurface beneath the trench to support remediation decisions. The modeling indicated the following results:

- The Cold Creek hydrogeologic unit has a large impact on the modeled migration of carbon tetrachloride through the vadose zone.
- The lateral extent of the modeled dense non-aqueous liquid has not moved laterally outside the footprint of the disposal facility.
- The lateral extent of the modeled vapor-phase plume was much greater than the lateral extent of the dense non-aqueous liquid.
- The vapor-phase plume caused some contamination of underlying groundwater in the model.

Vadose Zone

Subsurface source characterization, vadose zone monitoring, soil-vapor monitoring, and sediment sampling were conducted in FY 2004. The complete discussion of these activities can be found in Chapter 3.

Geophysical logging in new and existing boreholes is used for stratigraphic correlation and to detect and quantify radioactive contaminants. By comparing logs run at different times, DOE can detect whether radionuclides have moved in the vadose zone.

Remedial investigation reports were issued in FY 2004 that include the results of laboratory analyses of vadose zone samples collected in recent years from boreholes or test pits at various waste sites in the 200 Areas.

During FY 2004, DOE published the results of characterization of two boreholes placed through a 1973 tank leak in the T Tank Farm, 200 West Area. The results of the characterization were compared to characterization results obtained 10 years ago to determine whether contaminants have migrated in the vadose zone. The results were not definitive but suggest that there has been some vertical movement of nitrate and perhaps technetium-99 during the last 10 years. Also during FY 2004, samples from one borehole in the C Tank Farm were studied to characterize contaminants from a potential tank leak in the 1960s.

Borehole geophysics continued to provide vadose zone characterization data in FY 2004. Geophysical logging in new and existing boreholes is used for stratigraphic correlation and to detect and quantify radioactive contaminants. Baseline characterization logging was performed at the 216-A-27 crib, in the B/C crib area, and in the vicinity of the 216-T-6 crib. The B/C cribs area is also the subject of a remedial investigation, and the seven existing boreholes were logged to support remedial investigations.

Spectral gamma logs from 769 existing monitoring boreholes in the single-shell tank farms are used to characterize the subsurface contamination with gamma-emitting radionuclides. During FY 2004, routine monitoring activities were performed in 23 boreholes in BX, BY, C, and S Tank Farms. In general, contaminant plumes identified by baseline characterization appear to be stable over time. In FY 2004, only two boreholes (one each at C and S Tank Farms) exhibited movement to a degree that can be confirmed over a relatively short time interval. However, high-activity zones that constitute the bulk of contaminant inventory in the vadose zone are difficult to monitor over the short term because of the relative error associated with the high-rate logging system.

During waste retrieval operations at single-shell tank farms, monitoring is performed in adjacent boreholes to detect any leaks that may be associated with the retrieval operation. Both gamma activity and neutron moisture measurements are made. During 2004, retrieval operations were continued in tanks C-106 and S-112 and adjacent boreholes were logged.

Composite leachate samples from the Environmental Restoration Disposal Facility contained detectable concentrations of common metals, anions, and mobile radionuclides. Concentrations of chromium, nitrate, gross alpha, technetium-99, and uranium have been generally increasing since 2001. The facility is lined, and there is no evidence of impacts to groundwater.

Soil gas at the Solid Waste Landfill is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the reporting period.

Casing corrosion of two wells at Waste Management Area A-AX was apparently caused by chloride in the annular seal of the well and a wet sediment layer in the vadose zone.

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. As of October 2004, ~78,300 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991.

Corrosion of the stainless steel casing in two groundwater monitoring wells at Waste Management Area A-AX in the 200 East Area has made the wells unsuitable for use. The corrosion occurred above the water table, and DOE began investigating the cause in FY 2004. Analysis of sidewall core samples yielded a clear relationship between chloride concentration and well casing corrosion. The concentration of chloride in the samples was greatest at the same depth as the degraded well casing. This finding implies that the annular seal material contained the source of chloride in the sidewall core samples. Preliminary results indicate that the advanced well casing corrosion was caused by chloride-facilitated crevice corrosion and stress corrosion cracking. It is possible that the well casing was damaged during installation, which would have accelerated stress corrosion cracking. Additionally, a silt lens likely exacerbated this process by providing a continual source of moisture, which generated localized pore water with high chloride concentrations.

Continued Monitoring

DOE will continue to monitor groundwater to meet the requirements of AEA, CERCLA, RCRA, and DOE Orders. During ongoing groundwater remediation, the groundwater project will monitor, assess, and report on activities at groundwater operable units. Both the unconfined and upper-confined aquifers are monitored and data are maintained and managed in a centralized database. Monitoring well locations, frequencies, and analytical constituents will continue to be documented each year. Water-level monitoring will continue to be performed to characterize groundwater flow and to determine the impact of Hanford Site operations on the flow system.

As such, groundwater monitoring remains a part of the Hanford Site baseline throughout the cleanup mission and will remain a component of long-term stewardship after remediation is completed.

Details about groundwater monitoring on the Hanford Site can be found online at http://www.hanford.gov/cp/gpp/.

Contents

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1.0 Introduction

M. J. Hartman

The U.S. Department of Energy (DOE) has committed to a mission to protect the Columbia River from contaminated groundwater resulting from past, present, and future operations and to protect and remediate groundwater. *Hanford Site Groundwater Strategy* (DOE/RL-2002-59) focuses on three key areas: groundwater protection, groundwater monitoring, and remediation of contaminated groundwater.

One of the implementing documents for the groundwater strategy is *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection* (DOE/RL-2002-68). DOE established the Groundwater Remediation Project, managed by Fluor Hanford Inc., to implement the accelerated plan. Protection of Hanford's groundwater requires an aggressive plan to limit and control the continued migration of contaminants already in the soil and the groundwater. To do this, the Groundwater Remediation Project performs the following tasks:

- Prevent degradation of groundwater by (a) remediating high-risk waste sites, (b) shrinking the contaminated area, and (c) reducing natural and artificial recharge.
- Remediate groundwater.
- Monitor groundwater.

DOE monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the *Atomic Energy Act of 1954* (AEA), the *Resource Conservation and Recovery Act* (RCRA), the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and Washington Administrative Code. DOE manages these activities through the Groundwater Performance Assessment Project (groundwater project), which is conducted by Pacific Northwest National Laboratory. The groundwater project is under the umbrella of the Groundwater Remediation Project.

CERCLA regulates waste sites that were active before RCRA took effect. It covers sites where radioactive or hazardous waste was disposed or leaked and also requires groundwater monitoring where appropriate.

1.1 Purpose and Scope

This document presents results of groundwater monitoring to meet the requirements of AEA and RCRA sites and those CERCLA groundwater operable units where cleanup decisions have not yet been made (Table 1.1-1). This report also summarizes groundwater remediation, vadose zone monitoring and characterization, groundwater modeling, and well installation activities. Monitoring results primarily rely on data from samples collected in fiscal year (FY) 2004, i.e., October 1, 2003 through September 30, 2004.

This report is designed to meet the following objectives:

- ***Provide a comprehensive report of groundwater conditions on the Hanford Site.***
- ***Fulfill the reporting requirements of RCRA, CERCLA (for operable units where cleanup decisions have not yet been made), DOE Orders, and Washington Administrative Code.***
- ***Summarize the results of groundwater monitoring conducted to assess the effects of interim remedial actions conducted under CERCLA.***
- ***Describe the results of vadose zone monitoring, characterization, and studies.***
- ***Summarize groundwater modeling activities.***
- ***Summarize the installation, maintenance, and decommissioning of Hanford Site monitoring wells.***

Groundwater remediation and associated monitoring is the responsibility of Fluor Hanford, Inc. Vadose zone monitoring and characterization are conducted by Bechtel Hanford, Inc.; CH2M HILL Hanford Group, Inc.; Fluor Hanford, Inc.; and Pacific Northwest National Laboratory.

Background information, including descriptions of regulatory requirements, waste sites, analytical methods, regional geology, and statistics is included in a separately published companion volume, *Hanford Site Groundwater: Setting, Sources and Methods* (PNNL-13080), and in the most recent update, which was provided in PNNL-13788, Appendix C. Those changes have been incorporated into the electronic version of PNNL-13080, provided with this groundwater monitoring report.

As in previous reports, this report includes a set of electronic files that contain groundwater data for the fiscal year and previous years.

RCRA regulates facilities used to treat, store, or dispose of hazardous, non-radioactive waste. At Hanford, the law applies to sites that contained hazardous or mixed (hazardous and radioactive) waste. RCRA stipulates requirements for monitoring the groundwater beneath these sites.

1.2 Related Reports

Other reports and databases relating to Hanford Site groundwater include the following:

- Hanford Environmental Information System (HEIS) — This is the main environmental database for the Hanford Site that stores groundwater chemistry data, as well as other environmental data (e.g., soil chemistry, survey data).
- Quarterly data transmittals — DOE transmits informal reports quarterly to the Washington State Department of Ecology after groundwater data collected for the RCRA program have been verified and evaluated. These reports describe changes or highlights of the quarter with reference to HEIS for the analytical results.
- *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations* (DOE/RL-2004-21) — This report evaluates the performance of groundwater remediation systems in the 100-K, 100-N, 100-D, and 100-H Areas.
- *Fiscal Year 2003 Annual Summary Report for the In Situ Redox Manipulation Operations* (DOE/RL-2004-06) — This report describes activities related to the remediation system in the southwest 100-D Area.
- *Fiscal Year 2003 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations* (DOE/RL-2003-58) — This report evaluates the performance of groundwater remediation systems in the 200 West Area.
- *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2003* (WMP-21327) — This report describes activities related to vadose zone remediation in the 200 West Area.
- *Hanford Site Environmental Report for Calendar Year 2003* (PNNL-14687) — This annual report summarizes environmental data, including riverbank springs and river water. It also describes environmental management performance and reports the status of compliance with environmental regulations.
- *Hanford Site Climatological Data Summary 2003 with Historical Data* (PNNL-14616) — This annual report summarizes data on temperature, precipitation, and other weather conditions that may impact groundwater recharge.

Units of Measure

μg/L	micrograms per liter
μS/cm	microsiemens per centimeter
M	molar
mg/L	milligrams per liter
mm/yr	millimeters per year
mrem/yr	millirem per year
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/mg	picocuries per milligram
ppb	parts per billion
ppm	parts per million
ppmv	parts per million volume

1.3 Conventions Used in This Report

Contaminant plume maps in this report, unless specified otherwise, are based on average FY 2004 data for each well, excluding data that appear erroneous. The maps are hand-contoured by project staff based on current and historical data, source knowledge, and flow directions. The maps use data from FY 2002 and 2003 if there were no new data for a well in FY 2004. These older data, and data from aquifer tubes along the Columbia River, are given less "weight" than the current well data when the maps are contoured. The maps show data from wells completed at or near the top of the aquifer. Concentrations of most contaminants decrease with depth, but carbon tetrachloride distribution at depth may be significantly different from distribution at the top of the aquifer, as discussed in Section 2.8 of this report.

Trend plots generally include analytical results that appear to be erroneous if they do not distort the scale or obscure the data trends. If the outlying data distort the figure, they are not plotted. All of the data, with appropriate data quality flags, are included in the data files that accompany this report and are available in the HEIS database. Trend plots in this report use open symbols to show values so low the laboratory could not detect them. These results are typically reported and plotted as values that represent the detection limit.

This report uses the following conventions for chemical results:

- Text, figures, and tables express nitrate and nitrite as the NO_3^- and NO_2^- ions, respectively.
- Figures showing chromium include total chromium in filtered samples and hexavalent chromium in filtered or unfiltered samples. Dissolved chromium in Hanford Site groundwater is virtually all hexavalent (WHC-SD-EN-TI-302), so filtered total chromium represents hexavalent chromium.
- Contaminant concentrations are compared with state or federally enforceable drinking water standards (Table 1.1-2). Although Hanford Site groundwater is not generally used for drinking, these levels provide perspective on contaminant concentrations. Radionuclide concentrations also are compared with DOE derived concentration guides (Table 1.1-3).

Conversion Table

The primary units of measurement in this report are metric. To convert metric units to English units, use the information provided in this table.

Multiply	By	To Obtain
centimeters	0.394	inches
meters	3.28	feet
kilometers	0.621	miles
kilograms	2.205	pounds
liters	0.2642	gallons
square meters	10.76	square feet
hectares	2.47	acres
square kilometers	0.386	square miles
cubic meters	1.308	cubic yards
curie	3.7×10^{10}	becquerel
picocurie	0.03704	becquerel
rem	0.01	sievert
°C	(°C x 9/5) + 32	°F

Common Abbreviations

AEA	*Atomic Energy Act of 1954*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
NAVD88	North American Vertical Datum of 1988
RCRA	*Resource Conservation and Recovery Act*

Table 1.1-1. Reporting Requirements for Groundwater Monitoring

Operable Unit or Facility	Formal Report	Supplemental Reports or Summaries
	CERCLA	
Operable units without RODs (100-BC-5, 100-FR-3, 200-BP-5, 200-PO-1)	This report	Unit manager's meeting presentations
Operable units with interim RODs managed by FH (100-KR-4, 100-NR-2, 100-HR-3, 200-UP-1, 200-ZP-1)	Interim action annual reports (summarized in this report)	Unit manager's meeting presentations; this report
Operable unit with interim ROD managed by PNNL (300-FF-5)	Separate annual reports beginning FY 2005 (summarized in this report)	Unit manager's meeting presentations; this report
Operable unit with final ROD managed by PNNL (1100-EM-1)	This report	None
ERDF	Separate annual report covers groundwater and leachate (summarized in this report)	This report
	RCRA Units	
Detection sites (116-N-1 and -3, 120-N-1 and -2, 216-A-29, 216-B-63, 216-S-10, B Pond, IDF, LERF, LLBG, NRDWL, WMA A-AX, WMA C)	This report	Informal quarterly reports to Ecology
Assessment sites (216-U-12; PUREX cribs; WMAs B-BX-BY, S-SX, T, TX-TY, and U)	This report; also occasional assessment reports	Informal quarterly reports to Ecology
Corrective action sites (116-H-6, 316-5)	Semiannual letter reports to Ecology; this report	Informal quarterly reports to Ecology
	Other Facilities	
AEA sites (K Basins, 400 Area water supply wells)	This report	Quarterly reports to facility operators and DOE
SALDS (WAC 173-216)	Separate annual report	This report
TEDF (WAC 173-216)	This report	None
WAC 173-304 site (SWL)	This report for groundwater; separate report for leachate and soil gas	None

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AEA = *Atomic Energy Act of 1954*.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act*.
DOE = U.S. Department of Energy.
Ecology = Washington State Department of Ecology.
ERDF = Environmental Restoration Disposal Facility.
FH = Fluor Hanford, Inc.
FY = Fiscal year.
IDF = Integrated Disposal Facility (planned).
LERF = Liquid Effluent Retention Facility.
LLBG = Low-level burial grounds.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PNNL = Pacific Northwest National Laboratory.
PUREX = Plutonium-Uranium Extraction (Plant).
RCRA = *Resource Conservation and Recovery Act*.
ROD = Record of decision.
SALDS = State-Approved Land Disposal Site.
SWL = Solid Waste Landfill.
TEDF = Treated Effluent Disposal Facility.
WAC = Washington Administrative Code.
WMA = Waste management area.

Table 1.1-2. Drinking Water Standards

Constituent	DWS	Agency(a)
Aluminum(b)	50 to 200 µg/L	EPA, DOH
Antimony	6 µg/L	EPA, DOH
Arsenic	10 µg/L(c)	EPA, DOH
Barium	2,000 µg/L	EPA, DOH
Cadmium	5 µg/L	EPA
Carbon tetrachloride	5 µg/L	EPA, DOH
Chloride	250 mg/L(b)	EPA, DOH
Chloroform (THM)(d)	80 µg/L	EPA
Chromium	100 µg/L	EPA, DOH
cis-1,2-Dichloroethene	70 µg/L	EPA, DOH
Copper	1,000 µg/L(b)	EPA, DOH
Cyanide	200 µg/L	EPA, DOH
1,4-Dichlorobenzene	75 µg/L	EPA
Fluoride	4,000 µg/L	EPA, DOH
	2,000 µg/L(b)	EPA, DOH
Iron	300 µg/L(b)	EPA, DOH
Lead	15 µg/L(e)	EPA
Manganese	50 µg/L(b)	EPA, DOH
Mercury (inorganic)	2 µg/L	EPA, DOH
Methylene chloride	5 µg/L	EPA, DOH
Nitrate, as NO_3^-	45 mg/L	EPA, DOH
Nitrite, as NO_2^-	3.3 mg/L	EPA, DOH
Pentachlorophenol	1 µg/L	EPA, DOH
pH	6.5 to 8.5(b)	EPA
Selenium	50 µg/L	EPA, DOH
Silver	100 µg/L(b)	EPA, DOH
Sulfate	250 mg/L(b)	EPA, DOH
Tetrachloroethene	5 µg/L	EPA, DOH
Thallium	2 µg/L	EPA, DOH
Total dissolved solids	500 mg/L(b)	EPA
1,1,1-Trichloroethane	200 µg/L	EPA, DOH
Trichloroethene	5 µg/L	EPA, DOH
Zinc	5,000 µg/L(b)	EPA, DOH
Antimony-125	300 pCi/L(f)	EPA
Beta particle and photon activity	4 mrem/yr(g)	EPA, DOH
Carbon-14	2,000 pCi/L(f)	EPA
Cesium-137	200 pCi/L(f)	EPA
Cobalt-60	100 pCi/L(f)	EPA
Iodine-129	1 pCi/L(f)	EPA
Ruthenium-106	30 pCi/L(f)	EPA
Strontium-90	8 pCi/L(f)	EPA, DOH
Technetium-99	900 pCi/L(f)	EPA
Total alpha (excluding uranium)	15 pCi/L(f)	EPA, DOH
Tritium	20,000 pCi/L(f)	EPA, DOH
Uranium	30 µg/L	EPA, DOH

(a) DOH = Washington State Department of Health at WAC 246-290; EPA = U.S. Environmental Protection Agency at 40 CFR 141, 40 CFR 143, and EPA 822-R-96-001.

(b) Secondary drinking water standard.

(c) Becomes effective January 23, 2006.

(d) Standard is for total trihalomethanes (THM).

(e) Action level.

(f) Concentration assumed to yield an annual dose equivalent of 4 mrem/yr.

(g) Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

DWS = Drinking water standard.

Table 1.1-3. Derived Concentration Guides[a,b,c] and 4-mrem Effective Dose Equivalent Concentrations for Drinking Water[d]

Radionuclide	Derived Concentration Guide, pCi/L	4-mrem Effective Dose Equivalent, pCi/L
Tritium	2,000,000	80,000
Carbon-14	70,000	2,800
Cobalt-60	5,000	200
Strontium-90	1,000	40
Technetium-99	100,000	4,000
Ruthenium-103	50,000	2,000
Ruthenium-106	6,000	240
Antimony-125	60,000	2,400
Iodine-129	500	20
Iodine-131	3,000	120
Cesium-134	2,000	80
Cesium-137	3,000	120
Uranium-234	500	20
Uranium-235	600	24
Uranium-238	600	24
Plutonium-238	40	1.6
Plutonium-239	30	1.2
Plutonium-240	30	1.2
Americium-241	30	1.2

(a) Concentration of a specific radionuclide in water that could be continuously consumed at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr.

(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford Site operations, and may be adjusted upward (larger) if accurate solubility information is available.

(c) From DOE Order 5400.5.

(d) Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/yr if consumed at average annual rates. EPA drinking water standards for radionuclides listed in Table 1.1-2 were derived based on a 4-mrem/yr dose standard using maximum permissible concentrations in water specified in *National Bureau of Standards Handbook* 69 (U.S. Department of Commerce, as amended August 1963). The 4-mrem/yr dose standard listed in this table was calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (as implemented in DOE Order 5400.5 in 1993).

DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.

For additional information on contaminants that are found at the Hanford Site, see "Summary Fact Sheets for Selected Environmental Contaminants to Support Health Risk Analysis" (Peterson et al. 2002), available on the website of Environmental Assessment Division, Argonne National Laboratory (http://www.ead.anl.gov). Click on "publications" and search for the title.

2.0 Groundwater

This section discusses groundwater flow and chemistry on the Hanford Site. Section 2.1 gives a general overview of site-wide flow and plumes. Sections 2.2 through 2.13 describe groundwater for each of the groundwater interest areas/operable units. These regions are presented in geographic order (north to south, west to east). Monitoring of specific units under the *Comprehensive Environmental Response, Compensation, and Liability Act*, *Resource Conservation and Recovery Act*, or Washington Administrative Code are discussed within relevant sections. Section 2.14 describes groundwater flow and chemistry in the confined aquifers.

Waste sites, hydrogeology, and methods of sampling and analysis are described in *Hanford Site Groundwater: Settings, Sources, and Methods* (PNNL-13080).

2.1 Overview of Hanford Site Groundwater

M. J. Hartman, J. P. McDonald, and C. J. Thompson

This section provides a broad picture of groundwater flow and contaminant distribution beneath the Hanford Site. Table 2.1-1 summarizes fiscal year (FY) 2004 highlights or changes for the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) groundwater operable units, *Resource Conservation and Recovery Act* (RCRA) sites, and other regulated units and indicates where to find additional information in this report. Details for specific locations are included in Sections 2.2 through 2.14. Supporting tables and figures for sites monitored under CERCLA are compiled in Appendix A. Appendix B includes tables and figures for facilities monitored under RCRA or other regulations. Appendix C describes results of the quality control program.

Groundwater monitoring objectives of RCRA, CERCLA, and the *Atomic Energy Act of 1954* (AEA) often differ slightly, and the contaminants monitored are not always the same. For RCRA regulated units, monitoring focuses on non-radioactive dangerous waste constituents. Radionuclides (source, special nuclear and by-product materials) may be monitored in some RCRA unit wells to support objectives of monitoring under AEA and/or CERCLA. Please note that pursuant to RCRA, the source, special nuclear and by-product material components of radioactive mixed waste are not regulated under RCRA and are regulated by the U.S. Department of Energy (DOE) acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit or other RCRA regulatory requirements.

DOE monitors groundwater quality across the Hanford Site to know what contaminants are present and how they are moving.

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semiconsolidated sediment of the Hanford and Ringold Formations, which was deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are confined locally by layers of silt and clay. Confined aquifers occur within the underlying basalt and associated sedimentary interbeds.

For site characterization and cleanup, waste sites are grouped into source operable units, and the groundwater beneath the sites is divided into groundwater operable units. The formal, groundwater operable units do not include the entire Hanford Site, and in the case of the 200 Areas operable units, comprise just a single boundary line. Therefore, to provide scheduling, data review, and interpretation for the entire Hanford Site, the Groundwater Performance Assessment Project (groundwater project) has informally defined "groundwater interest areas" that generally correspond to the groundwater operable units. Figure 2.1-1 illustrates these interest areas and the operable unit boundaries.

Well location maps for each geographic region are included in Sections 2.2 through 2.14. Wells in the 600 Area (i.e., portions of the Hanford Site other than the former operational areas) are shown in Figure 2.1-2.

Groundwater is the water that fills the pores or cracks between grains in a layer of sediment or rock. Monitoring the groundwater helps determine what contamination exists beneath the Hanford Site. This information will help regulatory agencies and DOE make cleanup decisions based on scientific information and technical capabilities.

DOE monitors groundwater on the Hanford Site to help determine what chemical and radiological contaminants have made their way to groundwater and how they have migrated. Groundwater monitoring is a part of the cleanup mission and will remain a component of long-term stewardship after remediation is completed.

Monitoring points near the river, called aquifer tubes, provide additional information on water quality near the Columbia River. The aquifer tubes are located in the 100 Areas, the Hanford town site, and in FY 2004, in the 300-FF-5 Operable Unit. Their locations are shown on well location maps in applicable sections of this report.

Groundwater in the unconfined aquifer generally flows west to east beneath the Hanford Site and discharges to the Columbia River.

2.1.1 Groundwater Flow

During March and early April 2004, 869 water-level measurements were collected from the unconfined aquifer system and the underlying confined aquifers beneath the Hanford Site. These data are used to (1) prepare contour maps that indicate the general direction of groundwater movement within an aquifer; (2) determine hydraulic gradients, which in conjunction with the hydraulic properties of the aquifer, are used to compute groundwater flow velocities; (3) support groundwater model calibration; and (4) interpret sampling results. This section describes the results of a regional-scale analysis of these data for the unconfined aquifer, which is the aquifer most affected by Hanford operations. Flow in the confined aquifer in the lower Ringold Formation and the upper basalt-confined aquifer is discussed in Section 2.14. For more information regarding water-level monitoring activities, see PNNL-13021.

2.1.1.1 March 2004 Water Table

Figure 2.1-3 presents the March 2004 water-table map for the Hanford Site. Groundwater in the unconfined aquifer generally flows from west to east and discharges to the Columbia River. Steep gradients occur in the west, east, and north regions of the site. Shallow gradients occur southeast of the 100-F Area and in a broad arc extending from west of the 100-B/C Area southeast between Gable Butte and Gable Mountain (Gable Gap), and through the 200 East Area into the central portion of the Hanford Site. The steep gradients in the west and east are due to the presence of the relatively low permeability sediment of the Ringold Formation at the water table, while the low gradient areas are associated with the highly permeable sand and gravel of the Hanford formation.

North of Gable Butte and Gable Mountain, groundwater generally flows from west to east and discharges to the Columbia River. Groundwater enters this region from the Columbia River west of the 100-B/C Area, through Gable Gap, and through the gap between Umtanum Ridge and Gable Butte. An apparent groundwater mound exists ~2 kilometers north of Gable Mountain, and is associated with low conductivity Ringold Formation muds at the water table. This mound is contoured as if it were part of the unconfined aquifer, but it could also represent a perched zone above the regional water table. There is insufficient information to distinguish between these possibilities.

Over much of the Hanford Site, the water table continued to decline. The declining water table caused some monitoring wells to go dry; new wells are being installed.

Past effluent discharges at U Pond and other facilities caused a groundwater mound to form beneath the 200 West Area. These discharges had largely ceased by the mid-1990s, but a remnant mound remains, which is apparent from the shape of the water-table contours passing through the 200 West Area. Currently, the water-table elevation is ~12 meters above the estimated pre-Hanford water table.(a) Scientists predict that when equilibrium conditions are established, the water table may be ~5 to 7 meters higher than the pre-Hanford water table because of artificial recharge from offsite irrigation (PNNL-11801). The water table beneath the 200 West Area is locally perturbed by discharges associated with the State-Approved Land Disposal Site, as well as by operation of two groundwater remediation pump-and-treat systems (at the 200-UP-1 and 200-ZP-1 Operable Units).

(a) Based on the February 2004 water-level elevation in well 299-W18-15 (137.1 meters NAVD88) and the pre-Hanford water-table elevation at the location of this well estimated from BNWL-B-360 (~125.1 meters NAVD88). The peak historical water-level elevation within the 200 West Area occurred at well 299-W18-15 in 1984 (149.1 meters NAVD88).

Groundwater flow in the central portion of the Hanford Site, encompassing the 200 East Area, is significantly affected by the presence of a buried flood channel, which lies in a northwest to southeast orientation (PNNL-12261). The water table in this area is relatively flat because of the presence of highly permeable sediment of the Hanford formation at the water table. Uncertainty in the hydraulic head measurements is larger than the magnitude of the hydraulic gradient, which makes hydraulic gradient determinations problematic in this area. Groundwater flow in this region also is significantly affected by the presence of low permeability sediment of the Ringold Formation at the water table east and northeast of the 200 East Area, as well as basalt above the water table. The extent of the basalt units above the water table continues to increase due to the declining water table, resulting in an even greater effect on groundwater flow in this area. The mapped extent of these units was revised for the March 2004 water-table map, to take into account further declines in the water table. The water table beneath the 200 East Area is ~2.4 meters higher than pre-Hanford conditions.(b) Scientists estimate that when equilibrium conditions are established in the 200 East Area, the water table will be near its pre-Hanford elevation (PNNL-11801).

From the 200 East Area, groundwater flows toward the southeast and east, where it enters the Columbia River. In the south part of the site, flow converges on the 300 Area from the northwest, west, and southwest.

In addition to the Hanford Site water table, Figure 2.1-3 depicts the water table north and east of the Columbia River (using a 50-meter-contour interval), based on water-level measurements collected during March 2000. The offsite water table is heavily influenced by irrigation practices, and the configuration of the water table is significantly controlled by topography. Many of the contour flexures and mounds represent valleys and higher plateau areas. Hydraulic head north and east of the Columbia River are significantly higher than on the Hanford Site, as evidenced by the proximity of the 150-meter contour to the Columbia River. Therefore, it is unlikely that groundwater contaminants from the Hanford Site would migrate underneath the Columbia River to these offsite areas. PNL-8122 contains a more complete discussion of the offsite water table.

2.1.1.2 Water-Table Changes from FY 2003

In the 200 East Area, the elevation of the water table declined by an average of 0.09 meter from March 2003 to March 2004. This is greater than the previous annual decline (0.04 meter from March 2002 to March 2003, PNNL-14548), but is still less than the normal decline seen in earlier years (e.g., 0.19 meter from March 2001 to March 2002, PNNL-14187). The region affected by this smaller than normal decline extends from Gable Gap through the 200 East Area to the Central Landfill, i.e., in the highly conductive sediment of the Hanford formation. This fluctuation in the rate of water-table decline is demonstrated by the hydrograph for well 299-E32-8 in the northwest part of the 200 East Area (Figure 2.1-4). Possible explanations for this perturbation of the water table continue to be investigated.

During FY 2004, staff sampled 730 wells and 134 aquifer tubes for radiological and chemical constituents.

In the 100-D Area, the water-table elevation increased in the vicinity of the 182-D reservoir due to water leaking from this facility. The resulting groundwater mound is evident from the shape of the 118-meter water-level contour in Figure 2.5-3 of Section 2.5. Section 2.5 provides additional information regarding this leak.

Over much of the rest of the Hanford Site, the long-term decline in the water-table elevation continued, although increases did occur in some areas. The water-table elevation increased in many areas along the Columbia River north of Gable Butte and Gable Mountain as well as in the 300 Area. These increases are attributed to changes in river stage. In the

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(b) Based on the average water-level elevation measured in 15 wells within the 200 East Area during March 2004, which have been corrected for deviations of the borehole from vertical (122.3 meters NAVD88), and the pre-Hanford water-table elevation for the 200 East Area estimated from BNWL-B-360 (~119.9 meters NAVD88).

200 West Area, the water table declined by an average of 0.21 meter (in those areas not influenced by pump-and-treat remediation systems).

2.1.2 Groundwater Contaminants

Tritium, nitrate, and iodine-129 are the most widespread contaminants on the Hanford Site.

During FY 2004, Hanford Site staff sampled 730 wells and 134 aquifer tubes for radiological and chemical constituents. Many of the wells were sampled multiple times, for a total of 2,026 sampling trips.

Chromium (total or hexavalent) was the most frequently analyzed constituent, analyzed 1,768 times. Anions, tritium, iodine-129, metals, technetium-99, strontium-90, and volatile organic compounds were other commonly analyzed constituents (Table 2.1-2). The data from many wells on the Hanford Site are used to meet the objectives of multiple regulations, including AEA, CERCLA, and RCRA. Sampling and analysis are coordinated to avoid unnecessary costs.

Monitoring water quality along the river is accomplished by collecting samples from (a) aquifer tubes having sample ports at several depths beneath the shoreline, (b) riverbank springs, and (c) near-shore river water. Use of aquifer tubes at riverbank springs is included in CERCLA monitoring plans for groundwater operable units in the 100 and 300 Areas. Representatives from the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) meet annually with DOE and its contractors to plan the annual sampling event, which usually occurs during the fall months (DOE/RL-2000-59). DOE installed 108 new aquifer tubes in FY 2004 to improve coverage in the 100 Areas and to monitor the 300 Area shoreline for the first time.

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their distribution in the unconfined aquifer is shown in Figures 2.1-5, 2.1-6, and 2.1-7. The most prominent portions of these plumes originated at waste sites in the 200 Areas and spread toward the southeast. Nitrate and tritium also had significant sources in the 100 Areas. Other contaminant plumes on the Hanford Site are listed below:

- Carbon tetrachloride and associated trichloroethene in the 200 West Area.
- Chromium in the 100 Areas.
- Chromium in the 200 West Area and in the 600 Area south of the 200 Areas.
- Strontium-90 in the 100 Areas.
- Technetium-99 and uranium that extend eastward from the 200 West Area.
- Technetium-99 and uranium with minor amounts of cyanide and cobalt-60 in the northwest 200 East Area.
- Uranium in the 300 Area.

Although some contaminants exceed drinking water standards in groundwater samples, the concentrations measured in river water remained far below standards.

The distribution of hexavalent chromium in aquifer tubes along the 100 Areas is illustrated in Figure 2.1-8. The highest concentrations are detected along the south 100-D Area shoreline.

Table 2.1-3 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants that exceed water quality standards. Analytical results including FY 2004 and historical data are included in the data files accompanying this report.

With the exception of carbon tetrachloride, the highest concentrations of contaminants on the Hanford Site remain near the water table. Relatively few wells are completed deeper in the aquifer, but in most cases, these detect lower levels of contamination than their shallow counterparts. A confined aquifer in the Ringold sediment east of the 200 East Area is contaminated with tritium at levels near those in the unconfined aquifer. However, tritium levels drop sharply a short distance downgradient, as discussed in Section 2.14. Deeper still, in the upper basalt-confined aquifer ~25 meters below the water table, contamination has been detected in only two wells, both near the 200 East Area (see Section 2.14).

Carbon tetrachloride data have been collected from various depths within the unconfined aquifer in recent years. In some cases, concentrations are higher near the bottom of the aquifer than near the water table. Section 2.8 discusses the vertical distribution of carbon tetrachloride.

The discharge of the Columbia River along the Hanford Reach is controlled by releases from the Priest Rapids Dam, located upstream of the Hanford Site. Daily discharge cycles can cause river elevation changes of up to several meters along the reactor areas. These fluctuations create a bank storage zone containing highly variable water movement patterns. The influx of river water may dilute contamination carried toward the river by groundwater, prior to its discharge through the riverbed sediment and river bank springs. Seasonal discharge cycles also influence the release of groundwater into the river environment.

2.1.3 Groundwater Remediation

DOE is working to clean up groundwater contamination that may pose a risk to human health or the environment. Decision-making efforts are organized by groundwater operable unit. The text below summarizes the status of remediation in each operable unit and Table 2.1-4 lists the volume of water treated and amount of contaminant removed. Additional details are provided elsewhere in Chapter 2.

DOE is working to clean up groundwater contamination that may pose a risk to human health or the environment. Interim remedial actions reduce the movement of contaminants until final cleanup decisions are made.

DOE, EPA, and Ecology have created records of decision for seven groundwater operable units:

- **100-HR-3 (100-D and 100-H Areas) and 100-KR-4 (100-K Area)** – Chromium may pose a threat to aquatic organisms in the Columbia River. In the 100-K, 100-D, and 100-H Areas, interim action pump-and-treat systems reduce the amount of chromium reaching the river. A second system began to operate in the 100-D Area in FY 2004. Also in the 100-D Area, an innovative treatment method immobilizes chromium in the aquifer. In FY 2004, chromium concentrations at all these interim action sites remained above remediation goals (ROD 1996a, 1999a).
- **100-NR-2 (100-N Area)** – Strontium-90 concentrations remained much higher than the drinking water standard in wells at the river shore in FY 2004. DOE has operated a pump-and-treat system for strontium-90 as an interim action since 1995 and is investigating alternative remediation methods (phytoremediation and apatite sequestration; ROD 1999b).
- **200-UP-1 (200 West Area)** – DOE has operated an interim action pump-and-treat system for technetium-99 and uranium since 1995. In FY 2004, all concentrations in the extraction and monitoring wells were below the remediation goals (ROD 1997). A new extraction well was put online in FY 2004.
- **200-ZP-1 (200 West Area)** – DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride from spreading since 1994 (ROD 1995a). More recently, carbon tetrachloride concentrations have been detected above the remedial action goal north of the Plutonium Finishing Plant, just west of the TX-TY Tank Farm. Because of these changes, plans are now underway to expand the pump-and-treat system by adding additional extraction wells.
- **300-FF-5 (300 Area and satellite areas to the north)** – The interim action involves natural attenuation of the cis-1,2-dichloroethene, trichloroethene, and uranium plumes in the 300 Area. In FY 2004, concentrations of the organic contaminants were low, but uranium remained elevated (ROD 1996b). DOE and EPA are investigating alternative forms of remediation via a remedial investigation/feasibility study process.

- **1100-EM-1 (Richland North Area)** – DOE and regulatory agencies have determined that the final cleanup action will be monitored natural attenuation of the contaminant plumes (ROD 1993).

At the 100-BC-5, 100-FR-3, 200-BP-5, and 200-PO-1 operable units, monitoring indicates there is no imminent threat to human health or the environment, so no interim remedial actions are occurring. Remedial investigations and feasibility studies will be conducted to support final remediation decisions for these operable units. Meanwhile, waste sites and plumes will continue to be monitored.

2.1.4 Quality Control Highlights

Groundwater data quality is assessed and enhanced by a multifaceted quality assurance/quality control program. Major components of the program include performance evaluation studies, field quality control samples, blind standards, laboratory quality control samples, and laboratory audits. Overall evaluation of these components indicates that the data for FY 2004 are reliable and defensible. Details of the quality control program for FY 2004 are included in Appendix C. Highlights include the following:

- During FY 2004, 87% of the groundwater monitoring data was considered complete. The groundwater project is attempting to improve completeness by working with the laboratories to reduce laboratory blank contamination.
- Analytical services are performed by four offsite contract laboratories. All four laboratories participated in two or more national performance evaluation studies. Overall, the percentage of acceptable results for FY 2004 was 95%; the percentages for the individual laboratories ranged from 91% to 100%.
- Field quality control samples include three types of field blanks (full trip, field transfer, and equipment blanks), field duplicates, and split samples. Greater than 95% of field blank and field duplicate results for FY 2004 were acceptable, indicating little problem with contamination and good precision overall. A limited number of split samples were collected during the year; the analyzing laboratories demonstrated reasonable agreement.
- Recommended holding times were met for 95% of non-radiological sample analysis requests for both long-term and interim-action monitoring. In general, the missed holding times should not have a significant impact on the data.
- Laboratory performance on blind standards was very good overall – 90% of the results were acceptable.
- Approximately 97% of the laboratory quality control results for FY 2004 were within the acceptance limits, suggesting that the analyses were in control and reliable data were generated. Specifically, 99% of the method blanks, 98% of the laboratory control samples, 95% of the matrix spikes, 96% of the matrix duplicates, and 95% of the surrogates were within the acceptance limits.
- Seven audits of the commercial laboratories were conducted by DOE and its contractors. Several minor findings and observations were identified along with a number of proficiencies. Corrective actions have been accepted for all of the audits.

Evaluation of the groundwater project quality assurance program indicates that the data for FY 2004 are reliable and defensible.

Table 2.1-1. Groundwater Operable Units and Regulated Units on the Hanford Site

Site or Operable Unit	Type of Monitoring Program	Text Section	FY 2004 Highlights
CERCLA Groundwater Operable Units (well/constituent tables in Appendix A)			
100-BC-5	Long-term monitoring	2.2	Revised sampling and analysis plan
100-FR-3	Long-term monitoring	2.7	Revised sampling and analysis plan
100-HR-3 (D pump and treat)	IRA; interim ROD	2.5	Chromium > remediation goal; second system added; three wells installed
100-HR-3 (D redox site)	IRA; interim ROD	2.5	Chromium > remediation goal
100-HR-3 (H pump and treat)	IRA; interim ROD	2.6	Chromium > remediation goal
100-KR-4 (pump and treat)	IRA; interim ROD	2.3	Chromium > remediation goal; two wells installed
100-NR-2 (pump and treat)	IRA; interim ROD	2.4	No decrease in plume size; investigating alternatives; baseline monitoring to support planned rebound study; three wells installed
200-BP-5	Long-term monitoring	2.10	Revised sampling and analysis plan
200-PO-1	Long-term monitoring	2.11	New sampling and analysis plan
200-UP-1 (pump and treat)	Interim action ROD	2.9	Technetium-99 and uranium < remediation goal; rebound study planned; seven wells installed
200-ZP-1 (pump and treat)	Interim action ROD	2.8	System to be expanded; four wells installed
300-FF-5 (300 Area)	Natural attenuation; interim ROD	2.12	Average TCE <5 µg/L; uranium remains elevated; RI/FS began
300-FF-5 (north)	Operations and Maintenance plan	2.12	Tritium levels decreasing
1100-EM-1	Natural attenuation; final ROD	2.13	Average TCE <5 µg/L since FY 2001
Regulated Units (well location maps, well/constituent tables, statistics tables, and flow rates in Appendix B)			
100-K basins	AEA	2.3.3	No leaks detected
116-N-1 (1301-N) facility	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.4.3.1	Continued detection[(a)]
116-N-3 (1325-N) facility	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.4.3.3	Continued detection[(a)]
120-N-1, 120-N-2 (1324-N/NA) facilities	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.4.3.2	Continued detection[(a)]
116-H-6 (183-H) evaporation basins	WAC 173-303-645(11)(g)	2.6.3	Monitoring during IRA; chromium, nitrate, technetium-99, uranium
200 Area TEDF	WAC 173-216	2.11.3.8	No influence in upper aquifer
216-A-29 ditch	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.11.3.3	Continued detection[(a)]
216-B-3 pond	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.11.3.5	Reverted to conventional statistics
216-B-63 trench	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.10.3.2	Continued detection[(a)]
216-S-10 pond and ditch	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.9.3.3	Continued detection;[(a)] two shallow and one deep downgradient wells remain
216-U-12 crib	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.9.3.4	Continued assessment; two downgradient wells remain
316-5 process trenches	WAC 173-303-645(11)(g)	2.12.3	Monitoring during natural attenuation IRA
ERDF	CERCLA	2.9.3.5	No impact on groundwater
LERF	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.10.3.5	Insufficient wells; no statistical comparisons

Table 2.1-1. (contd)

Site or Operable Unit	Type of Monitoring Program	Text	FY 2004 Highlights
Regulated Units (well location maps, well/constituent tables, statistics tables, and flow rates in Appendix B)			
LLWMA 1	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.10.3.3	Continued detection[(a)]
LLWMA 2	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.10.3.4	Continued detection;[(a)] north wells dry; no unconfined aquifer in north
LLWMA 3	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.8.3.1	Continued detection;[(a)] three wells went dry
LLWMA 4	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.8.3.2	Continued detection until last shallow downgradient well went dry
NRDWL	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.11.3.6	Continued detection[(a)]
PUREX cribs	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.11.3.1	Continued assessment; iodine-129, nitrate, and tritium
SALDS	WAC 173-216	2.8.3.5	No permit limits exceeded; two dry wells
SST WMA A-AX	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.11.3.2	Continued detection;[(a)] two corroded wells decommissioned; two new wells installed
SST WMA B-BX-BY	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.10.3.1	Continued assessment; nitrate, nitrite, technetium-99, uranium; three wells installed
SST WMA C	WAC 173-303-400; 40 CFR 265.93(b); AEA	2.10.3.6	Temporarily ceased CIP comparisons
SST WMA S-SX	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.9.3.2	Continued assessment; chromium, technetium-99; new well planned
SST WMA T	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.8.3.3	Continued assessment; technetium-99; new wells planned
SST WMA TX-TY	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.8.3.4	Continued assessment; chromium, technetium-99; new well planned
SST WMA U	WAC 173-303-400; 40 CFR 265.93(d); AEA	2.9.3.1	Continued assessment; nitrate, technetium-99; one well installed
SWL	WAC 173-304	2.11.3.7	Five constituents exceeded background or standards; low levels of organics

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(a) Analysis of RCRA CIP provided no evidence of groundwater contamination with hazardous constituents from the unit.

AEA = *Atomic Energy Act of 1954*.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act*.
CFR = Code of Federal Regulations.
CIP = Contamination indicator parameters.
ERDF = Environmental Restoration Disposal Facility.
FY = Fiscal year.
IRA = Interim remedial action.
LERF = Liquid Effluent Retention Facility.
LLWMA = Low-level waste management area.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PUREX = Plutonium-Uranium Extraction Plant.
RCRA = *Resource Conservation and Recovery Act*.
RI/FS = Remedial investigation/feasibility study.
ROD = Record of decision.
SALDS = State-Approved Land Disposal Site.
SST = Single-shell tank.
SWL = Solid Waste Landfill.
TCE = Trichloroethene.
TEDF = Treated Effluent Disposal Facility.
WAC = Washington Administrative Code.
WMA = Waste management area.

Table 2.1-2. Number of Groundwater Analyses by Groundwater Interest Area,[(a)] FY 2004

Constituent	Site Total	100-BC-5	100-KR-4	100-NR-2	100-HR-3-D	100-HR-3-H	100-FR-3	200-ZP-1	200-UP-1	200-BP-5	200-PO-1	300-FF-5	1100-EM-1
Carbon tetrachloride	585	4	1	0	0	0	25	214	103	7	59	136	36
Chromium (total and hexavalent)	1,768	42	203	72	421	177	58	181	179	229	159	36	11
Iodine-129	382	0	0	0	0	0	0	79	72	95	120	13	3
Nitrate (anions)	1,367	19	72	77	87	52	44	234	197	233	225	78	49
Plutonium-239/240	31	4	0	0	0	0	0	6	0	20	0	1	0
Strontium-90	346	20	54	66	17	23	11	22	25	40	62	6	0
Technetium-99	702	9	18	0	10	28	1	185	192	210	36	10	3
Trichloroethene (VOA)	584	4	1	0	0	0	25	213	103	7	59	136	36
Tritium	1,054	30	96	66	49	32	24	194	70	201	150	87	55
Uranium	644	4	0	8	41	28	0	48	151	173	12	163	16

FY = Fiscal year.
VOA = Volatile organic analysis.
(a) Groundwater interest areas are shown on Figure 2.1-1.

Table 2.1-3. Maximum Concentrations of Selected Groundwater Contaminants in FY 2004 in Groundwater Interest Areas (see Figure 2.1-1)

		100-BC-5		100-KR-4		100-NR-2		100-HR-3-D		100-HR-3-H		100-FR-3	
Contaminant, units (alphabetical order)	DWS [DCG][a]	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes
Antimony (filtered), µg/L[b]	6			**31.1**		**57.4**							
Arsenic (filtered), µg/L	10							8.5					
Carbon tetrachloride, µg/L	5												
Carbon-14, pCi/L	2,000 [70,000]			**15,300**	181								
Cesium-137, pCi/L	200 [3,000]												
Chloroform, µg/L	100			0.2								0.6	0.2
Chromium (dissolved), µg/L	100	19.1	28.1	**565**	72.2	**170**	36.3	**3,830**	**363**	**132**	52.3	97.8	13.9
cis-1,2-dichloroethene, µg/L	70												
Cobalt-60, pCi/L	100 [5,000]												
Cyanide, µg/L	200												
Fluoride, mg/L	4	0.4	0.2	0.5	0.4	0.9	0.3	0.5		0.5	0.2	0.9	0.2
Gross alpha, pCi/L	15	2.4		7.6		5.2		8.0		**36.8**		13.6	
Gross beta, pCi/L	50	45.8		**3,860**	3.7	**16,900**	**7,710**	**375**		**134**		45	
Iodine-129, pCi/L	1 [500]												
Nitrate, mg/L	45	27.4	28.8	**132**	41.2	**270**	6.8	**74.4**	40.3	**192**	**491**	**166**	**52.7**
Nitrite, mg/L	3.3		0.72	0.49		1.68	0.12	**4.60**	0.17				0.19
Plutonium-239/240, pCi/L[c]	NA [30]												
Strontium-90, pCi/L	8 [1,000]	**39.0**	0.6	**2,380**	1.4	**7,390**	**3,830**	**8.2**		**29.6**	**2.4**	**22.6**	**1.2**
Technetium-99, pCi/L	900 [100,000]	109	124	117						485		150	
Trichloroethene, µg/L	5			**10.0**								**19.0**	
Tritium, pCi/L	20,000 [2,000,000]	**41,000**	**20,100**	**636,000**	11,900	**28,600**	5,240	**25,200**	**31,900**	5,750		8,240	798
Uranium, µg/L	30							7.6		**54.3**	1.7		

Table 2.1.3. (contd)

		200-ZP-1	200-UP-1	200-BP-5	200-PO-1	300-FF-5		1100-EM-1		
Contaminant, units (alphabetical order)	DWS [DCG][a]	Wells	Wells	Wells	Wells	Wells	Aquifer Tubes	Wells	AREVA[d]	Richland Landfill[e]
Antimony (filtered), µg/L[b]	6	**46.2**	**41.0**							1.8
Arsenic (filtered), µg/L	10	10.0	6.7	**11.7**	**12.4**					10
Carbon tetrachloride, µg/L	5	**9,700**	**650**			0.5				<1
Carbon-14, pCi/L	2,000 [70,000]	8.7								
Cesium-137, pCi/L	200 [3,000]			**1,150**						
Chloroform, µg/L	100	**150**	19.0		0.6	4.0		0.3		5.6
Chromium (dissolved), µg/L	100	**733**	**558**	56.8	73.7	8.8	0.4			31
cis-1,2-Dichloroethene, µg/L	70	0.1	0.3		0.2	**150**	0.2			**70**
Cobalt-60, pCi/L	100 [5,000]	9.6		**109**						
Cyanide, µg/L	200	12.3	25.1	**357**	10.0					
Fluoride, mg/L	4	**4.6**	0.6	0.8	**7.6**	0.7	0.6	1.4	**4.19**	
Gross alpha, pCi/L	15	10.1	**16.6**	**323**	**16.9**	**66.1**		8.5	**119**	
Gross beta, pCi/L	50	**6,050**	**18,100**	**13,400**	**4,290**	**82.6**		10.2	49	
Iodine-129, pCi/L	1 [500]	**24.8**	**13.6**	**5.8**	**10.2**					
Nitrate, mg/L	45	**3,430**	**522**	**1,070**	**132**	**101**	**67.3**	**239**[f]	**282**	**53.1**
Nitrite, mg/L	3.3	0.361	**11.7**	1.28	1.05	0.28				
Plutonium-239/240, pCi/L[c]	NA [30]			**66.2**						
Strontium-90, pCi/L	8 [1,000]	1.4	**35.0**	**6,360**	**21.1**	3.8				
Technetium-99, pCi/L	900 [100,000]	**21,400**	**46,100**	**11,100**	**13,100**	30.1		24.4		
Trichloroethene, µg/L	5	**26.0**	**7.1**		0.8	**5.4**	**6.8**	2.3	4.6	**28**
Tritium, pCi/L	20,000 [2,000,000]	**1,830,000**	**339,000**	**39,100**	**616,000**	***2,320,000***		394		
Uranium, µg/L	30	**250**	**599**	**590**	2.8	**127**	**241**	19.6		

Note: Table lists highest concentration for FY 2004 in each groundwater interest area. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank space indicates the constituent was undetected or not analyzed.

(a) DWS = Drinking water standard; DCG = DOE derived concentration guide. See Tables 1.1-2 and 1.1-3 in Section 1.0 for more information on these standards.

(b) Detection limit is higher than DWS. Not a known contaminant of interest on the Hanford Site.

(c) There is no drinking water standard for plutonium-239/240.

(d) AREVA (formerly Framatome ANP) data from October 2003 to March 2004 (EMF-1865, Addenda 35 and 37).

(e) City of Richland data from October 2003 to June 2004 (City of Richland 2004a, 2004b, 2004c).

(f) From offsite contaminant sources.

DOE = U.S. Department of Energy.

FY = Fiscal year.

Table 2.1-4. Hanford Site Groundwater and Vadose Zone Remediation

			Average Concentration in FY 2004		Volume of Water Treated (million liters)		Amount of Contaminant Removed	
Remediation Site	Year Initiated	Contaminant	Influent	Effluent	FY 2004	Since Startup	FY 2004	Since Startup
			Pump-and-Treat Systems					
100-KR-4	1997	Hexavalent chromium	64 µg/L	4 µg/L	518.9	2,590	31.5 kg	244.3 kg
100-NR-2	1995	Strontium-90	2,027 pCi/L	431 pCi/L	116.2	986	0.2 Ci	1.6 Ci
100-HR-3 North 100-D	1997	Hexavalent chromium	188 µg/L	6 µg/L	172.8	1,090	30.9 kg	192.2 kg
100-HR-3 Central 100-D	2004	Hexavalent chromium	950 µg/L	<5 µg/L	7.9	7,900	6.4 kg	6.4 kg
100-HR-3, 100-H	1997	Hexavalent chromium	26 µg/L	6 µg/L	161.9	1,100	4.1 kg	37.3 kg
200-UP-1	1994	Uranium	251.2 µg/L	undetected	93.8	801.2	23.5 kg	5,207 kg
		Technetium-99	2,207 pCi/L	undetected			12 g (0.2 Ci)	114.1 g (2.39 Ci)
		Carbon tetrachloride	58.2 µg/L	undetected			5.4 kg	31.2 kg
		Nitrate	55.5 mg/L	undetected			5,207 kg	32,550 kg
WMA S-SX (299-W23-19)(a)	2003	Technetium-99	43,263 pCi/L	--	0.01169	0.0277	0.043 g (0.00073 Ci)	0.11 g (0.0019 Ci)
200-ZP-1	1994	Carbon tetrachloride	3,079 µg/L	<5 µg/L	274.5	2,420	840.4 kg	8,508 kg
			Other Remediation					
100-HR-3, South 100-D	1999	Hexavalent chromium	Permeable barrier, in situ redox manipulation. Concentrations in most compliance wells downgradient of barrier have decreased, but chromium rebounding in some barrier wells.					
200-ZP-1	1992	Carbon tetrachloride	Soil-vapor extraction (256 kg removed in FY 2004; 78,300 kg removed since startup).					
300-FF-5	1996	TCE cis-1,2-DCE Uranium	Natural attenuation selected as interim action. TCE and cis-1,2-DCE have declined below remedial action goals. Uranium is not attenuating at an acceptable rate and alternative forms of remediation are being investigated.					
1100-EM-1	1993	TCE	Natural attenuation selected as final remedy. Concentrations remain below remedial action goals.					

DCE = Dichloroethene.
FY = Fiscal year.
TCE = Trichloroethene.
WMA = Waste management area.
(a) Well is pumped to remove 3,785 liters after each sampling event.

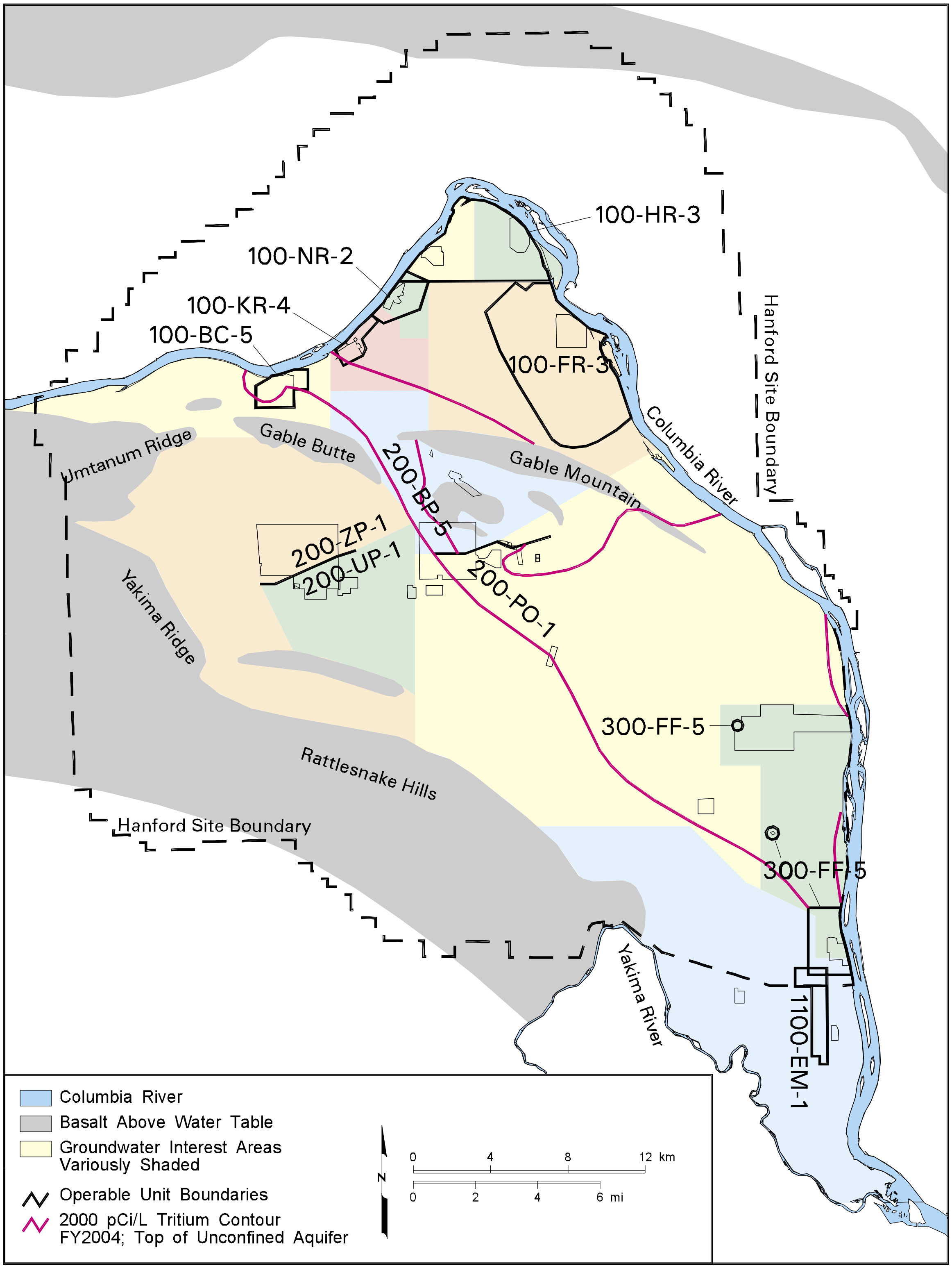

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Figure 2.1-1. Groundwater Operable Units and Groundwater Interest Areas on the Hanford Site

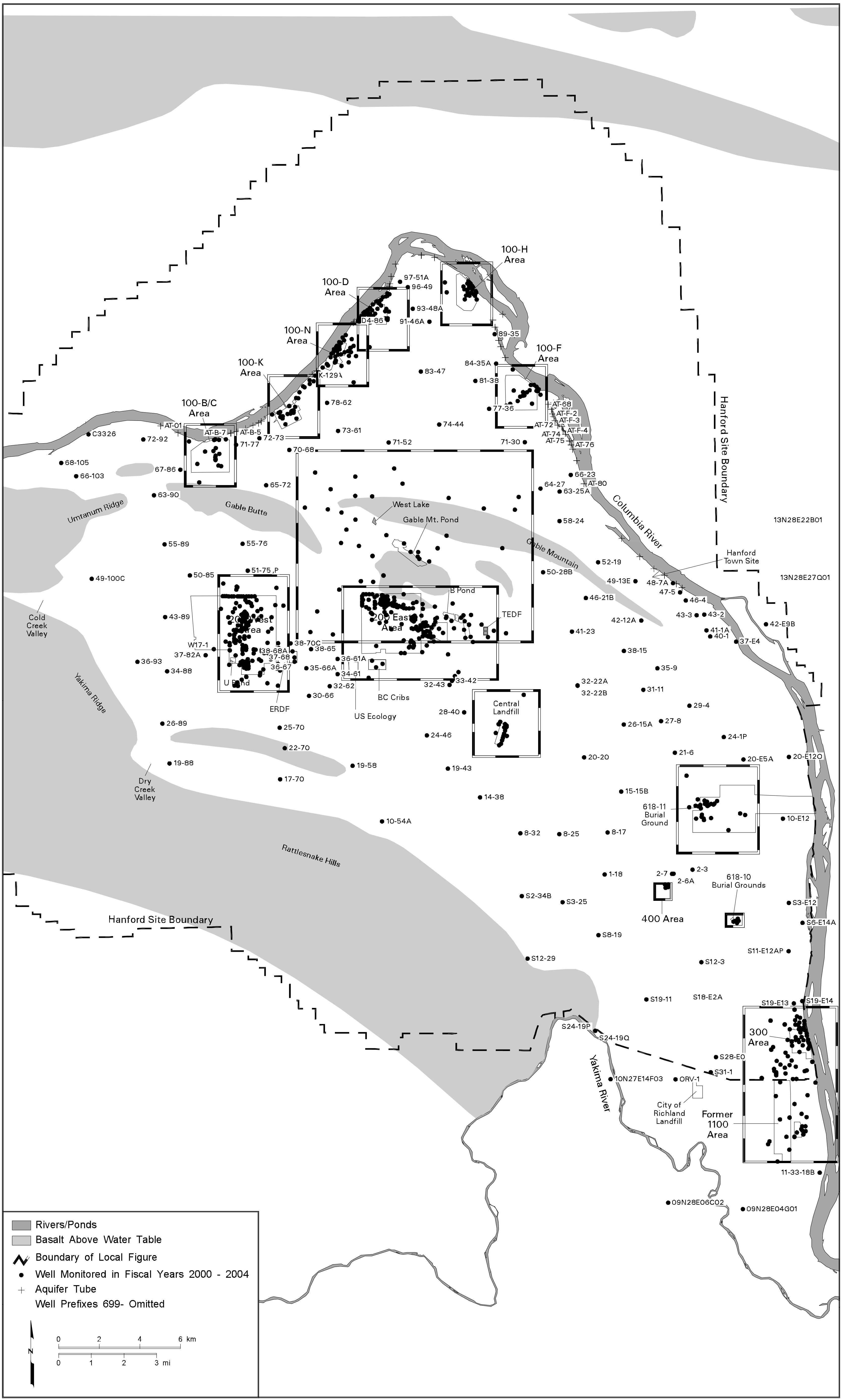

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Figure 2.1-2. Groundwater Monitoring Wells in the 600 Area

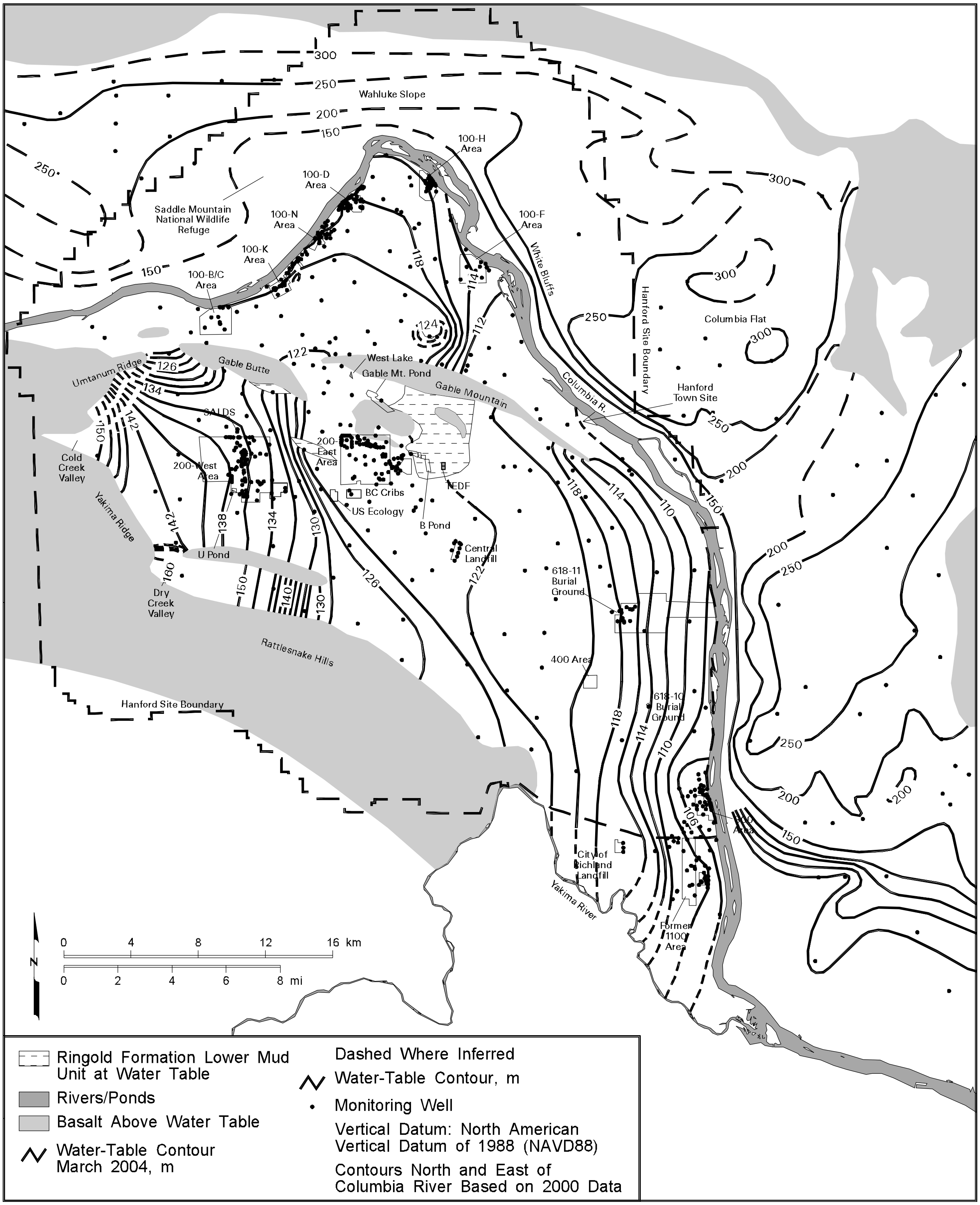

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Figure 2.1-3. Hanford Site and Outlying Areas Water-Table Map, March 2004

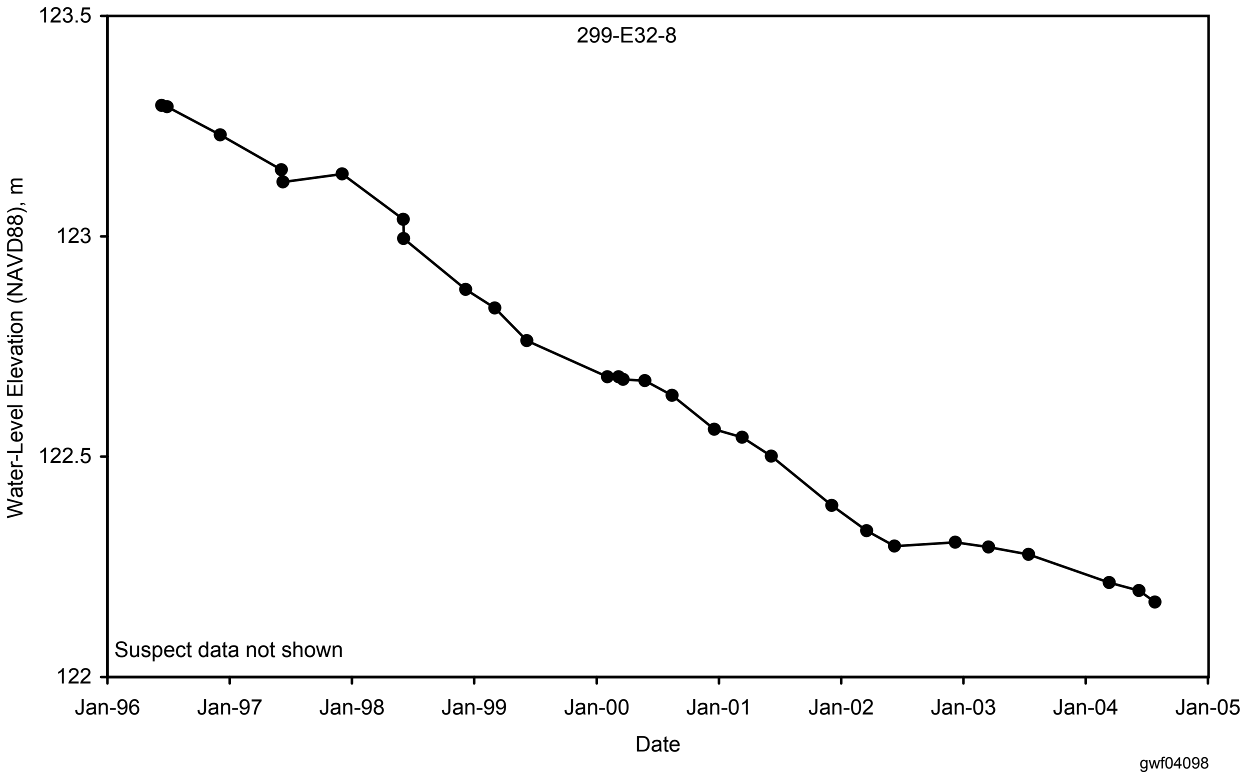

Figure 2.1-4. Water Level in Well 299-E32-8, Northwest 200 East Area

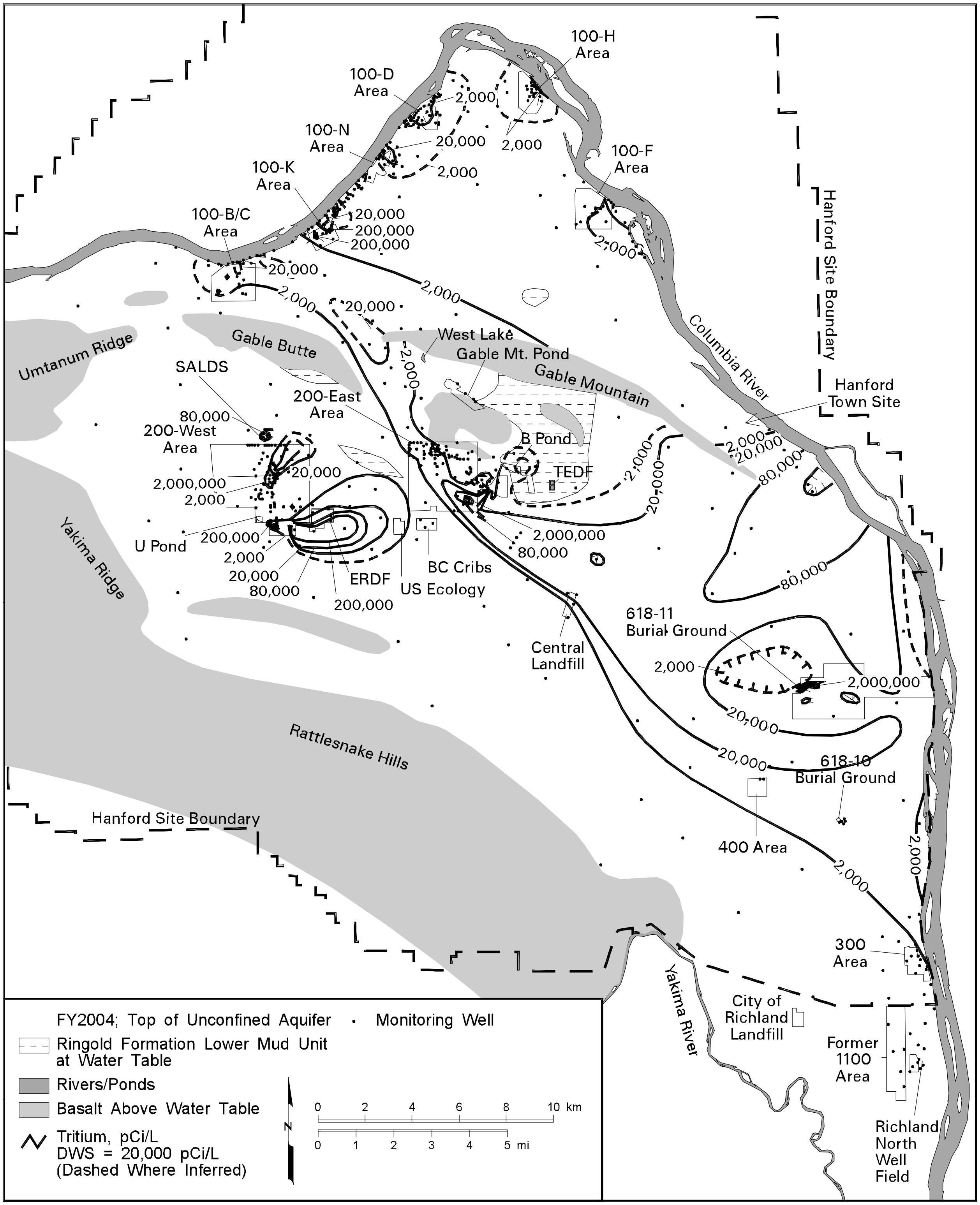

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Figure 2.1-5. Average FY 2004 Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer

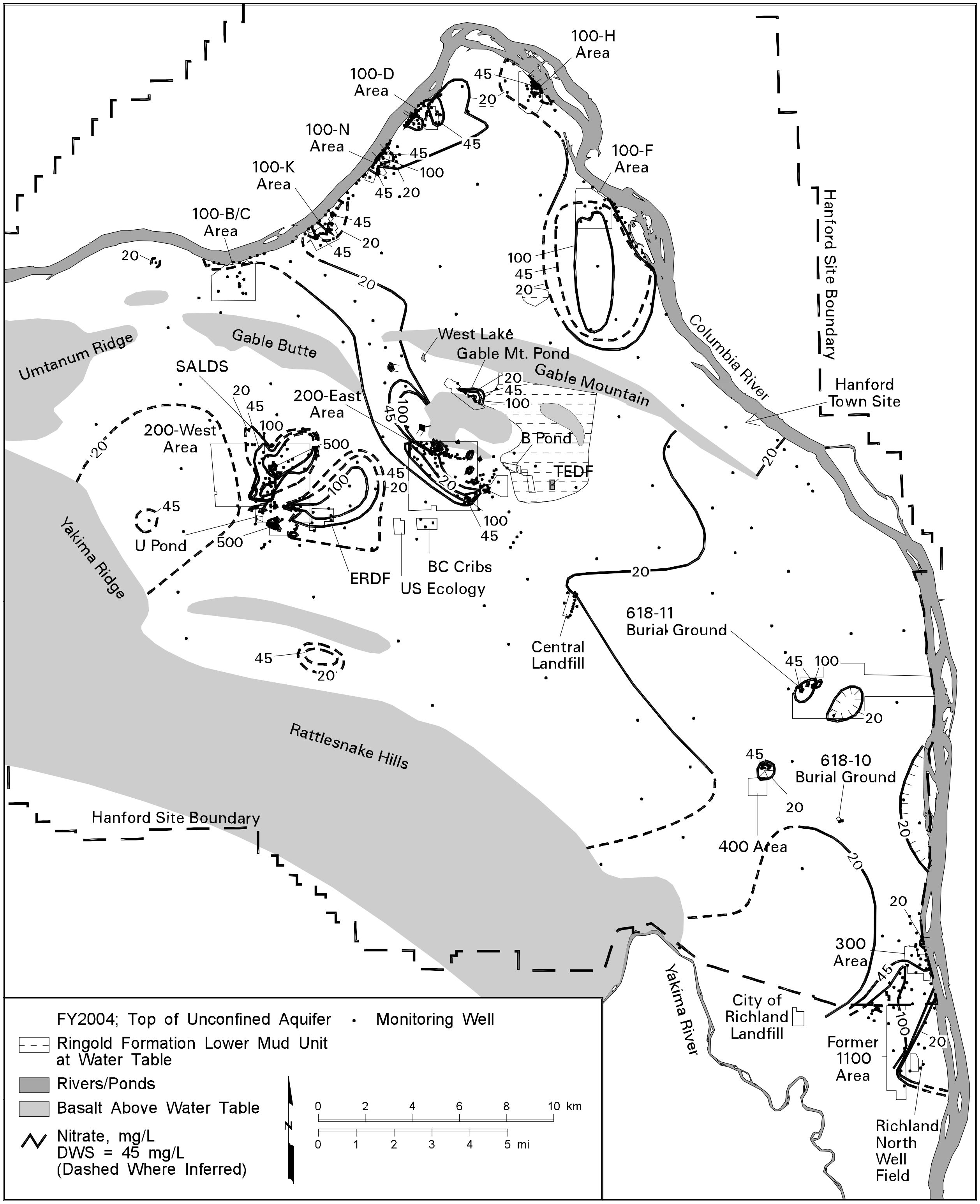

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Figure 2.1-6. Average FY 2004 Nitrate Concentrations on the Hanford Site, Top of Unconfined Aquifer

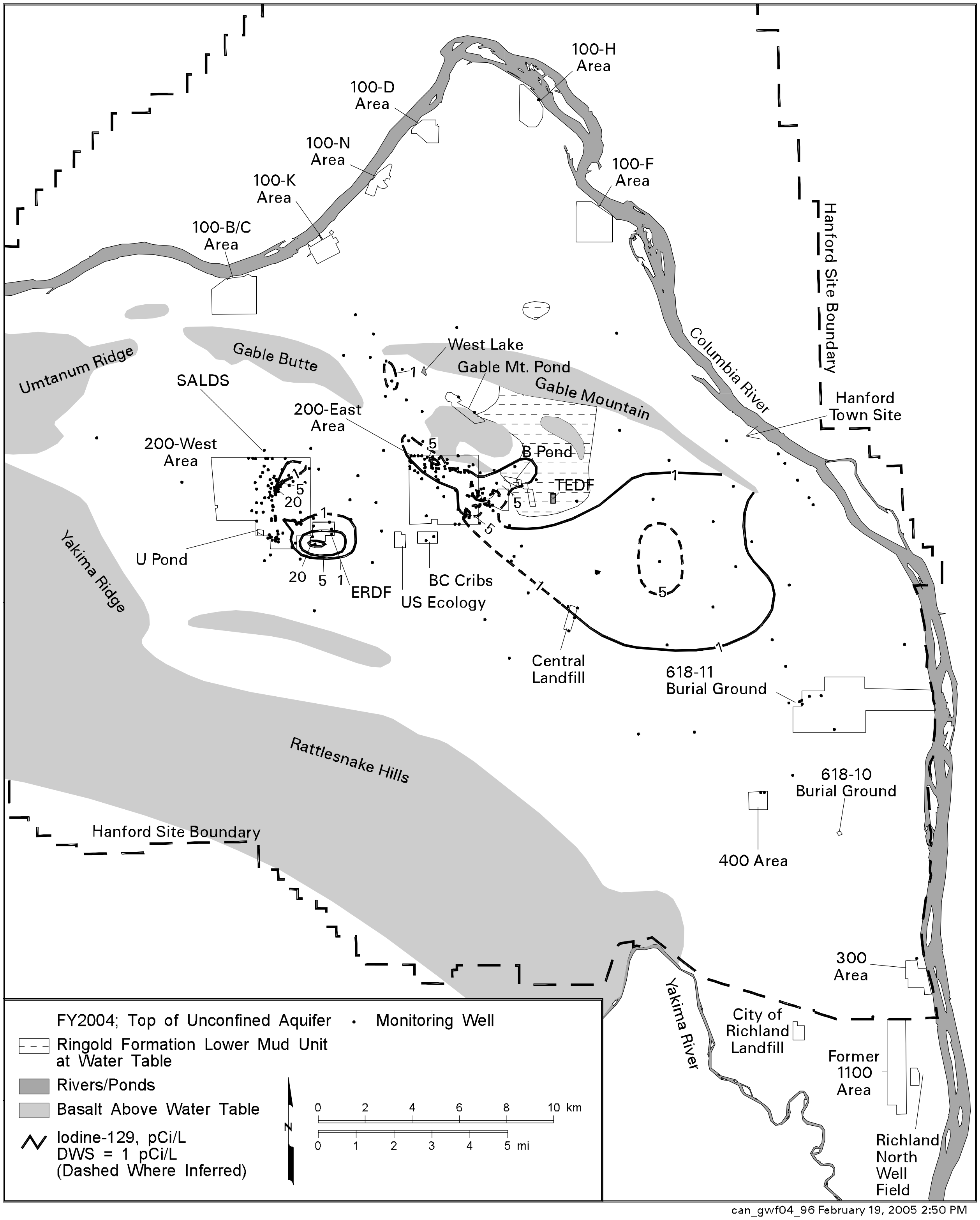

Figure 2.1-7. Average FY 2004 Iodine-129 Concentrations on the Hanford Site, Top of Unconfined Aquifer

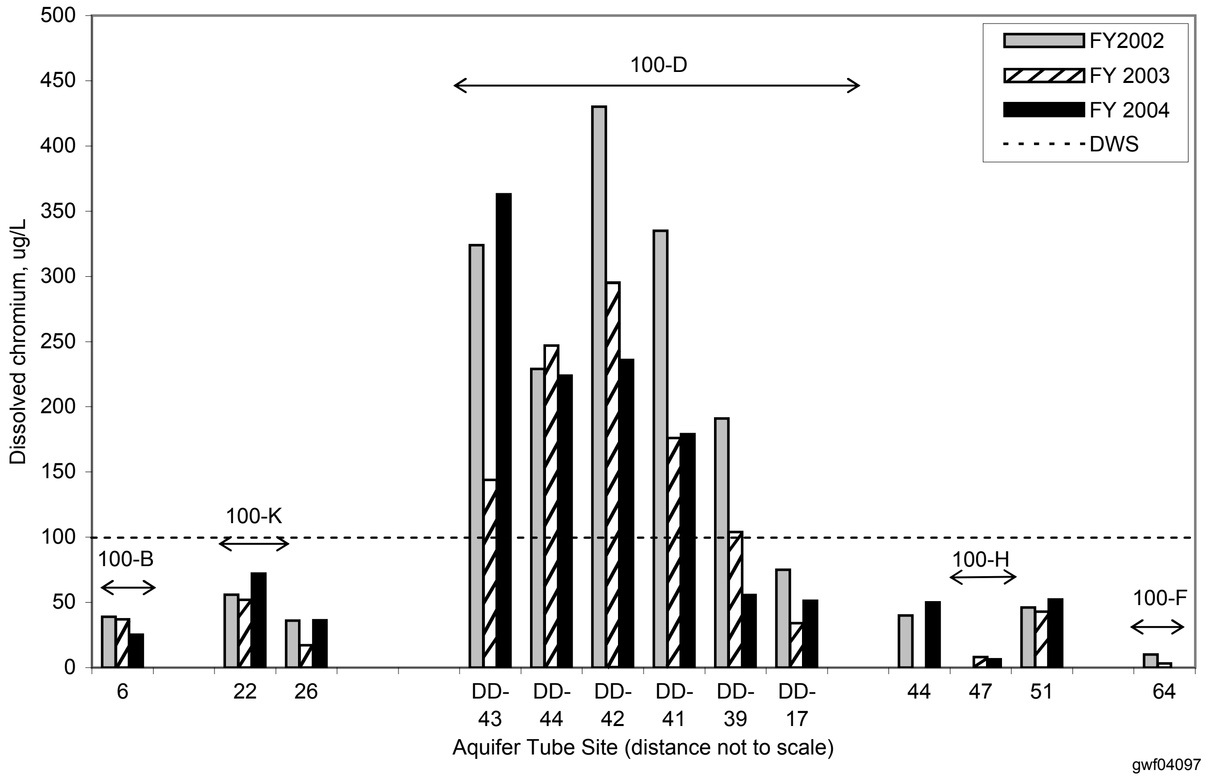

Figure 2.1-8. Dissolved Chromium at Selected Aquifer Tube Sites, 100 Areas

2.2 100-BC-5 Operable Unit

M. J. Hartman

The scope of this section is the 100-BC-5 groundwater interest area, which includes the 100-BC-5 Operable Unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined "groundwater interest areas" informally to facilitate scheduling, data review, and interpretation. Figure 2.2-1 shows facilities, wells, and shoreline monitoring sites in the 100-B/C Area.

Groundwater enters the 100-B/C Area from the Columbia River and the gap between Umtanum Ridge and Gable Butte and through Gable Gap to the southeast (see Figure 2.1-3 in Section 2.1). Groundwater flows primarily to the north beneath the 100-B/C Area and discharges to the Columbia River (Figure 2.2-2). The hydraulic gradient is very flat in the south 100-B/C Area and in the west part of the interest area (see Figure 2.1-3 in Section 2.1).

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Groundwater monitoring for the requirements under the *Atomic Energy Act of 1954* are completely integrated with CERCLA monitoring. There are no active waste disposal facilities or *Resource Conservation and Recovery Act* (RCRA) sites in the 100-B/C Area.

Strontium-90 and tritium exceeded drinking water standards in groundwater at the 100-BC-5 Operable Unit during FY 2004. Both contaminants are limited to the upper aquifer and are not detected in deep wells.

2.2.1 Groundwater Contaminants

Wells in the 100-BC-5 Operable Unit are sampled annually to biennially for the contaminants of concern: strontium-90, tritium, and hexavalent chromium. Contaminants of concern were determined based on results of the data quality objectives process (PNNL-14287). This section describes distributions and trends for the contaminants of concern plus nitrate and technetium-99 beneath the 100-BC-5 groundwater interest area.

2.2.1.1 Strontium-90

The strontium-90 plume beneath 100-B/C Area is wedge-shaped, with an apex in the central 100-B/C Area, extending and spreading north toward the Columbia River (Figure 2.2-3). The plume has not changed significantly in over 10 years.

Strontium-90 concentrations continued to exceed the 8-pCi/L drinking water standard in several wells. In most wells, the concentrations vary but are not increasing or decreasing overall. The maximum strontium-90 concentration in fiscal year (FY) 2004 was 39 pCi/L in well 199-B3-1, near the 116-B-1 trench. Well 199-B3-46 typically has higher concentrations (e.g., 98.9 pCi/L in FY 2003), but it was not sampled in FY 2004 (see Section 2.2.2).

Strontium-90 is limited to the top of the aquifer. None is detected in deeper well 199-B2-12.

Twelve aquifer tubes were sampled for strontium-90 in FY 2004. Strontium-90 was detected only in tubes 07-D, 11-D, and 14-D (all <0.6 pCi/L). These tubes are the deepest

Groundwater monitoring in the 100-BC-5 groundwater interest area includes integrated CERCLA and AEA monitoring:

- ***Sixteen wells, twelve aquifer tube sites, and two seeps were sampled as scheduled; two wells were not sampled as scheduled (see Appendix A).***
- ***The sampling and analysis plan was revised and approved in FY 2004 for implementation in FY 2005.***

in their multi-depth clusters and the shallower tubes were not sampled for strontium-90. Typically only the tubes with the highest specific conductance, usually the deep tubes, are sampled for laboratory analyses. This practice gives the highest concentration of most contaminants, but because strontium-90 is limited to the top of the aquifer in the 100-B/C Area, the deep samples may have missed the highest concentrations of that less mobile contaminant. Data from previous years include some strontium-90 measurements from mid-level tubes 05-M and 06-M, with results from 13 to 17 pCi/L. In FY 2005, all tube depths will be analyzed for strontium-90.

Two shoreline seeps were sampled for strontium-90. Seep 037-1 had no detectable strontium-90 in October and November 2003. Seep 39-2 had 4.04 pCi/L strontium-90 in October 2003.

2.2.1.2 Tritium

A tritium plume with concentrations above 2,000 pCi/L underlies the north 100-B/C Area and extends west and east of the area boundaries (Figure 2.2-4). In most wells, tritium concentrations have been declining since 1997 or 1998.

In FY 2004, tritium concentrations exceeded the 20,000-pCi/L drinking water standard in one well and one aquifer tube in the 100-B/C Area, but one well historically above the standard was not sampled. The tritium concentration rose above the standard for the first time since 1999 in well 199-B5-2, located between the former B Reactor and the 116-C-5 retention basin. The new value remained far below a 1997 peak value (Figure 2.2-5). Well 199-B3-47, a well near the Columbia River that typically exceeds the standard, was not sampled in FY 2004 (Section 2.2.2). The maximum tritium concentration in aquifer tubes in FY 2004 was 20,100 pCi/L in new tube AT-B-7-M, northeast of the main 100-B/C Area. Tube 06-D, near well 199-B3-47, was just below the drinking water standard at 19,700 pCi/L (Figure 2.2-6). Tritium concentrations have shown an overall decline at this tube site since sampling began in 1997. Tritium in seeps ranged from 3,190 to 5,850 pCi/L in October and November 2003.

Plume areas (square kilometers) above the drinking water standard at the 100-BC-5 Operable Unit:

Strontium-90 — 0.86
****Tritium — 0.16***

****Excludes plume from 200-BP-5 Operable Unit.***

A sharp decrease in tritium and specific conductance in well 199-B5-1 may indicate dilution of groundwater with fresh water (Figure 2.2-7). The well is located in the west-central 100-B/C Area and is not near other monitoring wells or liquid waste sites. Water is pumped from the Columbia River to a reservoir and filter plant southwest of well 199-B5-1.

Well 199-B8-6, near the 118-B-1 burial ground in southwest 100-B/C Area, was not scheduled for sampling in FY 2004 but had tritium concentrations above the drinking water standard in 1998 to 2002. The well will be sampled in FY 2005.

Well 699-72-73, east of the 100-B/C Area (see Figure 2.1-2 in Section 2.1 for well location) has elevated tritium that migrated from the 200 East Area and moved through Gable Gap (see Figure 2.1-5 in Section 2.1). The tritium concentration in well 699-72-73 peaked at over 20,000 pCi/L in 2001 and was 16,300 pCi/L in FY 2004 (Figure 2.2-8). New aquifer tubes east of the 100-B/C Area had tritium concentrations at or near 20,000 pCi/L in FY 2004. Well 699-72-73 and the aquifer tubes also had elevated nitrate and technetium-99 from the 200 East Area plume.

Chromium exceeded the 10-μg/L aquatic standard in several 100-B/C wells and aquifer tubes. Concentrations are steady or declining.

2.2.1.3 Chromium

Chromium concentrations have remained below the 100-μg/L drinking water standard in the 100-B/C Area in recent years. In FY 2004, chromium concentrations ranged from undetected to 19.1 μg/L, exceeding the 10 μg/L aquatic standard in five wells. Wells 199-B4-1 and 199-B4-47 typically exceed 20 μg/L (~35 μg/L in FY 2003) but were not sampled in FY 2004 (Section 2.2.2). The wells will be sampled in the future. Chromium trends in monitoring wells in the 100-B/C Area tend to be flat or declining.

Dissolved chromium in aquifer tubes along the 100-B/C shoreline exceeded the 10-µg/L aquatic standard in 6 tubes, and was >20 µg/L in 3 tubes. The highest concentrations were at tube sites 05 and 06 (Figure 2.2-9). The maximum concentration was 28.1 µg/L in tube 05-D.

Dissolved chromium in seep samples ranged from 1.5 to 16.9 µg/L in October and November 2003.

2.2.1.4 Nitrate

Nitrate is not a contaminant of concern in the 100-BC-5 Operable Unit and relatively few wells were sampled for this constituent in FY 2004. Concentrations continued to be below the 45-mg/L drinking water standard and were highest (>20 mg/L) in wells monitoring the north 100-B/C Area. Aquifer tubes in this region had lower nitrate concentrations than nearby wells.

Well 699-72-73, located between 100-B/C and 100-K Areas, had a nitrate concentration of 27.4 mg/L in October 2003. Like tritium, the source of this nitrate is believed to be the 200 East Area. Aquifer tubes AT-B-5-D and 14-D, also located east of the main 100-B/C Area, had nitrate concentrations of ~25 and 29 mg/L in FY 2004.

The nitrate concentration in well 699-72-92, west of the 100-B/C Area (see Figure 2.1-2 in Section 2.1 for well location) was 23 mg/L in FY 2004, comparable with past data. The source of this nitrate is unknown.

Tritium, nitrate, and technetium-99 are detected in wells and aquifer tubes east of the 100-B/C Area. This contamination most likely migrated from the 200 East Area.

2.2.1.5 Technetium-99

Technetium-99 is not a contaminant of concern for the 100-BC-5 Operable Unit. It was detected in the 100-B/C Area groundwater in the early 1990s at levels generally less than 100 pCi/L (drinking water standard is 900 pCi/L) but has not been analyzed since then. Several wells in the 600 Area between the 100-B/C and 100-K Areas are routinely monitored for technetium-99, and those wells detected levels of 110 to 130 pCi/L in FY 2004. Technetium-99 also was analyzed in aquifer tubes east of the main 100-B/C Area. The maximum concentration in an aquifer tube in FY 2004 was 124 pCi/L in tube 14-D. Like tritium and nitrate, technetium-99 in this region is believed to have a source in the 200 East Area.

2.2.2 Operable Unit Monitoring

A record of decision has not yet been developed for the 100-BC-5 Operable Unit, and no active remediation of groundwater is underway. Monitoring contaminant conditions has continued since the initial remedial investigation, and while waste site remedial actions are conducted. A pilot-scale test ecological risk investigation was started in FY 2004, which will serve as a prototype for the other reactor areas. A focused feasibility study, which looks at remedial action alternatives for groundwater, will start in FY 2005.

The sampling and analysis plan that was in effect during FY 2004 (DOE/RL-2003-38, Rev. 0, as revised in unit manager's meetings and documented in Fruchter 2004[a]) specified annual sampling of 12 wells, 12 aquifer tube sites, and 2 seeps and biennial sampling of 13 wells (Appendix A). Of these, 18 wells and all of the aquifer tube sites and seeps were scheduled for sampling in FY 2004. Two wells (199-B3-46 and 199-B3-47) were not sampled. The sampling and analysis plan called for sampling these wells at various depths with a special sampling device. The work was delayed into FY 2005. Tritium was not analyzed in one

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(a) Letter report PNNL-LTR-040317-1BC5 from J.S. Fruchter, Pacific Northwest National Laboratory, to recipients of Sampling and Analysis Plan, *Page Changes for 100-BC-5 and 100-FR-3 Groundwater Sampling and Analysis Plans*, dated March 17, 2004.

aquifer tube and strontium-90 was not analyzed in three wells and two aquifer tubes because of scheduling errors. The impact of these omissions is minimal because the plumes could be defined without these data.

Fourteen new aquifer tubes at six tube sites were installed in FY 2004 as proposed in the original sampling and analysis plan. The addition of the new tubes improved monitoring coverage at the shoreline and will continue to aid in defining plumes and tracking contaminant trends.

The sampling and analysis plan was revised in FY 2004 (DOE/RL-2003-38, Rev. 1) for implementation in FY 2005. The overall approach to monitoring remains the same, but sampling frequency and constituents were modified in some wells to reflect data collected and evaluated after publication of the first plan.

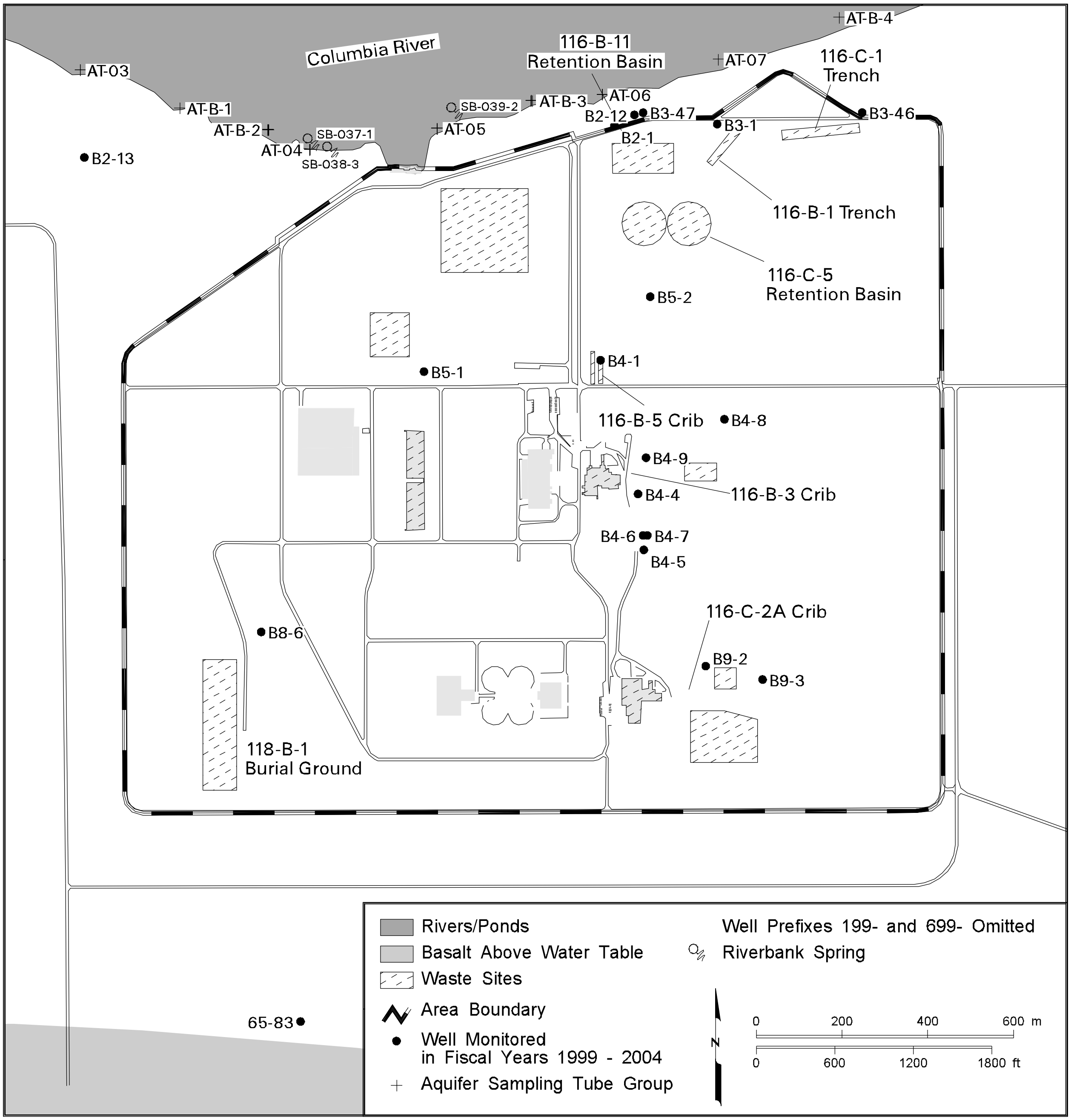

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Figure 2.2-1. Groundwater Monitoring Wells in the 100-B/C Area

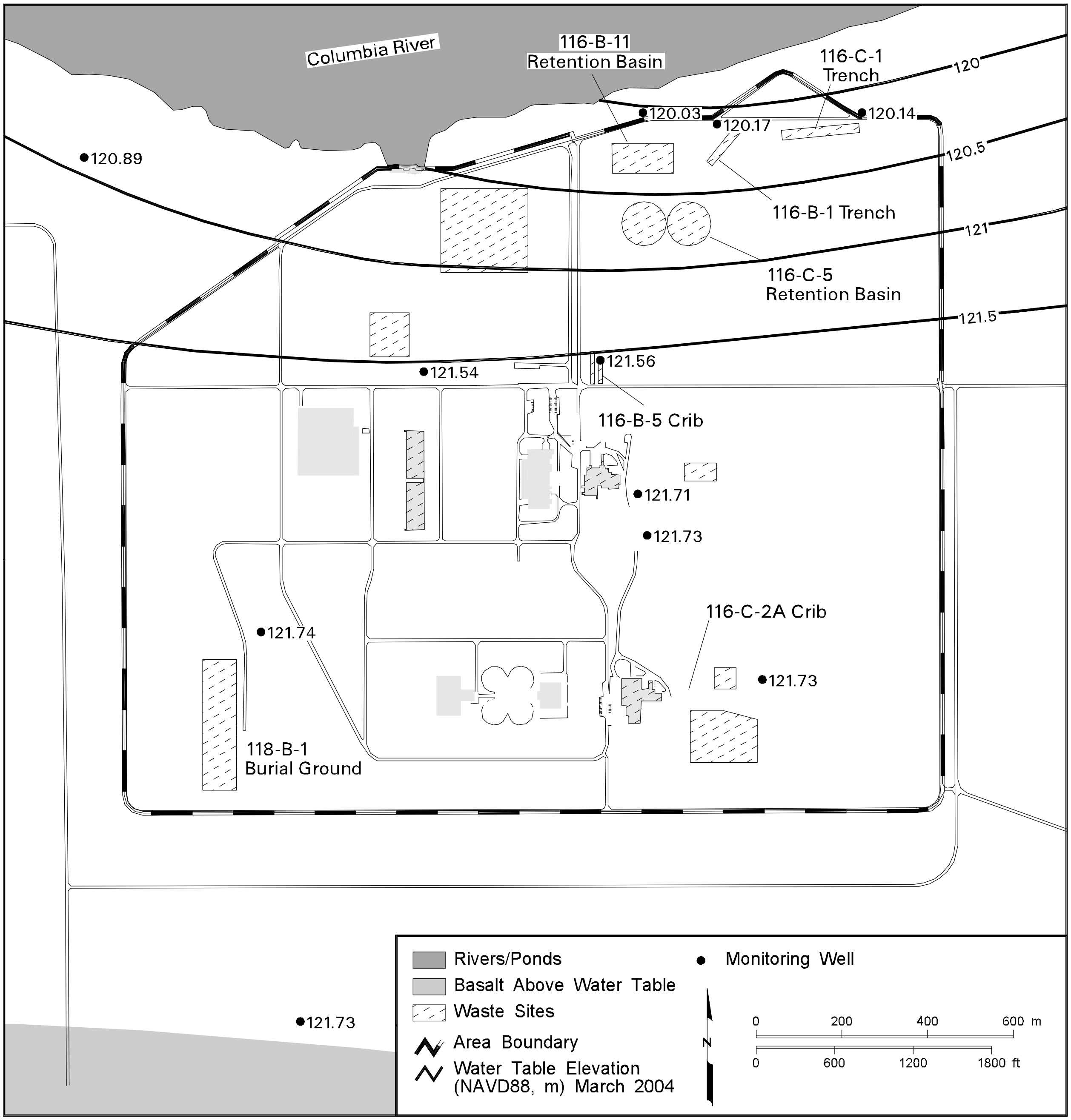

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Figure 2.2-2. 100-B/C Area Water-Table Map, March 2004

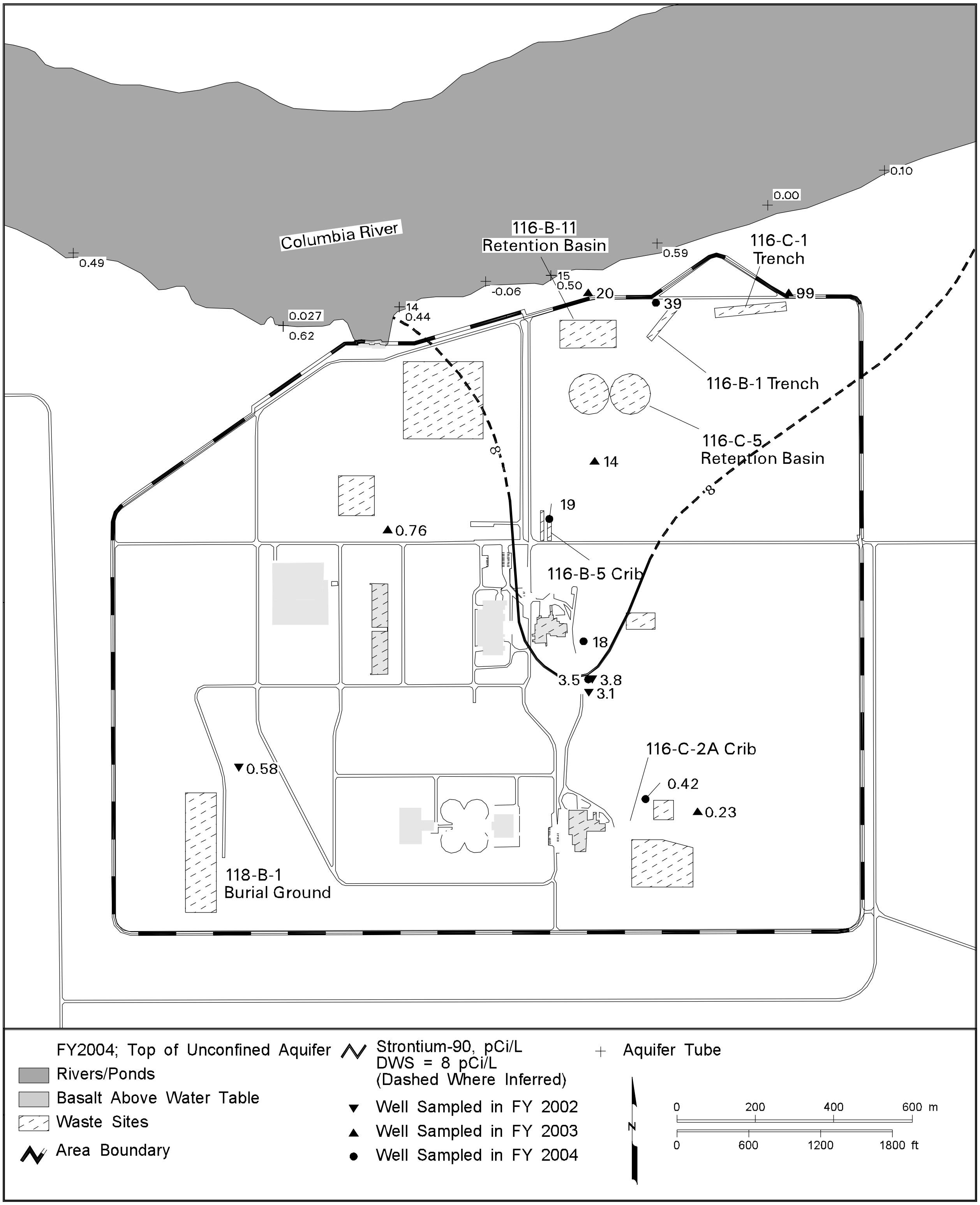

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Figure 2.2-3. Average Strontium-90 Concentrations in the 100-B/C Area, Top of Unconfined Aquifer

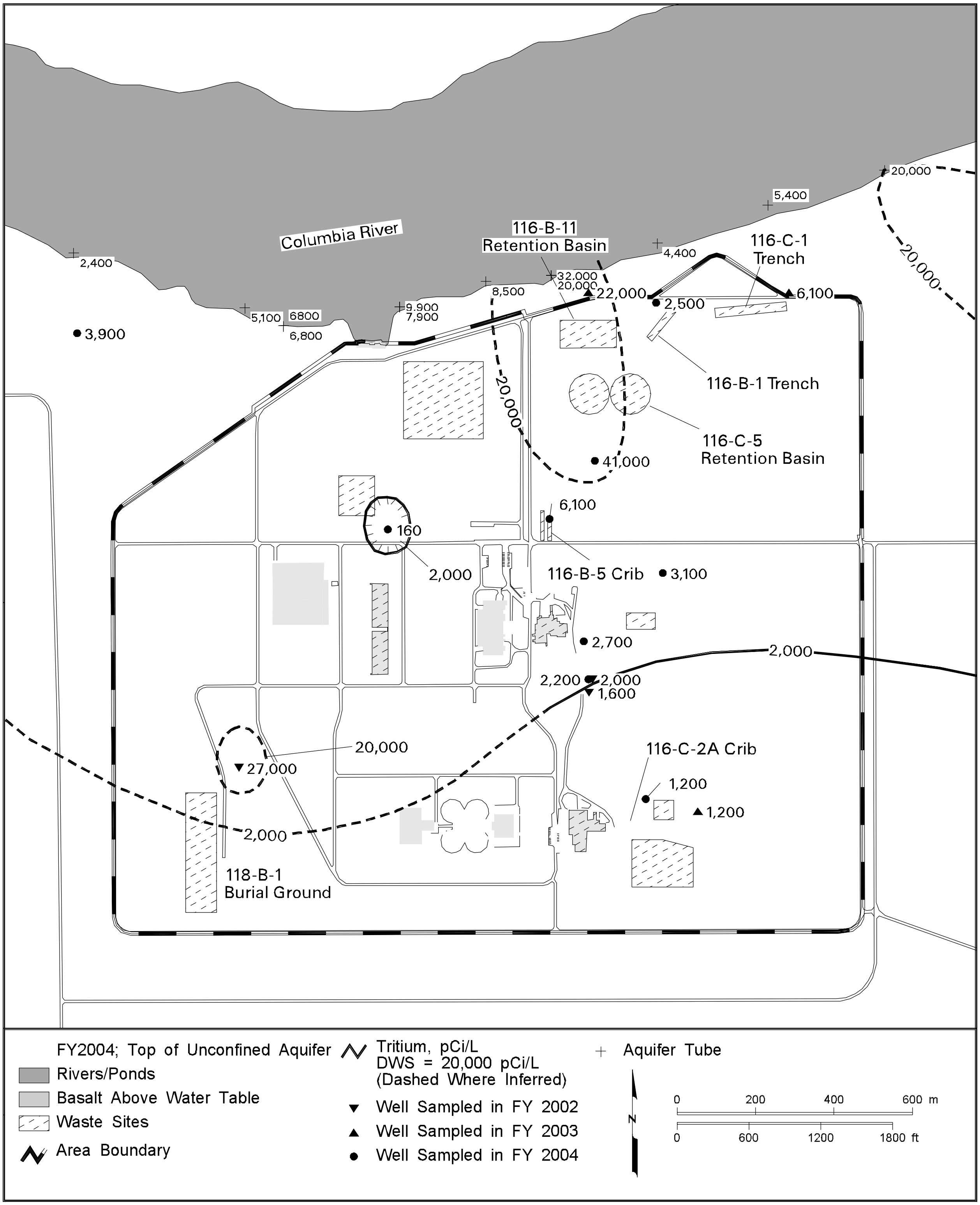

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Figure 2.2-4. Average Tritium Concentrations in the 100-B/C Area, Top of Unconfined Aquifer

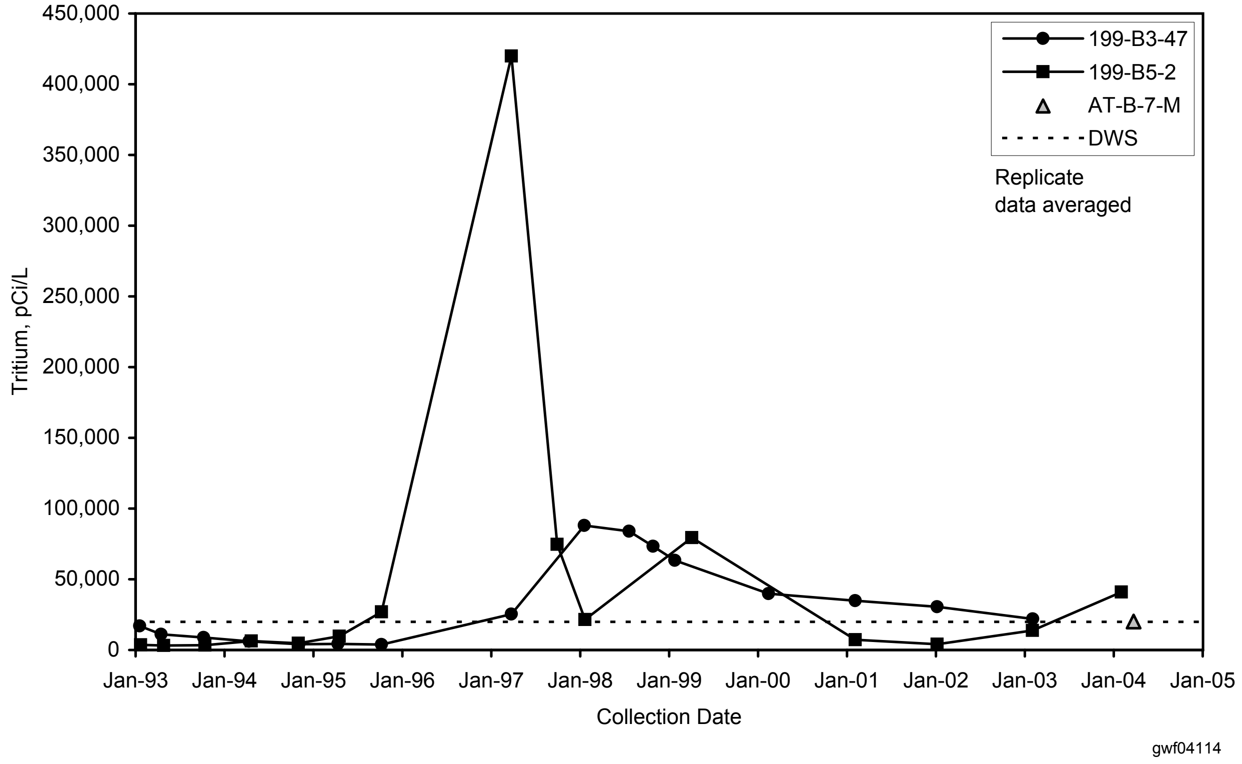

Figure 2.2-5. Tritium Concentrations in North 100-B/C Area

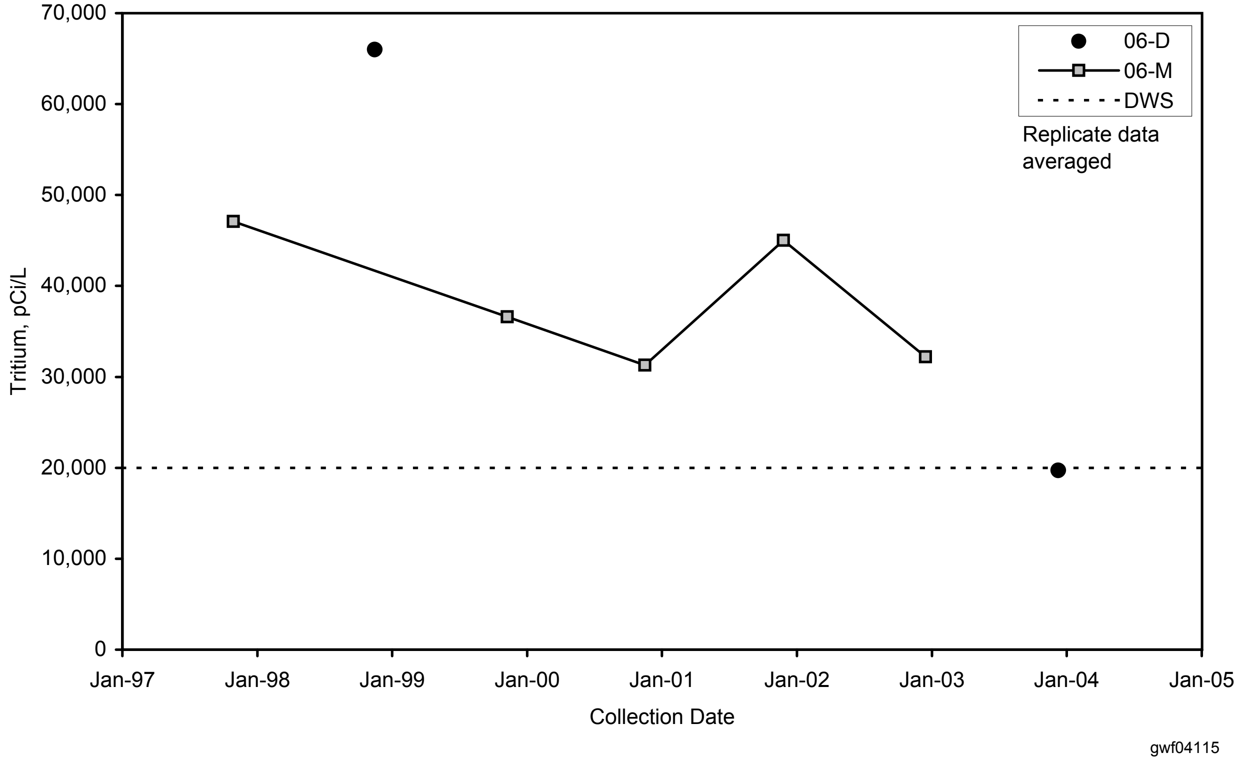

Figure 2.2-6. Tritium Concentrations at Aquifer Tube Site 6

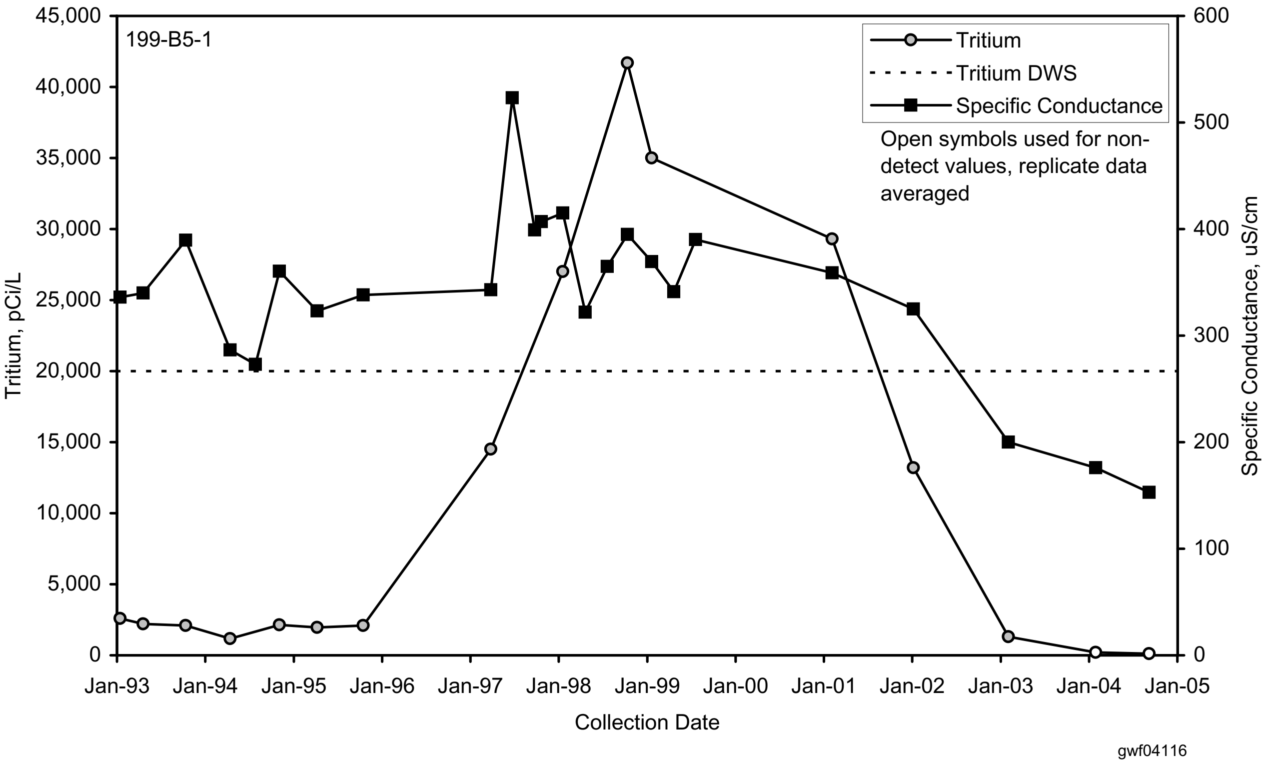

Figure 2.2-7. Tritium Concentrations and Specific Conductance in Well 199-B5-1, West-Central 100-B/C Area

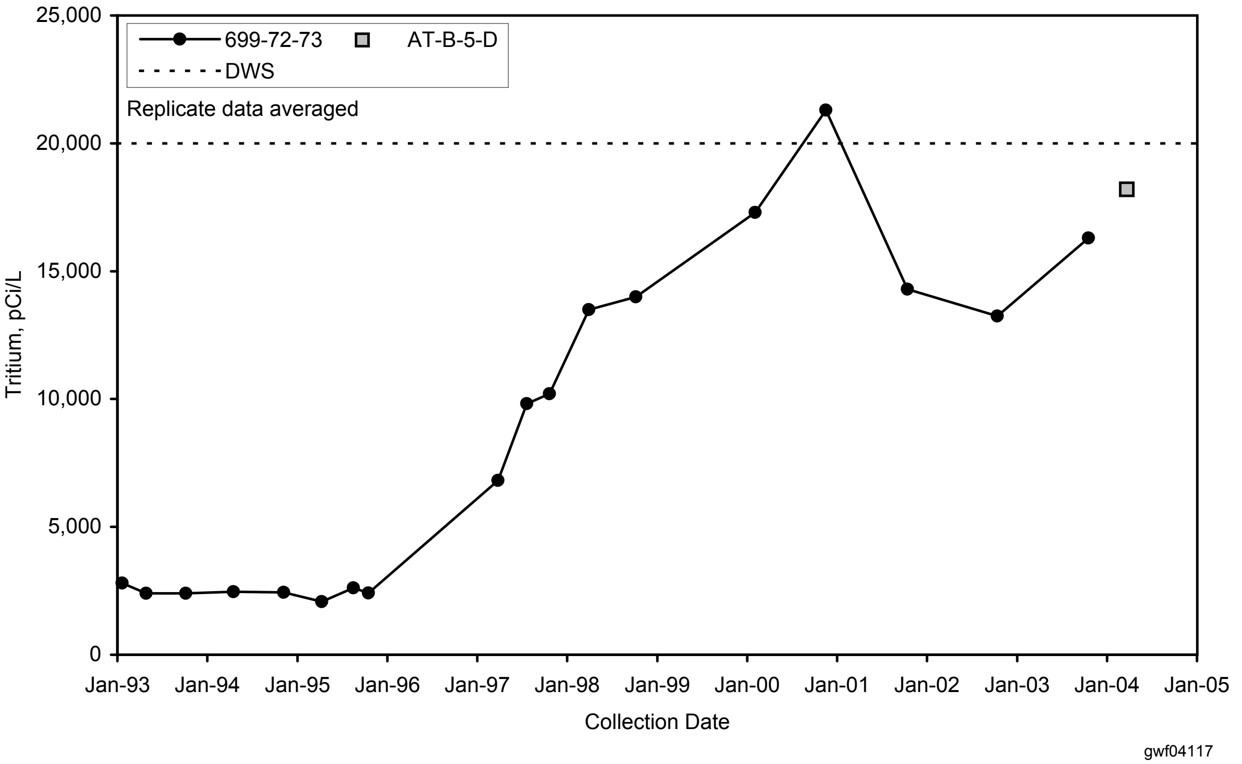

Figure 2.2-8. Tritium Concentrations East of 100-B/C Area

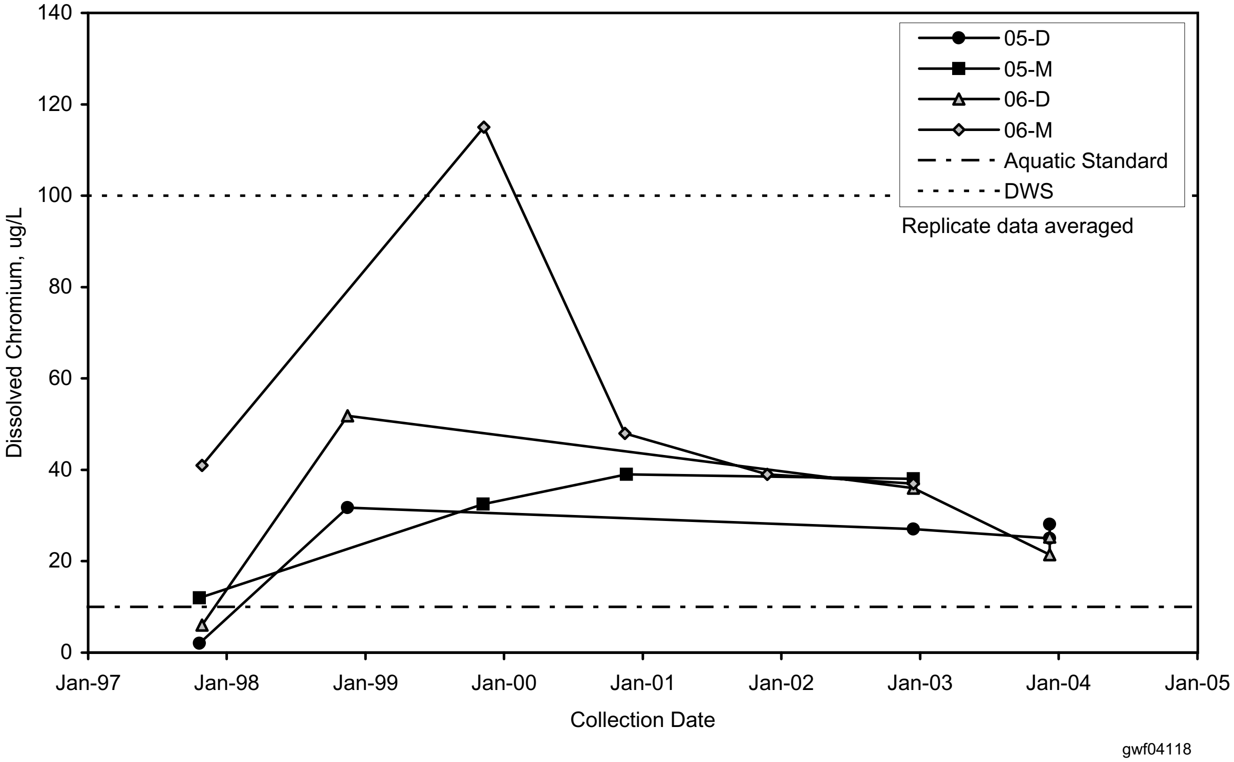

Figure 2.2-9. Chromium Concentrations at Aquifer Tubes at 100-B/C Area

2.3 100-KR-4 Operable Unit

R. E. Peterson and L. C. Swanson

This section discusses groundwater conditions in the 100-KR-4 Operable Unit, which includes all groundwater potentially impacted by contaminant releases from the facilities and waste sites within the 100-KR-1, 100-KR-2, and 100-KR-3 source operable units. Most of the facilities and waste sites associated with former production reactor operations are contained within the 100-K Area, which includes the KE and KW Reactors and their support facilities. A description of 100-K Area facilities, reactor operations, and designated waste sites as grouped into operable units, is presented in WHC-SD-EN-TI-239, which is the primary source for historical information presented below. The operable unit lies within a larger groundwater interest area, as defined by the Groundwater Performance Assessment Project (groundwater project) (see Figure 2.1-1 in Section 2.1). These interest areas are defined to facilitate scheduling, data review, and interpretation. Figure 2.3-1 is a location map showing 100-K Area facilities, waste sites, monitoring wells, and shoreline monitoring sites.

Chromium is the contaminant of concern currently being targeted by interim remedial action.

The principal groundwater issues during fiscal year (FY) 2004 (the period October 2003 thru September 2004) for the 100-K Area involved (a) a chromium plume created by past disposal to a large infiltration trench located near the river, (b) contamination associated with past discharges to the ground near the KE and KW Reactor buildings, and (c) groundwater conditions near the fuel storage basins associated with each reactor building. Remedial actions during FY 2004 included (a) removing contaminated facilities and soil associated with past operations, (b) removing and re-packaging irradiated fuel stored in basins at each reactor building, (c) initiating cleanup of the highly contaminated fuel storage basins themselves, and (d) operating the pump-and-treatment system that removes hexavalent chromium from the aquifer beneath the 116-K-2 trench.

Groundwater monitoring in the 100-KR-4 groundwater interest area includes the following monitoring activities:

CERCLA Long-Term Monitoring

- ***Twenty-five wells are sampled annually or biennially for contaminants of concern and constituents of interest.***
- ***Riverbank springs (three locations) and aquifer tubes (sixteen locations) are sampled annually along the 100-K Area river shore.***
- ***During FY 2004, all wells were sampled as scheduled; several aquifer tube sites and riverbank springs that were scheduled did not produce water for samples.***

CERCLA Interim Remedial Action Performance Evaluation

- ***Four compliance wells and nine extraction wells are sampled monthly for hexavalent chromium.***
- ***Eight performance wells are sampled monthly or semiannually to track changes in chromium and co-contaminant concentrations.***
- ***Treatment system influent and effluent chromium concentrations are sampled weekly.***
- ***During FY 2004, all wells were sampled as scheduled except for missing monthly samples for several wells in December.***

Facility Monitoring

- ***Five wells are sampled quarterly to detect potential shielding water loss to the ground from the KW and KE Basins.***
- ***Four wells are sampled quarterly to monitor plumes created by past leakage from the KE Basin.***
- ***Riverbank springs (two locations) and aquifer tubes (six locations) are sampled annually to monitor conditions at the rivershore.***
- ***In FY 2004, all wells were sampled as scheduled.***

Groundwater flow beneath the 100-K Area is generally to the northwest, with average rates of flow toward the river in the range 0.1 to 0.3 meter per day, as estimated from hydraulic gradients, and from migration rates of plumes. Figure 2.3-1 shows water-table elevation contours; flow direction is generally perpendicular to contours. The best-supported estimate for groundwater movement between the KE Reactor and the river is 0.12 meter per day, and is based on the migration of a plume created by a leak from the KE Basin in 1993. This suggests a 10- to 12-year travel time for fully dissolved waste constituents, such as nitrate, to travel from the vicinity of the KE Reactor to the river (PNNL-14031). Waste constituents that interact with sediment, such as strontium-90 and carbon-14, travel more slowly. Groundwater discharge to the Columbia River occurs through the riverbed sediment, and to a limited degree, as riverbank springs during periods of low river stage.

Groundwater flow is generally to the northwest, toward the Columbia River.

The current movement of contaminant plumes beneath most of the 100-K Area is controlled by the flow of groundwater under natural conditions, i.e., there are no effluent disposal operations that alter gradients. The exception is the region to the northeast of the KE Reactor where the pump-and-treat system is operating. Here, treated effluent is injected back into the aquifer. A mound has formed on the water table, and a radial flow pattern has developed around the injection sites (DOE/RL-2004-21).

Near the Columbia River, the groundwater system is influenced by fluctuations in river discharge, which is controlled by releases from Priest Rapids Dam. The pattern of movement and the rate at which groundwater discharges to the river are affected by these fluctuations. Because river water infiltrates the banks during periods of high river discharge, contaminants carried by groundwater may become diluted prior to release to the river through riverbed sediment and via riverbank springs.

Groundwater monitoring in the 100-K Area is conducted under two regulatory drivers: the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) governs the 100-KR-4 Operable Unit, while the *Atomic Energy Act of 1954* provides the basis for monitoring the fuel storage basins at each reactor building (i.e., K Basins). CERCLA requirements are further subdivided into monitoring conducted to (a) characterize and track all contaminants of potential concern in the operable unit, and (b) evaluate the performance of the pump-and-treat system that removes chromium from groundwater contaminated by past disposal to the 116-K-2 trench.

During FY 2004, essentially all sampling and analysis activities, as described in monitoring plans approved by the regulatory agencies, were implemented. Changes to schedules presented in the plans were caused by the loss of one monitoring well (199-K-33) because of remedial action excavation activity; the addition of several wells to the pump-and-treat system and a replacement well for 199-K-33 (new well 199-K-132); and minor changes to scheduling dates and analysis suites in response to new information that became available during the year (see Appendices A and B).

Plume areas (square kilometers) above the drinking water standard at the 100-KR-4 Operable Unit:

Chromium — 0.09
Nitrate — 0.30
Strontium-90 — 0.13
Tritium — 0.26
Trichloroethene — 0.03

2.3.1 Groundwater Contaminants

Chromium has been identified as a contaminant of concern in the 100-KR-4 Operable Unit that warrants interim remedial action (ROD 1996a). Where groundwater containing chromium discharges into the river environment, there exists a potential risk of harm to aquatic life. A pump-and-treat system currently operates to reduce the concentrations and total mass of chromium in groundwater in part of the operable unit. Other contaminants of potential concern in the operable unit include carbon-14, nitrate, strontium-90, technetium-99, trichloroethene, and tritium. These constituents are being monitored while source removal actions continue.

The following descriptions of contaminants refer to conditions at wells that monitor the uppermost hydrologic unit. Only one well exists in the 100-K Area that is completed to monitor conditions below the uppermost aquifer, and groundwater at that deep well is essentially contaminant free.

2.3.1.1 Chromium

Chromium was used in large quantities at each of the single-pass production reactor areas during the years of operation (1955 through 1971 for KE and KW Reactors). Sodium dichromate was added to reactor coolant as a corrosion inhibitor. The hexavalent form of chromium is fully soluble in water and is toxic to aquatic organisms and humans. The relevant Washington State standards are: 10 µg/L for aquatic organisms (measured as hexavalent chromium) and 100 µg/L (measured as total chromium) for drinking water supplies.

The distribution of chromium in groundwater beneath the 100-K Area during 2004 is shown in Figure 2.3-2. The contour shapes reflect the various source locations and the direction of plume migration inferred from water-table gradients.

Chromium Beneath 116-K-2 Trench. The largest area of chromium contamination is associated with the 116-K-2 trench, which received large volumes of reactor coolant. The interpretation shown in Figure 2.3-2 assumes that chromium detected at well 699-78-62, which is east of the 100-K Area (Figure 2.3-1), was pushed inland by radial flow around a mound beneath the 116-K-2 trench during the operating years. (Note: If this assumption is incorrect, the area of contamination is considerably smaller.) The trench plume is the target of a pump-and-treat system intended to protect aquatic receptors in the Columbia River by extracting and treating groundwater (ROD 1996a), thus reducing the flux of chromium to the river ecosystem and the total amount of chromium in the environment. The system began operating in October 1997 (see Section 2.3.2).

The largest area of chromium contamination is associated with past disposal to the 116-K-2 trench. Concentrations are decreasing or constant in most wells.

Concentrations at wells that monitor the trench plume are typically <100 µg/L (the drinking water standard) and appear to be decreasing with time or remaining nearly constant, with exceptions at several locations. The decrease is a combined consequence of the pump-and-treat operation and natural attenuation by dispersion. Figures 2.3-3, 2.3-4, and 2.3-5 illustrate concentration trends for monitoring wells within this plume area.

Exceptions to the generally decreasing trend occur at wells 199-K-111A and 199-K-18, both located near the southwest edge of the plume, where concentrations have been increasing during recent years, although a leveling-off of the rate of increase appears to have started (Figure 2.3-4). The cause for these trends is believed to be related to the altered flow pattern in the area as a result of the extraction and injection of groundwater. Chromium concentrations are higher at aquifer tube site AT-K-3, compared to conditions immediately upstream and downstream along this segment of shoreline. It appears that an area of elevated chromium may be present in the region immediately south of well 199-K-18.

At the northeast end of the trench, chromium concentrations are gradually decreasing, though conditions at wells 199-K-37 and 199-K-130 suggest recently rising trends (Figure 2.3-5). Also, newly installed well 199-K-131, which is located ~300 meters northeast of well 199-K-130, revealed chromium concentrations that suggest the plume boundaries extend farther to the northeast than previously anticipated. Results from aquifer tubes for this part of shoreline indicated a gradually decreasing trend in concentrations (PNNL-14444).

Chromium Near KE and KW Reactors. Two additional areas contain elevated concentrations of chromium, although the extent of each is poorly defined. Near KE Reactor, a plume extends from the southeast side of the water treatment plant basins, where contaminated soil in the vicinity of a former sodium dichromate storage tank and railcar transfer station is the likely source (WHC-SD-EN-TI-239). Periodic events appear to remobilize chromium and create concentration changes in groundwater, as seen at well 199-K-36 (Figure 2.3-6). Leakage of clean water from the water treatment plant basins may provide the remobilization mechanism. Migration downgradient beyond the KE Reactor does not appear to have occurred, as shown by the low concentrations at well 199-K-23.

Near KW Reactor, elevated chromium concentrations are present at several wells, with the suspected source being sodium dichromate in the vadose zone at as yet unidentified locations. Candidate locations include the storage tank and transfer station at the southeast side of the KW Water Treatment Plant (same as at KE), and also the underground piping associated with the system used to add sodium dichromate to coolant makeup water. Figure 2.3-7 shows concentration trends for wells located within this plume. (Note that the abrupt drop in concentrations at well 199-K-108A in 1999 was caused by groundwater being diluted from an unknown clean water source.) Monitoring results from sites near the Columbia River (well 199-K-31, aquifer tube sites AT-K-1 and AT-17, and riverbank spring SK-063) do not show evidence that this plume has yet reached the river. However, newly installed well 199-K-132, which is located mid-distance between KW Reactor and the Columbia River, revealed a hexavalent chromium concentration of ~120 µg/L in samples collected during well development.

2.3.1.2 Tritium

Tritium was common in effluent discharged during reactor operations. However, some of the tritium currently observed in groundwater was introduced after the shutdown of the reactors in 1971. Current sources and potential sources for providing tritium to groundwater include shielding water contained in the KE and KW Basins; the soil columns beneath the former reactor atmosphere gas condensate cribs located to the east of each reactor building; and possibly irradiated materials contained in the 118-K-1 burial ground. Tritium has a radioactive decay half-life of 12.3 years. The drinking water standard for this radionuclide is 20,000 pCi/L.

The KE and KW condensate cribs, which were continuing sources for tritium in groundwater, were removed during FY 2004.

The distribution of tritium in groundwater beneath the 100-K Area during 2004 is shown in Figure 2.3-8. The contour shapes reflect several past and present source locations, as well as the direction of plume migration inferred from water-table gradients. The highest tritium concentrations are associated with the areas immediately downgradient of the 116-KE-1 and 116-KW-1 condensate cribs at each reactor. These cribs were excavated and backfilled with clean material during the period December 2003 to March 2004. Some contaminated soil remained at the bottom of the excavations. Because tritium is present in the shielding water of each fuel storage basin, concentrations in groundwater are closely monitored for evidence of shielding water loss to the ground (PNNL-14033). There is evidence to suggest that tritium releases from materials in the 118-K-1 burial ground are currently affecting groundwater, causing the area of groundwater contamination north of the burial ground (Figure 2.3-8).

Tritium Near KE Reactor. The plume shown in Figure 2.3-8 near KE Reactor has been formed by tritium from past disposal to the former 116-KE-1 condensate crib; leaks to the ground from KE Basin (1976 to 1979, and again in 1993); and possible releases from the vadose zone beneath the 116-KE-3 drain field and associated catch tank (100-K-68 "D-sump"). The tritium distribution pattern reflects a coalescing of plumes from these sources and the timing of release from each source. The highest concentrations are immediately downgradient of the former 116-KE-1 crib. Recent trends for tritium and carbon-14 at a well near this source are shown in Figure 2.3-9.

Recent variability in tritium concentrations observed near each reactor building do not have a clear explanation.

Tritium concentration trends in wells most likely to detect shielding water loss to the ground from KE Basin are shown in Figure 2.3-10. The recent increases at wells 199-K-27 and 199-K-109A are unexplained, although there is no evidence from facility operations suggesting a significant loss of shielding water. Technetium-99, a second indicator of shielding water, has not been detected at these wells. The earlier increased concentrations at well 199-K-29 during the period 2001 to 2002 are believed to reflect the plume associated with the former 116-KE-1 crib.

Tritium Near KW Reactor. The tritium plume mapped near the KW Reactor is associated with effluent disposed to the former 116-KW-1 crib during the operating years. An unexplained increase in tritium concentrations at well 199-K-106A, located downgradient of the crib, began in 2001, abruptly peaked in 2003, and remained at elevated levels during 2004 (Figure 2.3-11). Other constituents showing a similar trend included nitrate and groundwater temperature. Carbon-14, which was disposed to the crib but is less mobile than tritium, did not follow the tritium trend. The cause for the recent change in the tritium trend at well 199-K-106A is presumed to be remobilization of contaminants at the 116-KW-1 crib and underlying soil column, although a driving mechanism has not been positively identified. Also, technetium-99 was detected at low concentrations (25 to 65 pCi/L) in samples from well 199-K-106A collected during peak tritium concentrations. The origin for technetium-99 at this location is unknown.

There is no evidence in groundwater data to suggest water loss to the ground from the KW Basin in recent years. Tritium concentrations in wells most likely to detect shielding water are shown in Figure 2.3-12. The groundwater concentrations are significantly lower than concentrations in KW Basin shielding water. The recent change in concentrations at well 199-K-34 has no obvious explanation, but trend changes of this magnitude have occurred in the past.

Tritium Near the 118-K-1 Burial Ground. Tritium concentrations at well 199-K-111A, located at the northwest corner of the burial ground, began rising abruptly in mid-2000 to a peak value of 98,200 pCi/L in April 2002 (Figure 2.3-13). Since that time, concentrations have steadily declined and are currently at 13,900 pCi/L (July 2004). The next nearest downgradient monitoring well is 199-K-18, located ~450 meters downgradient of 199-K-111A. Tritium concentrations show a gradual rise at that well.

Tritium concentrations in groundwater near the 100-K burial ground have decreased markedly during the past 2 years.

The source for the tritium near the burial ground was the subject of a detailed investigation during 2002 of groundwater movement and soil gas in the vicinity of the burial ground (PNNL-14031). The best explanation to date for the elevated tritium trend is that a tritium plume lies to the east of the well, i.e., beneath the burial ground. This plume may have been displaced to the west under the influence of the groundwater mound that has formed beneath the pump-and-treat injection site (see water-table contours in Figure 2.3-1). Supporting this idea is (a) the pattern of groundwater movement inferred from water-table gradients, (b) gradually increasing chromium concentrations as the pump-and-treat plume shifts somewhat to the west (Figure 2.3-4), and (c) the absence of other constituents that would identify known tritium sources.

An additional soil-gas survey was conducted during 2003 along the perimeter of the burial ground on the side closest to the river (PNNL-14548). Soil gas was analyzed for helium isotopes (helium-3 is a decay product of tritium). An excess of helium-3, as compared to ambient air amounts, was measured at all sites, indicating the nearby presence of tritium. The pattern of isotope ratios suggests the likelihood of a tritium source in the burial ground, along with an underlying groundwater plume.

Tritium Near 116-K-2 Trench. Groundwater downgradient of the trench typically contains low concentrations of tritium, i.e., <2,000 pCi/L. The exception occurs at the southwest end of the trench, where recent concentrations range between 42,000 and 65,000 pCi/L at wells 199-K-18 and 199-K-120A (a pump-and-treat system extraction well) during the past few years. The trend at well 199-K-19 has risen steadily since 1992. The source for this tritium is uncertain; it may represent past disposal to the 116-K-1 crib or possibly tritium from a source farther inland, such as a previously unidentified burial ground source.

Tritium is being re-introduced to the aquifer via injection of the effluent from the pump-and-treat system (see Figure 2.3-1 for location of injection wells). The average tritium concentration in effluent was 8,600 pCi/L (November 2004), and most of the tritium comes from extraction well 199-K-120A, where concentrations were ~50,000 pCi/L in 2004. Injected effluent appears to have started arriving at downgradient wells 199-K-119A and 199-K-125A as early as 2000, as shown by increasing tritium concentrations at those wells (Figure 2.3-14). Increasing trends are also present at nearby wells 199-K-116A and 199-K-127.

2.3.1.3 Carbon-14

Condensate from gas circulated through the KE and KW Reactors contained carbon-14 (along with tritium) and was discharged to infiltration cribs at the east side of each reactor building. Release of carbon-14 from the cribs, which were excavated and backfilled during 2004, was the source for the two carbon-14 plumes near each reactor. The drinking water standard is 2,000 pCi/L, which is exceeded at several wells that monitor these plumes. The half-life for carbon-14 is 5,730 years. The radionuclide exchanges with carbon in carbonate minerals, and so its movement is more restricted and variable than a non-retarded constituent like tritium.

The two plumes appear to be positioned between the crib source locations and the Columbia River. There is some evidence that the plume front in the region of the 116-KW-1 crib has reached the river; samples from aquifer tube 17-D have shown concentrations up to 680 pCi/L in the past, which is above background levels. Measured concentrations along the shoreline in the region of the 116-KE-1 crib are very low and likely to be representative of background levels. Current concentrations of carbon-14 in groundwater at wells immediately downgradient of each crib are shown in Figures 2.3-9 and 2.3-11. Near the 116-KE-1 crib, the concentration is ~6,900 pCi/L and near the 116-KW-1 crib, ~15,300 pCi/L.

Carbon-14 has also been detected in an area upgradient of the 116-KW-1 condensate crib, at well 199-K-108A. Concentrations exceeded the drinking water standard during the mid-1990s, with monitoring results relatively constant at ~4,000 pCi/L. During 2000, groundwater at this location became diluted by clean water from an unknown source, and contamination indicators were dramatically reduced in concentration. During 2004, it appears as though the dilution by clean water has stopped, and monitoring data suggest a return to pre-diluted conditions has started.

2.3.1.4 Strontium-90

Strontium-90 was released to the environment at 100-K Area primarily via used reactor coolant. It may also have been present in fuel storage basin shielding water, which was discharged to nearby drain fields/injection wells during the reactor operating period. Strontium-90 is currently present at relatively high concentrations in the shielding water at KE and KW Basins. The radionuclide is moderately mobile in the environment and has a half-life of ~29 years. The drinking water standard is 8 pCi/L, which is based on a radiological dose rate. If strontium-90 is the only beta-emitting radionuclide present in a groundwater sample, the associated gross beta concentration will be approximately twice that for the strontium-90 concentration.

Strontium-90 was apparently remobilized during the 1990s by high water-table conditions, and possibly by infiltrating water, thus affecting underlying groundwater.

Strontium-90 Near the KE and KW Reactors. The highest concentrations in 100-K Area groundwater have been observed near the northwest corner of the KE Reactor, at well 199-K-109A and reached a peak of ~18,000 pCi/L in 1997. Concentrations declined following the peak, and since 2002, have remained variable within the range of several hundred up to ~2,400 pCi/L (Figure 2.3-15). The elevated gross beta concentrations also observed in groundwater at this location appear to be caused primary by strontium-90. The elevated concentrations during the period 1996 through 2000 correlate with a period of sustained high water-table conditions (see hydrograph on Figure 2.3-15), which may have remobilized strontium-90 that remains in the soil beneath the 116-KE-3 drain field. Infiltration of water from leaking fire hydrant utility lines during this time period may also have contributed to flushing residual contamination from the vadose zone beneath the former drain field (PNNL-12023).

Strontium-90 concentrations are lower at equivalent locations near KW Reactor and during 2004 continued to range from 20 to 50 pCi/L, with essentially constant trends. Leakage from hydrant utility lines has not been observed near the northwest corner of the KW Basin and adjacent drain field. There are indications at well 199-K-107A of temporarily elevated levels during the high water-table conditions in 1996 and 1997, based on gross beta measurements.

Strontium-90 Near the 116-K-2 Trench. The effluent disposed to the 116-K-2 trench contained strontium-90, which is still present in groundwater affected by trench operations.

The highest concentrations are generally <40 pCi/L and limited in areal extent; most observed concentrations are near or below the 8-pCi/L drinking water standard. Also, most concentration trends indicate a gradual decline.

2.3.1.5 Other Constituents

Nitrate is widely distributed beneath the 100-K Area; potential sources include currently active septic systems and past-practices waste sites. The distribution patterns do not clearly delineate specific source sites. Nitrate exceeds the 45-mg/L drinking water standard in some areas. Concentration trends vary depending on monitoring location; the cause for the variability is likely to be shifts in plume position because of groundwater flow.

Trichloroethene has been detected at wells 199-K-106A and 199-K-33, which are located downgradient of the 116-KE-1 crib, at concentrations above the 5-µg/L drinking water standard. Concentrations in FY 2004 continued at ~10 µg/L, although trends at both wells suggest gradually decreasing concentrations. A replacement well for 199-K-33, which was decommissioned in June 2003, was installed in July 2004; analytical data for samples from this new well (199-K-132) are not yet available.

In the past, several metals have been measured in filtered samples at concentrations above the drinking water standard (e.g., aluminum, iron, manganese, and nickel). These occurrences have not been positively connected to waste sites or waste streams. They are not considered contaminants of concern because of (a) limited areal extent, (b) sporadic occurrence, and (c) possibility that their occurrence may be related to well construction and, therefore, not representative of groundwater conditions.

Nitrate and trichloroethene concentrations exceed drinking water standards in some 100-K Area monitoring wells.

2.3.2 Interim Groundwater Remediation for Chromium

This CERCLA interim remedial action involves a pump-and-treat system designed to remove hexavalent chromium from groundwater in the region between the 116-K-2 trench and the Columbia River (DOE/RL-96-84). Hexavalent chromium poses a threat to aquatic organisms that use the riverbed substrate for habitat. Fall Chinook salmon, which spawn in riverbed gravels, are of particular concern in the Hanford Reach. As described in the record of decision (ROD 1996a), the protection standard for aquatic life is 11 µg/L as measured in riverbed substrate pore water. Because some dilution of contaminants by river water occurs along the pathway between the aquifer and riverbed substrate, the record of decision considers a value of 22 µg/L in near-river compliance wells as being protective of aquatic life.

The interim remedial action consists of a pump-and-treat system involving nine extraction wells, five injection wells, and an ion-exchange resin treatment system that removes hexavalent chromium from the extracted groundwater (DOE/RL-2004-21). The system began operating in October 1997. Performance monitoring of the pump-and-treat system is described in an interim remedial action monitoring plan (DOE/RL-96-90). Four wells, located between the extraction wells and the Columbia River, have been identified as compliance monitoring locations. Eight additional wells are used to help evaluate the performance of the system regarding aquifer conditions. Eleven aquifer tube sites located along the rivershore, which include four sites newly equipped during 2004, are also monitored. Lists of sampling frequencies and analyses performed are included in Appendix A.

The remedial action objectives for the 100-KR-4 Operable Unit (ROD 1996a) are:

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

The contaminant of concern is hexavalent chromium. The record of decision identifies the cleanup goal at compliance wells as 22 µg/L.

The results of the interim remedial action for chromium are described in an annual summary report for each calendar year, which is prepared by the remedial action contractor (e.g., DOE/RL-2004-21). Highlights from the summary report for calendar year 2003 (the most recent report available), with updates for volumes treated and mass removed through September 2004, are presented in the following sections.

2.3.2.1 Progress During FY 2004

During the period October 1, 2003, through September 30, 2004, ~518.9 million liters of groundwater were extracted and treated, and 31.5 kilograms of chromium were removed. Since the startup of operations in October 1997, the total volume extracted is ~2.59 billion liters and total mass of chromium removed is ~244.3 kilograms. The yearly average flow rate for each extraction well ranges between 52 and 162 liters per minute, with a combined average flow rate of 995 liters per minute during 2003 (DOE/RL-2004-21).

A new monitoring well (199-K-131) was installed during FY 2004 to help define the northern extent of the plume. The first result for hexavalent chromium in groundwater at this well showed a concentration of 63 µg/L, which exceeds the remedial action goal of 22 µg/L for the interim remedial action. This result suggests that the chromium plume associated with the trench extends farther to the northeast than previously anticipated.

2.3.2.2 Influence on Aquifer Conditions

Chromium concentrations within the target plume area show generally decreasing trends, though two wells show distinctly increasing trends (Figures 2.3-3, 2.3-4, and 2.3-5). Strong decreasing trends are present at wells 199-K-20 and 199-K-117A. A more gradual decrease is indicated at well 199-K-114A, where groundwater is periodically diluted by river water. Increasing concentrations occur at wells 199-K-18 and 199-K-130. The cause for these increases is discussed in Section 2.3.1.1.

Concentrations at or below the remedial action goal (22 µg/L) for near-river wells are consistently observed only at well 199-K-117A. Chromium levels in compliance well 199-K-114A have fluctuated above and below the target level for several years, depending on river stage (Figure 2.3-3). As a result, well 199-K-114A will be converted to an extraction well in early FY 2005.

Levels of chromium contamination appear to be generally decreasing in the area of the pump-and-treat system.

In addition to the pump-and-treatment system, other technologies are being considered for cleanup of groundwater contaminated by hexavalent chromium. A treatability test involving the injection of calcium polysulfide into the aquifer is scheduled for FY 2005 in the vicinity of well 199-K-126. While this technology has been used to remediate several chromium sites in the United States, it has not been applied at the Hanford Site. The calcium polysulfide acts to reduce hexavalent chromium in the aquifer by converting it to the less-toxic and less mobile trivalent form.

Chromium concentrations in aquifer tubes along the shore segment affected by the plume appear to have decreased with time, although the results are limited in number and are not adjusted for mixing with river water (PNNL-14444). When results are available for tube samples from several depths at a particular site, the deeper site typically shows the higher concentration, thus revealing the diluting effect of river water that infiltrates the riverbank during high river stage.

The injection of treated effluent at five wells has created a mound of uncertain magnitude on the water table. The injected treated effluent appears to have migrated downgradient as far as extraction wells 199-K-119A and 199-K-125A, as shown by the increasing tritium concentrations in those wells during recent years (Figure 2.3-14). Tritium is a good tracer for the effects of injection, as effluent concentrations are higher than in groundwater near most of the extraction wells. The mounding may also have caused the boundary of the chromium plume, and perhaps an unmapped tritium plume, to shift to the west, where the boundary(ies) may now be detected at well 199-K-111A (Figures 2.3-4 and 2.3-13).

Uncertainties regarding the pump-and-treat system's influence on aquifer conditions involve the (1) extent of plume inland of the trench, and whether or not chromium observed at well 699-78-62 is part of the plume; (2) source for chromium and tritium at wells 199-K-18 and 199-K-120A, where concentrations are increasing; and (3) height and extent of the mound created at the injection site.

2.3.3 Facility Monitoring: 100-K Basins

Basins within the KE and KW Reactor buildings have been used to store irradiated fuel from the last run of the 100-N Reactor, along with other miscellaneous fuel recovered during remedial actions at other reactor areas. As of fall 2004, all of this fuel has been removed, re-packaged, and moved to a better storage facility in the Central Plateau as part of the Spent Nuclear Fuels Project. Tri-Party Agreement (Ecology et al. 1989) Milestone M-34-00 covers the fuel removal and basin cleanup project. The following activities were accomplished during FY 2004:

- Completed removal of all irradiated nuclear fuel (~2,300 tons) in October 2004.
- Started removal of contaminated sludge (~50 cubic meters) at KE Basin in June 2004.
- Filled discharge chute at KE Basin with concrete in August 2004. Leakage via construction joints associated with this structure was the source of previous shielding water loss that impacted groundwater in 1993.

All spent fuel has been removed from the K Basins. Work to remove radioactive sludge is underway.

Groundwater Monitoring. Groundwater monitoring near the K Basins is conducted under a subtask within the groundwater project. The K Basins sampling and analysis schedule complements schedules associated with the 100-KR-4 Operable Unit. The monitoring plan (PNNL-14033) describes the objectives for the subtask:

- Characterize groundwater conditions between the K Basins and the Columbia River to provide a periodic status of current conditions and the attenuation of plumes.
- Distinguish between groundwater contamination associated with K Basins and contamination from other past-practices sources to help guide operational and remedial action decisions.
- Maintain a strategy for the potential expansion of monitoring capabilities to respond to future basin-related issues.

The primary indicator for detecting shielding water in groundwater is tritium, which is present at concentrations in the millions-of-picocuries range in the KE and KW Basins. Other less mobile radionuclides (e.g., strontium-90, cesium-137) are also present at relatively high concentrations in shielding water. However, if small volumes or low rates of leakage were to occur, these contaminants might not show up in groundwater because they would be retained in the vadose zone. One additional tracer for shielding water is technetium-99, which is mobile, like tritium, but is at relatively low concentrations in shielding water. Therefore, it might not be apparent in groundwater if only small volumes of basin water are involved.

Recent Monitoring Issues. In January 2003, tritium concentrations increased at wells 199-K-27 and 199-K-109A, which are located adjacent to the KE Basin on its northwest side (see Figure 2.3-1 for locations and Figure 2.3-10 for concentration trends). There has been no unexplained loss of water from the basin to account for the trend changes in groundwater. However, it is possible that very low rates of loss from the basin to the ground might not be detected by basin volume monitoring and that a relatively small volume of shielding water could account for the trend changes seen in groundwater. Other past-practices disposal sites are located in the area but are not in the direct groundwater flow paths monitored by these wells.

Near the KW Reactor, tritium concentrations at a well downgradient of the former 116-KW-1 condensate crib have been rising gradually since 2001, with a sharp peaking in mid-2003 (see Figure 2.3-11). The source for the tritium is believed to be the vadose zone beneath the former crib, and is not related to water loss from the KW Basin.

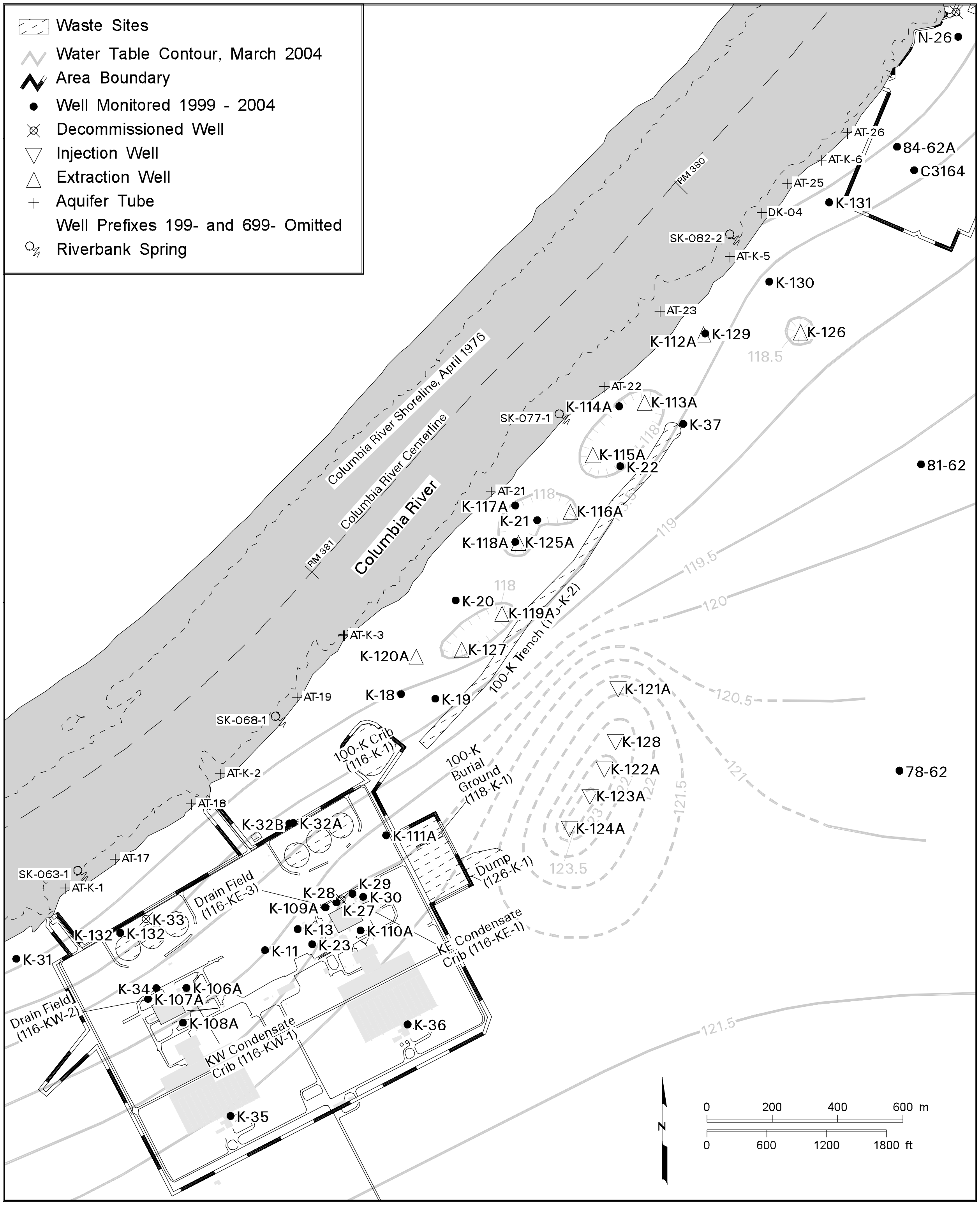

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Figure 2.3-1. Location Map for 100-K Area Facilities, Waste Sites, Monitoring Wells, and Shoreline Monitoring Sites

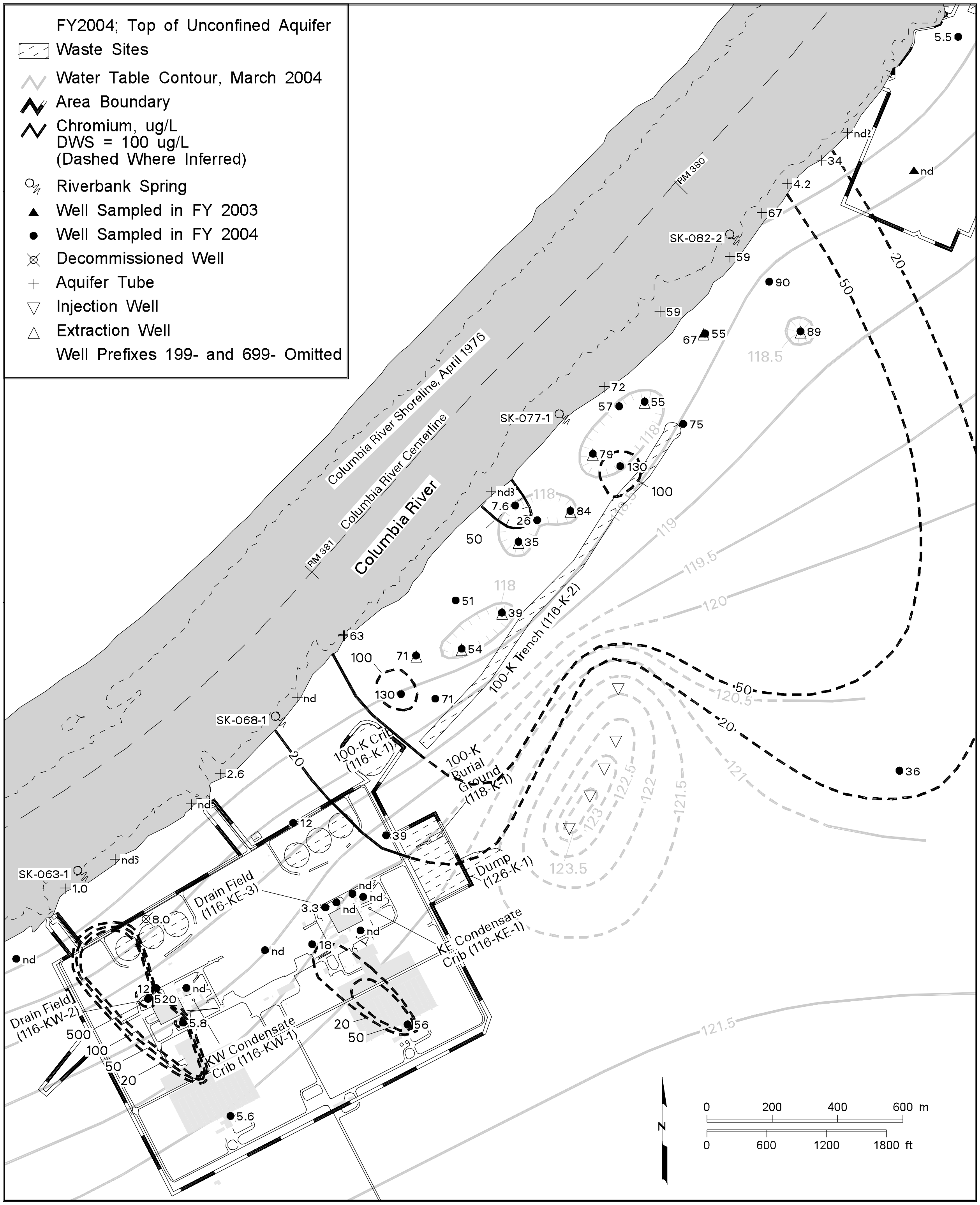

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Figure 2.3-2. Chromium Distribution in 100-K Area Groundwater, FY 2004

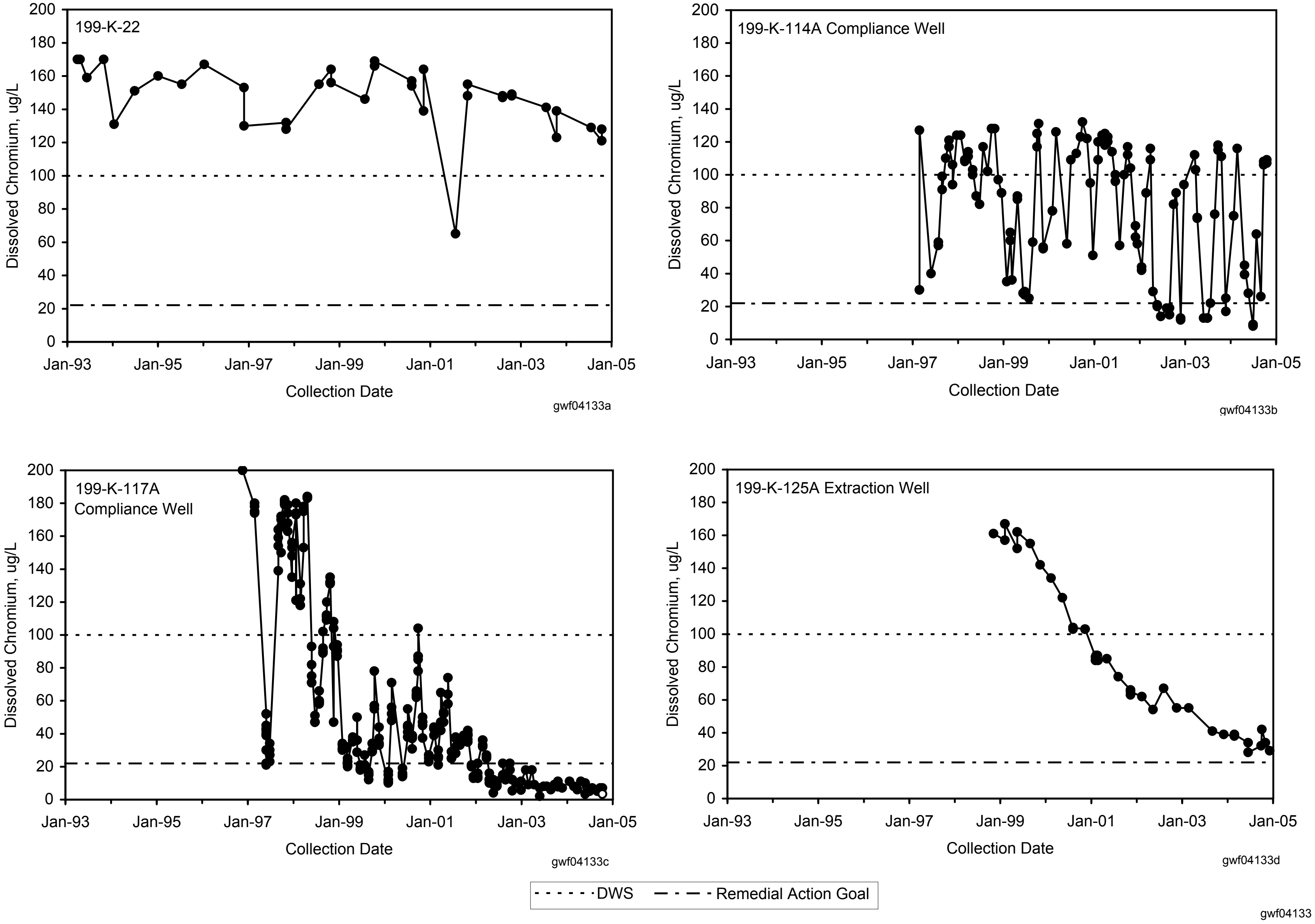

Figure 2.3-3. Chromium Concentrations in Wells Located in the Central Portion of the Interim Remedial Action Plume

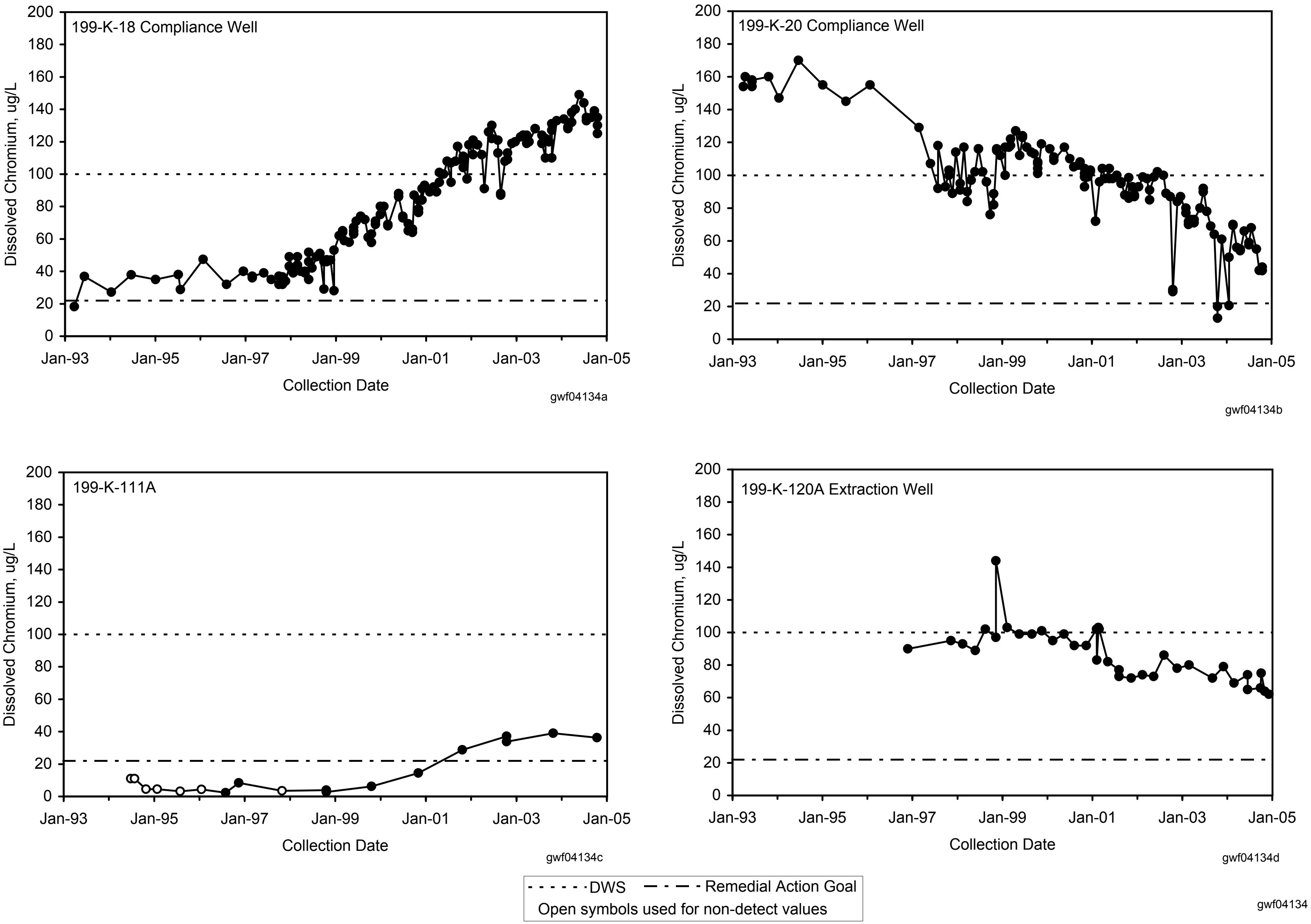

Figure 2.3-4. Chromium Concentrations in Wells Located at the Southwest Edge of the Interim Remedial Action Plume

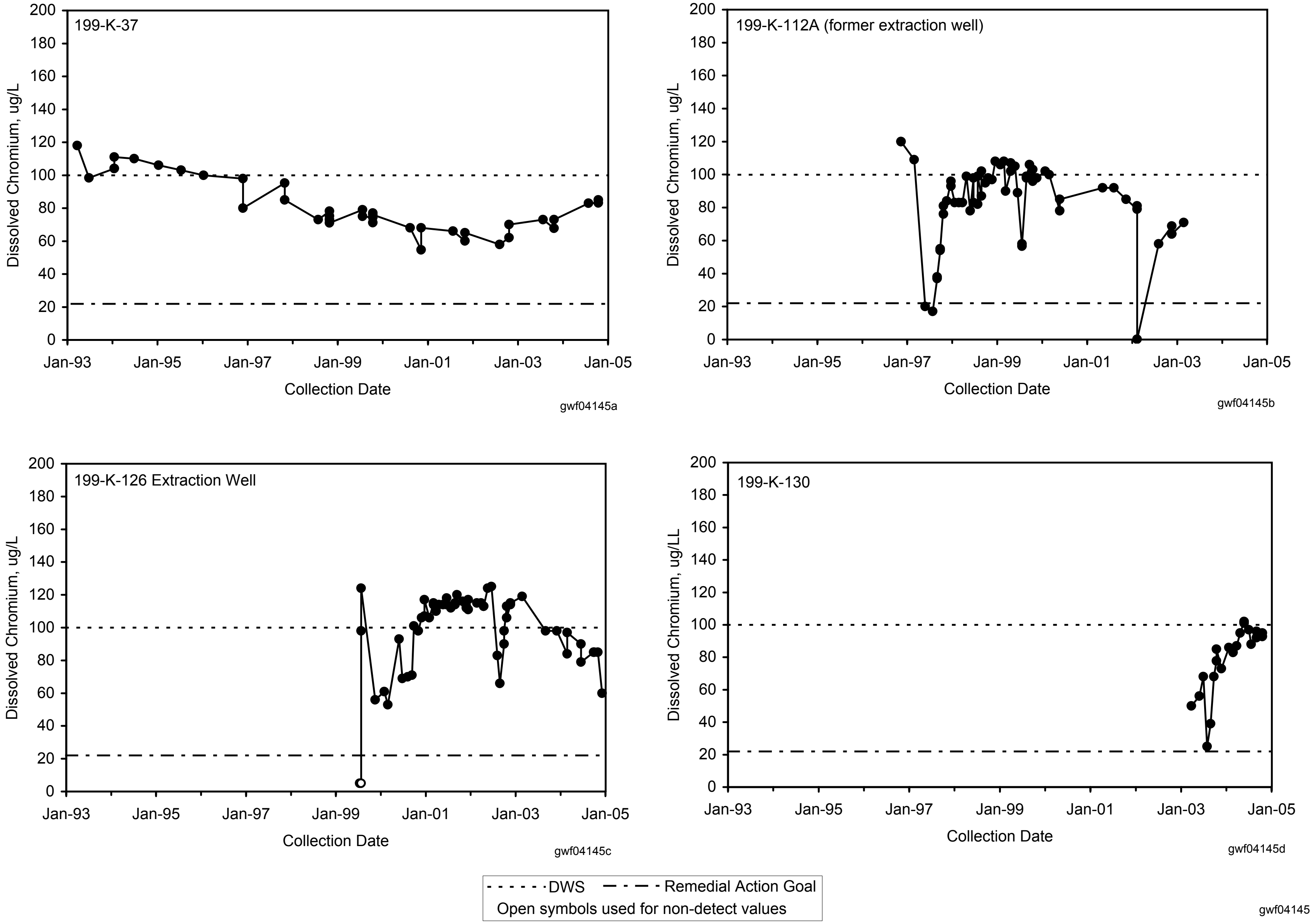

Figure 2.3-5. Chromium Concentrations in Wells Located at the Northeast Edge of the Interim Remedial Action Plume

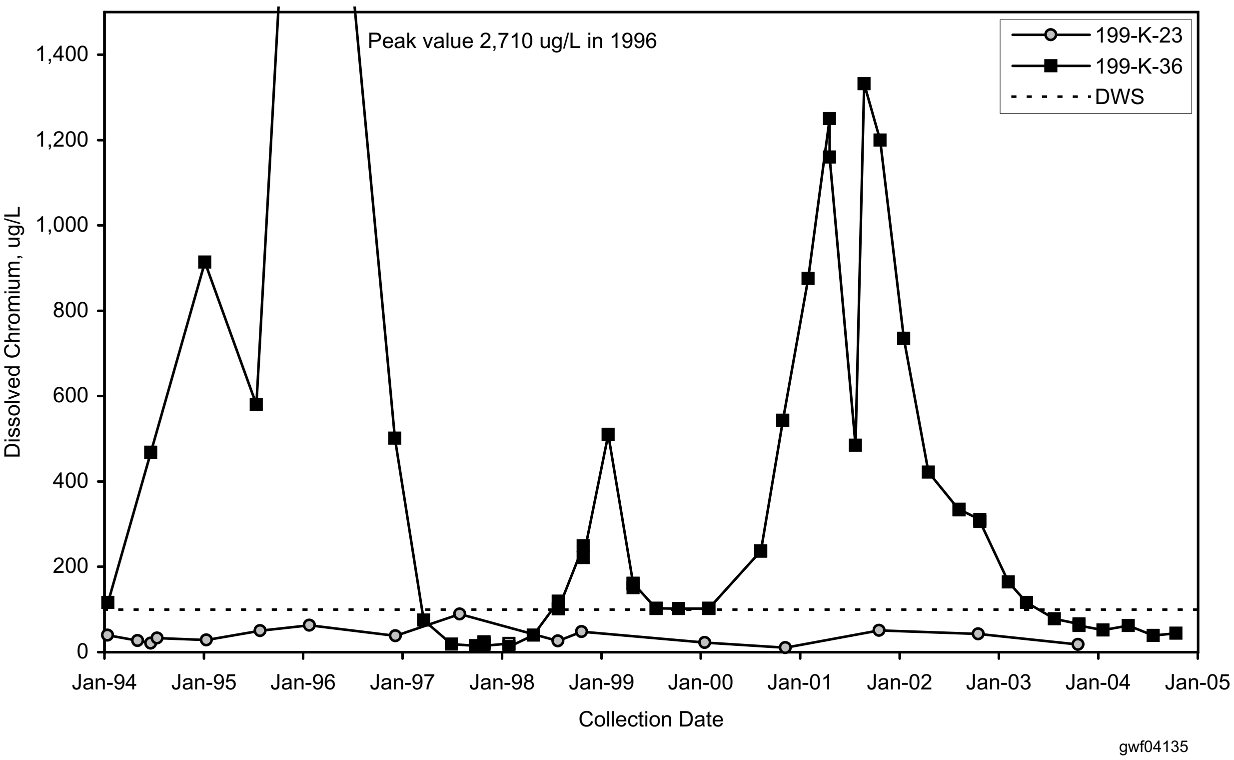

Figure 2.3-6. Chromium Concentrations Near KE Water Treatment Plant Basins

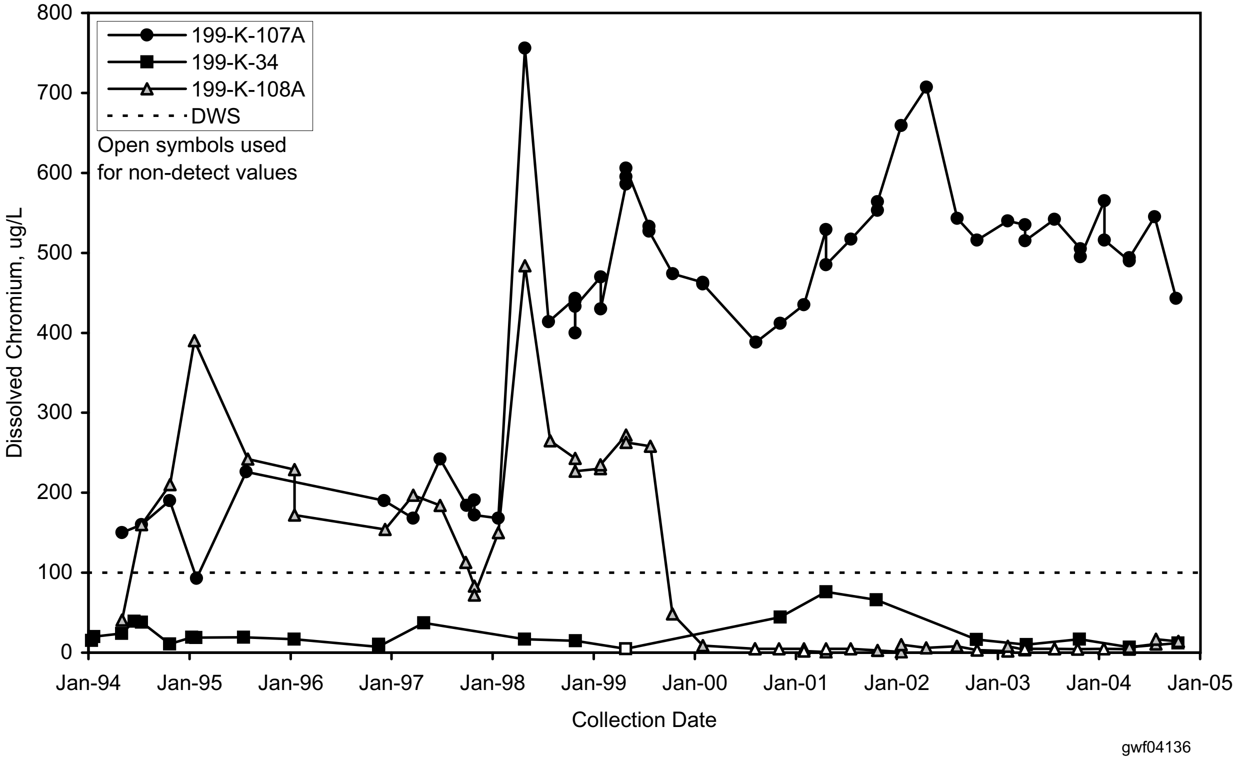

Figure 2.3-7. Chromium Concentrations Near KW Reactor

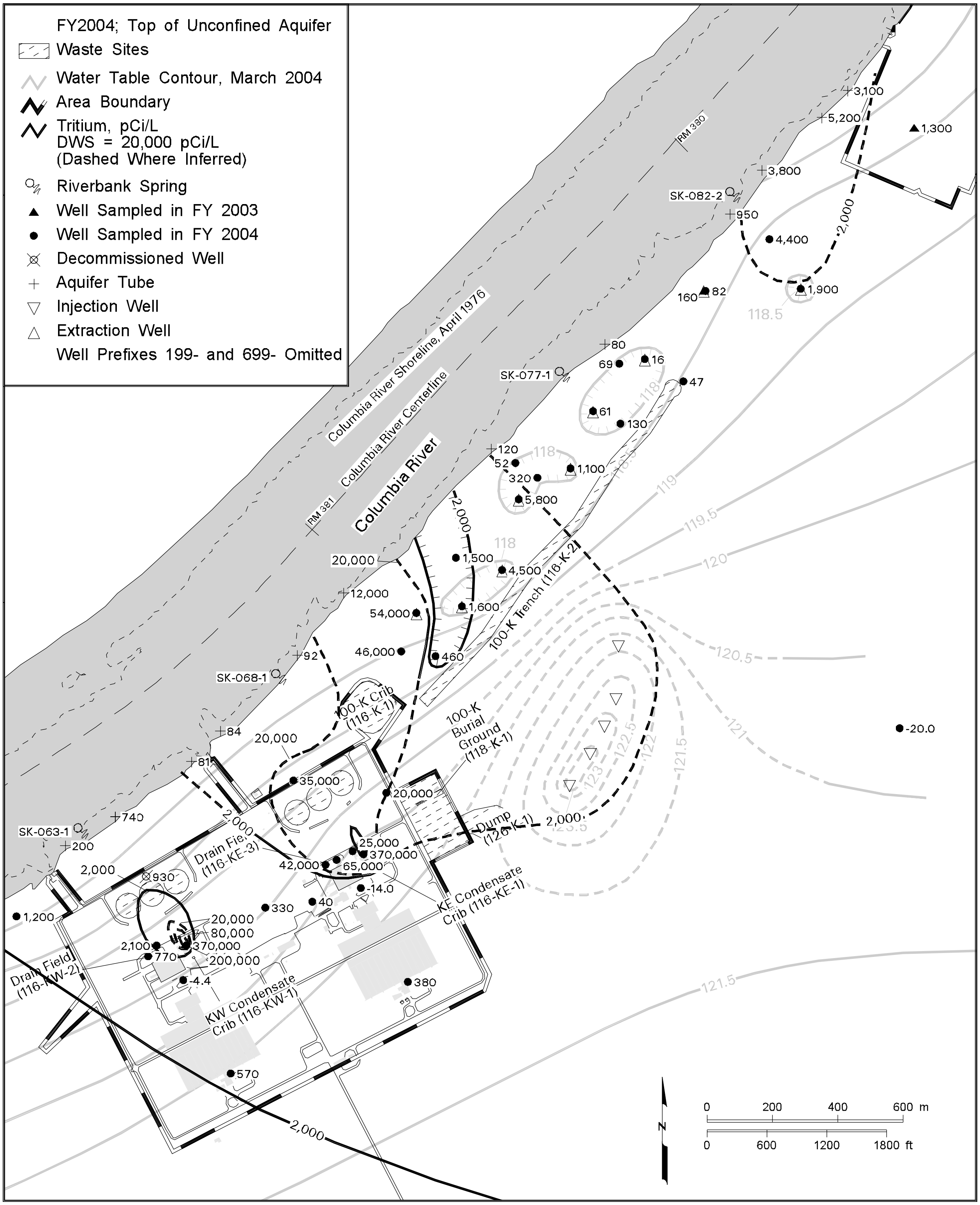

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Figure 2.3-8. Tritium Distribution in 100-K Area Groundwater, FY 2004

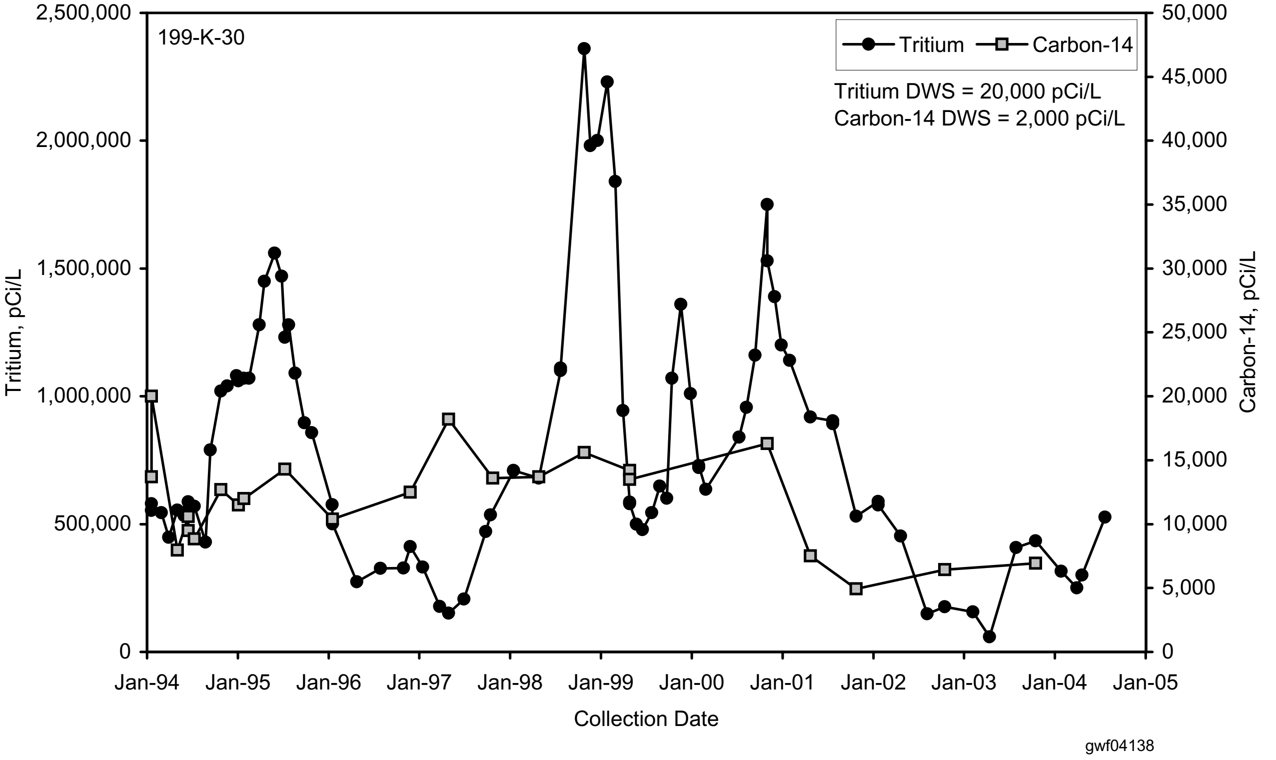

Figure 2.3-9. Tritium and Carbon-14 Concentrations Near the 116-KE-1 Crib

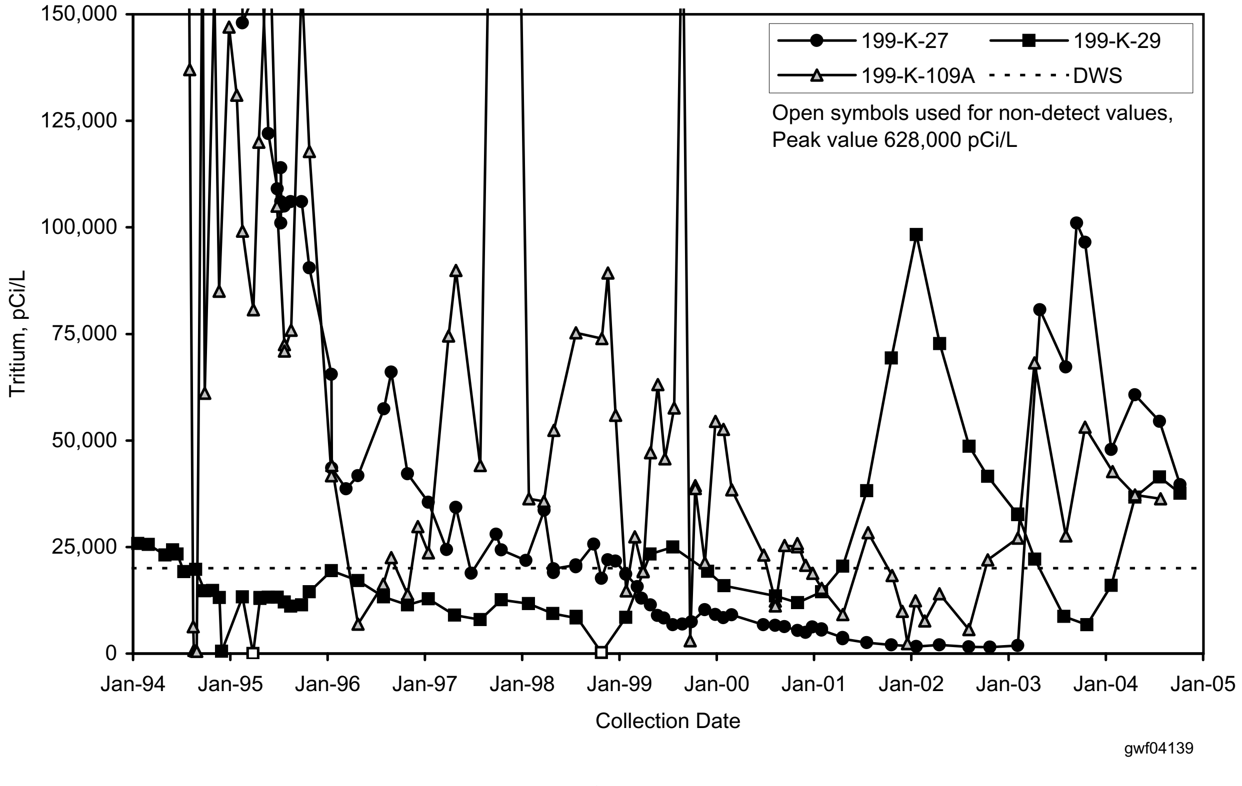

Figure 2.3-10. Tritium Concentrations Near KE Basin

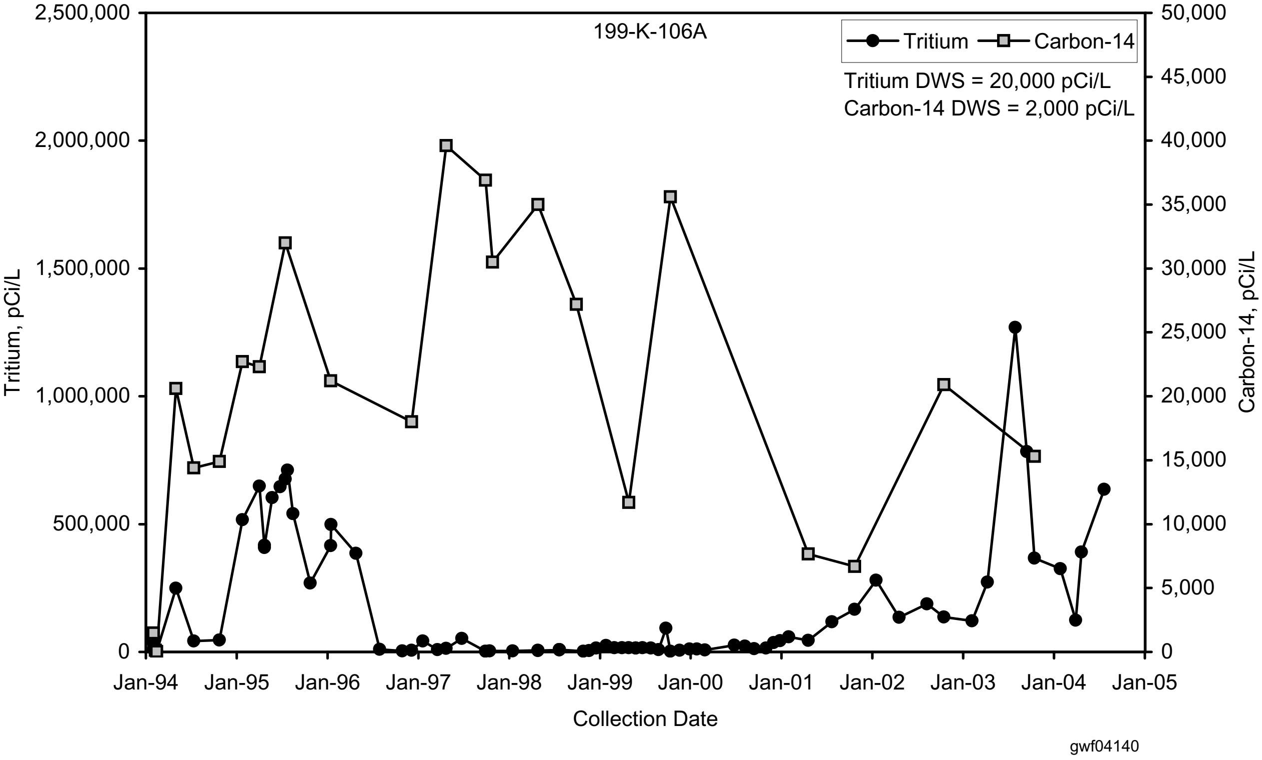

Figure 2.3-11. Tritium and Carbon-14 Concentrations Near the 116-KW-1 Crib

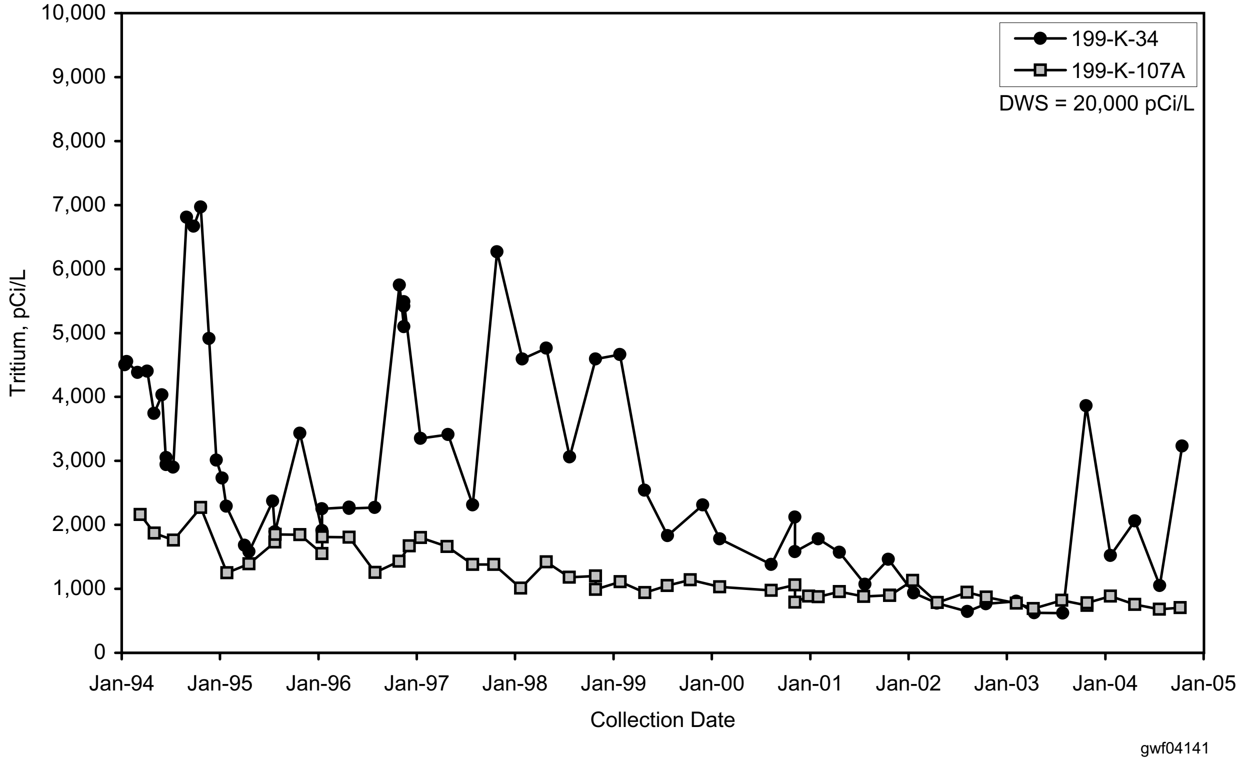

Figure 2.3-12. Tritium Concentrations Near KW Basin

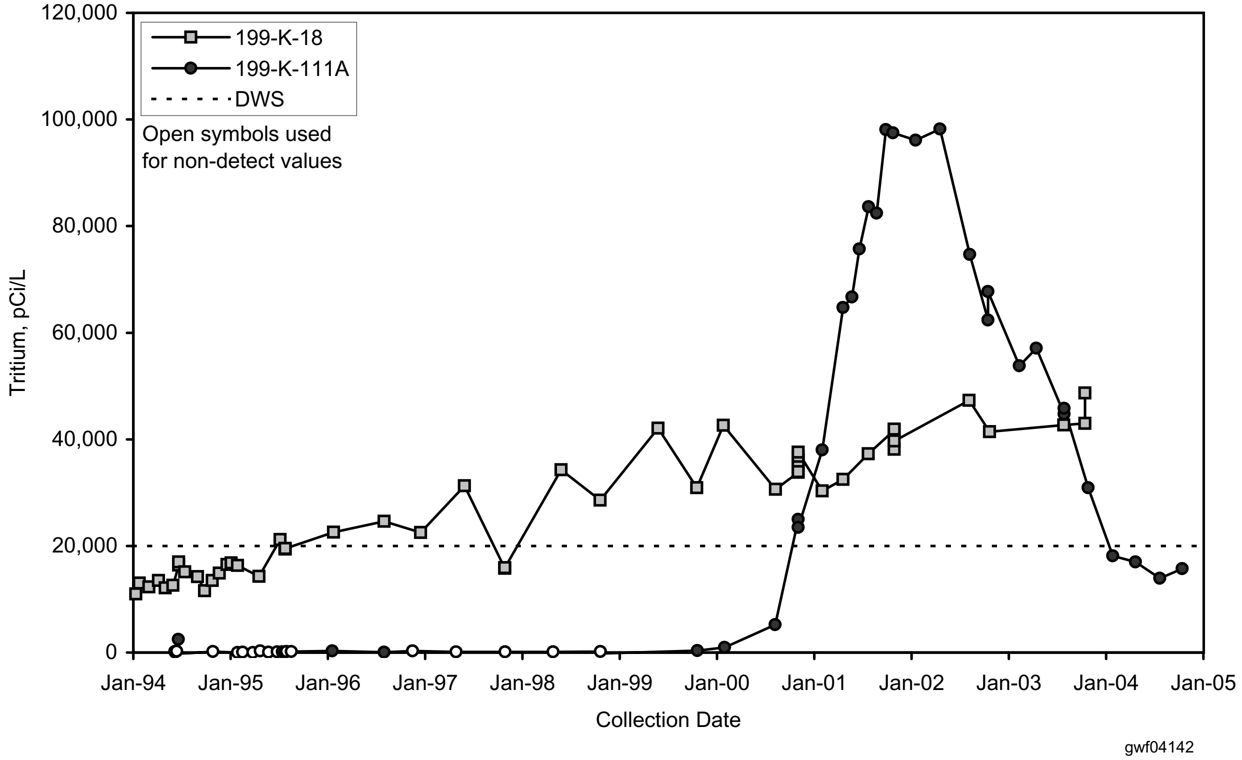

Figure 2.3-13. Tritium Concentrations Near 118-K-1 Burial Ground

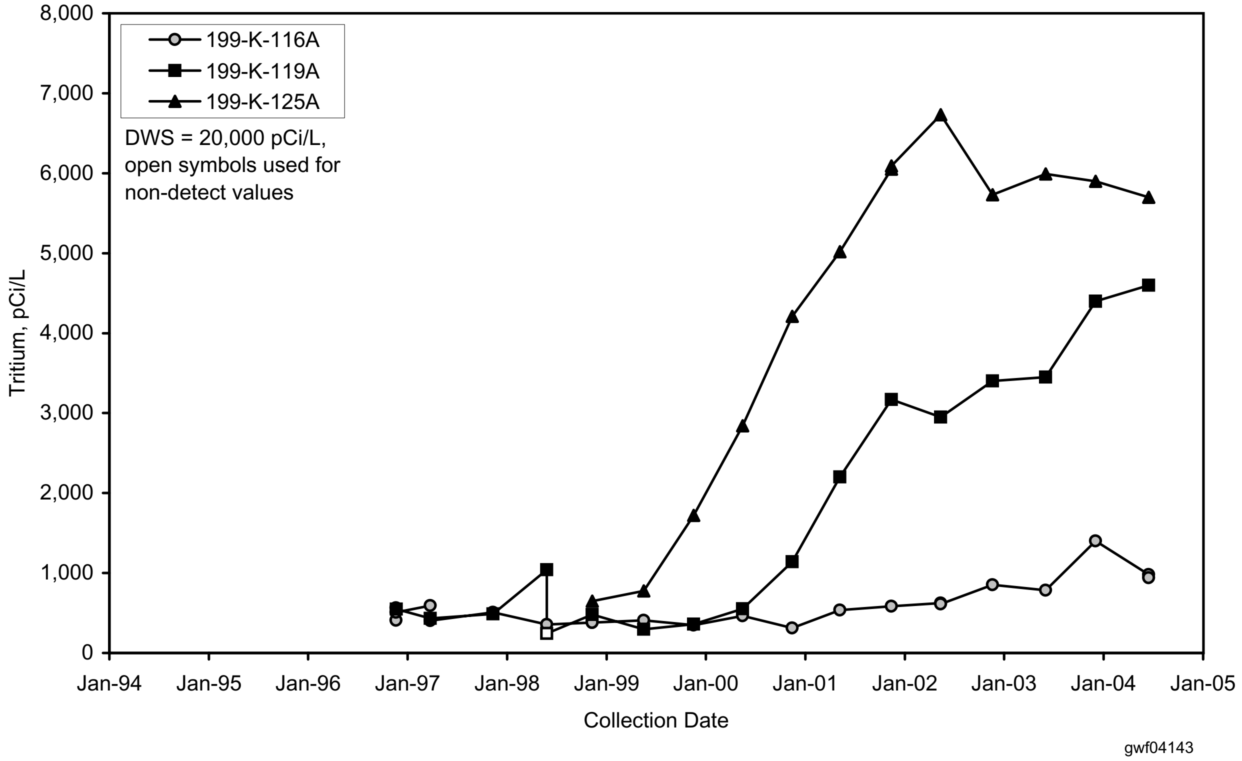

Figure 2.3-14. Tritium Concentrations in Wells Downgradient of the Pump-and-Treat Injection Site

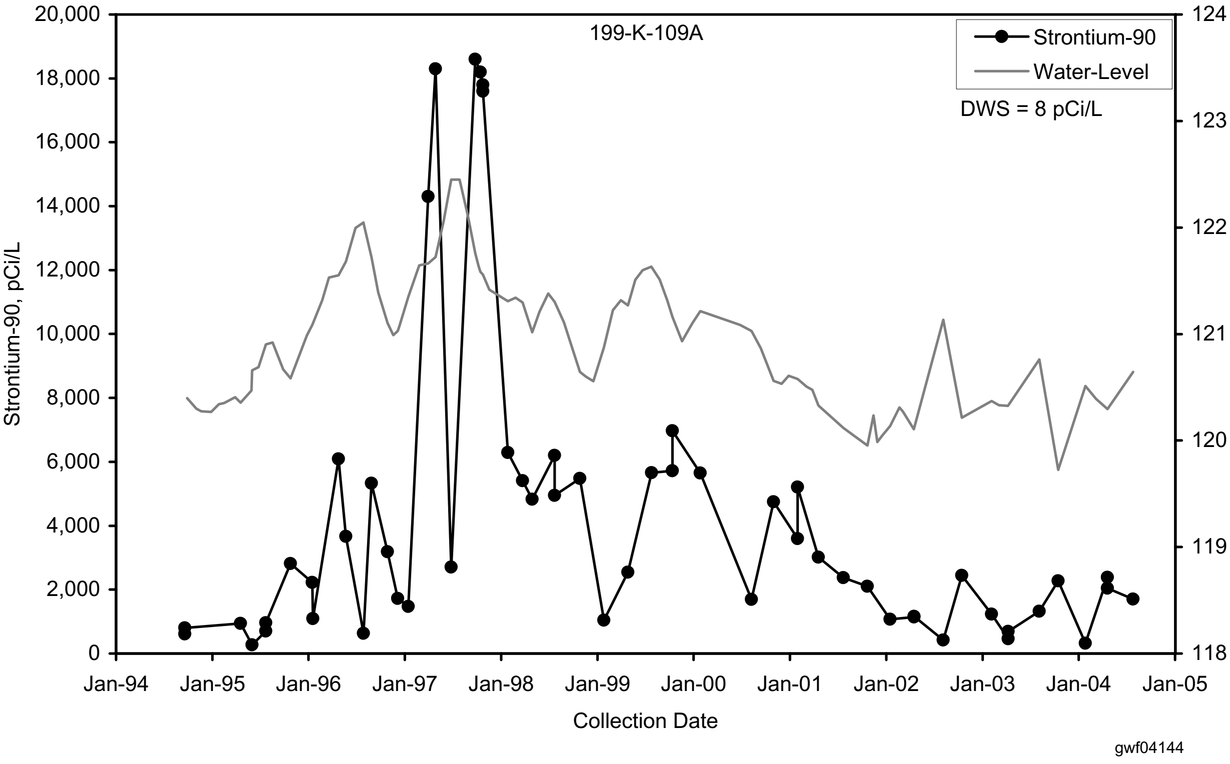

Figure 2.3-15. Strontium-90 Concentrations and Water-Table Elevation Near KE Basin

2.4 100-NR-2 Operable Unit

M. J. Hartman and L. C. Swanson

The scope of this section is the 100-NR-2 groundwater interest area, which includes the 100-NR-2 Operable Unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined the "interest areas" informally to facilitate scheduling, data review, and interpretation. Figure 2.4-1 shows facilities, wells, and shoreline monitoring sites in this region. Strontium-90 is the contaminant of greatest significance in groundwater at this operable unit. Groundwater is monitored to assess the performance of a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) interim action pump-and-treat system for strontium-90, to monitor three *Resource Conservation and Recovery Act* (RCRA) sites, and to track other contaminant plumes for the *Atomic Energy Act of 1954* (AEA).

Groundwater flows primarily to the north and northwest, toward the Columbia River (Figure 2.4-2). Water levels fluctuate with river stage and are also affected by groundwater extraction near the 116-N-1 liquid waste disposal facility (116-N-1 facility) and injection near the 116-N-3 liquid waste disposal facility (116-N-3 facility) . Data from a new shoreline well cluster showed an upward gradient, as expected in this discharge area. The deepest well is ~6 meters deeper than the shallowest well and the upward gradient in June 2004 was ~0.013.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under AEA, CERCLA, or RCRA monitoring.

2.4.1 Groundwater Contaminants

This section describes distributions and trends for the constituents of interest for the 100-NR-2 groundwater interest area. In addition to the strontium-90 plume, contaminants of concern include tritium, nitrate, sulfate, petroleum hydrocarbons, manganese, and chromium.

Groundwater monitoring in the 100-NR-2 groundwater interest area includes the following monitoring activities:

CERCLA Monitoring

- ***Six wells are sampled semiannually for strontium-90 and co-contaminants.***
- ***Fifteen wells are sampled annually for strontium-90 and/or co-contaminants.***
- ***In FY 2004, all wells were sampled as scheduled.***
- ***Additional baseline monitoring began in June 2004.***

Facility Monitoring

- ***Five wells are sampled semiannually for the 116-N-1 liquid waste disposal facility for requirements of RCRA and AEA.***
- ***Five wells are sampled semiannually for the 120-N-1 percolation pond and 120-N-2 surface impoundment for requirements of RCRA and AEA.***
- ***Five wells were sampled semiannually for the 116-N-3 liquid waste disposal facility for requirements of RCRA.***
- ***In FY 2004, one RCRA well was not sampled as scheduled (see text and Appendix B).***
- ***Monitoring is coordinated with other programs to avoid duplication.***

AEA Monitoring

- ***Wells sampled annually or triennially to track plumes, trends, and general chemistry.***
- ***Monitoring is coordinated with other programs to avoid duplication.***

2.4.1.1 Strontium-90

The size and shape of the strontium-90 plume change very little from year to year, extending from beneath the 116-N-1 and 116-N-3 facilities to the Columbia River at levels above the 8 pCi/L drinking water standard (Figure 2.4-3).

Changes in strontium-90 concentrations often relate to water-table fluctuations because strontium-90 from the vadose zone beneath former waste sites is mobilized by a high water table (Figure 2.4-4). Concentrations are highest in well 199-N-67, where the maximum value in fiscal year (FY) 2004 was 7,390 pCi/L, exceeding the U.S. Department of Energy (DOE) derived concentration guide of 1,000 pCi/L.

Strontium-90 is the most significant groundwater contaminant beneath the 100-NR-2 Operable Unit. The general shape of the plume has not changed in many years.

The portion of the plume downgradient of the 116-N-1 facility is the focus of a pump-and-treat system that has been operating since 1995 (Section 2.4.2). Strontium-90 trends in extraction wells are shown in Figure 2.4-5. Well 199-N-103A had a relatively stable trend since FY 2001, while wells 199-N-75, 199-N-105A, and 199-N-106A appear to have decreasing trends in recent years. Well 199-N-106A, located farthest north beyond the tail end of the trench, continued to have the highest concentrations in any of the extraction wells.

Wells on the south edge of the plume show declining concentrations, which may indicate the plume is gradually shrinking in this region. For example, the strontium-90 concentration well 199-N-57 dropped to 7.3 pCi/L in FY 2004, the first time it has been below the drinking water standard (Figure 2.4-6).

In FY 2004, staff conducted additional studies of strontium-90 concentrations near the Columbia River shoreline. Previous data from a series of steel casings set into the gravel at the river shore demonstrated that concentrations of the contaminant are highest at the shoreline near wells NS-2, NS-3, and NS-4. In FY 2004, new clusters of wells and aquifer tubes were installed in the high-strontium portion of the shoreline. Sampling results from the wells confirmed observations elsewhere in the 100-N Area that strontium-90 contamination is concentrated in the top of the aquifer. For example, in September 2004, well 199-N-119, which is completed at the top of the aquifer, had 280 pCi/L of strontium-90 while deeper wells 199-N-120 and 199-N-121 had 4.6 and 4.9 pCi/L, respectively. Additional details on this study are included as Section 2.4.4.

2.4.1.2 Tritium

The tritium plume has diminished in the years since effluent discharge to the 116-N-1 and 116-N-3 facilities ceased in 1991. The remaining plume extends from the south part of the 116-N-3 facility to the river to the northwest at levels above the 20,000-pCi/L drinking water standard (see Figure 2.4-5 in PNNL-14548 for FY 2003 plume map). Tritium contamination is observed throughout the upper aquifer and also in well 199-N-80, which monitors a confined aquifer in the Ringold Formation.

The highest concentrations are currently in wells near the Columbia River where levels continued to decline (Figure 2.4-7). The maximum concentration was 28,600 pCi/L in well 199-N-14.

2.4.1.3 Nitrate

A plume of nitrate with concentrations exceeding the 45-mg/L drinking water standard appeared to expand in FY 2004 as concentrations increased in many wells (Figure 2.4-8). The reason for the increase is unknown and nitrate trends are different from those of other 100-N Area contaminants. The highest nitrate concentrations in FY 2004 were again in well 199-N-67 near the 116-N-1 facility, with a maximum concentration of 270 mg/L.

Figure 2.4-9 shows nitrate trend plots for wells near the 116-N-1 and 116-N-3 facilities for their entire period of record. The 116-N-1 facility was in use through 1985 and the 116-N-3 facility was in use from 1983 to 1991. Nitrate concentrations were

Plume areas (square kilometers) above the drinking water standard at the 100-NR-2 Operable Unit:

Nitrate — 0.35
Strontium-90 — 0.57
Tritium — 0.27

high in the mid-1980s in both wells and declined sharply by 1990. Recent concentrations have returned to levels observed in the mid-1980s.

Near the 120-N-1 percolation pond in south 100-N Area, nitrate concentrations also increased in the 1990s (Figure 2.4-10). During the pond's period of use (1977 to 1990), only low levels of nitrate (~1 mg/L) were detected in effluent to the facility (see Appendix B of DOE/RL-96-39). Monitoring began in 1987 and nitrate concentrations in groundwater were also low (1 to 4 mg/L). Nitrate levels exceeded the drinking water standard in well 199-N-59 from 1998 to 2002, which was the last time the well could be sampled. Nearby well 199-N-72 has lower nitrate levels but showed a sharp increase in FY 2004.

Nitrate concentrations continued to increase in FY 2004.

Anomalously low nitrate concentrations continued to be observed in well 199-N-18 (undetected). The low concentrations are believed to be caused by chemical reduction of the nitrate caused by biodegradation of hydrocarbons (Section 2.4.1.5). Other chemical constituents and parameters also support the interpretation of chemical reduction around well 199-N-18: low dissolved oxygen, low pH, detectable nitrite, and high concentrations of metals (especially iron and manganese).

2.4.1.4 Sulfate

The former 120-N-1 percolation pond introduced sulfate and sodium to 100-N Area groundwater. Sulfate concentrations remained elevated in groundwater north and northwest of the 120-N-1 site. A second area of elevated sulfate concentrations underlies the 116-N-3 trench. This contamination is residual from previous flow conditions that carried sulfate from the 120-N-1 percolation pond inland and then toward the north. Sulfate distribution changed little between FY 2003 and 2004 (see Figure 2.4-8 of PNNL-14548 for FY 2003 plume map).

The highest sulfate concentration in FY 2004 was 201 mg/L in well 199-N-3, at the north edge of the main plume. Levels have been steady in well 199-N-3 since 2002. Well 199-N-59, adjacent to the former source, had sulfate concentrations above the 250-mg/L secondary drinking water standard in previous years, but it could not be sampled in FY 2004 because it was dry.

Petroleum products continued to be detected in 100-N Area groundwater. DOE installed a passive treatment system in a well with floating petroleum product.

2.4.1.5 Petroleum Products

Petroleum products from a 1960s leak (DOE/RL-95-111) continued to be detected in 100-N Area groundwater. Of the affected wells, 199-N-18 is closest to the former leak site and had the highest levels of groundwater contamination. Total petroleum hydrocarbons (TPH) in the diesel range was 150 mg/L in March and 340 mg/L in September (Figure 2.4-11).

Fluor Hanford, Inc. began a remedial action to remove the free product from well 199-N-18 in October 2003 and continued the action throughout FY 2004. A passive treatment method removes residual amounts of diesel from the well. The method employs a polymer that selectively absorbs petroleum from the surface of the water like a sponge. A cylinder of the material is lowered into the well for a 2-week period, after which it is removed, weighed, and replaced with a new unit. This procedure will be repeated every 2 weeks for a year. The 1-year observation period will be used to evaluate the mass removal rate of the petroleum hydrocarbon from well 199-N-18.

Evidence of low levels of hydrocarbon contamination has been observed in wells 199-N-3, 199-N-19, and 199-N-96A in the past (PNNL-14187, Section 2.4). These wells are located near 199-N-18 and may be influenced by contamination from the same source. In FY 2004, total organic carbon was elevated in wells 199-N-3 (1,800 μg/L) and 199-N-96A (4,000 μg/L).

Near the N Reactor building, well 199-N-16 also has evidence of petroleum contamination, believed to be from a separate past source. TPH-diesel was measured at up to 6.1 mg/L in FY 2004, about the same as in 2003.

2.4.1.6 Manganese and Iron

Manganese continued to exceed the 50-µg/L secondary drinking water standard in two wells affected by petroleum contamination: 199-N-16 (860 µg/L) and 199-N-18 (2,480 µg/L). Iron also exceeded its secondary drinking water standard (300 µg/L) in these wells (1,510 and 26,300 µg/L in wells 199-N-16 and 199-N-18, respectively). Biodegradation of the hydrocarbons creates reducing conditions, which increases the solubility of metals such as manganese and iron from the well casing or aquifer sediment.

The manganese concentration in well 199-N-26, located in south 100-N Area, increased in FY 2004 from 12.5 µg/L in 2003 to 88.9 µg/L in 2004. Iron decreased during the same period. The high manganese value may be erroneous and the well will be sampled again in FY 2005.

Manganese concentrations exceeded the secondary drinking water standard in one sample each from new wells 199-N-119, 199-N-120, and 199-N-121, and new aquifer tube NS-2A-23cm. Subsequent samples showed lower concentrations, suggesting the elevated values were related to installation activities and do not represent groundwater quality.

A pump-and-treat system at the 100-NR-2 Operable Unit satisfied its objectives in FY 2004, but has not affected the distribution or concentration of strontium-90 in the aquifer to any observable extent.

2.4.1.7 Chromium

Only one well in the 100-N Area has chromium concentrations above the 100-µg/L drinking water standard. Well 199-N-80, which is completed in a thin, confined aquifer in the Ringold Formation, typically has chromium concentrations of ~170 µg/L. The source for chromium in this deep horizon is unknown. The highest concentration in shallow wells in FY 2004 was 11.7 µg/L in well 199-N-41.

2.4.2 Interim Groundwater Remediation for Strontium-90

A pump-and-treat system has been operating in the 100-N Area since 1995 as part of a CERCLA interim action for the 100-NR-2 Operable Unit (ROD 1999b). The objectives of the pump-and -treat system include the following:

The remedial action objectives in the 100-NR-2 Operable Unit (ROD 1999b) are:

- *Protect the Columbia River from the adverse impact of groundwater contamination by limiting exposure pathways, reducing or removing sources, controlling groundwater movement, or reducing the concentration of contaminants.*
- *Protect the unconfined aquifer by implementing remedial actions that reduce the concentration of contaminants.*
- *Obtain information to evaluate technologies to remove strontium-90 and evaluate the impact to ecological receptors.*
- *Prevent destruction of sensitive wildlife habitat and minimize the disruption of cultural resources.*

During their 5-year review (EPA 2001), EPA added a requirement for DOE to investigate alternative remedial action technologies for strontium-90.

- Reduce strontium-90 contaminant flux from the groundwater to the Columbia River.
- Evaluate commercially available treatment options for strontium-90.
- Provide data necessary to set demonstrable strontium-90 groundwater cleanup standards.

The monitoring requirements for the pump-and-treat system at this operable unit are specified by Tri-Party Agreement Change Control Form M-15-96-08 as modified by Fluor Hanford, Inc.(a) Wells, constituents, and sampling frequencies for interim action monitoring are shown in Appendix A. During FY 2004, all wells were sampled as scheduled.

DOE initiated supplemental monitoring of the shoreline area affected by the pump-and-treat system in June 2004 to establish a baseline of monthly sampling results with which to compare results after

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(a) Letter FH-0205249 from RT Wilde (Fluor Hanford, Inc.) to JS Fruchter (Pacific Northwest National Laboratory), *Revised FY 2003 Sampling Schedule for Groundwater Remediation Monitoring*, dated November 11, 2002.

a possible shutdown of the pump-and-treat system (date is yet to be determined). The supplemental monitoring program, which is not described in a formal monitoring plan, is summarized in Appendix A. This monitoring is integrated with a special study of 100-N groundwater described in Section 2.4.4.

2.4.2.1 Progress During FY 2004

The pump-and-treat system satisfied its objectives again in FY 2004, but has not affected the distribution or concentration of strontium-90 in the aquifer to any observable extent. The extraction wells create a hydraulic sink between the 116-N-1 facility and the Columbia River and, thus, reduce or reverse the hydraulic gradient in the groundwater toward the Columbia River. The reduction or reversal of the hydraulic gradient results in less groundwater and strontium-90 discharging to the Columbia River through the N Springs area. However, the pump-and-treat system is not capable of completely controlling the water discharged because of the cyclical river stage and bank storage effects of the Columbia River.

Additional details on the pump-and-treat system and operational data for calendar year 2003, are available in DOE/RL-2004-21. An upcoming report will present results for calendar year 2004.

No cesium-137 or cobalt-60 was detected in 100-N Area groundwater in FY 2004.

2.4.2.2 Influence on Aquifer Conditions

The extraction wells have created an area of lower strontium-90 concentrations between the 116-N-1 trench and the Columbia River (Figure 2.4-3). However, this area does not represent significant clean up of the aquifer. The low concentrations are believed to be caused by (a) drawdown of the water table (strontium-90 concentrations are highest at the top of the aquifer and in the vadose zone); and (b) dilution with river water drawn in by pumping.

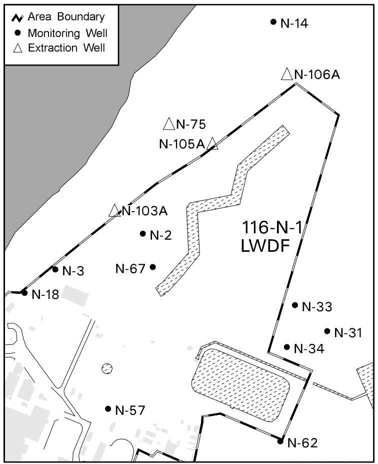
Figure 2.4-5 shows strontium-90 concentrations with time in 100-N Area extraction wells. Concentrations vary in response to a fluctuating water table and other changes in groundwater flow, but there are no clear upward or downward trends overall.

Because the pump-and-treat system is ineffective as a long-term remediation solution, other technologies are being considered to accelerate removal of the strontium-90 from the groundwater. Two promising technologies were tested in the laboratory in FY 2004: phytoremediation (using plants as a strontium-90 uptake mechanism) and sequestration by apatite (creating a permeable reactive barrier that would capture strontium-90 as groundwater flows through the barrier). Additional studies and scaled-up activities are planned for FY 2005. These efforts include (1) completing the greenhouse phytoremediation studies and starting a field demonstration, and (2) completing the aqueous apatite injection, sorption/desorption studies in laboratory columns and conducting intermediate scale tests.

During FY 2004, the pump-and-treat system extracted ~116 million liters of groundwater from the 100-N Area, removing ~0.2 curie of strontium-90. The pump-and-treat system has removed ~1.6 curies of strontium-90 from the 100-N Area groundwater since startup in 1995, compared to a total inventory in the aquifer estimated to exceed 75 curies. Current estimates indicate that it will take >300 years before the strontium 90 concentrations reach permissible levels (DOE/RL-95-110) as a result of radioactive decay. For this reason, DOE is investigating and evaluating alternative remediation technologies.

2.4.3 Facility Monitoring

This section describes results of monitoring individual facilities: the 116-N-1 and 116-N-2 liquid waste disposal facilities, 120-N-1 percolation pond, and 120-N-2 surface impoundment. Groundwater is monitored at these facilities to meet the requirements



of RCRA for hazardous waste constituents and AEA for source, special nuclear, and by-product materials. Data from facility-specific monitoring are also integrated into the CERCLA groundwater investigations. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations for each facility. As discussed in Section 2.1, pursuant to RCRA units, DOE has sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials. Groundwater data for these facilities are available in the Hanford Environmental Information System (HEIS 1994) and on the data files accompanying this report. Additional information including well and constituent lists, maps, flow rates, and statistical tables are included in Appendix B.

2.4.3.1 116-N-1 (1301-N) Liquid Waste Disposal Facility

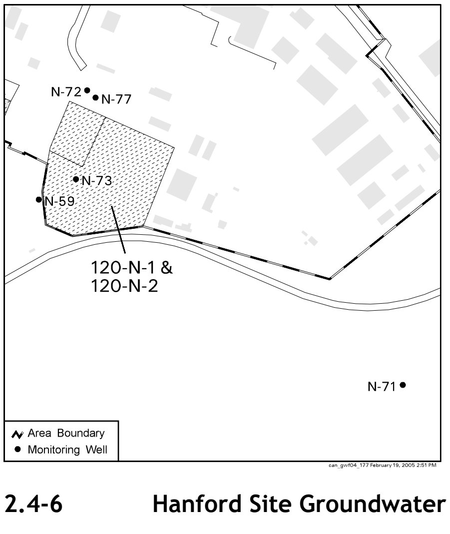
This facility contaminated groundwater with radionuclides during its period of use in the 1960s through 1985. Strontium-90 and tritium are the only radionuclides that remain elevated in groundwater today. Results of monitoring were discussed in Section 2.4.1. The facility is being excavated to remove shallow vadose zone sediment, where most of the radionuclide contamination resides. Wells 199-N-67, 199-N-103A, and 199-N-105A were monitored for strontium-90 and gamma activity semiannually to look for potential impacts of source remediation and dust control on groundwater. Strontium-90 results did not suggest any impacts of remediation and no gamma-emitters were detected.

This facility is included in the Hanford Facility RCRA Permit (Ecology 1994a). The closure plan (see Appendix A of DOE/RL-96-39) states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. That plan and a supplemental plan (PNNL-13914) are similar to an interim status indicator evaluation program (40 CFR 265.93(b), as referenced by WAC 173-303-400).

Upgradient and downgradient wells were sampled twice in FY 2004 for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters, as planned (see Appendix B). The fall sampling of upgradient well 199-N-34 was delayed until October 2004, but results are included with this FY 2004 discussion.

Average specific conductance in downgradient well 199-N-3 continued to exceed the critical mean value in March and September 2004. Prior assessment results (WHC-SD-EN-EV-003) indicated the elevated specific conductance is related to constituents from an upgradient facility. Other indicators remained below critical mean values in FY 2004. The site will remain in detection monitoring and there are no plans to modify the network in FY 2005. Upgradient/downgradient comparison values for indicator parameters have been revised based on recent data for use in FY 2005 comparisons (see Appendix B).

2.4.3.2 120-N-1 (1324-NA) Percolation Pond and 120-N-2 (1324-N) Surface Impoundment



These facilities were used to treat and dispose of corrosive, non-radioactive waste from 1977 to 1990. They have been remediated and backfilled.

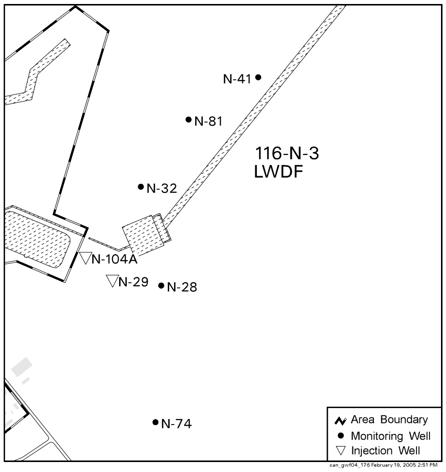
These facilities are included in the Hanford Facility RCRA Permit (Ecology 1994a). The closure plan (see Appendix B of DOE/RL-96-39) states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. That plan, and a supplemental plan (PNNL-13914), are similar to an interim status indicator evaluation program (40 CFR 265.93(b), as referenced by WAC 173-303-400).

During FY 2004, four of the five monitoring wells for this site were sampled twice for contamination indicator parameters and groundwater quality and site-specific parameters, as planned (see Appendix B). Downgradient well 199-N-59 contained too little water to sample in March and September 2004.

Average specific conductance values in wells downgradient of the facilities continued to exceed the critical mean values in FY 2004. A previous groundwater quality assessment indicated that the high specific conductance is caused by sulfate and sodium (WHC-SD-EN-EV-003), which are not listed hazardous waste constituents. Because an assessment has already been completed and non-listed constituents caused the high conductance, detection monitoring will continue. Other indicators remained below critical mean values in FY 2004 and there are no plans to modify the network in FY 2004. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in FY 2005 comparisons (see Appendix B).

2.4.3.3 116-N-3 (1325-N) Liquid Waste Disposal Facility

This facility contaminated groundwater with radionuclides during its period of use from 1983 to 1991. Strontium-90 and tritium are the only radionuclides that remain elevated in groundwater today. Results of monitoring were discussed in Section 2.4.1. The facility was excavated to remove the shallow vadose zone material, which contains the highest concentrations of radionuclides. The site is scheduled to be backfilled with clean soil in FY 2005. Well 199-N-81 was monitored for strontium-90 and gamma semiannually to look for potential impacts of source remediation and dust control on groundwater. Strontium-90 results did not suggest any impacts of remediation and no gamma-emitters were detected.



This facility is included in the Hanford Facility RCRA Permit (Ecology 1994a). The closure plan (Appendix A of DOE/RL-96-39) states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. That plan, and a supplemental plan (PNNL-13914), are similar to an interim status indicator evaluation program (40 CFR 265.93(b), as referenced by WAC 173-303-400).

During FY 2004, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters, as planned (see Appendix B).

Average specific conductance values in downgradient well 199-N-41 continued to exceed the critical mean value in March and September 2004, although levels are declining. This was a continuation of previous exceedances noted in 1999 through 2003. DOE notified Washington State Department of Ecology of that original exceedance and submitted an assessment report that concluded the exceedance was caused by past discharges to an upgradient facility. Detection monitoring will continue in FY 2005. Other indicators remained below critical mean values in FY 2004 and there are no plans to modify the network during FY 2005. Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in FY 2005 (see Appendix B).

Preliminary results from monitoring three new river tubes show that in most cases strontium-90 concentrations were highest in June when the river stage was highest.

2.4.4 100-N Science and Technology Project

Under the remediation task of DOE's Science and Technology Project, Pacific Northwest National Laboratory is performing a series of activities to develop better estimates of groundwater and contaminant flux to the river and provide technical basis for developing a remedial approach. The project completed the following activities during FY 2004:

- Installed three clusters of river tubes to monitor water beneath the river bed.
- Installed a cluster of wells on the shoreline to monitor three depths in the aquifer near the river.
- Ran water-level recorders in additional wells.

Preliminary results of this work are summarized below. Details will be published in upcoming reports for the Science and Technology Project.

Eight river tubes were installed at three locations in the river bed where strontium-90 concentrations were expected to be highest (Figure 2.4-12). The river tubes are similar to aquifer tubes installed elsewhere on the Hanford Site (DOE/RL-2000-59), but differ slightly in their construction and depth. The river tubes are constructed of galvanized pipe ~3 centimeters in diameter with ~45 centimeters of perforated pipe and a screen mesh at the bottom. The new tubes and their depths are listed in Table 2.4-1.

In February and March 2004, the Science and Technology Project installed data loggers in cluster NS-3A for a continuous record of specific conductance, temperature, and water level. Figure 2.4-13 shows how specific conductance changed in each tube between March and September 2004. When river stage began to increase in late April, specific conductance began to rise in the river tubes, most notably in the shallowest tube (10 centimeters) and the deepest tube (176 centimeters). These increases in specific conductance were the opposite of what was expected. Specific conductance in other aquifer tubes decreases with increasing river stage. After a few weeks, specific conductance in the 100-N Area river tubes declined again as river stage continued to increase. Specific conductance increased again in June, then declined through late summer.

Another surprising result was that the shallowest tube, completed just 10 centimeters below the riverbed, had higher specific conductance than either of the deeper tubes for virtually the entire period of record. At other aquifer tubes on the Hanford Site, the shallowest tubes typically have the lowest specific conductance. Note that the 100-N Area river tubes are shallower than typical aquifer tubes.

A cluster of new wells monitors three depths on the 100-N Area shoreline.

The Science and Technology Project sampled the river tubes at low, high, and intermediate river stage conditions (April, June, and September 2004, respectively). The groundwater project began sampling the tubes in June, with a comprehensive set of analyses quarterly and screening parameters monthly. Preliminary results show that in most cases strontium-90 (and gross beta) concentrations were higher in samples collected in June (high river) than in April (low river) or September (falling river) (Figure 2.4-14). As with the specific conductance results, the higher strontium-90 result in June was unexpected. Although strontium-90 can increase with high water-levels in inland wells due to mobilized contamination from the vadose zone, that effect would not be expected in the river tubes, where the sediments are continually saturated. The project will continue to collect and evaluate data in FY 2005.

The river tubes also provided data on depth distribution of strontium-90 and other contaminants beneath the river. In clusters NS-3A and NS-4A, the highest concentrations were observed in the mid-depth tubes (87 centimeters below the river bottom; Figure 2.4-14). At NS-4A, the shallow tube (17 centimeters) had higher concentrations than the deep tube (138 centimeters).

Three new monitoring wells were installed on the 100-N Area shoreline in FY 2004 (Table 2.4-1). Well 199-N-119 monitors near the water table, 199-N-120 monitors the middle of the aquifer, and 199-N-120 monitors the base of the aquifer (see Figure 2.4-12 for locations). Figure 2.4-15 shows gross beta (indicating strontium-90) and specific conductance concentrations with depth in the well cluster. Gross beta is highest in the shallowest well, which is consistent with data collected elsewhere in the 100-N Area. Specific conductance was low in the shallow and mid-level wells, and higher in the deeper well. Tritium was undetected in wells 199-N-119 and 199-N-120 and ranged from 597 to 1,640 pCi/L in the deeper well, 199-N-121.

Table 2.4-1. Construction Details for New River Tubes and Wells

Well ID	Well/Tube Name	Type	Depth Below Land Surface (or River Bottom)
C4585	NS-2A-23cm	River tube	23 cm
C4586	NS-2A-87cm	River tube	87 cm
C4587	NS-2A-168cm	River tube	168 cm
C4588	NS-3A-10cm	River tube	10 cm
C4590	NS-3A-87cm	River tube	87 cm
C4589	NS-3A-176cm	River tube	176 cm
C4640	NS-4A-17cm	River tube	17 cm
C4641	NS-4A-183cm	River tube	183 cm
C4471	199-N-119	Well	7.0 m
C4472	199-N-120	Well	9.3 m
C4473	199-N-121	Well	12.8 m

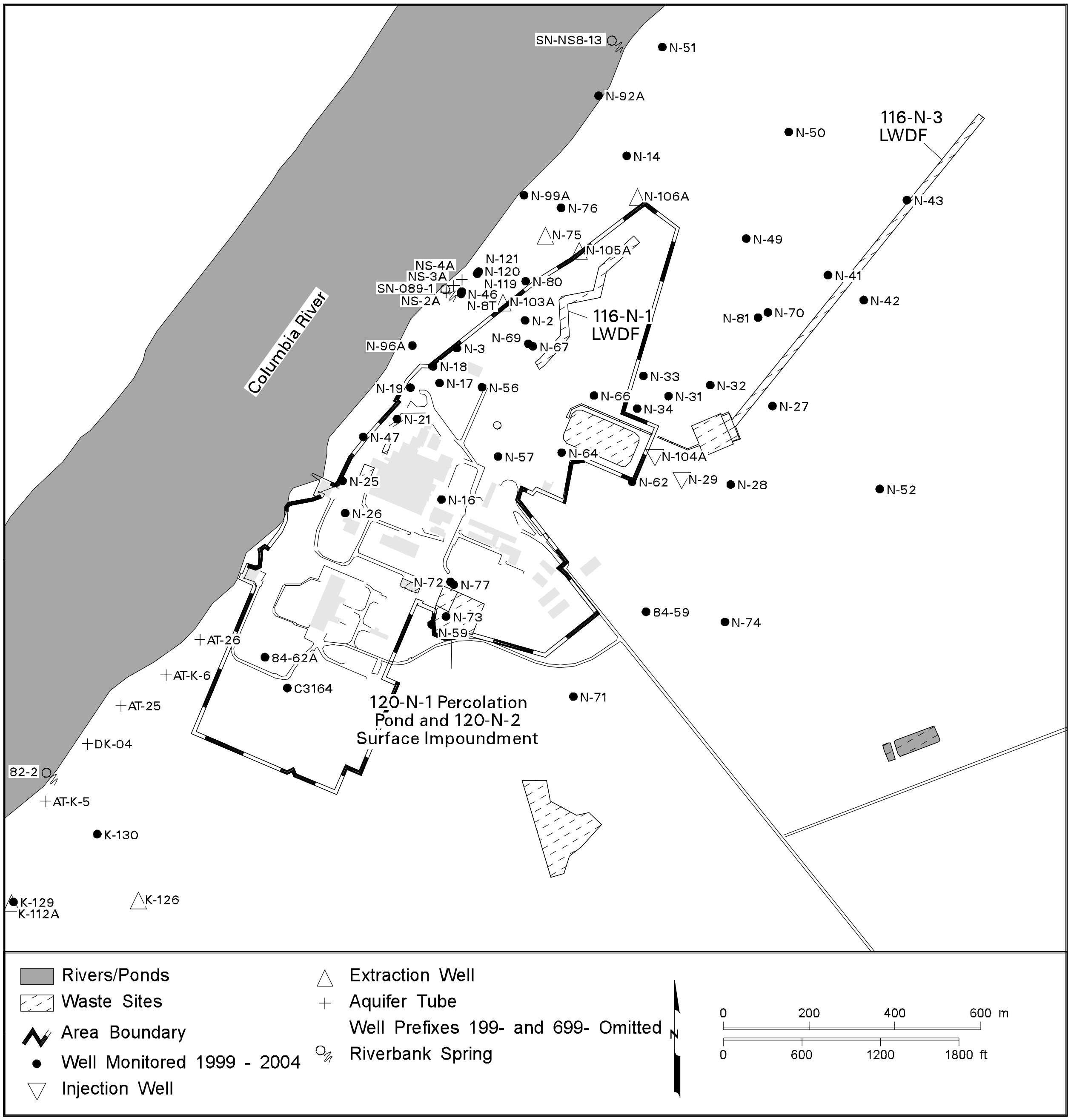


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Figure 2.4-1. Groundwater Monitoring Wells in the 100-N Area

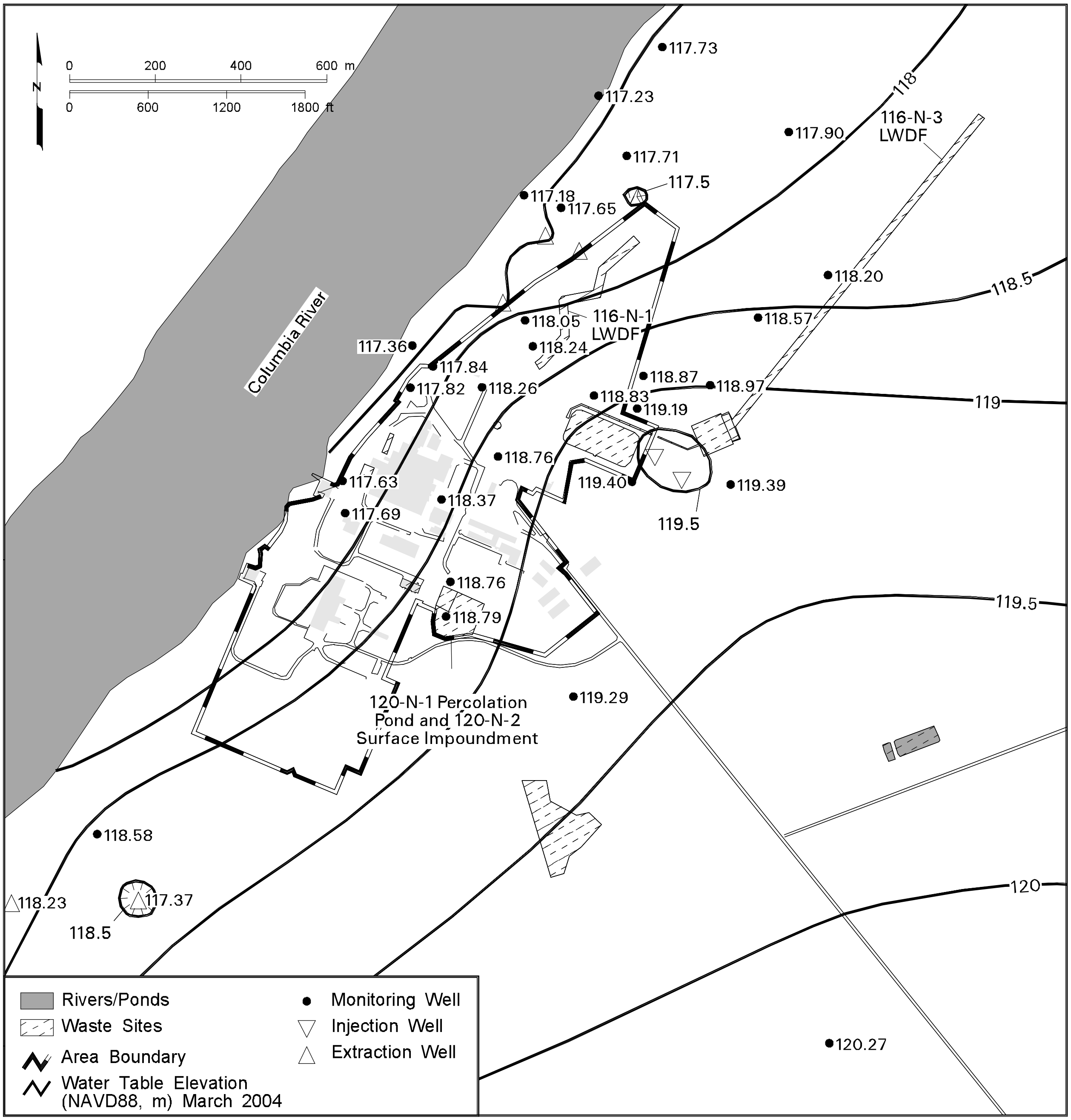

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Figure 2.4-2. Water Table Beneath 100-N Area, March 2004

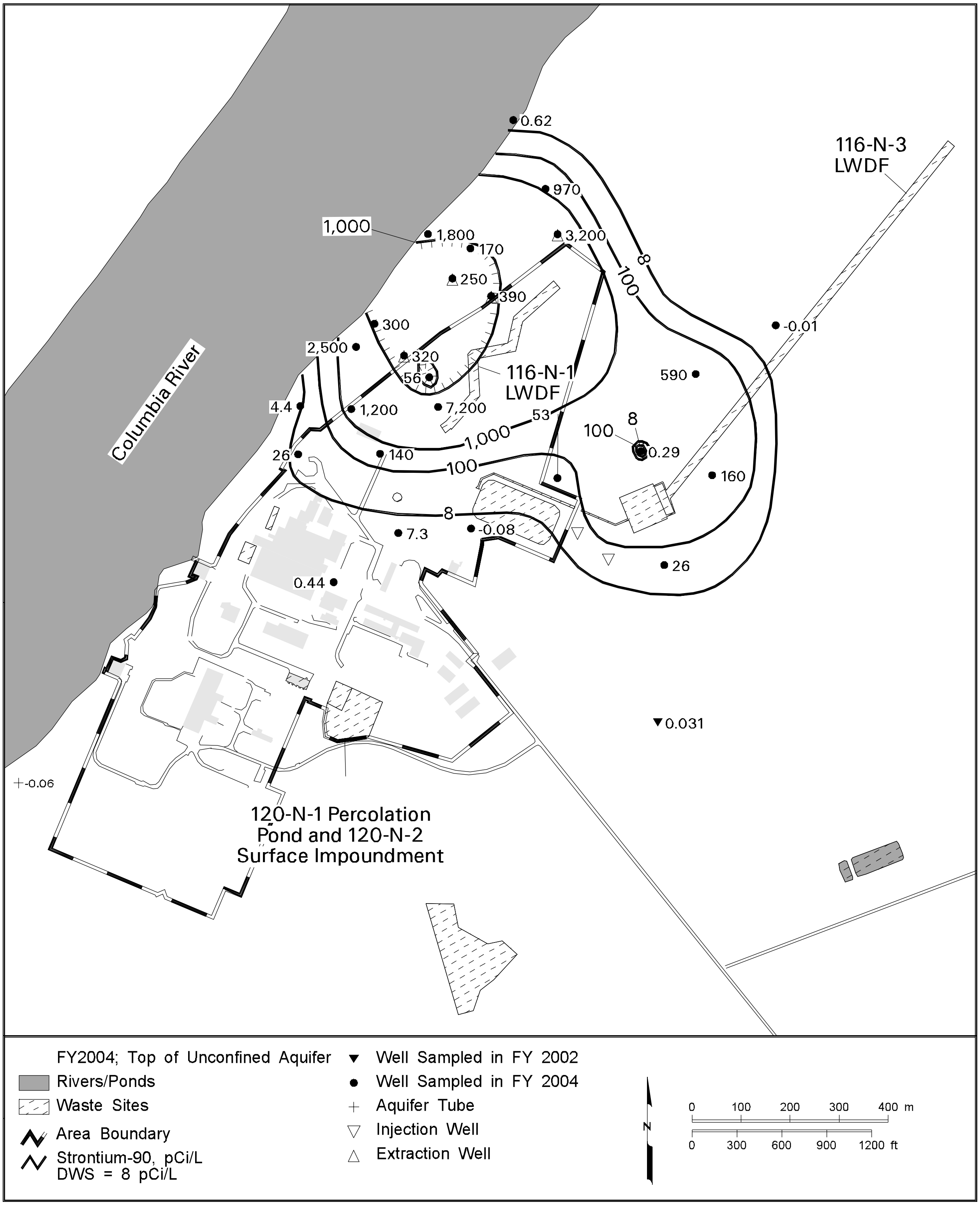

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Figure 2.4-3. Average Strontium-90 Concentrations in the 100-N Area, Top of Unconfined Aquifer

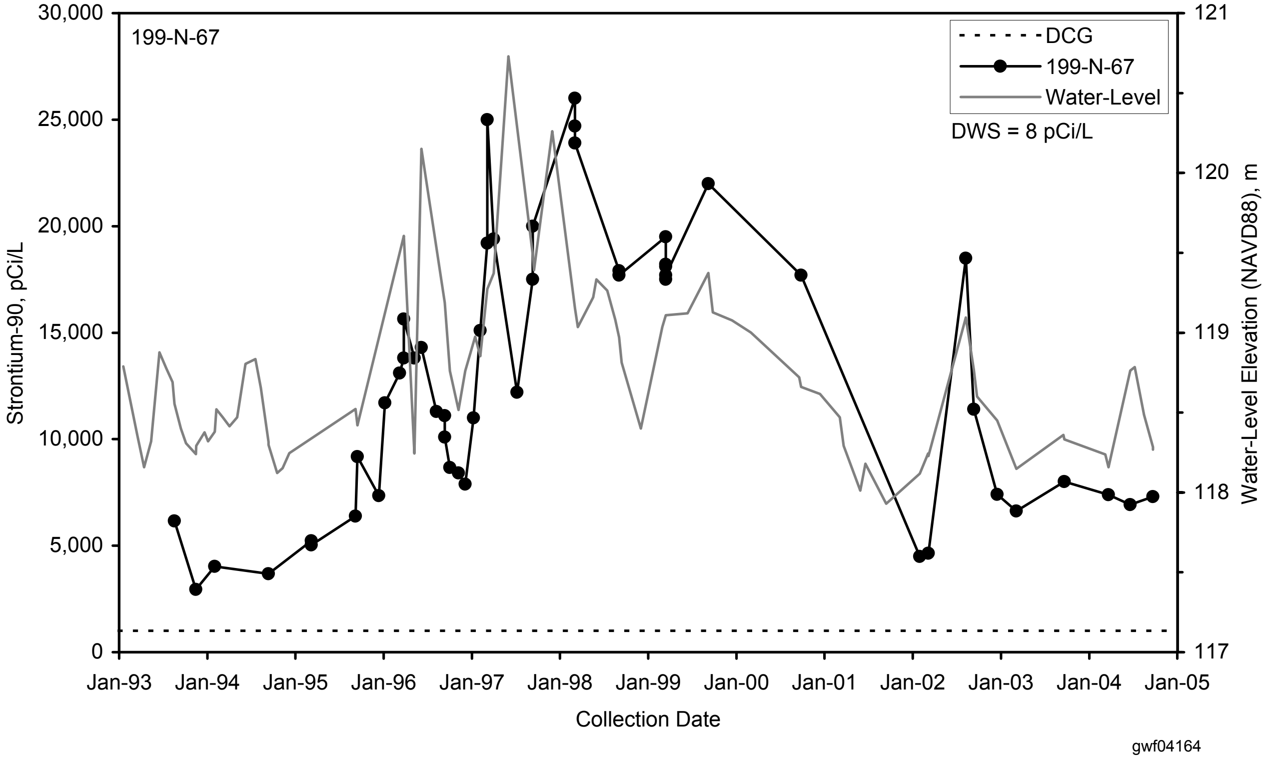

Figure 2.4-4. Strontium-90 Concentrations and Water Level Near the 116-N-1 Facility

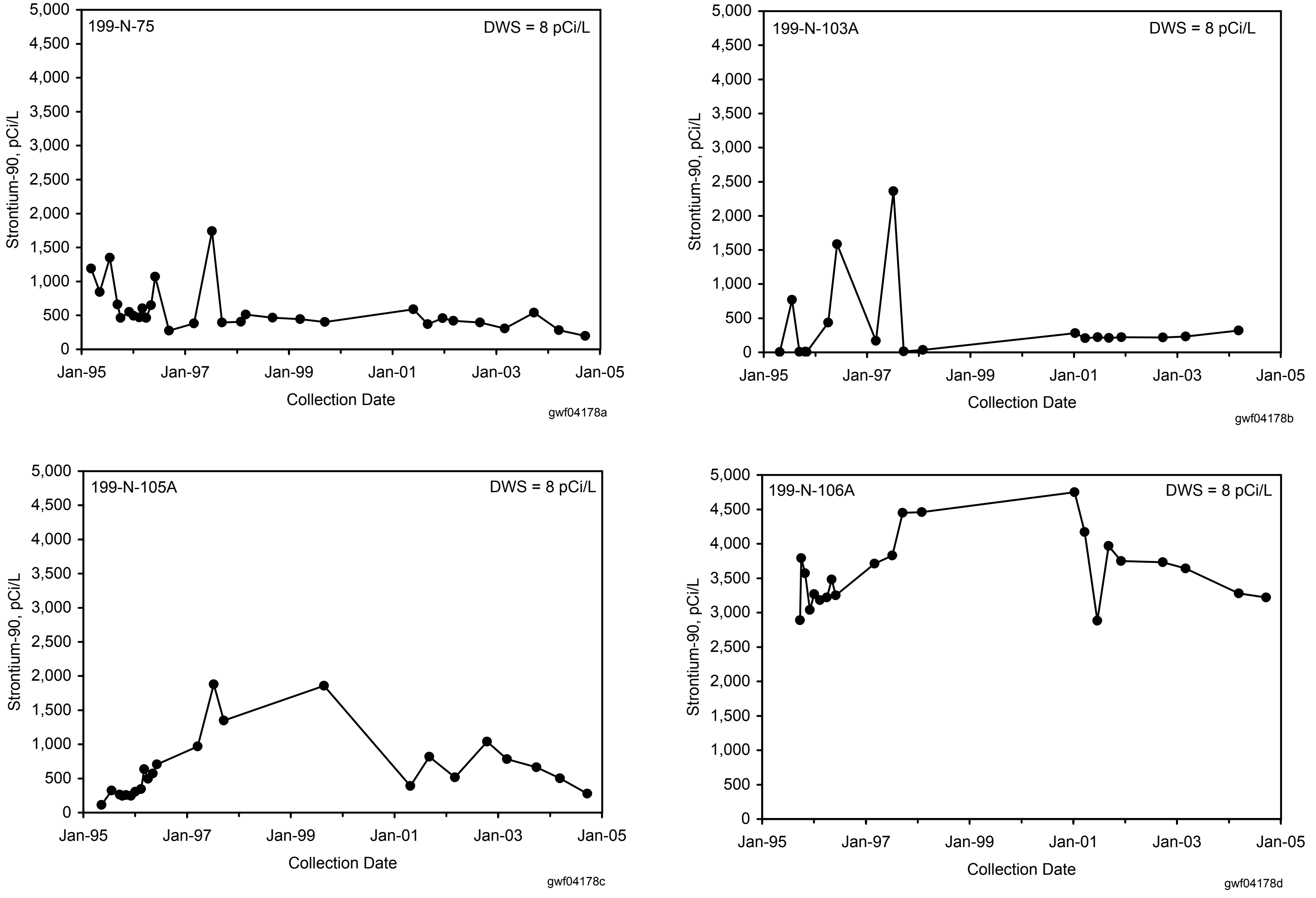

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Figure 2.4-5. Strontium-90 Concentrations in 100-N Area Extraction Wells

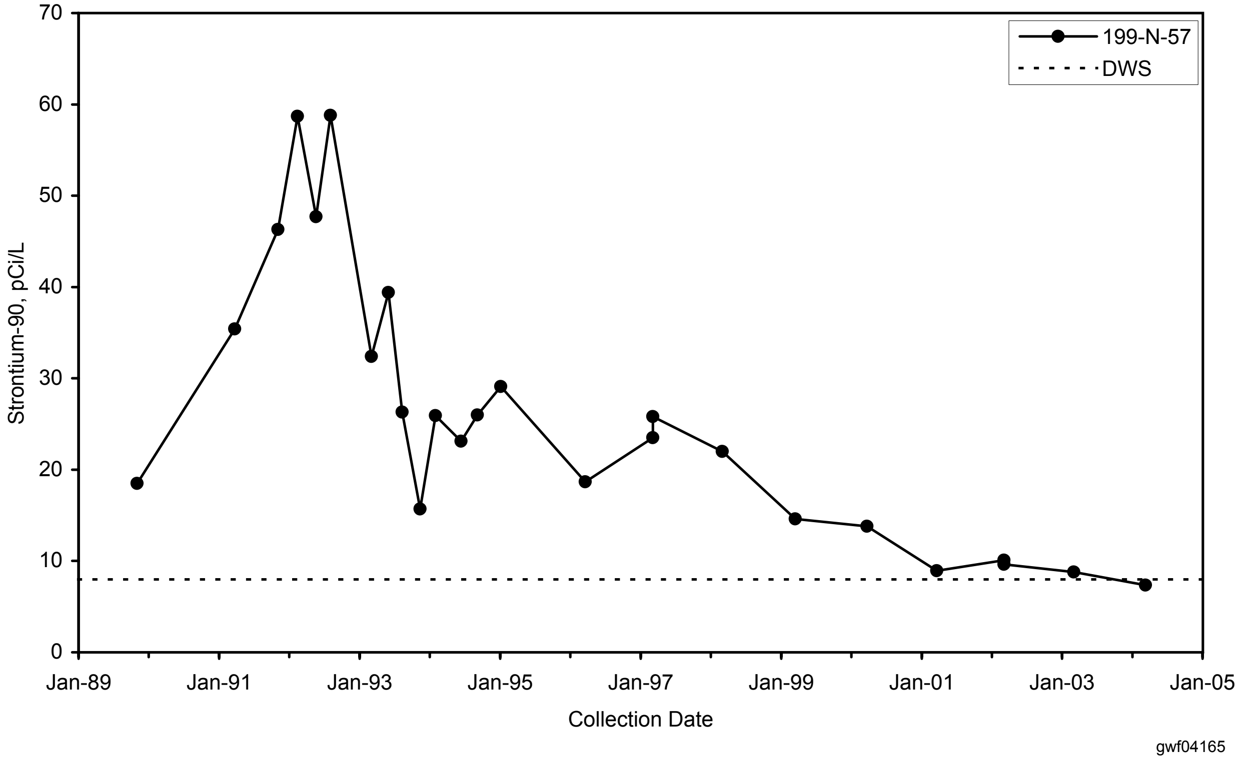

Figure 2.4-6. Strontium-90 Concentrations at the South Edge of the Plume

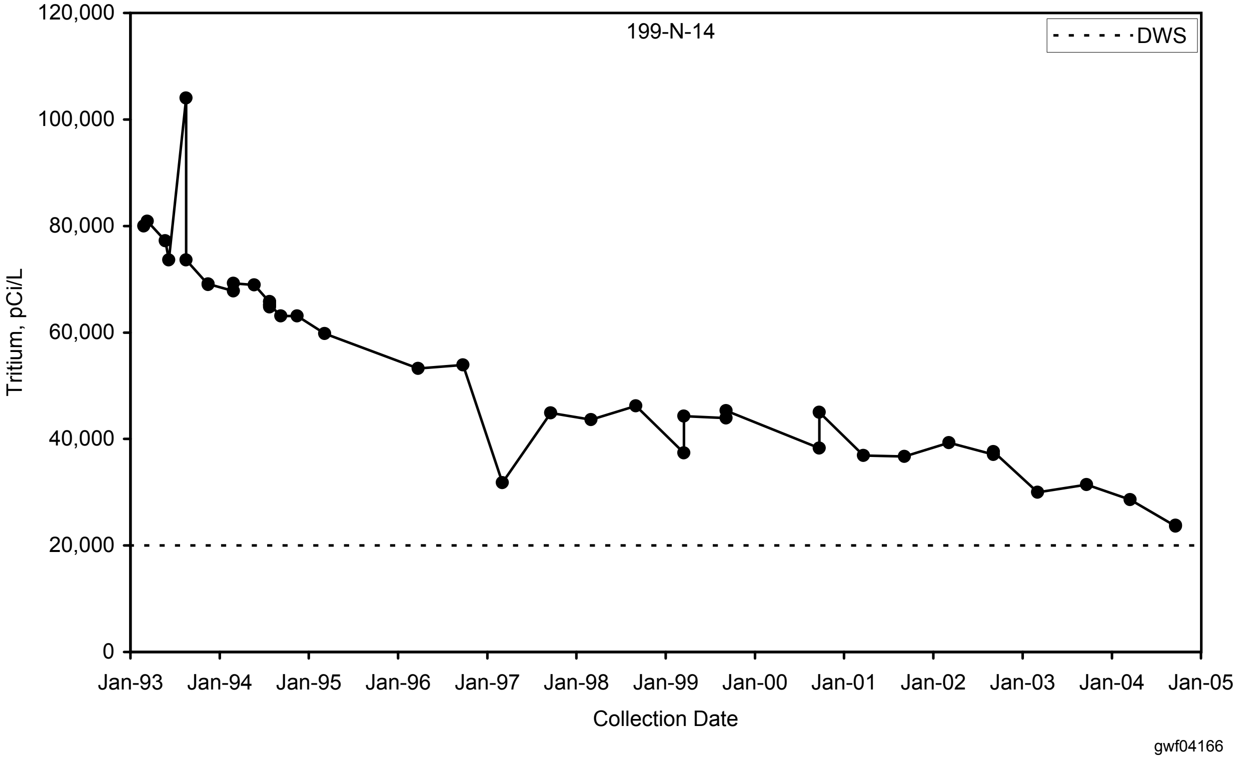

Figure 2.4-7. Tritium Concentrations North of the 116-N-1 Facility

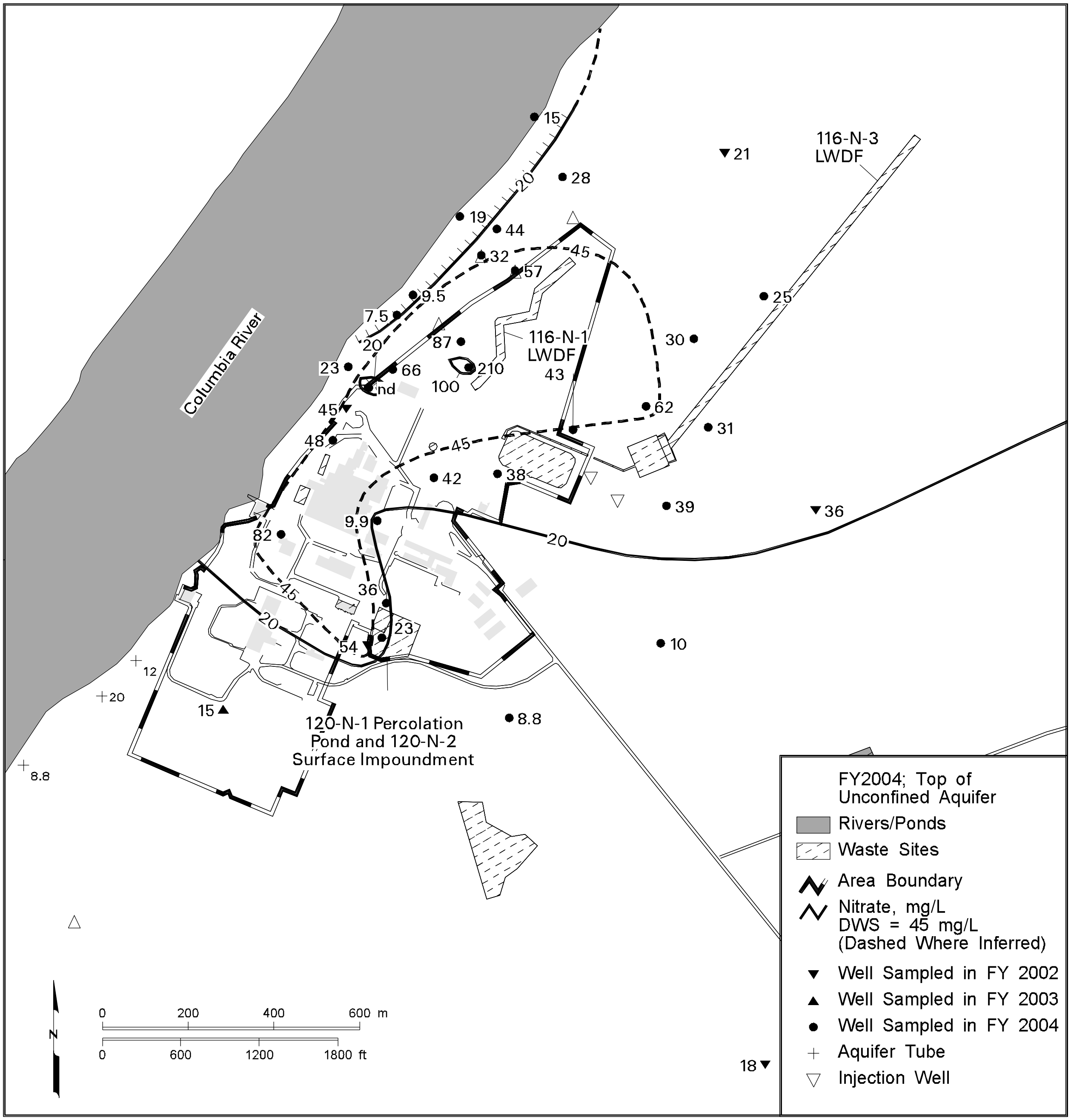

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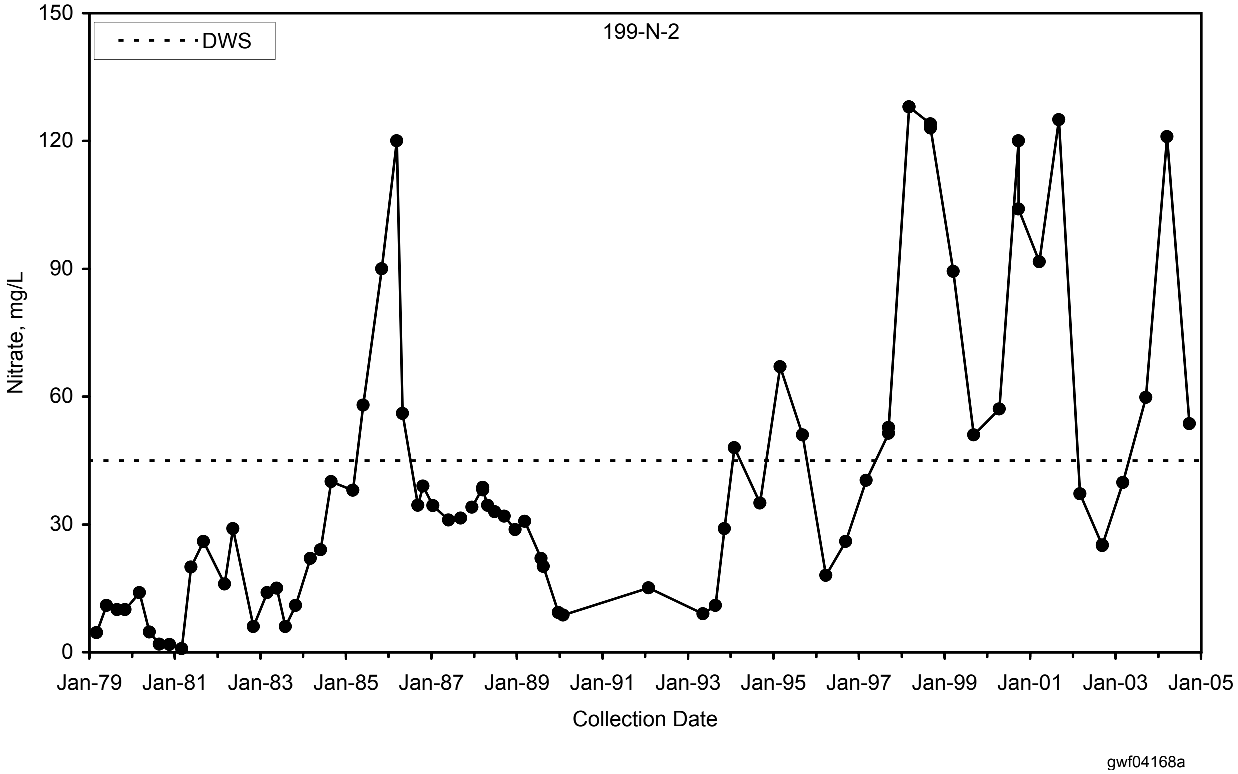
Figure 2.4-8. Average Nitrate Concentrations in the 100-N Area, Top of Unconfined Aquifer



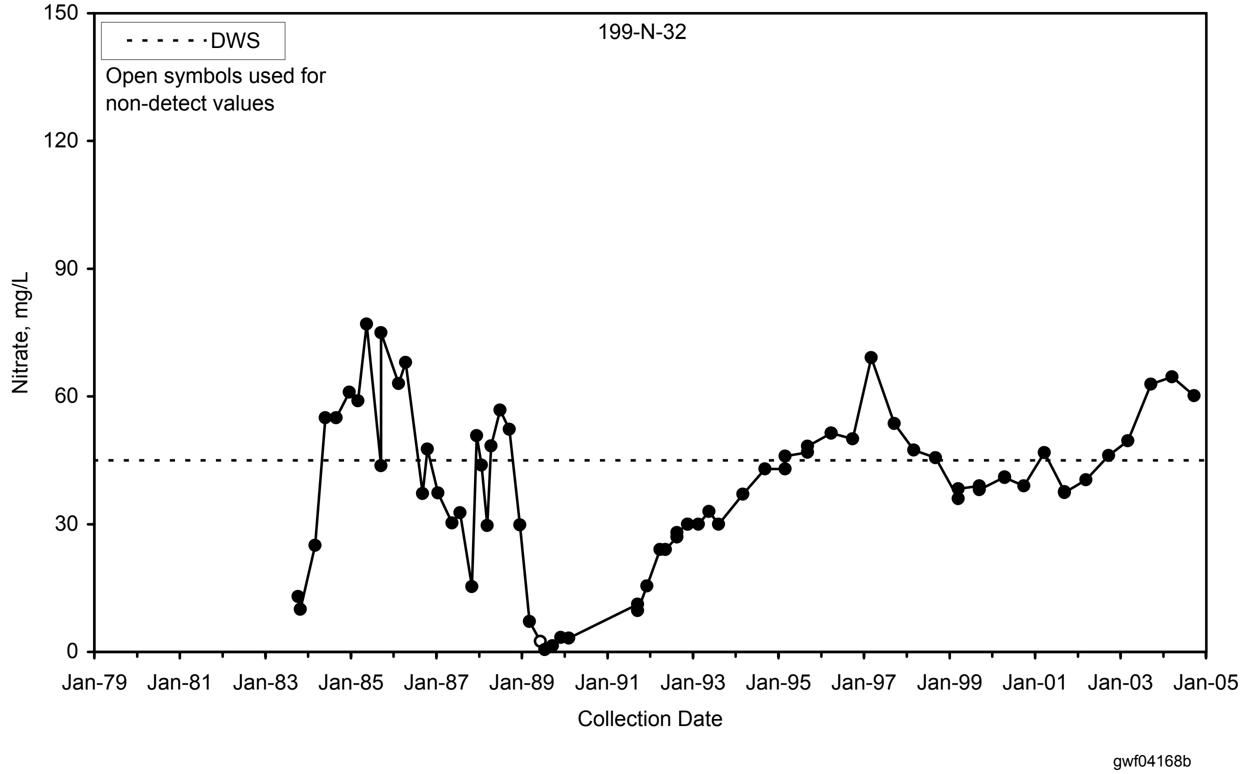


Figure 2.4-9. Nitrate Concentrations Near the 116-N-1 Facility (199-N-2) and 116-N-3 Facility (199-N-32)

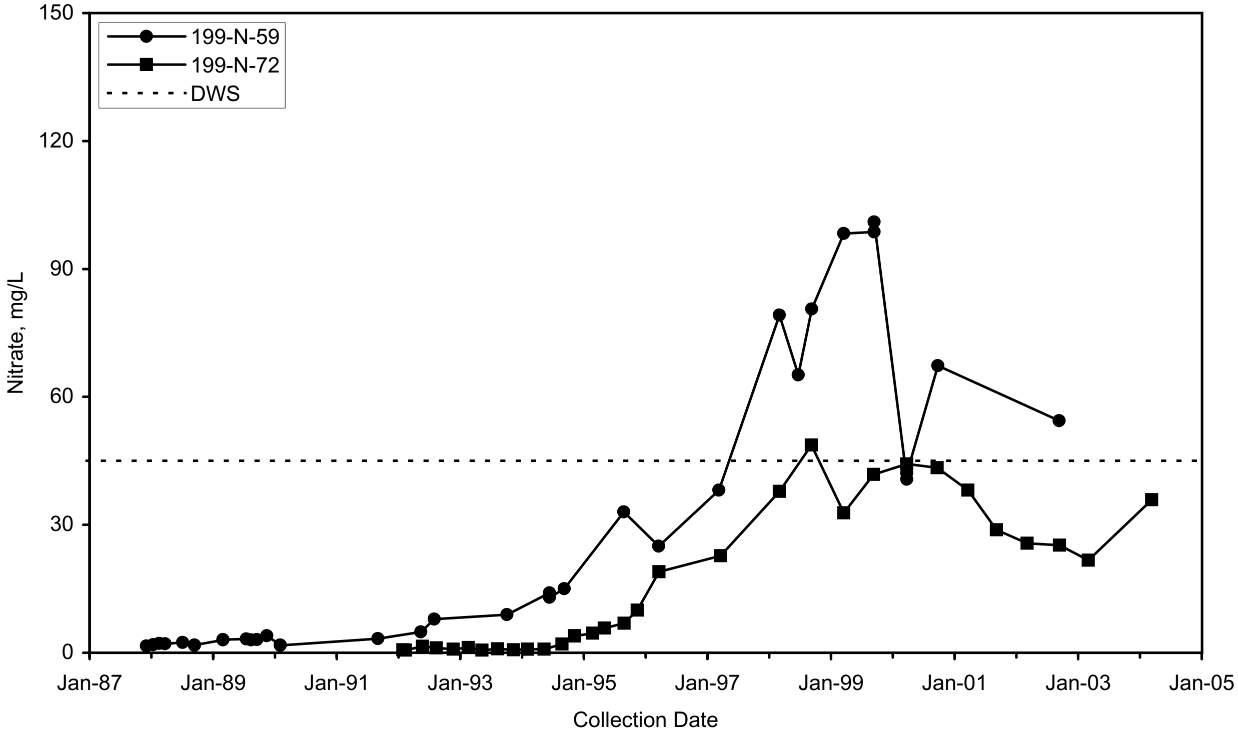


Figure 2.4-10. Nitrate Concentrations Near the 120-N-1 Percolation Pond in South 100-N Area

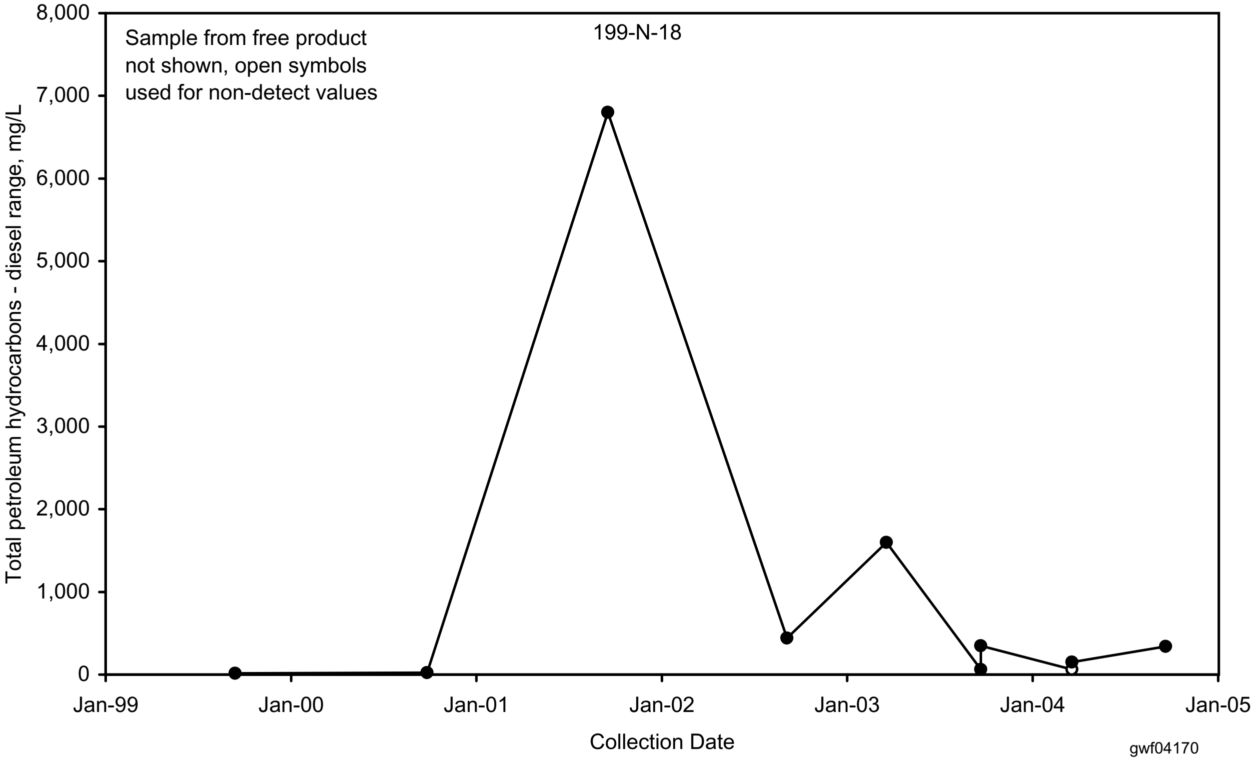


Figure 2.4-11. Petroleum Hydrocarbons Near Former Petroleum Leak Site

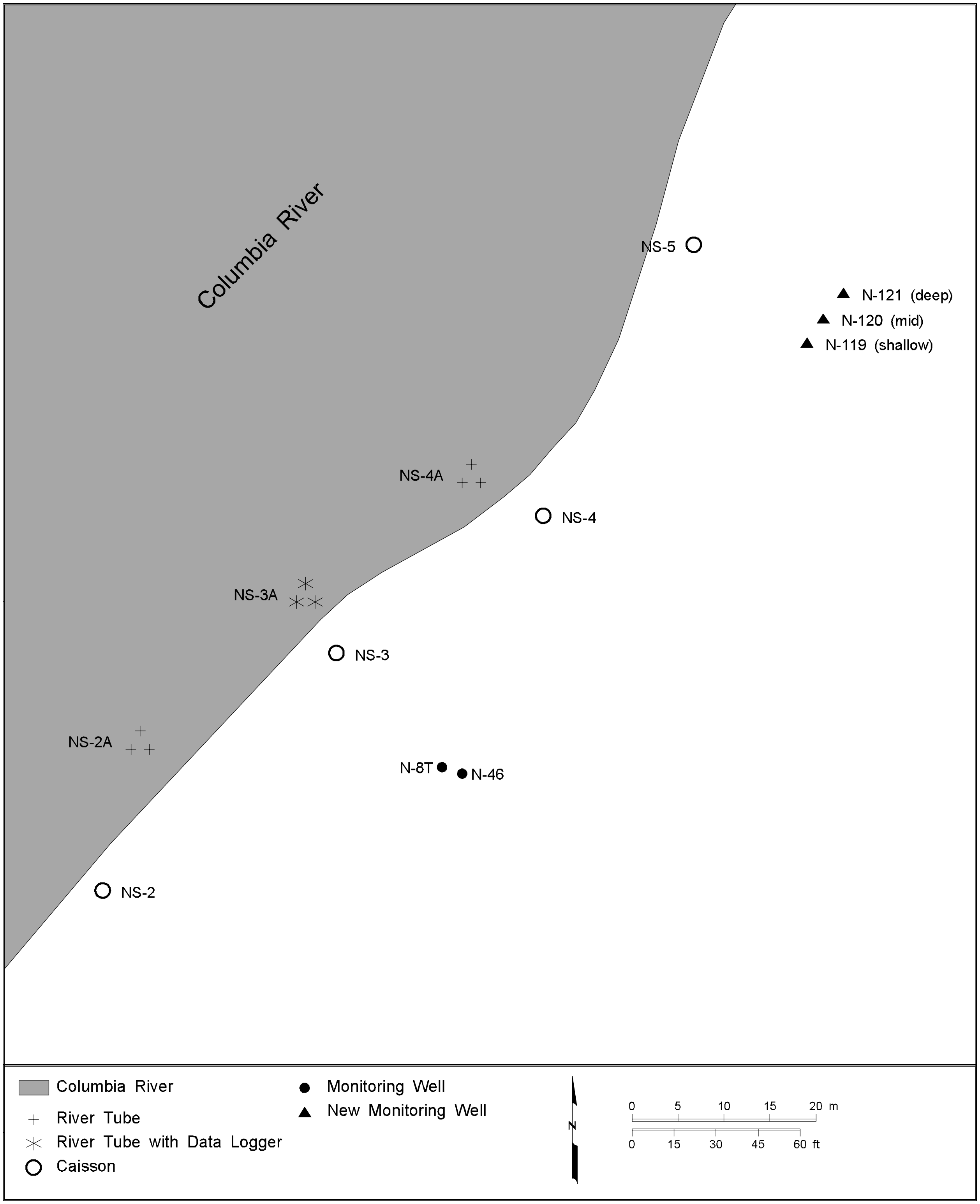


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Figure 2.4-12. Monitoring Sites at the 100-N Area Shoreline

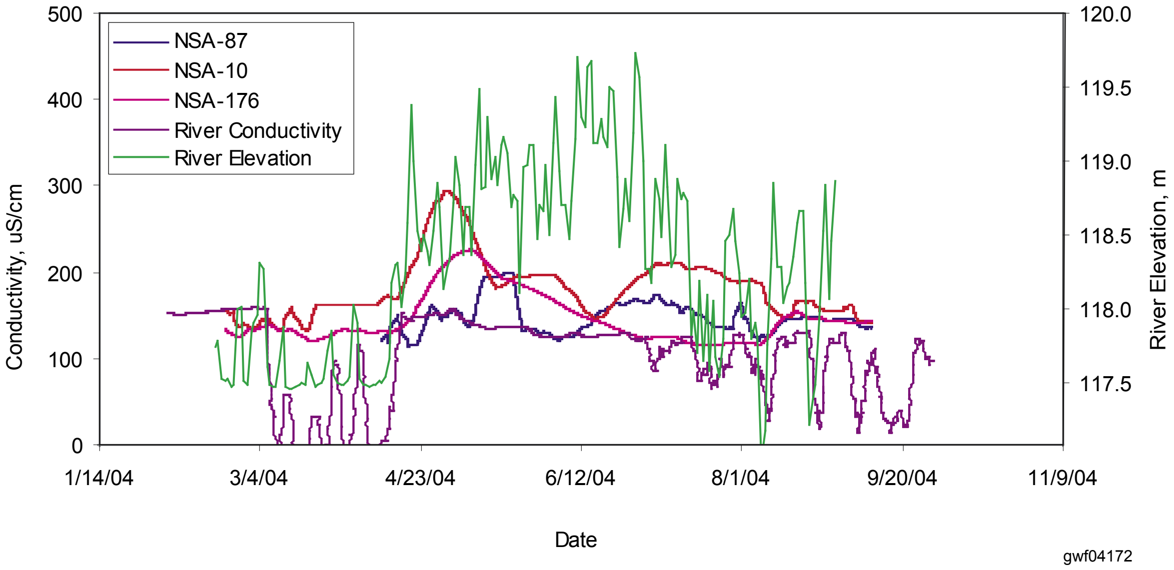

Figure 2.4-13. Three-Day Average of Specific Conductance Relative to River Stage, FY 2004

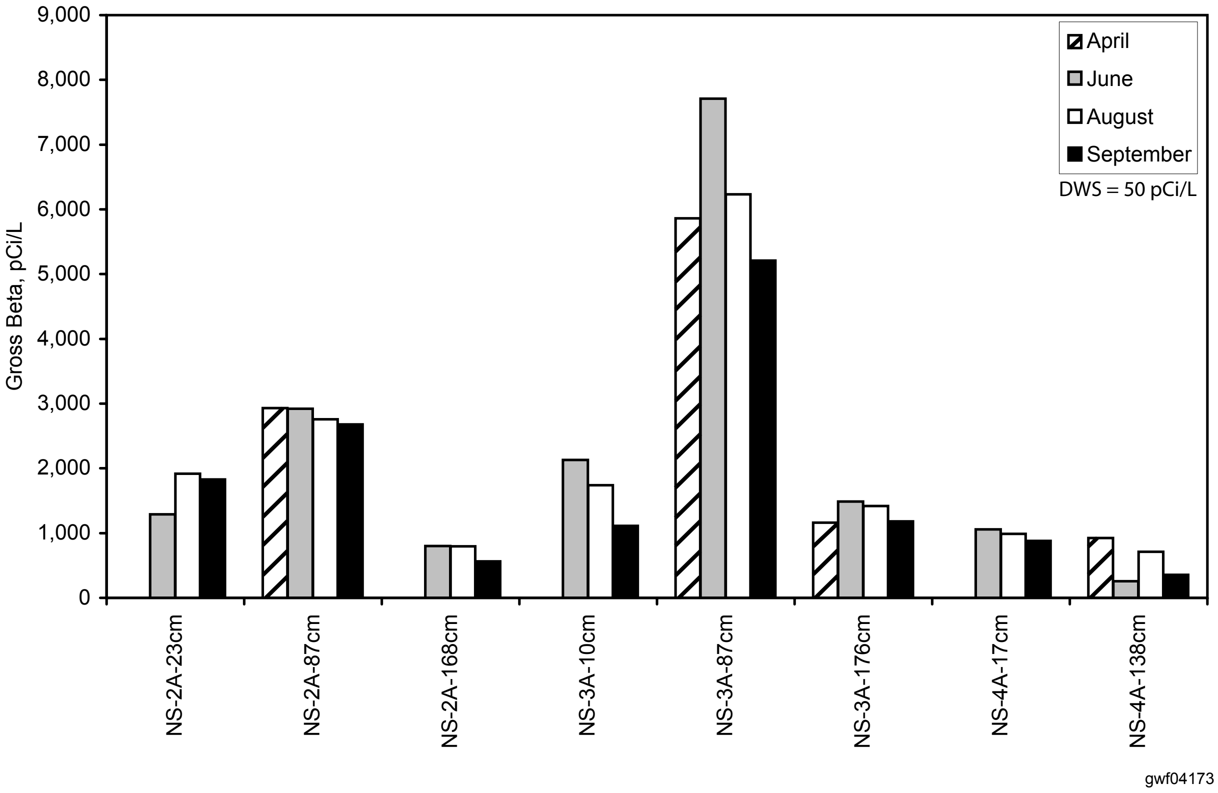

Figure 2.4-14. Gross Beta Concentrations in 100-N Area River Tubes, FY 2004

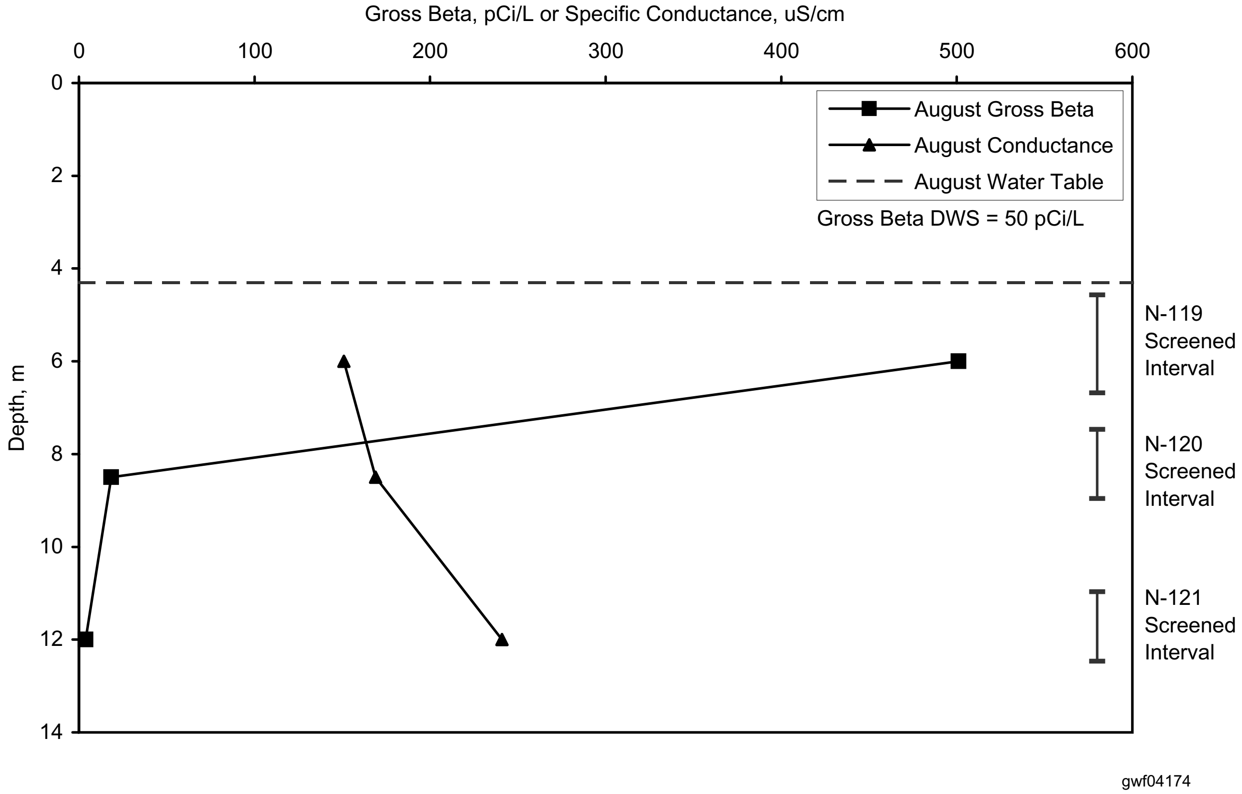

Figure 2.4-15. Gross Beta and Specific Conductance with Depth in Wells on the 100-N Area Shoreline, FY 2004

2.5 100-HR-3-D Operable Unit

M. J. Hartman, R. O. Mahood, and L. C. Swanson

The scope of this section is the 100-HR-3-D groundwater interest area that occupies the west half of the 100-HR-3 Operable Unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined the "interest areas" informally to facilitate scheduling, data review, and interpretation. Figures 2.5-1 and 2.5-2 show facilities, wells, and shoreline monitoring sites in this region. Hexavalent chromium is the contaminant of greatest significance in groundwater. Groundwater is monitored to assess the performance of two *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) interim actions for chromium: a pump-and-treat system and an in situ reduction-oxidation manipulation (redox) system. Groundwater also is monitored to track other contaminant plumes including strontium-90, tritium, nitrate, and sulfate.

Hexavalent chromium is the contaminant of greatest concern in the 100-D Area.

Groundwater flows primarily to the north and northwest, to the Columbia River (Figure 2.5-3). Near the Columbia River, including the redox site, the average flow direction is toward the northwest. Farther inland, average flow is northward.

The 182-D reservoir is used to store Columbia River water prior to treatment. The reservoir developed a leak in 2003 and 2004 that was of sufficient volume to create a measurable groundwater mound beneath the reservoir. Data from water-level recorders in new wells 199-D5-32, 199-D5-33, and 199-D5-34 helped define the mound early in fiscal year (FY) 2004. The leak was virtually stopped by lowering the water level in the reservoir, and the mound quickly dissipated. While the mound was present, it created radial groundwater flow locally and contributed to a separation of the north and south chromium plumes.

The remainder of this section describes contaminant plumes and concentration trends for the constituents of interest under CERCLA and *Atomic Energy Act of 1954* (AEA) monitoring.

2.5.1 Groundwater Contaminants

This section describes the distribution and trends of chromium, strontium-90, tritium, nitrate, and sulfate in groundwater in the 100-D Area.

2.5.1.1 Chromium

Chromium contamination underlies most of the 100-D Area in two plumes (Figures 2.5-4 and 2.5-5). The north plume had sources in the central 100-D Area and the south plume had unknown sources near the former 183-DR filter plant. In FY 2002 and 2003, available data suggested that the two plumes had merged at the 100-µg/L contour (drinking water standard) and perhaps the 500-µg/L contour (PNNL-14187; PNNL-14548). However, data from new wells in the central 100-D Area indicated the lobes were separated into two distinct plumes. Chromium concentrations are variable in the central and south 100-D Area and the plumes are dynamic.

Groundwater monitoring in the 100-HR-3-D groundwater interest area includes the following monitoring activities:

- ***A pump-and-treat system in north 100-D Area has operated since 1997, and a second system was added in FY 2004. Wells are monitored monthly to biennially for chromium and co-contaminants.***
- ***An in situ redox system operates in the southwest 100-D Area. Compliance wells, barrier wells, additional wells, and aquifer tubes are monitored monthly to annually.***

North Plume. The north chromium plume was formerly oriented south-north, but has spread westward in recent years. At the 100-µg/L contour the plume is roughly triangular, with one corner near the former D Reactor, where waste disposal facilities contaminated the groundwater with chromium, which moved north and west with groundwater flow. The north corner of this plume is influenced by the 100-HR-3-D pump-and-treat system that is designed to reduce the flux of chromium to the river (see Section 2.5.2.1). The highest concentrations in the north plume are on the southwest side of the plume (e.g., 2,400 µg/L in well 199-D5-41).

At 100-D Area, three remediation systems help reduce the amount of chromium reaching the Columbia River: two pump-and-treat systems in the north and in situ remediation in the southwest.

Near the former sources, chromium continued a gradual decline in most wells (e.g., well 199-D5-16 in Figure 2.5-6). Well 199-D5-15 is an exception to this declining trend, with variable concentrations since FY 1997. Specific conductance and other constituents varied with the chromium, suggesting dilution of groundwater with fresh water. Staff repaired leaking fire hydrants and capped unused water lines in the 100-D Area in FY 2004 to reduce the amount of artificial recharge. Quarterly sampling of well 199-D5-15 in FY 2004 showed higher levels of chromium than in the previous few years (Figure 2.5-6), perhaps in response to these repairs.

In the north 100-D Area near the pump-and-treat system, compliance wells continued to show variable chromium concentrations, with the lowest concentrations in the early summer when river stage was high (Figure 2.5-7). The concentrations remained above the remedial action goal in the compliance wells except for a few samples collected in early summer.

On the southwest side of the north plume, chromium concentrations increased sharply in wells 199-D5-20 and 199-D5-41 beginning in FY 2002 and remained high in FY 2004 (Figure 2.5-8). The high concentrations in well 199-D5-20, which is located near the Columbia River, indicated that chromium was moving between the two remediation systems. In July 2004, a new pump-and-treat system began operating in this region (see Section 2.5.2.1).

New aquifer tubes were installed at three sites in the north 100-D Area in FY 2004. Chromium concentrations in AT-D-2-S and AT-D-3-D were 156 and 294 µg/L, respectively. These are an order of magnitude higher than levels seen in the other aquifer tubes in this region, and higher than concentrations in the compliance wells. Tube site AT-D-2 is located downgradient of well 199-D5-20 and AT-D-3 is located farther north (see Figure 2.5-1 for locations).

South Plume. This chromium plume lies south and southwest of the 182-D reservoir and west of the 183-DR filter plant, extending to the Columbia River (Figures 2.5-4 and 2.5-5). The core of the plume, with concentrations >500 µg/L, is oriented southeast-northwest, perpendicular to the Columbia River. The redox barrier intersects the south chromium plume and terminates the highest-concentration portion of the plume.

Plume areas (square kilometers) above the drinking water standard at the 100-HR-3-D Operable Unit:

Chromium — 0.97
Nitrate — 0.87
Tritium — 0.04

Concentrations dropped nearly 1,000 µg/L in FY 2004 in well 199-D5-38 and more than 2,000 µg/L in well 199-D5-39, near the north edge of the south plume (Figure 2.5-9). Well 199-D5-39 had the highest chromium concentration in the 100-D Area at the beginning of FY 2004 (3,830 µg/L) but finished the year at 1,280 µg/L. The sudden declines are probably related to dilution from the 182-D reservoir, which leaked in FY 2003 and part of FY 2004.

Compliance monitoring wells downgradient of the redox barrier show inconsistent trends (Figure 2.5-10). The northernmost well, 199-D4-83, shows variable chromium concentrations with no clear trend. Well 199-D4-39, near the north end of the barrier, shows the most variability and the concentrations increased 89% between August/September 2003 and August/September 2004. South of well 199-D4-39, wells 199-D4-23, 199-D4-38, 199-D4-84, 199-D4-85, and 199-D4-86 all show an overall decline, although with some variability. Chromium concentrations in these wells declined ~50% between August/September 2003 and August/September 2004.

Aquifer tubes provide additional monitoring points along the 100-D Area shoreline (Figure 2.5-11). Four tube sites in the south chromium plume had concentrations above 100 µg/L, with a FY 2004 maximum of 363 µg/L at tube DD-43-3. Chromium concentrations in several of the tubes in this region have declined since they were first sampled in 1997. The decline may be caused, in part, by remediation effects (Figure 2.5-12).

Chromium concentrations have increased in recent years in some of the redox barrier wells, as reported previously (DOE/RL-2003-05). Section 2.5.2.2 contains more information about these wells.

New aquifer tubes in the north 100-D Area showed higher chromium concentrations than previously measured in other aquifer tubes in that region.

2.5.1.2 Strontium-90

Two locations in the 100-D Area have a history of strontium-90 detections in groundwater: near the former retention basins in the north and near D Reactor in central 100-D Area.

Near the former retention basins, one sample from well 199-D8-68 exceeded the drinking water standard (8 pCi/L) once in FY 2004 (Figure 2.5-13); other samples from that well during the year were below the standard. Strontium-90 was also detected in six other wells in this region, but at levels below the drinking water standard.

Near the former D Reactor, strontium-90 increased to 4.9 pCi/L in well 199-D5-15 (Figure 2.5-14). Nearby well 199-D5-16 continued to have no detectable strontium-90.

2.5.1.3 Tritium

Tritium concentrations in FY 2004 ranged from below detection limits to above the 20,000-pCi/L drinking water standard. The highest concentrations were detected in wells in the south 100-D Area, and are believed to represent groundwater that flowed north from the 100-N Area. Part of the 100-N Area tritium plume moved inland when groundwater mounds were present beneath liquid waste disposal facilities; that contamination is now moving north and northwest. The highest value in the 100-D Area was 25,200 pCi/L in well 199-D4-19, where concentrations are increasing gradually (Figure 2.5-15). The tritium concentration in nearby aquifer tube DD-44-4 was 31,900 pCi/L, and has also increased.

Tritium concentrations continued to be above 10,000 pCi/L near the former reactor buildings in FY 2004. Levels increased to 19,000 pCi/L in well 199-D5-17 near DR Reactor after several years of stability (~15,000 pCi/L).

Tritium contamination in the south 100-D Area may have originated in the 100-N Area.

2.5.1.4 Nitrate and Nitrite

Nitrate distribution (Figure 2.5-16) is generally similar to chromium in the 100-D Area; both constituents form two plumes. Nitrate concentrations continued to exceed the 45-mg/L drinking water standard in both plumes, with a FY 2004 maximum concentration of 74 mg/L in well 199-D5-16 near D Reactor. The south plume is truncated by the redox system, which converts the nitrate to nitrite.

Nitrate trends in the central 100-D Area do not follow chromium trends. Nitrate concentrations are steady in wells 199-D5-20 and 199-D5-41, which showed sharply increasing chromium.

Downgradient of the redox barrier, nitrate concentrations decreased in compliance wells, falling to levels below the drinking water standard for the first time in wells 199-D4-84 and 199-D4-85. As with chromium, these decreases are believed to be related to redox effects.

Like chromium, nitrate concentrations in some redox barrier wells (e.g., 199-D4-26 and 199-D4-32) have risen in recent years, suggesting a loss of reducing conditions.

Samples from four new aquifer tubes were analyzed for nitrate. The highest result was 40.3 mg/L in tube AT-D-1-S in the central shoreline.

Nitrite continued to be detected in redox barrier wells but was below detection limits in downgradient wells. Nitrite concentrations exceeded the 3.3-mg/L drinking water standard three wells (maximum 4.27 mg/L in barrier well 199-D4-32).

2.5.1.5 Sulfate

Sulfate concentrations are >100 mg/L beneath much of the 100-D Area. Excluding wells influenced by the redox system, concentrations all were below the 250-mg/L secondary drinking water standard in FY 2004.

Injections of sodium dithionite solution at the redox site increases sulfate concentrations in the barrier and in some downgradient wells and aquifer tubes. For example, sulfate concentrations in downgradient wells 199-D4-23 and 199-D4-84 exceeded the 250-mg/L secondary drinking water standard in FY 2004. The maximum concentration downgradient of the barrier was 580 mg/L in well 199-D4-23 (Figure 2.5-17).

2.5.2 Interim Groundwater Remediation for Chromium

Hexavalent chromium is the contaminant of greatest concern in the 100-D Area. Two CERCLA remediation systems have been implemented as interim actions to reduce the amount of chromium reaching the Columbia River: a pump-and-treat remediation system in the north and in situ redox manipulation barrier in the southwest. A second pump-and-treat system was installed and became operational in FY 2004 between the existing system and the redox barrier.

Fourteen new aquifer tubes at five sites were installed in the 100-D Area shoreline. The new tubes extend from just north of the redox barrier to north of the pump-and-treat system. Pertinent results from aquifer tube sampling were discussed in Section 2.5.1.

In September, 2004, a test of the Enhanced Access Penetration System (EAPS) was conducted in the south chromium plume at 100-D Area. The EAPS combines a cone penetrometer with a small-diameter air-rotary drilling system to allow subsurface access in areas that are not conducive to conventional push technology. The EAPS successfully drilled to the bottom of the unconfined aquifer (>30 meters below the surface) through sand and cobbles. Total drilling time was ~8 hours. A small-diameter well (nominal 2.5-centimeter diameter; 199-D5-93) was installed with a pre-packed sand screen, and the well was completed by sealing with bentonite and grout. A variance for the well was required because the annular seal for the well was thinner than called for in the regulations. Washington State Department of Ecology granted this variance on the condition that a report on the quality of data produced by the well be submitted by September 2006.

The remedial action objectives of the 100-HR-3 Operable Unit (ROD 1996a, 1999a) are:

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

The contaminant of concern is hexavalent chromium. The records of decision set the cleanup goal at compliance wells as 22 µg/L for the pump-and-treat system and 20 µg/L for the redox system. EPA specified enhancements needed to the pump-and-treat system in their 5-year review (EPA 2001).

2.5.2.1 Pump-and-Treat Systems

The original pump-and-treat system in the 100-HR-3-D Operable Unit includes four extraction wells located near the former 116-D-7 and 116-DR-9 retention basins. The system began operating in July 1997. Groundwater is pumped from extraction wells 199-D8-53, 199-D8-54A, 199-D8-68, and 199-D8-72, and then transferred via pipeline to the 100-H Area where it is treated and injected into the aquifer. Monitoring requirements for this system are included in DOE/RL-96-90, as modified by DOE/RL-96-84. Long-term monitoring requirements in the 100-D Area were derived from Change Control Form 107 as modified by Fluor Hanford, Inc.[a] Wells, constituents, and sampling frequencies for interim

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[a] Letter FH-0205249 from RT Wilde (Fluor Hanford, Inc.) to JS Fruchter (Pacific Northwest National Laboratory), *Revised FY 2003 Sampling Schedule for Groundwater Remediation Monitoring*, dated November 11, 2002.

action monitoring are shown in Appendix A. One well (199-D4-15) scheduled for monthly sampling was not sampled in July because of a pump problem. Details regarding 100-HR-3-D pump-and-treat operations may be found in the annual reports that are issued by the U.S. Department of Energy (DOE). Figure 2.5-1 displays well locations.

A second pump-and-treat system came on-line at the end of July 2004 to address increasing hexavalent chromium levels in monitoring wells southwest of the original pump-and-treat system. The new system is located between the current extraction wells and the redox barrier. Groundwater is withdrawn from wells 199-D5-20, 199-D5-32, and 199-D5-37, treated in the 100-D Area using a metal chelating medium called MR3, and injected into well 199-D5-42. If the small scale system works as planned, the system may be expanded in FY 2005 to remediate a larger area. An upcoming report on the 100 Areas pump-and-treat systems will provide a more detailed discussion of this new technology and its application in the 100-D Area.

During FY 2004, two pump-and-treat system extracted ~181 million liters of groundwater from the 100-D Area, removing ~37.3 kilograms of hexavalent chromium.

Progress During FY 2004. The 100-D Area pump-and-treat system is reducing overall contamination in the operable unit by removing contaminant mass. During FY 2004, the system extracted ~172.8 million liters of groundwater from the 100-D Area, removing ~30.9 kilograms of hexavalent chromium. An additional ~7.9 million liters were processed and ~6.4 kilograms of chromium removed by the new pump-and-treat system.

A total of ~192.2 kilograms of hexavalent chromium has been removed from original targeted plume area since startup of the system in July 1997. An additional ~30 kilograms of hexavalent chromium were removed during a pilot-scale test conducted in the 100-D reactor area between August 1992 and August 1994 (DOE/RL-95-83). The total hexavalent chromium in the plume has been estimated at 590 kilograms (DOE/RL-94-95). This amount does not include the chromium plume in the southwest 100-D Area nor in the vadose zone.

Influence on Aquifer Conditions. In FY 2004, chromium concentrations remained elevated in the 100-D Area. Hexavalent chromium concentrations in compliance wells varied inversely with river stage. The range of concentrations observed in FY 2004 were similar to those observed the previous two years. Figure 2.5-7 shows chromium trends for the two compliance wells, 199-D8-69 and 199-D8-70. Chromium remained above the remedial action goal (22 μg/L) in both of the wells throughout FY 2004 except for one measurement in each well in the early summer when Columbia River run-off was greatest. Results of performance monitoring are incorporated with the discussion of general contamination in Section 2.5.1.

DOE/RL-2004-21 presents results of operational monitoring and additional details about the pump-and-treat system for calendar year 2003. Results for 2004 will be included in an upcoming report on the 100 Areas pump-and-treat systems.

2.5.2.2 In Situ Redox Manipulation System

This treatment system uses a change in redox potential to reduce dissolved hexavalent chromium in groundwater to trivalent chromium, a much less soluble and less toxic species. Objectives of the redox interim action are the same as for the 100-D Area pump-and-treat system except that the remedial action goal for chromium at the redox site is 20 μg/L. Remedial action monitoring is described in DOE/RL-99-51. Wells, constituents, and sampling frequencies are listed in Appendix A.

Progress During FY 2004. The redox treatment zone is ~680 meters in length, aligned parallel to the Columbia River shoreline and ~100 to 200 meters inland. The treatment zone is designed to reduce the concentration of hexavalent chromium in groundwater to ≤20 μg/L at seven compliance wells situated between the treatment zone and Columbia River. The 20-μg/L goal was met at only one of the seven compliance wells, 199-D4-86, located at the southwest extent of the barrier. Concentrations in the other compliance wells were generally decreasing except for well 199-D4-39, as discussed in Section 2.5.1 (Figure 2.5-10). The reason for the increase is not understood at this time.

Chromium concentrations have increased sharply in one redox compliance well but continued decreasing in other compliance wells. Concentrations increased in some barrier wells.

Institutional controls continue to protect the public by preventing access to hexavalent chromium in the groundwater. Sampling and analysis of groundwater from compliance wells, monitoring wells, aquifer tubes, and redox treatment zone wells continues to provide information leading to selection of the final remedy.

An automated water-level monitoring system installed in eleven wells and at the Columbia River also provide information leading to selection of the final remedy. Hydrographs of data from the automated water-level monitoring systems installed in four wells showed responses to the re-filling of the 182-D reservoir in July 2003 and the subsequent decline and dissipation of that mound into FY 2004.

Influence on Aquifer Conditions. In FY 2004, as well as in previous years, chromium concentrations increased in redox barrier wells beyond what was expected based on the design. At the end of the fourth quarter, ~85% of the barrier wells were below the remedial action goal of 20 µg/L. Chromium concentrations in the barrier wells ranged from below detection limits to 1,380 µg/L.[b] Almost all of the elevated concentrations are in the northeast part of the barrier.

To evaluate the reason for the increasing concentrations a team of experts convened with key Hanford Site technical personnel to review site conditions and processes in establishing the barrier. The panel concluded that the primary cause of the premature breakdown in reductive capacity was physical and chemical aquifer heterogeneity. These conditions lead to the following:

- Lack of ferrous iron in some intervals (needed for long-term reducing conditions).
- High flow rates through preferential pathways (incomplete reducing conditions).
- Presence of competing oxidants (uses up reductant targeted for hexavalent chromium).

The remaining wells in the barrier treatment zone appear to be intact and functioning as designed. DOE is working with the regulatory agencies and technical experts to develop corrective actions to mend the barrier where hexavalent chromium concentrations are elevated.

2.5.3 Chromium Sensor Deployment

As part of the Advanced Monitoring Systems Initiative, DOE deployed a chromium sensor on the 100-D Area shoreline in FY 2004. The purpose of the deployment was to demonstrate the efficacy of such a system in the field. Chromium sensors could be used routinely in the 100-D Area to measure chromium concentrations in monitoring wells and aquifer tubes at more frequent intervals than is practical using manual sampling techniques.

Burge Environmental developed a universal platform to use with various types of analytical sensors in the field. The platform was previously used at other locations to monitor trichloroethene in monitoring wells and at groundwater treatment systems. For the 100-D Area deployment, Burge Environmental coupled the platform with analytical systems for hexavalent chromium and specific conductance. Two aquifer tubes downgradient of the redox site, DD-39-1 and DD-39-3, were plumbed into the sensor.

Figure 2.5-18 illustrates the complete universal platform deployed in the field. The monitoring system comprises several modules for sample collection, calibration, analysis, data acquisition/control, and communication. A field deployment box was used to mount solar cell panels and house the batteries, air system, and communication module. A piece of plastic casing passed through the bottom of the field deployment box and ~1 meter into the soil. The analytical and calibration modules were mounted inside the casing for temperature control.

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[b] Redox operational data; not in Hanford Environmental Information System (HEIS).

The system collected samples with a peristaltic pump that ran off batteries charged by solar cells. A valve directed the sample to either the calibration module or the analytical chamber. The calibration module performed two functions: creating blank water and creating three-step calibration curves. Sample water diverted to the calibration module was passed through a filter of granular ferric hydroxide to remove the hexavalent chromium from the water, creating the "blank water." Blank water was used to clean the system and create the three-step calibration curve. After the initial deployment, the system was modified to include a specific conductance sensor.

A serial cable connected a modem, located in the field deployment box, to a small programmable logic controller located on the analytical/calibration unit. A computer located at a trailer ~0.8 kilometer from the monitoring location controlled the monitoring system via a radio modem. The program on the computer sent commands and received data via the radio modem. The modem was capable of operating at distances of 20 kilometers. The computer located in the trailer was remotely controlled by users in more distant locations.

A chromium sensor was installed at an aquifer tube site on the 100-D Area shoreline to measure chromium concentrations automatically.

Deployment of the sensor demonstrated that the system can

- Measure chromium concentrations reliably. Data compared favorably to laboratory data from samples collected during installation and to historical data.
- Measure specific conductance, which gives information on the source of the water (river or groundwater).
- Create calibration curves.
- Perform 90 to 100 analyses before replenishing reagent.
- Operate using solar cells for power.
- Be controlled and data can be accessed from remote locations.

The deployment encountered the following difficulties:

- The volume of water that had to be pumped to purge the system was initially too high. This problem related to the diameter of the aquifer tubes. Smaller-diameter tubes were inserted inside the aquifer tubes to reduce the volume of water pumped to flush the system and analyze the sample.
- The compressor overheated. A cooling fan was installed and a regulatory switch was replaced.
- A leak developed in the reaction chamber and was repaired.
- Communication difficulties associated with use of a non-dedicated phone line to access the computer arose. Staff resolved the problem.
- Air bubbles in the line affected specific conductance measurements. This problem could be solved by changing the design of the conductivity sensor.

Results of this limited deployment showed that this type of sensor is a viable alternative to manual sampling and analysis of chromium at shoreline sites at the Hanford Site. The system can be designed to measure other constituents and to sample monitoring wells also.

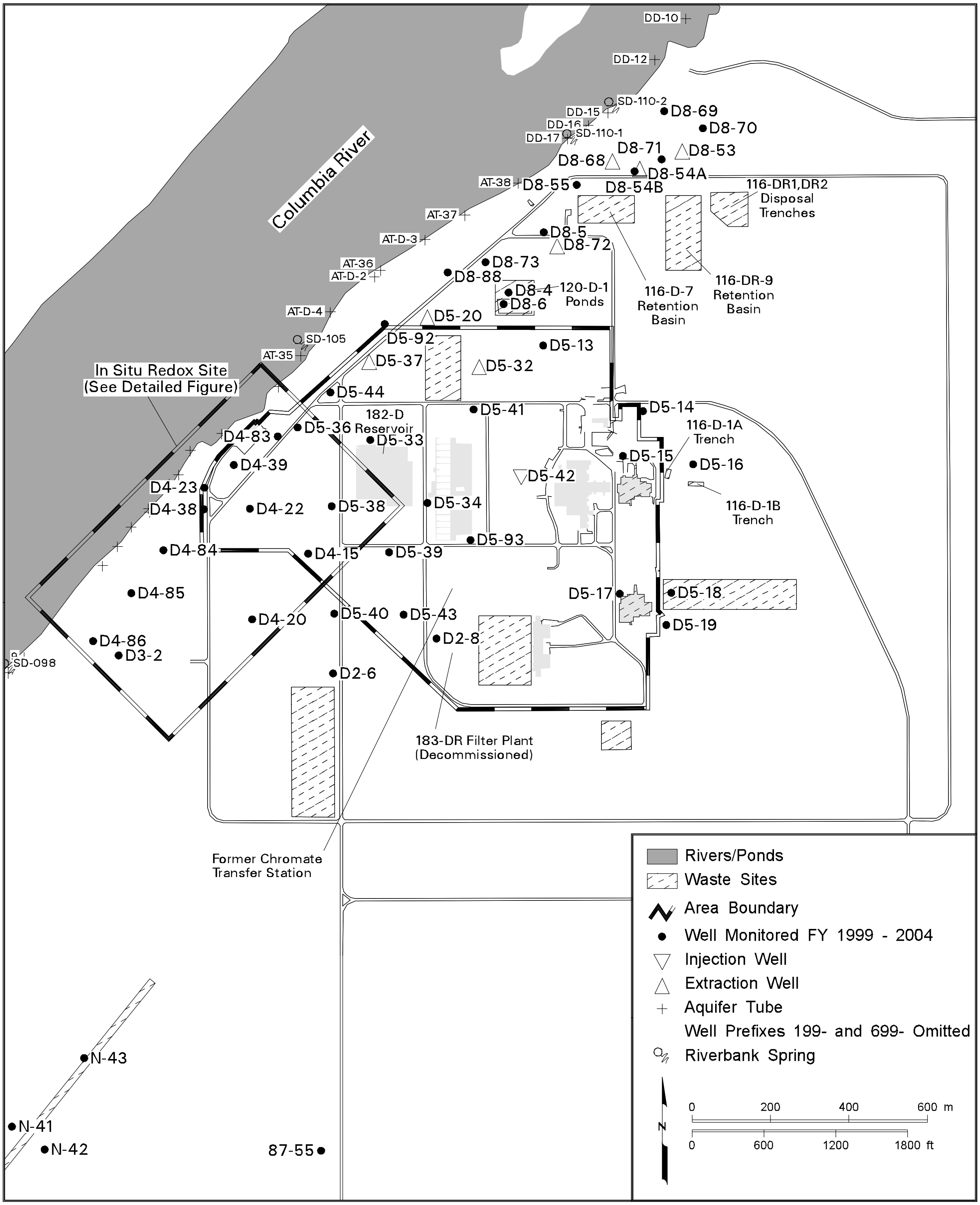

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Figure 2.5-1. Groundwater Monitoring Wells in the 100-D Area

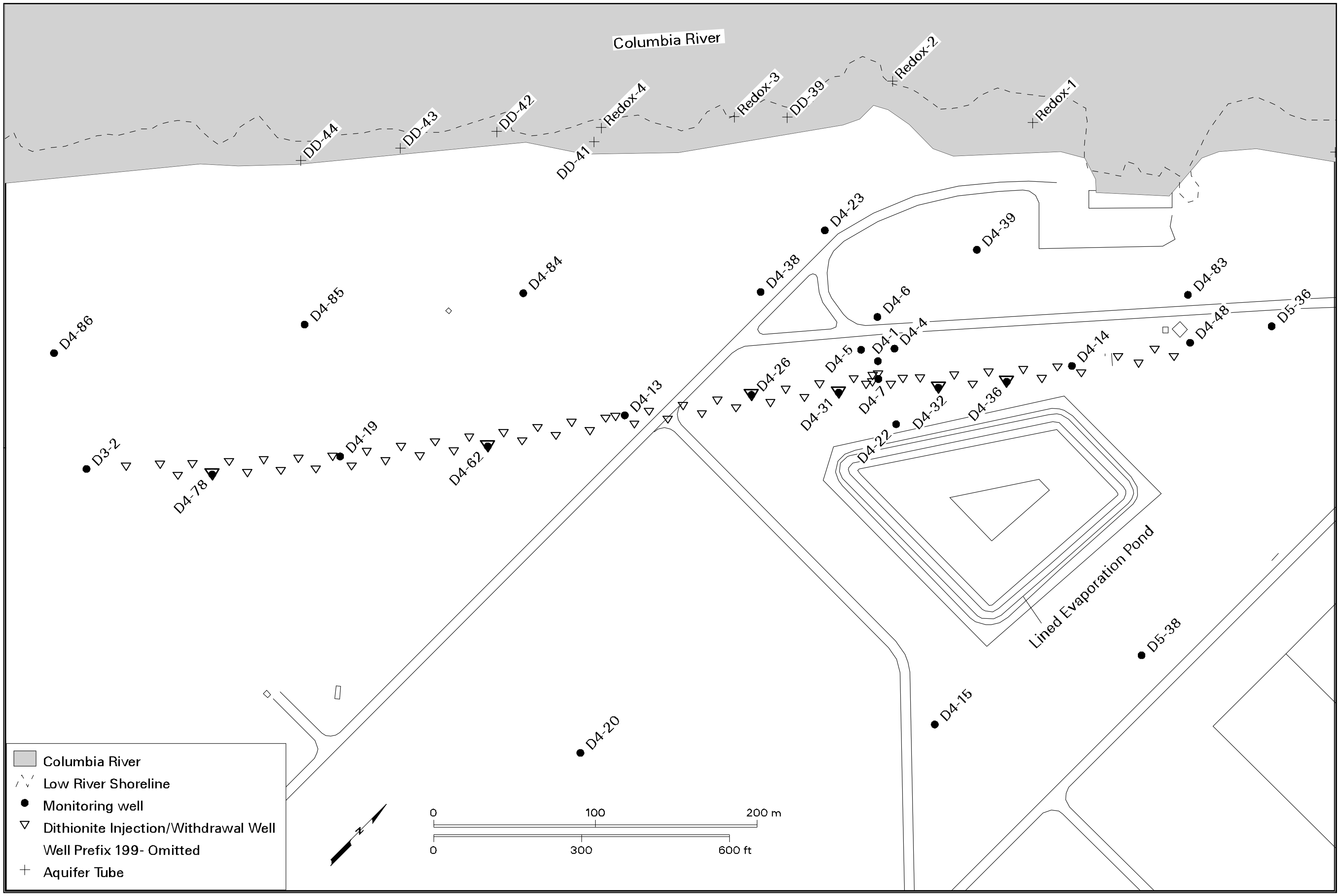

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Figure 2.5-2. Groundwater Monitoring Wells Near the Redox Site in 100-D Area

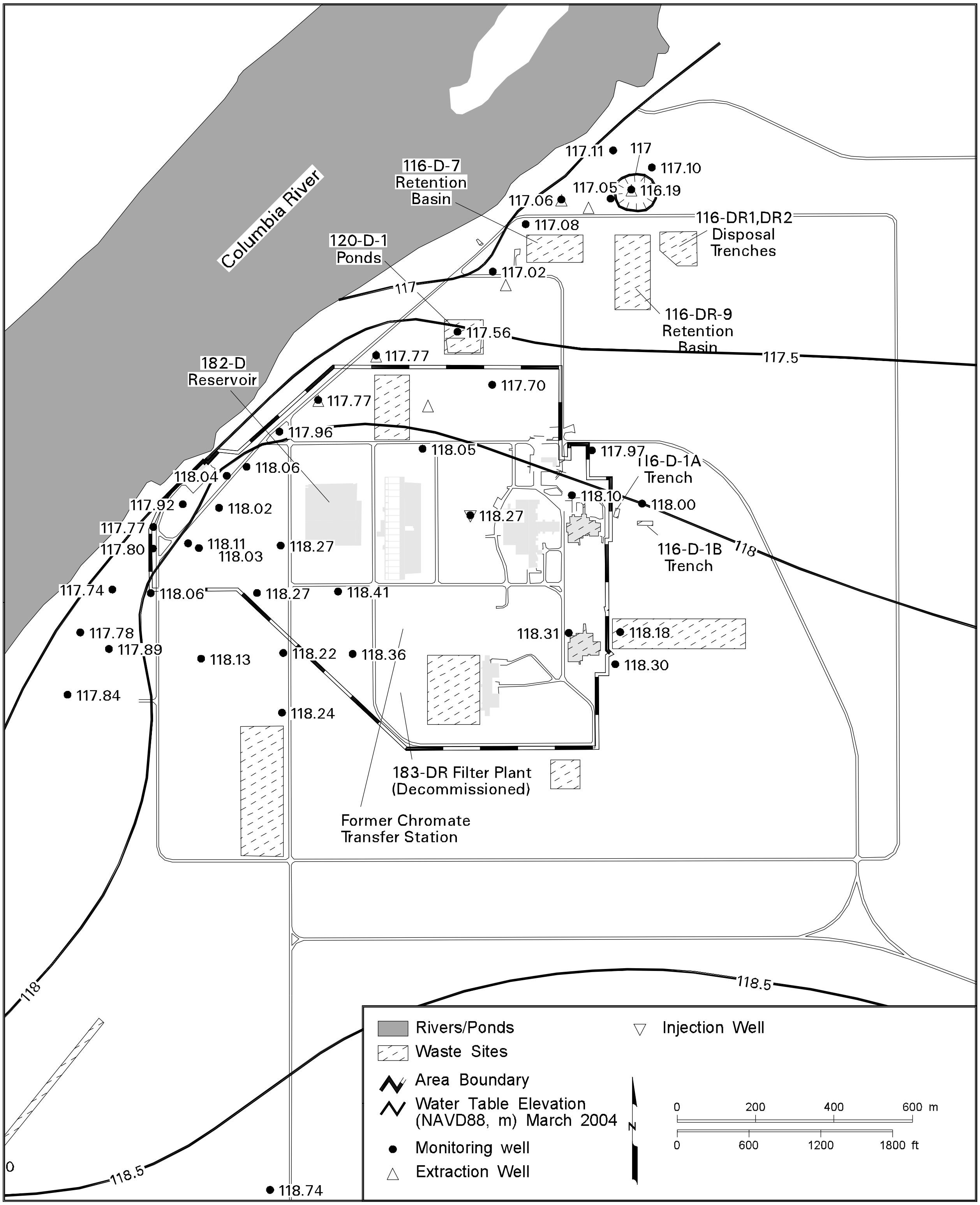

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Figure 2.5-3. 100-D Area Water-Table Map, March 2004

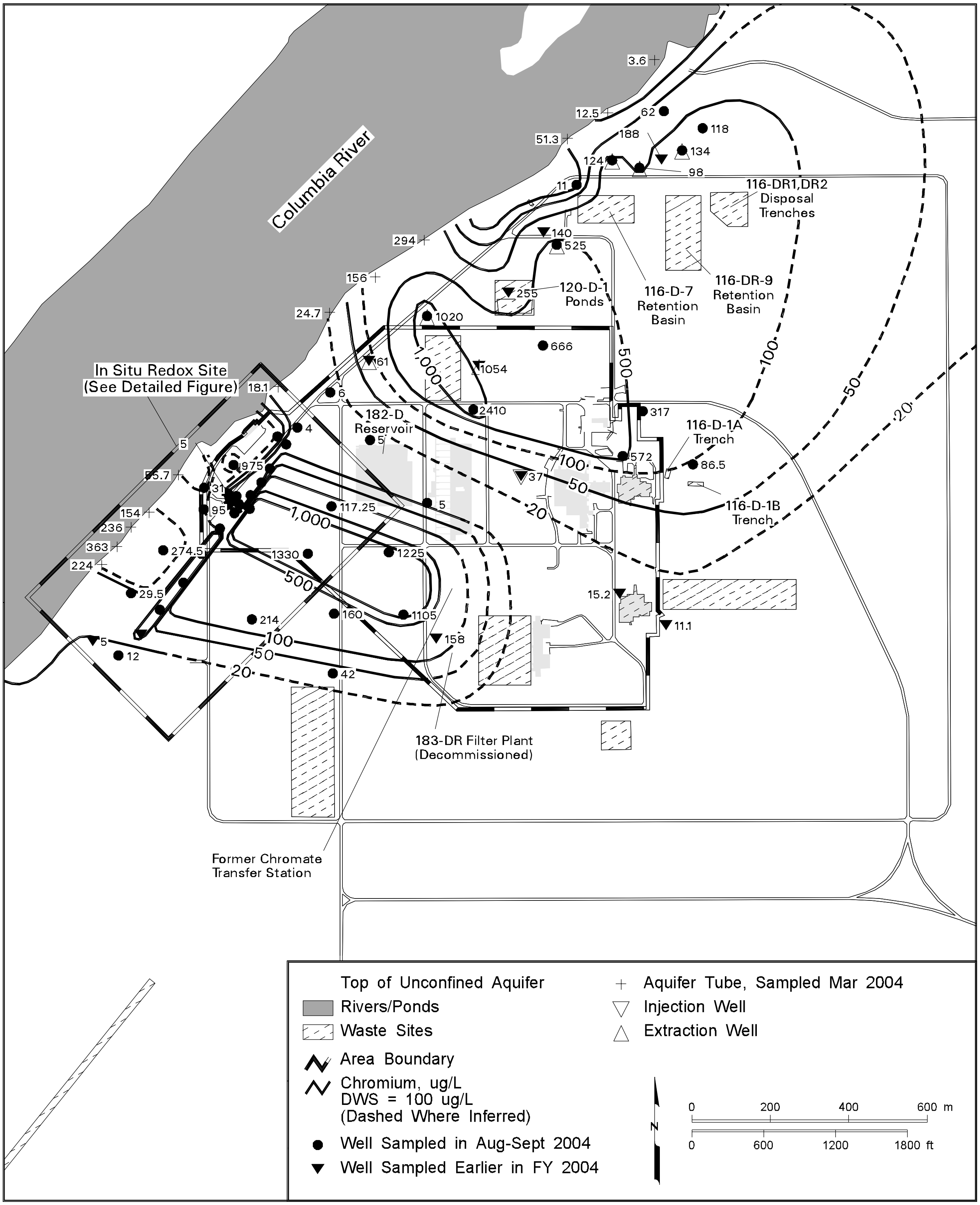

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Figure 2.5-4. Dissolved Chromium Concentrations in the 100-D Area, Top of Unconfined Aquifer, August-September 2004

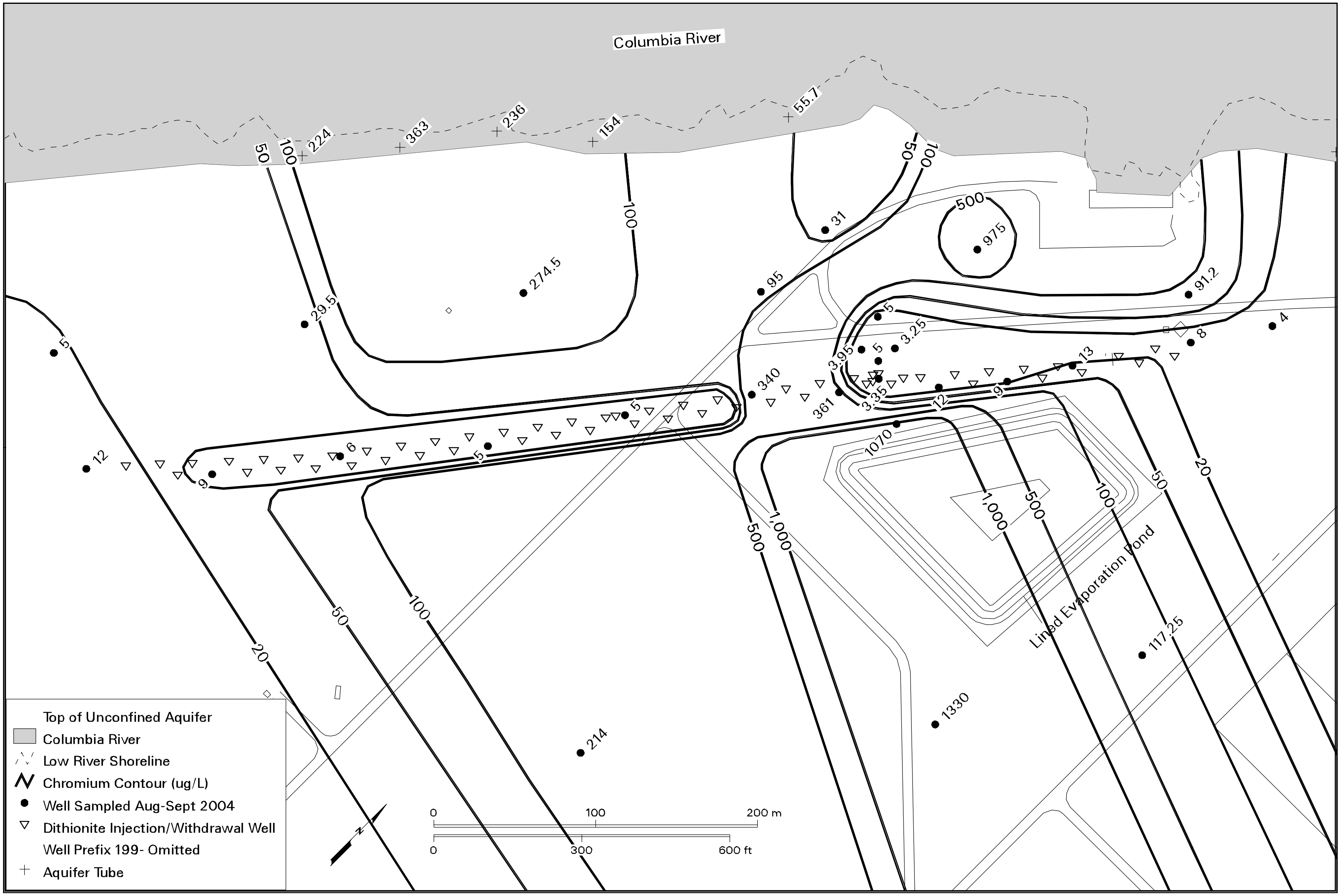

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Figure 2.5-5. Dissolved Chromium Concentrations Near the Redox Site, 100-D Area, August-September 2004

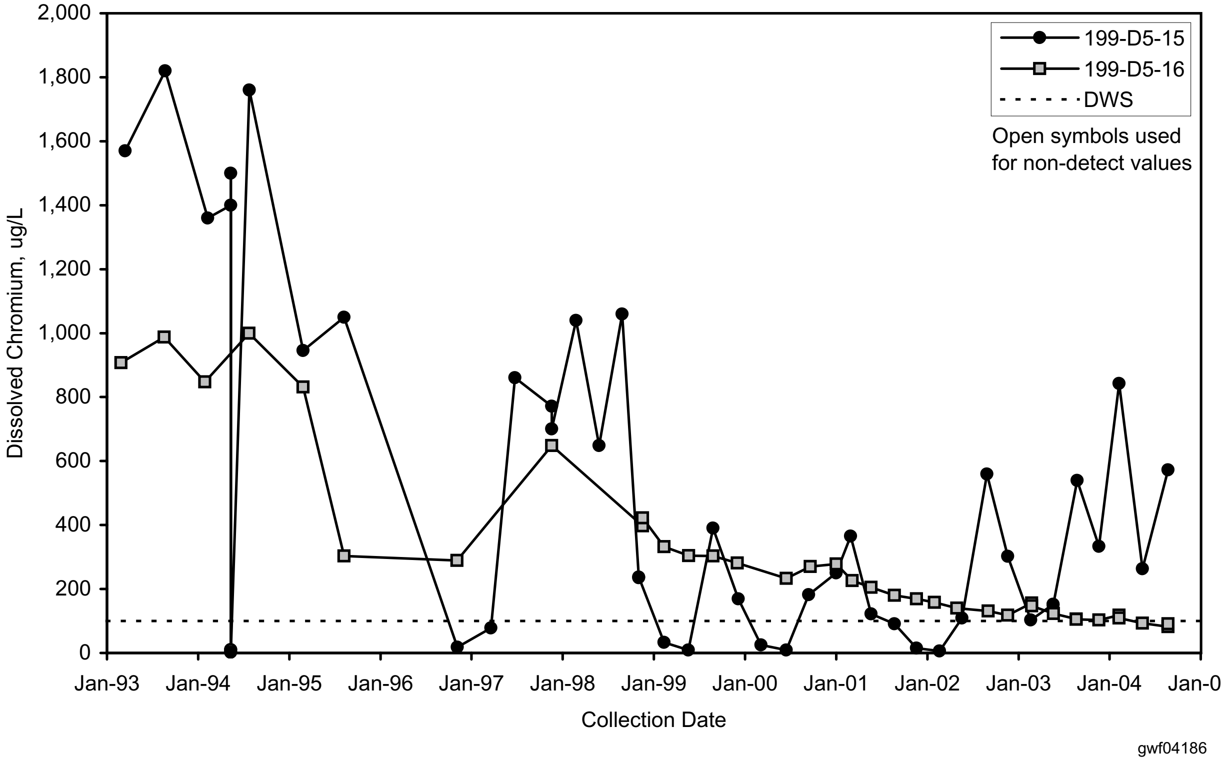

Figure 2.5-6. Chromium Concentrations in Wells Near the Former D Reactor

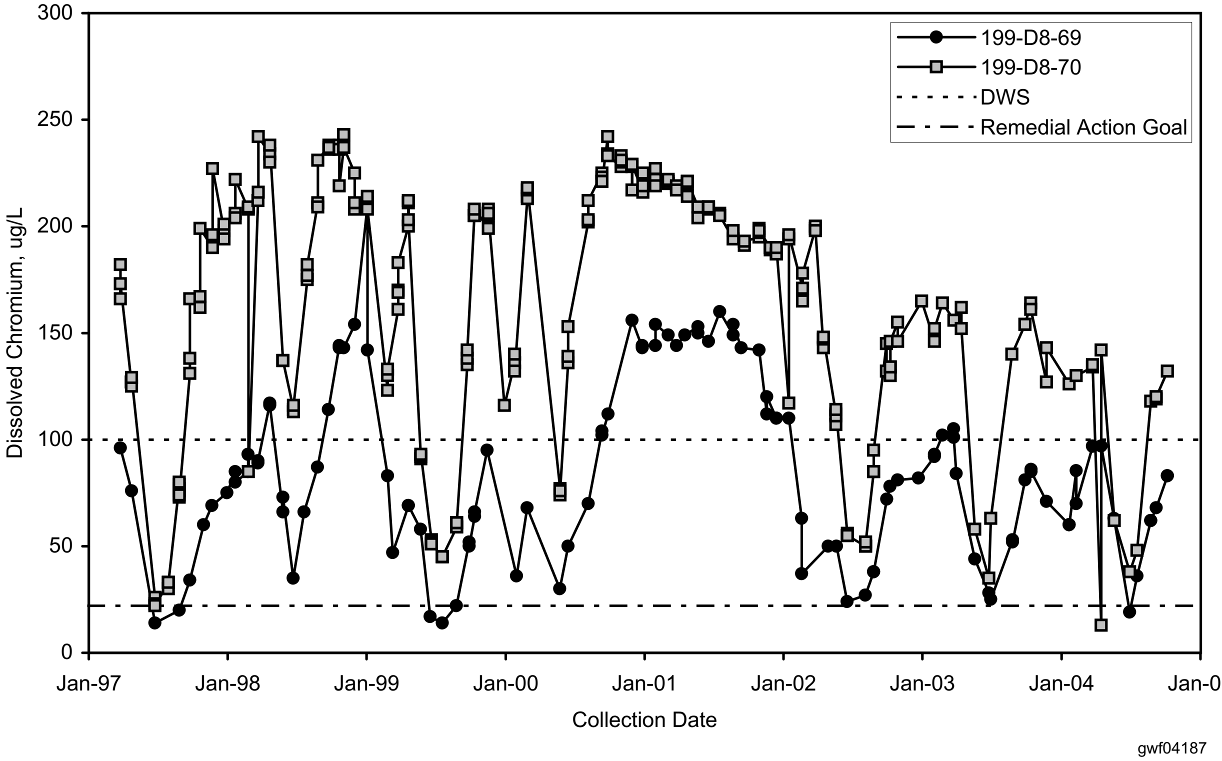

Figure 2.5-7. Dissolved Chromium Concentrations in Compliance Wells for the 100-HR-3 Pump-and-Treat System at 100-D Area

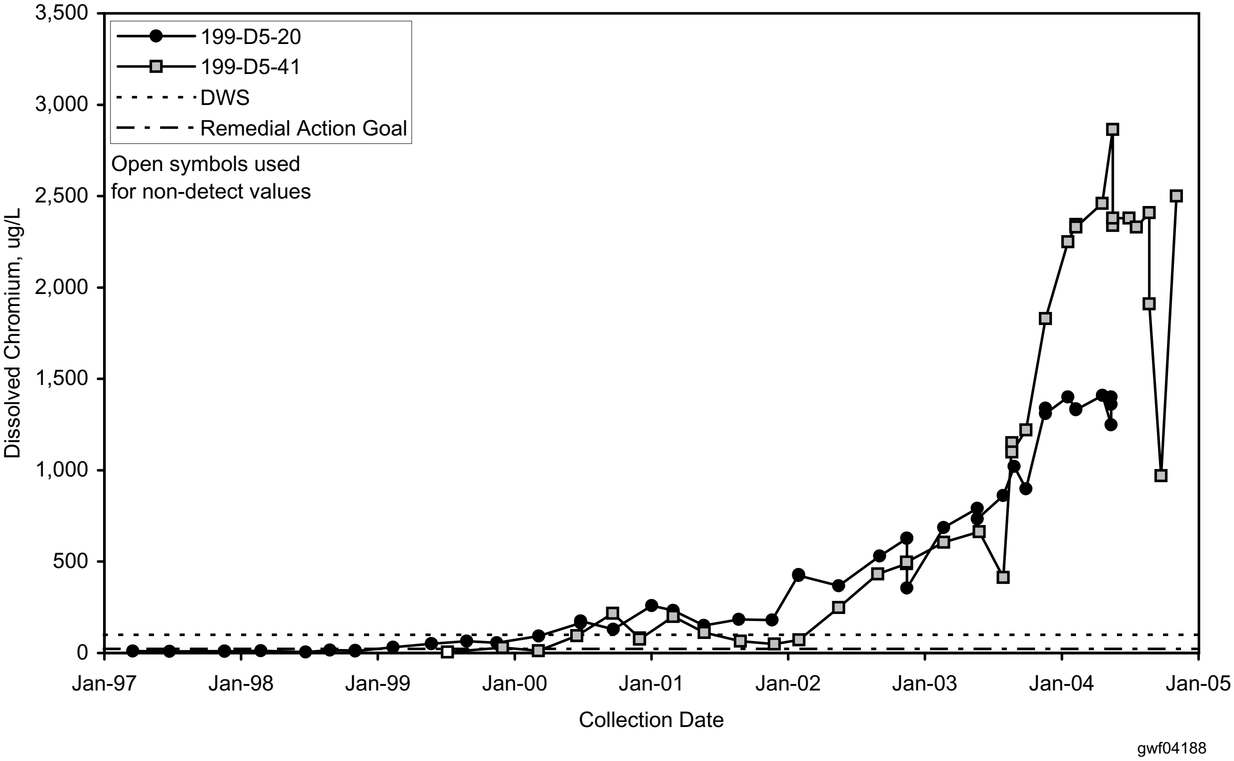

Figure 2.5-8. Dissolved Chromium Concentrations in Central 100-D Area

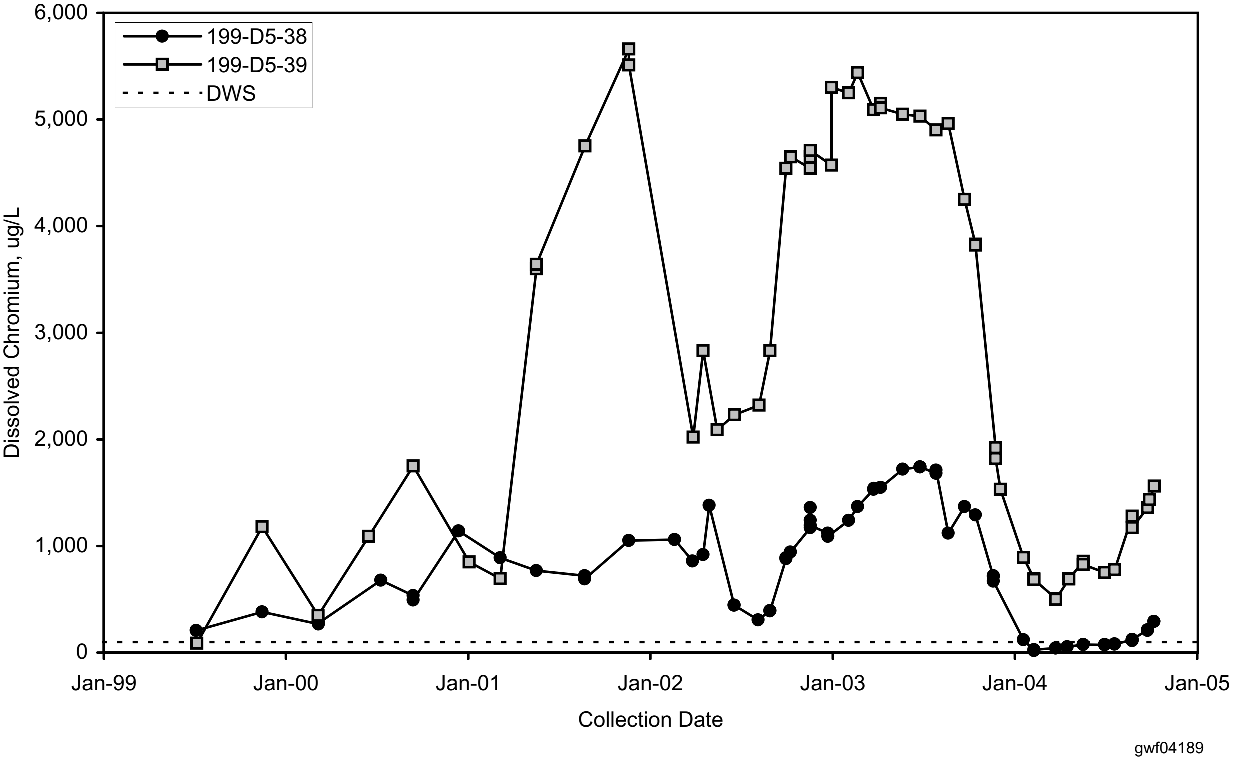

Figure 2.5-9. Dissolved Chromium Concentrations in South 100-D Area

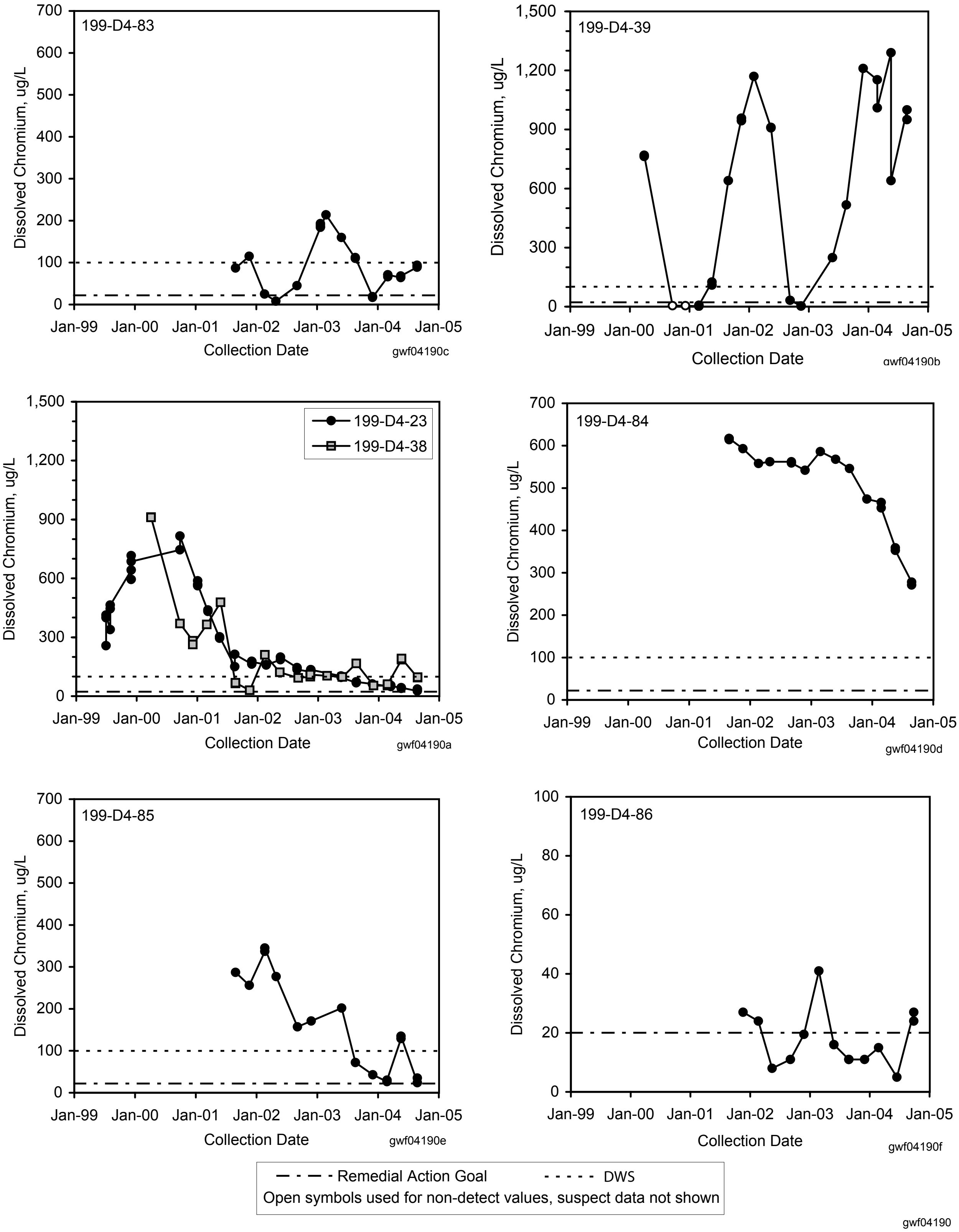

Figure 2.5-10. Dissolved Chromium Concentrations in Compliance Wells Downgradient of the Redox Barrier

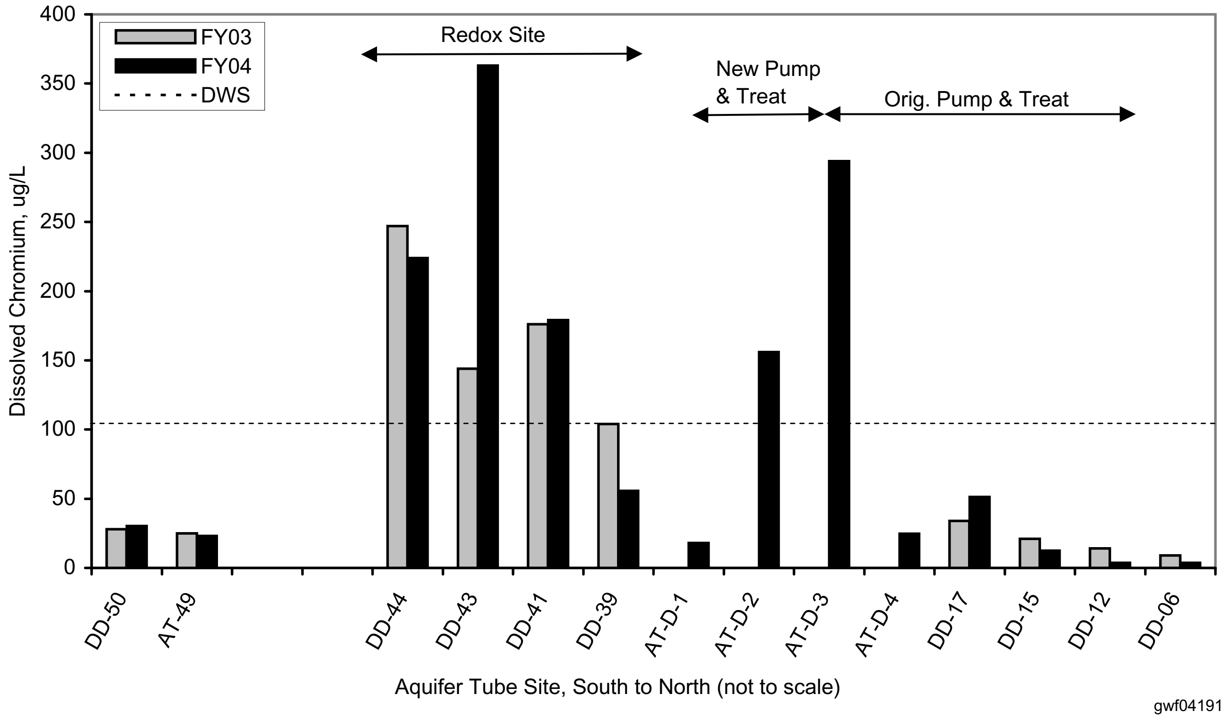

Figure 2.5-11. Hexavalent Chromium in Aquifer Tubes at 100-D Area, FY 2004

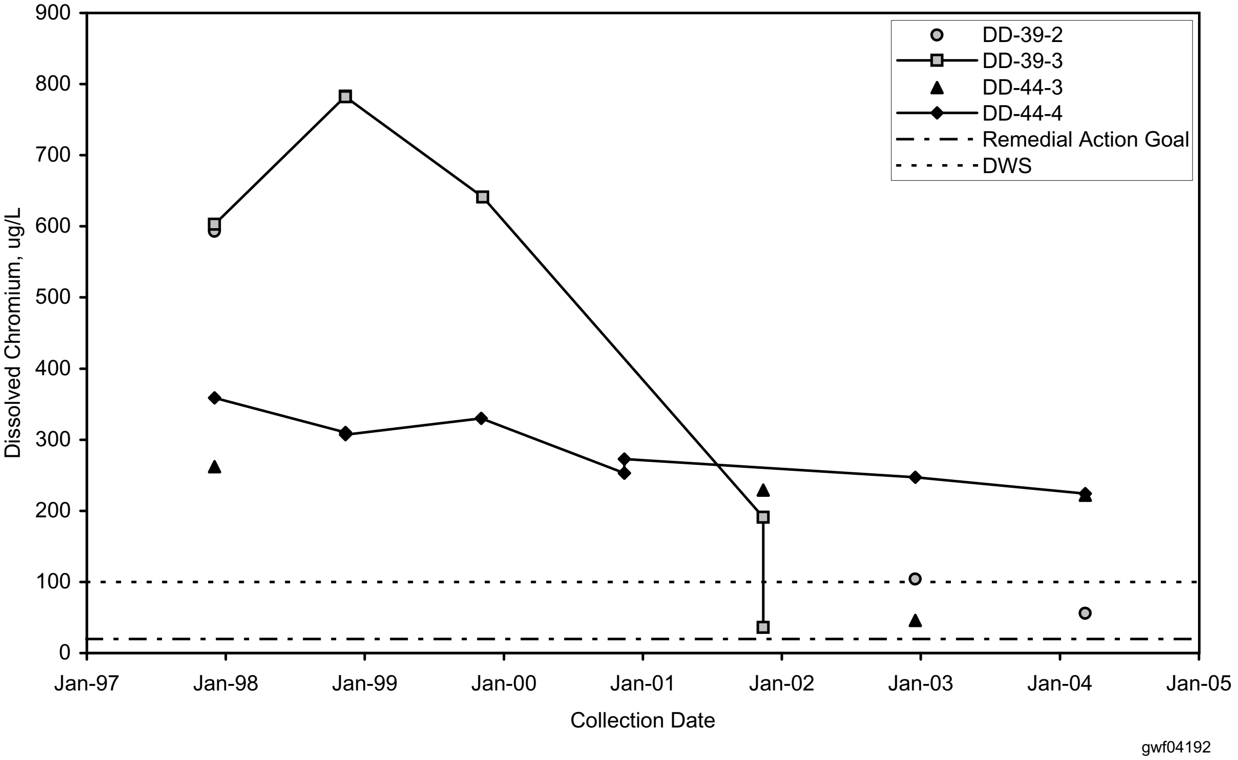

Figure 2.5-12. Hexavalent Chromium in Aquifer Tubes Downgradient of Redox Barrier

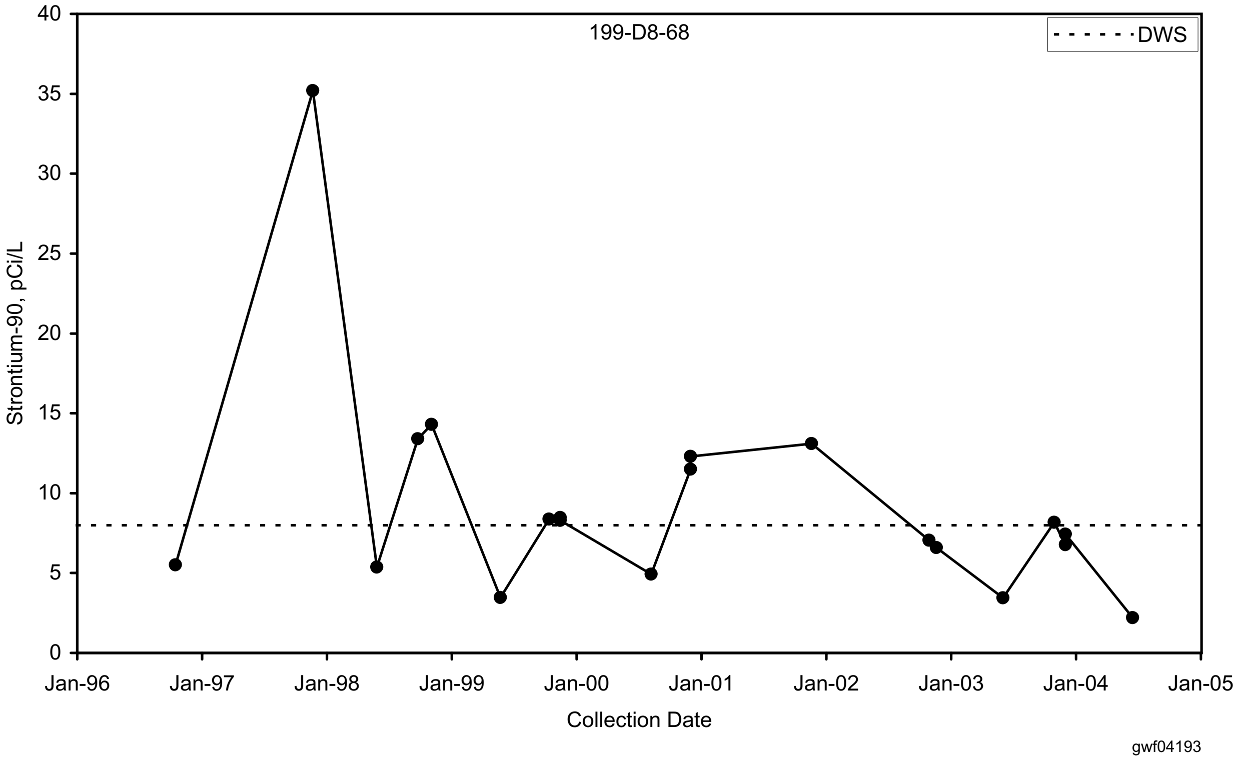

Figure 2.5-13. Strontium-90 Concentrations in Well 199-D8-68 Near Former Retention Basin

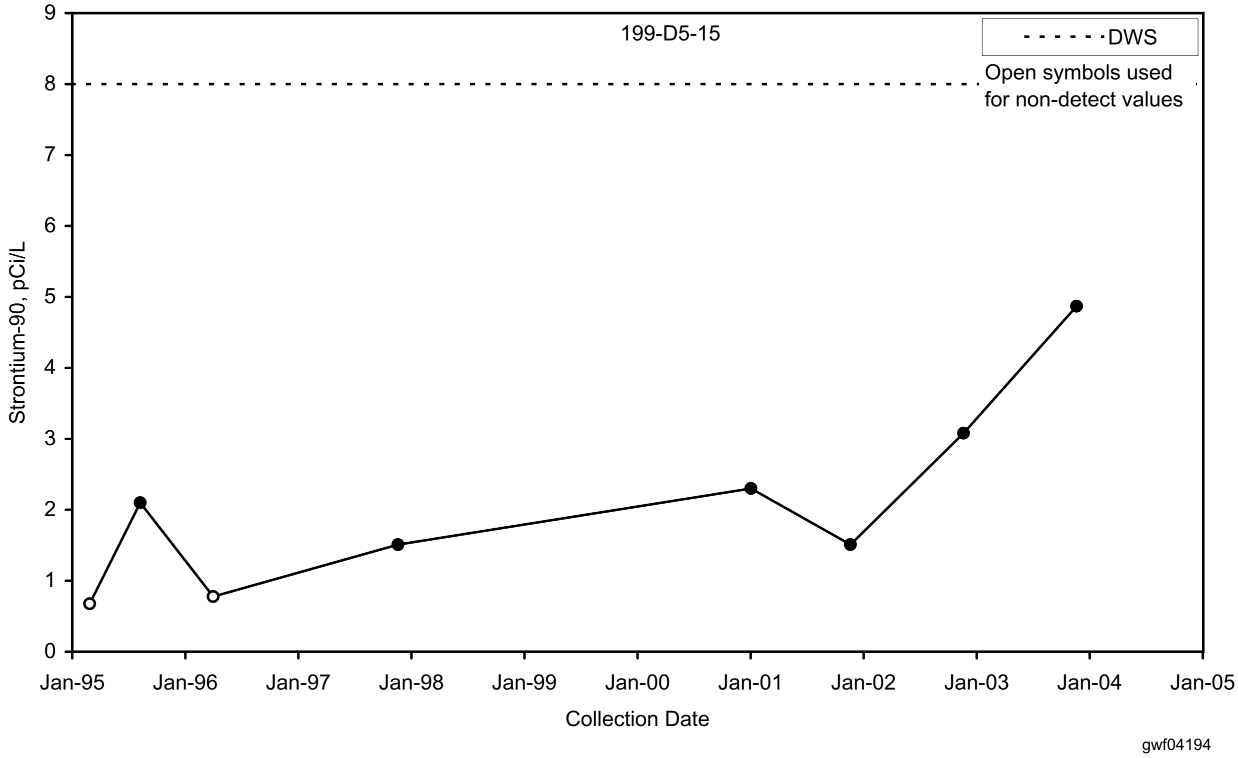

Figure 2.5-14. Strontium-90 Concentrations in Well 199-D5-15 Near Former D Reactor

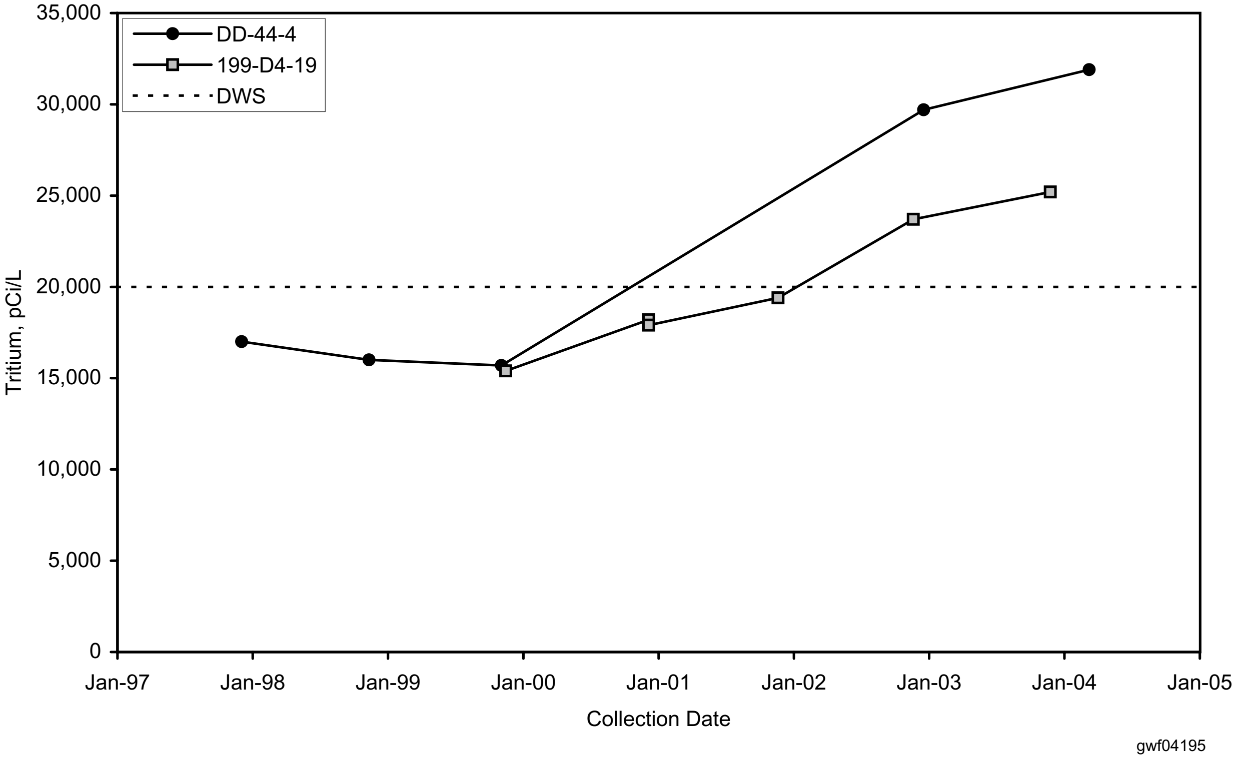

Figure 2.5-15. Tritium Concentrations in the South 100-D Area Near Columbia River

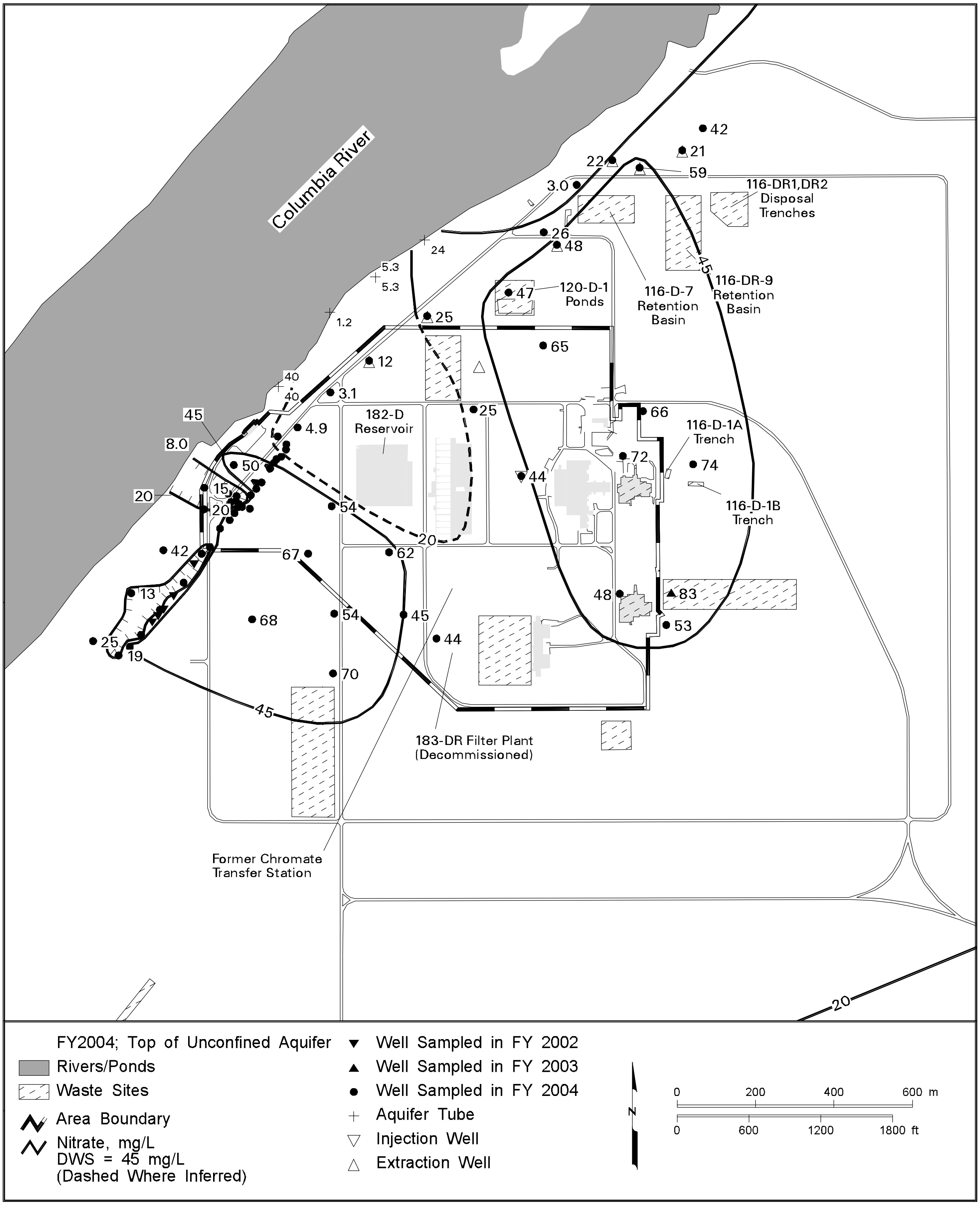

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Figure 2.5-16. Average Nitrate Concentrations in the 100-D Area, Top of Unconfined Aquifer

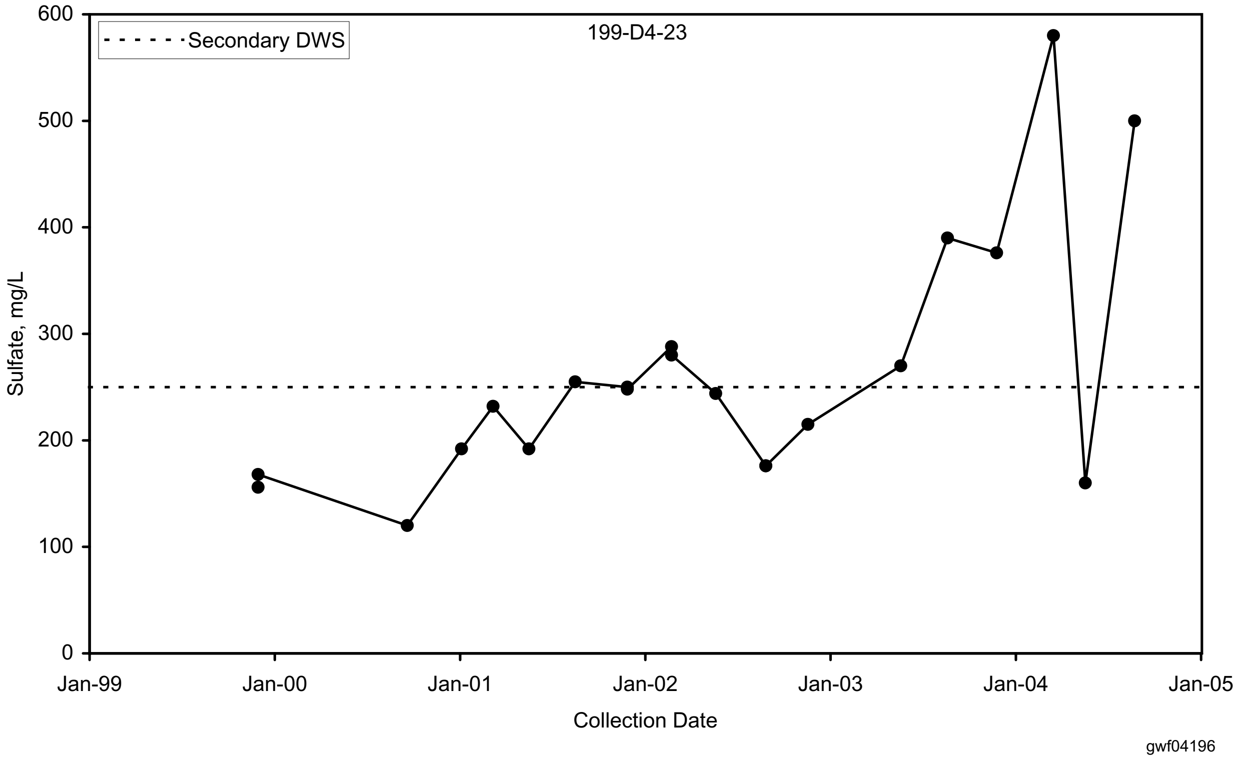

Figure 2.5-17. Sulfate Concentrations Downgradient of the Redox Barrier

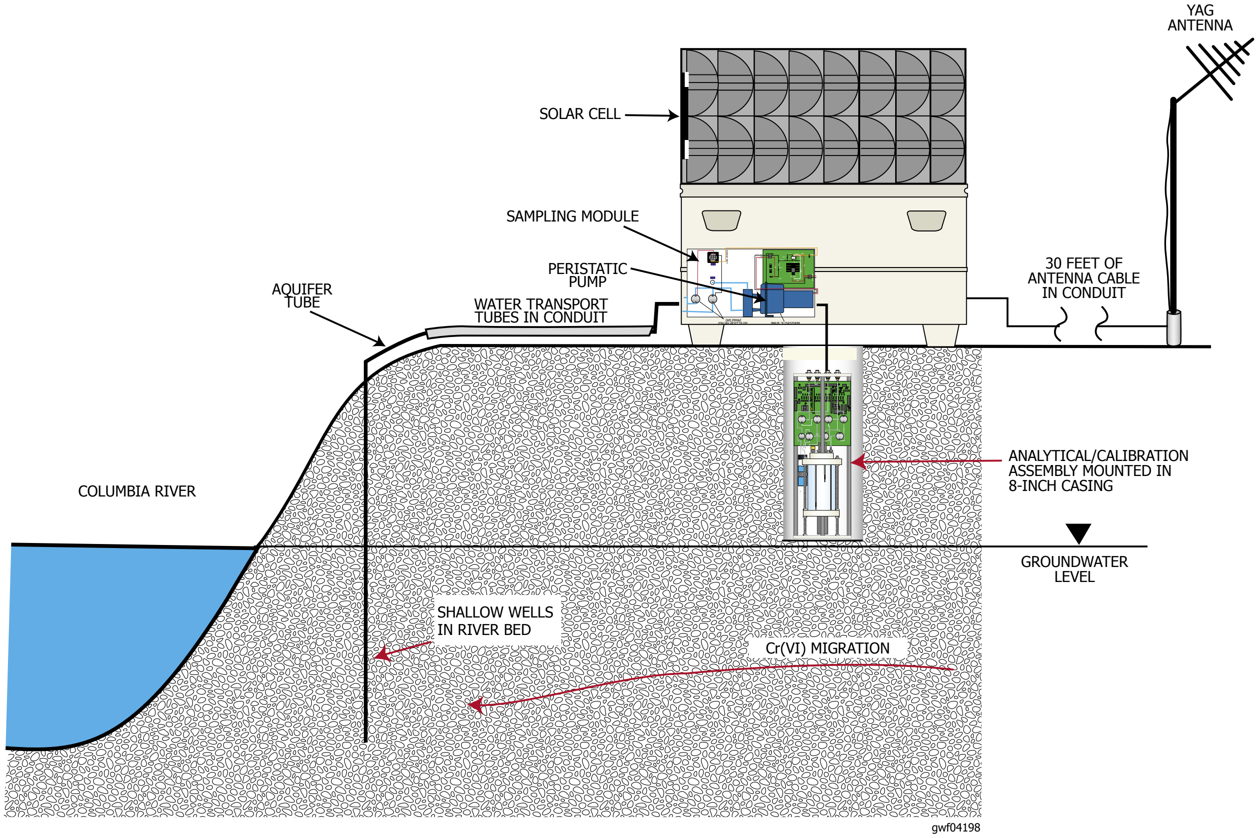

Figure 2.5-18. Field Deployment of Chromium Sensor (Burge Environmental)

2.6 100-HR-3-H Operable Unit

M. J. Hartman and L. C. Swanson

The scope of this section is the 100-HR-3-H groundwater interest area, which is the east portion of the 100-HR-3 Operable Unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined the "interest areas" informally to facilitate scheduling, data review, and interpretation. Figure 2.6-1 shows facilities, wells, and shoreline monitoring sites in this region. Chromium is the contaminant of greatest significance in groundwater. Groundwater is monitored to assess the performance of a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) interim action pump-and-treat system for chromium, to track other contaminant plumes, and for the 116-H-6 evaporation basins, a *Resource Conservation and Recovery Act* (RCRA) unit.

Groundwater flows primarily from the southwest to northeast, toward the Columbia River (Figure 2.6-2). Local flow directions are influenced by groundwater extraction and injection. Groundwater flows generally toward the northeast across the entire horn of the Columbia River north of Gable Mountain, so groundwater approaching the 100-H Area may contain contaminants that originated in the 100-D and 100-N Areas.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of interest (Section 2.6.1), summarizes groundwater remediation (Section 2.6.2), and discusses groundwater monitoring of individual facilities (Section 2.6.3). Section 2.6.4 summarizes recent bioremediation research at the 100-H Area.

Hexavalent chromium is the groundwater contaminant of greatest concern in the 100-H Area. A pump-and-treat system helps reduce the amount reaching the Columbia River.

2.6.1 Groundwater Contaminants

This section describes monitoring results for chromium, strontium-90, technetium-99, uranium, nitrate, and tritium.

2.6.1.1 Chromium

Hexavalent chromium is the contaminant of concern for the 100-HR-3 groundwater interim action, which includes the 100-H Area. The pump-and-treat system is discussed in Section 2.6.2. This section describes the distribution and trends of hexavalent chromium. Results for filtered samples analyzed for total chromium represent hexavalent chromium, which is more soluble than trivalent chromium. Many groundwater samples also are analyzed specifically for hexavalent chromium.

Dissolved chromium continued to exceed the remedial action goal of 22 μg/L beneath a portion of the 100-H Area (Figure 2.6-3), but concentrations are decreasing and the

Groundwater monitoring in the 100-HR-3-H groundwater interest area includes the following monitoring activities:

CERCLA and AEA Monitoring

- ***Wells are sampled monthly to biennially for chromium and co-contaminants.***
- ***Aquifer tubes are sampled annually for chromium and co-contaminants.***
- ***In FY 2004, one well was not sampled as scheduled (see text and Appendix A).***

Facility Monitoring – 116-H-6 Evaporation Basins

- ***Four downgradient wells are sampled annually for chromium, nitrate, technetium-99, and uranium for requirements of RCRA and AEA.***
- ***Sampling is coordinated with CERCLA to avoid duplication.***
- ***In FY 2004, all wells were sampled as scheduled.***

region with concentrations >22 µg/L at the top of the aquifer shrank between fiscal years (FY) 2003 and 2004. The plume had various sources, but the highest concentrations in FY 2004 continued to be near the former 116-H-6 evaporation basins, where the maximum concentrations ranged from 65 to 81 µg/L. Chromium concentrations in this area decreased more than an order of magnitude since the 1980s and have remained level since 2002 (Figure 2.6-4).

Four wells were monitored monthly as compliance wells for the 100-HR-3 pump-and-treat system (Figure 2.6-5; Section 2.6.2). Wells 199-H4-5 and 199-H4-64 are located northeast of the former 116-H-6 evaporation basins. Well 199-H4-4 is located within the plume east of the former 116-H-6 evaporation basins. Well 199-H4-63 is located farther south between the former 116-H-7 retention basin and the Columbia River. Concentrations in these wells varied inversely with river stage and continued to exceed the remedial action goal of 22 µg/L during most of FY 2004.

Chromium concentrations at 100-H Area vary with river stage but are declining overall.

Chromium concentrations in most of the aquifer tubes along the shoreline of the 100-HR-3 interest area exceeded the 10-µg/L aquatic standard, and three tube sites exceeded the 22-µg/L remediation goal. The highest concentrations were north and south of the main 100-H Area. The northern tubes, 43-D and 44-D, had concentrations of 48 and 50 µg/L respectively, levels that have been typical of these tube sites (Figure 2.6-6). This contamination is believed to be connected to an upgradient plume seen in well 699-97-43 and is discussed below. South of the main 100-H Area, the maximum chromium concentration at tube site 51 was also ~50 µg/L (Figure 2.6-6). This contamination could have moved south along the shoreline from 100-H Area sources. Chromium was lower in tubes monitoring the shoreline downgradient of the 100-H Area pump-and-treat system (~11 to 20 µg/L; Figure 2.6-7).

Chromium concentrations in deeper wells 199-H4-12C and 199-H4-15CS continued to exceed the 100-µg/L drinking water standard (maximum 132 µg/L), but are declining. Co-contaminants nitrate, technetium-99, and uranium are low in the deeper well. The source of this deeper chromium is unknown.

Wells upgradient of the 100-H Area continued to have chromium concentrations above the drinking water standard (104 µg/L in well 699-97-43). The source of this contamination is probably an old plume that originated in the 100-D Area when a water-table mound was present there (WHC-SD-EN-TI-023).

2.6.1.2 Strontium-90

Strontium-90 concentrations continued to exceed the 8-pCi/L drinking water standard beneath a portion of the southeast 100-H Area near the former retention basin and disposal trenches. The plume distribution has not changed appreciably in over 10 years. The highest concentrations in FY 2003 and 2004 were ~20 to 25 pCi/L. Concentrations are somewhat variable but are neither increasing nor decreasing overall. Strontium-90 was not analyzed in aquifer tubes near the 100-H Area in FY 2004, but has exceeded the drinking water standard at tube site 47 in the past.

2.6.1.3 Technetium-99 and Uranium

Technetium-99 is elevated in groundwater downgradient of the former 116-H-6 evaporation basins, but levels were below the 900-pCi/L drinking water standard in FY 2004. Well 199-H4-3, immediately downgradient of the basins, historically has shown the highest technetium-99 concentrations and detected 485 pCi/L in FY 2004 (Figure 2.6-8). Concentrations have declined two orders of magnitude since the mid-1990s, but increased gradually during the past 2 years. Nearby well 199-H4-9 had high technetium-99 in FY 2003 (986 pCi/L), but the concentration decreased to 326 pCi/L in May 2004 (Figure 2.6-8).

Uranium also is elevated in groundwater downgradient of the former 116-H-6 evaporation basins and exceeded the 30-µg/L drinking water standard only in

Plume areas (square kilometers) above the drinking water standard at the 100-HR-3-H Operable Unit:

Chromium — 0.11
Nitrate — 0.24
Strontium-90 — 0.18
Uranium — 0.01

well 199-H4-3 (54.3 µg/L in December 2003). Uranium in well 199-H4-9 decreased from FY 2003 (54.5 µg/L) to 19.3 µg/L in May 2004.

Technetium-99 and uranium were analyzed in three new aquifer tubes in FY 2004. The new tubes are located directly downgradient of the former 116-H-6 basins. Technetium-99 was undetected and the maximum uranium concentration was 1.65 µg/L.

2.6.1.4 Tritium

Tritium concentrations are generally below 5,000 pCi/L beneath the 100-H Area. Concentrations vary seasonally in wells near the river and are declining in most inland wells. Concentrations are slightly higher in upgradient wells (5,000 to 6,000 pCi/L) but are declining.

2.6.1.5 Nitrate

Nitrate concentrations continued to exceed the 45-mg/L drinking water standard in numerous wells near the former 116-H-6 evaporation basins and in several wells in the southeast 100-H Area (Figure 2.6-9).

The maximum nitrate concentration in FY 2004 was 192 mg/L in well 199-H4-3. Trends in that area vary seasonally, but the peaks have diminished over the years, and concentrations are declining overall. The nitrate concentrations in well 199-H4-9, northeast of the basins, increased sharply in FY 2003 (474 mg/L) but decreased to 60.6 mg/L in November 2003.

Nitrate concentrations exceed drinking water standards near the former 116-H-6 evaporation basins and in southeast 100-H Area.

A second nitrate plume in the southeast 100-H Area is detected at levels above the drinking water standard in wells surrounding the 116-H-1 trench. New data from aquifer tube sites 48 through 51, which had not been sampled for nitrate in the past 3 fiscal years, exceeded the drinking water standard (46 to 49 mg/L). The plume map in Figure 2.6-9, which incorporates the new data, shows a larger nitrate plume in this region than in previous years.

2.6.2 Interim Groundwater Remediation for Chromium

A pump-and-treat system operates in the 100-H Area as part of a CERCLA interim action for the 100-HR-3-H Operable Unit (ROD 1996a). Interim remedial action monitoring is described in DOE/RL-96-90. Figure 2.6-1 displays locations of extraction and injection wells and Appendix A lists sampling frequencies and constituents. In FY 2004, well 199-H4-45 was not sampled as scheduled. Wasps had built nests in the area around the well with radiologically contaminated mud. The well cannot be sampled until workers clean up the nests.

Eight new aquifer tubes at three sites were installed in the 100-H Area shoreline. Tube sites AT-H-1, AT-H-2, and AT-H-3 are located downgradient of the former 116-H-6 evaporation basins. Together with older aquifer tube sites, the new sites monitor the shoreline downgradient of the extraction wells. Pertinent results from aquifer tube sampling were discussed in Section 2.6.1.

2.6.2.1 Progress During FY 2004

The 100-H Area pump-and-treat system is reducing overall contamination in the operable unit by removing contaminant mass. During FY 2004, the pump-and-treat system extracted ~161.9 million liters of groundwater from the 100-H Area, removing ~4.1 kilograms of hexavalent chromium.

The remedial action objectives for the 100-HR-3 Operable Unit (ROD 1996a) are:

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

The contaminant of concern is hexavalent chromium. The record of decision specifies the cleanup goal at compliance wells as 22 µg/L. EPA specified enhancements needed to the system in their 5-year review (EPA 2001).

The pump-and-treat system has removed ~37.3 kilograms of hexavalent chromium from the 100-H Area groundwater since startup in July 1997. This represents a large fraction of the ~42 kilograms of chromium estimated in the plume in 1992 (WHC-SA-1674-VA). That estimate did not include chromium from upgradient nor in the vadose zone.

During FY 2004, the pump-and-treat system at 100-H Area extracted ~161.9 million liters of groundwater, removing ~4.1 kilograms of hexavalent chromium.

2.6.2.2 Influence on Aquifer Conditions

Chromium concentrations in 100-H Area groundwater have declined, and the size of the plume at the top of the aquifer has shrunk since the pump-and-treat system began to operate in 1997. These changes are likely due to a combination of natural processes (e.g., dispersion) and the effects of the pump-and-treat system. Because the size of the plume is smaller and concentrations of hexavalent chromium have declined below the remedial action goal of 22 μg/L in some extraction wells, the system is being changed to enhance and accelerate cleanup. In October 2004, Washington State Department of Ecology (Ecology) approved the following modifications to the 100-H extraction and injection well network:

- 199-H3-2A will be converted from an extraction to an injection well.
- 199-H4-18 will be converted from a monitoring to an injection well.
- 199-H4-64 and 199-H4-4 will be converted from compliance wells to extraction wells.
- 199-H4-7 will be converted from an extraction to a monitoring well.
- Only one of the three previous injection wells (199-H3-3, 199-H3-4, and 199-H3-5) will continue to be used.

Current extraction wells 199-H4-11, 199-H4-12A, and 199-H4-15A will remain extraction wells.

Hexavalent chromium concentrations in compliance wells vary inversely with river stage. The ranges of concentration observed in FY 2004 were similar to those observed the last 2 years. Figure 2.6-5 shows chromium trends for the compliance wells. Chromium declined beneath the remedial action goal (22 μg/L) in wells 199-H4-4 and 199-H4-16 in the summer, but exceeded that level for the rest of the year. In the other two compliance wells, 199-H4-5 and 199-H4-64, chromium concentrations were above the goal throughout the year with no clear upward or downward trend over the last 3 years.

Results of performance monitoring are incorporated with the discussion of general contamination in Section 2.6.1. Results of operational monitoring and additional details about the pump-and-treat system for calendar year 2003 can be found in DOE/RL-2004-21. Results for 2004 will be published in an upcoming annual report on the 100-HR-3, 100-KR-4, and 100-NR-2 pump-and-treat systems.

2.6.3 Facility Monitoring: 116-H-6 (183-H) Evaporation Basins

The 116-H-6 (183-H) evaporation basins are the only RCRA site in the 100-H Area. The site is monitored during the post-closure period under corrective action monitoring requirements of WAC 173-303-645(11)(g). The objective of monitoring is to track contaminant trends during the operation of the CERCLA interim action for chromium. Lists of wells and constituents monitored and a well location map are included in Appendix B.

The unit was incorporated into the Hanford Facility RCRA Permit (Ecology 1994a). Groundwater remediation is integrated with the 100-HR-3 Operable Unit, where remediation for chromium is underway. While the pump-and-treat system is operating, RCRA monitoring consists of annual sampling of four wells for chromium, fluoride, nitrate, technetium-99, and uranium. The latter two constituents are not regulated under RCRA but were included in the monitoring plan for completeness and were incorporated by reference in the Hanford

Facility RCRA Permit (Ecology 1994a). The objective of monitoring during the operation of the pump-and-treat system is to determine whether concentrations of the contaminants of concern are decreasing. The U.S. Department of Energy (DOE) proposed a change to the monitoring requirements with a permit modification in FY 2004. The proposed change would bring the site under a post-closure monitoring program that is integrated with the CERCLA monitoring program, as allowed under Section II.K.7 of the Hanford Facility RCRA Permit (Ecology 1994a).

The four wells in the RCRA network were sampled as scheduled in FY 2004 for the constituents of interest listed in the groundwater monitoring plan. Trends in the constituents of interest (except fluoride) were discussed in Section 2.6.1. Fluoride concentrations remained low (<300 µg/L) in groundwater downgradient of the 116-H-6 evaporation basins.

Two semiannual letter reports(a) that document the effectiveness of the corrective action program were submitted to Ecology during FY 2004. The current monitoring network was designed to accommodate groundwater flow imposed by the pump-and-treat system, and no changes are planned for FY 2005.

2.6.4 Bioremediation Research

DOE's Natural and Accelerated Bioremediation Research (NABIR) Program conducted field tests near the 100-H Area in FY 2003 and 2004 to demonstrate the feasibility of a remediation technology to immobilize hexavalent chromium in the aquifer (Hazen et al. 2004). The goal of the NABIR Program is to provide the fundamental science to serve as the basis for the development of cost-effective bioremediation of radionuclides and metals in the subsurface at DOE sites. Scientists from Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, and Regenesis Ltd. performed the 100-H Area investigations. Additional details about the test are available at http://esd.lbl.gov/ERT/hanford100h.

Bioremediation is the process by which living organisms break down or transform hazardous contaminants to environmentally safe levels in soil, water, or other materials.

The test site was west of the 100-H Area where researchers installed two wells near existing well 699-96-43 (Figure 2.6-1). Researchers identified several types of bacteria in the sediment, including species that are known to reduce or sorb hexavalent chromium. The natural microbial population is likely insufficient for direct chromium reduction, but the population was successfully stimulated during the field tests.

To assess the background hydraulic properties of the Hanford formation and to design the test, researchers performed three bromide tracer tests and two pumping tests (concurrent with the bromide tracer tests). Geophysicists also collected cross-borehole measurements.

In August 2004, staff conducted pilot field-scale biostimulation by injecting Hydrogen Release Compound®(b) (HRC) and a bromide tracer in one of the wells, then pumped the observation well for 27 days. HRC is a polylactate ester that is specifically designed to slowly release lactic acid when contacted with water. Microbial cell counts reached their maximum 13 to 17 days after the injection. The injection resulted in highly reducing conditions: dissolved oxygen dropped from 8.2 to 0.35 mg/L, redox potential from 240 to -130 mV, and pH from 8.9 to 6.5. Geophysical cross-borehole tomography confirmed the distribution of the HRC plume in the subsurface between the injection and pumping wells. After pumping ceased, background microbial conditions began to recover under natural groundwater flow. Additional work is planned for summer 2005.

(a) Letter report 04-AMCP-0278 from KA Klein, U.S. Department of Energy Richland Operations Office, to JA Hedges, Washington State Department of Ecology, *Resource Conservation and Recovery Act (RCRA) Final Status Corrective Action Semiannual Reports for July through December 2003*, dated June 23, 2004.

Letter report 05-AMCP-0027 from MS McCormick, DOE/RL, to JA Hedges, Washington State Department of Ecology, *Resource Conservation and Recovery Act (RCRA) Final Status Corrective Action Semiannual Reports for January through June 2004*, dated October 26, 2004.

(b) HRC is a registered trademark of Regenesis, San Clemente, California.

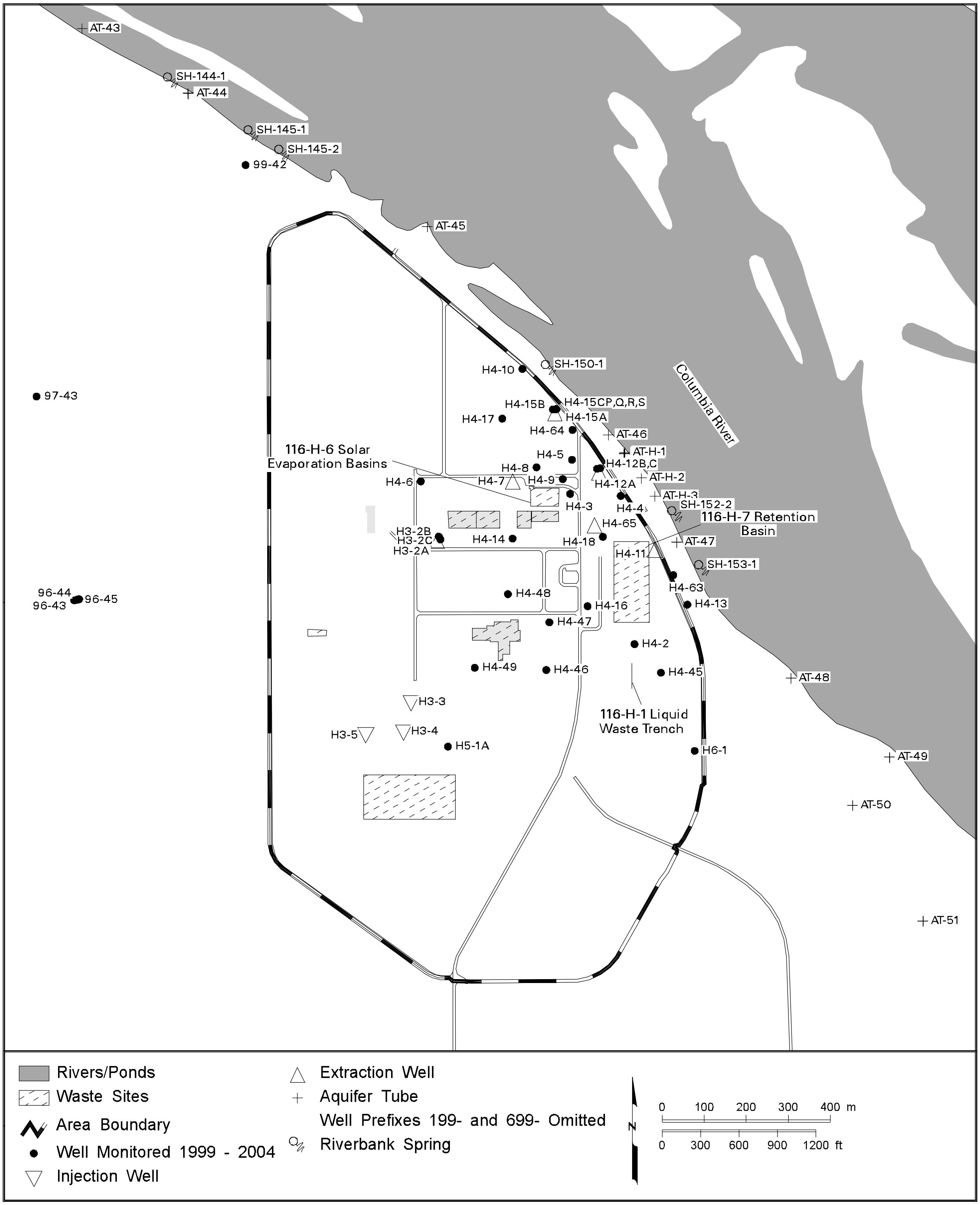

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Figure 2.6-1. Groundwater Monitoring Wells in the 100-H Area

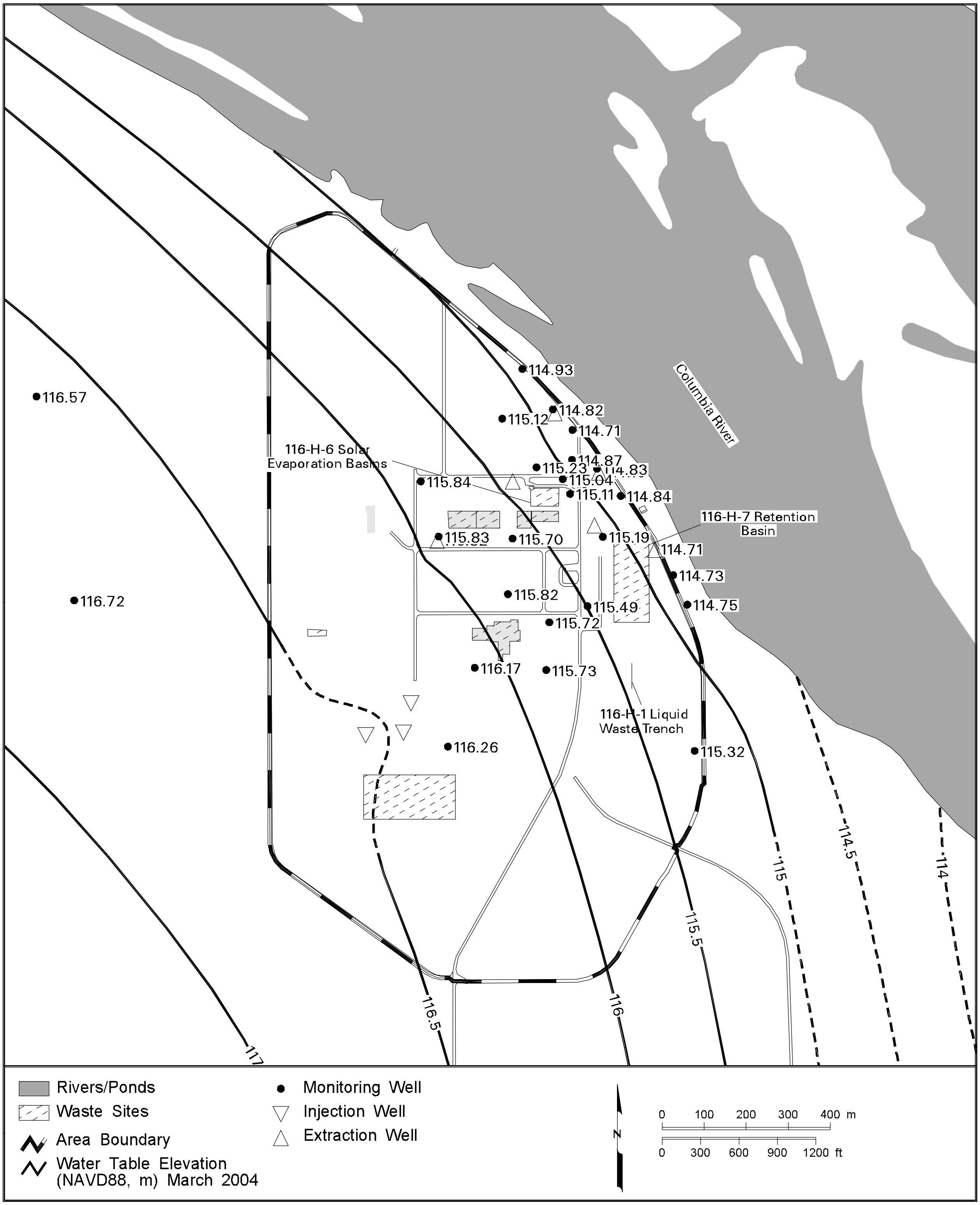

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Figure 2.6-2. 100-H Area Water-Table Map, March 2004

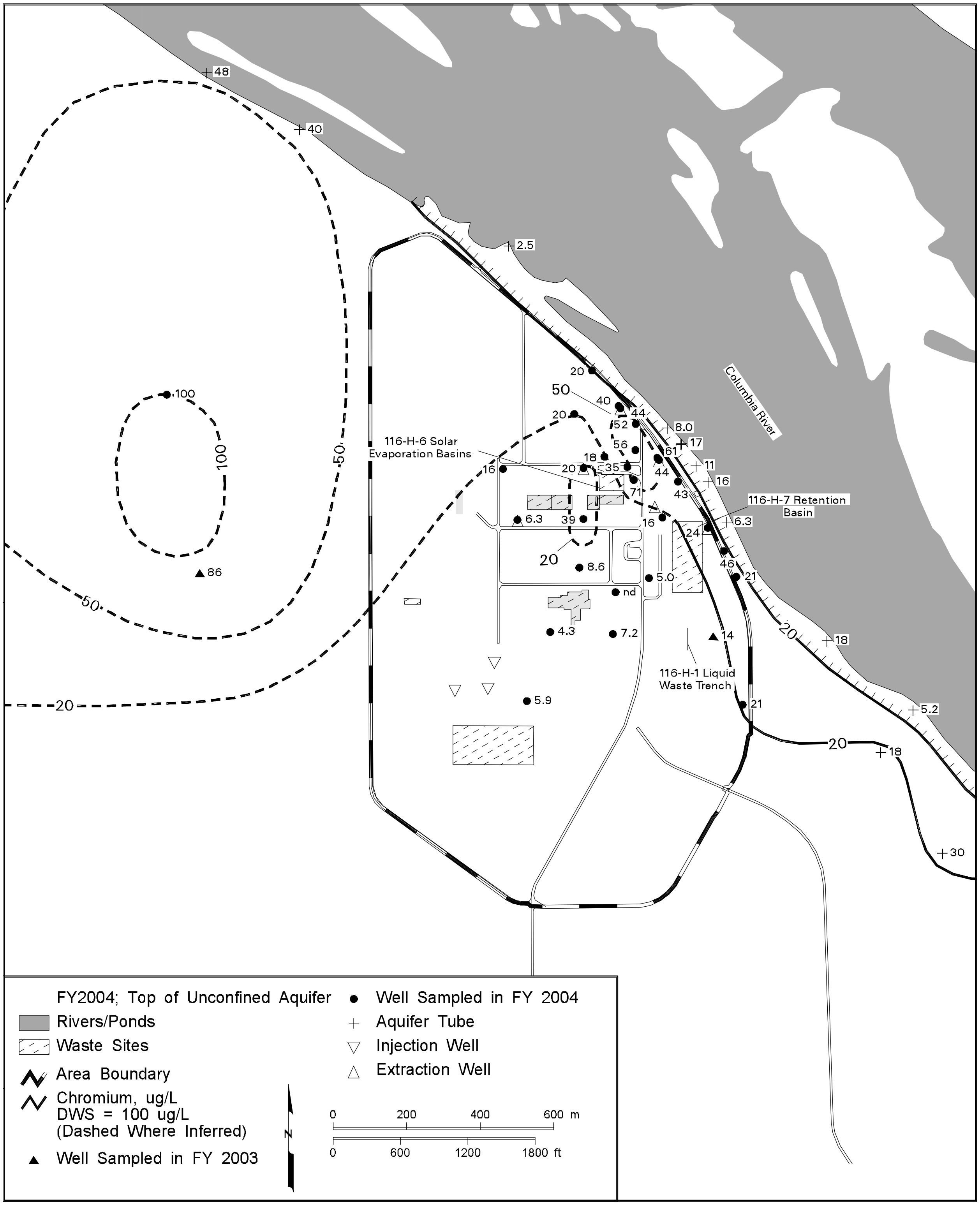


Figure 2.6-3. Average Chromium Concentrations in the 100-H Area, Top of Unconfined Aquifer

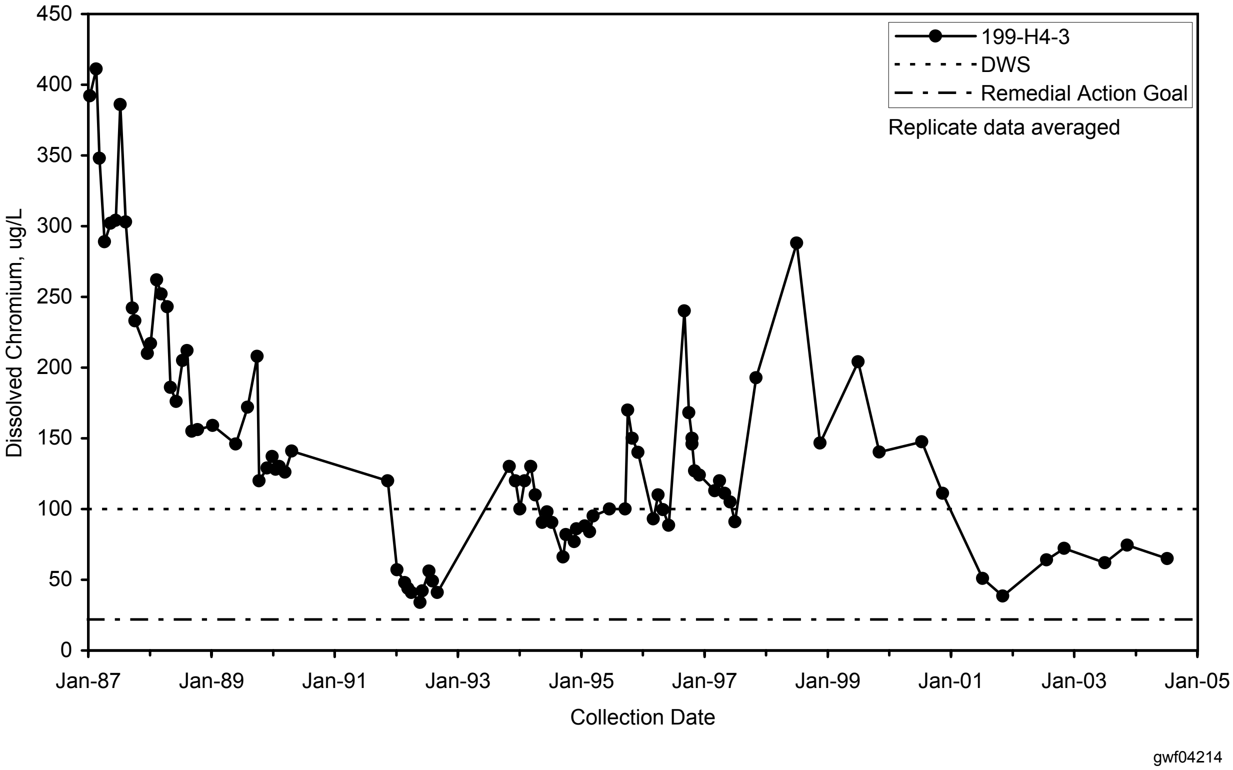
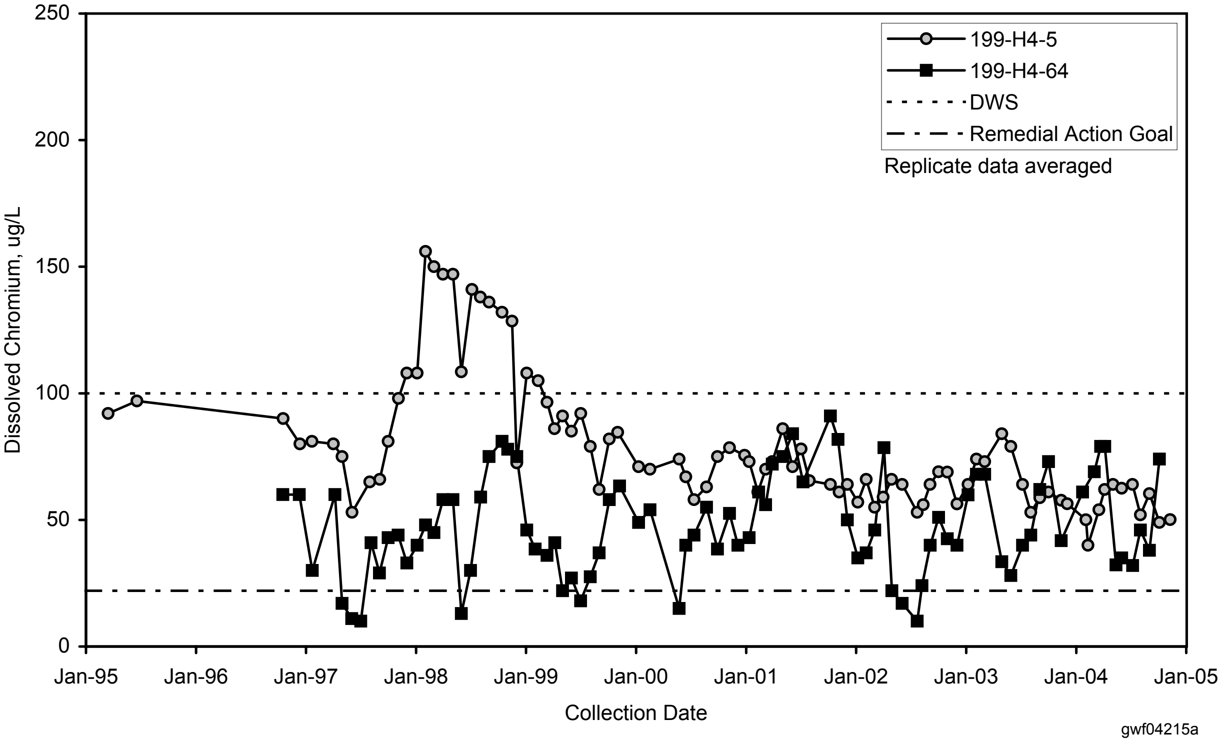


Figure 2.6-4. Chromium Concentrations Downgradient of 116-H-6 Evaporation Basins



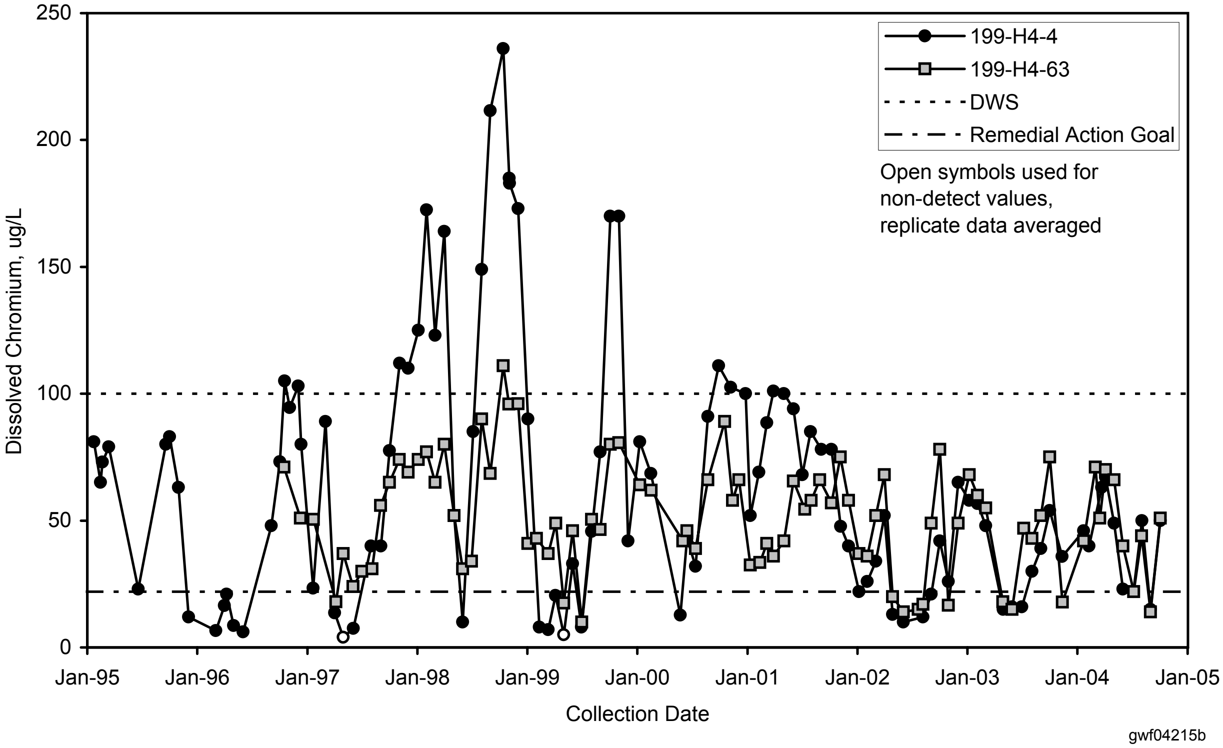


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Figure 2.6-5. Chromium Concentrations in Compliance Wells for the 100-HR-3 Pump-and-Treat System at 100-H Area

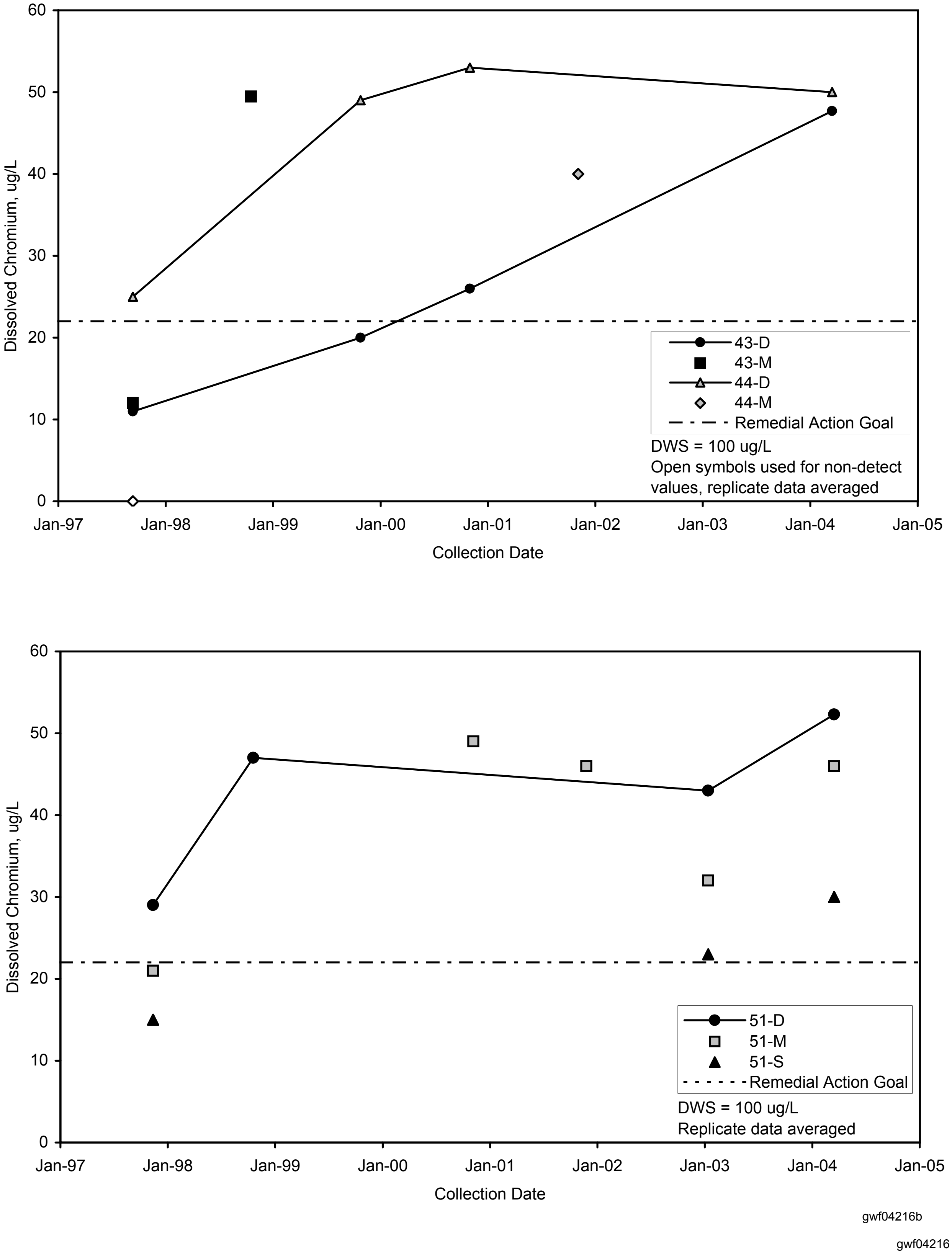

Figure 2.6-6. Chromium Concentrations in Aquifer Tubes North (top panel) and South (bottom panel) of the Main 100-H Area

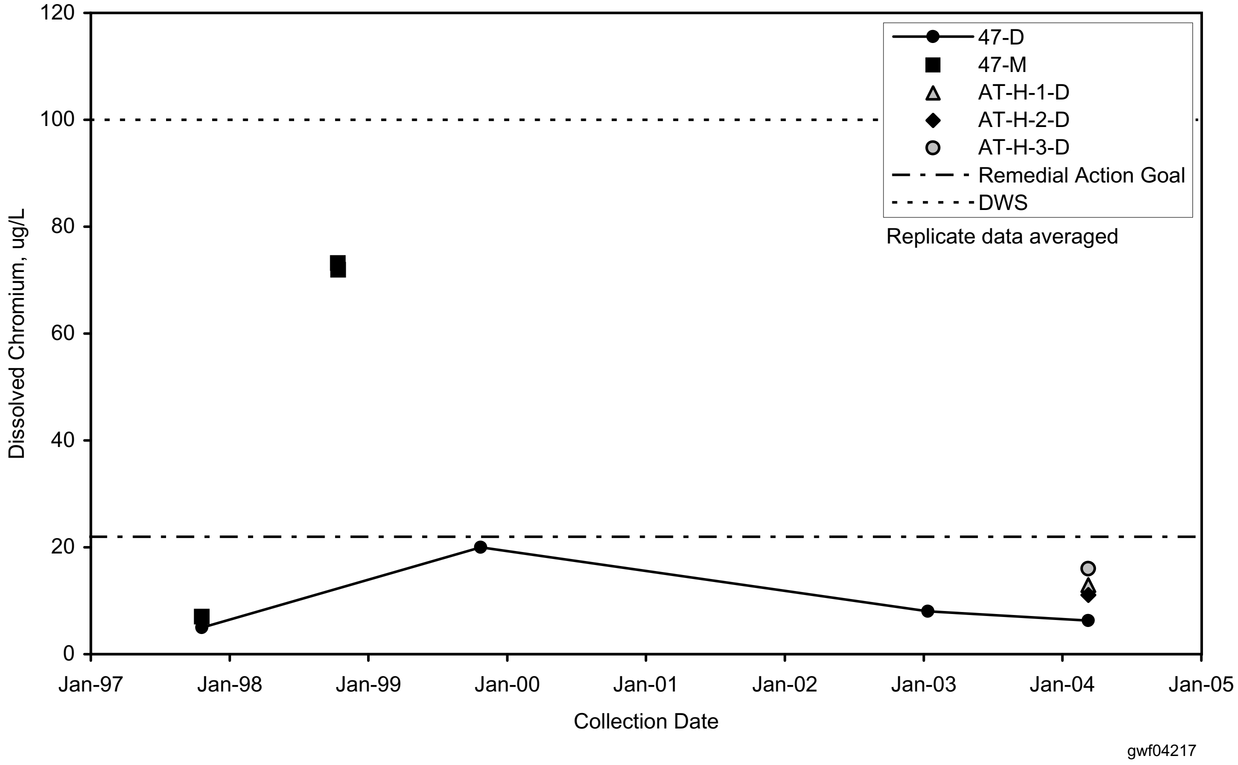

Figure 2.6-7. Chromium Concentrations in Aquifer Tubes Downgradient of 100-H Pump-and-Treat System

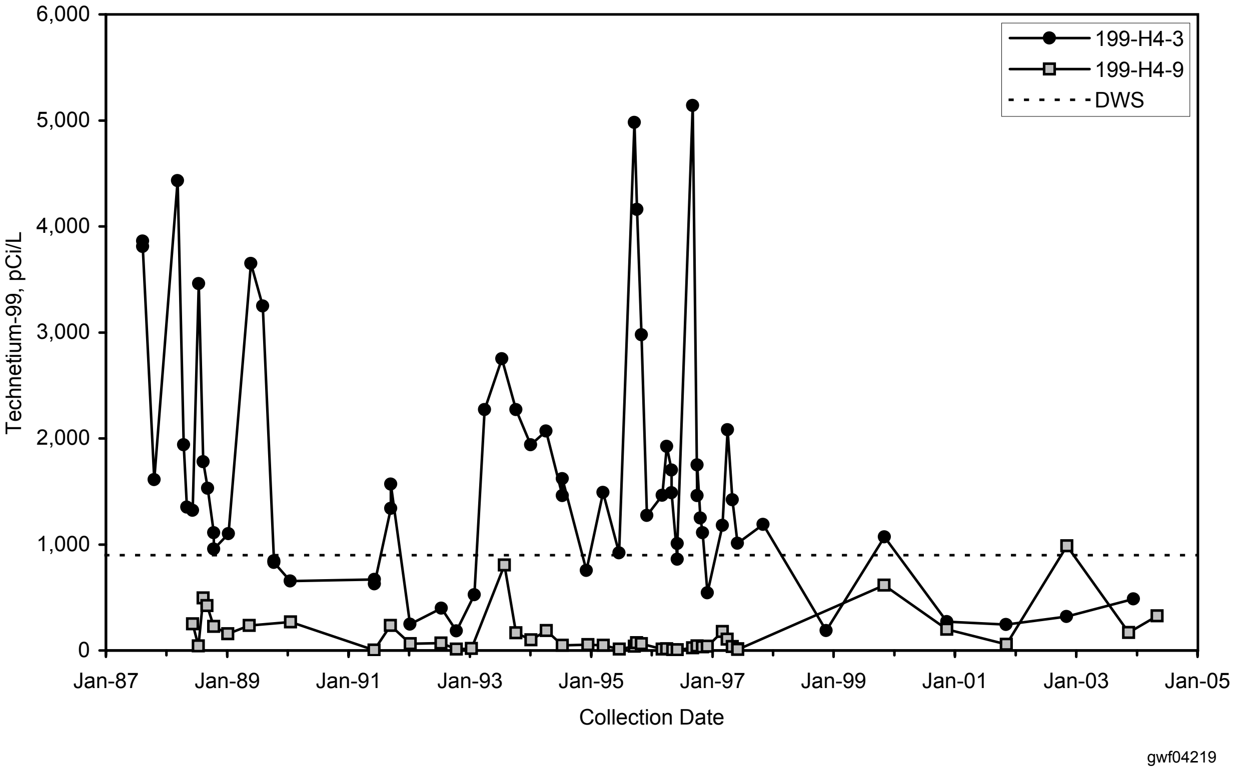

Figure 2.6-8. Technetium-99 Concentrations in Wells Near the 116-H-6 Evaporation Basins

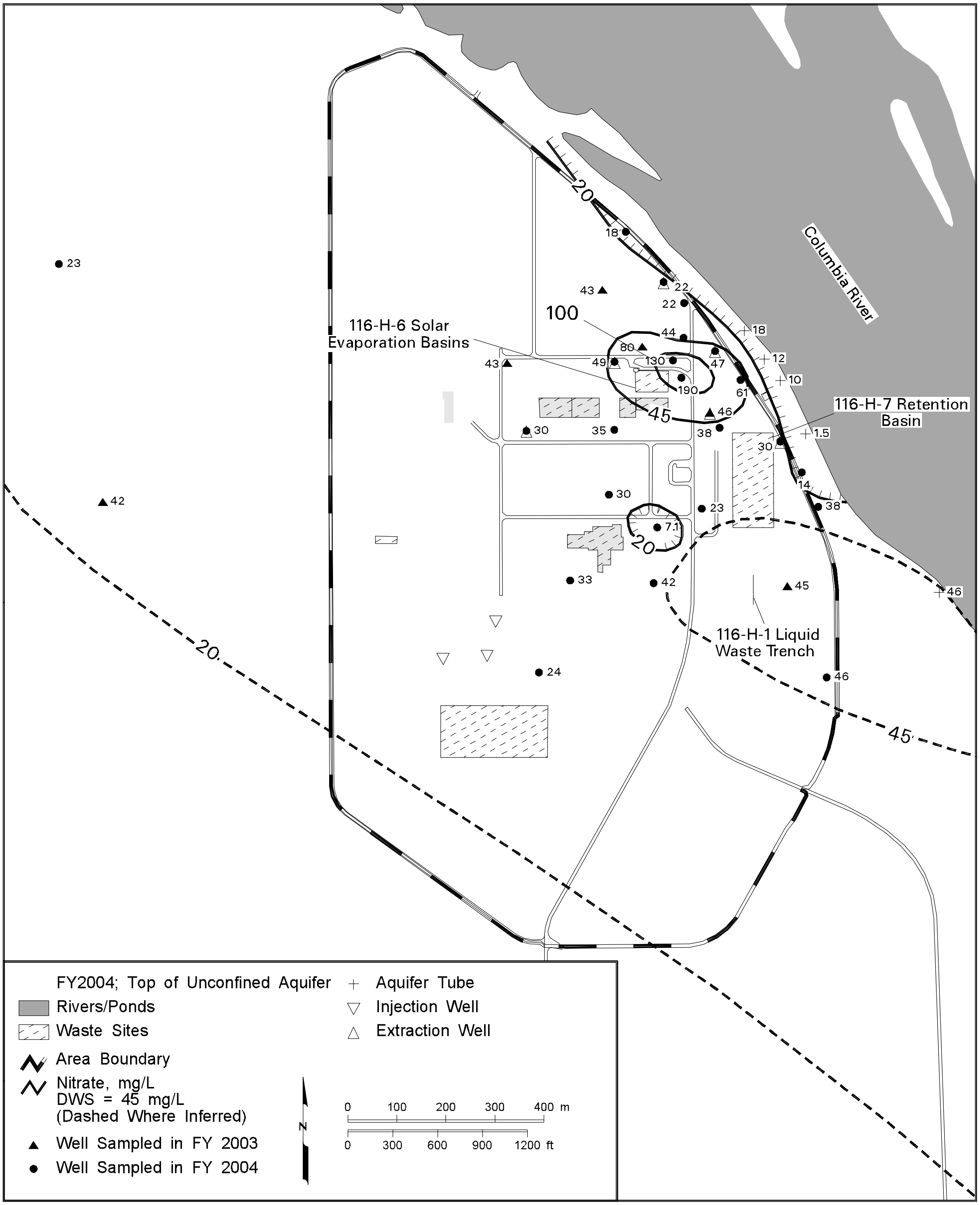

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Figure 2.6-9. Average Nitrate Concentrations in the 100-H Area, Top of Unconfined Aquifer

2.7 100-FR-3 Operable Unit

M. J. Hartman

The scope of this section is the 100-FR-3 groundwater interest area, which encompasses the 100-FR-3 Operable Unit and a large section of the 600 Area north of Gable Mountain (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined "groundwater interest areas" informally to facilitate scheduling, data review, and interpretation. Figure 2.7-1 shows facilities, wells, and shoreline monitoring sites in the 100-F Area.

Groundwater flows primarily to the east and southeast beneath the 100-F Area (Figure 2.7-2). Movement of the nitrate plume indicates flow to the south-southeast.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Groundwater monitoring for the *Atomic Energy Act of 1954* (AEA) is integrated fully with CERCLA monitoring. Most of the former waste sites in the 100-F Area have been excavated and backfilled. There are no active waste disposal facilities or *Resource Conservation and Recovery Act* (RCRA) sites in the 100-F Area.

A nitrate plume extends from the central 100-F Area south into the 600 Area.

2.7.1 Groundwater Contaminants

This section describes the distribution and trends of the contaminants of concern for the 100-FR-3 Operable Unit: nitrate, strontium-90, tritium, trichloroethene, uranium, and hexavalent chromium.

2.7.1.1 Nitrate

A large nitrate plume with concentrations above the 45-mg/L drinking water standard extends from the 100-F Area southward (see Figure 2.1-6 in Section 2.1). The interpretation of the plume between the 100-F Area and Gable Mountain is uncertain because many of the wells have not been sampled for nitrate routinely. In fiscal year (FY) 2004, well 699-62-31 (located ~4 kilometers south of the 100-F Area; see Figure 2.1-2 in Section 2.1) was sampled for the first time in 10 years. The nitrate concentration was 102 mg/L, twice the levels detected in 1991 to 1993, indicating that the plume has moved farther south than previously known.

Wells in the main 100-F Area continued to show levels of nitrate that exceeded the drinking water standard. The highest nitrate concentration in the 100-F Area was 166 mg/L in well 199-F7-3, which is in the southwest 100-F Area. Concentrations rose gradually in this well from 1996 to 2003, but declined slightly in FY 2004 (Figure 2.7-3). Most wells in 100-F Area have decreasing or steady trends in nitrate (e.g., well 199-F8-4 in Figure 2.7-3).

Aquifer tubes south of the main 100-F Area had elevated nitrate concentrations. The maximum value, 52.7 mg/L, was from tube 75-M. This was the only tube in the 100-FR-3 interest area with a result above the drinking water standard.

Groundwater monitoring in the 100-FR-3 groundwater interest area includes integrated CERCLA and AEA monitoring:

- ***Nine wells, twenty-two aquifer tubes, and three seeps are sampled annually.***
- ***Twenty-nine wells are sampled biennially; fourteen of these were scheduled in FY 2004.***
- ***All wells were sampled as scheduled.***
- ***Seven aquifer tube sites and two seeps were not sampled (see Appendix A).***

2.7.1.2 Strontium-90

Strontium-90 concentrations continued to exceed the 8-pCi/L drinking water standard beneath a portion of the 100-F Area around the 116-F-14 retention basin and nearby disposal trenches (Figure 2.7-4). The plume has not changed significantly in over 10 years.

Plume areas (square kilometers) above the drinking water standard at the 100-FR-3 Operable Unit:

Nitrate — 17.65
Strontium-90 — 0.16
Trichloroethene — 2.37

Well 199-F5-1 continued to have the highest strontium-90 concentrations at 22.6 pCi/L in FY 2004 (Figure 2.7-5). The peak in concentrations in the mid to late 1990s was caused by higher-than-average water levels, which mobilized strontium-90 in the lower vadose zone and increased concentrations in groundwater. Strontium-90 concentrations continued to decline in FY 2004. Strontium-90 exceeded the drinking water standard in two other wells in FY 2004: 199-F5-44 (8.36 pCi/L) and 199-F5-46 (11.3 pCi/L) (Figure 2.7-5).

Well 199-F5-3 historically had strontium-90 concentrations in the hundreds. The well no longer produces enough water to sample, despite numerous attempts to clean and develop it. It was removed from the sampling schedule during FY 2004.

Like other 100-F Area contaminants, strontium-90 appears to be limited to the shallow portion of the aquifer. No strontium-90 is detected in deep well 199-F5-43B, while adjacent well 199-F5-43A typically detects 2 to 4 pCi/L of strontium-90.

Strontium-90 was analyzed in samples from four aquifer tubes and was detected in two of them: 64-D (1.23 pCi/L) and 65-S (0.77 pCi/L). Both sites are adjacent to the strontium-90 plume in the aquifer. Only one depth at each tube site was selected for laboratory analyses in FY 2004. At aquifer tube site 64, this practice may have missed the highest concentrations of strontium-90, which is concentrated higher in the aquifer. The revised sampling and analysis plan calls for sampling all tube depths for strontium-90.

2.7.1.3 Tritium

Trichloroethene exceeds the drinking water standard in southwest 100-F Area.

Tritium concentrations exceed 2,000 pCi/L beneath the south 100-F Area, but have remained below the 20,000-pCi/L drinking water standard in all wells since FY 2003. The plume extends southward into the 600 Area (see Figure 2.1-5 in Section 2.1), but its axis strikes approximately southeast instead of south like the nitrate plume.

Concentrations of tritium are declining and ranged from undetected to 8,240 pCi/L in FY 2004. The highest concentration was in well 199-F8-3, located near the 118-F-6 burial ground.

2.7.1.4 Trichloroethene

Trichloroethene concentrations in the southwest 100-F Area typically exceed the 5-µg/L drinking water standard (Figure 2.7-6). The maximum concentration in FY 2004 was 19 µg/L in well 199-F7-1, which showed a gradually increasing trend since FY 2000 (Figure 2.7-7). Concentrations also exceeded the standard in nearby wells 199-F7-3 and 699-77-36.

Farther north, trichloroethene is detected in several wells and concentrations in well 199-F7-2 hover around the drinking water standard (5.8 µg/L in FY 2004).

Gross alpha concentrations increased in two wells, indicating possible increases in uranium.

Trichloroethene has been detected in several wells located far west of the 100-F Area. Wells 699-71-52 and 699-83-47 have consistently detected ~2 to 3 µg/L trichloroethene in recent years (see Figure 2.1-2 in Section 2.1 for well locations). Other wells west of the 600 Area have shown no detectable trichloroethene.

No trichloroethene was detected in aquifer tubes or spring 207-1 in FY 2004.

2.7.1.5 Uranium and Gross Alpha

Gross alpha is monitored in the 100-FR-3 Operable Unit to screen for uranium. All gross alpha results for FY 2004 were below the 15-pCi/L drinking water standard. Gross alpha concentrations increased sharply in wells 199-F5-46 (located near the former F Reactor) and 199-F8-4 (in southeast 100-F Area) (Figure 2.7-8). The cause of these increases in different parts of the area is unknown. Beginning in FY 2005, uranium will be monitored in these and nearby wells.

2.7.1.6 Hexavalent Chromium

Dissolved chromium concentrations continued to be above background in several wells in the east 100-F Area, but were below the 100-µg/L drinking water standard in FY 2004. Concentrations are typically highest in wells near the former retention basins and disposal trenches. Dissolved chromium increased sharply in well 199-F5-6 to 98 µg/L, just below the standard (Figure 2.7-9). Nearby well 199-F5-44 has shown an increasing chromium trend over the last 10 years, but concentrations remained much lower than in 199-F5-6, possibly because well 199-F5-44 is closer to the Columbia River. Chromium will be sampled annually in well 199-F5-6 to continue tracking its trend.

The chromium concentration in one well increased sharply and was near the drinking water standard in FY 2004.

About 4 kilometers west of the 100-F Area, chromium continued to be above background levels in well 699-83-47. The concentration in FY 2004 was 28 µg/L, part of a gradually decreasing trend. This well also detects trichloroethene, as discussed in Section 2.7.1.4.

Chromium concentrations in aquifer tubes were generally low, but exceeded the 10-µg/L aquatic standard in tubes 72-D and 75-M, located south of the main 100-F Area. The maximum concentration in FY 2004 was 13.9 µg/L.

2.7.2 Operable Unit Monitoring

A record of decision has not yet been developed for the 100-FR-3 Operable Unit, and no active remediation of groundwater is underway. Monitoring contaminant conditions has continued since the initial remedial investigation and while waste site remedial actions are conducted. A focused feasibility study, which looks at remedial action alternatives for groundwater, will start in FY 2005.

The sampling and analysis plan that was in effect during FY 2004 (DOE/RL-2003-49, Rev. 0, as revised in unit manager's meetings and documented in Fruchter 2004[a]) specified annual sampling of 9 wells, 22 aquifer tube sites, and 3 seeps and biennial sampling of 29 wells (Appendix A).

All of the wells scheduled for sampling in FY 2004 were sampled; some additional wells not required to be sampled in FY 2004 also were sampled. Well 199-F5-6 was sampled with a standard pump instead of the Spyder sampling assembly. Multi-depth Spyder sampling was delayed until FY 2005.

Until groundwater remediation decisions are made for the 100-FR-3 Operable Unit, the groundwater project will continue to monitor contaminant plumes and trends.

Seven of 22 aquifer tube sites were not sampled because the tubes had been destroyed, could not be located, or were under water at the time of sampling (see Appendix A). The list of tubes to be monitored was revised accordingly for future years.

All three seeps were sampled in November 2003. However, two of them had low specific conductance, indicating they were primarily river water, and no additional analyses were performed. The other tube, 207-1, was sampled as scheduled, but alkalinity was not analyzed.

Twelve new aquifer tubes at four tube sites were installed in FY 2004 as proposed in the original sampling and analysis plan. The addition of the new tubes improved monitoring coverage at the shoreline and will continue to aid in defining plumes and tracking contaminant trends.

(a) Letter PNNL-LTR-040317-1BC5 from JS Fruchter, Pacific Northwest National Laboratory, to Recipients of Sampling and Analysis Plan, *Page Changes for 100-BC-5 and 100-FR-3 Groundwater Sampling and Analysis Plans*, dated March, 17, 2004.

The sampling and analysis plan was revised in FY 2004 (DOE/RL-2003-49, Rev. 1) for implementation in FY 2005. The overall approach to monitoring remains the same, but sampling frequency and constituents were modified in some wells to reflect data collected and evaluated after publication of the first plan.

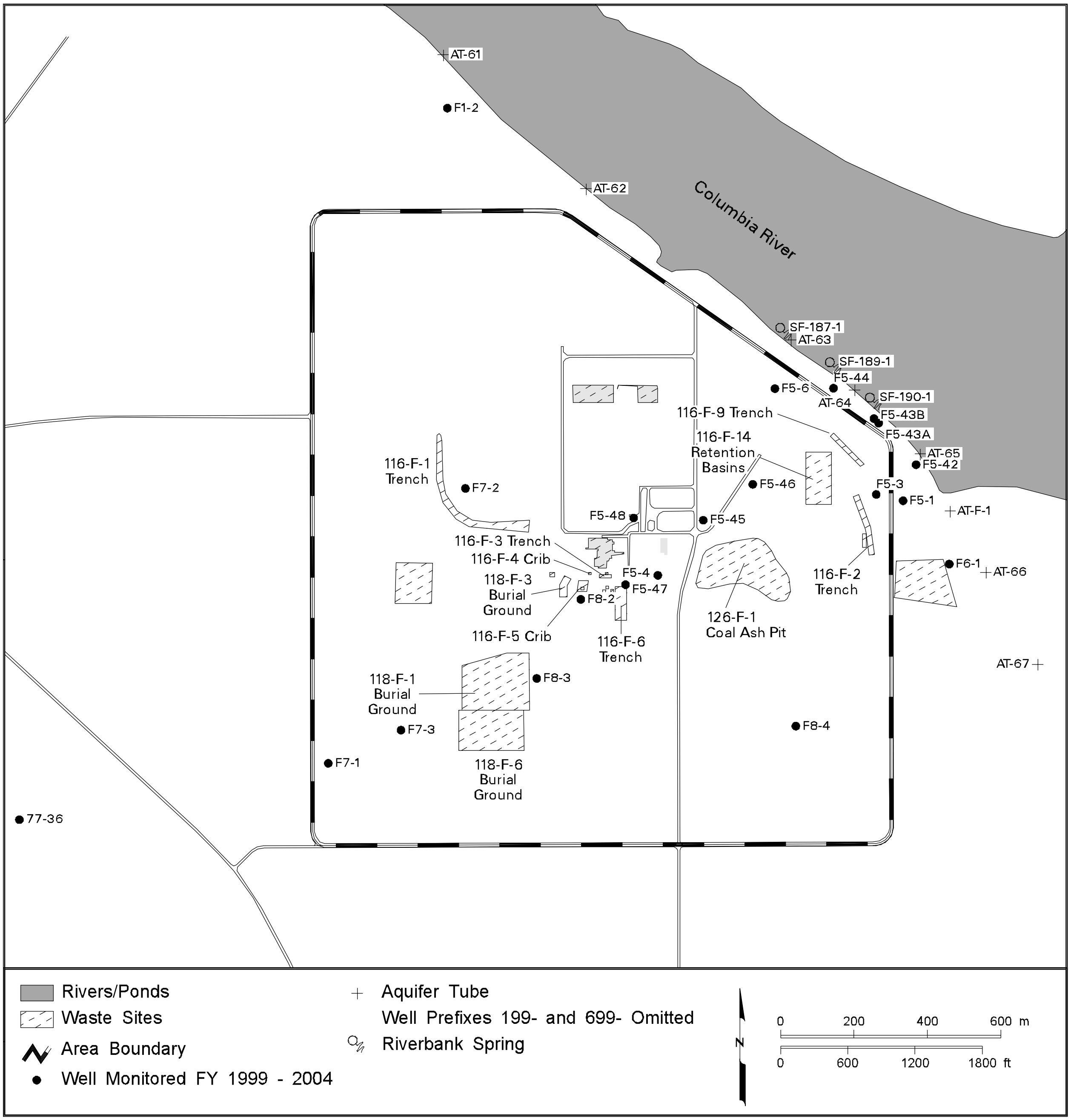

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Figure 2.7-1. Groundwater Monitoring Wells in the 100-F Area

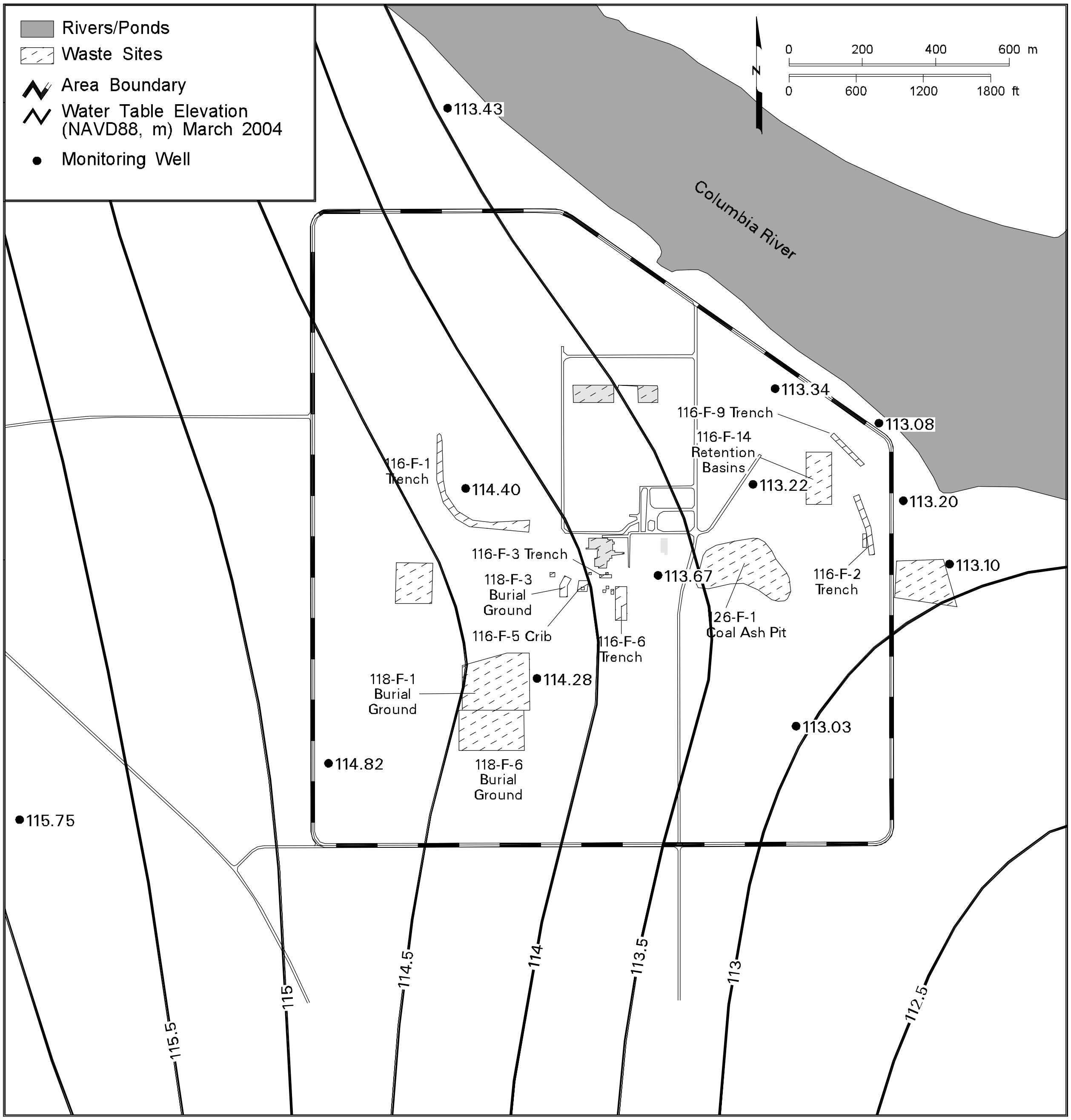

Figure 2.7-2. 100-F Area Water-Table Map, March 2004

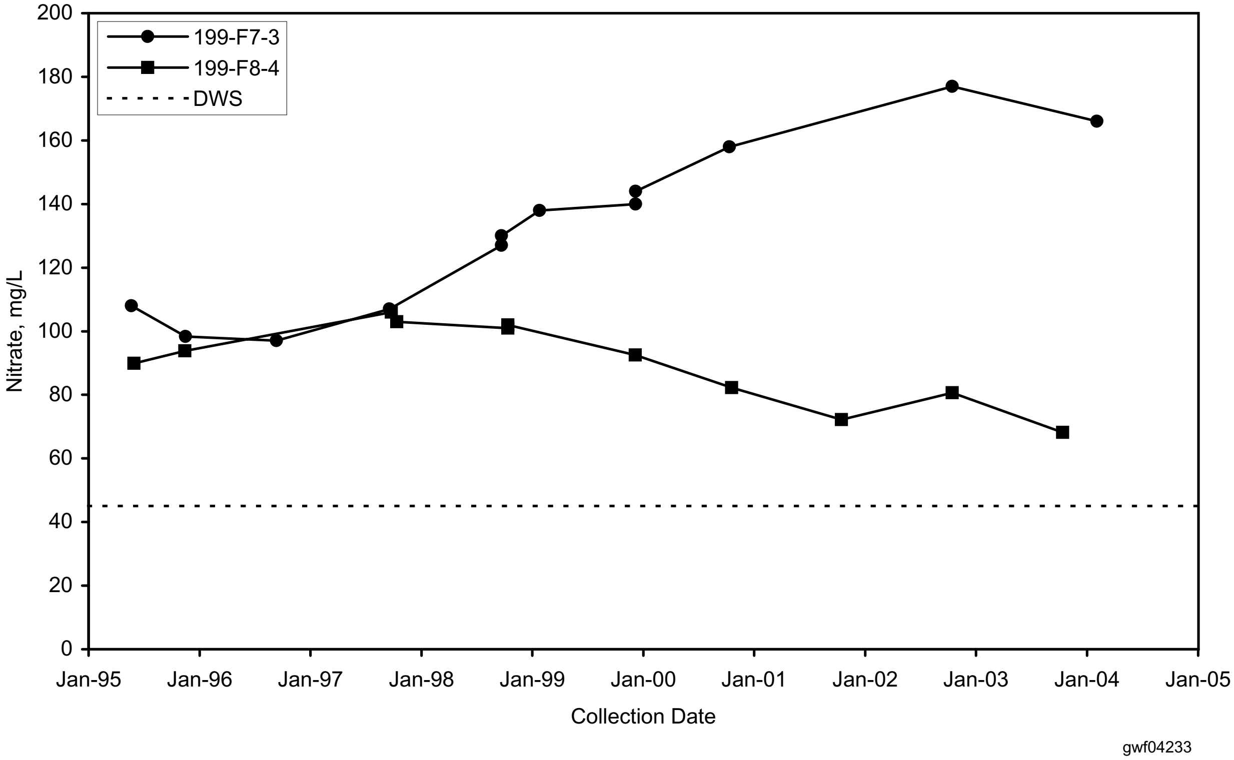

Figure 2.7-3. Nitrate Concentrations in Southeast (Well 199-F8-4) and Southwest (Well 199-F7-3) 100-F Area

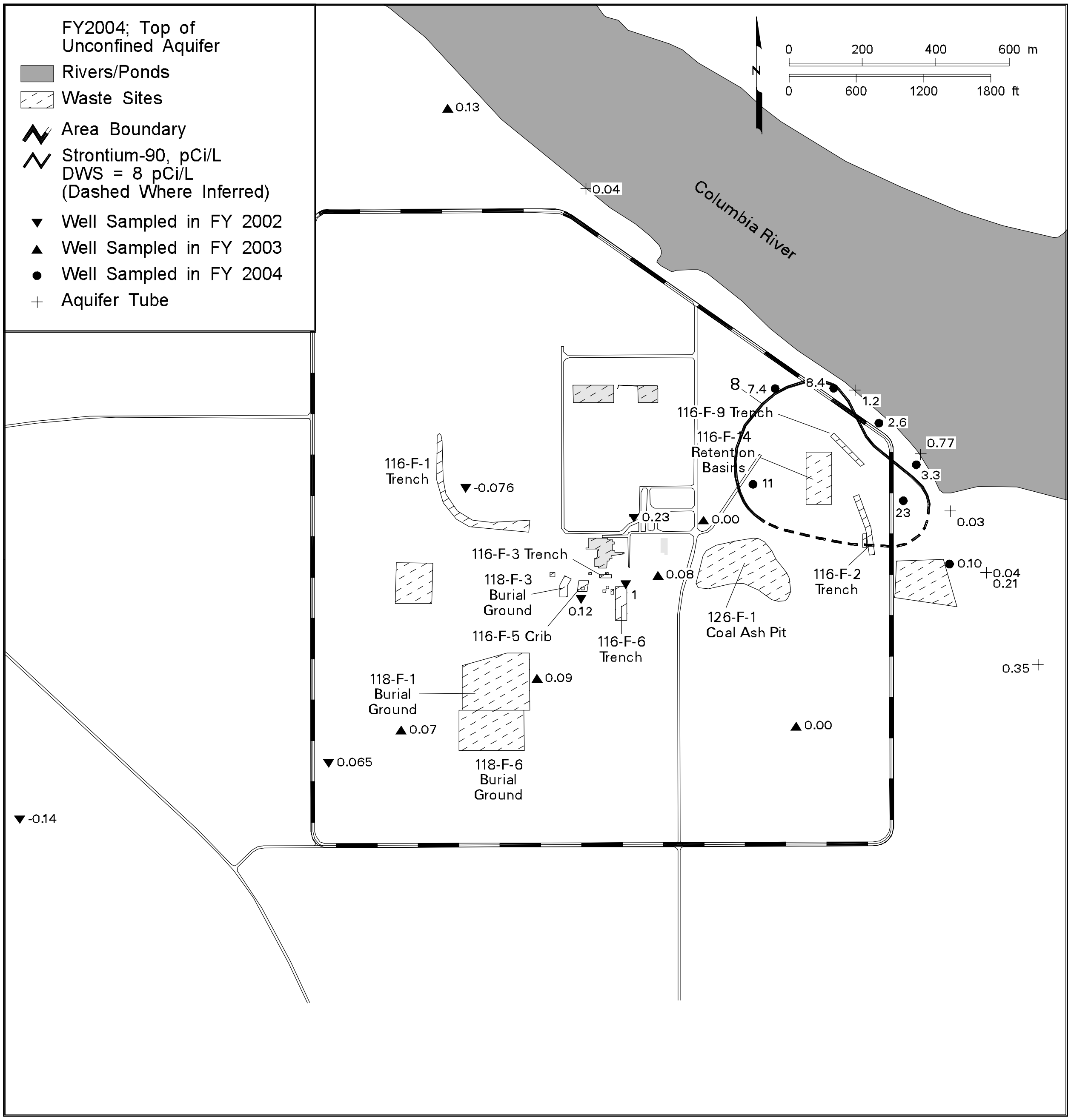

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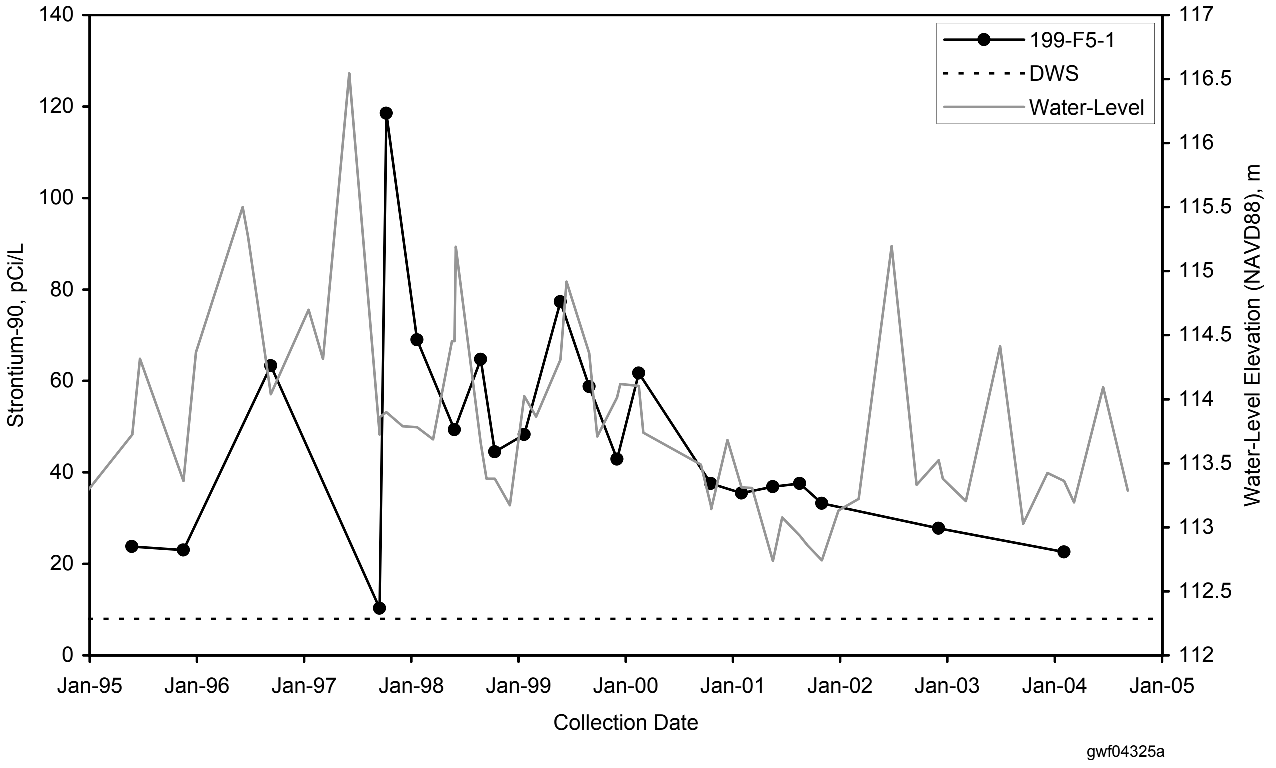
Figure 2.7-4. Average Strontium-90 Concentrations in the 100-F Area, Top of Unconfined Aquifer



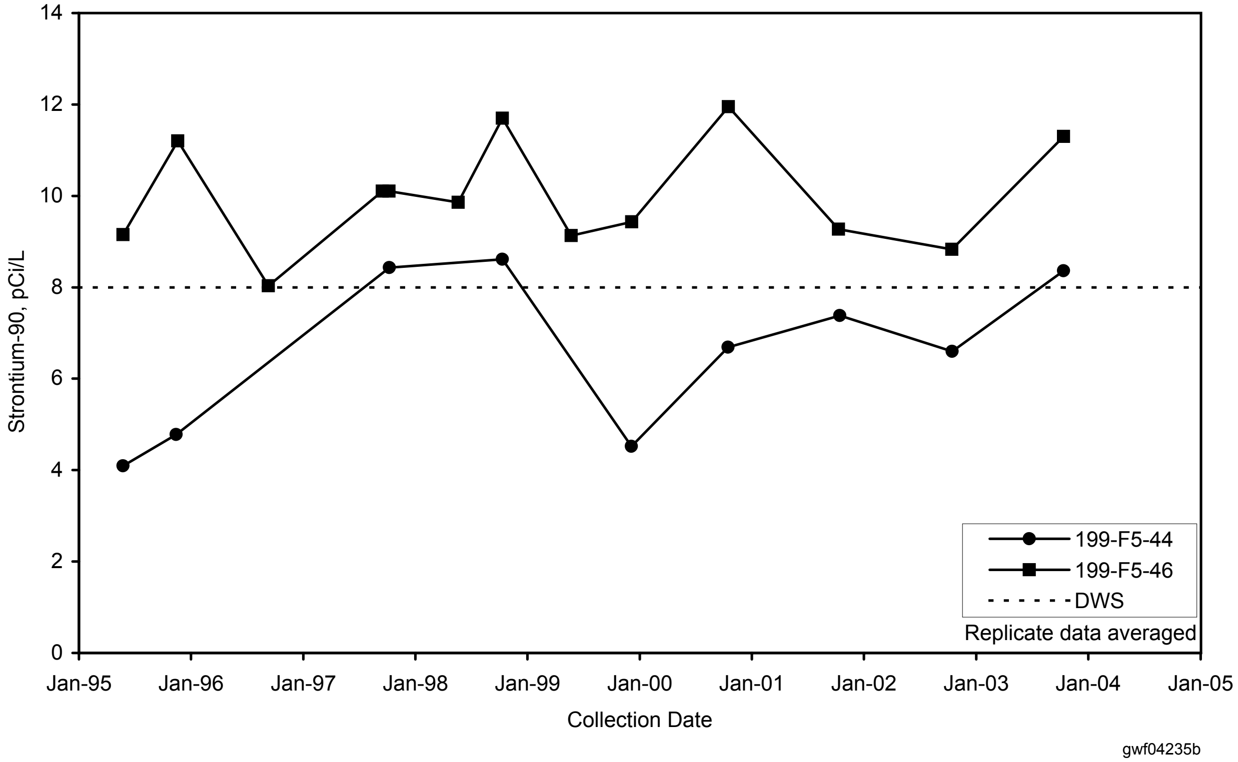


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Figure 2.7-5. Strontium-90 Concentrations Near the 116-F-14 Retention Basins

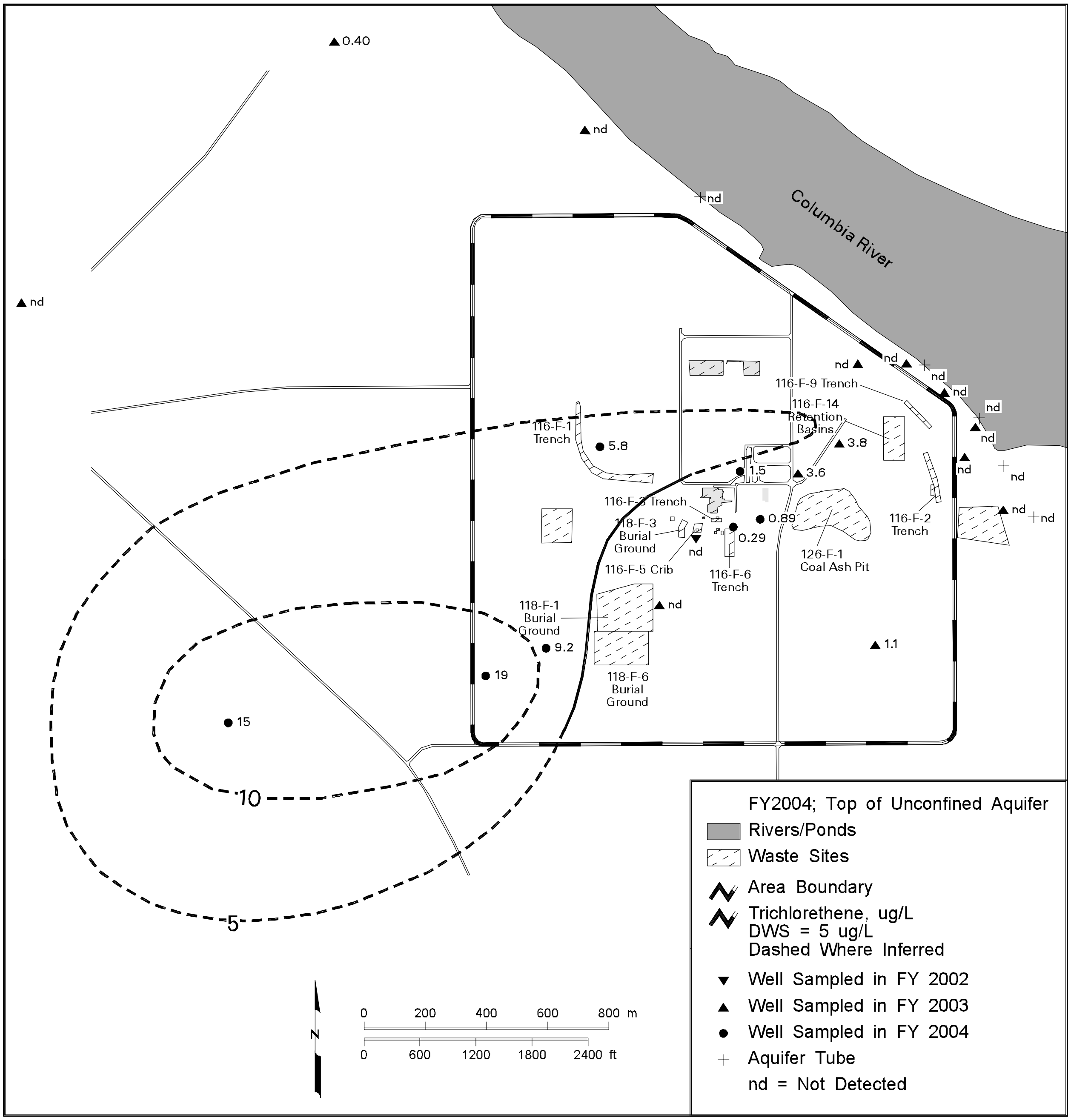

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Figure 2.7-6. Average Trichloroethene Concentrations in the 100-F Area, Top of Unconfined Aquifer

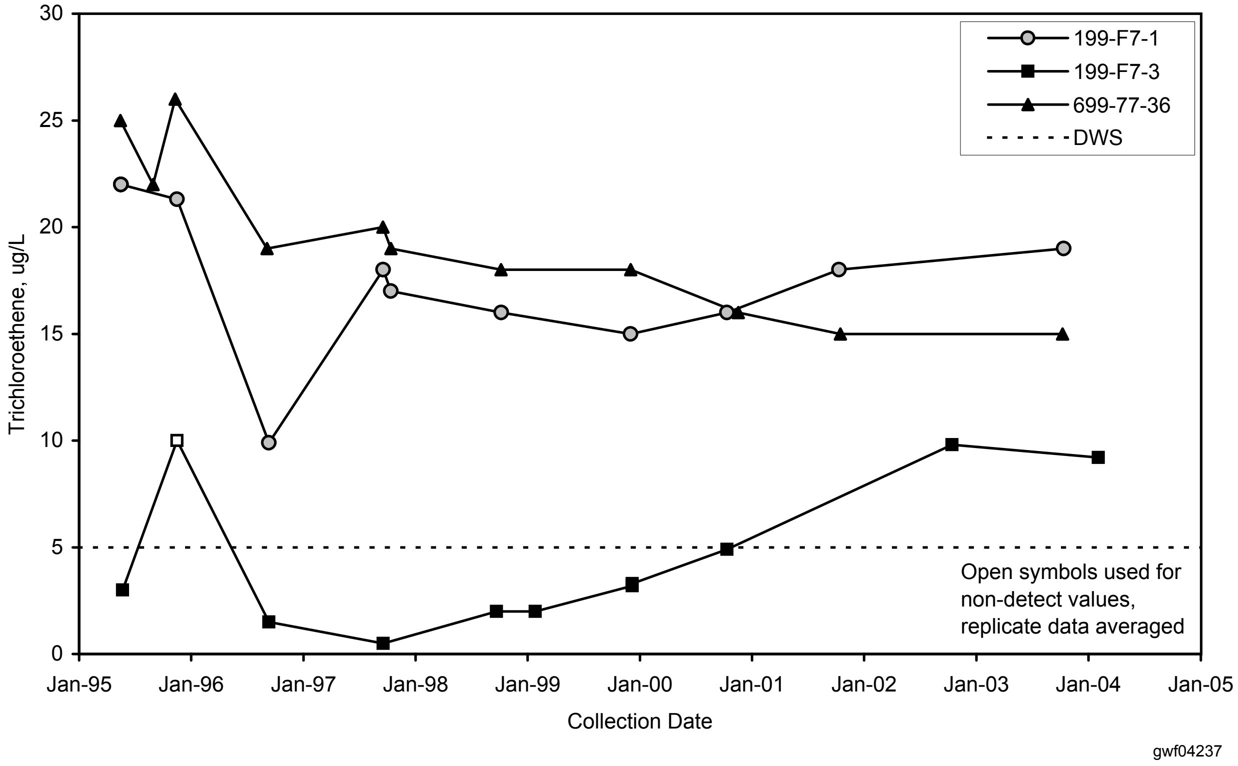


Figure 2.7-7. Trichloroethene Concentrations in the Southwest 100-F Area

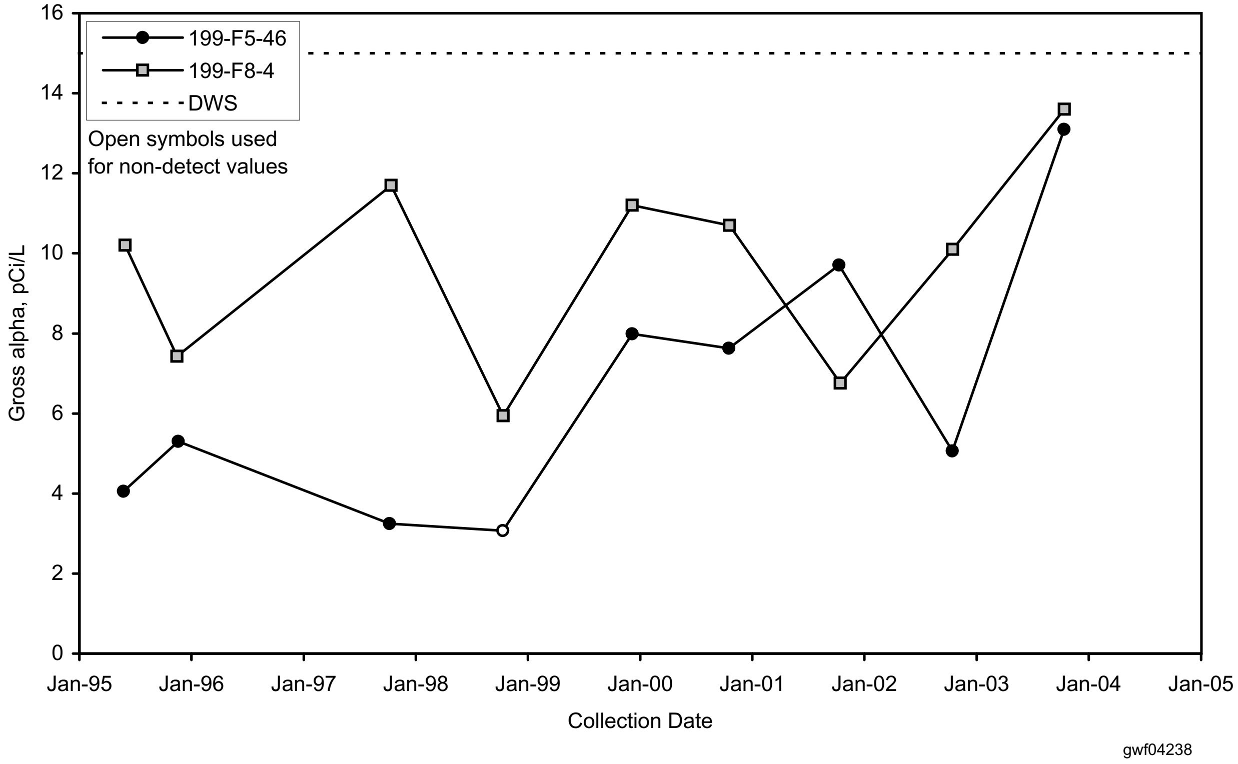


Figure 2.7-8. Gross Alpha Concentrations in Well 199-F5-46, Near the 100-F Reactor Building, and Well 199-F8-4, Southeast 100-F Area

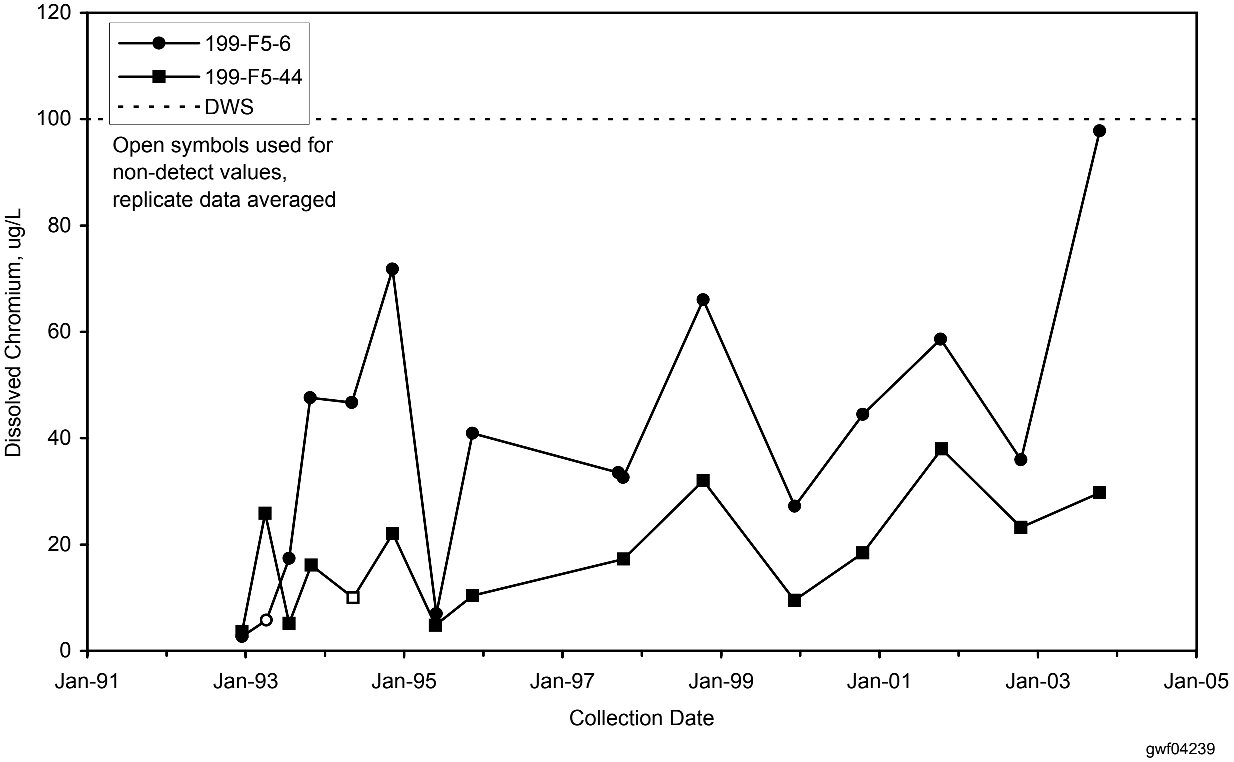


Figure 2.7-9. Chromium Concentrations in Wells 199-F5-6 and 199-F5-44, Northeast 100-F Area

2.8 200-ZP-1 Operable Unit

P. E. Dresel, D. B. Barnett, D. G. Horton, and L. C. Swanson

The scope of this section encompasses the 200-ZP-1 Operable Unit and surroundings. This region is informally termed the 200-ZP-1 groundwater interest area (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined groundwater interest areas informally to facilitate scheduling, data review, and interpretation. Figure 2.8-1 shows facilities and wells in this region. Groundwater is monitored to assess the performance of an interim action pump-and-treat system for carbon tetrachloride contamination, to track other contaminant plumes, and for four *Resource Conservation and Recovery Act* (RCRA) units and the State-Approved Land Disposal Site. Data from facility-specific monitoring are also integrated into the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) groundwater investigations. The major contamination plumes in this area include carbon tetrachloride, chloroform, trichloroethene, nitrate, chromium, fluoride, tritium, iodine-129, technetium-99, and uranium.

Carbon tetrachloride is the primary contaminant of concern in this operable unit.

Within the 200-ZP-1 Operable Unit, interim actions have been implemented for remediation of carbon tetrachloride, chloroform, and trichloroethene in the vicinity of the 216-Z liquid waste disposal units (216-Z cribs and trenches). Remediation of other groundwater contaminants will be determined through the remedial investigation/feasibility study (RI/FS) process per Section 5.5 of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989). A *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* was prepared in fiscal year (FY) 2004 (DOE/RL-2003-55).

Groundwater in the north portion of the 200 West Area predominantly flows toward the east-northeast but is locally influenced by the 200-ZP-1 Operable Unit pump-and-treat system and effluent discharges to the State-Approved Land Disposal Site (Figure 2.8-2). The water table in the 200 West Area was raised by past discharge of wastewater and the aquifer is still reequilibrating after the termination of discharges. Thus, the flow direction is changing with time. The flow direction in the north part of the operable unit has changed ~35 degrees over the past decade from a north-northeast direction to a more eastward direction.

Groundwater monitoring in the 200-ZP-1 groundwater interest area includes the following monitoring activities:

CERCLA Monitoring

- ***Extraction wells are sampled monthly (when operating).***
- ***New wells are sampled quarterly for the first year, then wells are sampled semiannually to biennially.***
- ***In FY 2004, nine wells were not sampled as scheduled (see Appendix A).***

Facility Monitoring

- ***Wells are sampled semiannually for Low-Level Waste Management Area 3.***
- ***Wells are sampled semiannually for Low-Level Waste Management Area 4.***
- ***Wells are sampled quarterly to semiannually for Waste Management Area T.***
- ***Wells are sampled quarterly to semiannually for Waste Management Area TX-TY.***
- ***Wells are sampled quarterly to semiannually for the State-Approved Land Disposal Site.***
- ***In FY 2004, five RCRA wells were not sampled as scheduled (see text and Appendix B).***
- ***In FY 2004, three wells were not sampled as scheduled at the State-Approved Land Disposal Site.***

Groundwater flows west to east except where affected by pumping or injection.

Flow in the central part of the 200 West Area (the south part of the 200-ZP-1 Operable Unit) is heavily influenced by the operation of the 200-ZP-1 groundwater pump-and-treat remediation system. This system extracts water from the vicinity of the 216-Z cribs and trenches shown on Figure 2.8-1, treats it to remove carbon tetrachloride, then re-injects the water into the aquifer to the west of the area. A small groundwater mound is associated with the injection wells, and a region of drawdown is associated with the extraction wells, causing flow to converge on the extraction zone from all directions. These flow conditions are expected to continue until the end of the pump-and-treat program, at which time the flow direction will resume a west to east pattern.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under CERCLA, RCRA, state permits, or *Atomic Energy Act of 1954* (AEA) monitoring.

2.8.1 Groundwater Contaminants

The groundwater contaminants of concern discussed below are defined in the 200-ZP-1 RI/FS work plan (DOE/RL-2003-55). The contaminants of concern and their preliminary target action levels, defined in the work plan, are listed in Table 2.8-1. In addition, the table summarizes the sampling results for each contaminant of concern in the 200-ZP-1 sampling and analysis plan (DOE/RL-2003-55; Appendix A) and other wells within the general area. The contaminants of concern that exceeded the preliminary target action levels are discussed below.

2.8.1.1 Carbon Tetrachloride

Carbon tetrachloride contamination is found at levels greater than the drinking water standard (5 µg/L) in the groundwater under most of the 200 West Area (Figure 2.8-3). The main sources are believed to be the 216-Z cribs and trenches that received waste from the Plutonium Finishing Plant. Other possible carbon tetrachloride sources exist in the north part of the operable unit and investigation of carbon tetrachloride in the vadose zone in Low-Level Waste Management Area 4, and waste retrieval is ongoing. The maximum carbon tetrachloride levels in groundwater are found near the Plutonium Finishing Plant and range up to 9,700 µg/L in individual samples. During FY 2004, extraction well 299-W15-34 had the highest average concentration (5,700 µg/L).

Plume areas (square kilometers) above the drinking water standard at the 200-ZP-1 Operable Unit:

****Carbon tetrachloride — 10.93***
Chromium — 0.05
Iodine-129 — 0.65
Nitrate — 6.08
Technetium-99 — 0.11
Trichloroethene — 0.81
Tritium — 0.76
Uranium — 0.16

****Also includes portion of plume beneath 200-UP-1 Operable Unit.***

Carbon tetrachloride remediation is the subject of the 200-ZP-1 interim record of decision (ROD 1995a). The target for remediation is the area with concentrations >2,000 to 3,000 µg/L in the vicinity of the 216-Z cribs and trenches. The remediation activities and more details on the contaminant distribution are summarized in Section 2.8.2.

Significant features of the carbon tetrachloride plume at the top of the aquifer include:

- The area of carbon tetrachloride >4,000 µg/L in the vicinity of the 216-Z cribs and trenches is decreasing due to the remediation (see Section 2.8.2.1).
- An area of carbon tetrachloride at levels >2,000 µg/L extends north to the vicinity of Waste Management Area TX-TY. The west side of this lobe is defined by new monitoring well 299-W15-43, where the average concentration was 1,800 µg/L, slightly lower than in FY 2003. This well was drilled early in FY 2003. Sampling for carbon tetrachloride at well 299-W15-44 located northeast of extraction well 299-W15-34 showed an average concentration of 2,300 µg/L in FY 2004. The carbon tetrachloride contamination reaches the north part of Waste Management Area TX-TY where concentrations in well 299-W15-765 averaged 3,400 µg/L. Thus, the contamination at levels above 2,000 µg/L extends beyond the capture zone of the 200-ZP-1 remediation system (see Section 2.8.2.2).

- Levels of carbon tetrachloride >1,000 µg/L are seen in the north part of the operable unit. Well 299-W11-10 near the east boundary of the 200 West Area consistently shows high carbon tetrachloride concentrations. The extent beyond the area boundary for this high concentration has not been determined since there are no wells for ~2 kilometers downgradient.
- In the past several years, increasing concentrations of carbon tetrachloride have been seen in the vicinity of the tank farms in Waste Management Area S-SX (in the 200-UP-1 Operable Unit). Concentrations appear to have leveled off or declined in several wells in this area, but more time is needed to confirm the trends. Carbon tetrachloride concentrations continue to increase on the east side of Waste Management Area S-SX, indicating that the plume is moving downgradient.
- The extent of carbon tetrachloride at the drinking water standard (5 µg/L) shown in Figure 2.8-3 did not change significantly from the previous year.

Carbon tetrachloride contamination is found at levels greater than the drinking water standard (5 µg/L) in groundwater beneath most of the 200 West Area.

Carbon tetrachloride concentrations in some locations are higher at depth than at the top of the unconfined aquifer. Carbon tetrachloride may have moved deeper in the aquifer as a dense, non-aqueous liquid or under hydrodynamic gradients when dissolved. The depth distribution of carbon tetrachloride is part of an ongoing investigation under the 200-ZP-1 RI/FS. Recent information includes the following:

- Depth-discrete data collected during drilling of well 299-W13-1, located in east-central 200 West Area. The carbon tetrachloride concentration near the water table was 32 µg/L and increased with depth (Figure 2.8-4). The carbon tetrachloride concentrations peaked at 1,300 µg/L at the top of the lower mud unit. Samples collected below the lower mud unit had lower concentrations – from 643 µg/L just below the unit and declining to 132 µg/L at the top of basalt. Trichloroethene and chloroform showed similar trends with trichloroethene reaching a maximum concentration of 10.4 µg/L above the lower mud unit and chloroform reaching a maximum of 83 µg/L in the same interval. The concentrations above the lower mud unit are considerably higher than seen in other wells so the well was screened at that depth. The drilling samples confirm the relatively low concentrations at the water table in the east-central 200 West Area.
- Well 299-W17-1 was also sampled at intervals down to the lower mud unit during drilling in FY 2004. This well is located upgradient of the 200 West Area. No volatile organic compounds were detected in the depth-discrete samples.
- Carbon tetrachloride concentrations continue their overall upward trend in well 299-W15-17, located west of the 216-Z cribs and trenches and completed above the Ringold lower mud unit. The maximum concentration detected in FY 2004 was 28 µg/L, far below the concentration in nearby wells completed at the top of the unconfined aquifer.
- Monitoring wells completed at depth in the unconfined aquifer near the 200-UP-1 pump-and-treat system showed carbon tetrachloride levels of 130 µg/L in well 299-W19-34A at ~25 meters below the water table and 85 µg/L in well 299-W19-34B at ~50 meters below the water table (near the top of the Ringold lower mud unit).
- Information on the vertical distribution of carbon tetrachloride is also available from vertical profiling in wells with long screened intervals as reported previously (e.g., PNNL-11793; PNNL-12086; PNNL-13788; BHI-00952-01; BHI-01121; BHI-01311). These reports document areas where the maximum carbon tetrachloride concentration is lower at the water table than found at depth. However, the available data set is insufficient to map out the depth distribution of carbon tetrachloride.

Sampling during drilling of a well in the east part of the 200 West Area showed high carbon tetrachloride concentrations near the bottom of the unconfined aquifer.

2.8.1.2 Trichloroethene

Trichloroethene is also detected at levels above the drinking water standard in the 200-ZP-1 Operable Unit, and the contamination extends into the 200-UP-1 Operable Unit

Trichloroethene is detected at levels above the drinking water standard in the 200-ZP-1 Operable Unit.

(Figure 2.8-5). Levels are lower and the extent is generally less than for carbon tetrachloride. The maximum trichloroethene detected in FY 2004 routine monitoring was 15 µg/L in well 299-W15-44, south of Waste Management Area TX-TY. As stated in the discussion of carbon tetrachloride contamination, the trichloroethene in well 299-W13-1 reached a maximum near the top of the lower mud unit (bottom of the unconfined aquifer).

2.8.1.3 Chloroform

Chloroform concentrations in the 200-ZP-1 wells remained below the 80-µg/L drinking water standard (the standard is defined for total trihalomethane). The 200-ZP-1 RI/FS work plan (DOE/RL-2003-55) designates a preliminary target action level of 7.17 µg/L based on the cleanup levels and risk calculations under the *Model Toxics Control Act* (WAC 173-340) cleanup regulation methods. The maximum concentration detected in routine samples was 46 µg/L. One sample collected during drilling of well 299-W13-1 was above the chloroform drinking water standard. As stated in the discussion of carbon tetrachloride contamination, the chloroform in well 299-W13-1 reached a maximum of 83 µg/L near the top of the lower mud unit (bottom of the unconfined aquifer). One drilling sample from well 299-W15-46 in FY 2004 was also above the drinking water standard. Drilling of well 299-W15-46 continued into FY 2005, and the data will be integrated and evaluated after completion of the well. Possible chloroform sources include biodegradation of carbon tetrachloride.

2.8.1.4 Nitrate

Nitrate continued to be present in groundwater at concentrations in excess of the drinking water standard (45 mg/L) beneath much of the 200-ZP-1 Operable Unit (Figure 2.8-6). The maximum concentration in this vicinity during FY 2004 was 3,430 mg/L in well 299-W10-4 near the 216-T-36 crib, south of Waste Management Area T. Nitrate concentrations are increasing rapidly in this well as discussed in Section 2.8.3.3. The nitrate contamination is more widespread than the tritium, iodine-129, or technetium-99 contamination discussed in Sections 2.8.1.7, 2.8.1.8, and 2.8.1.9, respectively. There probably are multiple sources of nitrate in this area, including the 216-Z crib and trench disposal facilities.

A well near the 216-T-36 crib has the highest nitrate concentration (3,430 mg/L) on the Hanford Site.

Elevated nitrate on the east side of Waste Management Area TX-TY, in well 299-W14-13, is correlated with elevated chromium, tritium, iodine-129, and technetium-99. Because of the lower levels in surrounding wells, this contamination is interpreted as being from a nearby source and is discussed further in Section 2.8.3.4.

Elevated nitrate levels are found in the west part of the Hanford Site (see Figure 2.1-6 in Section 2.1). This contamination is believed to be due to offsite agriculture because it is persistent, far upgradient of the site waste disposal areas, and is not associated with other Hanford contaminants. Other constituents indicative of Hanford contamination, such as tritium, are low in this area. One well (699-36-93, see Figure 2.1-2 in Section 2.1 for location) in the west part of the Hanford Site had nitrate levels (49 mg/L) above the drinking water standard (45 mg/L) in FY 2003. Most wells in the west part of the site, upgradient of the production areas, were not scheduled for sampling in FY 2004.

2.8.1.5 Chromium

Chromium contamination is found at levels above the drinking water standard (100 µg/L) in filtered samples in the immediate vicinity of Waste Management Areas T and TX-TY (Figure 2.8-7). The plume in the vicinity of Waste Management Area T has changed little in size over the past decade, although the extent of lower concentrations beyond the 200 West Area fence line is uncertain due to the lower density of monitoring wells. The highest levels are found near the 216-T-36 crib, upgradient of Waste Management Area T, in well 299-W10-4 where the highest concentration in FY 2004 was 686 µg/L and the average concentration was 460 µg/L. Chromium concentrations are increasing in this well, along with nitrate and technetium-99 concentrations. Chromium near Waste Management Area T is discussed in more detail in Section 2.8.3.3.

Chromium is also elevated east of Waste Management Area TX-TY in well 299-W14-13. The concentrations detected in filtered samples from this well in FY 2004 rose from 573 µg/L in November to 733 µg/L in August. The chromium contamination is associated with elevated nitrate, tritium, technetium-99, and iodine-129. The contamination is discussed further in Section 2.8.3.4.

2.8.1.6 Fluoride

Fluoride contamination at levels greater than the primary drinking water standard (4 mg/L) has been seen in a restricted area around Waste Management Area T in past years. However, all wells had average concentrations below the drinking water standard in FY 2004 (Figure 2.8-8) so the plume appears to be dissipating slowly. Two wells had individual results above the drinking water standard.

2.8.1.7 Tritium

Tritium contamination at levels greater than the drinking water standard in the 200-ZP-1 Operable Unit is mainly restricted to a plume extending northeast from waste disposal facilities in the vicinity of Waste Management Areas T and TX-TY. There are multiple potential sources of tritium in this vicinity. In addition, tritium from permitted discharge at the State-Approved Land Disposal Site is found in the groundwater (Figure 2.8-9). Tritium at the State-Approved Land Disposal Site is discussed in Section 2.8.3.5.

The highest tritium concentrations were in well 299-W14-13, located east of Waste Management Area TX-TY, where the average concentration in FY 2004 was 1.7 million pCi/L, slightly lower than in FY 2003. The maximum tritium concentration detected in this well was 2.94 million pCi/L in FY 2000. Well 299-W14-13 replaced well 299-W14-12, and the trend plot for these two wells indicates that the high contamination levels arrived at this location in ~1999 (Figure 2.8-10). High levels of chromium, nitrate, technetium-99, and iodine-129 are associated with the tritium contamination. This contamination is discussed further in Section 2.8.3.4.

The highest tritium concentrations were in a well east of Waste Management Areas T and TX-TY where the average concentration was 1.7 million pCi/L.

Overall, tritium levels in the 200-ZP-1 Operable Unit are fairly low with only four wells having average concentrations >30,000 pCi/L in FY 2004 (excluding the State-Approved Land Disposal Site wells). Aside from well 299-W14-13, well 299-W14-15 had an average tritium concentration of 33,000 pCi/L, well 299-W11-12 had an average tritium concentration of 49,000 pCi/L, and well 299-W11-14 had an average tritium concentration of 55,000 pCi/L. Well 299-W11-12 is located southeast of Waste Management Area T, so the waste management area is probably not a major tritium source. The tritium concentration in well 299-W11-12 is declining.

2.8.1.8 Iodine-129

An iodine-129 plume is found in the 200-ZP-1 Operable Unit emanating from the vicinity of Waste Management Area TX-TY and extending to the northeast (Figure 2.8-11). The highest concentration detected in FY 2004 was in well 299-W14-13, where the average concentration was 18 pCi/L. Iodine-129 near Waste Management Area TX-TY is discussed further in Section 2.8.3.4. Iodine-129 contamination at levels above the drinking water standard does not appear to extend beyond the 200 West Area boundary.

Iodine-129 concentrations in one well in the 200-ZP-1 Operable Unit are among the highest on the Hanford Site.

2.8.1.9 Technetium-99

Technetium-99 within the 200-ZP-1 Operable Unit is found at levels above the drinking water standard (900 pCi/L) only on the downgradient side of Waste Management Areas T and TX-TY (Figure 2.8-12). However, evidence points to multiple sources of technetium-99 within those areas.

Near Waste Management Area T, technetium-99 concentrations continued to increase in wells on the east side (downgradient) of the tank farm. Well 299-W11-39, near the northeast corner of the waste management area, had the highest concentration in the area with values in FY 2004 ranging from 10,000 to 21,400 pCi/L, approximately double the

FY 2003 concentration. Technetium-99 contamination around Waste Management Area T is discussed in greater detail in Section 2.8.3.3.

Technetium-99 within the 200-ZP-1 Operable Unit is found above the drinking water standard only on the downgradient side of Waste Management Areas T and TX-TY.

Technetium-99 concentrations east of Waste Management Area TX-TY in well 299-W14-13 continued to be much higher than in surrounding wells and showed a generally increasing trend. The fiscal year average concentration in this well was 8,280 pCi/L. This contamination is associated with elevated levels of chromium, nitrate, tritium, and iodine-129. Contamination exhibited in this area is discussed further in Section 2.8.3.4.

The maximum technetium-99 detected in 200-ZP-1 extraction wells was in well 299-W15-35 where the concentrations in FY 2004 ranged from 280 to 360 pCi/L. Since technetium-99 is not removed by the treatment system, technetium-99 is being re-injected to the aquifer in the treated water. Well 299-W15-15, lying north-northeast of the injection wells, has exhibited increasing technetium-99 concentrations, rising from 18 pCi/L in May 1994 to 170 pCi/L in July 2004. This change suggests that injected water may be flowing toward this monitoring well. However, the concentrations are over one-third the highest technetium-99 concentration in any extraction well. This, and the distance of the wells in question from the injection wells, suggests the possibility that part of the technetium may be from upgradient. Technetium-99 may have moved to the west under past flow conditions and be re-entering the area under present flow conditions. The increase in technetium-99 at well 299-W15-15 has accompanied a marked decrease in carbon tetrachloride concentrations, from a maximum of 1,850 µg/L in January 1997 to 21 µg/L in July 2004.

2.8.1.10 Uranium

Few analyses for uranium were performed on groundwater samples from the 200-ZP-1 Operable Unit during FY 2004 because most wells showed insignificant levels in previous monitoring. Some wells monitored near the single-shell tank farms and low-level burial grounds are sampled for gross alpha measurements, which would show an increase if uranium contamination appeared. Uranium was detected above the 30-µg/L drinking water standard in wells 299-W11-14 and 299-W11-37 in northeast 200 West Area. The uranium concentration detected in well 299-W11-37 ranged from 194 to 250 µg/L. Uranium was also above the drinking water standard near the southwest corner (upgradient) of Low-Level Waste Management Area 4 in well 299-W18-21. The concentration in well 299-W18-21 ranged from 25.4 to 32.5 µg/L in FY 2004.

2.8.1.11 Other Contaminants of Concern

Most of the other contaminants of concern in the 200-ZP-1 RI/FS work plan (DOE/RL-2003-55) were not detected in FY 2004 sampling (see Table 2.8-1). Other contaminants of concern that were detected are discussed in this section.

Arsenic is listed as a contaminant of concern in the 200-ZP-1 RI/FS work plan (DOE/RL-2003-55). Arsenic was not detected at levels above the 10-µg/L drinking water standard/preliminary target action level in any of the routine samples. One of two samples from well 299-W10-4 had an arsenic level of 10 µg/L reported, while the other was 1.8 µg/L. However, a sample collected from drilling of well 299-W15-46, near the 216-Z-9 trench had a reported arsenic concentration of 38.7 µg/L. That sample was not filtered and turbidity was not reported.

Manganese was detected at levels above the 50-µg/L preliminary target action level in well 299-W10-27, but not in any wells sampled under the RI/FS work plan. Manganese levels in well 299-W10-27 declined from 239 µg/L in November 2003 to 172 µg/L in August 2004. Manganese concentrations have declined overall since this well was installed and first sampled in 2001. It is not uncommon for new wells on the Hanford Site to have elevated manganese values in the first few years of sampling.

Antimony was detected in three wells at levels above the 10-µg/L preliminary target action level. Antimony was not detected in subsequent samples so these results are considered to be false positives. Analytical problems with antimony have recently been identified (see Appendix C) and the groundwater project is working with the laboratory to institute corrective measures.

Iron was present at levels above the 300-µg/L preliminary target action level in one unfiltered sample from well 699-48-77A, near the State-Approved Land Disposal Site. Iron is a naturally occurring component of the aquifer sediment and is found in well materials so seeing elevated iron levels in unfiltered samples is not surprising.

Silver was reported above the 80 µg/L preliminary target action level in one sample from well 299-W15-44, south of Waste Management Area TX-TY. Silver was not detected in previous and subsequent samples so this is considered to be a false positive sample.

The pump-and-treat system is successfully containing and capturing the highest concentration portion of the carbon tetrachloride plume near the top of the aquifer.

2.8.2 Interim Groundwater Remediation for Carbon Tetrachloride

A pump-and-treat system is in operation for the 200-ZP-1 Operable Unit to contain and capture the high concentration portion of the carbon tetrachloride plume located in the vicinity of the 216-Z cribs and trenches and the Plutonium Finishing Plant. The pump-and-treat system for the 200-ZP-1 Operable Unit was implemented in three phases as a CERCLA interim remedial action starting in 1996.

The remedial action objectives for the interim action pump-and-treat system are to capture the high concentration area of the carbon tetrachloride plume and to reduce contaminant mass (ROD 1995a). The high concentration area is defined as that area inside the 2,000- to 3,000-µg/L plume contour. More recently, carbon tetrachloride concentrations have been detected above the remedial action goal north of the Plutonium Finishing Plant, just west of the TX-TY Tank Farm. Because of these changes, plans are now underway to expand the pump-and-treat system by adding additional extraction wells in this area. Also, concentrations near the remedial action goal have been found in the east-central 200 West Area, suggesting that additional characterization of the deeper aquifer should be performed. Contamination deeper in the aquifer is being addressed in the CERCLA investigations.

The remedial action objectives for the 200-ZP-1 Operable Unit (ROD 1995a) are:

- *Reduce contamination in the area of highest concentration of carbon tetrachloride.*
- *Prevent further movement of these contaminants from the highest concentration area.*
- *Provide information that will lead to development of a final remedy that will protect human health and the environment.*

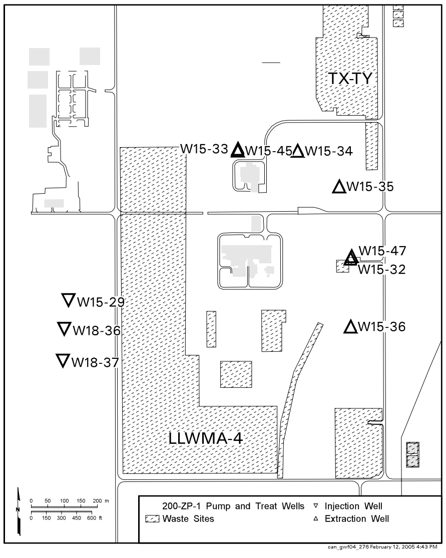
EPA specified enhancements needed to the system in their 5-year review (EPA 2001). The record of decision for the interim remedial measure states the high concentration portion of the plume corresponds to the area within the 2,000- to 3,000-µg/L contour of carbon tetrachloride.

A summary of the remediation activities and progress is given in the following sections. For more details on pump-and-treat results for FY 2003, see DOE/RL-2004-72. Results for 2004 will be published in an upcoming report on the 200 West Area remedial actions. Sampling for the groundwater remediation is integrated with the RI/FS work plan (DOE/RL-2003-55).

During FY 2004, the pump-and-treat system extracted ~274 million liters of groundwater, removing ~840 kilograms of carbon tetrachloride.

2.8.2.1 Progress During FY 2004

Carbon tetrachloride contamination was reduced in the area of highest concentrations through mass removal. Approximately 274.5 million liters of contaminated groundwater were treated in FY 2004 at an average flow rate of ~540 liters per minute (includes all downtime). Two of the extraction wells were replaced this year because of decreased production under a declining water table. The new extractions wells, which became operational in April and August 2004, respectively, are 299-W15-45 (replacing 299-W15-33) and 299-W15-47 (replacing 299-W15-32). These new wells boosted the overall system production rate to ~785 liters per minute for the last 2 months of the fiscal year.



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Extraction well concentrations ranged from 560 to over 5,000 µg/L, while influent concentrations measured at the influent tank ranged from 2,500 to 3,700 µg/L. Carbon tetrachloride trends in extraction wells are shown in Figure 2.8-13. Treatment of the 274.5 million liters of groundwater resulted in the removal of 840.4 kilograms of carbon tetrachloride during FY 2004. Since startup of pump-and-treat system operations in August 1994, treatment of >2.4 billion liters of groundwater has led to the removal of >8,500 kilograms of carbon tetrachloride.

Technetium-99 samples are collected to ascertain if the pump-and-treat system is being affected by radiological contamination. No technetium-99 concentrations were above the drinking water standard (900 pCi/L). The highest measured concentrations in the area of the pump-and-treat system were 242 and 380 pCi/L at extraction wells 299-W15-32 and 299-W15-35, respectively. Technetium-99 acts as a tracer and has been detected in wells downgradient from the injection wells. At well 299-W15-15, the measured technetium-99 concentration has increased from 18.5 pCi/L in 1994 to 170 pCi/L while carbon tetrachloride concentrations have simultaneously decreased from 1,400 to 21 pCi/L

2.8.2.2 Influence on Aquifer Conditions

During FY 2004, the >2,000-µg/L center of the carbon tetrachloride plume near the top of the unconfined aquifer continued to shrink in the original target area of the plume (beneath the Plutonium Finishing Plant) (Figure 2.8-3). The 4,000-µg/L-plume contour has also been shrinking and at the end of the fiscal year only encompassed extraction well 299-W15-34. During FY 2002, four wells defined the >4,000-µg/L contour: 299-W15-1, 299-W15-31A, 299-W15-33, and 299-W15-34; and in FY 2003 only two wells: 299-W15-1 and 299-W15-34.

During FY 2004, the >2,000-µg/L center of the carbon tetrachloride plume at the top of the aquifer continued to shrink in the plume beneath the Plutonium Finishing Plant.

Concentrations of carbon tetrachloride continued to decline to the west of the Plutonium Finishing Plant in response to pumping from the extraction wells and the arrival of clean groundwater from the injection wells. In this area, well 299-W15-30 reached a concentration of 6,500 µg/L in 1997. By August 2004, carbon tetrachloride concentrations had decreased to 1,300 µg/L.

Carbon tetrachloride levels in former southernmost extraction well 299-W15-37 are still low at 84 µg/L indicating there is no loss of control of the plume at the south edge. At extraction well 299-W15-36, 190 meters farther north, concentrations have declined to 820 µg/L. This value is well below 2,000 µg/L. These changes show that the pump-and-treat system is having the desired remediation effect. Further consideration is being given to shutting down this extraction well to ensure that higher concentrations are not pulled to the south.

Recently installed monitoring wells have revealed that carbon tetrachloride concentrations are above 2,000 µg/L north of the pump-and-treat system and west of the TX-TY Tank Farm. This area is outside the capture zone of the pump-and-treat system. For this reason, plans are in place to expand the pump-and-treat system to this north area in FY 2005. It is likely that wells 299-W15-765, 299-W15-40, 299-W15-43, and 299-W15-44 will be brought on line as additional extraction wells.

In addition, vertical profile sampling at new monitoring well 299-W13-1, installed in the east-central 200 West Area in December 2003, demonstrated the presence of carbon tetrachloride at above drinking water standard to concentrations near the remedial action goal throughout the thickness of the aquifer (see Section 2.8.1). Following well installation, carbon tetrachloride concentrations have increased to 1,900 µg/L. Additional wells have been proposed for aquifer monitoring between the 216-Z-9 crib and this well along a track predicted by particle tracking models.

Regional groundwater flow in the vicinity of the pump-and-treat system is still to the east-northeast (Figure 2.8-2). Water levels continued to decline at an annual rate of ~0.37 meter per year (DOE/RL-2004-72). This rate of decline is equivalent to the FY 2003 rate. The declining water levels will continue to be an issue as additional monitoring wells go dry. Numerous wells monitored for the 200-ZP-1 Operable Unit have gone dry in recent years. Six wells scheduled for sampling under the 200-ZP-1 plan were dry (Appendix A). Well decommissioning is discussed in Chapter 5.

In conclusion, the pump-and-treat system appears to be hydraulically containing the high-concentration portion of the target carbon tetrachloride plume and reducing contaminant mass in the baseline area. Contaminant concentrations have decreased most notably in the monitoring wells, but also in the extraction wells. An existing plume north of the pump-and-treat system will require additional extraction wells for containment and mass removal. This system upgrade is planned for FY 2005. Additional characterization may be required to evaluate the distribution of carbon tetrachloride deeper in the aquifer.

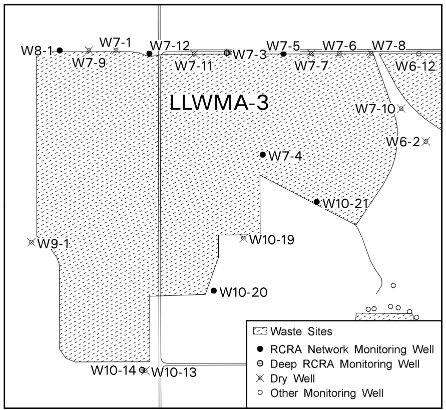
Carbon tetrachloride contamination at levels above 2,000 µg/L extends beyond the capture zone of the current remediation system. System upgrades to address this are planned for FY 2005.

2.8.3 Facility Monitoring

This section describes results of monitoring individual facilities such as treatment, storage, and disposal units or tank farms. Some of these facilities are monitored under the requirements of RCRA for hazardous waste constituents and AEA for source, special nuclear, and by-product materials. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for each facility. As discussed in Section 2.1 for RCRA sites, DOE has sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials. Groundwater data for these facilities are available in the Hanford Environmental Information System (HEIS 1994) and on the data files accompanying this report. Additional information including well and constituent lists, maps, flow rates, and statistical tables are included in Appendix B.

2.8.3.1 Low-Level Waste Management Area 3

Groundwater at Low-Level Waste Management Area 3 continued to be monitored under RCRA and AEA. Under 40 CFR 265.93(b) as referenced by WAC 173-303-400, the well network was sampled semiannually for RCRA indicator and site-specific parameters (WHC-SD-EN-AP-015; see Appendix B). Eight of 11 wells attempted for sampling in FY 2004 were successfully sampled. Wells 299-W10-19, 299-W7-1, and 299-W7-7 went dry this year and have been removed from the sampling schedule. Well decommissioning is discussed in Chapter 5. New downgradient well locations have been identified and prioritized under the Tri-Party Agreement (Ecology et al. 1989) M-24 milestone. Well installation at Low-Level Waste Management Area 3 is scheduled to begin in calendar year 2005.



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Initial analysis of the April samples from well 299-W7-12 indicated total organic carbon exceeded the statistical comparison value since the average of the quadruplicates was 1,500 µg/L. The samples were re-analyzed and the results came back much lower. Confirmation sampling was performed in June, and the average value was less than the comparison value at 650 µg/L. Thus, the original results are interpreted as being due to laboratory error.

An application was submitted to the Washington State Department of Ecology (Ecology) in June 2002 to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994a). This would have the effect of changing the groundwater monitoring requirements for the burial grounds from interim status monitoring to final status monitoring. As part of the application, new groundwater monitoring wells, constituents, and statistical evaluations are proposed. Workshops with Ecology to address this application are in progress.

The groundwater flow in this portion of the 200 West Area is to the east-northeast (70 degrees), based on trend surface fit to water-level measurements, with a calculated gradient of 0.0013. The estimated flow rate at Low-Level Waste Management Area 3, using this gradient is 0.0001 to 0.2 meter per day (see Appendix B).

Under current flow directions, previously designated upgradient wells 299-W10-19 and 299-W10-20 remain upgradient of the east portion of the waste management area, but are downgradient of the southwest part of the waste management area. Nitrate and carbon tetrachloride routinely exceed drinking water standards in these wells. Flow and monitoring data since RCRA monitoring was instituted in the 1980s indicate that these constituents are from plumes originating from sources to the south. Currently, there are no monitoring wells on the west (upgradient) side of Low-Level Waste Management Area 3. If wells 299-W10-19 and 299-W10-20 are used for statistical comparisons, then no downgradient wells exceed the statistical comparison value for the indicator parameters, pH, specific conductance, total organic carbon, and total organic halides. Past carbon tetrachloride results from well 299-W9-1, on the west side of Low-Level Waste Management 3, are all less than 10 µg/L. This well has gone dry.

New monitoring wells will be installed during 2005 to replace wells that have gone dry in Low-Level Waste Management Areas 3 and 4.

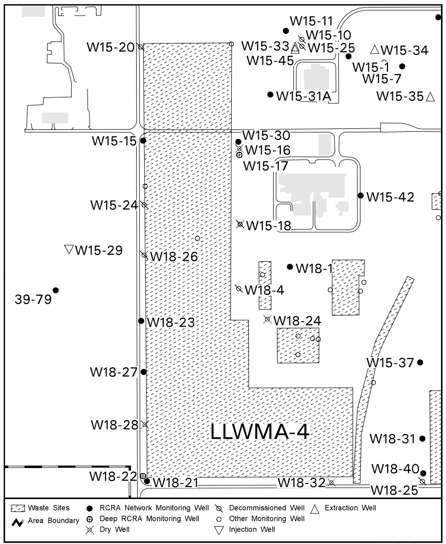
Performance assessment monitoring of radionuclides at Low-Level Waste Management Area 3 is designed to complement RCRA detection monitoring and is aimed specifically at monitoring radionuclide materials that are not regulated under RCRA. The current goal of performance assessment monitoring at Low-Level Waste Management Area 3 is to gather data to assess changes in concentrations at downgradient wells using statistical tests and to provide sufficient supporting information from upgradient wells to interpret the changes. Under the current monitoring plan (DOE/RL-2000-72), technetium-99, iodine-129, and uranium are monitored specifically for performance assessment.

Contaminant characteristics in groundwater at Low-Level Waste Management Area 3 include the following:

- Technetium-99 concentrations are all <100 pCi/L and generally show steady or declining trends. The highest concentration in FY 2004 was 58 pCi/L in well 299-W10-21, located on the south edge of Low-Level Waste Management Area 3. Although this well is currently downgradient of part of the burial ground, it has likely been impacted by activities to the south that imposed northward flow for a time. Technetium-99 was also detected in wells 299-W7-4, 299-W7-12, and 299-W10-20 in FY 2004. The technetium-99 distribution in the 200-ZP-1 Operable Unit is discussed in Section 2.8.1.9.
- Uranium concentrations at Low-Level Waste Management Area 3 are <3 µg/L.
- Iodine-129 was not detected in any wells at Low-Level Waste Management Area 3. The minimum detectable activity is ~0.3 pCi/L.
- Tritium concentrations were all less than the drinking water standard, and tritium was undetected in most wells.
- As discussed in Sections 2.8.1.1, 2.8.1.2, and 2.8.1.3, carbon tetrachloride and associated trichloroethene and chloroform concentrations in Low-Level Waste Management Area 3 wells are consistent with those seen in regional plumes.
- The nitrate distribution at Low-Level Waste Management Area 3 is consistent with regional plumes, as discussed in Section 2.8.1.4.

2.8.3.2 Low-Level Waste Management Area 4

Groundwater at Low-Level Waste Management Area 4 continued to be monitored under RCRA and AEA. Under 40 CFR 265.93(b) as referenced by WAC 173-303-400, the well network was sampled semiannually for RCRA indicator and site-specific parameters (WHC-SD-EN-AP-015; see Appendix B). Of the six wells where sampling was attempted



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during FY 2004, sampling was successful in five of the wells. Sampling of well 299-W15-16 was unsuccessful in the second sampling event, and the well has been determined to have too little water for future sampling. Well 299-W15-30 will be used as a replacement for well 299-W15-16. New downgradient well locations have been identified and prioritized under the Tri-Party Agreement M-24 milestone. Well installation at Low-Level Waste Management Area 4 is scheduled to begin in calendar year 2005. Decommissioning of wells that are no longer needed is discussed in Chapter 5.

An application was submitted to Ecology in June 2002 to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994a). This would have the effect of changing the groundwater monitoring requirements for the burial grounds from interim status monitoring to final status monitoring. As part of the application, new groundwater monitoring wells, constituents, and statistical evaluations are proposed. Workshops with Ecology to address this application are in progress.

The groundwater flow in this portion of the 200 West Area is generally to the east (90 degrees) with a calculated gradient of 0.002. The flow direction is affected to a large degree by the 200-ZP-1 pump-and-treat system, which has extraction wells to the east and injection wells to the west of this RCRA site. The estimated flow rate at Low-Level Waste Management Area 4 using this gradient is 0.02 to 0.5 meter per day (see Appendix B).

Downgradient well 299-W15-16 continued to exceed the statistical comparison value for total organic halides in the January 2004 sample. The well could not be sampled in June 2004 due to declining water levels. This well was originally an upgradient well under past flow conditions and is still affected by contamination from sources in or near the 216-Z cribs and trenches. DOE reported the exceedance to the U.S. Environmental Protection Agency and Ecology in August 1999. The elevated total organic halide concentrations are consistent with observed levels of carbon tetrachloride from Plutonium Finishing Plant operations (see Section 2.8.1.1). Carbon tetrachloride and other volatile organic compounds were detected in the trenches and vadose zone within Low-Level Waste Management Area 4 during FY 2002. Investigation of the vadose zone is ongoing in FY 2004 as part of the 200-PW-1 Operable Unit. Statistical comparison values for use in FY 2005 are listed in Appendix B.

Performance assessment monitoring of radionuclides at Low-Level Waste Management Area 4 is designed to complement the RCRA detection monitoring. The current goal of performance assessment monitoring at Low-Level Waste Management Area 4 is to gather data to assess changes in concentrations at downgradient wells using statistical tests and to provide sufficient supporting information from upgradient wells to interpret the changes. Under the current monitoring plan (DOE/RL-2000-72), technetium-99, iodine-129, and uranium are monitored specifically for performance assessment.

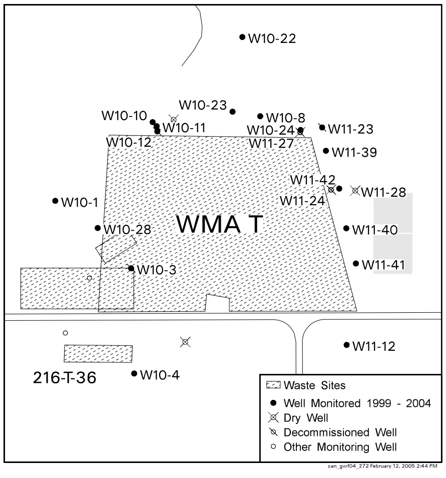
Contaminant characteristics at Low-Level Waste Management Area 4 include the following:

- Technetium-99 concentrations remained slightly elevated in two wells on the west (upgradient) of Low-Level Waste Management Area 4 (wells 299-W15-15 and 299-W18-23). Technetium-99 concentrations were all <150 pCi/L. As discussed in Section 2.8.1.9, this occurrence may result at least in part from technetium-99 in water injected by the 200-ZP-1 pump-and-treat system. However, the concentrations are over one-third the highest technetium-99 concentration in any extraction well. This, and the distance of the wells in question from the injection wells, suggests that part of the technetium-99 may be from upgradient. Technetium-99 may have moved to the west under past flow conditions and be re-entering the area under present flow conditions.

- Uranium concentrations are elevated in upgradient well 299-W18-21 in the southwest corner of the waste management area. Concentrations were just over the 30 µg/L drinking water standard in the January sample but less than the drinking water standard in July.
- Iodine-129 was not detected in Low-Level Waste Management Area 4 wells. The minimum detectable activity is ~0.3 pCi/L.
- Tritium levels were all less than the drinking water standard.
- Nitrate continues to exceed the drinking water standard at many monitoring wells in Low-Level Waste Management Area 4. This contamination is not believed to be related to waste disposal at the burial grounds. Some of the nitrate contamination is related to injection of 200-ZP-1 treated water upgradient of the burial ground. The treatment system does not remove nitrate from the water.
- In the southwest corner of Low-Level Waste Management Area 4, upgradient monitoring well 299-W18-21 has slowly increasing nitrate concentrations that have not been associated with the large contaminant plumes of the 200 West Area. The FY 2004 average nitrate concentration in this well was 112 mg/L.
- Carbon tetrachloride and associated trichloroethene and chloroform in the groundwater beneath Low-Level Waste Management Area 4 are consistent with regional plumes as shown in Sections 2.8.1.1, 2.8.1.2, and 2.8.1.3. Investigation of carbon tetrachloride in the vadose zone at Low-Level Waste Management Area 4 is continuing.

2.8.3.3 Waste Management Area T

Waste Management Area T is located in the north-central part of the 200 West Area and consists of the T Tank Farm and ancillary equipment (e.g., diversion boxes and pipelines). The tank farm contains twelve 2-million-liter tanks and four 208,000-liter tanks constructed between 1943 and 1944. Seven of the tanks in the waste management area are known or suspected to have leaked. This section describes groundwater monitoring at Waste Management Area T. A well location map and a table of wells and analytes for this waste management area are included in Appendix B. Section 3.1.2 discusses vadose zone characterization at the waste management area.



The objective of RCRA groundwater monitoring at Waste Management Area T is to assess the extent and rate of movement of dangerous waste in groundwater that have a source from the waste management area [40 CFR 265.93(d) as referenced by WAC 173-303-400]. The current groundwater assessment plan is PNNL-12057 and PNNL-12057-ICN-1. In addition to monitoring dangerous waste constituents for RCRA assessments, the site is monitored for CERCLA and AEA purposes. Waste Management Area T was originally placed in RCRA assessment monitoring because of elevated specific conductance in downgradient well 299-W10-15 (WHC-SD-EN-AP-132). However, it remained in assessment because of contaminants observed in downgradient well 299-W11-27 (PNNL-11809). Dangerous waste constituents found beneath Waste Management Area T in FY 2004 are chromium and nitrate. Other non-RCRA constituents found beneath the waste management area in FY 2004 include carbon tetrachloride, trichloroethene, tritium, and technetium-99. These constituents are attributed to Plutonium Finishing Plant operations and are discussed in Sections 2.8.1.1 and 2.8.1.2. The tritium is believed to be part of a large regional plume and is not attributed to the T Tank Farm. The technetium-99 plume, located east (downgradient) of the T Tank Farm, is attributed to the tank farm.

Calculated average linear flow velocities in wells at Waste Management Area T range from 0.017 to 0.28 meter per day with most values <0.1 meter per day. Groundwater flow direction beneath the waste management area is between 85 and 98 degrees from north as determined by trend surface analyses (PNNL-13378; PNNL-14113).

The monitoring network for Waste Management Area T includes eleven wells that are sampled quarterly and two wells sampled semiannually. Two new RCRA assessment monitoring wells (Figure 2.8-1) are planned to be installed in calendar year 2005. The first new well, 299-W11-25, is to assess the vertical extent of contamination near the northeast corner of the waste management area and will be drilled to 36 meters below the water table. The second new well has not been assigned a name. This second well will be ~75 meters downgradient of the waste management area and will assess the horizontal extent of contamination. The location and design for these wells were determined in Data Quality Objectives workshops with the regulatory agencies (CP-15329).

A plume map depicting the FY 2004 average chromium concentration in wells near the Waste Management Area T is shown in Figure 2.8-7. The map shows that chromium is elevated in several wells at the waste management area. The highest concentrations in FY 2004 were in upgradient well 299-W10-28 (average 270 μg/L) and well 299-W10-4 (average 460 μg/L) located south of the waste management area. The chromium concentration in FY 2004 also exceeded the drinking water standard in two downgradient wells, 299-W11-41 (average 150 μg/L) and 299-W11-42 (average 150 μg/L). The chromium concentration increased in all wells that exceed the drinking water standard (100 μg/L) during FY 2004. The largest increase was in well 299-W10-4, where the chromium concentration increased from 347 μg/L at the end of FY 2003 to 686 μg/L at the end of FY 2004.

The fluoride concentration, which had exceeded the primary drinking water standard (4 mg/L) in FY 2003, decreased to average less than 4 mg/L in all wells during 2004 (see Figure 2.8-8). Two wells had individual results above the standard. Well 299-W10-23 had a maximum concentration of 4.1 mg/L and well 299-W10-8 had a maximum concentration of 4.6 mg/L.

Nitrate concentration exceeded the drinking water standard of 45 mg/L in all wells in the waste management area monitoring network in FY 2004. Figure 2.8-6 shows a plume map for nitrate in the area. Nitrate concentrations remained fairly level in most wells at the waste management area during FY 2004. Nitrate concentrations increased, however, in three wells. By far the largest increase in nitrate concentration during the fiscal year was in well 299-W10-4 (Figure 2.8-14). Smaller increases in nitrate concentration were noted in downgradient wells 299-W11-41 and 299-W11-42. These latter two wells are downgradient of well 299-W10-4, and the most likely source for the increasing nitrate downgradient of Waste Management Area T is the source for the high nitrate in well 299-W10-4. A more detailed discussion of nitrate contamination in the north central part of 200 West Area is given in Section 2.8.1.4.

Tritium exceeded the interim drinking water standard (20,000 pCi/L) in one well, 299-W11-12, at Waste Management Area T. The well is located at the southwest corner of the waste management area, and the source of the tritium encountered at that location is thought to be farther south near the TX and TY Tank Farms. A more detailed discussion of tritium in the groundwater beneath the north part of 200 West Area is in Section 2.8.1.7.

Technetium-99 concentrations increased in four wells downgradient of Waste Management Area T in FY 2004.

Technetium-99 exceeded the interim drinking water standard (900 pCi/L) in five downgradient wells at Waste Management Area T in FY 2004. The technetium-99 concentration remained fairly level throughout the year in well 299-W10-24, located at the northeast corner of the waste management unit where the technetium-99 plume was first detected in late 1995 (in well 299-W11-27, now dry). The technetium-99 concentration increased in all four downgradient wells south of well 299-W10-24 during FY 2004. The largest increase and the highest concentrations are in well 299-W11-39 where the technetium-99 concentration increased from 9,140 pCi/L at the end of FY 2003 to 21,400 pCi/L at the end of FY 2004.

In 1998, a vertical profile of technetium-99 concentration was made in well 299-W10-24, located ~30 meters northwest of well 299-W11-39. That profile showed that the highest technetium-99 concentration was near the water table and that the concentration decreased with depth in the aquifer. This suggests that the technetium-99 concentration in well 299-W11-39 may be greater than 21,400 pCi/L because of dilution with low technetium-99 bearing water from deeper in the aquifer. However, the situation is complicated by vertical changes in the formation permeability in the well screen interval. A tracer dilution test by Spane et al. (PNNL-14113) showed very little dispersion of the tracer in the lowermost two electrodes in well 299-W11-39, which was interpreted as "stagnant" lateral flow, or low permeability conditions, in the lowermost ~2.5 meters of the well screen section. Figure 2.8-15 shows technetium-99 concentration trends with time at selected Waste Management Area T wells.

In 1998, Hodges (PNNL-11809) used tritium/technetium-99 and nitrate/technetium-99 ratios from groundwater samples in the area of Waste Management Area T to distinguish waste disposed to cribs and trenches in the area of the waste management area from evaporator condensate waste and waste discharged from the Plutonium Finishing Plant. In 2004, similar ratios were used to compare contaminant concentrations in groundwater, tank fluids leaked from tanks T-106 and T-101, and effluent compositions disposed to cribs and trenches in the T Tank Farm area. This was done to support the Waste Management Areas T and TX-TY field investigation report (PNNL-14849). That report found that the groundwater concentrations for technetium-99 and chromium behave quite differently at different areas around Waste Management Area T. The concentrations of both constituents track each other through time in upgradient wells at the waste management area (Figure 2.8-15a). The same relationship holds for wells north of the waste management area (Figure 2.8-15b). The technetium-99/chromium concentration relationship is different in wells located at the northeast corner of the waste management area (Figure 2.8-15c) and on the east, or downgradient, side of the waste management area (Figure 2.8-15d) where the two constituents do not track each other.

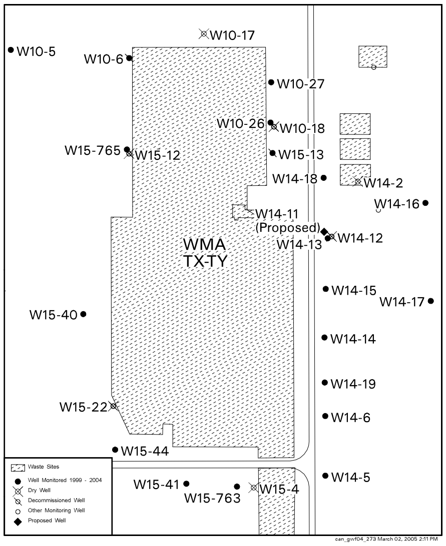
The most likely source for the chromium at Waste Management Area T is one or more of the cribs and trenches west and southwest of the tank farm.

Figure 2.8-16 shows the technetium-99/chromium groundwater concentration ratios versus time for samples from selected wells at Waste Management Area T. The figure also shows the concentration ratios expected in the leaked tank waste from tanks T-101 and T-106 (RPP-7218) and the waste disposed to the cribs and trenches located west of Waste Management Area T (BHI-01496): 216-T-5, 216-T-7, and 216-T-32. The data plotted in Figure 2.8-16a show that the technetium-99/chromium ratio in samples from upgradient wells has a signature similar to the upgradient crib and trench disposal sites. Figure 2.8-16b shows that samples from wells north of the waste management area have a similar composition as those from upgradient wells. This information, and the information in Figure 2.8-15, suggest that the contamination detected in wells north of Waste Management Area T in the late 1990s is similar to that found upgradient of the waste management area today and is dominated by crib waste.

Figure 2.8-16c suggests a different source for the contamination at the northeast corner of Waste Management Area T. A technetium-99, chromium, nitrate, and tritium plume was first detected in this area in well 299-W11-27 in early 1996. Since that time, the technetium-99/chromium composition of the groundwater in that well has evolved toward tank waste compositions. Three other wells in the area also have tank waste compositions. The technetium-99/chromium ratios greater than the estimated tank waste ratios are similar to data from vadose zone pore water collected from the tank T-106 leak plume and probably reflect the slight retardation of chromium relative to technetium-99 (PNNL-14849).

At the beginning of monitoring the wells east of Waste Management Area T in 1997, the technetium-99/chromium ratios for groundwater in that area were the same as those from upgradient wells and wells at the northeast corner of the waste management area (Figure 2.8-16d). More recent samples from the east wells indicate that the tank waste initially identified at the northeast corner of the waste management area is now found along the east edge of the waste management area and mixing with the crib waste that was initially sampled in the east wells. This is coincident with a shift in groundwater flow direction from toward the north before 1997 to toward the east or slightly southeast after 1997.

2.8.3.4 Waste Management Area TX-TY



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Waste Management Area TX-TY is located in the north-central part of the 200 West Area and consists of the TX and TY Tank Farms and ancillary equipment (e.g., diversion boxes and pipelines). The tank farms contain twenty-four 2.9-million-liter tanks constructed between 1944 and 1952. Twelve of the tanks in the waste management area are known or suspected to have leaked. A well location map and a table of wells and analytes for this waste management area are shown in Appendix B.

Waste management Area TX-TY was originally placed in RCRA assessment monitoring (40 CFR 265.93(d) as referenced by WAC 173-303-400) because of elevated specific conductance in downgradient wells 299-W10-27 and 299-W14-12 (WHC-SD-EN-AP-132). The current groundwater assessment plan is PNNL-12072 and PNNL-12072-ICN-1. The objective of RCRA groundwater monitoring at Waste Management Area TX-TY is to assess the extent and rate of movement of dangerous waste in groundwater that have a source from the waste management area. In addition to monitoring dangerous waste constituents for RCRA assessments, the site is monitored for AEA and CERCLA.

The monitoring network for Waste Management Area TX-TY includes sixteen wells that are sampled quarterly. Well 299-W14-5, which is located southeast of the waste management area, went dry in May 2004. One new RCRA assessment monitoring well, 299-W14-11 (Figure 2.8-1), is planned to be installed during calendar year 2005. The new well is to assess the vertical extent of contamination downgradient of the waste management area and will be drilled to 36 meters below the water table. The location and design of the new well were determined in Data Quality Objectives workshops with the regulatory agencies (CP-15329).

Calculated average linear flow velocities in wells at Waste Management Area TX-TY range from 0.0007 to 2.46 meters per day with most values <0.1 meter per day. Groundwater flow velocities as determined from aquifer tracer tests range between 0.191 and 1.1 meter per day (PNNL-13378; PNNL-14113; PNNL-14186). Groundwater flow direction varies beneath the site. Trend surface analysis for the northeast part of the waste management area, at the TY Tank Farm, shows a groundwater flow direction of 108 degrees, or to the east-southeast (PNNL-13378). Farther south, along the downgradient side of the TX Tank Farm, groundwater flow direction changes from 108 degrees at well 299-W14-13 to 133 degrees (southeast) at well 299-W14-14 (PNNL-13378; PNNL-14311; PNNL-14186). South of Waste Management Area TX-TY, groundwater flow direction, as determined by water-level measurements, is toward the south or southwest. The change in flow direction at Waste Management Area TX-TY is due to the 200-ZP-1 pump-and-treat system extraction wells located south of the waste management area. In the north part of the waste management area, flow direction generally follows the pre-Hanford Site direction of east to southeast.

Dangerous waste constituents found beneath Waste Management Area TX-TY in FY 2004 are chromium and nitrate. Other non-RCRA constituents found beneath the waste management area in 2004 include carbon tetrachloride, trichloroethene, tritium, technetium-99, and iodine-129. The carbon tetrachloride and trichloroethene are attributed to Plutonium Finishing Plant operations and are discussed in Sections 2.8.1.1 and 2.8.1.2.

Nitrate concentrations exceeded the drinking water standard (45 mg/L) in all wells in the Waste Management Area TX-TY monitoring network in FY 2004. Figure 2.8-6 shows a plume map for nitrate in the area. The highest nitrate concentration at the waste management area was 580 mg/L at the end of the FY 2004 (August) in well 299-W14-13. This was an increase from 394 mg/L at the end of the previous fiscal year. Much of the nitrate contamination at Waste Management Area TX-TY is attributed to Plutonium Finishing Plant operations as well as past-practice disposal to cribs and trenches in the area. Some nitrate contamination may be from Waste Management Area TX-TY,

Waste Management Area TX-TY may have contributed to chromium and radionuclide contamination in groundwater.

although distinguishing the different sources is extremely difficult. More discussion of nitrate in north-central 200 West Area is given in Section 2.8.1.4.

Chromium was detected above the drinking water standard (100 µg/L) only in well 299-W14-13 at Waste Management Area TX-TY during FY 2004. Figure 2.8-17 shows a time series plot for chromium concentration in the well. The figure shows that the chromium concentration increased substantially during FY 2004 from 540 µg/L in August 2003 to 733 µg/L in August 2004. Chromium concentrations in wells adjacent to well 299-W14-13 were all less than the drinking water standard during the fiscal year indicating that the chromium contamination is limited to the area of well 299-W14-13. The most likely source for the chromium in well 299-W14-13 is assumed to be Waste Management Area TX-TY because no alternative sources have been identified.

Tritium exceeded the interim drinking water standard (20,000 pCi/L) in two wells at Waste Management Area TX-TY. The tritium concentration in well 299-W14-13 in August 2004 was 1.82 million pCi/L, which is up from 1.62 million pCi/L at the end of FY 2003. Tritium also exceeded the interim drinking water standard in well 299-W14-15, located ~50 meters south of well 299-W14-13. The tritium concentration in the well at the end of FY 2003 was 38,500 pCi/L. The tritium concentration decreased during the first three quarters of FY 2004 to 23,100 pCi/L before increasing to 59,800 pCi/L in the last quarter of the fiscal year. The relatively large increase during the last part of the year may indicate that the contamination in well 299-W14-13 is now being encountered in well 299-W14-15 or may represent local fluctuations at well 299-W14-15. However, nitrate increased by 151 mg/L, technetium-99 increased by 266 pCi/L, and iodine-129 was detected for the first time since February 2003 very near the detection limit at 2.67 pCi/L in well 299-W14-15 during the last quarter of FY 2004. These changes are shown on Figure 2.8-18.

The source for the high tritium in well 299-W14-13 could be Waste Management Area TX-TY, the 242-T Evaporator, the 216-T-19 crib and tile field (which received evaporator condensate from the 242-T Evaporator), the 216-T-26 through 216-T-28 cribs, or a combination of these potential sources.

Technetium-99 exceeded the interim drinking water standard (900 pCi/L) in one well (299-W14-13) at Waste Management Area TX-TY in FY 2004. The technetium-99 concentration increased throughout the year from 7,910 pCi/L in August 2003 to 9,080 pCi/L in August 2004. This increase is part of a long-term trend. Figure 2.8-19 is a trend plot for technetium-99 in well 299-W14-13. The source for the technetium-99 in well 299-W14-13 could be Waste Management Area TX-TY or one of the past-practice disposal facilities in the area or both.

Iodine-129 was detected in two wells at Waste Management Area TX-TY during FY 2004. The highest iodine-129 concentration measured at the waste management area during the reporting periods was 24.8 pCi/L in the February 2004 sample from well 299-W14-13 (Figure 2.8-20). The interpretation of the iodine-129 data is hampered by several things. First, the preparation method for iodine-129 analyses was changed between May and August 2004. Second, relatively high non-detect values occurred periodically using the pre-May sample preparation method. Often non-detect values were as great or greater than previous or subsequent detectable values. Third, there is apparent poor precision associated with the new preparation method (16.2 and 28.6 pCi/L in the May 2004 duplicates). All of these factors make interpretation of the iodine-129 data difficult. The groundwater project is working to resolve these problems (see Appendix C).

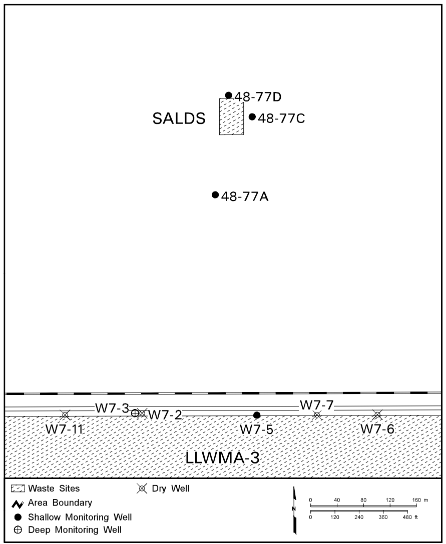
Iodine-129 was detected in a single sample from well 299-W14-15 with a concentration of 2.67 pCi/L in August 2004. This is the first detectable iodine-129 in the well since February 2003 (Figure 2.8-21).

2.8.3.5 Groundwater Monitoring for the State-Approved Land Disposal Site

The Hanford Site 200 Area Effluent Treatment Facility processes contaminated aqueous waste from Hanford Site facilities. The treated wastewater occasionally contains tritium, which is not removed by the Effluent Treatment Facility, and is discharged to the 200 Area State-Approved Land Disposal Site. During FY 2004 (through July 31) 70.3 million liters of water were discharged to the State-Approved Land Disposal Site as documented in the annual report for the site (WMP-22329).

The State-Approved Land Disposal Site is used for disposal of treated water that occasionally contains tritium.

A state waste discharge permit (WAC 173-216) requires groundwater monitoring at this site. The permit was granted in June 1995, and the site began to operate in December 1995. Groundwater monitoring requirements are described in the site monitoring plan (PNNL-13121). Groundwater monitoring for tritium only is conducted in 19 wells near the facility (Appendix B). The permit stipulates requirements for groundwater monitoring and establishes enforcement limits for concentrations of 15 constituents in 3 additional wells immediately surrounding the facility (Appendix B, Table B.44).



Wells immediately surrounding the facility were sampled in October 2003, and January, April, and September 2004 (see Appendix B). Tritium-tracking wells were sampled in January, March, April, and September 2004, although some of these events were scheduled for the 200-ZP-1 Operable Unit monitoring. Water-level measurements in three wells nearest the State-Approved Land Disposal Site indicate the continuation of a small hydraulic mound beneath the site as a result of discharges. This feature is directing groundwater flow radially outward a short distance before the regional northeastward flow predominates. This condition also places several wells south of the State-Approved Land Disposal Site hydraulically downgradient of the facility.

Many of the wells south of the State-Approved Land Disposal Site in the tritium-tracking network have gone dry. Specifically, wells 299-W7-1, 299-W7-6, 299-W7-7, 299-W7-9, and 299-W6-7 have gone dry in the past few years.

Average tritium concentrations decreased in all three State-Approved Land Disposal Site proximal wells during FY 2004 compared with FY 2003 (Figure 2.8-22; see also Figure 2.8-9 for tritium distribution contours). During FY 2004, maximum tritium concentrations for State-Approved Land Disposal Site proximal wells were 116,000 pCi/L in well 699-48-77A (April 2004), 229,000 pCi/L in well 699-48-77C (October 2003), and 95,000 pCi/L in well 699-48-77D (April 2004). Fluctuations in tritium concentrations in well 699-48-77A probably reflect changes in the amount of tritium in the discharge.

Concentrations of all chemical constituents with permit limits were within those limits during all of FY 2004. Benzene, tetrahydrofuran, copper, and mercury were below method detection limits in all samples. Lead and cadmium produced detectable concentrations of 2.3 and 0.085 μg/L, respectively, from the April 2004 sample of well 699-48-77A. Concentrations of major cations and anions continued below background concentrations observed prior to operation of the facility. This condition is due to dilution by the clean water discharged to the State-Approved Land Disposal Site.

Average tritium concentrations decreased in all three proximal wells at the State-Approved Land Disposal Site during FY 2004.

Hydraulic head in March 2004 (Figure 2.8-2) changed very little from that of March 2003 in the vicinity of the State-Approved Land Disposal Site. Head in well 699-48-77A for March 2004 was ~0.24 meter higher than for the same period in 2003, but this well responds rapidly to changes in discharge from the facility, and the overall trend for head remains downward.

Numerical flow-and-transport modeling of the State-Approved Land Disposal Site was conducted in August 2004, as required by the permit. Results of this model are summarized in Chapter 4.0.

Table 2.8-1. Contaminants of Concern in all Wells in the 200-ZP-1 Groundwater Interest Area

Constituent	Filtered	Wells	Results	Detects	Rejects	Minimum	Maximum	Average	Action Level	Action Level Source	Results Above Standard	Wells Above Standard
1,1,1-Trichloroethane, µg/L	N	46	109	8	0	0.19	1.2	0.44	200	MCL		
1,2-Dichloroethane, µg/L	N	46	109	5	0	0.089	0.22	0.14	5	CRDL		
2-Butanone, µg/L	N	46	130	1	0	1.4	1.4	1.40	4,800	CLARC		
4-Methyl-2-pentanone, µg/L	N	46	109	3	0	0.35	0.93	0.54	640	CLARC		
Acetone, µg/L	N	46	130	37	0	0.67	8.2	1.75	800	CLARC		
Antimony, µg/L	N	7	22	0	0	--	--	--	10	CRDL		
Antimony, µg/L	Y	31	166	3	1	40.9	46.2	43.77	10	CRDL	3	3
Arsenic, µg/L	Y	9	14	3	0	1.8	10	6.63	10	CRDL		
Benzene, µg/L	N	46	124	0	0	--	--	--	5	CRDL		
Cadmium, µg/L	N	7	28	1	0	0.085	0.085	0.09	5	MCL		
Cadmium, µg/L	Y	31	166	2	1	2.1	2.5	2.30	5	MCL		
Carbon disulfide, µg/L	N	46	109	8	0	0.24	2	0.78	800	CLARC		
Carbon tetrachloride, µg/L	N	46	200	180	7	0.19	9,700	2,001	3	CRDL	116	46
Carbon tetrachloride, µg/L	Y	2	11	0	0	--	--	--	3	CRDL		
Carbon-14, pCi/L	N	5	6	3	0	5.34	8.66	6.75	2,000	MCL		
Cesium-137, pCi/L	N	9	28	0	0	--	--	--	60	MCL		
Chlorobenzene, µg/L	N	6	19	0	0	--	--	--	100	MCL		
Chloroform, µg/L	N	46	200	175	0	0.075	82.3	15.47	7	CLARC	85	30
Chloroform, µg/L	Y	2	11	0	0	--	--	--	7	CLARC		
Chromium, µg/L	N	7	22	19	0	7.4	76.8	25.78	100	MCL		
Chromium, µg/L	Y	31	166	124	1	3.5	733	82.67	100	MCL	23	6
cis-1,2-Dichloroethene, µg/L	N	46	109	6	0	0.07	0.12	0.11	70	MCL		
Cyanide, µg/L	N	6	11	2	0	6	12.3	9.15	200	MCL		
Ethylbenzene, µg/L	N	46	107	1	0	0.2	0.2	0.20	700	MCL		
Fluoride, µg/L	N	47	208	208	0	170	4,600	864	4,000	MCL	2	2
Fluoride, µg/L	Y	1	3	3	1	260	1,300	920	4,000	MCL		
Hexavalent chromium, µg/L	N	3	3	3	0	3	8	6.00	48	CLARC		

Table 2.8-1. (contd)

Constituent	Filtered	Wells	Results	Detects	Rejects	Minimum	Maximum	Average	Action Level	Action Level Source	Results Above Standard	Wells Above Standard
Hexavalent chromium, µg/L	Y	8	9	8	0	4.4	75.9	22.04	48	CLARC	1	1
Iodine-129, pCi/L	N	27	78	8	2	0.765	26.8	12.61	1	MCL	5	3
Iron, µg/L	N	7	22	19	0	71.3	509	183	300	2nd MCL	3	3
Iron, µg/L	Y	31	166	63	1	11	228	53.95	300	2nd MCL		
Lead, µg/L	N	1	13	1	0	2.3	2.3	2.30	15	MCL		
Lead, µg/L	Y	13	29	0	0	--	--	--	15	MCL		
Lithium, µg/L	Y	5	6	2	0	9.7	12.7	11.20	--	TBD		
Magnesium, µg/L	N	7	22	22	0	4,110	19,800	11,164	--	TBD		
Magnesium, µg/L	Y	31	166	166	1	4,260	136,000	21,967	--	TBD		
Manganese, µg/L	N	7	22	19	0	0.97	10.1	3.64	50	2nd MCL		
Manganese, µg/L	Y	31	166	142	1	1	239	10.49	50	2nd MCL	4	1
Mercury, µg/L	N	1	13	0	0	--	--	--	2	MCL		
Mercury, µg/L	Y	13	29	0	0	--	--	--	2	MCL		
Methylene chloride, µg/L	N	46	130	27	0	0.31	5	1.37	5	MCL		
n-Butylbenzene, µg/L	N	6	7	0	0	--	--	--	320	CLARC		
Neptunium-237, pCi/L	N	5	6	0	0	--	--	--	15	MCL		
Nickel, µg/L	N	7	22	8	0	14.8	32.3	18.79	320	CLARC		
Nickel, µg/L	Y	31	166	17	1	10.1	63	23.09	320	CLARC		
Nitrate, µg/L	N	47	229	229	0	257	3,430,000	219,060	12,400	Background	193	69
Nitrate, µg/L	Y	1	3	3	1	4,870	96,900	64,023	12,400	Background	1	1
Nitrite, µg/L	N	47	208	8	1	32.8	1,250	310	3,268	MCL		
Nitrite, µg/L	Y	1	3	0	1	--	--	--	3,268	MCL		
Phenols (total):				0	0	--	--	--		TBD		
2,3,4,6-Tetrachlorophenol, µg/L	N	7	12	2	0	7.6	7.9	7.75				
2,4,5-Trichlorophenol, µg/L	N	7	12	0	0	--	--	--				
2,4,6-Trichlorophenol, µg/L	N	7	12	0	0	--	--	--				
2,4-Dichlorophenol, µg/L	N	12	18	0	0	--	--	--				

Table 2.8-1. (contd)

Constituent	Filtered	Wells	Results	Detects	Rejects	Minimum	Maximum	Average	Action Level	Action Level Source	Results Above Standard	Wells Above Standard
2,4-Dimethylphenol, µg/L	N	7	12	0	0	0	0	0				
2,4-Dinitrophenol, µg/L	N	7	12	0	0	0	0	0				
2,6-Dichlorophenol, µg/L	N	7	12	0	0	0	0	0				
2-Chlorophenol, µg/L	N	7	12	0	0	0	0	0				
2-Methylphenol (cresol, o-), µg/L	N	12	18	0	0	0	0	0				
2-Nitrophenol, µg/L	N	12	18	0	0	0	0	0				
2-secButyl-4,6-dinitrophenol (Dinoseb), µg/L	N	7	12	0	0	0	0	0				
3+4 Methylphenol (cresol, m+p), µg/L	N	12	18	0	0	0	0	0				
4,6-Dinitro-2-methylphenol, µg/L	N	7	12	0	0	0	0	0				
4-Chloro-3-methylphenol, µg/L	N	7	12	0	0	0	0	0				
4-Methylphenol (cresol, p-), µg/L	N	5	6	0	0	0	0	0				
4-Nitrophenol, µg/L	N	7	12	0	0	0	0	0				
Pentachlorophenol, µg/L	N	12	18	0	0	0	0	0				
Phenol, µg/L	N	12	23	0	0	0	0	0				
Protactinium-231, pCi/L	N	5	6	0	0	0	0	0	15	MCL		
Selenium-79, pCi/L	N	5	6	0	0	0	0	0		MCL		
Silver, µg/L	N	7	22	0	0	0	0	0	80	CLARC		
Silver, µg/L	Y	31	166	11	1	1.9	85	10.86	80	CLARC	1	1
Strontium-90, pCi/L	N	5	21		0	0	0	0	8	MCL		
Technetium-99, pCi/L	N	38	180	161	0	10.8	21,400	1,160	900	MCL	27	7
Technetium-99, pCi/L	Y	1	3	2	1	250	299	274	900	MCL		
Tetrachloroethene, µg/L	N	46	131	66	0	0.17	3	0.93	5	CRDL		
Tetrachloroethene, µg/L	Y	2	11	0	0	0	0	0	5	CRDL		
Toluene, µg/L	N	46	124	0	0	0	0	0	1000	MCL		
trans-1,2-Dichloroethene, µg/L	N	46	109	0	0	0	0	0	100	MCL		

Table 2.8-1. (contd)

Constituent	Filtered	Wells	Results	Detects	Rejects	Minimum	Maximum	Average	Action Level	Action Level Source	Results Above Standard	Wells Above Standard
Trichloroethene, µg/L	N	46	200	153	1	0.21	26	6.04	5	CRDL	49	18
Trichloroethene, µg/L	Y	2	11	0	0	0	0	0	5	CRDL		
Tritium, pCi/L	N	35	191	156	0	219	1,830,000	71,392	20000	MCL	28	9
Tritium, pCi/L	Y		2	0	0	0	0	0	20000	MCL		
Uranium, µg/L	N	20	46	46	0	0.0877	250	13.45	30	MCL	4	2
Vanadium, µg/L	N	7	22	22	0	16.4	63.8	37.30	112	CLARC		
Vanadium, µg/L	Y	31	166	165	1	5.9	77.7	30.57	112	CLARC		
Xylenes (total), µg/L	N	46	109	0	0	0	0	0	10000	MCL		

CLARC = Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation (Ecology 2001).
CRDL = Contract-required detection limit.
MCL = Maximum contaminant level.
TBD = To be determined.

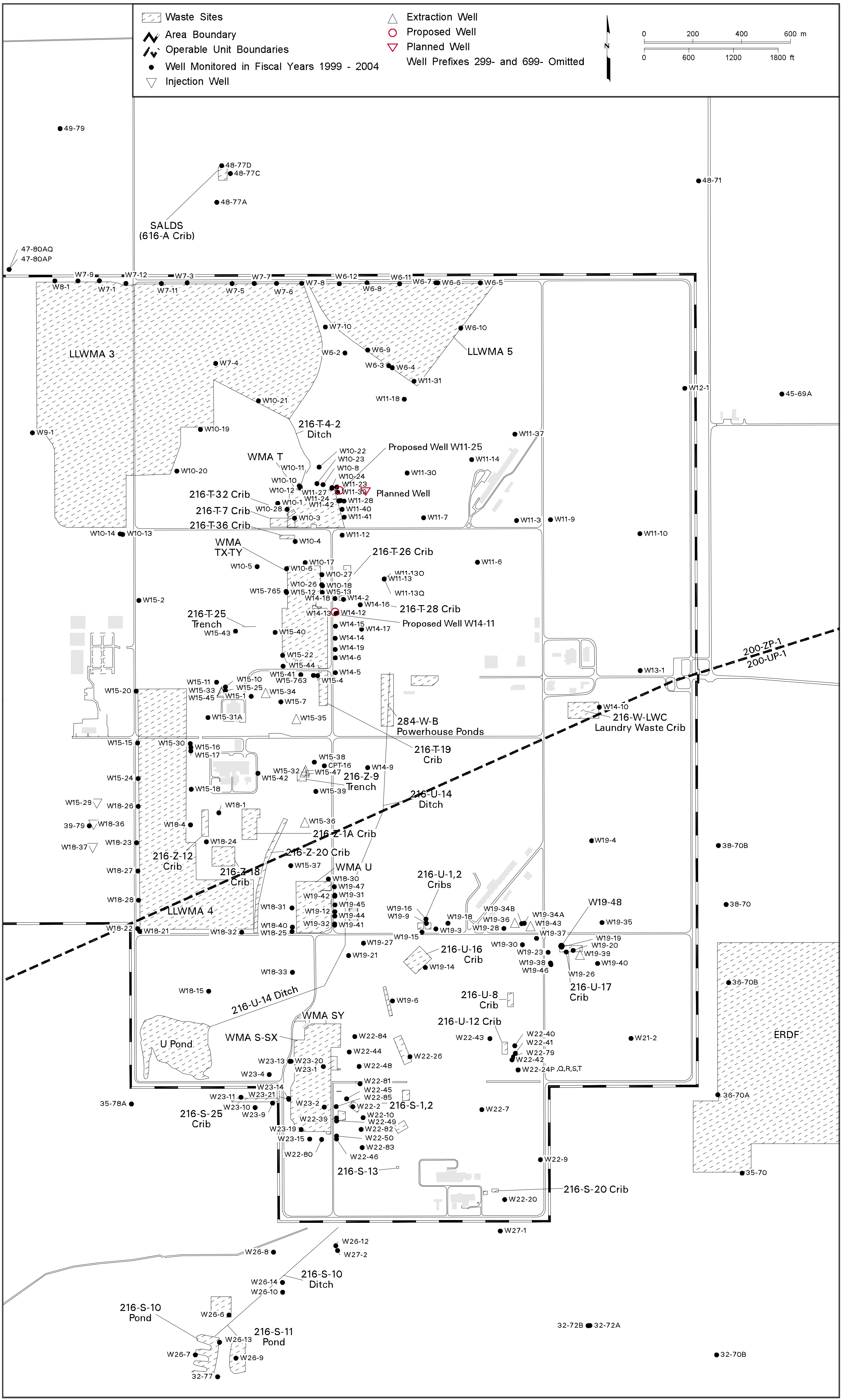


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Figure 2.8-1. Groundwater Monitoring Wells in the 200 West Area

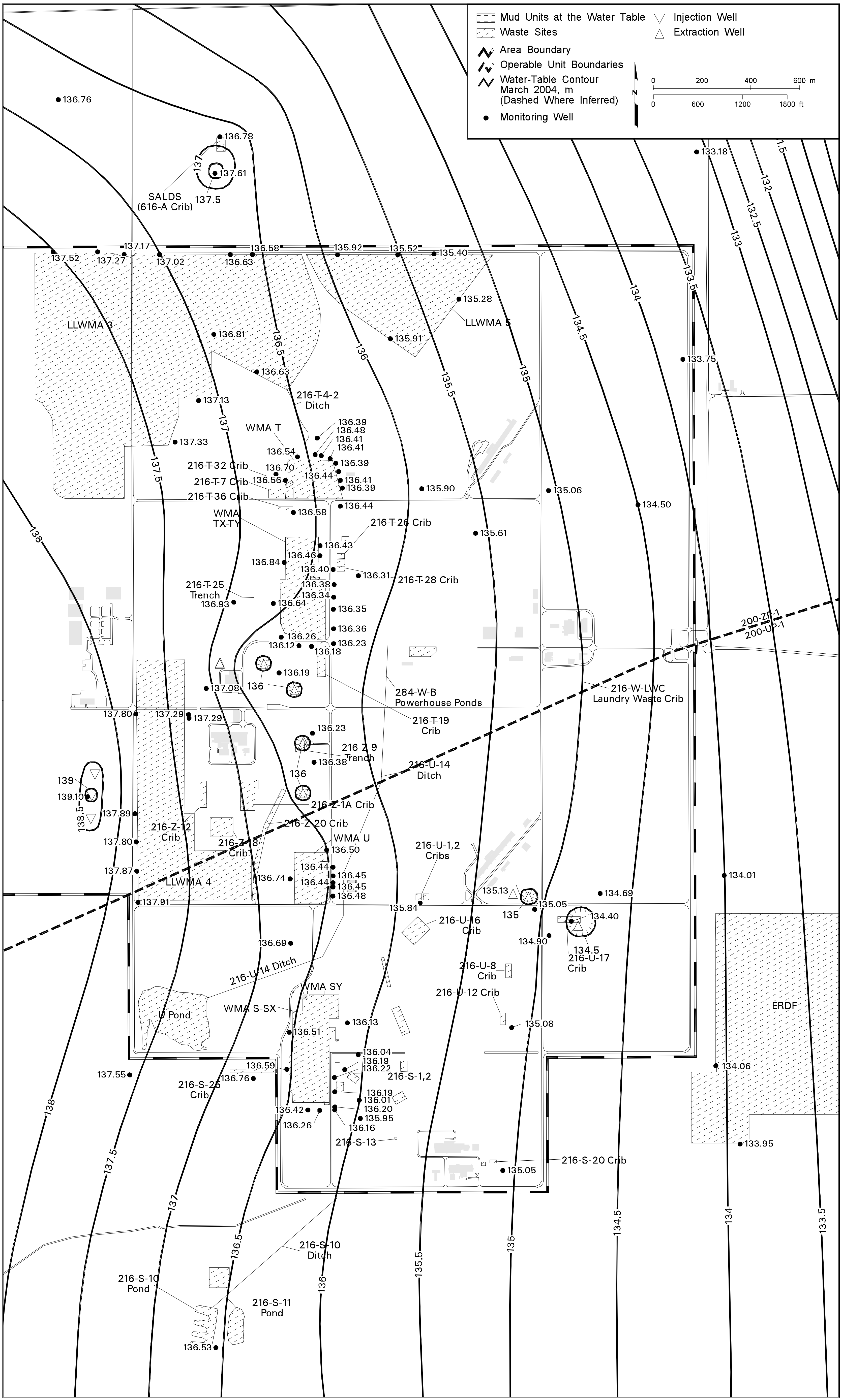

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Figure 2.8-2. Water-Table Contours in the 200 West Area

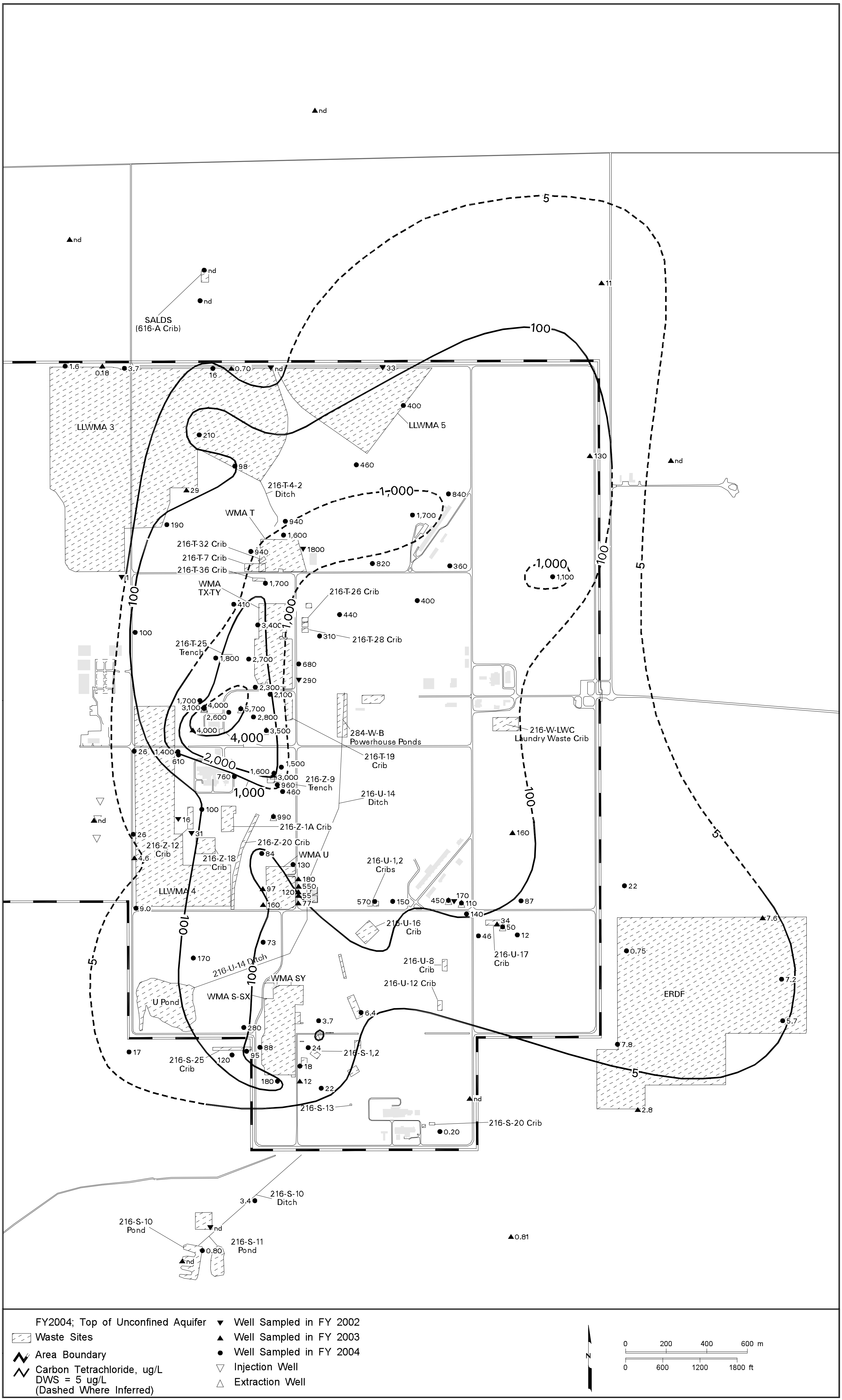

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Figure 2.8-3. Average Carbon Tetrachloride Concentrations in 200 West Area, Top of Unconfined Aquifer

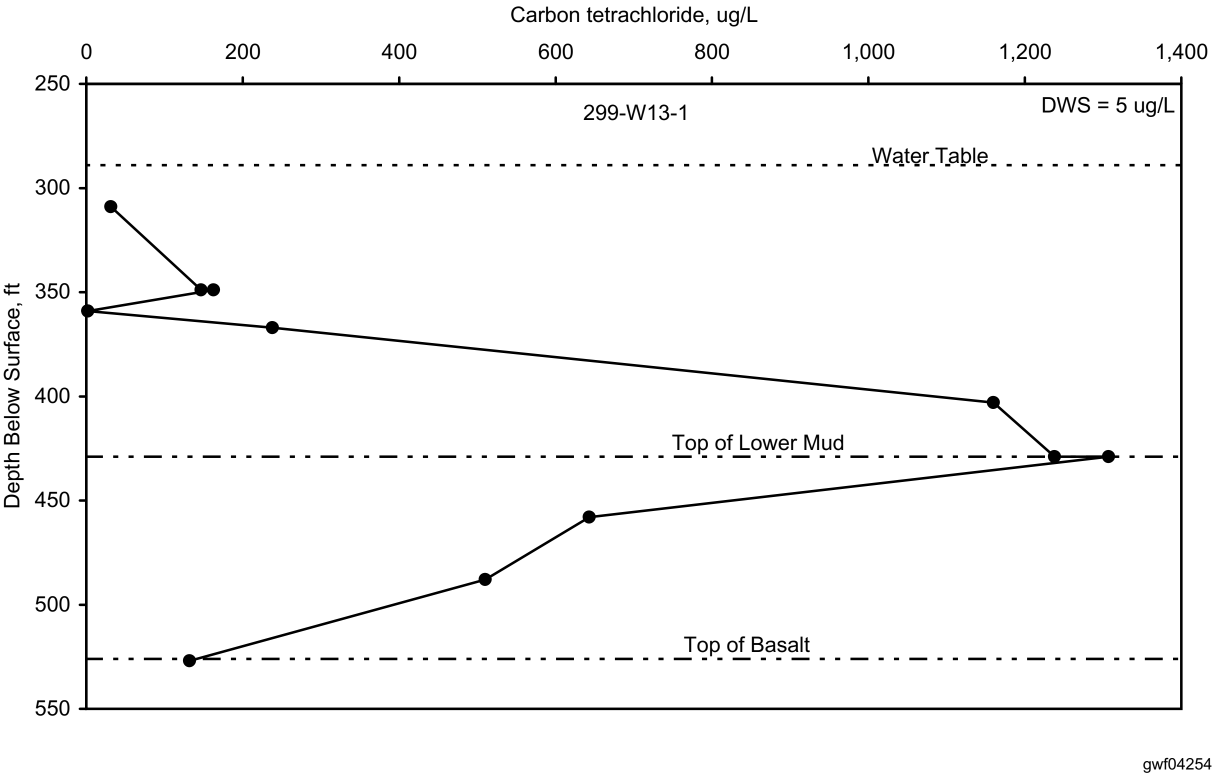

Figure 2.8-4. Carbon Tetrachloride Concentration with Depth during Drilling of Well 299-W13-1

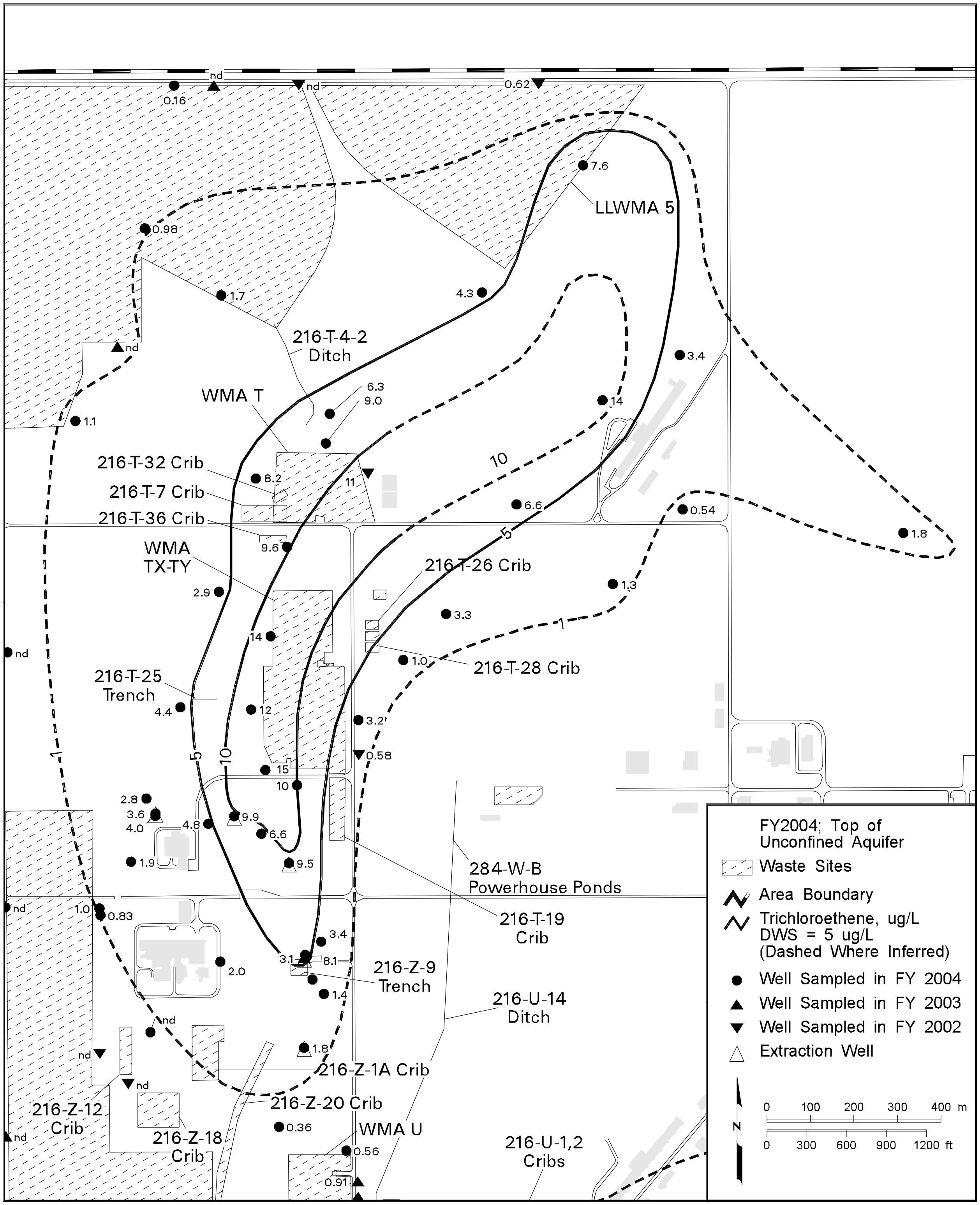

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Figure 2.8-5. Average Trichloroethene Concentrations in Central and North 200 West Area, Top of Unconfined Aquifer

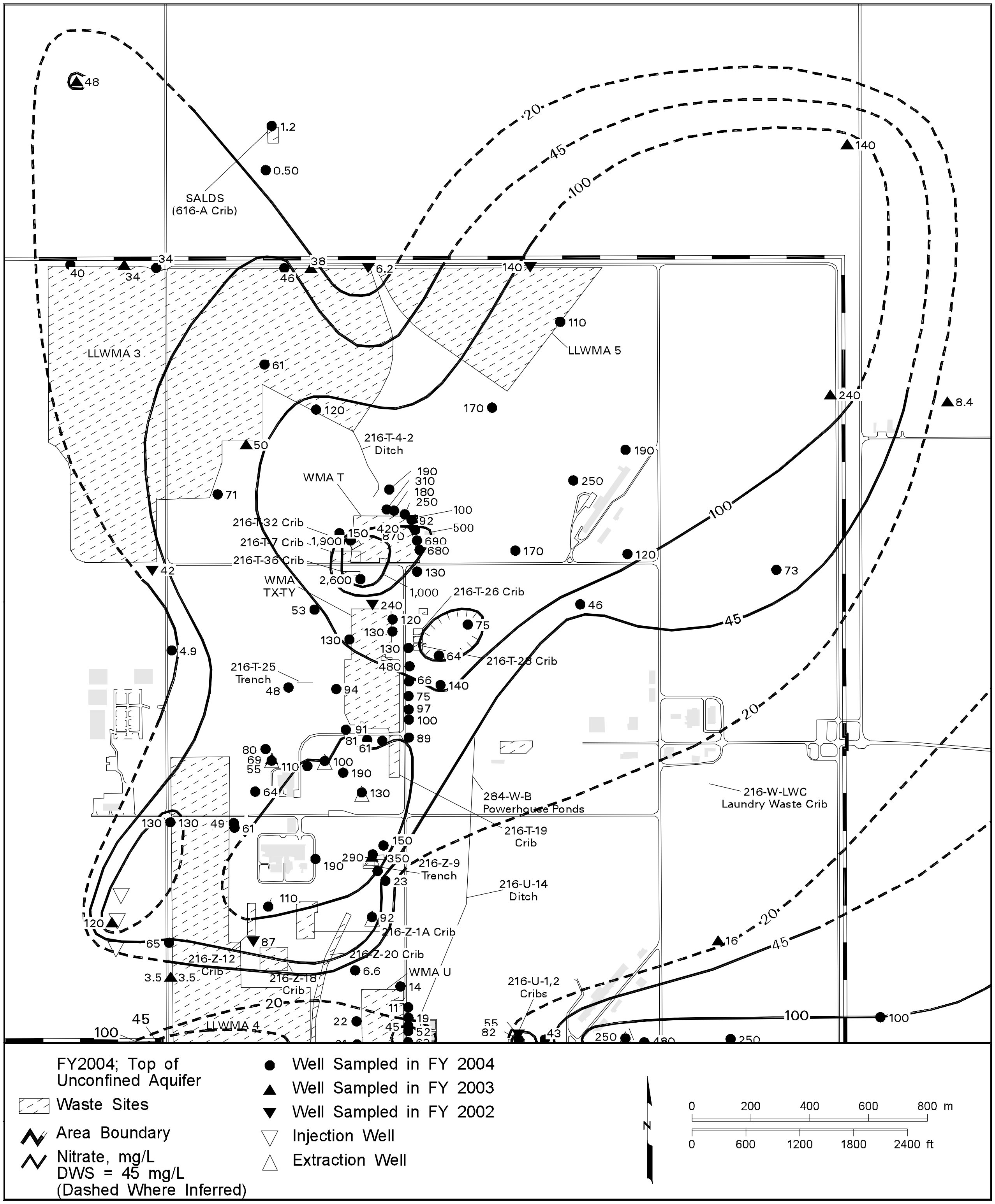

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Figure 2.8-6. Average Nitrate Concentrations in Central and North 200 West Area, Top of Unconfined Aquifer

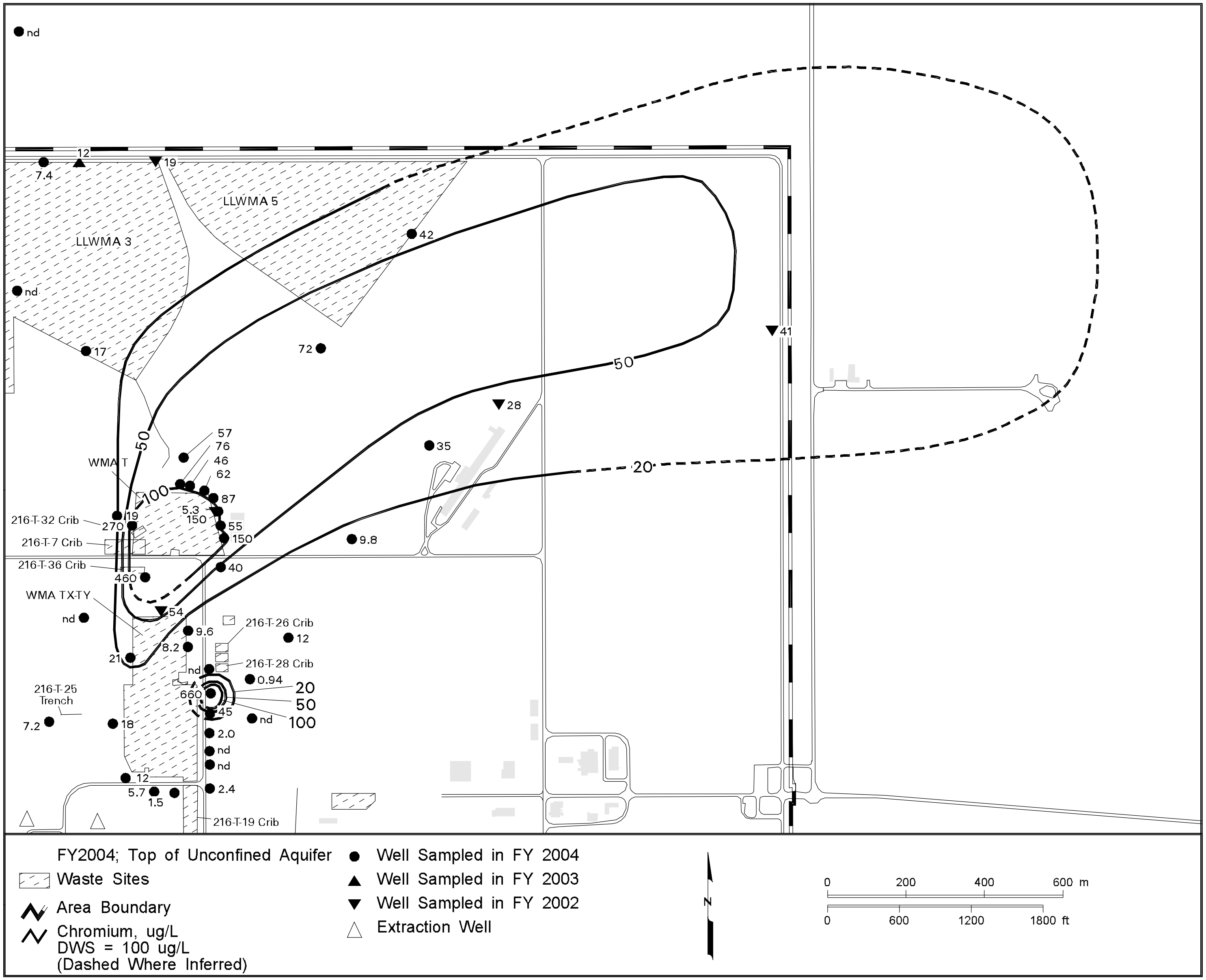

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Figure 2.8-7. Average Dissolved Chromium Concentrations Near Waste Management Areas T and TX-TY, Top of Unconfined Aquifer

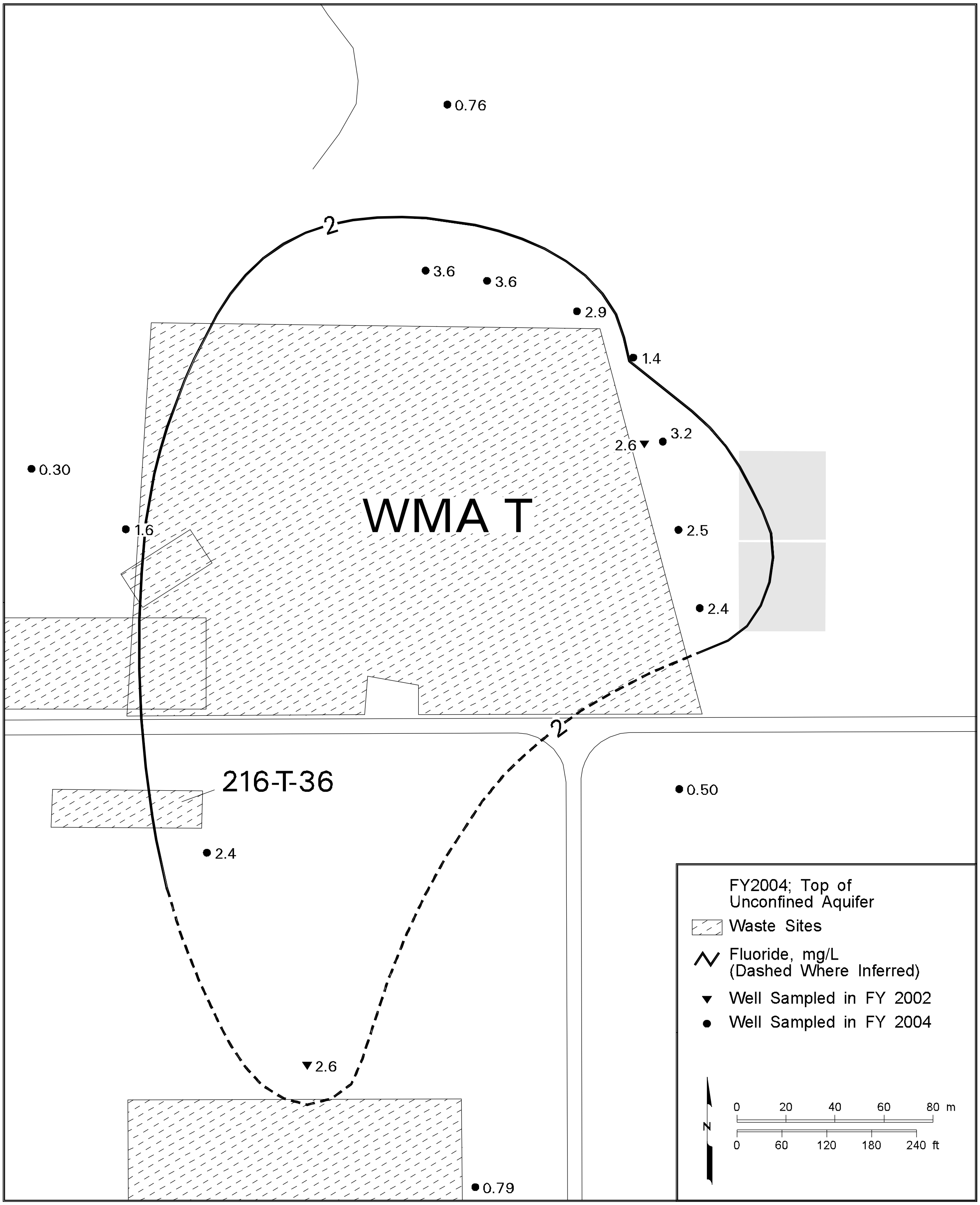

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Figure 2.8-8. Average Fluoride Concentrations Near Waste Management Area T in North 200 West Area, Top of the Unconfined Aquifer

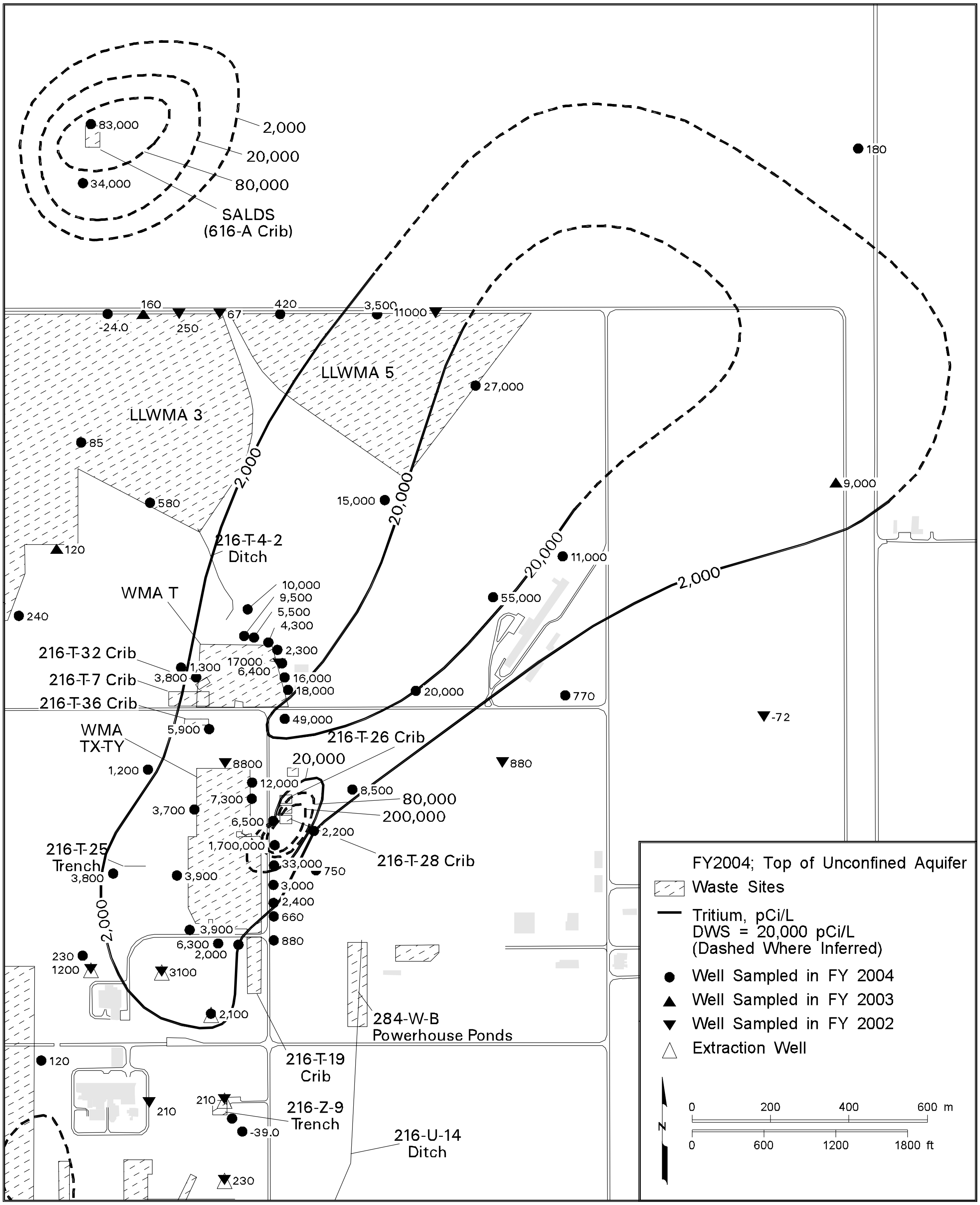

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Figure 2.8-9. Average Tritium Concentrations in North 200 West Area, Top of Unconfined Aquifer

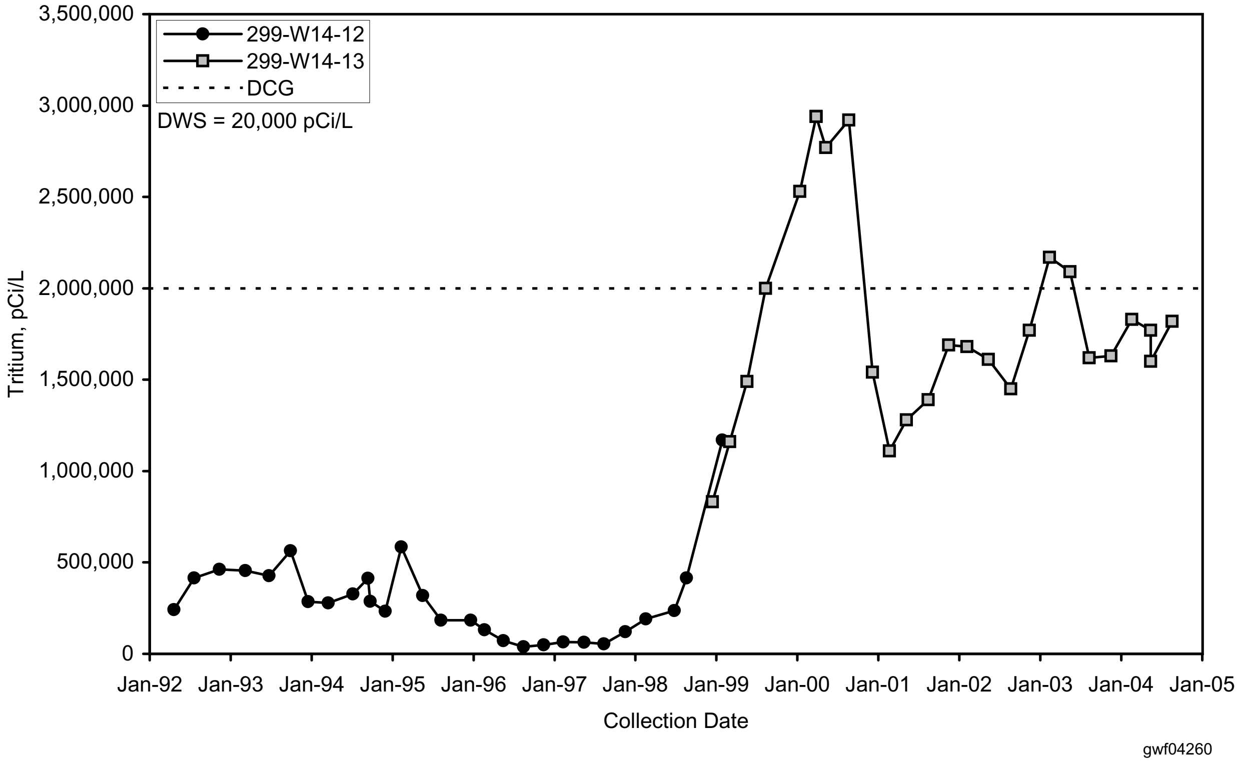

Figure 2.8-10. Tritium Concentrations versus Time in Wells 299-W14-12 and 299-W14-13 at Waste Management Area TX-TY

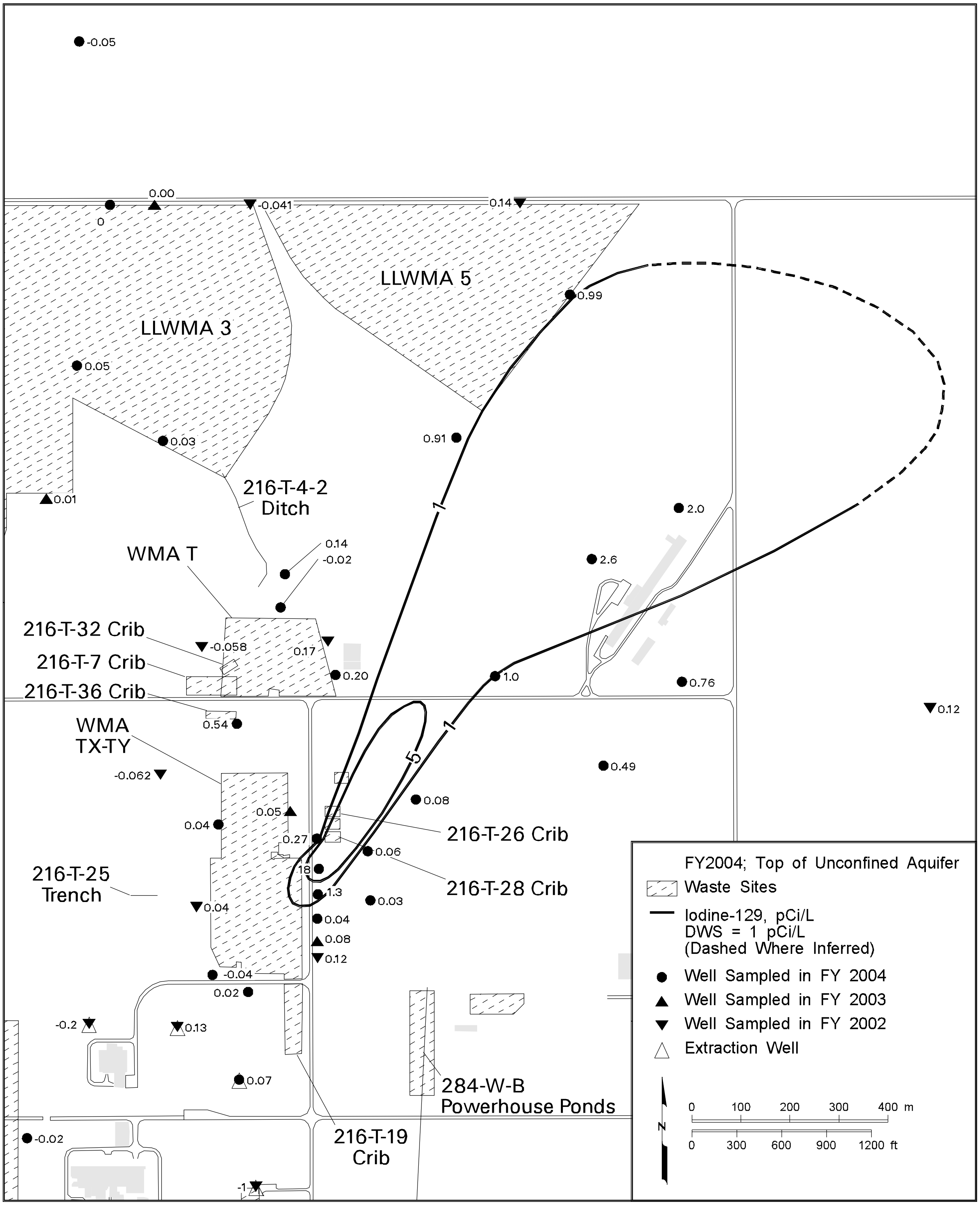

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Figure 2.8-11. Average Iodine-129 Concentrations in North 200 West Area, Top of Unconfined Aquifer

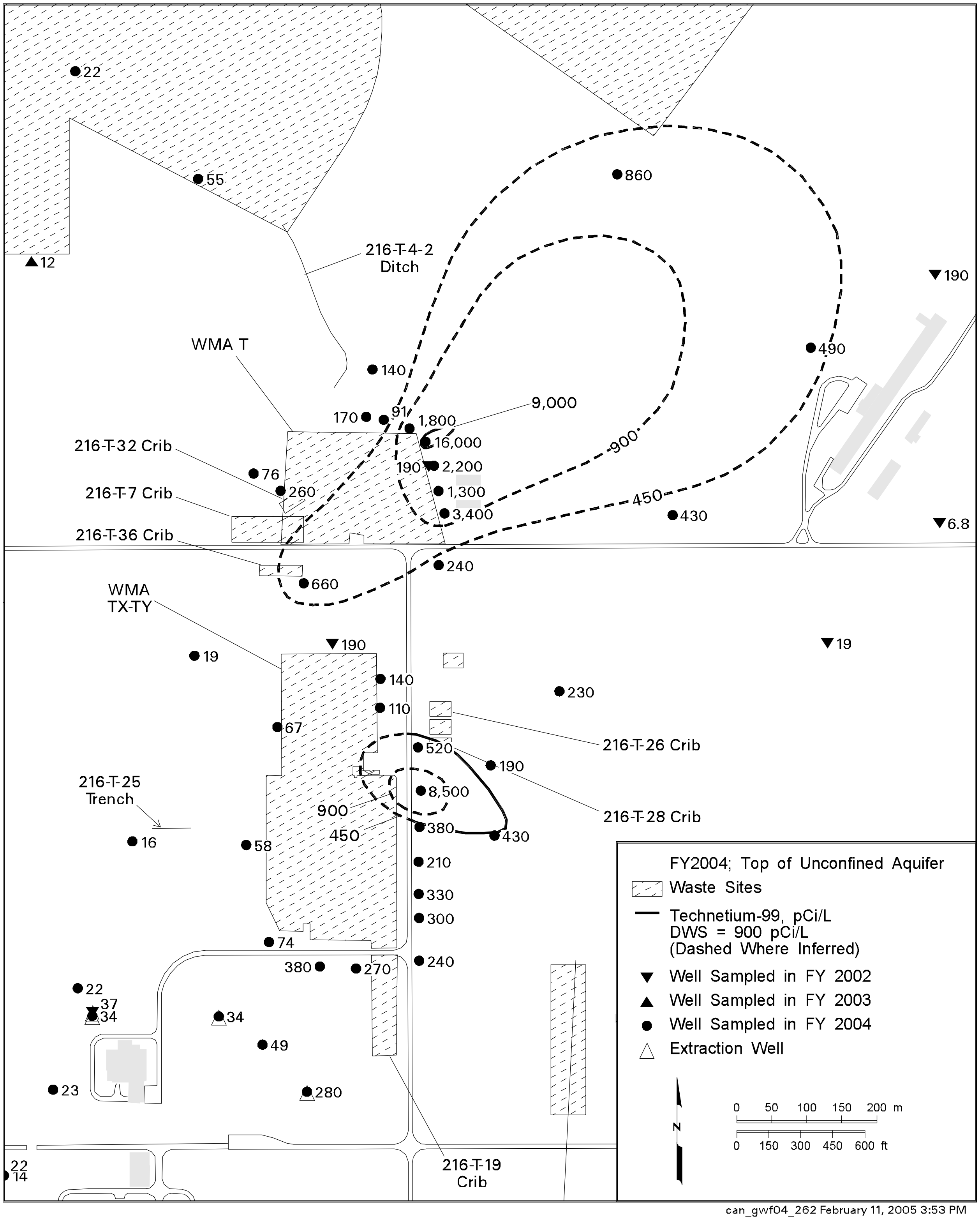

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Figure 2.8-12. Average Technetium-99 Concentrations in North 200 West Area, Top of Unconfined Aquifer

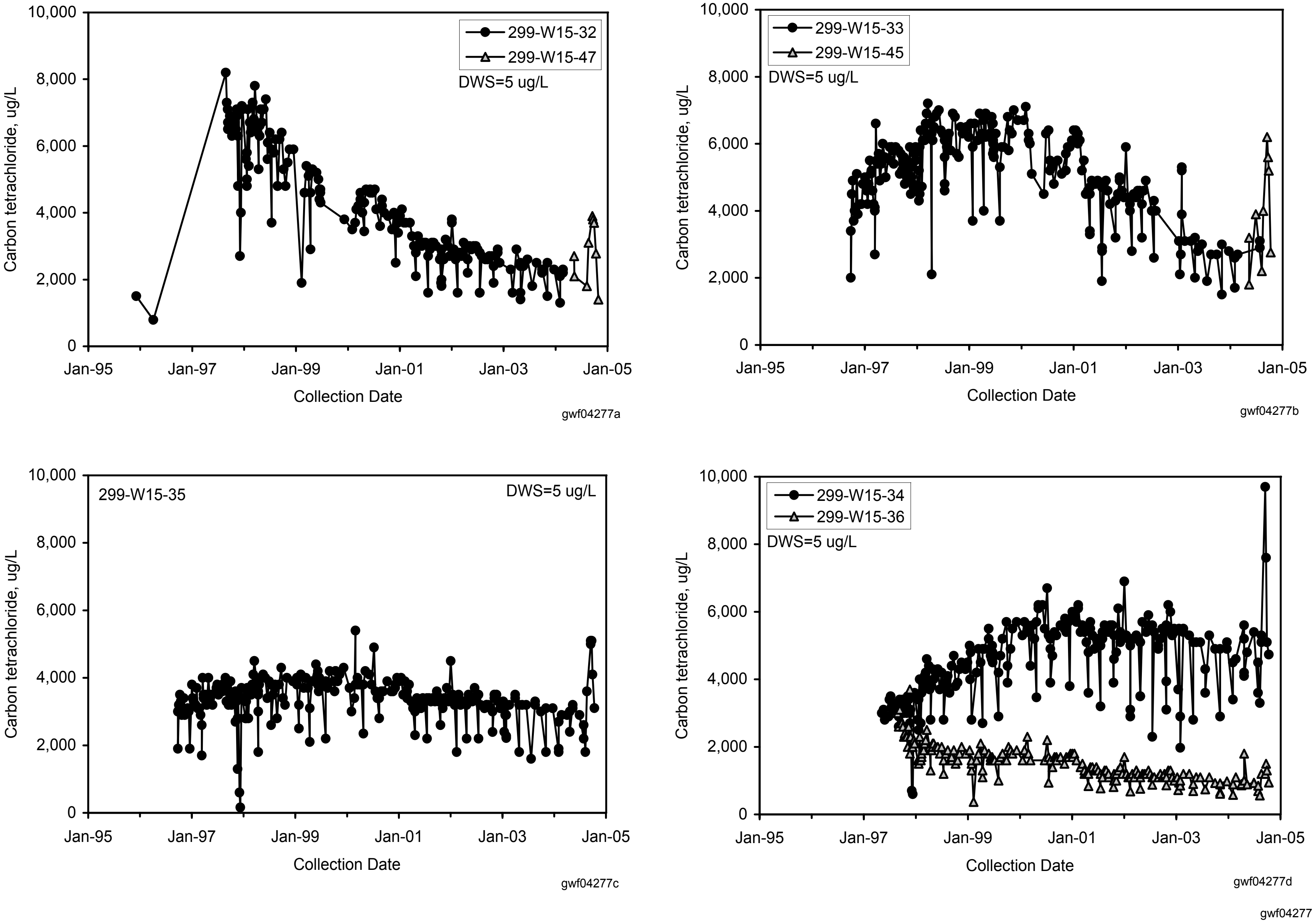


Figure 2.8-13. Carbon Tetrachloride Trends in Extraction Wells at the 200-ZP-1 Operable Unit

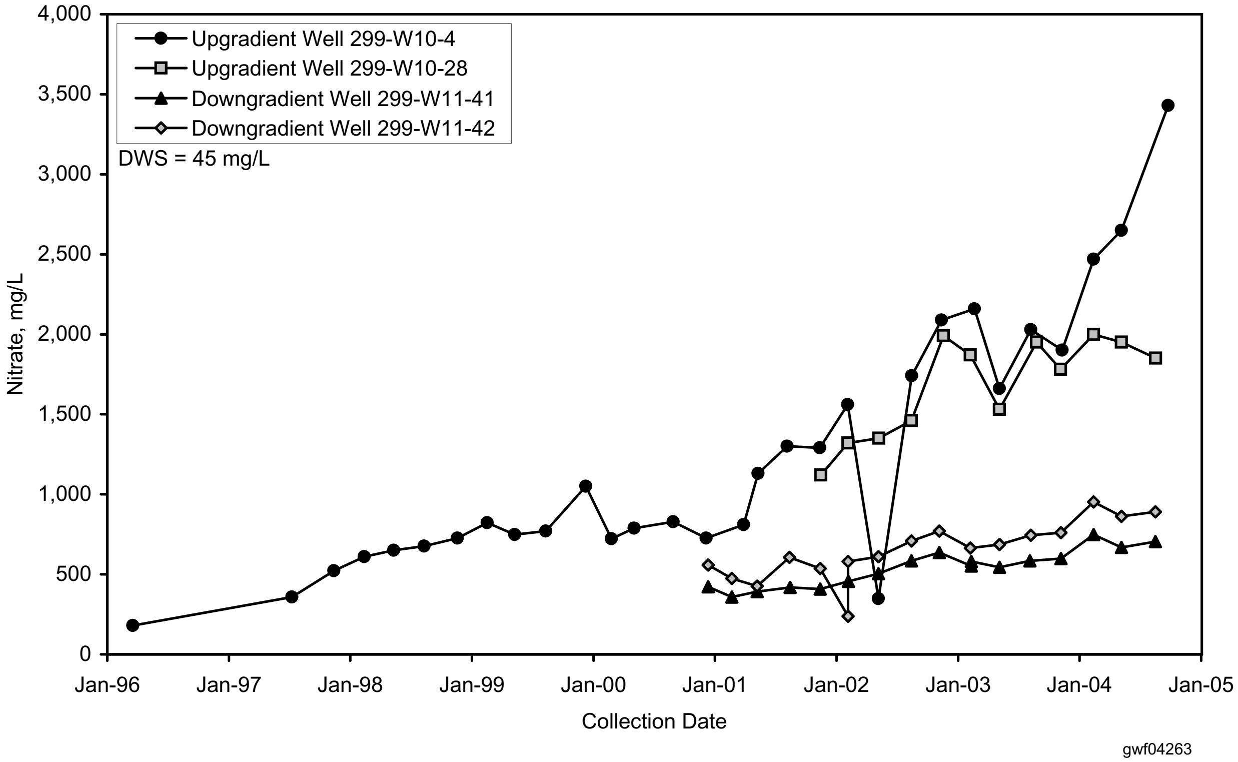
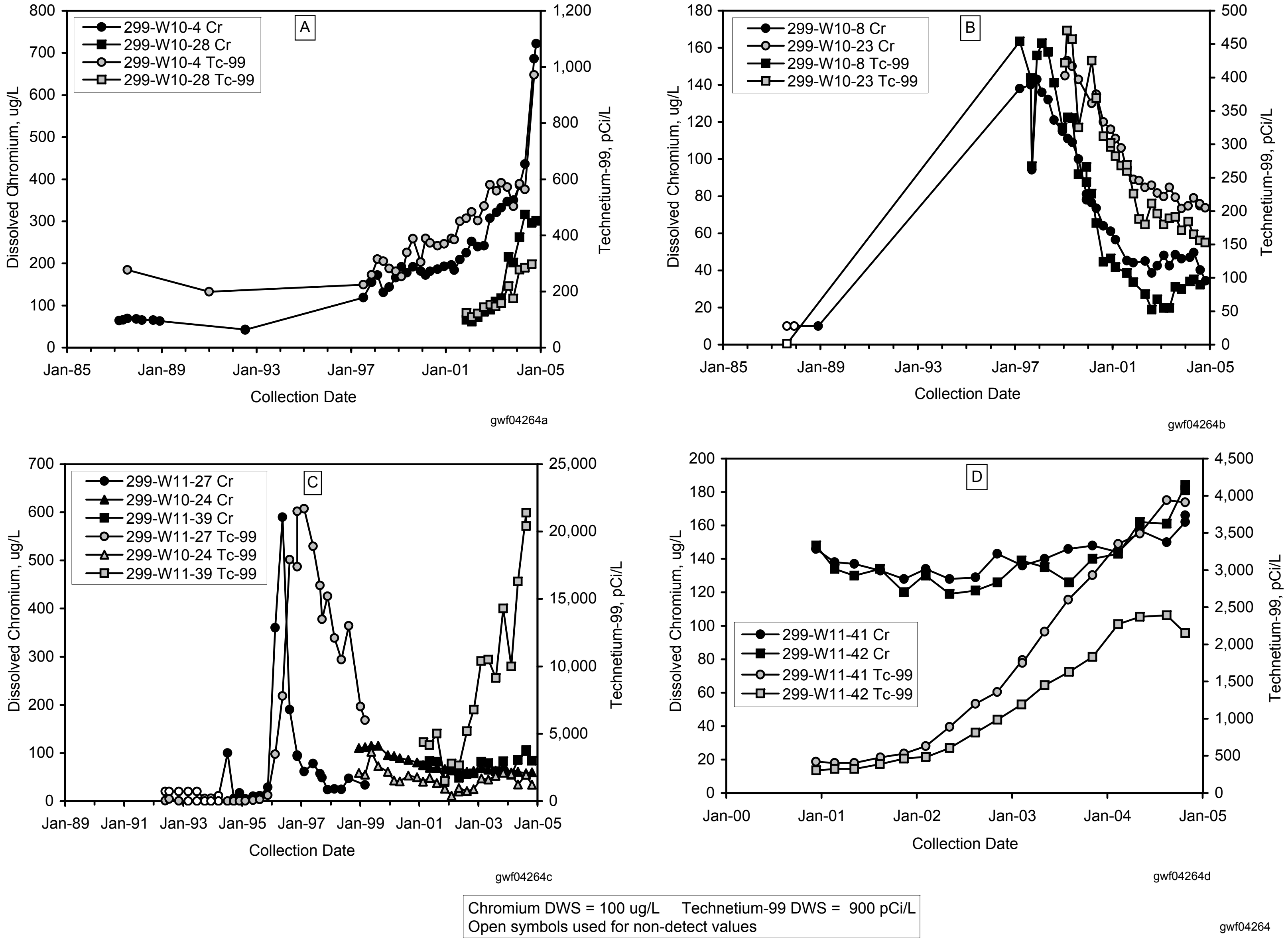


Figure 2.8-14. Nitrate Concentrations in Selected Wells at Waste Management Area T



Chromium DWS = 100 ug/L Technetium-99 DWS = 900 pCi/L
Open symbols used for non-detect values

Figure 2.8-15. Chromium and Technetium-99 Concentrations in Selected Wells at Waste Management Area T (a) western (upgradient wells), (b) northern wells, (c) northeastern wells (downgradient), (d) eastern (downgradient) wells

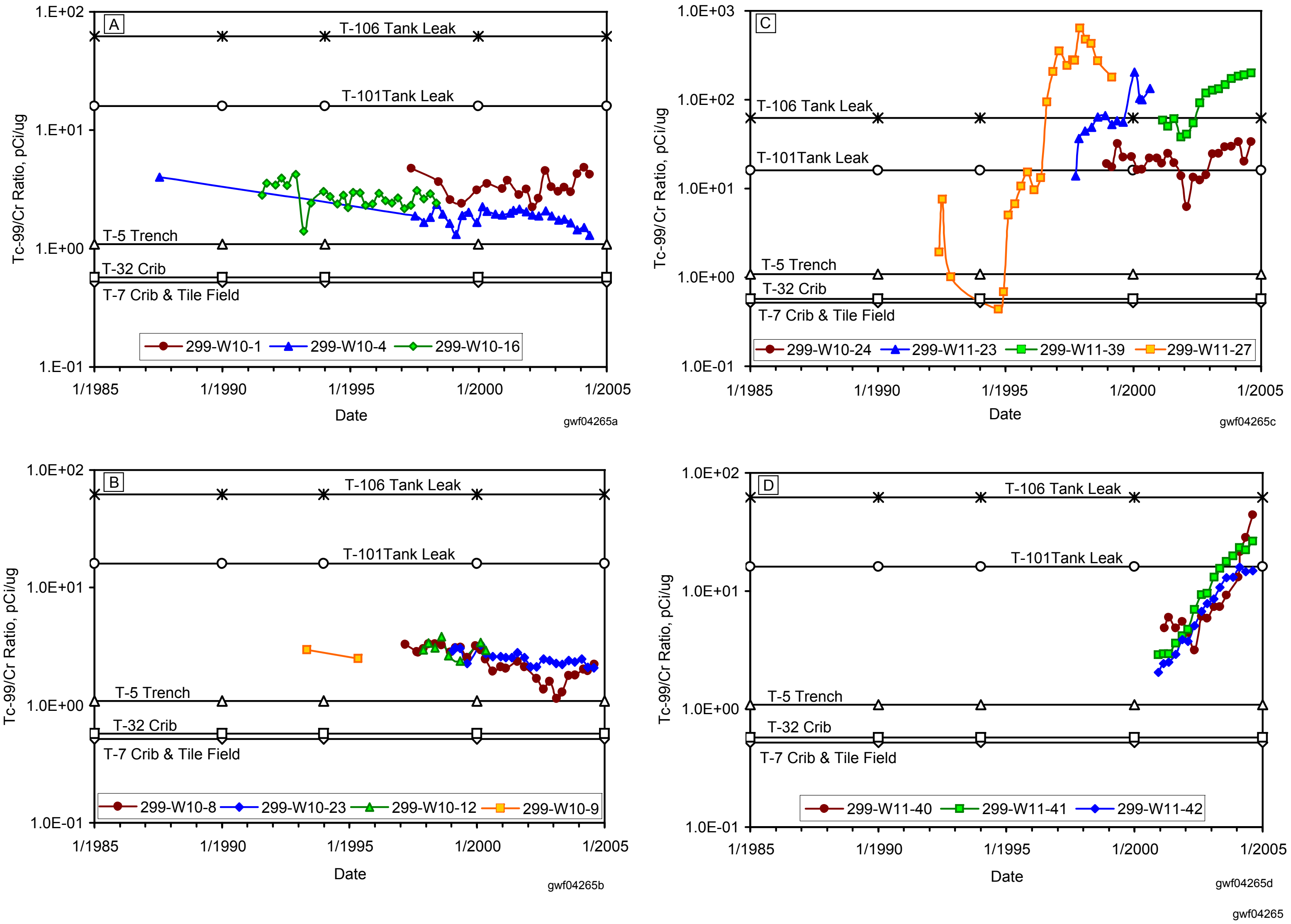


Figure 2.8-16. Technetium-99/Chromium Concentration Ratios in Samples from Selected Wells at Waste Management Area T (a) western (upgradient) wells, (b) northeastern wells (downgradient), (c) northern wells, and (d) eastern (downgradient) wells (modified from PNNL-14849)

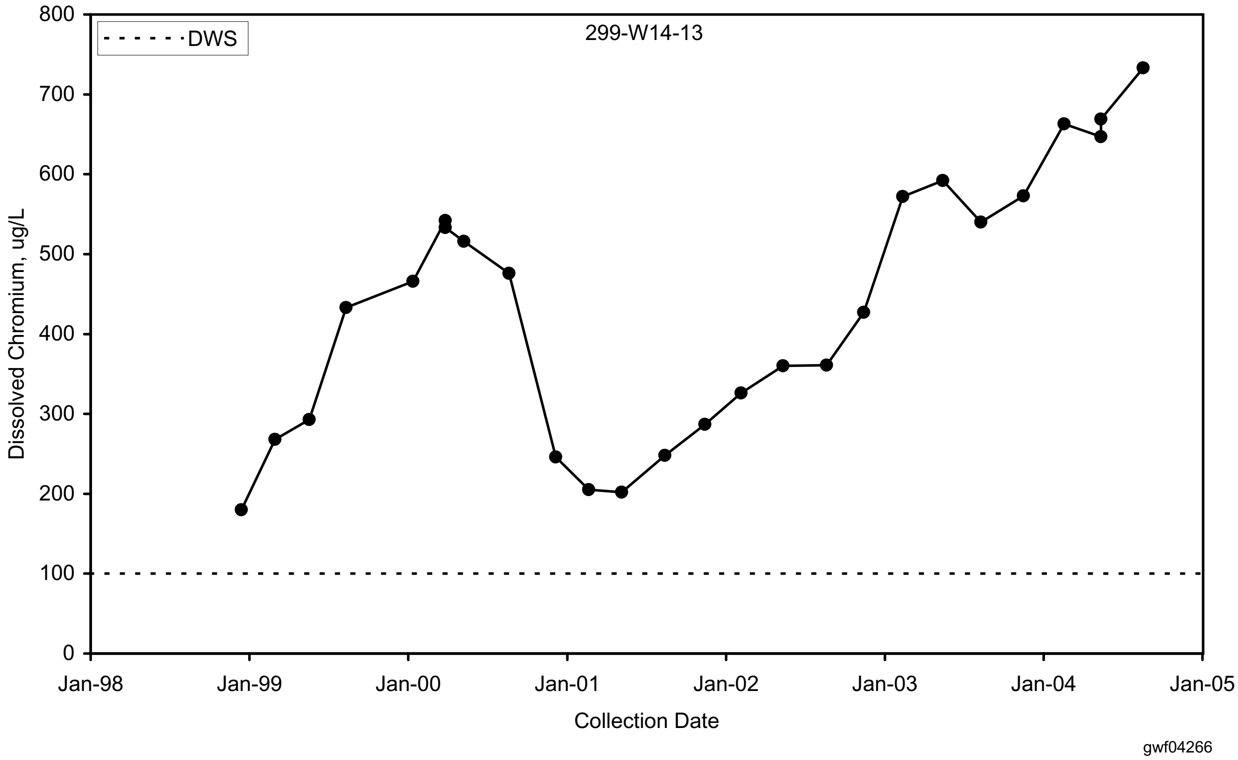


Figure 2.8-17. Chromium Concentrations in Well 299-W14-13, East of Waste Management Area TX-TY

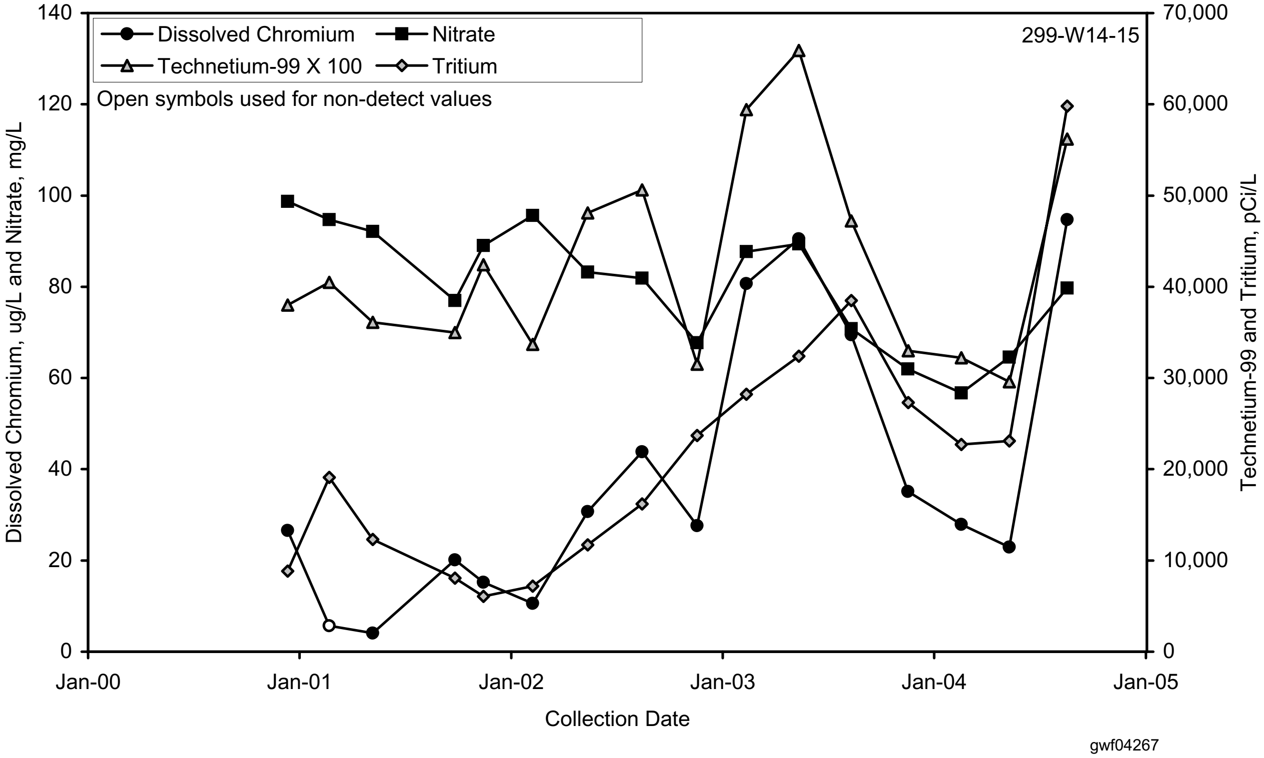


Figure 2.8-18. Concentrations of Chromium, Nitrate, Tritium, and Technetium-99 in Well 299-W14-15 at Waste Management Area TX-TY

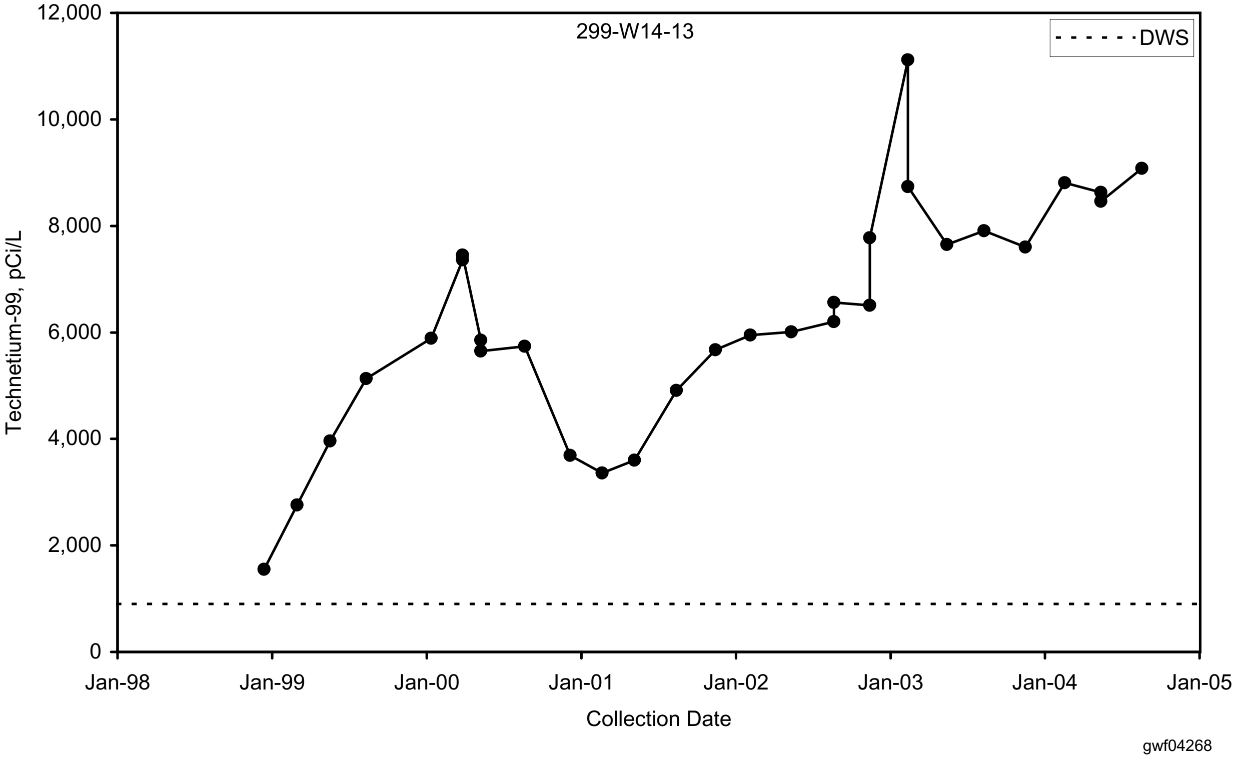


Figure 2.8-19. Technetium-99 Concentrations in Well 299-W14-13, East of Waste Management Area TX-TY

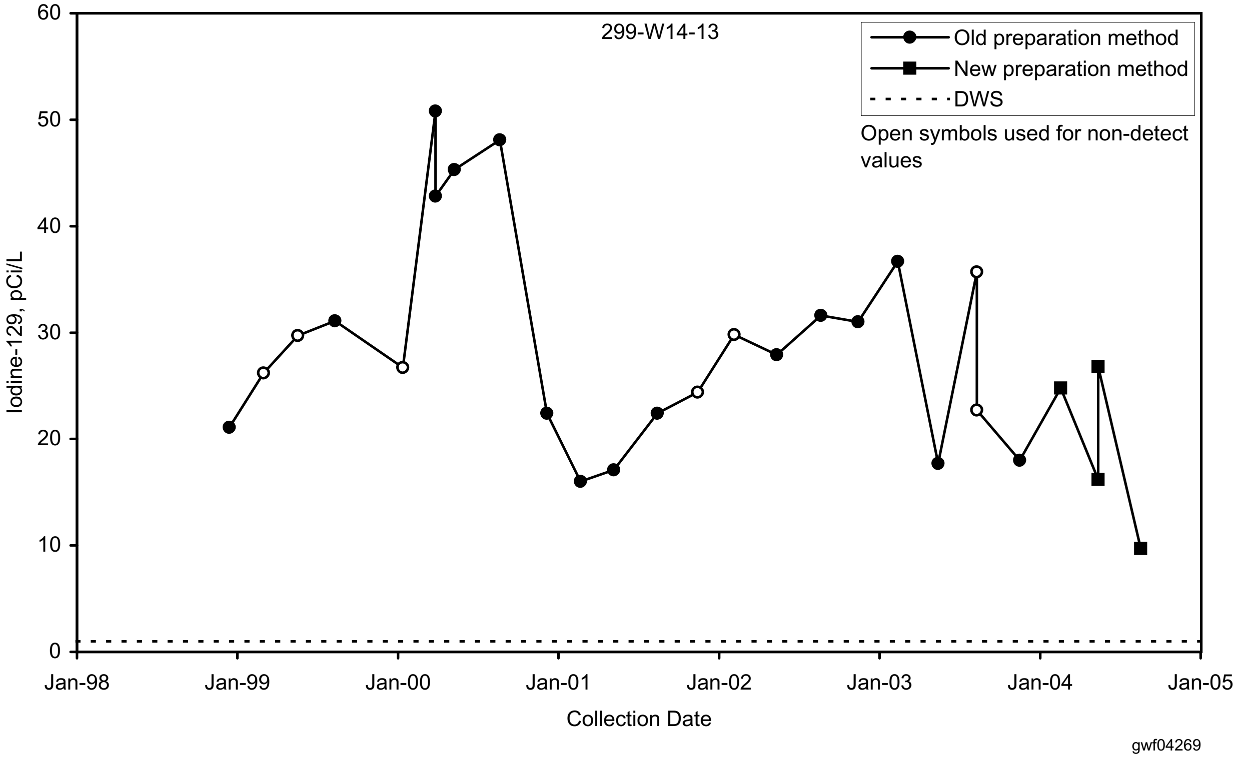


Figure 2.8-20. Iodine-129 Concentrations in Well 299-W14-13, East of Waste Management Area TX-TY

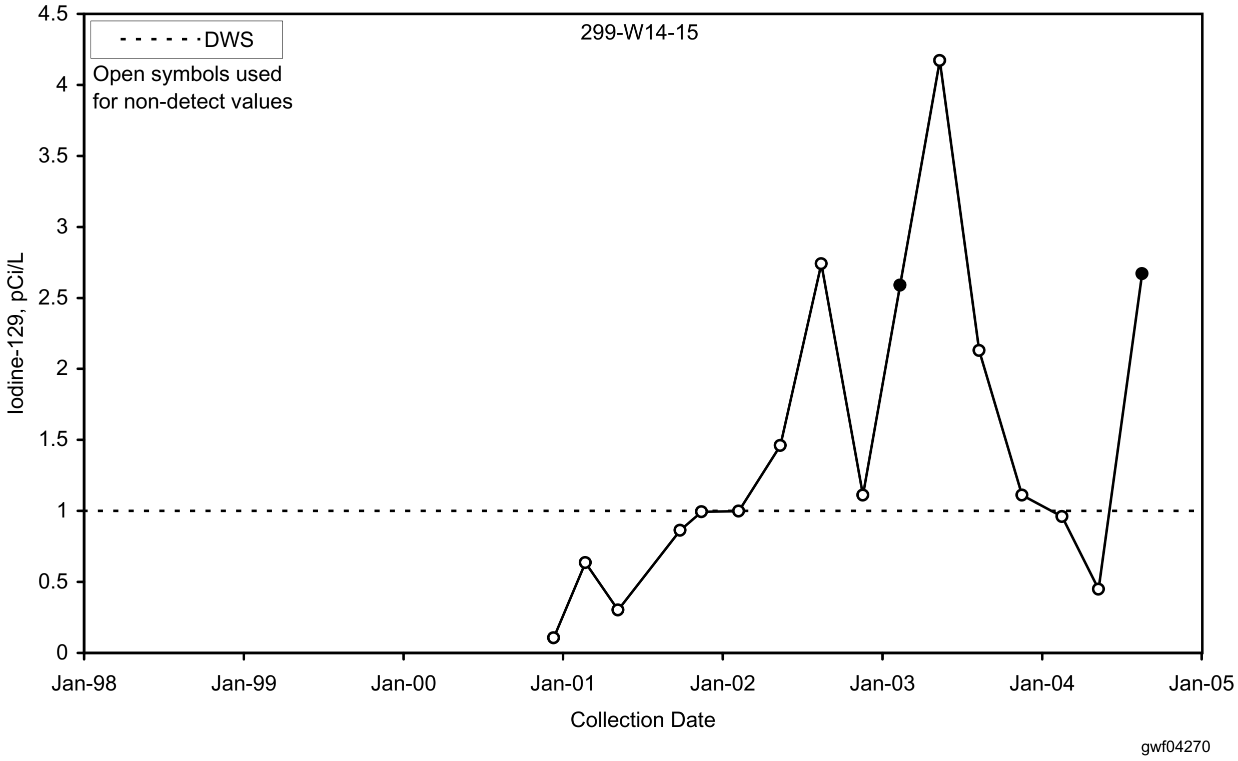


Figure 2.8-21. Iodine-129 Concentrations in Well 299-W14-15, East of Waste Management Area TX-TY

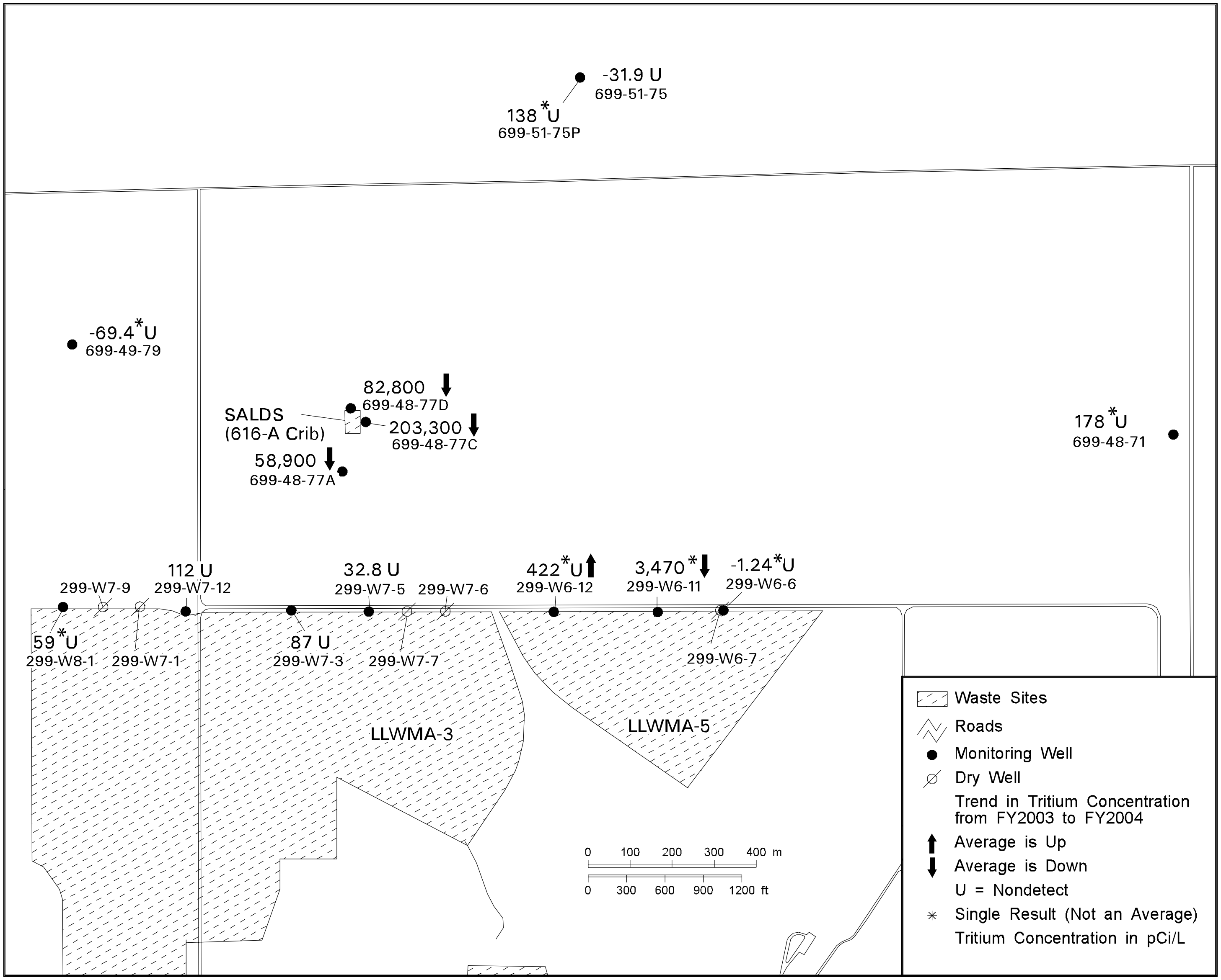


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Figure 2.8-22. Tritium Concentrations in Groundwater for the SALDS Tritium-Tracking Network, FY 2004, Indicating Change from FY 2003 Results (As indicated in the legend, these results are either averages for FY 2004 or single results, i.e., sampled only once.)

2.9 200-UP-1 Operable Unit

J. P. McDonald, R. M. Smith, B. A. Williams, L. C. Swanson, S. W. Petersen, and R. L. Weiss

The scope of this section is the 200-UP-1 groundwater interest area, which includes the 200-UP-1 groundwater operable unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined the groundwater interest areas informally to facilitate scheduling, data review, and interpretation. Figure 2.9-1 shows facilities and groundwater monitoring wells in this region. Technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form extensive plumes within the region. Groundwater is monitored (1) to track existing contaminant plumes within the operable unit; (2) to assess the performance of an interim action pump-and-treat system for remediation of technetium-99 and uranium; (3) for the *Resource Conservation and Recovery Act* (RCRA) units at Waste Management Areas U and S-SX, 216-S-10 pond and ditch, and 216-U-12 crib; and (4) for the Environmental Restoration Disposal Facility under a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) record of decision (ROD 1995b). In addition to the above mentioned constituents, high-priority contaminants of concern include strontium-90, trichloroethene, chloroform, chromium, cadmium, and arsenic.

The sampling and analysis plan for fiscal year (FY) 2004 sampling of the 200-UP-1 Operable Unit is incorporated into the Draft *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-92-76, Rev. 1, Draft A), which was revised during the year to support FY 2005 sampling (DOE/RL-92-76, Rev. 1, Draft B).

Technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form extensive plumes within the region.

Groundwater monitoring in the 200-UP-1 groundwater interest area includes the following monitoring activities:

CERCLA Monitoring

- ***Five monitoring wells are sampled annually or semiannually at the pump-and-treat area.***
- ***Three extraction wells are sampled annually or semiannually at the pump-and-treat area.***
- ***One monitoring well is sampled biennially at the pump-and-treat area.***
- ***Thirty-six wells are sampled annually, semiannually, or biennially for 12 constituents of concern throughout the remainder of the 200-UP-1 Operable Unit (outside of the pump-and-treat area).***
- ***Four wells are sampled semiannually at the Environmental Restoration Disposal Facility.***
- ***In FY 2004, all wells were sampled as scheduled.***

Facility Monitoring

- ***Two wells are sampled quarterly at the 216-U-12 crib.***
- ***Eight wells are sampled quarterly at Waste Management Area U.***
- ***Sixteen wells are sampled quarterly at Waste Management Area S-SX.***
- ***Three wells are sampled semiannually for the 216-S-10 pond and ditch.***
- ***In FY 2004, all wells were sampled as scheduled although the December 2003 sampling for many wells at Waste Management Area S-SX was delayed until early February 2004 due to the weather.***
- ***Sampling is coordinated with other programs to avoid duplication.***

AEA Monitoring

- ***Twelve wells are sampled annually or semiannually for contaminants, radionuclides, and general chemistry not otherwise scheduled under CERCLA and RCRA.***
- ***In FY 2004, all wells were sampled as scheduled.***
- ***Sampling is coordinated with CERCLA and RCRA sampling to avoid duplication.***

This plan integrates CERCLA and *Atomic Energy Act of 1954* (AEA) monitoring, and is a revision of the original integrated plan issued during June 2002 (DOE/RL-2002-10). The objectives of this monitoring are to regionally determine the spatial extent of existing contaminant plumes within the operable unit, assess the performance of an interim remedial action pump-and-treat system, and to identify emerging contamination issues. Appendix A presents the monitoring well network for the 200-UP-1 Operable Unit, including a well list, sampling frequencies, and analyte lists.

Groundwater flows primarily to the east within the 200-UP-1 groundwater interest area (see Figure 2.8-2 in Section 2.8). Water levels have been falling in this area since the 1980s, and flow directions have changed from southeast to east during this time. From March 2003 to March 2004, the water-table elevation fell by an average of 0.25 meter in the south 200 West Area. Groundwater flow is not significantly influenced by the pump-and-treat system at the 200-UP-1 Operable Unit. Groundwater pumping rates associated with this system are relatively low, so the hydraulic effect is localized.

Plume areas (square kilometers) above the drinking water standard at the 200-UP-1 Operable Unit:

Chromium — 1.07
Iodine-129 — 4.51
Nitrate — 6.86
Technetium-99 — 0.12
Trichloroethene — 0.07
Tritium — 6.67
Uranium — 0.56

****Carbon tetrachloride included in Section 2.8.***

Eight new monitoring wells were installed in the operable unit during calendar year 2004. Five wells are located outside the 200 West Area boundary to the east (699-30-66, 699-36-70B, 699-38-70B, 699-38-70C, and 699-40-65), one at the 200-UP-1 pump-and-treat area (299-W19-48), one to the south of the pump-and-treat area (299-W21-2), and one at Waste Management Area U (299-W19-47). Sampling results for these wells are included in the following sections, as appropriate.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under CERCLA, RCRA, and AEA monitoring.

2.9.1 Groundwater Contaminants

The following sections give an overview of the contaminant plumes and contaminants of concern for the 200-UP-1 groundwater interest area. It is a summary of the combined results of CERCLA, RCRA, and AEA monitoring performed in this area. The focus of this section is the top of the unconfined aquifer. Information on the vertical distribution of contaminants in the aquifer is given where available.

2.9.1.1 Technetium-99

Technetium-99 above the drinking water standard occurs in two regions of the 200-UP-1 groundwater interest area: an extensive, three-part plume downgradient from the 216-U-1,2 cribs and two small plumes at Waste Management Area S-SX (Figure 2.9-2). The large plume originated from the 216-U-1,2 cribs, which were active in the 1950s and 1960s. When effluent was disposed at the nearby 216-U-16 crib in the mid-1980s, it migrated north along a caliche layer and mobilized the technetium-99 and uranium in the soil column beneath the 216-U-1,2 cribs, adding to the groundwater plume (DOE/RL-92-76, Rev. 1, Draft B).

Technetium-99 concentrations declined downgradient of the 216-U-1,2 cribs due to the effects of a pump-and-treat system.

During FY 2004, peak concentrations continued to decline in the central part of this plume due to the operation of an interim remedial action pump-and-treat system. All measured concentrations remained below the remedial action goal of 9,000 pCi/L. The maximum concentration measured was 5,900 pCi/L found in well 299-W19-36 (the maximum during FY 2003 was 18,200 pCi/L in well 299-W19-43). Two wells (299-W19-9 and 299-W19-18) located at or just downgradient of the 216-U-1,2 cribs were sampled during FY 2004. Technetium-99 concentrations were found below the drinking water standard (900 pCi/L) in both wells, indicating that the crib and vadose zone beneath it do not represent a significant ongoing source of technetium-99. The trend is stable in well 299-W19-18, but increased during the fiscal year in well 299-W19-9 to 760 pCi/L. Refer to Section 2.9.2 for a more thorough discussion of the pump-and-treat remediation system.

To the east of the 200 West Area, technetium-99 concentrations also declined as the plume attenuated. In one of the new wells (699-38-70C) located ~650 meters east of the 200 West Area boundary, technetium-99 concentrations (ranging from 1,000 to 1,600 pCi/L) above the drinking water standard (900 pCi/L) were found throughout the unconfined aquifer from the water table to the Ringold Formation lower mud unit. The well was completed at a depth of ~30 meters below the water table (2 meters above the lower mud unit), and the measured technetium-99 concentration from the well at this depth was 1,000 pCi/L.

Concentrations of technetium-99 in well 299-W23-19, at Waste Management Area S-SX, reached 188,000 pCi/L in January 2003, the highest value ever measured in Hanford groundwater. Values remained stable at ~42,500 pCi/L during FY 2004.

At Waste Management Area S-SX, a technetium-99 plume originates from the southwest corner of the waste management area and another plume originates from the north part. During FY 2004, the technetium-99 concentration in well 299-W23-19 (located at the southwest corner of this waste management area near the source of the south plume) remained stable at ~42,500 pCi/L (Figure 2.9-3). The technetium-99 concentration at this well had risen to 188,000 pCi/L in January 2003 (above the U.S. Department of Energy [DOE] derived concentration guide of 100,000 pCi/L), then fell to ~74,300 pCi/L by the end of the fiscal year. This plume is migrating to the east-southeast, and the plume front has entered a region of sparse well coverage and cannot be tracked further. The north plume originates from the S Tank Farm and appears to be shifting more to the north as it migrates eastward. The peak concentration measured in this plume during the fiscal year was 4,200 pCi/L in well 299-W22-48. Refer to Section 2.9.3.2 for more information about technetium-99 at this waste management area.

Technetium-99 is found in the downgradient wells at Waste Management Area U. However, concentrations are below the drinking water standard. The maximum concentration measured during FY 2004 was 740 pCi/L in well 299-W19-45. Refer to Section 2.9.3.1 for more information about technetium-99 at this waste management area.

The 216-U-12 crib is a confirmed source of technetium-99 to the groundwater (PNNL-11574). Although the monitoring well coverage downgradient of this crib is sparse, the measured concentrations available (wells 299-W22-79 and 699-36-70A) are below the drinking water standard.

2.9.1.2 Uranium

Within the 200-UP-1 groundwater interest area, uranium primarily occurs in an extensive plume downgradient from the 216-U-1,2 cribs (Figure 2.9-4) and is associated with the technetium-99 plume here. The plume extends a total of ~1.5 kilometers to the east and northeast. The uranium originated from the 216-U-1,2 cribs, which were active in the 1950s and 1960s. Additional mass was added to the plume when effluent disposed of at the nearby 216-U-16 crib in the mid-1980s migrated north along a caliche layer and mobilized the technetium-99 and uranium in the soil column beneath the 216-U-1,2 cribs (DOE/RL-92-76, Rev. 1, Draft B).

Uranium responds more slowly than technetium-99 to the pump-and-treat system. All concentrations were below the remedial action goal (480 μg/L) but remain above the drinking water standard (30 μg/L) in wells within the pump-and-treat area.

An interim remedial action pump-and-treat system continued to operate during FY 2004, and concentrations in this plume generally declined or remained stable. During the fiscal year, all measured uranium concentrations were below the remedial action goal of 480 μg/L for all wells within the area designated for pump-and-treat remediation. The maximum concentration measured in this area during FY 2004 was 440 μg/L in well 299-W19-36 (the maximum during FY 2003 was 1,200 μg/L in well 299-W19-43). Uranium is not as mobile as technetium-99 in groundwater, so uranium concentrations are not falling as rapidly as the technetium-99 concentrations. All measured uranium concentrations within the remediation target area remained above the drinking water standard (30 μg/L).

During FY 2004, uranium was found at 600 μg/L in well 299-W19-18 located 70 meters downgradient of the 216-U-1,2 cribs. The historical peak uranium concentration in this well was 9,650 μg/L in the late 1980s. Uranium concentrations for this well are shown in Figure 2.9-5. Concentrations have changed little over the past 10 years – the trend exhibits what appears to be a tailing effect. Perhaps when uranium from beneath the cribs reached the groundwater, a good portion of it precipitated or sorbed onto sediment grains. This region may be acting as an ongoing source in the aquifer as the uranium slowly desorbs into the groundwater. Another possibility is the uranium continues to leach from the vadose zone beneath the cribs.

A small uranium plume has previously been depicted beneath the 216-S-13 crib (PNNL-14548). This facility was active in the 1950s and 1960s, resulting in uranium concentrations above the drinking water standard in well 299-W22-21, which monitored the groundwater near the crib. This well was periodically sampled until 1997, but has since gone dry. There are no longer any useable wells in this vicinity. It has been 7 years since a groundwater sample was collected near this crib, so whether or not uranium occurs in groundwater above the drinking water standard is unknown. This issue is expected to be addressed as part of the remedial investigation process.

2.9.1.3 Tritium

The tritium plume emanating from the southeast 200 West Area has nearly stopped spreading in most directions and is contracting in some areas.

Disposal facilities associated with the Reduction Oxidation (REDOX) Plant are the primary sources of tritium in the 200-UP-1 groundwater interest area. The REDOX Plant operated from 1952 until 1967, although effluent releases continued to occur after this time. A large tritium plume emanates from the south part of the 200 West Area to the east and northeast (extending ~5 kilometers). Two high concentration areas occur within this plume – a large one extending to the east and northeast from the 200 West Area and a smaller one extending ~550 meters to the east-southeast from the vicinity of the 216-S-25 crib (Figure 2.9-6).

Most wells east of the 200 West Area are scheduled for biennial sampling; they were last sampled during FY 2003 and are not due to be sampled again until FY 2005. Measured concentrations in the central part of the plume range from ~200,000 to 600,000 pCi/L. Although tritium concentrations are increasing in some wells within this central part, concentrations are declining in most wells. The overall picture is of a plume that has nearly stopped spreading in most directions and is contracting in some areas as radiological decay dominates over advective transport. Well 699-38-65, located ~1.6 kilometers east of the 200 West Area boundary, was sampled during FY 2004, and the tritium concentration here has declined to below the drinking water standard (Figure 2.9-7). This decline may be caused by a relatively high concentration portion of the plume migrating away from this well, coupled with radiological decay. Major cation and anion concentrations (including nitrate) are relatively stable in this well, thus making it unlikely that a nearby source of water is entering the aquifer and diluting the plume. (The drinking water standard for tritium is 20,000 pCi/L.)

Measured tritium concentrations near the 216-S-25 crib were generally stable or declining during FY 2004. The concentration adjacent to the crib (at well 299-W23-9) declined from 288,000 pCi/L in January 2003 to 102,000 pCi/L in August 2004, indicating that the strength of the tritium source is declining (the nitrate concentration has also declined). This part of the plume is migrating to the east-southeast, passing beneath Waste Management Area S-SX. The front of this high concentration area has now entered an area of sparse well coverage and will not be able to be tracked further (the next downgradient well is ~600 meters away).

A portion of the iodine-129 plume is migrating to the east out of the 200 West Area.

Information on the vertical distribution of tritium in the aquifer is sparse. Three of the eight wells (299-W19-48, 699-30-66, and 699-36-70B) installed within the operable unit during calendar year 2004 were sampled for tritium at different depths during drilling. The results indicate that tritium mainly occurs in the upper part of the aquifer near the water table. However, none of these wells were completed in a high concentration portion of the plume.

2.9.1.4 Iodine-129

Iodine-129 plumes in the 200-UP-1 groundwater interest area originate from both U Plant and REDOX Plant disposal facilities (Figure 2.9-8). One plume emanates from the vicinity of the 216-U-1,2 cribs, while another originates from the south part of the 200 West Area. At the current level of monitoring detail, these plumes merge downgradient and become indistinguishable. This combined plume (as denoted by the 1-pCi/L contour level) extends to the east and northeast a total distance of ~3.5 kilometers.

As stated in PNNL-14548, a high concentration portion of the iodine-129 plume is believed to be migrating to the east out of the 200 West Area into the surrounding 600 Area. Measured concentrations in the central part of this plume range from 5 to 35 pCi/L. Iodine-129 concentrations were generally stable or had decreased slightly compared to FY 2003. The concentration has been falling rapidly in well 699-38-65, the same well in which tritium concentrations have also been declining (see Section 2.9.1.3). Iodine-129 is essentially no longer detectable in this well. (The drinking water standard for iodine-129 is 1 pCi/L.)

2.9.1.5 Strontium-90

During FY 2004, 30 analyses for strontium-90 were performed on samples collected from 14 wells within the groundwater interest area. Strontium-90 was found above detection limits in only one well: 299-W22-10, located downgradient of the 216-S-1,2 cribs. The result was 35 pCi/L, which is above the 8 pCi/L drinking water standard. Concentrations have been falling here since December 2001, when a peak value of 76 pCi/L was measured. Apparently, a small plume in the aquifer is migrating past this well. These cribs received highly acidic waste from the REDOX Plant between 1952 to 1956. In 1955, the waste is believed to have corroded the casing of a nearby well (299-W22-3), which allowed the effluent to bypass the soil column and flow down the well directly into groundwater (Waste Information Data System).

2.9.1.6 Chlorinated Hydrocarbons

Carbon tetrachloride is widespread in the 200-UP-1 groundwater interest area. The plume originated from disposal facilities associated with the Plutonium Finishing Plant in the 200-ZP-1 groundwater interest area.

Carbon tetrachloride is widespread in the 200-UP-1 groundwater interest area. The maximum concentration measured during FY 2004 was 650 μg/L in well 299-W19-36, an extraction well for the 200-UP-1 pump-and-treat system. Recent sampling at discrete vertical intervals within the aquifer beneath the 200 West Area (during well installation) demonstrate that carbon tetrachloride concentrations can increase with depth down to the Ringold Formation lower mud unit, at least in some areas. Well 299-W19-36 is screened near the water table, so concentrations higher than 650 μg/L may occur at depth. Carbon tetrachloride originated from disposal facilities associated with the Plutonium Finishing Plant, which is part of the 200-ZP-1 groundwater interest area. (For a more thorough discussion of carbon tetrachloride in the 200 West Area, see Section 2.8.)

Chloroform is a degradation product of carbon tetrachloride. A total of 104 chloroform analyses were performed on samples from 42 wells within the 200-UP-1 groundwater interest area, and there were no exceedances of the 100-μg/L drinking water standard. The maximum measured concentration was 22 μg/L in a sample collected 46 meters below the water table (3 meters above the Ringold Formation lower mud unit) during installation of well 699-38-70B.

During drilling of two new wells within the operable unit, carbon tetrachloride and trichloroethene concentrations were found to increase with depth in the aquifer.

Trichloroethene is found within the 200-UP-1 groundwater interest area above the drinking water standard (5 μg/L) in two regions – one near and downgradient from the pump-and-treat system and another near the 216-S-20 crib. A total of 104 trichloroethene analyses were performed on samples from 42 wells within the interest area, and the drinking water standard was exceeded in four wells (299-W19-35, 299-W22-20, 699-38-70B, and 699-38-70C). However, concentrations are not significantly above the drinking water standard – the maximum concentration measured was 9 μg/L.

Two new wells were installed outside the 200 West Area downgradient of the pump-and-treat system during FY 2004 (699-38-70B and 699-38-70C), and trichloroethene was found above the drinking water standard in both wells. Both wells were advanced to the Ringold Formation lower mud unit, and groundwater samples were collected at various depths within the aquifer during drilling. As is the case for carbon tetrachloride, trichloroethene concentrations generally increased with depth down to the lower mud unit. The peak concentration in well 699-38-70B was 8 µg/L at 37 meters below the water table (12 meters above the lower mud unit). The peak concentration at well 699-38-70C was 9 µg/L at 19 meters below the water table (15 meters above the lower mud unit). These results indicate that the occurrence trichloroethene above the drinking water standard is more widespread than previously recognized.

The peak measured trichloroethene concentration downgradient of the 216-S-20 crib was 6 µg/L in well 299-W22-20, down from 11 µg/L the year before. In FY 2002, trichloroethene exceeded the drinking water standard at well 299-W19-34B (6 µg/L), completed deep in the aquifer at the pump-and-treat site. The concentration here has now fallen to 3 µg/L, which is below the drinking water standard (5 µg/L).

2.9.1.7 Chromium

Chromium is found in four regions of the 200-UP-1 groundwater interest area: at Waste Management Area S-SX, at the 216-S-10 pond and ditch, in the vicinity of the 216-S-20 crib, and in the 600 Area east and southeast of the 200 West Area. During FY 2004, samples from three wells exceeded the drinking water standard (100 µg/L): well 299-W22-20 at the 216-S-20 crib (560 µg/L), and wells 299-W23-19 (320 µg/L) and 299-W22-50 (120 µg/L) at Waste Management Area S-SX. During FY 2003, wells 699-32-62 in the 600 Area and 299-W26-7 at the 216-S-10 pond and ditch had chromium concentrations exceeding the drinking water standard. Neither of these wells were sampled during the fiscal year; well 699-32-62 is scheduled for biennial sampling and well 299-W26-7 went dry during FY 2003. Chromium at Waste Management Area S-SX is discussed in Section 2.9.3.2, and chromium at the 216-S-10 pond and ditch is discussed in Section 2.9.3.3.

Chromium is frequently detected in filtered samples east and southeast of the 200 West Area. The concentration in well 699-32-62 was 174 µg/L in FY 2003. The chromium concentrations have declined slowly since chromium was first analyzed at this well in 1992. The sources and extent of this contamination are uncertain. The location of this plume is consistent with disposal to the REDOX Plant ponds/ditches south and southwest of the 200 West Area. Chromium is detected in several other wells in this area, but its extent to the south of well 699-32-62 is poorly defined.

2.9.1.8 Nitrate

Nitrate plumes in the 200-UP-1 groundwater interest area originated from both U Plant and REDOX Plant disposal facilities and are widespread throughout the area. The multiple sources of nitrate from U Plant include the 216-U-1,2; 216-U-8; and 216-U-12 cribs. The nitrate plumes from these and other sources merge downgradient into a single large plume, which extends to the east and northeast a total distance of ~4 kilometers (Figure 2.9-9). Nitrate sources from the REDOX Plant disposal facilities may also have contributed to this plume. Only a few wells within this plume (outside of the 200 West Area) were sampled during the fiscal year – most are scheduled for biennial sampling and were sampled during FY 2003. This plume continues to migrate slowly to the east, as evidenced by an increasing nitrate trend in well 699-40-62 at the eastern edge of this plume.

Multiple sources of nitrate created a large plume, which is moving to the east.

The nitrate distribution depicted in Figure 2.9-9 represents nitrate concentrations at the water table, since most of the wells are screened across the water table. However, two of the new wells (699-38-70B and 699-38-70C) installed within the groundwater interest area during FY 2004 were screened near the bottom of the aquifer, just above the Ringold Formation lower mud unit. Both wells are located outside the 200 West Area downgradient from the pump-and-treat system. In well 699-38-70B, nitrate concentrations at the bottom of the aquifer were measured at 16 mg/L. In well 699-38-70C, however, the measured nitrate concentration was 190 mg/L. This result indicates that high nitrate concentrations occur deep in the unconfined aquifer in some places. Neither of these wells were sampled for nitrate at the water table during drilling; therefore, a direct comparison of shallow versus deep concentrations cannot be made. Three of the new wells were sampled for nitrate during drilling. At wells 299-W19-48 and 699-36-70B, elevated nitrate occurs only near the water table, while in well 699-30-66, nitrate occurs throughout the aquifer thickness (down to the lower mud unit) at approximately half the drinking water standard (45 mg/L).

In Figure 2.9-9, a nitrate plume is depicted extending from west and southwest of Low-Level Waste Management Area 4 to Waste Management Area U. In well 299-W18-21, an upgradient well for Low-Level Waste Management Area 4, nitrate concentrations have been rising since 1993. In the two upgradient wells (299-W18-31 and 299-W18-40) for the U Tank Farm, nitrate concentrations have been rising significantly since ~2001 and exceeded 20 mg/L during FY 2004. Nitrate in all three of these wells is interpreted to be a single plume, which implies an advective travel time of ~8 years from well 299-W18-21 to the U Tank Farm. This travel time is within the range expected based on the reported groundwater flow velocities for Low-Level Waste Management Area 1 and the U Tank Farm. The source of this plume is not certain, but since 299-W18-21 is an upgradient well at Low-Level Waste Management Area 4, the plume is depicted in Figure 2.9-9 as emanating from somewhere west and southwest of Low-Level Waste Management Area 4. The only known waste site in this area is the 216-U-11 trench, which received overflow water from the 216-U-10 pond during the 1940s and 1950s. However, it has not been confirmed that this trench is the source of the nitrate.

The groundwater flow direction has changed over the years in the area west and southwest from Low-Level Waste Management Area 1. While U Pond and the 216-U-14 ditch were active, a groundwater mound resulted in westward flow in this area. Since discharges to ground ceased in the mid-1990s, the groundwater flow has resumed its pre-Hanford flow direction toward the east. This perhaps explains why nitrate began to rise in well 299-W18-21 in the mid-1990s. It is also theoretically possible that a nitrate plume migrated toward the west under past flow conditions and is now returning to the 200 West Area under eastward flow. If this were the case, however, it is expected that the plume would have dispersed considerably causing more wells to be impacted than is currently being observed.

Waste Management Area U is also a source of nitrate to groundwater (see Section 2.9.3.1). Nitrate concentrations in several of the downgradient wells remained above the drinking water standard during the fiscal year. The peak measured nitrate concentration at the U Tank Farm during FY 2004 was 65 mg/L in well 299-W19-41.

Nitrate occurs in two small plumes associated with REDOX Plant disposal facilities: one near the 216-S-20 crib and another near the 216-S-25 crib. In well 299-W22-20, downgradient of the 216-S-20 crib, the average nitrate concentration for FY 2004 was 100 mg/L, up from 92 mg/L the year before. From 1952 through 1972, this crib received waste from laboratory hoods and decontamination sinks in the 222-S Building, along with laboratory waste from the 300 Area.

There is a nitrate plume associated with the tritium plume emanating from the vicinity of the 216-S-25 crib. In well 299-W23-9, at the downgradient end of this crib, nitrate concentrations increased from FY 2000 through 2003, suggesting an additional release of nitrate to the aquifer from the soil column beneath the crib. This release may be diminishing, because the FY 2004 concentration was 240 mg/L, down from 480 mg/L the year before (the tritium concentration has also declined).

Nitrate also appears to be associated with the technetium-99 plume in this vicinity from Waste Management Area S-SX (see Section 2.9.3.2). The peak nitrate concentration in this area occurred in well 299-W23-19 at the southwest corner of Waste Management Area S-SX. The September 2004 sample yielded a concentration of 360 mg/L, which is significantly lower than last year's peak concentration of 1,680 mg/L.

2.9.1.9 Other Constituents

During FY 2003, 1,4-dioxane was detected at 160 µg/L in a sample collected from well 299-W22-20, which is located downgradient from the 216-S-20 crib. This well was sampled twice during FY 2004, and 1,4-dioxane was not detected in either sample. The well is filling in with silt, making the use of sampling pumps problematic. The first sample was collected during March using a Kabis sampler without purging the well; 1,4-dioxane was not detected in that sample, but since the well was not purged, it was suspected that a representative sample was not obtained. Another sample was collected in September with the Kabis sampler, immediately after purging three borehole volumes with a dart bailer. No 1,4-dioxane was detected in that sample. Therefore, 1,4-dioxane is no longer present in the aquifer near this well. Perhaps a small pulse of 1,4-dioxane entered the aquifer from the vadose zone and has now moved downgradient of well 299-W22-20. During FY 2004, 60 analyses for 1,4-dioxane were performed on samples from 35 wells within the entire groundwater interest area, and there were no detections of this constituent.

In FY 2003, 1,4-dioxane was detected in a single well near the 216-S-20 crib but was not detected during FY 2004.

Arsenic and cadmium are both listed as contaminants of concern for the 200-UP-1 Operable Unit. During FY 2004, there were no detections for either constituent above a drinking water standard. The arsenic drinking water standard is 10 µg/L, and the cadmium drinking water standard is 5 µg/L.

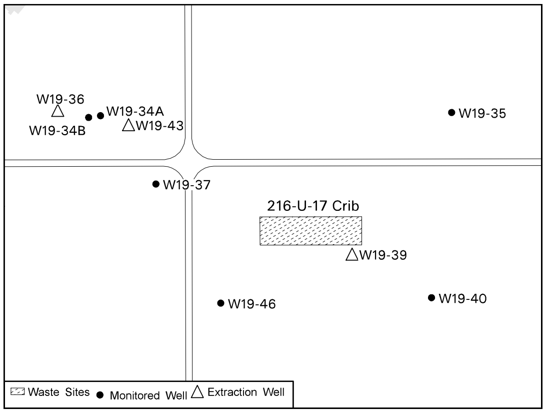
The contaminants of concern for the 200-UP-1 Operable Unit have been classified into an initial list of high priority constituents that resulted from a data quality objective process to support integrated CERCLA/AEA monitoring, as well as additional contaminants of concern that resulted from a data quality objective process to support the remedial investigation/feasibility study (DOE/RL-92-76, Rev. 1, Draft B). Most of the groundwater sampling conducted within the operable unit is for the high priority constituents. To determine if the additional constituents occur in groundwater within the operable unit, seven wells were sampled for the additional constituents during FY 2004. The seven wells selected are 299-W19-43 and 299-W19-46 within the pump-and-treat area; 699-38-70 downgradient of the pump-and-treat area; and 299-W22-83, 299-W23-4, 299-W23-10, and 299-W23-21 in the vicinity of the 216-S-25 crib and S-SX Tank Farm. These additional constituents of concern are documented in the remedial investigation/feasibility study work plan (DOE/RL-92-76, Rev. 1, Draft B) and include an extended list of volatile organic compounds, metals, anions, ammonium ion, ammonia, cyanide, sulfide, cresols, phenols, total petroleum hydrocarbons (kerosene range), beta emitters (carbon-14 and selenium-79), alpha emitters (neptunium-237 and protactinium-231), and gamma emitters (cesium-137 and cobalt-60).

In 7 wells supporting the remedial investigation/ feasibility study, there were no detections above a drinking water standard for 35 additional constituents of concern.

Other than those constituents that are ubiquitous in groundwater (i.e., magnesium, manganese, and vanadium), there were no confirmed detections of an additional contaminant of concern in the groundwater. Only two of the additional contaminants of concern (other than those widely occurring) were found at levels above twice their detection limit: selenium-79 in well 299-W22-83 (at 20.3 pCi/L with a minimum detectable activity of 8.16 pCi/L) and tetrachloroethene in well 299-W23-21 (at 1.3 µg/L with a detection limit of 0.17 µg/L). The selenium-79 result in well 299-W22-83 should be viewed as tentative until it is confirmed with another sample result (scheduled for FY 2005), since the reported value is only 2.5 times the minimum detectable activity. The tetrachloroethene result may be a false positive, because this constituent was not detected in three other samples collected from this well during FY 2004. The drinking water standard for tetrachloroethene is 5 µg/L. Selenium-79 does not have an established drinking water standard, but a concentration of 630 pCi/L equates to a radiological dose of 4 millirem per year for a drinking water exposure scenario, which is a radiological dose limit established by DOE. Sulfide (1,600 µg/L) and cyanide (25 µg/L) were detected in well 699-38-70 but were not detected in a concurrent duplicate sample. Sulfide was detected in two other wells (at 1,200 µg/L in both wells 299-W22-83 and 299-W23-10) at less than twice the detection limit (700 µg/L), but could be false positives given the results at well 699-38-70. Other constituents were found very near their detection limits and were qualified by the analytical laboratory as being estimates and are assumed to be false positives. Magnesium, manganese, and vanadium are metals widely found in groundwater, and their reported values were consistent with levels typically found within the groundwater interest area.

2.9.2 Interim Groundwater Remediation for Technetium-99 and Uranium

The pump-and-treat system at the 200-UP-1 Operable Unit operates as an interim action to contain the high concentration portions of the technetium-99 and uranium plumes emanating from the 216-U-1,2 cribs and to reduce the concentrations in these plumes (ROD 1997). The remedial action goal for the interim action is 9,000 pCi/L for technetium-99 and 480 µg/L for uranium. These concentrations are 10 times the technetium-99 drinking water standard and 10 times the uranium cleanup level under the *Model Toxics Control Act* (WAC 173-340) at the time the record of decision was issued. After removal from the three extraction wells, groundwater is transported via pipeline from the 200 West Area ~11 kilometers to the Effluent Treatment Facility in the 200 East Area. The treated groundwater is disposed at the Treated Effluent Disposal Facility and the State-Approved Land Disposal Site. The sampling and analysis plan for FY 2004 sampling is incorporated into the Draft *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-92-76, Rev. 1, Draft A). Appendix A presents the monitoring well network, including a well list, sampling frequencies, and analyte lists. All wells were sampled as scheduled.



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2.9.2.1 Progress During FY 2004

During the fiscal year, ~93.8 million liters of contaminated water from the 200-UP-1 Operable Unit were treated at the Effluent Treatment Facility. Over 801 million liters have been treated since startup of remediation activities in FY 1994. During FY 2004, 23.5 kilograms of uranium and 12 grams (0.2 curie) of technetium-99 were removed from the aquifer. In addition, 5.4 kilograms of carbon tetrachloride and 5,207 kilograms of nitrate (secondary contaminants of concern) were removed. These values along with the amount of mass removed since startup of operations are given in Table 2.9-1.

The average extraction system pumping rate for the entire year was 177.9 liters per minute, which is below the remedial design of 189.3 liters per minute. In January 2004, a third extraction well, 299-W19-36, was brought on line in addition to wells 299-W19-39 and 299-W19-43. With this additional extraction well and more consistent operations, the average pumping rate has increased to 192.2 liters per minute. Even so, overall extraction well production rates continue to decrease because of the regionally declining water table.

Another effect of the regionally declining groundwater level is a reduced ability to monitor and track plume changes, because several monitoring wells in the baseline plume area have gone dry. To improve plume tracking, new well 299-W19-48 was drilled upgradient of well 299-W19-39 at the end of

The remedial action objectives for the 200-UP-1 Operable Unit (ROD 1997) are:

- ***Reduce contamination in the areas with the highest concentration to below 480 µg/L for uranium and 9,000 pCi/L for technetium-99.***
- ***Reduce potential adverse human health risks through reduction of contaminant mass.***
- ***Prevent further movement of these contaminants from the highest contamination area.***
- ***Provide information that will lead to the development and implementation of a final remedy that will protect human health and the environment.***

EPA specified enhancements needed to the system in their 5-year review (EPA 2001).

During FY 2004, concentrations of technetium-99 and uranium were below their remedial action goals, and the high concentration portions of the plumes were hydraulically contained.

calendar year 2004. For more detailed information about operations during FY 2004, refer to the pump-and-treat annual report (DOE/RL-2004-72.)

2.9.2.2 Influence on Aquifer Conditions

Throughout the entire FY 2004, measured technetium-99 and uranium concentrations were below their respective remedial action goals at all four wells in the baseline plume area (i.e., that portion of the plume originally designed to be contained by the treatment system). In addition, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained. Figures 2.9-10 and 2.9-11 show measured technetium-99 and uranium concentrations for several wells in the pump-and-treat area. Figures 2.9-12 and 2.9-13 show the technetium-99 and uranium plumes at the pump-and-treat area, based on average concentrations for the fiscal year. Maps depicting the baseline technetium-99 and uranium plumes in 1995 and the current plumes in 2004 are presented in the report summary.

Technetium-99 and uranium concentrations in compliance wells 299-W19-40 and 299-W19-35, and in monitoring well 299-W19-37 midway between the extraction wells, also remained below the remedial action goal. Uranium concentrations at all wells within the pump-and-treat area remain above the revised drinking water standard of 30 µg/L, however.

During FY 2004, the water-level declined 0.4 meter, which is similar to the 0.38-meter decline observed in FY 2003. The water-level decline is responsible for reduced pumping rates at the three extraction wells and for causing a number of wells in the monitoring network to go dry. New monitoring well 299-W19-48 was installed the end of calendar year 2004 between monitoring well 299-W19-37 and extraction well 299-W19-39. This area has posted some of the highest historical concentrations of technetium-99 and uranium. The purpose of this new well is to characterize the extent of contamination with depth and ascertain the effectiveness of the pump-and-treat system in meeting the remedial action goals.

A rebound test is planned for calendar year 2005 to determine whether or not contaminant concentrations will remain below the remedial action goals with the pumping wells turned off.

Since contaminant concentrations have been below the remedial action goals for the entire FY 2004, a rebound test is planned for calendar year 2005. The purpose of this study is to determine whether or not contaminant concentrations will remain below the remedial action goals with the pumping wells turned off. The current plan is to shut off all three extraction wells in January 2005 and initiate a monthly sampling and analysis program for monitoring changes in contaminant concentrations. After a 1-year monitoring period, the path forward for the pump-and-treat system will be decided.

2.9.2.3 Geochemical Evaluation of Uranium Mobilization

Beginning in FY 2001, MSE Technology Applications, Inc. was funded by the U.S. Department of Energy (DOE) Headquarters to develop a conceptual model of uranium movement in the 200-UP-1 Operable Unit. This work was completed at the end of FY 2004. The primary task associated with this project was a geochemical modeling effort, with the goal of producing an acceptable correlation between predicted and observed concentrations of uranium in the groundwater. The scope of the project for the 200-UP-1 Operable Unit included the following tasks:

- Sample the soil and pore water for analysis of chemical and physical properties to develop a geochemical model describing uranium partitioning between the soil and the groundwater for the site.
- Use the geochemical model to investigate the partitioning relationships that may exist for potential contaminant transport paths at the site.
- Simulate uranium transport for potential transport paths at the site, including its source.
- Update the conceptual model of uranium transport at the site with the model, providing the best fit of the simulated results with observed data.

The computer model used was PHREEQCI (Parkhurst and Appelo 1999), which is a public domain equilibrium geochemical modeling program developed and supported by the U.S. Geological Survey. The modeling efforts focused on the processes (aqueous speciation, surface complexation, and precipitation) that may have controlled uranium mobility beneath the 216-U-1,2 cribs. The key modeling elements included simulating one-dimensional advective transport of the waste to the aquifer, mixing of contaminated water from the unsaturated zone with the aquifer water, and advective transport of atmospheric water through the contaminated sediments. Several scenarios were considered for the potential pathways of the crib waste to the aquifer. The scenarios were also modeled using a range of parameter values (e.g., unsaturated soil column volume, water saturation ratio, waste pore volumes, and mixing ratios). Each model predicted uranium concentrations at the water-table interface and in the aquifer that could be compared to measured, historical concentrations or used to predict future concentrations.

The conceptual model for uranium movement to the groundwater, as summarized in BHI-01311, is that contamination from the 216-U-1,2 cribs was initially retained above the Cold Creek unit and later mobilized by high-volume acidic discharges from the 216-U-16 crib. The uranium contamination reached the groundwater through a break in the continuity of the Cold Creek unit underlying the cribs, such as an erosional feature that is infilled with coarser materials, a permeable clastic dike, or an old borehole that was not adequately sealed. The results of the current modeling effort are consistent with this conceptual model and agree well with historical data of uranium contamination in groundwater. This modeling effort concluded that the uranium in the vadose zone likely sorbed on the sediment and did not precipitate to form a solid phase uranium source (e.g., sodium autunite precipitate).

A geochemical model of uranium migration beneath the 216-U-1,2 cribs indicates that uranium sorbs to sediment grains instead of precipitating to form a solid phase.

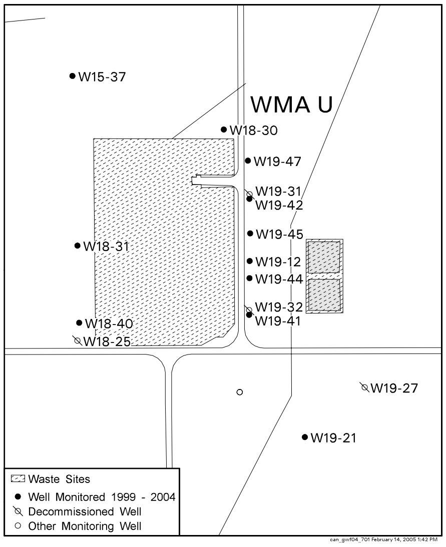
2.9.3 Facility Monitoring

This section describes results of monitoring individual facilities such as treatment, storage, and disposal units or tank farms. Some of these facilities are monitored under the requirements of RCRA for hazardous waste constituents and the AEA for source, special nuclear and by-product materials. Data from facility-specific monitoring are also integrated into the CERCLA groundwater investigations. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for each facility. As discussed in Section 2.1 pursuant to RCRA, the source, special nuclear, and by-product material component of radioactive mixed waste are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority.

Detailed groundwater monitoring is conducted at five facilities within the groundwater interest area. Four of these sites are monitored in accordance with RCRA regulations. Assessment monitoring is conducted at Waste Management Areas U and S-SX and the 216-U-12 crib; detection monitoring is conducted at the 216-S-10 pond and ditch. Groundwater monitoring at the Environmental Restoration Disposal Facility is conducted in accordance with a CERCLA record of decision (ROD 1995b). Groundwater data for these facilities are available on the Hanford Environmental Information System (HEIS 1994) and on the data files accompanying this report.

2.9.3.1 Single-Shell Tank Waste Management Area U

The objective of RCRA monitoring at this waste management area is to assess the nature and extent of groundwater contamination with hazardous constituents and determine their rate of movement in the aquifer [40 CFR 265.93(d) as referenced by WAC 173-303-400]. Groundwater monitoring under the AEA tracks radionuclides in the waste management area and surrounding vicinity. Appendix B includes a well location map and lists of wells and constituents monitored for Waste Management Area U.



Waste Management Area U was placed into assessment status in 2000 when specific conductance in groundwater monitoring wells downgradient of the waste management area exceeded upgradient levels (PNNL-13185). An assessment of that finding determined that the waste management area had affected groundwater quality with elevated concentrations of nitrate and possibly chromium in wells downgradient of the waste management area (PNNL-13282). The contaminant concentrations did not exceed their respective drinking water standards, and the area affected appeared to be limited to the southeast corner of the waste management area. A groundwater quality assessment plan (PNNL-13612) was prepared in 2001. The plan was modified in 2003 (PNNL-13612-ICN-1) to include monitoring of new wells 299-W18-40, 299-W19-44, and 299-W19-45 and to modify the analyte list. The plan as modified serves as the current plan by which groundwater quality is assessed at Waste Management Area U.

The monitoring network includes eight wells sampled quarterly – two upgradient and six downgradient of the waste management area. All eight wells were sampled each quarter during FY 2004. As part of the Tri-Party Agreement (Ecology et al. 1989) M-24 milestone process for installation of new wells, it was decided to construct one additional well in 2004 on the northeast side of the waste management area, due east of the 244-UR vault. This well was completed in September 2004; it will be sampled for the first time in November 2004 and then quarterly thereafter with the other wells in the network. With the completion of this well, all monitoring points identified for the waste management area are being monitored. The monitoring network is adequate to assess the impact of the waste management area on groundwater quality beneath the site.

Monitoring shows that Waste Management Area U contaminated groundwater with nitrate, technetium-99, and chromium.

Groundwater flow conditions at Waste Management Area U have varied greatly over the past several decades because of changing wastewater disposal in areas surrounding the waste management area, but groundwater flow has been generally to the east since 1996. During FY 2004, the direction and velocity of groundwater flow have remained the same as in the previous year. The rate at which the water table is dropping has also remained constant at ~0.3 meter per year in all of the monitoring wells during FY 2004. Therefore, the hydraulic gradient has not changed. The average linear velocity calculated based on a hydraulic conductivity of 6.12 meters per day, a specific yield of 0.17 determined in well 299-W19-42 (PNNL-13378), and a gradient of 0.0021 is ~0.08 meter per day (see Appendix B). This rate is consistent with the regional groundwater flow interpretation.

Groundwater chemistry beneath Waste Management Area U in FY 2004 has remained similar to that presented in past years for wells downgradient of the waste management area. The waste management area has been identified as the source for a small contaminant plume that is limited to the downgradient (east) side of the site (PNNL-13282). Plume constituents of interest include chromium, nitrate, and technetium-99. In the past, the plume has been delineated by the extent of elevated specific conductance because the plume contains soluble salts comprised of the anions nitrate, chloride, and sulfate that are accompanied by the cations calcium, magnesium, and sodium. Technetium-99, a tank waste constituent, has also been detected on the downgradient side of Waste Management Area U; its distribution has been closely related to that of nitrate.

The highest concentration of chromium was once (1997) approximately half the drinking water standard; however, in August 2004, chromium was only detected in one well, where it was reported at <4 µg/L. Chromium no longer appears to be an issue at Waste Management Area U.

During FY 2004, nitrate concentrations continued to increase in all monitoring wells at Waste Management Area U, including the two upgradient wells. Nitrate concentrations increased above the drinking water standard (45 mg/L) in downgradient wells 299-W19-12 and 299-W19-44. Along with downgradient well 299-W19-41, these are the only wells with nitrate concentrations above the drinking water standard at the waste management area. The highest downgradient nitrate concentrations (~63 mg/L) are nearly three times the concentrations found in upgradient wells. These observations and the nitrate plume map (Figure 2.9-9) indicate that a regional upgradient nitrate plume is encroaching into groundwater beneath the waste management area and mixing with the nitrate plume emanating from the waste management area.

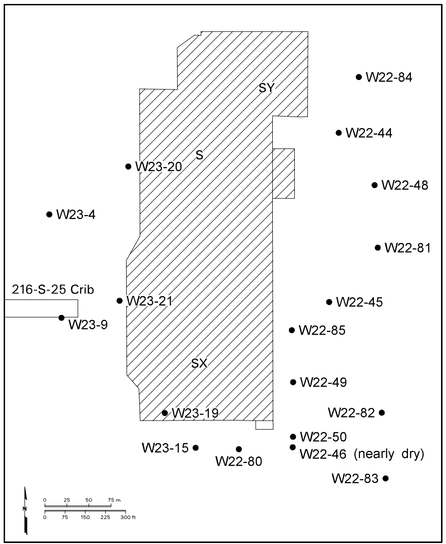
Nitrate and technetium-99, while thought to be related in the past, now appear to have different trends on the downgradient (east) side of the waste management area (Figures 2.9-14 and 2.9-15). These constituents are both very mobile in groundwater and would be expected to travel together if they were from the same source. Nitrate concentrations decrease regularly from a high of 63.3 mg/L in well 299-W19-41 (south end of the line of wells) to a low of 15.1 mg/L in well 299-W18-30 (north end of the line of wells). Technetium-99 concentrations differ from this pattern where the low concentrations are on the north and south ends of the line of downgradient wells and increasing to a maximum of 745 pCi/L (below the drinking water standard of 900 pCi/L) in well 299-W19-45 located in the middle of the line of wells. An interesting observation is that technetium-99 concentrations in the three wells north of well 299-W19-12 are all increasing, and those from well 299-W19-12 and south are all decreasing. The technetium-99 concentration in well 299-W19-45, where the highest concentration is now found, jumped by nearly a factor of 3 in August 2004. These observations indicate that nitrate and technetium-99 are from different sources and some of the differences may be related to the intrusion of an upgradient nitrate plume into the waste management area.

Carbon tetrachloride is found in groundwater beneath Waste Management Area U at concentrations above its drinking water standard of 5 µg/L. Well 299-W18-30 is the only well analyzed for carbon tetrachloride and it contained levels of 130 µg/L in August 2004. The regional carbon tetrachloride distribution (see Figure 2.8-3 in Section 2.8) indicates that the source of carbon tetrachloride found in the Waste Management Area U vicinity is from liquid waste disposal sites at the Plutonium Finishing Plant located northwest of the waste management area.

2.9.3.2 Single-Shell Tank Waste Management Area S-SX

The objective of RCRA monitoring at this waste management area is to assess the nature and extent of groundwater contamination with hazardous constituents and determine their rate of movement in the aquifer. Groundwater monitoring under the AEA tracks radionuclides in the waste management area and surrounding vicinity. Appendix B includes a well location map and lists of wells and constituents monitored for Waste Management Area S-SX. During 2004, waste retrieval operations were conducted on tank S-112 in the S Tank Farm. Vadose zone monitoring during these activities are described in Section 3.2.

Waste Management Area S-SX was placed into assessment status [40 CFR 265.93(d) as referenced by WAC 173-303-400] in 1996 at the direction of Washington State Department of Ecology (Ecology) because of elevated specific conductance and technetium-99 (not regulated by RCRA) in downgradient monitoring wells. A groundwater quality assessment plan (WHC-SD-EN-AP-191) was prepared in 1996 and the planned assessment work conducted in 1996 and 1997. An assessment of the waste management area determined (first determination) that multiple sources within the waste management area had affected groundwater quality with elevated concentrations of nitrate, technetium-99, and chromium in wells downgradient of the waste management area (PNNL-11810). A second groundwater quality assessment plan (PNNL-12114) was prepared in 1999 to further evaluate the contamination found. Since that time, two groundwater quality assessment reports have been published (PNNL-13441; PNNL-13801) covering the time period from November 1997 through December 2001, and the assessment plan was revised twice (PNNL-12114-ICN-1; PNNL-12114-ICN-2) to account



for new wells added to the monitoring network and revisions to the sampling and analysis schedule. The plan as modified serves as the current plan by which groundwater quality is assessed at Waste Management Area S-SX.

The monitoring network consists of 16 wells: 2 upgradient and 13 downgradient of the waste management area, and 1 well located within the area. The wells are sampled quarterly. All 16 wells were sampled each quarter during FY 2004, although the sampling of 5 of the wells was delayed from December 2003 to early February 2004 because of cold weather in December and January. As part of the Tri-Party Agreement M-24 milestone process for installation of new wells, it was decided to construct one additional well in 2004 southeast of the waste management area, due south of well 299-W22-46, to better define the south boundary of a contaminant plume in this area. The need and specifications for this well are described in CP-15329. This well will be installed in 2005. Over the past several years, the leading fronts of contaminant plumes emanating from the waste management area have migrated beyond the farthest downgradient monitoring wells in the network. Additional, further downgradient wells have been identified to monitor these areas. These wells are also identified in CP-15329, but have yet to be included in the Tri-Party Agreement M-24 milestone process.

Sources within Waste Management Area S-SX have contaminated groundwater with nitrate, chromium, and technetium-99. The south portion of the plumes expanded in FY 2004.

Groundwater Flow. During FY 2004, the direction and velocity of groundwater flow remained the same as in the previous year, in spite of the falling water table. The rate at which the water table is dropping remained the same as last year, which is estimated at ~0.3 meter per year. This decline was the same in all wells across the waste management area; therefore, the hydraulic gradient has remained stable. Estimates of groundwater flow velocity, using travel times for tritium and technetium-99 between monitoring wells in the vicinity of Waste Management Area S-SX, suggest groundwater flow rates of 25 to 50 meters per year, or 0.07 to 0.14 meter per day. Calculated average linear velocities (using Darcy's method) based on hydraulic conductivity and tracer test data, also suggest similar flow rates (0.009 to 0.36 meter per day; see Appendix B). The groundwater flow direction inferred from water-table elevation contours suggests an east-southeast flow direction over the larger area around the waste management area (see Figure 2.8-2 in Section 2.8). This direction of flow is consistent with the shape of the contaminant plume on the south side of the waste management area and the direction in which it is expanding.

Groundwater Contamination. Groundwater beneath this waste management area is contaminated with nitrate, hexavalent chromium, and technetium-99 attributed to two general source areas within the waste management area. One source area is in the S Tank Farm and the other is located to the south in the SX Tank Farm. The nitrate, chromium, and technetium-99 plumes are depicted in Figures 2.9-16, 2.9-17, and 2.9-18, which show average concentrations for the fiscal year. Carbon tetrachloride (see Figure 2.8-3 in Section 2.8) is also present in groundwater beneath the waste management area, but its source is upgradient of the waste management area (PNNL-13441). Tritium is also present beneath the waste management area as seen in Figure 2.9-6, but its source is the 216-S-25 crib located just west (upgradient) of the SX Tank Farm (PNNL-13441).

The north plume, with a source in the S Tank Farm, has migrated eastward mainly through well 299-W22-48. During FY 2004, constituent concentrations in this plume (chromium, nitrate, and technetium-99) increased significantly in well 299-W22-44. This well is located north of well 299-W22-48, where concentrations of the same constituents decreased during FY 2004 and are now about the same as in well 299-W22-44. The bulk of the contaminant plume is now in the area surrounding wells 299-W22-44 and 299-W22-48, which is more northward than in previous years. The plume is bounded by wells 299-W22-84 on the north and 299-W22-81 on the south, because chromium, nitrate, and technetium-99 concentrations are significantly less than the two wells in the middle of the plume.

The contaminant plumes located in the south portion of the waste management area comprise nitrate, chromium, and technetium-99 just as in the S Tank Farm plume to the north. In addition, tritium and carbon tetrachloride plumes are present beneath the waste management area, but their sources are the 216-S-25 crib and the Plutonium Finishing Plant cribs, respectively (PNNL-13441). The nitrate plume originated in the tank farm as well as in the 216-S-25 crib, as suggested by its distribution in Figure 2.9-16. The downgradient migrating nitrate front, as indicated by the 45-mg/L isopleth, was beyond the farthest downgradient monitoring well 299-W22-83 for the entire year. Nitrate concentrations in this well increased from 45.2 mg/L at the end of FY 2003 to a maximum of 70.2 mg/L in June 2004. The same pattern was observed for the chromium (Figure 2.9-17) and technetium-99 (Figure 2.9-18) distributions at the distal end of the plume, but major differences were observed in the plume near the source area as represented by well 299-W23-19.

In the vicinity of the SX Tank Farm plume source area, chromium concentrations increased during FY 2004 by approximately five-fold from 58 µg/L to 320 µg/L in well 299-W23-19, well above the drinking water standard of 100 µg/L (Figure 2.9-19). This indicates that a new pulse of chromium contaminated water has reached groundwater. Figure 2.9-17 shows that this pulse of chromium is distinct from an earlier pulse that is now located in the middle of the plume area. The middle of the plume is represented by well 299-W22-50, where chromium concentrations have reached a peak and have been decreasing throughout 2004 (Figure 2.9-20). This earlier chromium pulse has continued to migrate downgradient where the peak has yet to reach well 299-W22-83, but chromium concentrations in this well are increasing and approaching the drinking water standard (Figure 2.9-21).

Technetium-99 trends differed greatly from chromium trends in the SX Tank Farm plume source area (i.e., well 299-W23-19) as seen in Figure 2.9-19. During FY 2004, when chromium concentrations increased five-fold, technetium-99 concentrations remained stable at ~45,000 pCi/L after decreasing four-fold in 2003 from 188,000 pCi/L. These opposite trends indicate that chromium and technetium-99 may have different sources within the tank farm. The surprising aspect of these observations is that they occurred during the time in which well 299-W23-19 was purged for a minimum of 3,785 liters of water after each quarterly sampling event. The large volume purge was started in March 2003 and continued through 2004. Because of the rapid decrease in technetium-99 concentrations through the rest of 2003, it could be interpreted that the purging had a beneficial influence on the technetium-99 concentrations. However, because technetium-99 concentrations suddenly stabilized throughout 2004 and chromium concentrations rose rapidly even while the practice of purging continued, the effect of purging on contaminant concentrations may not be as significant as indicated by the 2003 technetium-99 trends. At the middle (Figure 2.9-20) and distal end (Figure 2.9-21) of the SX Tank Farm plume, trends for nitrate, chromium, and technetium are similar, indicating either a single source or that the constituents arrived at the water from different sources within the waste management area but at the same time in the past.

In 2003, DOE and Ecology agreed to the practice of extended purging during sampling at well 299-W23-19 to remove technetium-99 from the groundwater. This practice continued during FY 2004.

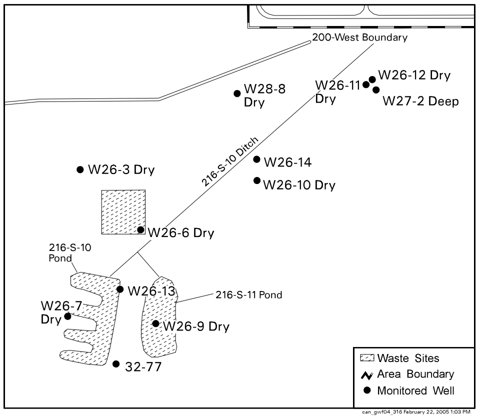
In figures depicting nitrate, chromium, and technetium-99 distributions, a low concentration island has been drawn in each plume at wells 299-W22-80 and 299-W23-15 to reflect preliminary information that may indicate the constituent concentrations in samples collected from these wells are artificially low. The evidence includes (1) aquifer tests that indicate a natural upward flow exists in the screened section of well 299-W22-80 and (2) preliminary time series sampling during extensive pumping that indicates water near well 299-W22-80 (which is sampled using standard well purging protocol) is much less contaminated than water in the surrounding area. Therefore, clean water near the bottom of well 299-W22-80 may be migrating up through the well and diluting the plume in the upper part of the aquifer. A similar process is assumed to be occurring at well 299-W23-15 due to its proximity to well 299-W22-80 and similarly low concentrations. The contaminant plumes are also interpreted as occurring farther to the south than previously depicted (e.g., PNNL-14548). This interpretation is based on preliminary information collected during

FY 2005 at a new well installed ~50 meters south of well 299-W22-46, which became available prior to completion. These observations will be more fully investigated in the future.

Specific Conductance Measurements in Well 299-W23-19. Well 299-W23-19 was re-configured in February and March 2003 and instrumented with a permanent sampling pump and four specific conductance probes located at regularly spaced vertical positions in the well screen. Also, at the request of Ecology, the practice of purging at least 3,785 liters of water from the well after each quarterly sampling event was started in March 2003. Details for the installation are presented in the annual report for 2003 (PNNL-14548). This work was done to test the possibility that fluctuations in sample groundwater chemistry reflected actual variations in the plume. Specific conductance is a measure of the quantity of the major dissolved constituents such as calcium, magnesium, chloride, and nitrate in the water. Because these constituents are major components of the contaminant plume, specific conductance is an easily measured indicator of the plume location and spatial and temporal variations in the plume. Specific conductance measurements collected in 2004 are presented in Figure 2.9-22. The same data collected for the June 2004 sampling and purging event are presented in Figure 2.9-23.

Figure 2.9-22 shows, as reported in 2003, that sampling greatly perturbs the water chemistry in the well. Figure 2.9-23 presents an expanded view of the data during the June 15, 2004, sampling and purging event. Figure 2.9-23 shows the magnitude of the difference in groundwater composition between static and dynamic conditions in the well. Prior to 0800 hours, measurements were made under static conditions. When the pump was turned on, specific conductance increased in the upper three probes, but dropped in probe #4, the deepest probe located ~1 meter below the pump intake and ~0.7 meter above the bottom of the well. Because the pump intake is set between probes #3 and #4, water pumped to the ground surface would have a composition that is a blend of water passing these two probes. Figure 2.9-23 shows that during the extended purging, when the pumping rate is increased four-fold, the water level drops below the uppermost probe #1 (shown in blue) causing the probe to report conductance values of zero. When pumping is stopped, the well recovers and probe #1 is rewetted. The general responses are the same as reported in 2003 and indicate that static measurements (no active pumping) can vary depending on where the measurements are made in the well, and that the contamination resides in the upper portion of the aquifer, largely above probe #3.

Groundwater Treatment. To remove technetium-99 from the groundwater, the practice of extended purging during sampling at well 299-W23-19 was continued during FY 2004. This practice was agreed to by DOE and Ecology and was begun in 2003. After samples are collected from this well each quarter, purging of the well is continued at a higher flow rate until a minimum of 3,785 liters of water is removed from the aquifer. This water is transferred to the Effluent Treatment Facility for treatment and disposal. Table 2.9-2 presents the date, amount of water collected, and a calculation of the mass and activity of technetium-99 removed from the aquifer. A total of ~0.0007 curie (~0.043 gram) of technetium-99 was recovered during FY 2004. Since the start of this treatment in 2003, a total of ~0.002 curie (~0.110 gram) of technetium-99 has been recovered.



2.9.3.3 216-S-10 Pond and Ditch

The 216-S-10 pond and ditch was active from 1951 through 1991, and received effluent primarily from the REDOX Plant chemical sewer. The site is monitored semiannually under RCRA interim status indicator evaluation [WAC 173-303-400 and by reference 40 CFR 265.93(b)] to detect any effect on groundwater that may occur from past facility operations. Groundwater monitoring under the AEA tracks radionuclides in the waste management area and surrounding vicinity. Appendix B includes a well location map and lists of wells and constituents monitored for the 216-S-10 pond and ditch.

RCRA groundwater monitoring has been conducted in accordance with interim status requirements since 1991. The 216-S-10 facility has not received liquid waste since October 1991 and is scheduled to be closed under a Part B Permit after 2006 in accordance with the Tri-Party Agreement (Ecology et al. 1989) permit modification schedule, and in accordance with a future CERCLA record of decision. Results of the CERCLA 200-CS-1 Chemical Sewer Group Operable Unit remedial investigation conducted during FY 2003 at the 216-S-10 pond and ditch are detailed in Section 3.1.

All but three of the monitoring wells for the 216-S-10 pond and ditch have gone dry.

The water table beneath the 216-S-10 pond and ditch continued to decline in FY 2004. The current RCRA monitoring network consists of two downgradient wells (the others having gone dry): well 299-W26-13 located near the pond and new well 299-W26-14 located just east of the central portion of the ditch. Upgradient well 299-W26-7 went dry in 2003. The network also includes one deep downgradient well, 299-W27-2, which is screened at the bottom of the uppermost unconfined aquifer. RCRA requirements for interim status monitoring specify that a minimum of one upgradient and three downgradient monitoring wells are needed to monitor the site. The groundwater monitoring plan, updated in 2002 (PNNL-14070), proposed to deepen or replace two existing dry wells to bring the facility back into compliance with RCRA and Washington Administrative Code (WAC) requirements. All new RCRA wells installed at Hanford are negotiated annually by Ecology, DOE, and EPA and approved under the Tri-Party Agreement (Ecology et al. 1989) Milestone M-24-00.

During 2004, the only exceedance of a drinking water standard occurred in the deep well 299-W27-2 for carbon tetrachloride, which is believed to have come from an upgradient source. Nickel is also elevated in this well, but its source is unknown. The long, gradual increase in nickel concentrations, followed by a stable elevated trend in FY 2004, suggests this occurrence is not an analytical or sampling artifact but may be due to corrosion of stainless steel well materials. Similar increases in nickel have occasionally been noted in other wells as they go dry (e.g., well 299-W7-1).

Elevated chromium concentrations at well 299-W26-7 (now dry) have varied above the 100-μg/L drinking water standard during the past 10-year life of the well. This may have been caused by short-term releases migrating through the vadose zone from past effluent releases in the pond. For example, historical records document a 1983 release to the 216-S-10 facility of a high-salt waste (simulated tank waste) containing hexavalent chromium. Although well 299-W26-7 was designated as an upgradient well, it is located very close to one lobe of the pond system and could easily have been affected by drainage spreading laterally in the vadose zone (see Appendix B). A REDOX Plant disposal pond, which is located immediately upgradient of the 216-S-10 pond and ditch, has not been ruled out as a potential source of chromium contamination.

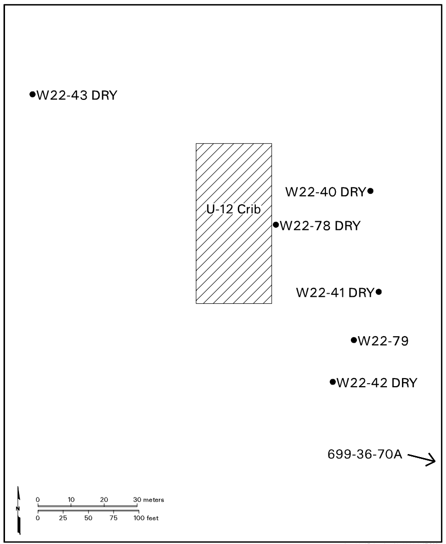
There were no exceedances of an indicator parameter during FY 2004, so the 216-S-10 pond and ditch remains in detection monitoring.

Nitrate concentrations were covariate with chromium concentrations in dry wells 299-W26-7, 299-W26-9, 299-W26-10, and 299-W26-12. The upgradient well 299-W26-7 had the highest nitrate concentrations. This and other data presented in PNNL-14070 suggests that the 216-S-10 pond could be the source of this nitrate and chromium increase. Although chromium and nitrate were elevated in the dry upgradient well 299-W26-7, significant concentrations of these constituents have not been detected in the downgradient wells. Chromium concentrations in new well 299-W26-13 (located nearby and just downgradient of well 299-W26-7) are only slightly elevated above the chromium concentrations in the other two downgradient wells, which are near background.

Because the only upgradient well, 299-W26-7, went dry in year 2003, the comparison of RCRA indicator parameters (specific conductance, pH, total organic carbon, and total organic halides) between upgradient and downgradient wells was conducted using the most recent collected background values of contaminant indicator parameters from well 299-W26-7 before it went dry (see Appendix B). When data from a new upgradient well become available, new background values will be calculated and used for the required upgradient/downgradient comparisons. Based on statistical evaluations of contamination indicator parameters conducted during FY 2004, there are no statistically significant differences (i.e., constituents in the downgradient wells are not elevated compared to the upgradient well). Therefore, this site remains in detection monitoring.

Based on regional groundwater elevations, the groundwater flow direction continues toward the east-southeast. The average linear velocity has not changed significantly since last year and ranges from 0.007 to 0.3 meter per day.

2.9.3.4 216-U-12 Crib



The 216-U-12 crib is located ~600 meters south of U Plant in the southeast portion of the 200 West Area. The crib is an unlined, gravel-bottom, percolation crib 3 meters by 30 meters, and 4.6 meters deep. The crib received process effluent from U Plant, including corrosive liquid condensate from the 224-U Building, and operated from 1960 through 1972 and from 1981 until it was permanently retired in February 1988. A yearly average of over 1.02 x 10^7 L/yr of effluent was disposed to the crib from 1960 through 1972 (RHO-CD-673). Total volume disposed to the 216-U-12 crib exceeded 1.33 x 10^8 L from 1960 through 1972.

The objective of RCRA monitoring at the 216-U-12 crib is to assess the nature and extent of groundwater contamination with hazardous constituents and determine their rate of movement in the aquifer. Groundwater monitoring under the AEA tracks radionuclides at this crib and surrounding vicinity. Appendix B includes a well location map and lists of wells and constituents monitored for the 216-U-12 crib.

In FY 2004, the 216-U-12 crib was regulated under a RCRA interim-status assessment program [WAC 173-303-400 and by reference 40 CFR 265.93(d)]. Monitoring was conducted under a groundwater assessment sampling and analysis plan issued during 2003 (PNNL-14301). The number of network monitoring wells in FY 2004 remained the same as FY 2003. Declining water levels in the 200 West Area have reduced the 216-U-12 crib monitoring network from the original four wells to just two downgradient wells (299-W22-79 and 699-36-70A), which is fewer than the minimum number of wells required by RCRA. Ecology, EPA, and DOE annually negotiate the location and priority of installation for future Hanford Site groundwater monitoring wells under Tri-Party Milestone M-24-00. The 216-U-12 crib network is sampled quarterly for the constituents of interest (see Appendix B).

The current objectives of interim status assessment monitoring for the 216-U-12 crib include the following:

- Continue groundwater monitoring to assess the migration of potential dangerous waste constituents out of the vadose zone into the groundwater.
- Monitor under interim status assessment until a final status monitoring plan is implemented following closure of the facility.

The 216-U-12 crib contributed to nitrate and technetium-99 contamination.

These objectives support the delineation of the existing known plumes, which through RCRA/CERCLA integration, is being managed under the CERCLA 200-UP-1 monitoring program. The existing plumes co-mingle with plumes from other U Plant and REDOX Plant source areas, making it difficult to distinguish the specific plumes emanating from the 216-U-12 crib.

Future closure of the 216-U-12 crib will be coordinated with and conducted under CERCLA per the U Plant waste sites focused feasibility study (DOE/RL-2003-23) and proposed plan (DOE/RL-2003-24). The 216-U-12 crib will be closed under RCRA final status requirements (WAC 173-303-645) based on a modified program as allowed by the Tri-Party Agreement action plan, Section 5.5. A revised and updated groundwater monitoring plan for the 216-U-12 crib, containing the proposed final status approach [as required under WAC 173-303-645(11)], is being reviewed by the regulatory agencies. This plan is intended to serve as a transition to a monitoring approach that embraces both the RCRA treatment, storage, and disposal unit (i.e., 216-U-12 crib) and the 200-UW-1 U Plant area waste sites operable unit. RCRA closure requirements for the 216-U-12 crib will be fulfilled by the CERCLA/RCRA integration process for the 200-UW-1 and 200-UP-1 Operable Units. RCRA interim status groundwater monitoring objectives, as stated above, will remain the same until closure of the crib and then shift to the regulatory approved final status closure/post-closure plan. The 200-UP-1 Operable Unit is responsible for contaminants within the groundwater beneath the 200-UW-1 Operable Unit.

All but two monitoring wells at the 216-U-12 crib have gone dry.

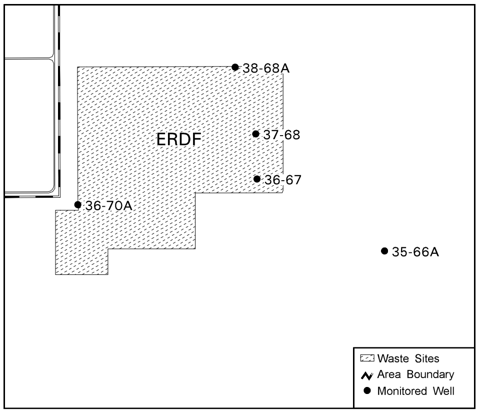
The 216-U-12 crib was placed into assessment status due to elevated specific conductance downgradient of the facility. Elevated calcium and nitrate are the major contributors to the specific conductance. Technetium-99 is also defined as a co-contaminant that is migrating with nitrate in the groundwater. These constituents are being evaluated through quarterly groundwater monitoring. The regional nitrate and technetium-99 plumes are actually a co-mingled series of smaller plumes with sources from several cribs (216-U-1,2; 216-U-8; and 216-U-12) in the U Plant area.

The key indicator parameter, specific conductance, remained relatively unchanged during 2004 in both network wells 299-W22-79 and 699-36-70A. During 2004, nitrate continued to decline below the drinking water standard (45 mg/L) in well 299-W22-79 and remained relatively unchanged above the standard in far field well 699-36-70A. The co-contaminant, technetium-99 (which is not regulated under RCRA), remains elevated slightly above background in both network wells (highest value reported for FY 2004 was 64 pCi/L in well 699-36-70A). All other constituents remained on trend at or near background throughout the year.

There are not enough network wells at the 216-U-12 crib to determine groundwater flow direction; however, based on the surrounding regional groundwater elevations, the direction of groundwater flow beneath the 216-U-12 crib continues relatively unchanged toward the east-southeast to east (see Figure 2.8-2 in Section 2.8). The pre-Hanford flow direction in the vicinity of the 216-U-12 crib is believed to have been from west to east, and it is expected that groundwater flow will eventually return to a more eastward direction. Average linear groundwater flow velocities remain relatively the same as last year and range from 0.01 to 0.003 meter per day (see Appendix B).

2.9.3.5 Environmental Restoration Disposal Facility

The Environmental Restoration Disposal Facility is a low-level, mixed waste facility where waste from surface remedial actions on the Hanford Site is disposed. The site is designed to meet RCRA standards, although it is not permitted as a RCRA facility. Groundwater monitoring is conducted in accordance with a CERCLA record of decision (ROD 1995b). One upgradient well (699-36-70A) and three downgradient wells (699-37-68, 699-36-67, and 699-35-66A) are sampled semiannually, typically in the second and fourth quarters of the fiscal year. All four wells were sampled as planned during FY 2004, although some wells were sampled later than others due to maintenance issues. For a discussion of leachate monitoring at this facility, see Section 3.2. Appendix B contains additional information regarding the Environmental Restoration Disposal Facility. See BHI-01738 for calendar year 2003 groundwater and leachate monitoring results. Calendar year 2004 results will be described in an upcoming report. See BHI-00873 for the sampling and analysis plan.



Results of groundwater monitoring at the Environmental Restoration Disposal Facility continued to indicate that the facility has not adversely impacted groundwater quality. Several constituents are present in the groundwater at or above drinking water standards (tritium, iodine-129, nitrate, and carbon tetrachloride), but these constituents are elevated in both the upgradient and downgradient wells. Figures 2.9-6, 2.9-8, and 2.9-9, and Figure 2.8-3 in

Section 2.8 indicate that these plumes originate in the 200 West Area and have migrated into the vicinity of the Environmental Restoration Disposal Facility.

Results of groundwater monitoring at the Environmental Restoration Disposal Facility continued to indicate that the facility has not adversely impacted groundwater quality.

Both filtered and unfiltered samples are collected for metals (except for uranium samples, which are unfiltered). Overall, the FY 2004 sampling results appear more stable than the previous fiscal year, likely due (at least in part) to lower and more stable turbidity observed in the samples. High turbidity (suspended solids) is a common source for variability in water sample analytical results.

It was previously noted (PNNL-14548) that values for gross beta in well 699-35-66A, and gross beta, unfiltered total chromium, and unfiltered zinc in well 699-37-68, were higher than normal. These metals results were associated with higher than normal turbidity in the samples (filtered chromium and zinc were on trend). Samples collected during FY 2004 in this well had lower turbidity values; the gross beta values stabilized, and the unfiltered total chromium and unfiltered zinc values decreased. None of these constituents, when filtered, have exceeded a drinking water standard, but future results will continue to be evaluated. Potential new out of trend values (high) were noted for the following: gross alpha, technetium-99, and unfiltered zinc in well 699-35-66A; and technetium-99 in well 699-37-68. Values for all these constituents remained well below drinking water standards. The technetium-99 increases are not large relative to previous years (maximum measured value in FY 2004 was 68 pCi/L); however, both wells show a nominal tripling of the technetium-99 concentrations over the last 6 years. It is possible that this increase is due to plumes from the 200 West Area migrating into the vicinity of the Environmental Restoration Disposal Facility.

Table 2.9-1. Summary of Contaminant Mass Removed from the Aquifer during Pump-and-Treat Operations at the 200-UP-1 Operable Unit, FY 2004 and Totals Since Startup of Operations

Contaminant	Fiscal Year 2004	Since Startup (March 1994)
Uranium	23.5 kg	203 kg
Technetium-99	12 g (0.2 Ci)	114.1 g (1.94 Ci)
Carbon tetrachloride	5.4 kg	31.2 kg
Nitrate	5,207 kg	32,550 kg

Table 2.9-2. Quantity of Treated Groundwater and Technetium-99 Mass Removed from the Aquifer during Extended Purging at Well 299-W23-19, FY 2004

Sample Date	Volume of Water Treated Liters (gal)	Technetium-99 Concentration (pCi/L)	Activity of Technetium-99 Removed (Ci)	Mass of Technetium-99 Removed (g)
December 16, 2003	3,944 (1,042)	43,000	0.00017	0.010
March 22, 2004	4,845 (1,280)	42,200	0.00020	0.012
June 15, 2004	3,989 (1,054)	41,800	0.00017	0.010
September 29, 2004	4,111 (1,086)	46,100	0.00019	0.011
Totals	16,889 (4,462)	NA	0.00073	0.043

NA = Not applicable.

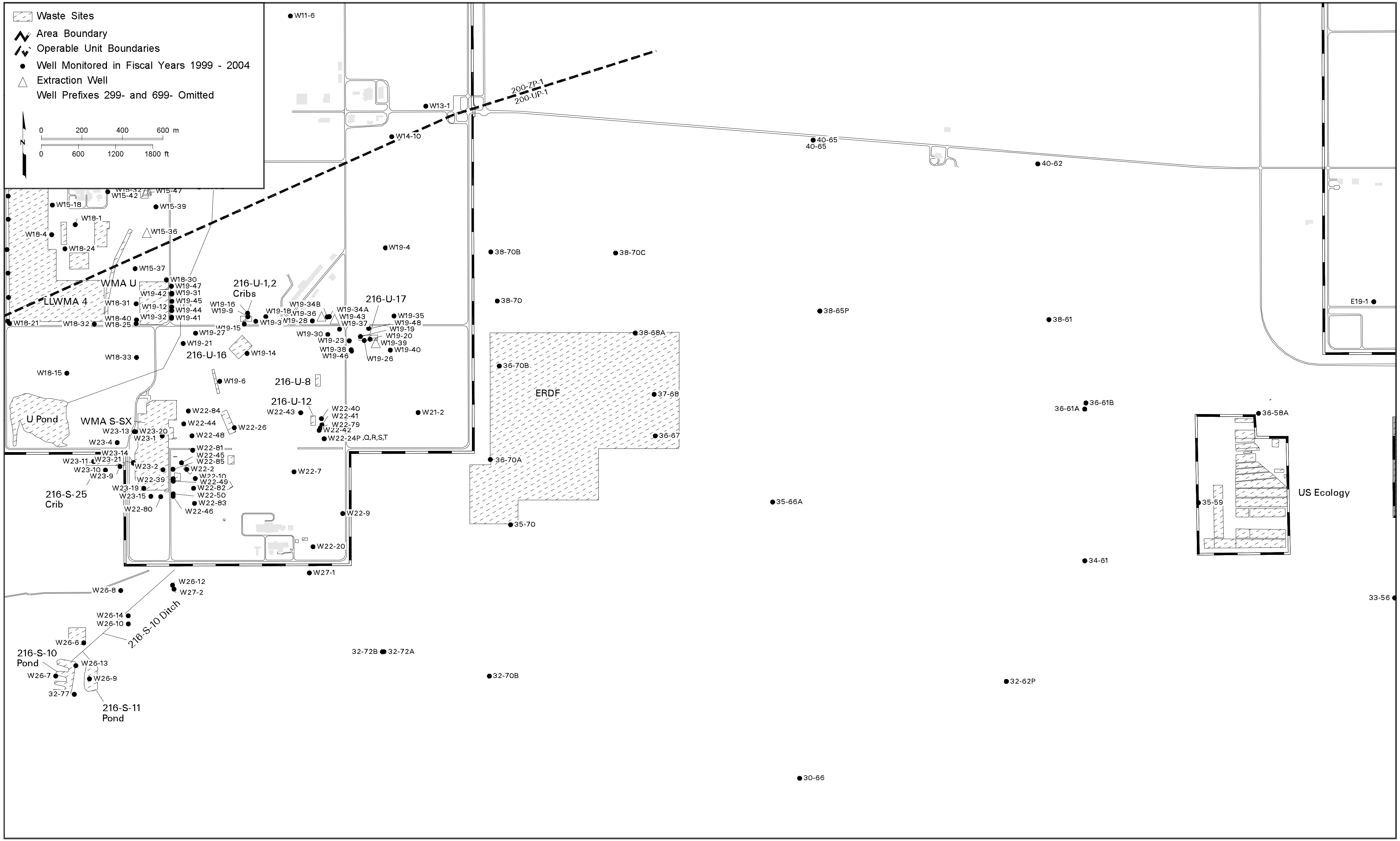


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Figure 2.9-1. Facilities and Groundwater Monitoring Wells in the 200-UP-1 Groundwater Interest Area

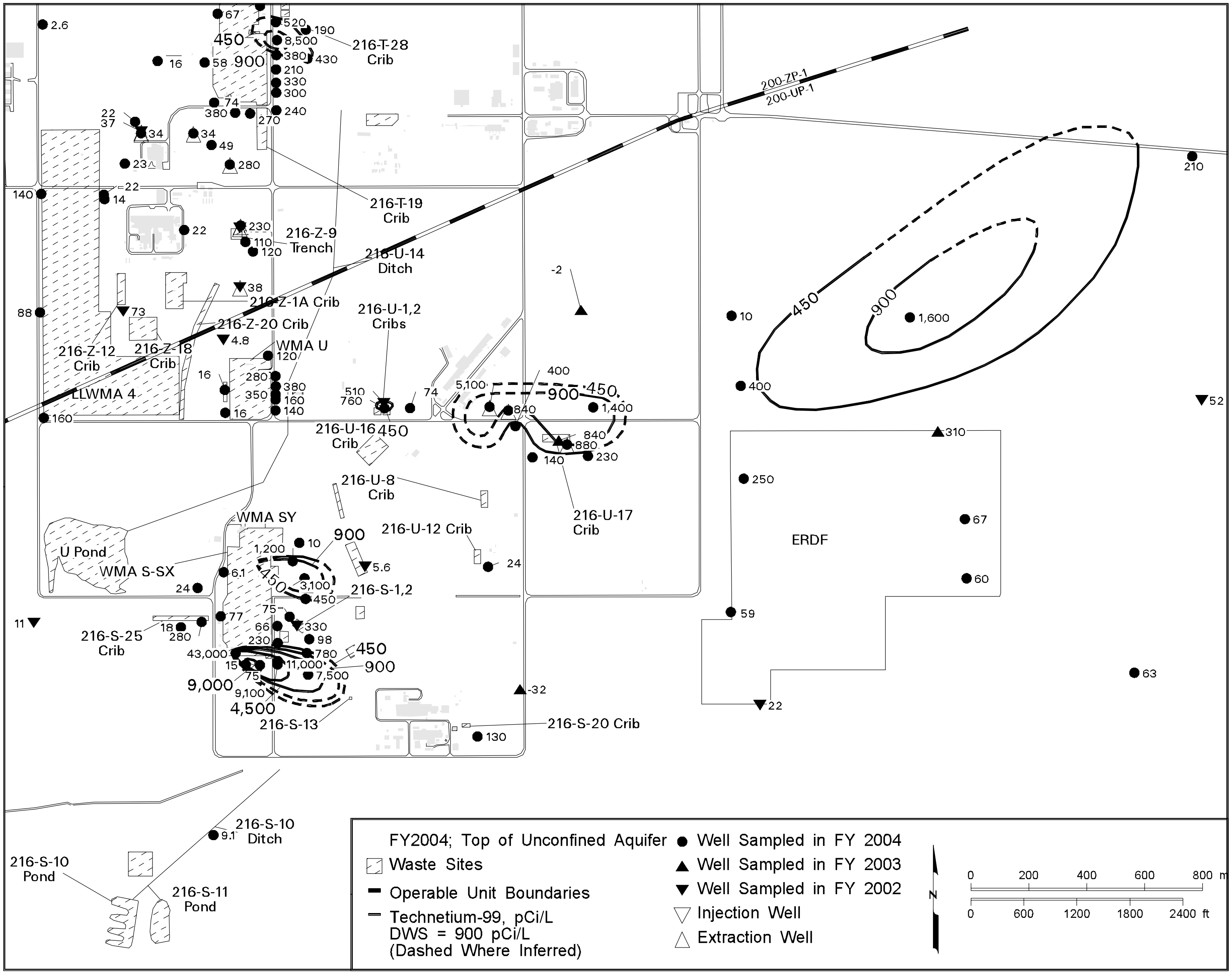

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Figure 2.9-2. Average Technetium-99 Concentrations in the 200-UP-1 Groundwater Interest Area, Top of Unconfined Aquifer

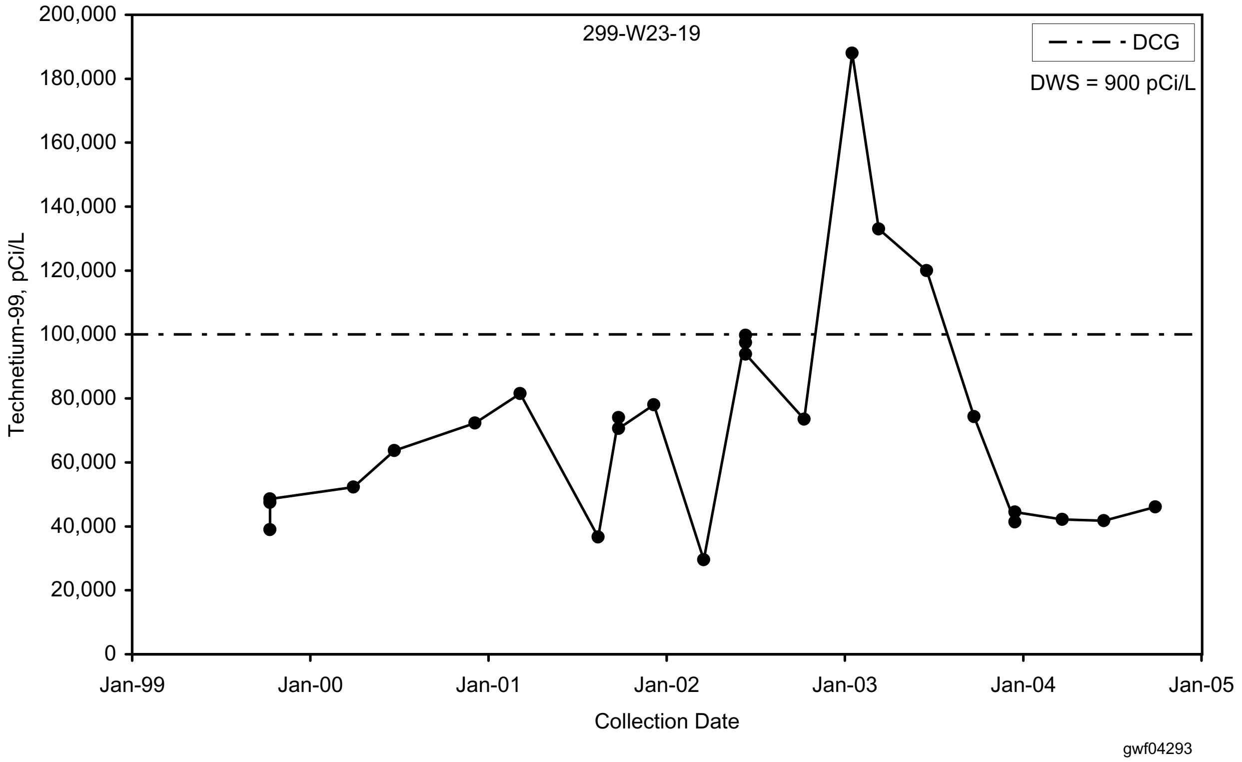

Figure 2.9-3. Technetium-99 Concentrations at Waste Management Area S-SX

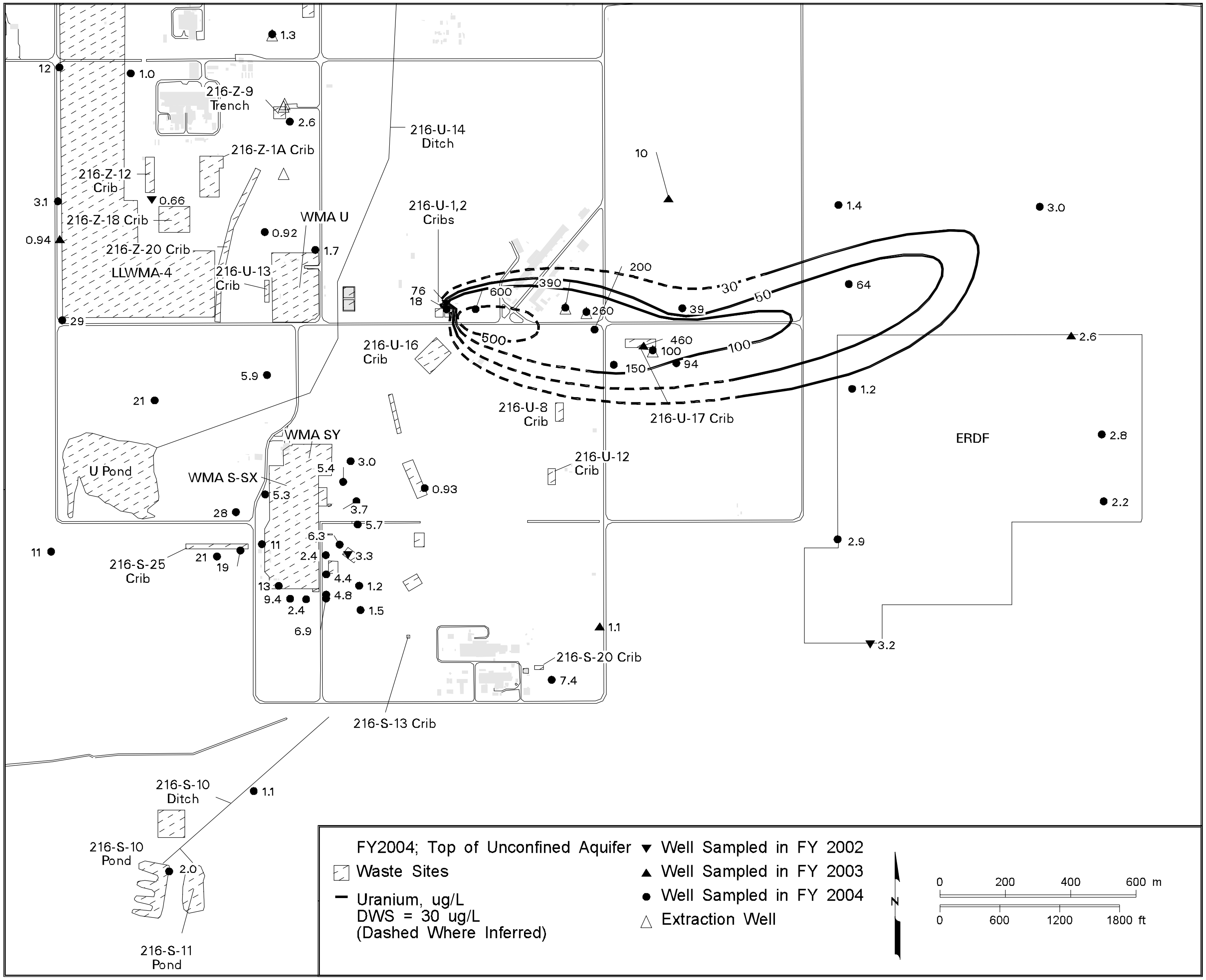

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Figure 2.9-4. Average Uranium Concentrations in the 200-UP-1 Groundwater Interest Area, Top of Unconfined Aquifer

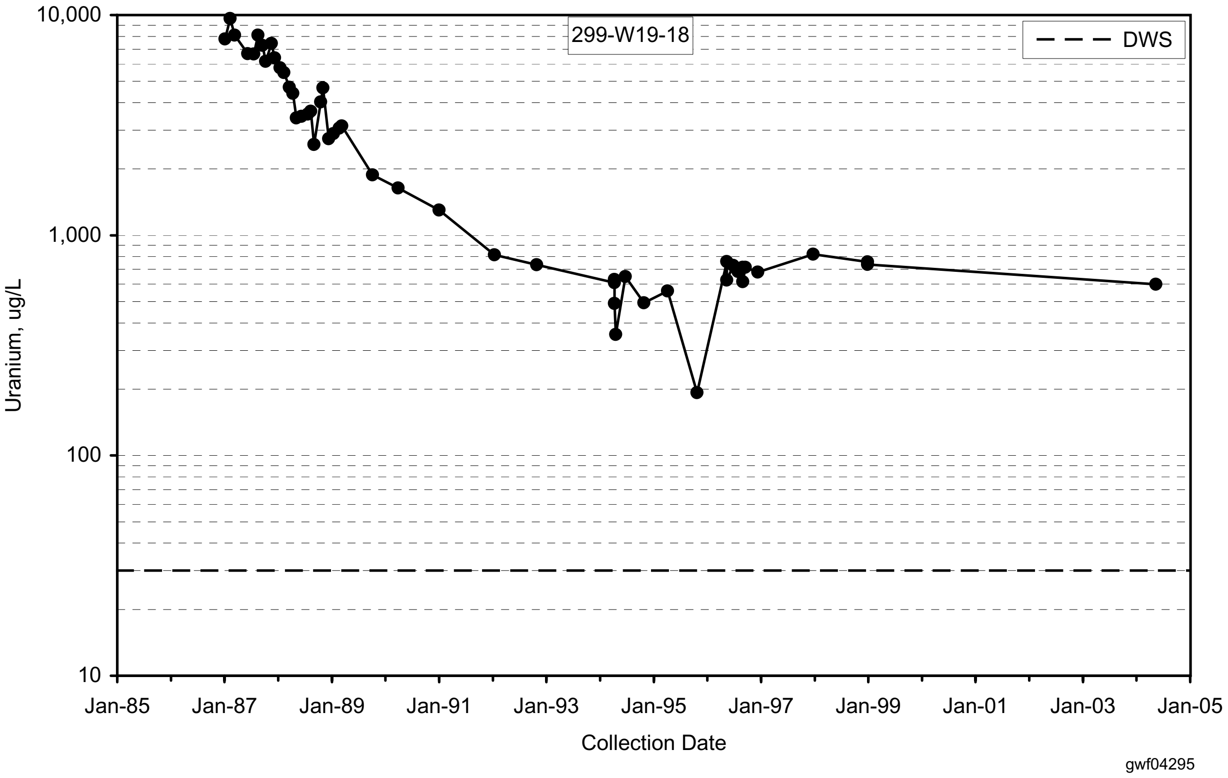

Figure 2.9-5. Uranium Concentrations Near the 216-U-1,2 Cribs

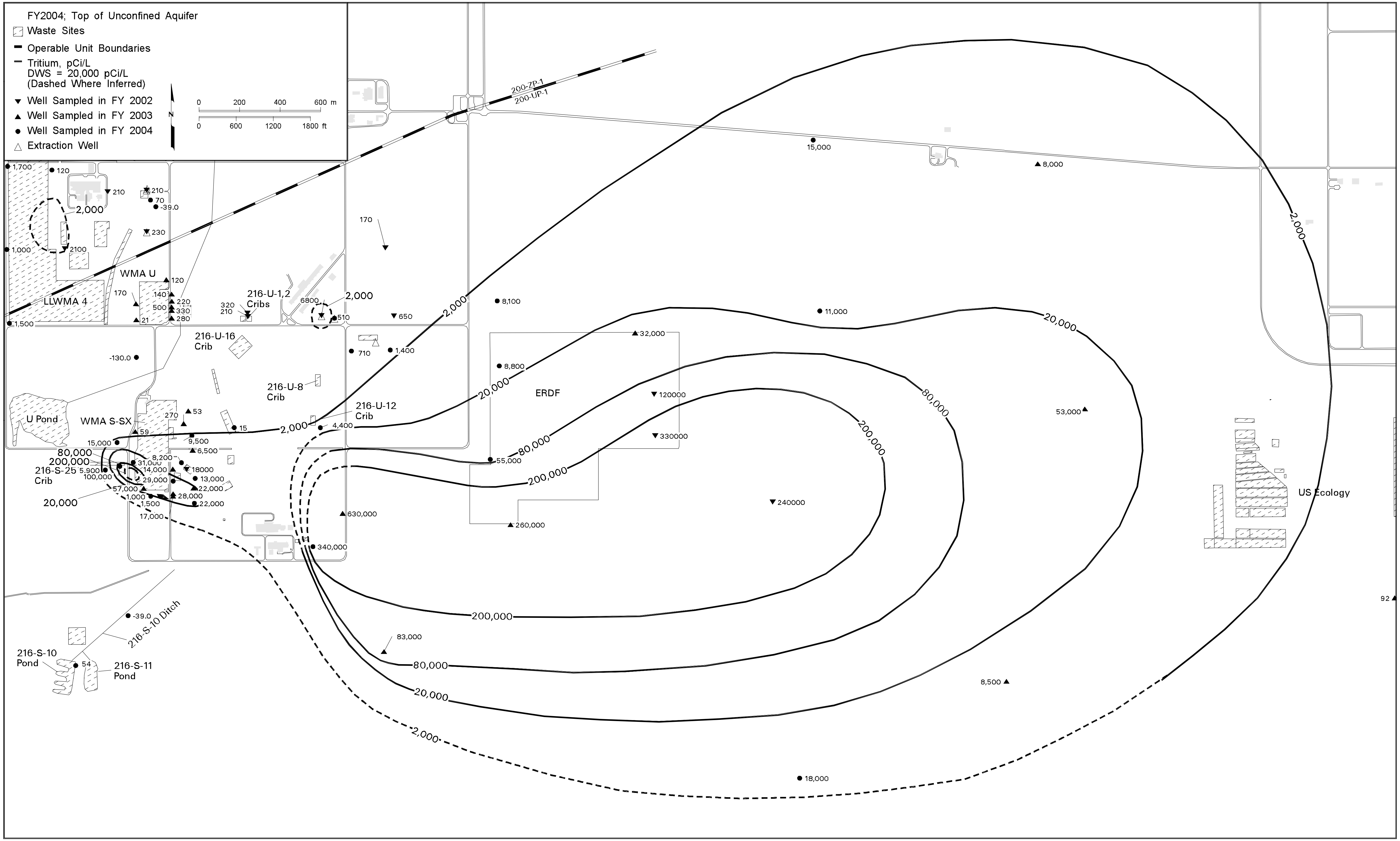

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Figure 2.9-6. Average Tritium Concentrations in the 200-UP-1 Groundwater Interest Area, Top of Unconfined Aquifer

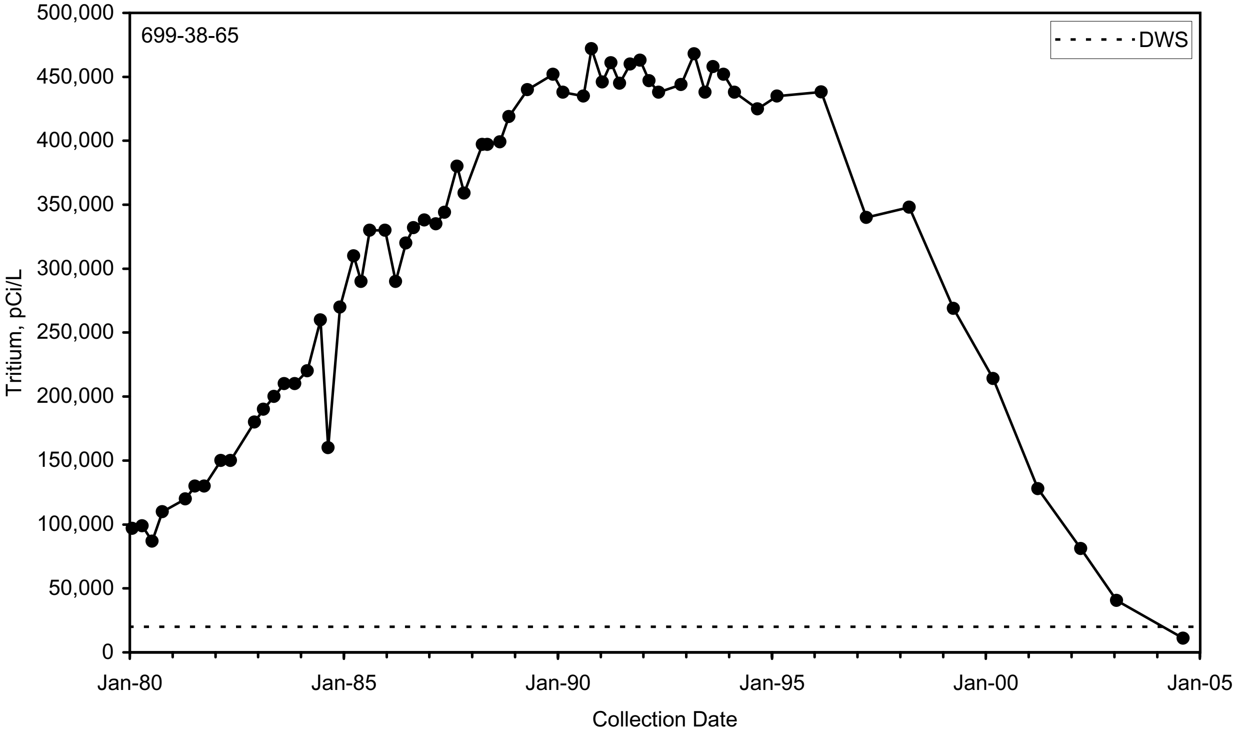

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Figure 2.9-7. Tritium Concentrations East of the 200 West Area

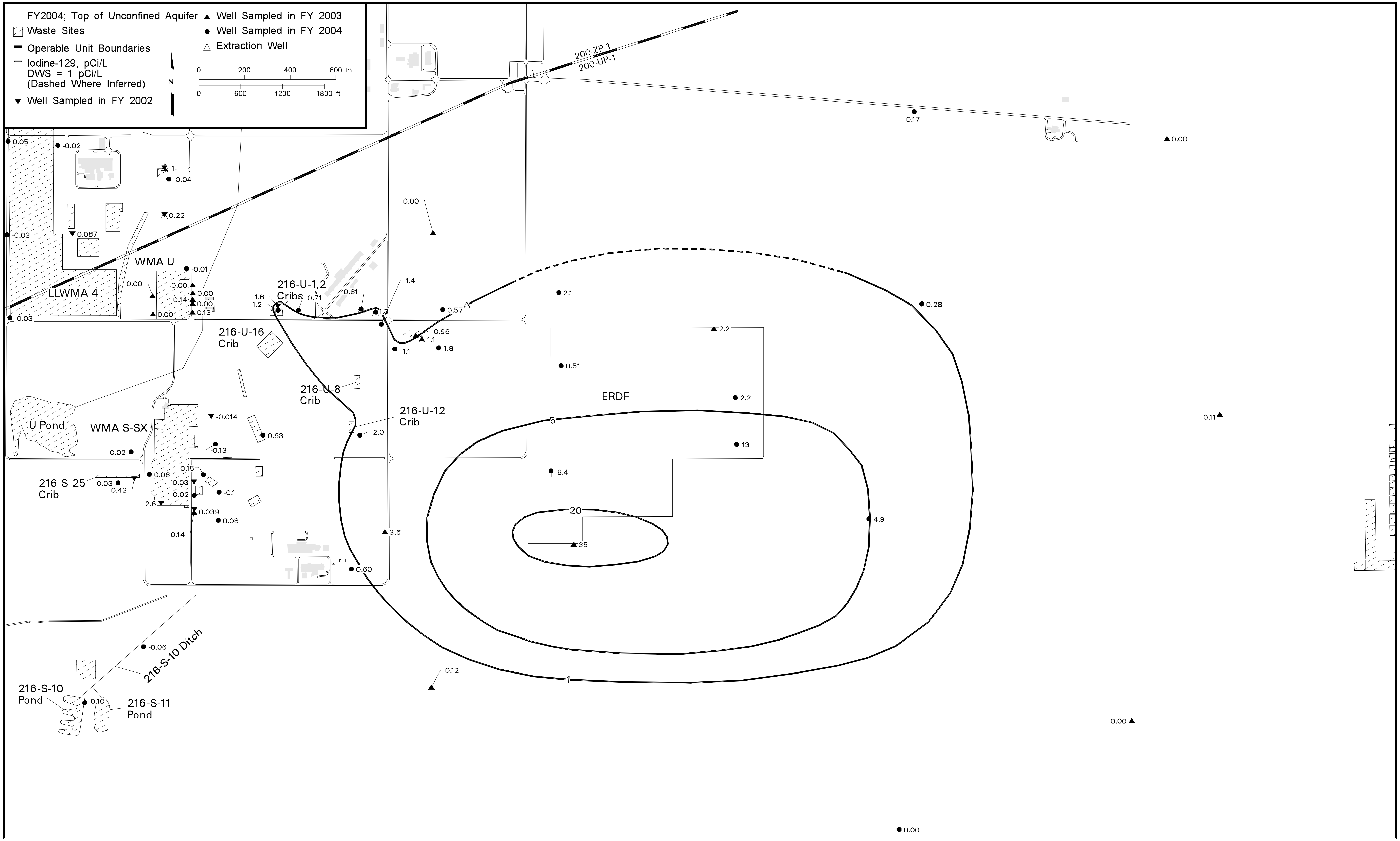

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Figure 2.9-8. Average Iodine-129 Concentrations in the 200-UP-1 Groundwater Interest Area, Top of Unconfined Aquifer

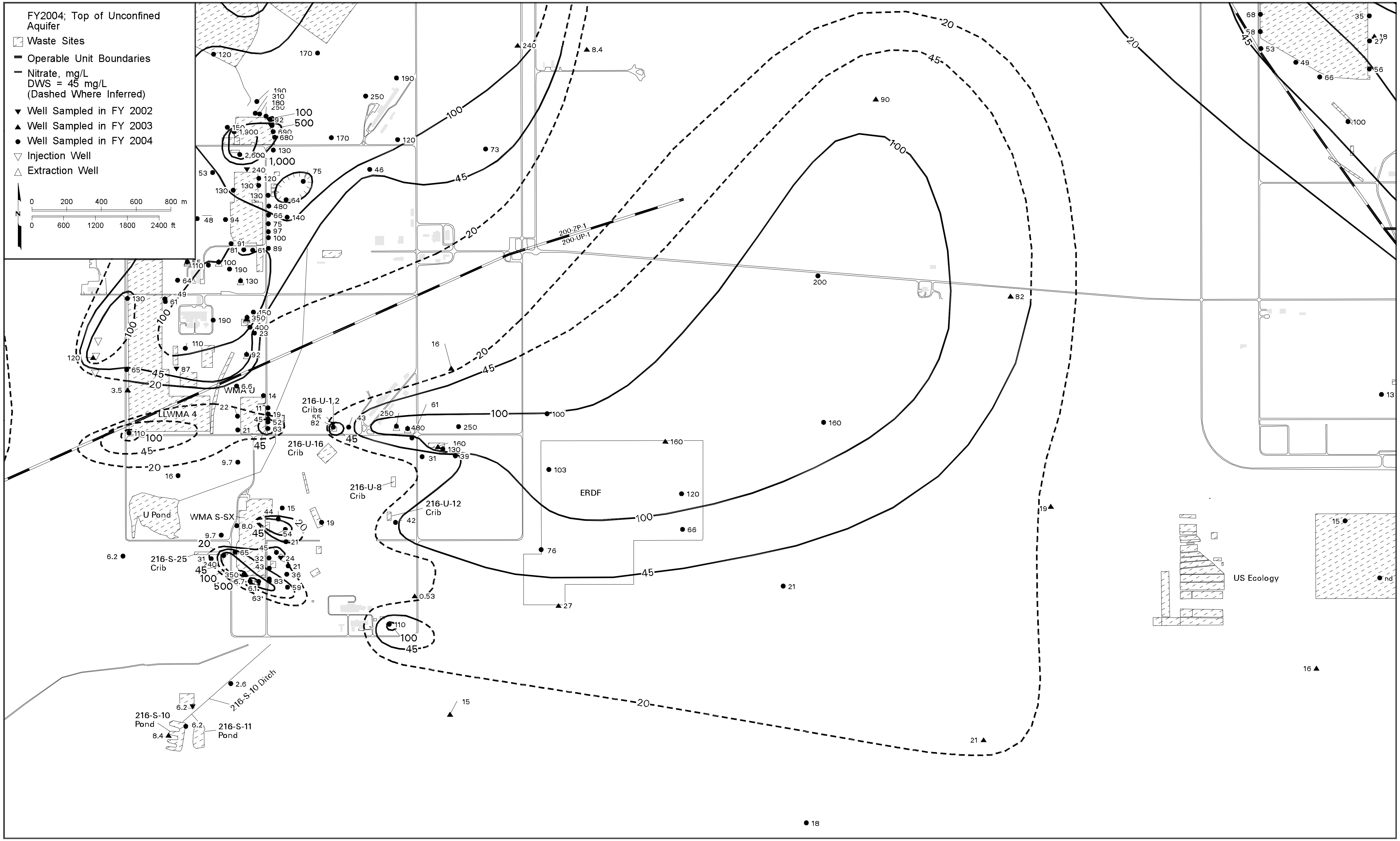

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Figure 2.9-9. Average Nitrate Concentrations in the 200-UP-1 Groundwater Interest Area, Top of Unconfined Aquifer

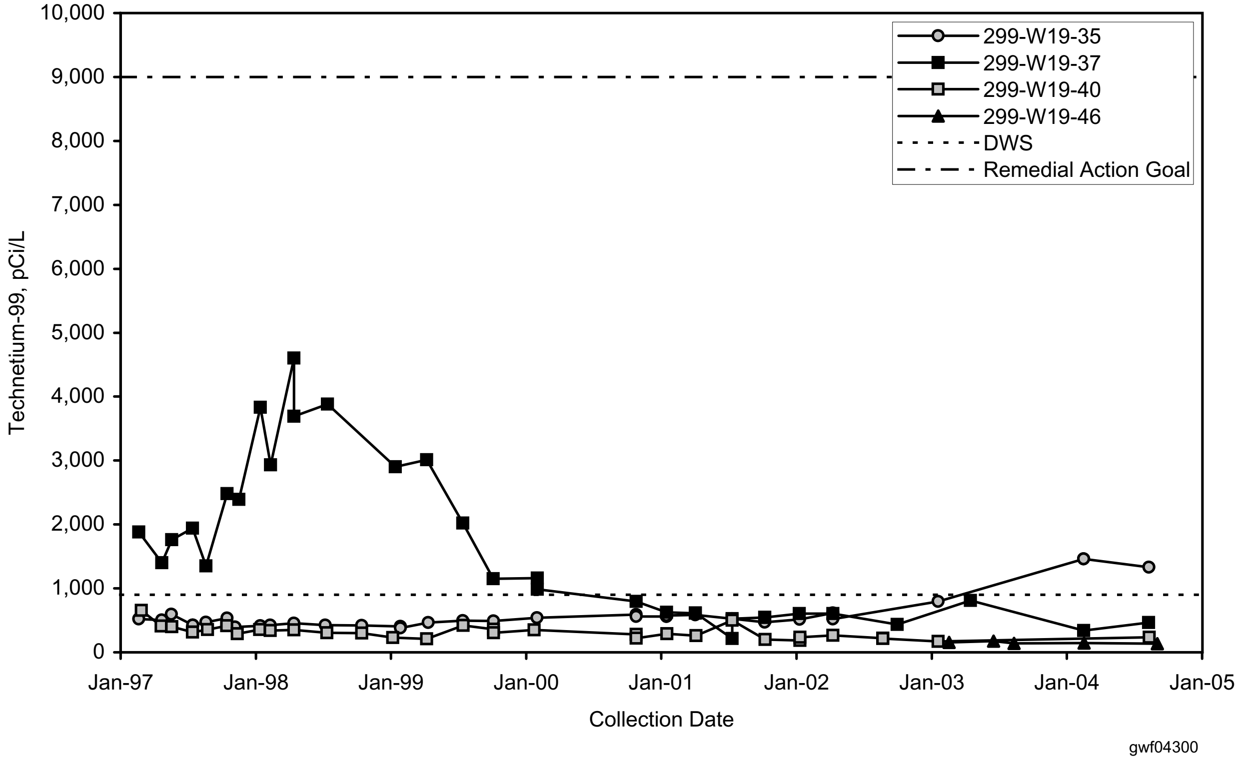

Figure 2.9-10. Technetium-99 Concentrations in Monitoring Wells at the 200-UP-1 Pump-and-Treat Area

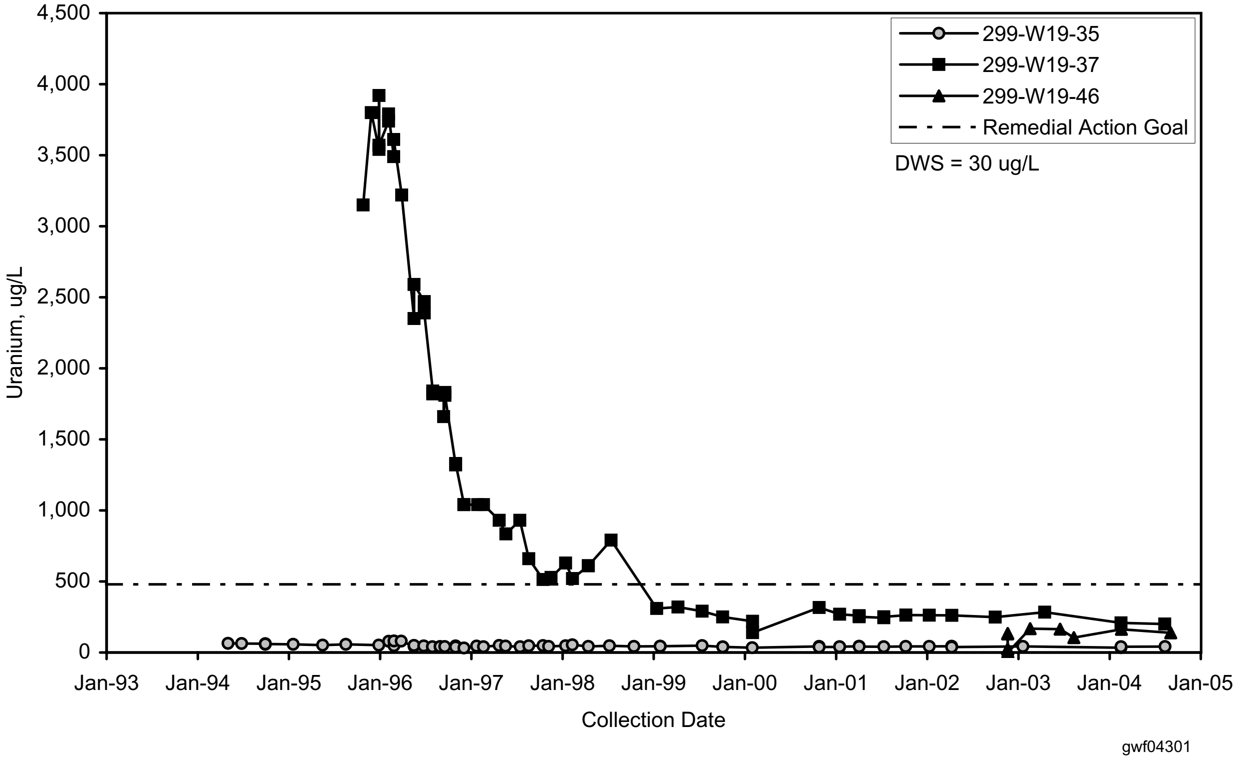

Figure 2.9-11. Uranium Concentrations in Monitoring Wells at the 200-UP-1 Pump-and-Treat Area

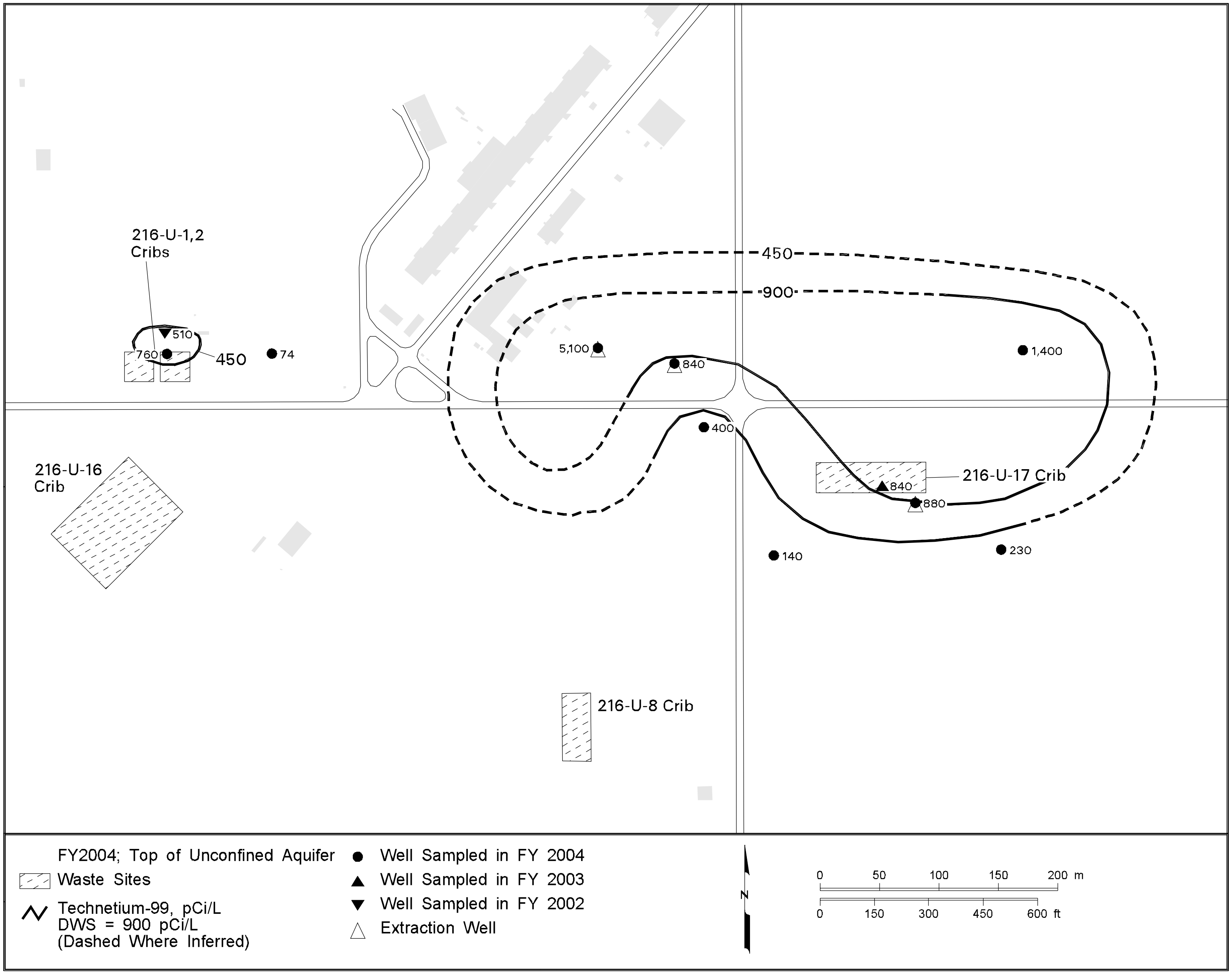

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Figure 2.9-12. Average Technetium-99 Concentrations in the 200-UP-1 Pump-and-Treat Area, Top of Unconfined Aquifer

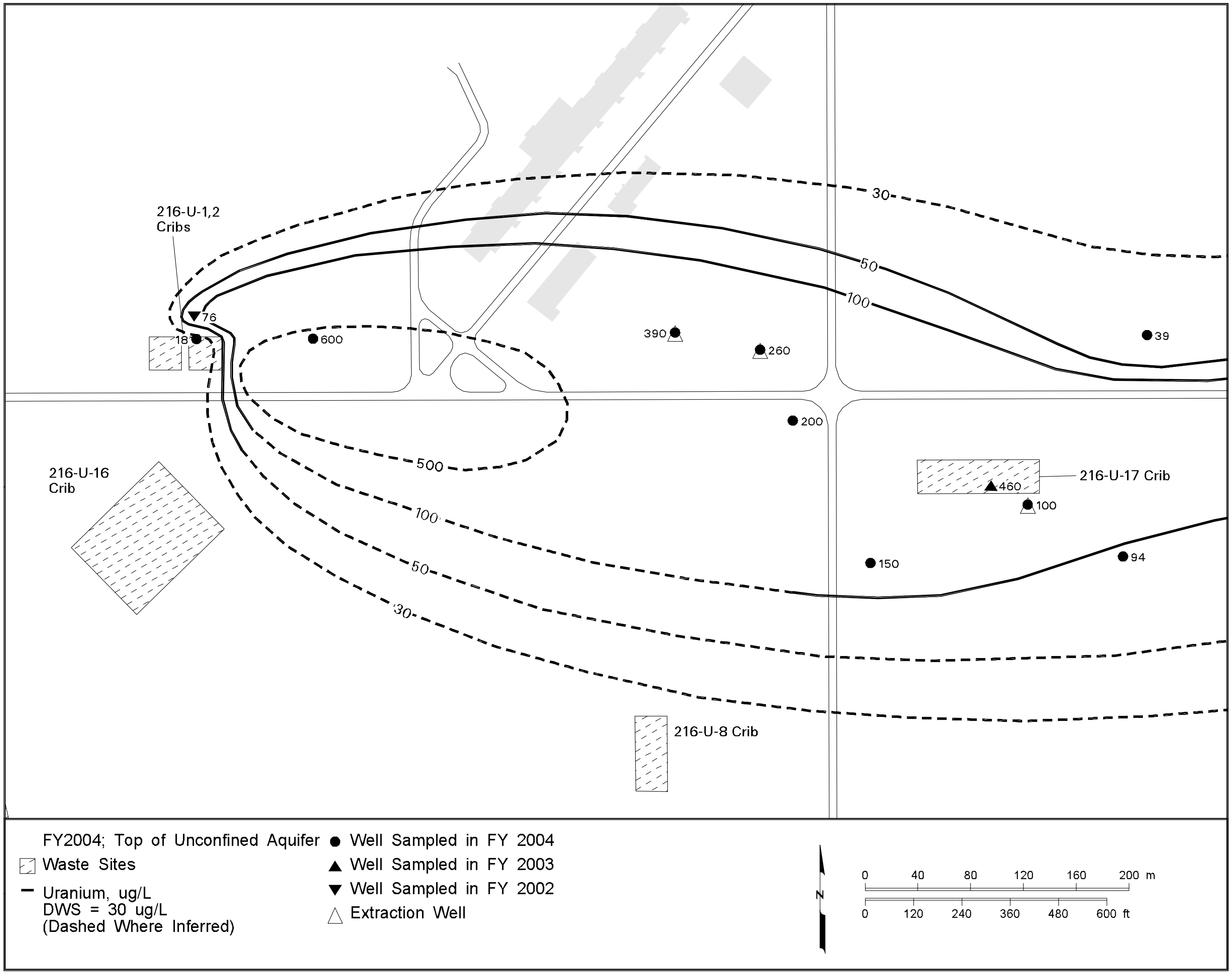

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Figure 2.9-13. Average Uranium Concentrations in the 200-UP-1 Pump-and-Treat Area, Top of Unconfined Aquifer

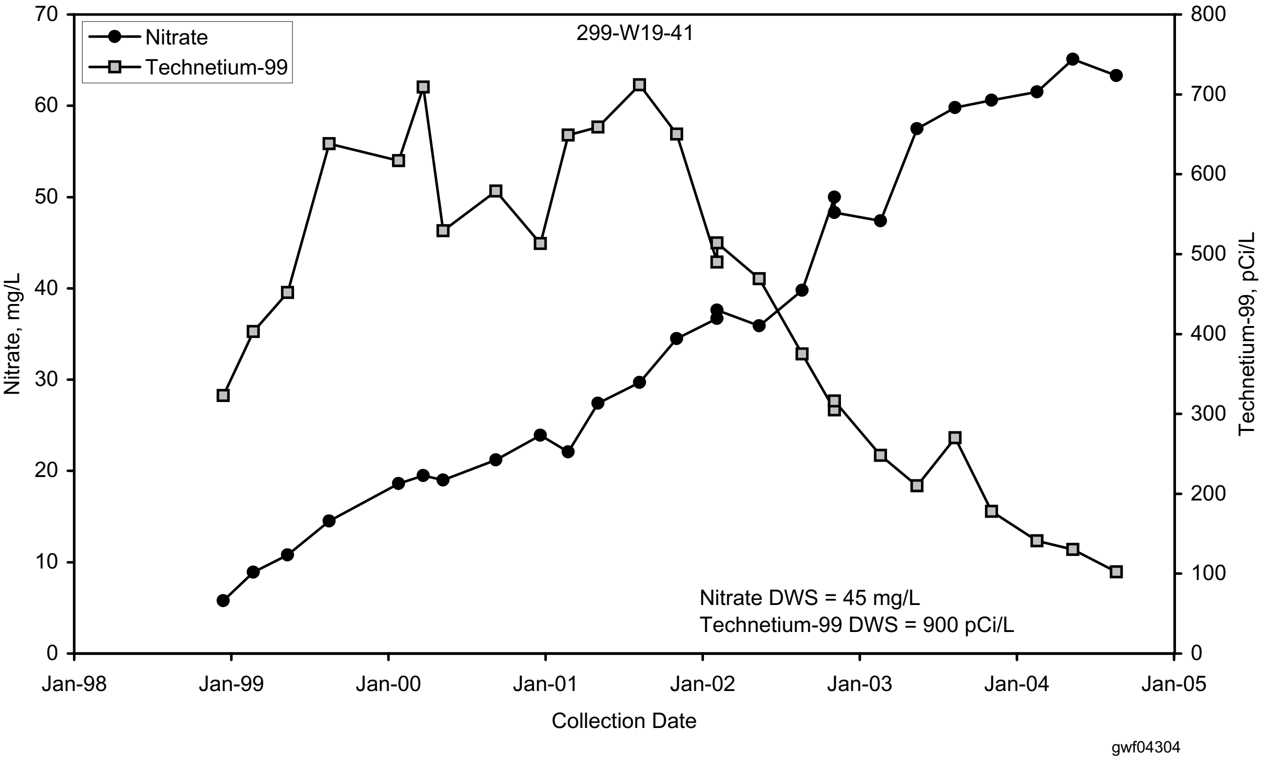

Figure 2.9-14. Trends for Nitrate and Technetium-99 Concentrations in Well 299-W19-41 at Waste Management Area U

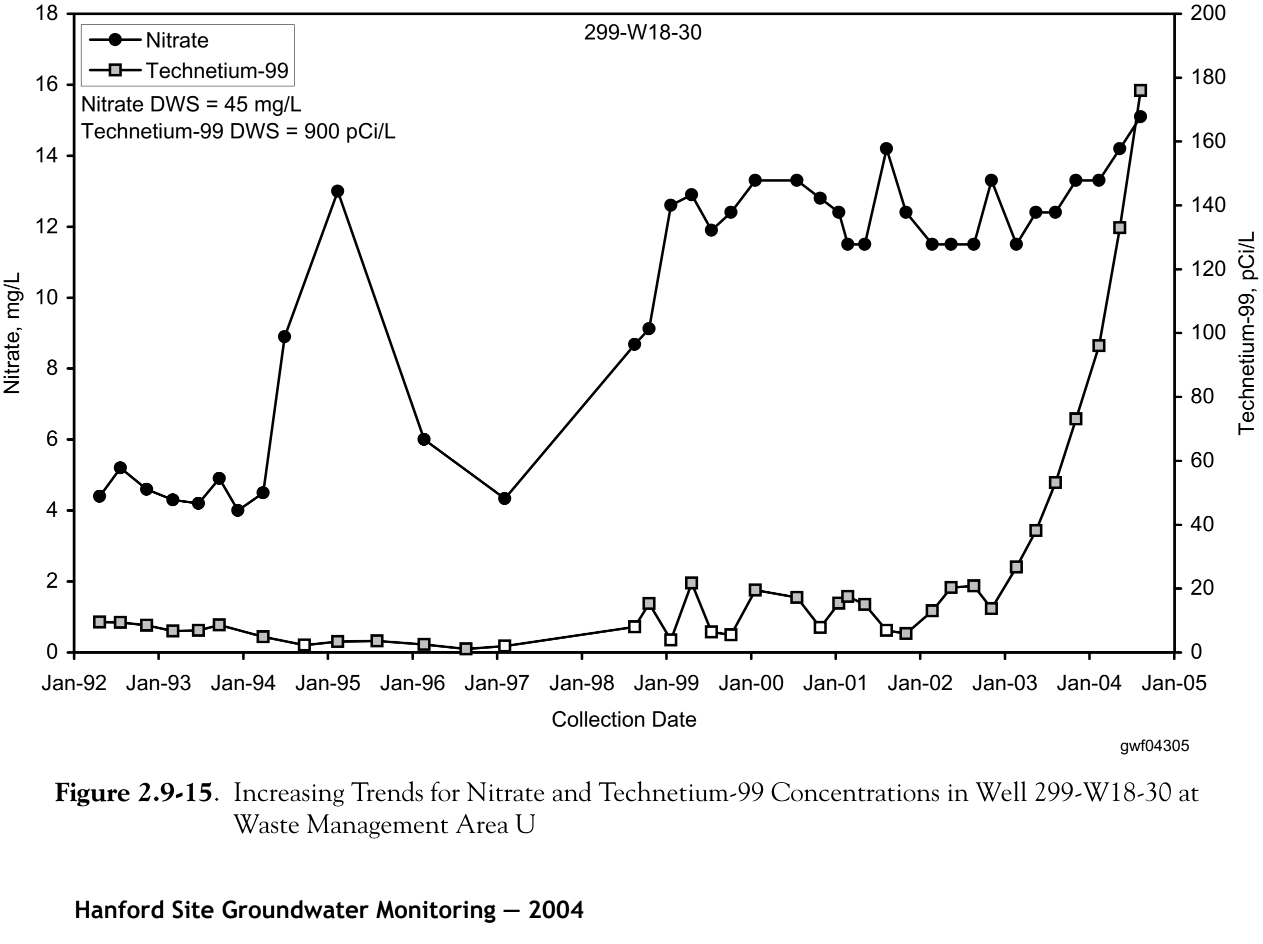

Figure 2.9-15. Increasing Trends for Nitrate and Technetium-99 Concentrations in Well 299-W18-30 at Waste Management Area U

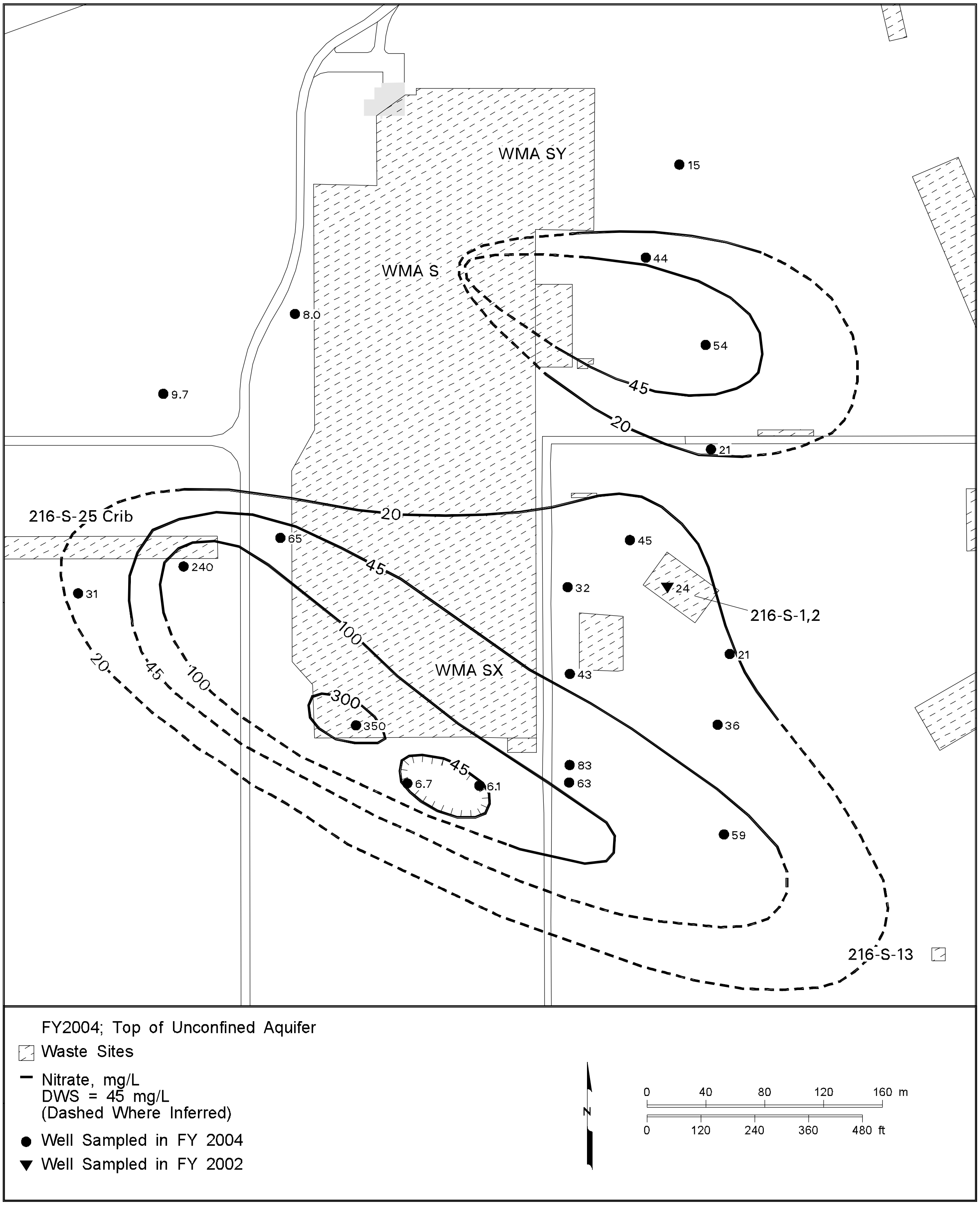

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Figure 2.9-16. Average Nitrate Concentrations at Waste Management Area S-SX, Top of Unconfined Aquifer

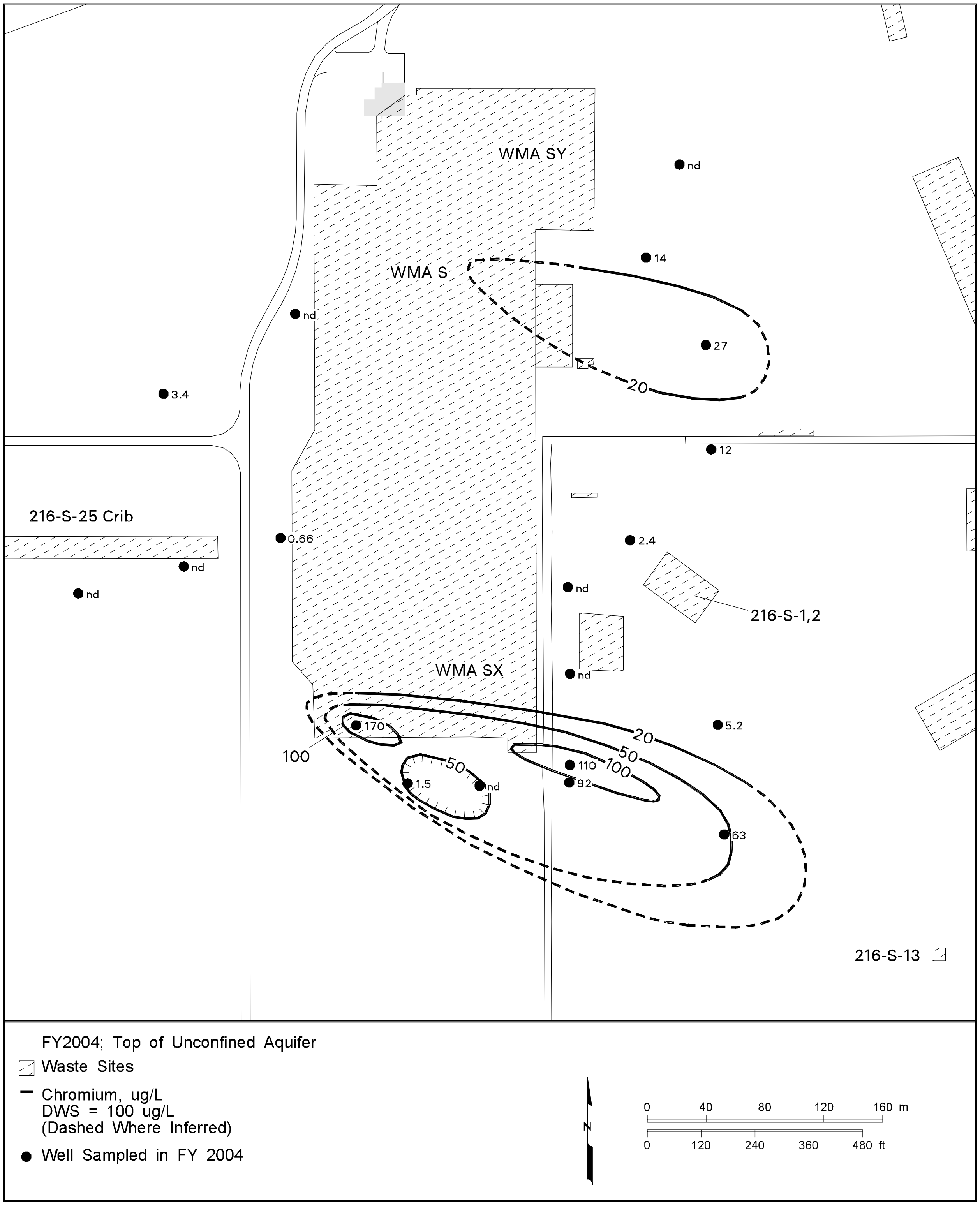

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Figure 2.9-17. Average Chromium Concentrations at Waste Management Area S-SX, Top of Unconfined Aquifer

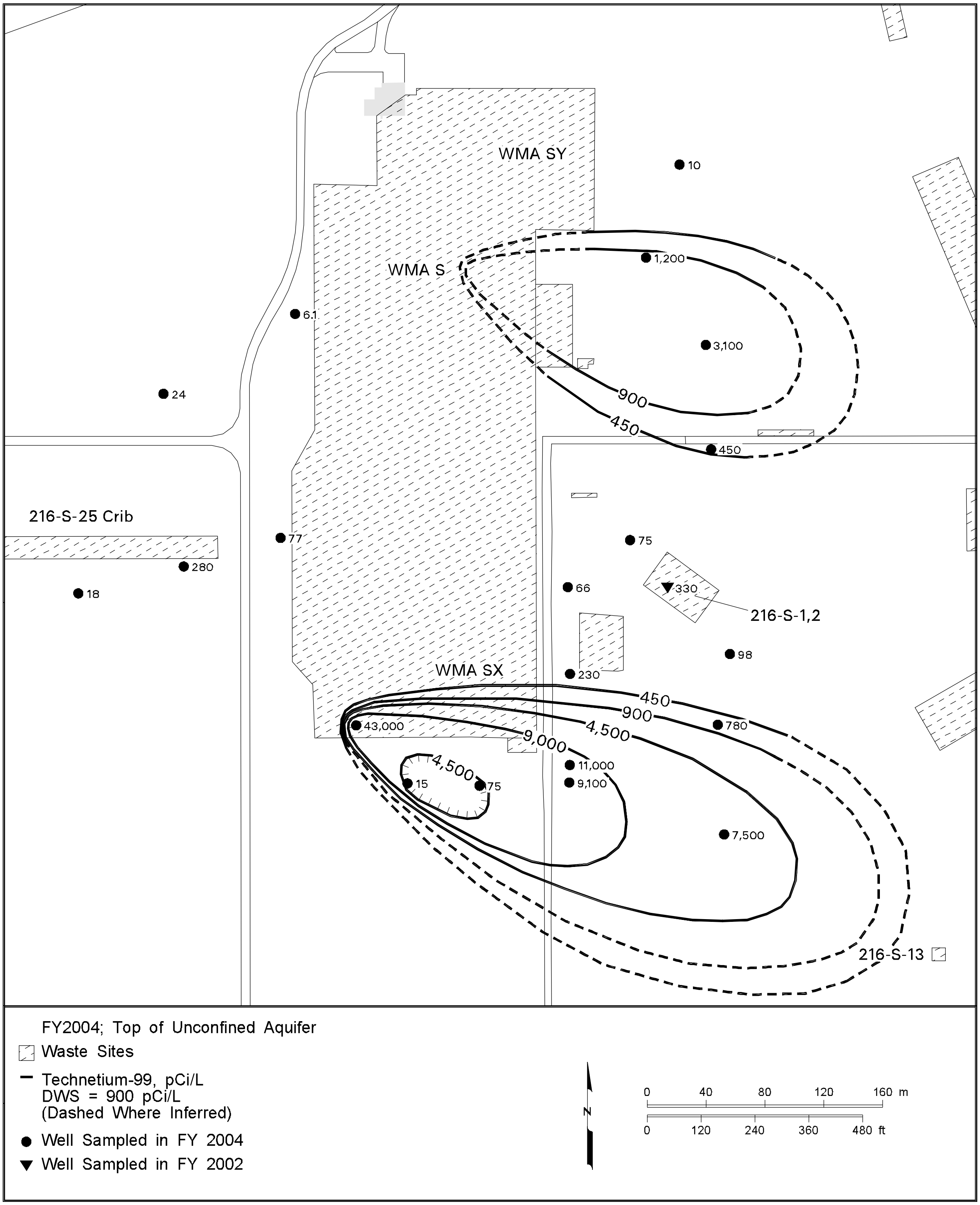


Figure 2.9-18. Average Technetium-99 Concentrations at Waste Management Area S-SX, Top of Unconfined Aquifer

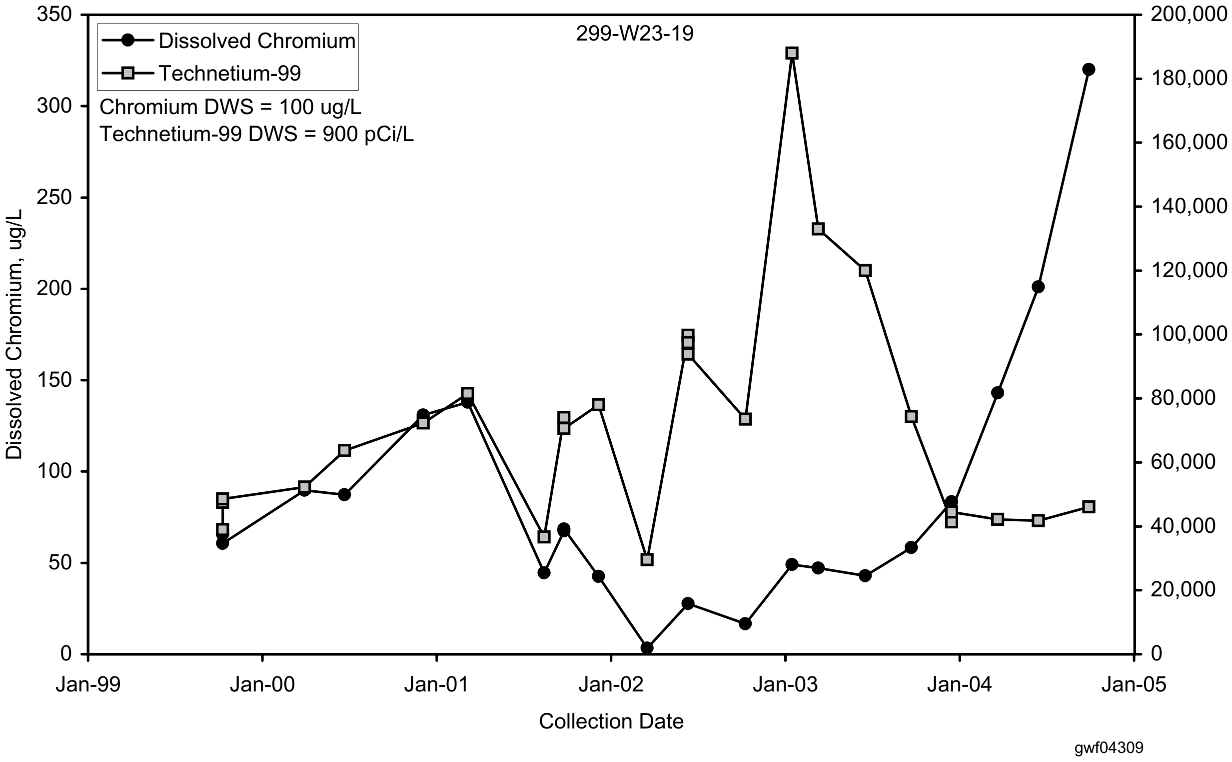


Figure 2.9-19. Chromium and Technetium-99 Concentrations in Well 299-W23-19 Near a Source Area Within the South Portion of Waste Management Area S-SX

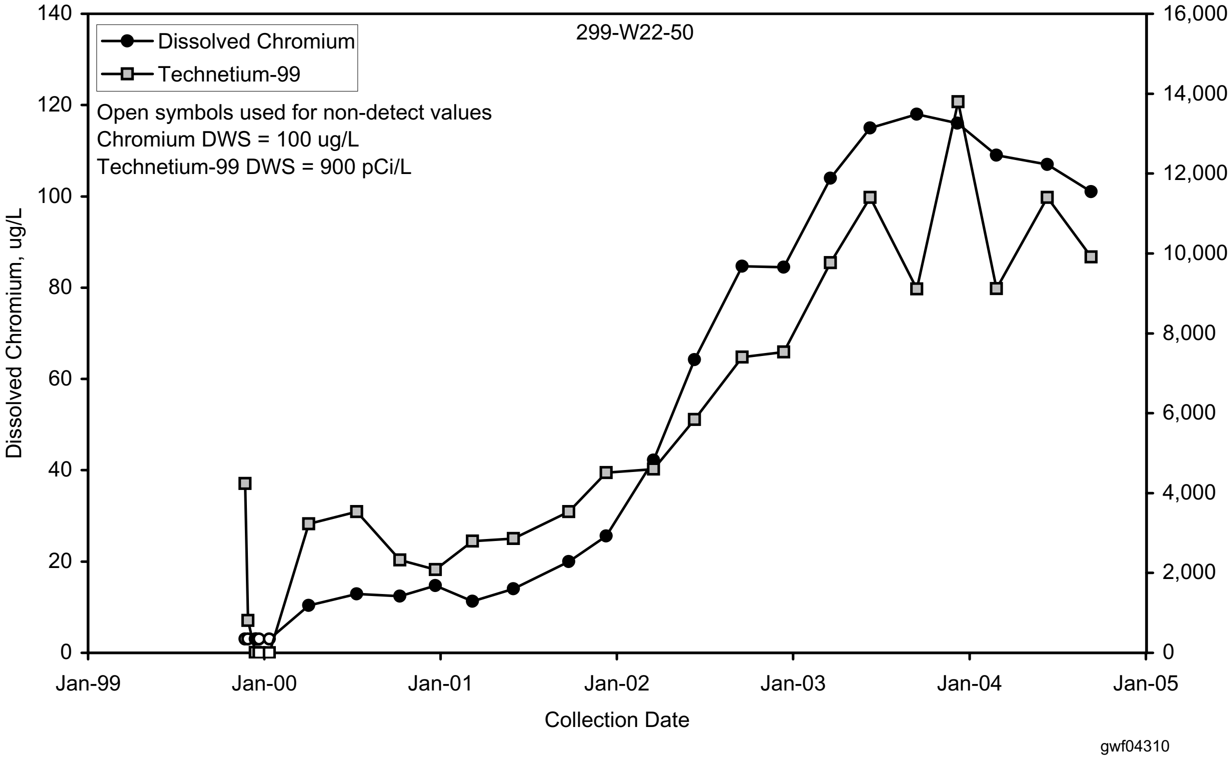


Figure 2.9-20. Chromium and Technetium-99 Concentrations in Well 299-W22-50 Near the Middle of a Plume Emanating from the South Portion of Waste Management Area S-SX

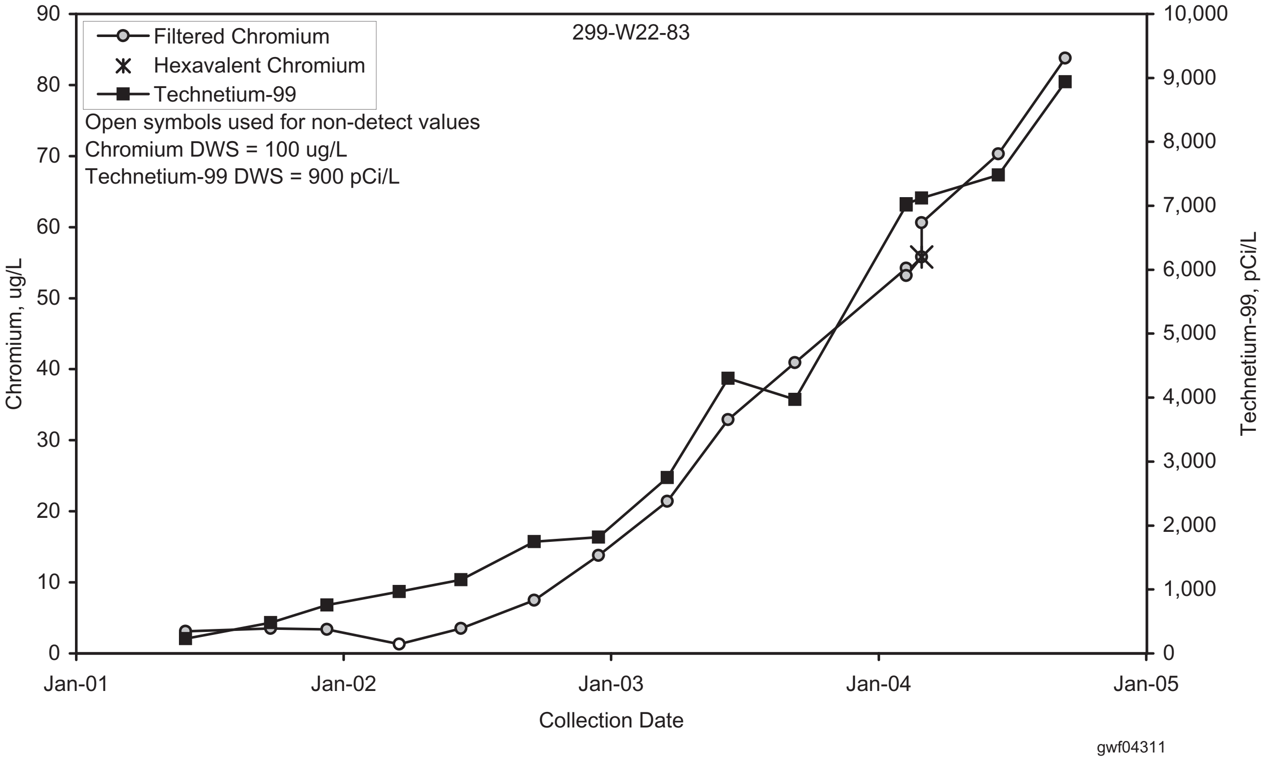


Figure 2.9-21. Chromium and Technetium-99 Concentrations in Well 299-W22-83 Near the Distal End of a Plume Emanating from the South Portion of Waste Management Area S-SX

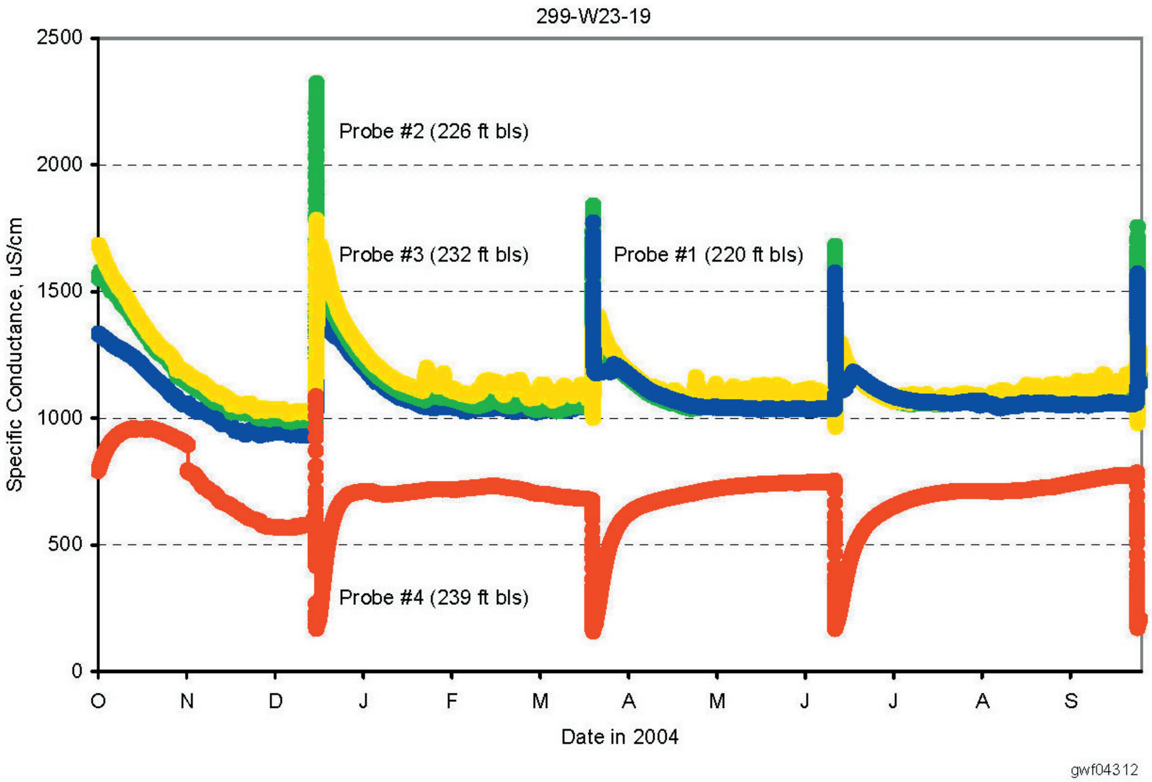


Figure 2.9-22. FY 2004 Wellbore-Fluid Specific Conductance Measurements Collected in Well 299-W23-19 at Waste Management Area S-SX (Data from probe #4 are shown for information purposes but are considered unreliable.)

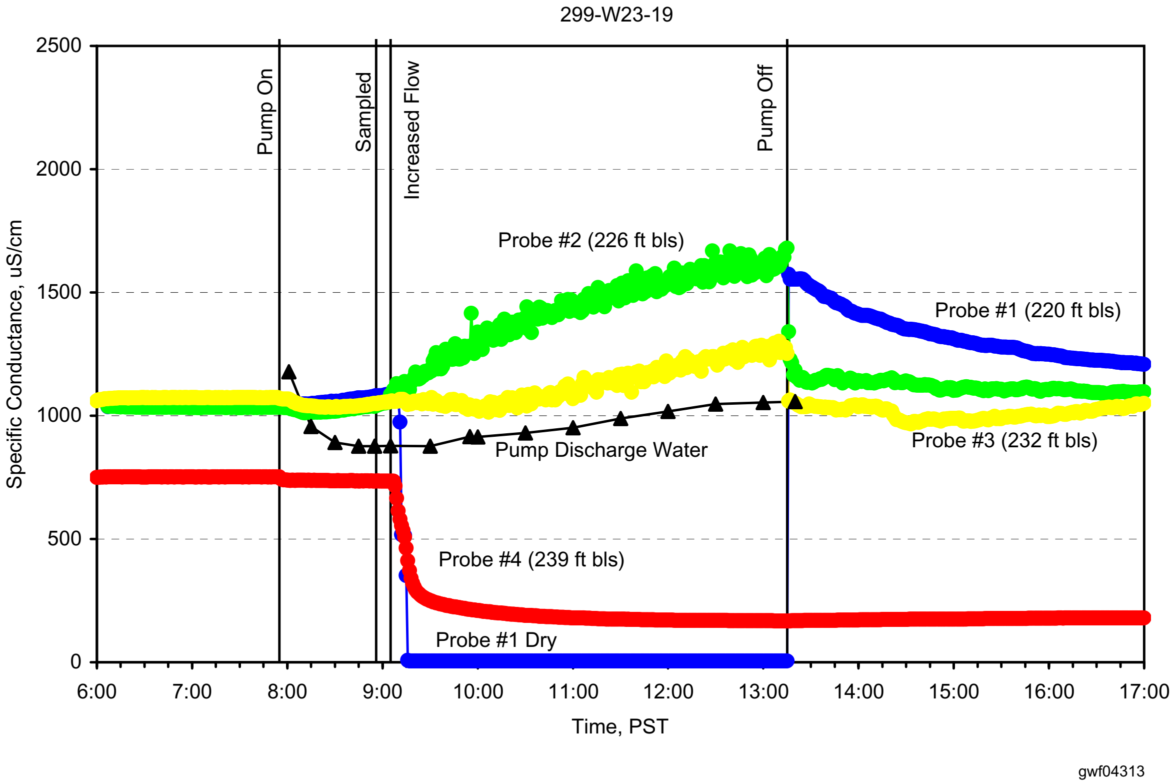


Figure 2.9-23. Wellbore-Fluid Specific Conductance Measurements Collected during Sampling on June 15, 2004, in Well 299-W23-19 (Data from probe #4 are shown for information purposes but are considered unreliable.)

2.10 200-BP-5 Operable Unit

E. C. Thornton, P. E. Dresel, S. M. Narbutovskih, M. D. Sweeney, and J. P. McDonald

The scope of this section is the 200-BP-5 groundwater interest area, which includes the 200-BP-5 Operable Unit (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) defined groundwater interest areas to aid in planning, scheduling, and interpreting groundwater data. This operable unit includes several *Resource Conservation and Recovery Act* (RCRA) units and *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) past-practice sites in the north part of the 200 East Area and extends to the north to Gable Gap. Figures 2.10-1 and 2.10-2 show facilities and wells in this operable unit. The south part of the 200 East Area lies within the 200-PO-1 Operable Unit and is discussed in Section 2.11. The boundary between the two operable units is shown in Figure 2.10-1.

Technetium-99 is the contaminant of greatest concern in the 200-BP-5 Operable Unit.

Technetium-99 is the contaminant of greatest concern in the 200-BP-5 Operable Unit owing to its mobility and broad areal extent of contamination (DOE/RL-2001-49; PNNL-14049). Groundwater is monitored in this operable unit to define the regional extent of technetium-99 and other significant contaminants across the operable unit as well as the local extent of contamination associated with specific RCRA treatment, storage, and disposal units in the area.

The small differences in water-table elevation across the operable unit make it difficult to determine the direction of groundwater flow from water-table maps (see Figure 2.1-3 in Section 2.1). Groundwater currently entering the 200 East Area from the west divides and flows to the Columbia River along two separate paths: one to the southeast and one to the

Groundwater monitoring in the 200-BP-5 Operable Unit includes the following monitoring activities:

CERCLA Monitoring

- *CERCLA sampling was conducted at 59 wells in the 200-BP-5 Operable Unit.*
- *One well located near B Pond could not be sampled because it is dry (see Appendix A).*
- *One well in the Gable Gap area could not be sampled because it is dry (see Appendix A).*
- *One well could not be sampled at Gable Mountain Pond because it is dry (see Appendix A).*
- *One well located in Waste Management Area B-BX-BY could not be sampled because it is currently being used for vadose zone monitoring activities (see Appendix A).*

Facility Monitoring

- *Twenty-five wells are sampled quarterly to semiannually at Waste Management Area B-BX-BY.*
- *Sampling at one well at Waste Management Area B-BX-BY has been postponed owing to safety concerns.*
- *Twelve wells are sampled quarterly to semiannually at the 216-B-63 trench.*
- *Seventeen wells are sampled semiannually at Low-Level Waste Management Area 1.*
- *Eleven wells are sampled semiannually at Low-Level Waste Management Area 2.*
- *Two wells are sampled semiannually at the Liquid Effluent Retention Facility.*
- *Nine wells are sampled quarterly at Waste Management Area C.*
- *All RCRA wells were sampled as scheduled (see Appendix B).*

AEA Monitoring

- *Wells are sampled annually to triennially within the 200-BP-5 Operable Unit for constituents related to general water chemistry.*
- *Six guard wells are sampled annually at Gable Gap.*
- *Wells are sampled annually to triennially in the upper basalt-confined aquifers (see Section 2.14.1).*

northwest though Gable Gap. The water table has been generally declining following the decrease in liquid effluent discharges to the soil in the 200 East Area. This appears to have resulted in changes in groundwater flow directions in the northwest part of the 200 East Area. Our ability to describe current flow characteristics, however, is limited owing to the low hydraulic gradients present. The extent of the basalt units above the water table also continues to increase due to the declining water table, resulting in an effect on groundwater flow in this area.

Techniques used to determine groundwater flow in the 200-BP-5 Operable Unit consist of water-table maps, plume and contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells. These techniques have been applied extensively in an effort to understand the direction of groundwater flow around the RCRA units in the 200-BP-5 Operable Unit and are discussed in more detail later in Section 2.10.3. General inferences regarding groundwater flow direction based on plume configurations (especially tritium, nitrate, iodine-129, and technetium-99) are also discussed in Section 2.10.1.

Water-level measurements are generally made in March and are used to construct Hanford Site water-table maps. Small differences in water-elevations make it difficult to define the water-table surface in 200-BP-5 Operable Unit. Other significant sources of error in water-elevation measurements are related to changes in barometric pressure and to borehole deviations from vertical. A set of water-elevation measurements were collected in July 2004, when the variation in barometric pressure was minimal. The results of this effort are presented in the water-table map shown in Figure 2.10-3. The map elevation contours suggest that there is a general water-elevation low trending in a northwest-southeast direction across the 200 East Area, which is consistent with the geometry of contaminant plumes in the region and also with the trend of high-permeability aquifer sediment. The observation that an isopotential contour appears to be roughly parallel to the basalt subcrop, however, also suggests a southwestward component of flow in the vicinity of Waste Management Area B-BX-BY, the 216-B-63 trench, and Low-Level Waste Management Area 2. Several possible water-elevation highs within this trend may be related to local releases of water or, alternatively, may be regions of lower hydraulic conductivity. Significant uncertainty owing to possible errors besides barometric pressure effects, in particular borehole deviations from vertical make interpretation of water-level measurement results somewhat tenuous. Another collection of water-elevation measurements may be undertaken in July 2005. An ongoing effort to provide corrections to borehole deviation error will also continue. These activities may allow more detailed interpretation of water-level information to be presented.

The upper basalt-confined aquifer is also monitored in the 200-BP-5 Operable Unit because of the potential for migration of contaminants from the overlying unconfined aquifer (Section 2.14). The basalt north of the 200 East Area was significantly eroded by late Pleistocene flooding, which may facilitate aquifer intercommunication. Discharge to overlying or underlying aquifers in the vicinity of the Gable Butte/Gable Mountain structural area, for example, may occur through erosional windows in the basalt where removal of the Elephant Mountain basalt has left a region of intercommunication between the Rattlesnake Ridge interbed aquifer and the unconfined aquifer.

Section 2.10.1 provides general information regarding geometry of contaminant plumes and concentration trends for contaminants of concern. Specific information regarding contaminant distribution for RCRA units within the 200-BP-5 Operable Unit is presented in Section 2.10.3.

Plume areas (square kilometers) above the drinking water standard at the 200-BP-5 Operable Unit:

Iodine-129 — 3.49
Nitrate — 5.08
Strontium-90 — 0.72
Technetium-99 — 2.18
******Tritium — 3.44***
Uranium — 0.19

****Includes entire plume through Gable Gap and between 100-B/C and 100-K Areas.***

2.10.1 Groundwater Contaminants

This section describes the distribution of groundwater contaminants of concern in the 200-BP-5 Operable Unit. Specific information is provided for several CERCLA units (the

216-B-5 reverse well, BY cribs, and Gable Mountain Pond) as well as general information regarding regional contaminant distribution, particularly in the Gable Gap area. Contaminants of concern for this operable unit include tritium, uranium, iodine-129, cobalt-60, cyanide, strontium-90, cesium-137, plutonium-239/240, and nitrate (PNNL-14049).

Plume maps presented in this section are based on annual average values from wells completed at the top of the unconfined aquifer.

2.10.1.1 Tritium

Tritium contamination is widespread throughout the northwest part of the 200 East Area. The contamination extends north through the gap between Gable Mountain and Gable Butte and to the Columbia River and southeast through the 200-PO-1 Operable Unit (Figure 2.10-4). Tritium contamination from the 200-BP-5 Operable Unit has declined greatly because of natural decay and dispersion. A number of waste disposal facilities in the 200 East Area have contributed to tritium contamination in the operable unit. Wells in the vicinity of the 216-B-5 injection well had concentrations of tritium below the drinking water standard in fiscal year (FY) 2004.

The tritium plume extends northward through Gable Gap.

Tritium at levels above the drinking water standard can be found between Gable Mountain and Gable Butte (Figure 2.10-3). Concentrations in monitoring well 699-61-62 in Gable Gap continued to decline with a measured value for FY 2004 of 21,000 pCi/L (see Figure 2.1-2 in Section 2.1 and Figure 2.10-2 for locations of 600 Area wells). Tritium concentrations in wells 699-60-60 (25,000 pCi/L) and 699-64-62 (19,000 pCi/L) also declined somewhat in FY 2004. Well 699-72-73, located between the 100-B/C and 100-K Areas, exceeded the drinking water standard for the first time in FY 2001, but tritium concentrations have subsequently declined and a value of 16,000 pCi/L was reported in FY 2004.

Tritium values have increased during the last several years at the south end of Waste Management Area B-BX-BY. The maximum tritium value in this region in FY 2004 was 19,900 pCi/L in well 299-E33-21 (Section 2.10.3.1).

2.10.1.2 Nitrate

A nitrate plume originating in the 200 East Area extends beyond the boundary fence line northwest toward the Columbia River (Figure 2.10-5). The plume within the 200 East Area has two parts: (1) a west plume that extends through the west portion of Low-Level Waste Management Area 1 and (2) an east plume extending from the BY and surrounding cribs toward the northwest. The two plumes appear to join northwest of the 200 East Area and extend through the gap between Gable Butte and Gable Mountain to the Columbia River at levels less than the drinking water standard (45 mg/L).

The west part of the nitrate plume, extending through the west portion of Low-Level Waste Management Area 1, appears to be part of a larger plume extending from the 200-PO-1 Operable Unit. This plume apparently moved to the northwest under past flow conditions during the period of high discharge to 200 East Area facilities and B Pond.

The highest nitrate concentrations are in the vicinity of the BY and 216-B-8 cribs.

The highest nitrate concentrations are in the vicinity of the BY and 216-B-8 cribs. High concentrations of nitrate are associated with the cobalt-60, cyanide, and technetium-99 plume originating from the BY cribs (PNNL-13080). The highest nitrate concentrations measured in FY 2004, were found in well 299-E33-4 (1,070 mg/L), near the BY cribs. The highest value for nitrate associated with the 216-B-8 crib during FY 2004 was a concentration of 575 mg/L reported for well 299-E33-16. The ratio of nitrate to technetium-99 in well 299-E33-16 is high compared to the ratio of nitrate to technetium-99 in wells near the BY cribs, indicating an additional nitrate source associated with the 216-B-8 crib (PNNL-14187).

Nitrate continued to be detected in wells monitoring Gable Mountain Pond at levels above the drinking water standard (Figure 2.10-5). A nitrate value of 90.7 mg/L was measured in FY 2004 at well 699-53-47A.

2.10.1.3 Iodine-129

Iodine-129 contamination is present throughout the west portion of the 200-BP-5 Operable Unit. Like the tritium plume, the iodine-129 plume extends to the northwest toward the Gable Mountain/Gable Butte gap and southeast through the 200-PO-1 Operable Unit (Figure 2.10-6). Unlike tritium, however, levels greater than the iodine-129 drinking water standard (1 pCi/L) have not passed the gap between Gable Mountain and Gable Butte. A band of elevated iodine-129 concentrations (~5 pCi/L) exists in Waste Management Area B-BX-BY but decreased in extent in FY 2004 relative to FY 2003. Interpretation of the iodine-129 configuration in this area is complicated by elevated detection limits that result from interference of technetium-99. In addition, the current laboratory reporting system produced some values reported as not detected at levels greater than the drinking water standard (1 pCi/L) (Appendix C).

2.10.1.4 Technetium-99

A plume of technetium-99 extends from the area of the BY cribs and Waste Management Area B-BX-BY to the northwest (Figure 2.10-7). A significant portion of the plume is north of the 200 East boundary and is interpreted to represent early releases of technetium-99 from the BY cribs (PNNL-13080). Detection of technetium-99 at levels lower than the 900-pCi/L drinking water standard north of the gap between Gable Mountain and Gable Butte indicates that technetium-99 has moved north into, and through, the gap.

A plume of technetium-99 extends from the area of the BY cribs to beyond the north boundary of 200 East Area. The plume has moved through Gable Gap at levels below the drinking water standards.

Technetium-99 was not routinely measured in groundwater prior to the late 1980s, limiting the information on historical trends. In addition, well coverage is limited. Thus, there is considerable uncertainty in the extent of technetium-99 contamination. Interpretation of the exact configuration and extent of the technetium-99 plume north of the 200 East Area is also complicated by the variable concentrations seen in wells that are relatively close together (see Figure 2.1-2 in Section 2.1 and Figure 2.10-2 for 600 Area well locations). For example, concentrations of technetium-99 less than the drinking water standard were consistently detected in well 699-49-55A since the early 1990s (16 pCi/L in FY 2001 and 249 pCi/L in FY 2004). This well was used as the injection well in 1995 for pump-and-treat operations and has had low technetium-99 values relative to nearby wells since then (Figure 2.10-7).

Seven wells were successfully sampled in the Gable Gap area north of the 200 East Area boundary in FY 2004 (Figure 2.10-7). Concentrations of technetium-99 were generally similar for FY 2003 and 2004. Well 699-49-57A has had greater concentrations in FY 2003 and 2004 versus 2001 as shown in Figure 2.10-8, but data is not sufficient to determine if concentrations are currently in a declining or increasing trend.

Well 699-52-57, located north of well 699-49-57A, had consistently low technetium-99 concentrations (<90 pCi/L) throughout the 1990s; however, the water table fell below the screen in 1999 so the well can no longer be sampled. A review of well construction and logging information suggests that this well was not drilled to the top of the basalt and may lie in an erosional window where the Elephant Mountain Member has been removed, thereby juxtaposing the unconfined aquifer in the Hanford formation and the upper basalt-confined aquifer in the Rattlesnake interbed (see Section 2.14.2.1). DOE/RL-2001-49 proposed that well 699-52-57 be deepened, if possible, to permit sampling activities to continue at this location and to obtain additional geological information.

In the late 1990s, rising technetium-99 concentrations were seen in the BY crib area in wells 299-E33-7 and 299-E33-38 (Figure 2.10-8). In early 1999, the trends for both wells began to track together and reached an apparent maximum in late 2000. These trends may reflect pervasive transport of contamination from the vadose zone at the BY cribs and relatively recent breakthrough into the saturated zone. In particular, high concentrations of technetium-99 in well 299-E33-38 (average of 9,800 pCi/L in FY 2003) and 299-E33-4 (11,000 pCi/L reported for a sample collected in June of 2004) suggest a continuing source of contamination from the BY cribs to groundwater. A general correlation of concentration trends for technetium-99, nitrate, cobalt-60, and cyanide in wells 299-E33-7 and 299-E33-38 and local distribution of these constituents suggests that the primary source of technetium-99 contamination is related to past discharges of ferrocyanide containing waste to the BY cribs (PNNL-13080; PNNL-14049).

2.10.1.5 Cobalt-60 and Cyanide

Cobalt-60 and cyanide continued to be detected in a number of wells in the 200-BP-5 Operable Unit. Cobalt-60 has a relatively short half-life (5.3 years) and is currently only found at levels less than the drinking water standard (100 pCi/L). Cyanide is found at levels above the drinking water standard (200 µg/L). These constituents are useful for distinguishing contaminant groups and contaminant sources and are generally associated with ferrocyanide waste streams. Thus, cyanide and cobalt-60 are generally found together in this area.

The maximum cyanide concentrations in this area in FY 2004 was 357 µg/L from well 299-E33-7 located in the northern part of the BY cribs. Cyanide contamination trends in wells 299-E33-7 and 299-E33-38 are similar to those of technetium-99, cobalt-60, and nitrate and may be related to past discharges of ferrocyanide waste to the BY cribs (PNNL-13080; PNNL-14049).

The highest cobalt-60 values in FY 2004 also were detected in wells monitoring the BY cribs, and the cribs are believed to be the source of this contamination. The highest cobalt-60 concentrations in FY 2004 were in wells 299-E33-4 (109 pCi/L) and 299-E33-7 (45.2 pCi/L), located in the north part of the BY cribs. Well 299-E33-38, located in the south part of the cribs, had a maximum cobalt-60 value of 42.6 pCi/L in FY 2004.

2.10.1.6 Uranium

Uranium contamination in the 200-BP-5 Operable Unit is limited to three isolated areas:

- Wells monitoring Waste Management Area B-BX-BY and BY cribs.
- Wells near the 216-B-5 injection well.
- Wells 299-E28-21 and 299-E28-18 at the 216-B-62 crib.

Wells in all three of these areas exceeded the drinking water standard (30 µg/L) during FY 2004.

Uranium contamination in the 200-BP-5 Operable Unit is limited to three isolated areas: Waste Management Area B-BX-BY and surrounding cribs, 216-B-5 injection well, and 216-B-62 crib.

Waste Management Area B-BX-BY. The largest uranium plume in the 200 East Area may have sources at Waste Management Area B-BX-BY. Currently, the highest uranium concentrations in the 200-BP-5 Operable Unit are found within and to the east of the BY Tank Farm (Figure 2.10-9). The contamination is present in a narrow northwest-southeast band but is increasing to the south along the west side of Waste Management Area B-BX-BY. One interpretation is that the plume may originate from a release at tank BX-102 (RPP-10098; PNNL-14187; Christensen et al. 2004) and is migrating through the vadose zone from a perched water table; another is that the plume originates from nearby cribs that received waste similar to tank waste. In FY 2004, the highest concentrations were detected in wells 299-E33-9 and 299-E33-44, with annual average concentrations of 550 and 290 µg/L, respectively. Section 2.10.3.1 includes additional discussion of uranium at Waste Management Area B-BX-BY.

216-B-5 Injection Well. Uranium contamination is associated with the cesium-137, plutonium, and strontium-90 contamination found at the former 216-B-5 injection well. The highest uranium concentration detected in FY 2004 at this site was 62.8 µg/L in well 299-E28-23, located only ~1 meter from the injection well. Uranium concentrations are roughly stable in well 299-E28-23. Uranium values were significantly lower in wells 299-E28-24 and 299-E28-25 located further from the injection well. Uranium values of 35.7 and 36.1 µg/L were reported for well 299-E28-6, located south of the injection well, in FY 2004. Uranium concentrations are declining in well 299-E28-6.

216-B-62 Crib. Uranium was detected consistently at levels slightly above the drinking water standard (30 μg/L) in wells monitoring the 216-B-62 crib, located west of B Plant. Uranium concentrations were over 200 μg/L in the mid-1980s, but declined to current levels by the early 1990s. The maximum FY 2004 uranium concentration at the 216-B-62 crib was 36 μg/L reported for well 299-E28-18. Uranium also has been found along the west side of Low-Level Waste Management Area 1, but no wells exceeded the drinking water standard in FY 2004. The uranium detected near Low-Level Waste Management Area 1 may have originated at the 216-B-62 crib.

2.10.1.7 Cesium-137 and Strontium-90

Cesium-137 and strontium-90 have relatively low mobility and are generally found near their source. Several wells near the 216-B-5 injection well have had elevated concentrations of strontium-90. Four wells (299-E28-2, 299-E28-23, 299-E28-24, and 299-E28-25) had concentrations of strontium-90 above the drinking water standard (8.0 pCi/L) in FY 2004. Two of the wells have had concentrations greater than the U.S. Department of Energy (DOE) derived concentration guide (1,000 pCi/L) in past years and in FY 2004 (Figure 2.10-10). The highest strontium-90 concentration was reported for well 299-E28-23, which averaged 5,990 pCi/L in FY 2004. Strontium-90 also exceeded the DOE derived concentration guide in well 299-E28-25, which averaged 2,080 pCi/L in FY 2004.

Wells near the 216-B-5 injection well have elevated concentrations of low-mobility contaminants including cesium-137, plutonium, and strontium-90.

Well 299-E28-23 near the 216-B-5 injection well has consistently had concentrations of cesium-137 greater than the drinking water standard (200 pCi/L) but less than the DOE derived concentration guide (3,000 pCi/L). In FY 2004, an average value of 1,195 pCi/L was reported for this well, which exhibits a generally declining trend. An increase in cesium-137 was observed in well 299-E28-25 (238 pCi/L). All other wells sampled at this site had cesium-137 concentrations below the drinking water standard in FY 2004.

Strontium-90 concentrations showed a declining trend in 1997, 2000, 2003, and 2004 versus a rising trend before FY 1999 in several wells near Gable Mountain Pond. Strontium-90 was detected in groundwater at levels above the DOE derived concentration guide in the only well that was sampled at Gable Mountain Pond in FY 2000, but was below it in FY 2003 and 2004. The concentration in samples from that well, 699-53-47A, was 806 pCi/L in FY 2003 and 720 pCi/L in FY 2004 versus 1,210 pCi/L in FY 2000 (Figure 2.10-11).

2.10.1.8 Plutonium

Plutonium-239 and plutonium-240 were detected in past years in samples taken from several wells near the 216-B-5 injection well. Plutonium contamination is relatively immobile and, therefore, is found only near the source, which was the injection well. The highest reported plutonium concentration in FY 2004 was for well 299-E28-23, which had a filtered value of 5.27 pCi/L and an unfiltered value of 66.2 pCi/L. Thus, the unfiltered value for this well exceeded the DOE derived concentration guide for plutonium (30 pCi/L), but the filtered value was below it. The lower concentration in the filtered versus unfiltered samples suggests that a portion of the plutonium is associated with particulates. For comparison, the gross alpha drinking water standard is 15 pCi/L. The concentration of plutonium in well 299-E28-33 has not exhibited a change in trend in recent years. Other wells sampled at the 216-B-5 injection well site have indicated plutonium levels were below the DOE derived concentration guide in recent years.

2.10.1.9 Other Constituents

Several other constituents exceeded drinking water standards in the 200-BP-5 Operable Unit in FY 2004. A maximum of 11.7 μg/L was reported for arsenic versus the drinking water standard of 10 μg/L. This may be a laboratory analytical problem since there are no known sources of arsenic in the 200-BP-5 Operable Unit. Numerous measurements of gross alpha and gross beta exceeding their drinking water standard have also been reported during FY 2004 and are related to radionuclide contaminants discussed in the preceding sections.

2.10.2 Operable Unit Monitoring

CERCLA monitoring requirements in the 200-BP-5 Operable Unit have been defined in the sampling and analysis plan (DOE/RL-2001-49). CERCLA monitoring includes regional plumes, the 216-B-5 injection well site, the BY cribs, and Gable Mountain Pond. Results of monitoring are discussed in Section 2.10.1. An interim or final record of decision has not been established yet for the 200-BP-5 Operable Unit. This report is the only formal report presently being prepared on a regular basis for the unit.

The 200-BP-5 monitoring network and analytes are listed in Appendix A. In FY 2004, sampling was planned for 63 wells. Of these, 59 wells were successfully sampled and 4 wells could not be sampled. Three of the wells that could not be sampled were determined to be dry. These wells included 699-43-40 near B Pond, 699-50-53A in the Gable Gap area, and 699-53-48B at Gable Mountain Pond. The fourth well, 299-E33-46, is being used for vadose zone monitoring activities and cannot be sampled. The sampling and analysis plan was revised in late FY 2004 to integrate *Atomic Energy Act of 1954* (AEA) monitoring and make slight modifications in the 200-BP-5 monitoring network. The monitoring plan (DOE/RL-2001-49) has been revised and will be implemented in FY 2005.

DOE/RL-2001-49 proposed that an additional monitoring well be installed south of Gable Gap and on the west margin of the technetium-99 plume (see DOE/RL-2001-49 for specific location). This well, which has been approved for drilling in FY 2005, will serve to better define plume extent and geometry. Installation of new wells in this area is also important from a hydrogeological standpoint because additional wells will provide information regarding groundwater flow (based on the gradient of the water table) and will help to better define the elevation of the top of the basalt in this area and the geometry of the anticlinal structure in the gap. The latter information is needed to support predictions of future groundwater flow and contaminant migration through the gap.

CERCLA monitoring in the 200-BP-5 Operable Unit includes sampling of the regional plumes, 216-B-5 injection well site, BY cribs, and Gable Mountain Pond.

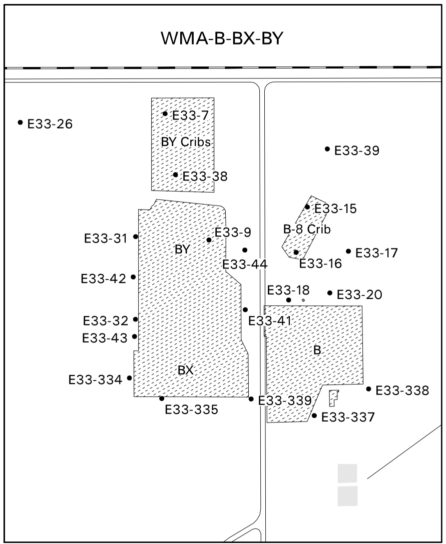
2.10.3 Facility Monitoring

This section describes results of monitoring of individual units such as treatment, storage, and disposal units or tank farms. Some of these facilities are monitored under the requirements of RCRA for hazardous waste constituents and AEA for source, special nuclear, and by-product materials. Data from facility-specific monitoring are also integrated into the CERCLA groundwater investigations. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for each facility. As discussed in Section 2.1, pursuant to RCRA, the source, special nuclear and by-product material components of radioactive mixed waste are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority.

The 200-BP-5 Operable Unit contains six RCRA sites with groundwater monitoring requirements: Waste Management Area B-BX-BY, 216-B-63 trench, Low-Level Waste Management Areas 1 and 2, Liquid Effluent Retention Facility, and Waste Management Area C. This section summarizes results of statistical comparisons, assessment studies, and other developments for FY 2004. Groundwater data are available in the Hanford Environmental Information System (HEIS 1994) and on the data files accompanying this report. Additional information including well and constituent lists, maps, flow rates, and statistical tables are included in Appendix B.

2.10.3.1 Waste Management Area B-BX-BY

Single-shell tank farms B, BX, and BY, located in the northwest part of the 200 East Area, along with ancillary waste transfer lines and diversion boxes comprise Waste Management Area B-BX-BY. It is monitored under the requirements of RCRA and AEA. The site was placed in a RCRA groundwater quality assessment program in 1996 (40 CFR 265.93[d] as referenced by WAC 173-303-400) when specific conductance at a downgradient well became



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elevated above the critical mean. In a first determination assessment report (PNNL-11826), released in 1998, it was shown that residual waste in the vadose zone related to a tank farm leak in 1951 had, most likely, been driven to the groundwater close to well 299-E33-41 by recent fresh water flooding from leaking water lines. Based on 40 CFR 265.93 [d] paragraph (7), the site must continue in quarterly monitoring to determine contaminant levels and the rate/extent of migration until final facility closure (PNNL-11826).

RCRA wells were sampled quarterly to assess the rate and extent of groundwater contamination associated with the waste management area B-BX-BY (Appendix B). One exception is well 299-E33-9, located in the BY Tank Farm. This well has not been sampled since March 2004 because access to the tank farm is restricted due to health concerns associated with hazardous vapors from the tanks. This well usually marks the highest uranium concentrations found at this waste management area and the surrounding area. During FY 2004, three new downgradient RCRA monitoring wells were installed according to the assessment plan (PNNL-13022) along the south and southeast side of the waste management area to improve the monitoring network. These wells were sampled beginning in November 2004.

In addition, outlying wells were sampled to provide coverage of surrounding past-practice liquid effluent disposal facilities to distinguish non-tank farm sources that may have impacted groundwater quality from tank-related sources. Radionuclides are tracked under AEA monitoring at the site. Appendix B includes a well location map, a list of wells and the constituents monitored for Waste Management Area B-BX-BY.

In summary, assessment studies have identified several distinct groups of contaminants based on chemical associations, spatial and temporal relationships, historic plume movement, knowledge of process chemistry, pattern matching and characteristic chemical ratios of constituent concentrations (PNNL-13116; PNNL-14187; PNNL-14548; PNNL-SA-39825):

Assessment studies at Waste Management Area B-BX-BY have identified several distinct groups of contaminants.

- ***Uranium, technetium-99, nitrate, sulfate, and nitrite***. These contaminants are located under and east of the BY Tank Farm. The highest levels of uranium, both spatially and temporally, are found in this location with significantly lower levels of co-varying contaminants, such as nitrate, compared to concentrations in surrounding areas such as the 241-B 8 crib. Additionally, the nitrate-to-technetium ratio indicates a local source different from the surrounding areas. This area is the only location, until recently, that shows elevated nitrite (PNNL-13788; PNNL-14187; PNNL-SA-39825). Past leaks of processing waste from the tank farms have left contaminated soils under the farms, which are, most likely, the source of this contamination found in the groundwater. Further assessment of this plume is ongoing.
- ***Tritium***. This contamination is found on the southwest corner and along the south border of the waste management area. The tritium concentration has been found to rise sharply from the local background value of ~1,800 pCi/L to levels close to the drinking water standard (20,000 pCi/L) in seven wells at nearly the same time beginning in early 1999. There are only low levels of nitrate, technetium-99, and uranium associated with this local tritium plume. The sharply rising trends shown in Figure 2.10-12 indicate the wells are close to the area where the tritium is entering the groundwater (PNNL-13788, PNNL-14187, PNNL-SA-39825). Movement through the vadose zone from a perched water table with elevated tritium located ~4.5 meters above the water table under the BX Tank Farm is, most likely, the source of this contamination. The tritium in this perched water table may be related to tank condensate collected from the tanks in the past.
- ***Technetium-99, nitrate, cobalt-60, and cyanide***. These contaminants are found under the BY cribs and may be impacting the groundwater under the north edge of the BY Tank

Farm. Until recently, this location had the highest concentrations of technetium-99 and cyanide found in areas surrounding the waste management area. The maximum technetium-99 concentration was over 13,000 pCi/L, higher than seen to the south and southeast. The maximum cyanide level, which co-varies with the technetium-99, was over 400 μg/L during the peak of the contamination observed in late 2000 to early 2001. This is also the location of elevated cobalt-60 contamination that co-varies with the cyanide. The nitrate-to-technetium-99 ratios also indicated that the sources of groundwater contamination observed under the BY cribs are different from those observed under the tank farms or near the other surrounding discharge facilities (PNNL-13788; PNNL-14187; PNNL-SA-39825). These contaminants are attributed to residual waste in the vadose zone associated with the original discharges of tank supernatant to the BY cribs in the mid-1950s. At present, it is not clear whether the uranium found in one well (299-E33-38) located between the BY cribs and BY Tank Farm is associated with discharges to the BY cribs or a 1951 unplanned release in the BX Tank Farm.

- ***Nitrate and technetium-99***. Located under the 241-B-8 crib is another unique grouping of contaminants. Until recently, this was the location of the maximum nitrate concentration (695 mg/L in November 2000) found in the area. This area lacks the cyanide and cobalt-60 found under the BY cribs and the high levels of uranium and nitrite associated with the contamination under the BY Tank Farm. Additionally, there does not appear to be a connection with the tritium plume found under the BX Tank Farm. The contaminant signature has a distinctly different nitrate-to-technetium-99 ratio signature than the other groups. Residual waste left in the vadose zone under and around the 241-B-8 crib is, most likely, the source for groundwater contamination in this location and is not associated with the waste management area (PNNL-13788; PNNL-14187; PNNL-SA-39825).

Sources within Waste Management Area B-BX-BY have contaminated groundwater with uranium, technetium-99, tritium, and nitrate.

The first two contaminant groups are attributed to the tank farms. Consequently the following discussion, which covers the FY 2004 assessment monitoring, will focus on contamination under and near the B-BX-BY Tank Farms. References to the other two groups are made, as necessary, to distinguish between the sources.

The hydraulic gradient is nearly flat across Waste Management Area B-BX-BY, making it difficult to determine upgradient versus downgradient wells based on water elevations alone. Consequently, inaccuracies in water elevations caused by measurement errors, deviations from vertical of the borehole, errors in well elevation surveys, and temporal pressure effects associated with changing weather conditions become more important when the difference in elevations between wells is <7 centimeters as at Waste Management Area B-BX-BY (PNNL-12086; PNNL-13116; PNNL-13022; PNNL-13023; and PNNL-13078). Consequently, flow directions were estimated using an in situ flow technique, the colloidal borescope (PNNL-13404; Narbutovskih et al. 2002; PNNL-14187) and local hydrographs. The results of these studies indicate a southward flow direction across the waste management area. The direction of groundwater flow tends to be west-southwest from the BY cribs across the north part of the BY Tank Farm and south to southeast along the south boundary of the waste management area. Local structural highs in the basalt, however, may affect flow directions near any specific well.

Based on in situ techniques, the flow rate appears to be nearly stagnant area under the BY cribs and the BY Tank Farm where the aquifer is as thin as 0.5 meter because the water table is receding to pre-Hanford conditions. In situ flow measurements indicate a faster flow rate in the south where the aquifer is over ~4.6 meters thick. An estimated flow rate in the south is based on hydraulic conductivities calculated from a recent multi-stress slug test (PNNL-14186). This test was performed over several depth intervals during the drilling of well 299-E33-49 in FY 2004. Estimated hydraulic conductivity values ranged from 1,270 to 2,520 meters per day, which is expected for the highly permeable lower Hanford formation found in the aquifer. The estimated groundwater flow rates calculated using the Darcy equation range from 0.6 to 1.2 meters per day (Appendix B, Table B.1). The average water-table decline beneath the waste management area was 12 centimeters in FY 2004. If the water table declines to pre-Hanford levels, the edge of the unconfined aquifer will recede, leaving dry sediment under the BY cribs and most of the BY Tank Farm with no aquifer below. For example, well 299-E33-6 at the BY cribs is already dry down to basalt.

Since the initial assessment investigation (PNNL-11826), a further determination was conducted to identify the source of rising technetium-99, nitrate, nitrite, and uranium observed under and east of the BY Tank Farm. With 180-degree changes in flow directions from pre-Hanford times to conditions during peak operations and with the existence of a significant perching horizon, located ~4.6 meters above the water table, distinguishing contaminant sources has been difficult. The results of this investigation, presented in PNNL-SA-39825 and PNNL-14187, show that the contamination observed in downgradient wells around Waste Management Area B-BX-BY is due, primarily, to vertical movement of residual waste left in the soil under the tank farms. Although the source of the water driver and vadose zone migration pathways are not clearly understood, the water driver appears to be related to long-term steady-state recharge from natural precipitation and leaks from nearby fresh water lines. At this time, it has been reasonably established that most of the contamination found in the groundwater at Waste Management Area B-BX-BY is from local, residual soil contamination associated with past tank farm operations.

Contamination from the vadose zone appears to be moving down to groundwater.

General trends for nitrate have continued to remain steady or fluctuated with no defined trend during FY 2004 as shown in wells 299-E33-32, 299-E33-42, and 299-E33-43 (Figure 2.10-13). The measures taken in the last few years to control surface run off water into and around the farm may be having some effect by controlling or redirecting infiltration. However, nitrate levels remain elevated above pre-1997 values that were at or close to groundwater background levels of less than 12 mg/L (WHC-EP-0595). The steady trend shown in wells 299-E33-32, 299-E33-42, and 299-E33-43 is also seen in other wells around the site. The exception is well 299-E33-44 where nitrate levels have increased sharply over the last quarter of the FY 2004 from 268 to 403 µg/L. Other wells in the area displaying distinct increases are wells 299-E33-7, located in the BY cribs to the north, and 299-E33-15, located to the northeast in the 241-B-8 crib, both upgradient of Waste Management Area B-BX-BY (PNNL-14548). Downgradient from the 241-B-8 crib, a center for some of the highest nitrate in the area, well 299-E33-17 is also increasing in nitrate. Current changes in nitrate in well 299-E33-9, where the highest uranium concentrations have been detected, are not known since this well cannot be sampled as explained above.

Technetium-99 concentrations show trends similar to nitrate (Figure 2.10-14), although the corresponding technetium-99 increase in well 299-E33-15 is not as evident as it is for nitrate. It can be seen by comparing the temporal offset of peak technetium-99 levels between wells 299-E33-7 and 299-E33-44 versus 299-E33-16, the contamination appears to be moving from the northwest to the southeast. Alternatively, the water source forcing the contamination to migrate through the vadose zone may be moving in a southeastward direction.

Further evidence that the peak contamination observed in late 2000 to early 2001 was driven from the vadose zone to the groundwater can be found by comparing chloride trends across the site (PNNL-14187; PNNL-SA-39825). Groundwater background chloride values at the Hanford site are generally less than 9 mg/L (WHC-EP-0595). There are no direct chloride sources associated with tank waste. Chloride levels can be increased in the groundwater, however, by infiltrating raw water (non-chlorinated) from the surface that dissolves chloride deposited naturally over geologic time in near surface sediment. As the water moves through the vadose zone, the chloride concentration increases resulting in values above background as shown at the State-Approved Land Disposal Site (PNNL-14038; PNNL-11633). Figure 2.10-15 shows chloride trends for wells where the groundwater displayed the maximum concentrations of nitrate, technetium-99, and uranium at the waste management area during the late 2000 event. As can be seen, chloride levels were the highest under the BY Tank Farm in well 299-E33-9 at 53 mg/L, 6 times the background value. Other high chloride values (greater than 5 times background) are found under the BY cribs to the north in well 299-E33-7 where the high levels of nitrate and technetium-99 are accompanied by elevated cyanide and cobalt-60. Also displayed are elevated chloride values in late 2000 for wells 299-E33-31 and 299-E33-26. These wells are located around the 216-B-57 crib. Ponded precipitation or runoff water from the crib cap may have contributed to this water source. Variations in chloride levels provide insight to the sources of water drivers, both natural and manmade that are the key to understanding the complex groundwater chemistry patterns at Waste Management Area B-BX-BY.

When discussing sources for the high uranium found under the BY Tank Farm, it is important to recognize that the uranium contamination does not travel alone but is associated with the mobile contaminants from the original processing source. For example, as shown in Figure 2.10-16, uranium levels under the BY Tank Farm, east, southeast, and north of the farm are correlated with the rising technetium-99 and nitrate contamination. However, the peak values from late 2000 to early 2001 indicate that the uranium's movement is retarded with respect to the mobile technetium-99. As shown by nitrate-to-technetium-99 ratios in previous studies (PNNL-14187; PNNL-SA-39825), multiple sources are contributing to the groundwater in this area. The co-variation of technetium-99, although offset in time, shows that the uranium has a common source with the technetium-99. The correlation between the technetium-99 and uranium trends in Figure 2.10-16 shows that the uranium is traveling with the technetium-99 and is, most likely, from the same contaminated soils as the elevated technetium-99, nitrate, and other corresponding contaminants.

When uranium trends are compared, as in Figure 2.10-17, for wells located south and north of well 299-E33-9, it can be seen that the center of the uranium plume in the groundwater is located under the BY Tank Farm as indicated by the high concentration in wells 299-E33-9 and 299-E33-44. The uranium value in the groundwater under the BY Tank Farm was 590 µg/L and rising when last sampled in March 2004. This location is also where the corresponding maximum chloride levels indicate the recent water driver was centered or close to it. The difference in trend relationships between uranium and technetium-99 may have occurred when the contaminants migrated through the vadose zone in the past, possibly when the waste was released in 1951, while the chloride trends reflect the more recent water driver impacting the groundwater in late 2000 and early 2001. This two part scenario accounts for past multiple releases of waste both intentional and unplanned in multiple locations, mixing of waste sources in the vadose zone over time, which, when combined with one or more recent fresh water incursions produces the numerous and complex groundwater plumes observed today.

Another plume with locally high tritium, exceeding the drinking water standard of 20,000 pCi/L at times, is found along the south border of the waste management area (Figure 2.10-12). This plume is migrating to the south to southeast as seen by the offset and decreased concentration in newly installed wells 299-E33-335, 299-E33-337, and 299-E33-339 with respect to well 299-E33-43. At present, it is unknown why the initial values at wells 299-E33-337 and 299-E33-339 were high in 2001. Recent small increases in uranium (less than 10 µg/L) along this southern boundary also indicate movement to the south. Migration through the vadose zone from a tritium-rich perched water table located ~4.6 meters above the top of the unconfined aquifer under the B and BX Tank Farms is probably the cause of this contamination (RPP-10098). Maximum levels exceeded the drinking water standard on the southwest corner of the BX Tank Farm at 20,600 pCi/L in August 2003.

The historical discharge of effluent to the ground in and around Waste Management Area B-BX-BY resulted in complex patterns of groundwater contamination.

The historical discharge of effluent to the ground in and around Waste Management Area B-BX-BY resulted in complex patterns of groundwater contamination. The highest level of technetium-99 was located beneath the BY cribs to the north and is attributed to discharges to the cribs in the mid-1950s. Associated with high concentrations of nitrate, cyanide, and some cobalt-60, this contamination forms a plume that possibly affects the groundwater under the north part of Waste Management Area B-BX-BY. Elevated uranium with technetium-99, nitrate, sulfate, and nitrite is found locally beneath the BY Tank Farm while a small tritium plume exists along the southern margin of the waste management area. Evidence was discussed in PNNL-14187 with further data shown above that indicate the contamination seen in and around Waste Management Area B-BX-BY is entering the groundwater in multiple areas from the vadose zone and is sourced in the contaminated soils under both the tank farms and the surrounding cribs. Residual wastes left in the vadose zone from unplanned releases associated with the waste management area are, most likely, contributing to the uranium, nitrate, technetium-99, tritium, and other contamination in the vicinity of the BY and BX Tank Farms (PNNL-SA-39825; PNNL-14187). Quarterly monitoring of the groundwater at Waste Management Area B-BX-BY will continue.

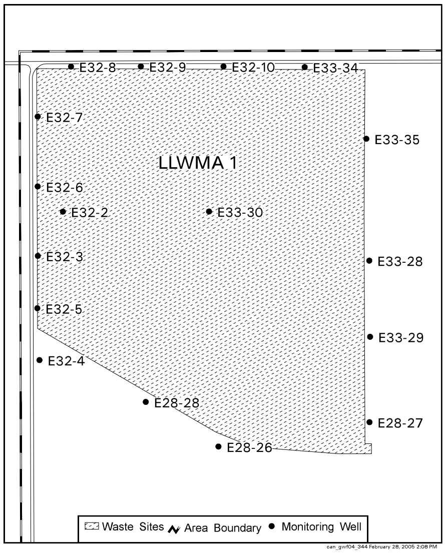
2.10.3.2 216-B-63 Trench

This RCRA unit continued to be monitored under an interim status detection program [40 CFR 265.93(b) as referenced by WAC 173-303-400] in FY 2004. The monitoring network was sampled twice, as scheduled, for 12 wells during the year (PNNL-14112, Appendix B). Wells 299-E33-33 and 299-E33-36 exceeded the critical mean for total organic carbon in April, May, and June 2004. The exceedances occurred at a time when a series of anomalously high total organic carbon results were reported across the Hanford Site. Preliminary results indicate that laboratory error may have contributed to the elevated results.

Sampling results for the 216-B-63 trench have historically supported the interpretation that the facility has not affected groundwater.

Several non-hazardous constituents that had been rising in concentration slowly and persistently over a decade have, in most instances, stabilized or have declined in concentration. Results from past sampling efforts have indicated stable or declining concentration of anions. The result from FY 2004 shows a pattern of increase in anions in wells on both ends of the 216-B-63 trench, with wells in the center still exhibiting either slight downward trend changes, or with no significant change in trend. Sulfate continues to be the exception, showing an increase in nearly every well tested in FY 2004. The greatest increases in concentration, however, follow the same pattern as the anions; the increases in trend are greatest at the two opposing ends of the trench.

The monitoring well network for the 216-B-63 trench is shared with both the Low-Level Waste Management Area 2 and the B-BX-BY Tank Farms. Samples are gathered twice a year in spring and fall (see Appendix B). Due to the low hydraulic gradient and the highly transmissive media in 200 East Area, the rate of groundwater movement near the 216-B-63 trench is low, approximating 0.1 meter per day (see Appendix B). The monitoring network for the 216-B-63 trench currently meets RCRA requirements as defined in the monitoring plan.



Vadose zone characterization activities conducted at the 216-B-63 trench in FY 2004 are discussed in Section 3.1.1.

2.10.3.3 Low-Level Waste Management Area 1

Groundwater at Low-Level Waste Management Area 1 continued to be monitored under RCRA and AEA. Under 40 CFR 265.93(b) as referenced by WAC 173-303-400, the well network was sampled semiannually for RCRA indicator and site-specific parameters (WHC-SD-EN-AP-015; DOE/RL-2000-72; Appendix B). All 17 wells were successfully sampled during both samplings.

An application was submitted to the Washington State Department of Ecology (Ecology) in June 2002 to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994a). This would have the effect of changing the groundwater monitoring requirements for the burial grounds from interim status monitoring to final status monitoring. As part of the application, new groundwater monitoring constituents and statistical evaluations are proposed. Workshops with the Ecology to address this application are in progress and include discussions on the adequacy of the well network.

The groundwater gradient in this part of the 200 East Area is almost flat making the determination of groundwater flow direction difficult (Figure 2.10-3). Based on contaminant plumes, flow direction to the northwest over the long-term is indicated (Figures 2.10-4 through 2.10-7). Past analysis of water-level data also indicate flow toward the northwest. Trend surface analysis performed on FY 2003 water-level data indicated flow direction ranging from northwest to east-southeast (PNNL-14548). Trend surface analysis performed on FY 2004 data indicated flow direction ranging from 305 degrees to 355 degrees (approximately west-northwest to north) for three of the four data sets. The December 2003 data indicated a flow direction of 105 degrees (approximately east-southeast). The December data could be responding to water-level trends noted in FY 2003 (PNNL-14548) or be the result of greater measurement uncertainty. The calculated gradient is ~0.00002 with flow rate estimates ranging from ~0.005 to 0.2 meter per day. The data suggest that the flow direction remains largely to the northwest but is dynamic due to the influence of minor relative water level variation between wells. For this reason, no attempt will be made to update the interim status designation of upgradient and downgradient wells until a stable flow direction is re-established.

Specific conductance continued to exceed the statistical upgradient/downgradient comparison value (critical mean) in downgradient well 299-E33-34, with values ranging from 1,048 to 1,195 µS/cm. In FY 2004, well 299-E32-10, west of well 299-E33-34, also exceeded the statistical comparison value. The exceedance is related to a regional nitrate plume (Figure 2.10-5). DOE notified Ecology of the exceedance in 1999. Other indicator parameters remained below critical mean values in downgradient wells. Statistical comparison values to be used for indicator parameters in FY 2005 are listed in Appendix B.

Contaminant levels beneath Low-Level Waste Management Area 1 are consistent with regional plumes.

Performance assessment monitoring of radionuclides at Low-Level Waste Management Area 1 is designed to complement the RCRA detection monitoring and is aimed specifically at monitoring radionuclide materials that are not regulated under RCRA. The current goal of performance assessment monitoring at Low-Level Waste Management Area 1 is to gather data to assess changes in concentrations at downgradient wells using statistical tests and to provide sufficient supporting information from upgradient wells to interpret the changes. Under the current monitoring plan (DOE/RL-2000-72), only technetium-99 is monitored specifically for performance assessment.

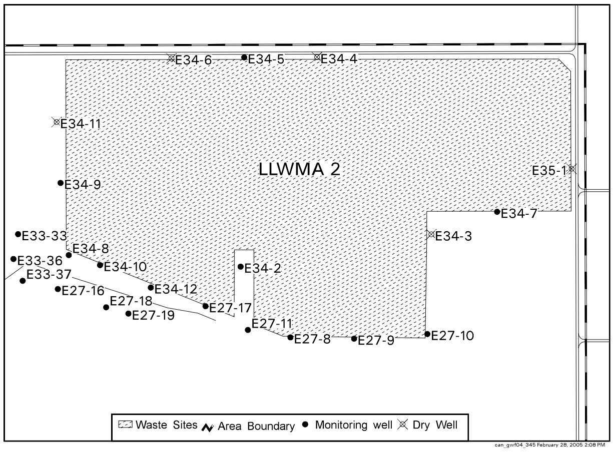
Contaminant characteristics at Low-Level Waste Management Area 1 include the following:

- Technetium 99 concentrations continued to be elevated in several wells (299-E33-34, 299-E32-10, 299-E33-35) near the northeast corner of Low-Level Waste Management Area 1. Concentrations in FY 2004 (maximum of 7,730 pCi/L in well 299-E33-34) were lower than the maximum concentration seen in 2001 (8,170 pCi/L in well 299-E33-34). The contamination levels are consistent with regional plumes (Figure 2.10-7).
- Uranium values increased only slightly to 107 µg/L at well 299-E33-34 in the northeast corner of the waste management area after a steep increase in 2002. This is associated with a relatively recent plume originating in the vicinity of Waste Management Area B-BX-BY (Figure 2.10-9). The uranium plume has impacted other wells surrounding this part of the waste management area, but concentrations are not as high.
- Uranium levels are increasing in a number of wells on the west side of Low-Level Waste Management Area 1 but remained below the drinking water standard (30 µg/L). A maximum of 21.3 µg/L was detected in well 299-E32-3. Comparable or higher concentrations have been seen in past years in wells farther south (e.g., wells 299-E28-26, 299-E28-28, and 299-E32-5), so it is possible that the increases indicate a shift in preexisting plumes and not new contamination from the waste management area. This conceptual model cannot be confirmed at present, however.

- Tritium contamination is also believed to be from regional plumes, not related to the burial grounds (Figure 2.10-4). Tritium concentrations were less than the drinking water standard in FY 2004.
- Iodine-129 contamination in this area is consistent with regional plumes and believed to be from liquid waste facilities, not related to the burial grounds (Figure 2.10-6).
- Nitrate contamination at Low-Level Waste Management Area 1 is mapped as two separate plumes at the drinking water standard, both extending from areas outside of the burial ground. The contours shown in Figure 2.10-5 are similar to those from previous years. The highest concentrations are in the northeast plume, coincident with the technetium-99 plume discussed above. Thus, the northeast nitrate plume has a likely source in the BY cribs.
- Low levels of chromium contamination are seen in filtered samples from well 299-E33-34, in the northeast corner of Low-Level Waste Management Area 1. The FY 2004 average chromium concentration was 19 µg/L. This is consistent with other contaminant trends observed in the area and near Waste Management Area B-BX-BY where the concentrations ranged up to 48 µg/L in FY 2004. The drinking water standard for chromium is 100 µg/L.

2.10.3.4 Low-Level Waste Management Area 2

Groundwater at Low-Level Waste Management Area 2 continued to be monitored under RCRA and AEA. Under 40 CFR 265.93(b) as referenced by WAC 173-303-400, the well network was sampled semiannually for RCRA indicator and site-specific parameters (WHC-SD-EN-AP-015; DOE/RL-2000-72; Appendix B). The well network was sampled twice for indicator and site-specific parameters. Sampling was successful at 11 wells for both sampling rounds. Other wells in the unit have gone dry in recent years.



An application was submitted to Ecology in June 2002 to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994a). This would have the effect of changing the groundwater monitoring requirements for the burial grounds from interim status monitoring to final status monitoring. As part of the application, new groundwater monitoring constituents and statistical evaluations are proposed. No new wells were proposed, in spite of wells going dry, because the water-table elevation is receding below the top of the basalt. Deeper aquifers are isolated from the burial grounds by the low-permeability basalts (see as-built diagrams in Appendix B, PNNL-6820). Workshops with Ecology to address this application are in progress and include discussions on the adequacy of the well network.

The groundwater gradient in this part of the 200 East Area is almost flat making the determination of groundwater flow direction difficult. Groundwater flow appears to be generally to the west based on small differences in head at wells along the south boundary of Low-Level Waste Management Area 2. Trend surface analysis performed on FY 2002 data indicated flow generally to the southwest; however, no realistic flow direction could be determined from trend surface analysis of FY 2003 data due to further flattening of the water table (PNNL-14548). FY 2004 trend surface analysis also produced no consistent flow direction unless well 299-E34-5 is included in the analysis. The current interpretation of the basalt surface and water levels suggests well 299-E34-5 is isolated from the rest of the aquifer under Low-Level Waste Management Area 2 by basalt extending above the water table. If it is assumed this well is in communication with the unconfined aquifer and it is included in the trend surface analysis, the calculated flow is to the south or south-southwest. Flow to the southwest is also indicated by the movement of the nitrate plume from well 299-E34-7 to well 299-E27-10 (discussed further below). For this reason, no attempt will be made to update upgradient well designations used in the statistical tests until a stable flow direction is evident. The basalt surface above the water table in the north part of Low-Level Waste Management Area 2 constrains possible flow directions for the unconfined aquifer. However, it is possible that the flow is influenced by continued drainage of the unsaturated sediment and recharge moving laterally on the basalt surface to the saturated aquifer sediment. The gradient calculated from wells along the south boundary of the burial ground is 0.00003. The estimated flow rate at Low-Level Waste Management Area 2, using this gradient, is 0.04 to 0.6 meter per day (Appendix B).

Statistical comparison values for indicator parameters were not exceeded for any downgradient wells in FY 2004. Upgradient well 299-E34-7, however, is no longer used to calculate critical mean values because of the anomalous chemistry in this well. Appendix B lists the statistical comparison values based on data for the other upgradient wells.

Well 299-E34-7 has high specific conductance, total organic carbons, and total organic halides. The major contributors to the elevated specific conductance are sulfate, chloride, nitrate, and calcium. The source of the elevated specific conductance is not known. The specific conductance declined during FY 2004.

The cause of the elevated levels of total organic carbon and total organic halides is also not known. Total organic carbon levels declined slightly from FY 2003. The FY 2004 average total organic carbon concentration was 3,940 µg/L. The average total organic halide concentration was 16.7 µg/L, lower than in FY 2003. FY 2003 and 2004 samples from well 299-E34-7 were analyzed for an extensive list of constituents and other possible contaminants identified in 40 CFR 264, Appendix IX. No organic constituents were detected consistently and those detected were at low levels, often associated with blank contamination that appears to be false-positive results (Table 2.10-1). The levels of Appendix IX constituents are far lower than the total organic carbon.

Levels of specific conductance, total organic carbon, and total organic halides in an upgradient well at Low-Level Waste Management Area 2 are elevated. The source is unknown.

The constituents causing the increased specific conductance seen in well 299-E34-7 are beginning to impact wells farther southwest, well 299-E27-10 and well 299-E27-9. Sulfate, chloride, nitrate, and calcium are all increasing in these wells but remain at lower concentrations than seen in well 299-E34-7. The concentrations in well 299-E27-10 are higher than in well 299-E27-9, indicating the plume is spreading toward the southwest and west. The nitrate trend for these three wells is shown in Figure 2.10-18 as an example of the increases.

Performance assessment monitoring of radionuclides at Low-Level Waste Management Area 2 is designed to complement the RCRA detection monitoring and is aimed specifically at monitoring radionuclide materials that are not regulated under RCRA. The current goal of performance assessment monitoring at Low-Level Waste Management Area 2 is to gather data to assess changes in concentrations at downgradient wells using statistical tests and to provide sufficient supporting information from upgradient wells to interpret the changes. Under the current monitoring plan (DOE/RL-2000-72), technetium-99, iodine-129, and uranium are monitored specifically for performance assessment.

Contaminant characteristics at Low-Level Waste Management Area 2 include the following:

- Technetium-99 concentration continued to increase in upgradient well 299-E27-10 southeast of Waste Management Area 2, where the concentration reached 64 pCi/L in FY 2004. This contamination is believed to be from past disposal of liquid waste in the 200 East Area and unrelated to Low-Level Waste Management Area 2 because this is an upgradient well. Other wells in the monitoring network have lower technetium-99 concentrations.
- Tritium contamination is found at levels less than the drinking water standard. The tritium concentrations are consistent with regional plumes (Figure 2.10-4 and Section 2.10.1.1).

- Iodine-129 concentrations are <5 pCi/L in Low-Level Waste Management Area 2 wells. The levels are consistent with the regional iodine-129 plume (Figure 2.10-6 and Section 2.10.1.3) and do not appear to be related to a burial ground source.
- Uranium concentrations in Low-Level Waste Management Area 2 samples are <5 µg/L and do not indicate a burial ground source.
- Nitrate contamination at levels above the drinking water standard is restricted to upgradient wells on the eastern side of Low-Level Waste Management Area 2.

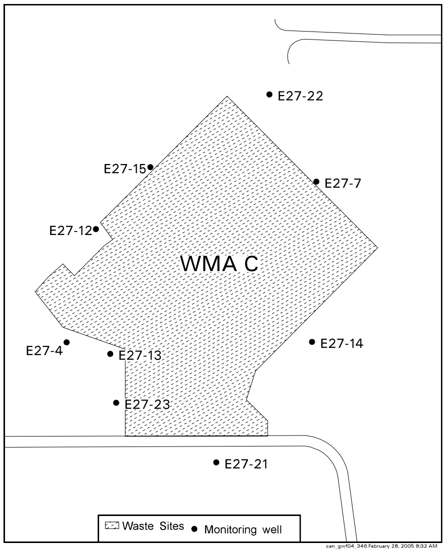
2.10.3.5 Liquid Effluent Retention Facility

The Liquid Effluent Retention Facility is monitored by two wells.

The Liquid Effluent Retention Facility is an active, lined facility that is identified in the Hanford Facility RCRA Permit (Ecology 1994a). Groundwater at this facility is monitored to meet requirements of RCRA under 40 CFR 265.93(b) as referenced by WAC 173-303-400. A RCRA final status detection-monitoring program was in place at the Liquid Effluent Retention Facility until June 1999 when downgradient well 299-E26-9 no longer provided representative groundwater information (i.e., went dry). Ecology granted a variance in September 1999 to allow DOE to operate the remaining network wells as the compliance system. This variance gave DOE 18 months, or until the next downgradient well became non-functional, to develop and deploy an alternative monitoring system. Ecology rescinded the variance in January 2001 when downgradient well 299-E35-2 no longer produced representative samples. A letter from Ecology directed DOE to discontinue statistical evaluation of groundwater sample results effective January 14, 2001. Since that time, DOE has continued to sample the remaining wells according to WHC-SD-EN-AP-024, but no longer performs statistical evaluations of the results. The groundwater monitoring network is not compliant with the groundwater monitoring requirements of WAC 173-303-645. DOE and Ecology are exploring alternative approaches to environmental groundwater monitoring at the facility to meet compliance with hazardous waste regulations.

Two wells were successfully sampled semiannually at the Liquid Effluent Retention Facility in FY 2004 (Appendix B). Results for specific conductance (consisting largely of elevated levels of sulfate) have been rising in concentration since 1994 mirroring a regional trend (PNNL-14187). The FY 2004 increase in specific conductance and sulfate has not been as dramatic as in past fiscal year sampling efforts. No other contamination indicator parameters have shown increases over FY 2004.

2.10.3.6 Waste Management Area C



Located in the northeast part of the 200 East Area, Waste Management Area C consists of the C Tank Farm, the 244-CR vault, ancillary waste transfer lines, and seven diversion boxes. Groundwater at this waste management area is monitored to meet requirements of RCRA under 40 CFR 265.93(b) as referenced by WAC 173-303-400 and AEA. The objective of RCRA monitoring at this site is to determine if groundwater quality has been compromised by dangerous waste constituents associated with the tank farm. Groundwater monitoring at the C Tank Farm continued under an interim status indicator evaluation program in FY 2004 [40 CFR 265.93(b) as referenced by WAC 173-303-400]. Wells were sampled quarterly at the request of Ecology. In addition, the required detection sampling was conducted twice per year for indicator and site-specific parameters (Appendix B). Radionuclides are tracked under AEA monitoring at the site. Appendix B includes a well location map, a list of wells, and the constituents monitored for Waste Management Area C. The following discussion covers monitoring conducted during FY 2004 and the local hydrogeology of the waste management area. Vadose zone characterization activities conducted at Waste Management Area C in FY 2004 are discussed in Section 3.1.3. Waste retrieval operations and related borehole logging activities are also included in Section 3.3.

In summary, contamination in the groundwater began rising between 1995 and 1998 depending on the location and continued to increase downgradient during FY 2004. Contamination consists primarily of elevated nitrate, technetium-99, sulfate, chloride, and cyanide. The original upgradient well 299-E27-7 is close to the northeast fence line and to ancillary equipment used for farm activities. Furthermore, contaminant levels have been rising in the groundwater at this location making upgradient/downgradient comparisons difficult due to varying levels of specific conductance. Consequently in FY 2003, a new upgradient well was installed to the north (well 299-E27-22) along with three new downgradient wells (wells 299-E27-4, 299-E27-21 and 299-E27-23) to improve the monitoring network at the site as required by the site monitoring plan (PNNL-13024).

Upgradient/downgradient comparisons were temporarily suspended for specific conductance until data from the new upgradient well, providing a more stable baseline, could be included in the statistical analysis. A new critical mean for specific conductance has been calculated (Appendix B), and upgradient/downgradient comparisons began in FY 2005. The remaining indicator parameters (pH, total organic carbon, and total organic halide) did not exceed the upgradient/downgradient comparison values in downgradient wells during FY 2004.

A general flow direction ranging from south-southwest to southwest has been determined for this site using in situ flow measurements with the colloidal borescope, plume tracking, and water elevations corrected for borehole deviations from vertical (PNNL-13788). Hydrographs (Figure 2.10-19) confirm that the flow direction has not changed and remains to the southwest, which is consistent with the regional water-table map (PNNL-14187). The rate of groundwater flow is based on hydraulic conductivities calculated from a multi-stress slug test performed over four depth intervals during the drilling of well 299-E27-22 (PNNL-14186). Estimated conductivity values ranged from 1,890 to 6,888 meters per day, as expected for the highly permeable lower Hanford formation sediments found in the aquifer at Waste Management Area C. The estimated groundwater flow rates calculated using the Darcy equation range from 1.4 to 4.8 meters per day (Appendix B). The rate of water table decline beneath Waste Management Area C was 9 to 10 centimeters this last year. If this rate continues, older wells from the original network should be usable for at least 6 years.

Contaminant concentrations, including technetium-99, continued to rise in groundwater at Waste Management Area C.

In the following discussion, data values are given for the September 2004 sampling event. Specific conductance was elevated in upgradient in wells 299-E27-22 (495 µS/cm) and 299-E27-7 (629 µS/cm). Although an increasing trend is observed in well 299-E27-7, there are not enough data to discern a trend for well 299-E27-22 (Figure 2.10-20). The highest value downgradient (736 µS/cm) was found south of the farm in well 299-E27-14. Values downgradient on the southwest side of the farm range from 399 to 335 µS/cm. The increasing specific conductance is caused primarily by rising sulfate and calcium along with nitrate and some chloride (PNNL-14187). Sulfate dominates with the highest values for FY 2004 found in the east corner of the farm ranging from 179 mg/L in downgradient well 299-E27-14 to 150 mg/L in upgradient well 299-E27-7. Although there have been high values for anions, with a maximum of 671 mg/L for sulfate observed upgradient, there is a good correlation between sulfate and increasing technetium-99 (2,450 pCi/L) in the downgradient well 299-E27-14 (Figure 2.10-21). Thus, downgradient of the site, the rising specific conductance appears to be related to a chemical nuclear processing source. It was shown in PNNL-13404 that the rising contamination of both technetium-99 and nitrate in well 299-E27-14 began approximately in 1994, peaking in September 1998. Sluicing activities began in November 1998. Thus, there is not a clear indication from trend plots that the contamination in the groundwater at Waste Management Area C is directly related to the tank sluicing activities. On the north side of the site where technetium-99 levels are low in the new upgradient well 299-E27-22 (77.4 pCi/L) and in 299-E27-7 (95.4 pCi/L) but the sulfate concentration is high, there may be influences from the high sulfate concentrations further upgradient (PNNL-14548).

To date, the highest value of technetium-99 observed in the groundwater at the farm is 8,370 pCi/L (June 2004). This elevated technetium-99 was found with low levels of nitrate (22 mg/L) in the new downgradient well 299-E27-4, located south of the west corner of the farm. Technetium-99 values at the other downgradient wells ranged from 2,450 pCi/L at well 299-E27-14 to 1,800 pCi/L at well 299-E27-23. Further downgradient, a September 2004 value of 718 pCi/L was observed at well 299-E27-21. The nitrate to technetium-99 ratio at well 299-E27-4 is 2.6, indicating the source of this contaminated groundwater may be related to a tank source, the same as nearby well 299-E27-13, as discussed in PNNL-14187 and PNNL-14548. In general, nitrate to technetium-99 ratios lower than 10 suggest the source is related to residual tank waste in the vadose zone.

Cyanide levels have risen and become more steady in the groundwater at this site, especially in upgradient well, 299-E27-7, with a maximum value of 44.6 μg/L observed in September 2004. The presence of cyanide in the groundwater also suggests the source is associated with tank-related waste left in the vadose zone, because the C Tank Farm is the only known local source for cyanide (HNF-SD-WM-TI-740). Additionally, the sharp rise and fall of the technetium-99 peak at well 299-E27-7 (Figure 2.10-22) indicates a short travel distance from the point of entry into the groundwater to the well (PNNL-14548) implying the source is close to the farm. A comparison to the data in well 299-E27-22, confirms that technetium-99 levels upgradient are presently low. Further insight into the source of the groundwater contamination at this waste management area may be possible when trends become recognizable in the new downgradient wells.

Table 2.10-1. Organic Constituents Reported in Well 299-E34-7, Low-Level Waste Management Area 2, FY 2004

Constituent	Number of Detects	Number of Results	Maximum Reported (μg/L)	Notes
1,2,3,4,7,8-Hexachlorodibenzofuran	1	2	0.00000063	Contamination in associated blank; not all qualitative identification criteria met
Acetone	2	6	3.6	Common laboratory contaminant
Bis(2-ethylhexyl) phthalate	1	6		Common laboratory contaminant
Bromomethane	3	6	0.57	Blank contamination in two-thirds reported detects
Chloromethane	2	6	0.3	
Di-n-octylphthalate	1	6	2.5	Common laboratory contaminant
Dicamba	1	6	0.17	
Diethylphthalate	1	6	2.4	Common laboratory contaminant
Endrin aldehyde	1	6	0.076	
Hexachlorodibenzofurans	1	2	0.00000063	Contamination in associated blank; not all qualitative identification criteria met
Methylene chloride	1	6	0.78	Contamination in associated blank; common laboratory contaminant
Octachlorodibenzo-p-dioxin	2	2	0.0000025	Contamination in associated blank; not all qualitative identification criteria met in one sample
Octachlorodibenzofuran	1	2	0.0000022	Contamination in associated blank
Oil and grease	1	6	1,200	

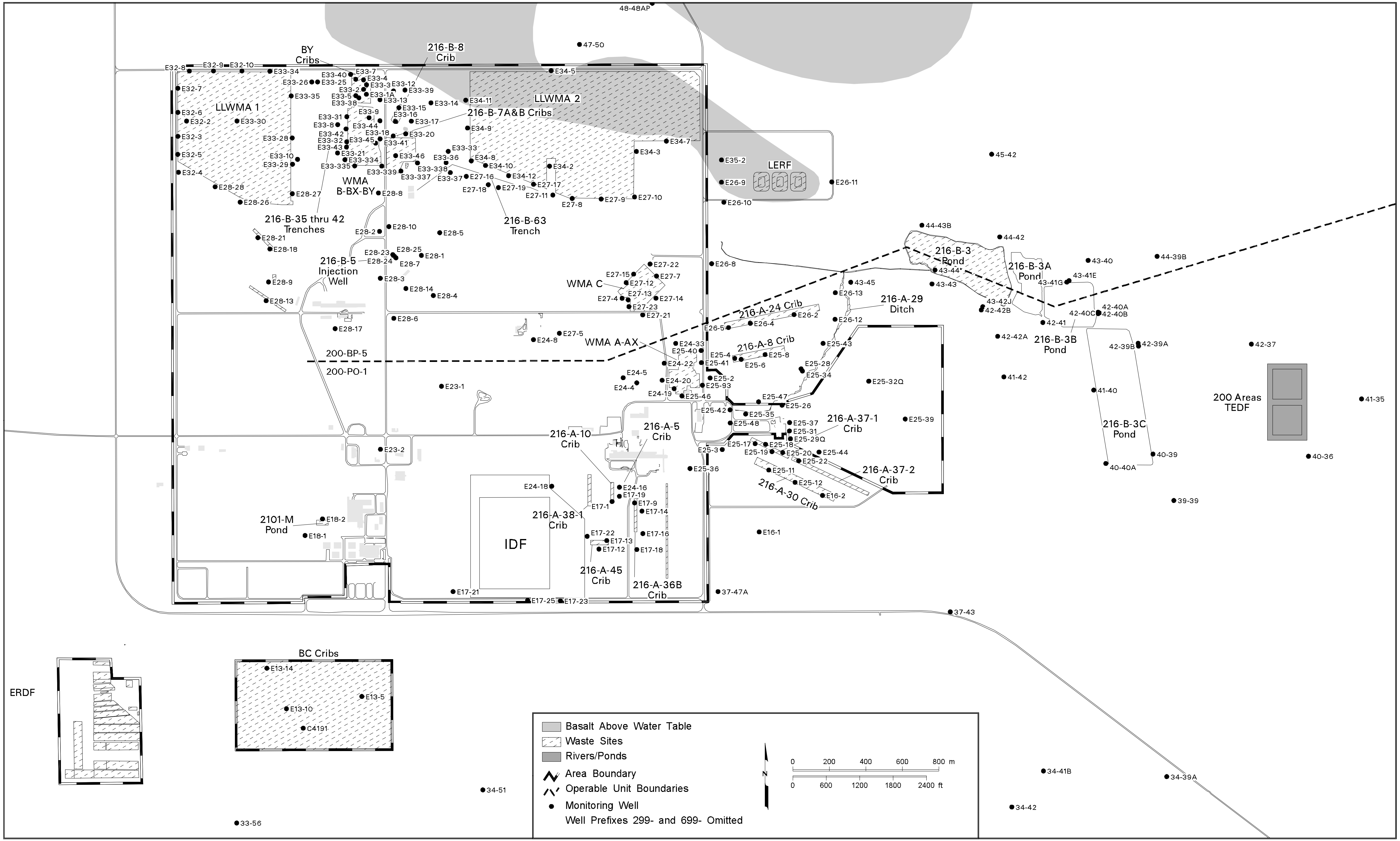


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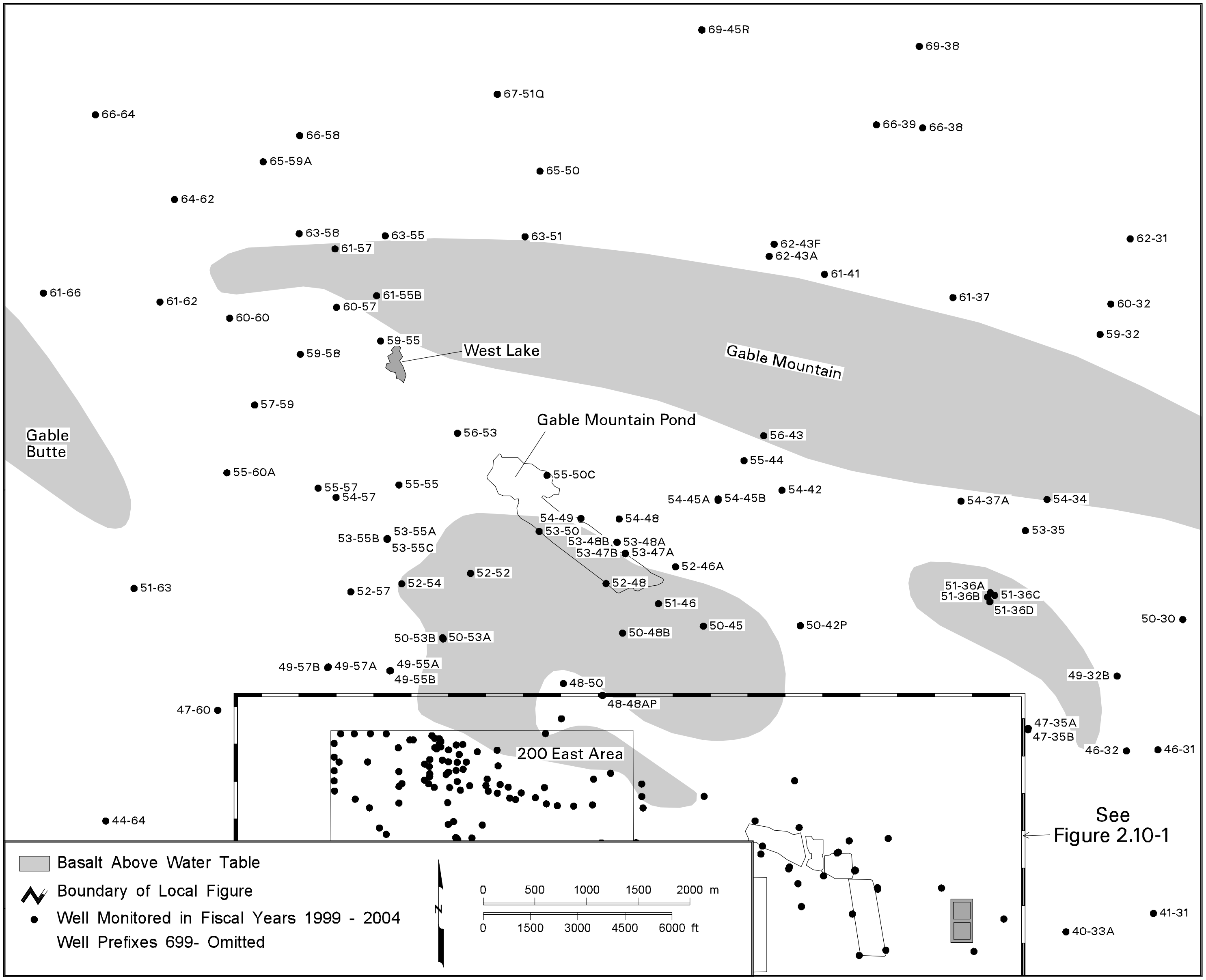
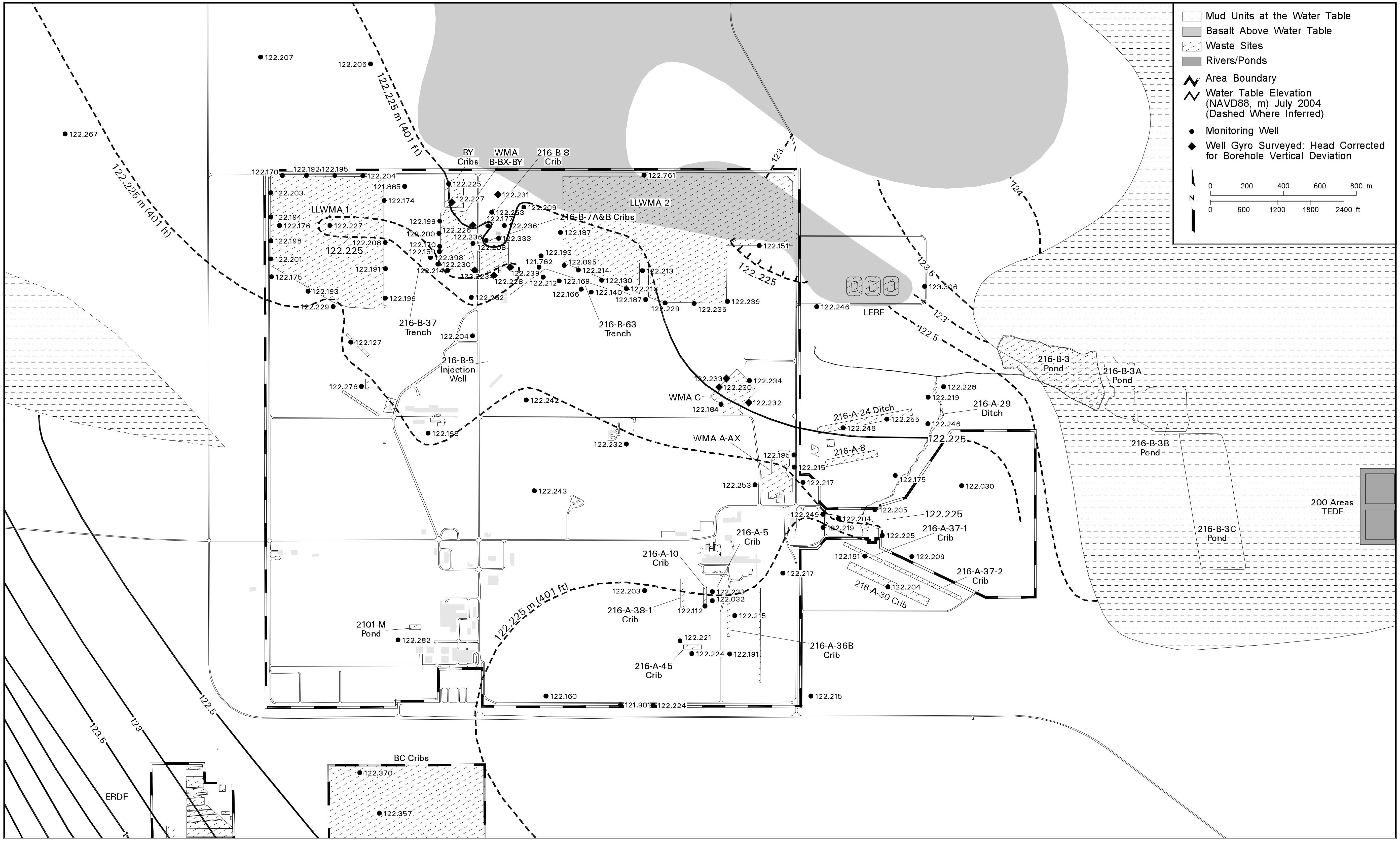
Figure 2.10-1. Groundwater Monitoring Wells in the 200 East Area



can_gwf04_322 February 18, 2005 1:55 PM

Figure 2.10-2. Groundwater Monitoring Wells Located in the 600 Area Associated with the 200-BP-5 Operable Unit



can_gwf04_342 March 02, 2005 2:11 PM

Figure 2.10-3. 200 East Area Water-Table Map, July 2004

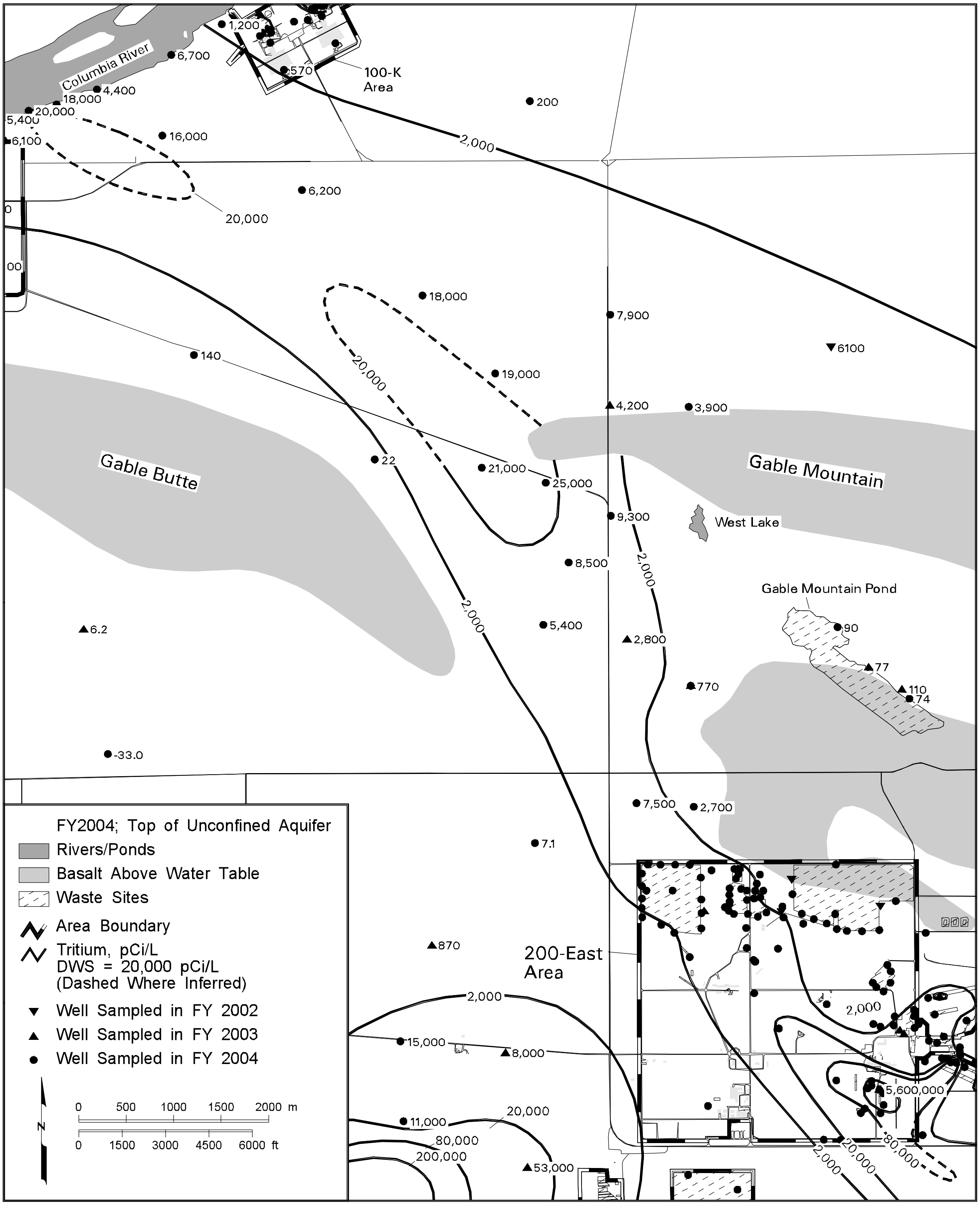


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Figure 2.10-4. Average Tritium Concentrations in the 200-BP-5 Operable Unit and Vicinity, Top of Unconfined Aquifer

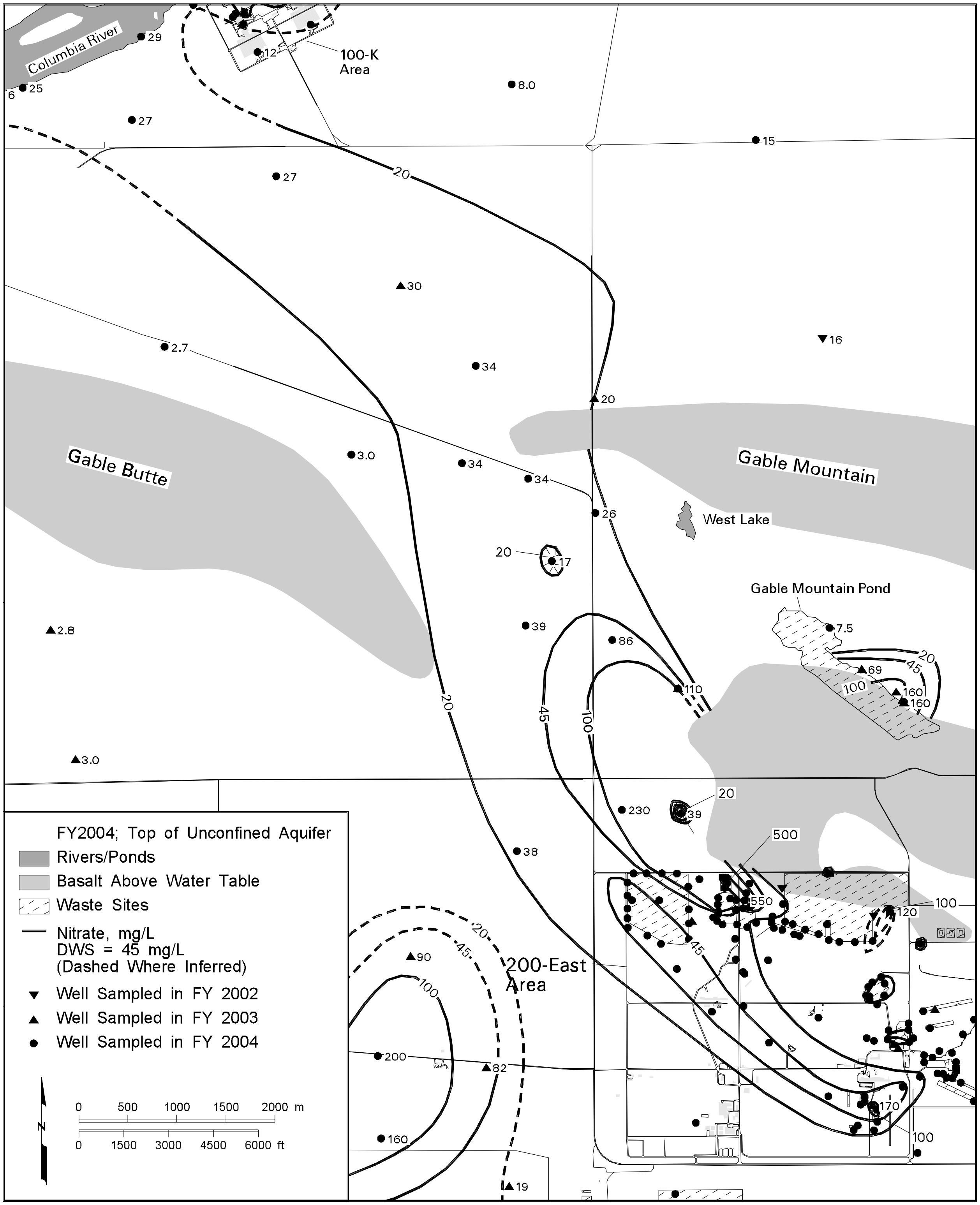

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Figure 2.10-5. Average Nitrate Concentrations in the 200-BP-5 Operable Unit and Vicinity, Top of Unconfined Aquifer

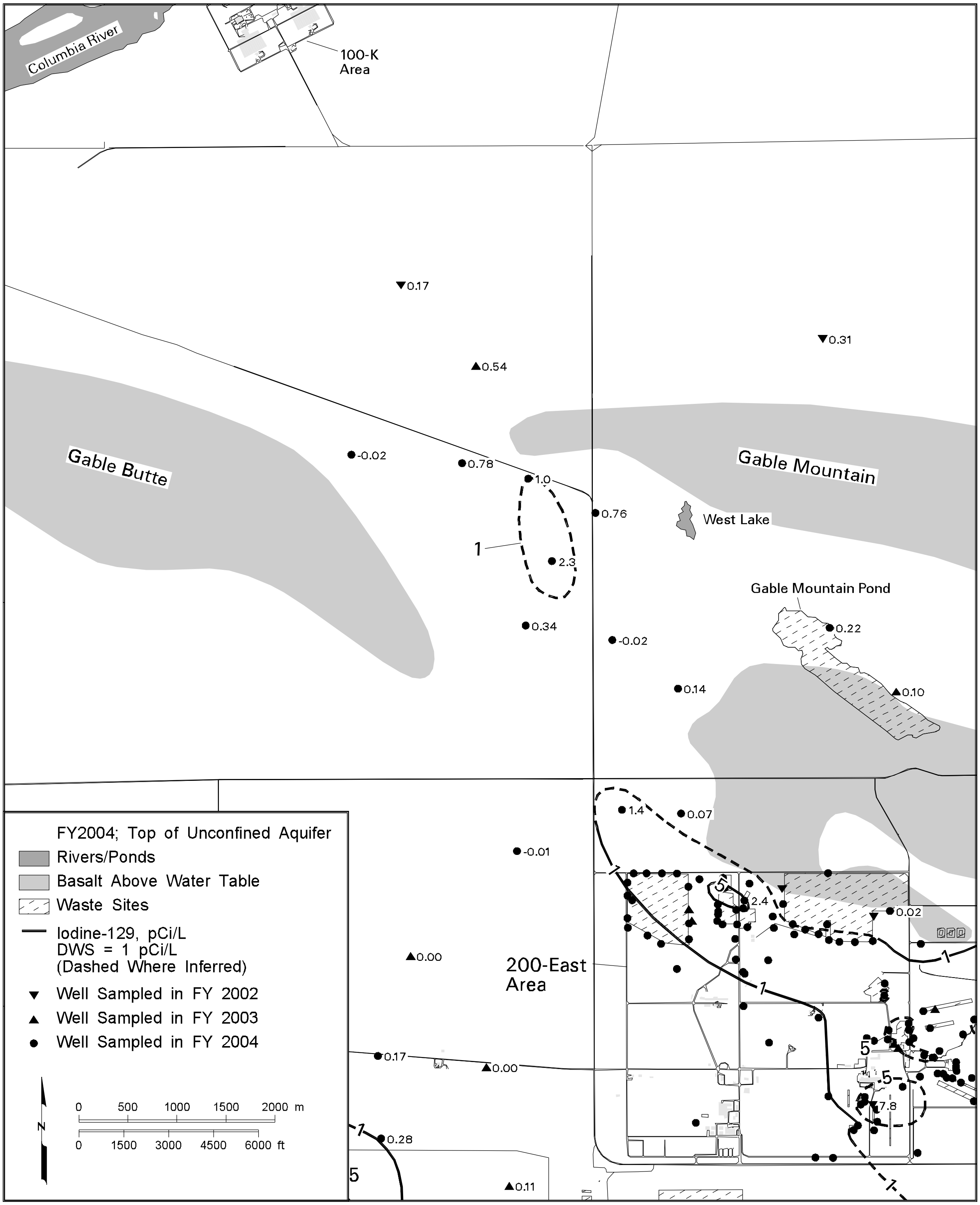

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Figure 2.10-6. Average Iodine-129 Concentrations in the 200-BP-5 Operable Unit and Vicinity, Top of Unconfined Aquifer

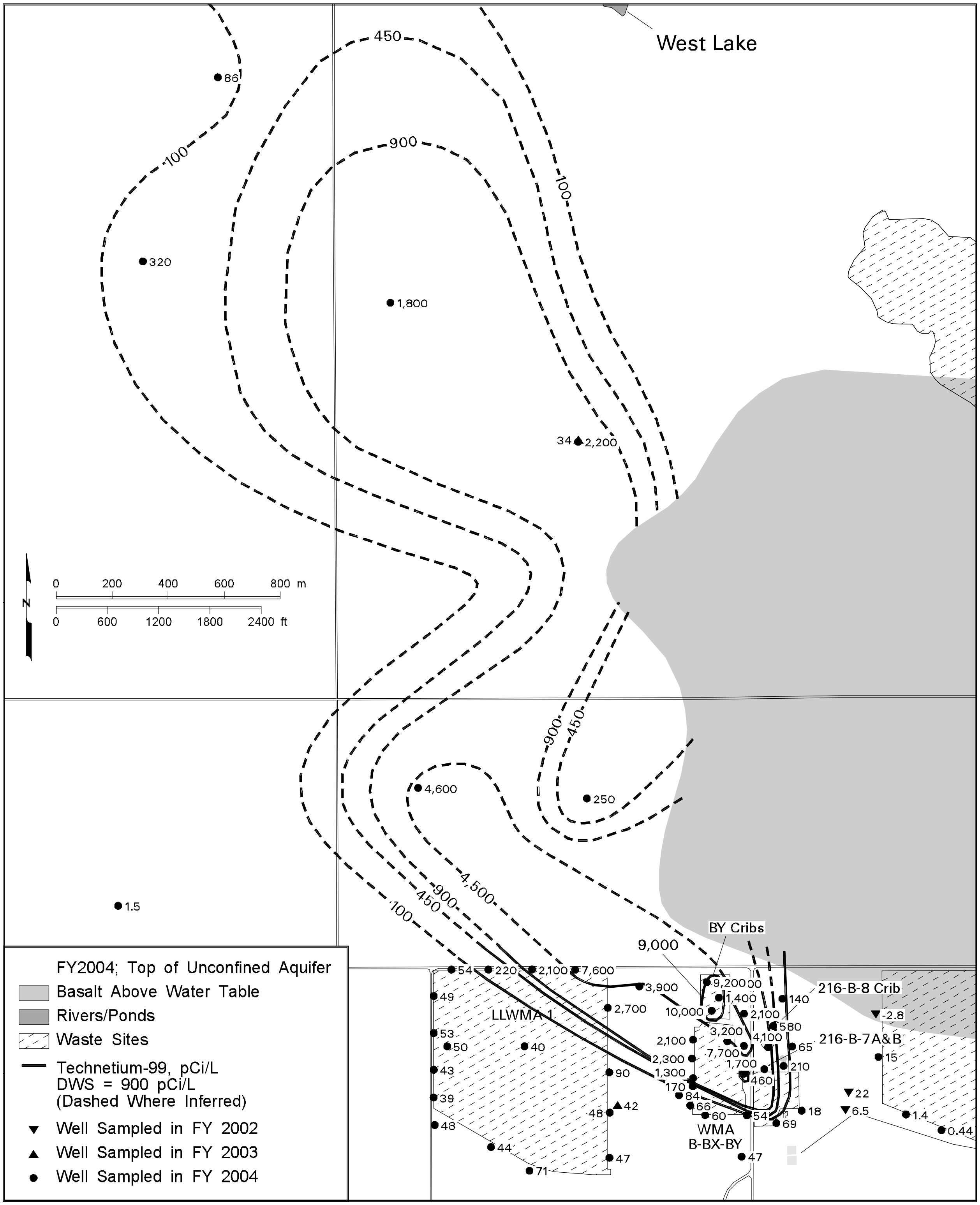

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Figure 2.10-7. Average Technetium-99 Concentrations in the North 200 East Area, Top of Unconfined Aquifer

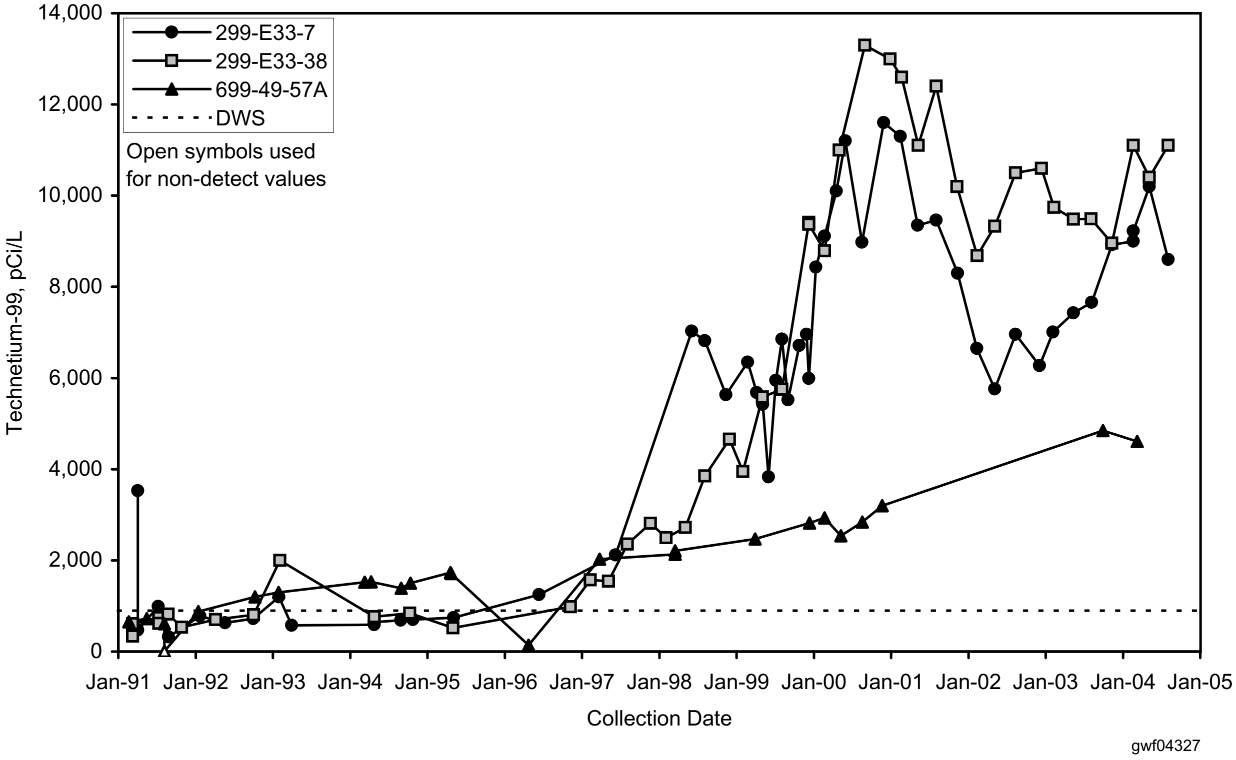

Figure 2.10-8. Technetium-99 Concentrations in Wells 299-E33-7 and 299-E33-38 at the BY Cribs and Well 699-49-57A North of 200 East Area

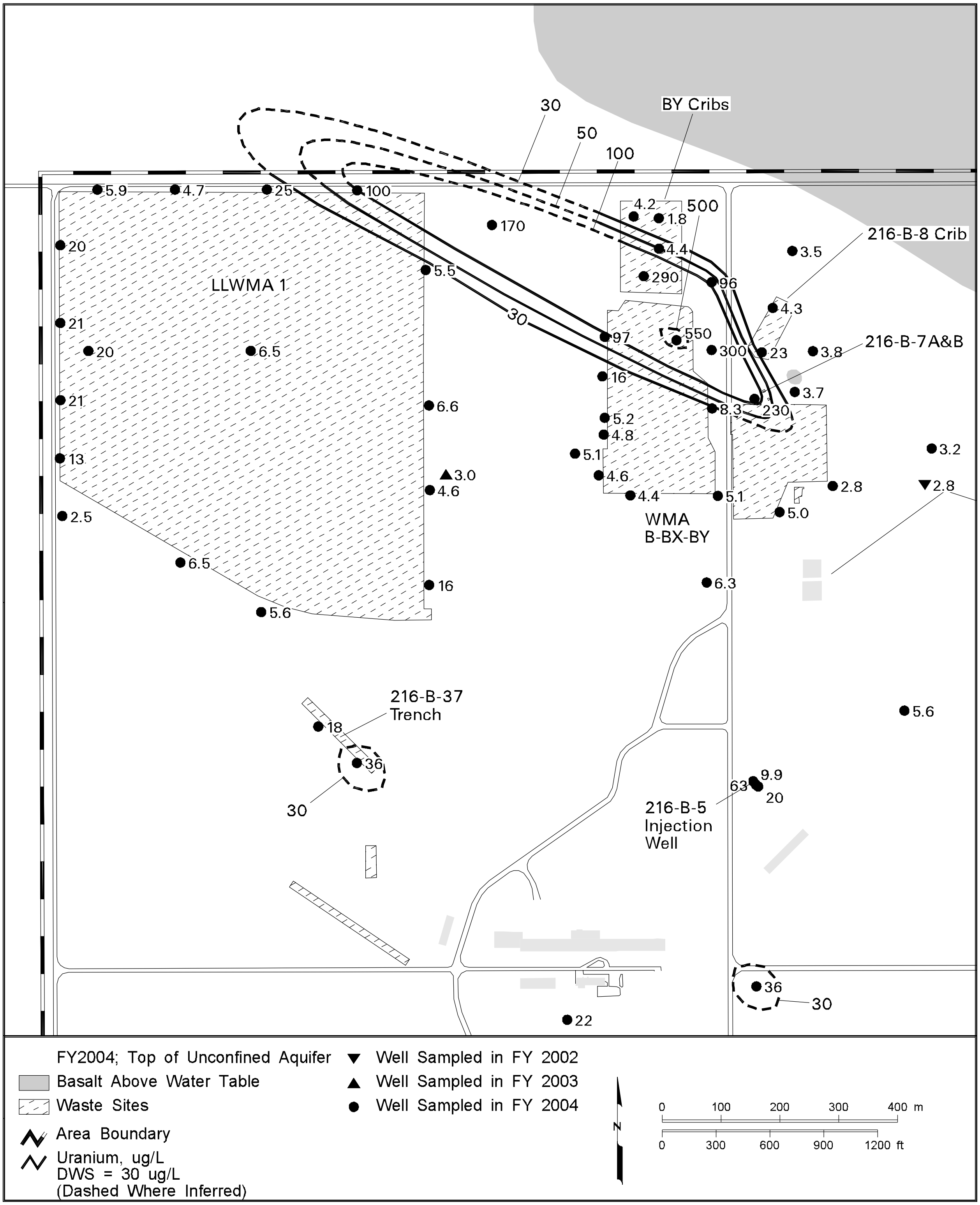

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Figure 2.10-9. Average Uranium Concentrations in the Vicinity of BY Cribs, Top of Unconfined Aquifer

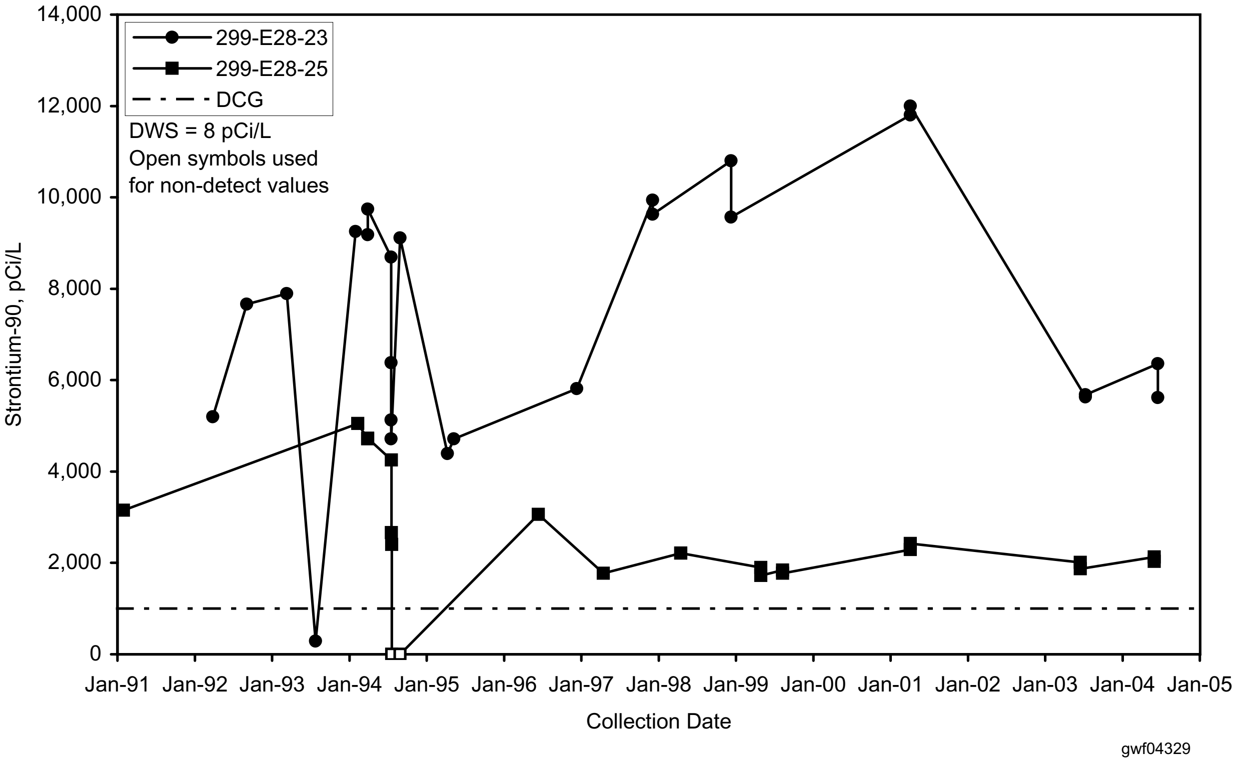


Figure 2.10-10. Strontium-90 Concentrations in Wells 299-E28-23 and 299-E28-25 at the 216-B-5 Injection Well Site, Top of Unconfined Aquifer

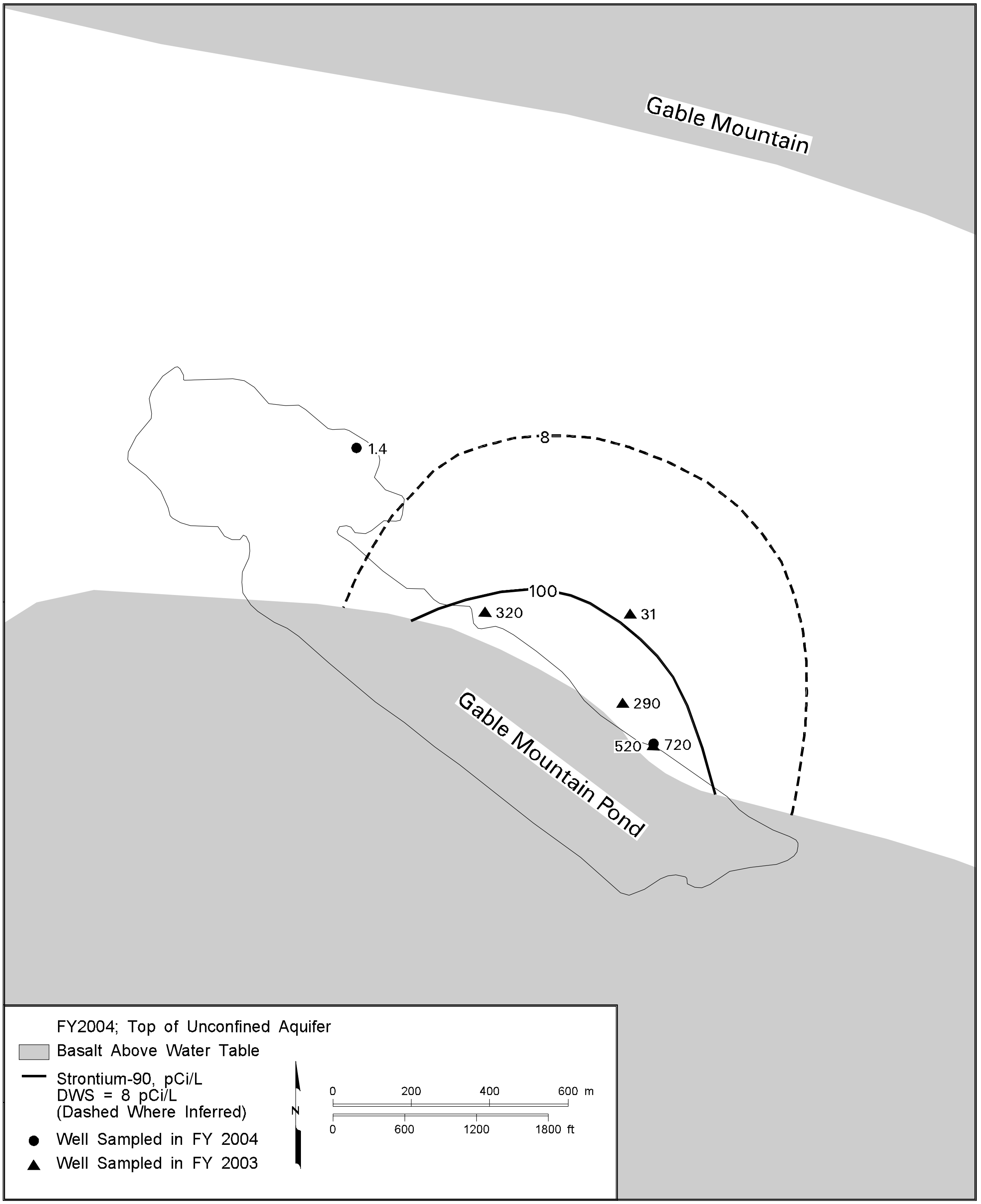


Figure 2.10-11. Strontium-90 Concentrations at Gable Mountain Pond, Top of Unconfined Aquifer

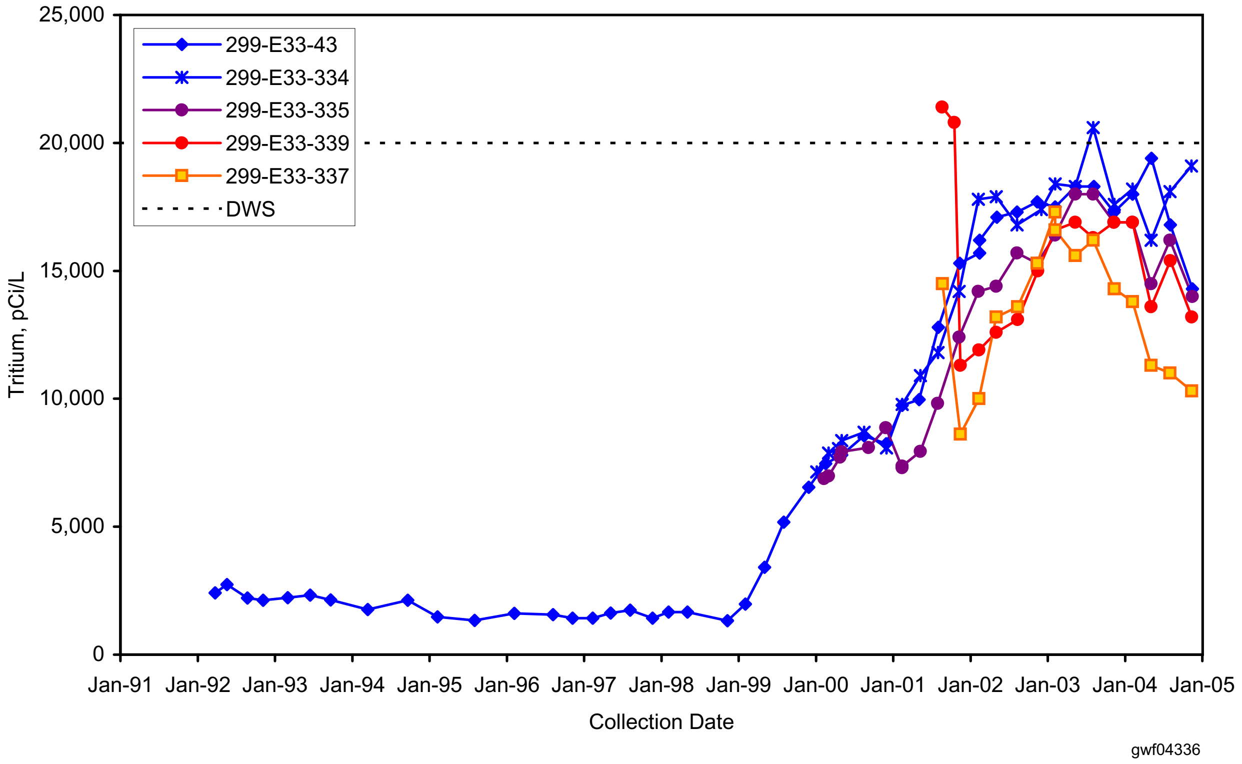


Figure 2.10-12. Trend Plots of Tritium at Waste Management Area B-BX-BY

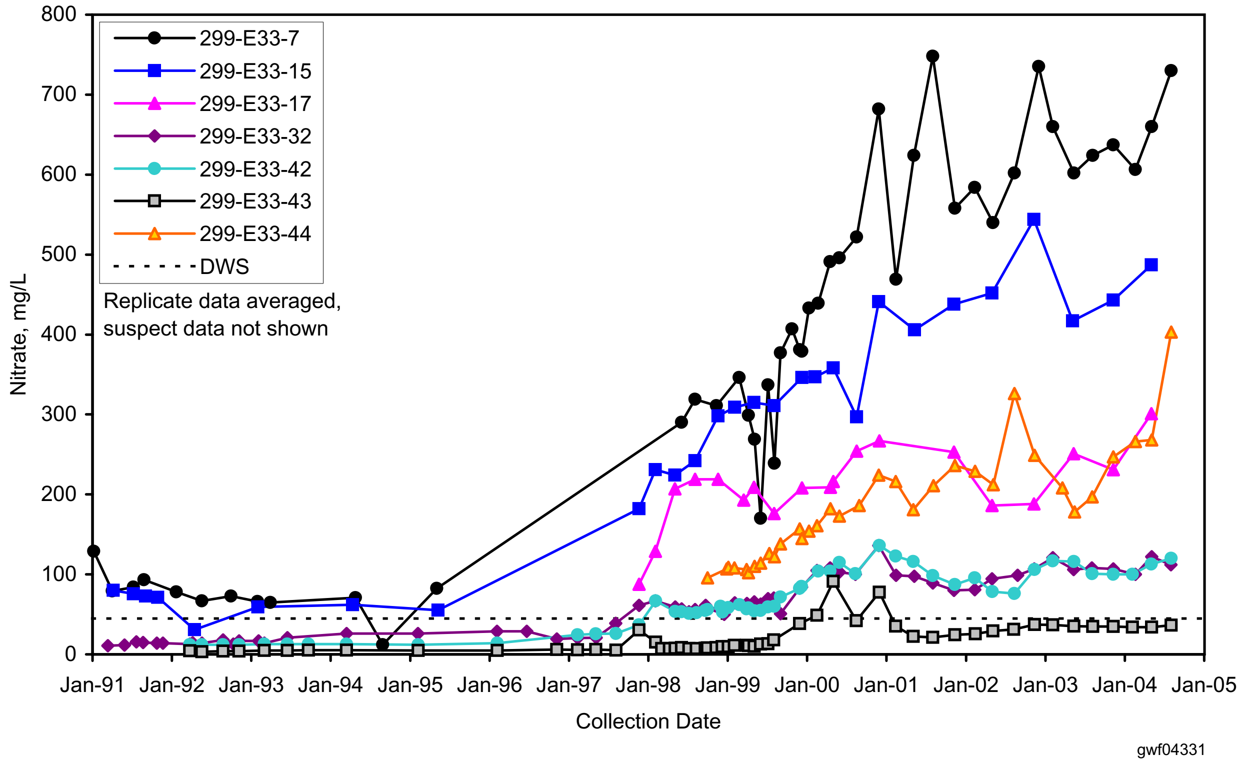


Figure 2.10-13. Trend Plots of Nitrate Concentrations at Waste Management Area B-BX-BY

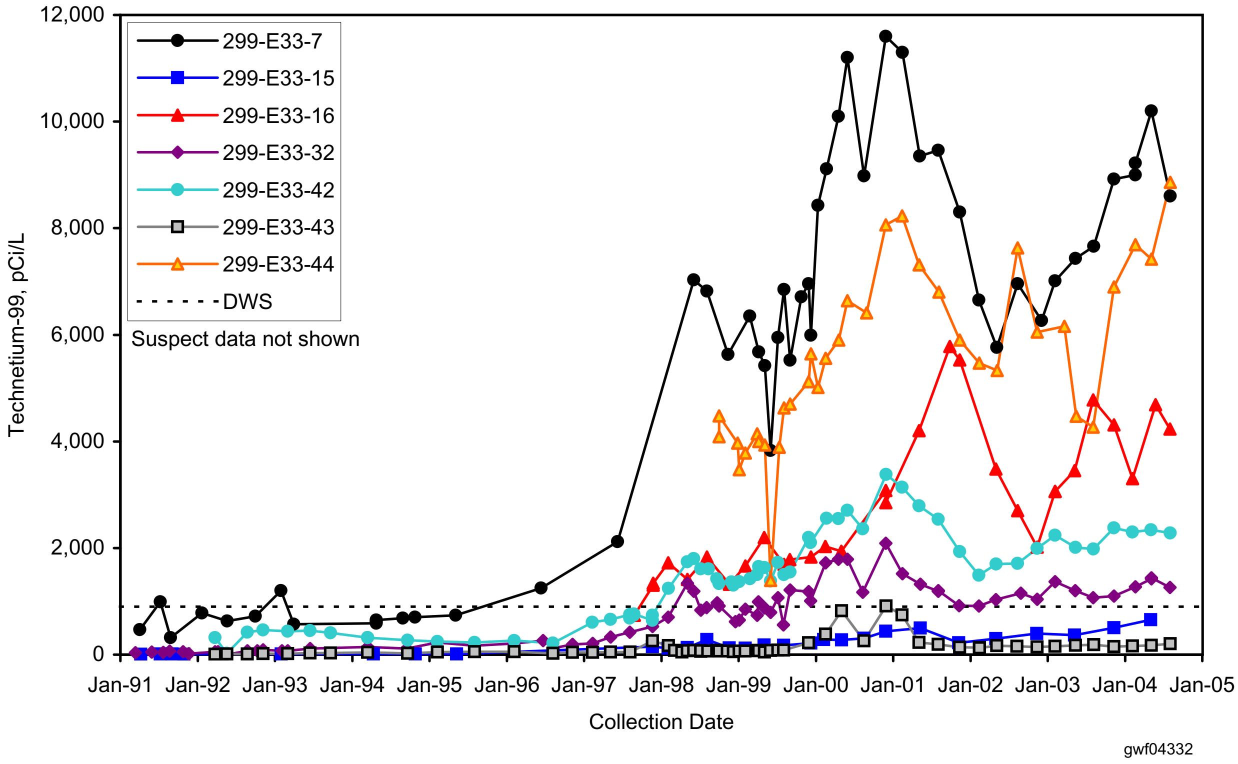


Figure 2.10-14. Trend Plots of Technetium-99 Concentrations at Waste Management Area B-BX-BY

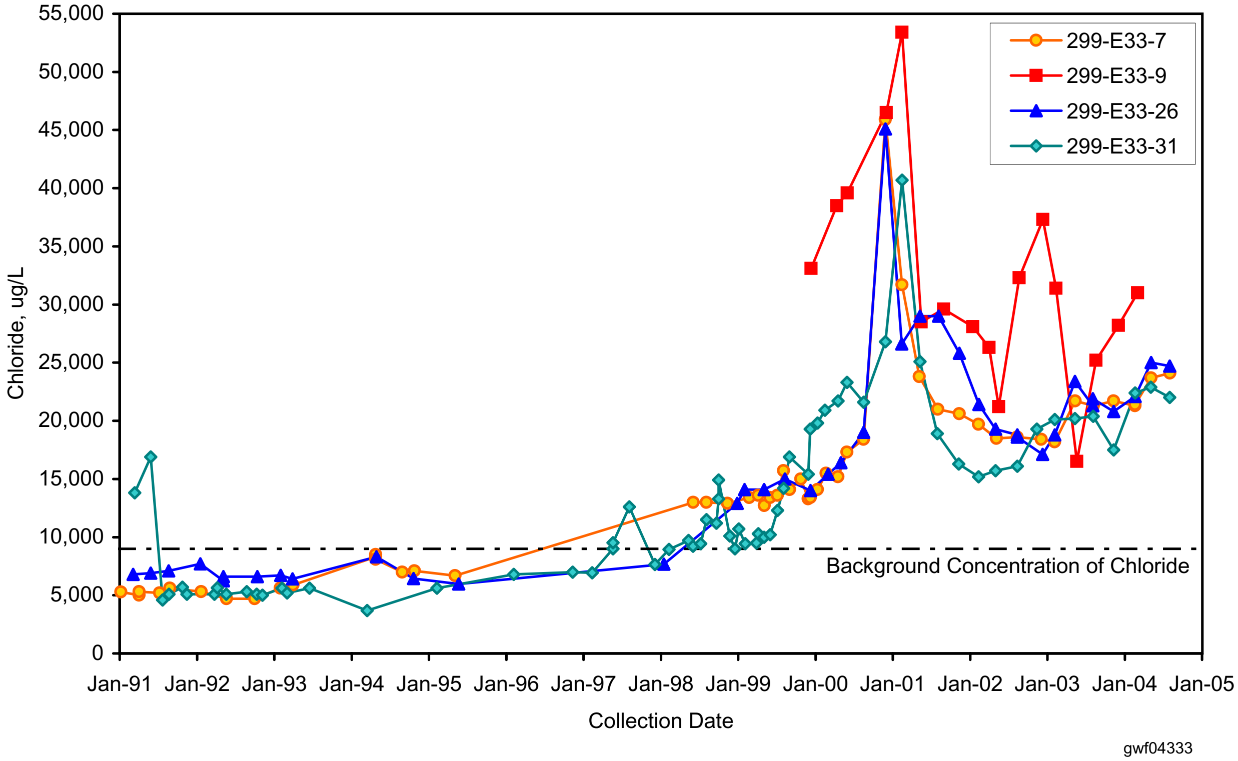


Figure 2.10-15. Trend Plots of Chloride at Waste Management Area B-BX-BY

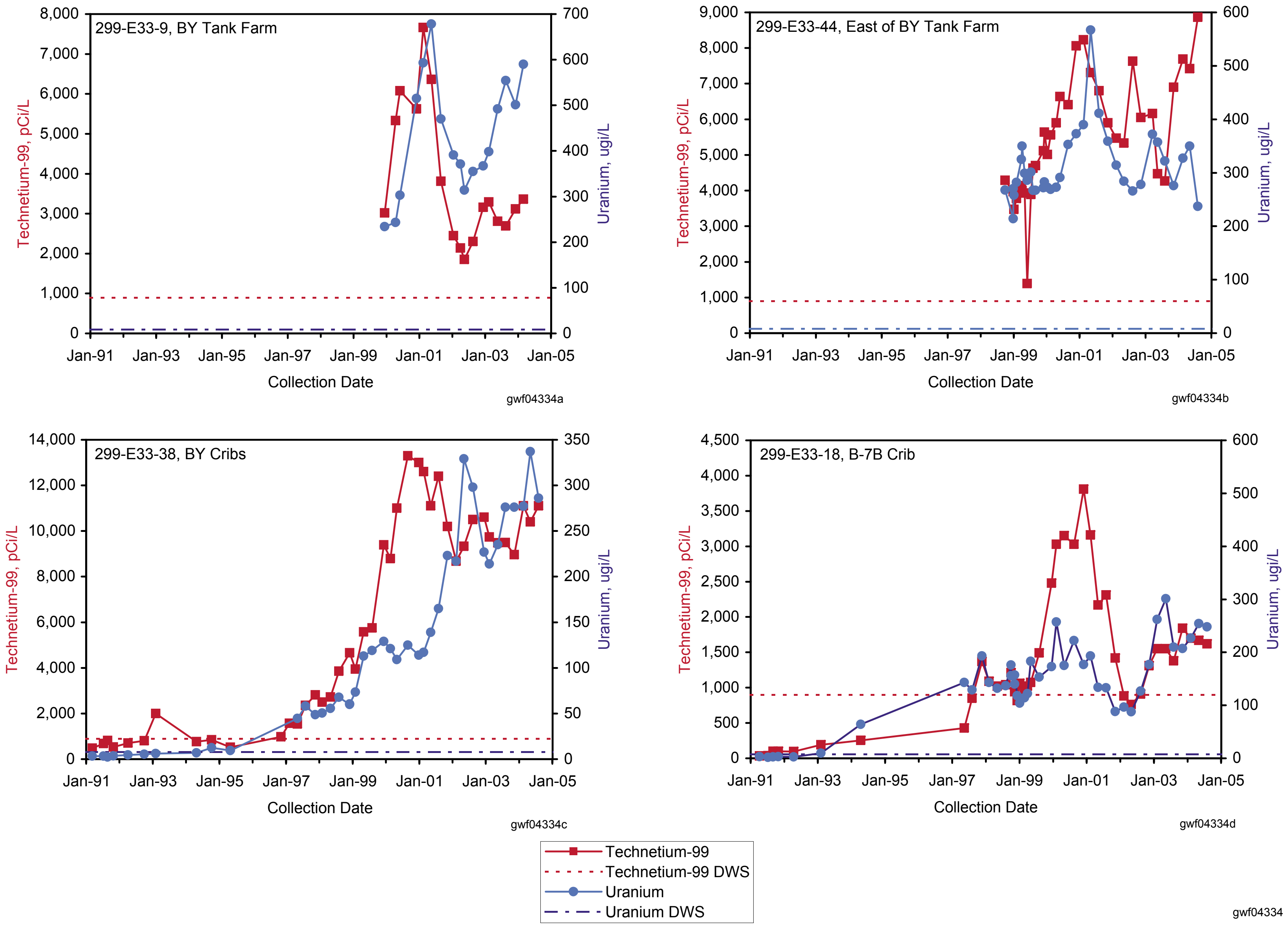


Figure 2.10-16. Trend Plots of Technetium-99 versus Uranium for Waste Management Area B-BX-BY

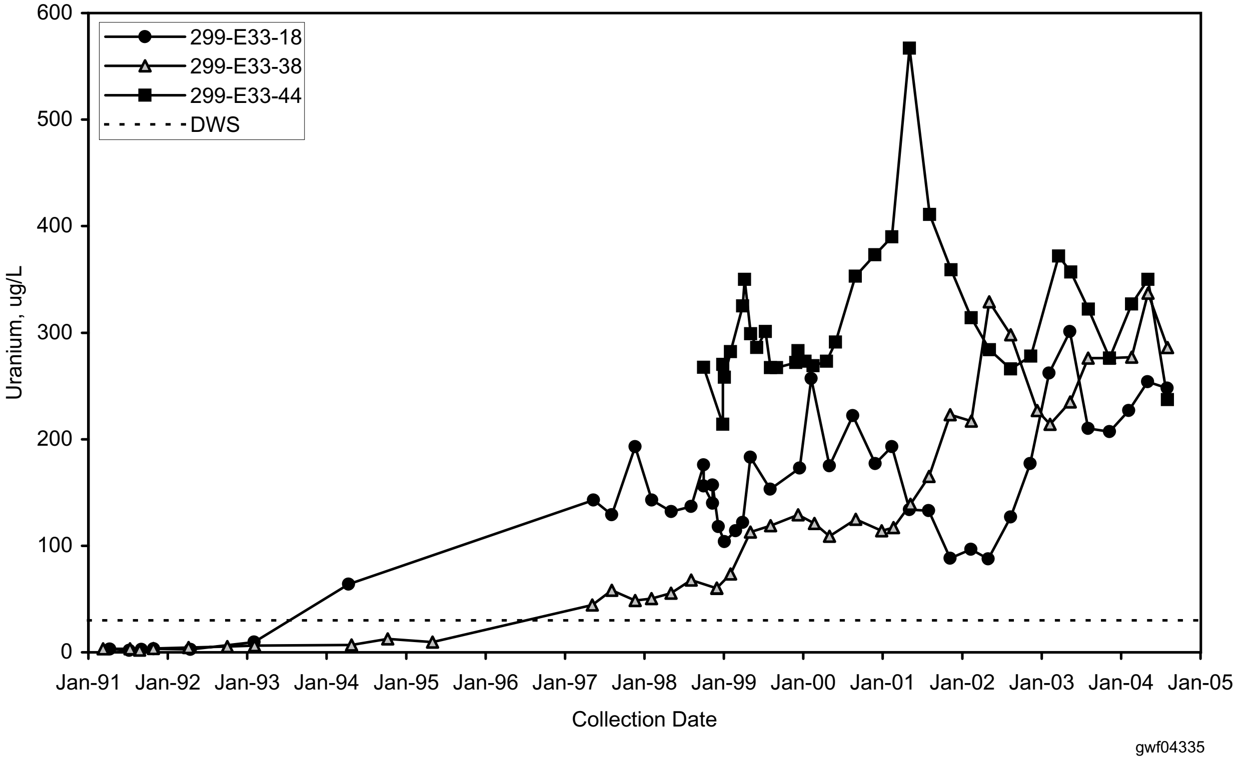


Figure 2.10-17. Trend Plots of Uranium at Waste Management Area B-BX-BY

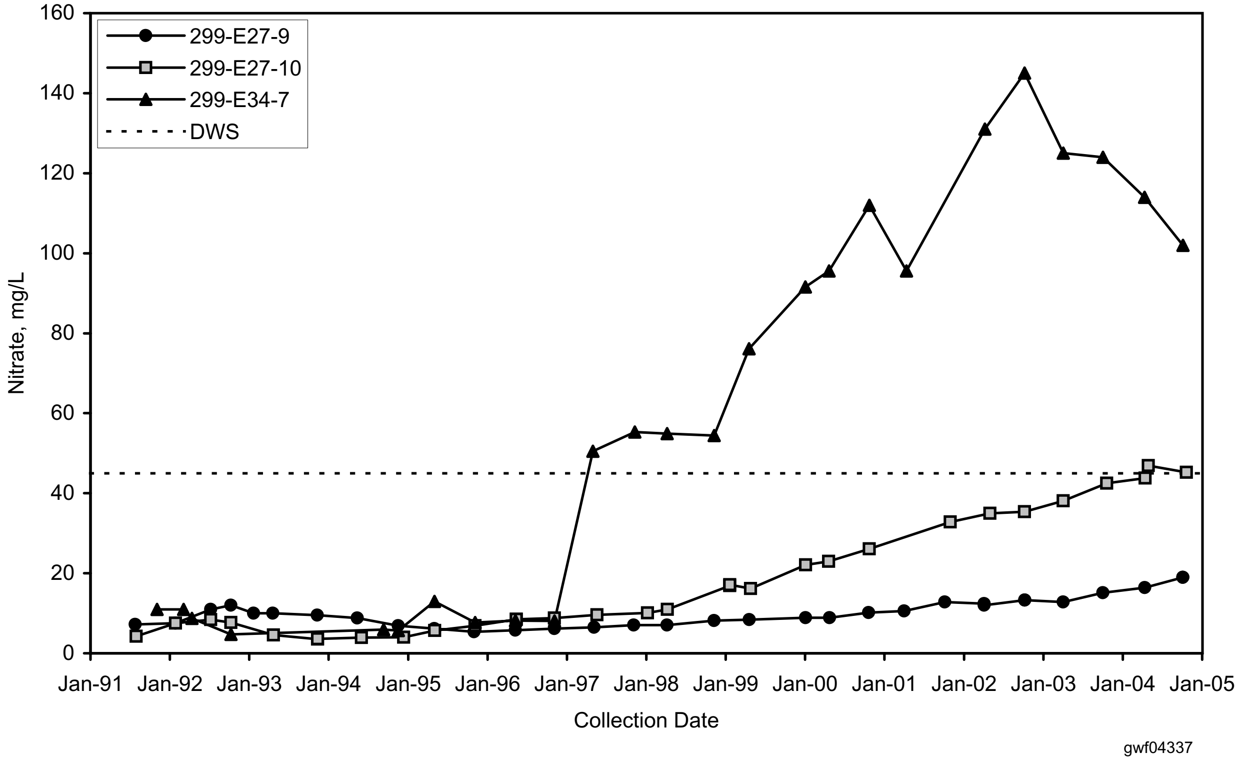


Figure 2.10-18. Nitrate Concentrations in Low-Level Waste Management Area 2 Wells 299-E34-7, 299-E27-10, and 299-E27-9

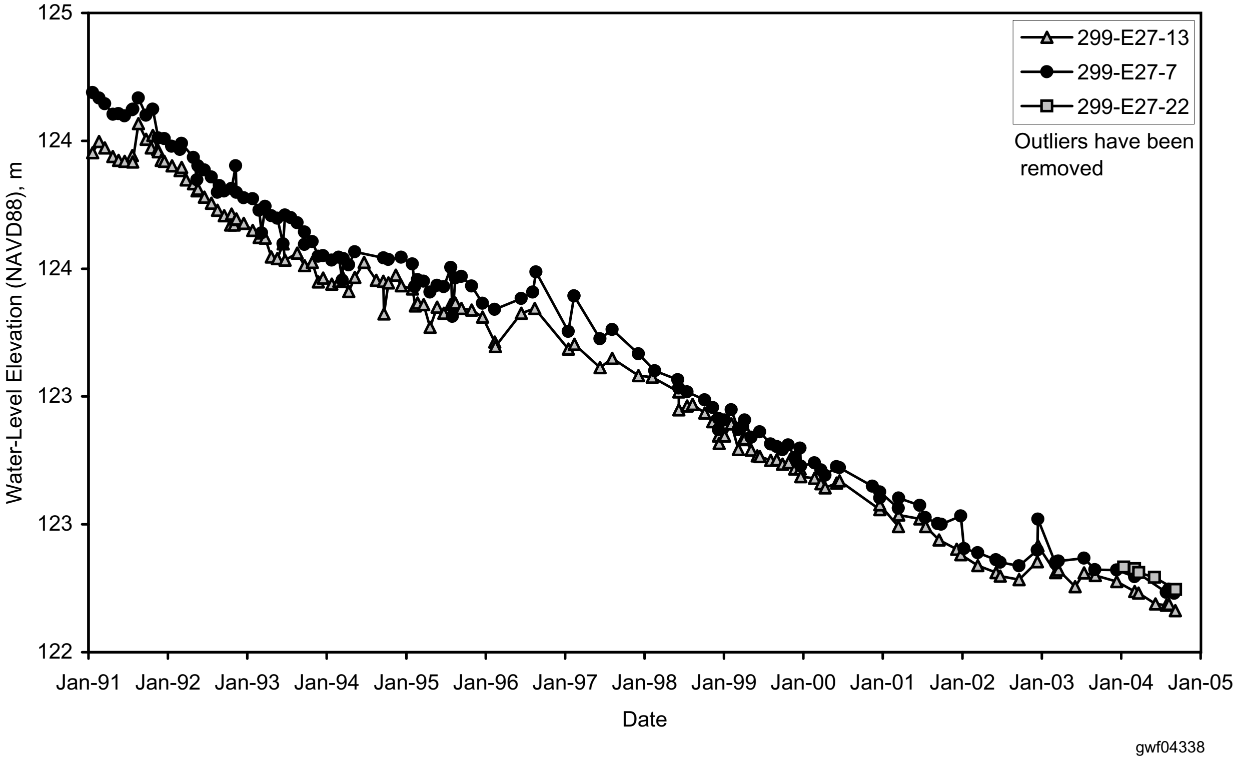


Figure 2.10-19. Hydrographs Comparing Water Levels from Upgradient Wells 299-E27-22 and 299-E27-7 to Downgradient Well 299-E27-13 at Waste Management Area C

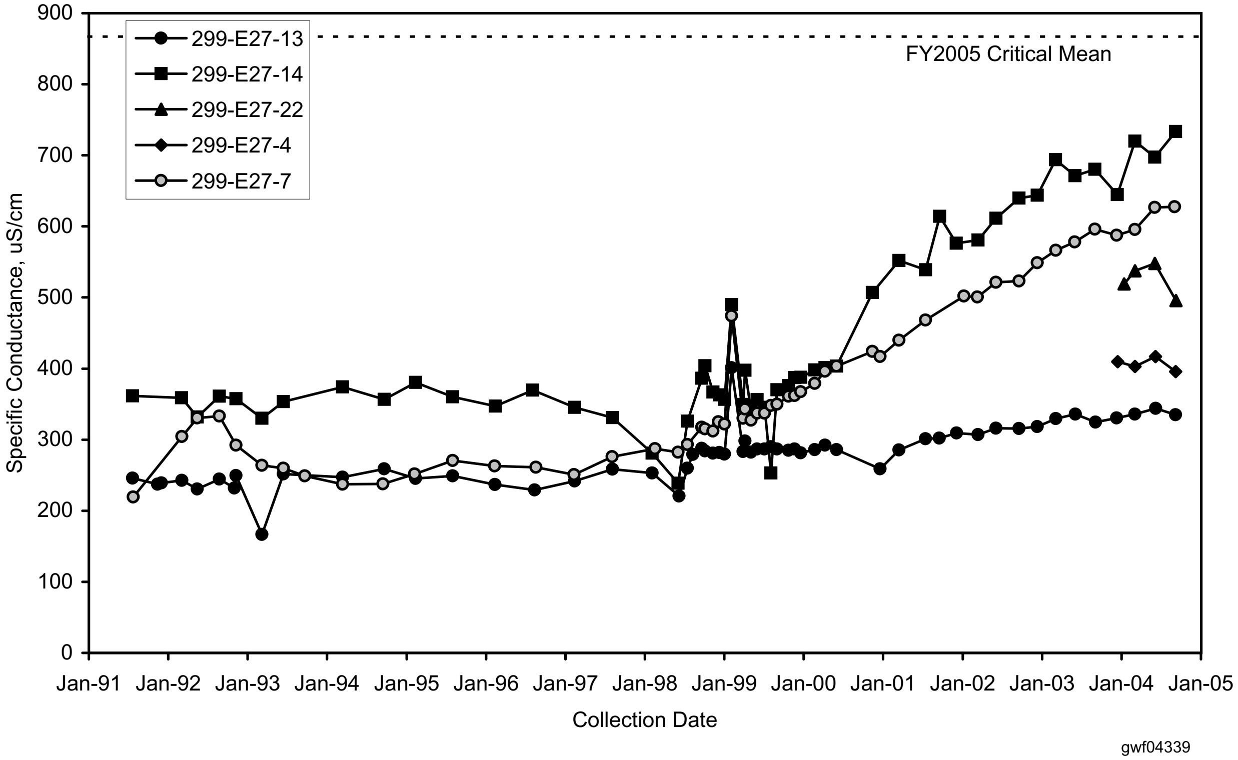


Figure 2.10-20. Specific Conductance Trends in the Groundwater at Waste Management Area C

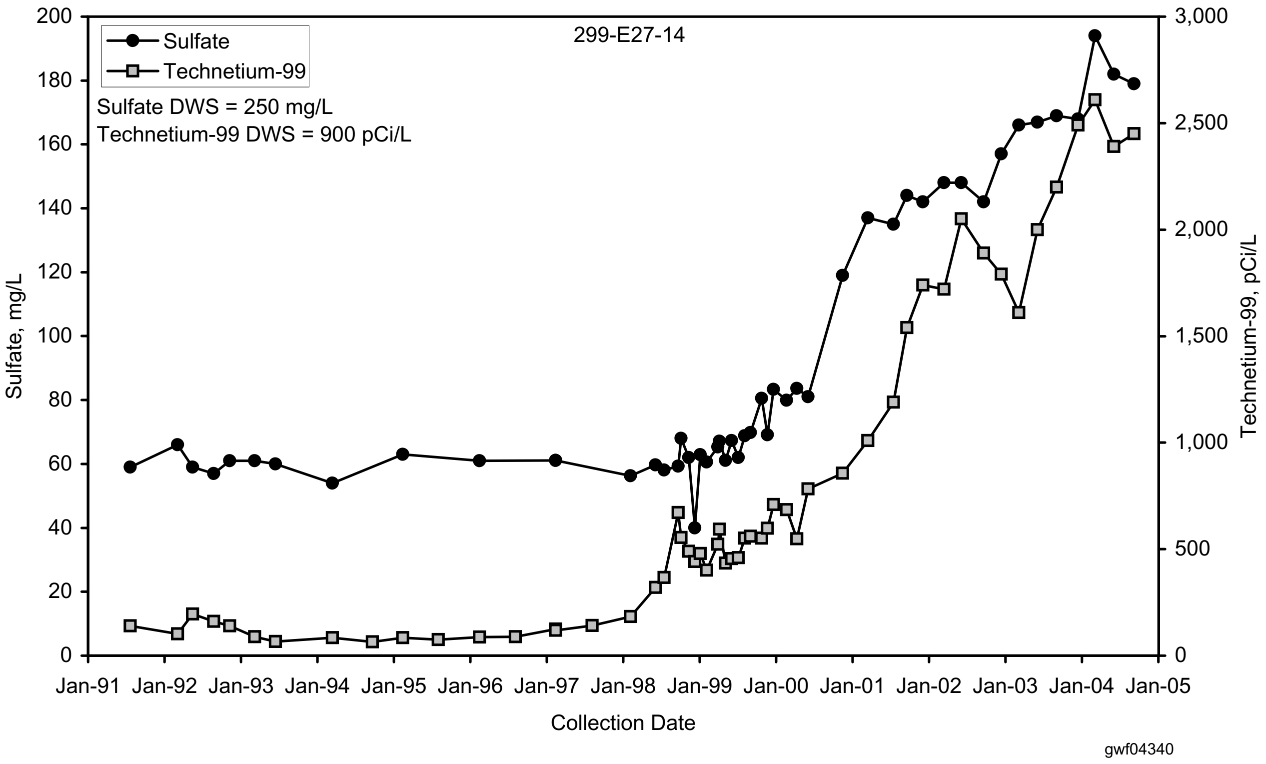


Figure 2.10-21. A Comparison of the Sulfate Trend to the Technetium-99 Trend in Downgradient Well 299-E27-14 at Waste Management Area C

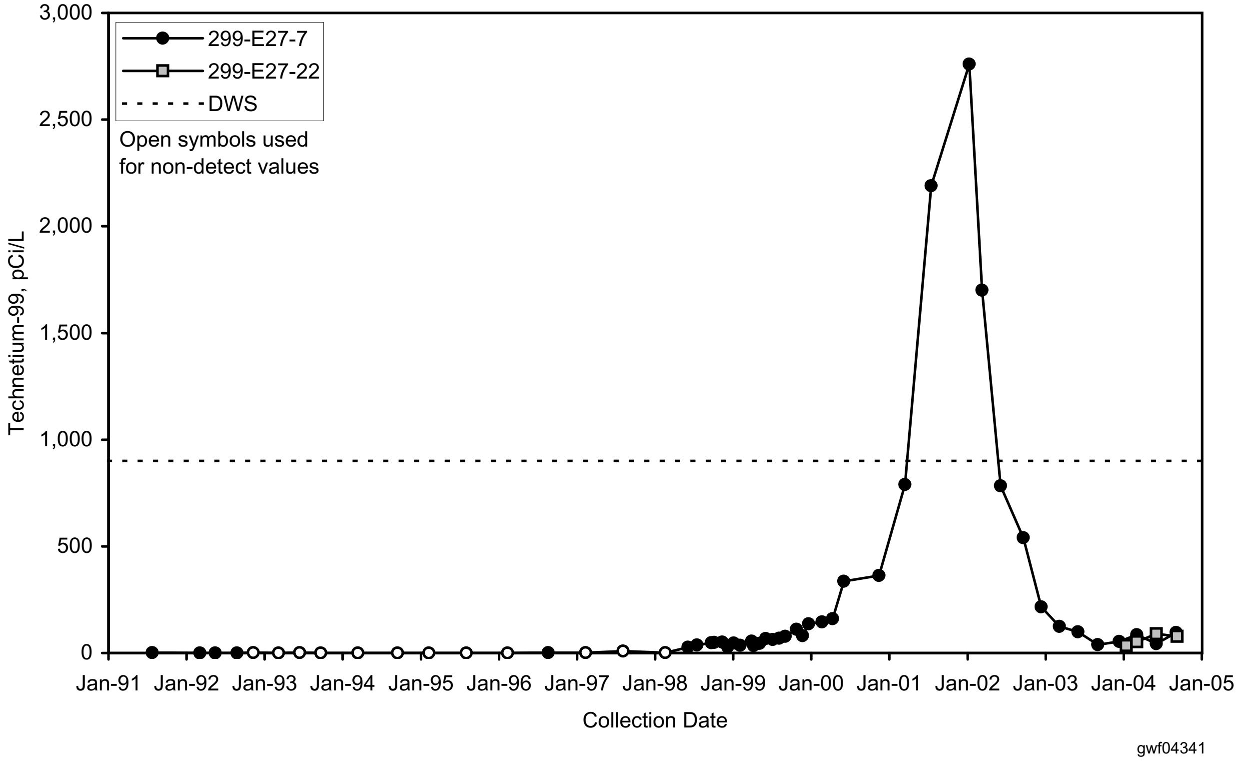


Figure 2.10-22. Technetium-99 Concentrations for Upgradient Wells 299-E27-7 and 299-E27-22 at Waste Management Area C

2.11 200-PO-1 Operable Unit

J. W. Lindberg, S. M. Narbutovskih, M. D. Sweeney, D. B. Barnett, D. G. Horton, and E. C. Thornton

The scope of this section is the 200-PO-1 groundwater interest area, which includes the 200-PO-1 Operable Unit (see Figure 2.1-1 in Section 2.1). This area encompasses the south portion of the 200 East Area and a large triangle-shaped portion of the Hanford Site extending to the Hanford town site to the east and the 300-FF-5 groundwater interest area to the southeast. The 216-B-3 pond (B Pond) straddles two operable units but is considered part of the 200-PO-1 interest area. The Groundwater Performance Assessment Project (groundwater project) established the interest areas to aid in planning, scheduling, and interpretation. Figure 2.11-1 shows facilities and near-field wells. Figure 2.1-2 in Section 2.1 shows the locations of 600 Area wells including 200-PO-1 Operable Unit far-field well and shoreline monitoring sites in this region. Tritium, nitrate, and iodine-129 are the contaminants of greatest significance in groundwater. Other contaminants of concern include arsenic, chromium, cyanide, manganese, strontium-90, technetium-99, and vanadium.

Tritium, nitrate, and iodine-129 are the contaminants of greatest significance in this operable unit.

The primary monitoring objective is to meet the groundwater monitoring requirements for the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), *Resource Conservation and Recovery Act* (RCRA), Washington Administrative Code (WAC), and the *Atomic Energy Act of 1954* (AEA) as directed in U.S. Department of Energy (DOE) Orders. The long-term goal for CERCLA is to monitor the contaminants of concern until final cleanup decisions are made. Included within the operable unit are six RCRA units

Groundwater monitoring in the 200-PO-1 groundwater interest area includes the following monitoring activities:

CERCLA Monitoring

- *One-hundred-twenty wells (79 far-field and 41 near-field wells) are sampled annually to triennially for tritium, nitrate, and iodine-129 plus other constituents depending on location. The 79 far-field wells are also the far-field wells of the RCRA PUREX cribs site.*
- *In FY 2004, 16 of the 120 wells were not sampled as scheduled (see Section 2.11.2 and Appendix A for details).*

Facility Monitoring

- *Groundwater monitoring of the eight wells at the Integrated Disposal Facility has not started. Construction of the facility began in September 2004.*
- *Eleven near-field wells are sampled quarterly to triennially at the RCRA PUREX cribs facility for RCRA and AEA monitoring.*
- *Seven wells at the single-shell tank Waste Management Area A-AX are monitored semiannually for RCRA and AEA monitoring. Two wells were decommissioned after problems with corrosion.*
- *Nine wells are sampled semiannually at the 216-A-29 ditch for RCRA monitoring.*
- *Four wells are sampled semiannually sampling at the 216-B-3 pond (B Pond) for RCRA and AEA monitoring.*
- *Three wells are sampled quarterly at the 200 Area Treated Effluent Disposal Facility under a Washington State waste discharge permit (WAC 173-216).*
- *Nine wells are sampled semiannually at the Nonradioactive Dangerous Waste Landfill for RCRA and AEA monitoring.*
- *Ten wells at the Solid Waste Landfill are sampled quarterly under a Washington State solid waste landfill permit (WAC 173-304). One of the downgradient wells went dry in FY 2003.*
- *Three water supply wells at the 400 Area are sampled quarterly to annually for AEA.*

including the Plutonium-Uranium Extraction (PUREX) cribs (called the RCRA PUREX cribs), Waste Management Area A-AX (single-shell tanks), 216-A-29 ditch, Integrated Disposal Facility, B Pond, and the Nonradioactive Dangerous Waste Landfill. Two other facilities that are not regulated under RCRA but are subject to WAC requirements are the 200 Area Treated Effluent Disposal Facility and the Solid Waste Landfill.

Groundwater in the 200-PO-1 Operable Unit flows to the southeast and east.

Groundwater in the unconfined aquifer generally flows southeastward in the west portion of the operable unit and northeastward, eastward, and southeastward in the east portions of the operable unit as groundwater approaches the Columbia River (see Figure 2.1-3 in Section 2.1). A detailed discussion of 200 East Area hydrogeology can be found in PNNL-12261. Further discussions of more local groundwater flow characteristics are found in Section 2.11.3.

The remainder of this section describes contaminant plumes and concentration trends for the contaminants of concern under CERCLA, RCRA, AEA, and WAC monitoring.

2.11.1 Groundwater Contaminants

This section describes the major contaminants of concern within the 200-PO-1 Operable Unit. They include tritium, nitrate, iodine-129, technetium-99, strontium-90, arsenic, chromium, cyanide, manganese, and vanadium. Greater details at various RCRA or WAC facilities are discussed in Section 2.11.3.

2.11.1.1 Tritium

The source for the large tritium plume that extends from the southeast portion of the 200 East Area to the Columbia River (see Figure 2.1-5 in Section 2.1) is in the vicinity of the PUREX cribs.[a] The highest concentrations of tritium (drinking water standard 20,000 pCi/L) in this plume remain near these cribs. The highest level recorded during fiscal year (FY) 2003 was 5.57 million pCi/L at well 299-E17-9 at the north end of crib 216-A-36B for a sample collected in October 2002. This well went dry after that sampling event and was replaced by existing well 299-E17-16, which had a reported level of 231,000 pCi/L for a sample collected in April 2003 and 223,000 pCi/L for a sampled collected October 2003. The highest reported level of tritium during FY 2004 was 616,000 pCi/L for a sample collected January 2004 at well 299-E17-14 (also at the 216-A-36B crib). Thus, the current groundwater monitoring network may not reflect the highest concentration of tritium in the plume.

Concentrations of tritium continue to decline as the plume is attenuating naturally.

Concentrations of tritium continue to decline as the plume is attenuating naturally due to radioactive decay and dispersion combined with the general decreasing source that resulted from the termination of PUREX Plant operations. Wells in the east portion of the 200-PO-1 Operable Unit have tritium concentrations above 80,000 pCi/L (see Figure 2.1-5 in Section 2.1) from an early period of discharge to the PUREX cribs (PNNL-11141). These wells are expected to continue to experience decreasing concentrations as pulses representing the two periods of PUREX Plant operations move beyond the wells into the river. These wells more distant from the source are sampled once ever three years and most were sampled during FY 2004. Generally, wells near the PUREX cribs show a steady to decreasing trend as demonstrated in the trend plot for well 299-E17-14 (Figure 2.11-2).

The zone of lower tritium concentration near Energy Northwest (see Figure 2.1-5 in Section 2.1) may be due to a zone of lower hydraulic conductivity in the unconfined aquifer. At that site, the water table is within the upper portion of the Ringold Formation that locally may have a greater degree of cementation. Tritium at the 618-11 burial grounds located just west of Energy Northwest is discussed in Section 2.12.1.6.

(a) The term "PUREX cribs" refers to all the cribs in the southeast part of the 200 Area and east of the 200 East Area where PUREX wastewater was discharged. Three of these cribs are monitored under RCRA and are termed RCRA PUREX cribs (see Section 2.11.3.2).

Tritium was also detected in the lower portions of the unconfined aquifer, the lower Ringold Formation confined aquifer, and a basalt-confined aquifer. This information was derived from 13 wells screened in the lower portions of the unconfined aquifer (lower Ringold Formation unconfined aquifer), 8 wells in confined aquifers in the lower Ringold Formation, and 5 basalt-confined aquifer wells. (Note: These 26 wells are the only wells providing information on the deep subsurface. The potential for deep aquifer contamination outside of the areas of these 26 wells is unknown.) Locations where tritium was detected in the lower unconfined aquifer include near the Hanford town site, B Pond, 216-A-29 ditch, 400 Area water-supply wells, 200 Area Treated Effluent Disposal Facility, 618-11 burial ground, and the general area immediately southeast of the 200 East Area. Exceedances of the drinking water standard (20,000 pCi/L) were found in the lower portions of the unconfined aquifer at B Pond (21,300 pCi/L) and the Hanford town site (82,000 pCi/L), and in the Ringold confined aquifer only at B Pond (47,500 pCi/L). The only deep basalt well where tritium was found in significant levels was well 699-42-40C at B Pond (5,080 pCi/L).

2.11.1.2 Iodine-129

The iodine-129 plume (see Figure 2.1-7 in Section 2.1) extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes (see Figures 2.1-5 and 2.1-6 in Section 2.1). There is very little difference between this year's map and the corresponding map in last year's groundwater annual report (PNNL-14548, Figure 2.1-7). Although the iodine-129 plume is dispersing, it is doing so at a very slow rate.

The iodine-129 plume is dispersing, but at a very slow rate.

The highest iodine-129 concentrations (drinking water standard 1.0 pCi/L) detected in the 200 East Area in FY 2004 were near the PUREX cribs and Waste Management Areas A-AX and C (see Figure 2.1-7 in Section 2.1). The maximum concentration of iodine-129 detected in FY 2004 was 10.2 pCi/L at well 299-E17-14 near the 216-A-36B crib. Concentrations of iodine-129 in groundwater near the PUREX cribs are generally declining slowly or are stable, as shown for wells 299-E17-1 (Figure 2.11-3) and well 299-E17-14 (Figure 2.11-4). Concentrations of iodine-129 in wells near the Columbia River on the east side of the 200-PO-1 Operable Unit continue to be less than 1.0 pCi/L (not detectable).

Iodine-129 was detected in the lower portions (or base) of the Ringold Formation unconfined aquifer near the 216-A-29 ditch and B Pond. In both of these areas, the concentrations exceeded the drinking water standard (1.0 pCi/L) with the highest reported occurrence near the 216-A-29 ditch (5.0 pCi/L). Iodine-129 was not detected during FY 2004 in the eight wells screened in the Ringold Formation confined aquifer.

2.11.1.3 Nitrate

The extent of the nitrate plume that originates from the 200 East Area (see Figure 2.1-6 in Section 2.1) is nearly identical to the tritium plume. However, the area with nitrate concentration above the drinking water standard (>45 mg/L) is more restricted than the area with tritium above its drinking water standard of 20,000 pCi/L. Nitrate at levels above the drinking water standard north of the 400 Area and at Energy Northwest, within the area impacted by the PUREX cribs, can be attributed to wastewater disposal or activities in those areas. The nitrate plume (see Figure 2.1-6 in Section 2.1) appears to have receded slightly over previous years throughout most of its extent except for the south-most portions of the plume near the 300 Area (Section 2.12.1.5) and in the immediate vicinity of the PUREX cribs (PNNL-14187; PNNL-14548).

The nitrate plume appears to have receded slightly over previous years throughout most of its extent.

Near two PUREX cribs (216-A-10 and 216-A-36B), the wells generally showed an increase in nitrate concentration during FY 2004. Furthermore, the highest concentrations of nitrate in the 200-PO-1 Operable Unit during FY 2004 occurred near these two cribs. The maximum nitrate concentration observed was 132 mg/L at well 299-E17-14 at the 216-A-36B crib during July 2004. The general increase in nitrate concentration extends northwestward near an upgradient well (299-E24-18) for the 216-A-10 and 216-A-36B cribs (Figure 2.11-5). Because well 299-E24-18 showed increased concentrations of nitrate, it is not clear whether there are other localized sources of nitrate or there are some local irregularities in groundwater flow direction that are not fully understood.

Nitrate was detected in the lower portions (or base) of the Ringold Formation unconfined aquifer near the Hanford town site, 216-A-29 ditch, Nonradioactive Dangerous Waste Landfill, B Pond, PUREX cribs, 200 Area Treated Effluent Disposal Facility, and the 400 Area water supply wells. The highest detected level was 9 mg/L at the Hanford town site. Nitrate was also detected in the lower Ringold Formation confined aquifer at B Pond and the 618-11 burial ground. The highest detected level in the confined aquifer was 2.7 mg/L at B Pond. Nitrate did not exceed the 45-mg/L drinking water standard at any of the wells screened in the lower portions of the unconfined aquifer or Ringold Formation confined aquifer.

2.11.1.4 Strontium-90

There is a small plume of strontium-90 (a beta-emitter) at the 216-A-10 and 216-A-36B cribs. It is also detected at Waste Management Area A-AX and at the 216-A-37-1 crib. The only well with strontium-90 concentration above the drinking water standard (8 pCi/L) during FY 2004 was well 299-E17-14 with a maximum of 21 pCi/L. Well 299-E17-14 is near the 216-A-36B crib and shows an increasing trend from 1997 to 2001, and then no overall increase or decrease (Figure 2.11-6). The impact is localized because of the low mobility of strontium-90 compared to tritium, iodine-129, and nitrate. This result is consistent, in part, with a gross beta concentration of 64 pCi/L in the same well. The drinking water standard for gross beta is 50 pCi/L.

The newly installed well (299-E25-93) at Waste Management Area A-AX had technetium-99 levels ranging from 8,670 to 13,100 pCi/L during FY 2004.

2.11.1.5 Technetium-99

Technetium-99 is detected at Waste Management Area A-AX in concentrations well above the drinking water standard (900 pCi/L) and is detected indirectly at the PUREX cribs. Although most results at Waste Management Area A-AX were well below the drinking water standard, groundwater samples collected from well 299-E25-93 (a new well installed in late 2003) had technetium-99 concentrations ranging from 8,670 to 13,100 pCi/L during FY 2004. (For more information about technetium-99 at Waste Management Area A-AX, refer to Section 2.11.3.3.)

The result for gross beta (64 pCi/L) at well 299-E17-14 (at the 216-A-36B crib) is more than can be accounted for from the strontium-90 result (21 pCi/L) in the same well. If strontium-90 was the only beta-emitter present, gross beta would be ~42 pCi/L. Therefore, the 64 pCi/L result must include another beta-emitter. The higher result is most likely due to technetium-99, another beta-emitter. (The estimated technetium-99 would be ~66 pCi/L.) The last technetium-99 result from well 299-E17-14 was 209 pCi/L in FY 1994. Technetium-99 is no longer routinely analyzed in PUREX cribs well samples because previous results were significantly less than the drinking water standard (900 pCi/L), and gross beta analysis could be used as a screening tool for technetium-99 and other beta-emitters.

2.11.1.6 Other Constituents

Arsenic, chromium, manganese, cobalt-60, cyanide, and vanadium are also contaminants of concern at various facilities within the 200-PO-1 Operable Unit. Cobalt-60, cyanide, and vanadium are potential contaminants of concern at the BC cribs, and will be analyzed when the new sampling and analysis plan for the 200-PO-1 Operable Unit is implemented in FY 2005.

Filtered arsenic and chromium are routinely analyzed in samples of 200-PO-1 Operable Unit wells. Results show that filtered arsenic was detected (e.g., 3 to 9 µg/L) for PUREX cribs wells for FY 2004 but in concentrations similar to Hanford groundwater background values (DOE/RL-96-61). Filtered chromium continued to exceed the drinking water standard (100 µg/L) at wells near Waste Management Area A-AX (Section 2.11.3.3), but the elevated results are interpreted to be related to the corrosion of the stainless steel casing.

Plume areas (square kilometers) above the drinking water standard at the 200-PO-1 Operable Unit:

Chromium — 0.01
Iodine-129 — 65.79
Nitrate — 0.05
Strontium-90 — 0.01
**Tritium — 126.63*

**Includes portion of plume beneath 300-FF-5 Operable Unit.*

Filtered manganese was not detected above the secondary drinking water standard (50 µg/L) at the PUREX cribs or Waste Management Area A-AX as it has in past years. The trend for filtered manganese at these sites was erratic, supporting the suggestion that these spurious occurrences are possibly related to corrosion of the well casing or screen.

A plume of chromium flowing from the southwest toward the northeast is detected by wells southwest and within the BC cribs area (see Section 2.9.1). However, the most elevated concentration ever detected was 73.3 µg/L in May of 1998. During FY 2004, the maximum concentration at wells monitoring the BC cribs was 41 µg/L.

2.11.2 Operable Unit Monitoring

The 200-PO-1 Operable Unit contains a large section of the Hanford Site (see Figure 2.1-1 in Section 2.1). Its boundaries are generally defined by the largest contamination plume of the operable unit, tritium. The north boundary is the line separating the 200-BP-5 Operable Unit with the 200-PO-1 Operable Unit in the 200 East Area and the 2,000-pCi/L tritium contour line that trends eastward toward the Columbia River. The southwest boundary is the 2,000-pCi/L tritium contour line. The south boundary coincides with the north boundary of the 300-FF-5 Operable Unit, and the east boundary is the Columbia River. The 200-PO-1 Operable Unit also contains the BC cribs area because they are known to have received liquid waste from PUREX plant operations.

Groundwater monitoring at the 200-PO-1 Operable Unit ensures that requirements for CERCLA and AEA are met. The long-term goal is to monitor the groundwater contaminants of concern until final cleanup decisions are made. A record of decision has not been written for this operable unit. The results of 200-PO-1 Operable Unit groundwater monitoring for FY 2004 included in this annual report constitute the official report for FY 2004. There is no separate report as there is for operable units with remediation.

During FY 2004, the 200-PO-1 Operable Unit was monitored under DOE/RL-2003-04, which was based on the results of a data quality objectives process (PNNL-14049). Major groundwater contaminants of concern are tritium, nitrate, and iodine-129. Minor groundwater contaminants of concern are arsenic, chromium, cyanide, manganese, strontium-90, technetium-99, and vanadium (see Section 2.11.1 for maps and descriptions of plumes and trends). Because many of the wells are older designs and have not been sampled recently, groundwater sampling was unsuccessful at 11 of the scheduled wells during FY 2004. Two of these wells were decommissioned, three went dry, and two had safety concerns due to procedural problems with air-lift sampling. In addition, five other wells were not sampled because of scheduling errors. A table of 200-PO-1 Operable Unit monitoring wells, including details of monitoring frequency, constituents analyzed, and sampling difficulties (if applicable) for FY 2004, is provided in Appendix A, Table A.13.

Filtered manganese was the only contaminant discovered above drinking water standards in groundwater samples collected from an exploratory borehole at the BC cribs area.

Thirteen wells near the BC cribs and 11 wells near Waste Management Area A-AX are scheduled for decommissioning during FY 2005. These 24 wells will be sampled early in FY 2005. For the 13 BC cribs wells, this may be the last opportunity to sample these wells. They are being decommissioned because they are in the way of an impermeable cover that is expected to be placed over the BC cribs area. The 11 wells at Waste Management Area A-AX will be sampled and evaluated for possible continued use to monitor cribs and to provide a monitoring location between Waste Management Areas A-AX and C.

An exploratory borehole at the 216-B-26 trench (BC cribs area) was drilled through the vadose zone to groundwater (~105 meters), and sediment samples were collected and analyzed for suspected contaminants. Uranium, cesium-137, and strontium-90 were discovered at shallow depths, and technetium-99 and nitrate were discovered at the 31-meter level (see Chapter 3 for more detailed information about this and other vadose zone studies at the BC cribs area). A groundwater sample collected at the water table showed that the only constituent above background levels was manganese at 208 µg/L (drinking water standard 50 µg/L). The manganese is probably an artifact of the drilling process. Results from both the vadose zone studies at the BC cribs area (Chapter 3) and the groundwater sampling results from the exploratory borehole will aid in the selection of groundwater constituents monitored in BC cribs in the future.

2.11.3 Facility Monitoring

This section describes results of monitoring individual facilities such as treatment, storage, or disposal units or tank farms. Groundwater at some of these facilities are monitored under the requirements of RCRA for hazardous waste constituents and AEA for radionuclides including source, special nuclear, and by-product materials. Data from facility-specific monitoring are also integrated into the CERCLA groundwater investigations. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations for each facility. As discussed in Section 2.1, pursuant to RCRA, the source, special nuclear, and by-product material components of radioactive mixed waste are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority. Groundwater data for these facilities are available in the Hanford Environmental Information System (HEIS 1994) and on the data files accompanying this report. Additional information including well and constituent lists, maps, flow rates, and statistical tables are included in Appendix B.

The 200-PO-1 Operable Unit contains six RCRA sites, two sites regulated by WAC, and one site regulated exclusively under AEA groundwater requirements (Figure 2.11-1):

RCRA Sites

- PUREX cribs (216-A-10, 216-A-36B, and 216-A-37-1).
- Single-shell tanks at Waste Management Area A-AX.
- 216-A-29 ditch.
- Integrated Disposal Facility (not yet operational).
- 216-3 Pond.
- Non-Radioactive Dangerous Waste Facility (see Figure 2.1-2 in Section 2.1).

Sites Regulated under WAC

- Solid Waste Landfill
- Treated Effluent Disposal Facility

AEA-Regulated Sites

- 400 Area Water Supply Wells

RCRA assessment monitoring shows that the nitrate plume is generally attenuating, except for the area immediately around the PUREX cribs.

This section summarizes results of statistical comparisons, assessment studies, and other developments for FY 2004. Groundwater data are available in the Hanford Environmental Information System and in the data files accompanying this report.

2.11.3.1 Integrated Disposal Facility

The Integrated Disposal Facility will consist of an expandable, lined landfill covering ~20 hectares located in the south-central part of 200 East Area (see Figure 2.11-1 for location of the site and Appendix B for a list of network wells, their locations, and groundwater constituents monitored). The landfill will be divided lengthwise into two distinct cells, one for the disposal of low-level radioactive waste and the other for the disposal of mixed waste. The facility will be a RCRA-compliant landfill (i.e., a double-lined trench with leachate collection system) that is ~410 meters wide by 501 meters in length and up to 13.2 meters deep. The landfill will contain four layers of waste containers separated vertically by 0.9 meter of soil. The approximate volume of waste to be deposited will be 100 hectare-meters. The waste will be segregated into a RCRA-permitted side and a non-RCRA-permitted side.

Construction began in September 2004. DOE submitted a Part B RCRA permit application to the Washington State Department of Ecology (Ecology), and it will be incorporated into the Hanford Facility RCRA Permit after approval.

The groundwater monitoring network will consist of three upgradient wells and five downgradient wells (Appendix B) as required under WAC 173-303-645(G). Three wells remain to be installed; two will be installed in FY 2005; the third will be installed at a future date when required by facility expansion.

The indicator parameters that will be routinely monitored are chromium, specific conductance (field), total organic carbon, total organic halides, and pH (field). Supplemental parameters include alkalinity, anions, inductively coupled plasma metals, and turbidity (Appendix B). The indicator parameters will be used to monitor for hazardous constituents reaching the groundwater as a result of Integrated Disposal Facility operations.

Total organic carbon and total organic halides are indicator parameters selected to monitor impacts of RCRA-regulated organic constituents on the groundwater quality. Specific conductance is selected as an indicator parameter to monitor the effect of metals and anions on groundwater quality; pH is a general indicator of groundwater quality. Chromium is included as an indicator parameter because hexavalent chromium is one of the more mobile of the regulated metals expected at the Integrated Disposal Facility and should be one of the first constituents to enter groundwater if the regulated facility impacts groundwater.

The Integrated Disposal Facility will be divided lengthwise into two distinct cells, one for the disposal of low-level radioactive waste and the other for the disposal of mixed waste.

Analyses of alkalinity, anions, and metals are to provide supplemental data on general groundwater chemistry beneath the Integrated Disposal Facility. This information aids data interpretation and quality control. Supplemental parameters will not be used in statistical evaluations. Turbidity is analyzed at the well just before sampling and provides an indication of the amount of particulate matter in suspension at the time of sampling.

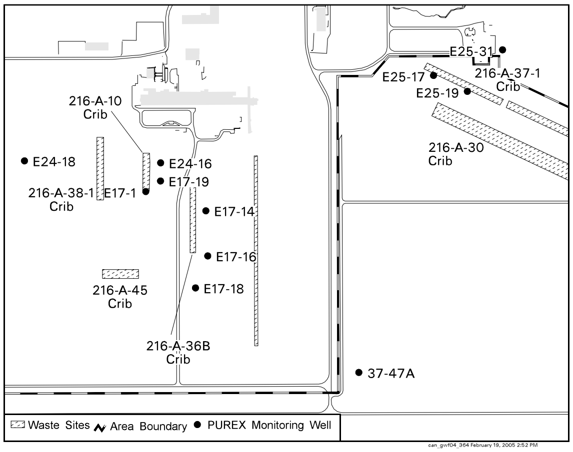
Monitoring will begin when all FY 2005 wells are installed. All indicator parameters will be monitored twice each quarter and supplemental parameters once each quarter to determine background concentrations. After the first year, indicator parameters will be monitored by collecting for independent samples twice per year, and supplemental parameters will be monitored once semiannually. In addition, field measurements of temperature and turbidity will be made at each sampling event.

During the first sampling event at each well, samples will be collected for analysis of the Appendix IX constituents (40 CFR 264) included in Chapter 1 of the Integrated Disposal Facility permit application. During FY 2005, an operational monitoring plan will be written and implemented that will include radioactive groundwater constituents such as tritium, iodine-129, and technetium-99.

2.11.3.2 RCRA PUREX Cribs

The RCRA PUREX cribs are located in the southeast part of the 200 East Area and include three cribs (216-A-10, 216-A-36B, and 216-A-37-1) monitored under RCRA interim status to assess groundwater quality. Other nearby cribs also received PUREX waste (e.g., 216-A-45 crib) but are not regulated as RCRA treatment, storage, and disposal units. They are monitored collectively under the 200-PO-1 Operable Unit. Vadose zone characterization near the RCRA PUREX cribs during FY 2004 are discussed in Section 3.1.1.

The objective of RCRA monitoring at these cribs is to assess the nature and extent of groundwater contamination with hazardous constituents and determine their rate of movement in the aquifer [40 CFR 265-93(d) as referenced by WAC 173-303-400]. Groundwater monitoring under AEA tracks radionuclides at the cribs and surrounding vicinity. Appendix B includes a well location map and lists of wells and constituents monitored for the RCRA PUREX cribs.



Groundwater flow for the two west cribs (216-A-10 and 216-A-36B) is most likely toward the southeast; for the 216-A-37-1 crib, it is south or southwest. (See Appendix B for more information on flow direction and rate information). The RCRA PUREX cribs are located in a region where several groundwater contamination plumes contain constituents that exceed drinking water standards. The similarities in effluent constituents disposed to these cribs, as well as to the 216-A-45 crib, make determining the contribution of the RCRA PUREX cribs difficult. During FY 2004, tritium, iodine-129, nitrate, strontium-90, and gross beta exceeded drinking water standards in RCRA PUREX cribs wells (see Sections 2.11.1.1 to 2.11.1.5 for more information on these constituents).

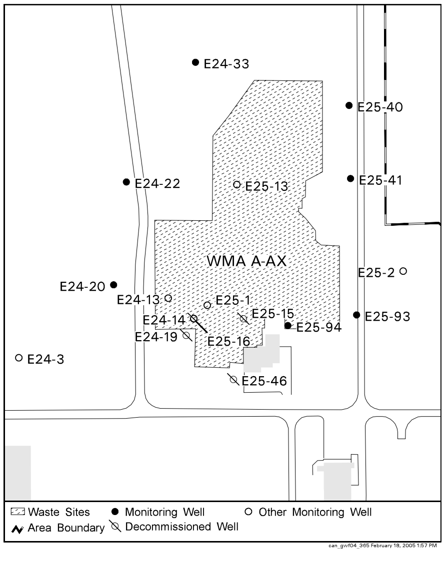
During FY 2004, tritium, iodine-129, nitrate, strontium-90, and gross beta exceeded drinking water standards in wells monitoring the RCRA PUREX cribs.

The RCRA PUREX cribs groundwater monitoring plan (PNNL-11523) organized the downgradient wells into two groups, near-field wells and far-field wells. The 11 near-field wells are shown in Figure 2.11-1 and Appendix B. The far-field wells include 78 wells that coincide with the same wells used for monitoring the major plumes of the 200-PO-1 Operable Unit (see Figure 2.1-2 in Section 2.1). The far-field wells are necessary to monitor the large tritium, nitrate, and iodine-129 plumes (see Figures 2.1-5, 2.1-6, and 2.1-7 in Section 2.1) that extend southeastward of the PUREX cribs area to the Columbia River and are discussed in Sections 2.11.1.1 through 2.11.1.3.

The tritium, iodine-129, and nitrate plumes (see Figures 2.1-5, 2.1-6, and 2.1-7 in Section 2.1), throughout the majority of their extent, are generally attenuating, except for nitrate in the area of the RCRA PUREX cribs. In recent years, the concentration of nitrate in RCRA PUREX cribs near-field wells has either held steady or risen (Section 2.11.1.3). The reason for the increased concentrations of nitrate in recent years is not known. However, it may be related to vadose zone inventory that continues to migrate to the saturated zone or to changes in groundwater flow paths due to the decreased amount of groundwater flow from B Pond and a greater contribution of groundwater flow from the northwest.

Strontium-90, a beta-emitter, occurs as a small plume at the 216-A-10 and 216-A-36B crib (Section 2.11.1.4). The plume there exceeded the drinking water standard for strontium-90 (8 pCi/L) at one well where there has been an increasing trend since 1997.

The well with the highest concentration of tritium went dry during FY 2003 and was replaced with an existing well with historically lower activity levels of tritium. Therefore, the zones of highest tritium levels are most likely no longer being monitored (north end of the 216-A-36B crib). However, the well network is adequate for determining the plume extent of the major and minor contaminants of concern and general concentrations throughout most of the plume areas.



2.11.3.3 Single-Shell Tank Waste Management Area A-AX

Located along the east border of the 200 East Area, Waste Management Area A-AX consists of the A Tank Farm, AX Tank Farm, 244-AR vault, ancillary waste transfer lines, and seven diversion boxes.

Groundwater monitoring at Waste Management A-AX continued under a RCRA interim status indicator evaluation program in FY 2004 (PNNL-13023-ICN-1). The objective of RCRA monitoring at this waste management area is to determine if groundwater quality has been compromised by dangerous waste constituents associated with the tank farms. Groundwater monitoring at A-AX Tank Farm continued under an interim status indicator evaluation program in FY 2004 [40 CFR 265.93(b) as referenced by WAC 173-303-400]. Radionuclides are tracked under AEA monitoring at the site. Appendix B includes a well location map, lists of wells and the constituents monitored for Waste Management Area A-AX.

The flow direction, determined by using local hydrographs and in situ flow measurements with the colloidal borescope, is east southeast to southeast (PNNL-14187). The saturated screen interval ranges from 1.7 to 3.5 meters in

RCRA network wells while the aquifer thickness is ~27 meters. The average rate of water-table decline was 9 centimeters in 2004. Some downgradient RCRA-compliant wells may be dry in ~7 years. The estimated flow rate at Waste Management Area A-AX is 1.2 to 2.2 meters per day (see Appendix B, Table B.2) depending on the hydraulic conductivity value used in the Darcy equation.

The monitoring network includes two monitoring wells installed in FY 2004, two installed in FY 2003, and five older wells. The network now meets the requirements of the groundwater monitoring plan (PNNL-13023).

Two wells were decommissioned in FY 2004 after a borehole video survey confirmed that they were corroded.

One of the new wells installed in FY 2004 is a downgradient well that replaces wells 299-E24-19 and 299-E25-46. These wells were decommissioned this year after it was confirmed with a borehole video survey that each well suffered from extensive corrosion of the casing in the vadose zone in proximity to a wet silt zone. Figure 2.11-7 shows the extent of the damage in wells 299-E24-19 and 299-E25-46. The silt layer is at a depth of ~84 to 86 meters below top of casing, corresponding to the location of the rotted out casings. The groundwater at both well locations displayed high levels of dissolved chromium, nickel, and manganese (PNNL-13788; PNNL-14548). Chromium levels began rising in well 299-E24-19 shortly after installation in 1991. However, chromium did not begin to appear in well 299-E25-46 until 1997 rising to over 6,000 µg/L by early 2003 during an extensive purge test. Installed in 1992, the corrosion in this well appears to have developed later, but rapidly dissolved the casing in 5 to 6 years. Sampled water was frequently described as green or yellow tinged. Local to the well bore, the pH is as low as 5.8 (measured during well purging), a result of the corrosive activity. Prior studies with extensive purge testing combined with the inverse relationship between chromium and pH plus the lack of correlation with processing waste constituents indicated that casing corrosion was the cause of the elevated metals in the groundwater (PNNL-13788; PNNL-14187; PNNL-14548).

Well maintenance reports from borehole videos surveys conducted in 1990 for two older wells (299-E25-16 and 299-E25-15 that are not compliant with WAC 173-160), located inside the A Tank Farm, describe rusted out or rotted casings at approximately the same depths as the corroded casings in the RCRA wells. A silt layer appears to be located once again at the approximate depth of the corrosion. These wells, installed in 1969, are cased with carbon steel.

A vadose zone investigation into the cause of casing corrosion is currently being conducted by the CH2M HILL Hanford Group Vadose Zone Project. Early results suggest that chloride introduced with the bentonite seal combined with damaged casing and the moisture in the silt may be the cause of the corrosion. Consequently, newly installed wells in the area have been sealed through this zone with cement instead of the usual bentonite. Further discussion of the results from this study can be found in Chapter 3 of this report.

Nitrate and technetium-99 exceeded drinking water standards in the new downgradient well 299-E25-93 at Waste Management Area A-AX.

Increasing levels of chromium (73.7 µg/L) at downgradient well 299-E25-40 prompted a recent borehole video in this well. Although corrosion is not extensive enough to detect elevated nickel and manganese, the video did confirm that the upper section of the screen is beginning to suffer from stainless steel corrosion. Groundwater monitoring will continue in this well along with regular borehole video surveys to document the progression of the corrosion and the resulting effect on groundwater quality. This study should assist in identifying when casing corrosion may be occurring in other Hanford wells.

In FY 2004, Waste Management A-AX wells were sampled twice for groundwater contamination indicators and site-specific parameters (Appendix B, Table B.29). Table B.30 in Appendix B lists updated upgradient/downgradient comparison values for statistical evaluations in FY 2005. Indicator parameter data from monitoring wells were statistically evaluated, and values from downgradient wells were compared to those established from the upgradient well. Except as noted below for total organic carbon, the indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values in downgradient wells during FY 2004. However, the inclusion of specific conductance data from upgradient well 299-E24-22 has lowered the critical mean for FY 2005 from 647 µS/cm, used in FY 2004, to 522 µS/cm for FY 2005 (Figure 2.11-8). The December 2004 values ranged from 533 to 535 µS/cm for specific conductance at well 299-E25-93, which exceeded the critical mean value of 522 µS/cm. However, confirmation sampling results were lower than the critical mean.

Although results from four quarters of data, collected at the new well 299-E24-22, show that the groundwater is relatively clean upgradient from the waste management area, initial data from the new downgradient well 299-E25-93 showed high levels of contamination for the first sampling event in December 2003. The total organic carbon value, averaged over four duplicate samples, was 3,600 µg/L, well over the FY 2004 critical mean of 2,360 µg/L for this site. Results from verification sampling in March 2004 averaged 1,700 µg/L, which, although below the critical mean, is above the limit of quantitation of 1,370 µg/L. Unless a stable trend of elevated total organic carbon above the limit of quantitation is established, it is not clear whether elevated total organic carbon is an issue at this site.

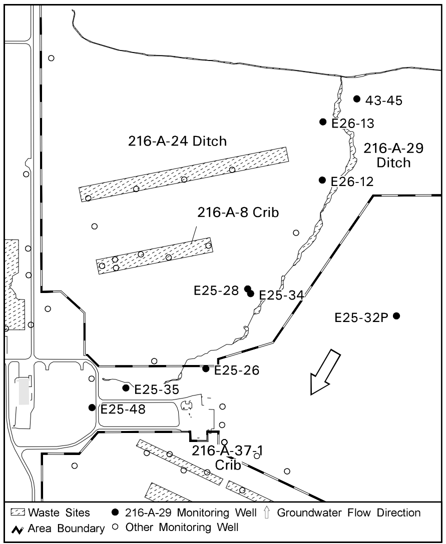
Along with the high total organic carbon, downgradient well 299-E25-93 is elevated in nitrate (maximum of 46.9 mg/L) and technetium-99 (maximum of 13,100 pCi/L). The drinking water standard for nitrate is 45 mg/L and 900 pCi/L for technetium-99. Although nitrate values range from 12.8 to 46.9 µg/L upgradient of the A Tank Farm, technetium-99 levels are low ranging from 18.7 to 36.5 pCi/L for the last sampling event. The next highest technetium-99 value of 274 pCi/L in downgradient wells is found at well 299-E25-41 where this level has been observed for the last 2 years.

Well 299-E25-93 was placed on quarterly sampling in June 2004 to establish a more detailed trend in the observed contamination. Although the source of the technetium-99 observed in well 299-E25-93 may appear to be associated with the A Tank Farm, sampling is currently being conducted at nearby cribs to determine if the groundwater under the cribs shows similar chemistry and contaminant levels. DOE and the regulatory agencies will investigate technetium-99 and other radionuclides under the operable unit (CERCLA) and related dangerous waste constituents (RCRA).

Two downgradient wells at the 216-A-29 ditch continue to have exceedances of specific conductance critical mean.

2.11.3.4 216-A-29 Ditch

The groundwater beneath the 216-A-29 ditch is monitored for evidence of hazardous waste migration as required by interim status RCRA regulations [40 CFR 265.93(b) as referenced by WAC 173-303-400]. The groundwater monitoring network at this facility is sampled twice annually for constituents that include contamination indicator parameters, annual groundwater quality parameters, and site-specific constituents (PNNL-13047; see Appendix B for list of network wells, their locations, and groundwater constituents monitored). The well network is adequate for the current groundwater flow directions. Vadose zone characterization was accomplished at the 216-A-29 ditch during FY 2004 and is discussed in Section 3.1.1.



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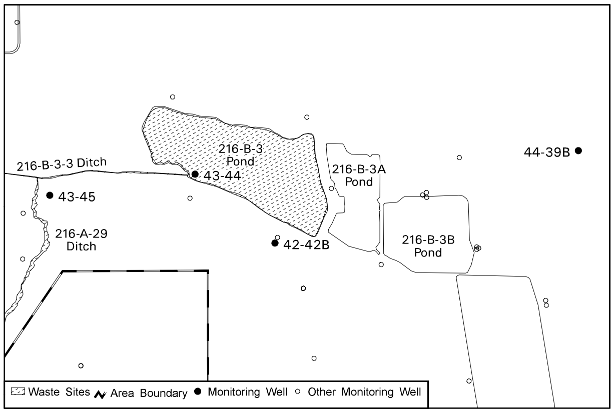
Except for specific conductance, indicator parameters in downgradient wells did not exceed critical mean values in FY 2004. Specific conductance exceeded its critical mean value in three downgradient wells during FY 2003 (299-E26-13, 299-E25-48, and 299-E25-35). During FY 2004, specific conductance did not exceed the critical mean in well 299-E26-13, although the other two wells still showed the exceedance. The reason for the exceedance at wells 299-E25-48 and 299-E25-35, which lie at the head end of the 216-A-29 ditch, is the high sulfate concentrations in groundwater associated with discharges of sulfuric acid. The reason for the elevation in wells in other portions of the ditch is unknown.

Two of the three wells that exceeded the critical mean for specific conductance in FY 2003 continued to exhibit an increasing trend. The trend for the third well has reached a plateau. Elevated sulfate levels have been shown to increase specific conductance at the 216-A-29 ditch in the past (WHC-SD-EN-EV-032). Sulfate levels continued to rise in network wells – most of them with concomitant rise in specific conductance. This association has also been reported near the Liquid Effluent Retention Facility, Low-Level Waste Management Area 2, and Waste Management Areas A-AX and C. All of these facilities are located at the west edge of the decommissioned B Pond. Dissipation of the pond may have slowed the procession of a sulfate plume front that is moving southeast toward the east boundary of 200 East Area.

The direction of groundwater flow near the 216-A-29 ditch is generally to the south-southwest and the gradient is largely flat. The tritium plume emanating from the southeast corner of 200 East provides indirect evidence of the groundwater flow direction. The causes for the low gradient and indecipherable flow direction include the desaturation of the vadose zone beneath B Pond and the interaction of the lower mud with the unconfined unit beneath the 216-A-29 ditch. The B Pond continues to create a small hydraulic barrier that contributes to now localized reversals of groundwater flow. The lower mud unit of the Ringold Formation inhibits flow to the east near the 216-A-29 ditch and groundwater is, therefore, forced to the south. The resulting groundwater flow rate is low, not exceeding ~0.1 meter per day.

2.11.3.5 216-B-3 Pond Facility (B Pond)



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The B Pond system includes the main pond and three expansion ponds. The main pond and an adjacent portion of 216-B-3-3 ditch are regulated under RCRA and require groundwater monitoring under 40 CFR 265.93(b) as referenced by WAC 173-303-400. These features are the regulated remnants of a more expansive system of ponds and ditches, most of which have been clean closed (PNNL-13367).

The B Pond system returned to a conventional RCRA interim status, detection monitoring schedule beginning in January 2004. This change marked the end of a period of experimental approach to groundwater monitoring at the B Pond system (PNNL-13367-ICN-1). Through a variance agreement with Ecology, the experimental approach allowed intrawell comparisons of site-specific parameters, gross alpha, gross beta, and specific conductance using a control-chart method with the Shewhart-CUSUM statistical analyses. The agreement also required monitoring of cadmium, lead, mercury, and silver annually for a 4-year period (that concludes in January 2005), then to discontinue monitoring if concentrations remain below drinking water standards. The specific results of this trial approach are presented in PNNL-14521.

In summary, well 699-43-45 was the only well in the network during the entire trial period that produced results exceeding the lowest control limit (mean + 2 sigma). One result for gross beta in this well (8.61 pCi/L) briefly exceeded the mean + 2 sigma control limit of 8.08 pCi/L for the Shewhart and CUSUM in early 2002, then returned to levels below the control limit.

In January, 2004, gross beta activity rose to an all-time maximum of 9.54 pCi/L before again returning to a lower activity (6.25 pCi/L) in July 2004. Temporal trends in the B Pond system wells for specific conductance, gross beta, and, to a lesser degree, gross alpha, likely represent a recovery of groundwater to natural concentrations of these parameters, following the historical diluting effects of the B Pond discharges (PNNL-13367). Of the four metals (cadmium, lead, mercury, and silver), all were below detection limits for January 2004 sampling. These results were the same as for FY 2003, except for silver that was detected during FY 2003.

The current network wells and hydraulic gradient configuration allows upgradient/downgradient comparisons as prescribed by RCRA/WAC procedures for interim-status facilities. The groundwater monitoring well network for the B Pond system consists of a total of four wells (see Appendix B). Well 699-44-39B, is located in an area currently

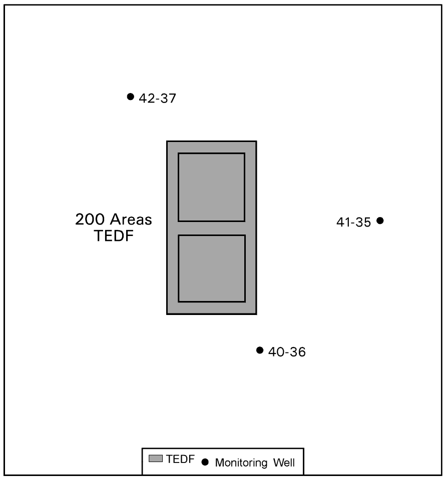
The B Pond system returned to a conventional RCRA interim status, detection monitoring schedule beginning in January 2004 after a period of experimental approach to monitoring.

upgradient of the B Pond, with three wells (699-42-42B, 699-43-44, and 699-43-45) located at the downgradient edges of the main pond and 216-B-3-3 ditch.

Background calculations of critical means for total organic carbon, total organic halides, specific conductance, and pH are based on the four most recent sampling events, including the two events in FY 2004 (see Table B.11, Appendix B). The earliest of these events go back to calendar year 2000, because total organic halides and total organic carbon were discontinued during the period of variance. In FY 2004, no results exceeded the critical means for total organic halides, total organic carbon, and field parameters are well within historical ranges, with the exception of pH and specific conductance in well 699-43-45. These two parameters indicate a slight upward trend over the past several years, and probably represent a gradual return to pre-operational conditions in the aquifer.

Based on July 2004 water-level measurements, groundwater flows west-southwest beneath the B Pond system at an estimated rate of 0.016 meter per day (Appendix B). Head measurements in vertically separated wells 699-43-41E and 699-43-41G indicated that a downward flow potential still exists near the main pond, although it is diminishing. The head difference between these two wells, as determined by March 2003 water levels, was 0.58 meter, compared with the March 2004 difference of 0.16 meter.

2.11.3.6 200 Area Treated Effluent Disposal Facility



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The 200 Area Treated Effluent Disposal Facility is located southeast of the B Pond RCRA facility and has received effluent since June 1995. Groundwater beneath the facility is monitored under a Washington State waste discharge permit (WAC 173-216; PNNL-13032). Three wells, 699-40-36, 699-41-35, and 699-42-37 (Figure 2.11-1), monitor groundwater beneath the facility.

Because there was no unconfined aquifer beneath the 200 Area Treated Effluent Disposal Facility at the time of construction, the groundwater monitoring wells were installed in the Ringold Formation confined aquifer, which was the uppermost aquifer beneath the facility (see also Section 2.14). Thus, these three wells are isolated from the effects of the effluent by the relatively impermeable Ringold unit 8 silt and clay stratum (PNNL-14098). The quarterly analytical results from the wells are used to demonstrate continuation of the isolation.

Based on hydraulic head calculations for March 2004, and estimates of effective porosity and hydraulic conductivity, groundwater flow potential in the confined aquifer beneath the 200 Area Treated Effluent Disposal Facility is directed southwest at 0.004 meter per day. Historically, major ionic composition and extremely low tritium concentrations have suggested that groundwater in the confined Ringold Formation beneath this facility is older than groundwater in the adjacent unconfined aquifers, and thus unaffected chemically and radiologically by Hanford Site operations. Results of annual low-level tritium analyses confirm this assumption. However, hydraulic head continues to decline in all three wells at the Treated Effluent Disposal Facility, as a result of the dissipating pressure effects of historical discharges at the nearby B Pond facility.

At the 200 Area Treated Effluent Disposal Facility, all scheduled groundwater samples were collected during FY 2004 and no enforcement limits were exceeded.

Groundwater samples are collected quarterly from wells for a list of constituents required by the state waste-discharge permit ST-4502 (Ecology 2000). Three of the constituents (cadmium, lead, and pH) are compared with specific enforcement limits set by the permit (see Appendix B). All scheduled samples were collected during FY 2004, and no enforcement limits were exceeded. Most results for anions, metals, and radionuclide indicators have been below Hanford Site groundwater background levels (e.g., WHC-EP-0595 and DOE/RL-96-61) since monitoring began at the site.

2.11.3.7 Nonradioactive Dangerous Waste Landfill

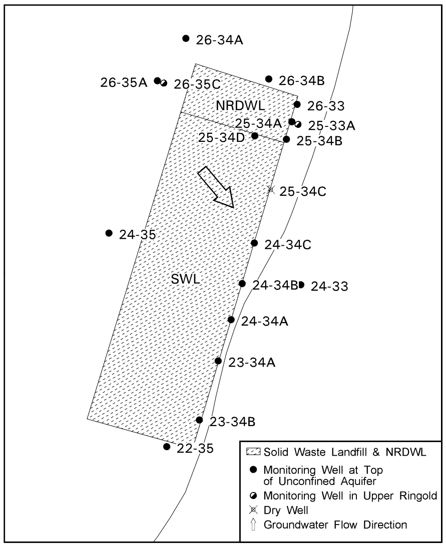
The Nonradioactive Dangerous Waste Landfill is located southeast of the 200 East Area next to the Solid Waste Landfill. The two landfills are collectively called the Central Landfill (see Figure 2.1-2 in Section 2.1). The objective of RCRA monitoring at the Nonradioactive

Dangerous Waste Landfill is to determine if hazardous waste constituents from the landfill have contaminated groundwater [40 CFR 265.93(b) as referenced by WAC 173-303-400]. Groundwater monitoring under AEA tracks radionuclides (from upgradient areas) in groundwater at the landfill and surrounding area. Appendix B includes a well location map and lists of wells and constituents monitored for the landfill.

Indicator parameters remained below their critical mean values in downgradient wells at the Nonradioactive Dangerous Waste Landfill.

Monitoring of the Nonradioactive Dangerous Waste Landfill focuses on the RCRA interim status indicator parameters: pH, specific conductance, total organic carbon, and total organic halides (PNNL-11523; Appendix B). Volatile organic compounds are monitored because they may represent groundwater contamination originating from this landfill. Nitrate is present in groundwater and has a source in the 200 East Area (see Section 2.11.1.3). The groundwater quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate) are required analytes but during FY 2004 were either not detected or were not reported in concentrations significantly above background concentrations.

Wells at the Nonradioactive Dangerous Waste Landfill (Appendix B) are sampled semiannually, usually in February and August. All of the wells of the network were sampled as scheduled during FY 2004, although one well experienced problems and was sampled ~1 month later.



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There were no exceedances of indicator parameters in downgradient wells where valid upgradient/downgradient comparisons could be made. Reported results for required phenol, anion, and inductively coupled plasma metal analytes were all either non-detects or at levels consistent with reported background values.

Seven volatile organic compounds were detected in the Nonradioactive Dangerous Waste Landfill network wells during FY 2004 including 1,1,1-trichloroethane, 1,1-dichloroethane, 1,4-dichlorobenzene, acetone, chloroform, tetrachloroethene, and trichloroethene. The levels reported were all well below drinking water standards. The source of volatile organic compounds in these wells could be either the Solid Waste Landfill (see Section 2.11.3.7) or the Nonradioactive Dangerous Waste Landfill.

Two wells experienced minor sampling difficulties during FY 2004, but the problems were quickly remedied and the wells were quickly restored to use. Therefore, the current well network is deemed adequate to monitor groundwater at the Nonradioactive Dangerous Waste Landfill, and at this time there are no changes planned for the well network.

2.11.3.8 Solid Waste Landfill

The Solid Waste Landfill is located with the Nonradioactive Dangerous Waste Landfill at the Central Landfill (see Figure 2.1-2 in Section 2.1). It is regulated by Ecology under WAC 173-304. WAC 173-304 constituents and site-specific constituents (including volatile organic compounds and filtered arsenic) are analyzed on groundwater samples collected quarterly (PNNL-13014; Appendix B). Compliance is determined by comparing results from monitoring downgradient wells with statistically derived background threshold values from upgradient wells. Groundwater flow direction is southeast as determined from the general direction of movement of major 200 East Area plumes (see beginning of Section 2.11). The well network for the Solid Waste Landfill includes two upgradient and seven downgradient wells and is shown in Appendix B.

Disposed waste at the Solid Waste Landfill has impacted groundwater including minor volatile organic compound contamination.

Disposed waste at the Solid Waste Landfill has impacted groundwater including minor volatile organic compound contamination (Table 2.11-1). The contamination (tetrachloroethene) was below drinking water standards but exceeded levels defined in WAC 173-200 (Washington State groundwater quality criteria) for the same analyte (0.8 μg/L). Some downgradient wells show higher specific conductance, chloride, sulfate, and coliform bacteria levels, and lower pH than upgradient wells. The lower pH apparently is a result of high concentrations of carbon dioxide in the vadose zone resulting from the degradation of sewage material disposed to the Solid Waste Landfill (see Section 5.3 of DOE/RL-93-88; PNL-7147; WHC-SD-EN-TI-199).

WAC 173-304 Parameters. Each WAC 173-304 parameter is discussed separately below. See Appendix B for a complete list of all results for required constituents at the Solid Waste Landfill during FY 2004. Table 2.11-1 shows the results for the volatile organic compounds during the same period.

- ***Temperature*** – Groundwater temperatures measured during sampling in downgradient wells of the Solid Waste Landfill network ranged from 16.9°C to 21.8°C. The reported value of 21.8°C was from the downgradient well 699-24-33 and is the only reported temperature above the 20.7 background threshold value for the Solid Waste Landfill during FY 2004. Temperatures at this well have been relatively steady for several years. See Appendix B for a total list of FY 2004 background threshold values for WAC 173-304 required parameters.
- ***Specific Conductance*** – Specific conductance measurements on samples taken from all downgradient wells during FY 2004 exceeded the background threshold value of 583 µS/cm. The range in downgradient wells was 662 to 849 µS/cm. All seven of the downgradient wells also exceeded the maximum contaminant level (700 µS/cm; WAC 246-290-310) in FY 2004. Since 2001, the trend for specific conductance in Solid Waste Landfill network wells has been holding steady.
- ***Field-measured pH*** – Measured values in network wells ranged from 6.59 to 7.35 during FY 2004. Reported results were lower than the background threshold range (6.68 to 7.84) in three downgradient wells: 699-23-34A, 699-23-34B, and 699-24-34B.
- ***Total organic carbon*** – The only reported result that exceeded the background threshold value (1,510 µg/L) during FY 2004 was 1,600 µg/L for a sample collected from downgradient well 699-22-35 on August 26, 2004. In previous years, spurious values for total organic carbon as high as 8,700 µg/L have been reported in Solid Waste Landfill wells providing reasonable doubt about the representativeness of these high results. However, elevated total organic carbon is consistent with what might be expected when groundwater is contaminated with sewage as it has at the Solid Waste Landfill.
- ***Chloride*** – The August 26, 2004, sample (result 8.4 mg/L) was the only one during FY 2004 to exceed the background threshold value for chloride (7.8 mg/L). Chloride concentrations have been increasing in this well since 1998.
- ***Nitrate*** – Nitrate concentrations in downgradient wells ranged from 2.7 to 3.7 mg/L during FY 2004. Neither the background threshold value (29 mg/L) nor the drinking water standard (45 mg/L) were exceeded in any well downgradient of the Solid Waste Landfill. The source of nitrate contamination at the Solid Waste Landfill is from upgradient sources in the 200 East Area (see Section 2.11.1.3).
- ***Nitrite*** – Nitrate was not detected in any Solid Waste Landfill well during FY 2004. Background threshold value for nitrite was 59.0 µg/L.
- ***Ammonium*** – Results for ammonium ion in all Solid Waste Landfill wells during FY 2004 were below the method detection limit (21.6 µg/L). Background threshold value for nitrate was 118 µg/L.
- ***Sulfate*** – Reported results in downgradient wells ranged 38.7 to 50.3 mg/L during FY 2004. The background threshold value was 47.2 mg/L and was exceeded at five downgradient wells. Sulfate trends are holding steady to rising since 1998 in downgradient Solid Waste Landfill wells.
- ***Filtered iron*** – Values for filtered iron ranged from 28.2 to 70.7 µg/L in downgradient wells. The background threshold value was 160 µg/L, which was not exceeded at any of the downgradient wells.

Downgradient concentrations continued to exceed background threshold values for several constituents including specific conductance, pH, chloride, sulfate, chemical oxygen demand, and coliform bacteria.

- ***Filtered zinc*** – Reported values for filtered zinc during FY 2004 ranged from less than the analysis method detection limit (1.5 µg/L) to 21.1 µg/L in downgradient wells. The background threshold value was 42.3 µg/L, and none of the results exceeded it during FY 2004.
- ***Filtered manganese*** – Reported values for filtered manganese in downgradient wells ranged from 0.99 µg/L (the method detection limit) to 5.1 µg/L. The background threshold value (10 µg/L) was not exceeded at any Solid Waste Landfill well during FY 2004.
- ***Chemical oxygen demand*** – Chemical oxygen demand at downgradient Solid Waste Landfill wells during FY 2004 ranged from 3.6 mg/L (the method detection limit) to 18 mg/L. The background threshold value (10 mg/L) was exceeded at five of the seven downgradient wells. Historically, chemical oxygen demand results have been mostly below the method detection limit with the exception of a few spurious values. During FY 2004, the spurious values were during the third and four quarters (the May and August 2004 sampling events). However, elevated chemical oxygen demand values could be typical of groundwater contaminated by sewage, which was known to be discharged to Solid Waste Landfill trenches.
- ***Coliform bacteria*** – Two downgradient wells and one upgradient well had reported results that exceeded the background threshold value (3.7 colonies/100 ml). The highest value reported during FY 2004 was 120 colonies/100 ml at the upgradient well 699-24-35. Elevated results for coliform bacteria at Solid Waste Landfill wells have historically been random and sporadic and, therefore, suspicious. However, like total organic carbon and chemical oxygen demand, elevated levels of coliform bacterial are expected in groundwater contaminated when sewage was known to be disposed at the Solid Waste Landfill.

Site-Specific Parameters. Site-specific parameters at the Solid Waste Landfill include chlorinated hydrocarbons and two constituents (1,4-dioxane and filtered arsenic) detected by the leachate collection system (see Section 3.2.2). Slightly elevated concentrations of chlorinated hydrocarbons continued to be detected at the Solid Waste Landfill during FY 2004. Tetrachloroethene and filtered arsenic exceeded the groundwater criteria set forth in WAC 173-200. The range of reported concentrations of chlorinated hydrocarbons is given in Table 2.11-1.

Slightly elevated concentrations of chlorinated hydrocarbons continued to be detected at the Solid Waste Landfill during FY 2004.

Chlorinated hydrocarbons were detected in all Solid Waste Landfill network wells, including the upgradient wells. The chlorinated hydrocarbons detected included 1,1,1-trichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, chloroform, cis-1,2-dichloroethene, tetrachloroethene, and trichloroethene.

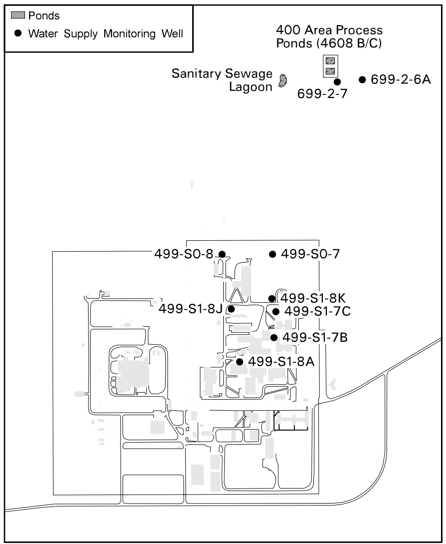
Of those chlorinated hydrocarbons detected, only tetrachloroethene exceeded the WAC 173-200 concentration limit of 0.8 µg/L during FY 2004, and the exceedance was at all seven of the downgradient wells and one of the upgradient wells. The highest concentration recorded was at well 699-24-34B with a value of 1.9 µg/L. The historical trend at all of the downgradient wells is slightly downward, and this trend continued during FY 2004. None of the reported results for tetrachloroethene (or any of the chlorinated hydrocarbons) exceeded drinking water standards.

The most likely cause of the widespread, low-level chlorinated hydrocarbon contamination at the Solid Waste Landfill, including the upgradient wells and the adjacent Nonradioactive Dangerous Waste Landfill wells, is the dissolution of vadose zone vapors into groundwater. However, the source of the vapors is uncertain. Possible sources include chlorinated hydrocarbons dissolved in the liquid sewage or the catch tank liquid from the 1100 Area heavy equipment garage and bus shop that were disposed to the Solid Waste Landfill (PNNL-13014).

Filtered arsenic (drinking water standard 10 µg/L; WAC 173-200 limit 0.05 µg/L) was detected at all Solid Waste Landfill wells. The highest concentration detected was 3.4 µg/L (at well 699-26-35A, an upgradient well). Although filtered arsenic was discovered in the leachate collection system at the trenches, the occurrence of arsenic in groundwater at the Solid Waste Landfill is probably due to natural processes (i.e., occurs naturally in Hanford Site groundwater – Hanford Site background is ~10 µg/L; DOE/RL-92-23), or there is an upgradient source (e.g., 200 East Area).

Another constituent found in the leachate collection system of the Solid Waste Landfill is 1,4-dioxane. Therefore, groundwater samples were specifically tested for this constituent also. It was not detected in any of the network wells. However, the instrument detection limit for 1,4-dioxane in the analytical method used was 11 µg/L. The WAC 173-200 limit is 7 µg/L.

During FY 2003, sampling difficulties at well 699-25-34C became severe enough that it was dropped from the sampling schedule. With the loss of this well, the number of downgradient wells dropped from eight to seven. An early analysis indicated that the well simply went dry. However, the local elevation of the water table is ~2 meters above the bottom of the well screen. An investigation is continuing to determine the reason for sampling difficulties at this well. Even if the well is eventually determined to be permanently out of service, well 699-24-33 is downgradient of well 699-25-34C and may eliminate the need for a replacement well.



2.11.3.9 400 Area Water Supply Wells

The 400 Area on the Hanford Site is the location of the Fast Flux Test Facility, a liquid-metal (sodium) cooled test reactor. DOE awarded a contract to SEC Closure Alliance at the end of September 2004 to finish shutting down the Fast Flux Test Facility. However, protests were filed with the Government Accountability Office by two of the competing companies. On January 13, 2005, the Government Accountability Office dismissed one protest but sustained the second. DOE will review the decision by the Government Accountability Office and determine the most appropriate course of action.

Primary groundwater monitoring activities in the 400 Area involve monitoring of the 400 Area water supply wells. Monitoring is also conducted to provide information needed to describe the nature and extent of site-wide contamination (primarily nitrate, tritium, and iodine-129). This section discusses the monitoring of the 400 Area water supply wells, specifically tritium, and general aspects of groundwater chemistry in the 400 Area. The water supply wells were sampled quarterly as scheduled in FY 2004.

Tritium concentrations in all samples from 400 Area water supply wells were below the drinking water standard in FY 2004.

Monitoring of the 4608-B/C ponds (also called the 400 Area process ponds) was previously conducted for compliance with a waste discharge permit. Groundwater monitoring of this site under the waste discharge permit was discontinued after FY 2003 in accordance with a recent modification of the permit (September 18, 2003). Groundwater monitoring of the two wells at the 400 Area process ponds will continue under the 200-PO-1 Operable Unit well network.

The Hanford Site water-table map (see Figure 2.1-3 in Section 2.1) indicates that flow is generally to the east-southeast across the 400 Area. The water table is located near the contact of the Hanford and Ringold Formations, which is ~49 meters below ground surface (WHC-EP-0587). Hanford formation sediment dominates groundwater flow in the 400 Area because of its relatively high permeability compared to that of sediment in the Ringold Formation.

Elevated levels of tritium associated with the groundwater plume from the vicinity of the PUREX Plant in the 200 East Area were identified in 400 Area wells as in previous years (see Figure 2.1-6 in Section 2.1). The lower concentrations of tritium north of the 400 Area are probably related to discharge at the process ponds. Groundwater tritium levels are relevant to the water supply wells, which provide drinking water and emergency supply water for the 400 Area. Well 499-S1-8J serves as the main water supply well, while wells 499-S0-7 and 499-S0-8 are backup supply wells. Well 499-S1-8J has lower tritium concentrations because it is screened at a greater depth than the other two water supply wells. The tritium concentrations in wells 499-S0-7, 499-S0-8, and 499-S1-8J are compared in Figure 2.11-9 to that of the 400 Area drinking water supply. Tritium was measured at levels below the drinking water standard (20,000 pCi/L) in all three of the water supply wells in FY 2004. Tritium levels in well 499-S1-8J (the main water supply well) during FY 2004 ranged from 2,680 to 2,970 pCi/L.

Tritium remained below the drinking water standard (20,000 pCi/L) and the 4-millirem-per-year dose equivalent in the drinking water supply, sampled at a tap, for all sampling events in FY 2004 (Figure 2.11-9). Nitrate remained below the drinking water standard in FY 2004 for the water supply wells. Data from FY 2004 and earlier from 400 Area and surrounding wells indicates no other constituents are present at levels above their drinking water standards.

Table 2.11-1. Ranges of Reported Volatile Organic Compound Concentrations in Solid Waste Landfill Wells during FY 2004

Constituent	Limit (µg/L)(a)	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
1,1,1-trichloroethane	WAC 200	<0.17 - 2.2	<1.17 - 1.9	1.5 - 2.1	1.1 - 1.3	1.5 - 1.8	1.3 - 1.7	0.9 - 1.2	1.2 - 1.4	0.7 - 0.9
1,1,2-trichloroethane	MCL 5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-dichloroethane	WAC 0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,4-dichlorobenzene	WAC 4.0	<0.11	<0.11 - 0.2	1.6 - 2.2	<0.11	<0.11	<0.11 - 0.12	<0.11	<0.11	<0.11
1,4-dioxane	WAC 7.0	<11	<11	<11	<11	<11	<11	<11	<11	<11
Carbon tetrachloride	WAC 0.3	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Chloroform	WAC 7.0	0.16 - 0.21	0.19 - 0.29	0.31 - 0.56	<0.11 - 0.08	<0.07 - 0.10	<0.11 - 0.08	<0.07 - 0.08	<0.11	0.12 - 0.15
cis-1,2-dichloroethene	MCL 70	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11 - 0.2	<0.11	<0.11	<0.11
Tetrachloroethene	WAC 0.8	0.71 - 1.1	**1.1 - 1.7**	0.76 - **1.1**	**1.4 - 1.9**	**1.2 - 1.4**	**1.4 - 1.9**	**1.2 - 1.6**	0.7 - **1.0**	0.56 - 0.74
trans-1,2-dichloroethene	MCL 100	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Trichloroethene	WAC 3.0	0.35 - 0.54	0.35 - 0.61	0.35 - 0.51	0.63 - 0.83	0.59 - 0.7	0.56 - 0.77	0.58 - 0.76	0.32 - 0.45	<0.09 - 0.42

(a) MCL = Maximum contaminant level.
WAC = Washington Administrative Code.

Values in **bold** type equal or exceed WAC 173-200-40.

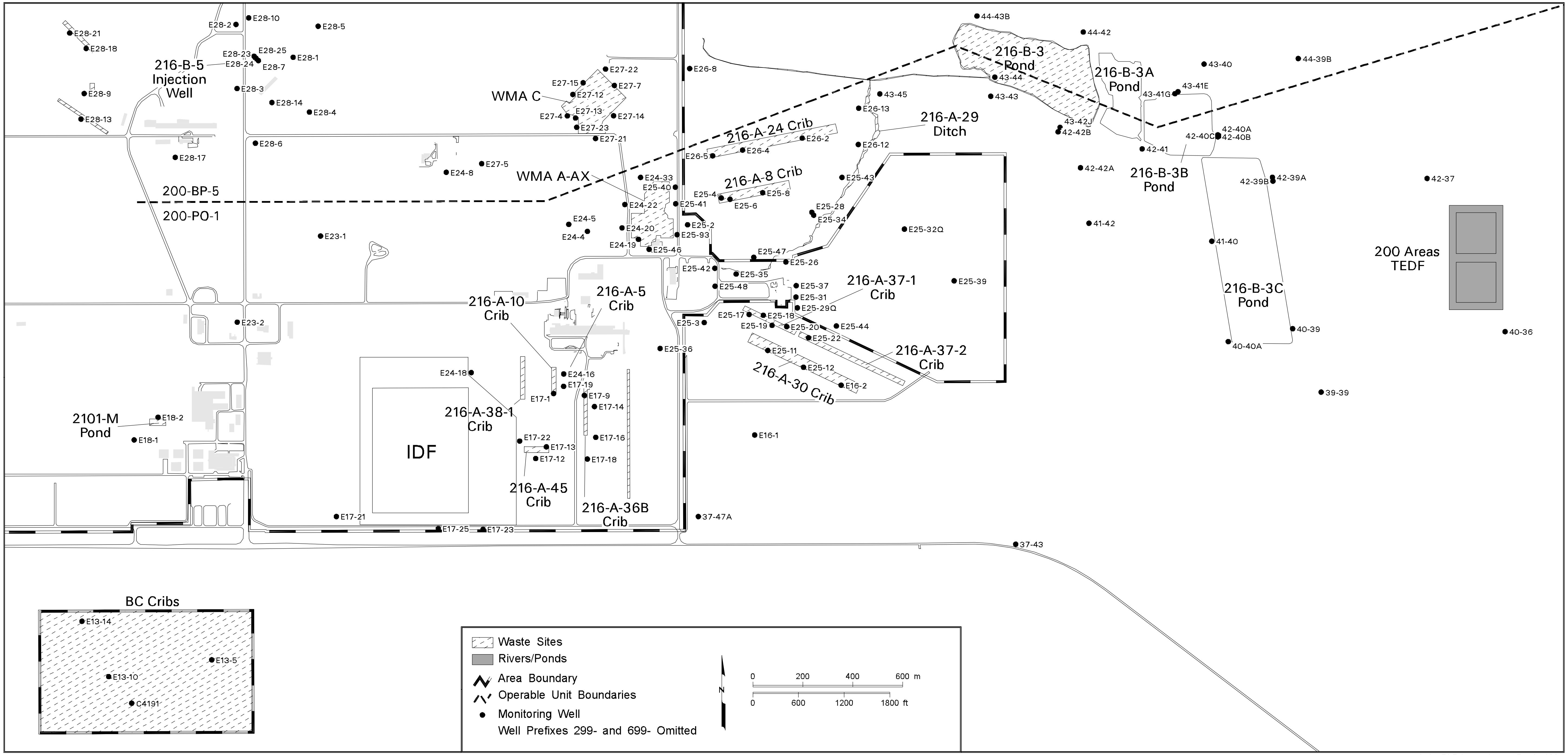


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Figure 2.11-1. Groundwater Monitoring Wells in the North Portion of 200-PO-1 Operable Unit

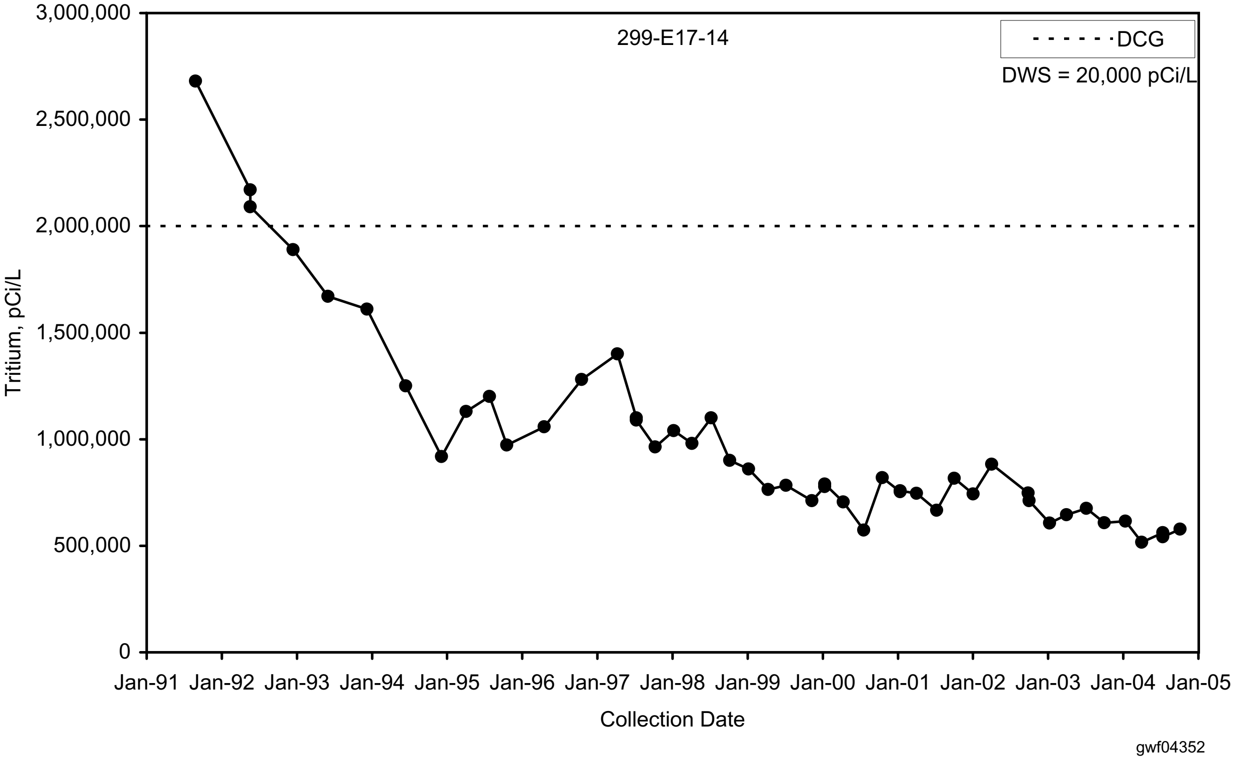


Figure 2.11-2. Tritium Concentrations at the 216-A-36B Crib, Well 299-E17-14

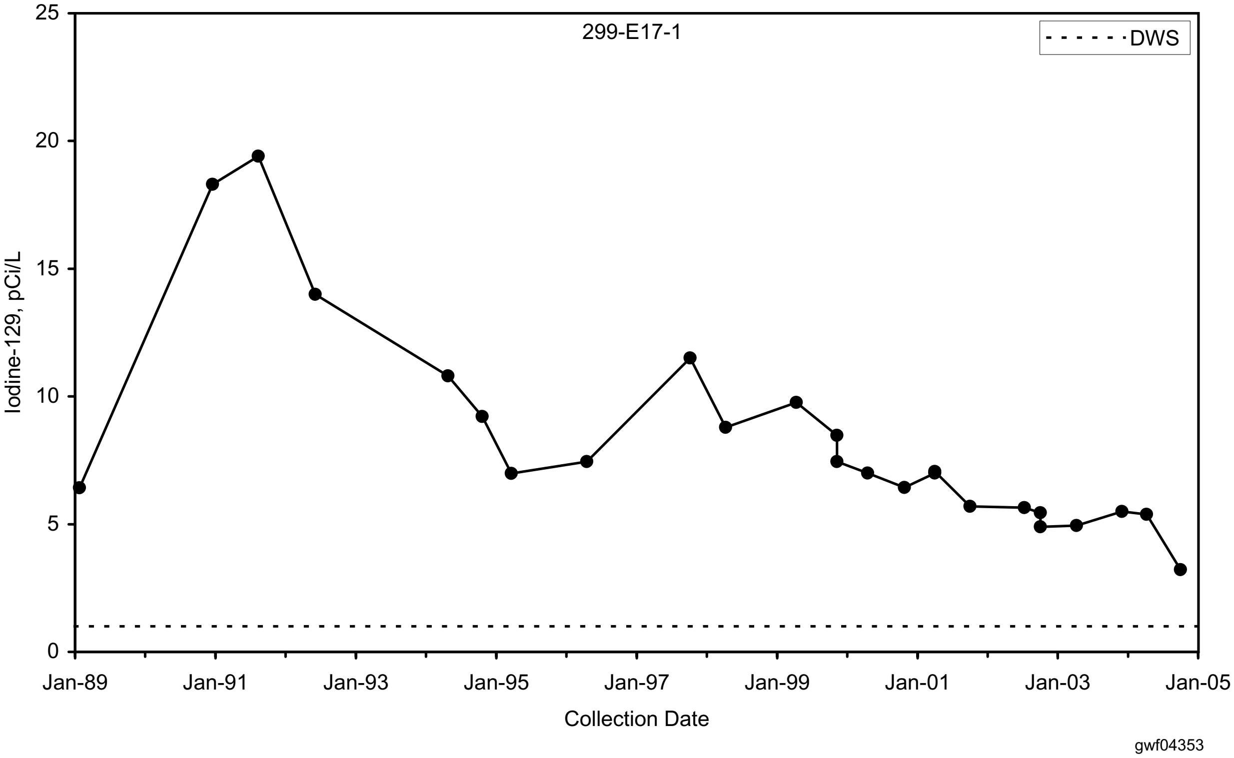


Figure 2.11-3. Iodine-129 Concentrations at the 216-A-10 Crib, Well 299-E17-1

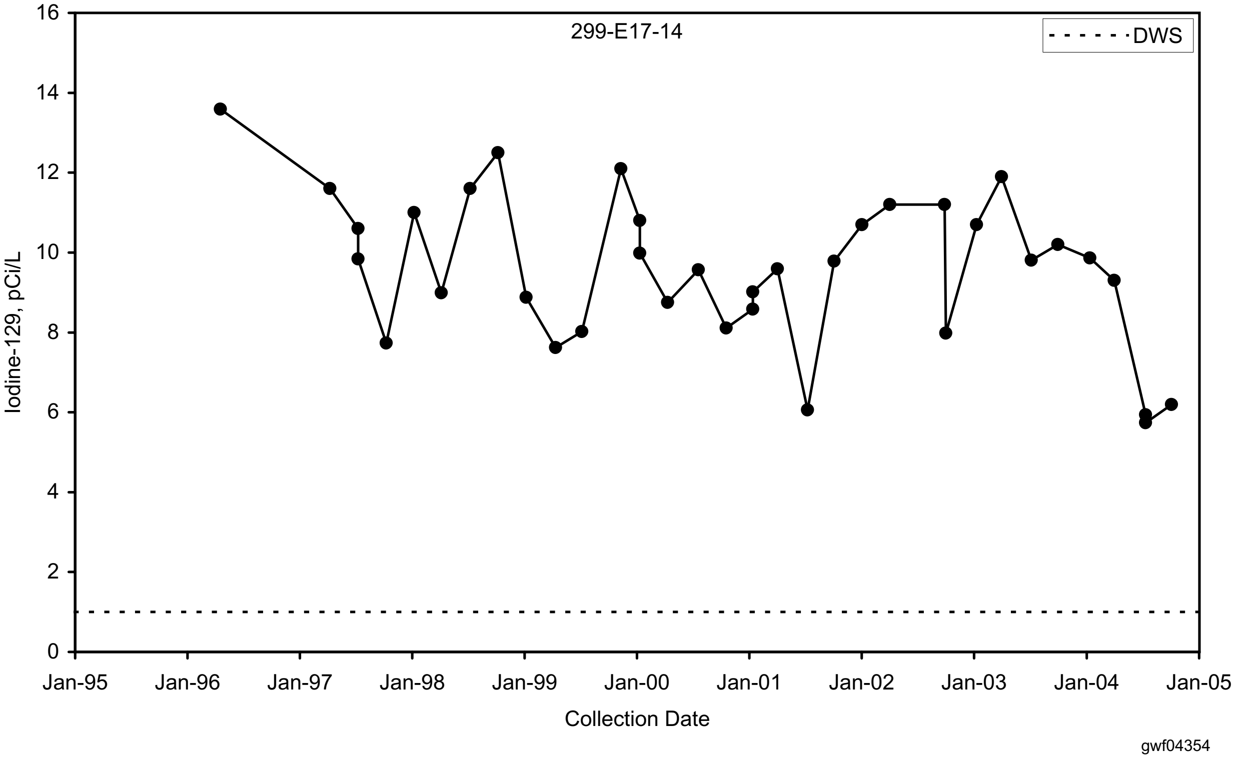


Figure 2.11-4. Iodine-129 Concentrations at the 216-A-36B Crib, Well 299-E17-14

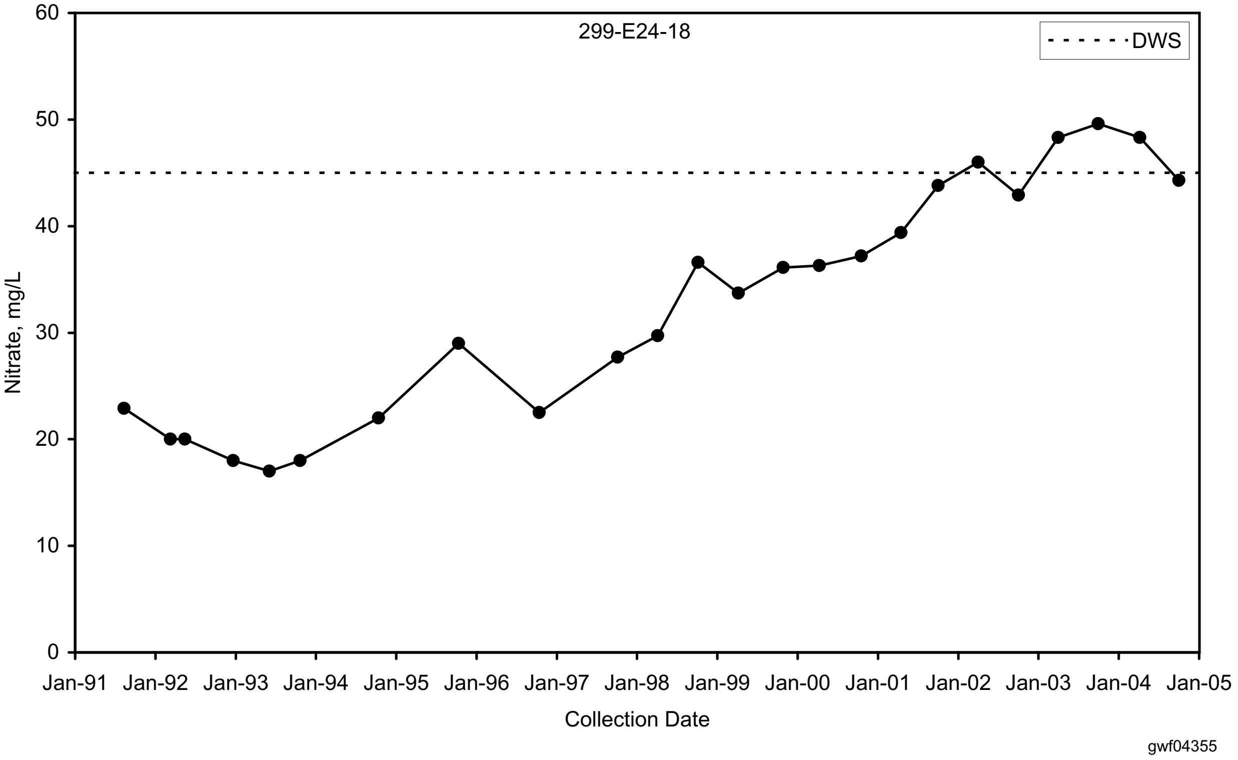


Figure 2.11-5. Nitrate Concentrations at Upgradient Well 299-E24-18 for the RCRA PUREX Cribs

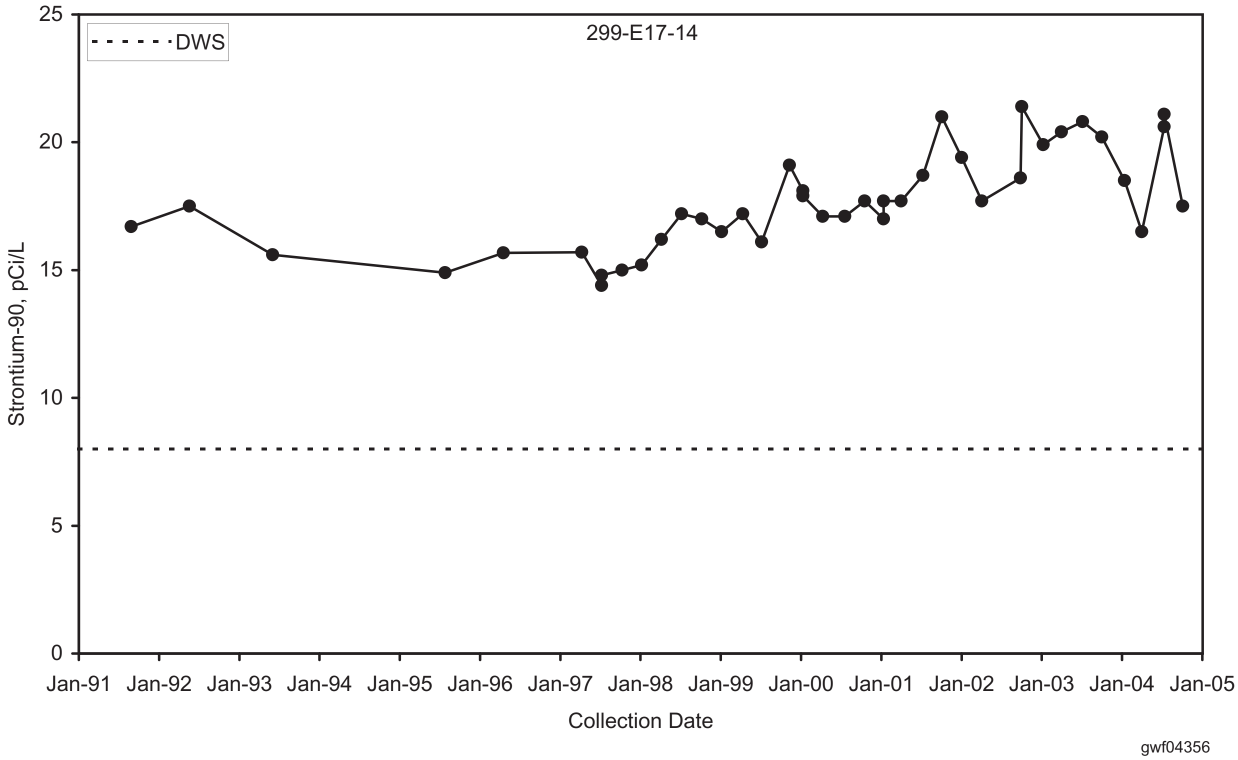
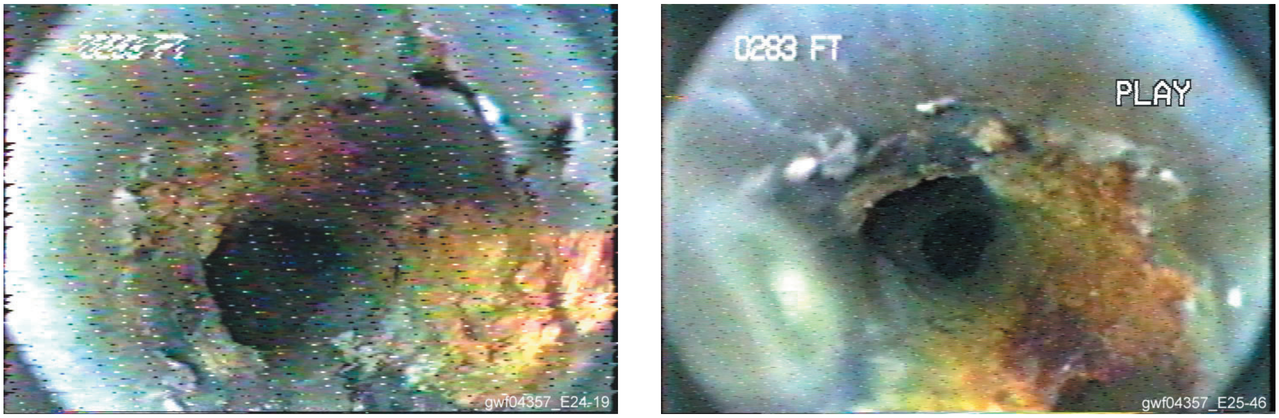


Figure 2.11-6. Strontium-90 Concentrations at the 216-A-36B Crib



(a) (b)

Figure 2.11-7. Borehole Photos of Corroded Casing in Wells 299-E24-19 (a) and 299-E25-46 (b). The corrosion corresponds to a wet silt layer at a depth of 84 to 86 meters.

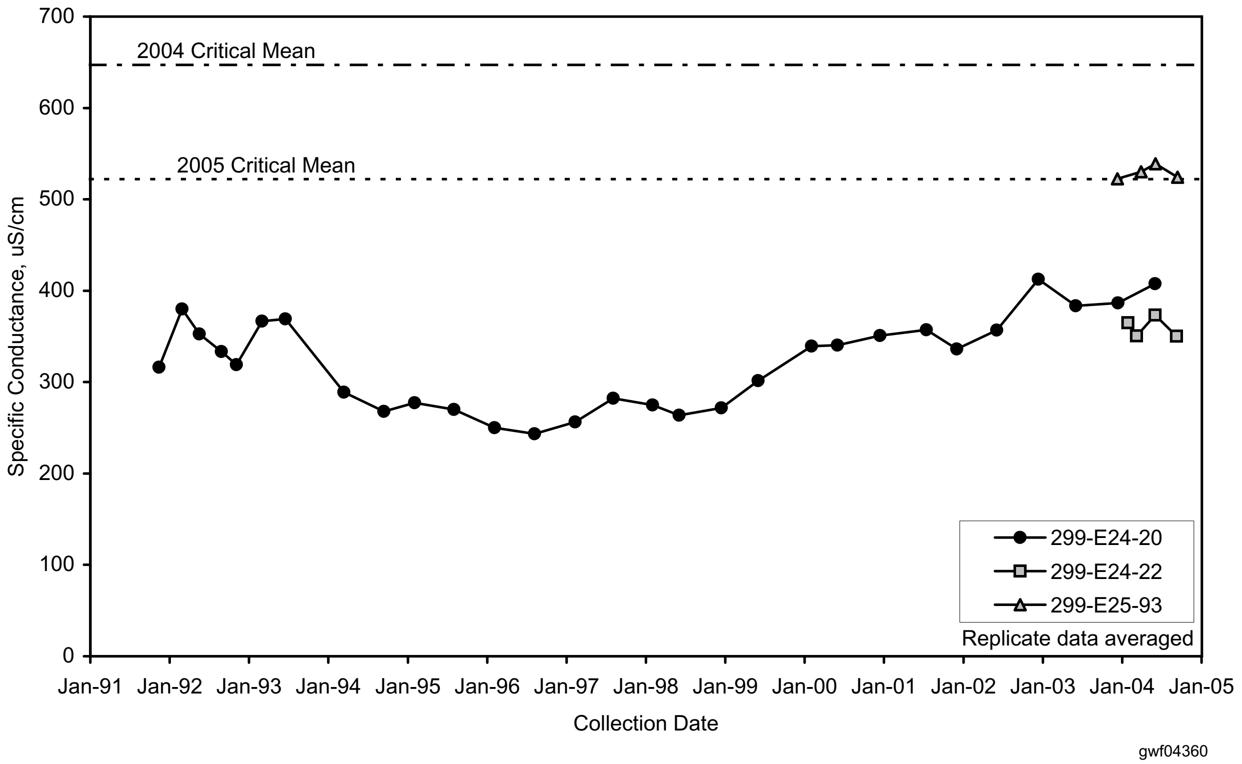


Figure 2.11-8. Trends in Specific Conductance for Upgradient Wells 299-E24-20 and 299-E24-22 Compared to Data from New Downgradient Well 299-E25-93 at Waste Management Area A-AX

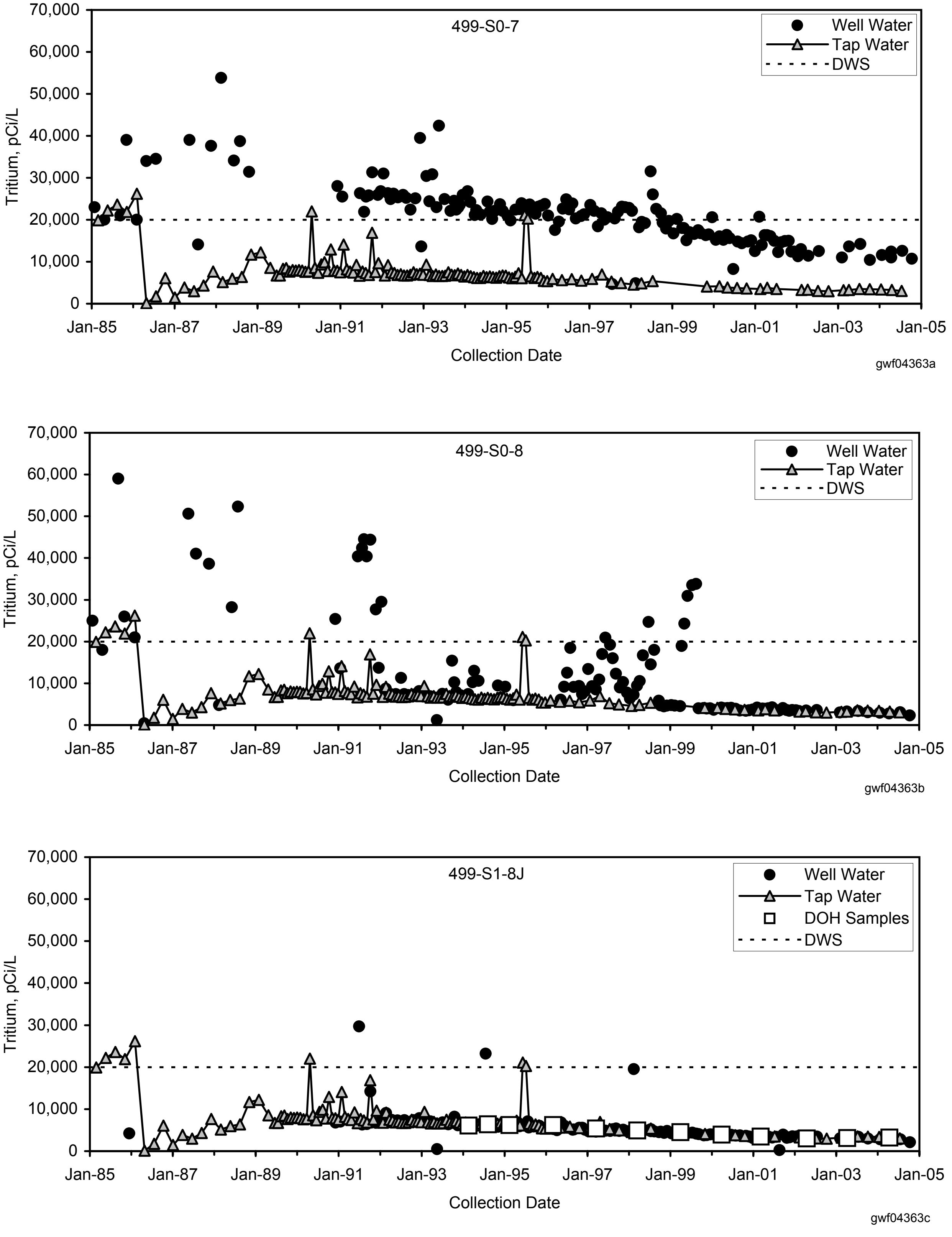


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Figure 2.11-9. Comparison of Tritium Concentrations in 400 Area Water Supply Wells

2.12 300-FF-5 Operable Unit

J. W. Lindberg and R. E. Peterson

The 300-FF-5 Operable Unit includes groundwater affected by releases from sources in the 300 Area, 618-11 burial ground area, and 316-4 cribs/618-10 burial ground area. The operable unit lies within a larger groundwater interest area (see Figure 2.1-1 in Section 2.1), which has been defined by the Groundwater Performance Assessment Project (groundwater project) for scheduling, data evaluation, and interpretation purposes. Groundwater investigations are underway in the operable unit to (a) identify natural processes that reduce the levels of contaminants of potential concern, (b) track changes in the extent of contaminants and their concentration trends with time, and (c) comply with *Resource Conservation and Recovery Act* (RCRA) regulatory requirements associated with the 316-5 process trenches.

Uranium is the contaminant of greatest significance in groundwater at this operable unit.

The 300-FF-5 Operable Unit is divided into two geographical regions: the 300 Area and 300-FF-5 North, which includes the two outlying waste site areas (Figure 2.12-1). The 300 Area contains former nuclear fuel fabrication facilities, fuels research laboratories, liquid effluent disposal sites (e.g., process trenches, process ponds), and several solid waste burial grounds. An index map to 300 Area facilities, waste sites, groundwater wells, and shoreline monitoring sites is shown in Figure 2.12-2. Approximately 30 wells and 8 aquifer sampling tube sites along the Columbia River are in use to monitor groundwater conditions beneath the 300 Area. The 300-FF-5 North region includes groundwater beneath the 618-11 burial ground near Energy Northwest, and beneath the 618-10 burial ground and 316-4 cribs, which are located south of the 618-11 burial ground and northwest of the 300 Area. An index map to the 300-FF-5 North region is provided as Figure 2.12-3. The 300-FF-5 North region uses 11 of the 41 monitoring wells in service for the 300-FF-5 Operable Unit.

Groundwater flow in the unconfined aquifer beneath the 300-FF-5 groundwater interest area is generally to the east and southeast. Beneath the 300 Area, flow in the unconfined aquifer is generally to the southeast. Flow into the 300 Area converges from regions

Groundwater monitoring in the 300-FF-5 groundwater interest area includes the following monitoring activities:

CERCLA Long-Term Monitoring

- ***Twenty-six wells are sampled semiannually for uranium and volatile organic compounds.***
- ***Thirteen wells are sampled semiannually for nitrate (upgradient source).***
- ***Twelve wells are sampled semiannually for tritium (upgradient source).***
- ***Aquifer tubes, riverbank springs, sediment, and associated biota are sampled annually (coordinated with Public Safety and Resource Protection Program monitoring).***
- ***In FY 2004, all wells were sampled as planned.***

Facility Corrective Action Monitoring at 316-5 Process Trenches

- ***Eight wells were sampled eight times during FY 2004 for uranium and volatile organic carbons under existing groundwater monitoring plan.***
- ***In FY 2004, all wells were sampled as planned, except for three wells in December 2003 (see Section 2.12.3 and Appendix B).***
- ***Monitoring was coordinated with other programs to avoid duplication.***

AEA Monitoring

- ***Eight wells are sampled semiannually to annually for uranium to monitor deep unconfined and confined Ringold Formation aquifers.***
- ***Monitoring is coordinated with CERCLA and RCRA sampling to avoid duplication.***

to the northwest, west, and southwest, with ultimate discharge to the Columbia River (Figure 2.12-4). During fiscal year (FY) 2004, in the north and central portion of the 300 Area, flow direction was southeast during March 2004, and east in the south portion of the 300 Area, as inferred from water-table gradients. These are typical directions for groundwater flow when the river is at low-to-medium stage. As the river stage rises during late May or June, the direction of groundwater flow can temporarily shift to a more southward direction. Changes in river-stage elevation are correlated to changes in water-level elevations at wells located inland as much as 360 meters from the river (PNL-8580).

Groundwater flows toward the east and southeast across the 300-FF-5 interest area and discharges to the Columbia River.

The remainder of this section describes contaminant plumes and concentration trends for contaminants of potential concern listed in sampling and analysis plans that support *Comprehensive Environmental Resource, Compensation, and Liability Act* (CERCLA) and RCRA requirements.

2.12.1 Groundwater Contaminants

The contaminant of greatest significance in groundwater beneath the 300 Area is uranium, which has persisted as a plume for a long time. Additional contaminants of potential concern from 300 Area sources are volatile organic compounds (cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene) and strontium-90. Constituents from sources outside of the 300 Area that migrate into the region include tritium, nitrate, and trichloroethene.

For the 300-FF-5 North region, the contaminant of greatest significance is tritium at the 618-11 burial ground, where a high concentration plume of limited areal extent is present. Contaminants of potential concern being monitored at the 316-4/618-10 waste sites area are uranium and tributyl phosphate. Tritium and nitrate migrate into the 300-FF-5 North region from upgradient sources in the 200 East Area.

2.12.1.1 Uranium

Uranium is a contaminant of concern in groundwater beneath the 300 Area and 316-4/618-10 area. In the 300 Area, it was introduced to groundwater by disposal of fuel fabrication effluent to large infiltration ponds and trenches. At the 316-4 cribs, it was disposed to open-bottomed infiltration cribs along with liquid effluent containing organic compounds. Uranium is moderately mobile in groundwater, with some sorption onto sediment particles. The mobility of uranium within waste sites, the underlying vadose zone, and in the aquifer is highly variable and dependent on (a) the chemical makeup of the waste effluent and (b) the subsurface geochemical environment, especially the carbonate concentration, pH, and surface properties of minerals (PNNL-14022).

The U.S. Environmental Protection Agency (EPA) drinking water standard for uranium is 30 μg/L; uranium's toxicity for humans is associated with damage to internal organs. Protection standards for freshwater aquatic organisms have not been established, so the drinking water standard is used by default as criteria for protection. Uranium in groundwater is typically monitored using chemical analyses for total uranium in unfiltered samples. In the river environment, uranium in shoreline media and river water is monitored using analyses for specific isotopes. Results for each type of analysis can be converted to the other to provide comparable data sets.

Plume areas (square kilometers) above the drinking water standard at the 300-FF-5 Operable Unit:

**Nitrate — 0.61*
Trichloroethene — 0.01
***Tritium — 0.19*
Uranium — 0.42

** Excludes nitrate from offsite sources.*
*** Excludes tritium from 200-PO-1 Operable Unit.*

300 Area Uranium Plume. The persistent uranium plume in the 300 Area, as defined by concentrations exceeding 10 μg/L, covers an area of ~1 square kilometer. The area of the plume where concentrations exceed the 30-μg/L drinking water standard is ~0.4 square kilometer (Figures 2.12-5 and 2.12-6). Although the areal extent of the plume is quite consistent from year to year, the concentrations of uranium within the plume vary throughout the year. These changes within the plume during various seasons are related to changes in river stage, which cause the water-table elevation beneath the 300 Area to fluctuate, and also result in river water infiltrating the near-river aquifer causing dilution of contaminants. Throughout most of the year (i.e., August through April), the river maintains a low-to-moderate river stage elevation, while the stage is typically high during late May and June. Figure 2.12-5 shows the uranium plume indicated by results for samples collected in December 2003, which is considered representative of the August through April time period.

Seasonal river stage conditions cause variability in uranium concentrations in groundwater.

Uranium concentrations in 300 Area groundwater are influenced by fluctuations in water-table elevation, which are, in turn, influenced by river stage fluctuations. Higher concentrations during periods of high water-table elevations (usually in June of each year) may be associated with remobilization of uranium in the lower vadose zone at locations near former waste disposal sites (e.g., the 316-3 trenches). As an example, Figure 2.12-7 shows the effect of yearly rises in river level near the 300 Area process trenches (well 399-1-17A). Conversely, uranium concentrations at wells located close to the river during June (such as well 399-1-16A) may be lower than those observed during other seasons. The lower concentrations are caused by infiltrating river water mixing with groundwater, thus diluting the contamination (Figure 2.12-8). There is also the possibility of increased absorption of uranium onto aquifer solids in sediment saturated by river water, thus reducing the dissolved component of uranium. Investigations of uranium mobility have shown that sorption is increased in a chemical environment that is low in carbonate; river water contains less carbonate than groundwater (PNNL-SA-33304; PNNL-14022).

During June 2004, the elevated river stage typical of the spring runoff each year was not as pronounced compared to the typically higher stages of previous years. Therefore, the uranium plume for June 2004 (Figure 2.12-6) is very similar to the December 2003 plume. The most obvious difference in concentrations between the December 2003 and June 2004 conditions occurred at well 399-3-11, which is near the 316-3 trenches (also called the 307 trenches). The December 2003 result at that well was 24 µg/L, whereas the June 2004 result was 107 µg/L.

Uranium contamination is primarily limited to the uppermost part of the unconfined aquifer at the 300 Area.

Concentrations at a well located close to the most recently active waste site (i.e., well 399-1-17A at the 316-5 process trenches) indicate a gradual decline since the mid-1990s (Figure 2.12-9) though levels appear to have remained fairly constant for the most recent sampling results. At locations farther downgradient from this waste site, concentration trends reveal the passage of a relatively high concentration pulse (Figure 2.12-10), which is related to the high river stage during the spring runoffs of 1996 and 1997, and possibly to extensive source excavation activities that started in the mid-1990s. Concentrations at other locations within the plume area show variable trends. In the absence of current disposal of effluent to waste sites and the removal of some past-practice waste sites by excavation, the most likely controls on long-term concentration trends are (a) plume migration and (b) recharge of the plume by continuing releases from vadose zone sediment and possibly from aquifer solids as well. Short-term variability in concentrations is caused by seasonal changes in water-table elevation and groundwater/river water interaction near the shoreline.

Uranium contamination appears to be limited to the uppermost part of the unconfined aquifer, i.e., near the water table. The plume maps prepared for this report represent conditions near the water table. Several wells in the 300 Area are screened at the bottom of the unconfined aquifer; uranium concentrations in samples from these wells range from non-detect to ~14 µg/L in recent samples. The higher values are found near the most recently active source – the 316-5 process trenches. Uranium has not been detected at the few wells that monitor the uppermost confined aquifer.

New aquifer tubes adjacent to the Columbia River show high uranium concentrations near the core area of the groundwater plume.

During FY 2004, aquifer tubes were installed at eight locations along the 300 Area shoreline. The initial samples from these tubes revealed uranium concentrations ranging from 10 up to 241 µg/L, with the highest values adjacent to the central core area of the groundwater plume. Additional investigation of uranium in the zone of interaction between groundwater and river water is underway in FY 2005. Some preliminary results confirm the presumption that the uranium plume is primarily confined to the uppermost depths of the unconfined aquifer, and that the relatively high current concentrations observed near the river represent the passage of a "pulse" created during the mid-1990s.

Uranium Near 316-4 Cribs/618-10 Burial Ground. Uranium concentrations above natural background levels (i.e., 5 to 8 µg/L) are found in groundwater near the 316-4 cribs and 618-10 burial ground. Concentrations at wells 699-S6-E4A and 699-S6-E4L, which are located adjacent to the cribs and southeast perimeter of the burial ground, were higher than background but generally lower than the drinking water standard of 30 µg/L during FY 2004. The exceptions are the most recent values at well 699-S6-E4L, where concentrations appear to be gradually increasing and currently exceed the standard, with a high value of 30.6 µg/L in June 2004 (Figure 2.12-11). Uranium concentrations at well 699-S6-E4A also appear to be increasing slightly, as do results for gross alpha and gross beta. These gradually increasing trends apparently started in 2003 before excavation of the 316-4 cribs began in late September 2004.

2.12.1.2 Organic Compounds

Constituents of concern in groundwater of the 300 Area include cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene. In the 300-FF-5 North region, organic compounds previously identified as a potential concern are present at the 316-4/618-10 waste sites and include tributyl phosphate and petroleum hydrocarbons.

Several volatile organic compounds were detected in the 300-FF-5 Operable Unit during FY 2004, but only trichloroethene and cis-1,2-dichloroethene were reported in concentrations that exceeded the drinking water standards.

300 Area Organic Compounds. Cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene were detected in 300 Area groundwater samples during FY 2004, but only cis-1,2-dichloroethene and trichloroethene were found to be in concentrations exceeding the drinking water standards (70 and 5 µg/L, respectively). Cis-1,2-dichloroethene was detected in 11 wells near or downgradient of the 316-5 process trenches. Seven of the wells are screened at the water table and four at the base of the unconfined aquifer. Only well 399-1-16B, screened at the base of the unconfined aquifer, had reported cis-1,2-dichloroethene results that exceeded the 70-µg/L drinking water standard. During FY 2004, the reported values of cis-1,2-dichloroethene ranged from 95 and 150 µg/L at well 399-1-16B. Two other reported values were 200 and 280 µg/L, but they are potentially exaggerated because they exceeded the calibration range of the laboratory analytical equipment (gas chromatograph/mass spectrometer). The trend for cis-1,2-dichloroethene in this well is holding relatively steady between 100 and 200 µg/L (Figure 2.12-12).

Trichloroethene was detected in 24 wells in the 300 Area and also in other wells offsite to the southwest where there is a source of trichloroethene groundwater contamination (Figure 2.12-13). Another source of trichloroethene groundwater contamination is the 316-5 process trenches. Of the 24 wells in the 300 Area where trichloroethene was detected during FY 2004, all but two are screened at the water table. The two wells screened at the base of the unconfined aquifer where trichloroethene was detected are wells 399-1-16B and 399-1-8, which are downgradient of the 316-5 process trenches. The only well in the 300 Area where trichloroethene was reported above the drinking water standard (5 µg/L) was well 399-1-7, which is also located downgradient of the 316-5 process trenches. Although the average concentration of uranium in well 399-1-7 was lower than the drinking water standard during FY 2004, the reported value for June 2004 was 5.4 µg/L. The trend for trichloroethene in well 399-1-7 is erratic with elevated values reported in the June samples of 2002, 2003, and 2004 (Figure 2.12-14). The reason for the elevated levels in June is unknown, but it may be related to higher water-table conditions in June (similar to trend for uranium in some wells). A value of 6.8 µg/L was measured in a sample from a newly installed aquifer tube located along the downgradient flow path from well 399-1-7.

Tetrachloroethene (drinking water standard 5.0 µg/L) was detected at very low concentrations in 14 wells in the 300 Area during FY 2004. Most of these wells are downgradient of the 316-5 process trenches, and all but one of these wells is screened at the water table. The one well where tetrachloroethene was detected at the base of the unconfined aquifer (well 399-1-16B) is also the same well with the highest reported concentration during FY 2004 (1.7 µg/L). The other 13 wells had reported levels of tetrachloroethene that ranged from 0.18 to 0.59 µg/L. Reported levels of tetrachloroethene in wells downgradient of the 316-5 process trenches have been as high as 38 µg/L (July 1998 in well 399-1-17A) in previous years, but during FY 2004 reported concentrations remained low.

Elsewhere in the 300 Area, contamination by petroleum hydrocarbons was suspected during remedial actions at the 618-4 and 618-5 burial grounds. However, groundwater samples from wells 399-1-15 and 399-1-6 have not revealed petroleum hydrocarbon contamination to date.

Organic Compounds in the 300-FF-5 North Region. Tributyl phosphate has been detected in the past at well 699-S6-E4A located adjacent to the 316-4 cribs. The cribs received effluent containing tributyl phosphate, among other contaminants such as uranium. The single tributyl phosphate result for that well during FY 2004 indicated non-detect. Samples from nearby newly constructed wells 699-S6-E4K and 699-S6-E4L also indicate non-detections. Tributyl phosphate became of interest in 1996 following refurbishment of well 699-S6-E4A, when contamination in the vadose zone and/or within the well was remobilized. A value of 1,500 µg/L was observed at that time. Subsequent monitoring showed that the occurrence is very localized. The semivolatile compound tends to bind in the vadose zone beneath waste sites that received effluent containing tributyl phosphate, where it slowly degrades with time. It is not very soluble in water and, therefore, not widely dispersed via water transport mechanisms. There is no drinking water standard for tributyl phosphate.

Petroleum hydrocarbons (both diesel and gasoline) were also detected in groundwater near the 316-4 cribs during well refurbishment activities in the mid-1990s (well 699-S6-E4A). Monitoring conducted since that time has shown non-detections.

2.12.1.3 Strontium-90

Strontium-90 has been detected as an isolated occurrence at well 399-3-11 in previous years (PNNL-13788). The drinking water standard is 8 pCi/L. The highest concentration measured in recent years was 8.7 pCi/L in 1995. Since then, concentrations have varied between 3 and 8 pCi/L. Reported results from well 399-3-11 during FY 2004 were 3.4 and 3.8 pCi/L for samples collected during December 2003 and June 2004, respectively. The source of the strontium-90 is unknown, but it may be from the location of the decommissioned (and backfilled) 316-3 trenches ~60 meters north-northwest of well 399-3-11.

2.12.1.4 Nitrate

Groundwater in the 300 Area and 300-FF-5 North region is contaminated with nitrate from upgradient sources. In the 300 Area the source is to the southwest, while in the 300-FF-5 North region, the source is the 200 East Area (see Section 2.11.1.3).

Nitrate in the 300 Area. Nitrate was detected in all wells in the 300 Area during FY 2004. Figure 2.12-15 shows the distribution of nitrate in the 300 Area and 1100-EM-1 Operable Unit (see Figure 2.1-6 in Section 2.1 for map of nitrate across the entire Hanford Site). Wells within the 300 Area have nitrate concentrations below the 45-mg/L drinking water standard, but concentrations increase to the southwest toward the groundwater contamination source. The highest concentration reported during FY 2004 was at well 399-5-1 (southwest 300 Area) with a reported level of 21.8 mg/L.

Nitrate in the 300-FF-5 North Region. The 300-FF-5 North region is within the large nitrate plume coming from the 200 East Area. Background levels of nitrate upgradient of the 618-11 burial ground are in the range of 20 to 40 mg/L. In the vicinity of the 618-11 burial ground, the concentrations of nitrate are somewhat higher, with values at wells 699-13-3A and 699-12-2C as high as ~80 mg/L during FY 2004. These higher values may reflect the influence of an active septic system operated by Energy Northwest.

Groundwater in the 300 Area and 300-FF-5 North region is contaminated with nitrate from sources outside of the operable unit. Concentrations are generally below the drinking water standard (45 mg/L).

2.12.1.5 Tritium

Tritium contamination in groundwater in the 300-FF-5 Operable Unit has two sources. One is the site-wide tritium plume that originates in the 200 East Area (see Figure 2.1-5 in Section 2.1 and Section 2.11.1.1). The other is the 618-11 burial ground in the 300-FF-5 North region. Concentrations attributed to the site-wide tritium plume as it reaches the 300 Area are shown in Figure 2.12-16 and range from 100 to 10,000 pCi/L, depending on location. Wells located toward the northeast have higher concentrations than those toward the southwest. Contours on tritium maps similar to Figure 2.12-16 in the last few years have shifted very little, thus indicating that the tritium plume in the north part of the 300 Area has changed very little.

High concentrations of tritium detected in 1999 at the 618-11 burial ground are believed to be the result of tritium release from buried material.

Tritium at 618-11 Burial Ground. High concentrations of tritium were detected in early 1999 at well 699-13-3A, which is located immediately to the east of the 618-11 burial ground fence. Following this unexpected discovery, investigations were undertaken to characterize the plume (PNNL-13228) and to learn more about the source for the tritium (PNNL-13675). These investigations revealed that the 618-11 burial ground was the likely source for the tritium, and that the extent of the plume was a relatively narrow tongue extending east-northeast (Figure 2.12-17). Concentrations of tritium within the narrow plume ~1 kilometer distance from the burial ground were indistinguishable from background levels associated with the site-wide plume.

Since 1999, the concentration of tritium at well 699-13-3A, where the high concentrations of tritium were first discovered in 1999, rose to >8 million pCi/L in 2000, and then started a rapid decrease to current levels, which have been in the 1.9 to 2.2 million pCi/L range for sampling events during FY 2004 (Figure 2.12-18). This trend suggests that an episodic event may have occurred that caused a release of tritium from buried materials and/or a remobilization of tritium in the vadose zone sufficient to impact groundwater.

2.12.2 Operable Unit Monitoring and Interim Action

Groundwater investigations associated with the 300-FF-5 Operable Unit continued during FY 2004 under a revised operation and maintenance plan (DOE/RL-95-73). This document was revised in response to an action item contained in the first 5-year review of the record of decision for interim remedial action (Action Item 300-4; ROD 1996b). The geographical scope of the operable unit was subsequently expanded via an explanation of significance difference to include two additional outlying areas (EPA 2000). The operable unit currently includes groundwater beneath the 300 Area, 618-11 burial ground, and 618-10 burial ground and adjacent 316-4 cribs (Figure 2.12-1). The following discussion refers to two sub-divisions of the operable unit: 300 Area and 300-FF-5 North region, the latter containing the outlying waste sites.

The remedial action objectives for groundwater in the 300-FF-5 Operable Unit (ROD 1996b) are:

- *Protect human and ecological receptors from exposure to contaminants in the soil and debris.*
- *Protect receptors from exposure to contaminants in the groundwater and control the sources of contamination to minimize future impacts to groundwater.*
- *Protect the Columbia River such that contaminants in the groundwater or soil after remediation do not result in an impact to the river that would exceed the Washington State surface water quality standards.*

The record of decision sets the objective concentrations as the drinking water standards for cis-1,2-dichloroethene, trichloroethene, and uranium. In 2000, EPA expanded the record of decision to include groundwater beneath the 300-FF-5 North region (EPA 2000).

2.12.2.1 Monitoring Activities

Forty-one monitoring wells, eight aquifer tubes sites (installed in February 2004), and two riverbank springs were sampled as planned in FY 2004, with the exception of three wells being missed in December 2003 for logistical reasons. See Appendix A for the list of sites.

Groundwater monitoring for the 300 Area portion of the operable unit included semiannual sampling at monitoring wells during December and June, with the intent of characterizing average seasonal conditions (December) and the spring period of high water-table elevations (June) that are caused by the spring runoff to the Columbia River (see Figures 2.12-5 and 2.12-6). Along the 300 Area shoreline, sampling and analysis at various sites and of various media are being conducted under several programs, with primarily annual sampling. Under CERCLA, near-river wells, shoreline aquifer tubes, and riverbank springs are sampled to provide data on the distribution and concentration trends of contaminants in groundwater near the point-of-discharge to the river ecosystem. Under the Public Safety and Resource Protection Program, an integrated effort involving the Surface Environmental Surveillance Project and the Ecological Monitoring and Compliance Project is producing additional data on contaminants at the groundwater/river interface. Media sampled include riverbed pore water and sediment, river water, and various aquatic biota. To date, clams have been shown to be good indicators of environmental health where uranium-contaminated groundwater discharges to the riverbed (PNNL-13692). Also during 2004, additional research on the interaction between groundwater and surface water at the 300 and 100-N Areas was initiated by the Remediation Science and Technology Project and continues for 2005. Finally, the 300 Area is included as part of the River Corridor Baseline Risk Assessment, which started in 2004.

In the 300-FF-5 North region, monitoring the tritium plume that extends downgradient of the 618-11 burial ground continued during FY 2004, primarily with quarterly sampling of wells used to define the plume. For wells closest to the burial ground, concentrations show a declining trend (see Section 2.12.1.6 and Figures 2.12-17 and 2.12-18). At other wells, changes in concentrations seem to reflect lateral spreading and gradual migration of the plume to the east. An updated characterization of this plume is being prepared to support the focused feasibility study for 300-FF-5, which is in progress during 2005, and also the 5-year review of the record of decision for the operable unit.

Monitoring results from two new wells do not reveal any evidence that a groundwater plume originates from the 618-10 burial ground.

At the 316-4/618-10 waste sites, monitoring frequency was increased during late FY 2004 to better detect changes associated with excavation of the 316-4 cribs. Remedial action associated with the cribs began near the end of FY 2004 with site preparation activities (actual excavation began in October 2004). A slight rise in uranium concentrations was observed at two nearby wells (Figure 2.12-11), which raised suspicions that contamination in the vadose zone was being remobilized. Near the 618-10 burial ground, an earlier soil-gas investigation around the perimeter fence was completed as part of planning for two new monitoring wells, 699-S6-E4K and 699-S6-E4L (PNNL-14320). Slightly elevated helium-3/helium-4 ratios were observed at several soil-gas sample sites and were attributed to tritium in the site-wide plume, whose leading edge is in this area. Subsequent sampling of the two new wells has not revealed any evidence for a groundwater plume whose origin is the burial ground. Water-quality conditions at those wells reflect the site-wide tritium plume from 200 East Area, which contains co-contaminants nitrate and iodine-129.

2.12.2.2 Interim Remedial Action Progress

The record of decision for the operable unit (ROD 1996b; EPA 2000) describes the selected interim action remedy as:

- Continued monitoring of groundwater that is contaminated above health-based levels to ensure that concentrations continue to decrease.
- Institutional controls to ensure that groundwater use is restricted to prevent unacceptable exposures to groundwater contamination.

Implementation of the interim remedy is described in the updated and expanded operations and maintenance plan (DOE/RL-95-73) and a sampling and analysis plan (DOE/RL-2002-11). Key elements of the remedy include (a) continued monitoring of groundwater to verify previously modeled predictions of contaminant attenuation, and (b) evaluating the need for active remedial measures. Continued monitoring involves sampling and analysis of groundwater collected from wells and shoreline sites, and also developing new information on (1) the recharge of mapped plumes because of release from the vadose zone and/or aquifer solids, (2) the characteristics of discharge from the aquifer to the Columbia River, and (3) dispersal of contaminants in the river environment via biota pathways. The intent of monitoring during the interim action period is to build a technical basis for including monitored natural attenuation as a component in a future record of decision, which may also involve active remedial measures.

As stated in the operations and maintenance plan's Executive Summary (DOE/RL-95-73), specific monitoring objectives include the following:

"1. Verify that natural attenuation reduces groundwater contamination concentrations to drinking water maximum contaminant levels over a reasonable time period.

2. Confirm that contaminant concentrations in the river seeps do not exceed ambient water-quality criteria or established remediation goals (drinking water standards).

3. Validate contaminant fate and transport conceptual models."

Dissemination of new information on achieving these objectives has been accomplished via monthly briefings at the 300 Area Unit Managers' Meetings. Minutes of these meetings are included in the U.S. Department of Energy's (DOE) Administrative Record for the 300-FF-5 Operable Unit. During FY 2005, additional reports are being prepared that describe in detail the natural processes that control the level of contamination in the operable unit.

Analytical results for samples of groundwater, surface water, sediment, and biota are stored in the Hanford Environmental Information System database (HEIS 1994). Groundwater data are summarized in an annual report (this document), while results for other media are described in an annual environmental report (e.g., PNNL-14687). Data and interpretations are also presented in topical reports as the need arises.

The CERCLA process includes a requirement to review the effectiveness of records of decision every 5 years, if contamination remains in the operable unit involved. The results of the first 5-year review (EPA 2001) indicated that the remedial actions at 300 Area source waste sites were proceeding in an effective manner to protect human health and the environment. EPA re-affirmed that the cleanup goals and remedy selection for groundwater are still appropriate at the time the first 5-year review was released. The next 5-year review will be conducted during 2005 and made available to the public by spring 2006.

During FY 2004, new work was started on computer simulation of the uranium plume and review of remedial action alternatives for uranium.

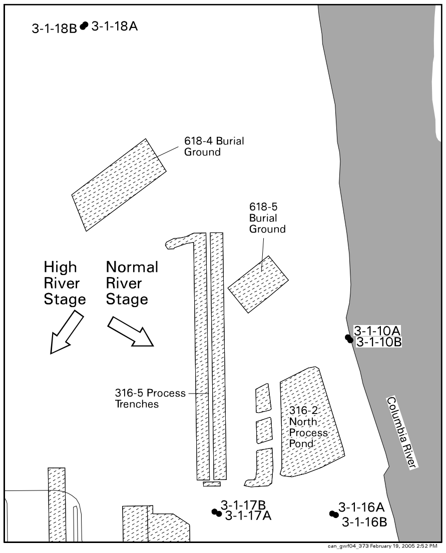
Numerous activities were initiated during FY 2004 to provide updated information on contamination in the subsurface at the 300 Area and outlying waste sites. These activities are part of extending the scope of the original remedial investigation (DOE/RL-94-85) to provide more information on what controls the persistence of the 300 Area uranium plume and how contaminant levels have changed during the 10 years since the original record of decision (ROD 1996b). Several projects were started to develop computer simulations for groundwater flow and contaminant transport in the 300 Area. An update to the original focused feasibility study for remedial action alternatives for groundwater was also started. Published reports containing the results of these investigations will become available during FY 2005.

The following is a brief status of how well the monitoring objectives for contaminants of concern are being met for the 300-FF-5 Operable Unit. Contaminants of concern for the 300 Area region, as identified in the record of decision (ROD 1996b), are uranium, trichloroethene, and cis-1,2-dichloroethene. Contaminants of concern for the 300-FF-5 North region, as identified in the explanation of significant differences (EPA 2000), are tritium at the 618-11 waste site and uranium and tributyl phosphate at the 316-4/618-10 waste sites.

1. Objective: "Verify that natural attenuation reduces groundwater contamination concentrations to drinking water maximum contaminant levels over a reasonable time period."
    - Since ~1998, uranium concentrations at many 300 Area monitoring wells have shown a declining trend, although not necessarily to the 30-µg/L standard or lower. Investigation of changes in the areal extent, contaminated volume, and mass of dissolved uranium are consistent with the interpretation of an overall declining level of contamination for recent years. Dispersion by groundwater flow and a reduction in the rate of uranium recharge from the vadose zone appear to have the largest effect on the level of contamination in the aquifer.
    - Uranium near the 316-4 waste site increased during 2004 to slightly exceed the drinking water standard; the cause of this trend is currently not known.
    - Volatile organic compounds in the 300 Area are generally present at concentrations below the drinking water standard. The exceptions are cis-1,2-dichloroethene at one well, which remains relatively constant at concentrations approximately twice the standard, with no apparent attenuation. Also, trichloroethane exceeds the standard at one well and one aquifer tube.
    - Volatile organic compounds at the 316-4 waste site remain undetected in groundwater, though significant concentrations are present in the vadose zone at the waste site, as revealed by sampling during excavation activities in fall 2004.
    - A tritium plume created by releases from the 618-11 burial ground has not changed shape appreciably or migrated a significant distance during the past year. Concentrations have decreased at wells nearest the source but remain well above the drinking water standard. Attenuation appears to be primarily controlled by radioactive decay.
2. Objective: "Confirm that contaminant concentrations in the river seeps do not exceed ambient water-quality criteria or established remediation goals (drinking water standards)."
    - Uranium concentrations remain above the drinking water standard at several riverbank spring locations. The gross alpha associated with this uranium also exceeds the 15-pCi/L drinking water standard. The maximum concentrations for trichloroethene are below the standard, and cis-1,2-dichloroethene was not detected in riverbank springs (PNNL-14687; fall 2003 results)
    - Groundwater contamination associated with the outlying waste sites (i.e., 300-FF-5 North region) has not been identified in riverbank springs.
3. Objective: "Validate contaminant fate and transport conceptual models."
    - Considerable effort has gone into developing groundwater flow and contaminant transport computer models for the aquifer beneath the 300 Area during FY 2004. Useable output from these models is expected to become available during early 2005 and will support the focused feasibility study for uranium remedial action options, as well as other objectives not related to the CERCLA program.
    - Research activities associated with the mobility of uranium have produced new information that will be incorporated into computer models for uranium transport. Although transport modeling will always include some degree of uncertainty caused by a lack of data on uranium inventory in the subsurface, the new flow and transport models should provide much better predictions for the future behavior of the uranium plume than those previously available (e.g., DOE/RL-94-85).

2.12.3 Facility Monitoring — 316-5 Process Trenches

This section describes results of monitoring groundwater at the 316-5 process trenches, a RCRA treatment, storage, or disposal unit in the Hanford Facility RCRA Permit (Ecology 1994a). This facility is monitored under the requirements of RCRA for hazardous waste constituents and *Atomic Energy Act of 1954* for radionuclides. Hazardous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for the facility. As discussed in Section 2.1, with respect to RCRA sites, DOE has the sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials at DOE-owned nuclear facilities.



The 300 Area process trenches received effluent discharges of dangerous mixed waste from fuel fabrication and nuclear research laboratories in the 300 Area from 1975 through 1994. Groundwater monitoring at the 300 Area process trenches is conducted in accordance with Washington Administrative Code (WAC) 173-303-645(11), Corrective Action Program, and Part VI, Chapter 1 of the Hanford Facility RCRA Permit (Ecology 1994a). The modified closure plan (DOE/RL-93-73), which is incorporated into the Hanford Facility RCRA Permit, indicates that groundwater remediation is deferred to the CERCLA 300-FF-5 Operable Unit.

During FY 2004, RCRA groundwater monitoring at the 300 Area process trenches was operated under an existing plan (WHC-SD-EN-AP-185) that has been in effect since 1997. Appendix B lists groundwater monitoring wells and constituents monitored for the 300 Area process trenches. Constituents monitored under RCRA are uranium, cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene. (Note: Uranium is not regulated under RCRA but was included in the monitoring plan for completeness and incorporated by reference into the Hanford Facility RCRA Permit [Ecology 1994b].) The characteristics in the groundwater flow affected by discharges to the 316-5 process trenches are discussed in Section 2.12.1. The sampling frequency at the eight wells of the monitoring network is monthly for eight months of the fiscal year (December, January, February, March, June, July, August, and September). This sampling schedule was designed to accommodate two semiannual sampling periods with four time-independent samples collected during each period. During FY 2004, the December 2003 samples were not collected from three wells (399-1-16A, 399-1-16B, and 399-1-18A) because sampling teams fell behind schedule. All other sampling events were accomplished as scheduled.

Only two of the contaminants of concern remain above drinking water standards, uranium and cis-1,2-dichloroethene.

Only two contaminants of concern for RCRA monitoring remain above the drinking water standards, uranium and cis-1,2-dichloroethene. Uranium concentrations in the well nearest the process trenches have decreased or remained constant during recent years (Figure 2.12-9). Farther downgradient along the flow path from the process trenches, concentrations increased, then decreased, suggesting the passage of higher concentrations created by high water-table conditions during high river stages of 1997 and 1998 (Figure 2.12-10).

Well 399-1-16B, a well installed a the base of the unconfined aquifer downgradient of the 300 Area process trenches, is the only network well having reported levels of cis-1,2-dichloroethene above the drinking water standard (70 μg/L). The concentration appears to be holding steady, neither significantly increasing or decreasing in concentration with time (Figure 2.12-12), although fluctuating between 100 and 200 μg/L. Other volatile organic compounds such as trichloroethene and tetrachloroethene continue to be detected in network wells at the 300 Area process trenches but generally at levels lower than drinking water standards, except for June samples at one well (399-1-7) (Section 2.12.1.2).

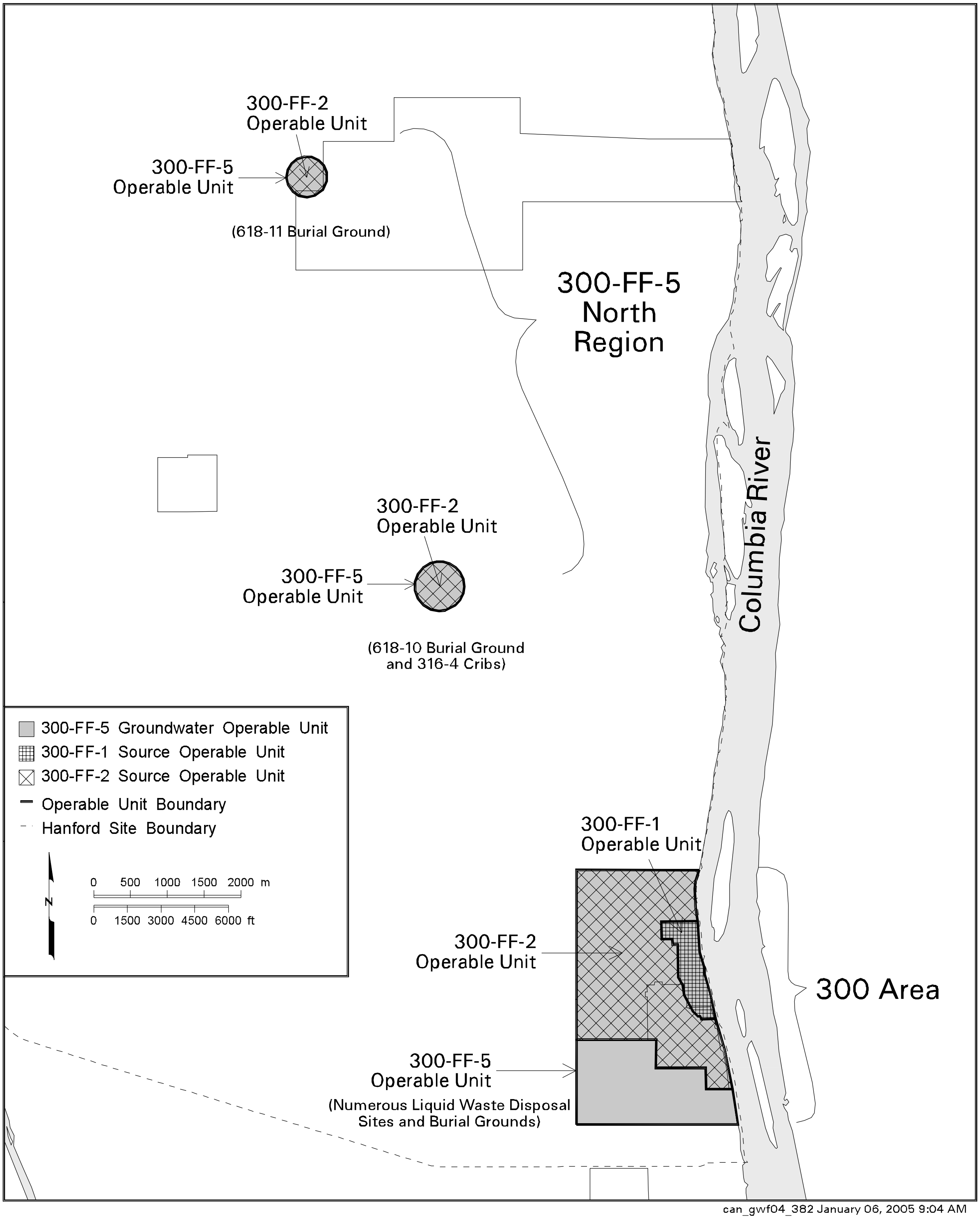


Figure 2.12-1. Geographical Subdivisions of the 300-FF-5 Operable Unit

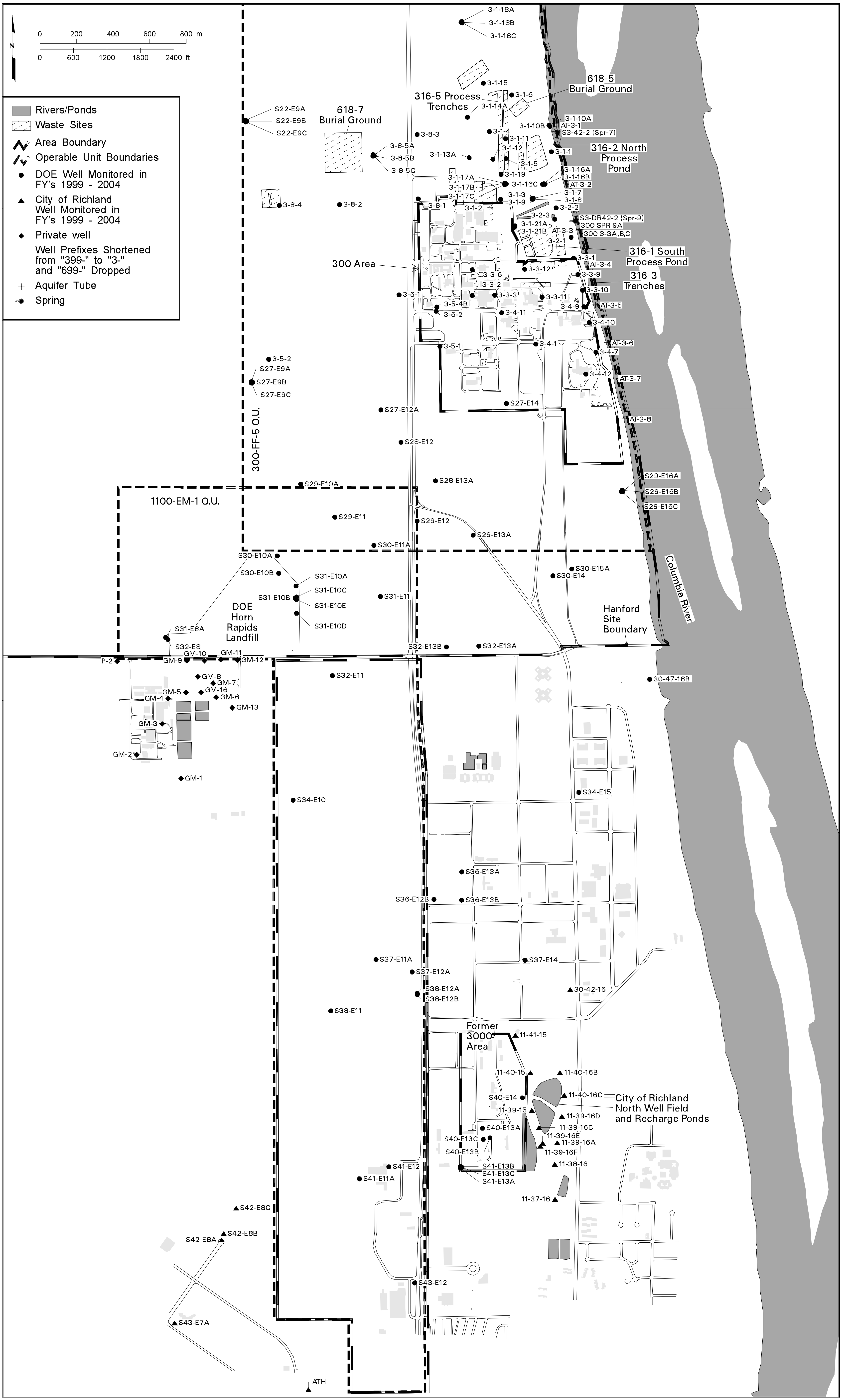


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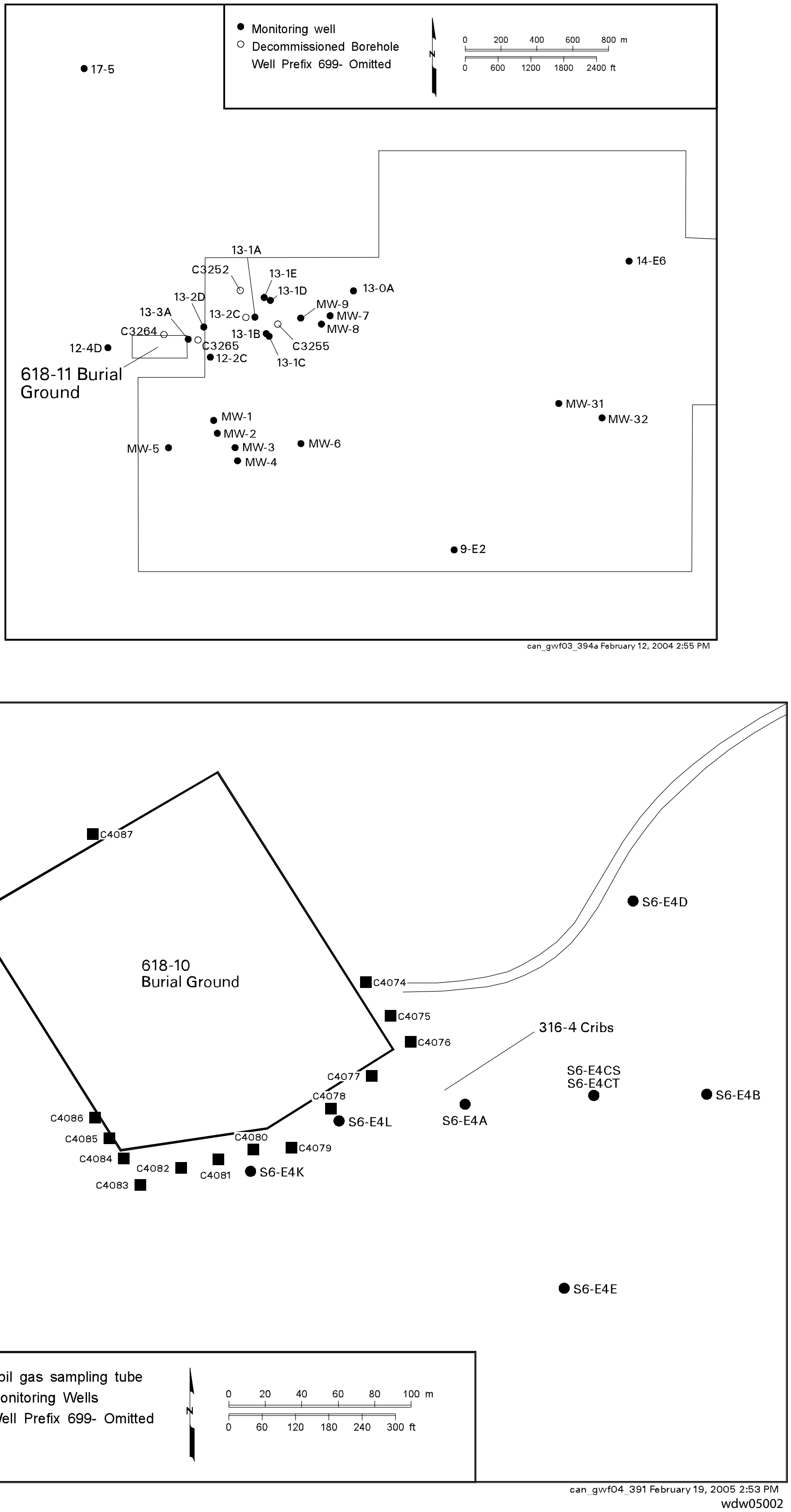
Figure 2.12-2. Groundwater Monitoring Wells in the 300 and 1100-EM-1 Areas



can_gwf03_394a February 12, 2004 2:55 PM

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Figure 2.12-3. Groundwater Monitoring Wells in the 300-FF-5 North Region

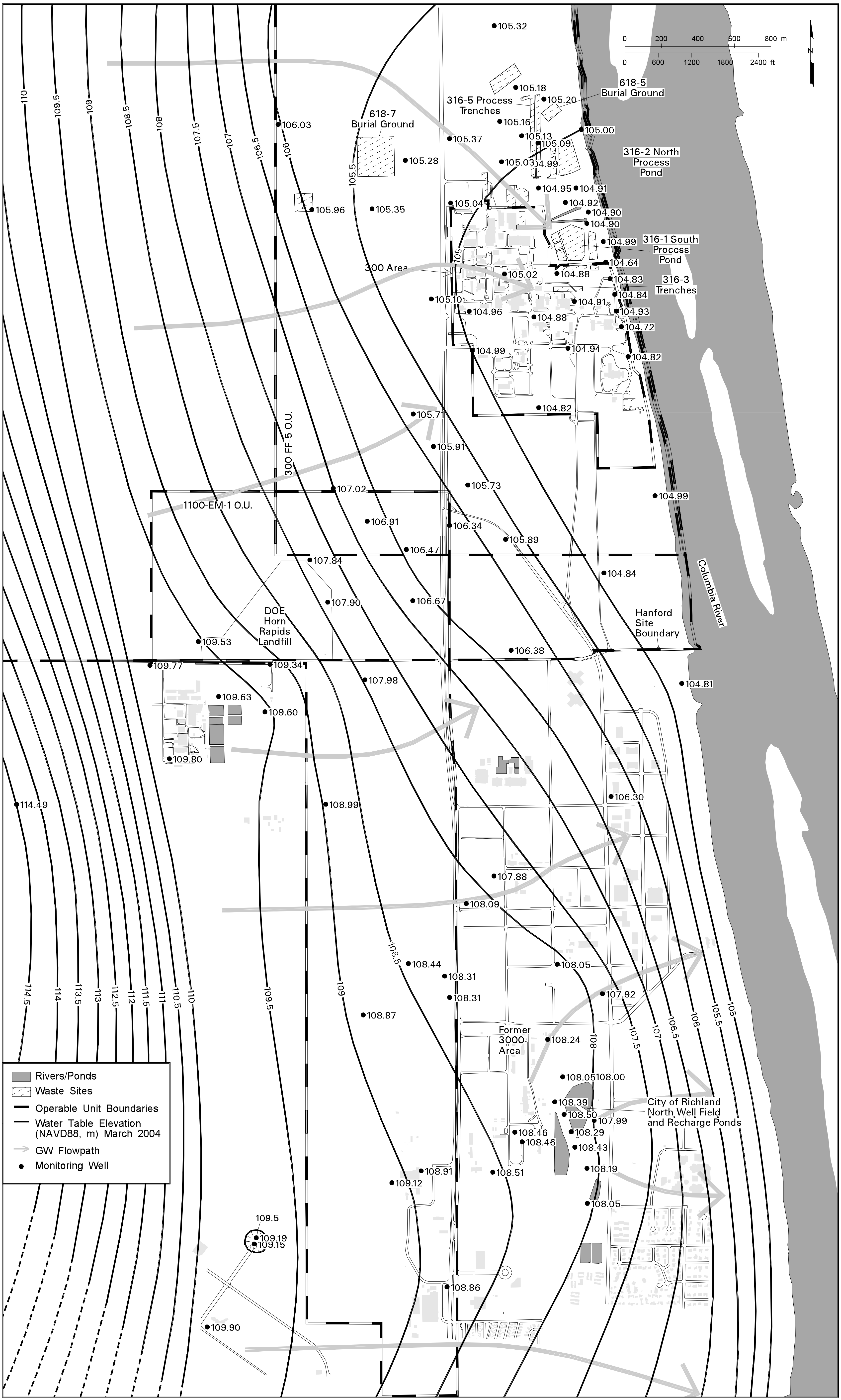

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Figure 2.12-4. Water-Table Map for the 300 and 1100-EM-1 Areas, March 2004

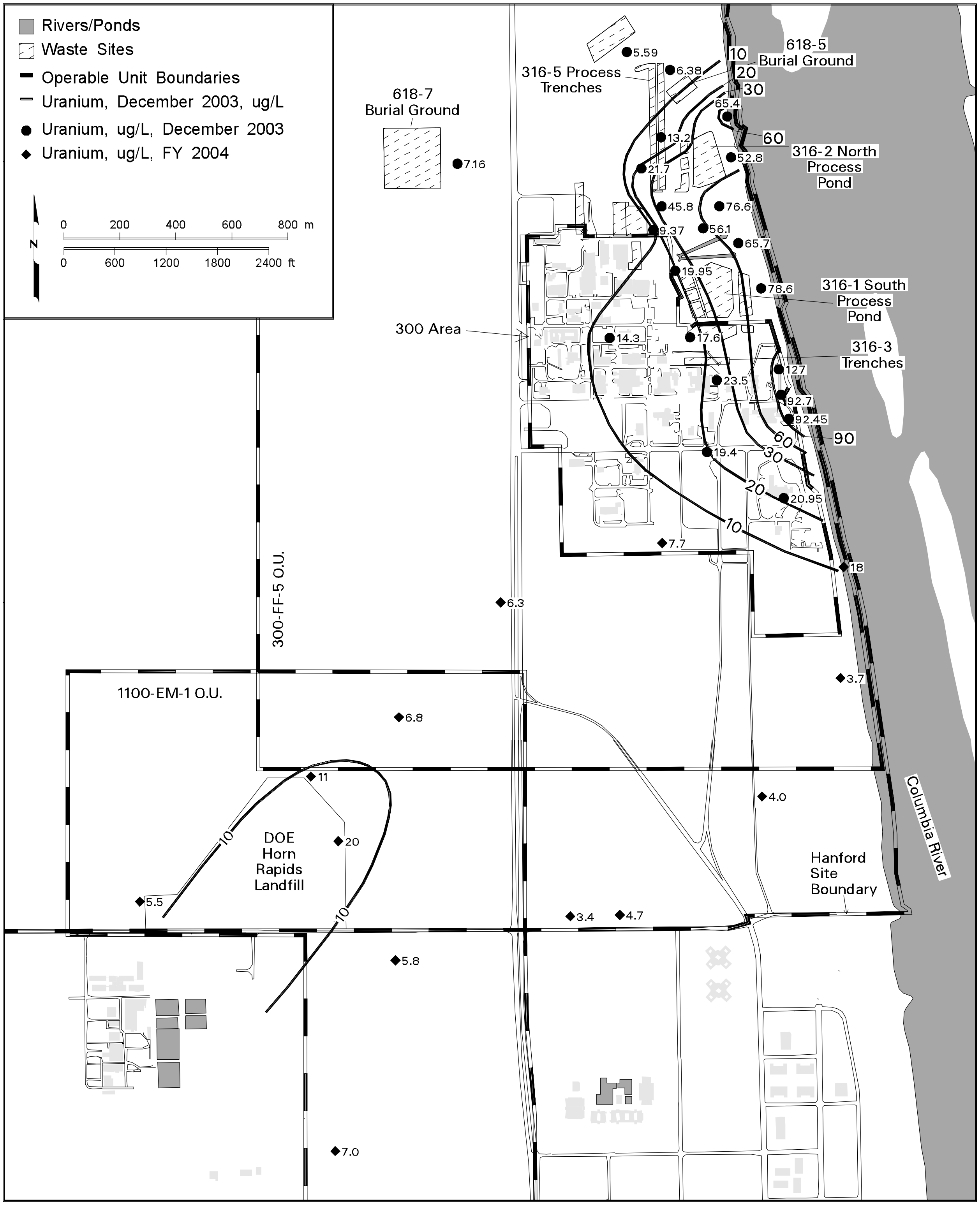

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Figure 2.12-5. Uranium Concentrations at Wells in the 300 Area, December 2003, Top of Unconfined Aquifer

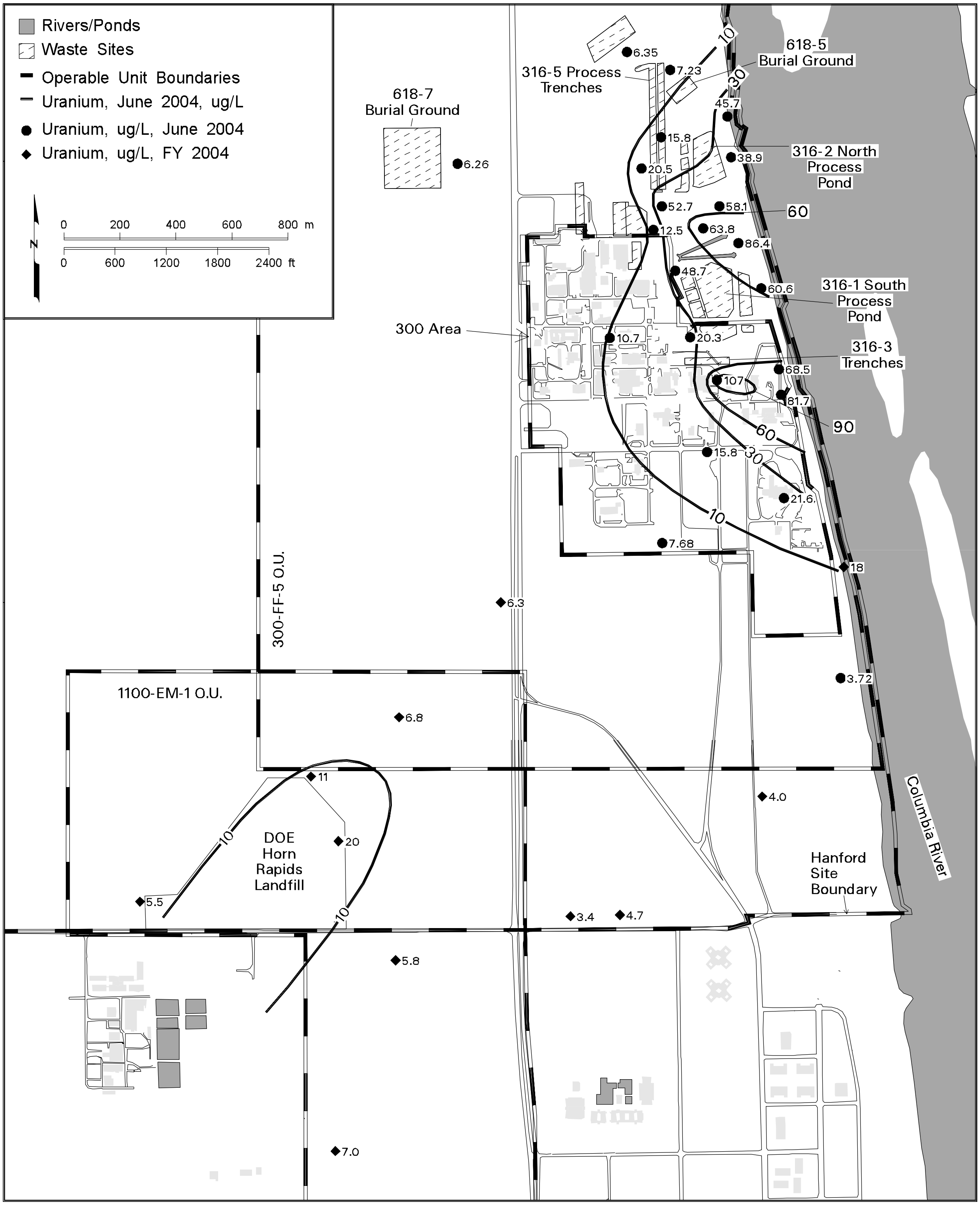

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Figure 2.12-6. Uranium Concentrations at Wells in the 300 Area, June 2004, Top of Unconfined Aquifer

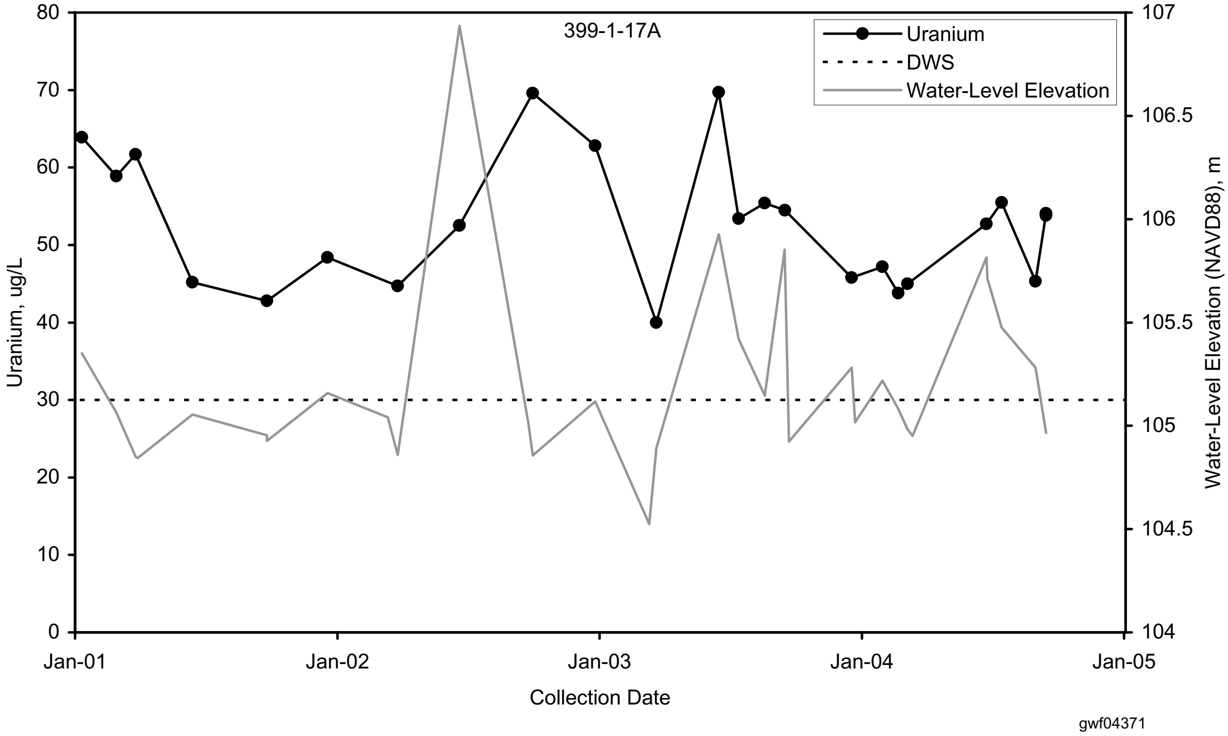

Figure 2.12-7. Uranium Concentrations in Well 399-1-17A Showing Positive Correlation with Rising Water-Table Elevations. This well location is far enough from the Columbia River to generally avoid mixing of groundwater and river water.

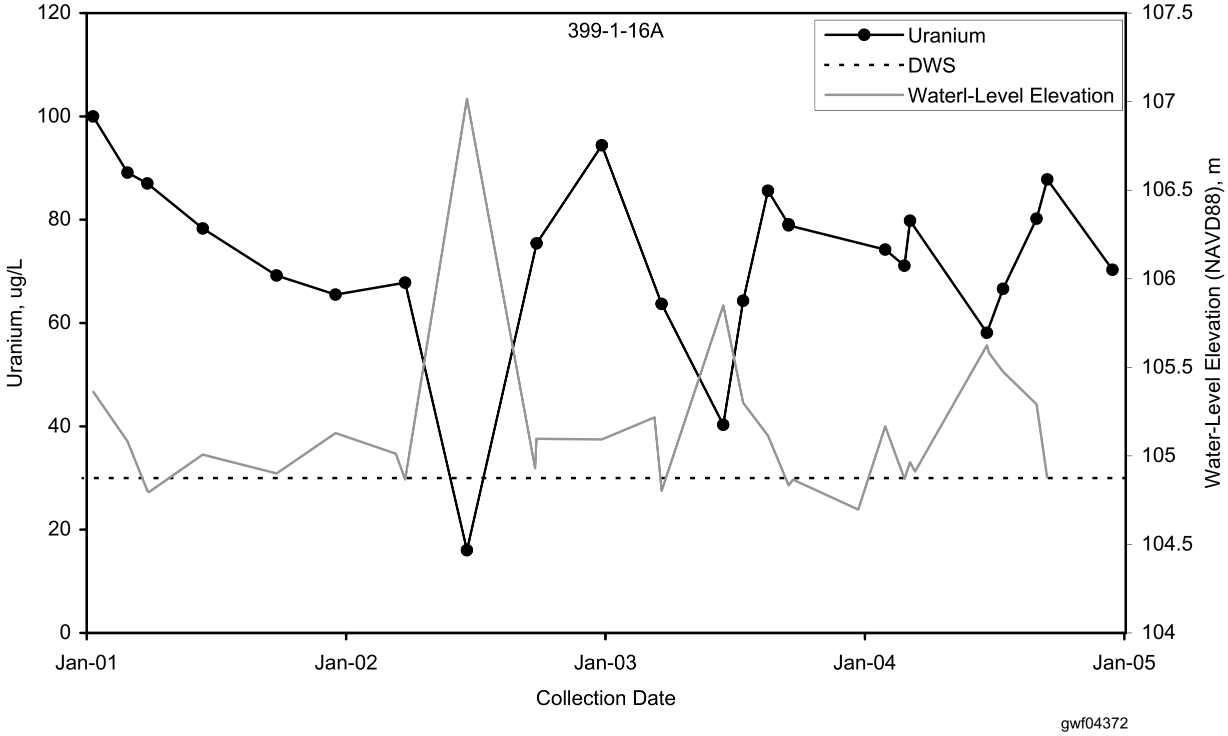

Figure 2.12-8. Uranium Concentrations in Well 399-1-16A Showing Positive Correlation with Rising Water-Table Elevations. This well location is close to the Columbia River and groundwater mixes with river water during high river stages (June).

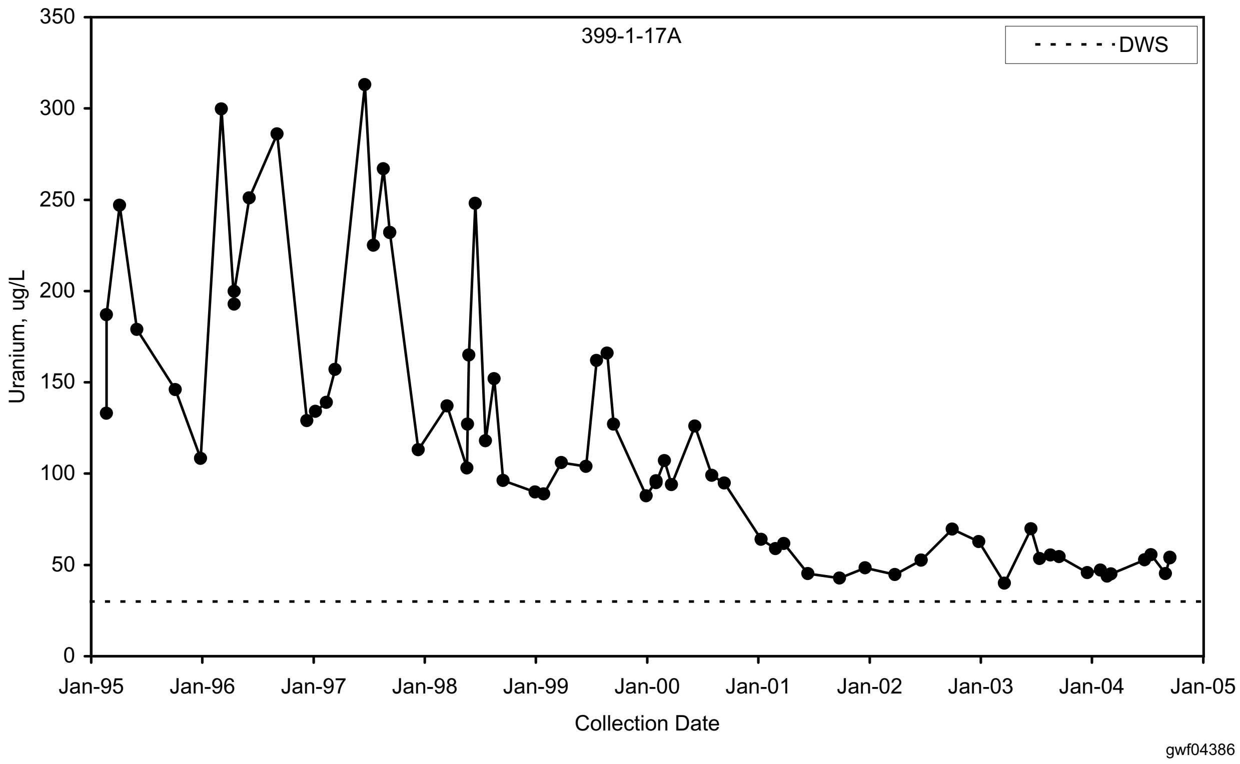

Figure 2.12-9. Uranium Concentrations at Well 399-1-17A Showing Long-Term Gradual Decline Since 1997

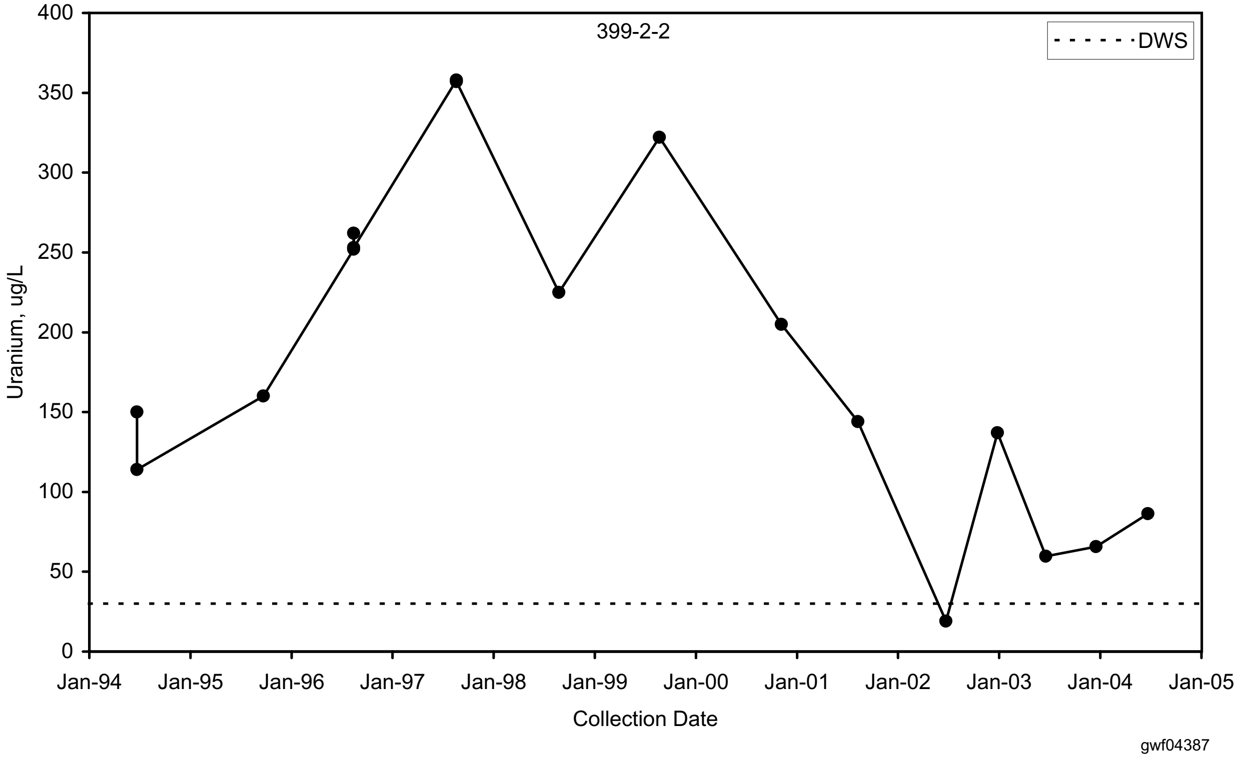

Figure 2.12-10. Uranium Concentrations at Well 399-2-2 Showing Increase and Decrease Since 1994

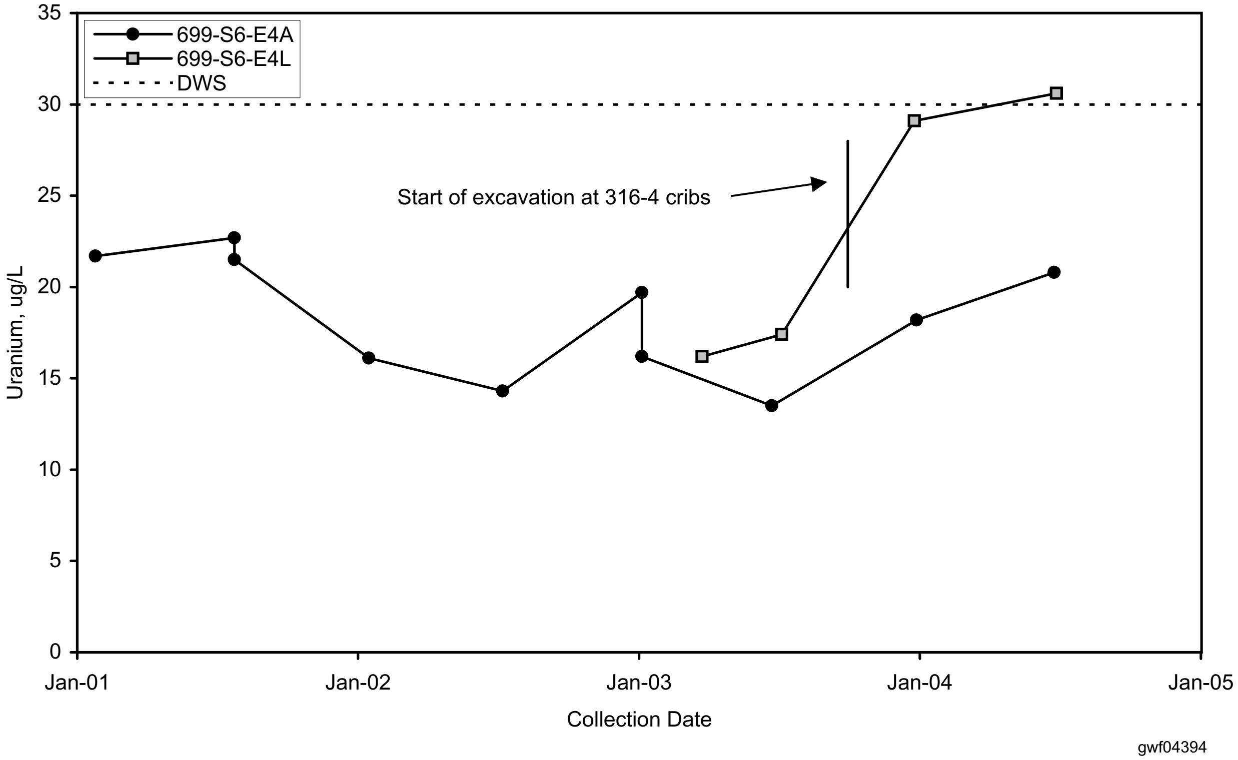

Figure 2.12-11. Uranium Concentrations at Wells Near the 316-4 Cribs Remedial Action Site

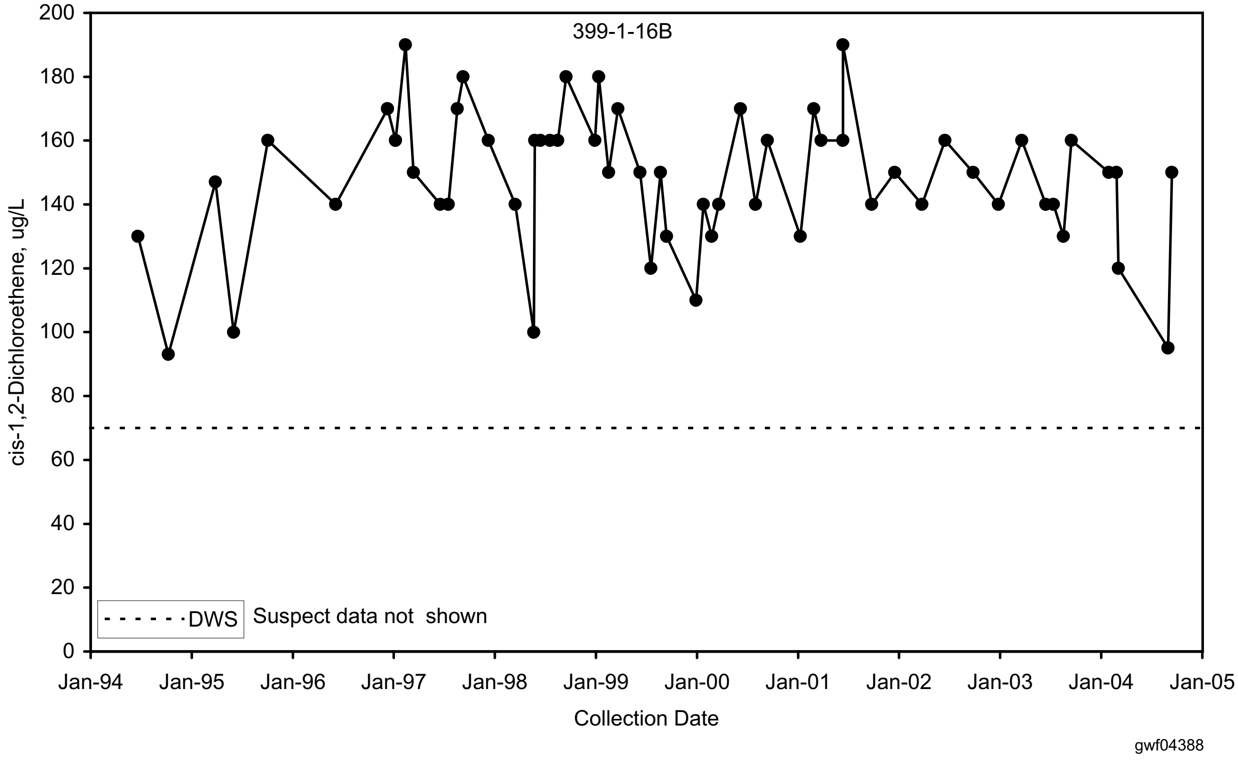

Figure 2.12-12. Concentrations of cis-1,2-Dichloroethene at Well 399-1-16B

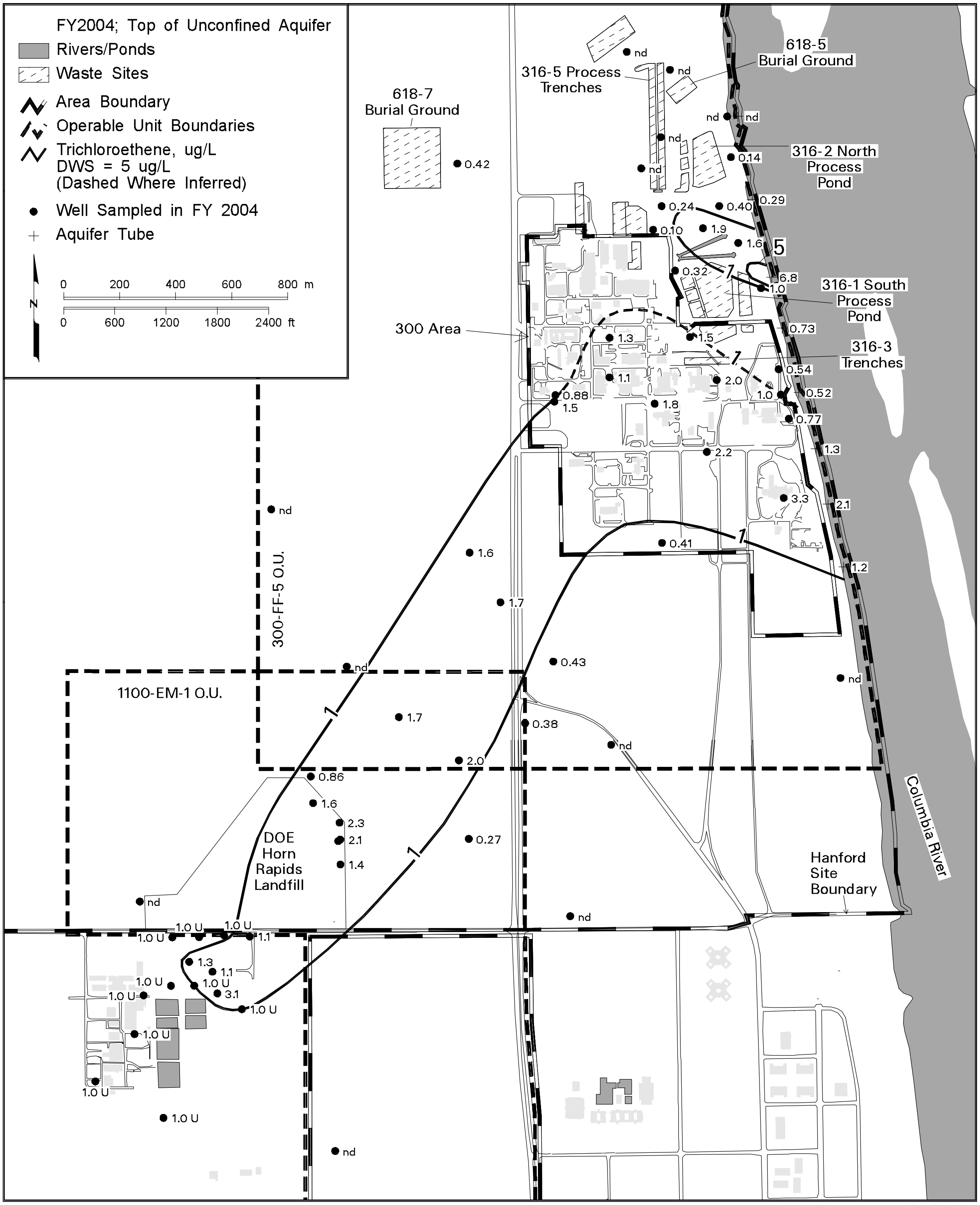

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Figure 2.12-13. Average Trichloroethene Concentrations in the 300 and 1100-EM-1 Areas, Top of Unconfined Aquifer

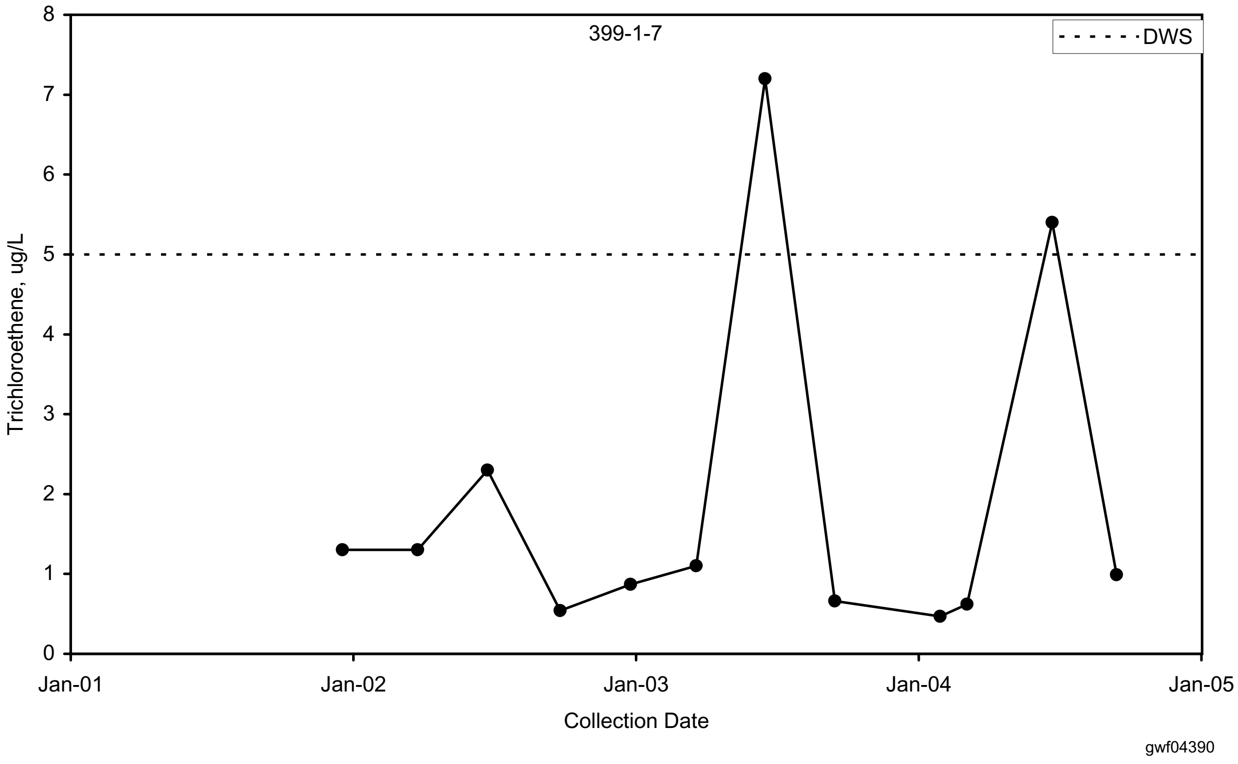

Figure 2.12-14. Trichloroethene Concentrations in Well 399-1-7

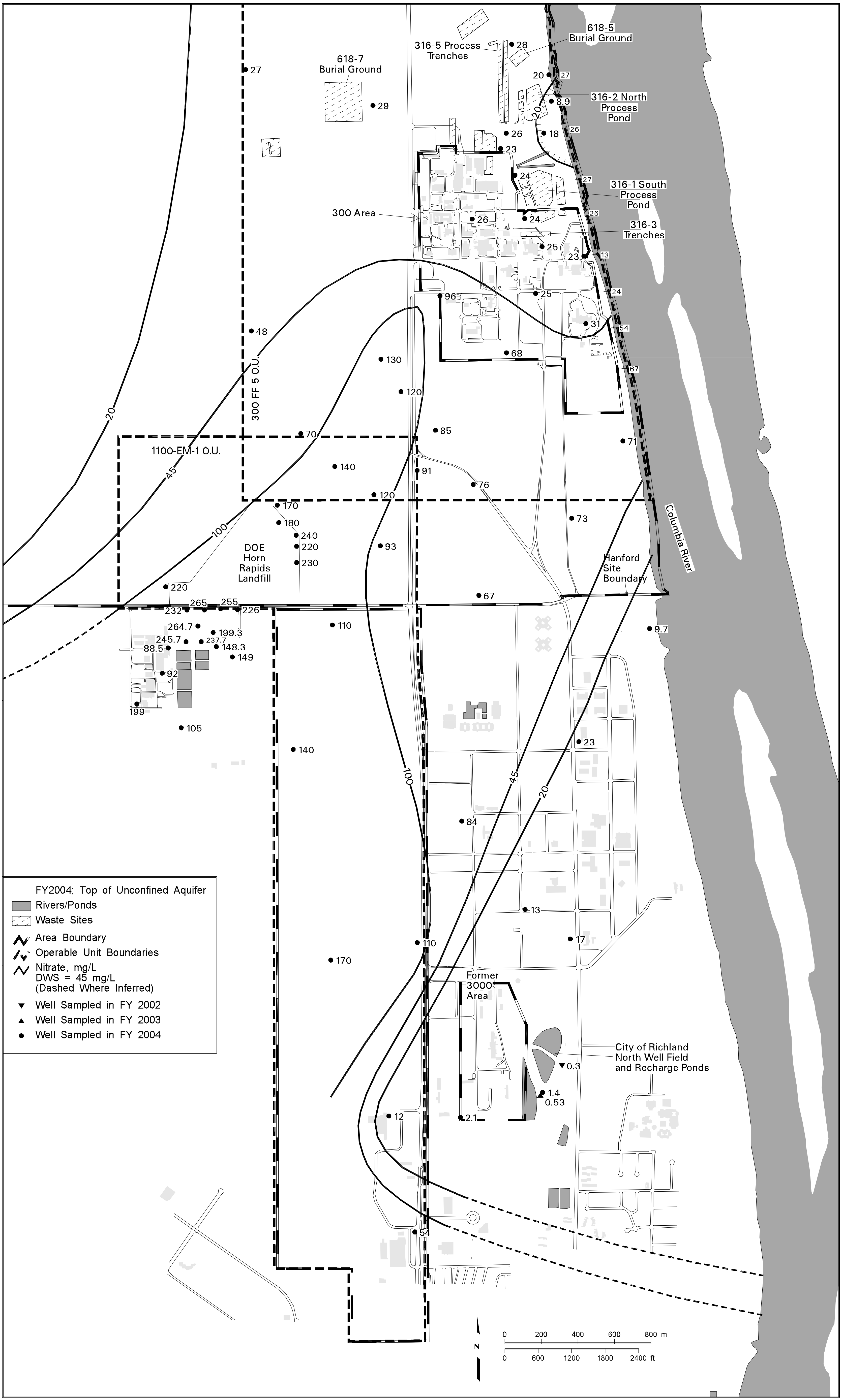

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Figure 2.12-15. Nitrate Concentrations in the 300 and 1100-EM-1 Areas

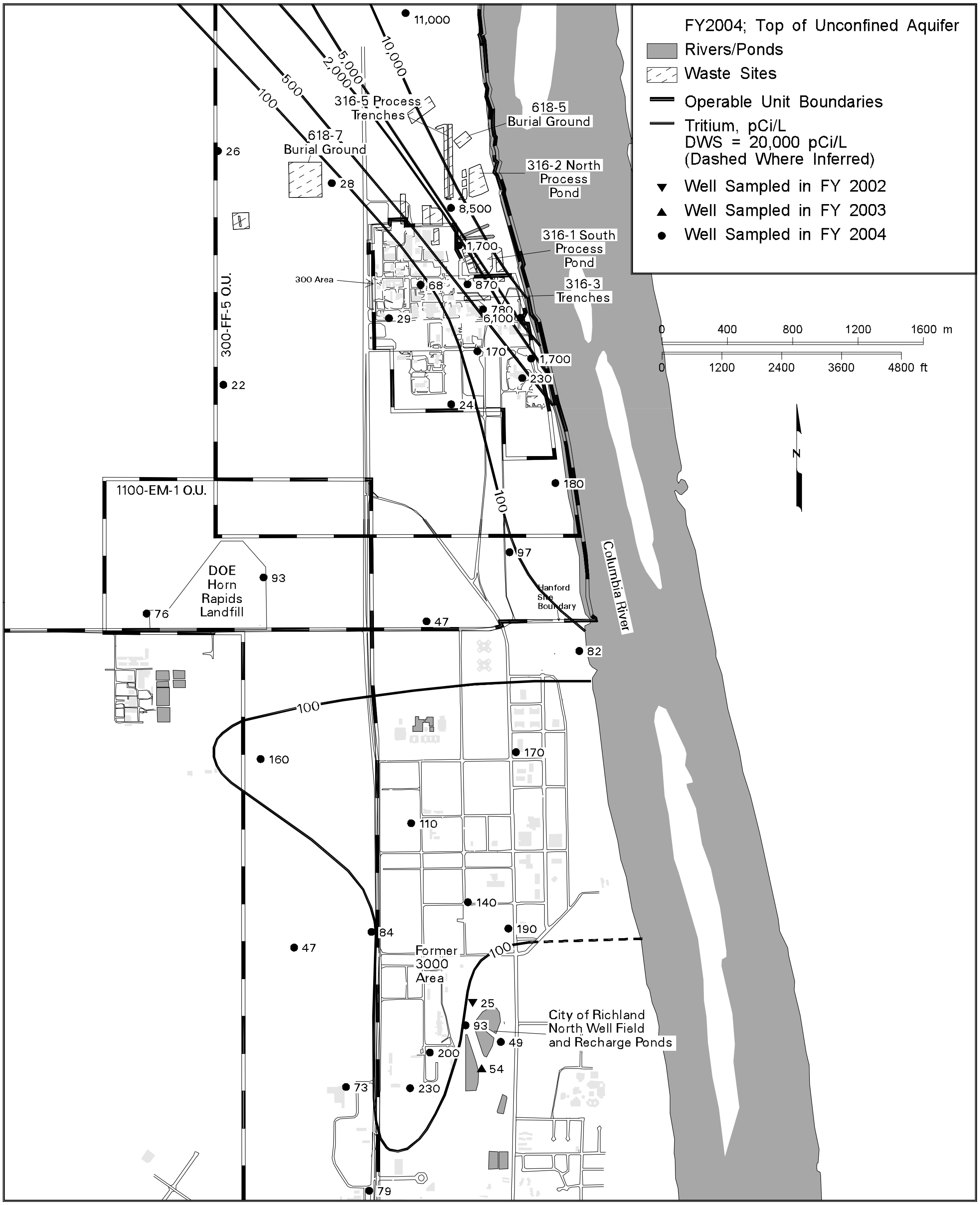

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Figure 2.12-16. Average Tritium Concentrations in Groundwater in the 300 and 1100-EM-1 Areas, Top of Unconfined Aquifer

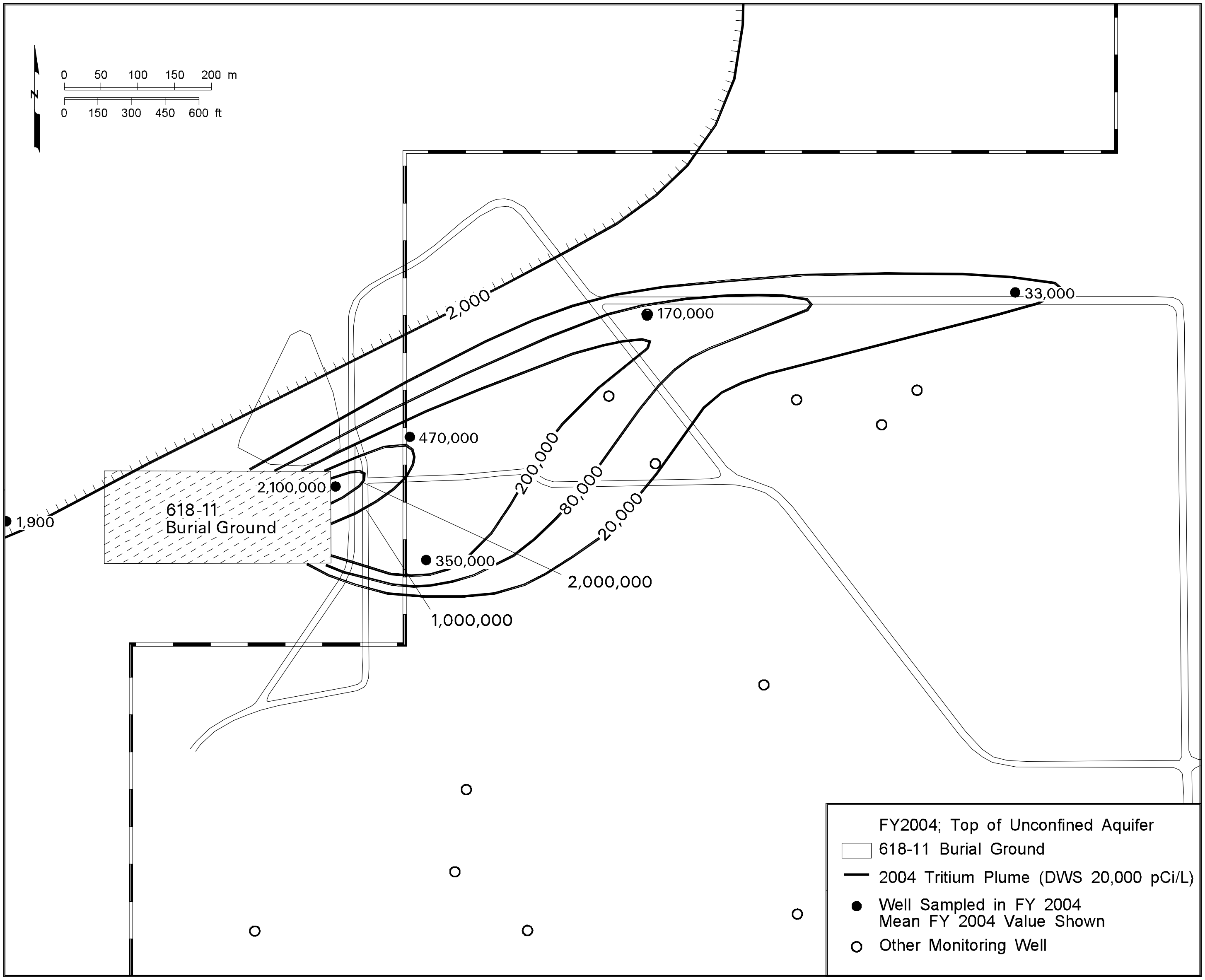

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Figure 2.12-17. Tritium Concentrations from the 618-11 Burial Ground, Top of Unconfined Aquifer (Distribution was partially defined by soil-gas data collected in previous years.)

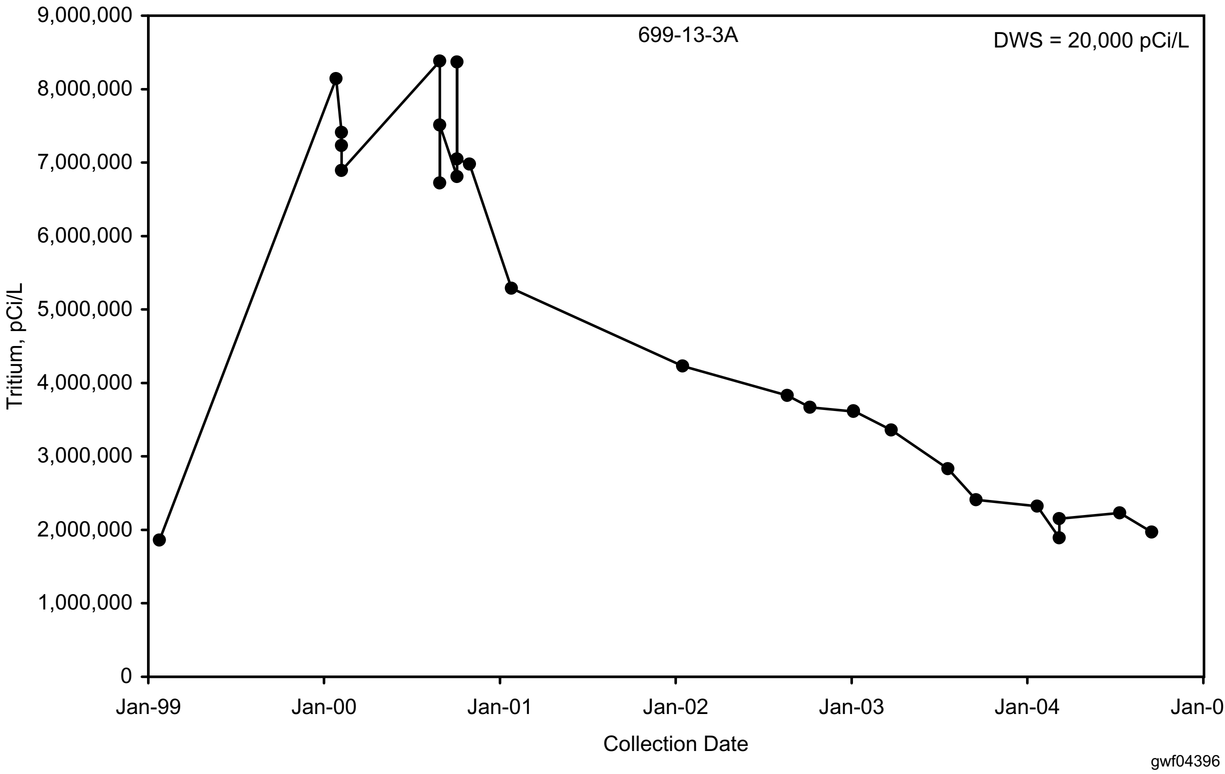

Figure 2.12-18. Tritium Concentrations at Well 699-13-3A Near 618-11 Burial Ground

2.13 1100-EM-1 Operable Unit

D. R. Newcomer

The scope of this section is the 1100-EM-1 groundwater interest area, which includes the 1100-EM-1 Operable Unit, a large portion of the south Hanford Site, and the offsite area to the south of the Hanford Site, including the former 1100 and 3000 Areas (see Figure 2.1-1 in Section 2.1). The Groundwater Performance Assessment Project (groundwater project) established the groundwater interest areas to aid planning, scheduling, and data interpretation. Figure 2.12-2 in Section 2.12 shows facilities, wells, and shoreline monitoring sites in this region. The focus of this section is the central and east portions of the 1100-EM-1 groundwater interest area near the south boundary of the Hanford Site. Trichloroethene and nitrate are the contaminants of greatest significance in groundwater. Groundwater is monitored to assess the performance of natural attenuation of volatile organic compounds. In addition to the trichloroethene plume, contaminants of concern include breakdown products of trichloroethene (vinyl chloride and 1,1-dichloroethene) and nitrate.

Trichloroethene and nitrate are the contaminants of greatest significance in groundwater at the 1100-EM-1 Operable Unit.

Figure 2.12-4 in Section 2.12 shows the March 2004 water-table elevations and corresponding groundwater flow directions for the east portion of the 1100-EM-1 groundwater interest area. Groundwater in the 1100-EM-1 groundwater interest area generally flows eastward from the Yakima River (see Figure 2.1-3 in Section 2.1) and discharges to the Columbia River. In the northeast part of the 1100-EM-1 groundwater interest area, groundwater flows northeast and converges with groundwater entering the 300 Area before discharging to the Columbia River. In the east-central part of the 1100-EM-1 groundwater interest area, groundwater flow from the west is diverted to the northeast and southeast around a recharge mound before discharging to the Columbia River.

2.13.1 Groundwater Contaminants

This section describes the distribution of groundwater contaminants in the 1100-EM-1 groundwater interest area. Groundwater contaminants discussed are chlorinated hydrocarbons (primarily trichloroethene), tritium, nitrate, uranium, ammonia, and fluoride.

2.13.1.1 Chlorinated Hydrocarbons

Trichloroethene contamination occurs in the 1100-EM-1 groundwater interest area beneath the U.S. Department of Energy's (DOE's) inactive Horn Rapids Landfill and offsite in AREVA (formerly Framatome ANP) wells (see Figure 2.12-13 in Section 2.12).

Groundwater monitoring in the 1100-EM-1 groundwater interest area includes the following monitoring activities:

CERCLA Monitoring

- ***Fourteen compliance wells are sampled annually for trichloroethene, breakdown products, and nitrate.***
- ***One well is sampled annually for filtered chromium.***
- ***In FY 2004, all 1100-EM-1 monitoring wells were sampled as scheduled (see Appendix A).***

AEA Monitoring

- ***Approximately forty wells are sampled annually and semiannually for tritium, volatile organic compounds, nitrate, and general chemistry.***
- ***Four wells are sampled quarterly for tritium.***
- ***A few isolated wells are sampled annually for uranium, gross alpha, gross beta, technetium-99, and ammonia.***

The distribution of trichloroethene in the upper part of the unconfined aquifer shows that the plume has an elongated configuration. This configuration indicates a northeast flow direction toward the 300 Area.

The average of quarterly trichloroethene sample concentrations continued to be <5 µg/L in all AREVA wells during the first three quarters of fiscal year (FY) 2004 (EMF-1865, Addenda 35 and 37). The maximum of these average trichloroethene concentrations of quarterly samples was 3.2 µg/L immediately downgradient of the process lagoons. The past use of solvent to install and maintain process lagoon liners at AREVA is the only potential source of trichloroethene identified in the eastern portion of the 1100-EM-1 groundwater interest area (DOE/RL-92-67).

Trichloroethene concentrations decreased to very low levels near DOE's Horn Rapids Landfill in FY 2004.

Trichloroethene concentrations have decreased in essentially all the plume areas near DOE's Horn Rapids Landfill. Trichloroethene concentrations decreased by more than an order of magnitude in this area since monitoring began in 1990 (Figure 2.13-1). In FY 2004, average trichloroethene concentrations were all <5 µg/L, ranging from less than detection to 2.3 µg/L downgradient of the landfill. The decreased concentrations in the majority of wells downgradient of DOE's Horn Rapids Landfill suggest that some elements of natural attenuation (e.g., volatilization, passive pumping) may have reduced the plume mass. For a discussion of trichloroethene in the 300 Area, see Section 2.12.1.2.

Potential breakdown products of trichloroethene, including vinyl chloride and 1,1-dichloroethene, continued to show levels less than their respective minimum detection limits during FY 2004.

The city of Richland monitors upper unconfined groundwater quarterly for chemical constituents at their Horn Rapids Sanitary Landfill (formerly Richland Landfill). The landfill is located in the central portion of the 1100-EM-1 groundwater interest area adjacent to the southern boundary of the Hanford Site (refer to Figure 2.1-2 in Section 2.1 for location). Chlorinated hydrocarbons were detected in city landfill monitoring wells between ~1 and 1.5 kilometers south of the Hanford Site boundary at levels above their respective drinking water standards during FY 2004 (City of Richland 2004a, 2004b, 2004c). The highest average concentrations for FY 2004 were 32.1 µg/L 1,1-dichloroethane, 65.1 µg/L cis-1,2-dichloroethene, 65.6 µg/L tetrachloroethene, and 26.9 µg/L trichloroethene. During FY 2004, these constituents were found to be below their respective minimum detection limits at onsite well 699-S31-1 just northeast of the city's sanitary landfill.

A confined aquifer in the Ringold Formation is monitored for trichloroethene downgradient of the landfill. This confined aquifer lies below a clayey silt aquitard, but above the basalt surface, at a depth of ~18 to 21 meters below the water table. Trichloroethene has not been detected in this confined aquifer since monitoring began in 1991, which suggests that the trichloroethene plume in the unconfined aquifer did not migrate downward into the underlying confined aquifer.

2.13.1.2 Tritium

The 200 Area tritium plume extends southward toward the 1100-EM-1 groundwater interest area at levels below 2,000 pCi/L. Tritium continues to be closely monitored because of its potential impact to the city of Richland's North Well Field (see Figure 2.12-16 in Section 2.12). South of the 300 Area, tritium levels were slightly elevated above background in wells west and north of the city of Richland's North Well Field during FY 2004. The background geometric mean tritium concentration in the upper part of the unconfined aquifer was determined to be 63.9 pCi/L (DOE/RL-96-61). The average tritium concentration from monthly Columbia River samples collected at the Richland Pumphouse was 56.8 pCi/L during FY 2004. However, these levels are far below the drinking water standard (20,000 pCi/L). Trends in tritium concentrations in wells west and north of the city of Richland's North Well Field have consistently shown fluctuating levels in the last few years, as shown in Figure 2.13-2.

Plume areas (square kilometers) above the drinking water standard at the 1100-EM-1 Operable Unit:

****Nitrate — 4.10***

****Also includes portion of plume beneath 300-FF-5 Operable Unit.***

Tritium is not migrating in groundwater from the 200 Areas tritium plume to the well field. Several factors limit the migration of the tritium plume into the east portion of the 1100-EM-1 groundwater interest area:

- Groundwater generally flows from west to east between the Yakima River and the Columbia River.
- Artificial recharge from agricultural irrigation in the west and central portions of the 1100-EM-1 groundwater interest area south of the Hanford Site contributes to the eastward flow.
- Groundwater flow is directed outward from the elevated groundwater levels at the city of Richland's North Well Field recharge ponds.

These factors produce converging flow lines in the 300 Area and discharge to the Columbia River (see Figure 2.12-4 in Section 2.12). Figure 2.12-16 in Section 2.12 shows a region of low tritium concentrations between the 200 Areas tritium plume and the slightly elevated tritium concentrations near the North Richland Well Field and recharge ponds. Thus, there is no indication that the tritium plume is migrating southward and affecting the well field. Tritium in the 300 Area is discussed in Section 2.12.

Monitoring data show that the Richland North Well Field is not contaminated by the Hanford Site tritium plume through the groundwater flow system.

2.13.1.3 Nitrate

The nitrate distribution in the east portion of the 1100-EM-1 groundwater interest area is shown in Figure 2.12-15 in Section 2.12. Nitrate contamination in this area is likely the result of industrial and agricultural uses off the Hanford Site. Agricultural uses include application of fertilizers onto irrigation circles in the central portion of the 1100-EM-1 groundwater interest area (see Figure 2.12-2 in Section 2.12).

Concentrations above the drinking water standard (45 mg/L) are found over much of the east portion of the 1100-EM-1 groundwater interest area and continued to increase in a number of wells in FY 2004 (Figure 2.13-3). Some of the highest nitrate levels occur near an offsite industrial facility (AREVA) and DOE's inactive Horn Rapids Landfill. Elevated nitrate near these areas is likely the result of agricultural activities to the west and southwest. Another potential source of nitrate is the ConAgra (Lamb Weston) facility located southwest of the 1100-EM-1 groundwater interest area. An example of elevated nitrate concentrations showing an increasing trend continues to occur along the west edge of DOE's Horn Rapids Landfill immediately north of the industrial facility (well 699-S31-E8A in Figure 2.13-3). The highest nitrate concentration in this area was 265 mg/L immediately downgradient of the AREVA facility. Nitrate data for the offsite wells are reported in EMF-1865, Addenda 35 and 37. Nitrate concentrations continued to be elevated in wells downgradient of DOE's inactive Horn Rapids Landfill in FY 2004. The highest average nitrate concentration in this area was 239 mg/L. The shape of the plume (as defined by the 100-mg/L contour) near the AREVA facility and DOE's inactive Horn Rapids Landfill indicates that nitrate in these areas continues to migrate in a northeast direction toward the 300 Area. Groundwater and aquifer tube sample data, shown in Figure 2.12-15 in Section 2.12, indicates that groundwater with nitrate levels above the drinking water standard discharges to the Columbia River immediately south of the 300 Area.

Nitrate contamination in groundwater is the result of industrial and agricultural uses off the Hanford Site.

The nitrate plume map indicates that the eastward migration of nitrate is being diverted around the groundwater mound that is in the vicinity of the recharge ponds (see Figure 2.12-15 in Section 2.12). Nitrate levels in wells at the well field continued to be lower than ambient groundwater, a result of recharge from infiltration of river water at the recharge ponds.

2.13.1.4 Gross Alpha and Uranium

Elevated levels of gross alpha and uranium occur downgradient of an offsite industrial facility (AREVA) near DOE's inactive Horn Rapids Landfill. The highest gross alpha level was an average of 101 pCi/L immediately downgradient of this facility during FY 2004 (EMF-1865, Addenda 35 and 37). Most of the wells downgradient of the AREVA facility showed average gross alpha levels that were above the drinking water standard (15 pCi/L), which excludes uranium. However, it is probable that the gross alpha levels are largely attributed to uranium because of industrial uses offsite. If gross alpha is attributed to uranium with natural isotopic abundances, then 101 pCi/L gross alpha is equivalent to ~146 µg/L uranium, which is above the drinking water standard (30 µg/L) for uranium.

The distribution of uranium near DOE's inactive Horn Rapids Landfill is shown in Figure 2.12-5 in Section 2.12. The map shows a small plume of uranium with levels less than the drinking water standard (30 µg/L) near the landfill. Uranium concentrations in wells downgradient of the landfill increased between FY 2003 and 2004. Uranium concentrations ranged up to 19.6 µg/L, with the highest concentration immediately downgradient of DOE's Horn Rapids Landfill (Figure 2.13-4). At this time, the landfill is not considered a source of the uranium contamination in groundwater because no uranium sources exist in the landfill. The shape of the uranium contours suggests a uranium source off the Hanford Site.

Uranium contamination is present near DOE's inactive Horn Rapids Landfill, but the source is located offsite.

2.13.1.5 Other Constituents

Ammonia, fluoride, and gross beta are found at low levels in wells near an offsite industrial facility (AREVA).

Ammonia – Concentrations of ammonia in the AREVA facility wells generally remained steady in FY 2004 (EMF-1865, Addenda 35 and 37). The highest average concentration detected was 12.4 mg/L (as NH_3) in well SPC-GM-8. Ammonia is typically absorbed by plants and soil microorganisms or is taken up as an exchangeable ion on soil particles (Hausenbuiller 1972). However, ammonia is usually less stable than nitrate in a biological system like the soil medium and is rapidly converted to nitrate. Ammonia was detected in several wells downgradient of the AREVA facility in FY 2004. The fact that ammonia is found in the groundwater suggests that relatively high concentrations reached the soil column.

Fluoride – One well downgradient of AREVA showed a fluoride concentration above the drinking water standard (4 mg/L) in FY 2004 (EMF-1865, Addenda 35 and 37). The highest average concentration was 4.2 mg/L in well SPC-GM-4. Fluoride contamination is most likely the result of past processing at the AREVA facility. Average fluoride concentrations in onsite wells for this area continued to be <1 mg/L.

Gross Beta – Gross beta continued to be detected in wells downgradient of AREVA during FY 2004 (EMF-1865, Addenda 35 and 37). The highest average gross beta measurement in FY 2004 was 38.5 pCi/L in well SPC-GM-8. Low levels of technetium-99, detected near DOE's inactive Horn Rapids Landfill, may be related to the gross beta measurements.

2.13.2 Operable Unit Monitoring

The 1100-EM-1 Operable Unit contains DOE's inactive Horn Rapids Landfill. Results of the *Comprehensive Environmental Response, Compensation, and Liability Act* investigation for this operable unit are presented in the final remedy investigation study (DOE/RL-92-67) and the record of decision (ROD 1993). The selected remedy for 1100-EM-1 Operable Unit groundwater is monitored natural attenuation of volatile organic compounds, with institutional controls on drilling of new water supply wells. The monitoring objective was to continue groundwater monitoring of wells downgradient of the DOE's Horn Rapids Landfill during a period of 5 years (DOE/RL-95-50; PNNL-12220). The U.S. Environmental Protection Agency conducted a 5-year

The remedial action objectives for the 1100-EM-1 Operable Unit (ROD 1993) are:

- ***Attain concentration of <5 µg/L trichloroethene at designated point of compliance.***
- ***Protect environmental receptors in surface waters by reducing groundwater contaminant concentrations in the plume.***

review in 2001, and no groundwater monitoring changes were required at the DOE's Horn Rapids Landfill (EPA 2001). The reporting requirements for the 1100-EM-1 Operable Unit are addressed by this report.

All wells in the 1100-EM-1 network were sampled as scheduled in FY 2004. A list of required wells and constituents are provided in Appendix A. Monitoring includes analysis for trichloroethene, its breakdown products (e.g., vinyl chloride and 1,1-dichloroethene), and nitrate in wells downgradient of DOE's inactive Horn Rapids Landfill. The FY 2004 results for these analyses are discussed in Sections 2.13.1.1 (chlorinated hydrocarbons) and 2.13.1.3 (nitrate). A secondary objective was to sample chromium in one well downgradient of the 1171 Building. Filtered chromium was not detected in this well in FY 2004.

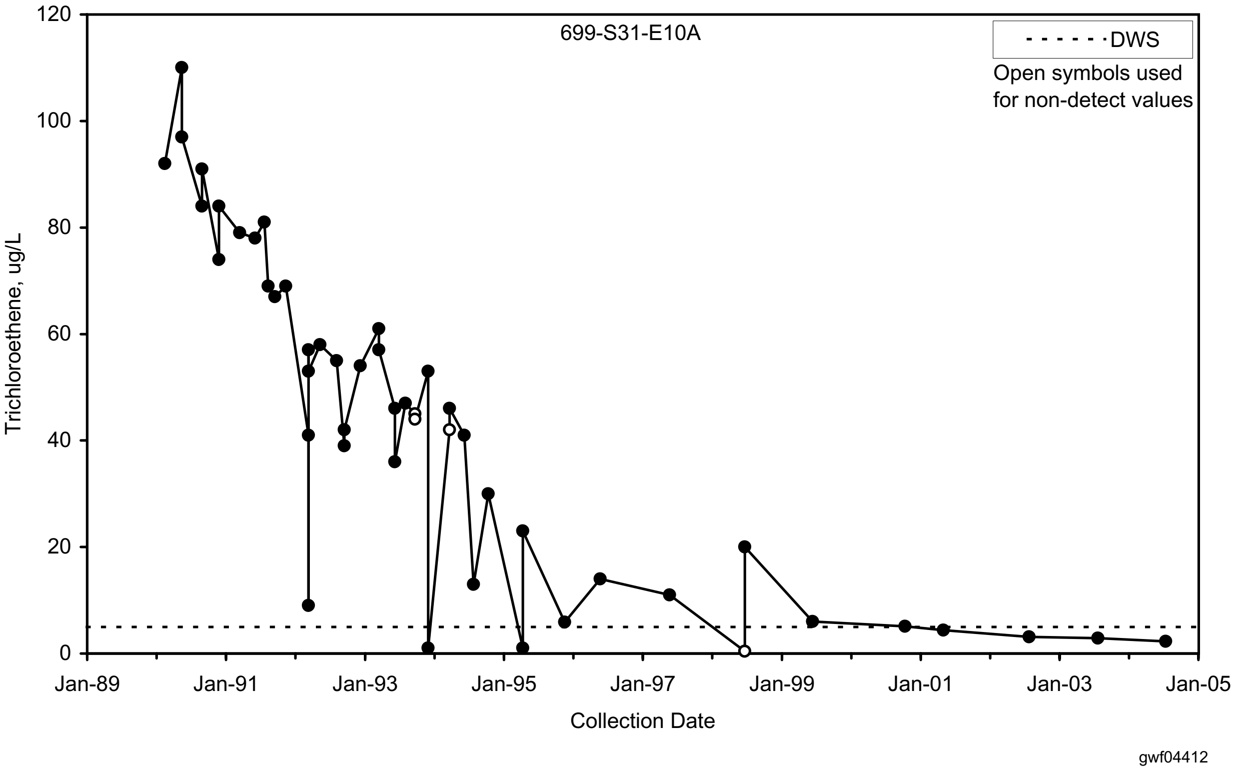

Figure 2.13-1. Trichloroethene Concentrations Near the U.S. Department of Energy's Inactive Horn Rapids Landfill

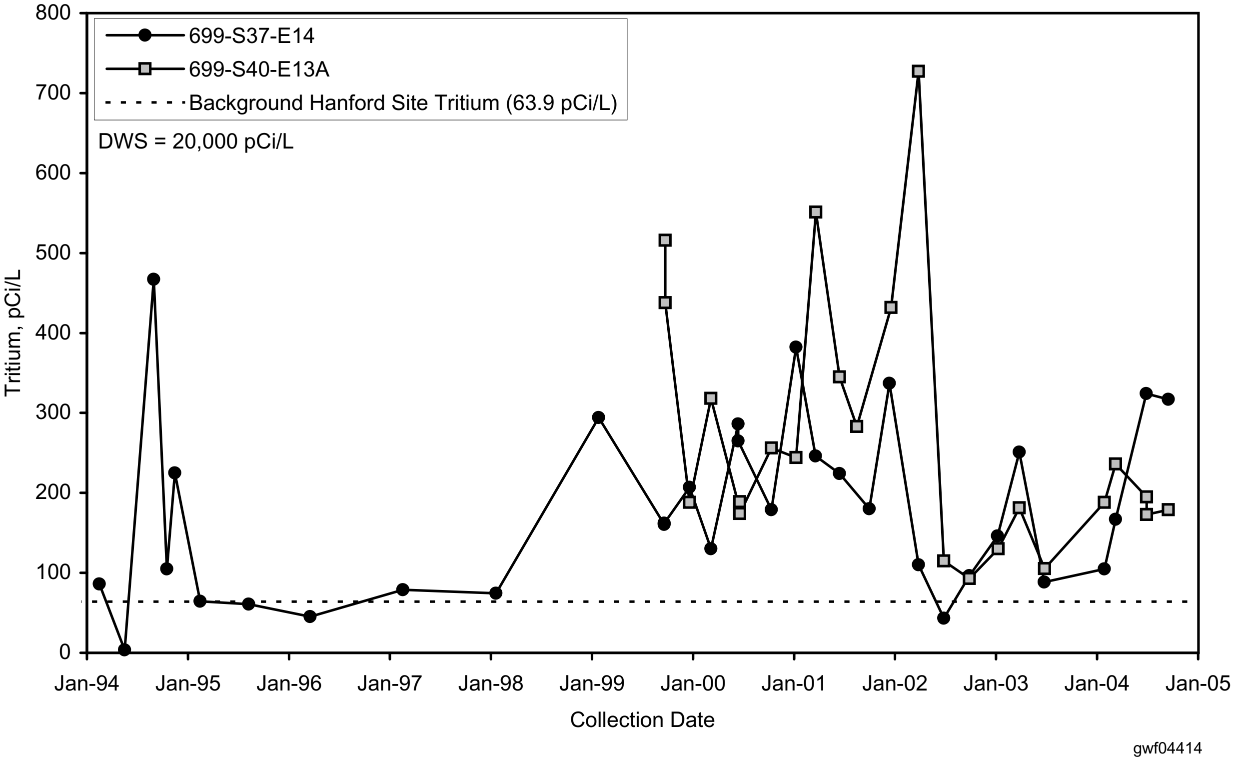

Figure 2.13-2. Tritium Concentrations in Wells Monitoring the 1100-EM-1 Groundwater Interest Area

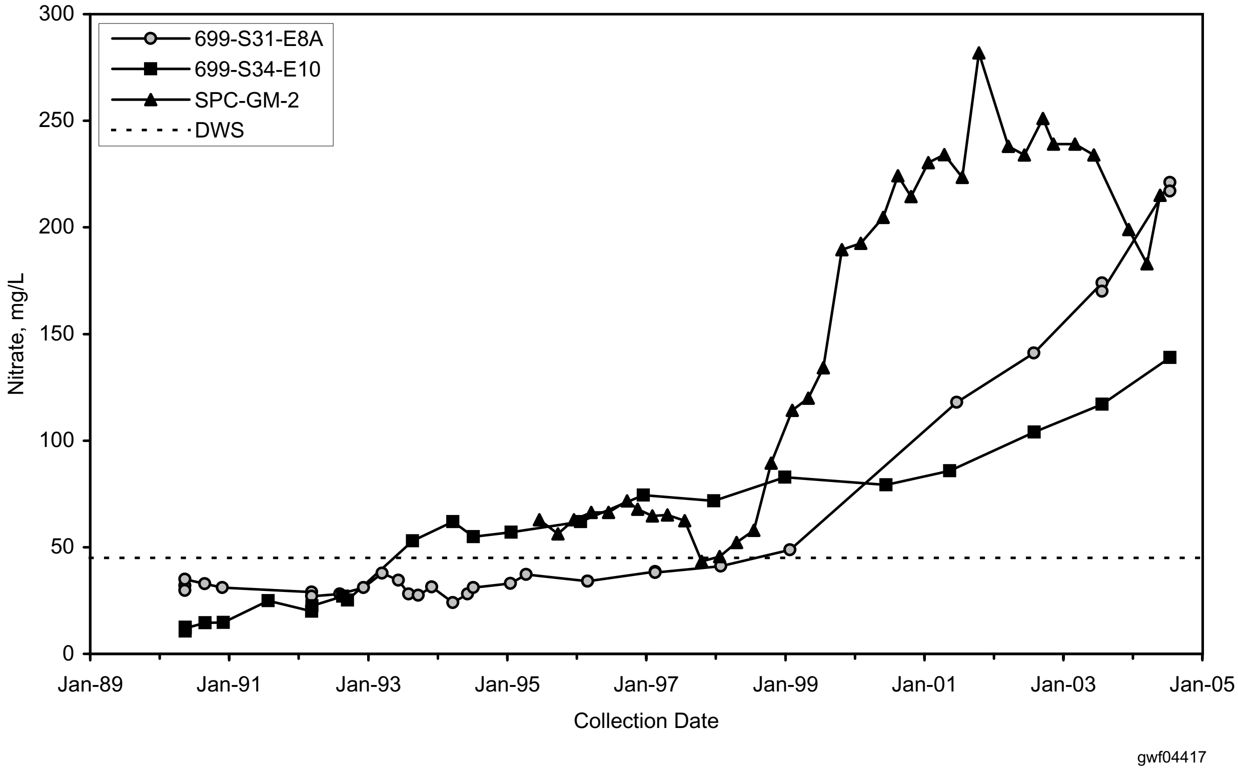

Figure 2.13-3. Nitrate Concentrations in Wells Monitoring the 1100-EM-1 Groundwater Interest Area (data for well SPC-GM-2 taken from EMF-1865)

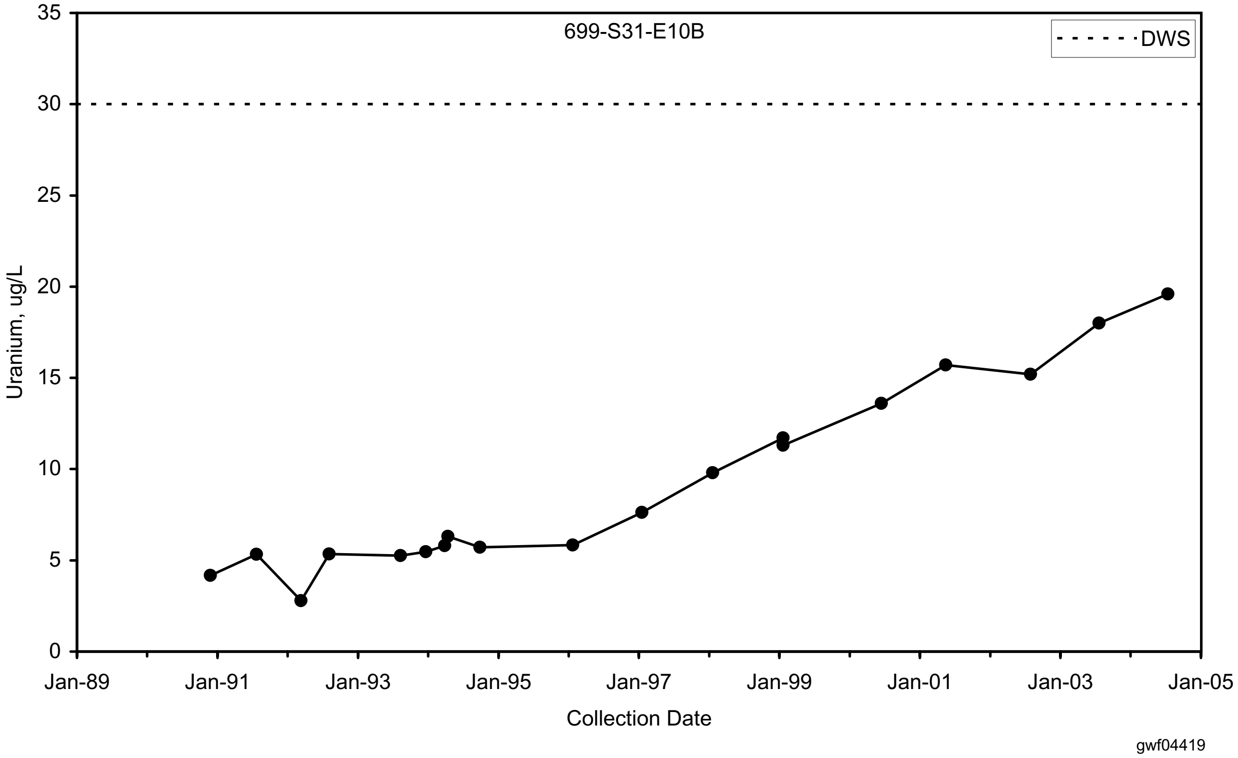

Figure 2.13-4. Uranium Concentrations Near the U.S. Department of Energy's Inactive Horn Rapids Landfill

2.14 Confined Aquifers

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This section describes groundwater flow and quality within the Ringold Formation and upper basalt-confined aquifers. The Ringold Formation confined aquifer is described only for the 200 Areas Central Plateau and the area near the inactive B Pond system because few wells monitor this aquifer. The upper basalt-confined aquifer is described for much of the Hanford Site, primarily the area south of Gable Butte and Gable Mountain.

2.14.1 Ringold Formation Confined Aquifer

Groundwater quality in the Ringold Formation confined aquifer is monitored because of the potential for downward migration of contaminants from the overlying unconfined aquifer.

The Ringold Formation confined aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of the Ringold formation (unit 9). It is confined below by basalt and above by the lower mud unit (unit 8).

2.14.1.1 Groundwater Flow in the Ringold Formation Confined Aquifer

Figure 2.14-1 presents the potentiometric surface for a portion of the confined aquifer in the Ringold Formation. This map is incomplete and subject to uncertainty because only a few wells monitor this aquifer.

Groundwater in the Ringold Formation confined aquifer flows generally west to east in the vicinity of the 200 West Area and west to east along the south boundary of the aquifer. These flow patterns indicate that recharge occurs west of the 200 West Area (Cold Creek Valley) as well as from the Dry Creek Valley and possibly the Rattlesnake Hills. In the central portion of the aquifer, flow converges on the 200 East Area from the west, south, and east. The 200 East Area is a discharge area for this aquifer, since the confining mud unit (unit 8) is absent. Hydraulic heads indicate a slight upward gradient in this area, which suggests that groundwater discharging from the confined aquifer recharges the overlying unconfined aquifer. After discharging to the unconfined aquifer, the groundwater is interpreted to flow generally southeastward over the top of the confining unit. This is possible because of the southward dip of the suprabasalt strata.

Groundwater in the Ringold Formation confined aquifer flows generally west to east in the vicinity of the 200 West Area and west to east along the south boundary of the aquifer.

A groundwater mound is present in the Ringold Formation confined aquifer northeast of B Pond as a remnant of past wastewater discharges to this facility. This mound results in southwest flow beneath B Pond, because the May Junction Fault, located east of B Pond, acts as a hydrologic barrier preventing flow to the east (PNNL-12261). A stagnation point occurs south of B Pond, where the flow of water divides with some moving northwest toward the 200 East Area and some moving toward the east or southeast.

The contours on Figure 2.14-1 are similar to the potentiometric surface for the upper basalt-confined aquifer (see Section 2.14.2.1). Hydraulic head and flow patterns in the central portion of the Hanford Site are very similar in both aquifers. The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding (RHO-BWI-LD-5), which facilitates intercommunication between the unconfined and confined aquifers in the Ringold Formation and the upper basalt-confined aquifer system.

Water levels generally declined in this aquifer during the period from March 2003 to March 2004. Declines ranged from 0.04 to 0.21 meter. The declining water levels are due to the near cessation of wastewater disposal to the soil column at Hanford. As in previous years, the declines were largest in the 200 West Area and the B Pond vicinity.

2.14.1.2 Groundwater Quality in the Ringold Formation Confined Aquifer

During FY 2004, only a few wells were sampled that are completed in the Ringold Formation confined aquifer. Data indicate that groundwater in the vicinity of the 200 Area Treated Effluent Disposal Facility has not been displaced or diluted by wastewater associated with 200 East Area operations.

The 200 Areas Central Plateau and the area near the inactive B Pond system are the two known areas where contamination can migrate from the unconfined aquifer into the confined Ringold aquifer. Groundwater chemistry data for the Ringold Formation confined aquifer are extremely limited because of the lack of deep well completions in the aquifer. During fiscal year (FY) 2004, eight wells were sampled that are completed in the Ringold Formation confined aquifer (Figure 2.14-2). Data for constituents of interest are listed in Table 2.14-1. The only changes worth noting are that the average gross beta results for the wells at the 200 Area Treated Effluent Disposal Facility wells for FY 2004 are roughly double those reported in FY 2003, and slightly higher in well 699-48-77C. The 200 Area Treated Effluent Disposal Facility is located east of the 200 East Area. These results are well below drinking water standards, with the highest average of 9.78 pCi/L in well 699-41-35.

South and southeast of the B Pond system the major ion composition of groundwater becomes less calcium-bicarbonate type and more of a sodium bicarbonate water. Low tritium concentrations in the area near the 200 Area Treated Effluent Disposal Facility also indicate that groundwater is older in this area and has not been displaced or diluted by wastewater associated with 200 East Area operations (PNNL-13032). Results from FY 2004 continued to support this assumption.

Tritium has been discharged intermittently to the ground at the State-Approved Land Disposal Site north of the 200 West Area since late 1995. Tritium concentrations up to 980,000 pCi/L (February 2001) have reached the deepest well (699-48-77C) near this facility during the past few years, but the trend since then has been consistently downward, with the FY 2004 average of only 197,000 pCi/L. Although aquifer tests have indicated confined conditions at depth near this facility, apparently discharged effluent can be driven into these portions of the aquifer if sufficient head is available. An increase in hydraulic head of up to 1 meter above pre-operational conditions has resulted from discharges to the State-Approved Land Disposal Site in the immediate vicinity of the facility.

While effluent disposal was occurring at the B Pond system, groundwater mounding increased the driving head and forced groundwater and any associated contamination a limited distance into the Ringold confined aquifer. The groundwater moved laterally within the confined aquifer as long as the head remained high from the overlying groundwater mound, although low hydraulic conductivity in the region of the 200 Area Treated Effluent Disposal Facility limited actual flow in a southeastward direction. Groundwater analyses for FY 2004 at this facility continued to demonstrate isolation of the confined aquifer in this area from disposal activities. Well 699-42-37, which is the well nearest the B Pond system (see Figure 2.14-2 for well locations), typically produces higher concentrations of several major constituents than the more southward and eastward wells 699-40-36 and 699-41-35, respectively (see Section 2.11.3.6).

During FY 2004, iodine-129 was detected above the 1.0-pCi/L drinking water standard in two wells (299-E25-28 and 299-E25-34) in the east part of the 200 East Area (Table 2.14-1). Over the past few years, these wells have produced sporadic detections of iodine-129 showing no definitive trends. These wells are located in the area of the iodine-129 plume that is found in the overlying unconfined aquifer (see Figure 2.1-7 in Section 2.1).

2.14.2 Upper Basalt-Confined Aquifer

Upper basalt-confined aquifer groundwater quality is monitored because of the potential for downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer have the potential to migrate through the aquifer and deeper confined aquifers to areas off the Hanford Site. The upper basalt-confined aquifer is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources. Additional information regarding the potential for contaminants to migrate off the Hanford Site can be found in PNL-10817 and PNNL-14107.

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge Interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey Interbed, which is present only in the south portion of the site. An interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt and also may be significant to the lateral transmission of water. This system is confined by the dense, low-permeability, interior portions of basalt flows and in some places by Ringold Formation silt and clay units overlying the basalt.

Figure 2.14-2 shows the location of the upper basalt-confined aquifer monitoring wells on the Hanford Site. Most of the wells are completed in the Rattlesnake Ridge Interbed near the 200 East Area in the central part of the Hanford Site. A few wells are completed in the Elephant Mountain interflow zone, the Levey Interbed, or a composite of one or more interbeds and/or interflow zones within the upper Saddle Mountains Basalt.

2.14.2.1 Groundwater Flow in the Upper Basalt-Confined Aquifer

Recharge to the upper basalt-confined aquifer system is believed to occur along the margins of the Pasco Basin and results from the infiltration of precipitation and surface water where the basalt and interbeds are exposed at or near ground surface. Recharge may also occur through the Hanford/Ringold aquifer system in areas where the hydraulic gradient is downward, and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge. The Columbia River represents a discharge area for this aquifer system in the south portion of the site, but not for the north portion of the site (PNL-8869). Discharge also occurs to the overlying Hanford/Ringold aquifer system in areas where the hydraulic gradient is upward. Discharge to overlying or underlying aquifers in the vicinity of the Gable Butte/Gable Mountain structural area may occur through erosional windows in the basalt.

Groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River.

Groundwater flow rates within the Rattlesnake Ridge Interbed have been estimated to be between 0.7 and 2.9 meters per year (PNL-10817). This flow rate is considerably slower than most estimates for the overlying unconfined aquifer system. On average, the magnitude of the hydraulic gradient is lower than in the unconfined aquifer. In addition, the sediment comprising the interbed consists mostly of tuffaceous sandstone along with silts and clays, and is less permeable than the sediments in the unconfined aquifer.

Figure 2.14-3 presents an approximation of the March 2004 potentiometric surface for this aquifer system south of Gable Butte and Gable Mountain. The region to the north of Gable Butte and Gable Mountain was not contoured because of insufficient well control. (See PNL-8869 for a generalized potentiometric surface map of this area.) Because the Rattlesnake Ridge interbed is absent, the upper basalt-confined aquifer is interpreted to not exist in Cold Creek Valley and along the west portion of the Gable Mountain/Gable Butte structural area.

South of the Umtanum Ridge/Gable Mountain area, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River. In the vicinity of the 200 East Area, the potentiometric surface in Figure 2.14-3 is similar to the potentiometric surface for the Ringold Formation confined aquifer (compare with Figure 2.14-1). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication. In the vicinity of the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying Hanford/Ringold aquifer system is upward. Therefore, it is likely the upper basalt-confined aquifer system currently discharges to the overlying Hanford/Ringold aquifer system in this region.

There is a downward hydraulic gradient from the Hanford/Ringold aquifer system to the upper basalt-confined aquifer in the west portion of the Hanford Site, in the vicinity of the B Pond recharge mound, as well as in the regions north and east of the Columbia River (Figure 2.14-4). In the vicinity of B Pond, the vertical head gradient between the unconfined aquifer system and the upper basalt-confined aquifer system has diminished in recent years, but remains downward. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the Hanford/Ringold aquifer system. The May Junction Fault, located east of B Pond and in a north-south trend, acts as a barrier to groundwater flow in the Hanford/Ringold aquifer system (PNNL-12261). It may also impede the movement of water in the upper basalt-confined aquifer system.

The small amount of contamination detected in the upper basalt-confined aquifer is attributed to areas where confining units of basalt are absent or where wells provided a pathway for migration.

Water levels in the upper basalt-confined aquifer declined over most of the site from March 2003 to March 2004 but increased in two wells north of the 200 East Area toward Gable Gap. In the 200 East Area and to the immediate north and east (near B Pond), water-level changes ranged from an increase of 0.05 meter to a decline of 0.40 meter over the 12-month period. Water level declines near the 200 West Area ranged from 0.04 to 0.33 meter. The declines are in response to curtailed effluent disposal activities in the 200 Areas and are consistent with water-level declines in the overlying Hanford/Ringold aquifer system. The increase in water levels to the north of the 200 East Area may be a response to a fluctuation in the water-table elevation that began during FY 2003 (see Section 2.1).

In previous years, water levels in the basalt-confined aquifer had been rising along the Columbia River in the east part of the site (i.e., west of the river). This is interpreted to be the result of offsite irrigation east of the Columbia River (PNL-8869). From March 2003 to March 2004, water levels declined in this area over a range of ~0.25 to 0.30 meter. It is not unusual for these wells to exhibit short-term declines superimposed on the long-term increasing trend.

2.14.2.2 Groundwater Quality in the Upper Basalt-Confined Aquifer

The upper basalt-confined aquifer is affected much less from contamination than the overlying unconfined aquifer system. Contamination found in the upper basalt-confined aquifer is most likely attributed to areas where confining units of basalt have been eroded away or were never deposited and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. In some areas, wells penetrating the upper basalt-confined aquifer system provided a downward pathway for contaminant migration. Because of these factors, intercommunication between the aquifers permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination.

An area of intercommunication between the unconfined and upper basalt-confined aquifer systems was first identified in the northern part of the 200 East Area (RHO-BWI-ST-5; RHO-RE-ST-12 P). Several confined aquifer wells north and east of the 200 East Area have shown evidence of intercommunication with the overlying unconfined aquifer (PNL-10817). Intercommunication between the unconfined and confined aquifers in this region has been attributed to erosion of the upper Saddle Mountains Basalt and a downward hydraulic gradient that resulted from groundwater mounding associated with past wastewater disposal to the ground. However, the groundwater mound has diminished in recent years (see Section 2.14.1).

Wells completed in the upper basalt-confined aquifer system are routinely sampled on the Hanford Site. Most of these wells are sampled every 3 years and a few are sampled annually. During FY 2002 through 2004, 23 samples were collected from 18 wells and analyzed for chemical and radiological constituents. Many of the samples were analyzed for tritium, iodine-129, and nitrate because these constituents are (1) the most widespread in the overlying unconfined aquifer, (2) are some of the most mobile constituents in groundwater, and (3) provide an early warning for potential contamination in the upper basalt-confined aquifer system. Groundwater samples from the upper basalt-confined aquifer were also analyzed for anions (besides nitrate), cations, cyanide, gross alpha, gross beta, gamma-emitters, strontium-90, technetium-99, and uranium isotopes. Data for the primary constituents of interest are listed in Table 2.14-2. A full data set is included in the data files that accompany this report.

The spatial distribution of hydrochemical facies presented by Stiff diagrams can be used to show hydrochemical evolutionary patterns for upper basalt-confined aquifer groundwater (Figure 2.14-5). As shown in Figure 2.14-5, samples from wells in the Gable Mountain/200 East Area are characterized by Stiff diagram shapes indicating a Ca,Mg-HCO_3 composition. This composition, typical of less-chemically evolved groundwater, is indicative of recharge from the overlying unconfined aquifer system. The Gable Mountain/200 East Area was identified as a region of intercommunication between the upper basalt-confined aquifer and the overlying unconfined aquifer system (PNL-10817). A Ca,Mg-HCO_3 composition is also indicated for one sample from shallow upper basalt groundwater near the Yakima River. This composition is consistent with hydrochemical analysis results presented in PNL-10817 and PNNL-14107 for the Yakima River area and suggests recent local recharge from surface water. A predominantly Na-HCO_3 composition indicating a more evolved groundwater occurs at sample locations along the eastern margin of the Hanford Site. The Na-HCO_3 hydrochemical type groundwater is common near areas of discharge (i.e., Columbia River). The hydrochemistry distribution shown in Figure 2.14-5 and the groundwater flow patterns presented in Figure 2.14-3 are consistent with the conceptual model that for greater residence times and flow distances from known recharge areas, groundwater evolves from Ca,Mg-HCO_3 to Na-HCO_3 type waters.

Distribution of sample results for selected constituents and wells across the Hanford Site for FY 2002 through 2004 is shown in Figure 2.14-6. Tritium at the Hanford Site ranged from less than the detection limits near the discharge area in the eastern-southeastern portion of the Hanford Site to 5,080 pCi/L east of the 200 East Area. Concentrations have been decreasing at this location since 1996 (Figure 2.14-7). This elevated tritium is located in the 200 East Area/Gable Mountain region, an area of intercommunication with the overlying contaminated unconfined aquifer. Nearby wells completed in the Ringold Formation show elevated but declining trends. Near the 618-11 burial ground, where a source of tritium has contaminated the unconfined aquifer at high levels, tritium was detected at a concentration of 31.6 pCi/L in the upper basalt-confined aquifer in FY 2004.

In FY 2004, cyanide, nitrate, and technetium-99 were elevated in one well in the 200 East/Gable Mountain region, an area of intercommunication between the upper basalt-confined aquifer and the overlying unconfined aquifer.

In the north part of the 200 East Area, technetium-99 was elevated in the upper basalt-confined aquifer in one well (Figure 2.14-6). The technetium-99 concentration was 1,090 pCi/L in this well (299-E33-12) in 2004. However this level, which exceeds the drinking water standard (900 pCi/L), is slightly lower than concentrations since the early 1990s (Figure 2.14-8). Contamination in this well is attributed to migration of high-salt waste down the borehole during construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12 P). This well is located in the vicinity of a technetium-99 plume in the overlying unconfined aquifer (Section 2.10.1).

Cyanide and nitrate are also elevated in the same well (299-E33-12) that technetium-99 is elevated in (Figure 2.14-9). However, these co-contaminants are at levels that do not exceed their respective drinking water standards. Concentrations of cyanide and nitrate have not changed significantly at this well since the early 1990s. Like technetium-99, this contamination is associated with migration of high-salt waste down the borehole during well construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12 P). Cyanide and nitrate are co-contaminants with much higher concentrations in the unconfined aquifer in the north part of the 200 East Area.

Table 2.14-2 indicates that the majority of wells showing elevated nitrate in the upper basalt-confined aquifer occur near Gable Mountain and the 200 East Area. Elevated nitrate in the upper basalt-confined aquifer is a hydrochemical indicator of intercommunication with the overlying contaminated unconfined aquifer (RHO-BWI-ST-5; RHO-RE-ST-12 P; PNL-10817). Across the rest of the Hanford Site, nitrate levels in the upper basalt-confined aquifer ranged from less than detectable to ~1 mg/L in FY 2002 through 2004.

Some samples collected from upper basalt-confined aquifer wells were analyzed for iodine-129. These wells are located beneath or near the iodine-129 plume contained within the overlying unconfined aquifer. Iodine-129 was not detected in the upper basalt-confined aquifer during FY 2002 through 2004 (see Table 2.14-2).

Gamma-emitting isotopes were not detected in the upper basalt-confined aquifer on the Hanford Site

A few samples collected from upper basalt-confined aquifer wells were analyzed for gamma-emitting and uranium isotopes. Gamma-emitting isotopes were not detected in the upper basalt-confined aquifer on the Hanford Site, including the Gable Mountain/200 East Area. Uranium isotopes were not detected in this aquifer in the eastern part of the Hanford Site during FY 2002 through 2004 (Figure 2.14-6).

In summary, cyanide, nitrate, and technetium-99 were elevated in an upper basalt-confined aquifer well in the northern part of the 200 East Area. Migration of high-salt waste via the well during its construction is responsible for this contamination. Tritium was predominantly detected at low levels or was not detected. One elevated tritium concentration near the 200 East Area is associated with intercommunication between the upper basalt-confined aquifer and the overlying unconfined aquifer. Iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected above the minimum detection limits in the upper basalt-confined aquifer. Spatial distribution of hydrochemical data indicates that upper basalt-confined groundwater in the Gable Mountain/200 East Area and near the Yakima River are characterized by predominantly Ca,Mg-HCO_3, a less evolved water type. In contrast, a more evolved groundwater indicated by a Na-HCO_3 composition occurs in the upper basalt-confined aquifer along the eastern margin of the Hanford Site where the Columbia River serves as an area of groundwater discharge.

Table 2.14-1. Potential Contaminants in Ringold Confined Aquifer, FY 2004

Well	Sample Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)
299-E25-28	04/05/04	NA	NA	3.25	NA
299-E25-28	10/02/03	NA	NA	NA	1.54 A
299-E25-34	10/01/03+	NA	NA	3.20	1.11 A
299-W6-6	01/12/04	NA	NA	NA	NA
299-W7-3	03/22/04+	1.08 U	5.52 A	0.08 U	16.0 A
699-40-36	10/22/03+	2.86 A	9.62 A	NA	0.1 A
699-41-35	10/22/03+	3.94 A	9.78 A	NA	0.921 A
699-42-37	10/22/03+	6.0 A	7.4 A	NA	6.20 A
699-48-77C	10/22/03+	1.06 U	4.14 U	NA	0.631 A

Well	Sample Date	Specific Conductance (µS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)
299-E25-28	04/05/04	NA	NA	NA	NA
299-E25-28	10/02/03	223 A	NA	NA	2,030
299-E25-34	10/01/03+	208 A	NA	NA	358
299-W6-6	01/12/04	386	NA	NA	0.0 U
299-W7-3	03/22/04+	297 A	NA	0.0 UA	105 U
699-40-36	10/22/03+	304 A	NA	NA	20.70
699-41-35	10/22/03+	324 A	NA	NA	23.2 A
699-42-37	10/22/03+	359 A	NA	NA	13.50
699-48-77C	10/22/03+	223 A	0.24 U	NA	197,000 A

+ = Sampled one or more times in addition to and after the date shown.
A = Average of values above detection for multiple events.
NA = Not analyzed.
U = Below detection limit.

Table 2.14.2. Potential Contaminants in Upper Basalt-Confined Aquifer, FY 2002 through 2004

Well	Sample Date	Cesium-137 (pCi/L)	Cobalt-60 (µg/L)	Cyanide (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Specific Conductance (µS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)
299-E16-1	10/06/03	NA	NA	NA	0.289 U	12.2	NA	0.0487 U	307	NA	NA	9.11
299-E26-8	10/02/03	NA	NA	NA	4.32	12.1	NA	3.67	307	NA	NA	16.3
299-E33-12	06/21/04	-0.322 U	6.03 U	22.9	3.0	254	0.544 U	36.7 D	342	NA	1,090	153
399-5-2	06/23/04	NA	NA	NA	8.5	8.66	NA	0.0394 B	361	NA	NA	5.22 U
699-13-1C	10/27/03	NA	NA	NA	1.03 U	3.67	NA	0.0974 C	251	NA	NA	31.6
699-24-1P	11/01/01	NA	NA	NA	4.18	12.3	NA	0.00885 U	378	NA	NA	11.5
699-32-22B	10/08/03	NA	NA	NA	1.78 U	11.5	-0.0353 U	0.0487 U	395	NA	NA	6.08 U
699-32-22B	10/08/03	NA	NA	NA	1.1 U	12	0.00454 U	0.0487 U	395	NA	NA	12.5
699-42-E9B	08/09/02	1.64 U	-3.26 U	NA	0.415 U	5.84	-0.0745 U	0.02 U	425	NA	NA	1.2 U
699-42-E9B	08/09/02	-1.07 U	0.228 U	NA	-0.119 U	11.4	0.641 U	0.02 U	425	NA	NA	1.62 U
699-42-E9B	09/10/03	-0.446 U	-0.696 U	NA	0.862 U	6.52	0.0105 U	0.328	425	NA	NA	NA
699-42-E9B	07/19/04	2.88 U	-1.4 U	NA	0.62 U	11.4	0.0578 U	0.0177 U	431	NA	NA	0.168 U
699-42-40C	10/09/03	NA	NA	NA	1.8	12.6	0.253 U	4.87 D	324	NA	NA	5,080
699-49-57B	03/09/04	0.605 U	-0.488 U	4.7 U	1.61 U	5.72	-0.843 U	1.15	302	NA	-2.39 U	-28.5 U
699-50-53B	10/08/03	NA	NA	NA	NA	NA	0.0922 U	10.6 D	360	NA	1.38 U	-92.8 U
699-52-46A	06/30/04	NA	NA	NA	4.74	8.83	NA	1.86	338	0.16 U	NA	10.7
699-54-34	07/01/04	NA	NA	NA	1.51 U	6.68	NA	12.4 D	291	NA	NA	5.17 U
699-56-43	10/09/03	NA	NA	NA	2.47	6.33	NA	4.43 D	320	NA	NA	15.9
699-56-53	10/08/03	NA	NA	NA	2.41	8.41	NA	0.930	368	NA	NA	16.9 U
699-S11-E12AP	05/29/02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18.6
699-S11-E12AP	02/03/04	NA	NA	NA	NA	NA	NA	0.0487 U	335	NA	NA	-22.9 U
699-S2-34B	01/21/04	NA	NA	NA	NA	NA	NA	0.0487 U	591	NA	NA	-75 U
699-S24-19P	07/13/04	NA	NA	NA	NA	NA	NA	0.708	285	NA	NA	13.5

B = Analyt
C = Analyte detected in both the sample and the associated quality control blank.
D = Analyzed at a secondary dilution factor.
NA = Not analyzed.
U = Below detection limit.
Negative values occur when a sample has a lower count than the background.

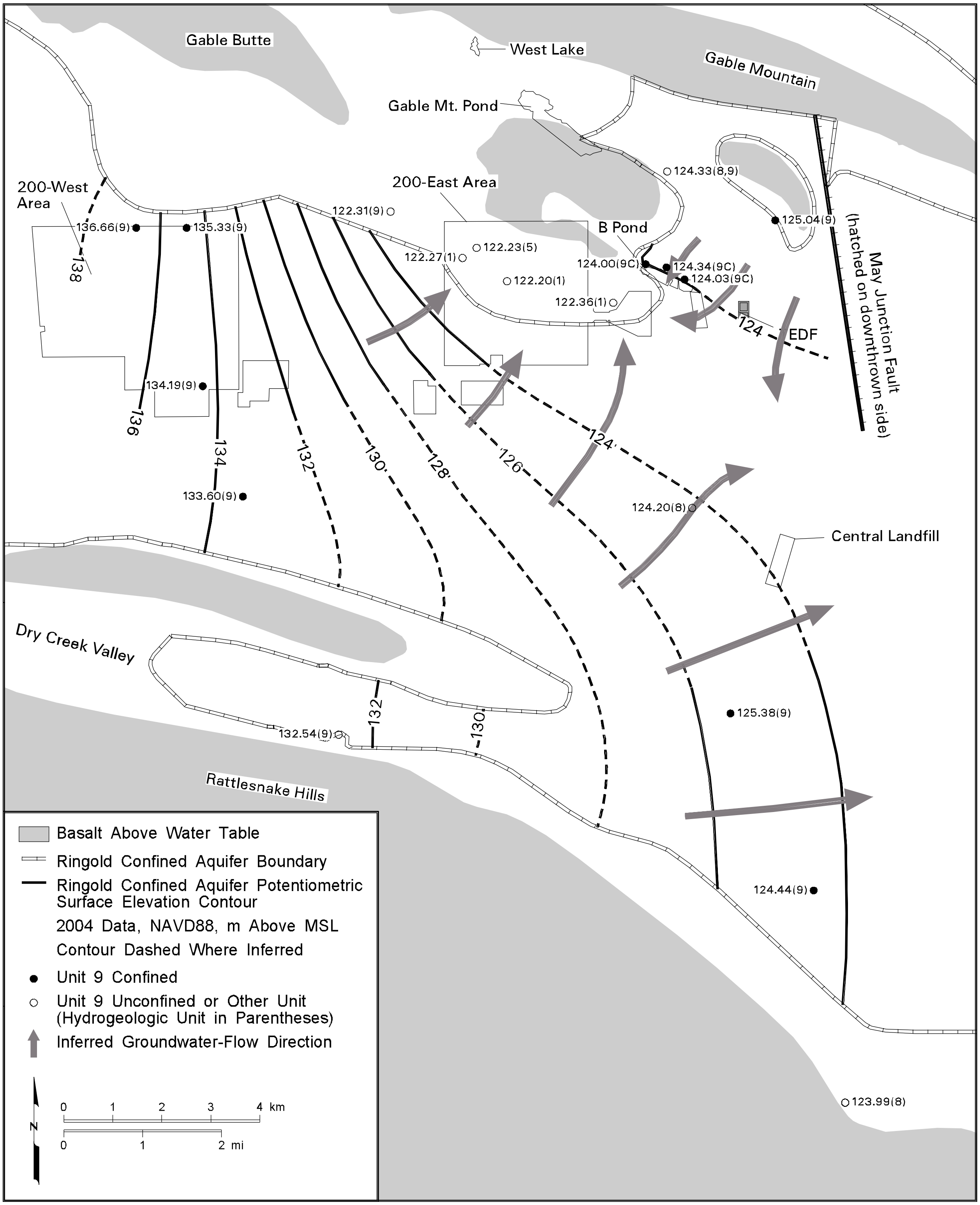

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Figure 2.14-1. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 2004

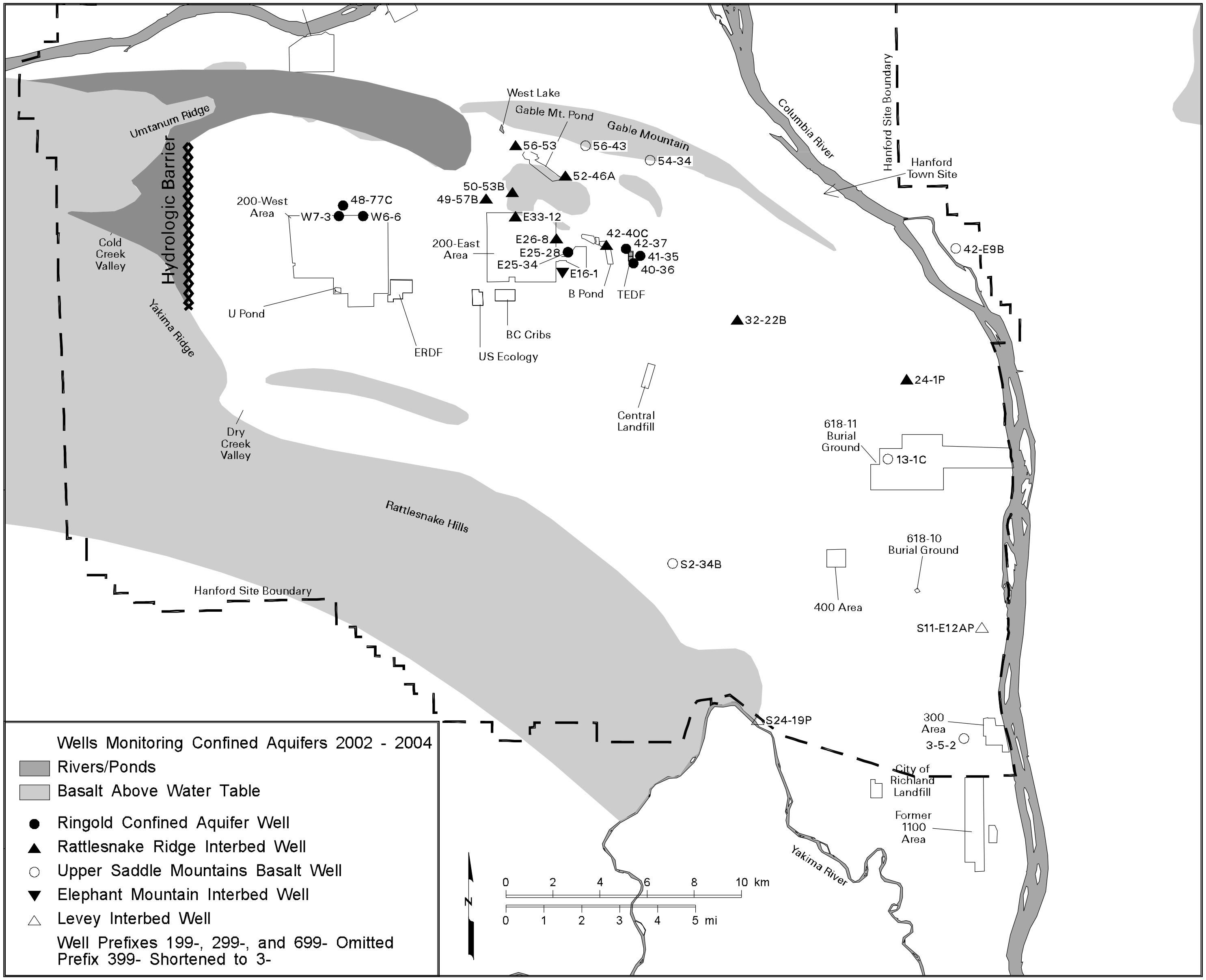

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Figure 2.14-2. Groundwater Monitoring Wells Sampled in the Ringold Confined and the Upper Basalt-Confined Aquifers, FY 2002 through 2004

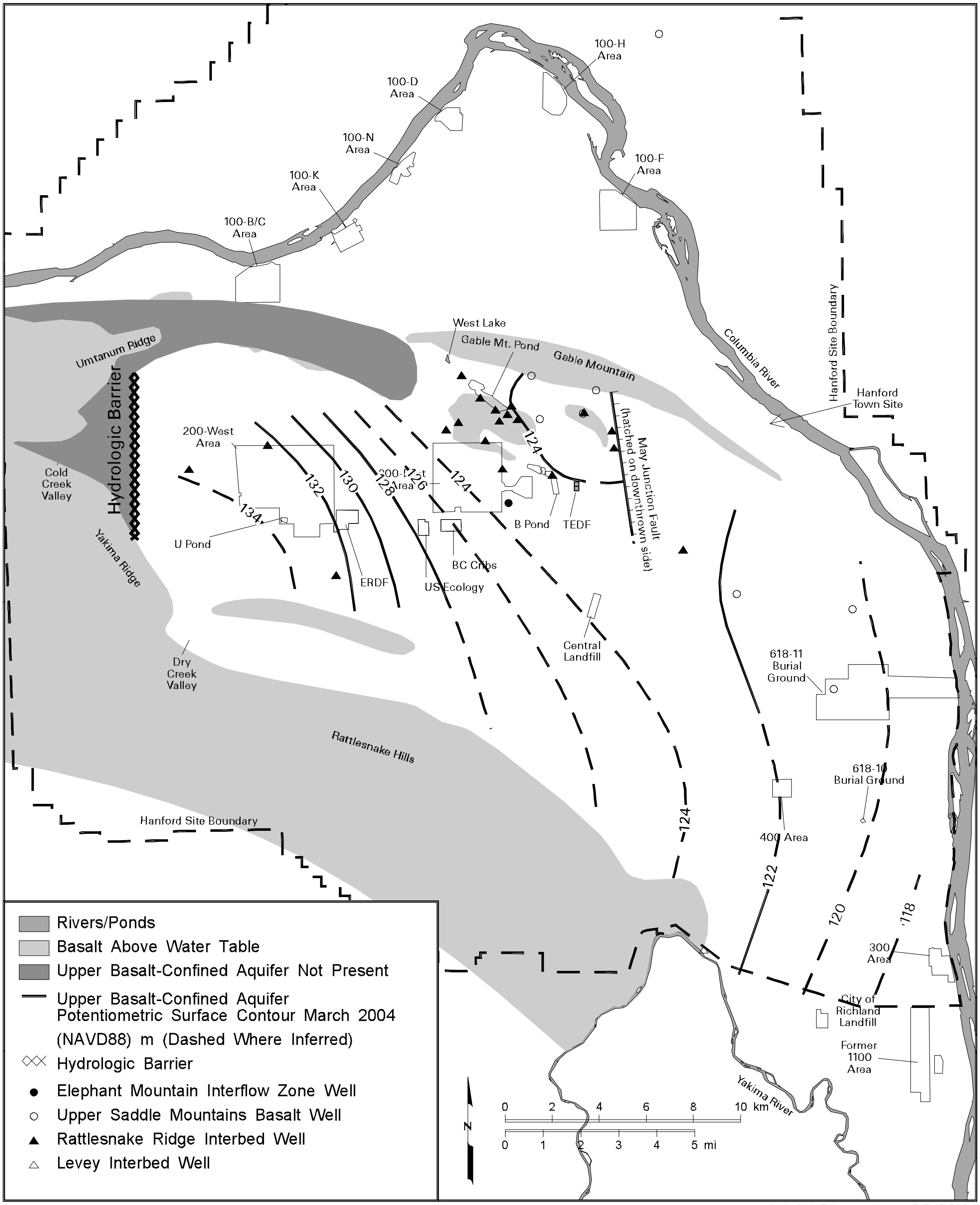

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Figure 2.14-3. Potentiometric Surface Map of Upper Basalt-Confined Aquifer System, March 2004

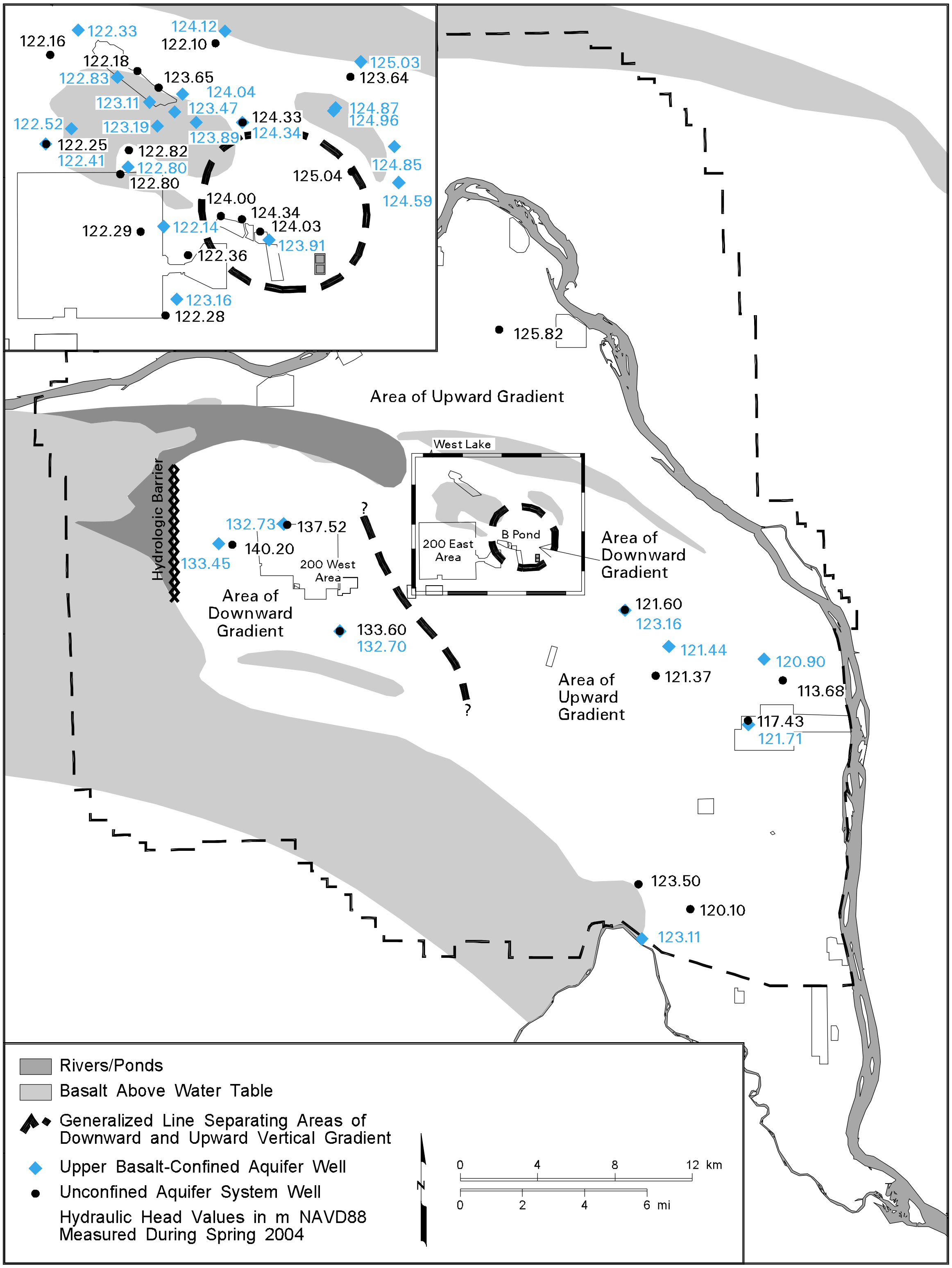

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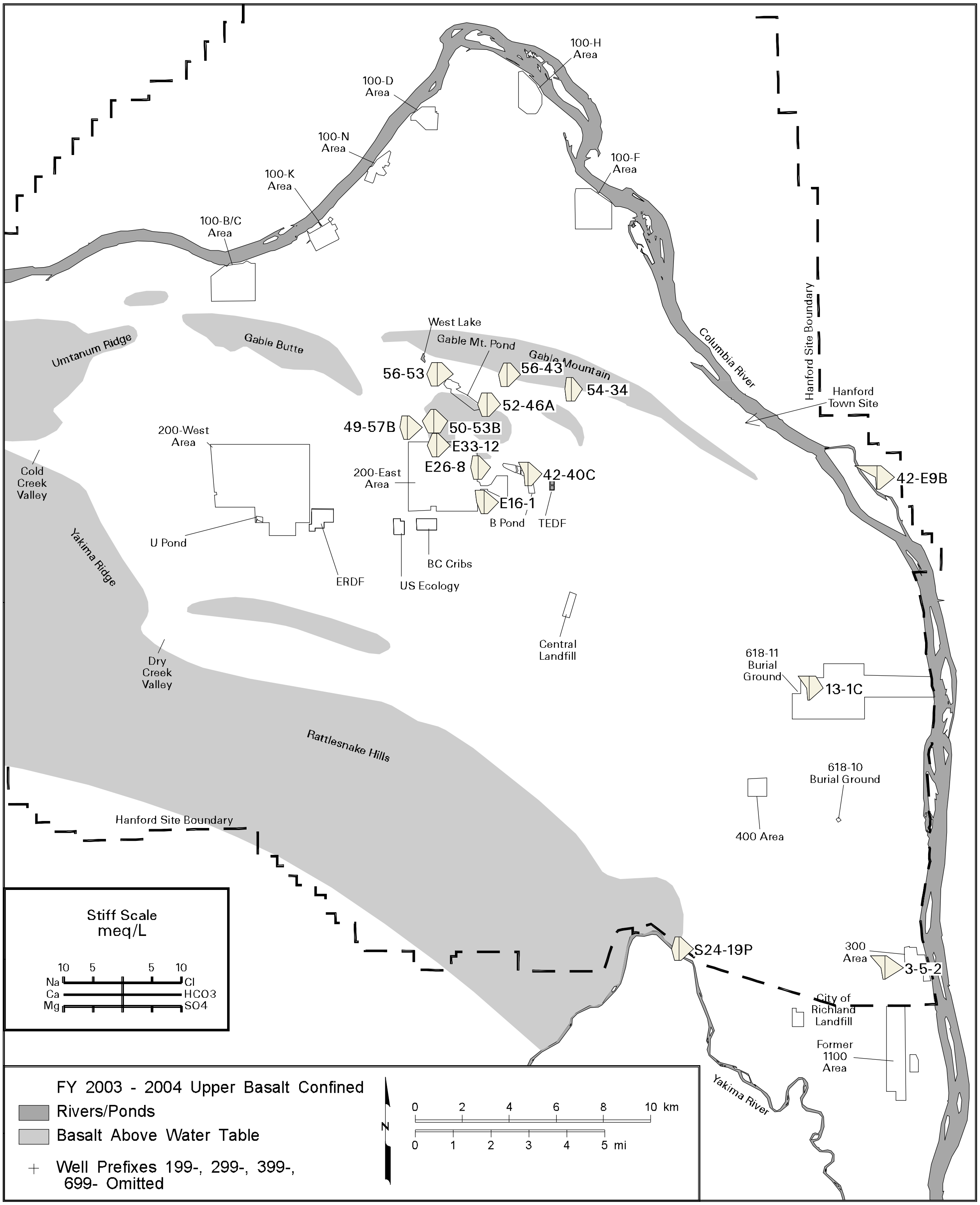
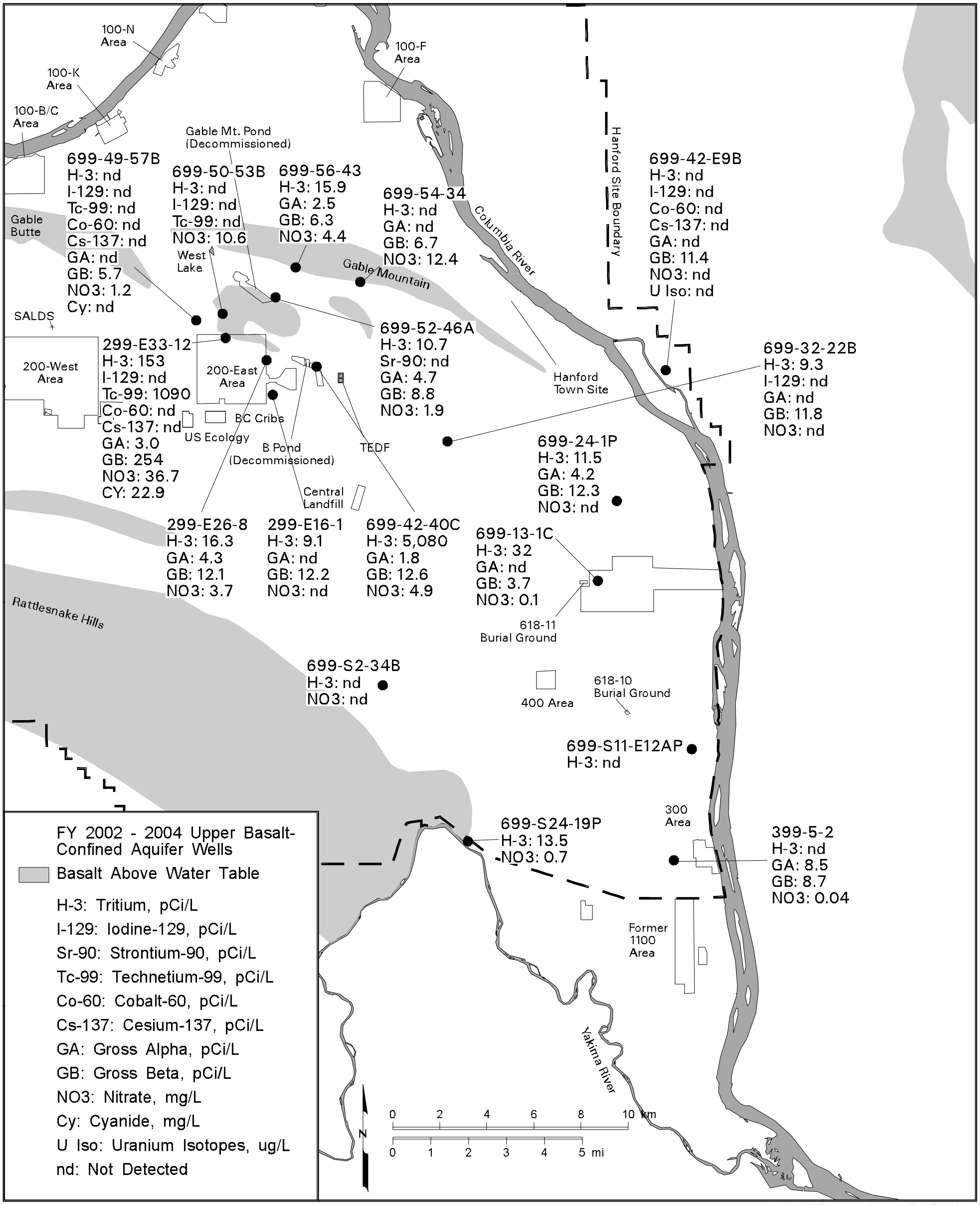
Figure 2.14-4. Comparison of Observed Heads for the Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer



can_gwf04_434 February 19, 2005 2:54 PM

Figure 2.14-5. Hydrochemical Stiff Diagrams for Groundwater Within the Upper Basalt-Confined Aquifer System, FY 2003 and 2004



can_gwf04_435 February 19, 2005 2:54 PM

Figure 2.14-6. Distribution of Chemical and Radiological Constituents in the Upper Basalt-Confined Aquifer, FY 2002 through 2004

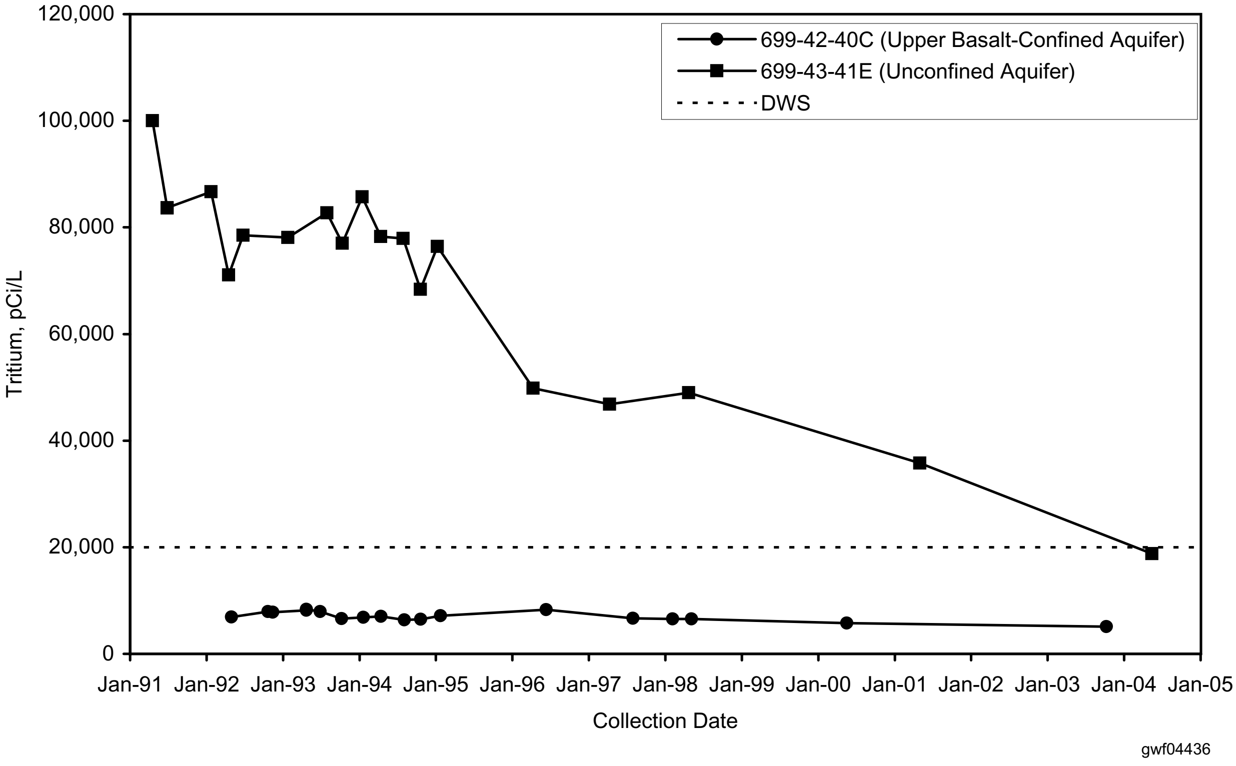


Figure 2.14-7. Tritium Concentrations in Wells 699-42-40C (Upper Basalt-Confined Aquifer) and 699-43-41E (Unconfined Aquifer)

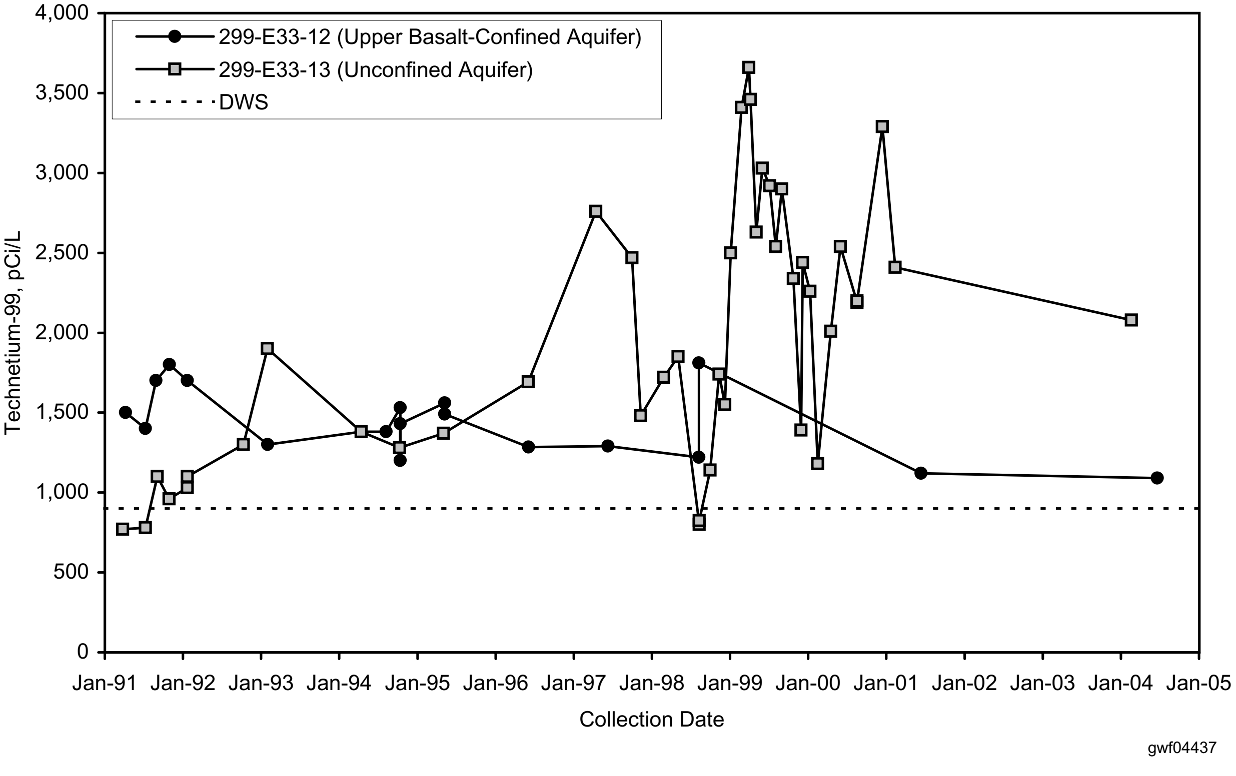


Figure 2.14-8. Technetium-99 Concentrations in Wells 299-E33-12 (Upper Basalt-Confined Aquifer) and 299-E33-13 (Unconfined Aquifer)

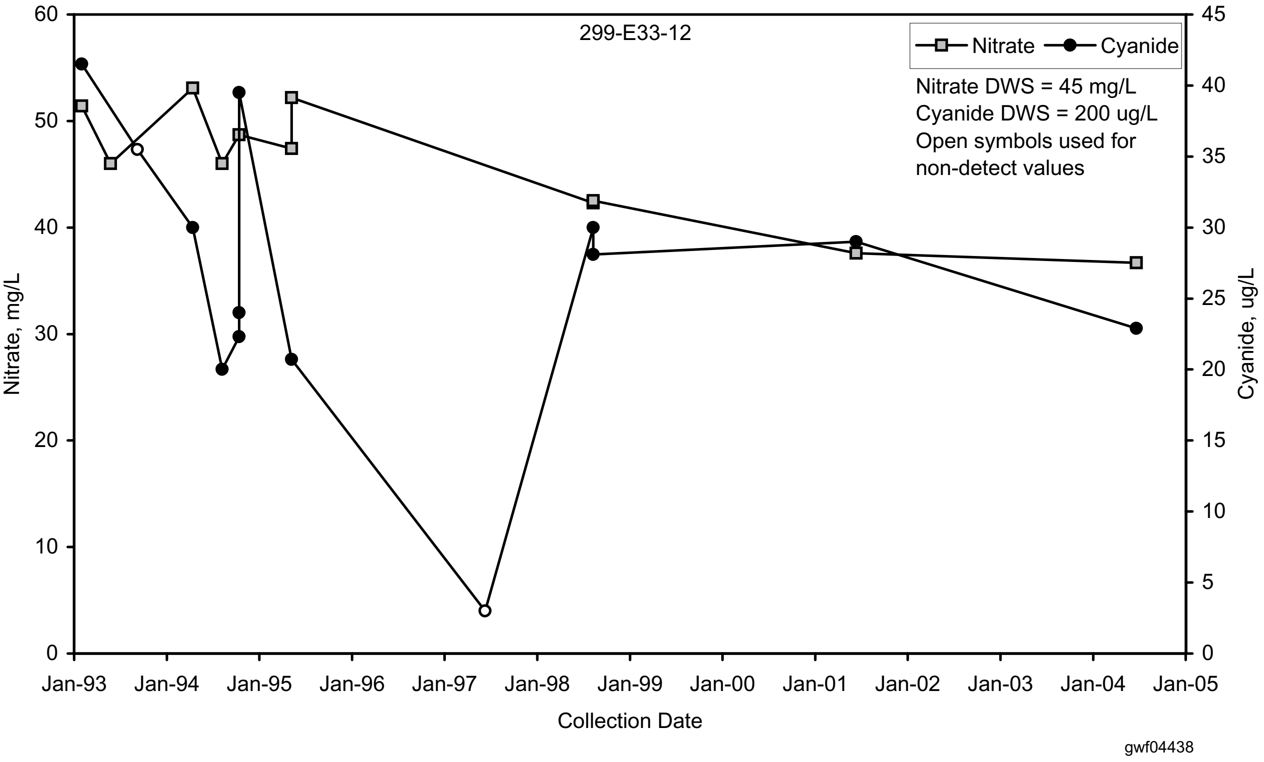


Figure 2.14-9. Cyanide and Nitrate Concentrations in Well 299-E33-12

3.0 Vadose Zone

D. G. Horton

At the Hanford Site, radioactive and hazardous waste in the soil column from past intentional liquid waste disposal, unplanned leaks, solid waste burial grounds, and underground tanks are potential sources of continuing and future vadose zone and groundwater contamination. Characterization of the subsurface and vadose zone monitoring were conducted during fiscal year (FY) 2004 to better understand the distribution of subsurface contaminants and to track the movement of vadose zone contamination. Also, several technical studies were completed; the results of these studies could lead to new understandings of moisture and contaminant movement in the vadose zone, contaminant interactions with the soil column, and new and improved methods to characterize and monitor the vadose zone. Finally, vadose zone characterization to assess remediation and post-remediation contamination was performed in FY 2004 as part of cleanup efforts at the Hanford Site.

This chapter summarizes major findings from those efforts, focused primarily on vadose zone soil contamination associated with past single-shell tank leaks and liquid disposal to ground as a result of spent fuel processing.

An overview of the major soil sources of groundwater contamination is provided in PNNL-13080. This chapter discusses vadose zone contamination that could affect groundwater in the future. An overall evaluation depends, to a large degree, on integration of vadose zone and groundwater monitoring and characterization data to present a comprehensive picture of contaminant fate and transport. Significant FY 2004 vadose zone results are summarized here. However, the bulk of the data interpretation on the effect to groundwater is presented and discussed in Chapter 2 of this document.

3.1 Vadose Zone Characterization

D. G. Horton

This section describes significant vadose zone characterization activities that occurred during fiscal year (FY) 2004. These characterization activities were done to further the understanding of physical and chemical properties of the vadose zone and vadose zone contamination and to delimit existing vadose zone contamination. During the year, geophysical logging, and laboratory analysis of chemical and radiological contaminants in soil samples were done to characterize existing vadose zone contaminant plumes and help plan future remedial actions.

During FY 2004, baseline spectral gamma logging and neutron moisture logging of boreholes continued at selected past-practice liquid disposal facilities. The results of this characterization will provide a baseline against which to compare subsequent logging events to monitoring for subsurface contaminant movement.

The results of extensive geochemical characterization of core samples from Waste Management Area C and Waste Management Area T became available in FY 2004. These data allow comparison of contaminated vadose zone sediment with uncontaminated sediment and descriptions of contaminant plumes beneath the single-shell tanks in the vicinity of the boreholes.

Characterization activities further the understanding of physical and chemical properties of the vadose zone.

3.1.1 Characterization to Support Remedial Investigations

D. G. Horton

The results of laboratory analyses for chemicals and radionuclides in support of remedial investigation at the 200-CS-1 Chemical Sewer Group Operable Unit (200-CS-1 Operable Unit), 200-CW-5 U Pond/Z Ditches Cooling Water Group Operable Unit (200-CW-5 Operable Unit), 200-PW-2 Uranium-Rich Process Waste Operable Unit (200-PW-2 Operable Unit), and 200-PW-4 General Process Condensate and Process Waste Operable Unit (200-PW-4 Operable Unit) became available in 2004. These operable units are not defined geographically, but instead, are defined by waste type. The characterization results will support remediation of past-practice liquid disposal facilities in the 200 Areas.

3.1.1.1 Vadose Zone Characterization at the 200-CS-1 Operable Unit

C. S. Cearlock

A remedial investigation was conducted from 1999 to 2003 for the 200-CS-1 Operable Unit. A remedial investigation report was issued in 2004 (DOE/RL-2004-17). This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section, and the reader is referred to the remedial investigation document.

Twelve test pits were excavated and four boreholes were drilled at four *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal units: 216-A-29 ditch, 216-B-63 trench, 216-S-10 ditch, and 216-S-10 pond. Details concerning borehole drilling and test pit excavation can be found in WMP-17755. One hundred and forty-six sediment samples were collected and analyzed for radionuclides, metals, anions, polychlorinated biphenyls, volatile and semivolatile organics, and physical properties. In addition, the four boreholes were logged with spectral gamma-ray and neutron moisture tools. Supplemental data were collected earlier at the 216-A-29 ditch and 216-B-63 trench and were included in the remedial investigation. The data were compared to background concentrations from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

The analytical results from samples taken from the three test pits at the 216-A-29 ditch and one test pit at the 216-B-63 ditch were summarized during 2003 in PNNL-14187 from activities described in BHI-01651. Part of that summary is included in this section for completeness.

216-A-29 Ditch. Borehole B8826 was drilled to 83.2 meters below ground surface near the head end of the 216-A-29 ditch. (The depth to groundwater in the area is ~86 meters below ground surface.) Perched water was encountered in the borehole at depths of ~78.6 to 78.9 meters overlying a dense, compacted silt and clay layer in the Hanford formation. Test pit AD-1 was excavated nearby at the head end of the ditch. Test pit AD-3 was excavated ~240 meters from the head end and test pit AD-2 was located at the far end of the ditch. Each test pit was excavated to depths between 4.6 and 5.2 meters. The location of the 216-A-29 ditch is shown on Figure 2.11-1 in Section 2.11, and the locations of the borehole and test pits are shown on Figure 3.1-1.

Generally, contamination is highest near the head end of and close to the surface of ditches and trenches used for past-practice liquid waste disposal.

Cesium-137 was the only manmade radionuclide detected in borehole B8826 by spectral gamma-ray logging. Cesium-137 was found between depths of 0.91 and 1.98 meters at concentrations between 0.5 and 62 pCi/g with the highest concentration at 1.5 meters depth.

Table 3.1-1 lists the highest concentrations and associated locations and depths for selected constituents. Maximum contaminant concentrations tended to be near the 1.2 to 1.8 meters level below the surface for most metals. In the test pits, all detected radionuclides (except tritium) with concentrations greater than 2 pCi/g were found between 0 and 2 meters below ground surface. The only radionuclide at a concentration greater than 2 pCi/g below 3.4 meters was tritium. The maximum tritium concentration was 7.05 pCi/g at 79.3 meters.

Metal concentrations in samples from the borehole exceeded background concentrations only at depths of 79.3 to 79.9 meters (except vanadium, which also exceeded background at 7.5 to 8.1 meters). This corresponds to the depth of a contact between sand and clay, which is probably responsible for the encountered perched water. Total chromium, copper, lead, nickel, and zinc exceeded background at 79 meters.

The highest concentrations of most constituents were in a sample from depths of 1.2 to 1.5 meters in test pit AD-1. Shallow samples from nearby borehole B8826 also had high radionuclide concentrations, and the same radionuclides were elevated at both locations (i.e., americium-241 and plutonium-239/240). The test pit and borehole are near the inlet to the ditch and are expected to have similar levels of contamination. Contaminant concentrations were lower at test pit AD-3 near the ditch center and even less at pit AD-2 near the far end of the ditch. However, cadmium and lead are elevated at test pit AD-2.

In addition to the constituents listed in Table 3.1-1, several organic compounds were detected in the test pit samples and borehole.

216-B-63 Trench. Borehole B8827 was drilled to 31.4 meters below ground surface near the inlet to the 216-B-63 trench. (The depth to groundwater at the 216-B-63 trench is ~78 meters below ground surface.) Test pit BT-1 was excavated near the middle of the trench and test pit BT-2 was excavated near the far end of the trench. Each test pit was excavated to between 5.5 and 7.6 meters. The location of the 216-B-63 trench is shown on Figure 2.11-1 in Section 2.11, and the locations of the borehole and test pits are shown on Figure 3.1-2.

Cesium-137 was the only manmade radionuclide detected in borehole B8826 by spectral gamma-ray logging. Cesium-137 was found between depths of 1.2 and 3.4 meters at concentrations between 0.5 and 22.4 pCi/g with the highest concentration at 2.7 meters.

Table 3.1-2 lists the highest concentrations and associated locations and depths for selected constituents. The only radionuclides in the test pits with concentrations greater than 2 pCi/g were cesium-137 and strontium-90. Strontium-90 was detected in sporadic locations throughout both test pits, whereas cesium-137 was found in only test pit BT-1 (with the exception of 0.817 pCi/g in the shallowest sample from pit BT-2). The only radionuclide with concentrations greater than 2 pCi/L in borehole B8827 was nickel-63 that was found throughout the borehole at concentrations between 2 and 15 pCi/g.

The highest concentrations of most constituents occurred at the bottom of the ditch, 3 meters below the surface, and tended to decrease with depth. High heavy metal concentrations tended to be near the ditch inlet in samples from borehole B8827 and just below the ditch's historic bottom. More soluble constituents, such as nitrate, tended to be found throughout the ditch. The largest nitrate concentration was 188 mg/kg in test pit BT-2 at the far end of the ditch.

In addition to the constituents listed in Table 3.1-2, several organic compounds were detected in the test pit samples and borehole.

216-S-10 Pond. Borehole B8817 was drilled to 73.4 meters below ground surface near the 216-S-10 pond. (The depth to groundwater at the 216-S-10 pond and ditch is ~70 meters below ground surface.) Four test pits, SP-1 through SP-4, were excavated in various parts of the pond. Each test pit was excavated to a depth of 7.6 meters. The location of the 216-S-10 pond and ditch is shown on Figure 2.9-1 in Section 2.9, and the location of the borehole and test pits are shown on Figure 3.1-3.

In addition to borehole B8817, wells 299-W26-6 and 699-32-77 were logged with a spectral gamma tool. No manmade radionuclides were found in B8817. Cesium-137 was detected near the surface of the other two wells with a maximum concentration of 2.5 pCi/g in well 299-W26-6.

Analytical results from samples from borehole B8817 showed nickel-63 to be the only radionuclide present. There was very little metal and anion contamination in the borehole samples. Table 3.1-3 shows the maximum concentrations of analytes exceeding background at the 216-S-10 pond. There appeared to be no discernible pattern with respect to lateral trends in contamination. Radionuclides, metals, soluble salts, and organics appear to be randomly distributed in the 216-S-10 pond.

216-S-10 Ditch. Borehole B8828 was drilled to 81.1 meters below ground surface near the center of the 216-S-10 ditch. Three test pits were excavated. Test pit SD-1 was excavated to a depth of 5.2 meters at the outflow end of the ditch where effluent from the ditch entered the 216-S-10 and 216-S-11 ponds. Test pit SD-2 was excavated to 0.9 meter at the inlet end of the ditch and test pit SD-3 was excavated to 4.6 meters at the middle of the ditch near borehole B8828.

The only manmade radionuclide detected by spectral gamma logging of borehole B8828 was cesium-137, which was found at several depths at a concentration near the 0.2 pCi/g detection limit. Nickel-63 was the only radionuclide found in the laboratory samples from the borehole. The only manmade radionuclides found in the test pit samples were cesium-137 and plutonium-239/240. However, nickel-63 was not an analyte for the test pit samples. The maximum concentration of radionuclides and non-radionuclide analytes exceeding background are listed in Table 3.1-4. Most of the maximum concentrations were associated with a single sample from depths of 0 to 0.5 meter in test pit SD-2, near the inlet to the ditch. This suggests most contamination associated with the 216-S-10 ditch is near the head end of the ditch and close to the surface.

Boreholes and test pits helped characterize the nature and vertical extent of contamination in the vadose zone underlying the 216-A-29 ditch, 216-B-63 trench, and 216-S-10 ditch and pond.

3.1.1.2 Vadose Zone Characterization at the 200-CW-5 Operable Unit

J. C. Bower

A remedial investigation was conducted from January to October 2002 for the 200-CW-5 Operable Unit. A remedial investigation report was issued in 2004 (DOE/RL-2003-11) fulfilling the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-15-40B (Ecology et al. 1989). The remedial investigation report includes the 200-CW-2 S pond and ditches, 200-CW-4 T pond and ditches, and the 200-SC-1 Steam Condensate Operable Units because they received similar waste as the 200-CW-5 Operable Unit, and the contaminant distribution beneath all these waste sites was expected to be the similar. The basis for this grouping is given in DOE/RL-96-81 and DOE/RL-98-28.

This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section and the reader is referred to the remedial investigation document.

The 216-Z-11 ditch is located south and southeast of the Plutonium Finishing Plant, 200 West Area (see Figure 2.9-1 in Section 2.9). Twenty GeoProbe®[a] soil probes were installed at the 216-Z-11 ditch in five transits. The locations of the five transits were at portions of the ditch where the highest transuranic contamination was expected. Each probe was logged with a gross gamma/passive neutron logging system to determine the gross concentration and type of gamma-emitting constituent present. The logging results were used to locate one borehole (C3808) in the area of the highest contamination in the ditch. The borehole was drilled through the 216-Z-11 ditch to a depth of 68.6 meters below ground surface and 33 soil samples were collected during drilling for physical property, chemical, and radionuclide analyses. Details on the drilling of borehole C3808 can be found in CP-12134. Borehole C3808 was also logged with gross gamma and passive neutron tools and soil gas was sampled. The location of the borehole is shown on Figure 3.1-4.

Samples from several boreholes adjacent to three ditches contained very little contamination and concentrations were <1 pCi/g.

Contamination was found in the vadose zone beneath the 216-Z-11 ditch to a depth of 12 meters below ground surface. Americium-241 and plutonium-239/240 were the dominant contaminants detected at the bottom of the ditch at ~2.3 to 2.6 meters below ground surface. Concentrations were 468 and 2,780 pCi/g, respectively. Maximum concentrations of americium-241 (919 pCi/g) and plutonium-239/240 (4,840 pCi/g) were detected ~1.2 meters beneath the bottom of the ditch.

Other radiological contaminants detected in borehole C3808 between 2.3 and 5.3 meters below ground surface include plutonium-238 (58.4 pCi/g), radium-226 (1.07 pCi/g), strontium-90 (2.73 pCi/g), and thorium-230 (8.43 pCi/g). At depths greater than 5.3 meters, the concentrations were less than 1 pCi/g.

Nitrite and total petroleum hydrocarbon exceeded screening levels in soil samples collected from borehole C3808. Nitrite was found between 3 and 5.3 meters below ground surface with a maximum concentration of 43 mg/kg at a depth of 3 meters. Concentrations decreased with depth to 5.3 meters. Total petroleum hydrocarbon was detected 3.0 to 3.8 meters below ground surface at 27 mg/kg.

Molybdenum was the only metal to exceed screening levels in soil sample from borehole C3808. Molybdenum was found at a concentration of 0.82 mg/kg between 46 and 47 meters below ground surface.

(a) GeoProbe is a registered trademark of Kejr, Inc., Salina, Kansas.

Contaminant concentrations found in borehole C3808 were lower than expected. Comparison of the data from the 216-Z-11 ditch with previously collected data from the adjacent 216-Z-1D and 216-Z-19 ditches showed significantly higher contaminant concentration in the latter two ditches. Because of that and because the 216-Z-11, 216-Z-1D, and 216-Z-19 ditches were known to converge in the area of the borehole, the remedial investigation included data from samples previously collected from the 216-Z-1D and 216-Z-19 ditches.

In 1959, nine surface grab samples were collected along the length of the 216-Z-1D ditch and analyzed for plutonium-239 and alpha activity. The plutonium-239 concentrations ranged from 24,000 to 780,000 pCi/g and alpha activity ranged from 26,000 to 860,000 pCi/g in the 216-Z-1D ditch samples. Additional samples from the ditch collected in 1959 had plutonium-239 concentrations between 1.27 million and 4.46 million pCi/g and alpha activity between 15,000 and 27.1 million pCi/g.

In 1981, boreholes drilled through the 216-Z-1D ditch found a major zone of contamination between 0.9 and 4.3 meters below ground surface where the maximum concentrations were plutonium-239/240 (380,000 pCi/g), plutonium-238 (5,252 pCi/g), and americium-241 (34,809 pCi/g). Contaminant concentrations decreased to less than 1 pCi/g at 6 meters below ground surface.

Also in 1981, soil samples were collected from the 216-Z-19 ditch to a depth of 4.9 meters. Data from those samples indicated that contaminants were present to 4.9 meters, and the highest levels of contamination were associated with the bottom of the ditch. Contaminant levels generally were higher near both ends of the ditch, and the maximum contaminant concentrations were near the end of the ditch near the 216-U-10 pond. Maximum plutonium-239/240 concentration was 13 million pCi/g and maximum americium-241 concentration was 7.86 million pCi/g. Also in 1981, samples from several boreholes located adjacent to the three ditches contained very little contamination and concentrations were less than 1 pCi/g.

Most contamination is confined to within 0.5 to 1.2 meters of ditch bottoms in the 200-CW-5 Operable Unit.

Based on all the data considered in the remedial investigation, the 216-Z-1D ditch contains the highest concentrations of contaminants, primarily plutonium-239/240. Most of the contamination is confined to within 0.5 to 1.2 meters of the ditch bottoms. Boreholes drilled in the vicinity of the Z ditches suggest that contamination is largely confined laterally to within a few meters of the ditch boundaries. The data also suggest that contamination is distributed over the entire length of the ditches and there is significant variability in concentrations among closely spaced samples.

3.1.1.3 Vadose Zone Characterization at the 200-PW-2 and 200-PW-4 Operable Units

L. C. Hulstrom

A remedial investigation was conducted from April to November 2003 for the 200-PW-2 and 200-PW-4 Operable Units. A remedial investigation report was issued in 2004 (DOE/RL-2004-25) fulfilling Tri-Party Agreement Milestone M-15-43B. This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section, and the reader is referred to the remedial investigation document.

A total of 175 samples were collected in the vadose zone at the 200-PW-2 and 200-PW-4 Operable Units as part of a remedial investigation.

Four boreholes were drilled for the 200-PW-2 Operable Unit (one each at the 216-A-10 crib, 216-A-19 trench, 216-A-36B crib, and the 216-B-12 crib) and one was drilled at the 216-A-37-1 crib for the 200-PW-4 Operable Unit. Four large-diameter push holes were placed at the 216-A-10 crib and one at the 207-A south retention basin. Two auger holes were also drilled in the 207-A south retention basin. Details concerning borehole drilling and sampling activities can be found in CP-18666. The four boreholes and five push holes were logged with spectral gamma and neutron moisture tools.

A total of 175 samples were collected from the boreholes. Samples were analyzed for ammonia, anions, hexavalent chromium, cyanide, metals, oil, grease, pesticides, herbicides, polychlorinated biphenyls, semivolatile organics, total petroleum hydrocarbons, radionuclides, volatile organics, moisture content, particle size distribution, and bulk density. The data were compared to background concentrations from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

The remedial investigation report included data collected in the early 1990s at the 216-U-8 and 216-U-12 cribs. A discussion of those data can be found in DOE/RL-95-13.

The concentrations of most constituents tended to decrease with depth below the bottom of the 216-A-19 trench.

216-A-19 Trench. The 216-A-19 trench is located between the 216-A-8 and 216-A-24 cribs, east of 200 East Area. The location of borehole C3245 is shown on Figure 3.1-5. Borehole C3245 was drilled through the 216-A-19 trench to 78.2 meters below ground surface total depth. (The depth to groundwater in the area is ~80 meters below ground surface.) The sediment encountered include 5.2 meters of trench backfill materials underlain by the sand and gravel of the Hanford formation. Cesium-137, uranium-235, and uranium-238 were the only manmade radionuclides found by geophysical logging. The cesium-137 concentration was up to 40 pCi/g between depths of 0.3 to 3.4 meters. The high cesium-137 concentrations at relatively shallow depths may have resulted from waste discharged to the 216-A-34 ditch, which may have overflowed into the 216-A-19 trench.

Geophysical logging of borehole C3245 showed that the uranium-238 concentrations were between 18 and 560 pCi/g in the depth interval 2 to 9.3 meters. The maximum concentrations of both cesium-137 and uranium-238 occurred at 2.4 meters below the surface. Uranium-235 at a concentration of 8 pCi/g was detected at 2.4 meters.

Samples were collected from ten depths in borehole C3245. Laboratory analysis of the samples showed that contamination is in the vadose zone beneath the 216-A-19 trench to a depth of 75.6 meters below ground surface. Table 3.1-5 shows the radionuclides detected with concentrations above 1 pCi/g and the non-radionuclides that exceeded screening levels. The table gives the maximum concentrations encountered and the associated depth. All detected radionuclides with concentrations greater than 1 pCi/g were found between 4.4 and 5.3 meters below ground surface. The bottom of the ditch was at 4.6 meters. The concentrations of most constituents decrease with depth below the bottom of the trench.

216-A-10 Crib. The location of the 216-A-10 crib is shown on Figure 2.10-1 in Section 2.10. Borehole C3247 was drilled near the center of the 216-A-10 crib to a total depth of 98.8 meters below ground surface. The location of the borehole is shown on Figure 3.1-6. (The depth to groundwater at the crib is ~98 meters below ground surface.) Crib fill materials were encountered to 13.7 meters. The Hanford formation sands and gravels were drilled from 13.7 meters to total depth. Two palesols were noted: one at 16.2 to 16.5 meters and the other at 88.5 to 89.3 meters below ground surface. Twelve samples were collected from the borehole. Five large-diameter push holes also were installed through the crib to depths between 18.3 and 27.8 meters. All of the push holes (as well as borehole C3247) were logged with a spectral gamma tool.

Spectral gamma logging found cesium-137 in all holes. The maximum cesium-137 concentration ranged from 1,300 to 3,600 pCi/g between 14 and 18.6 meters. Cesium-137 was found as deep as 25.6 meters in borehole C3247 but at levels near the minimum detection limit of 0.3 pCi/g.

For most radionuclides with concentrations greater than 2.5 pCi/g, the maximum concentrations were between 15.8 and 18.9 meters below ground surface. The exceptions are tritium and strontium-90, which were found deeper. Table 3.1-6 lists the maximum concentrations of radionuclides present at concentrations greater than 2.5 pCi/g.

216-A-36B Crib. The location of the 216-A-36B crib is shown on Figure 2.10-1 in Section 2.10. Borehole C4160 was drilled through the 216-A-36B crib to a depth of 97.8 meters. The location of borehole C4160 is shown on Figure 3.1-6. (The depth to groundwater at the crib is ~98 meters below ground surface.) The crib bottom was penetrated at ~8 meters below ground surface. Ammonia vapors were detected in the drill cutting during drilling. The ammonia content tended to increase with increasing silt and carbonate cement and decrease with increasing sand content. Twelve soil samples were collected from the borehole during drilling.

The spectral gamma log identified cesium-137 between 0 and 1.5 meters depth at concentrations of less than 10 pCi/g and between 6.1 and 29 meters depth with a maximum concentration of 2 million pCi/g at 8.2 meters. Cobalt-60 was detected between 11.5 and 18.2 meters below ground surface with a maximum concentration of 1.5 pCi/g at 15.2 meters.

Laboratory analyses of samples from borehole C4160 showed that radionuclide contamination was beneath the 216-A-36B crib to a depth of 96.5 meters. With two exceptions, the radionuclide contaminants with maximum concentrations greater than 3 pCi/g are found between the depths of 7.6 and 9.1 meters near the crib bottom. The exceptions are tritium, with a maximum concentration of 121 pCi/g at 87.6 meters, and potassium-40 with a maximum concentration of 19.4 pCi/g at 16.3 meters below ground surface. Table 3.1-7 gives the maximum concentrations for radionuclides with concentrations greater than 3 pCi/g and concentrations for non-radionuclides that exceeded the screening limit. The high concentrations of plutonium-239/240 and americium-241 indicate that some of the soil from this crib may be designated as transuranic waste.

The high concentrations of plutonium-239/240 and americium-241 indicate that some of the soil from the 216-A-36B crib may be designated as transuranic waste.

216-A-37-1 Crib. The location of the 216-A-37-1 crib is shown on Figure 2.10-1 in Section 2.10. Borehole C4106 was drilled through the 216-A-37-1 crib to a total depth of 84.8 meters. The location of the borehole is shown on Figure 3.1-7. (The depth to groundwater at the crib is ~85 meters below ground surface.) The bottom of the crib was found at 3.8 meters. Eleven samples were collected from the borehole during drilling.

Cesium-137 was the only manmade radionuclide detected by spectral gamma logging. Cesium-137 was detected at concentrations between 0.2 and 30 pCi/g between 2.7 and 11 meters.

Laboratory analysis of the eleven samples showed that three radionuclides were present at concentrations greater than 1 pCi/g and four metals and anions exceeded the screening limit. Table 3.1-8 provides the analytical results.

216-B-12 Crib. The 216-B-12 crib is located ~400 meters south of Low-Level Waste Management Area 1. Borehole C3246 was drilled through the 216-B-12 crib to a total depth of 93.3 meters below ground surface. The location of the borehole is shown on Figure 3.1-8. (The depth to groundwater at the crib is ~92 meters below ground surface.) The bottom of the crib was encountered at 9.8 meters. Nine samples for analytical testing were collected from the borehole. High levels of radiation and ammonia were detected during drilling.

Cesium-137, europium-154, and uranium-238 were found by spectral gamma logging. Cesium-137 was identified between the surface and 2.1 meters at concentrations between 0.3 and 12 pCi/g and between 9.1 and 33.6 meters at concentrations between 0.6 and 121,000 pCi/g. The maximum concentration of cesium-137 was at 10.7 meters depth, which corresponds with the maximum cesium-137 found in soil samples (Table 3.1-9). Europium-154 was detected at 9.4 meters with a concentration of 9 pCi/g; uranium-238 was found at 35.8 meters with a concentration of 13 pCi/g.

Laboratory analyses of samples from borehole C3246 showed that most radionuclides with concentrations greater than 1 pCi/g had maximum values at or above a depth of 12.1 meters. Table 3.1-9 gives the maximum concentrations of radioisotopes with concentrations greater than 1 pCi/g and non-radionuclides that exceeded the screening limit.

Little radionuclide contamination was detected in the vadose zone beneath the 207-A south retention basin.

207-A South Retention Basin. The 207-A south retention basin is located south of Waste Management Area A-AX. Three types of samples were collected at the 207-A south retention basin: three samples of the concrete and polyurethane sealant, four soil samples from each of three borehole drilled through the basin floor, and composite samples of soil and water from residual runoff in the basin.

Relatively little radionuclide contamination was detected in the vadose zone beneath the basin. The only radionuclides with concentrations greater than 1.5 pCi/g were thorium-234 (3.16 pCi/g) and tritium (16.6 pCi/g). No non-radionuclide exceeded screening levels.

Organics related to the polyurethane sealant were found in the concrete samples. Also, tributyl phosphate, which was in the process condensates stored in the basin, was present in small amounts in the concrete. The composite soil and water had gross beta at 15 pCi/L, gross alpha at 2 pCi/L and total organic carbon at 18.9 mg/L in the water. No other measurements were elevated above normal levels.

3.1.2 Characterization at Waste Management Area T

R. J. Serne, B. N. Bjornstad, D. G. Horton, D. C. Lanigan, C. W. Lindenmeier, M. J. Lindberg, R. E. Clayton, V. L. LeGore, K. N. Geiszler, S. R. Baum, M. M. Valenta, I. V. Kutnyakov, T. S. Vickerman, R. D. Orr, and C. F. Brown

The Vadose Zone Project managed by CH2M HILL Hanford Group, Inc. drilled two characterization boreholes (C4104 and C4105) in the T Tank Farm, 200 West Area, during 2003. The boreholes were sampled, and the samples analyzed during 2003 and 2004. The details of drilling and sampling can be found in RPP-16340 and RPP-17275. The details of the analytical work and the interpretation of the results can be found in PNNL-14849. This section summarizes the more important findings in PNNL-14849.

Two boreholes were extended from the ground surface down to refusal in the Ringold Formation member of Wooded Island and were located to evaluate the 1973 leak from tank T-106. Borehole C4104 was drilled as close as possible (~4 meters south) to the existing borehole, 299-W10-196, which was drilled through the T-106 leak in 1992 and 1993, to allow comparisons of the extent of vertical migration that occurred over the 10-year period. Borehole C4105 was drilled ~26.8 meters west of borehole C4104. The bottom of tank T-106 is ~13 meters below ground surface. The water table at the T Tank Farm is ~71 meters below ground surface.

Nitrate distribution suggests that fluid leaked from tank T-106 has spread at least 26 meters laterally in the Cold Creek unit and Ringold Formation.

Sediment samples from both boreholes were analyzed for the following parameters: moisture content, gamma-emitting radionuclides, 1:1 water extracts (which provides soil pH, electrical conductivity, cation, trace metal, radionuclide, and anion data), total and inorganic carbon, and 8 M nitric acid extracts.

Moisture content, pH, electrical conductivity, nitrate, technetium-99, sodium, and uranium concentrations were selected as the main indicators of the leading edge of the contaminant plume. Of these parameters, the moisture content, pH, sodium, and uranium were not indicative of the extent of contamination. The moisture content turned out to be more a function of grain size than a direct measure of leaked tank liquid. The pH never exceeded 10, which was unexpected based on the assumption that the tank liquid was caustic to very caustic (>1 M hydroxide). The uranium data suggested that only small quantities were present in the leaked liquid, and the sodium data showed obvious ion exchange with the sediments that retarded its migration.

The nitrate water extract concentrations from borehole C4104 were elevated from 19.5 meters below ground surface to the bottom of the borehole at 38.7 meters below ground surface. The highest nitrate concentration was 2,565.63 µg/g at 35 meters below ground surface, which is 1,000 times background. The nitrate concentrations in water extracts from borehole C4105 were elevated between ~26.5 and 39.6 meters below ground surface with the highest nitrate concentration of 1,511 µg/g occurring at a depth of 26.8 meters.

The distribution of contaminants in the vadose zone in 1973 suggested that the leak occurred near the southeast quadrant of tank T-106 in the vicinity of borehole C4104. The current distribution of nitrate suggests that the leaked liquid has penetrated as deep as the Ringold Formation member of Taylor Flat (upper contact 32.9 to 33.8 meters below ground surface) and has spread at least 26.5 meters laterally in the Cold Creek unit and Ringold Formation member of Taylor Flat to borehole C4105. Comparing the nitrate concentrations in samples from borehole C4104 with the concentrations in samples from nearby borehole 299-W10-196 suggests that the maximum concentration of nitrate may be ~1.8 meters deeper in C4104 than it was in borehole 299-W10-196 in 1993. This could be the result of vertical migration during the last 10 years or could represent simultaneous deposition of nitrate from a non-planar wetting front.

The technetium-99 water extract concentrations from borehole C4104 were elevated from 12 meters below ground surface to the bottom of the borehole. The highest technetium-99 concentrations were in the Ringold Formation member of Taylor Flat and reached 6,110 pCi/g. The high concentrations of technetium-99 between 29 and 32 meters below ground surface in the lower Cold Creek unit found in borehole 299-W10-196 in 1993 are not present in borehole C4104 in 2004. This may indicate vertical redistribution of technetium-99 during the last 10 years. The maximum concentrations of technetium-99 in borehole C4105 were in the upper Cold Creek unit and reached 1,650 pCi/g. The upper Cold Creek unit is a silt-rich unit, which may perch water in some areas.

Neither the nitrate nor the technetium-99 distribution identifies the leading edge of the contamination because neither borehole penetrated the bottom of the plume. The profiles do suggest that the center of mass of the tank-related liquid resides in the fine-grained sediments of the Ringold Formation member of Taylor Flat.

The in situ desorption K_d results suggest that technetium-99 and cobalt-60 are very mobile, uranium is considerably less mobile, and chromium is the least mobile.

Site-specific desorption K_d values for technetium-99, uranium, chromium, and cobalt-60 (borehole C4104 only) were calculated from the data from boreholes C4104 and C4105 by dividing the mass per gram of sediment by the estimated pore water concentration of the constituent obtained from the dilution-corrected 1:1 water extract concentrations. The full suite of data can be found in PNNL-14849. The K_d data show two trends. First, where there are significant concentrations of contaminants in the sediments (between depths of 14.12 and 38.1 meters in borehole C4104 and between 21.34 and 39.62 meters in borehole C4105), the K_d values for uranium and chromium are smaller (i.e., the contaminants are more mobile) than their values at shallower and deeper depths. This is caused both by (1) more saline pore water (competing ions) and (2) higher contributions of waste species for chromium and uranium being present, which are generally more water leachable than naturally present species.

The second trend shows that the desorption K_d values for technetium-99 and cobalt-60 in the main portion of the vadose zone plumes are very close to 0 mL/g, whereas the desorption K_d values for uranium in the main portion of the plumes varies between 0.06 and 2 mL/g in borehole C4104 and between 30 and 80 mL/g in borehole C4105. The desorption K_d values for chromium in the zones where elevated chromium are present vary between 0.5 and 5 mL/g in both boreholes. The in situ desorption K_d results suggest that technetium-99 and cobalt-60 are very mobile, uranium is considerably less mobile, and chromium is the least mobile. These variations in K_d results have applications in modeling. However, these variations are only applicable to these boreholes in this specific geochemical environment.

3.1.3 Vadose Zone Characterization at Waste Management Area C

C. F. Brown and R. J. Serne

The magnitude of contamination found in borehole C4297 at the C Tank Farm is not as great as that found in boreholes at other tank farms.

The Vadose Zone Project managed by CH2M Hill Hanford Group, Inc. drilled one characterization borehole (C4297) in the C Tank Farm during FY 2004 (see Figure 2.10-1 in Section 2.10 for location of Waste Management Area C). The borehole was placed southwest of tank C-105 to investigate: (1) a liquid level drop, believed to be due to evaporation, which occurred in tank C-105 between 1963 and 1967 and (2) vadose zone monitoring data (spectral gamma data from drywell 30-05-07) that indicate two high cesium-137 zones located near and just below the bottom of tank C-105. This section summarizes the results of the characterization effort. The complete results will be published in FY 2005.

Total depth of the borehole was based on rapid turnaround analysis of key mobile contaminants (technetium-99 and nitrate) in grab samples collected as part of the drilling activities. Previous research had shown that technetium-99 and nitrate profiling accurately identifies the maximum vertical penetration of tank waste leaks into the vadose zone (PNNL-13757-2; PNNL-13757-4; PNNL-14083). Advancement of the borehole was halted in the Hanford formation sand sequence (H2 subunit of WHC-SD-EN-TI-290) at a total depth of 59.9 meters below ground surface after technetium-99 was no longer identified in water extracts from seven grab samples representing the final 9 meters of borehole depth. In all, 10 cores (35 samples) were retrieved from borehole C4297 between depths of 7.8 and 41.1 meters. Additionally, 112 grab samples were collected between depths of 0.8 and 63.8 meters. All of the core samples were submitted for radiological, chemical, and geochemical analyses; a summary of the analyses is presented here.

Field measurements included geophysical logging of the characterization borehole using a spectral gamma tool. Cesium-137, cobalt-60, and europium-154 were identified on the log. The maximum cesium-137 concentration was 1,700 pCi/g at ~4.3 meters depth; the maximum cobalt-60 concentration was 1 pCi/g at ~4.5 meters depth; and the maximum europium-154 concentration was 400 pCi/g at ~ 4 meters depth.

Laboratory tests were conducted to characterize the sediment and identify water-leachable constituents. Testing consisted primarily of 1:1 sediment:water extractions that were used to calculate the elemental concentrations of water soluble constituents in the solid and estimate in situ pore water chemistry conditions. Additionally, 8 M nitric acid extractions were used to provide a measure of the total leachable sediment content of contaminants. Radioanalytical analyses of the sediment samples consisted of gamma energy analysis as well as total beta and alpha measurements of the 1:1 sediment:water and 8 M nitric acid extracts.

Of the geochemical parameters measured in the core samples, pH and electrical conductivity, as well as concentrations of nitrate, sodium, uranium, and technetium-99 in water extracts are the main indicators of vadose zone contamination. A spike was observed in both pH (2 pH unit increase) and electrical conductivity (a factor of 5 increase) in water extracts of sediment samples associated with the bottom of the tank. Similarly, sodium levels were elevated by up to a factor of 6 in water extracts of sediment samples from this depth (13 to 14.6 meters below ground surface). Evaluation of these data suggests that chemical reactions between alkaline fluids (possibly tank related) and the native sediment has created an ion exchange front, whereby sodium has replaced calcium and magnesium on the sediments' exchange sites, extending from ~13 meters to as deep as 20 meters below ground surface.

Water-extractable technetium-99 was observed in borehole C4297 grab and core samples from 13.3 to 52.3 meters below ground surface, with a peak water-extractable sediment activity of 5.84 pCi/g at 47.8 meters below ground surface. The profile of water-extractable nitrate from C4297 grab and core samples correlates well with the technetium-99 profile, with a peak water-extractable nitrate concentration of 17.3 µg/g occurring at 43.8 meters below ground surface. Water-extractable uranium was observed in C4297 grab and core samples from 13.3 to 18.6 meters below ground surface, with a peak water-extractable sediment concentration of 0.022 µg/g at 5.6 meters below ground surface. Minor amounts of beta activity were measured in the C4297 splitspoon acid-extract samples, with peak activities of 33.5 and 31.5 pCi/g occurring at 8.1 and 13 meters below ground surface, respectively. Gamma energy analysis of C4297 splitspoon samples resulted in the detection of no manmade gamma emitters in the sediment profile above concentrations of a few tenths of a picocurie per gram.

The magnitude of contamination found in borehole C4297 is not as great as that found in boreholes at other tank farms. Specifically, the peak water extractable technetium-99 concentration (5.84 pCi/g) measured in sediment samples from C4297 is three orders of magnitude less than the peak concentration measured in cores collected beneath tank SX-108 (10,300 pCi/g). Similarly, the peak acid-extractable uranium concentration (0.958 µg/g) measured in sediment samples from C4297 is three orders of magnitude less than the peak concentration measured in cores collected in the vicinity of tank BX-102 (1,787 µg/g).

3.1.4 Borehole Geophysics for Vadose Zone Characterization

R. G. McCain

As the prime contractor for the U.S. Department of Energy (DOE) Grand Junction Office, the S.M. Stoller Corporation (Stoller) provides geophysical logging services and technical support for the Hanford Site. Geophysical logging in new and existing boreholes is used for stratigraphic correlation and to detect and quantify radioactive contaminants.

Log data, log plots, and reports are accessible via the Internet at http://www.gj.em.doe.gov/hanf.

3.1.4.1 Available Logging Equipment

Borehole logging equipment currently in use for vadose zone characterization at the Hanford Site includes the spectral gamma logging system (SGLS) and the neutron moisture logging system (NMLS). The SGLS uses a cryogenically cooled, high-purity germanium detector to detect, identify, and quantify gamma-emitting radionuclides in the subsurface. Identification of naturally occurring and manmade radionuclides is based on detection of characteristic gamma rays emitted during decay of specific radionuclides. The SGLS is calibrated by measuring detector response to gamma rays from potassium, thorium, and uranium, resulting in a continuous detector response over an energy range from 180 KeV to 2.6 MeV. Minimum detection limits are provided for typical counting times and borehole environments. Corrections are available for dead time, well casing thickness, and the presence of water. A variation of the SGLS, known as the high-rate logging system, uses a much smaller detector than the SGLS and can collect log data in zones of very high gamma activity where the spectral gamma logging detector is saturated. When used in combination, the SGLS and high-rate logging system provide a measurement capability from ~0.1 to 10^9 pCi/g cesium-137.

Geophysical logging allows scientists to determine the characteristics of subsurface, geology, and contaminant distribution through cased or uncased boreholes.

Spectral gamma and total gamma logs are used for stratigraphic correlation, as well as for detection of manmade gamma-emitting radionuclides. Evaluation of high-resolution gamma energy spectra allows identification of radon accumulation in boreholes and differentiation between manmade and naturally occurring uranium. Long-lived radionuclides identifiable by spectral gamma logging include cobalt-60, cesium-137, europium-152 and europium-154, and neptunium-237. Plutonium-239 and americium-241 can also be detected, albeit at much higher concentrations because of the relatively low intensity of their characteristic gamma-ray emissions. In some cases, it is possible to qualitatively detect beta-emitting radionuclides (i.e., strontium-90) by the bremsstrahlung generated from interaction of beta particles and the steel casing. (Bremsstrahlung is electromagnetic radiation emitted when a charged particle changes its velocity.)

The NMLS uses a 50-mCi americium/beryllium source and helium-3 detector. Neutrons emitted from the source bombard the surrounding formation and are scattered back to the detector. In geologic media, the dominant mechanism for neutron scattering is interaction with hydrogen atoms, and the count rate at the detector is a function of the amount of hydrogen in the formation, which is generally an indicator of the moisture content. Neutron moisture logs are useful as an indication of in situ moisture content and for stratigraphic correlation. The NMLS is calibrated for moisture content in 15-centimeter- and 20-centimeter-diameter cased holes. For other borehole diameters, it can be used qualitatively to identify differences in moisture content. Neutron moisture logs are useful in correlation because fine-grained layers tend to have higher moisture content.

The passive neutron log measures the ambient neutron flux in the borehole. This log is a qualitative indicator of the presence of alpha-emitting radionuclides. Alpha particles emitted from decay of transuranic elements such as plutonium-239 or americium-241 interact with light elements in the soil (primarily oxygen), generating secondary neutrons by (alpha, n) reactions. These neutrons may penetrate the steel casing and be detected by the passive neutron log, or they may be slowed by interactions with the formation and eventually captured. Of the elements commonly present in soil, hydrogen is the most likely to interact with neutrons. Hydrogen has a high capture cross section and promptly emits a gamma ray at 2223.25 KeV, with an intensity of 1 gamma per capture. These gamma rays are detectable with the SGLS and subject to relatively little interference. Thus, the presence of the hydrogen capture line in passive gamma spectra is a qualitative indication of the presence of both soil moisture and alpha-emitting radionuclides.

The baseline characterization program establishes data against which future data can be compared to assess the movement of contaminants.

3.1.4.2 Baseline Characterization Program

The primary goal of the baseline characterization program is to collect initial SGLS data at waste sites in the Hanford 200 Area. These data are used to establish a baseline against which future log data are compared to assess contaminant mobility in the subsurface. The intent of the baseline characterization program is to log boreholes in a specific area, review and update historical log data, integrate the log results, and report the findings for that area. This approach is described in GJO-HGLP 1.7.1. A prioritized list of areas to be investigated and available boreholes organized by waste site is maintained by Stoller. This list is subject to change, depending on remedial investigation activities and the borehole decommissioning project.

During FY 2004, baseline characterization logging was performed at the 216-A-27 crib, in the B/C crib area, and in the vicinity of the 216-T-6 crib. The B/C cribs area is also the subject of remedial investigation activities, and the seven existing boreholes logged in this area could also be considered under remedial investigation support.

For the most part, the baseline characterization logging was superceded by logging for remedial investigation support in FY 2004. Priority for baseline logging operations was also subject to change as boreholes were identified for decommissioning. Boreholes selected for decommissioning are reviewed by Stoller and those in or near known waste sites are logged as part of the baseline program prior to decommissioning. In two cases, Stoller ran total gamma logs in two 600 Area boreholes scheduled for decommissioning. The purpose of these logs was to determine depths for multiple casing strings where as-built drawings were not available.

3.1.4.3 Remedial Investigation Support

In addition to baseline characterization, borehole geophysical logging also supports remedial investigations and feasibility studies for the Groundwater Remediation Project's assessment of the Central Plateau operable units. Geophysical logging is also performed in new and existing boreholes as requested by the responsible Hanford Site contractors. Log data plots and reports are provided to project representatives.

During FY 2004, logging operations to support remedial investigation activities were performed in 91 boreholes. In addition to spectral gamma logging, high rate logging, neutron moisture logging, and passive neutron logging were also performed in selected boreholes. Areas in which logging was performed included the 216-A-4, 216-A-8, and 216-A-10 cribs; the B/C cribs area; 216-S-7 and 216-S-20 cribs; the 216-T-28 crib; and the U Plant area. In the U Plant area, drive casings were driven specifically for geophysical logging to determine the maximum extent of lateral contaminant migration in the shallow vadose zone to support cover design.

During FY 2004, geophysical logging was performed at 91 boreholes to support remedial investigation activities.

In addition to logging operations in the 200 Area and vicinity, three existing extraction wells in the 100-D Area in situ redox manipulation project were logged to assess the ability of geophysical logs to detect subtle variations in stratigraphy which may affect contaminant migration in the shallow aquifer.

3.1.4.4 Groundwater Well Development

Spectral gamma logs are run in newly drilled RCRA groundwater wells prior to well completion. In many cases, neutron moisture logs are also run. These logs provide a record of vadose zone conditions at the well location and help stratigraphic interpretation. During FY 2004, 14 groundwater wells were logged.

3.1.5 Characterization of the BC Cribs and Trenches

J. W. Lindberg

Characterization of the BC cribs and trenches began in FY 2004 to support the 200-TW-1 Scavenged Waste Operable Unit feasibility study. The purpose of the characterization is to find the concentration and extent of subsurface contamination in the area. The location of the BC cribs is shown on Figure 2.10-1 in Section 2.10.

Field activities included drilling 14 shallow boreholes to find the most contaminated areas, drilling 3 deeper boreholes to characterize the contamination at depth, and surface geophysical surveys to identify existing infrastructure from legacy disposal activities and delineate the edges of a radionuclide and heavy metal contamination plume in the vadose zone. Preliminary results are summarized in this section. A more detailed discussion of the characterization activities will be included in the FY 2005 groundwater report after data become available.

Results of soil sampling and analysis in the shallow boreholes indicated that the surface contamination was greatest at two trenches: 216-B- 26 and 216-B-58. The three deeper soil borings focused on these two trenches. At trench 216-B-26, one borehole was drilled to the water table, soil samples were collected while drilling, and a water sample was collected from the aquifer. At trench 216-B-58, two 30.5-meter boreholes were drilled and soil samples were collected.

Preliminary results of soil sampling at the 216-B-26 trench indicated that there was significant near-surface contamination that included cesium-137 (529,000 pCi/g), strontium-90 (974,000 pCi/g), and uranium (56.9 mg/kg) contamination between 3.7 and 4.6 meters depth. The bottom of the trench is at ~3 meters depth. The maximum technetium-99 (92 pCi/g) and nitrate (4,090 mg/kg) concentrations occurred at ~30.5 meters depth. Soil samples in the two 30.5-meter boreholes, at the 216-B-58 trench, showed little contamination. The only significant contamination in the groundwater sample was filtered manganese with a concentration of 208 µg/L (drinking water standard 50 µg/L). High concentrations of manganese are common in recently drilled wells suggesting that the elevated manganese in the groundwater may not be related to BC cribs waste disposal.

The high resolution resistivity survey successfully identified subsurface contamination at the BC cribs and trenches.

The surface geophysical investigations (PNNL-14948) included magnetic gradiometry, electromagnetic induction, and high resolution resistivity. The magnetic and electromagnetic surveys were to provide rapid reconnaissance coverage to detect the presence of shallow, electrically-conductive material (liquid and metallic) and ferrous metallic material associated with historic disposal activities. These features were a concern because they could influence the subsequent high resolution resistivity survey.

The electromagnetic surveys found that only some of the trenches gave shallow electromagnetic responses and several showed unusual responses. All of the cribs responded to the electromagnetic surveys. Several pipelines and infrastructural features were detected.

The high resolution resistivity survey successfully identified subsurface contamination because the contaminant plume has electrical properties that were significantly different from the background Hanford formation. The plumes electrical signature was found to spread laterally beyond the edges of the trenches and cribs and vertically down to a hydraulically resistive layer at a depth of 42 meters below ground surface.

Table 3.1-1. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-A-29 Ditch[(a)]

Constituent	Concentration[(b)]	Location	Depth Below Ground Surface (m)
Acetone	13	Test pit AD-2	2.3
Americium-241	145	B8826	1.2
Ammonia	41.6	Test pit AD-1	1.2 to 1.5
Bis(2-ethylhexyl)phthalate	470	Borehole B8826	2.7
Chloride	226	Test pit AD-1	1.2 to 1.5
Cadmium	28	Test pit AD-1	1.2 to 1.5
Calcium	24,300	Test pit AD-3	1.8 to 2.1
Cesium-137	98	Test pit AD-1	1.2 to 1.5
Chromium	36.8	Test pit AD-1	1.2 to 1.5
Copper	172	Test pit AD-1	1.2 to 1.5
Lead	390	Test pit AD-1	1.2 to 1.5
Mercury	5.2	Test pit AD-1	1.2 to 1.5
Nickel	27.6	Test pit AD-1	1.2 to 1.5
Nitrate (as N)	209	Test pit AD-1	1.2 to 1.5
Potassium	2,230	Test pit AD-2	1.5 to 1.8
Plutonium-238	15.7	Borehole B8826	1.2 to 1.8
Plutonium-239/240	667	Borehole B8826	1.2 to 1.8
Silver	42	Test pit AD-1	1.2 to 1.5
Sulfate	2,970	Test pit AD-1	1.2 to 1.5
Tritium	7.05	Borehole B8826	79.2 to 79.8
Total petroleum hydrocarbons, kerosene range	440,000	Borehole B8826	1.2
Total uranium	5.28	Test pit AD-2	2.2 to 2.6
Vanadium	104	Test pit AD-2	1.5 to 1.8
Zinc	224	Test pit AD-1	1.2 to 1.5

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-2. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-B-63 Trench[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Acetone	66	Test pit BT-2	1.5
Benzene	8	Test pit BT-2	1.5
Cadmium	2.42	Borehole B8827	5.3 to 5.8
Cesium-137	3.56	Test pit BT-1	2.9 to 3.2
Chromium	21.9	Borehole B8827	3.8 to 4.4
Copper	30.6	Test pit BT-1	3.7 to 4.0
Methylene chloride	16	Test pit BT-1	5.2
Nickel	21.0	Borehole B8827	5.9 to 6.6
Nitrate (as N)	188	Test pit BT-2	1.5 to 1.8
Phosphate	6.4	Test pit BT-1	2.1 to 2.4
Strontium-90	24	Test pit BT-2	1.8 to 2.1
Toluene	5	Test pit BT-2A	7.3
Vanadium	86.6	Test pit BT-1	2.3 to 2.6
Xylene	8	Borehole 299-E33-333 (sampled in 1998)	45.7

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-3. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-S-10 Pond[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Acetone	26	Test pit SP-3	2.6
Barium	180	Test pit SP-1	6.1 to 6.4
2-Butanone	12	Borehole B8817	30.3
Carbon-14	12.2	Test pit SP-2	2.0 to 2.3
Chromium	26.2	Borehole B8817	60.1 to 60.7
Lead	10.3	Borehole B8817	15.3 to 15.9
Mercury	0.43	Test pit SP-2	3.5 to 3.8
Methylene chloride	23	Test pit SP-3	4.9
Nickel	25	Borehole B8817	60.1 to 60.7
Nickel-63	2.46	Borehole B8817	15.2 to 15.8
Nitrate (as N)	30	Test pit SP-3	4.9 to 5.2
Phosphate	3.8	Test pit SP-2	3.5 to 3.8
Plutonium-239/240	2.33	Test pit SP-2	3.5 to 3.8
Silver	8.3	Test pit SP-2	2.7 to 3.1
Vanadium	87.5	Borehole B8817	45.8 to 46.4
Zinc	201	Borehole B8817	60.1 to 60.7

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-4. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-S-10 Ditch[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Bis(2-ethylhexyl)phthalate	380	Test pit SD-1	2.6
Cesium-137	9.13	Test pit SD-2	0 to 0.5
Chromium	815	Test pit SD-2	0 to 0.5
Lead	30	Test pit SD-2	0 to 0.5
Mercury	4.3	Test pit SD-2	0 to 0.5
Methylene chloride	17.72	Borehole B8828	6.1
Nickel	21	Borehole B8828	45.8 to 46.4
Nickel-63	38.4	Borehole B8828	7.6 to 8.2
Nitrate (as N)	18	Borehole B8828	0 to 0.5
Phenanthrene	930	Test pit SD-2	0.4
Phosphate	2.4	Borehole B8828	61.0 to 61.6
Plutonium-239/240	3.24	Test pit SD-2	0 to 0.5
Silver	30	Test pit SD-2	0 to 0.5
Total petroleum hydrocarbons, kerosene range	19,000	Borehole B8828	45.7
Vanadium	131	Borehole B8828	61.0 to 61.6
Zinc	506	Test pit SD-2	0 to 0.5

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-5. Maximum Concentrations and Depths of Maximum Concentrations for Selected Constituents in Borehole C3245 at the 216-A-19 Trench[a]

Constituent	Maximum Concentration[b]	Depth of Maximum Concentration (m)
Manganese	538	5.3
Nickel-63	17.6	4.4
Nitrate	9,860	8.3
Strontium-90	20.0	5.3
Thorium-234	56.8	4.4
Uranium-233/234	6.0	4.4
Uranium-238	51	4.4
Uranium, total	130	6.9

(a) All data from DOE/RL-2004-25.

(b) Concentrations are mg/kg for non-radionuclides and pCi/g for radionuclides.

Table 3.1-6. Maximum Concentrations and Depths of Maximum Concentrations for Selected Constituents in Borehole C3247 at the 216-A-10 Crib(a)

Constituent	Maximum Concentration (pCi/g)	Depth of Maximum Concentration (m)
Americium-241	1,320	15.8
Carbon-14	7.5	19.0
Cesium-137	2,950	15.8
Iodine-129	38.8	19.0
Plutonium-238	316	15.8
Plutonium-239/240	7,110	15.8
Potassium-40	27.2	15.8
Strontium-90	44.7	38.9
Tritium	835	96.6

(a) All data from DOE/RL-2004-25.

Table 3.1-7. Maximum Concentrations of Selected Radionuclides and Non-Radionuclides in Samples from the 216-A-36B Crib(a)

Constituent	Maximum Concentration(b)	Depth of Maximum Concentration (m)
Americium-241	40,000	7.6
Ammonium (as N)	1550	7.3
Carbon-14	116	7.6
Cesium-137	2,650,000	7.6
Cobalt-60	623	7.6
Europium-154	1,800	7.6
Nickel	58,000	7.6
Nickel-63	181,000	7.6
Nitrate (as N)	289,000	16.3
Nitrite (as N)	18,800	7.6
Plutonium-239/240	98,000	7.6
Total radioactive strontium	92,000	8.4
Technetium-99	41.9	7.6
Thorium-230	11.4	9.1
Thorium-232	4.8	7.6
Tritium	76	87.6
Uranium (total)	36,800	9.1
Uranium-233/234	81.2	7.6
Uranium-235	3.3	7.6
Uranium-236	4.5	7.6
Uranium-238	70.9	7.6

(a) All data from DOE/RL-2004-25.
(b) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

Table 3.1-8. Concentrations for Selected Constituents in Samples from the 216-A-37-1 Crib

Constituent	Maximum Concentration[a]	Depth of Maximum Concentrations (m)
Aluminum	15,000	22
Manganese	652	15.2
Nickel-63	14.4	11.4
Nitrate (as N)	385	3.8
Strontium-90	1.7	3.8
Thallium	1.54	29.5
Tritium	267	14.5

(a) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

Table 3.1-9. Concentrations for Selected Constituents in Samples from the 216-B-12 Crib

Constituent	Maximum Concentration[a]	Depth of Maximum Concentrations (m)
Ammonium (as N)	404	28.6
Boron	1.3	14.5
Chromium (total)	30.4	91.5
Cesium-137	61,000	10.8
Europium-155	34.9	10.8
Mercury	1.3	10.8
Nitrate (as N)	165	10.8
Potassium-40	15.8	60.2
Silver	2.4	15.2
Strontium-90	12,700	10.8
Thorium	5.4	28.6
Thorium-228	7.54	10.8
Tributyl phosphate	2,000	12.2
Tritium	8.28	4.4
Uranium	42	60.2
Uranium-233/234	4.9	12.2
Uranium-238	5.10	12.2

(a) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

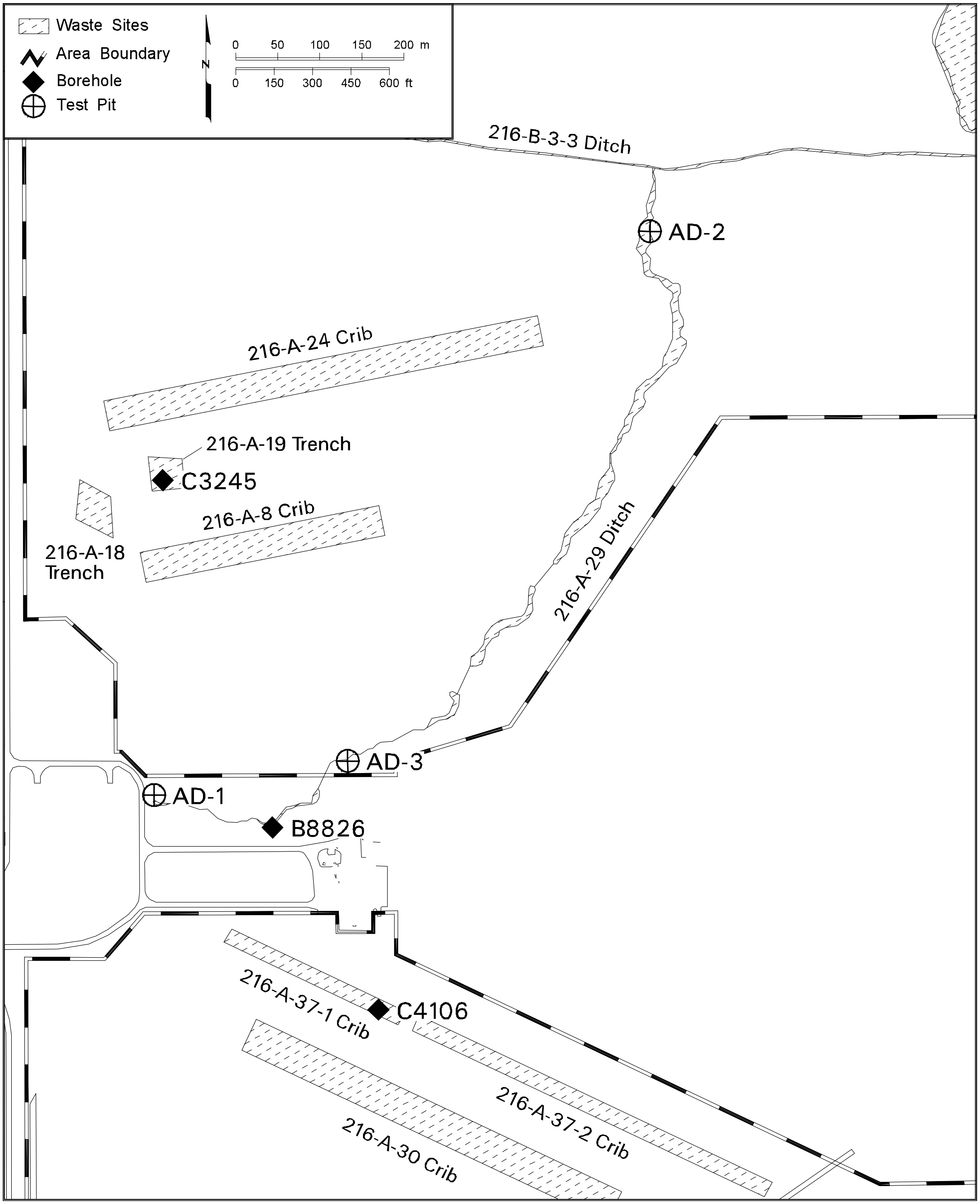


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Figure 3.1-1. Borehole and Test Pit Locations at the 216-A-29 Ditch

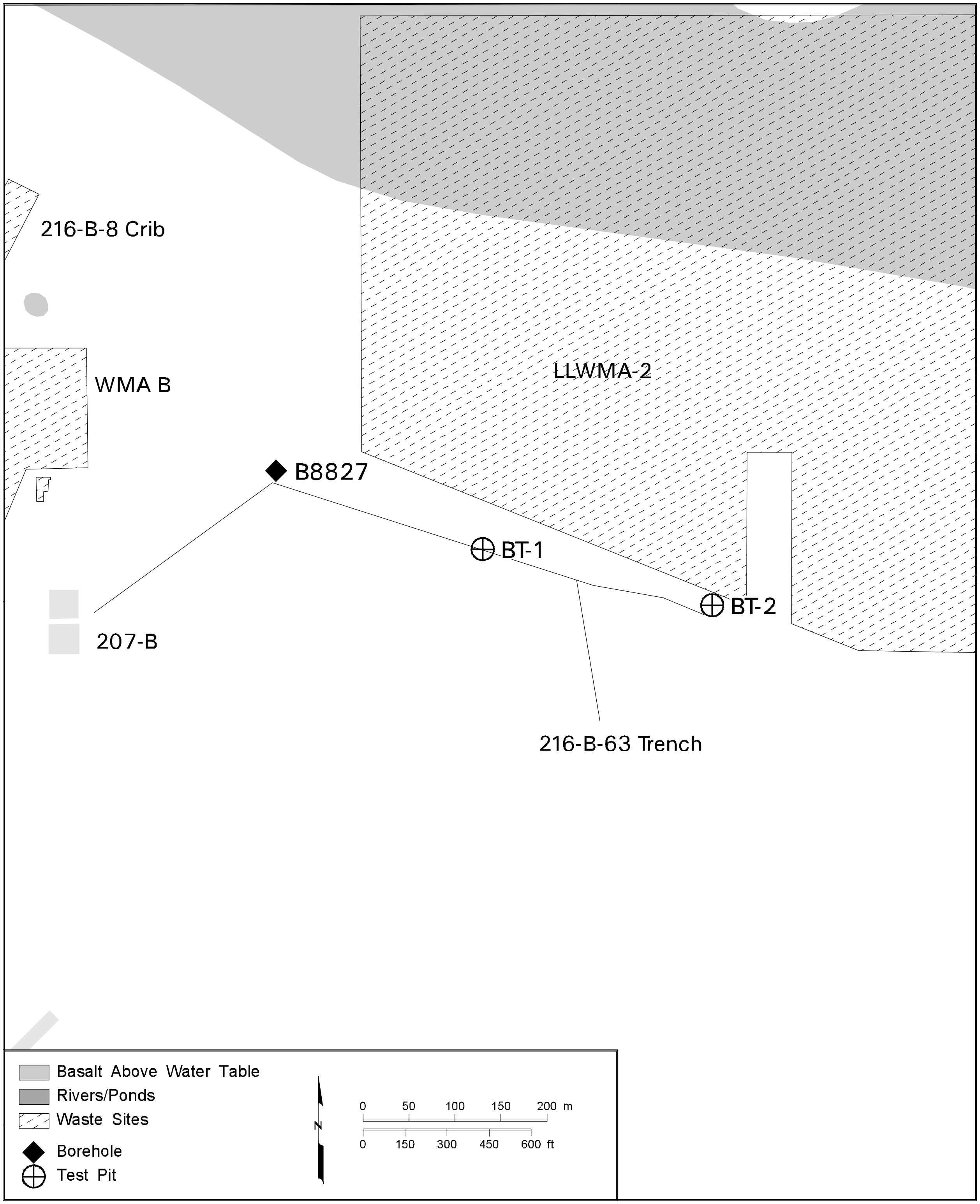

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Figure 3.1-2. Borehole and Test Pit Locations at the 216-B-63 Trench

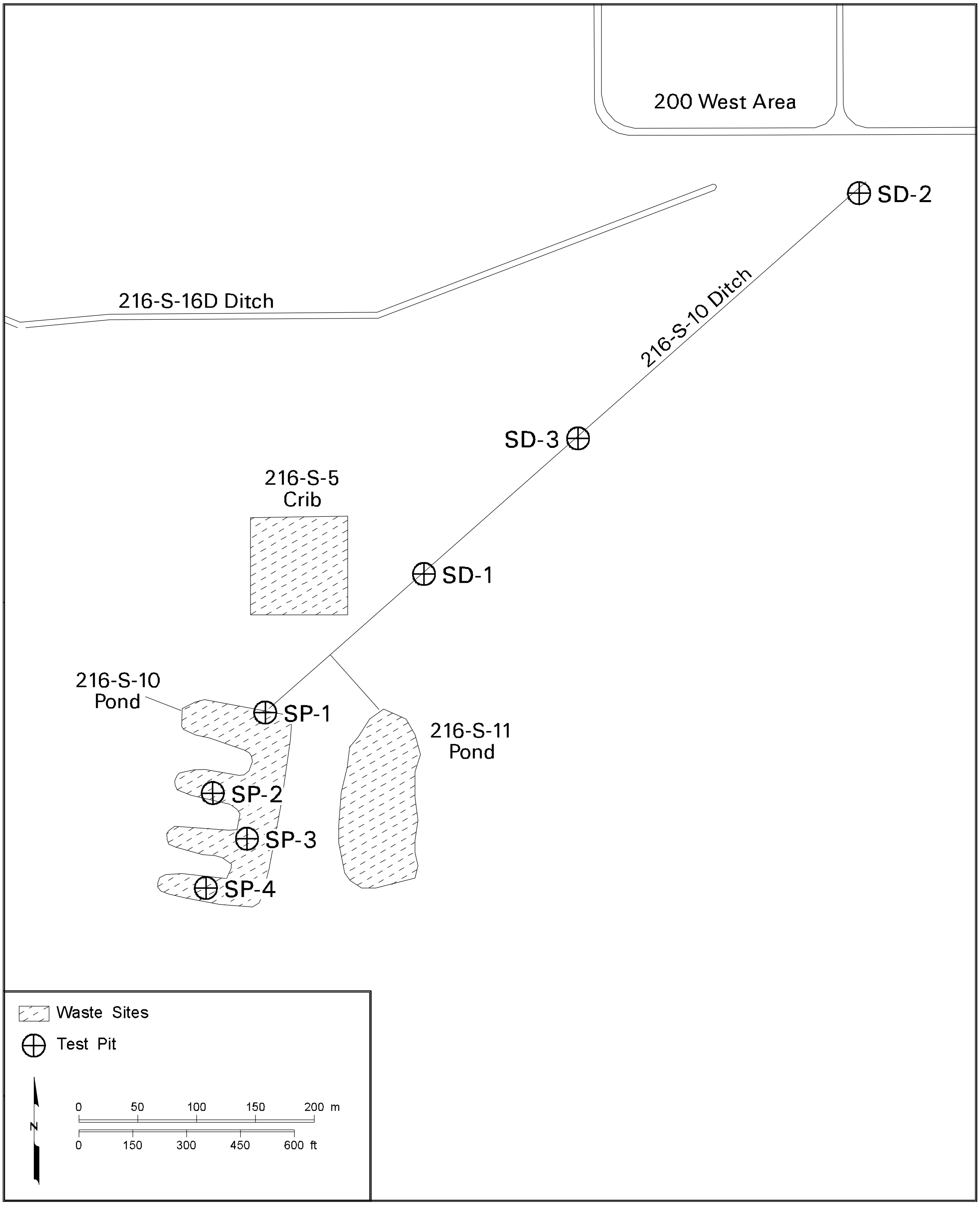

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Figure 3.1-3. Borehole and Test Pit Locations at the 216-S-10 Pond and 216-S-10 Ditch

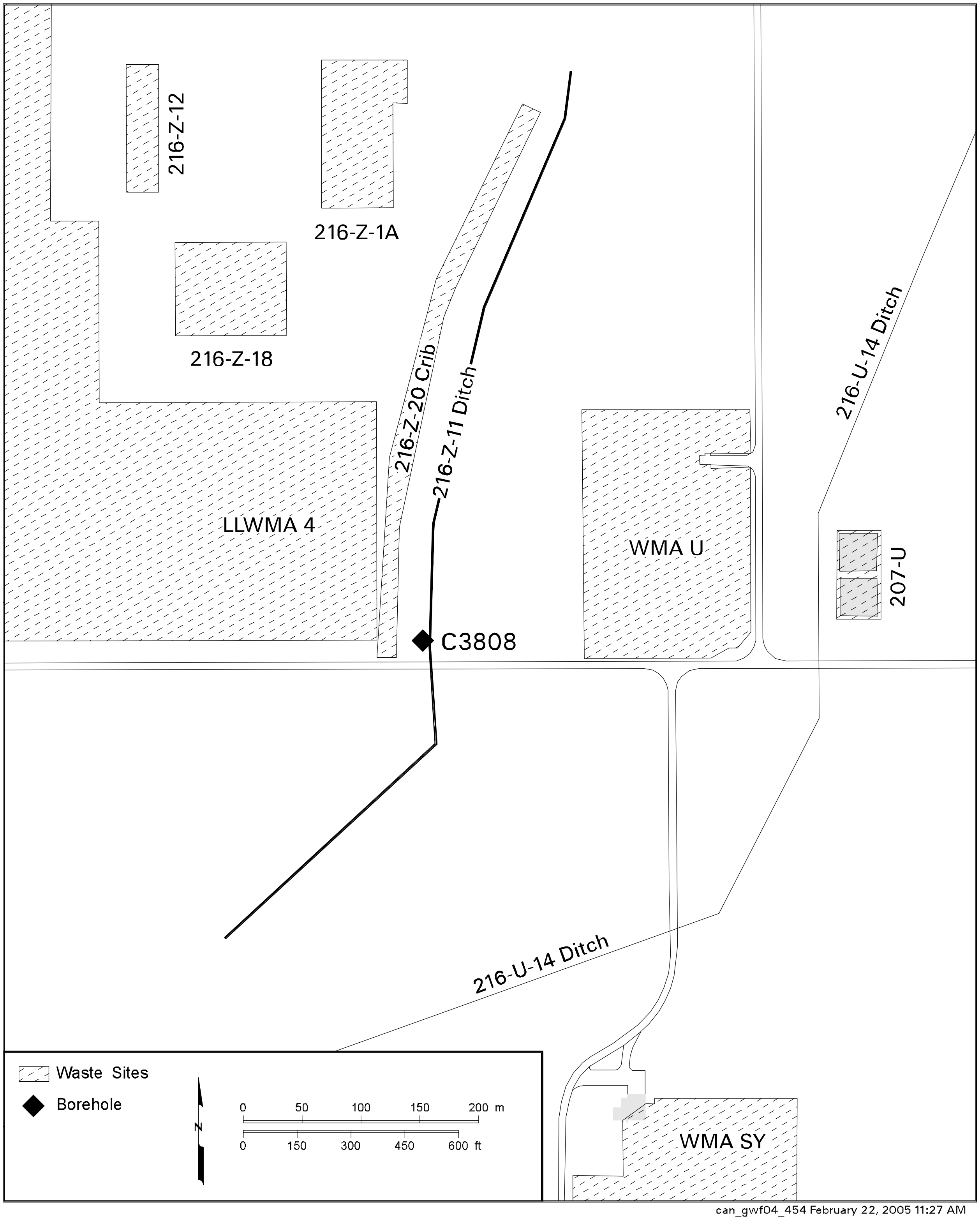

Figure 3.1-4. Location of Borehole C3808 at the 216-Z-11 Ditch

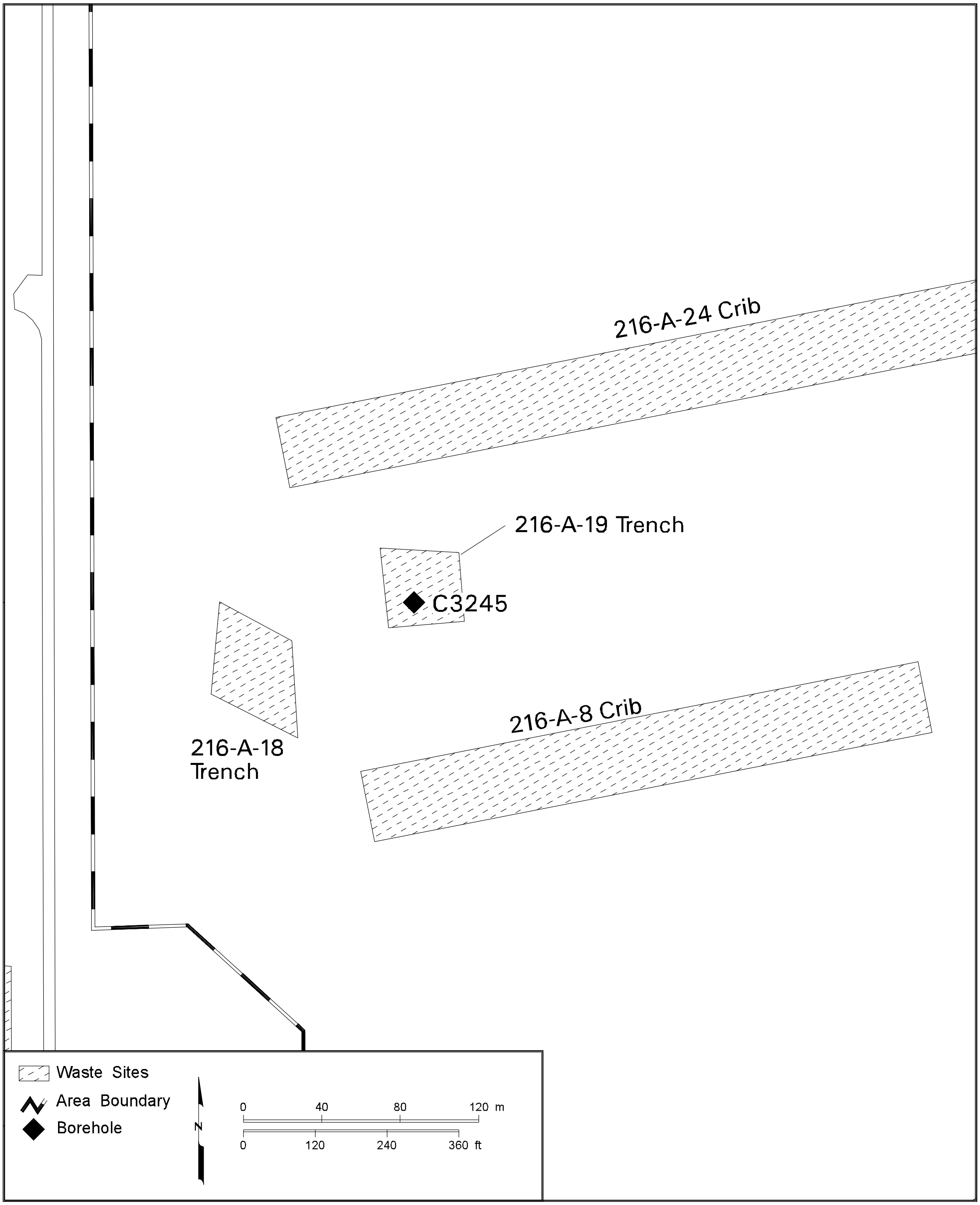

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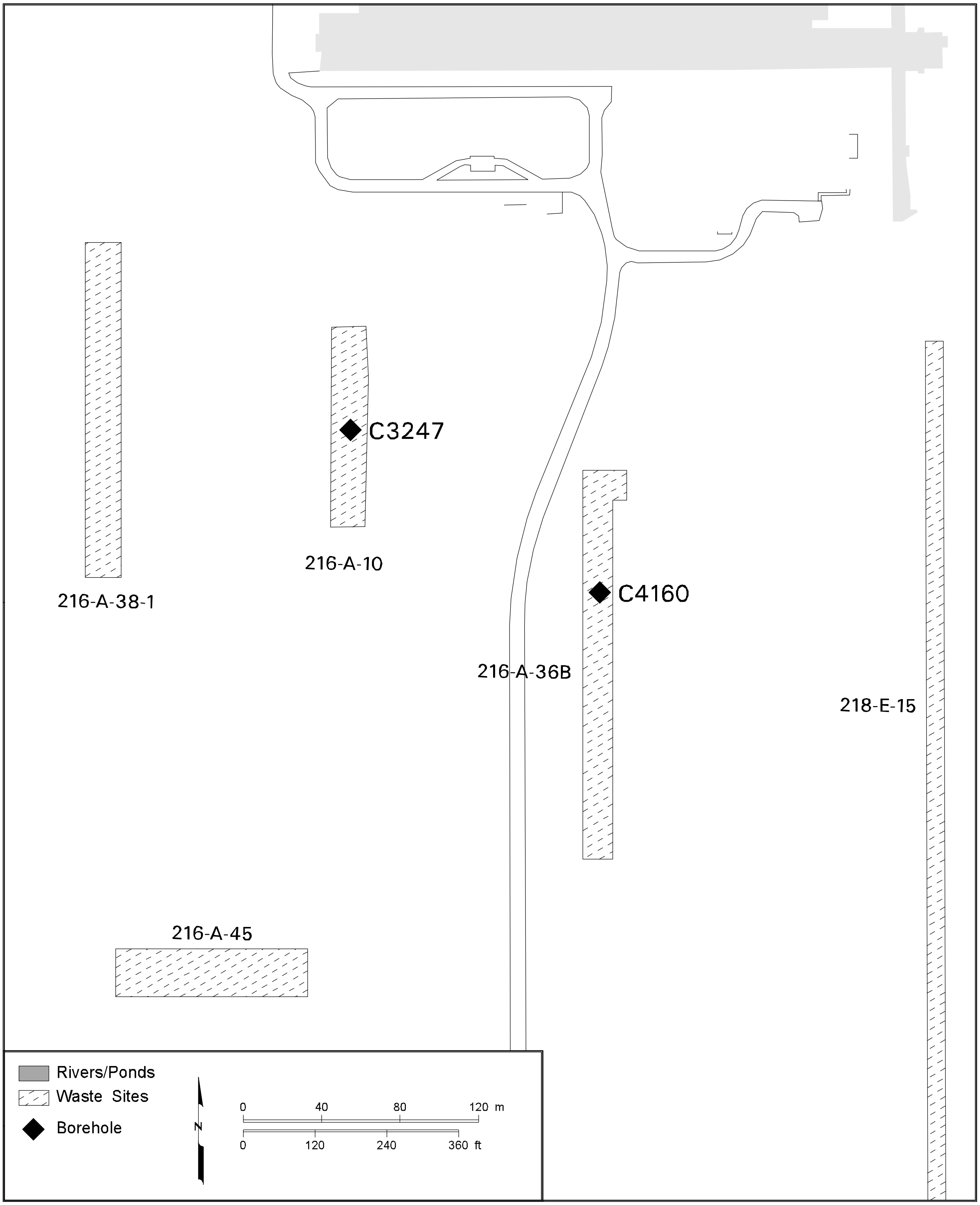
Figure 3.1-5. Location Map for Borehole C3245 at the 216-A-19 Trench



can_gwf04_456 February 11, 2005 8:58 AM

Figure 3.1-6. Borehole Location Map for the 216-A-10 and 216-A-36B Cribs

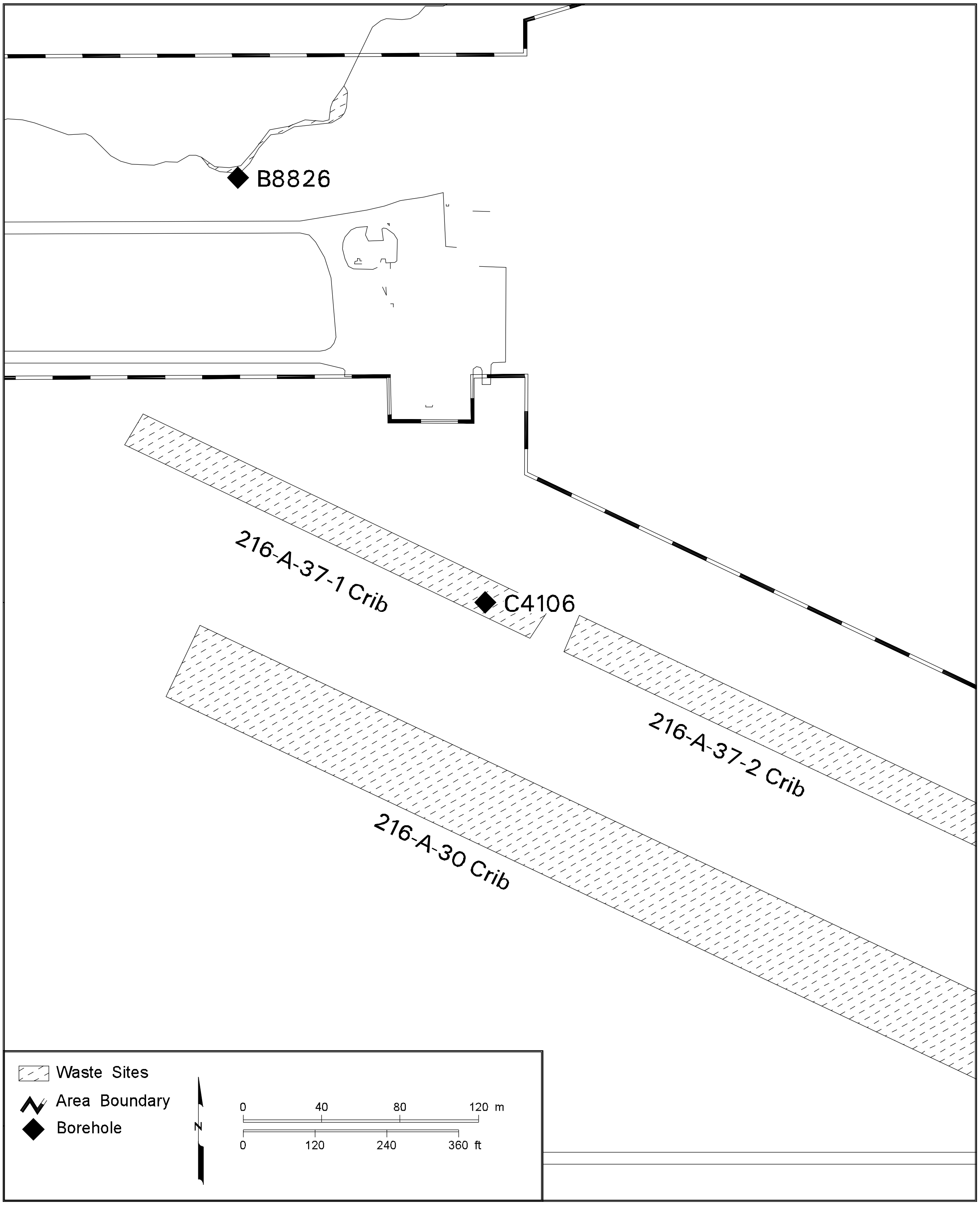


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Figure 3.1-7. Location Map for Borehole C4106 at the 216-A-37-1 Crib

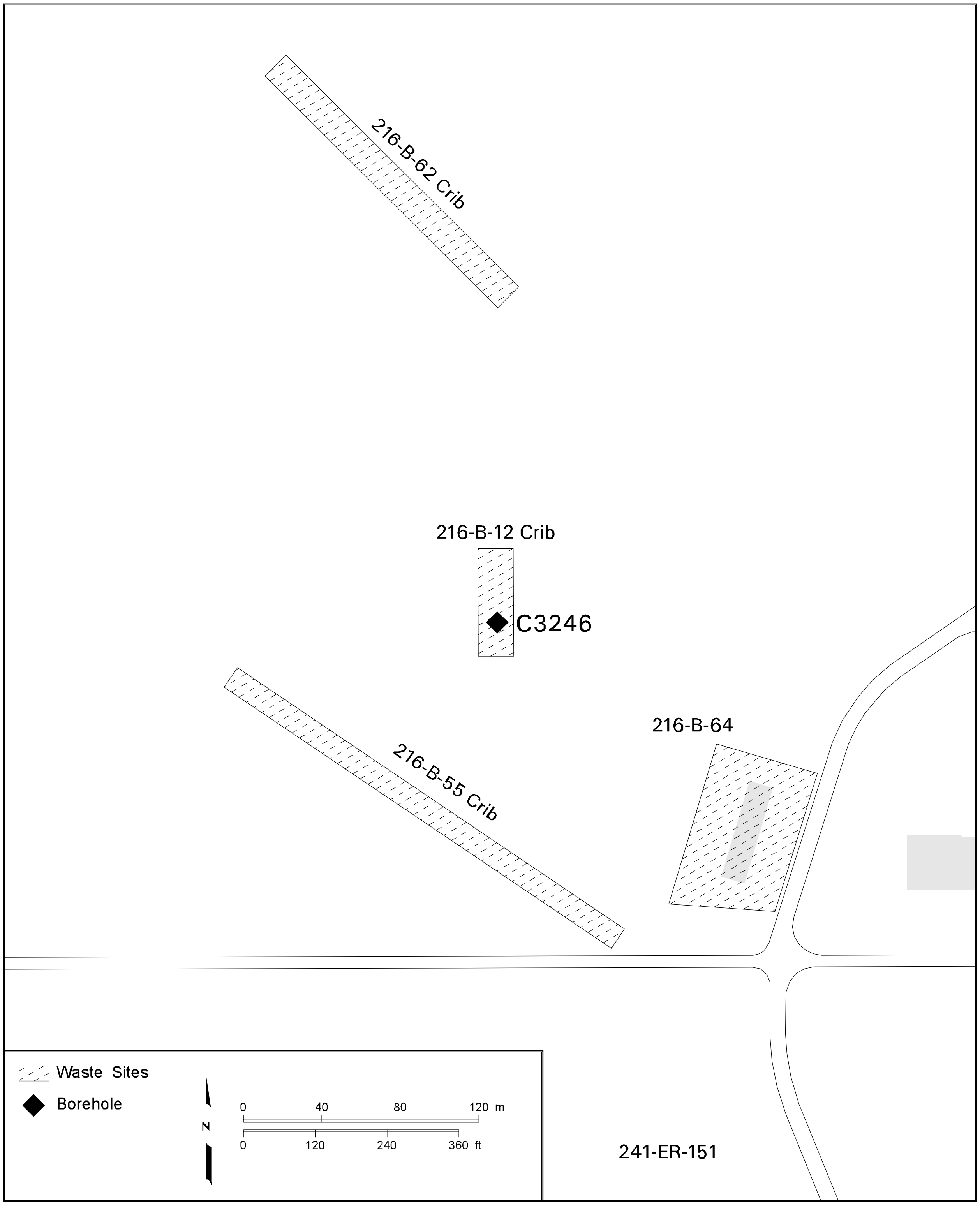

Figure 3.1-8. Location Map for Borehole C3248 at the 216-B-12 Crib

3.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four major areas on the Hanford Site in fiscal year (FY) 2004. Leachate and soil-gas monitoring continued at the Solid Waste Landfill and the Environmental Restoration Disposal Facility. Also, soil-gas monitoring at the carbon tetrachloride expedited-response-action site continued during FY 2004. Finally, geophysical borehole monitoring continued at single-shell tank farms for leak detection and subsurface contaminant migration during the fiscal year. This section summarizes these vadose zone monitoring activities.

3.2.1 Leachate Monitoring at the Environmental Restoration Disposal Facility

D. A. St. John and R. L. Weiss

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility to dispose of radioactive and mixed waste generated during waste management and remediation activities at the Hanford Site. In FY 2004, Bechtel Hanford, Inc. published the results of groundwater and leachate monitoring and sampling at the Environmental Restoration Disposal Facility during the calendar year 2003 (BHI-01738). The groundwater results are discussed in Section 2.9; this section summarizes the vadose zone results.

Concentrations of some constituents have been increasing in leachate from the Environmental Restoration Disposal Facility over the past 2 to 3 years.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200 East and 200 West Areas (see Figure 2.9-1 in Section 2.9), the facility is currently operating two disposal cells that became active during June 2000. Throughout calendar year 2003, ~598,216 metric tons of remediation waste were disposed at the facility. A total of ~4.2 million metric tons of remediation waste has been placed in the Environmental Restoration Disposal Facility from initial operations start-up through calendar year 2003.

Each cell was constructed with a double liner system to collect leachate resulting from water added as a dust suppressant and natural precipitation. The liners deliver the leachate to sumps beneath the cells where it is sampled. A composite sample of leachate was collected in duplicate in June and December of calendar year 2003 from the sumps associated with the upper liners of cells 1 through 4. The samples were analyzed for selected metals, anions, volatile organic compound, total dissolved solids, gross alpha, gross beta, and selected radionuclides. The purposes of the analyses are to provide data for leachate delisting analyses and to assess whether additional analytes should be added to the routine groundwater monitoring program at the Environmental Restoration Disposal Facility.

The composite leachate samples contained detectable concentration of common metals, anions, and mobile radionuclides. Constituents that were generally increasing in concentration since calendar year 2001 include nitrate, gross alpha, technetium-99, and total uranium. Chromium also has been increasing slightly since June 2001. Selenium and gross beta increased between June 2001 and December 2002, but decreased in calendar year 2003. The following is a summary of those analytes with increasing trends:

- Nitrate concentration has increased at a fairly stable rate from June 2001 (239 mg/L) to December 2003 (448 mg/L). A somewhat larger than normal increase in nitrate was reported for the main (primary) and duplicate sample collected during December 2003.
- Gross alpha increased from June 2001 (~110 pCi/L) to an average of 775 pCi/L in December 2003.

- Technetium-99 concentrations have increased slightly since first reported in June 2001 when concentrations averaged 496 pCi/L. The average technetium-99 concentration for December 2003 is 998 pCi/L. This is down somewhat from a concentration of 1,265 pCi/L in December 2002.
- Total uranium concentration has increased from an average of 216 µg/L in June 2001 to 1,350 µg/L in December 2003.

Groundwater monitoring data for nitrate, gross alpha, technetium-99, and uranium were examined to determine whether the Environmental Restoration Disposal Facility has affected groundwater. In all cases, groundwater concentrations for these constituents remained stable. Based on this comparison, it appears that the Environmental Restoration Disposal Facility leachate has not affected groundwater.

The target constituents for the groundwater monitoring program are consistent with the leachate monitoring program. Based on that evaluation, no additional constitutes are recommended for addition to the groundwater monitoring program at the Environmental Restoration Disposal Facility landfill.

3.2.2 Leachate and Soil-Gas Monitoring at the Solid Waste Landfill

B. B. Nelson-Maki and B. J. Dixon

Leachate is collected beneath part of the Solid Waste Landfill. The volume of leachate increased in FY 2004 because of increased precipitation.

The Solid Waste Landfill is a disposal facility in the center of the Hanford Site (part of the Central Landfill illustrated on Figure 2.1-1 in Section 2.1). The Solid Waste Landfill covers an area of ~26.7 hectares and began operating in 1973 to receive non-hazardous, non-radioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an "interim cover" consisting of 0.6 to 1.2 meters of soil was placed over all trenches. Current monitoring at the Solid Waste Landfill consists of quarterly sampling of groundwater, soil gas, and leachate. Recent groundwater monitoring results are discussed in Section 2.11. This section summarizes leachate and soil-gas monitoring results. The results are forwarded annually to Washington State Department of Ecology (Ecology).

In all, the Solid Waste Landfill consists of ~70 single trenches and 14 double trenches. Based on trench geometry and the thickness of the waste layer, the capacity of a trench per linear foot is 8.4 cubic meters for the single trenches and ~30.6 cubic meters for the double trenches. Based on this estimate, total design capacity of the Solid Waste Landfill is ~596,400 cubic meters.

One of the double trenches overlies a lined, basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. (All other trenches are unlined). This lysimeter covers an area of ~88 square meters. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, leachate collected from this lysimeter may not be representative of leachate drainage throughout the entire landfill area because the lysimeter only collects leachate from 1 of 84 trenches and is installed under one of the newer trenches built after implementation of regulations that restrict land disposal practices. Still, the lysimeter provides some indication of the rate of infiltration and some of the contaminants that may reach groundwater.

Leachate is collected from the basin lysimeter every 10 to 14 days. Figure 3.2-1 shows the rate of leachate generated over the past 4 years. Prior to calendar year 2003, the generation rate was consistently between 4 to 8 liters per day. However, during FY 2003 and 2004, the generation rate increased significantly. During FY 2004, the generation rate was ~19 liters per day. This increase is mainly attributed to above average rainfall recorded at the Hanford Site during the winter of 2003/2004. The Hanford Meteorological Station recorded 12.7 centimeters of rain during the 3-month period from December 2003 through February 2004. This was more than a 90% increase over the same 3-month winter average of 6.6 centimeters recorded at the Hanford Site dating back to 1946. Drainage from the winter rainfall started showing up in the lysimeter collection tank in late April 2004.

Leachate is sampled and tested quarterly for indicator parameters listed in WAC 173-304-490 and annually for site-specific constituents, which cover a complete range of metals and organics. Concentrations measured during FY 2004 are similar to previous concentrations and did not identify any areas of concern. Some of the indicator parameters and some organic constituents and metals continue to be above WAC 173-200 groundwater quality criteria and/or drinking water standards established in WAC 246-290-310. However, no constituent is above the maximum contaminant level at the point of compliance, which is the groundwater at the Solid Waste Landfill boundary (see Section 2.11.3.8). Table 3.2-1 shows analytical results for key constituents in the Solid Waste Landfill leachate.

Soil-gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Each station consists of two soil-gas probes at depths of ~2.75 and 4.6 meters. Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the reporting period.

3.2.3 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency (EPA) and Ecology authorized the U.S. Department of Energy (DOE) to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) expedited response action. The following discussion summarizes FY 2004 activities associated with the carbon tetrachloride removal. Detailed results will be published in FY 2005. For descriptions of past work, see BHI-00720, WMP-17869, WMP-21327, and Section 3.2.4 in PNNL-14548. WMP-21327 describes the soil-vapor extraction system and the well fields. See Figure 3.2-2 for locations of vapor extraction wells.

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area.

The 14.2-cubic-meter-per-minute soil-vapor extraction system operated at the combined 216-Z-1A/216-Z-12/216-Z-18 well field from April 1 through April 19 and from June 7 through September 23, 2004. The soil-vapor extraction system was not operated from April 19 through June 7, 2004, while the system was evaluated and reconfigured to address a safety concern. As a result, the period of operation was extended through October 31, 2004. The soil-vapor extraction system was operated at the 216-Z-9 well field from October 6 through October 31, 2004. The system was not operated at the 216-Z-9 well field earlier in 2004 to avoid interfering with characterization sampling that was conducted during drilling of a well at that site. The system was maintained in standby mode from October 1, 2003 through March 31, 2004. The 28.3- and 42.5-cubic-meter-per-minute soil-vapor extraction systems did not operate and were not maintained during FY 2004. Temporarily suspending soil-vapor extraction operations at each well field allows the carbon tetrachloride concentrations to recharge and be more economically extracted when operations resume.

To track the effectiveness of the remediation effort, soil-vapor concentrations of carbon tetrachloride were monitored at the inlet to the soil-vapor extraction system and at individual on-line extraction wells during the 7-month operating period. To assess the impact of the soil-vapor extraction system on subsurface concentrations, soil-vapor concentrations of carbon tetrachloride were monitored at off-line wells and probes during the entire fiscal year.

Remediation efforts during FY 2004 also included passive soil-vapor extraction.

3.2.3.1 Soil-Vapor Extraction

Approximately 78,300 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991.

Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed April 1, 2004, at the combined 216-Z-1A/216-Z-12/216-Z-18 well field. Initial on-line wells were selected within the perimeter of the 216-Z-1A tile field. As extraction continued, wells farther away from the tile field were brought on-line. Extraction wells open near the less-permeable Cold Creek unit, where the highest carbon tetrachloride concentrations have consistently been detected in the past, were selected to optimize mass removal of contaminant. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction inlet were ~20 parts per million vapor (ppmv) (Figure 3.2-3). When additional wells were added to the system, concentrations would increase slightly. After 18 weeks of extraction, concentrations had declined to ~13 ppmv.

Soil-vapor extraction resumed October 6, 2004, at the 216-Z-9 well field. Initial extraction was from a well close to the 216-Z-9 trench. As extraction continued, additional wells close to the trench were brought on-line. During the last week of extraction, wells farther away from the trench were added. During the nearly 4 weeks of extraction in October, the maximum carbon tetrachloride concentration measured at the soil-vapor extraction system inlet was ~172 ppmv (Figure 3.2-3). This concentration is significantly higher than the maximum concentration (109 ppmv) measured when the soil-vapor extraction system last operated at this site in 2002. The increased carbon tetrachloride concentrations reflect the recharge that occurred during the 27 months that vapor extraction was not operated at the 219-Z-9 site.

As of October 2004, ~78,300 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991 (Table 3.2-2). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at 216-Z-1A/216-Z-12/216-Z-18 well field and 22% of the mass at 216-Z-9 well field. This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory), dissolved in groundwater (2% of the original inventory), or biodegraded (1% of the original inventory) is still available in the vadose zone as residual mass (WMP-21327; WHC-SD-EN-TI-101).

3.2.3.2 Monitoring at Off-Line Wells and Probes

During FY 2004, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Cold Creek unit (~40 meters below ground surface), and near groundwater (~66 meters below ground surface). Soil-vapor concentrations were monitored near the ground surface and groundwater to evaluate whether non-operation of the soil-vapor extraction system negatively affects the atmosphere or groundwater. The maximum concentration detected near the ground surface (between 2 and 10 meters below ground surface) was 18 ppmv. Near the groundwater, at a depth of 55 meters below ground surface, the maximum concentration was 40 ppmv. Soil-vapor concentrations also were monitored above and within the Cold Creek unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. The maximum concentration detected near the Cold Creek unit (between 25 and 44 meters below ground surface) was 467 ppmv in well 299-W15-217 (35 meters below ground surface) adjacent to the 216-Z-9 trench. During monitoring in FY 1997, 1998, 1999, 2000, 2001, and 2003, the highest carbon tetrachloride concentrations also were detected in this well. Approximately 90 meters south of the 216-Z-9 trench, the maximum carbon tetrachloride concentration detected was 258 ppmv at soil-vapor probe CPT-28 (27 meters below ground surface). Approximately 200 meters north of the 216-Z-9 trench, the maximum carbon tetrachloride concentration detected was 34 ppmv at soil vapor probe CPT-9A (18 meters below ground surface). The maximum carbon tetrachloride concentration detected in the vadose zone overlying the Cold Creek unit (between 11 and 23 meters below ground surface) was 150 ppmv at soil vapor probe CPT-21A (14 meters below ground surface) near the 216-Z-9 trench.

At the 216-Z-1A/216-Z-12/216-Z-18 well field, the maximum carbon tetrachloride concentration detected near the Cold Creek unit was 266 ppmv in well 299-W18-167 (32 meters below ground surface) within the 216-Z-1A tile field. During monitoring in FY 1997 through 2003, the highest carbon tetrachloride concentrations in the 216-Z-1A/216-Z-12/216-Z-18 well field also were detected at wells within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in FY 2004 appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. This interpretation is supported by data that show carbon tetrachloride concentrations did not increase significantly at the near-surface monitoring probes. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations did not increase significantly near the water table during that time.

3.2.3.3 Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses naturally induced pressure gradients between the subsurface and the surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, whereas rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive soil-vapor extraction systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive soil-vapor extraction uses naturally induced pressure gradients to drive soil vapor to the surface.

Passive soil-vapor extraction systems were installed at the end of FY 1999 at eight boreholes that are open near the vadose-groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field. The passive systems are outfitted with check valves that only allow soil-vapor flow out of the borehole (i.e., one-way movement), and canisters holding granular activated carbon that adsorbs carbon tetrachloride upstream of the check valves before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which tends to dilute and spread carbon tetrachloride vapors in the subsurface.

The wells are sampled periodically upstream of the granular activated carbon canisters when atmospheric pressure is falling and the wells are venting. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-6, 299-W18-7, 299-W18-246, and 299-W18-252) in the vicinity of the 216-Z-1A tile field ranged from 24 to 48 ppmv. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-10, 299-W18-11, 299-W18-12, and 299-W18-247) in the vicinity of the 216-Z-18 crib ranged from 5 to 13 ppmv.

3.2.4 Vadose Zone Monitoring at Single-Shell Tank Farms

R. G. McCain

S.M. Stoller Corporation is responsible for technical oversight of borehole monitoring activities in the Hanford single-shell tank farms. From 1995 to 2000, spectral gamma logs from 769 existing monitoring boreholes in the single-shell tank farms were used to characterize the subsurface contamination in the vicinity of the farms. On the basis of the characterization data, a comprehensive monitoring project for existing boreholes in the tank farms was established in FY 2001. This project uses the radionuclide assessment system to detect subsurface contaminant plumes and/or movement of existing plumes in the immediate vicinity of the single-shell tanks. All data are available at http://gj.em.doe.gov/hanf.

Gamma-ray logging in single-shell tank farms is part of a secondary leak detection system. The gamma logs are used in conjunction with in-tank liquid observations for tank leak detection. RPP-9937 gives the functions and requirements for single-shell tank in-tank leak detection and monitoring.

The radionuclide assessment system uses scintillation detectors to measure borehole gamma activity. Although the energy resolution of scintillation detectors is poor relative to high-purity germanium detectors, scintillation detectors do not require cyrogenic cooling and are much simpler to operate. Because contaminant distribution and concentration levels are known from the baseline characterization project, it is not necessary to explicitly identify specific radionuclides. Migration of existing contamination and influx of new contamination are identified from changes in the overall gamma activity profile between successive measurements.

Routine vadose zone monitoring determines if contamination is moving beneath the tanks.

The emphasis on waste retrieval and tank closure activities has created a demand for more frequent monitoring activities in boreholes around tanks undergoing waste retrieval operations. These activities have resulted in a subdivision of the monitoring effort into two components: routine monitoring and retrieval monitoring.

3.2.4.1 Routine Monitoring Program

The routine monitoring project is described in GJO-HGLP 1.8.1. The goal of the monitoring project is to measure gamma activity in each of the 769 existing boreholes in the 12 single-shell tank farms at least once during a 5-year period. Some boreholes have been selected for more frequent monitoring: yearly, semiannually, or quarterly based on proximity to known or suspected subsurface contaminant plumes, proximity to tanks classified as leaking, and proximity to tanks known to contain relatively large volumes of drainable liquid. Monitoring results are corrected for radioactive decay when necessary and compared against previous results to determine if statistically significant changes have occurred. Routine monitoring results are summarized on a quarterly basis. Anomalies are investigated using additional logging tools, and a special report or memorandum may be issued if warranted.

One borehole at C Tank Farm and one borehole at S Tank Farm showed movement of contamination.

During FY 2004, routine monitoring activities were performed in 23 boreholes in BX, BY, C, and S Tank Farms. Most vadose zone contaminant plumes identified by baseline characterization activities appear to be stable over time. However, evidence of possible contaminant movement has been detected in 29 boreholes in 9 tank farms. In 27 of these boreholes, there appears to have been a change between the baseline and the first monitoring event, but the elapsed time between subsequent monitoring events is not yet sufficient to detect meaningful changes in the contaminant profile. In FY 2004, only two boreholes (30-06-10 and 40-02-03) exhibited movement to a degree that can be confirmed over a relatively short time interval. However, high-activity zones that constitute the bulk of contaminant inventory in the vadose zone are difficult to monitor over the short-term because of the relative error associated with the high-rate logging system.

Borehole 30-06-10 is located on the north side of tank C-106. Downward movement of cobalt-60 was detected in spectral gamma logging system logs run in March 1999 during repeat logging of the baseline characterization project. Baseline logs collected in January 1997 detected cobalt-60 from 26.2 to 35.4 meters. A repeat log collected in March 1999 showed the lower extent of the cobalt-60 plume at 37.8 meters. A third log in February 2004 showed cobalt-60 extending to the bottom of the borehole at 39.3 meters. Log data acquired from adjacent boreholes indicate that this contamination is related to a cobalt-60 plume originating from the vicinity of tank C-108 and migrating downward and eastward.

Borehole 40-02-03 is located on the northeast quadrant of tank S-102. Radiological assessment system logging conducted in July 2003 identified a probable increase in cesium-137 concentration between depths of 13.4 and 14.3 meters. This increase was confirmed by high-resolution spectral gamma logs collected in April 2004. Maximum cesium-137 concentration in this interval increased from May 1996 (~50 pCi/g) to April 2004 (~100 pCi/g).

Increasing demands for monitoring associated with retrieval operations have pre-empted both personnel and equipment. By April 2004, access to the single-shell tank farms was severely restricted in response to health and safety issues. Routine monitoring has not been performed since this interruption.

3.2.4.2 Monitoring for Retrieval Operations

During waste retrieval operations, monitoring is performed in adjacent boreholes to detect any leaks that may be associated with the retrieval operation. Both gamma activity and neutron moisture measurements are made. Gamma activity and moisture measurements are conducted in the month prior to initiation of retrieval activities to provide an updated baseline. During retrieval operations, borehole monitoring for both gamma activity and moisture is performed on a monthly basis. These measurements are supplemented by more frequent manual moisture measurements made with hand-held equipment over limited depth intervals. Additional gamma activity and moisture monitoring are performed within a month after retrieval operations are terminated and on a quarterly basis thereafter.

In C and S Tank Farms, monitoring activities were performed in a total of 24 boreholes to support waste retrieval.

During 2004, retrieval operations were continued in tanks C-106 and S-112. Retrieval operations scheduled to begin in tank S-102 were delayed due to health and safety issues. Monitoring activities were performed in a total of 24 boreholes in C and S Tank Farms to support retrieval operations. Multiple log runs were made in these holes, and neutron moisture logs were also run. These measurements were supplemented with more frequent measurements over limited depth intervals with hand-held moisture gages. No monitoring activities were performed between April to October 2004 because of access restrictions in tank farms. All logging done in support of retrieval operations is reported quarterly at http://gj.em.doe.gov/hanf.

Table 3.2-1. Analytical Results for Key Constituents in Solid Waste Landfill Leachate

	Results by Quarter					
Parameter	July-September 2003	October-December 2003	January-March 2004	April-June 2004	GWQC(a)	DWS(b)
pH	7.10	6.89	NT	7.23	6.5-8.5	NA
Conductivity (µS/cm)	1,950	2.11	NT	2.01	NA	700
Sulfate (mg/L)	9.24	6.33	NT	2.74	250	250
Chloride (mg/L)	265	266	NT	248	250	250
Fluoride (mg/L)	0.468	<0.115	NT	0.163	4	4
Total dissolved solids (mg/L)	NT	NT	NT	1.560	500	NA
Arsenic (µg/L)	NT	NT	NT	24.7	0.05	NA
Barium (µg/L)	NT	NT	NT	528	1,000	2,000
Manganese (µg/L)	1,550	1,700	NT	1,110	50	50
Nickel (µg/L)	NT	NT	NT	157	NA	100
Cadmium (µg/L)	NT	NT	NT	<0.100	10	5
Copper (µg/L)	NT	NT	NT	2.05	1,000	NA
Selenium (µg/L)	NT	NT	NT	3.47	10	50
Zinc (µg/L)	<6.00	<52	NT	947	5,000	5,000
Iron (µg/L)	626	14,000	NT	60.0	300	300
1,4-Dioxane (µg/L)	NT	NT	NT	77.0	7	NA
1,4-Dichlorobenzene (µg/L)	NT	NT	NT	17.0	4	NA
Methylene chloride (µg/L)	NT	NT	NT	<1.00	5	NA
Tetrachloroethene (µg/L)	NT	NT	NT	<1.00	0.8	5

(a) Groundwater Quality Criteria from WAC 173-200.
(b) Drinking water standard from WAC 246-290.
NA = Not applicable.
NT = Not tested.

Table 3.2-2. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973(a) (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990(b) (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to October 2004 (kg)
216-Z-1A	270,000	56,700	24,461(c)
216-Z-9	130,000 to 480,000	27,300 to 100,800	53,888
216-Z-18	170,000	35,700	--
Total	570,000 to 920,000	119,700 to 196,800	78,348

(a) Based on DOE/RL-91-32.
(b) Based on WHC-SD-EN-TI-101.
(c) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

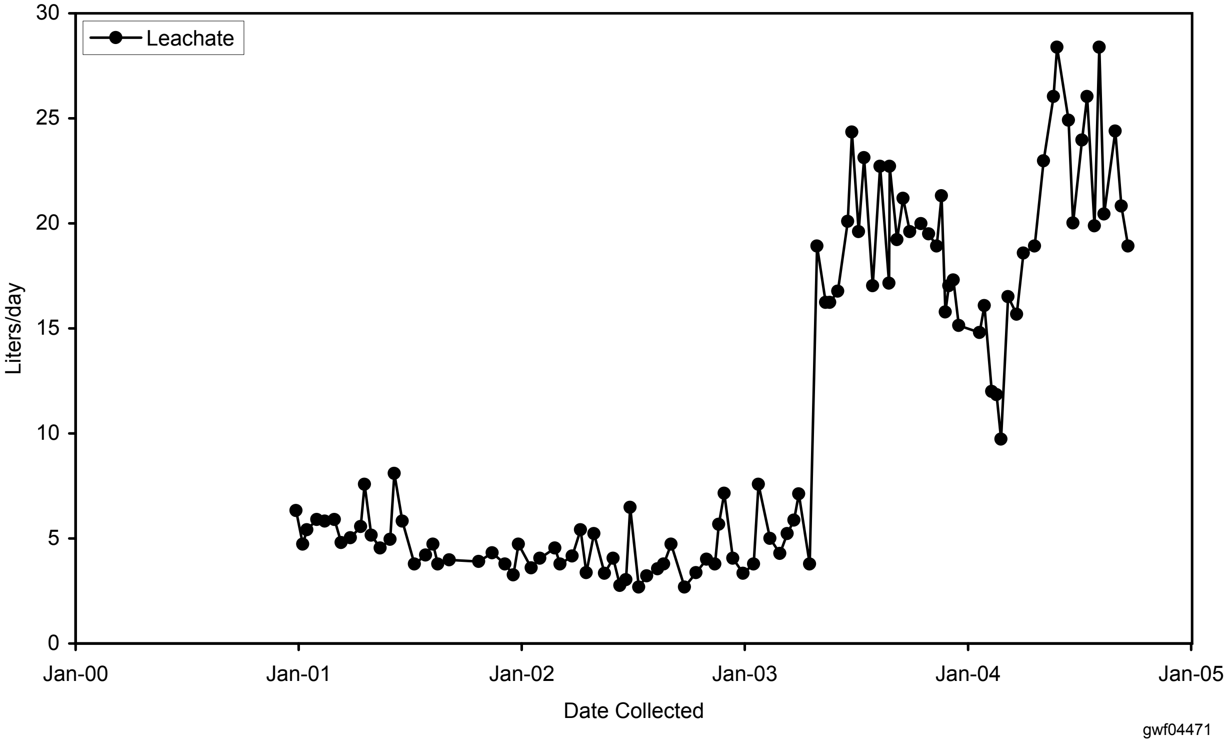

Figure 3.2-1. Leachate Collection Volumes at the Solid Waste Landfill

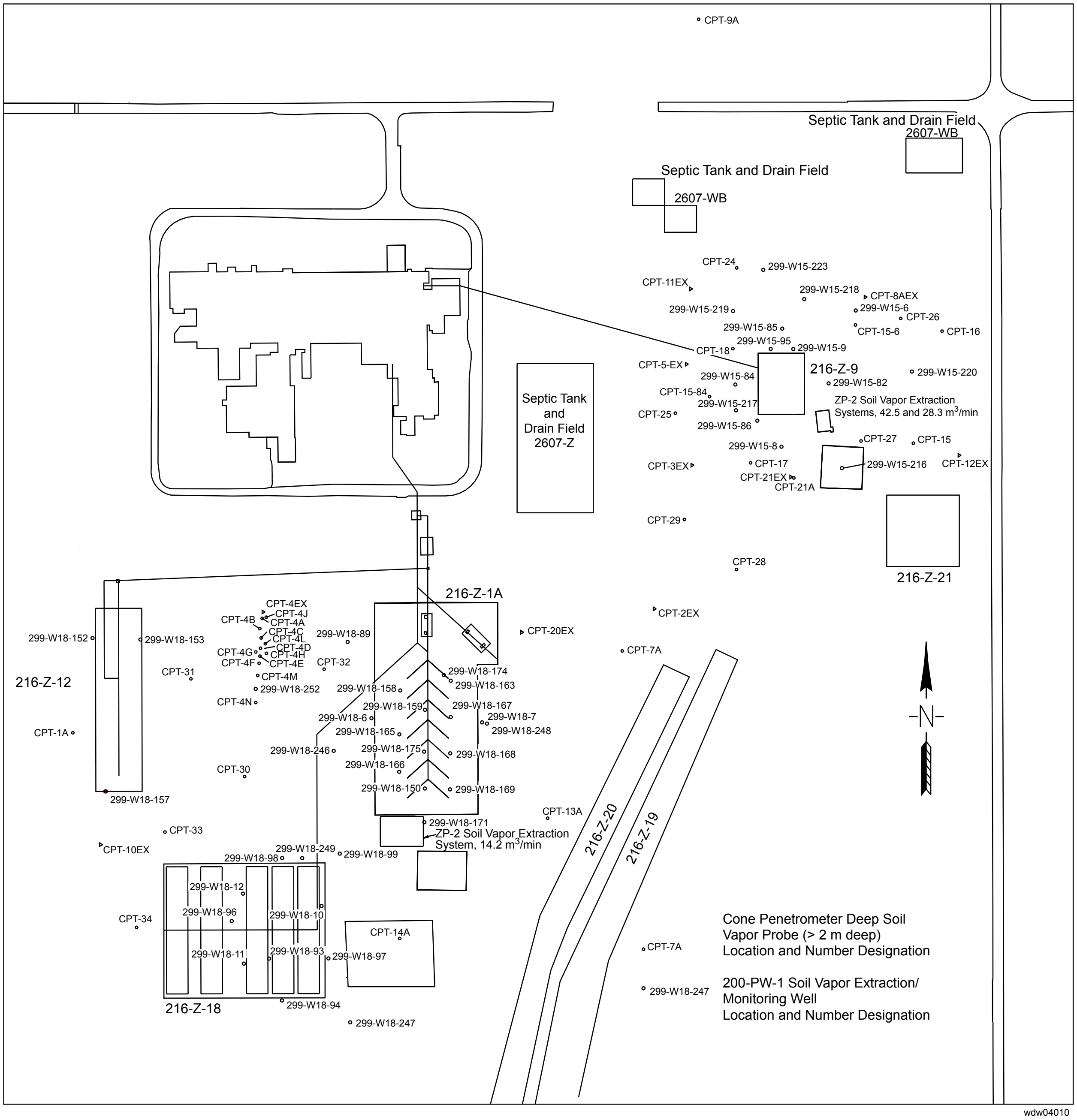

Figure 3.2-2. Locations of Carbon Tetrachloride Vapor-Extraction Wells at the 216-Z-1A/216-Z-12/216-Z-18 and the 216-Z-9 Well Fields

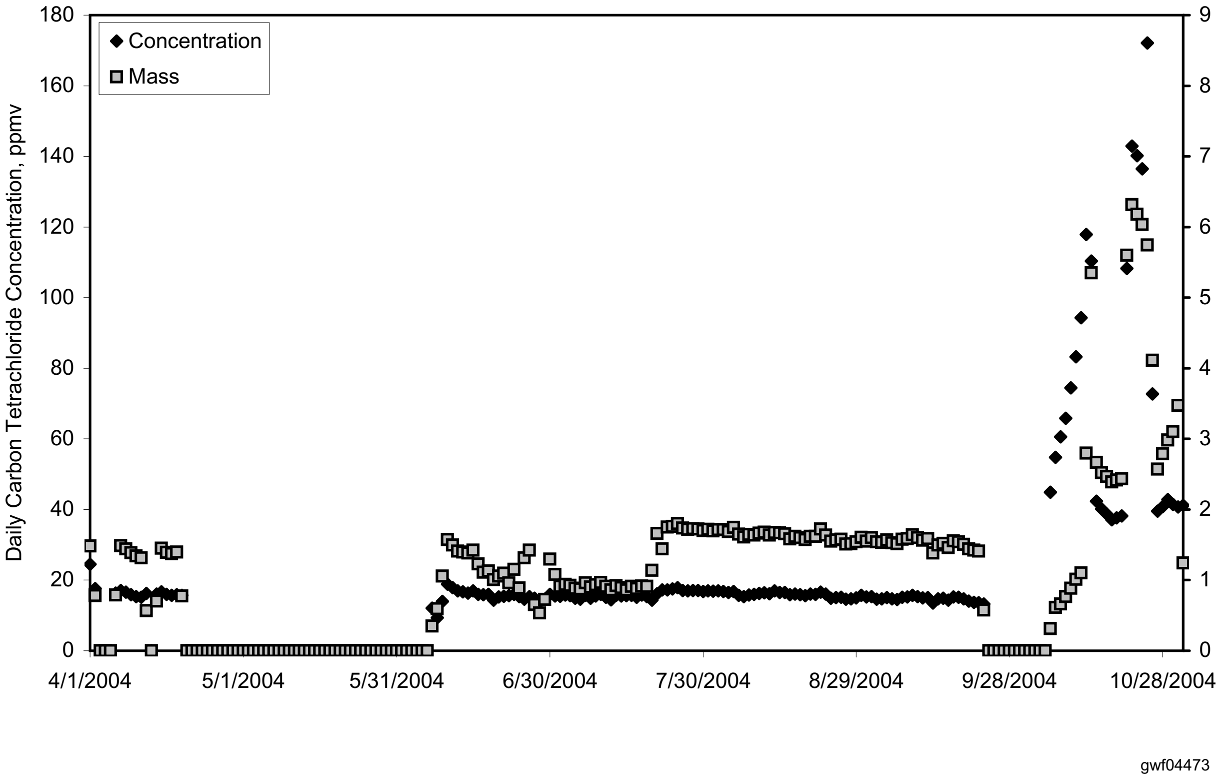

Figure 3.2-3. Time Series Concentrations and Mass of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-1A/216-Z-12/216-Z-18 Well Field

3.3 Vadose Zone Studies

D. G. Horton

This section summarizes the activities and results of several technical studies done at the Hanford Site in fiscal year (FY) 2004 to better understand the vadose zone sediment, vadose zone hydrology, and contamination. These studies are designed to result in new, innovative methods for cleanup and monitoring at the Hanford Site. These studies include experiments supporting in situ gaseous reduction of contaminants in the vadose zone and infiltration and recharge studies. Also, laboratory analyses were done on vadose zone sediment, bentonite well seal material, and perched water from the vadose zone to determine the reason for corrosion of relatively new well casing at Waste Management Area A-AX. Finally, development continued in 2004 to create a database of vadose zone geologic and geophysical data for use in subsurface characterization, monitoring, and modeling and for performance assessments.

Vadose zone studies are designed to result in new, innovative methods for cleanup and monitoring.

3.3.1 Investigation of Accelerated Casing Corrosion in Wells at Waste Management Area A-AX

C. F. Brown and R. J. Serne

The U.S. Department of Energy's (DOE's) Vadose Zone Project managed by CH2M HILL Hanford Group, Inc. asked Pacific Northwest National Laboratory to investigate the cause of accelerated corrosion of type 304L stainless steel casing in two *Resource Conservation and Recovery Act* (RCRA) groundwater monitoring wells located within Waste Management Area A-AX. Geochemical and selected physical characterization tests were performed on archived vadose zone sediment recovered during the installation of four RCRA monitoring wells 299-E24-19, 299-E24-20, 299-E24-22, and 299-E25-46; sidewall core samples collected during the decommissioning of corroded wells 299-E24-19 and 299-E25-46; a sample of Wyoming bentonite; and a sample of perched water collected during the recent installation of well 299-E24-33, located near the corroded wells. The locations of Waste Management Area A-AX and the sampled wells are shown on Figure 2.10-1 in Section 2.10. A photo of the corroded casing in well 299-E24-19 is shown in Figure 2.11-7 in Section 2.11. This section summarizes the casing corrosion investigation. The complete work will become available in FY 2005.

Casing corrosion occurred between 90.7 and 91.2 meters below ground surface in well 299-E24-19 and from 90.0 to 91.4 meters below ground surface in well 299-E25-46. Laboratory tests were conducted to characterize the sediment and identify water-leachable constituents. Testing consisted primarily of 1:1 sediment:water extractions, which were used to calculate the elemental concentrations of water soluble constituents in the solid and estimate in situ pore-water chemistry conditions (specifically with regard to chloride). Additionally, 8 M nitric acid extractions and x-ray diffraction analysis of the solids were used to provide a measure of the total leachable elements and any new crystalline phases that may have formed during the corrosion process.

The moisture content profile of the archived sediment samples collected during installation of the four RCRA groundwater monitoring wells correlated nicely with the lithology described in the well logs from the respective boreholes. The primary region of interest was the silt lens located between 88.6 and 91.9 meters below ground surface, which had an elevated moisture content ranging from 5.5% to 25.1%. The large degree of variability in the moisture content of the material collected from within the silt lens was a direct result of sample preservation. Unfortunately, several of the sample containers were not sealed tightly; therefore, evaporation likely occurred during the archive period, resulting in moisture content calculations that were not indicative of in situ conditions. Sediment samples collected above and below the silt lens were comprised primarily of coarse-grained sand, with moisture contents ranging from 0.4% to 3.7%. By contrast, the sidewall core samples collected at the time of well decommissioning had elevated moisture contents ranging from 30.4% to over 50%. The elevated moisture content in the sidewall core samples correlated well with, and has been attributed to, the composition of the material collected, namely, varying percentages of bentonite and silt lens material (confirmed via x-ray diffraction analysis).

The casing in two wells at Waste Management Area A-AX is believed to have corroded due to crevice corrosion and stress corrosion cracking in a high chloride environment facilitated by perched water.

The pH profile in water extracts of the archived sediment samples ranged from a low of 7.37 in well 299-E24-20 at 86.9 meters below ground surface to a high of 7.91 at well 299-E24-19 at 88.6 meters. The measured pH in extracts from the sidewall core samples was quite different, with an average solution pH for the seven samples of 2.2. An acidic pH in this environment indicates either the presence of acid as a subsurface contaminant, or more likely, is the result of the hydrolysis of metals during the breakdown/corrosion of the well casing. Not surprisingly, a water extract of the Wyoming bentonite test sample had a solution pH of 7.93. However, it was interesting to note that the dilution corrected pore-water electrical conductivity of the pure bentonite sample (Wyoming bentonite) was nearly a factor of two greater than any of the sediment samples tested. These data suggest that the bentonite material (backfill and seal) acted as a source of salinity for vadose zone pore water in the vicinity of the stainless steel casing.

During the course of this research effort, an emphasis was placed on determining the chloride content of the sediment samples. Two primary mechanisms that lead to stainless steel corrosion/failure in chloride containing environments are (1) crevice corrosion and (2) stress corrosion cracking (Sedriks 1996). Crevice corrosion occurs as a result of dissolution of metal from within the crevice followed by hydrolysis of the dissolved metal ions (Sedriks 1996). The end result of this process is a microclimate of pH <2 within the crevice with ambient (near neutral) solution outside the crevice. Stress corrosion cracking is characterized by the failure of stressed alloys in corrosive environments. This phenomenon requires static mechanical loading (caused by forming or welding of the material or perhaps stresses caused by pounding the casing into the sediment formation) in conjunction with an aggressive environment (Lacombe et al. 1993). In the neutral pH environments typically found in the vadose zone at the Hanford Site, 100 mg/L chloride is the critical threshold concentration beyond which stainless steel experiences pitting or stress corrosion cracking problems (Sedriks 1996).

The archived sediment samples, collected during installation of the four RCRA monitoring wells, had calculated pore-water chloride concentrations ranging from 28.8 to almost 600 mg/L. However, due to sample preservation problems, the measured moisture content of samples was artificially low and resulted in an exaggeration of the true pore-water chloride concentration. To confirm this hypothesis, the mass of chloride that was water-extractable from the archived sediment samples was corrected by field moisture logging data from similar lithologic units/depths collected during the installation of well 299-E24-20. Performing this calculation yielded calculated pore-water chloride concentrations in the archived sediment samples ranging from 25.5 to 95.5 mg/L. The one exception was in an archived silt lens sample from well 299-E25-46, which had a calculated pore-water chloride concentration of 127 mg/L. Therefore, it is unlikely that any of the archived sediment samples tested could generate pore waters with sufficient chloride content, with the exception of the silt lens sample from well 299-E25-46, to initiate corrosion of the well casing.

Interpretation of the laboratory data indicated that the Wyoming bentonite test sample was capable of generating localized vadose zone pore water with chloride concentrations in excess of 700 mg/L. The sidewall core samples from well 299-E24-19, which were comprised of a mixture of bentonite and silt lens material, had an average pore-water chloride concentration of 376 mg/L. The sidewall core samples collected from well 299-E25-46 had calculated pore-water chloride concentrations ranging from 1,200 to more than 10,000 mg/L. Therefore, the Wyoming bentonite test sample, as well as all of the sidewall core samples tested, were capable of generating pore waters with sufficient chloride concentrations to cause corrosion of the stainless steel well casing.

Analysis of the sidewall core samples yielded a clear relationship between chloride concentration and well casing corrosion. The sidewall core samples containing the greatest amount of chloride, 3,000 µg/g of sediment, came from the well that experienced the longest length of casing failure (1.38 meters in well 299-E25-46). All of the sidewall core samples from both of the decommissioned wells contained more chloride than the Wyoming bentonite test material. However, the chloride constituted a trace constituent of the sample and its presence in varying concentrations could be a result of the source of the bentonite and/or processing of the material by the vendor.

The sidewall core samples from well 299-E25-46 were very important to this study because they provided a lateral glimpse of the zone of corrosion adjacent to the casing. The concentration of chloride in the three samples was greatest in the sample collected closest to the degraded well casing, and decreased with increasing distance from the corroded casing. This finding implies that the annular seal material contained the source of chloride in the sidewall core samples. Testing is currently underway to determine if the bentonite material, or a contaminant contained therein, or a process performed during the installation of the now failed wells could has acted as the source of chloride. Regardless of the source of chloride, it is believed that the advanced well casing corrosion found at wells 299-E24-19 and 299-E25-46 was caused by chloride facilitated crevice corrosion and stress corrosion cracking. Furthermore, it is possible that the casing in wells 299-E24-19 and 299-E25-46 was damaged at the time of installation, which would have accelerated the stress corrosion cracking process. Additionally, the silts lens, located between 88.6 and 91.9 meters below ground surface, likely exacerbated this process by providing a continual source of moisture in contact with the chloride source, which generated localized pore waters with high chloride concentrations.

As a result of this study, cement grout was recently used instead of bentonite to seal the annulus of two new wells in zones with high moisture content.

3.3.2 Gaseous Reduction and Reoxidation Characteristics of Hanford Formation Sediment

E. C. Thornton, L. Zhong, and M. Oostrom

In situ gaseous treatment of sediment with diluted hydrogen sulfide could provide a way to immobilize various contaminants in the vadose zone. Reduction of metals and selected radionuclides, such as chromium, technetium, and uranium, is a possible approach to control contaminant transport through the unsaturated zone and, thus, protect the underlying aquifers. Laboratory testing has shown that sediment treated with diluted hydrogen sulfide in nitrogen reduces ferric oxides to ferrous oxides and ferrous sulfide. Ferrous sulfide, in particular, is a strong reducing agent that provides a long-term potential for maintaining a reduced environment. Therefore, treated sediment could be used to establish a permeable reactive barrier in the vadose zone that would reduce and precipitate contaminants entering the treated zone via infiltration of contaminated solutions from surface waste sites.

Recent laboratory research and development activities related to in situ gaseous treatment have focused on Hanford formation sediment and re-oxidation characteristics. This has provided information regarding consumption of hydrogen sulfide during treatment, which is needed to support field design and barrier installation activities. Since re-oxidation of the treated sediment will eventually occur, sediment re-oxidation testing activities have also been undertaken in the laboratory to provide a basis for estimating the lifetime of a vadose zone permeable reactive barrier.

Laboratory studies provide a basis to predict gas consumption and treatment time for in situ gaseous treatment of contaminants in the vadose zone.

3.3.2.1 Gaseous Treatment of Hanford Formation Sediment

Laboratory column tests were completed for the purpose of measuring the consumption of hydrogen sulfide during interaction with Hanford formation sediment. Conventional columns, measuring 30.4 centimeters long by 2.6 centimeters in diameter, were packed with Hanford formation sediment. Each column was treated with diluted hydrogen sulfide (200 ppm H_2S in N_2) until hydrogen sulfide breakthrough was complete (i.e., greater than 180 ppm H_2S detected in the column effluent). Gas flow rates were varied in four column tests from 200 to 500 millimeters per minute. Figure 3.3-1 illustrates that the breakthrough time increased as the flow rate was reduced.

Two tests were also conducted in a larger column measuring 158 centimeters long by 20.3 centimeters in diameter. The purpose of the larger column tests was to provide breakthrough data in a system where the linear velocity of gas flow is comparable to that expected in the vadose zone during in situ gaseous treatment. Nine sampling ports were located along the length of the larger column at a spacing of 15.2 centimeters. This permitted monitoring of the hydrogen sulfide reaction front along the length of the column as well as measuring breakthrough at the column outlet. Flow rates of the gas mixture were 1,800 and 4,000 milliliters per minute in the two larger column tests.

The relationship between the velocity of the reaction front and pore velocity for the conventional and large column tests is presented in Figure 3.3-2. The reaction front velocity is the time required for the column effluent concentration of hydrogen sulfide to attain 50% of the inlet concentration (i.e., effluent concentration is equal to 100 parts per million [ppm] hydrogen sulfide). The figure shows that the relationship is nonlinear, indicating that reaction kinetics are an important aspect of gaseous treatment. The empirical relationship presented, however, provides a basis for predicting gas consumption and treatment time requirements since pore velocity can be calculated given the geometry of the treatment cell and injection flow rates.

3.3.2.2 Reoxidation Behavior of Treated Sediment

Laboratory column tests also were done to evaluate the re-oxidation of gas treated sediment. This information is needed to determine the reductive capacity of treated sediment, which provides a basis for assessing the potential effectiveness of the permeable reactive barrier and estimating the lifetime of the barrier with respect to re-oxidation.

Four tests were conducted using the smaller columns mentioned above (30.4 centimeters long by 2.6 centimeters in diameter). The columns were packed with Hanford formation sediment and the sediment treated with 200 ppm H_2S/N_2 gas mixture at a flow rate of ~32 hours for each of the tests. The treated soil was then re-oxidized using deionized water equilibrated with a 21.5% oxygen in nitrogen gaseous mixture. The water was pumped through the treated soil at a different flow rate in each test over the range of 0.096 to 0.71 millimeter per minute and re-oxidation monitored by measuring the oxygen concentration of the column effluent. Re-oxidation was fast initially (i.e., no oxygen was observed in the effluents) and oxygen breakthrough was observed to begin in each test after ~20 column pore volumes were pumped through the column. The breakthrough curves were initially steep, but gradually flattened out with time and complete oxidation could not be achieved. The re-oxidation phase of the experiments was terminated when the oxygen concentration of the effluent was 80% or more of the concentration of the influent.

The relationship between the number of pore volumes of water pumped through the column to achieve initial oxygen breakthrough versus the linear pore velocity of water was determined using a power function ($R^2 = 0.9948$). The resulting curve is almost linear and indicates increased reductive capacity at lower flow rates (Figure 3.3-3). These results suggest that a higher percentage of the total reductive capacity would be utilized in maintaining an anoxic environment in a vadose zone barrier, since flow rates through the barrier would probably be much lower than employed in these tests. Application of these test results can provide a basis for estimating oxygen breakthrough characteristics of a vadose zone barrier at the flow rates expected to occur within a barrier.

3.3.2.3 Modeling Activities Conducted in Support of the In Situ Gaseous Treatment Approach

Calculations were done to estimate barrier lifetime. These calculations assume that the lifetime of the barrier is related to re-oxidation of iron in the treated zone and is an equilibrium process. Re-oxidation of iron in the barrier is thus related to oxygen flux into the barrier. This flux consists of two components – diffusion of oxygen from the surface to the treated vadose zone interval through the unsaturated portion of the sediment pore space and by vertical downwards flow of aerated pore water.

Initial calculations suggested that re-oxidation would require a very long period of time (hundreds to several thousands of years). A recent reassessment of these calculations indicates that barrier lifetime may be on the order of only several years. The primary reason for this discrepancy appears to be related to estimation of the oxygen diffusivity coefficient. The value of this parameter is fairly well known for oxygen gas (0.21 cm^2/s), but appears to be poorly known in partially saturated environments. A literature review is being conducted to further clarify this issue. However, a conservative approach is being taken at this time and a relatively short barrier lifetime is being assumed. Thus, periodic rejuvenation of the barrier through injection of H_2S/N_2 mixtures may be a necessary part of maintaining a vadose zone permeable reactive barrier.

Periodic rejuvenation of gases in an in situ reactive barrier may be necessary to maintain a permeable reactive barrier in the vadose zone.

3.3.3 Recharge Estimates Using Chloride Mass Balance at the Hanford Site

G. W. Gee and Z. F. Zhang, Pacific Northwest National Laboratory; S. W. Tyler and W. H. Albright, University of Nevada Reno; and M. J. Singleton, Lawrence Berkeley National Laboratory

The results of a multi-year study of recharge at the Hanford Site using chloride mass balance became available in 2004. The chloride-mass-balance method has been used extensively to estimate recharge in arid and semi-arid environments. This method was tested at the Hanford Site against 26 years of drainage from a 7.6-meter-deep lysimeter at a simulated waste-burial ground where removal of vegetation has increased recharge rates. This section describes those experiments.

In the chloride mass balance method, measurements of chloride in pore water are used to estimate the recharge rate when both precipitation and chloride inputs are known. The chloride mass balance for a soil profile at steady state can be written as:

$$P\ (Cl_p) = R\ (Cl_s)$$

where P = average annual precipitation (millimeters per year)

Cl_p = average chloride input from all sources, including wet and dry fallout (mg/L)

Cl_s = average chloride concentration of pore water below the root zone (mg/L)

R = average annual recharge rate (millimeters per year)

Lysimeters measure drainage of liquids such as precipitation through soil.

Key assumptions are (1) steady influx of water and chloride; (2) steady, vertical efflux of chloride below the root zone; (3) no soil sources or sinks for chloride; and (4) piston flow of chloride such that point measurements of solute concentrations can be used to represent a true spatial average of the soil chloride flux. With proper assumptions about average annual precipitation and chloride inputs, the only direct measurement required is the volume-averaged chloride concentration in the pore water.

Chloride mass balance has been applied for years to estimate recharge. However, in situations where there has been land-use change and recharge has increased, there have been few attempts to compare chloride mass balance with any independent or direct estimates of recharge. These experiments tested the chloride mass balance method for predicting recharge in a semi-arid climate setting, where land use has changed (i.e., soil disturbed and vegetation removed) and where the chloride flux could be quantitatively checked with lysimetry. Lysimetry is a method that can be used to directly measure the percolation of water through soils and determine both the flux rate and soluble constituents removed in the drainage (Gee and Hillel 1988; Gee et al. 2003).

For the past 25 years, the precipitation at the Hanford Meteorological Station has averaged 180 millimeters per year, about two thirds of this amount coming in winter months. For undisturbed sites, with shrub-steppe vegetation, actual evaporation is approximately equal to annual precipitation, so little drainage is expected. Chloride measurements made at the Hanford Site in areas of undisturbed shrub-steppe vegetation growing on coarse soil have shown significant bulges of high chloride (>100 mg/L) at shallow depths with corresponding recharge rates estimated to be much less than 1 millimeter per year (Prych 1995; Murphy et al. 1996; PNNL-13033). In contrast, for disturbed sites with little or no vegetation and coarse soil, actual evaporation can be less than two-thirds of the annual precipitation (Gee et al. 1992) resulting in drainage rates that exceed 50 millimeters per year. The corresponding chloride distributions are expected to be low at the disturbed sites containing coarse soils.

Chloride concentrations in drainage waters from a test lysimeter were in good agreement with those required in chloride mass balance estimates of lysimeter drainage rates.

Precipitation at the lysimeter test site was previously found to be ~6% more than at the Hanford Meteorological Station (PNL-6403), so precipitation was estimated to be 190 millimeters per year for the past 26 years at the lysimeter site. Chloride input from wet and dry fallout has been studied extensively by Murphy et al. (1996) and found to range from 0.22 to 0.23 mg/L. For the purposes of this study, 0.225 mg/L was selected for the chloride input at the lysimeter site.

Soil samples were taken at a simulated waste burial ground ~5 kilometers north of Richland from two sand-filled, 7.6-meter-deep lysimeters that were kept vegetation free for the past 26 years. The lysimeter soil is classified as 1% gravel, 95% sand, 3% silt, and 1% clay using the United States Department of Agriculture system (PNL-3304). Chloride analysis performed on samples of lysimeter soils taken at the time of construction (1978) showed the initial chloride concentration of the pore water in the lysimeter soil was 88 mg/L.

Lysimeter drainage was measured in two ways: (1) from the inception of drainage in 1981 until April 2000, drainage was measured by periodically collecting water in tared containers and weighing the containers in the laboratory and (2) in April 2000, the drainage collection was switched to an automatic tipping spoon (Pronamic Ltd.) rain gauge. During the past 20 years, the lysimeter drainage from the bare soil has averaged 34% of the total precipitation or ~55% of the winter precipitation.

In December 1996, soil cores were taken from the lysimeter at ten depths, from the surface to a depth of 7.1 meters. Each soil sample was analyzed for water content and then a 1:1 (solution:solid) extract was prepared and analyzed for chloride. Similarly, samples were taken in March 1998 and then again in September 2002. All samples were analyzed using similar equipment.

Table 3.3-1 shows the chloride concentrations for the soil samples and drainage water collected at three dates. (Note that fewer samples were taken in March 1998 than were taken at the other two sampling times.) Recharge estimates from soil cores are presented in Table 3.3-2 along with recharge estimates based on chloride in the drainage water. These values are compared to the measured drainage rate. It is apparent that the soil-core estimates underestimate the recharge by a factor of 5 or more for samples taken in 1996 and 2002 and by a factor of 2 or more for samples taken in 1998. The explanation for the differences in the 1998 data and the other two sampling events is that the chloride in the March 1998 samples was measured at field moisture, and the samples were not oven dried. The other sample sets were oven dried, which is the typical protocol for chloride mass balance analysis.

There are a number of uncertainties associated with the chloride mass balance method, one of which is the total chloride input. Chloride input was not measured directly but was derived from estimates made by Murphy et al. 1996. Table 3.3-2 shows that if the chloride input is increased 22%, from 0.225 to 0.275 mg/L, agreement is achieved between the 26-year average lysimeter drainage rate and that estimated from the chloride mass balance method using the drainage-water chloride as an estimate of the true pore-water chloride. While this modification can explain the difference between the chloride mass balance estimate using the drain water, it does not explain the large underestimation of recharge using the soil water extracts, because (1) it would take an unreasonably high chloride input value of above 1 mg/L and (2) if such a high chloride input value was used, it would make the drain water correspondingly to high, i.e., above 3 mg/L.

To investigate the discrepancy between the soil chloride concentrations and the observed drainage flux, the transport was modeled using a mobile/immobile water transport approach (van Genuchten and Wagenet 1989). Simulations were conducted with CXTFIT (Toride et al. 1995) under conditions of steady drainage (65 millimeters per year) over the first 16 years of drainage. Previous laboratory data (PNL-3304) suggested that the ratio of mobile water to total water content was ~0.65. Several simulations using this ratio failed to produce any similarities to the observed drainage and soil sample concentrations. The first simulation, which assumed a very slow exchange coefficient and a ratio of mobile water to total water of 0.65, was able to match the drainage water concentration, but soil water chloride (resident) concentrations were much higher than observed. Decreasing the exchange coefficient in subsequent simulations produced higher chloride concentrations in the drainage water than were observed, and also resulted in chloride concentrations varying down the length of the lysimeter at the end of the 16-year simulation period. Additionally, the chloride concentrations in the drainage water changed significantly with time; as opposed to the observed concentrations that are essentially unchanging in time between 1996 and 2002. Decreasing the mobile to total water content ratio produced much higher soil water chloride concentrations than were observed.

Slow mineral dissolution may explain elevated chloride concentrations in soil pore water compared to chloride concentrations in lysimeter drainage.

Only when the ratio of mobile to total water content was increased to 0.9 and an extremely slow exchange between the mobile and immobile phase ($\alpha=1 \times 10^{-5}$ years^{-1}) was chosen could simulated soil water and drainage water concentrations be well matched to those observed in the 1:1 dilutions and drainage water. Under this simulation, the chloride in the immobile phase is essentially unavailable for transport. These simulation results produced fairly uniform pore-water and drainage water chloride concentrations that changed only very slowly over time.

The parameters used above suggest that a small portion of the chloride in pore water is inaccessible to the recharge waters. The lack of significant temporal change in either the soil water chloride or drainage water, combined with the fairly uniform vertical distribution of soil water chloride suggests that the majority of pore water is mobile yet disconnected from a small mass of soil water chloride.

The small mass of immobile water is consistent with an incomplete flushing of the vadose zone by infiltration and is consistent with that seen by Jolly et al. (1989) following a change (increase) in recharge. The nature of the incomplete flushing could be either microscopic, with remnants of chloride remaining in dead end pores that are ubiquitous, or as large unflushed areas resulting from large-scale preferential flow. As will be discussed below, large-scale preferential flow is very unlikely to be occurring in the lysimeter. Rather, the findings of elevated soil water chloride, as compared to the drainage water, is consistent with widely dispersed storage of small amounts of residual chloride originally present when the soils were emplaced in the lysimeters.

Preferential flow probably is not an explanation of the high chloride concentrations found in the soil samples. The chloride concentrations of side port samples taken in 1996 were nearly the same as those found in borehole samples taken from the center of the lysimeter in 2002. If there were wall effects or other preferential flow occurring, it should have shown up as marked differences in the two tests.

Mineral dissolution is a possible mechanism for some of the high chloride numbers. PNNL-13033 reported chloride concentrations in Hanford formation minerals ranging from 100 to 230 ppm. If 0.1% of the chloride leached from minerals, this would account for a soil-solution concentration ranging from 0.10 to 0.23 mg/L. Such levels of chloride could possibly have leached from the samples, particularly after they had been dried and subsequently wetted with deionized water. The fact that the samples in 1998 were not oven dried and gave the best results, suggest that oven drying may release chloride from the sediments tested. While this hypothesis is not exhaustively tested, mineral dissolution may contribute to the high chloride values obtained with the 1:1 extracts. Additional chloride contamination from outside sources at the very low levels of chloride is also possible.

These observations raise concerns about using soil pore-water sampling in the chloride mass balance method for recharge rates much above a few millimeters per year at the Hanford Site and possibly at other locations where slow mineral dissolution or other sources of chloride release can confound the low concentration values of the soil chloride. It is further recommended that minimum soil-water dilutions be used when measuring chloride concentrations in soils to reduce the impacts of analytical errors and possible dissolution. Dilution errors may be reduced by using less than 1:1 extract ratios or by centrifuging field-moist samples (when the sample is wet enough), or by obtaining pore water directly in the field using solution sampling or wick lysimetry (Gee et al. 2003). This study indicates that at soil pore water concentrations below a few milligrams per liter, chloride sources other than from precipitation and fallout may contribute to errors in estimating recharge using the chloride mass balance method.

In summary, chloride concentrations found in drainage waters from the test lysimeter, were in good agreement with those required in chloride mass balance estimates to accurately predict lysimeter drainage rates. In contrast, the soil pore-water chloride was always elevated with respect to the drainage water. Slow dissolution of mineral chloride is a possible explanation for the observed elevated soil pore-water chloride and consistent with the 0.9 mobile (0.1 immobile) chloride transport analysis.

3.3.4 Recharge Predictions at Hanford Waste Sites

G. W. Gee, J. M. Keller, and A. L. Ward

Lysimeter studies were used to evaluate the drainage at some Hanford waste sites.

Studies of drainage, which leads to recharge in desert soil like that found at the Hanford Site, have been ongoing for more than two decades (PNL-6403; Gee and Hillel 1988; Gee et al. 1992, 1994; PNNL-13033). These studies have dispelled the myth that hot, dry desert conditions prevent deep drainage. In reality, significant drainage can occur under desert conditions, even when potential evaporation rates greatly exceed precipitation, particularly at locations where soil has been disturbed and vegetation removed. An analysis of drainage under conditions where surfaces are primarily coarse-textured and barren became available in FY 2004. That analysis compared two methods for estimating drainage rates from bare soil surfaces at the Hanford Site, namely Darcy's Law (or Richard's equation) and an empirical model approach.

Three sites with extensive drainage records were selected for the study: 300 North Lysimeter Site, Field Lysimeter Test Facility, and Solid Waste Landfill.

The 300 North Lysimeter Site, located ~6 kilometers due north of the 300 Area, contains two large drainage lysimeters (2.7-meter diameter, 7.6-meter deep) that have been monitored periodically for the past 26 years. Soil taken from the 300 North lysimeters were analyzed (PNL-6488) for unsaturated hydraulic conductivity using (1) the particle-size method of Arya and Paris (1981), (2) the steady-state column method of Klute and Dirksen (1986), (3) the Guelph Permeameter method of Reynolds and Elrick (1985), and (4) the instantaneous profile method of Watson (1966), where water contents were measured by neutron logging and pressure profiles measured with a nest of tensiometers. More recently, Gee and Ward (2002) reported values of the unsaturated conductivity of the 300 North lysimeter soil using the ultracentrifuge method of Nimmo et al. (1994). The soil-water pressure profile continues to be monitored in both lysimeters using tensiometers (Sisson et al. 2002) and soil-water content is monitored by capacitance methods and gravimetric sampling. In addition, field tests were run in the lysimeters to measure the dependence of unsaturated hydraulic conductivity on water content and soil-water pressure.

A soil texture model was developed to predict recharge in a range of soil types at the Hanford Site.

The Field Lysimeter Test Facility, located adjacent to the Hanford Meteorological Station near 200 West Area, contains a number of lysimeters designed to measure water balance using a wide range of surface cover materials, from coarse gravels to silt loam soil. Four of the lysimeters were used to measure drainage of coarse sediment under natural precipitation conditions.

The Solid Waste Landfill, located ~4 kilometers southeast of the 200 East Area, is instrumented with a 6.5-meter deep, basin (pan-type) lysimeter with a capture area of 85 square meters (HNF-7173). The lysimeter was placed at the bottom of the landfill trench and drainage has been collected from this site since July 1996 (HNF-7173).

The texture of the surface soils was determined using both dry and wet sieving followed by hydrometer analysis (Gee and Bauder 1986) for all three sites. Table 3.3-3 lists the lysimeter facilities used for the analysis and the soil and key textural characteristics for each of the lysimeters reported. Precipitation was measured at the Hanford Meteorological Station.

3.3.4.1 Drainage Estimation Methods

Deep drainage at waste burial sites on the Hanford Site is best analyzed by assessing the complete water balance of the surface soil. A simple water-balance model was developed for surface soil at the Hanford waste sites. The model assumes the following conditions:

1. Winter precipitation dominates the net infiltration process.
2. Water runoff and run-on volumes are negligible because most waste sites are relatively flat or bermed.
3. Annual water storage changes are negligible.
4. Soil texture (e.g., particle-size distribution) controls the amount of water retained in the surface and influences the overall evaporation rate.
5. The soil surface remains unvegetated (upward water movement is by evaporation only).
6. Water storage in the bare soil is largely confined to the top meter of soil.

Based on the above assumptions, the surface water balance can be written as:

$$D = (P1 + P2) - (E1 + E2)$$

where P1 = the winter (November through March) precipitation

P2 = non-winter (April through October) precipitation

E1 = the winter evaporation, and E2 is the non-winter evaporation.

Combining terms leads to the following expression:

$$D = P1 - Ef \; [4]$$

where Ef = (E1 + E2) – P2 is an evaporation factor dependent on soil texture and precipitation.

The equation seems simplistic but does estimate evaporation. The equation is empirical and only works for conditions where there are no plants, hence only evaporation and not evapotranspiration is considered. The equation is designed to estimate evaporation rates from bare surfaces, such as tank farms and other waste sites, that have been kept free of vegetation to minimize biointrusion and contaminant uptake by plants.

Based on an analysis of lysimeter records (Gee et al. 1992; PNNL-13033; PNNL-14744) and subsequent measurements made at the lysimeter sites through April 2004, the impact of precipitation and soil texture on drainage was determined for a variety of surface conditions ranging from clean, washed gravels to fine-textured silt loam soil.

Relationships between the evaporation factor (Ef) and grain-size were evaluated using drainage data from the lysimeters listed in Table 3.3-3 with the exception of the Solid Waste Landfill, which was used to test the texture model. The evaporation factor (Ef) was calculated for each of the four lysimeters using the average lysimeter drainage data from January 1, 1995, to April 1, 2004, and the average winter precipitation. Three different analyses of the relationship between Ef and grain-size were performed, including (1) Ef versus percent fines, as was done by Gee and Ward (2002); (2) Ef versus percent fines multiplied by the soil's D10 value (the diameter of sieve openings that will retain 10% of the soil); and (3) a multivariate analysis using percent fines, geometric mean particle diameter, d_g, and geometric standard deviation, σ_g, as the independent variables.

The texture model predicted drainage for a bare sand site with a precision of better than 15%. The model over-predicted drainage by ~30% at a vegetated site.

Darcy's Law Estimates of Drainage. Table 3.3-4 shows Darcy's Law drainage estimates from unsaturated hydraulic conductivity derived from the five different methods and the measured drainage for the 300 North lysimeter sandy soil. Field-measured soil-water pressures confirm that unit gradient conditions exist in the 300 North lysimeter (PNL-6403; Sisson et al. 2002) so use of the unsaturated conductivity value at field water content and soil-water pressures is justified. The five methods used to generate the unsaturated conductivity functions resulted in differences of more than three orders of magnitude. Compared to lysimeter (direct) measurements, the instantaneous profile method of Watson (1966) provided the best estimate of drainage, while the Guelph Permeameter provided the worst estimate.

Texture Models. The types of soil used to develop the Ef functions range from fine silt loam to coarse sandy gravel. Three of the soil samples contain similar percent fines (fraction less than 50 μm), yet are markedly different when comparing the total grain-size distribution. For example, d_g for the sand is 0.506 mm, which is appreciably smaller than the d_g for the sandy gravel at 7.529 mm (Table 3.3-3).

The cumulative drainage for the 300 North and Field Lysimeter Test Facility lysimeters used for the model calibration and the cumulative drainage for the Solid Waste Landfill is shown in Figure 3.3-4. Table 3.3-5 shows the average winter precipitation, as measured at the Hanford Meteorological Station, the average drainage and the calculated evaporation factor (Ef) for the five lysimeters during the time period used for model calibration. In addition, average winter precipitation, average drainage, and the calculated Ef for the sand lysimeter are shown from January 1982 to March 1993. The similarity of the calculated Ef for both the early and later time sand data sets illustrates the stability of Ef with differing precipitation conditions.

Figure 3.3-5 shows the relationships between Ef and two separate soil textural descriptors, with the developed Ef functions presented in Table 3.3-6. The relationship between Ef and percent fines used by Gee and Ward (2002) does not illustrate the difference in observed drainage from the sand and sandy gravel soil. While both types of soil possess the same fraction of fines, the presence of coarser soil particles in the sandy gravel decreases its overall storage capacity. To correct for the presence of a coarser soil fraction, two approaches were explored: (1) multiply the percent fines by the soil's D10 value and (2) perform a multivariate analysis using percent fines, d_g, and σ_g as the independent variables. From Figure 3.3-5, use of D10 in combination with percent fines allows the sandy gravel soil to be better represented. This improves the Ef relationship, yet retains the influence of the fine soil fraction in the overall evaporation rate. From Table 3.3-6, the use of multivariate analysis results in a r^2 value of unity due to the degrees of freedom of the regression being equal to zero. While this essentially renders statistical evaluation of the regression model meaningless, the model is included in the overall analysis to demonstrate the potential of using different statistical models to estimate Ef values. It is expected that as data from additional sites become available the regression models will be strengthened by their addition to the calibration data set. Future Ef regression models should include analysis such as the Akaike Information Criterion (Sakamoto et al. 1986; Yu et al. 1997) to identify when the addition of independent variables is offset by a significant reduction in regression error, while still retaining enough degrees of freedom to evaluate the regression model.

Results from the texture model using the two separate Ef functions for the 300 North site sand drainage during a 12-year period were not included in the calibration data set and for the independent drainage data from the Solid Waste Landfill are presented in Table 3.3-6. For the 300 North sand, drainage was accurately predicted using the multivariate Ef function and, to a lesser degree, from the percent fines and D10 Ef function. Comparison of the developed Ef functions versus the independent drainage data from the Solid Waste Landfill shows that for both relationships, the model under predicts the observed Ef of 70 millimeters per year, resulting in an over-predicted drainage. The Ef function developed using multivariate analysis provided the best estimate of Solid Waste Landfill drainage, calculating a drainage of 66 millimeters per year compared to a measured drainage rate of 51 millimeters per year. The Ef function using the percent fines times D10 descriptor performed similar to the multivariate analysis, estimating a drainage of 70 millimeters per year.

No attempt was made to keep the surface of the Solid Waste Landfill vegetation free, resulting in the potential for water uptake by plants. Indian wild rice (*oryzopsis hymenoides*) has invaded the site and while sparse, it is a perennial growth form that has a relatively deep rooting depth and most likely has contributed to the lower drainage rates observed at this site. Because the Ef functions were developed using drainage data from non-vegetated soil, the presence of vegetation would result in the under prediction of Ef as was seen in the results. Figure 3.3-6 shows the Solid Waste Landfill Ef from 1996 through 2004 calculated from measured drainage and precipitation. A general increase in Ef with time is observed, correlating with a decrease in drainage. The trend is likely because drainage will continue to decrease with further establishment of vegetation at the Solid Waste Landfill. These data illustrate the significance of vegetation in influencing water loss rates from surface soils. Where surfaces remain barren, such as at radioactive waste sites at the Hanford Site, the texture model is expected to provide reasonable predictions of drainage. The texture model was designed to be used at waste sites where the percent fines range from a few to more than 60% (i.e., coarse gravel to silt loam surfaces).

Not presented here are data from lysimeters containing coarse rock fragments or gravel with little or no fines. Open, coarse sediment with no fines are conditions at the Hanford Site that allow for significant advective heating during late spring through fall because of high thermal loading of the soil surface (Gee et al. 1997; Ward and Gee 2000; PNNL-13143).

There has been some effort over the past 10 years to stabilize the surface of Hanford Site waste sites for worker protection against radioactivity and for ease of access. The surfaces of a number of the tank farms have been recovered with commercial "road-base" material. While no exact specifications are available for the size distribution of this gravelly material, the major specification is that it contains what is called 3/4 minus material, meaning that the majority of the material passes through a 1.9-centimeter square sieve. Because retrieving material from within the tank farms is difficult, some road base material was collected from adjacent to the Field Lysimeter Test Facility; the texture analysis from this material was used to predict the average annual drainage rates for such materials that might exist over current waste sites at the Hanford Site. Table 3.3-7 shows the size-distribution statistics and expected drainage rates for a bare soil with 1.9-centimeter road-base and two types of synthetic soil consisting of road-base material with the addition of 10-percent fines and 20-percent fines. Predictions indicate that drainage would be substantial at all sites where road-base surfaces now exist over Hanford Site waste sites. However, modest increases in the percentage of fines significantly reduce the drainage. An increase in percent fines from 4% to 14% reduces the predicted drainage by as much as a factor of 4. An additional increase in percent fines to 24% further reduces the predicted drainage to less than 20 millimeters per year. Calculations of drainage from the synthetic soil assume that the thickness of the synthetic materials is at least 1 meter. As a first approximation, if the synthetic layer is less than 1 meter, the storage would be altered in proportion to the layer thickness; storage and, hence, drainage are functions of layer thickness, which is implicit in the empirical models presented here.

The two empirical texture models have obvious limitations. These include restriction to bare surfaces and assumptions of local climate conditions and soil layer thicknesses. In spite of these limitations, the models do surprisingly well in predicting drainage from bare waste sites. Where more site data are available, more sophisticated models may be justified.

Estimates of drainage rates from Darcy's Law using hydraulic property data may have large uncertainties, unless those estimates are tempered by calibration with actual field drainage data. Direct measures of drainage either at waste sites of concern or adjacent to them but with similar surface soil conditions will be useful in calibrating both simple models, such as those described here, or more complex models that require well-defined hydraulic properties. Whereas the texture models developed here are specific to the Hanford Site, the general approach may be applicable to other sites where similar conditions exist (i.e., bare soil surfaces where drainage is dominated by winter precipitation events).

Recharge studies such as this have important applicability to numerical models of vadose zone moisture and groundwater. The studies provide necessary input values for some models that predict fate and transport of contaminants in the subsurface. They also supply information to optimize surface cover design for contaminant remediation.

3.3.5 Borehole Geologic Information System

G. V. Last

A new computer tool is being developed to provide Hanford researchers a user friendly system to archive, retrieve, and interpret borehole geologic data.

DOE's Groundwater Remediation Project managed by Fluor Hanford, Inc. is developing an integrated borehole geologic data management and interpretation system to maximize the value and ease of use of geologic data. Borehole data are the cornerstone of subsurface characterization, monitoring, and performance assessment projects. These data often take great effort and expense to generate, yet, historically they have been managed in an ad hoc fashion, using a wide variety of formats (generally non-digital) and scattered across individual project records. The types of data included in the Hanford Borehole Geologic Information system include geologists and drillers logs, particle size distributions, calcium carbonate and moisture contents, geophysical logs, mineralogy, bulk rock chemical composition, and geochronology information.

The Hanford Borehole Geologic Information System (HBGIS) is a secure online web application supported by Microsoft SQL Server as a back end database (PNNL-SA-43003). HBGIS is designed to support the Hanford Site community with a user friendly graphical interface that provides a comprehensive information management system for archival, retrieval, and interpretation of data. As of September 2004, over 130 boreholes had been incorporated into this system. The HBGIS's unique feature is its ability to connect directly to different databases to obtain relevant borehole information rather than storing duplicate data available in the other Hanford Site databases. Existing databases currently accessed by the HBGIS include the Hanford Well Information System, the Hanford Environmental

Information System, the Virtual Library, and the Pacific Northwest National Laboratory geophysical log library. Links to other existing databases including the DOE, Office of Legacy Management's (formerly the Grand Junction Project Office) geophysical logging database may also be possible. The HBGIS data transformation option allows exporting data into graphical data processing software such as LogPlot and SoilVision.

For information about and access to the HBGIS, contact the Fluor Hanford, Inc., Groundwater Remediation Project, in Richland, Washington.

In parallel with the development of the HBGIS for accessing raw borehole geologic data, an apriori database of interpreted geologic contacts was assembled. Of the ~570 boreholes drilled within the 200 Areas, major geologic contact information was assembled for ~475, or 83%, of these boreholes (WMP-22817). Geologic contact information is used for geohydrologic and performance assessment modeling of the subsurface. Therefore, it is imperative to use a consistent set of the most accurate contact picks available for input into these models. As the raw data become more available through the HBGIS and as interpretations of these data are made, this geologic contacts database will continue to evolve.

During FY 2004, data packages providing vadose zone and geographic information were compiled. This data will be used for performance assessments.

3.3.6 Data Packages for the 2004 Composite Analysis and 2005 Integrated Disposal Facility Performance Assessment

G. V. Last and S. P. Reidel

The DOE Groundwater Remediation Project managed by Fluor Hanford, Inc. developed two vadose zone related data packages to support performance of the 2004 Composite Analysis. The vadose zone data package (PNNL-14702) describes the geologic framework, physical, hydrologic, and contaminant transport properties of the geologic materials and deep drainage (i.e., recharge) estimates. Much of the data and interpreted information were extracted from existing documents and databases.

The *Geographic and Operational Site Parameters List (GOSPL) Data Package for the 2004 Composite Analysis* (PNNL-14725) describes a number of key input parameters needed to simulate the performance of over 1,000 waste sites included in the 2004 Composite Analysis. Parameters described in the data package include information on individual waste sites (e.g., size, coordinates, type of site, operational dates), effluent types, release models, hydrostratigraphy, remedial actions, and infiltration assumptions. The data package describes the data fields, including the source(s) of data, and provides the resulting inputs assembled to facilitate the generation of keyword input files containing general information on each waste site, its operational/disposal history, and its environmental settings (past, current, and future).

A geologic data package (PNNL-14586) supporting the 2005 Integrated Disposal Facility performance assessment was released in March 2004. That data package compiles existing geologic data from the Integrated Disposal Facility area from both surface and subsurface geologic sources. The data quality and uncertainties in the data are discussed. Several cross sections, a fence diagram, and isopach maps are included in the report. The seismicity of the area and the results of hydrologic testing also are included.

Table 3.3-1. Chloride Concentrations (mg/L) Found in Soil and Drain Water Taken from the Lysimeter at Selected Times

Soil Sample Depth (m)	December 1996	March 1998	September 2002
0.0–0.5	7.0	--	--
0.5–1.0	5.0	--	--
1.0–1.5	3.2	1.5	6.1
1.5–2.0	4.8	1.6	5.6
2.0–2.5	5.8	--	3.9
3.0–3.5	6.7	--	6.7
4.0–4.5	5.7	1.5	4.6
5.5–6.0	7.8	1.6	4.9
6.5–7.0	7.4	--	4.7
7.0–7.5	4.5	--	5.2
Drain water	1.2	0.8	0.9

Table 3.3-2. Comparison of Measured and Estimated Drainage Rate (mm/yr) from Chloride Mass Balance Recharge Estimates Using Drainage Water and 1:1 Extract (pore water) Data Sets[a]

	Drainage rate (mm/yr)			
	December 1996	March 1998	September 2002	Average
	0.225 mg/L Chloride Input			
Soil samples	7	25	8	13
Drain water	37	53	48	46
Measured	64	66	61	62[b]
	0.275 mg/L Chloride Input			
Soil samples	10	37	11	19
Drain water	50	74	66	62
Measured	64	66	61	62[b]

(a) Assumes 190 mm/yr average precipitation with 0.225 mg/L average chloride input or 0.275 mg/L average chloride input.

(b) Twenty-six year average.

Table 3.3-3. Calculated Grain-Size Statistics for the Lysimeter Soil and Sediment

Lysimeter Location	Soil	% Fines (< 0.05 mm)	% Sand (0.05 – 2 mm) (%)	% Gravel (2 – 152 mm)	D10(a) (mm)	d_g(b) (mm)	σ_g(b) (mm)
300 North	Sand(c)	3	96	1	0.192	0.506	0.554
FLTF	Loamy sand(c)	18	79	3	0.021	0.219	0.226
FLTF	Silt loam(c)	63	37	0	0.004	0.031	0.319
FLTF	Sandy gravel(c)	3	16	81	0.697	7.529	0.217
SWL	Gravelly sand	4	36	60	0.183	4.687	0.092

(a) D10 = Diameter of sieve openings that will retain 10% of the soil.
(b) d_g and σ_g are geometric mean particle diameter and geometric standard deviation, respectively.
(c) Used in fitting of the evaporation factor, E_f.
FLTF = Field Lysimeter Test Facility.
SWL = Solid Waste Landfill.

Table 3.3-4. Darcy's Law Drainage Estimates from Unsaturated Hydraulic Conductivity Functions for 300 North Sand

Method	Soil-Water Pressure Head (mm/yr)	Unsaturated Hydraulic Conductivity (mm/yr)	Drainage (mm/yr)
Particle Size (Arya and Paris 1981)	--	3,700	3,700
Steady State Column (Klute and Dirksen 1986)	32,000	20	20–32,000
Guelph Permeameter (Reynolds and Elrick 1985)	189,000	--	189,000
Ultracentrifuge (Nimmo et al. 1994)	--	25,000	25,000
Instantaneous Profile (Watson 1966)	45–55	45–55	45–55
Direct Measure (drainage lysimeter)	--	--	56

Note: Assumes a unit-gradient condition at a soil-water content of 0.09 $m^3\ m^{-3}$ and a soil-water pressure head of -0.40 meter.

Table 3.3-5. Average Winter (November through March) Precipitation, Average Drainage, and Calculated Evaporation Factor from Lysimeter Records

Lysimeter Location	Soil	Observation Period	Average Winter Precipitation (mm/yr)	Average Drainage (mm/yr)	Evaporation Factor (mm/yr)
300 N	Sand(a)	1995-2004	129	73	56
FLTF	Loamy sand(a)	1995-2004	129	32	97
FLTF	Silt loam(a)	1995-2004	129	0	129
FLTF	Sandy gravel(a)	1995-2004	129	111	18
SWL	Gravelly sand	1996-2004	121	51	70
300 N	Sand	1982-1993	109	54	55

(a) Used in fitting of the evaporation factor (E_f).
Note: Measurements for the sand soils are from the same lysimeter but over different time periods.
300 N = 300 North Lysimeter Site.
FLTF = Field Lysimeter Test Facility.
SWL = Solid Waste Landfill.

Table 3.3-6. Relationship Between Evaporation Factor and Soil Textural Descriptors, Goodness of Fit, Predicted 300 North (1981-1993) Sand, and Solid Waste Landfill Drainage from Developed Evaporation Factor Functions, and the Corresponding Measured Drainage

Method	Relationship	Goodness of Fit (r^2)	Predicted 300 North Sand Drainage (mm/yr)	Measured 300 North Sand Drainage (mm/yr)	Predicted SWL Drainage (mm/yr)	Measured SWL Drainage (mm/yr)
1	E_f = 0.6609 (%fines x D10)$^{-0.8833}$	0.997	46	54	70	51
2	E_f = 102.331 + (83.935 x %fines) - (9.270 x d_g) - (80.224 x σ_g)	1.000	53	54	66	51

Note: The 300 North sand data set is from a 12-year record not used in the model calibration.
SWL = Solid Waste Landfill.

Table 3.3-7. Grain-Size Statistics and Predicted Drainage for Commercial Road-Base Material, Representing Tank Farm Surface Cover, and Two Synthetic Types of Soil

Soil	% Fines	% Sand	% Gravel	D10 (mm)	d_g (mm)	σ_g (mm)	Predicted Drainage (mm/yr)	
							Method 1	Method 2
Road-base	4	24	72	0.267	5.471	0.162	93	87
Synthetic A[(a)]	14	23	63	0.023	2.701	0.060	24	45
Synthetic B[(a)]	24	20	56	0.006	1.049	0.033	0	19

(a) Consists of road-base material with an addition of 10 and 20 percent fines.

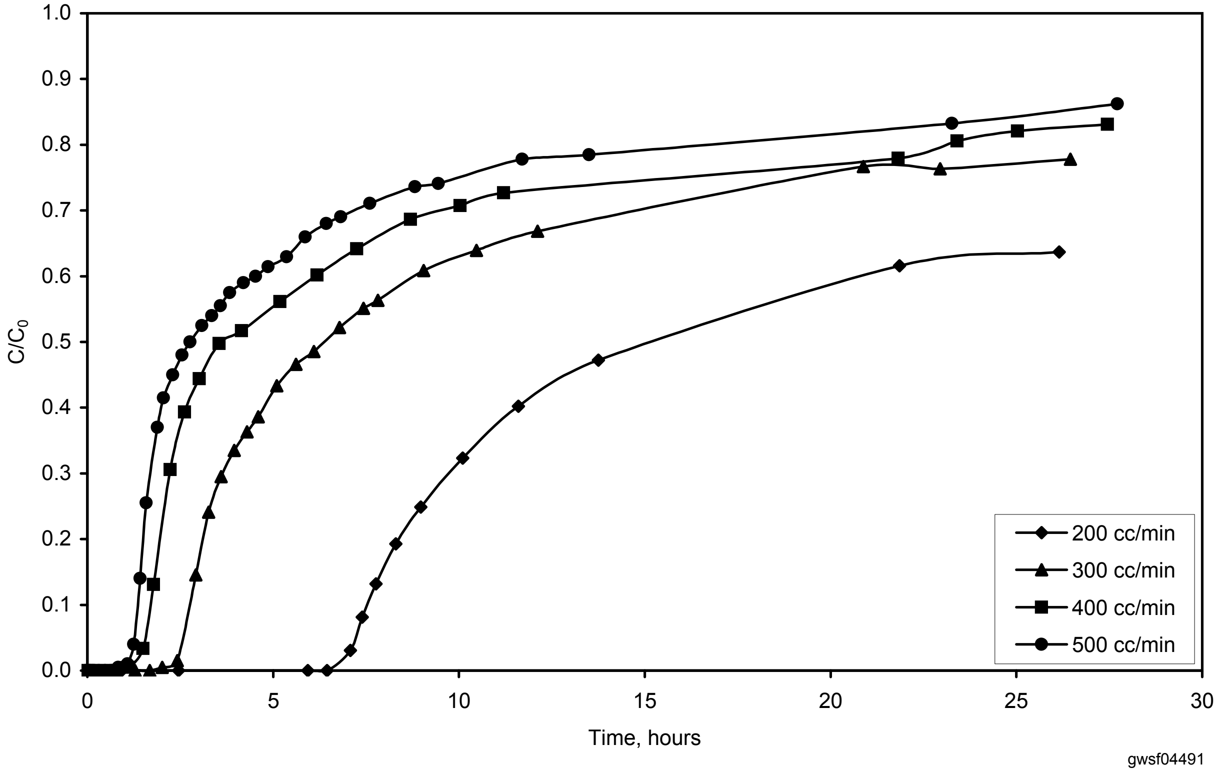

Figure 3.3-1. Hydrogen Sulfide Breakthrough Curves during the Initial 30 Hours of Small Column Treatment Tests with Hanford Formation Sediment

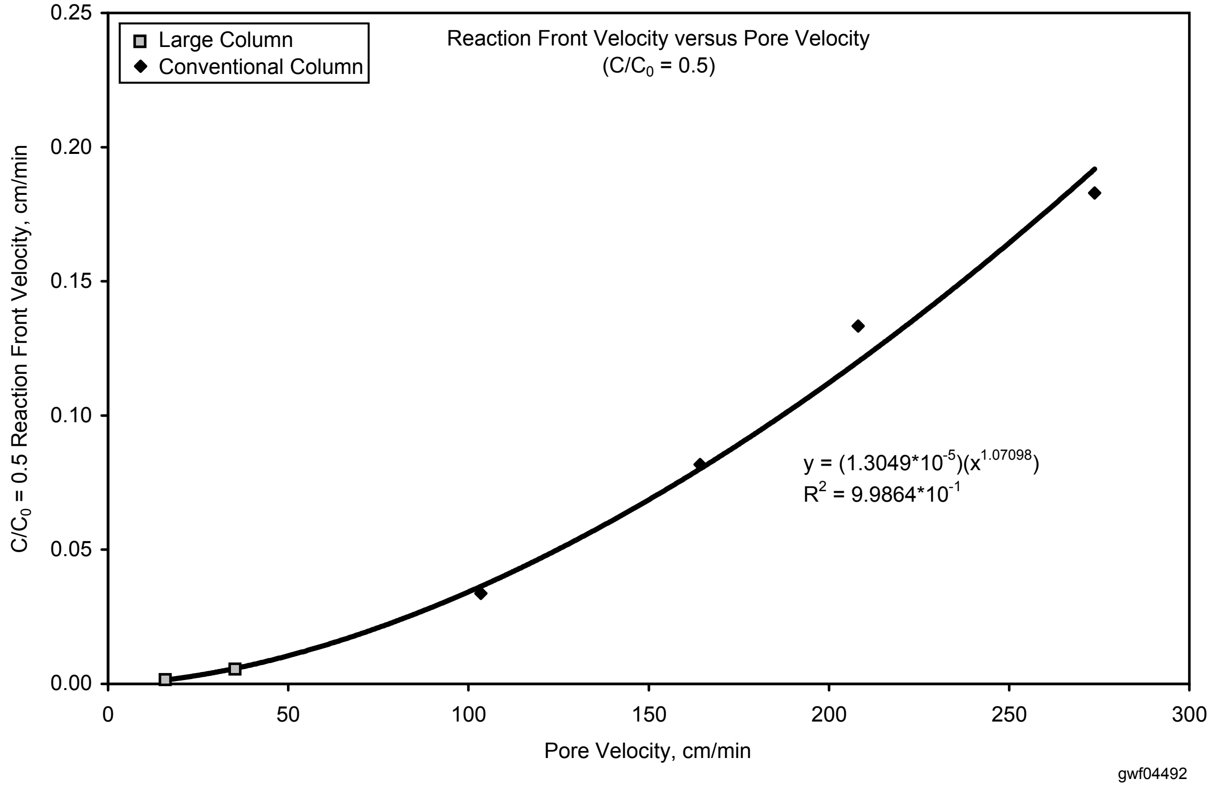

Figure 3.3-2. Reaction Front Velocity versus Pore Velocity for the Conventional and Large Column Gas Treatment Tests

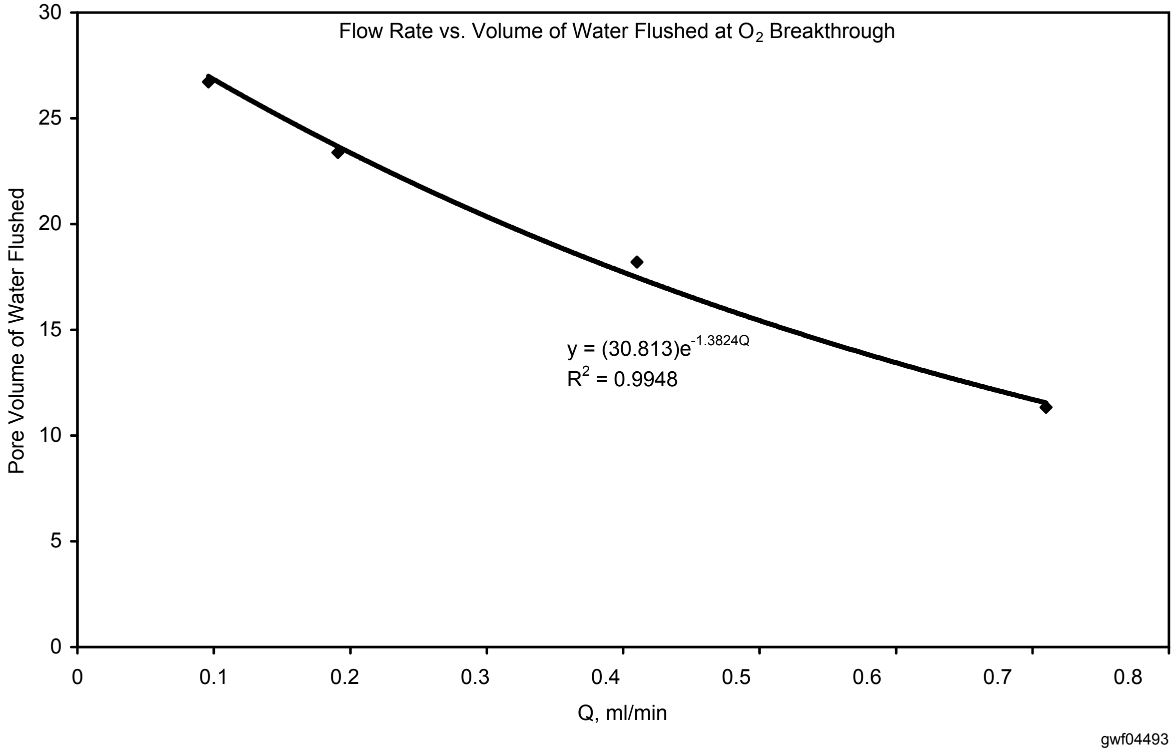

Figure 3.3-3. Water Flow Rate versus Number of Column Pore Volumes Associated with Initial Oxygen Breakthrough

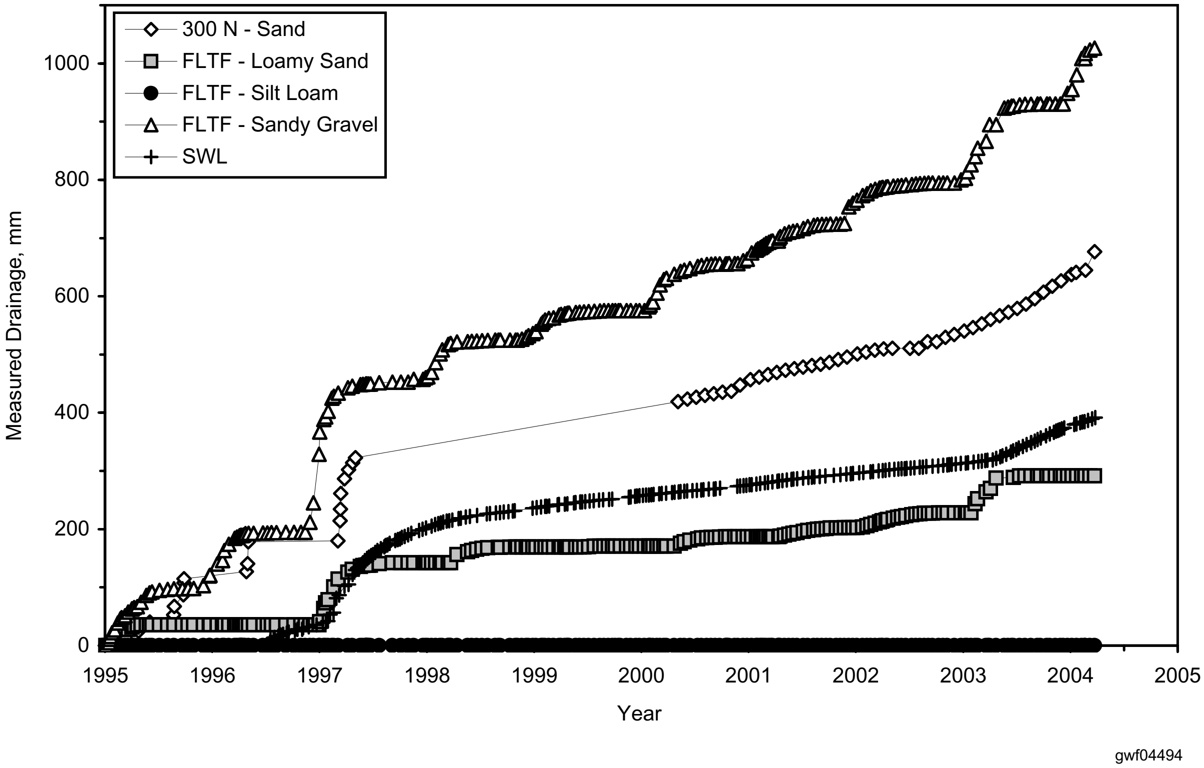

Figure 3.3-4. Cumulative Drainage for the 300 North and Field Lysimeter Test Facility Lysimeters from January 1, 1995, to April 2004, and Cumulative Drainage for the Solid Waste Landfill Lysimeter from July 1, 1996, to April 2004

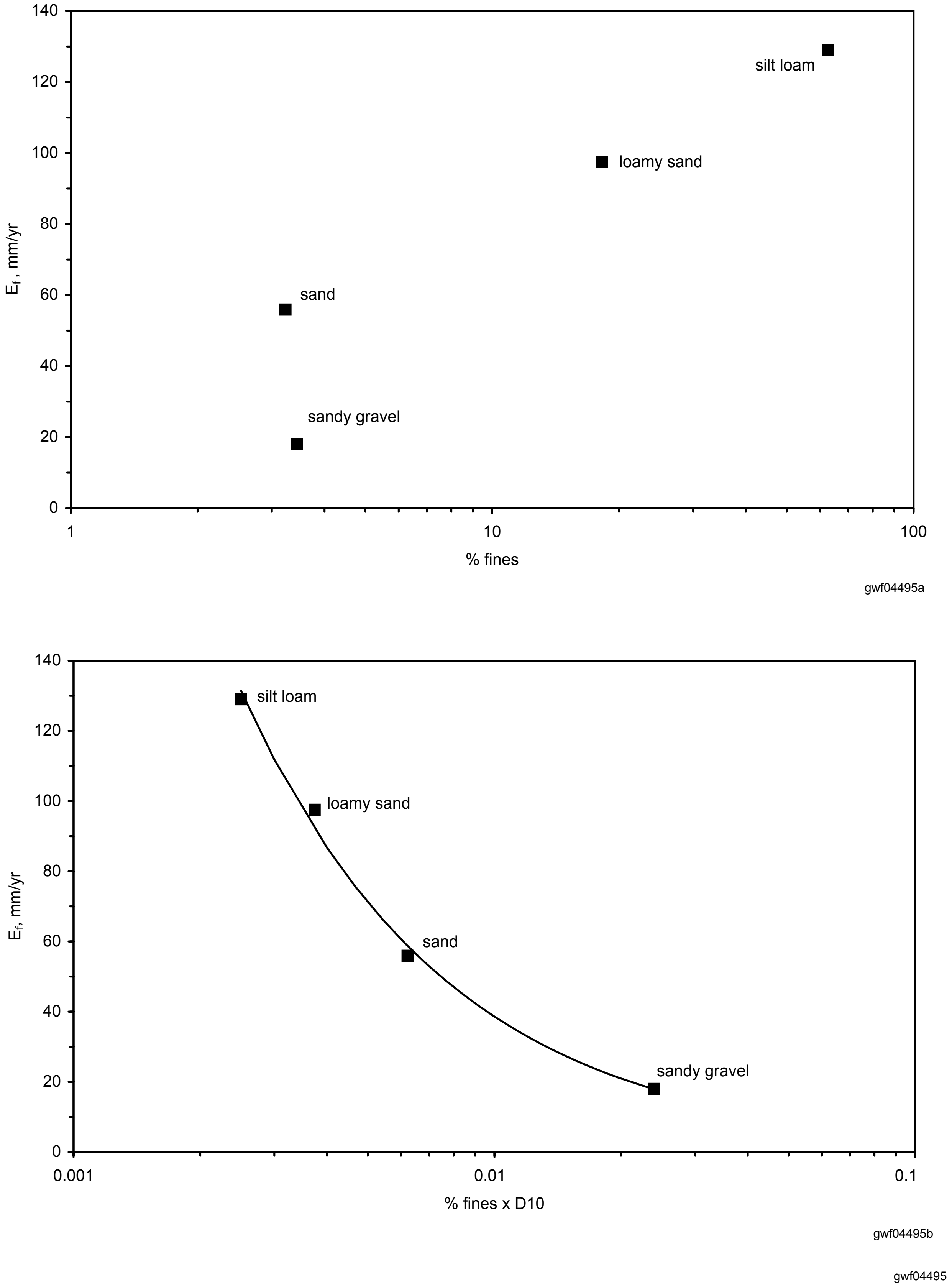

Figure 3.3-5. Relationship Between the Evaporation Factor, E_f, and (a) Percent Fines; (b) Percent Fines x D10 ($r^2 = 0.997$). The solid line represents the developed E_f function.

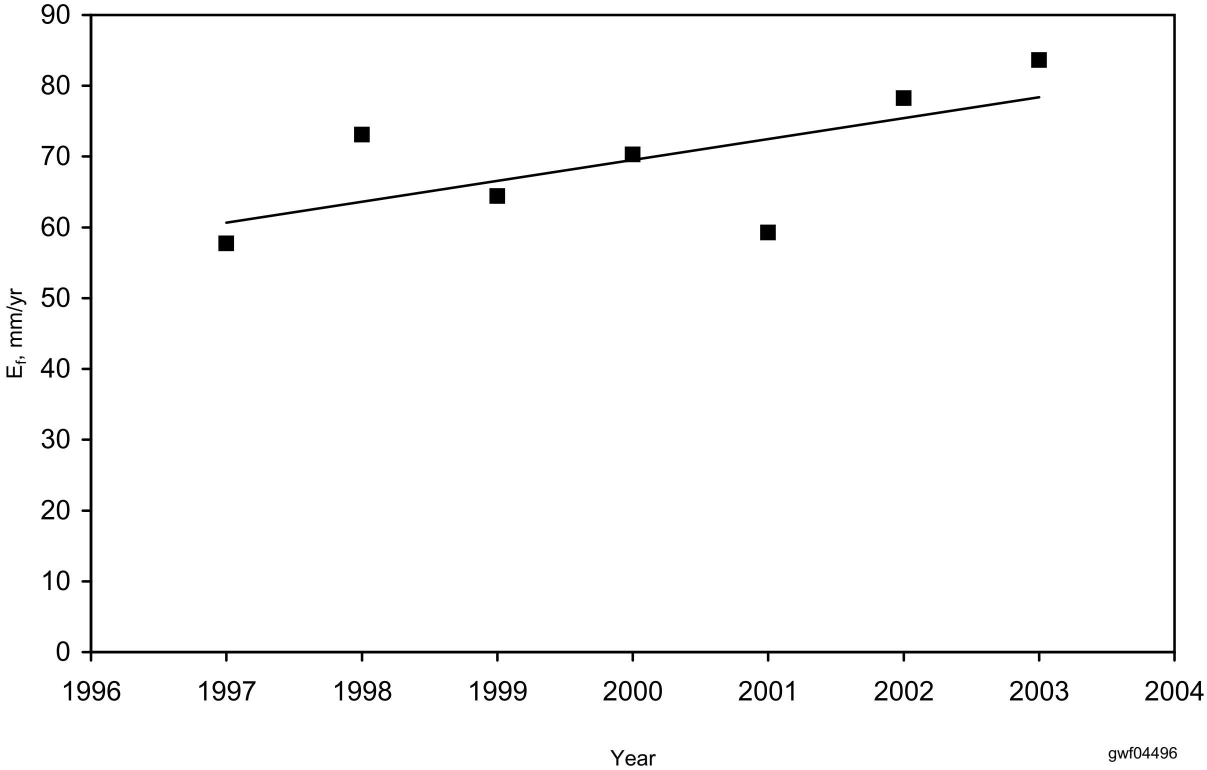

Figure 3.3-6. Solid Waste Landfill E_f Over Time as Calculated from Solid Waste Landfill

4.0 Groundwater Modeling

P. D. Thorne

Computer models are used to forecast future groundwater conditions and predict the movement of contaminants in groundwater. Such predictions are important in planning waste management and cleanup activities for the Hanford Site. Groundwater modeling activities that address problems on a Hanford site-wide scale, such as contaminant movement from the operational areas on the Central Plateau to the Columbia River, have been consolidated under the Groundwater Performance Assessment Project. The consolidation of site-wide modeling eliminates redundancy and promotes consistency of groundwater models (DOE/RL-2000-11). Other groundwater models are used to address issues at a local scale (i.e., <~10 kilometers). Local-scale modeling is used to predict the migration of dense, non-aqueous liquid disposed at the 216-Z-9 crib through the vadose zone and aquifer. Local-scale modeling of the 300 Area is currently being performed to support evaluation of remediation alternatives for the 300-FF-5 Operable Unit. Local-scale modeling has also been used for the past several years to design and evaluate pump-and-treat systems for local-scale groundwater contaminant plumes.

This chapter summarizes Hanford Site groundwater modeling activities for fiscal year (FY) 2004. Section 4.1 reports on the continuing development of the consolidated site-wide groundwater model. Section 4.2 describes the groundwater modeling component of the System Assessment Capability, which was used to perform an updated composite analysis of the combined effects of all radiological waste that will be left on the Hanford Site at the time of site closure. Section 4.3 presents summaries of three applications of the site-wide groundwater model to specific waste-site assessments, which include:

- Modeling the movement of tritium disposed to the State-Approved Land Disposal Site north of 200 West Area.
- Site-wide groundwater flow and transport calculations supporting the performance assessment for the Integrated Disposal Facility and the preliminary performance assessment for closure of single-shell tank farms.
- Site-wide modeling of dissolved carbon tetrachloride migration from 200 West Area through the groundwater considering different source conditions and various degrees of sorption and natural degradation.

Local-scale modeling of dense, non-aqueous liquid migration in the vadose zone and aquifer at the 216-Z-9 crib is summarized in Section 4.4. Modeling to support evaluation of remedial alternatives of the 300-FF-5 Operable Unit is described in Section 4.5. Section 4.6 describes local-scale modeling activities performed to assess groundwater pump-and-treat activities.

Groundwater flow and transport models based on alternative conceptual models are being developed to improve predictions of contaminant transport and to evaluate uncertainty in model results.

4.1 Site-Wide Groundwater Flow and Transport Model

A site-wide numerical model of groundwater flow and contaminant transport has been developed and is being improved and refined. The "base case" site-wide model is a three-dimensional representation of the aquifer system that has been calibrated to water-table changes observed in well data collected from 1943 to 2001 (PNNL-13447). The transient, inverse calibration was performed using UCODE, a universal inverse modeling code developed jointly by the U.S. Geological Survey and the International Groundwater Modeling Center of the Colorado School of Mines. The site-wide model is implemented using the Coupled Fluid Energy and Solute Transport (CFEST) code, which is the forward model whose parameters are estimated by UCODE.

During FY 2004, the pattern of geologic facies-zones within the Hanford formation and Ringold Formation gravel units of the model has evolved in a continuing effort to improve the calibration of Alternative Conceptual Model (ACM)-2 (PNNL-14398). The calibration involves adjusting the facies-zonation configuration, the hydraulic conductivities associated with the facies-zones, and the amounts of recharge to the system in an effort to match historical changes in water-table elevation and the historical movement of tritium. Changes were also made to the configuration of hydrogeologic units in the model based on new well data and reinterpretation of geological contacts at some locations. Progress on calibration of ACM-2 during FY 2004 is described in the following section (4.1.1). Section 4.1.2 provides background information about the site-wide groundwater model.

4.1.1 Improved Calibration of ACM-2 Based on Hydraulic Heads and Tritium Movement

The calibration of the "base case" model and ACM-1 (PNNL-13623) was linked to the distribution of unconfined aquifer transmissivity from an earlier two-dimensional steady-state model calibration (PNNL-11801). ACM-2 uses a facies-zonation approach in which zones of equal hydraulic conductivity are defined based on geological information. This approach is more closely aligned with the geologic structure of the aquifer system. It is also more suitable for the application of geostatistical methods to develop a range of probable conceptual models that will produce a range of results and thus help to quantify model uncertainty. The facies zones originally defined for ACM-2 Unit 1, the Hanford formation, are shown in Figure 4.1-1. Facies zones originally defined for Unit 5, which includes Ringold gravel units C and E and upper Ringold sand (BHI-00184), are shown in Figure 4.1-2. These zones were developed based on textural information in geologic descriptions from well drilling, knowledge of depositional environments, aquifer test information, and hydraulic head responses in wells (PNNL-14398).

ACM-2 resulted in a better fit to measure water-level data and is more closely aligned with the geologic structure of the aquifer system.

During FY 2004, calibration of ACM-2 based on hydraulic heads was refined by adding additional facies zones. The model was then further calibrated by using data and information on the historical movement of tritium in the calibration process. Hydraulic parameters associated with the faces zones are adjusted to achieve a better match between simulated tritium transport and the concentration of tritium observed at monitoring wells. Tritium was used in the calibration because it is the most widespread groundwater contaminant on the Hanford Site.

Calibration of ACM-2 based on observed tritium movement is continuing at the present time. Current planning calls for the eventual development of a range of alternative conceptual models with equally possible zonation patterns based on the available data. Calibration of a selection of models within this range of alternatives will help to capture the uncertainty in the model results, which will strengthen the technical defensibility of groundwater transport predictions and lead to a better basis for waste-management and cleanup decisions.

4.1.2 Background Information on the Site-Wide Groundwater Model

The site-wide groundwater flow and transport model was developed from information that included the following:

- Three-dimensional location and extent of major hydrogeologic units within the aquifer.
- Distribution of textural and lithologic properties of aquifer sediments.
- Spatial distributions of hydraulic and transport properties.
- Aquifer boundary conditions including potential groundwater recharge and discharge.
- Distribution and movement of contaminants indicated by groundwater sampling.

The model consists of nine separate hydrogeologic units, eight of which exist below the water table. The groundwater flow system is bounded by the Columbia River on the north and east and by the Yakima River and basalt ridges on the south and west, respectively. Additional information on the site-wide groundwater model is presented in PNNL-11801 and PNNL-13641.

The three-dimensional model was initially calibrated to historical changes in water-table elevation at the Hanford Site (PNNL-13447) in 2001. However, the hydraulic conductivity distribution of this initial calibration was linked to the transmissivity distribution from an earlier two-dimensional steady-state model calibration through scaling factors. ACM-1 (PNNL-13623) used the same calibration approach, but also incorporated interaction between the sedimentary, generally unconfined, aquifer system and the underlying basalt-confined aquifer system. Earlier models had assumed there was no movement of groundwater between these two aquifer systems.

Initial calibration of the facies-zone based ACM-2 to hydraulic head data was completed during FY 2003 (PNNL-14398). Six facies zones were defined for model Unit 1, the Hanford formation (Figure 4.1-1). Seven zones were defined for model Unit 5, which includes Lindsey's (BHI-00184; Figure 4.1-2) Ringold gravel units C and E and upper Ringold sand. Compared to the earlier ACM-1, the facies-based ACM-2 resulted in a better fit to measured water-level data. The sum of squared residual differences was 9% lower for ACM-2.

Uncertainty is inherent in all numerical models because of both incomplete information about the physical system and the impossibility of perfectly representing the system. An effort to incorporate uncertainty in the site-wide model began in 1999 with recommendations from an external peer review panel to establish a modeling framework that accepts the inherent uncertainty in model conceptual representations, inputs, and outputs (PNNL-13641). This framework will produce a range of predicted results for future groundwater conditions and contaminant transport based on differences in conceptual model assumptions. Uncertainty in model conceptualization has been found to be the most significant source of uncertainty in groundwater modeling (NUREG/CR-6805). As described in PNNL-13641, uncertainty in the site-wide groundwater model is being quantified through sensitivity analysis (e.g., alternative conceptual models and future scenarios) for those aspects of the analysis related to vagueness, and uncertainty analysis for those situations where the uncertainty (e.g., for parameters) can be represented by probability density functions.

4.2 System Assessment Capability

The System Assessment Capability is an integrated assessment tool. It includes several linked computer models designed to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors. It also incorporates modules that calculate the risks to human health and the environment. The groundwater module of the System Assessment Capability receives contaminant flux from the vadose zone module. It simulates contaminant movement through the uppermost aquifer system to the Columbia River and other potential exposure locations such as wells or seeps. The concentrations of contaminants in groundwater are then used in the risk module calculations.

During FY 2004 and 2005, the System Assessment Capability is being used to perform a revised composite analysis.

During FY 2004 and continuing into 2005, the System Assessment Capability is being used to perform a revised composite analysis. This is an update of the composite analysis described in PNNL-11800. It is designed to calculate the combined impacts of all radiological waste that will be left on the Hanford Site at the time of site closure.

The groundwater module is based on the site-wide groundwater model described in PNNL-13447. This model was used in the initial assessment performed during 2002 (PNNL-14027). For the revised composite analysis, the model grid was refined around the contaminant plume areas in the Central Plateau and downgradient to the Columbia

River. The original model was based on a 750-meter grid spacing. The grid was refined to ~80-meter spacing in 200 West Area, where the Ringold Formation is present at the water table, and to ~250-meter grid spacing in areas downgradient of 200 West Area, where the Hanford formation is present in the water table. The revised grid spacing was designed to improve the simulation of contaminant movement from regions of the lower permeability in the vicinity of 200 West Area to regions of higher permeability in the vicinity of 200 East Area and downgradient to the Columbia River. The updated grid is shown in Figure 4.2-1. Some minor changes to the geological interpretation and recharge boundaries were also incorporated in the updated model.

The System Assessment Capability can be used for a stochastic analysis, which means that selected parameters are represented by probability distributions from which values are selected. This results in a range of calculated risks that are designed to encompass the uncertainty in the analysis. For the groundwater module of the revised composite analysis, only the sorption coefficients of contaminants are represented stochastically. Other sources of uncertainty in the groundwater model, including conceptual model uncertainty, will eventually be incorporated based on the strategy described in Section 4.1.

Background information on design of the initial System Assessment Capability tool is summarized in BHI-01365. Results of an initial assessment performed with the System Assessment Capability are provided in PNNL-14027 and a description of the software is provided in PNNL-14852, Volumes 1, 2, and 3.

4.3 Applications of the Site-Wide Groundwater Model

This section describes three groundwater modeling activities that were implemented during FY 2004 to support specific waste site assessments.

State-Approved Land Disposal Site modeling results using the updated groundwater model differed significantly from those predicted in the 1997 modeling.

4.3.1 Modeling of Tritium Migration at the State-Approved Land Disposal Site

Treated water from the Hanford Site 200 Area Effluent Treatment Facility is discharged to a drain field at the State-Approved Land Disposal Site (SALDS—also see Section 2.8.3.5). SALDS is located immediately north of 200 West Area in the Central Plateau of the Hanford Site (see Figure 2.8-2 in Section 2.8). Although water discharged at SALDS has been treated to remove other contaminants, it may contain tritium, which is very difficult to remove from water.

Impacts from water and tritium disposal at the SALDS facility were previously modeled in 1997 (PNNL-11665.1). During FY 2004, the site-wide groundwater model was used for an updated assessment of the impacts of SALDS as reported in PNNL-14898. The updated assessment included the following objectives:

- Incorporate up-to-date historical discharge and groundwater monitoring data into groundwater flow and transport model.
- Incorporate more recent and accurate projections of future tritium disposal and water discharge volume to the SALDS.
- Predict the extent of lateral and vertical movement of the tritium plume from the SALDS.
- Recommend strategies for future monitoring based on model results.

The updated assessment incorporated refinements in the Hanford site-wide groundwater model (PNNL-13447). Model simulations were performed for the period 1944 through 2100 using the revised site-wide groundwater model. Artificial recharge at all active Hanford discharge sites was included in the model. However, contaminant release was limited to the tritium source at the SALDS facility. Potential effects from other sources of groundwater contamination are not considered in this analysis.

Records of treated water volumes and inventories of tritium discharged to the SALDS from its startup in 1995 through 2004 were compared with projected values used in the 1997 modeling. The results showed that while actual discharge volumes through June 2004 exceeded projections, cumulative tritium inventories discharged to the SALDS were only about half of the projected inventories.

The updated model used the reported SALDS discharge data for inputs of water volumes and tritium inventories through June 2004 and updated projections of expected water volumes and tritium inventories through 2030. Projected tritium discharges increase for the period after 2008 because of expected effluents originating from the Waste Treatment Plant and associated facilities. It was assumed that there will be no discharge of tritium after 2030.

Results of the revised model showed tritium concentrations increasing to between 800,000 and 900,000 pCi/L by 2006, then declining to ~300,000 pCi/L in 2008. Concentrations are then predicted to increase after 2009 to a maximum of just over 3 million pCi/L at the end of waste treatment operations. This increase in concentration results from the increased discharge of tritium associated with the Waste Treatment Plant. The previous modeling had suggested that tritium concentration levels would drop below 500 pCi/L by the 2090. However, with the updated increase in future tritium inventories in the current projections, modeled results suggest that tritium concentration levels would not drop below the 500 pCi/L level until about the year 2140.

Modeling results suggest that the current monitoring well network, which consists of 3 proximal monitoring wells and 16 tritium tracking wells, will continue to provide adequate coverage for monitoring the movement of tritium from the SALDS. Current predictions suggest that concentration levels of over 500 pCi/L will arrive at well 699-51-75P (see Figure 2.8-1 in Section 2.8) within the next 5 to 10 years. After discharges cease in 2030, simulation results suggest that the plume will not grow much beyond this observation well because continuing plume dispersion and radioactive decay of tritium will reduce concentrations in the aquifer.

4.3.2 Groundwater Calculations Supporting Performance Assessments

During FY 2004, the site-wide groundwater flow and transport model was used to perform calculations that support groundwater flow and transport analyses associated with the performance assessment for the Integrated Disposal Facility and the preliminary performance assessment for closure of single-shell tank farms. This work is documented in PNNL-14891. The standard approach of sequentially simulating mass release from a waste site, transport through the vadose zone, and transport of the resulting plume through the groundwater was compared with two alternative methods. The examined alternatives are (1) the "well intercept factor" approach, and (2) the "convolution" approach. The sequential simulation approach has been used extensively and is preferred when transient vadose zone and groundwater conditions are important and the combinations of inventory distributions and parameter sets are less than the number of simulations required. However, for assessments that consider only the impact of future releases, after the effects of transient changes to the vadose zone and aquifer are considered less important, steady-state flow conditions can be assumed and the alternative approaches may provide reasonable estimates of groundwater concentrations. The advantage of the alternative methods is that groundwater impacts can be calculated for a large number of waste inventory and release scenarios in a much shorter time.

The convolution approach for estimating groundwater concentrations involves simulating a groundwater concentration response resulting from a "unit" inventory release of a particular contaminant. A unit release in each of the process models (e.g., source release, vadose zone transport, and groundwater transport) can be simulated independently. This is repeated for each contaminant. The principle of superposition is then applied to determine the combined groundwater impacts of different contaminant inventory distributions. By assuming linearity, the unit release responses from each individual source area can be combined or superimposed. This approach can be used to estimate groundwater concentrations at specific locations and can be a preferred alternative when large combinations of inventory distributions, vadose zone, and groundwater flow and transport scenarios need to be simulated.

The well intercept factor approach for estimating groundwater concentrations involves simulating the groundwater system response to the influx of water from the overlying vadose zone over a specific water table surface area and with a given contaminant concentration. The ratio of the simulated concentration in the groundwater at a downgradient location to the contaminant concentration at the bottom of the vadose zone can then be used to estimate groundwater concentrations at those locations from other vadose zone contaminant concentrations that are calculated independently from waste release and vadose zone flow and transport models. The two performance assessment analyses intend to use well intercept factors as outlined in PNNL-13400. The flow and transport analysis applied to these calculations used both a site-wide regional-scale model and a local-scale model of the area near the Integrated Disposal Facility. The regional-scale model was used to evaluate flow conditions, groundwater transport, and impacts from the Integrated Disposal Facility and individual tank farm areas. Impacts were evaluated at the boundary of the "core zone," an area around the 200 East and 200 West Areas where groundwater use is expected to be restricted, and along the Columbia River. The local-scale model was used to evaluate effects from the transport of contaminants at a hypothetical well 100 meters downgradient of the Integrated Disposal Facility. Well intercept factors calculated for different Integrated Disposal Facility release areas and recharge rates using local-scale model and the regional-scale model are provided in PNNL-14891.

Additional simulations were also performed to evaluate the general performance of the well intercept factor approach in comparison to the standard sequential approach and the convolution approach. In these additional simulations, two release scenarios were evaluated to compare estimated groundwater concentrations using these different approaches. One case involved a hypothetical source release of technetium-99 near the Integrated Disposal Facility. The other case involved a hypothetical release of technetium-99 over a 600-year time frame from the S-SX Tank Farm area. These selected cases provide insight into the use of the well intercept factor approach for estimating groundwater concentrations from mass releases to the unconfined aquifer.

The analysis showed that the well intercept factor approach provided reasonable and accurate estimates of groundwater concentrations in the vicinity of the source release. However, for locations at greater distances, the convolution method more closely matched groundwater concentration results calculated with the standard sequential simulation approach. Results were generally influenced by two factors: (1) the duration of the source term release to the water table and (2) the downgradient distance.

For the long-term contaminant release scenario at the Integrated Disposal Facility, the convolution approach produced estimated peak groundwater concentrations that were ~4% higher at the core zone boundary and 10% lower along the river when compared to the sequential simulation approach. Results from the well intercept factor method were 10% higher at the core zone boundary and 12% higher along the river when compared to the sequential simulation approach.

For the short-term contaminant release scenario from the S-SX Tank Farm area, the convolution approach produced estimated concentrations that were closest to those calculated using the sequential simulation method. The convolution approach produced estimated peak groundwater concentrations that were ~7% higher at a 250-meter distance from the source, 5% lower at the core zone boundary, and 5% lower along the river when compared to the sequential simulation approach. Peak groundwater concentrations from the well intercept factor method were 50% higher at a 250-meter distance from the source, 3.6 times higher at the core zone boundary, and 2.1 times higher along the Columbia River when compared to the sequential simulation results.

4.3.3 Modeling of Carbon Tetrachloride from the 200 West Area

Studies of carbon tetrachloride transport through the unconfined aquifer system were performed based on an initial evaluation of the nature and extent of carbon tetrachloride contamination in the unconfined aquifer beneath the 200 West Area (PNNL-13560). In FY 2004, the model was extended to the Columbia River based on the site-wide groundwater model, and groundwater transport was simulated assuming different source conditions and various degrees of sorption and natural degradation for carbon tetrachloride. Simulated groundwater concentrations were compared at an arbitrary boundary ~5 kilometers from the source and at the Columbia River. Results of the updated modeling are documented in PNNL-14855. These modeling analyses resulted in the following conclusions.

With the assumption of a continuing source of carbon tetrachloride entering the groundwater from the vadose zone and with no sorption or abiotic degradation (i.e., Case 1a), the following was observed:

- Development and migration of a substantial carbon tetrachloride plume from source areas in the 200 West Area to the Columbia River. Predicted concentrations reached ~200 µg/L at the arbitrary boundary chosen for this analysis and ~34 µg/L along the Columbia River during the 1,000-year period of analysis. Both of these values exceed the drinking water standard of 5 µg/L.
- The equilibrium carbon tetrachloride release estimate in the source area was ~73 kg/yr.
- Initial conditions yielded an initial mass of ~542 kilograms in the aquifer, which grew to 58,050 kilograms after 1,000 years (the year 3000).

With the assumption of a continuing source with median value estimates of sorption and abiotic degradation (i.e., Case 1b), the following was observed:

- Limited development and migration of a carbon tetrachloride plume from source areas within the general vicinity of the 200 West Area. Predicted concentrations reached ~4.5 µg/L at the arbitrary boundary chosen for this analysis. Concentrations at discharge areas along the Columbia River were essentially zero during the 1,000-year period of analysis.
- The combination of sorption and abiotic degradation rate significantly limits aquifer source loading and the aquifer area and volume affected by the carbon tetrachloride plume migration. It should be mentioned that the most important parameter of the two is the abiotic degradation rate because retardation alone will not reduce concentrations other than through dilution because of hydrodynamic dispersivity.

Modeling showed the importance of sorption and abiotic degradation in determining whether carbon tetrachloride concentrations will exceed compliance limits (5 µg/L) outside the Central Plateau Core Zone.

Without a continuing source of carbon tetrachloride and no sorption or abiotic degradation, we observed results that were very similar whether the source area with the highest concentrations in the plume (i.e., all concentrations above 3,000 µg/L) was assumed to be removed from the aquifer (Case 2) or the existing plume was considered as an initial condition of aquifer contamination (Case 3). In both of these cases, the following was observed:

- A more limited development and migration of a carbon tetrachloride plume outside the 200 West Area toward the Columbia River than with the continuing source assumption evaluated in Case 1a.
- A predicted concentration profile reaching ~6.5 µg/L at the arbitrary boundary chosen over a period of ~600 years between 2100 and 2700. This contrasts with the rapidly rising and plateau profile of carbon tetrachloride concentrations predicted under the continuing source assumption evaluated in Case 1a.

- A concentration profile at discharge areas along the Columbia River that is well below the drinking water standard of 5 µg/L during the 1,000-year period of analysis.

The results of these analyses illustrate the importance of developing field-scale estimates for sorption and abiotic degradation of carbon tetrachloride. With no sorption and abiotic degradation, carbon tetrachloride concentrations will exceed the compliance limit of 5 µg/L outside the Central Plateau waste management area, and the aquifer source loading and area of the aquifer affected will continue to grow until river arrival rates of carbon tetrachloride equal source release rates estimated at 33 kg/yr. Results of these analyses also show the significant change in predictions between continual source release from the vadose zone and complete source removal.

4.4 Local-Scale Multi-Phase Modeling of Carbon Tetrachloride Movement

Simulations of the movement of carbon tetrachloride disposed at 216-Z-9 trench in the 200 West Area were performed using the multi-phase STOMP simulator (PNNL-14286). The carbon tetrachloride was modeled as a dense, non-aqueous liquid, a dissolved component of water in both the vadose zone and the aquifer, and as a gas mixed with air in the vadose zone. The purpose of this work was to enhance understanding of carbon tetrachloride in the subsurface beneath the 216-Z-9 trench. Discussion and results of the modeling effort are published in PNNL-14895.

Multi-phase modeling of carbon tetrachloride movement in the subsurface helps us evaluate remedial actions that will be most effective.

The geological representation applied in the model was based on a local refinement of the site-wide groundwater model with additional detail added for units in the vadose zone. A total of 12 stratigraphic units were included. The lateral scale of the model was 440 by 540 meters.

A total of 23 simulations, 1 base case, and 22 sensitivity runs were performed. Figure 4.4-1 shows the saturation of available pore space by dense, non-aqueous liquid beneath the 216-Z-9 trench for the base case. The concentrations of carbon tetrachloride dissolved in water in the vadose zone and aquifer for the base case are illustrated in Figure 4.4-2. The sensitivity cases examined the effects of variation in fluid properties; disposal rate, area, and volume; fluid retention; permeability; anisotropy; sorption; porosity; and residual saturation. Additional simulations were performed to assess the effects of soil-vapor extraction on the distribution of carbon tetrachloride. The simulation results provided the following information:

- The Cold Creek unit has a large impact on the migration of dense, non-aqueous liquid through the vadose zone.
- The modeled dense, non-aqueous liquid did not move laterally outside the footprint of the disposal facility.
- The lateral extent of the vapor-phase plume in the subsurface is much greater than the lateral extent of the dense, non-aqueous liquid.
- The vapor phase plume partitioned into the underlying groundwater and onto the solid phase as it moved through the vadose zone resulting in contamination of the groundwater.

4.5 Local-Scale Modeling Associated with the 300-FF-5 Operable Unit

Local-scale modeling of groundwater flow and uranium transport at the 300 Area is currently being performed to support the evaluation of remediation alternatives for the 300-FF-5 Operable Unit. During FY 2004, this modeling effort involved the development of a local-scale model of the 300-FF-5 Operable Unit area based on the STOMP code (PNNL-14286). Development of this local-scale model involved the construction of a model appropriate for the domain, spatial and temporal resolution, flow and transport processes, key sources, and boundary conditions. The development efforts make use of the following information:

- Estimates of hydraulic properties currently developed for the site-wide groundwater flow and transport model.
- A geological data set describing the configuration of major hydrogeologic units.
- Methods for directly translating the geological information to appropriate STOMP model input files.
- Current estimates of water sources and waste inventory information compiled under the System Assessment Capability for key waste facilities.
- Observed and predicted river stage and flow conditions for the Columbia River that are needed to establish model boundary conditions.
- Estimates of 300 Area uranium plume inventories based of interpretation of past and current field observations.

The primary accomplishments of this modeling effort completed in FY 2004 include completion of initial flow simulations with the newly developed STOMP model and compilation of data and information for the existing uranium plume that is currently being used to develop initial conditions for model simulations.

4.6 Local-Scale Modeling of Pump-and-Treat Systems

The Hanford environmental restoration contractor performs local-scale modeling to design and evaluate pump-and-treat systems for groundwater. The Micro-FEM code is used to model capture and injection zones of extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat systems over time. The local-scale model is used to evaluate the hydraulic effects of the remedial action sites in several different operational areas.

The operational areas and the contaminants of concern being treated at each are listed below:

- 100-KR-4 Operable Unit (100-K Area) – hexavalent chromium
- 100-NR-2 Operable Unit (100-N Area) – strontium-90
- 100-HR-3 Operable Unit (includes both 100-D and 100-H Areas) – hexavalent chromium
- 200-UP-1 Operable Unit (200 West Area) – technetium-99 and uranium
- 200-ZP-1 Operable Unit (200 West Area) – carbon tetrachloride

During FY 2004, these models were only updated to reflect the changing water-table elevation in the aquifer and changes in pumping rates. Additional information on the models is provided in DOE/RL-99-79, DOE/RL-2002-05, and DOE/RL-2002-67. Results of local-scale modeling of the pump-and-treat operations will be discussed in upcoming status reports for calendar year 2004.

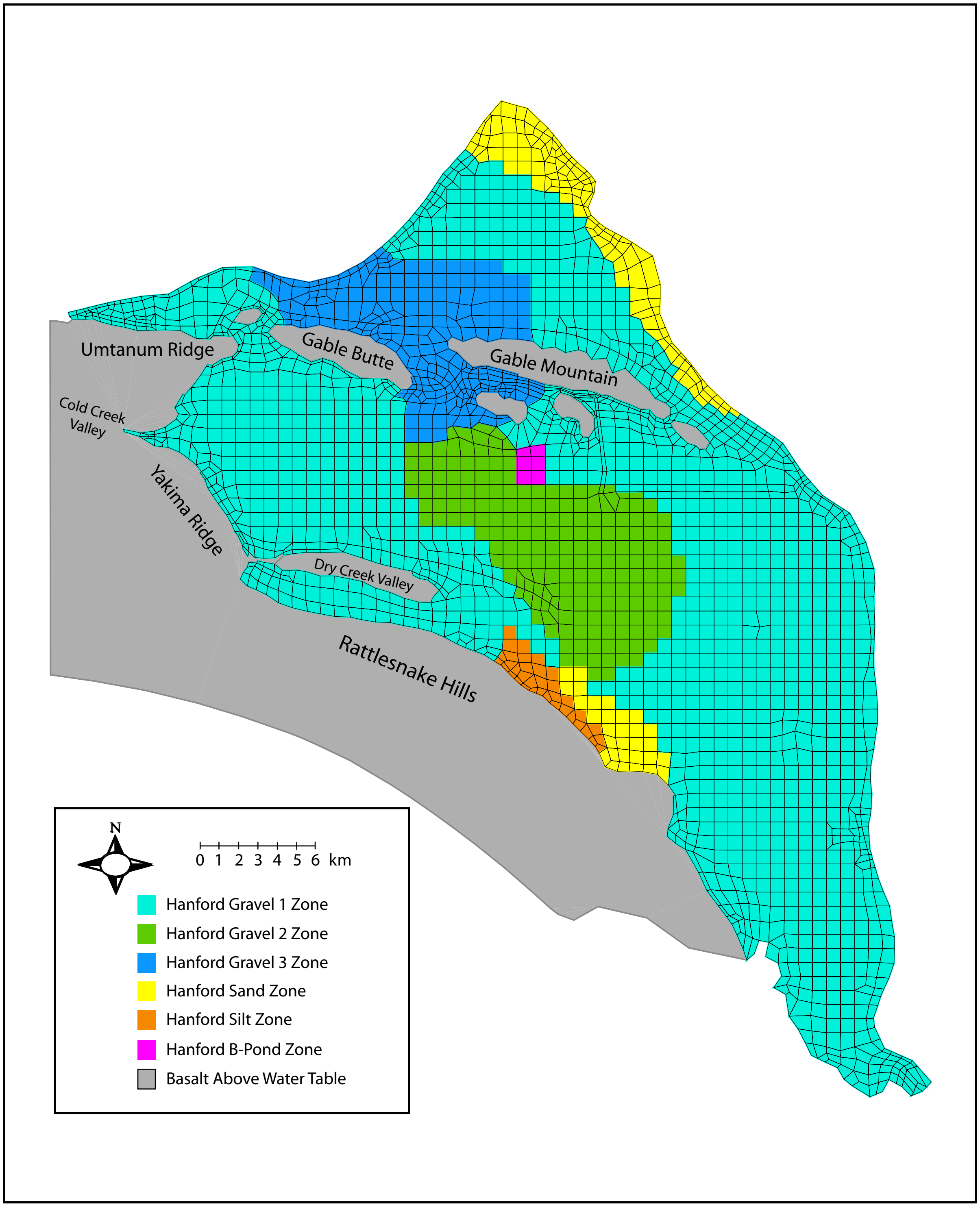

Figure 4.1-1. Facies Zones Defined for Alternative Conceptual Model 2, Unit 1

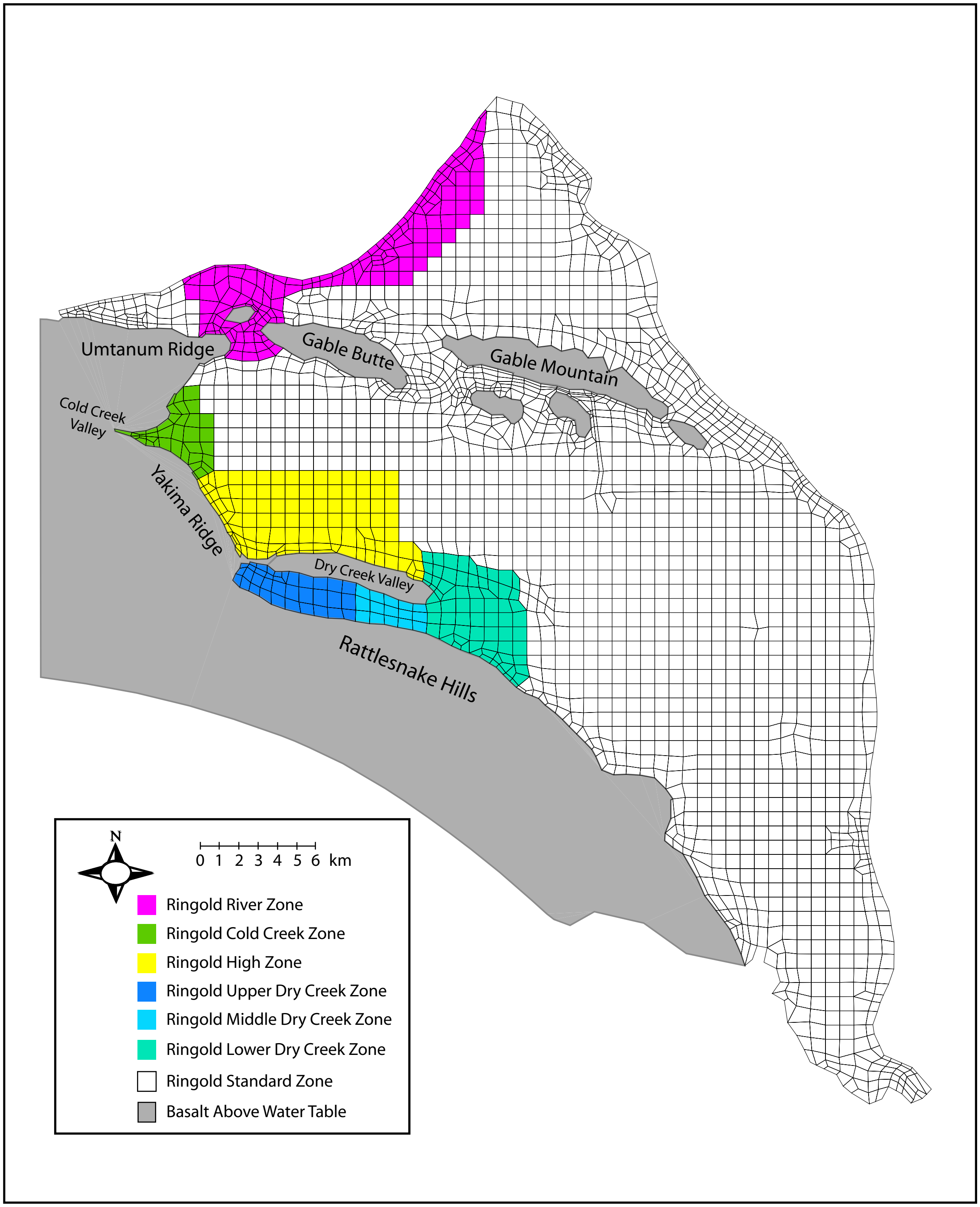

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Figure 4.1-2. Facies Zones Defined for Alternative Conceptual Model 2, Unit 5

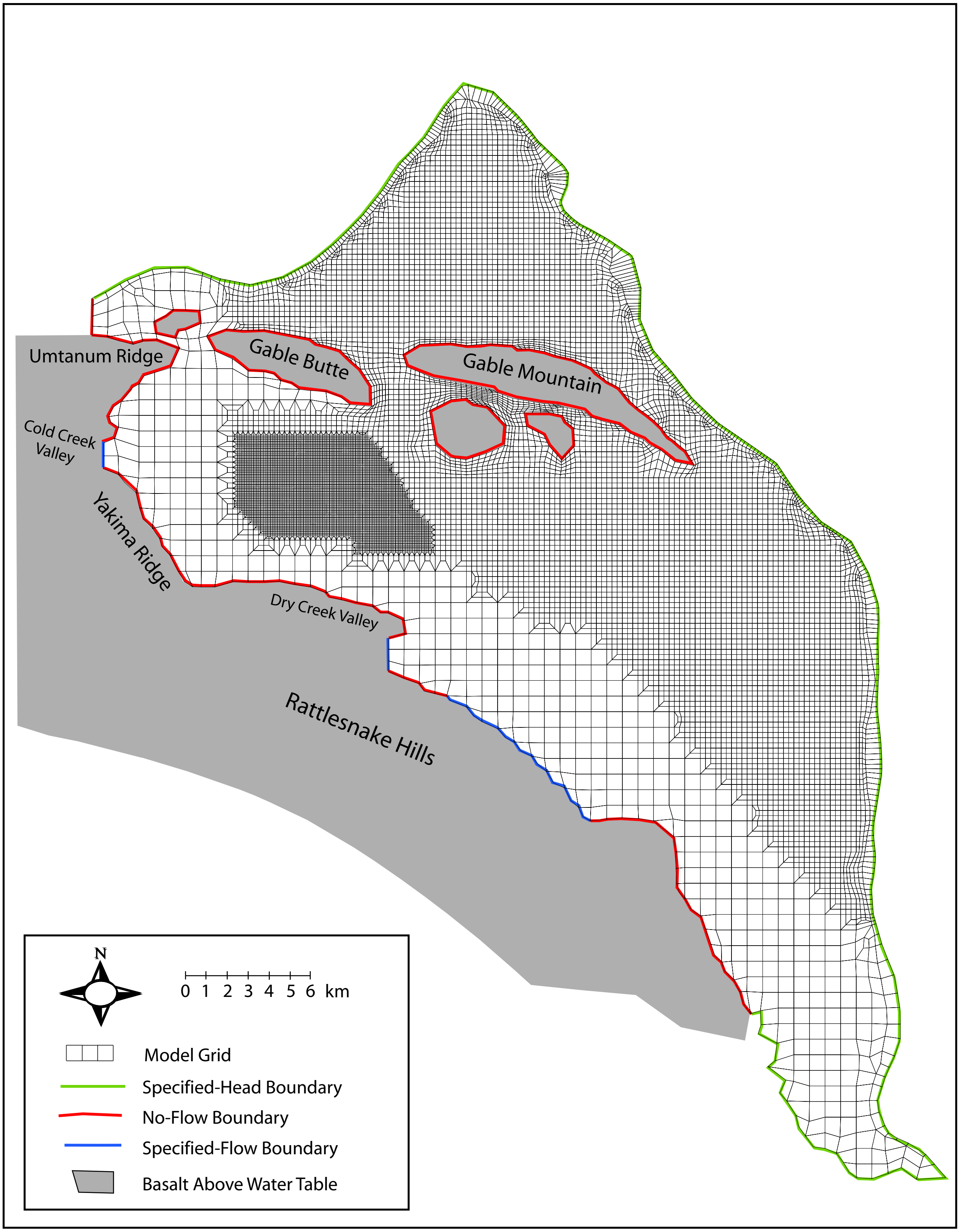

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Figure 4.2-1. Updated System Assessment Capability (SAC) Model Grid

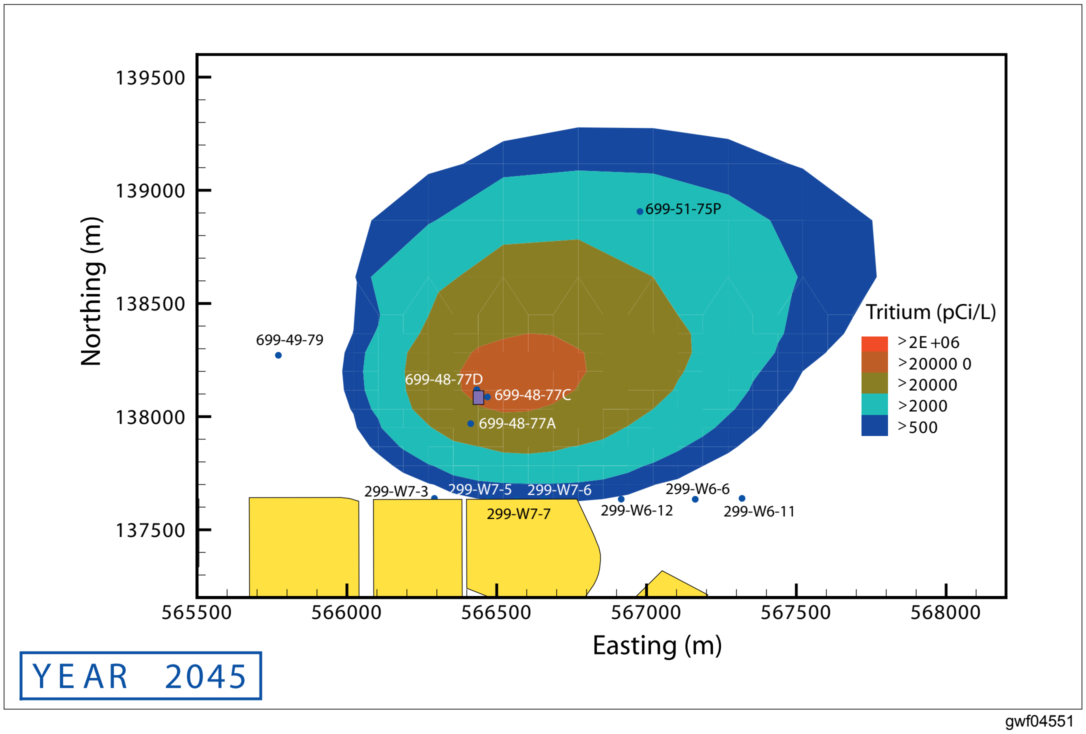

Figure 4.3-1. Simulated Tritium Plume at the State-Approved Land Disposal Site for 2045

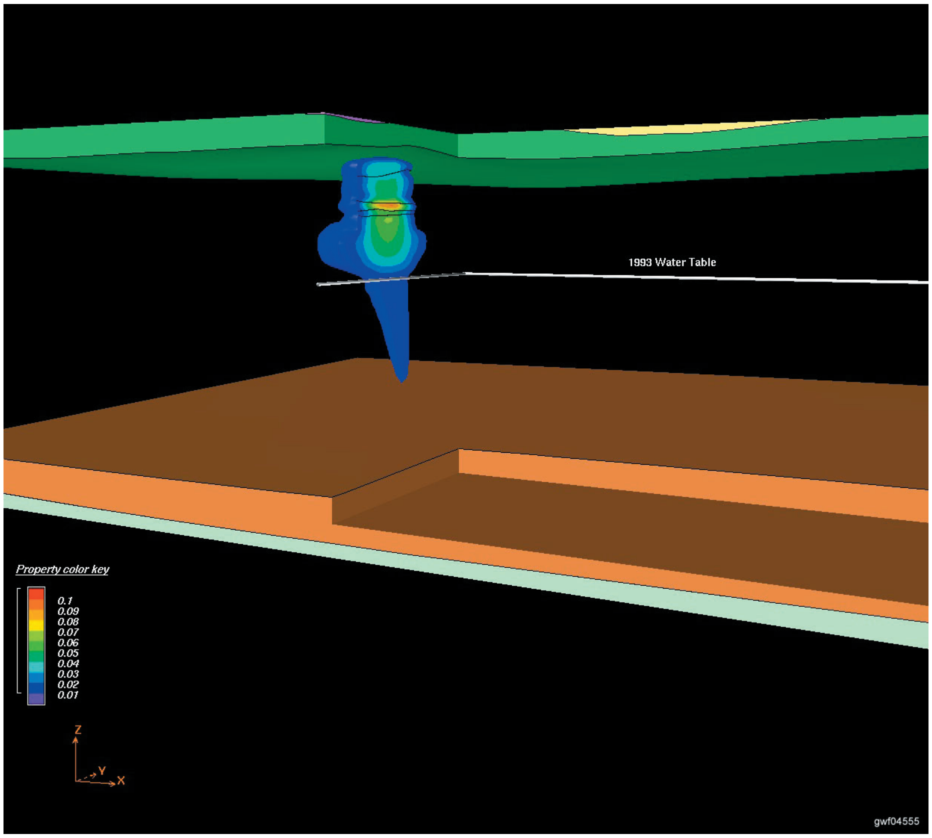

Figure 4.4-1. Simulated Saturation of Dense, Non-Aqueous Liquid at the 216-Z-9 Trench (after PNNL-14895)

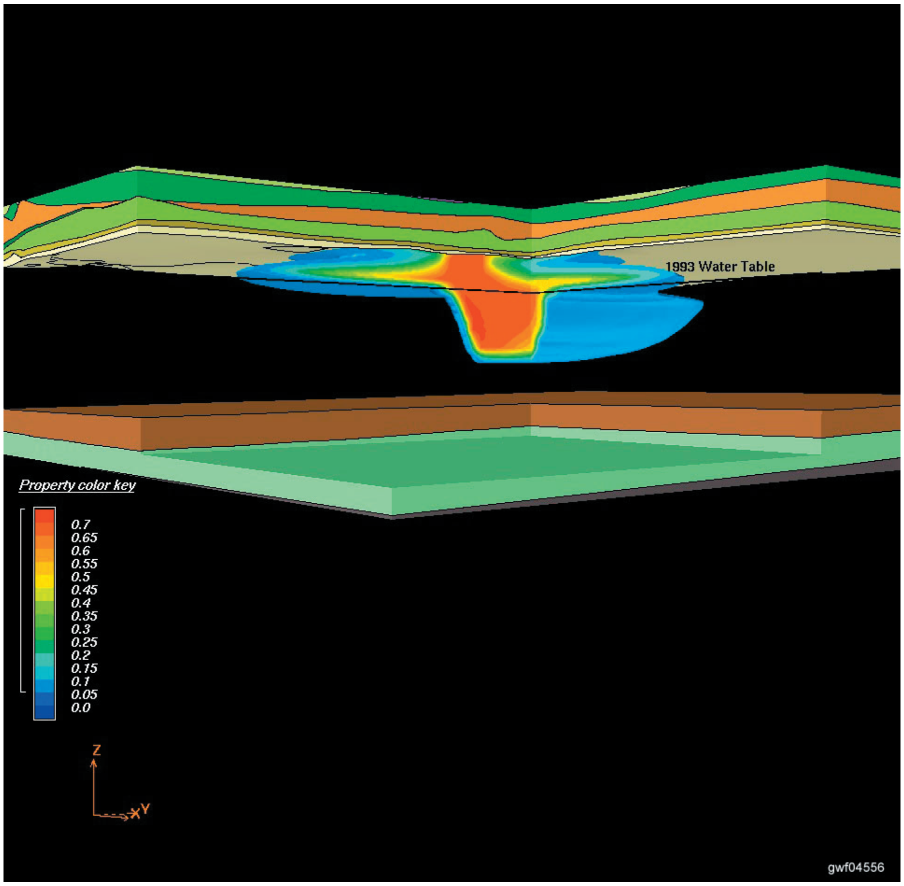

Figure 4.4-2. Simulated Carbon Tetrachloride Concentration in Water Within the Ringold Gravel for 1993 (after PNNL-14895)

5.0 Well Installation, Maintenance, and Decommissioning

B. A. Williams and G. G. Kelty

This section describes new well installation activities conducted on the Hanford Site during calendar year 2004. Well maintenance and decommissioning activities are summarized for fiscal year (FY) 2004. In addition, FY 2004 characterization boreholes and aquifer tube activities are provided.

5.1 Well Installation

Each year the Groundwater Remediation Project reviews the need for new monitoring wells. In FY 2004, 25 new wells were installed.

The Groundwater Performance Assessment Project (groundwater project) along with the Groundwater Remediation Project define the need for new wells at Hanford. Each year, the groundwater project identifies new wells to meet the requirements of the *Resource Conservation and Recovery Act* (RCRA) detection and assessment groundwater monitoring requirements; characterization and monitoring for the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA); and long-term monitoring of regional groundwater plumes under U.S. Department of Energy (DOE) Orders based on the *Atomic Energy Act of 1954* (AEA). These efforts include ongoing RCRA assessment of groundwater contamination, replacement of monitoring wells that go dry because of the declining water table, replacement of wells that pose contamination risks to the environment, improvement of spatial coverage of the monitoring networks or for plume monitoring, and vertical characterization of groundwater contamination.

The Groundwater Remediation Project, managed by Fluor Hanford, Inc., determines the need for new remediation (i.e., pump-and-treat systems) and performance assessment monitoring wells annually to fulfill obligations of CERCLA. Other projects may also request new wells based on specific needs (i.e., vadose investigations, seismic investigations, and other research).

Well needs are integrated and documented via the data quality objectives process (e.g., CP-15329). This process integrates the borehole and well data needs of the various Hanford Site regulatory driven projects (i.e., CERCLA, RCRA, and AEA). Based on the data quality objectives documentation, the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (the Tri-Parties) negotiated an integrated well drilling list that coordinates and prioritizes the requirements of RCRA,

Based on groundwater monitoring requirements, DOE, EPA, and Ecology agree on new wells needed and prioritize the requirements of RCRA, CERCLA, and AEA. During calendar year 2004, 25 new wells were installed on the Hanford Site:

- ***Six for RCRA monitoring.***
- ***Sixteen for CERCLA investigations or remediation.***
- ***Three for the 100-N barrier project.***

Also, there were 108 aquifer tubes installed during FY 2004 along the Columbia River shoreline.

Routine well maintenance is performed on a 5-year cycle to support groundwater sampling. Non-routine maintenance varies and depends on specific problems identified in the field. During FY 2004, 67 wells received routine maintenance and 278 wells received non-routine maintenance.

Wells are decommissioned when they are no longer used, they are in poor condition, or they pose an environmental, safety, or health hazard. During FY 2004, 98 wells were decommissioned.

CERCLA, and AEA. In 2004, as a result of this integration, the Tri-Parties approved Tri-Party Agreement (Ecology et al. 1989) Milestone M-24-57; the revised agreement now includes CERCLA (and AEA) wells along with RCRA. This agreement requires the installation of a minimum of 15 wells per year and includes a prioritized list and schedule for installation of 60 wells over 4 years during calendar years 2003 to 2006. New well proposals will continue to be reviewed and approved annually as defined under Tri-Party Agreement Milestone M-24-00. All new wells are constructed and decommissioned in accordance with the provisions of WAC 173-160.

During calendar year 2004, a total of 25 new wells were installed at the Hanford Site (Table 5.1-1), which are shown on Figure 5.1-1. Tri-Party Agreement Milestone M-24-57 approved the installation of 22 of these wells, which included 6 RCRA wells and 16 CERCLA wells. Three wells were also installed at 100-N Area to support monitoring at the 100-NR-2 (N Barrier).

A revised Tri-Party Agreement milestone includes a prioritized list and schedule for installation of 60 wells over 4 years.

Of the six RCRA wells, five were drilled in 200 East Area around Waste Management Area A-AX (2 wells) and B-BX-BY (3 wells) and the remaining well was drilled in 200 West Area at Waste Management Area U. The 16 CERCLA wells include 2 wells in the 100-K Area for chromium extraction and monitoring, 3 wells for the 100-HR-3 monitoring network at the 100-D Area, 4 wells for the 200-ZP-1 Operable Unit, and 7 wells for the 200-UP-1 Operable Unit in the 200 West Area.

Two temporary wells were constructed as seismic characterization wells to determine shear wave velocities in the Ringold Formation and Hanford formation to evaluate seismic hazards at the Waste Treatment Plant. The first well reached the top of basalt but had a cracked casing that could not be sealed. This limited its usefulness, so a second borehole was drilled to the top of the lower mud unit. This well was successful, and between the two boreholes a complete data set was obtained. Both seismic characterization wells will be decommissioned following data analysis and after it is determined that they will no longer be needed.

Data packages for new wells installed during calendar year 2004 will provide detailed information about the wells including the detailed geologic and geophysical descriptions and a complete set of sediment and groundwater sampling data results (e.g., PNNL-14320; CP-14265). Detailed drilling and construction records for the new wells are also electronically stored in the drilling contractor database.

During FY 2004, 108 aquifer tubes (Table 5.1-2) were installed along the Columbia River shoreline (Figure 5.1-1). Fifteen tubes were installed along the 100-BC-5 rivershore, 18 tubes along 100-KR-4 rivershore, 8 tubes along the 100-NR-2 rivershore, 14 tubes along the 100-HR-3-D rivershore, 8 tubes along the 100-HR-3-H rivershore, 12 tubes along the 100-FR-3 rivershore, and 33 tubes along the 300-FF-5 rivershore. The aquifer tubes were installed to fill in gaps in shoreline monitoring.

During FY 2004, 51 vadose characterization boreholes (i.e., cone penetrometers and direct push probes) were installed (Table 5.1-3). Of these, 39 direct push probes were installed at the U Plant Area (200 West Area) for geophysical logging in the vadose zone around various waste sources (i.e., cribs). Five cone penetrometers boreholes were installed for characterization around the A-8 crib located in the 200 East Area. Five cone penetrometers boreholes were also installed for BC Cribs plume characterization south of 200 East Area. Two characterization boreholes, one drilled by cable tool and one constructed by cone penetrometer were also installed in the single-shell tank farms. All vadose characterization boreholes will be decommissioned after data acquisition activities are completed. Chapter 3 provides more details about vadose characterization studies conducted during FY 2004.

5.2 Well Maintenance

Maintenance of groundwater wells is performed to meet regulatory requirements (e.g., Ecology 1994a, Condition II.F.2) as part of a scheduled preventive maintenance cycle (routine) or in response to problems identified in the field (non-routine). During FY 2004, routine maintenance was performed at 67 wells and non-routine maintenance at 278 wells. A summary of maintenance activities by regulatory program is presented in Table 5.2-1.

Routine maintenance is planned based on a 5-year cycle to support groundwater sampling and to minimize non-routine maintenance activities. At a minimum, routine maintenance includes the following tasks:

- Removing groundwater sampling pump systems or aquifer-testing equipment.
- Inspecting and repairing or replacing sampling pump systems or aquifer-testing equipment.
- Brushing or cleaning of well casing perforations or well screens.
- Removing debris and fill material.
- Developing the well.
- Performing borehole video camera survey.
- Re-installing sampling pumps and/or aquifer-testing instrumentation/equipment.
- Documenting well conditions and maintenance activities.

Non-routine maintenance tasks are varied and depend on the specific problem encountered at a well; these tasks include both surface and subsurface tasks. Surface tasks include conducting field inspections, well labeling, maintenance and replacement of locking well caps, casing repairs, diagnosis and repair of surface electrical, and pump-discharge fitting. Subsurface tasks include repairing and replacing sampling pumps, performing camera surveys, pump and equipment retrieval, and tubing replacement.

Well maintenance activities include casing repairs, repairing and replacing sampling pumps, pump and equipment retrieval, and tubing replacement.

5.3 Well Decommissioning

A well becomes a candidate for decommissioning (1) if its use has been permanently discontinued (i.e., it has gone dry); (2) if its condition is so poor that its continued use is impractical; (3) if it is in the path of intended remediation/excavation/construction activities; or (4) it poses an environmental, safety, or public health hazard. At this time, decommissioning is generally driven by the long-range environmental restoration schedule (DOE/RL-96-105), available funding, and provisions of WAC 173-160.

Approximately 6,277 wells have been identified within the Hanford Site. To date, 1,379 of these wells have been decommissioned (~22% of the total wells). During FY 2004, 1,253 wells were in use and 98 wells were decommissioned (Table 5.3-1). The location of wells decommissioned is shown on Figure 5.3-1. In 2003, it was discovered that two relatively new RCRA monitoring wells (299-E24-19 and 299-E25-46) in the single-shell tanks Waste Management Area A-AX, failed due to rapid corrosion of the stainless steel casing at the same relative interval within each well. DOE funded an investigation to determine what causes the rapid corrosion (see Section 3.3.1). Prior to decommissioning these two wells, sidewall core samples of the corroded interval in each well were collected. In addition, archived, lithology/depth equivalent sediment samples from nearby wells were collected. These samples, along with a sample of bentonite well seal material and perched water, collected from a lithologically equivalent interval in a nearby well (299-E24-33), were analyzed and evaluated to determine the cause of this corrosion. Details about this casing corrosion investigation are provided in Section 3.3.1.

Wells are filled with grout if they are in poor condition, interfere with surface construction activities, or are no longer used.

Decommissioning activities result in the permanent removal of a well, borehole, or piezometer from service and from the Hanford Site active well inventory. Decommissioning is performed in accordance with Ecology standards (WAC 173-160), applicable variances, and conditions defined in the Hanford Facility RCRA Permit (Ecology 1994a, Condition II.F.2). Decommissioning involves backfilling a well with impermeable material to prevent vertical movement of water and/or contaminants. For resource protection wells, decommissioning typically is performed by placing sand across the screen interval and filling the casing with an impermeable material (e.g., bentonite or cement grout). For older, non-compliant wells, the casing(s) is perforated and pressure grouted. The sealing of the annular space between the casing(s) and formation is intended to minimize the creation of preferential pathways. Where possible, the casing is removed and a brass survey marker identifying the well is set in grout at the surface and over the well location. If the casing cannot be removed, the casing is generally cut ~1 meter below ground surface and the identifying brass survey marker is set in the grout below land surface; the hole is then backfilled to grade.

Table 5.1-1. Well Installations for Calendar Year 2004

Well Name	Well ID	Program	Facility
199-D5-92	C4583	CERCLA	100-HR-3 OU/River
199-D8-73	C4474	CERCLA	100-HR-3 OU/River
199-D8-88	C4536	CERCLA	100-HR-3 OU/River
199-K-131	C4561	CERCLA	100-KR-4 OU/River
199-K-132	C4670	CERCLA	100-KR-4 OU/River
199-N-119	C4471	N-Barrier	100-NR-2 OU
199-N-120	C4472	N-Barrier	100-NR-2 OU
199-N-121	C4473	N-Barrier	100-NR-2 OU
299-E24-33	C4257	RCRA ORP	SST WMA A-AX
299-E25-94	C4665	RCRA RL	SST WMA A-AX
299-E33-47	C4259	RCRA ORP	SST WMA B-BX-BY
299-E33-48	C4260	RCRA ORP	SST WMA B-BX-BY
299-E33-49	C4261	RCRA ORP	SST WMA B-BX-BY
299-W13-1	C4238	CERCLA	200-ZP-1 OU
299-W15-47	C4184	CERCLA	200-ZP-1 OU
299-W15-49	C4301	CERCLA	200-ZP-1 OU
299-W18-16	C4303	CERCLA	200-ZP-1 OU
299-W19-47	C4258	RCRA ORP	SST WMA U
299-W19-48	C4300	CERCLA	200-UP-1 OU
299-W21-2	C4639	CERCLA	200-UP-1 OU
699-30-66	C4298	CERCLA	200-UP-1 OU
699-36-70B	C4299	CERCLA	200-UP-1 OU
699-38-70B	C4236	CERCLA	200-UP-1 OU
699-38-70C	C4256	CERCLA	200-UP-1 OU
699-40-65	C4235	CERCLA	200-UP-1 OU

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act.*
ORP = Office of River Protection.
OU = Operable Unit.
RCRA = *Resource Conservation and Recovery Act.*
RL = Richland Operations Office.
SST = Single-shell tank.
WMA = Waste management area.

Table 5.1-2. Aquifer Tubes Installed during FY 2004

Well ID (HEIS)	Tube Name (HEIS)	Shore Segment	Well ID (HEIS)	Tube Name (HEIS)	Shore Segment
C4376	AT-B-1-S	BC5	C4325	AT-H-3-D	HR3H
C4375	AT-B-1-M	BC5	C4391	AT-F-1-S	FR3
C4378	AT-B-2-S	BC5	C4390	AT-F-1-M	FR3
C4379	AT-B-2-M	BC5	C4389	AT-F-1-D	FR3
C4377	AT-B-2-D	BC5	C4394	AT-F-2-S	FR3
C4382	AT-B-3-S	BC5	C4393	AT-F-2-M	FR3
C4381	AT-B-3-M	BC5	C4392	AT-F-2-D	FR3
C4380	AT-B-3-D	BC5	C4385	AT-F-3-S	FR3
C4368	AT-B-4-S	BC5	C4384	AT-F-3-M	FR3
C4371	AT-B-7-S	BC5	C4383	AT-F-3-D	FR3
C4370	AT-B-7-M	BC5	C4388	AT-F-4-S	FR3
C4369	AT-B-7-D	BC5	C4387	AT-F-4-M	FR3
C4374	AT-B-5-S	BC5	C4386	AT-F-4-D	FR3
C4373	AT-B-5-M	BC5	C4347	AT-3-1-S	3FF5
C4372	AT-B-5-D	BC5	C4346	AT-3-1-M	3FF5
C4341	AT-K-1-S	KR4	C4345	AT-3-1-D(1)	3FF5
C4340	AT-K-1-M	KR4	C4348	AT-3-1-D(2)	3FF5
C4339	AT-K-1-D	KR4	C4350	AT-3-2-S	3FF5
C4329	AT-K-2-S	KR4	C4349	AT-3-2-M	3FF5
C4327	AT-K-2-M	KR4	C4353	AT-3-3-S	3FF5
C4328	AT-K-2-D	KR4	C4352	AT-3-3-M	3FF5
C4344	AT-K-3-S	KR4	C4351	AT-3-3-D	3FF5
C4343	AT-K-3-M	KR4	C4356	AT-3-4-S	3FF5
C4342	AT-K-3-D	KR4	C4355	AT-3-4-M	3FF5
C4338	AT-K-4-S	KR4	C4354	AT-3-4-D	3FF5
C4337	AT-K-4-M	KR4	C4358	AT-3-5-S	3FF5
C4336	AT-K-4-D	KR4	C4357	AT-3-5-M	3FF5
C4335	AT-K-5-S	KR4	C4361	AT-3-6-S	3FF5
C4331	AT-K-5-M	KR4	C4360	AT-3-6-M	3FF5
C4330	AT-K-5-D	KR4	C4359	AT-3-6-D	3FF5
C4333	AT-K-6-S	KR4	C4364	AT-3-7-S	3FF5
C4334	AT-K-6-M	KR4	C4363	AT-3-7-M	3FF5
C4332	AT-K-6-D	KR4	C4362	AT-3-7-D	3FF5
C4307	AT-D-1-S	HR3D	C4367	AT-3-8-S	3FF5
C4305	AT-D-1-D	HR3D	C4366	AT-3-8-M	3FF5
C4306	AT-D-1-M	HR3D	C4365	AT-3-8-D	3FF5
C4314	AT-D-4-S	HR3D	C4585	NS-2A-23cm	NR2
C4315	AT-D-4-M	HR3D	C4586	NS-2A-87cm	NR2
C4316	AT-D-4-D	HR3D	C4587	NS-2A-168cm	NR2
C4310	AT-D-2-S	HR3D	C4588	NS-3A-10cm	NR2
C4309	AT-D-2-M	HR3D	C4589	NS-3A-176cm	NR2
C4308	AT-D-2-D	HR3D	C4590	NS-3A-87cm	NR2
C4313	AT-D-3-S	HR3D	C4640	NS-4A-17cm	NR2
C4312	AT-D-3-M	HR3D	C4641	NS-4A-138cm	NR2
C4311	AT-D-3-D	HR3D	C4642	300SPR9A-19cm	3FF5
C4318	AT-D-5-M	HR3D	C4643	300SPR9A-86cm	3FF5
C4317	AT-D-5-D	HR3D	C4644	300SPR9A-142cm	3FF5
C4321	AT-H-1-S	HR3H	C4741	300-3-3C-409cm	3FF5
C4320	AT-H-1-M	HR3H	C4742	300-3-3C-589cm	3FF5
C4319	AT-H-1-D	HR3H	C4646	300-3-3B-376cm	3FF5
C4324	AT-H-2-S	HR3H	C4740	300-3-3B-518cm	3FF5
C4323	AT-H-2-M	HR3H	C4690	300-3-3A-124cm	3FF5
C4322	AT-H-2-D	HR3H	C4645	300-3-3A-410cm	3FF5
C4326	AT-H-3-S	HR3H	C4739	300-3-3A-579cm	3FF5

HEIS = Hanford Environmental Information System (database).
ID = Identification number.

Table 5.1-3. Characterization Boreholes, Soil-Gas Probes, and GeoProbe/Push Installations for FY 2004

ID	Program	Facility	Location
C4540	CERCLA/A-8 Crib	200-PO-1 OU	200 East Area
C4541	CERCLA/A-8 Crib	200-PO-1 OU	200 East Area
C4542	CERCLA/A-8 Crib	200-PO-1 OU	200 East Area
C4543	CERCLA/A-8 Crib	200-PO-1 OU	200 East Area
C4544	CERCLA/A-8 Crib	200-PO-1 OU	200 East Area
C4673	CERCLA/BC-Cribs	200-PO-1 OU	200 East Area
C4674	CERCLA/BC-Cribs	200-PO-1 OU	200 East Area
C4675	CERCLA/BC-Cribs	200-PO-1 OU	200 East Area
C4676	CERCLA/BC-Cribs	200-PO-1 OU	200 East Area
C4677	CERCLA/BC-Cribs	200-PO-1 OU	200 East Area
C4201	CERCLA	200-UP-1 OU	200 West Area
C4202	CERCLA	200-UP-1 OU	200 West Area
C4203	CERCLA	200-UP-1 OU	200 West Area
C4204	CERCLA	200-UP-1 OU	200 West Area
C4205	CERCLA	200-UP-1 OU	200 West Area
C4206	CERCLA	200-UP-1 OU	200 West Area
C4207	CERCLA	200-UP-1 OU	200 West Area
C4208	CERCLA	200-UP-1 OU	200 West Area
C4209	CERCLA	200-UP-1 OU	200 West Area
C4210	CERCLA	200-UP-1 OU	200 West Area
C4211	CERCLA	200-UP-1 OU	200 West Area
C4212	CERCLA	200-UP-1 OU	200 West Area
C4213	CERCLA	200-UP-1 OU	200 West Area
C4215	CERCLA	200-UP-1 OU	200 West Area
C4217	CERCLA	200-UP-1 OU	200 West Area
C4218	CERCLA	200-UP-1 OU	200 West Area
C4219	CERCLA	200-UP-1 OU	200 West Area
C4220	CERCLA	200-UP-1 OU	200 West Area
C4221	CERCLA	200-UP-1 OU	200 West Area
C4222	CERCLA	200-UP-1 OU	200 West Area
C4223	CERCLA	200-UP-1 OU	200 West Area
C4224	CERCLA	200-UP-1 OU	200 West Area
C4225	CERCLA	200-UP-1 OU	200 West Area
C4226	CERCLA	200-UP-1 OU	200 West Area
C4227	CERCLA	200-UP-1 OU	200 West Area
C4228	CERCLA	200-UP-1 OU	200 West Area
C4229	CERCLA	200-UP-1 OU	200 West Area
C4231	CERCLA	200-UP-1 OU	200 West Area
C4232	CERCLA	200-UP-1 OU	200 West Area
C4547	CERCLA	200-UP-1 OU	200 West Area
C4548	CERCLA	200-UP-1 OU	200 West Area
C4549	CERCLA	200-UP-1 OU	200 West Area
C4550	CERCLA	200-UP-1 OU	200 West Area

Table 5.1-3. (contd)

ID	Program	Facility	Location
C4551	CERCLA	200-UP-1 OU	200 West Area
C4552	CERCLA	200-UP-1 OU	200 West Area
C4553	CERCLA	200-UP-1 OU	200 West Area
C4554	CERCLA	200-UP-1 OU	200 West Area
C4555	CERCLA	200-UP-1 OU	200 West Area
C4556	CERCLA	200-UP-1 OU	200 West Area
C4292	RCRA-ORP	SST WMA C	200 East Area
C4409	RCRA-ORP	SST WMA C	200 East Area
C4562(a)	RCRA-IDF	IDF	200 East Area
C4666(a)	RCRA-IDF	IDF	200 East Area

(a) Temporary wells.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act.*
IDF = Integrated Disposal Facility.
ORP = Office of River Protection.
OU = Operable unit.
RCRA = *Resource Conservation and Recovery Act.*
SST = Single-shell tank.
WMA = Waste management area.

Table 5.2-1. Well Maintenance Summary for FY 2004

Program	Routine	Non-Routine
CERCLA	41	109
RCRA	26	169
Total	**67**	**278**

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act.*
RCRA = *Resource Conservation and Recovery Act.*

Table 5.3-1. Wells Decommissioned during FY 2004

Well Name	HEIS Well ID	Well Name	HEIS Well ID
299-E24-19	A4754	299-W26-9	A4995
299-E25-30(a)	A6035	299-W6-5	A5000
299-E25-30P(a)	A4776	299-W6-8	A5003
299-E25-30Q(a)	A4777	699-10-30A	A8179
299-E25-46	A4793	699-11-29	A8215
299-E26-1	A4798	699-16-23	A8341
299-E33-11	A6854	699-16-30A	A8342
299-E34-11	A4876	699-17-26A	A8361
299-E34-3	A4878	699-17-26B(a)	A8362
299-E34-4	A4879	699-17-26BP(a)	A9592
299-E34-6	A4881	699-17-26BQ(a)	A9593
299-E35-1	A4885	699-17-26BR(a)	A9594
299-W10-18	A4895	699-18-27D	A8386
299-W10-9	A4900	699-18-28	A8396
299-W11-1	A7275	699-19-26A	A8407
299-W11-15	A7281	699-19-26B(a)	A8408
299-W11-16	A7282	699-19-26BP(a)	A9601
299-W11-17	A7283	699-19-26BQ(a)	A9602
299-W11-19	A4904	699-21-30B	A8440
299-W11-2	A7276	699-25-31	A8461
299-W11-21	A7286	699-25-33B(a)	A8462
299-W11-23	A4905	699-25-33BP(a)	A8463
299-W11-24	A4906	699-25-33BQ(a)	A9619
299-W11-27	A4907	699-26-35D(a)	A8472
299-W11-2P(a)	A9463	699-26-35DP(a)	A9625
299-W11-2Q(a)	A9464	699-26-35DQ(a)	A9626
299-W11-2R(a)	A9465	699-35-28	A8555
299-W11-2S(a)	A9466	699-37-82B(a)	A8580
299-W11-2T(a)	A9467	699-37-82BP(a)	A9680
299-W11-35(a)	A9924	699-37-82BQ(a)	A9681
299-W11-35P(a)	B2406	699-37-82BR(a)	A9682
299-W11-35Q(a)	B2405	699-37-82BS(a)	A9683
299-W11-4	A7277	699-42-41	A5170
299-W11-5	A7278	699-43-43	A5179
299-W11-8	A7279	699-47-46A	A5200
299-W11-9	A4911	699-52-46B	A8841
299-W14-12	A4914	699-52-54	A5236
299-W15-12	A4917	699-53-48B	A5242
299-W15-18	A4922	699-55-50A(a)	A8865
299-W15-22	A4925	699-55-50AP(a)	A9738
299-W18-25	A4937	699-55-50AQ(a)	A9739
299-W18-251	A7731	699-55-50D	A8867
299-W18-4	A7522	699-56-51	A8891
299-W22-39	A4970	199-N-25	A4674
299-W22-41	A4972	199-N-12	A5824
299-W22-42	A4973	199-N-13	A5825
299-W23-13	A4982	199-N-22	A5827
299-W26-10	A4992	C3658	C3658
299-W26-3	A5444	C4584	C4584

(a) Piezometer wells with same well name but with suffix of one or more letters are all within a single large diameter casing.

HEIS = Hanford Environmental Information System.

ID = Identification.

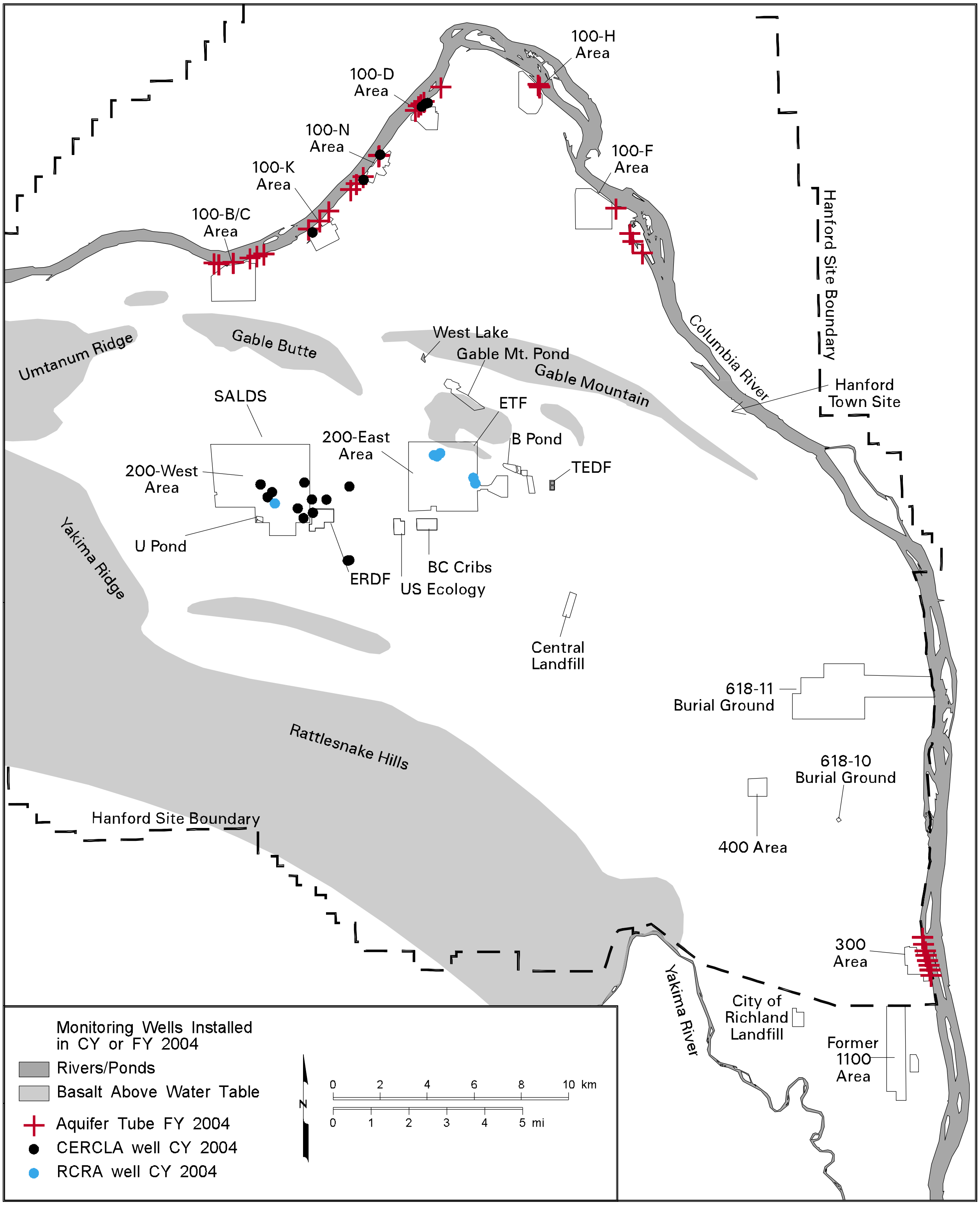

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Figure 5.1-1. Groundwater Monitoring Wells and Aquifer Tubes Installed in Calendar Year 2004

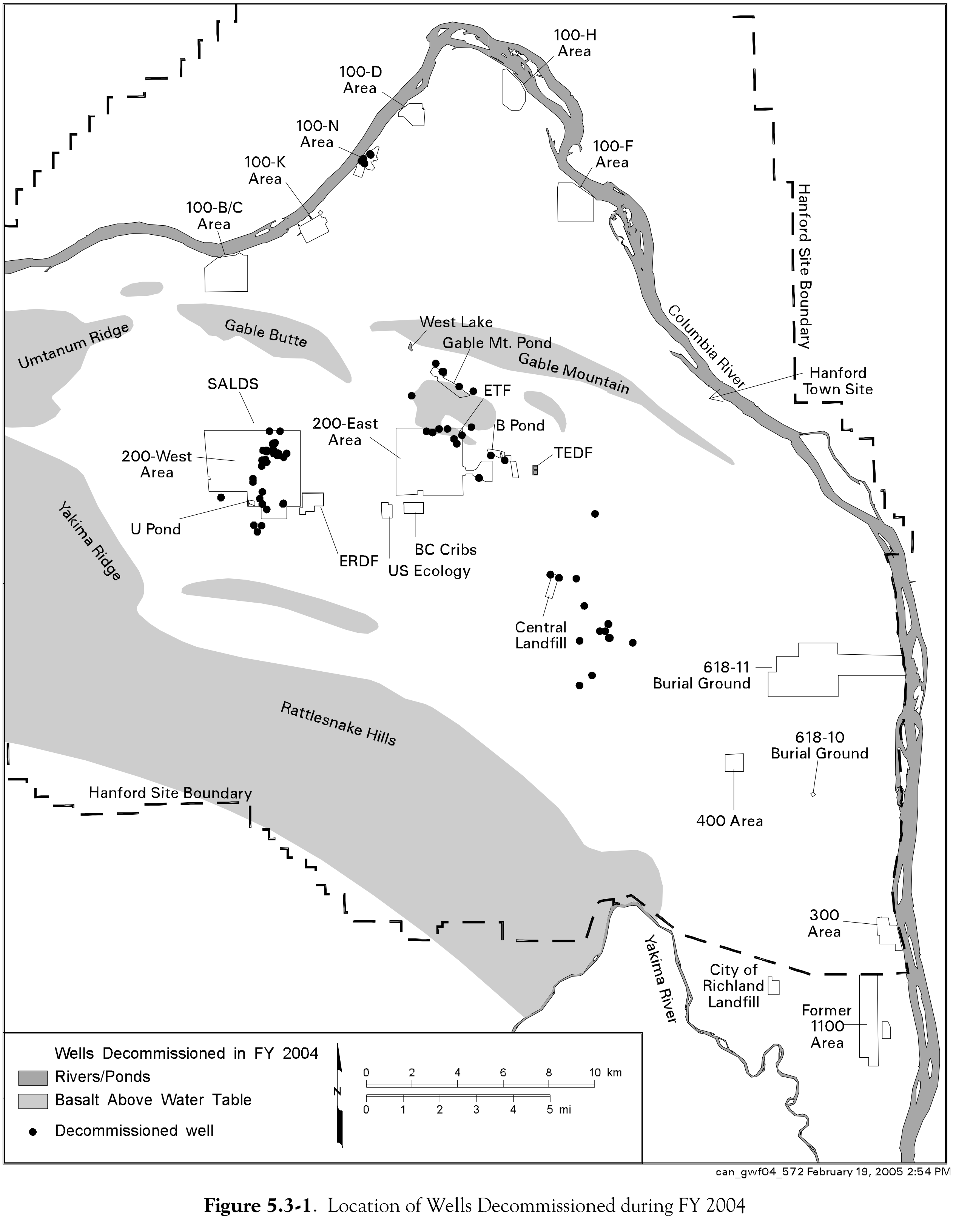

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Figure 5.3-1. Location of Wells Decommissioned during FY 2004

6.0 References

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Appendix A

Supporting Information for CERCLA Groundwater Operable Units

Contents

Tables

Figure

Appendix A

Supporting Information for CERCLA Groundwater Operable Units

The groundwater and vadose zone beneath contaminated portions of the Hanford Site are divided into 11 groundwater operable units. Figure A.1 shows the locations of these units and related groundwater interest areas on the Hanford Site. The groundwater project defined the interest areas informally to aid in planning, scheduling, and data interpretation.

Tables A.1 through A.16 list the constituents, monitoring wells, and the frequency of sampling for each operable units required by sampling and analysis plans or other documentation. The tables also indicate whether the wells were sampled as scheduled during fiscal year 2004.

In many cases, wells are sampled for additional constituents not strictly required by the plans. Those constituents are not listed in the tables of this appendix, but data files accompanying this report include all required and supplemental data.

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Table A.1. Monitoring Wells and Constituents for the 100-BC-5 Operable Unit (adapted from DOE/RL-2003-38)

Well	Alkalinity	Alpha	Anions	Beta	Hex Cr	Metals	Sr-90	Tritium	Sampled as Scheduled in FY 2004
199-B2-12	A	BO	A	BO		A	BO	A	Yes
199-B2-13	A	BE	A	BE		A	BE	A	No alpha, beta, Sr-90 (scheduling error)
199-B3-1	A		A		A		A	A	Yes
199-B3-46					A		A	A	No; preparatory work for multi-depth sampling delayed
199-B3-47	A	A	A	A	A		A	A	No; preparatory work for multi-depth sampling delayed
199-B4-1		BE		BE			BE	BE	Yes
199-B4-4		BE		BE			BE	BE	Yes
199-B4-5		BO		BO			BO	BO	Not scheduled
199-B4-6		BE		BE			BE	BE	Yes
199-B4-7		BO		BO			BO	BO	Not scheduled
199-B4-8	A	A	A	A		A	BE	A	No Sr-90 (scheduling error)
199-B5-1		A		A			BE	A	No Sr-90 (scheduling error)
199-B5-2		A		A	A		BO	A	Yes
199-B8-6		BO		BO			BO	BO	Not scheduled
199-B9-2		BE		BE			BE	BE	Yes
199-B9-3		BO		BO			BO	BO	Not scheduled
699-63-90		A		A				A	Yes
699-65-72	A		A			A		A	Yes
699-65-83								BE	Yes
699-66-103								BE	Yes
699-67-86								BO	Not scheduled
699-68-105								BO	Not scheduled
699-71-77								BO	Not scheduled
699-72-73			A					A	Yes
699-72-92			A					BO	Yes
AT-01					A		BE	A	Yes
AT-03					A		BE	A	Yes
AT-04					A		BE	A	Yes
AT-05					A		BE	A	Yes
AT-06					A		BE	A	Yes
AT-07					A		BE	A	Yes
AT-B-1					A		BE	A	No Sr-90 or tritium (scheduling error)
AT-B-2					A		BE	A	No Sr-90 (scheduling error)
AT-B-3					A		BE	A	Yes
AT-B-4					A		BE	A	Yes
AT-B-5					A		BE	A	Yes
AT-B-7					A		BE	A	Yes
Seep 037-1		A		A	A		BE	A	Total chromium instead of hexavalent
Seep 039-2		A		A	A		BE	A	Total chromium instead of hexavalent

A = Annual.
BE = Biennial, even fiscal year (e.g., (FY 2004).
BO = Biennial, odd fiscal year.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
Sr-90 = Strontium-90.

Table A.2. Monitoring Wells and Constituents for 100-KR-4 Pump-and-Treat System[(a)]

Well	Hex Cr	Sr-90	Tritium	Sampled as Scheduled in FY 2004
199-K-114A	M	A	A	Missed December[(b)] and March (pump problem)
199-K-117A	M	A	A	Missed December[(b)]
199-K-130	M	A	A	Missed December[(b)]
199-K-18	M	A	A	Missed December[(b)]
199-K-19	SA			Yes
199-K-20	M	A	A	Missed December[(b)]
199-K-21	SA			Yes (total, filtered chromium)
199-K-22	SA			Yes
199-K-37	SA			Yes

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004* , dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

(b) Sampling behind schedule; cancelled December event.

A = Annual.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
M = Monthly.
SA = Semiannual.
Sr-90 = Strontium-90.

Table A.3. Monitoring Wells and Constituents for 100-KR-4 Operable Unit Long-Term Monitoring(a)

Well	Alpha	Anions	Beta	C-14	Gamma	Hex Cr	Metals	Mercury	Sr-90	Tritium	Sampled as Scheduled in FY 2004
199-K-106A	BE	BE	BE		BE		BE			BE	Yes
199-K-107A	A	A	A		A	Q	A			A	Yes(b)
199-K-108A	A	A	A	A	A	Q	A			A	Yes(b)
199-K-109A	A	A	A		A		A		Q	A	Yes
199-K-11	BO	BO	BO		BO		BO			BO	Not scheduled
199-K-110A	BE	BE	BE		BE		BE			BE	Yes
199-K-111A	A	A	A	A	A		A			A	Yes
199-K-18	A	A	A		A		A			A	Yes
199-K-19	A	A	A		A		A			A	Yes
199-K-20	A	A	A		A		A			A	Yes
199-K-21	A	A	A		A		A			A	Yes
199-K-22	A	A	A		A		A			A	Yes
199-K-23	BO	BO	BO		BO		BO			BO	Not scheduled
199-K-27	BE	BE	BE		BE		BE		Q	BE	Yes
199-K-30	BO	BO	BO		BO		BO		Q	BO	Yes
199-K-31	A	A	A		A		A			A	Yes
199-K-32A	A	A	A	A	A		A			A	Yes
199-K-32B	A	A	A		A		A			A	Yes
199-K-34	BO	BO	BO		BO		BO			BO	Not scheduled
199-K-35	BO	BO	BO		BO		BO			BO	Not scheduled
199-K-36	A	A	A		A	Q	A	A		A	Yes(b)
199-K-37	A	A	A		A		A			A	Yes
699-70-68	BE	BE	BE		BE		BE			BE	Yes
699-73-61	BE	BE	BE		BE		BE			BE	Yes
699-78-62	BE	BE	BE		BE		BE			BE	Yes
SK-057-3	A	A	A		A		A			A	Yes
SK-077-1	A	A	A		A		A			A	Yes
SK-082-2	A	A	A		A		A			A	No

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004*, dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

(b) For quarterly wells, samples from one quarter (October 2003) were not analyzed specifically for hexavalent chromium because they were analyzed for filtered, total chromium under the ICP method.

A = Annual.
BE = Biennial, even fiscal year (e.g., FY 2004).
BO = Biennial, odd fiscal year.
C-14 = Carbon-14.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
ICP = Inductively coupled plasma.
Q = Quarterly.
Sr-90 = Strontium-90.

Table A.4. Monitoring Wells and Constituents for 100-NR-2 Interim Action[(a)]

Well	Alpha	Anions	Beta	Gamma	ICP	Oil/Grease	Sr-90	TPH	Tritium	Sampled as Scheduled in FY 2004
199-N-14		SA	SA		SA		SA		SA	Yes
199-N-16		A	A		A	A	A	A		Yes
199-N-18						A		A		Yes
199-N-2		A	A		A		A		A	Yes
199-N-21		A			A					Yes
199-N-27	A	A		A	A				A	Yes
199-N-3		SA	SA		SA		SA		SA	Yes
199-N-32		SA	SA	SA	SA		SA		SA	Yes
199-N-50			A						A	Yes
199-N-51			A						A	Yes
199-N-64		A	A		A		A		A	Yes
199-N-67	SA	SA	SA		SA		SA			Yes
199-N-70	A	A	A	A	A		A		A	Yes
199-N-74	A		A	A	A					Yes
199-N-75		SA	SA		SA		SA		SA	Yes
199-N-76		SA	SA	SA	SA		SA		SA	Yes
199-N-80	A	A	A	A	A		A		A	Yes
199-N-81		A	A		A		A		A	Yes
199-N-92A		A	A		A		A		A	Yes
199-N-96A		A	A		A		A		A	Yes
199-N-99A		A	A		A		A		A	Yes

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fruchter (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004* , dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

A = Annual.
FY = Fiscal year.
ICP = Inductively coupled plasma.
SA = Semiannual.
Sr-90 = Strontium-90.
TPH = Total petroleum hydrocarbons.

Table A.5. Monitoring Wells and Constituents for 100-NR-2 Baseline Monitoring

Well	Alkalinity	Alpha	Anions	Beta	DO	Gamma	Metals	Sr-90	Tritium	Sampled as Scheduled in FY 2004
199-N-46	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-67	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-92A	A	A	A	A	A	A	A	A	A	Yes
199-N-96A	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-99A	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-119	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-120	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
199-N-121	Q	Q	Q	M	M	Q	Q	Q	Q	Yes
NS-2A-23cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-2A-87cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-2A-168cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-3A-10cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-3A-87cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-3A-176cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-4A-17cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-4A-138cm	Q	Q	Q	M	M	Q	Q	Q	Q	Scheduling error; missed July
NS-2	Q	Q	Q	M	M	Q	Q	Q	Q	Access issues
NS-3	Q	Q	Q	M	M	Q	Q	Q	Q	Access issues
NS-4	Q	Q	Q	M	M	Q	Q	Q	Q	Access issues

Sampling initiated June 2004.

A = Annual.
DO = Dissolved oxygen.
FY = Fiscal year.
M = Monthly.
Q = Quarterly.
Sr-90 = Strontium-90.

Table A.6. Monitoring Wells and Constituents for 100-HR-3 Operable Unit In Situ Redox System (100-D Area)[(a)]

Well Name	Anions	Arsenic	DO	Hex Cr	Metals	Sulfate	Uranium	Sampled as Scheduled in FY 2004
199-D2-6	A	A	Q	Q	A	Q	A	Yes
199-D3-2	A	A	Q	Q	A	Q	A	Yes
199-D4-1	A	A	Q	Q	A	Q	A	Yes
199-D4-15	A	A	M	M	A	M	A	Missed June; scheduling error
199-D4-20	A	A	Q	Q	A	Q	A	Yes
199-D4-22	A	A	Q	Q	A	Q	A	Yes
199-D4-23	A	A	Q	Q	A	Q	A	Yes
199-D4-26	A	A	Q	Q	A	Q	A	Yes
199-D4-31	A	A	Q	Q	A	Q	A	Yes
199-D4-32	A	A	Q	Q	A	Q	A	Yes
199-D4-36	A	A	Q	Q	A	Q	A	Yes
199-D4-38	A	A	Q	Q	A	Q	A	Yes
199-D4-39	A	A	Q	Q	A	Q	A	Yes
199-D4-4	A	A	Q	Q	A	Q	A	Yes
199-D4-48	A	A	Q	Q	A	Q	A	Yes
199-D4-5	A	A	Q	Q	A	Q	A	Yes
199-D4-6	A	A	Q	Q	A	Q	A	Yes
199-D4-62	A	A	Q	Q	A	Q	A	Yes
199-D4-7	A	A	Q	Q	A	Q	A	Yes
199-D4-78	A	A	Q	Q	A	Q	A	Yes
199-D4-83	A	A	Q	Q	A	Q	A	Yes
199-D4-84	A	A	Q	Q	A	Q	A	Yes
199-D4-85	A	A	Q	Q	A	Q	A	Yes
199-D4-86	A	A	Q	Q	A	Q	A	Yes
199-D5-36	A	A	Q	Q	A	Q	A	Yes
199-D5-38	A	A	M	M	A	M	A	Yes
199-D5-39	A	A	M	M	A	M	A	Yes
199-D5-43	A	A	M	M	A	M	A	Yes

Note: For quarterly wells, samples from one quarter (November 2003) were not analyzed specifically for hexavalent chromium because they were analyzed for filtered, total chromium under the ICP method.

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004* , dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

A = Annual.
DO = Dissolved oxygen.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
ICP = Inductively coupled plasma.
M = Monthly.
Q = Quarterly.

Table A.7. Monitoring Wells and Constituents for 100-HR-3 Pump-and-Treat Systems (100-D and 100-H Areas)[(a)]

Well	Anions	Hex Cr	Sr-90	Tc-99	Tritium	Uranium	Sampled as Scheduled in FY 2004
199-D8-54B		SA					Yes
199-D8-69		M	A		A		Yes
199-D8-70		M	A		A		Yes
199-D8-71		SA					Yes
199-H4-10		SA					Yes
199-H4-12B		SA					Yes
199-H4-12C		SA					Yes
199-H4-13		SA					Yes
199-H4-14		SA					Yes
199-H4-15B		SA					Yes
199-H4-15CS		SA					Yes
199-H4-16		SA					Yes
199-H4-17		SA					Yes
199-H4-18		SA					Yes
199-H4-3		SA					Yes
199-H4-4	A	M	A	A	A	A	Yes
199-H4-45		SA					No; contaminated wasp nests
199-H4-46		SA					Yes
199-H4-48		SA					Yes
199-H4-49		SA					Yes
199-H4-5	A	M	A	A	A	A	Yes
199-H4-6		SA					Yes
199-H4-63	A	M	A	A	A	A	Yes
199-H4-64	A	M	A	A	A	A	Yes
199-H4-8		SA					Yes
199-H5-1A		SA					Yes

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fruchter (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004* , dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

A = Annual.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
M = Monthly.
SA = Semiannual.
Sr-90 = Strontium-90.
Tc-99 = Technetium-99.

Table A.8. Monitoring Wells and Constituents for 100-HR-3 Operable Unit Long-Term Monitoring (100-D and 100-H Area)(a)

Well	Alpha	Anions	Beta	Hex Cr	Metals	Tritium	Sampled as Scheduled in FY 2004
199-D2-6	A	Q	A	Q	A	A	Yes(b)
199-D3-2	A	Q	A	Q	A	A	Yes(b)
199-D4-13	A	Q	A	Q	A	A	Yes(b)
199-D4-14	A	Q	A	Q	A	A	Yes(b)
199-D4-15	A	M	A	M	A	A	Missed July; pump problem
199-D4-19	A	Q	A	Q	A	A	Yes(b)
199-D4-20	A	Q	A	Q	A	A	Yes(b)
199-D4-22	A	Q	A	Q	A	A	Yes(b)
199-D4-23	A	Q	A	Q	A	A	Yes(b)
199-D5-13	A	A	A	Q	A	A	Yes(b)
199-D5-14	A	A	A	Q	A	A	Yes(b)
199-D5-15	A	A	A	Q	A	A	Yes(b)
199-D5-16	A	A	A	Q	A	A	Yes(b)
199-D5-17	A	A	A		A	A	Yes(b)
199-D5-18	BO	BO	BO		BO	BO	Not scheduled
199-D5-19	BE	BE	BE		BE	BE	Yes
199-D5-20	A	A	A	Q	A	A	Converted to extraction well
199-D5-32				6(c)			Converted to extraction well
199-D5-33				6(c)			No
199-D5-34				6(c)			No
199-D5-36	A	Q	A	Q	A	A	Yes(b)
199-D5-37	A	Q	A	Q	A	A	Converted to extraction well
199-D5-38	A	M	A	M	A	A	Yes
199-D5-39	A	M	A	M	A	A	Yes
199-D5-40	A	Q	A	Q	A	A	Yes(b)
199-D5-41	A	Q	A	Q	A	A	Yes(b)
199-D5-42	A	Q	A	Q	A	A	Converted to injection well
199-D5-43	A	M	A	M	A	A	Yes
199-D5-44	A	Q	A	Q	A	A	Yes(b)
199-D8-4	A	A	A		A	A	Yes
199-D8-5	A	A	A		A	A	Yes
199-D8-54B	A	A	A		A	A	Yes
199-D8-55	A	A	A	Q	A	A	Yes(b)
199-H3-2A	A	A	A		A	A	Yes
199-H3-2C	BE	BE	BE		BE	BE	Yes
199-H4-10	A	A	A		A	A	Yes
199-H4-12C	A	A	A		A	A	Yes
199-H4-13	A	A	A		A	A	Yes
199-H4-14	BO	BO	BO		BO	BO	Not scheduled
199-H4-16	BO	BO	BO		BO	BO	Not scheduled
199-H4-17	BO	BO	BO		BO	BO	Not scheduled
199-H4-18	A	A	A		A	A	Yes
199-H4-3	A	A	A		A	A	Yes
199-H4-4	A	A	A		A	A	Yes
199-H4-45	A	A	A		A	A	No; contaminated wasp nests
199-H4-46	BO	BO	BO		BO	BO	Not scheduled
199-H4-47	BE	BE	BE		BE	BE	Yes
199-H4-48	BE	BE	BE		BE	BE	Yes

Table A.8. (contd)

Well	Alpha	Anions	Beta	Hex Cr	Metals	Tritium	Sampled as Scheduled in FY 2004
199-H4-49	BE	BE	BE		BE	BE	Yes
199-H4-5	A	A	A		A	A	Yes
199-H4-6	BO	BO	BO		BO	BO	Not scheduled
199-H4-63	A	A	A		A	A	Yes
199-H4-64	A	A	A		A	A	Yes
199-H4-8	BO	BO	BO		BO	BO	Not scheduled
199-H4-9	BE	BE	BE		BE	BE	Yes
199-H5-1A	BE	BE	BE		BE	BE	Yes
199-H6-1	A	A	A		A	A	Yes
699-91-46A	BE	BE	BE		BE	BE	Yes
699-93-48A	BE	BE	BE		BE	BE	Yes
699-96-43	BO	BO	BO		BO	BO	Not scheduled
699-96-49	BO	BO	BO		BO	BO	Not scheduled
699-97-43	BE	BE	BE		BE	BE	Yes
699-97-51A	A	A	A		A	A	Yes
SD-102-1	A	A	A		A	A	Yes
SD-110-1	A	A	A		A	A	Yes
SD-110-2	A	A	A		A	A	Yes
SD-98-1	A	A	A		A	A	Yes
SH-144-1	A	A	A		A	A	Yes
SH-145-1	A	A	A		A	A	Yes
SH-150-1	A	A	A		A	A	Yes
SH-152-2	A	A	A		A	A	No; under water
SH-153-1	A	A	A		A	A	Yes

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004, dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

(b) For quarterly wells, samples from one quarter (November 2003) were not analyzed specifically for hexavalent chromium because they were analyzed for filtered, total chromium under the ICP method.

(c) Letter of instruction specified sampling monthly from November through February, then quarterly for a total of six samples. Well 199-D5-33 was sampled March, May, and August; well 199-D5-34 was sampled January, February, May, and September.

A = Annual.
BE = Biennial, even fiscal year (e.g., FY 2004).
BO = Biennial, odd fiscal year.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
ICP = Inductively coupled plasma.
M = Monthly.
Q = Quarterly.

Table A.9. Monitoring Wells and Constituents for the 100-FR-3 Operable Unit (adapted from DOE/RL-2003-49)

Well	Alkalinity	Alpha	Anions	Hex Cr	Metals	Sr-90	Tritium	TCE (VOA)	Sampled as Scheduled in FY 2004
199-F1-2	BO		BO		BO				Not scheduled
199-F5-1	A	BE	A		A	BE	A		Yes
199-F5-3	A	BE	A			A	A		Removed from network
199-F5-4	A	BO	A		A		A	BO	Yes
199-F5-42	BO	BO	BO		BO	BO	BO		Not scheduled
199-F5-43A	BE	BE	BE		BE	BE	BE		Yes
199-F5-43B	BO	BO	BO		BO	BO	BO		Not scheduled
199-F5-44	BE	BE	BE		BE	BE	BE		Yes
199-F5-45	BO	BO	BO		BO	BO	BO		Not scheduled
199-F5-46	BE	BE	BE	BE	BE	BE	A		Yes
199-F5-47	A	BE	A		A		A	BE	Yes
199-F5-48	BO	BO	BO		BO		BO		Not scheduled
199-F5-6	BE	BE	BE		BE	BE	BE		Yes
199-F6-1	BO	BO	BO		BO	BO	BO		Not scheduled
199-F7-1	BE		BE		BE		BE	BE	Yes
199-F7-2	BE		BE		BE		BE		Yes
199-F7-3	BE	BE	BE		BE		BE	BE	Yes
199-F8-2	BO	BO	BO		BO		BO		Not scheduled
199-F8-3	BO	A	BO		BO		A	BO	Yes
199-F8-4	BE	A	BE		BE		BE		Yes
699-58-24	BE		BE		BE				Yes
699-60-32	BO		BO		BO				Not scheduled
699-61-37	BE		BE		BE				Yes
699-62-31	BE		BE		BE				Yes
699-62-43F	A		A				A		Yes
699-63-25A	BO		BO		BO				Not scheduled
699-63-55	BO		BO		BO		A		Not scheduled
699-64-27	BE		BE		BE				Yes
699-65-50	BO		BO		BO		BO		Not scheduled
699-66-23	BE		BE		BE				Yes
699-67-51	BO		BO		BO		BO		Not scheduled
699-69-45	BO		BO		BO			BO	Not scheduled
699-71-30	BO		BO		BO				Yes
699-71-52	BE		BE		BE			BE	Yes
699-74-44	BO		BO		BO			BO	Not scheduled
699-77-36	A		A		A			A	Yes
699-77-54	BO		BO		BO			BO	Not scheduled
699-83-47	BE		BE		BE			BE	Yes
699-84-35A	BE		BE		BE				Yes
AT-62	A		A	A	A			A	Yes
AT-63	A		A	A	A			A	No water
AT-64	A		A	A	A	A		A	Yes
AT-65	A		A	A	A	A		A	Yes
AT-66	A		A	A	A	A		A	Yes
AT-67	A		A	A	A			A	Yes
AT-68	A		A	A	A		A	A	Yes
AT-69	A		A	A	A		A	A	No; tube destroyed
AT-70	A		A	A	A		A	A	No; tube destroyed
AT-71	A		A	A	A		A	A	No; tube destroyed
AT-72	A		A	A	A		A	A	Yes
AT-73	A		A	A	A		A	A	No; tube under water
AT-74	A		A	A	A		A	A	Yes
AT-75	A		A	A	A			A	Yes
AT-76	A		A	A	A			A	Yes
AT-77	A		A	A	A			A	No; tube under water
AT-78	A		A	A	A			A	No; tube under water

Table A.9. (contd)

Well	Alkalinity	Alpha	Anions	Hex Cr	Metals	Sr-90	Tritium	TCE (VOA)	Sampled as Scheduled in FY 2004
AT-80	A		A	A	A			A	Yes
AT-F-1	A		A	A	A	A		A	Yes
AT-F-2	A		A	A	A		A	A	Yes
AT-F-3	A		A	A	A		A	A	Yes
AT-F-4	A		A	A	A		A	A	Yes
SF-187-1	A		A	A	A		A	A	No; conductivity too low
SF-190-4	A		A	A	A		A	A	No; conductivity too low
SF-207-1	A		A	A	A		A	A	No alkalinity

A = Annual.
BE = Biennial, even fiscal year (e.g., FY 2004).
BO = Biennial, odd fiscal year.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
Sr-90 = Strontium-90.
TCE = Trichloroethene.
VOA = Volatile organic analyses.

Table A.10. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit[(a)]

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Selenium	Phenols	Se-79	SVOA	Sr-90	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-W10-1		A	A						A										A		A	Yes
299-W10-13		BO																			BO	Not scheduled
299-W10-19		A							A												A	Dry
299-W10-20		BO																			BO	Yes
299-W10-21		A							A										A		A	Yes
299-W10-22		A						A	A								A		A	A	A	Yes
299-W10-23	Sup	A	A	Sup	Sup	Sup	Sup	A	A	Sup	Sup	Sup	Sup	Sup	Sup	Sup	A	Sup	A	A	A	No selenium
299-W10-4		SA	SA					SA	SA								SA		SA		SA	Yes
299-W10-5		A							A								A		A		A	Yes
299-W11-10		SA																			SA	Yes
299-W11-13		SA	SA					SA	SA								SA		SA		SA	Yes
299-W11-14	Sup	SA	Sup	Sup	Sup	Sup	Sup	SA	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	SA	SA	SA	No selenium
299-W11-18		A						A	A								A		A	A	A	Yes
299-W11-3		SA						SA											SA	SA	SA	Second sampling delayed until 11/2004
299-W11-37		SA						SA											SA	SA	SA	Yes
299-W11-6		SA						SA												SA	SA	Yes
299-W11-7		A	A					A	A								A			A	A	Yes
299-W12-1		A						A											A		A	Second sampling delayed until 10/2004
299-W14-14	Sup	A	Sup	Sup	Sup	Sup	Sup	A	A	Sup	Sup	Sup	Sup	Sup	Sup	Sup	A	Sup	A	Sup	A	No selenium
299-W14-16		A						A	A								A		A		A	Yes
299-W15-1		SA																			SA	Yes
299-W15-11		SA															SA		SA		SA	Yes
299-W15-15		A							A												A	Yes
299-W15-16		SA							SA								SA				SA	Sampled once, then dry
299-W15-17		SA							SA								SA				SA	Yes
299-W15-2		A															A				A	Yes
299-W15-30		SA							SA								SA				SA	Yes
299-W15-31A		SA															SA				SA	Yes
299-W15-34		A															A				A	Yes

Table A.10. (contd)

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Selenium	Phenols	Se-79	SVOA	Sr-90	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-W15-35	Sup	A	Sup	Sup	Sup	Sup	Sup	Sup	A	Sup	Sup	Sup	Sup	Sup	Sup	Sup	A	Sup	Sup	Sup	A	No selenium
299-W15-36		A																			A	Yes
299-W15-38		A							A												A	Yes
299-W15-39		SA																			SA	Yes
299-W15-40		SA							SA								SA		SA		SA	Yes
299-W15-41		SA							SA								SA		SA		SA	Missing 1 VOA
299-W15-42		SA							SA								SA				SA	Yes
299-W15-43		SA							SA								SA		SA		SA	Missing 1 metals
299-W15-44		SA						SA	SA								SA		SA		SA	Yes
299-W15-45		Q															Q				Q	Yes[(b)]
299-W15-47		Q															Q				Q	Yes[(b)]
299-W15-7		SA															SA				SA	Yes
299-W18-1		SA							SA												SA	Yes
299-W18-23		A															A			A	A	Yes
299-W18-27		A																		A	A	Dry
299-W6-10		A						A	A										A	A	A	Yes
299-W6-2		SA						SA	SA										SA		SA	Dry
299-W6-7		A						A	A										A		A	Dry
299-W7-12		BO																	BO		BO	Yes
299-W7-4	Sup	A	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	A	Several constituents missing
299-W7-7		A							A										A		A	Dry
299-W7-8		BO																	BO		BO	Not scheduled
299-W8-1		BE																	BE		BE	Yes
699-39-79		BO							BO												BO	Not scheduled
699-43-89		BO	BO					BO	BO							BO	BO		BO	BO	BO	Not scheduled
699-44-64		BO						BO									BO		BO	BO		Not scheduled
699-45-69A		BO						BO													BO	Not scheduled
699-47-60		BO						BO	BO								BO		BO	BO	BO	Not scheduled
699-48-71		BO						BO											BO	BO	BO	Not scheduled
699-48-77A	Sup	BO	Sup	Sup	Sup	Sup	Sup	Sup	BO	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	BO	Sup	BO	No selenium or phenols
699-55-60A		BO						BO	BO								BO		BO	BO	BO	Not scheduled

Table A.10. (contd)

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Selenium	Phenols	Se-79	SVOA	Sr-90	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
New Wells																						
299-W15-4A (new well C)		Q																			Q	Not completed in FY 2004
299-W18-16 (new well D)		Q																			Q	Not completed in FY 2004
299-W15-50 (new well E)		Q							Q												Q	Not completed in FY 2004
New well F	Sup	Q	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Q	Not yet installed
299-W13-1 (New well G)		Q																	Q		Q	Yes(b)
New well H																				Q	Q	Not yet installed
299-W17-1 (new well I)		Q															Q		Q		Q	Yes(b)

Sup = Supplemental analyses for additional constituents of concern. To be samled once in FY 2004 and once in FY 2006. If undetected, sampling will be discontinued. If detected, frequency to be determined.

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004, dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

(b) New wells began sampling part way through FY 2004.

A = Annual.
BE = Biennial, even fiscal year (e.g., FY 2004).
BO = Biennial, odd fiscal year.
C-14 = Carbon-14.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
I-129 = Iodine-129.
Q = Quarterly.
SA = Semiannual.
Se-79 = Selenium-79.
Sr-90 = Strontium-90.
SVOA = Semivolatile organic analyses.
Tc-99 = Technetium-99.
TPH = Total petroleum hydrocarbons.
VOA = Volatile organic analyses.

Table A.11. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit[(a)]

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Phenols	Se-79	SVOA	Sr-90	Sulfide	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-W15-37		A	A						A											A	A	Yes
299-W18-15		SA	SA																	SA	SA	Yes
299-W18-21		A	A														A			A	A	Yes
299-W18-22		A	A														A			A	A	Yes
299-W18-30		A	A					A												A	A	Yes
299-W18-33		A	A																A	A	A	Yes
299-W19-34A		A						A									A			A	A	Yes
299-W19-34B		BE						BE									BE			BE	BE	Yes
299-W19-35		SA						SA	SA								SA			SA	SA	Yes
299-W19-36		A						A									A			A	A	Yes
299-W19-37		SA						SA	SA								SA			SA	SA	Yes
299-W19-4		BO						BO									BO			BO	BO	Not scheduled
299-W19-40		A						A									A		A	A	A	Yes
299-W19-43	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Yes
299-W19-46	Sup	SA	Sup	Sup	Sup	Sup	Sup	SA	SA	Sup	Sup	Sup	Sup	Sup	Sup	Sup	SA	Sup	SA	SA	SA	Yes
299-W19-9		A	A					A									A			A	A	Yes
299-W22-20		A						A							A		A		A	A	A	Yes
299-W22-26		A						A	A										A	A	A	Yes
299-W22-45		A						A	A						A				A	A	A	Yes
299-W22-48		SA	SA					SA	SA						SA				SA	SA	SA	Yes
299-W22-49		SA						SA	SA						SA		SA		SA	SA	SA	Yes
299-W22-83	Sup	Q	Sup	Sup	Sup	Sup	Sup	Q	Q	Sup	Sup	Sup	Sup	Sup	Q	Sup	Q	Sup	Q	Q	Q	Yes
299-W22-9		BO						BO	BO						BO		BO		BO	BO	BO	Not scheduled
299-W23-10	Sup	SA	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	SA	Sup	SA	SA	SA	Yes
299-W23-15		SA															SA		SA	SA	SA	Yes

Table A.11. (contd)

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Phenols	Se-79	SVOA	Sr-90	Sulfide	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-W23-21	Sup	Q	Sup	Sup	Sup	Sup	Sup	Sup	Q	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Q	Sup	Q	Q	Q	Yes
299-W23-4	Sup	SA	SA	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	SA	SA	SA	Yes
299-W23-9		A															A		A	A	A	Yes
299-W26-13		BO						BO											BO	BO	BO	Not scheduled
299-W26-14		SA						SA	SA								SA		SA	SA	SA	Yes
699-32-62		BO						BO	BO										BO			Not scheduled
699-32-72A		BO						BO											BO		BO	Not scheduled
699-35-66A		BO						BO	BO										BO		BO	Not scheduled
699-35-70		BO						BO											BO		BO	Not scheduled
699-35-78A		A	A																	A	A	Yes
699-36-61A		BO						BO	BO										BO			Not scheduled
699-36-70A		A						A									A		A	A	A	Yes
699-38-65		A						A											A			Yes
699-38-68A		BO						BO									BO		BO	BO	BO	Not scheduled
699-38-70	Sup	A	Sup	Sup	Sup	Sup	Sup	A	Sup	Sup	Sup	Sup	Sup	Sup	Sup	Sup	A	Sup	A	A	A	Yes
699-40-62		BO						BO									BO		BO	BO	BO	Not scheduled
New Wells																						
699-W19-48 (new well K)		Q						Q									Q		Q	Q	Q	Not completed until FY 2005
New well L		Q															Q		Q	Q	Q	Not yet installed
New well M		Q						Q									Q		Q	Q	Q	Not yet installed
699-38-70C (new well N)		Q						Q									Q		Q	Q	Q	Yes[(b)]
699-38-70B (new well O)		Q						Q									Q			Q	Q	Yes[(b)]
699-36-70B (new well P)		Q						Q									Q		Q	Q	Q	Not completed until FY 2005

Table A.11. (contd)

Well	Ammonia	Anions	Arsenic	C-14	Cyanide	Gamma	Hex Cr	I-129	Metals	Mercury	Lead	Phenols	Se-79	SVOA	Sr-90	Sulfide	Tc-99	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-W21-2 (new well Q)		Q						Q									Q		Q	Q	Q	Not completed until FY 2005
699-30-66 (new well R)		Q						Q											Q	Q	Q	Not completed until FY 2005
699-40-65 (new well S)		Q						Q											Q			Yes$^{(b)}$

(a) Table based on requirements transmitted to the Groundwater Performance Assessment Project via letter, FH-0303686.1 from H Hermanas (Fluor Hanford, Inc.) to JS Fructher (Pacific Northwest National Laboratory), *Revision 1 to Tables Specifying Fluor Hanford Performance Sampling Requirements for Fiscal Year 2004*, dated February 24, 2004. See main text of this report for additional references for interim action monitoring requirements.

(b) Sampling new wells commenced part way through the year as they were completed.

Sup = Supplemental analyses for additional constituents of concern. To be samled once in FY 2004 and once in FY 2005. If undetected, frequency will reduce to every 5 years. If detected, frequency to be determined.

A = Annual.
BE = Biennial, even fiscal year (e.g., FY 2004).
BO = Biennial, odd fiscal year.
C-14 = Carbon-14.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
I-129 = Iodine-129.
Q = Quarterly.
SA = Semiannual.
Se-79 = Selenium-79.
Sr-90 = Strontium-90.
SVOA = Semivolatile organic analyses.
Tc-99 = Technetium-99.
TPH = Total petroleum hydrocarbons.
VOA = Volatile organic analyses.

Table A.12. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit (adapted from DOE/RL-2001-49)

Well Name	Anions	Cyanide	Gamma	I-129	Pu	Sr-90	Tc-99	Tritium	Uranium	Sampled in FY 2004
299-E27-14	A						A			Yes
299-E27-15	A						A			Yes
299-E27-7	A						A			Yes
299-E28-17	A		A		A	A			A	Yes
299-E28-18				A					A	Yes
299-E28-2			A	A	A	A	A	A		Yes
299-E28-21									A	Yes
299-E28-23			A		A	A			A	Yes
299-E28-24			A		A	A			A	Yes
299-E28-25			A		A	A			A	Yes
299-E28-26	A						A		A	Yes
299-E28-27	A		A	A	A	A	A		A	Yes
299-E28-5			A		A	A			A	Yes
299-E28-6			A		A	A			A	Yes
299-E28-8			A		A	A	A		A	Yes
299-E32-10		A	A				A		A	Yes
299-E32-4	A			A			A	A		Yes
299-E32-6	A						A			Yes
299-E32-9	A			A			A			Yes
299-E33-12							T			Yes
299-E33-13		A					A		A	Yes
299-E33-15	A						A			Yes
299-E33-16	A			A			A		A	Yes
299-E33-18				A			A		A	Yes
299-E33-26		A	A				A		A	Yes
299-E33-28	A						A			Yes
299-E33-30	A						A			Yes
299-E33-338							A		A	Yes
299-E33-34	A	A	A	A			A	A	A	Yes
299-E33-35	A	A					A		A	Yes
299-E33-38	A	A	A	A			A		A	Yes
299-E33-39	A			A			A	A		Yes
299-E33-41							A		A	Yes

Table A.12. (contd)

Well Name	Anions	Cyanide	Gamma	I-129	Pu	Sr-90	Tc-99	Tritium	Uranium	Sampled in FY 2004
299-E33-42				A			A		A	Yes
299-E33-43				A			A		A	Yes
299-E33-44			A				A		A	Yes
299-E33-46	A						A		A	Not sampleable(a)
299-E33-7	A	A	A	A			A		A	Yes
699-43-40				T				T		Dry
699-45-42				T				T		Yes
699-47-60	A			A			A	A		Yes
699-49-55A	A	A	A	A			A	A		Yes
699-49-57A	A	A	A	A			A	A	A	Yes
699-49-57B			T				T			Yes
699-50-53A	A	A	A	A			A			Dry
699-53-47A	A					A				Yes
699-53-47B	T					T				Not scheduled
699-53-48A	T					T				Not scheduled
699-53-48B						T				Dry
699-53-55A							T			Not scheduled
699-53-55B							T			Yes
699-53-55C	A	A	A	A			A	A		Yes
699-54-45A	T									Not scheduled
699-54-45B	T									Not scheduled
699-54-48						T				Not scheduled
699-54-49	T					T				Not scheduled
699-55-50C	A			A		A	A	A		Yes
699-55-57	A	A	A	A			A			Yes
699-55-60A	A	A	A	A			A	A		Yes
699-57-59	A			A			A	A		Yes
699-59-58	A			A			A	A		Yes
699-60-60	T			T			T	T		Yes
699-61-62	T			T		T	T	T		Yes
699-61-66	T			T			T	T		Yes
699-64-62	T						T	T		Yes
699-65-50							T			Yes

Table A.12. (contd)

Well Name	Anions	Cyanide	Gamma	I-129	Pu	Sr-90	Tc-99	Tritium	Uranium	Sampled in FY 2004
699-65-72								T		Yes
699-66-58							T	T		Yes
699-66-64							T	T		Yes
699-70-68							T	T		Yes
699-72-73	T							T		Yes
699-73-61								T		Yes

(a) Moisture log hole; not monitoring well. Mistakenly included in DOE/RL-2001-49.

A = Annual.
FY = Fiscal year.
I-129 = Iodine-129.
Pu = Plutonium.
Sr-90 = Strontium-90.
T = Triennial.
Tc-99 = Technetium-99.

Table A.13. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit (adapted from DOE/RL-2003-04)

Well	Alkalinity	Alpha	Ammonia	Anions	Arsenic	Beta	Coliform	Cyanide	Gamma	Hex Cr	I-129	ICP	Metals-Hg	Metals-Pb	Oil/Grease	Phenols	Pu	Semi-VOA	Sr-90	Tc-99	TDS	TOC	TOX	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
299-E13-5		A		A		A		A	A			A							A	A					A	A		No cyanide, Tc-99 or uranium; scheduling error
299-E16-1	T3	T3		T3		T3					T3	T3													T3			Not scheduled
299-E16-2				T1	T1						T1														T1			Yes
299-E17-12		A		A	A	A					A	A													A			Yes
299-E17-13	A	A		A	A	A					A	A							A						A			Yes
299-E17-14				T1	T1						T1														T1			Yes
299-E17-16				T1	T1						T1														T1			Yes
299-E17-18				T1	T1						T1														T1			Yes
299-E17-19				T1	T1						T1														T1			Yes
299-E23-1				T1	T1						T1														T1			Yes
299-E24-18				T1	T1						T1														T1			Yes
299-E24-19		A		A		A																						No; casing corroded
299-E24-20				T1	T1						T1														T1			Yes
299-E24-5				T1	T1						T1														T1			Yes
299-E25-17				T1	T1						T1														T1			Yes
299-E25-18				T1	T1						T1														T1			Yes
299-E25-19				T1	T1						T1														T1			Yes
299-E25-20				T1	T1						T1														T1			Yes
299-E25-22				T1	T1						T1														T1			Yes
299-E25-28				T1	T1						T1														T1			Yes
299-E25-29P				T1	T1						T1														T1			Yes
299-E25-29Q				T1	T1						T1														T1			Yes
299-E25-3				T1	T1						T1														T1			Yes
299-E25-32P				T1	T1						T1														T1			Yes
299-E25-32Q	T1			T1	T1						T1	T1													T1			Yes
299-E25-34				T1	T1						T1														T1			Yes
299-E25-35				T1	T1						T1														T1			Yes
299-E25-36				T1	T1						T1														T1			Yes
299-E25-37				T1	T1						T1														T1			Yes
299-E25-41				T1	T1						T1														T1			Yes
299-E25-42				T1	T1						T1														T1			Yes
299-E25-43				T1							T1														T1			Yes
299-E25-44											T1														T1			Yes
299-E25-46				T1							T1														T1			No; casing corroded
299-E25-47				T1							T1														T1			Yes
299-E25-6		T1		T1	T1	T1			T1		T1									T1					T1	T1		Yes
299-E26-4		A		A	A	A			A		A	A													A			No; scheduling error
499-S0-7	A	A	A	A		A					A	A													Q			Yes
499-S0-8	A	A		A		A					A	A													Q			Yes

Table A.13. (contd)

Well	Alkalinity	Alpha	Ammonia	Anions	Arsenic	Beta	Coliform	Cyanide	Gamma	Hex Cr	I-129	ICP	Metals-Hg	Metals-Pb	Oil/Grease	Phenols	Pu	Semi-VOA	Sr-90	Tc-99	TDS	TOC	TOX	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
499-S1-8J		A	A	A		A			A		A	A							A	A					Q	A	A	Yes
699-10-54A	T1								T1			T1							T1	T1		T1	T1					Yes
699-10-E12	A	A		A		A			A			A							A			A	A		A			Yes
699-12-4D				T1							T1														T1			Yes
699-13-1A		T1		T1		T1					T1														T1			Delayed till early FY 2005
699-13-1C	T3	T3		T3		T3						T3													T3			Sampled FY 2004
699-13-3A									A																		A	Yes
699-14-38				T1								T1													T1			Yes
699-17-5	T1	T1		T1		T1			T1		T1	T1							T1	T1					T1		T1	Yes
699-19-43				T1							T1	T1													T1			Yes
699-20-20		T1		T1		T1			T1		T1	T1								T1					T1			Yes
699-20-E12O	A	A		A		A			A		A	A							A	A		A	A		A			No Tc-99; scheduling error
699-20-E12S	T1			T1																					T1			Awaiting new sampling procedure to air lift
699-20-E5A				T1																					T1			Yes
699-21-6				T1							T1														T1			Yes
699-2-3				T1							T1														T1			Yes
699-24-1P	T1	T1		T1		T1						T1													T1			Awaiting new sampling procedure to air lift
699-24-34C				T1							T1														T1			Yes
699-24-46	A	A		A		A			A		T1	A							A	A		A	A		A			Yes
699-26-15A				T1							T1														T1			Yes
699-26-33	A	A		A		A			A		A	A							A	A		A	A		A			Yes
699-26-35A				T1							T1														T1			Yes
699-2-6A	Q	A		Q		A	A					A	A	A								Q			A			No, sampled only once; scheduling error; tritium & anions only(a)
699-2-7	Q	A		Q		A	A					A	A	A								Q			A			No, sampled only once; scheduling error; tritium & anions only(a)
699-27-8				T1							T1														T1			Dry
699-28-40				T1							T1	T1													T1			Yes
699-29-4				T1							T1														T1			Yes
699-31-11				T1							T1														T1			Yes
699-31-31	A	A		A		A			A		A	A							A	A		A	A		A			Yes
699-31-31P				T1							T1														T1			No; broken piezometer
699-32-22A	A	A		A		A			A		A	A							A	A		A	A		A			Yes

Table A.13. (contd)

Well	Alkalinity	Alpha	Ammonia	Anions	Arsenic	Beta	Coliform	Cyanide	Gamma	Hex Cr	I-129	ICP	Metals-Hg	Metals-Pb	Oil/Grease	Phenols	Pu	Semi-VOA	Sr-90	Tc-99	TDS	TOC	TOX	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
699-32-22B	T3	T3		T3		T3					T3	T3													T3			Yes
699-32-43	A	A		A		A			A		A	A							A	A		A	A		A			Yes
699-33-42				T1							T1	T1													T1			Yes
699-34-41B				A							A														A			Yes
699-34-42				T1							T1														T1			No I-129; laboratory failure
699-35-9				T1							T1														T1			Yes
699-37-43				T1							T1														T1			Yes
699-37-47A				T1	T1						T1														T1			Yes
699-37-E4	T1			T1							T1	T1													T1			Yes
699-38-15				T1							T1														T1			Yes
699-39-39				T1							T1														T1			Did not produce water
699-40-1				T1							T1														T1			Yes
699-40-33A				T1							T1														T1			Yes
699-41-1A	A	A		A		A			A		A	A							A	A		A	A		A			Yes
699-41-23	T1	A		A		A			T1		A	T1							T1	T1		T1	T1		A			Yes
699-41-40	T1	T1		T1		T1					T1														T1			Yes
699-42-12A				T1							T1														T1			Yes
699-42-39A				T1							T1														T1			Yes
699-42-39B	T1			T1							T1														T1			Yes
699-42-40C	T3	T3		T3		T3					T3	T3													T3			Sampled FY 2004
699-42-41				T1	T1						T1														T1			Decommissioned
699-42-42B	T1			T1							T1														T1			Yes
699-43-3				T1							T1														T1			Yes
699-43-40				T1	T1						T1														T1			Dry
699-43-41E				T1	T1						T1														T1			Yes
699-43-43				T1	T1						T1														T1			Decommissioned
699-43-45				T1	T1						T1														T1			Yes
699-44-39B				T1							T1														T1			Yes
699-45-42				T1							T1														T1			Yes
699-46-21B	T1	A		A		A			T1		T1	T1							T1	T1		T1	T1		A			Yes
699-46-4	A	A		A		A			A		A	A							A	A		A	A		A			Yes
699-47-5				T1							T1														T1			Yes
699-48-7A																									T1			Yes
699-49-13E		T1		T1		T1			T1		T1														T1			Yes
699-50-28B				T1							T1														T1			Yes
699-8-17	Q	A		Q		A	A				A	A	A	A								Q			A			No[b]
699-8-25				T1							T1														T1			Yes
699-9-E2		T1		T1		T1			T1		T1														T1			Yes
699-S11-E12AP																									A			Yes
699-S12-3				T1																					T1			Yes
699-S19-E13	SA	A		SA		A			A			A							A	A		A	A		SA			December; sampled in June

Table A.13. (contd)

Well	Alkalinity	Alpha	Ammonia	Anions	Arsenic	Beta	Coliform	Cyanide	Gamma	Hex Cr	I-129	ICP	Metals-Hg	Metals-Pb	Oil/Grease	Phenols	Pu	Semi-VOA	Sr-90	Tc-99	TDS	TOC	TOX	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
699-S19-E14				T1																					T1			Yes
699-S2-34B	A			A							A	A									A				A			No I-129 or TDS; sampler error
699-S3-25				T1																					T1			Yes
699-S3-E12	A	A		A		A			A			A							A	A		A	A		A			Yes
699-S6-E14A		T1		T1		T1			T1																T1			Yes
699-S6-E4A	A			A					A						SA	SA	A	SA	A					SA		SA	SA	SVOA, TPH; sampling error
699-S6-E4B		T1		T1		T1			T1																T1			No anions
699-S8-19				T1																					T1			Yes
81-D		A		A		A				A	A									A					A			No(c)
81-M		A		A		A				A	A									A					A			No(c)
81-S		A		A		A				A	A									A					A			No(c)
82-M		A		A		A				A	A									A					A			No(c)
82-S		A		A		A				A	A									A					A			No(c)
83-D		A		A		A				A	A									A					A			No(c)
84-D		A		A		A				A	A									A					A			No(c)
84-M		A		A		A				A	A									A					A			No(c)
84-S		A		A		A				A	A									A					A			No(c)
85-D		A		A		A				A	A									A					A			No(c)
85-M		A		A		A				A	A									A					A			No(c)
85-S		A		A		A				A	A									A					A			No(c)
86-D		A		A		A				A	A									A					A			No(c)
86-M		A		A		A				A	A									A					A			No(c)
86-S		A		A		A				A	A									A					A			No(c)

(a) Quarterly sampling and all constituents except tritium and anions were formerly sampled for 400 Area Process Ponds; ponds no longer required groundwater monitoring as of October 1, 2003.

(b) Formerly sampled for 400 Area Process Ponds; will change to triennial sampling for 200-PO-1 beginning in FY 2005.

(c) Scheduled to begin sampling in FY 2005.

A = Annual.
FY = Fiscal year.
Hex Cr = Hexavalent chromium.
I-129 = Iodine-129.
Sr-90 = Strontium-90.
SVOA = Semivolatile organic analyses.
T1 = Triennial cycle beginning FY 2001 (e.g., FY 2004).
T3 = Triennial cycle beginning FY 2003.
Tc-99 = Technetium-99.
TDS = Total dissolved solids.
TOC = Total organic carbon.
TOX = Total organic halides.
TPH = Total petroleum hyrdocarbons.
VOA = Volatile organic analyses.

Table A.14. Monitoring Wells, Aquifer Tubes, and Constituents for the 300-FF-5 Operable Unit, 300 Area (adapted from DOE/RL-2002-11)

Well	Alkalinity	Alpha	Anions	Beta	ICP Metals	Sr-90	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
399-1-1	SA		SA						SA	SA	Yes
399-1-10A	SA		SA						SA	SA	Yes
399-1-10B	SA							SA	SA	SA	Yes
399-1-11	SA								SA	SA	Yes
399-1-12	SA								SA	SA	Yes
399-1-15	SA	SA		SA			SA		SA	SA	Yes
399-1-16A	SA		SA						SA	SA	Missed December(a)
399-1-16B	SA								SA	SA	Missed December(a)
399-1-17A	SA	SA	SA	SA				SA	SA	SA	Yes
399-1-17B	SA								SA	SA	Yes
399-1-18A	SA		SA								Missed December(a)
399-1-18B	SA							SA			Yes
399-1-2	SA		SA						SA	SA	Yes
399-1-21A	SA							SA	SA	SA	Yes
399-1-21B	SA								SA	SA	Yes
399-1-6	SA		SA				SA		SA	SA	Yes
399-1-7	SA								SA	SA	Yes
399-1-8	SA								SA	SA	Yes
399-2-1	SA								SA	SA	Yes
399-2-2	SA								SA	SA	Yes
399-3-10	SA								SA	SA	Yes
399-3-11	SA	SA	SA	SA		SA		SA	SA	SA	Yes
399-3-12	SA		SA					SA	SA	SA	Yes
399-3-2	SA									SA	Yes
399-3-6	SA		SA					SA	SA	SA	Yes
399-4-1	SA		SA					SA	SA	SA	Yes
399-4-12	SA		SA					SA	SA	SA	Yes
399-4-9	SA		SA					SA	SA	SA	Yes
399-5-4B	SA							SA		SA	Yes
399-8-5A	SA	A	SA	SA				SA	SA	SA	Yes
AT-3-1-D	A		A		A				A	A	Yes
AT-3-1-M									A		Yes
AT-3-1-S									A		Yes

Table A.14. (contd)

Well	Alkalinity	Alpha	Anions	Beta	ICP Metals	Sr-90	TPH	Tritium	Uranium	VOA	Sampled as Scheduled in FY 2004
AT-3-2-M	A		A		A				A	A	Yes
AT-3-3-D	A		A		A				A	A	Yes
AT-3-3-M									A		Yes
AT-3-3-S									A		Yes
AT-3-4-D	A		A		A				A	A	Yes
AT-3-5-M	A		A		A				A	A	Yes
AT-3-6-D	A		A		A				A	A	Yes
AT-3-7-D	A		A		A				A	A	Yes
AT-3-8-D	A		A		A				A	A	Yes

(a) Sampling behind schedule; cancelled December event.

FY = Fiscal year.
ICP = Inductively coupled plasma.
SA = Semiannual.
Sr-90 = Strontium-90.
TPH = Total petroleum hydrocarbons.
VOA = Volatile organic analyses.

Table A.15. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, North (adapted from DOE/RL-2002-11)

Well	Alkalinity	Alpha	Anions	Beta	Gamma	Iodine-129	Metals	TPH	Technetium-99	Tritium	Uranium	VOA and SVOA	Sampled as Scheduled in FY 2004
699-12-2C	SA	Q	SA	Q	Q	SA	A			Q	Q	A	Yes
699-13-0A	SA	Q	SA	Q	Q	SA	A			Q	Q	A	Yes
699-13-1E	SA	Q	SA	Q	Q	SA	A			Q	Q	A	Yes
699-13-2D	SA	Q	SA	Q	Q	SA	A			Q	Q	A	Yes
699-13-3A	SA	Q	SA	Q	Q	SA	A		A	Q	Q	A	Yes
699-S6-E4A	SA	SA	SA	SA	SA		SA	A		SA	SA	SA	Yes
699-S6-E4B	SA	A		A	A					SA	A		Yes
699-S6-E4D	A	A		A	A				A	A	A		Yes
699-S6-E4E	SA	A		A	A					A	A		Yes
699-S6-E4K	SA	SA	SA	SA	SA		SA	SA	SA	SA	SA	SA	Yes
699-S6-E4L	SA	SA	SA	SA	SA		SA	SA	SA	SA	SA	SA	Yes

A = Annual.
FY = Fiscal year.
Q = Quarterly.
SA = Semiannually.
SVOA = Semivolatile organic analyses.
TPH = Total petroleum hydrocarbons.
VOA = Volatile organic analyses.

Table A.16. Monitoring Wells and Constituents for the 1100-EM-1 Operable Unit (adapted from PNNL-12220)

Well	Anions	Metals	VOA	Sampled as Scheduled in FY 2004
699-S27-E12A			A	Yes
699-S28-E12	A		A	Yes
699-S28-E13A	A		A	Yes
699-S29-E10A	A		A	Yes
699-S29-E11	A		A	Yes
699-S29-E12	A		A	Yes
699-S29-E13A	A		A	Yes
699-S30-E10A	A		A	Yes
699-S30-E10B	A		A	Yes
699-S30-E11A	A		A	Yes
699-S31-E10A	A		A	Yes
699-S31-E10C	A		A	Yes
699-S31-E10D	A		A	Yes
699-S31-E11	A		A	Yes
699-S41-E12		A		Yes

A = Annual.
FY = Fiscal year.
VOA = Volatile organic analyses.

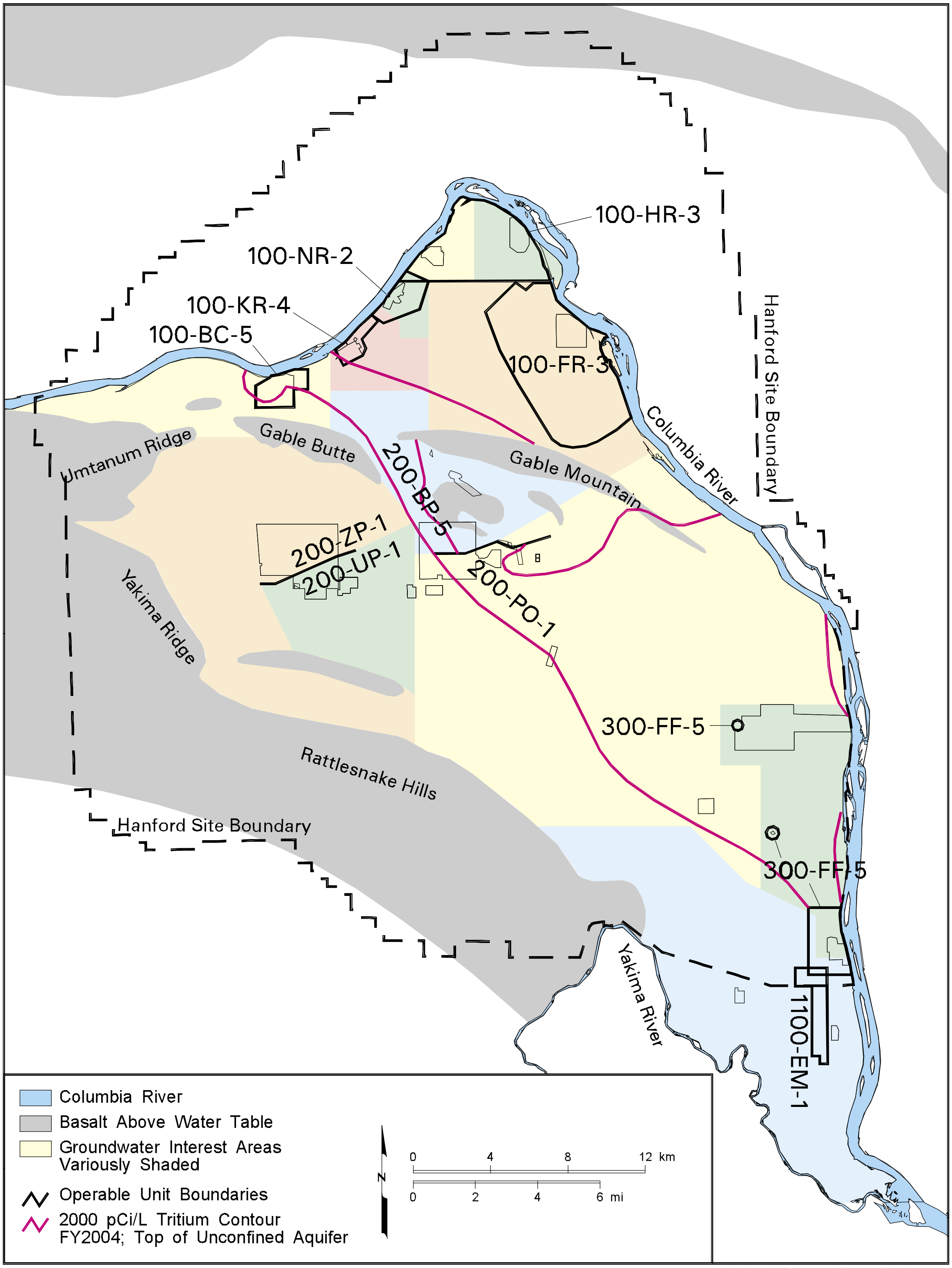

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Figure A.1. Groundwater Operable Units and Groundwater Interest Areas on the Hanford Site

Appendix B

Supporting Information for Monitored Facilities

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Appendix B

Supporting Information for Monitored Facilities

This appendix provides supplemental information for *Resource Conservation and Recovery Act* (RCRA) and other regulated units on the Hanford Site that require groundwater monitoring excluding *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) units (discussed in Appendix A). Site-specific discussions for each facility in Appendix B are found in the body of the document under the respective operable unit in which the facility lies (see Figure A.1 in Appendix A for operable units).

RCRA groundwater monitoring continued during fiscal year (FY) 2004 at 24 waste management areas (Figure B.1). Estimates of groundwater velocity, hydrologic properties, and associated references are shown in Table B.1 for all RCRA sites and two other regulated facilities. Tables B.2 through B.41 provide supporting information for these sites. Figures B.2 through B.20 show locations of monitoring wells.

This appendix also provides constituent lists, well network configurations, and other ancillary information for regulated facilities that fall outside of RCRA programs except CERCLA units. Some network wells in these facilities are shared with RCRA facilities (e.g., the State-Approved Land Disposal Site). Figure B.21 shows the general locations of these facilities. Locations of monitoring wells are shown in Figures B.22 through B.27. Tables B.38 through B.44 list the constituents list and/or results summaries for the facilities.

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Table B.1. Estimates of Groundwater Flow Rates at Hanford Site Facilities

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity(a)	Gradient(b)	Comments
116-N-1 LWDF	NW	0.07 to 1.2	Darcy	6.1 to 37 (PNL-8335)		0.0033	Gradient calculated between wells 199-N-66 and 199-N-2.
120-N-1 and 120-N-2	NW	0.07 to 1.4	Darcy	6.1 to 37 (PNL-8335)		0.0037	Gradient calculated between wells 199-N-72 and 199-N-26.
116-N-3 LWDF	N	0.04 to 0.77	Darcy	6.1 to 37 (PNL-8335)		0.0021	Gradient calculated between wells 199-N-28 and 199-N-81.
116-H-6 evaporation basins	E	0.17 to 4.8	Darcy	15 to 140 (PNL-6728)		0.0034	Gradient calculated between wells 199-H4-14 and 199-H4-3.
200 Area TEDF	SW	0.004	Darcy	1.1 (WHC-SD-EN-ES-004)	0.25(c)	0.0009	Gradient calculated between wells 699-41-35 and 699-40-36.
216-A-29 ditch	WSW	~0.01 to ~0.04	Darcy	18 (WHC-SD-EN-DP-047)		~0.0002	
216-B-3 pond	SW	0.016	Darcy	1.0 (WHC-SD-EN-EV-002; PNL-10195)	0.25	0.004	Gradient calculated between wells 699-44-39B and 699-43-44.
216-B-63 trench	SW	0.03 to 0.4	Darcy	52 to 200 (WHC-SD-EN-EV-002)		~0.0002	
216-S-10 pond	ESE	0.007 to 0.30	Darcy	10 (WHC-SD-EN-DP-052) 12 to 150 (BNWL-1709)		0.0002	Wells are dry. Gradient calculated using regional water-table maps.
216-U-12 crib	ESE	0.008 to 0.01	Darcy	4.2 to 5.4 (PNNL-13378)		0.0002	Wells are dry. Gradient calculated using regional water-table maps.
316-5 process trenches	SE	10.7 (PNL-5408)	Movement of PCE spill				
	SE	0.15 to 45	Darcy	150 to 15,000 (PNL-6716)		0.0003	
IDF	SE	0.002 to 0.0075	Darcy	68 to 75 (PNNL-13652; PNNL-11957)		0.00001	Uncertainty in gradient and rate of flow. Flow direction inferred from plume maps.
LERF	W	0.04 to 2.4	Darcy	6.1 to 120 (PNNL-11620)		0.002	

Table B.1. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity(a)	Gradient(b)	Comments
LLWMA 1	NW	~0.01 to ~1.6	Darcy	73 to 760 (PNL-6820)		0.00006	Uncertainty with flow direction, rate, and gradient.
LLWMA 2	W to SW	~0.04 to ~0.6	Darcy	430 to 2,000 (PNL-6820)		~0.00003	Gradient calculated between wells 299-E34-10 and 299-E27-9. Uncertainty with flow direction, rate, and gradient.
LLWMA 3	70° E of N	0.0001 to 0.14	Darcy	0.02 to 9.8 (PNL-6820)		0.0014	Flow direction from trend-surface analysis.
LLWMA 4	E to ENE	0.2 to 0.7	Darcy	24 (PNL-6820)		0.003	Flow direction is variable due to effects of pump-and-treat system.
NRDWL	125° E of N (based on plume maps)	0.015 to 0.02	Darcy	518 to 1,524 (WHC-EP-0021)		0.00001	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
PUREX cribs	SE	0.0006 to 0.3	Darcy	18 to 3,000 (PNNL-11523; PNNL-11523-ICN-1)		0.00001	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
SALDS	ENE	0.07 to 0.7	Darcy	3.5 to 36.3 (WHC-SD-C018H-RPT-003)	0.25	0.005	Gradient is calculated from maximum head difference observed between wells 699-48-77A and 699-48-77D during FY 2004 (02/24/04).
SWL	125° E of N (based on plume maps)	0.013 to 0.02	Darcy	640 to 1,280 (PNL-6820)		0.00001	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
WMA A-AX	SE	1.2 to 2.2	Darcy	1,981 to 2,519	0.2 to 0.3	0.000174	Gradient and flow rate calculated between wells 299-E24-20 and 299-E25-93.
WMA B-BX-BY	WSW (north half) SSE to SE (south half)	0.6 to 1.2	Darcy	1,270 to 2,520	0.3	0.00014	Flow rate uncertain. Hydraulic conductivity based on aquifer test data.(d)
WMA C	SW	1.4 to 4.8	Darcy	1,890 to 6,888 (PNNL-14656)	0.3	0.00033	Gradient and flow rate calculated between wells 299-E27-7 and 299-E27-13. Hydraulic conductivity based on a multi-stress slug test performed on well 299-E27-22 and reported in PNNL-14656.
WMA S-SX	E to ESE	0.07 to 0.14	Contaminant travel time (PNNL-13441)	NA	NA	NA	Based on inferred contaminant travel time between 216-S-25 crib and downgradient wells 299-W23-15 and 299-W22-46, and between wells 299-W22-46 and 299-W22-83.
		0.009 to 0.36	Darcy	0.58 to 17.2 (aquifer test data)	0.09 to 0.12	0.0018 to 0.0019	Based on aquifer tests (PNNL-13514 and PNNL-14113).

Table B.1. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity$^{(a)}$	Gradient$^{(b)}$	Comments
WMA T	5°N of E to 8°E of S	0.003 to 0.024 0.022 to 0.029	Darcy Tracer tests	1 to 28 (PNNL-13378; PNNL-14113; PNNL-14186)	0.04 to 1.1	0.001	Flow direction based on trend surface analysis: PNNL-14113, PNNL-13378.
WMA TX-TY (north part)	18° E of S to 43° E of S	0.0007 to 2.46 0.122 to 1.1	Darcy Tracer test	0.05 to 4.9 (PNNL-13378; PNNL-14113; PNNL-14186)	0.002 to 1	0.009	Flow direction based on trend surface analysis: PNNL-14113, PNNL-13378, and PNNL-14186.
WMA TX-TY (south part)	South to southwest	0.29 0.374	Darcy Tracer test	14.2 to 19.9 (PNNL-13378; PNNL-14113; PNNL-14186)	0.068	0.001	Flow direction based on water-table evaluations; Flow rate and direction affected by 200-ZP-1 pump-and treat in south part of WMA. PNNL-13514.
WMA U	E	0.008 to 0.20	Darcy	1.2 to 9.5 (PNNL-13378)		0.0021	

(a) Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system, unless otherwise noted.

(b) March 2004 unless noted otherwise.

(c) PNNL-11801.

(d) Letter report from FA Spane and DR Newcomer, Pacific Northwest National Laboratory, to JV Borghese, Fluor Hanford, Inc., *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of WMA B-BX-BY Well 299-E33-49 (C4261)*, dated October 8, 2004.

FY = Fiscal year.
IDF = Integrated Disposal Facility.
LERF = Liquid effluent retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste disposal facility.
NA = Not applicable.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PCE = Tetrachloroethene.
PUREX = Plutonium-Uranium Extraction (Plant).
SALDS = State-Approved Land Disposal Site.
SWL = Solid Waste Landfill.
TEDF = Treated Effluent Disposal Facility.
WMA = Waste management area.

Table B.2. Monitoring Wells and Constituents for 100-N Area Units (adapted from PNNL-13914)

Well(a)	Hydrogeologic Unit Monitored
116-N-1 (1301-N) Liquid Waste Disposal Facility	
199-N-2 (P)	Top of unconfined
199-N-3 (P)	Top of unconfined
199-N-34 (P)	Top of unconfined
199-N-57	Top of unconfined
199-N-105A(e)	Unconfined
120-N-1 and 120-N-2 (1324-N/NA) Liquid Waste Disposal Facilities	
199-N-59(d)	Top of unconfined
199-N-71	Top of unconfined
199-N-72	Top of unconfined
199-N-73	Top of unconfined
199-N-77(g)	Bottom of unconfined
116-N-3 (1325-N) Liquid Waste Disposal Facility	
199-N-28(g) (P)	Top of unconfined
199-N-32 (P)	Top of unconfined
199-N-41 (P)	Top of unconfined
199-N-74	Top of unconfined
199-N-81	Top of unconfined

Contamination Indicator Parameters(b)	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides
Site-Specific Parameters	
Alkalinity(c)	ICP metals (filtered)(c)
Anions(c)	Turbidity(b)
AEA Parameters	
Gross alpha(b,f)	

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA.
(b) Sampled semiannually.
(c) Sampled annually.
(d) Can be sampled only when water table is high. Not sampled in FY 2004.
(e) Extraction well; screened over entire thickness of aquifer.
(f) Gross alpha analyzed for wells 199-N-59 and 199-N-77 only.
(g) Used for supplemental information; no statistical evaluations.

Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.3. Critical Means for 116-N-1 (1301-N) Liquid Waste Disposal Facility for FY 2005 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	522.2	103.8	1,118	1,118
Field pH	8	7	6.0818	7.751	0.171	[6.65, 8.85]	[6.65, 8.85]
Total organic carbon,[(b)] µg/L	8	7	5.4079	296.35	240.487	1,676	1,680[(c)]
Total organic halides,[(b)] µg/L	8	7	5.4079	5.062	2.228	17.8	17.8

(a) Based on semiannual sampling events from March 2003 to September 2004 for upgradient well 199-N-57 and from September 2002 to March 2003 for upgradient well 199-N-34.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Rounded to the nearest 10 µg/L.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table B.4. Critical Means for 120-N-1 and 120-N-2 (1324-N/NA) Liquid Waste Disposal Facilities for FY 2005 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	7.5288	371.5	10.0	454	454
Field pH	5	4	9.0294	8.112	0.041	[7.70, 8.52]	[7.70, 8.52]
Total organic carbon,[(b)] µg/L	5	4	7.5288	239.5	163.883	1,591	1,590[(c)]
Total organic halides,[(b)] µg/L	5	4	7.5288	6.61	1.846	21.8	21.8

(a) Based on semiannual sampling events from September 2002 to September 2004 for upgradient well 199-N-71.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Rounded to the nearest 10 µg/L.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 12 comparisons.

Table B.5. Critical Means for 116-N-3 (1325-N) Liquid Waste Disposal Facility for FY 2005 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	8.1216	366.7	4.5	407	407
Field pH	5	4	9.7291	8.10	0.049	[7.58, 8.61]	[7.58, 8.61]
Total organic carbon,[(b,c)] µg/L	5	4	8.1216	NC	NC	NC	1,510
Total organic halides, µg/L	5	4	8.1216	7.27	2.056	25.6	25.6

(a) Based on semiannual sampling events from September 2002 to September 2004 for upgradient well 199-N-74.
(b) Critical means cannot be calculated because essentially all measurements are below vendor specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.6. Monitoring Wells and Constituents for the 116-H-6 (183-H) Evaporation Basins (adapted from PNNL-11573)

Well[(a)]	Hydrogeologic Unit Monitored
199-H4-3 (P)	Top of unconfined
199-H4-7[(b)]	Top of unconfined
199-H4-12A[(b)]	Top of unconfined
199-H4-12C	Mid-depth unconfined

Dangerous Waste Constituents	
Chromium (filtered)	Nitrate
Fluoride	
Site-Specific Parameters	
Alkalinity	pH
Anions	Specific conductance
ICP metals (filtered)	Turbidity
Other Parameters[(c)]	
Technetium-99	Uranium

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells are sampled annually.
(b) Also a CERCLA extraction well.
(c) Radionuclides not typically subject to RCRA monitoring, but included in the current Hanford Facility RCRA Permit (Ecology 1994) for this facility.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act.*
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act.*
WAC = Washington Administrative Code.

Table B.7. Monitoring Wells and Constituents for the 216-A-29 Ditch (adapted from PNNL-13047)

Well[a]	Hydrogeologic Unit Monitored
299-E25-26	Upper unconfined
299-E25-28[b]	Deep unconfined
299-E25-32P	Top of unconfined
299-E25-34	Top of unconfined
299-E25-35	Top of unconfined
299-E25-48	Top of unconfined
299-E26-12	Top of unconfined
299-E26-13	Top of unconfined
699-43-45	Top of unconfined

Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides
Site-Specific Parameters	
Alkalinity	Phenols
Anions	Turbidity
ICP metals (filtered)[c]	

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled quarterly.
(b) Used for supplemental information; no statistical evaluations.
(c) Analyzed annually.
Bold italic = Upgradient wells.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.8. Critical Means for the 216-A-29 Ditch for FY 2005 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	9.729	238.4	6.9	312	312
Field pH	5	4	11.629	8.39	0.099	[7.14, 9.65]	[7.14, 9.65]
Total organic carbon, µg/L	4[b]	3	15.145	316.88	157.366	2,982	2,980[c]
Total organic halides, µg/L	5	4	9.729	2.94	1.330	17.1	17.1

(a) Based on quarterly sampling events from November 2003 to October 2004 for upgradient well 699-43-45.
(b) Excluded suspected total organic carbon values collected in April 2004.
(c) Rounded to the nearest 10 µg/L.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 32 comparisons.

Table B.9. Monitoring Wells and Constituents for the 216-B-3 Pond (adapted from PNNL-13367-ICN-1)

Well[(a)]	Hydrogeologic Unit Monitored	Site-Specific Indicator Parameters	
699-42-42B	Top of uppermost	Specific conductance (field)	Total organic halides, pH
699-43-44	Bottom of uppermost	Total organic carbon	
699-43-45	Top of uppermost	Site-Specific Parameters	
699-44-39B	Top of uppermost	Anions[(b)]	Nitrate[(c)]
		Arsenic[(c)]	Phenols[(b)]
		Metals (filtered, unfiltered)[(b,d)]	Turbidity
		AEA Parameters	
		Gross alpha	Iodine-129[(c)]
		Gross beta	Tritium[(c)]

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually.
(b) Analyzed annually.
(c) Constituents of site-wide concern; selected wells analyzed under AEA monitoring.
(d) ICP plus cadmium, lead, mercury, and silver.

Bold italic = Upgradient well.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.10. Critical Means for the 216-B-3 Pond for FY 2005 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	8.1216	254.8	7.2	318	318
Field pH	5	4	9.7291	8.16	0.030	[7.83, 8.48]	[7.83, 8.48]
Total organic carbon, µg/L	5	4	8.1216	414.25	228.356	2,446	2,450[(c)]
Total organic halides,[(b)] µg/L	5	4	8.1216	NC	NC	NC	12.7

(a) Based on semiannual sampling events from June 2002 to July 2004 for specific conductance and field pH and from June 2000 to July 2004 for total organic carbon and total organic halides from upgradient well 699-44-39B. Background levels will be revised when data are available in 2005.
(b) Critical mean cannot be calculated because essentially all measurements are below vendor's specified method detection limit. Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
(c) Rounded to the nearest 10 µg/L.

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.11. Monitoring Wells and Constituents for the 216-B-63 Trench (adapted from PNNL-14112)

Well(a)
299-E27-8
299-E27-9
299-E27-11
299-E27-16
299-E27-17
299-E27-18
299-E27-19
299-E33-33
299-E33-36
299-E33-37
299-E34-8
299-E34-10

Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides

Site-Specific Parameters	
Alkalinity(b)	Phenols(b)
Anions(b)	Turbidity
ICP metals (filtered)(b)	

AEA Parameters(c)	
Gross alpha	Gross beta

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually. All wells completed at the top of the unconfined aquifer.
(b) Analyzed annually.
(c) Analyzed to support AEA monitoring.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.12. Critical Means for the 216-B-63 Trench for FY 2005 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	20	19	4.267	423.9	38.7	593	593
Field pH	20	19	4.572	8.076	0.069	[7.75, 8.40]	[7.75, 8.40]
Total organic carbon,(b) µg/L	20	19	4.267	330.5	230.068	1,336	1,510(c)
Total organic halides,(d) µg/L	20	19	4.267	NC	NC	NC	12.7(c)

(a) Based on semiannual sampling events from October 2002 to April 2004 for upgradient wells 299-E27-8, 299-E27-9, 299-E27-11, 299-E27-17, and 299-E34-10.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
(d) Critical mean cannot be calculated because essentially all measurements are below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table B.13. Monitoring Wells and Constituents for the 216-S-10 Pond and Ditch (adapted from PNNL-14070 and PNNL-14070-ICN-1)

Well[a]	Hydrogeologic Unit Monitored	Contamination Indicator Parameters	
299-W26-13	Top of unconfined	pH (field)	Specific conductance (field)
299-W26-14	Top of unconfined	Total organic carbon[b]	Total organic halides[b]
299-W27-2[c]	Base of unconfined		
		Site-Specific Parameters	
		Alkalinity[d]	ICP metals (filtered)[d]
		Anions[d]	Phenols[b,d]
		Hexavalent chromium (filtered)[e]	Turbidity[e]
			Volatile organic compounds[e]

(a) All wells constructed to WAC 173-160-400 standards and sampled semiannually.
(b) Not analyzed in well 299-W27-2.
(c) Used for supplemental information; no statistical evaluation.
(d) Analyzed annually only.
(e) Analyzed semiannually.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.14. Critical Means for the 216-S-10 Pond and Ditch for FY 2005 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	10.8689	269.8	2.2	296	296
Field pH	4	3	13.745	8.109	0.041	[7.49, 8.73]	[7.49, 8.73]
Total organic carbon,[b] µg/L	4	3	10.8689	195.625	90.884	1,300	1,510[c]
Total organic halides,[d] µg/L	4	3	10.8689	NC	NC	NC	12.7[c]

(a) Based on semiannual sampling events from December 2001 to June 2003 for upgradient well 299-W26-7, which went dry in 2003. Background levels will be revised when data from a new upgradient well are available.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
(d) Critical mean cannot be calculated because essentially all measurements are below vendor specified detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 12 comparisons.

Table B.15. Monitoring Wells and Constituents for the 216-U-12 Crib (adapted from WHC-SD-EN-AP-108, PNNL-14301, and PNNL-14301-ICN-1)

Well[a]	Contamination Indicator Parameters	
299-W22-79	pH (field)	Specific conductance (field)
699-36-70A		
	Site-Specific Parameters	
	Alkalinity[b,c]	ICP metals (filtered)[b]
	Anions	Total dissolved solids[b,d]
	Arsenic[b]	Turbidity
	CERCLA Parameters[c]	
	Iodine-129	Tritium
	Technetium-99	

(a) Both wells constructed to WAC 173-160-400 standards and sampled quarterly. Both wells completed at the top of the unconfined aquifer.
(b) Analyzed annually.
(c) Analyzed to support CERCLA monitoring (frequency varies).
(d) Well 699-36-70A only.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.16. Monitoring Wells and Constituents for the 316-5 Process Trenches (adapted from WHC-SD-EN-AP-185)

Well[a]	Hydrogeologic Unit Monitored	Field-Measured Parameters	
399-1-10A	Top of unconfined	pH	Turbidity
399-1-10B	Bottom of unconfined	Specific conductance	
399-1-16A	Top of unconfined		
399-1-16B	Bottom of unconfined	Site-Specific Parameters	
399-1-17A	Top of unconfined	cis-1,2-dichloroethene	Trichloroethene
399-1-17B	Bottom of unconfined	Tetrachloroethene	
399-1-18A	Top of unconfined		
399-1-18B	Bottom of unconfined	AEA Parameters	
		Uranium	

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled for four consecutive months, twice per year (semiannually).
AEA = *Atomic Energy Act of 1954*.
WAC = Washington Administrative Code.

Table B.17. Monitoring Wells and Constituents for the Integrated Disposal Facility (adapted from DOE/RL-2003-12)

Well(a)	Contaminants of Concern(b)	
299-E17-22	40 CFR 264, Appendix IX	
299-E17-23		
299-E17-25	Indicator Parameters(c)	
299-E18-1	Chromium (filtered)	Total organic carbon
299-E24-21	pH	Total organic halides
Proposed downgradient well 1	Specific conductance (field)	
Proposed downgradient well 2		
Proposed upgradient well 3	Supplemental Parameters(d)	
	Alkalinity	ICP metals
	Anions	Turbidity (field)

(a) All wells constructed to WAC 173-160-400 standards. All wells completed at the top of the unconfined aquifer. One upgradient well and one downgradient well scheduled for installation in late FY 2005. The second downgradient well is proposed for an unspecified time in the future.

(b) Sampled one time per well.

(c) Sampled two times per quarter for 1 year to establish background, then four times semiannually (total of eight samples per well per year) thereafter.

(d) Sampled semiannually.

Bold italic = Upgradient well.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.18. Monitoring Wells and Constituents for the Liquid Effluent Retention Facility (adapted from WHC-SD-EN-AP-024)

Well(a)	Hydrogeologic Unit Monitored	Contamination Indicator Parameters(b)	
299-E26-10 (S)	Top of unconfined	pH (field)	Total organic carbon
299-E26-11 (Q)	Top of unconfined	Specific conductance (field)	Total organic halides
		Site-Specific Parameters	
		Alkalinity(c)	Phenols(c)
		Ammonium(c)	Temperature
		Anions(c)	Turbidity
		ICP metals (filtered)(c)	Volatile organic compounds
		AEA Parameters(d)	
		Gross alpha(c)	Gross beta(c)

(a) Both wells constructed to WAC 172-160-400 standards. Both wells sampled quarterly.

(b) Statistical evaluations suspended in January 2001 because only one downgradient well is not dry.

(c) Analyzed annually.

(d) Analyzed to support AEA monitoring.

Bold italic = Upgradient well.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
(Q) = Sampled quarterly.
(S) = Sampled semiannually.
WAC = Washington Administrative Code.

Table B.19. Monitoring Wells and Constituents for Low-Level Waste Management Area 1 (adapted from WHC-SD-EN-AP-015)

Well[a]	RCRA Contamination Indicator Parameters	
299-E28-26	pH (field)	Total organic carbon
299-E28-27	Specific conductance (field)	Total organic halides
299-E28-28		
299-E32-2	RCRA Site-Specific Parameters	
299-E32-3	Alkalinity	Mercury (filtered)
299-E32-4	Anions	Phenols[b]
299-E32-5	ICP metals (filtered)	Turbidity
299-E32-6	Lead (filtered)	
299-E32-7		
299-E32-8	AEA Parameters[c]	
299-E32-9	Gross alpha	Tritium
299-E32-10	Gross beta	Uranium
299-E33-28	Technetium-99[d]	
299-E33-29		
299-E33-30		
299-E33-34		
299-E33-35		

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually. All wells completed at the top of the unconfined aquifer.
(b) Analyzed annually.
(c) Analyzed to support AEA monitoring.
(d) Performance assessment parameter.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.20. Critical Means for Low-Level Waste Management Area 1 for FY 2005 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	28	27	4.1542	490.5	52.1	711	711
Field pH	28	27	4.4138	8.026	0.133	[7.43, 8.62]	[7.43, 8.62]
Total organic carbon, µg/L	25[b]	24	4.2304	437.4	190.957	1,261	1,510[c]
Total organic halides,[d] µg/L	28	27	4.1542	NC	NC	NC	12.7[c]

(a) Based on semiannual sampling events from December 2002 to June 2004 for upgradient wells 299-E28-26, 299-E28-27, 299-E28-28, 299-E32-4, 299-E33-28, 299-E33-29, and 299-E33-35.
(b) Excluded suspected total organic carbon values collected in June 2003 from wells 299-E28-27, 299-E32-4, and 299-E33-28.
(c) Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
(d) Critical mean cannot be calculated because essentially all of the measurements are below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 68 comparisons.

Table B.21. Monitoring Wells and Constituents for Low-Level Waste Management Area 2 (adapted from WHC-SD-EN-AP-015)

Well[a]	RCRA Contamination Indicator Parameters	
299-E27-8	pH (field)	Total organic carbon
299-E27-9	Specific conductance (field)	Total organic halides
299-E27-10		
299-E27-11	RCRA Site-Specific Parameters	
299-E27-17	Alkalinity	Mercury (filtered)
299-E34-2[b]	Anions	Phenols[c]
299-E34-5[d]	ICP metals (filtered)	Polychlorinated biphenyls
299-E34-7	Lead (filtered)	Turbidity
299-E34-9		
299-E34-10	AEA Parameters[e]	
299-E34-12	Gross alpha	Technetium-99[f]
	Gross beta	Tritium
	Iodine-129[f]	Uranium[f]

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually. All wells completed at the top of the unconfined aquifer.
(b) This well went dry during FY 2003 after sampling was completed.
(c) Analyzed annually.
(d) Used for supplemental information; no statistical evaluation.
(e) Analyzed to support AEA monitoring.
(f) Performance assessment parameters.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.22. Critical Means for Low-Level Waste Management Area 2 for FY 2005 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	6	5	7.9757	827.8	59.1	1,337	1,337
Field pH	6	5	9.2355	7.878	0.085	[7.03, 8.72]	[7.03, 8.72]
Total organic carbon, µg/L	6	5	7.9757	631.88	388.086	3,975	3,980[b]
Total organic halides,[c] µg/L	6	5	7.9757	3.988	1.363	15.7	15.7

(a) Based on semiannual sampling events from May 2002 to April 2004 for upgradient well 299-E27-10. Data from well 299-E34-7 are excluded due to elevated levels of all indicator parameters.
(b) Rounded to the nearest 10 µg/L.
(c) Critical mean calculated from values below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 40 comparisons.

Table B.23. Monitoring Wells and Constituents for Low-Level Waste Management Area 3 (adapted from WHC-SD-EN-AP-015)

Well[a]	Hydrogeologic Unit Monitored
299-W7-1[b]	Top of unconfined
299-W7-3[c]	Deep unconfined
299-W7-4	Top of unconfined
299-W7-5	Top of unconfined
299-W7-7[b]	Top of unconfined
299-W7-12	Top of unconfined
299-W8-1	Top of unconfined
299-W10-14[c]	Deep unconfined
299-W10-19[b]	Top of unconfined
299-W10-20	Top of unconfined
299-W10-21	Top of unconfined

RCRA Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)
- Total organic carbon
- Total organic halides

RCRA Site-Specific Parameters

- Alkalinity
- Anions
- ICP metals (filtered)
- Lead (filtered)
- Mercury (filtered)
- Phenols
- Volatile organic compounds

AEA Parameters[d]

- Gross alpha
- Gross beta
- Iodine-129[e]
- Technetium-99[e]
- Tritium
- Turbidity
- Uranium[e]

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually.
(b) Well went dry in FY 2004.
(c) Used for supplemental information; no statistical evaluations.
(d) Analyzed to support AEA monitoring.
(e) Performance assessment parameters.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.24. Monitoring Wells and Constituents for Low-Level Waste Management Area 4 (adapted from WHC-SD-EN-AP-015)

Well(a)	Hydrogeologic Unit Monitored
299-W15-15	Top of unconfined
299-W15-16(b)	Top of unconfined
299-W15-17(c)	Deep unconfined
299-W18-21(b)	Top of unconfined
299-W18-22(c)	Deep unconfined
299-W18-23	Top of unconfined

RCRA Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides
RCRA Site-Specific Parameters	
Alkalinity	Mercury (filtered)
Anions	Phenols
ICP metals (filtered)	Turbidity
Lead (filtered)	Volatile organic compounds
AEA Parameters(d)	
Gross alpha	Technetium-99
Gross beta	Tritium
Iodine-129	Uranium(e)

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually.
(b) Well went dry in FY 2004.
(c) Used for supplemental information; no statistical evaluations.
(d) Analyzed to support AEA monitoring.
(e) Performance assessment parameter.

Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.25. Critical Means for Low-Level Waste Management Area 4 for FY 2005 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	12	11	4.3034	472.3	90.0	875	875
Field pH	12	11	4.7248	7.944	0.129	[7.31, 8.58]	[7.31, 8.58]
Total organic carbon, µg/L	10(b)	9	4.6231	434.625	190.407	1,358	1,510(c)
Total organic halides, µg/L	12	11	4.3034	19.054	17.841	99.0	99.0

(a) Based on semiannual sampling events from January 2003 to July 2004 for upgradient wells 299-W15-15, 299-W18-21, and 299-W18-23.
(b) Excluded suspected total organic carbon values collected in July 2003 from wells 299-W15-15 and 299-W18-21.
(c) Upgradient/downgradient comparison value is the most recently determined limit of quantification.

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.26. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill (adapted from PNNL-12227 and PNNL-12227-ICN-1)

Well(a)	Hydrogeologic Unit Monitored
699-25-33A(b)	Top of LPU(c)
699-25-34A	Top of unconfined
699-25-34B	Top of unconfined
699-25-34D	Top of unconfined
699-26-33	Top of unconfined
699-26-34A	Top of unconfined
699-26-34B	Top of unconfined
699-26-35A	Top of unconfined
699-26-35C(b)	Top of LPU(c)

Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides

Site-Specific Parameters	
Anions	Turbidity
ICP metals (filtered)	Volatile chlorinated hydrocarbons
Phenols(d)	

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually.
(b) Used for supplemental information; no statistical evaluation.
(c) Low-permeability unit (LPU) in upper Ringold Formation.
(d) Analyzed annually.
Bold italic = Upgradient wells.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.27. Critical Means for Nonradioactive Dangerous Waste Landfill for FY 2005 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.7282	545.3	4.7	574	574
Field pH	8	7	6.4295	7.219	0.058	[6.83, 7.61]	[6.83, 7.61]
Total organic carbon,(b) µg/L	6(c)	5	7.3884	NC	NC	NC	1,510(d)
Total organic halides,(b) µg/L	8	7	5.7282	NC	NC	NC	12.7(d)

(a) Based on most recent sampling events from February 2003 to August 2004 for upgradient wells 699-26-34A and 699-26-35A.
(b) Critical mean cannot be calculated because essentially all the measurements are below vendor's specified method detection limit.
(c) Excluded suspected total organic carbon values collected in February and August 2003 from well 699-26-35A.
(d) Upgradient/downgradient comparison value is the most recently determined limit of quantitation.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table B.28. Monitoring Wells and Constituents for PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1 (adapted from PNNL-11523 and PNNL-11523-ICN-1)

Well[a]	Hydrogeologic Unit Monitored
Upgradient Wells	
299-E24-18	Top of unconfined
299-E25-31	Top of unconfined
Near-Field Wells – 216-A-10 Crib	
299-E17-1 (P)	Top of unconfined
299-E17-19	Top of unconfined
299-E24-16 (Q)	Top of unconfined
Near-Field Wells – 216-A-36B Crib	
299-E17-14 (Q)	Top of unconfined
299-E17-16	Top of unconfined
299-E17-18	Top of unconfined
Near-Field Wells – 216-A-37-1 Crib	
299-E25-17 (P)	Top of unconfined
299-E25-19 (P,Q)	Top of unconfined
699-37-47A	Top of unconfined
Far-Field Wells[d]	
57 wells	Unconfined

Contamination Indicator Parameters	
pH (field)[b]	Specific conductance (field)[b]

Site-Specific Parameters	
Alkalinity	ICP metals (filtered)
Ammonium ion	Phenols
Anions[b]	Turbidity[b]
Arsenic (filtered)	

AEA Parameters[c]		
Gross alpha	Iodine-129[b]	Tritium[b]
Gross beta	Strontium-90	

(a) Wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. Wells sampled semiannually unless noted (Q), quarterly.

(b) Far-field wells analyzed for these constituents only.

(c) Analyzed to support AEA monitoring.

(d) Far-field wells sampled annually to triennially.

AEA = *Atomic Energy Act of 1954*.

ICP = Inductively coupled plasma emission spectroscopy.

PUREX = Plutonium-Uranium Extraction (Plant).

RCRA = *Resource Conservation and Recovery Act.*

WAC = Washington Administrative Code.

Table B.29. Monitoring Wells and Constituents for Waste Management Area A-AX (adapted from PNNL-13023-ICN-1)

Well(a)
299-E24-19(b)
299-E24-20
299-E24-22
299-E24-33(c)
299-E25-40
299-E25-41
299-E25-46(b)
299-E25-93
299-E25-94(c)

Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides
Site-Specific Parameters	
Alkalinity	ICP metals (filtered)
Anions	Phenols(d)
AEA Parameters(e)	
Gross beta	Technetium-99
Gross gamma(d)	Tritium(d)
Iodine-129(d)	Uranium(d)
Strontium-90(d)	

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled semiannually. All wells completed at the top of the unconfined aquifer.

(b) Decommissioned in 2003 due to corroded casing. Not sampled in FY 2004. Well 299-E25-94 drilled to replace wells 299-E24-19 and 299-E25-46.

(c) New well constructed in FY 2004. First samples scheduled for December 2004.

(d) Annually.

(e) Analyzed to support AEA monitoring.

Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
FY = Fiscal year.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.30. Critical Means for Waste Management Area A-AX for FY 2005 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	8	7	5.7282	378.6	23.6	522	522
Field pH	8	7	6.4295	8.078	0.070	[7.60, 8.55]	[7.60, 8.55]
Total organic carbon, μg/L	6(b)	5	7.3884	401.875	146.210	1,568	1,570(c)
Total organic halides,(d) μg/L	8	7	5.7282	4.15	3.115	23.1	23.1

(a) Based on semiannual sampling events from December 2002 to June 2004 for upgradient well 299-E24-20 and from quarterly sampling events from January 2004 to September 2004 for upgradient well 299-E24-22.

(b) Excluded suspected total organic carbon values collected in June 2003 from well 299-E24-20 and in September 2004 from well 299-E24-22.

(c) Rounded to the nearest 10 μg/L.

(d) Critical mean calculated from values reported below vendor's specified method detection limit.

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table B.31. Monitoring Wells and Constituents for Waste Management Area B-BX-BY (adapted from PNNL-13022, PNNL-13022-ICN-1, and PNNL-13022-ICN-2)

Well[(a)]	Contamination Indicator Parameters	
Near-Field Wells	pH	Total organic carbon
299-E33-7 (P)	Specific conductance	
299-E33-9 (P)		
299-E33-10 (P)	Site-Specific Parameters	
299-E33-15 (P)	Alkalinity	ICP metals (filtered)
299-E33-16 (P)	Anions	Turbidity
299-E33-17 (P)	Cyanide	
299-E33-18 (P)		
299-E33-20 (P)	AEA Parameters[(b)]	
299-E33-21 (P)	Gross alpha	Technetium-99
299-E33-31	Gross beta	Tritium
299-E33-32	Low-level gamma (cobalt-60,	Uranium
299-E33-38	cesium-137)	
299-E33-39		
299-E33-41		
299-E33-42		
299-E33-43		
299-E33-44		
299-E33-47[(c)]		
299-E33-48[(c)]		
299-E33-49[(c)]		
299-E33-334		
299-E33-335		
299-E33-337		
299-E33-338		
299-E33-339		
Far-Field Wells		
299-E28-8 (P)		
299-E33-26		
299-E33-28		

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA, and are completed in the unconfined aquifer. Wells sampled quarterly to support RCRA assessment.
(b) Analyzed to support AEA monitoring.
(c) New well constructed in FY 2004. First samples scheduled for December 2004.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954.*
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act.*
WAC = Washington Administrative Code.

Table B.32. Monitoring Wells and Constituents for Waste Management Area C (adapted from PNNL-13024-ICN-1, PNNL-13024-ICN-2, and PNNL-13024-ICN-3)

Well[a]
299-E27-4
299-E27-7 (P)
299-E27-12
299-E27-13
299-E27-14
299-E27-15
299-E27-21
299-E27-22
299-E27-23[b]

Contamination Indicator Parameters	
pH (field)	Total organic carbon
Specific conductance (field)	Total organic halides

Site-Specific Parameters	
Alkalinity	ICP metals (filtered)
Anions	Phenols
Cyanide	Turbidity

AEA Parameters[c]	
Gamma scan	Technetium-99
Gross beta	Total uranium

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells completed at the top of the unconfined aquifer. All wells sampled semiannually.
(b) Used for supplemental information; no statistical evaluation.
(c) Analyzed to support AEA monitoring.
Bold italic = Upgradient well.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.33. Critical Means for Waste Management Area C for FY 2005 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.7282	567.2	49.4	867	867
Field pH	8	7	6.4295	8.133	0.188	[6.85, 9.41]	[6.85, 9.41]
Total organic carbon,[b] µg/L	6	5	7.3884	535.21	303.472	2,957	2,960[c]
Total organic halides, µg/L	6	5	7.3884	6.362	2.836	29.0	29.0

(a) Based on quarterly sampling events from January 2004 to September 2004 for upgradient well 299-E27-22 and from December 2003 to September 2004 for upgradient well 299-E27-7.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Rounded to the nearest 10 µg/L.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table B.34. Monitoring Wells and Constituents for Waste Management Area S-SX (adapted from PNNL-12114-ICN-1 and PNNL-12114-ICN-2)

Well(a)	Contamination Indicator Parameters	
299-W22-44	pH (field)	Specific conductance (field)
299-W22-45		
299-W22-46	Site-Specific Parameters	
299-W22-48	Alkalinity	ICP metals (filtered)
299-W22-49	Anions	Turbidity
299-W22-50		
299-W22-80	AEA Parameters(b)	
299-W22-81	Gamma scan	Technetium-99
299-W22-82	(cesium-137)(c)	Tritium
299-W22-83	Gross beta(d)	Uranium
299-W22-84		
299-W22-85		
299-W23-15		
299-W23-19		
299-W23-20		
299-W23-21		

(a) All wells constructed to WAC 173-160-400 standards. All wells sampled quarterly, except for certain constituents as noted. All wells completed at the top of the unconfined aquifer.
(b) Analyzed to support AEA monitoring.
(c) Analysis done only on well 299-W23-19 annually.
(d) Analysis done only on well 299-W23-19 quarterly.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.35. Monitoring Wells and Constituents for Waste Management Area T (adapted from PNNL-12057-ICN-1)

Well[a]	Contamination Indicator Parameters	
299-W10-1 (P)	pH (field)	Specific conductance (field)
299-W10-4 (P)		
299-W10-8 (P)	Site-Specific Parameters	
299-W10-22 (S)	Alkalinity	Oxidation-reduction potential (field)
299-W10-23	Anions	
299-W10-24	Dissolved oxygen (field)	Turbidity (field)
299-W10-28	ICP metals (filtered)	
299-W11-7 (S,P)		
299-W11-12 (P)	AEA Parameters[b,c]	
299-W11-39	Gamma scan (cesium-137, cobalt-60)	Iodine-129
299-W11-40		Strontium-90
299-W11-41	Gross alpha	Technetium-99
299-W11-42	Gross beta	Tritium

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells sampled quarterly unless noted (S), semiannually. All wells completed at the top of the unconfined aquifer.

(b) Constituent list varies by well; applies only to AEA constituents.

(c) Analyzed to support AEA monitoring. AEA parameters vary in frequency of sampling and not all wells are analyzed for each constituent shown.

Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.36. Monitoring Wells and Constituents for Waste Management Area TX-TY (adapted from PNNL-12072-ICN-1)

Well[a]	Contamination Indicator Parameters	
299-W10-26	pH (field)	Specific conductance (field)
299-W10-27		
299-W14-6 (P)	Site-Specific Parameters	
299-W14-13	Alkalinity	Oxidation-reduction potential (field)
299-W14-14	Anions	
299-W14-15	Dissolved oxygen (field)	Turbidity (field)
299-W14-16	ICP metals (filtered)	
299-W14-17		
299-W14-18	AEA Parameters[b,c]	
299-W14-19	Gamma scan (cesium-137, cobalt-60)	Iodine-129
299-W15-40		Strontium-90
299-W15-41	Gross alpha	Technetium-99
299-W15-44	Gross beta	Tritium
299-W15-763		
299-W15-765		

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells sampled quarterly, but not all constituents are sought quarterly. All wells completed at the top of the unconfined aquifer.

(b) Constituent list varies by well; applies only to AEA constituents.

(c) Analyzed to support AEA monitoring. AEA parameters vary in frequency of sampling and not all wells are analyzed for each constituent shown.

Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.37. Monitoring Wells and Constituents for Waste Management Area U (adapted from PNNL-13612 and PNNL-13612-ICN-1)

Well(a)
299-W18-30
299-W18-31
299-W18-40
299-W19-12
299-W19-41
299-W19-42
299-W19-44
299-W19-45

Contamination Indicator Parameters	
pH (field)	Specific conductance (field)
Site-Specific Parameters	
Alkalinity	ICP metals (filtered)
Anions	Volatile organic compounds(b)
AEA Parameters(c)	
Gamma scan(b)	Technetium-99
Gross alpha(b)	Tritium(b)
Iodine-129(b)	

(a) All wells constructed to WAC-173-160-400 standards. All wells sampled quarterly. All wells completed at the top of the unconfined aquifer.
(b) Annually.
(c) Analyzed to support AEA monitoring.
Bold italic = Upgradient wells.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.38. Monitoring Wells and Constituents for the KE and KW Basins (adapted from PNNL-14033)

Well(a)
199-K-27 (P)
199-K-29 (P)
199-K-30 (P)
199-K-32A
199-K-34
199-K-106A
199-K-107A
199-K-108A (S)
199-K-109A
199-K-110A (S)
199-K-111A

Field Parameters	
pH	Temperature
Specific conductance	Turbidity
Site-Specific Parameters(b)	
Anions	ICP metals (filtered)
Carbon-14	Trichloroethene
AEA Parameters	
Gross alpha	Technetium-99
Gross beta	Tritium
Strontium-90	

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells sampled quarterly unless noted (S), semiannually. All wells completed at the top of the unconfined aquifer.
(b) Sampling frequency varies by constituent.
AEA = *Atomic Energy Act of 1954*.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.39. Monitoring Wells, Constituents, and Enforcement Limits for the 200 Area Treated Effluent Disposal Facility (adapted from PNNL-13032)

Well (a)	Constituent(b) and Enforcement Limit (µg/L)	
699-40-36	Cadmium = 5	Lead = 10
699-41-35	pH = 6.5 to 8.5 pH units	
699-42-37		

(a) All wells constructed to WAC 173-160-400 standards. All wells completed at the top of the Ringold confined aquifer.
(b) All wells sampled quarterly. All wells also monitored for ICP metals, anions, trace metals, alkalinity, specific conductance, total dissolved solids, turbidity, gross alpha, gross beta, and low-level tritium (annually). No enforcement limits for those constituents.
Bold italic = Upgradient well.
ICP = Inductively coupled plasma emission spectroscopy.
WAC = Washington Administrative Code.

Table B.40. Monitoring Wells and Constituents for the Environmental Restoration Disposal Facility (adapted from BHI-00873)

Well(a)	Field Parameters	
699-35-66A	pH (field)	Turbidity
699-36-67	Specific conductance (field)	
699-36-70A (P)		
699-37-68	Site-Specific Parameters	
	Alkalinity	ICP metals (dissolved and unfiltered)
	Anions	
	Carbon-14	Total dissolved solids
	Carbon tetrachloride	Total organic halides
	AEA Parameters(b)	
	Gross alpha	Radium
	Gross beta	Technetium-99
	Iodine-129	Uranium

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells sampled semiannually. All wells completed at the top of the unconfined aquifer.
(b) Sampled for AEA monitoring.
AEA = *Atomic Energy Act of 1954*.
Bold italic = Upgradient well.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.41. Monitoring Wells and Constituents for the Solid Waste Landfill (adapted from PNNL-13014)

Well(a)	Parameters/Constituents Required by WAC 173-304-490	
699-22-35	Ammonia	Nitrite
699-23-34A	Chemical oxygen demand	pH (field)
699-23-34B	Chloride	Specific conductance (field)
699-24-33(b) (P)	Dissolved iron	Sulfate
699-24-34A	Dissolved zinc	Temperature (field)
699-24-34B	Dissolved manganese	Total coliform
699-24-34C	Nitrate	Total organic carbon
699-24-35		
699-26-35A	Site-Specific Parameters	
	Anions (nitrate)	Volatile organic compounds
	ICP metals (filtered)	Arsenic (dissolved)

(a) All wells are constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. All wells sampled quarterly. All wells completed at the top of the unconfined aquifer.

(b) Used for supplemental information; no statistical evaluations.

Bold italic = Upgradient wells.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = *Resource Conservation and Recovery Act*.
WAC = Washington Administrative Code.

Table B.42. Analytical Results for Required Constituents(a) at the Solid Waste Landfill

Constituent, unit	Value(b)	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-33	Well 699-24-34A	Well 699-24-34B	Well 699-24-34C	Well 699-24-35	Well 699-26-35A
Ammonium, µg/L	118	November 2003	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6
		February 2004	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6
		May 2004	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6	<21.6
		August 2004	<21.6	<21.6	<21.6	<21.6	(c)	<21.6	<21.6	<21.6	<21.6
Chemical oxygen demand, mg/L	10	November 2003	<3.6	<3.6	<3.6	<3.6	<3.6	<3.6	5	<3.6	<3.6
		February 2004	<3.6	<3.6	<3.6	<3.6	<3.6	<3.6	<3.6	<3.6	<3.6
		May 2004	<9	<9	**10**	9	<9	**16**	**10**	9	<9
		August 2004	**10**	**17**	**15**	<7.1	(c)	**17**	**13**	**17**	9
Chloride, mg/L	7.82	November 2003	6.4	6.6	6.3	6.9	6.4	6.5	6.7	6.2	7
		February 2004	5.9	6.4	6.3	6.6	6.4	5.6	6.9	6.5	6.3
		May 2004	6.8	6.3	6.7	7.2	6.9	6.8	7	6.3	7.1
		August 2004	**8.4**	6.6	6.5	6.8	(c)	6.4	6.7	6.1	6.9
Coliform bacteria, Col/100 ml	1	November 2003	0	**18.3**	0	0	0	0	0	**120**	0
		February 2004	0	**4.1**	0	0	0	0	0	**129**	0
		May 2004	0	0	0	0	0	0	0	0	0
		August 2004	0	0	0	**5.2**	(c)	0	0	0	0
Iron, filtered, µg/L	160	November 2003	70.7	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5
		February 2004	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5
		May 2004	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5	<54.5
		August 2004	30.3	30.6	28.2	31.8	(c)	39	29.1	22	10.3
Manganese, filtered, µg/L	10	November 2003	5.1	2.4	2.7	1.9	3.1	2.6	3	2.5	1.7
		February 2004	<1.2	1.4	1.2	1.3	2.8	<1.2	2.8	4	<1.2
		May 2004	1.8	2.8	1.6	<1.2	2.2	1.3	1.8	1.6	1.6
		August 2004	1.4	1	<0.99	1.5	(c)	<0.99	1.3	<0.99	<0.99
Nitrate, mg/L	29	November 2003	3.7	3.3	3.5	3.2	2.7	2.9	3.5	2.6	3.9
		February 2004	3.6	3.3	3.4	3.1	2.7	2.9	3	2.6	3.9
		May 2004	3.7	3.5	3.7	3.3	3	3.3	3.2	2.5	4
		August 2004	3.5	3.3	3.3	2.8	(c)	2.8	2.9	2.7	3.6
Nitrite, mg/L	0.059	November 2003	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074
		February 2004	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074
		May 2004	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074
		August 2004	<0.0074	<0.0074	<0.0074	<0.0074	(c)	<0.0074	<0.0074	<0.0074	<0.0074

Table B.42. (contd)

Constituent, unit	Value[(b)]	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-33	Well 699-24-34A	Well 699-24-34B	Well 699-24-34C	Well 699-24-35	Well 699-26-35A
Field pH	6.68 - 7.84	November 2003	6.96	**6.59**	6.7	6.88	6.81	6.75	(c)	7.06	7.36
		February 2004	7.01	**6.65**	6.72	6.97	6.73	6.73	6.95	6.77	7.26
		May 2004	7.02	**6.59**	6.96	6.87	6.69	6.74	6.95	6.89	7.12
		August 2004	7.01	**6.62**	**6.68**	6.84	6.69	**6.65**	6.94	6.88	7.14
Specific conductance, µS/cm	583	November 2003	**827**	**754**	**796**	**772**	**687**	**704**	(c)	**601**	545
		February 2004	**829**	**755**	**795**	**745**	**695**	**676**	**738**	**611**	540
		May 2004	**849**	**766**	**801**	**773**	**662**	**707**	**742**	**601**	550
		August 2004	**834**	**761**	**801**	**771**	**675**	**703**	**705**	**604**	548
Sulfate, mg/L	47.2	November 2003	**47.4**	**48.8**	**48.1**	41.8	45.7	44.2	44.3	45.8	38.9
		February 2004	**47.4**	**49.2**	**47.4**	42.2	45.6	45.8	40	44.9	38.2
		May 2004	**48.4**	**50.3**	**49.1**	44	**48.7**	**48.8**	42.1	**47.6**	39.2
		August 2004	45.3	46.5	43.8	39.7	(c)	44	38.7	43.4	36.4
Temperature, °C	20.7	November 2003	16.9	18	18.7	20	18.7	19.2	(c)	18.5	19.8
		February 2004	18	18.1	17.9	18.9	17.8	18	18.1	17.9	18.8
		May 2004	18	18.6	18.2	21.8	18.8	19	19.2	17.9	18.9
		August 2004	18.7	19	18.2	19.5	19	20.1	18.5	18.7	19.5
Total organic carbon, mg/L	1.51	November 2003	0.43	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39
		February 2004	<0.39	<0.39	<0.39	0.4	0.48	<0.39	0.49	1	0.46
		May 2004	<0.39	0.41	<0.39	<0.39	0.5	0.45	0.54	0.56	0.43
		August 2004	**1.6**	0.44	0.54	<0.39	(c)	<0.39	0.46	<0.39	<0.39
Zinc, filtered, µg/L	42.3	November 2003	5.6	6.1	<2.7	9.6	<2.7	<2.7	10.3	5.7	10.7
		February 2004	<2.7	<2.7	<2.7	8.3	<2.7	<2.7	13.6	7.4	9.9
		May 2004	<2.7	<2.7	<2.7	21.1	<2.7	<2.7	11.3	6.5	6.5
		August 2004	<1.5	2.2	<1.5	15.1	(c)	<1.5	14.2	<1.5	6.4

(a) WAC 173-304.

(b) Number obtained from Table B.43, background threshold value.

(c) Sample not collected or constituent not analyzed.

Results in **bold** type exceed background threshold value.

Table B.43. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill

Constituent,(a) unit	W-test Statistic,(b) (log value)	W-test Statistic,(b) (raw data)	W-test(b) Critical Value, Wα(c)	Upper Tolerance Limit	Background Threshold Value
Temperature, °C	0.953 s	0.961 s	0.963	20.7(d)	20.7
Specific conductance, µS/cm	0.978 ns	NA	0.960	583(e)	583
Field pH	0.988 ns	NA	0.963	[6.68, 7.84](e)	[6.68, 7.84]
Total organic carbon, µg/L	NC	NC	NC	842(d) 1,510(f)	1,510
Chloride, µg/L	0.954 s	0.962 s	0.963	7,820(d)	7,820
Nitrate (as NO_3^-), µg/L	0.833 s	0.844 s	0.963	29,000(d)	29,000
Nitrite (as NO_2^-), µg/L	NC	NC	NC	59(f)	59
Ammonium (as NH_3^-) , µg/L	NC	NC	NC	90(d) 118(f)	118
Sulfate, µg/L	0.983 ns	NA	0.963	47,200(e)	47,200
Iron, dissolved, µg/L	0.960 s	0.802 s	0.962	160(d) 54.0(f)	160
Zinc, dissolved, µg/L	NC	NC	NC	42.3(d) 10.31(f)	42.3
Manganese, dissolved, µg/L	NC	NC	NC	10(d) 9(f)	10
Coliform bacteria, colonies/100 ml	NC	NC	NC	1(g)	1
Chemical oxygen demand, µg/L	NC	NC	NC	10,000(g)	10,000

(a) Constituents are specified in WAC 173-304-490(2)(d). Data collected from March 1993 to May 2000 from upgradient wells 699-24-35 and 699-26-35A.
(b) Shapiro and Francia (1972).
(c) Obtained from Table A-9 (Shapiro 1980) for α = 5%.
(d) Maximum value reported.
(e) Based on log-normal distribution.
(f) Based on limit of quantitation using method detection limit.
(g) Based on laboratory lowest detected result.
NA = Not applicable.
NC = Not calculated; insufficient measured values.
ns = Not significant at 0.05 level of significance.
s = Significant at 0.05 level of significance.

Table B.44. Monitoring Wells, Constituents, and Enforcement Limits for the State-Approved Land Disposal Site (adapted from PNNL-13121)

Well[(a)]	Hydrogeologic Unit Monitored
299-W6-6 (A)	Bottom of unconfined
299-W6-11 (A)	Top of unconfined
299-W6-12 (A)	Top of unconfined
299-W7-3 (S)	Bottom of unconfined
299-W7-5 (S)	Top of unconfined
299-W7-12 (A)	Top of unconfined
299-W8-1 (A)	Top of unconfined
699-48-71 (A,P)	Unconfined
699-48-77A (Q)	Ringold unit E; upper
699-48-77C (Q)	Ringold unit E; mid to lower
699-48-77D (Q)	Ringold unit E; upper
699-49-79 (A,P)	Top of unconfined
699-51-75 (S,P)	Top of unconfined
699-51-75P (A,P)	Lower unconfined

Constituent	Enforcement Limit (μg/L)
Acetone	160
Benzene	5
Cadmium, total	10
Chloroform	6.2
Copper, total	70
Lead, total	50
Mercury, total	2
pH	6.5 - 8.5 pH units
Sulfate	250,000
Tetrahydrofuran	100
Total dissolved solids	500,000

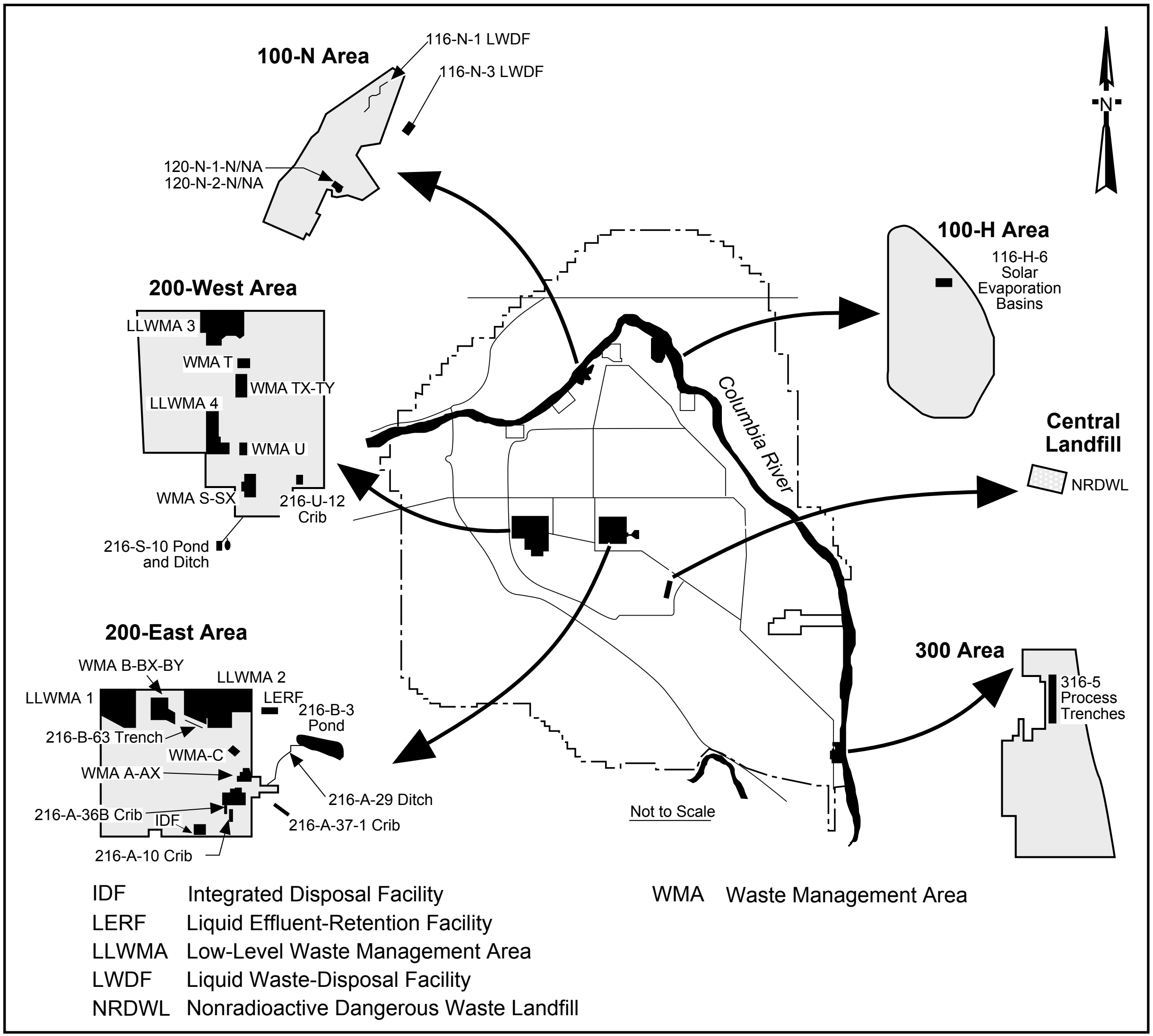
AEA Parameters	
Gross alpha	Strontium-90
Gross beta	Tritium

(a) All wells constructed to WAC 173-160-400 standards unless noted (P), pre-RCRA. Wells noted (A) sampled annually, (Q), quarterly, and (S), semiannually.

AEA = *Atomic Energy Act of 1954*.

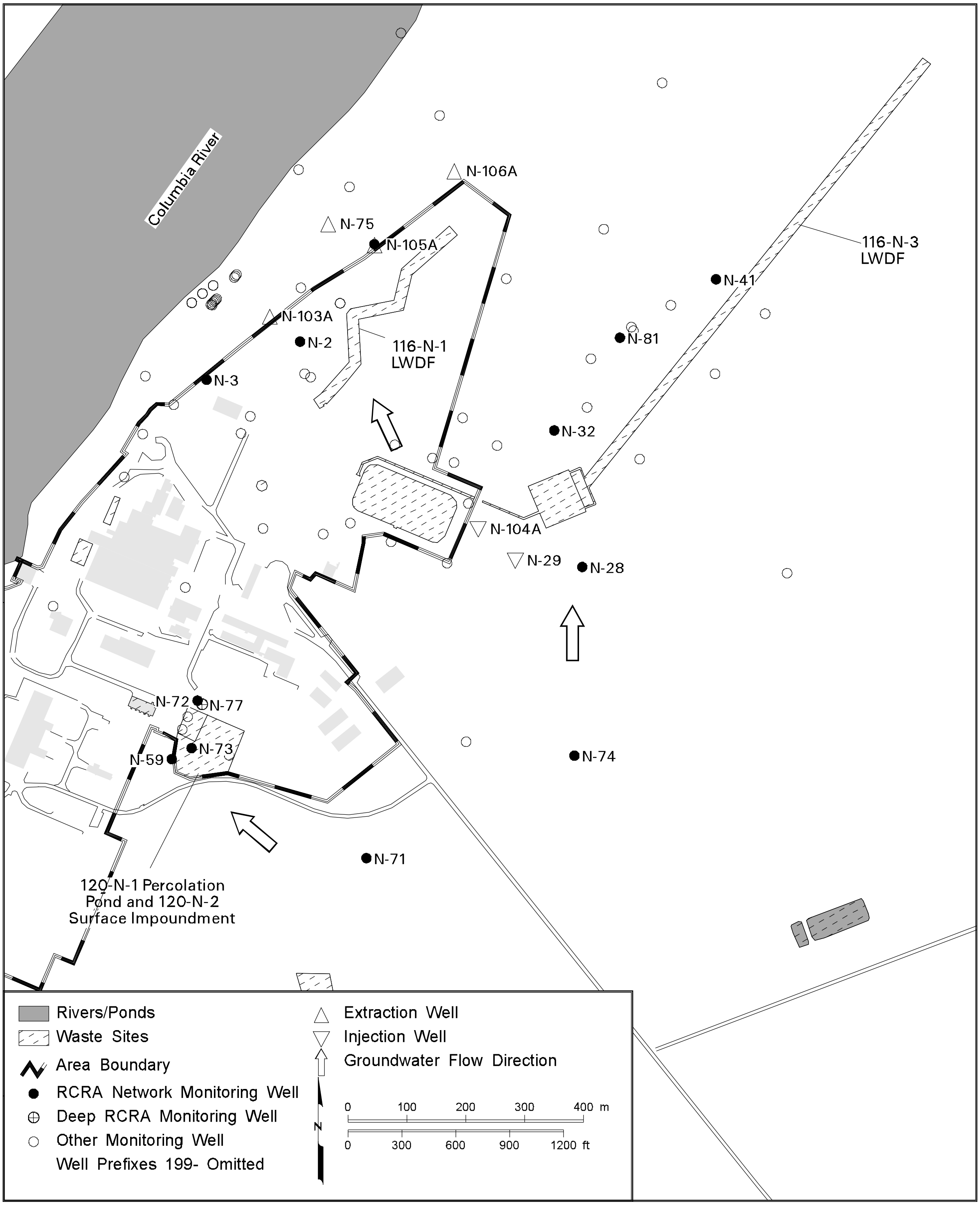
RCRA = *Resource Conservation and Recovery Act*.

WAC = Washington Administrative Code.



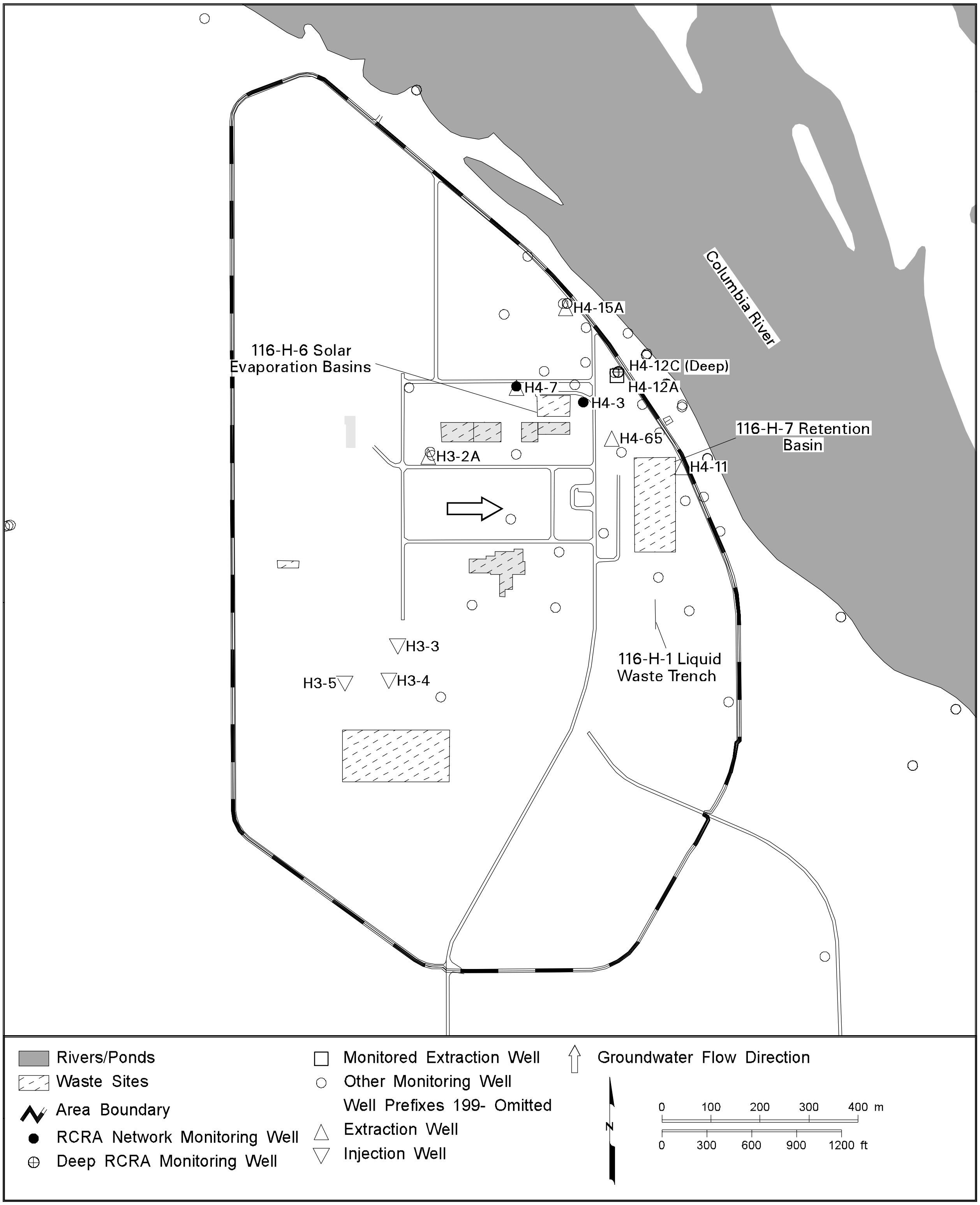
ecs05003/G00080088.3

Figure B.1. RCRA Units on the Hanford Site Requiring Groundwater Monitoring. (The 216-A-10, 216-A-36B, and 216-A-37-1 cribs are monitored as a single waste management unit, PUREX Cribs.)



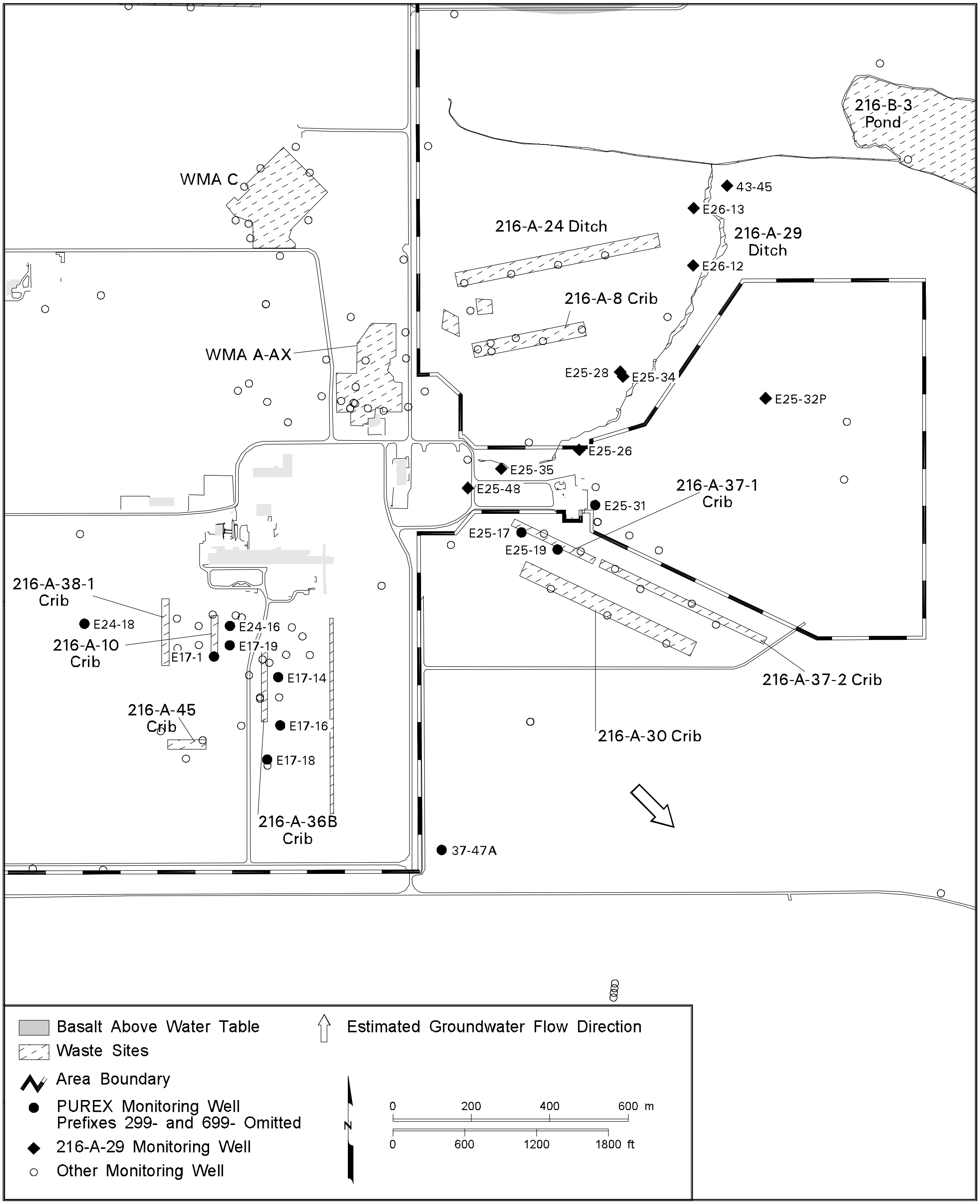
can_gwf04_612 February 19, 2005 11:27 AM

Figure B.2. Groundwater Monitoring Wells for 100-N Area RCRA Sites



can_gwf04_613 March 02, 2005 2:11 PM

Figure B.3. Groundwater Monitoring Wells at the 116-H-6 (183-H) Evaporation Basins



can_gwf04_614 February 22, 2005 6:59 AM

Figure B.4. Groundwater Monitoring Wells at the 216-A-29 Ditch and PUREX Cribs

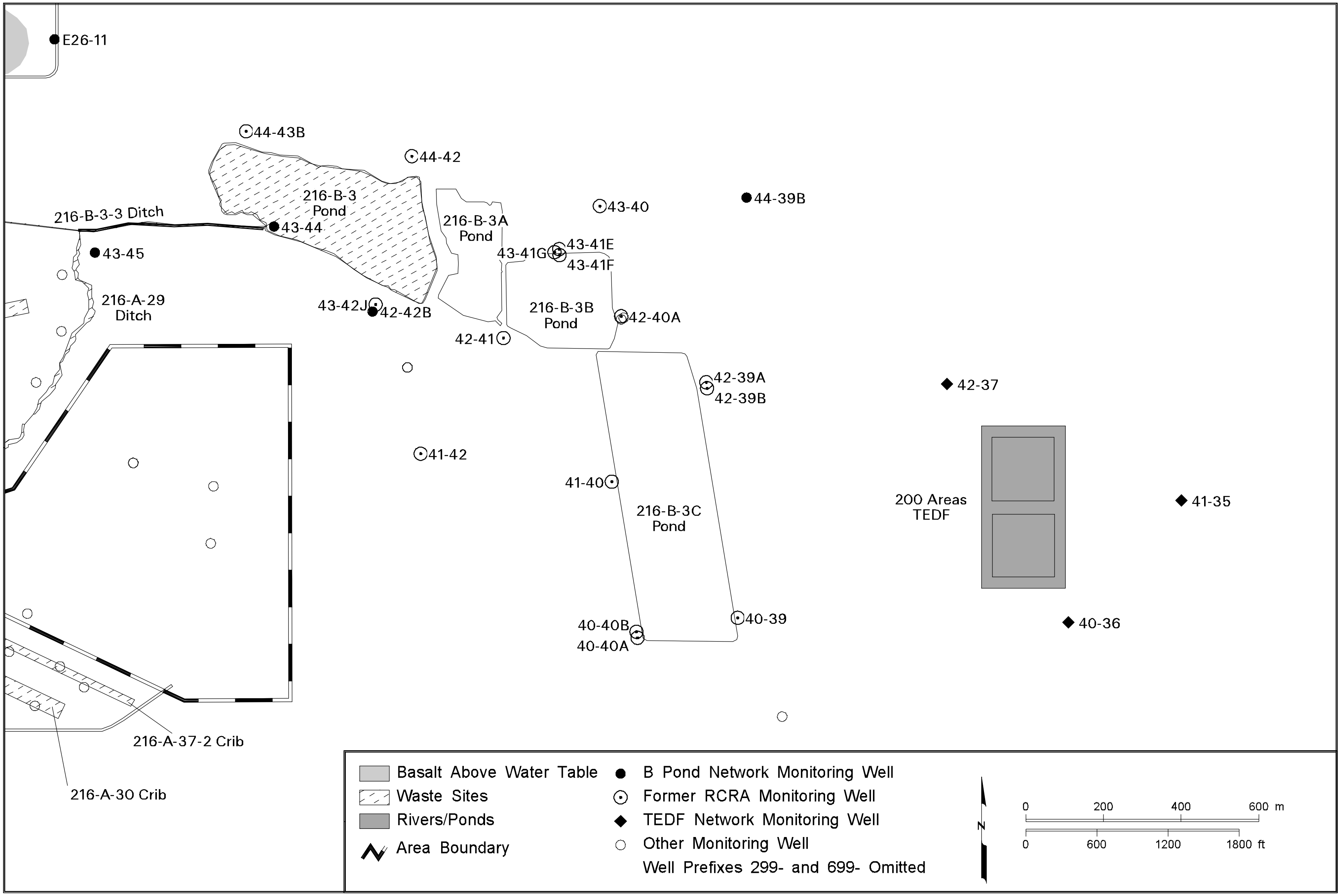


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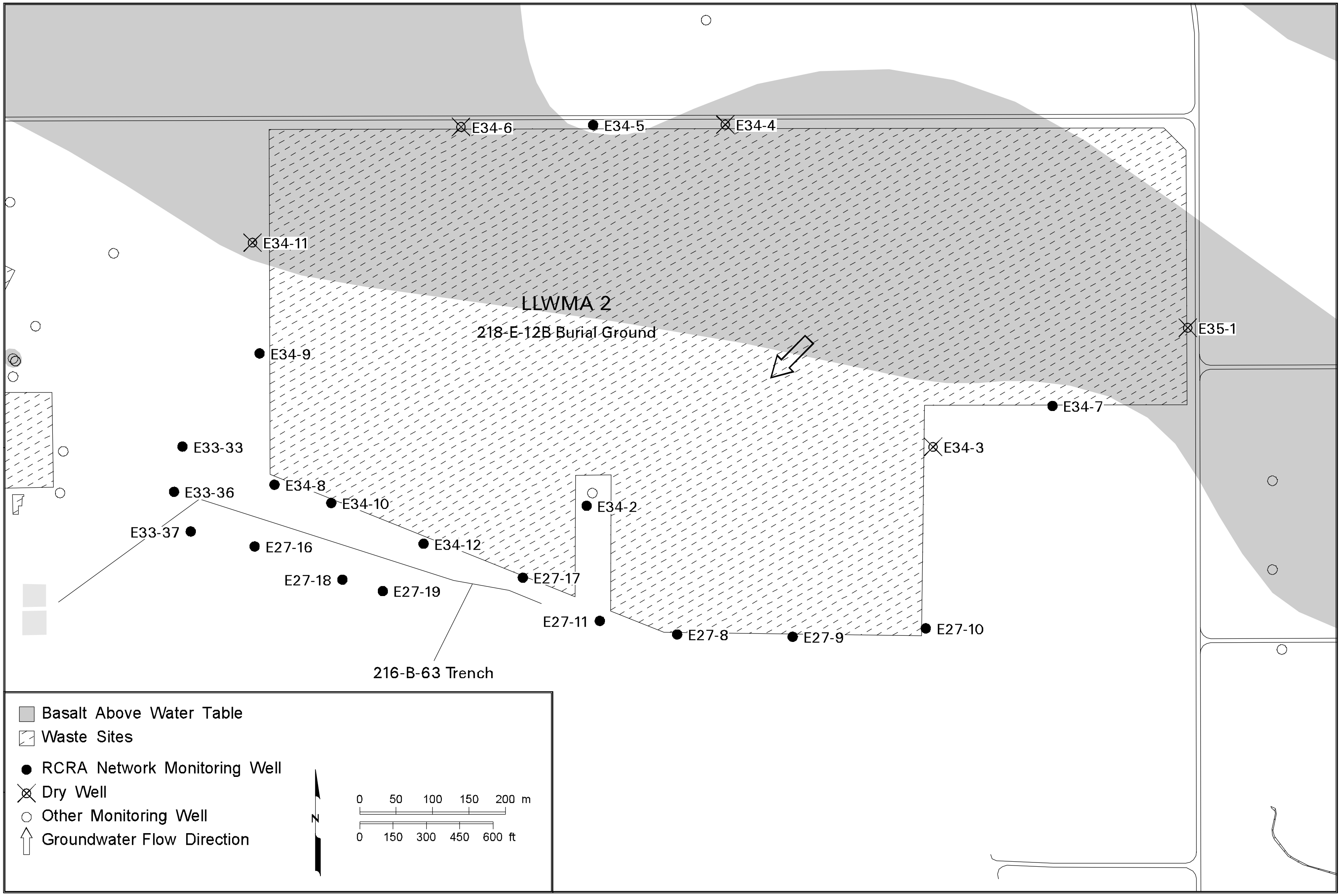
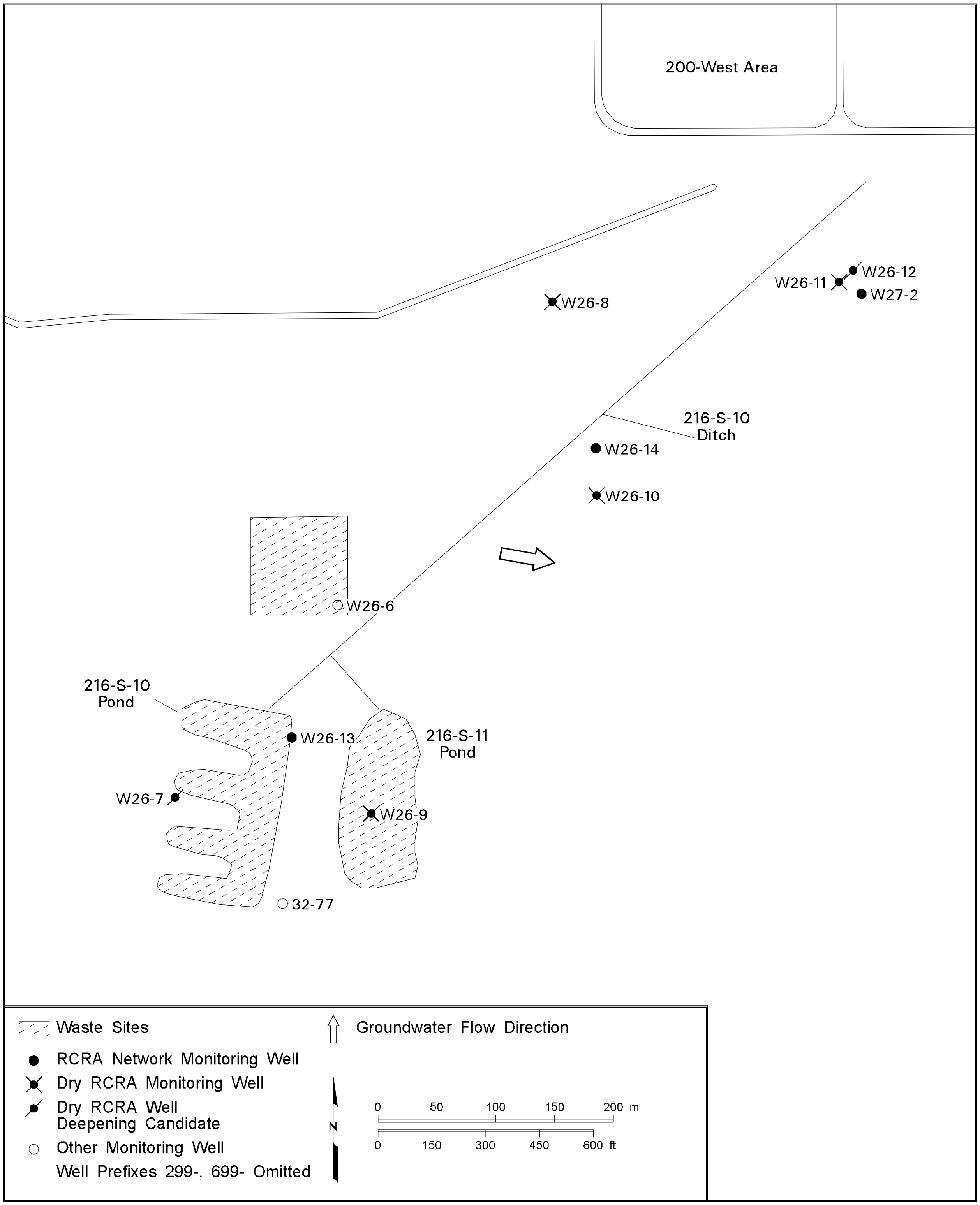
Figure B.5. Groundwater Monitoring Wells at the 216-B-3 Pond and 200 Area Treated Effluent Disposal Facility



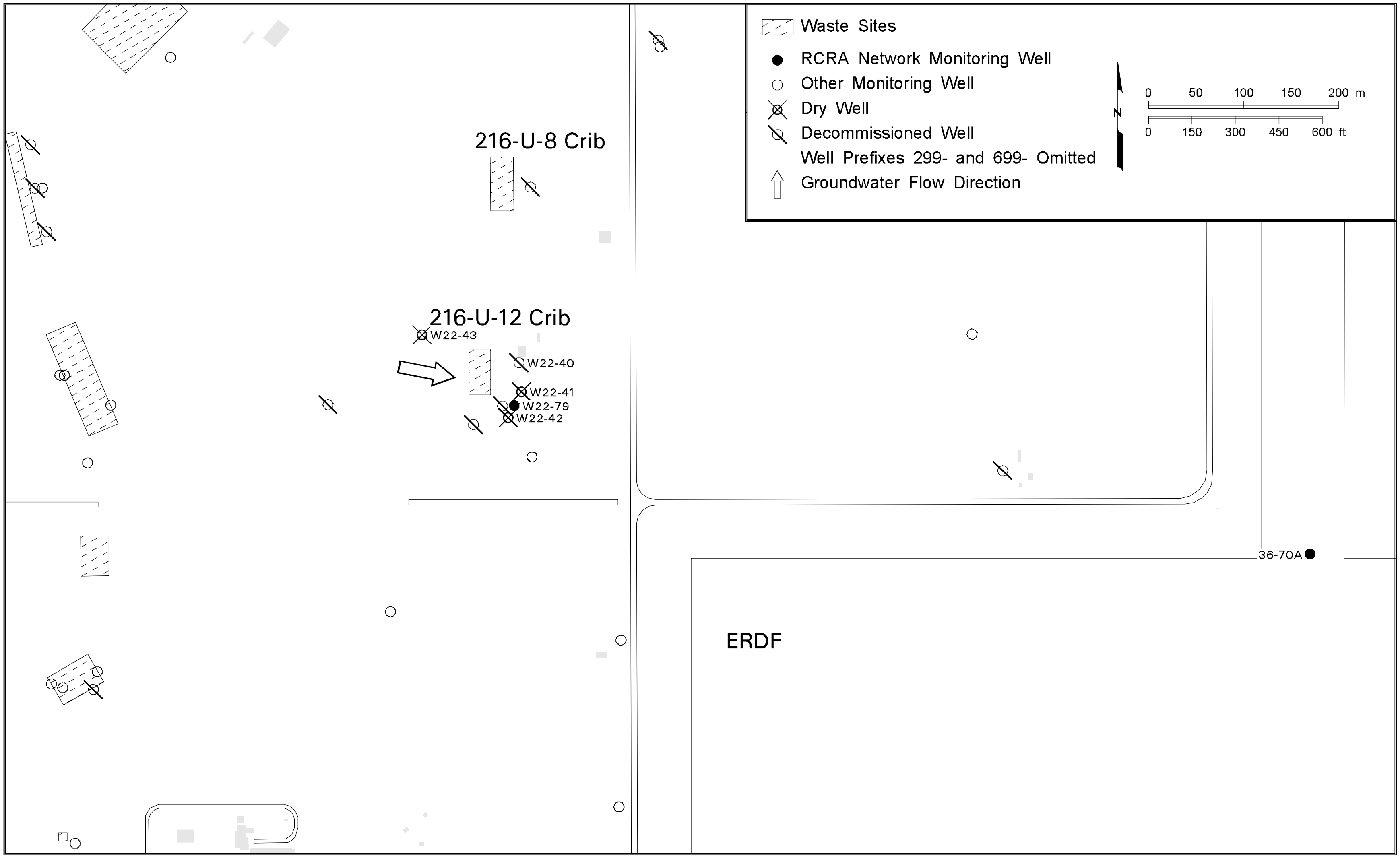
jpm_gwf04_616 February 02, 2005 9:18 AM

Figure B.6. Groundwater Monitoring Wells at the 216-B-63 Trench and Low-Level Waste Management Area 2



can_gwf04_617 February 12, 2005 10:00 AM

Figure B.7. Groundwater Monitoring Wells at the 216-S-10 Pond and Ditch



can_gwf04_618 February 12, 2005 10:03 AM

Figure B.8. Groundwater Monitoring Wells at the 216-U-12 Crib

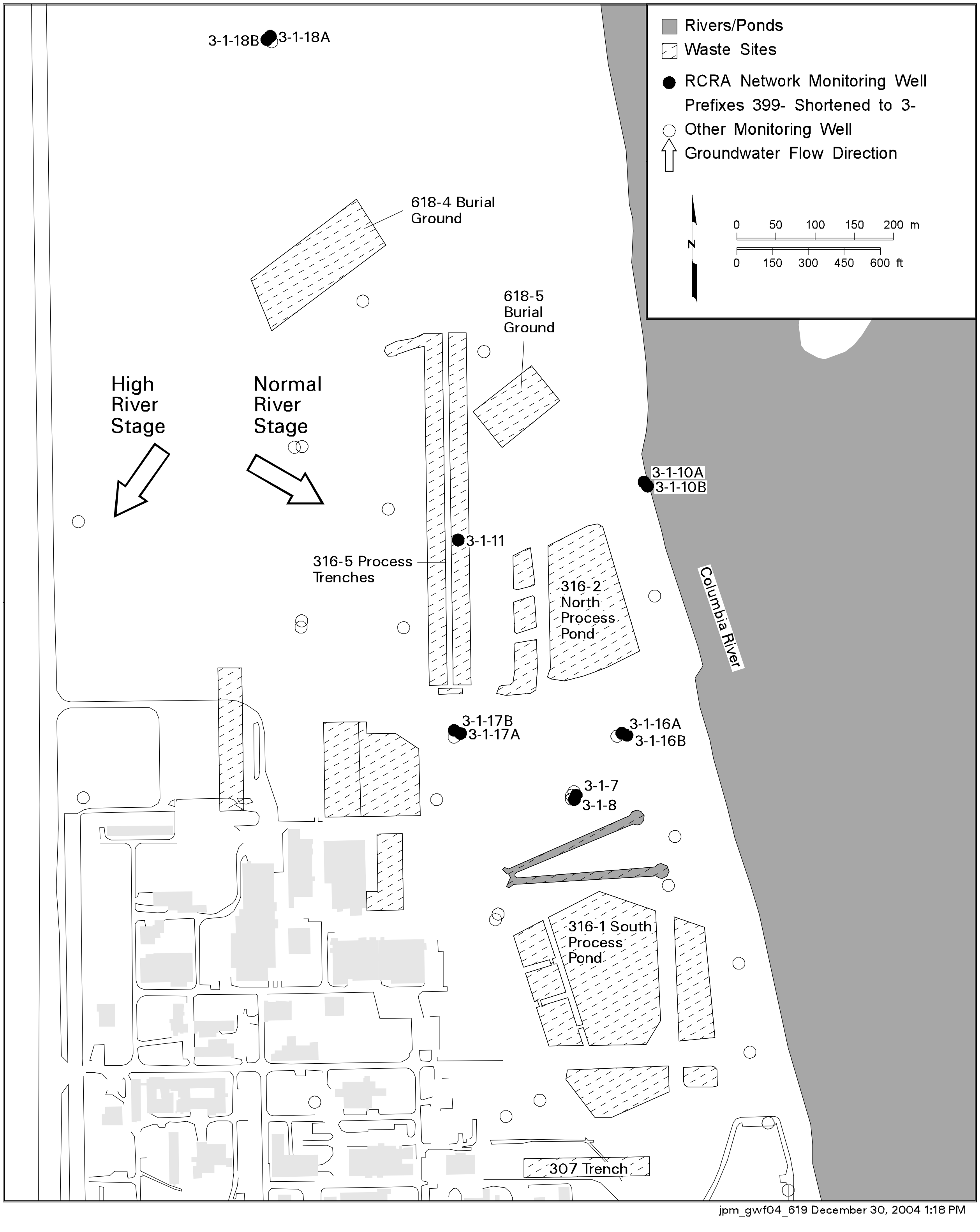
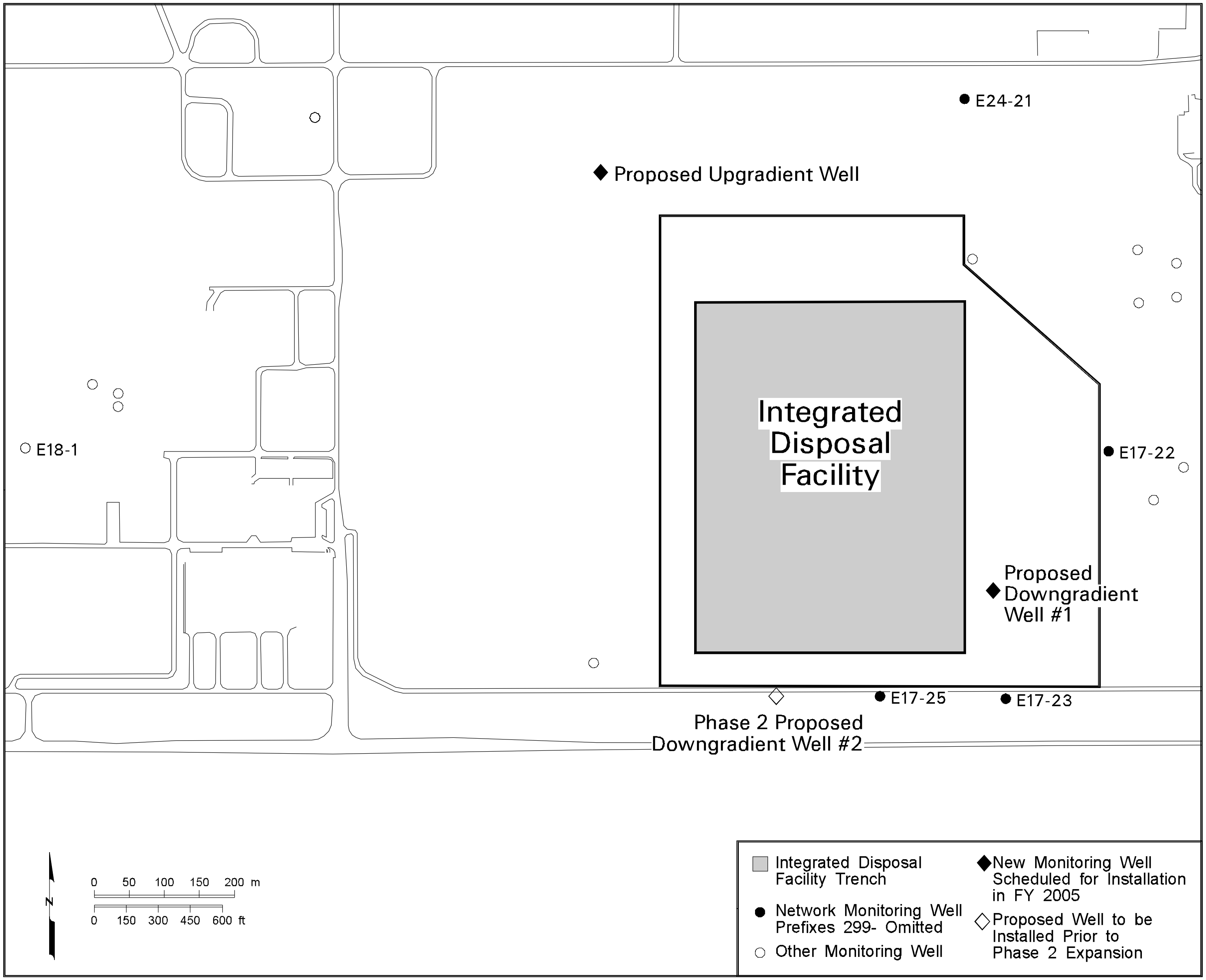
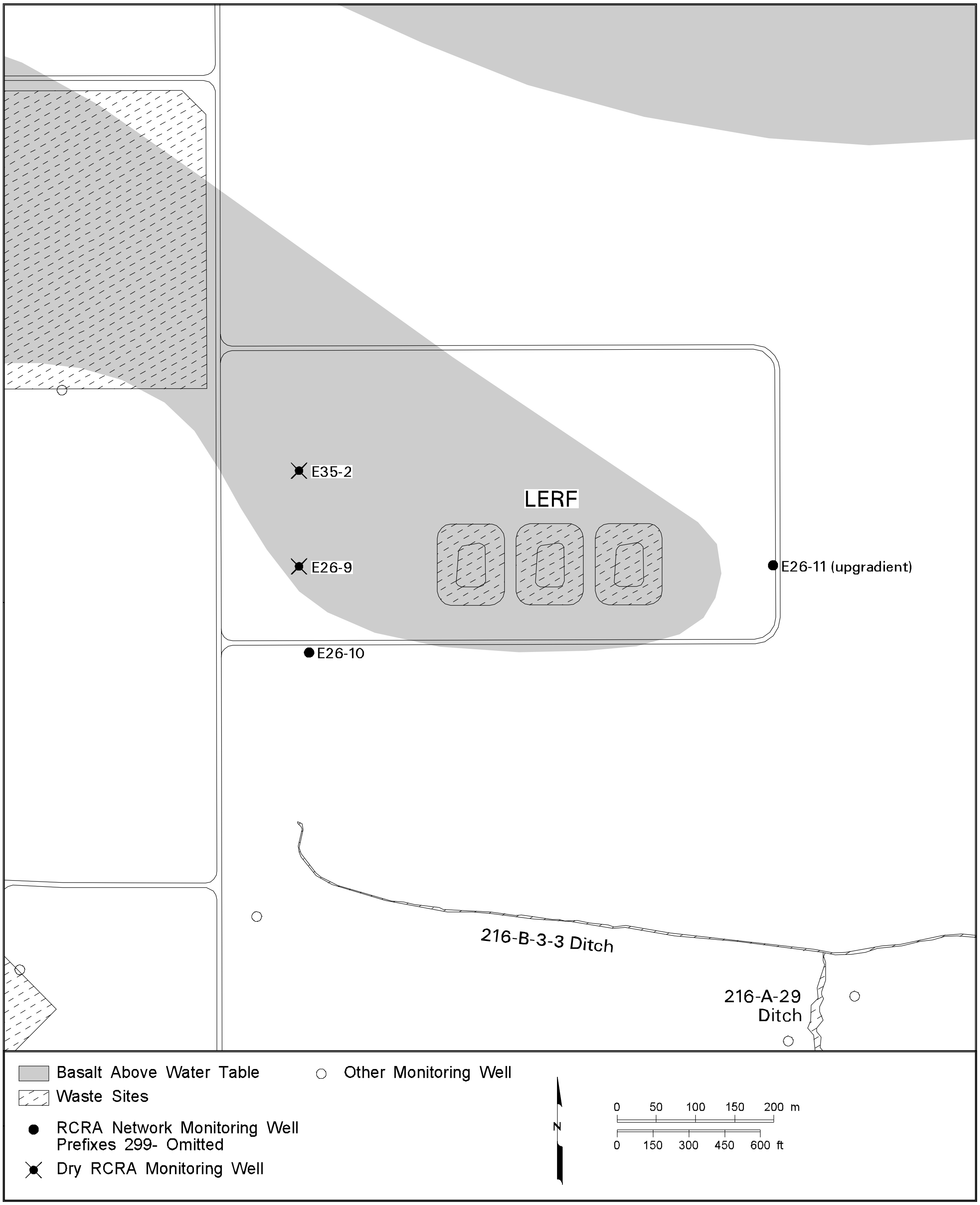


Figure B.9. Groundwater Monitoring Wells at the 316-5 Process Trenches



jpm_gwf04_620 January 05, 2005 5:41 PM

Figure B.10. Groundwater Monitoring Wells at the Integrated Disposal Facility



can_gwf04_621 February 14, 2005 8:15 AM

Figure B.11. Groundwater Monitoring Wells at the Liquid Effluent Retention Facility

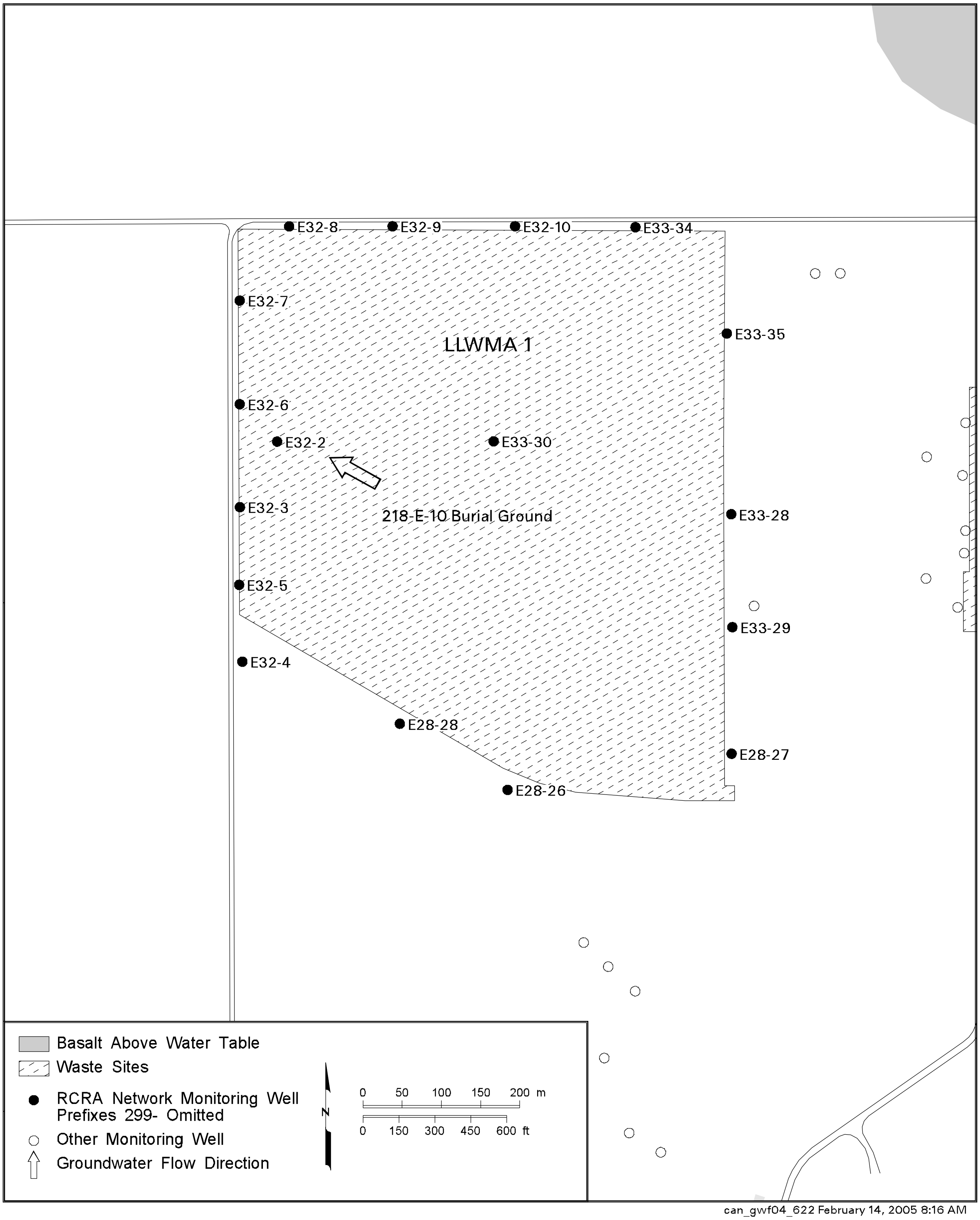
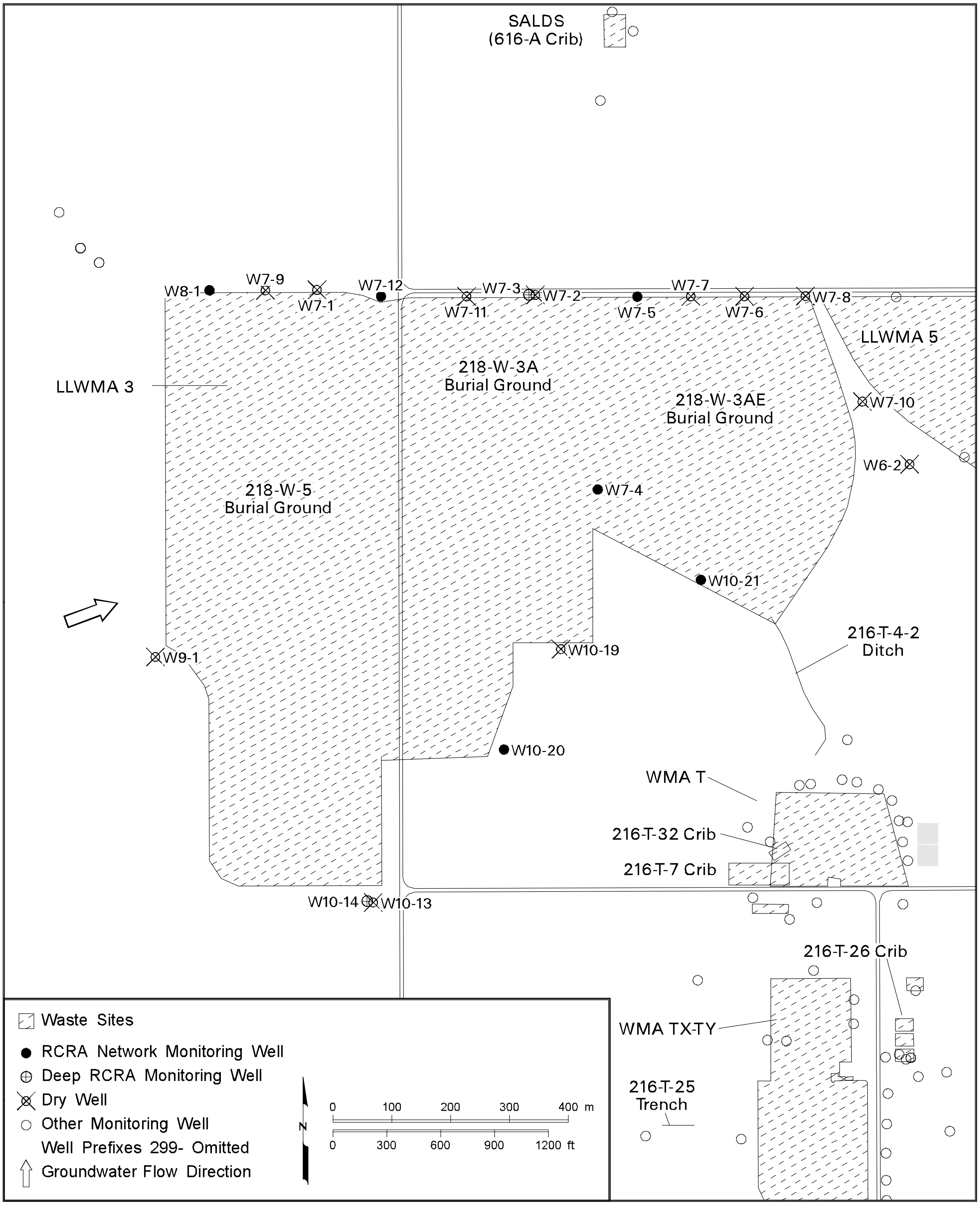
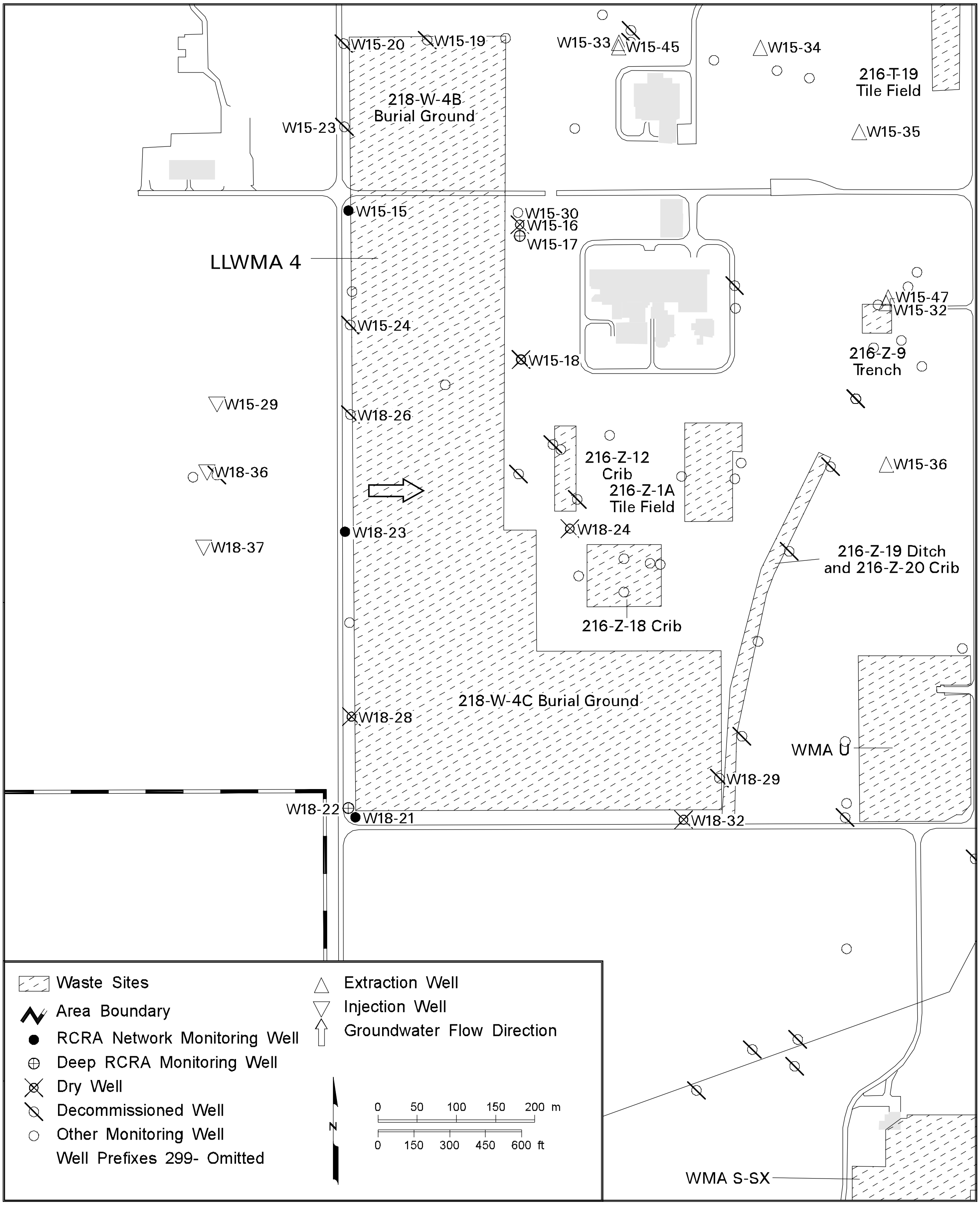


Figure B.12. Groundwater Monitoring Wells at Low-Level Waste Management Area 1



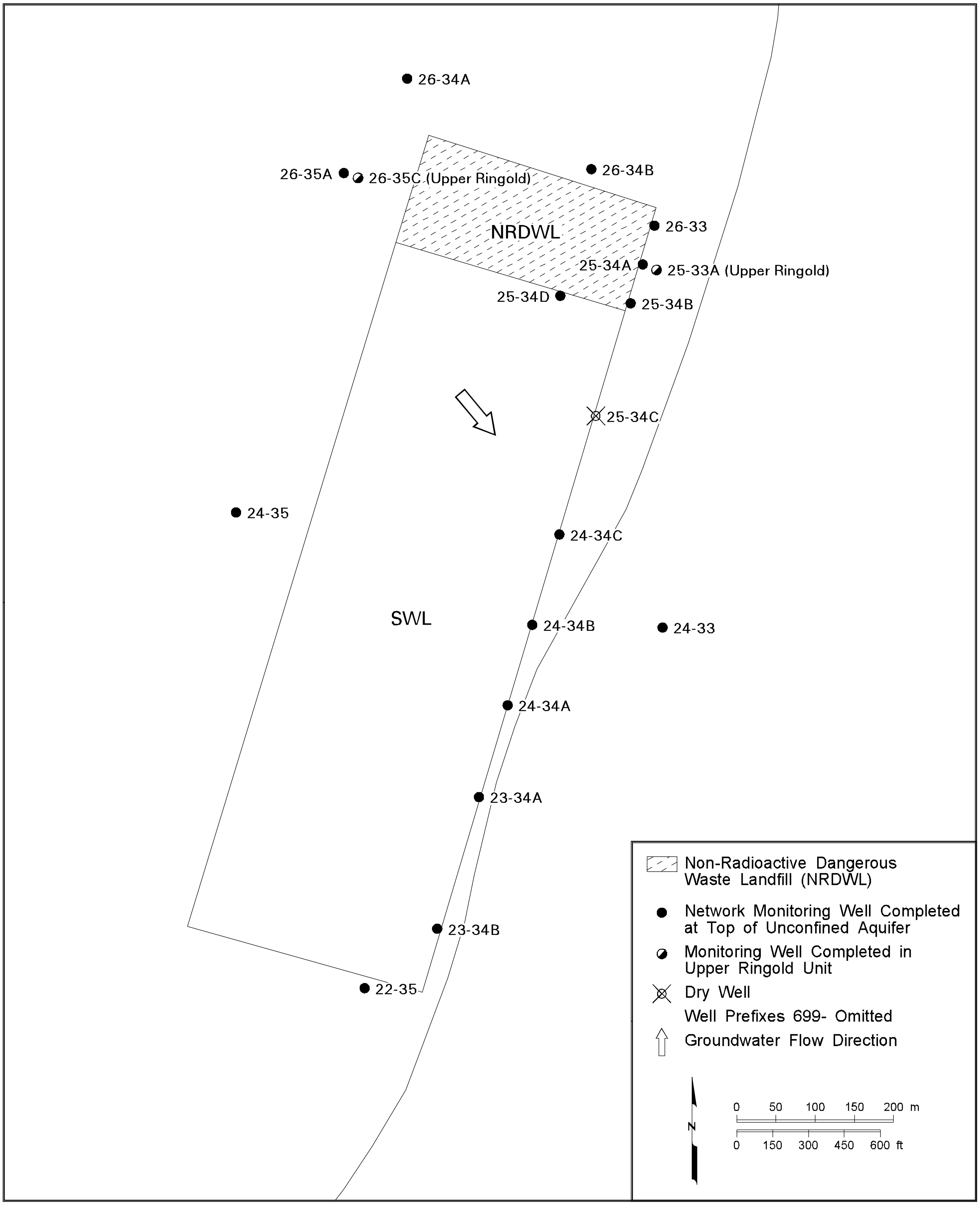
jpm_gwf04_623 February 02, 2005 9:19 AM

Figure B.13. Groundwater Monitoring Wells at Low-Level Waste Management Area 3



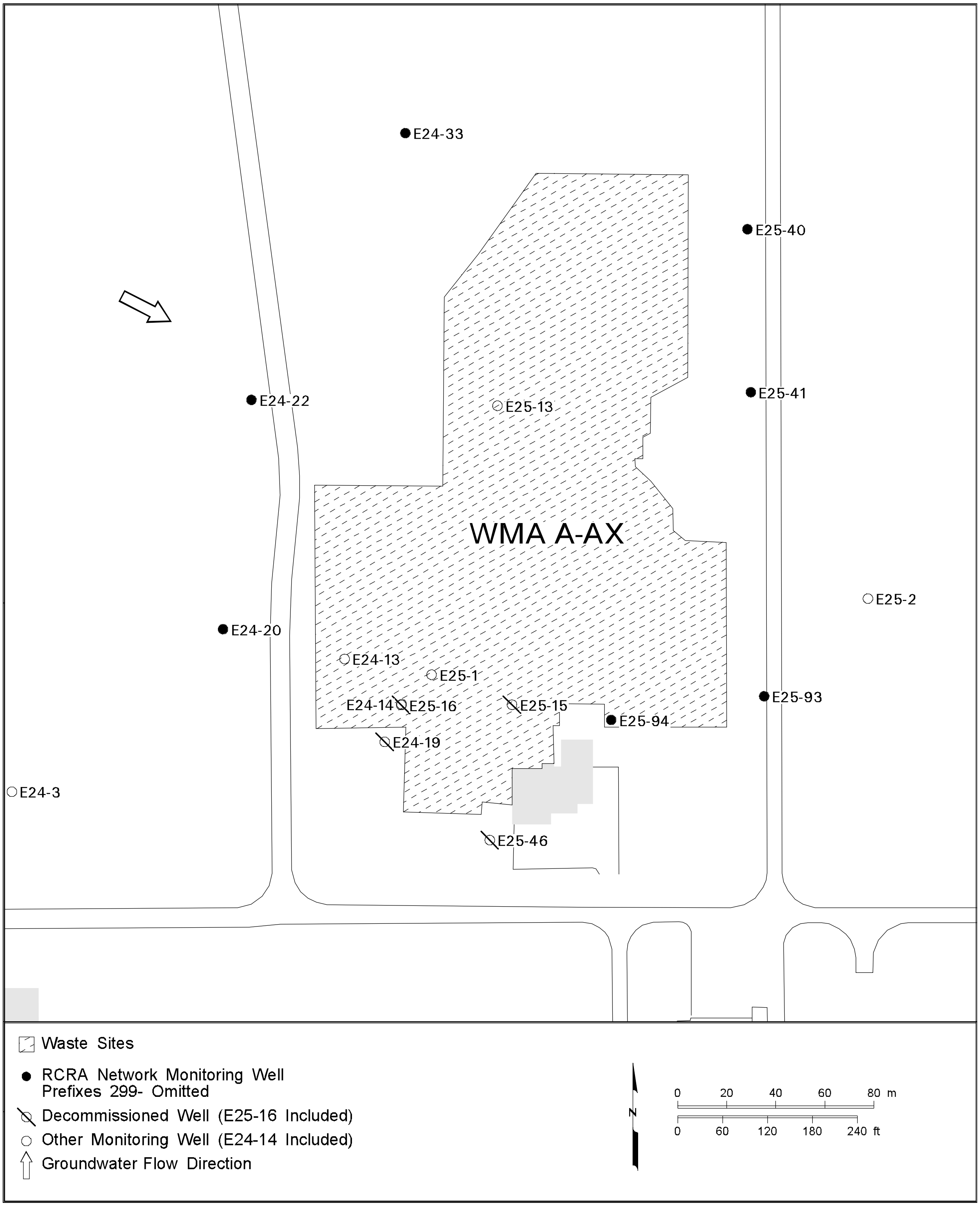
can_gwf04_624 February 17, 2005 4:03 PM

Figure B.14. Groundwater Monitoring Wells at Low-Level Waste Management Area 4



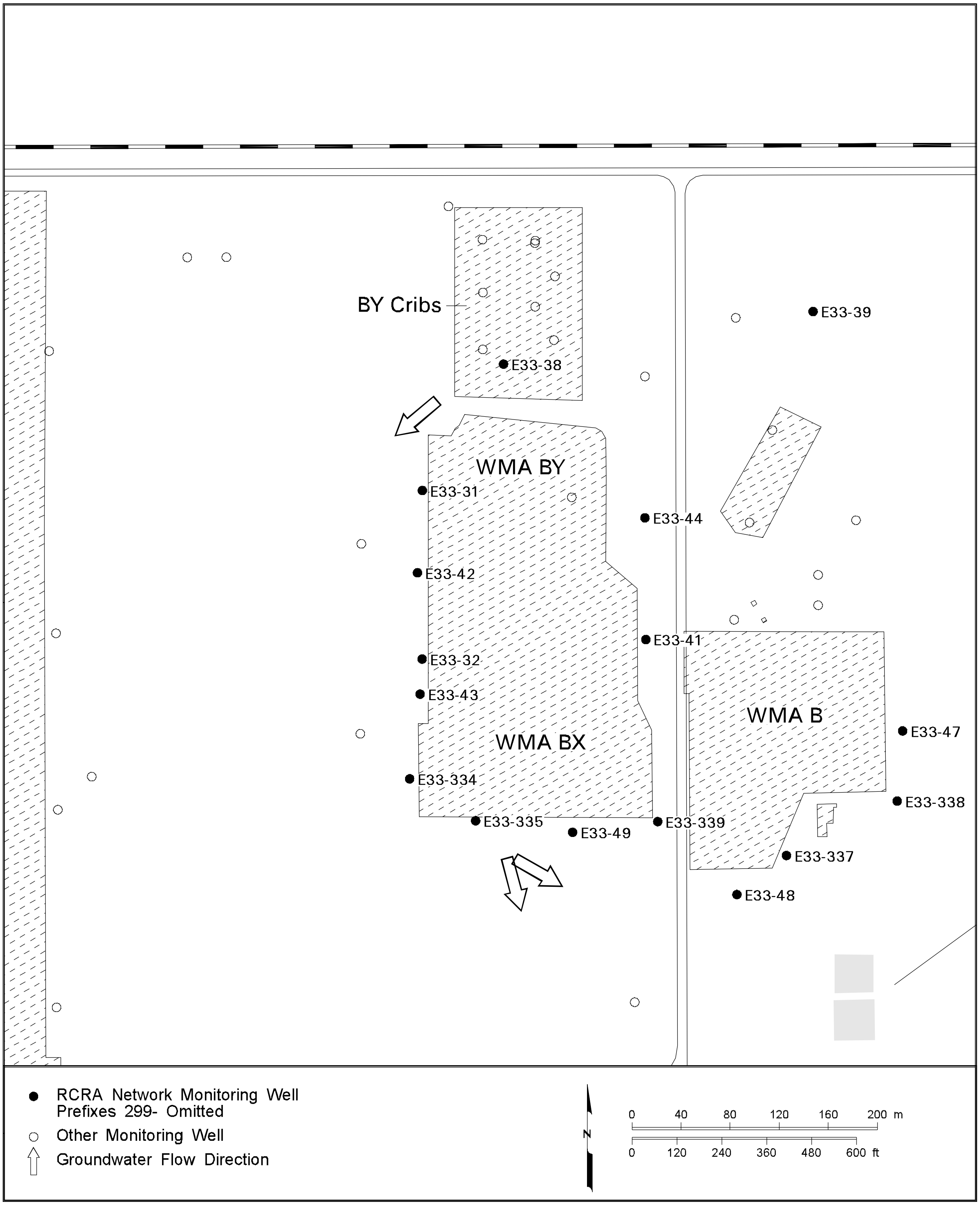
can_gwf04_625 February 14, 2005 3:01 PM

Figure B.15. Groundwater Monitoring Wells at the Nonradioactive Dangerous Waste Landfill



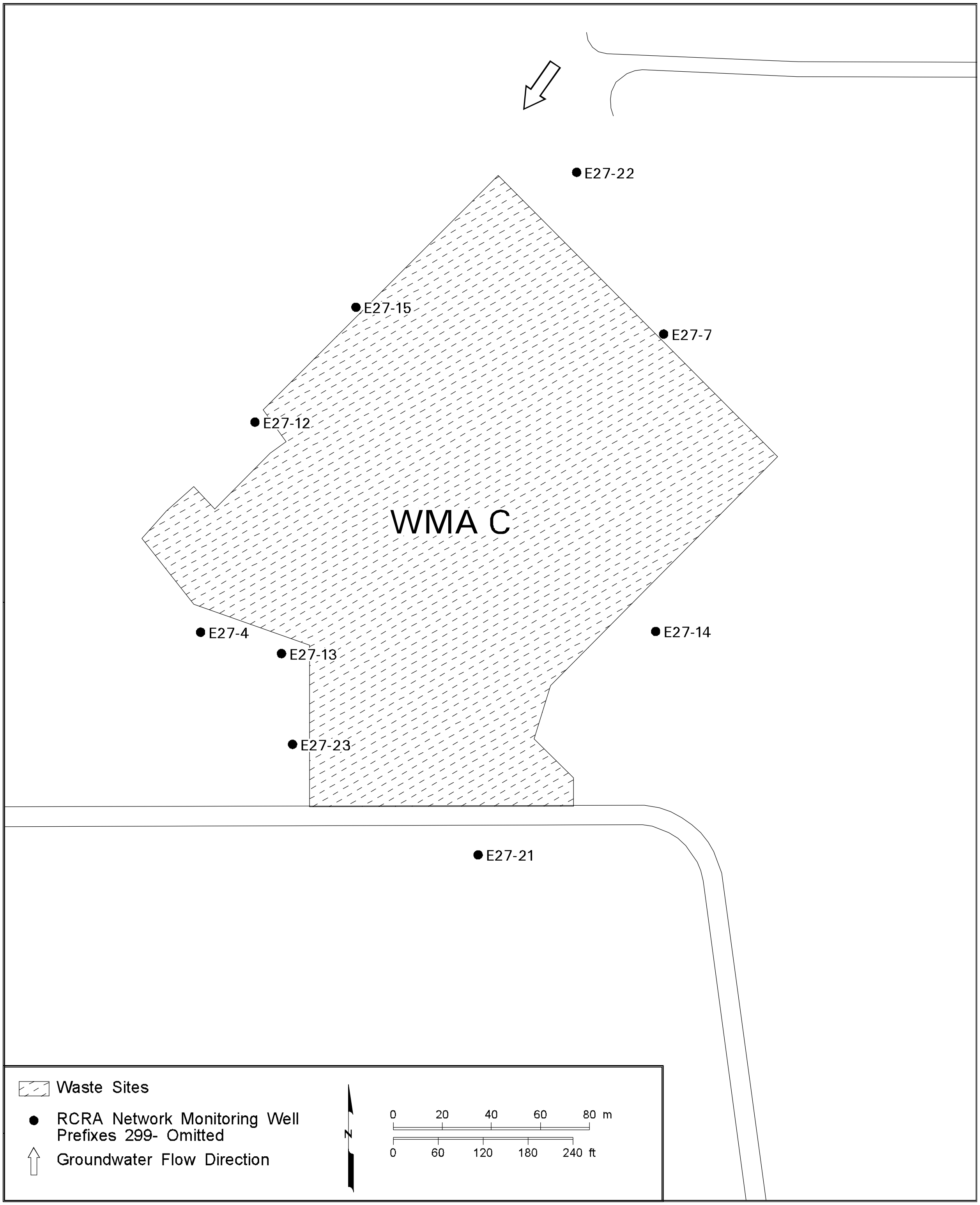
jpm_gwf04_626 February 02, 2005 9:48 AM

Figure B.16. Groundwater Monitoring Wells at Waste Management Area A-AX



can_gwf04_627 February 17, 2005 4:03 PM

Figure B.17. Groundwater Monitoring Wells at Waste Management Area B-BX-BY



can_gwf04_628 February 12, 2005 11:18

Figure B.18. Groundwater Monitoring Wells at Waste Management Area C

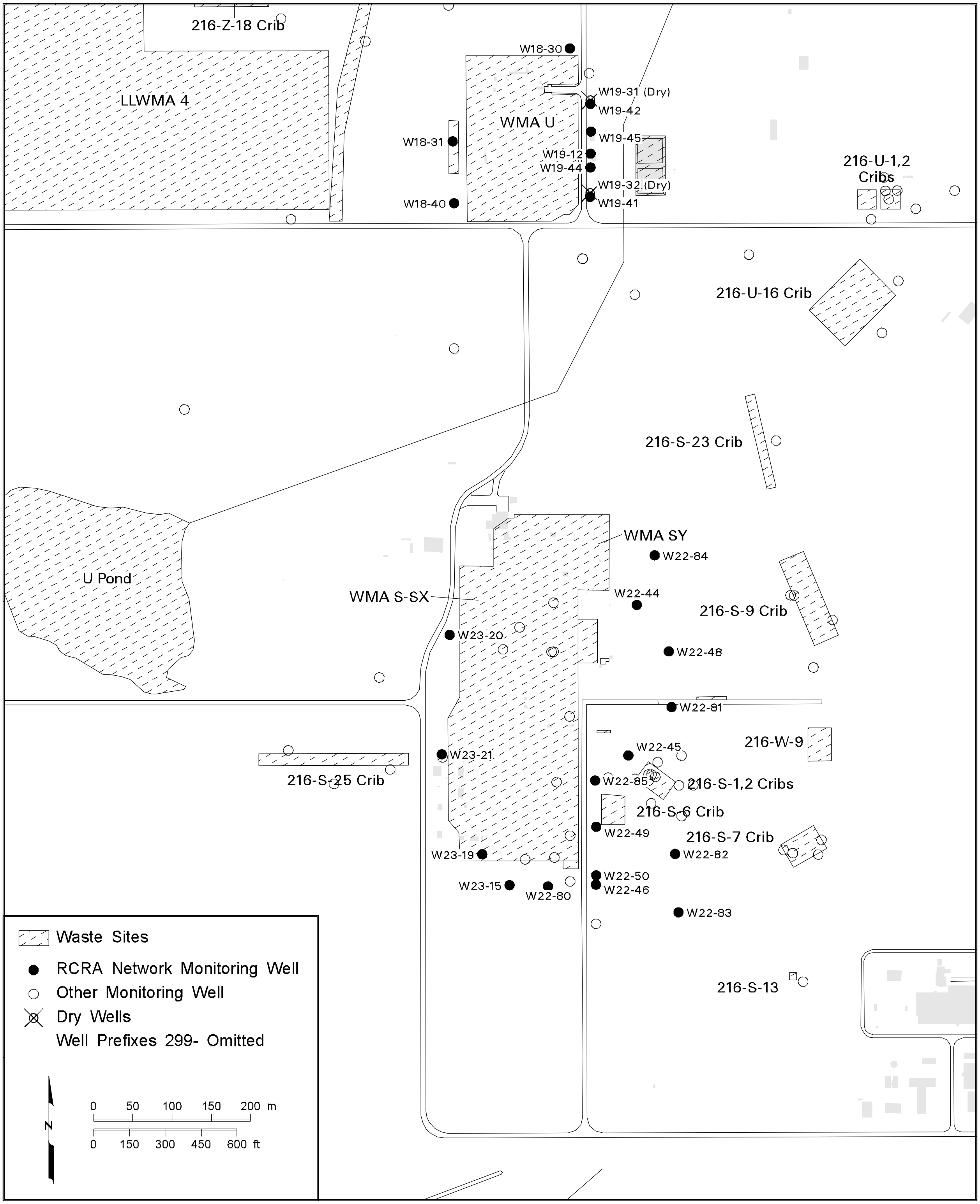
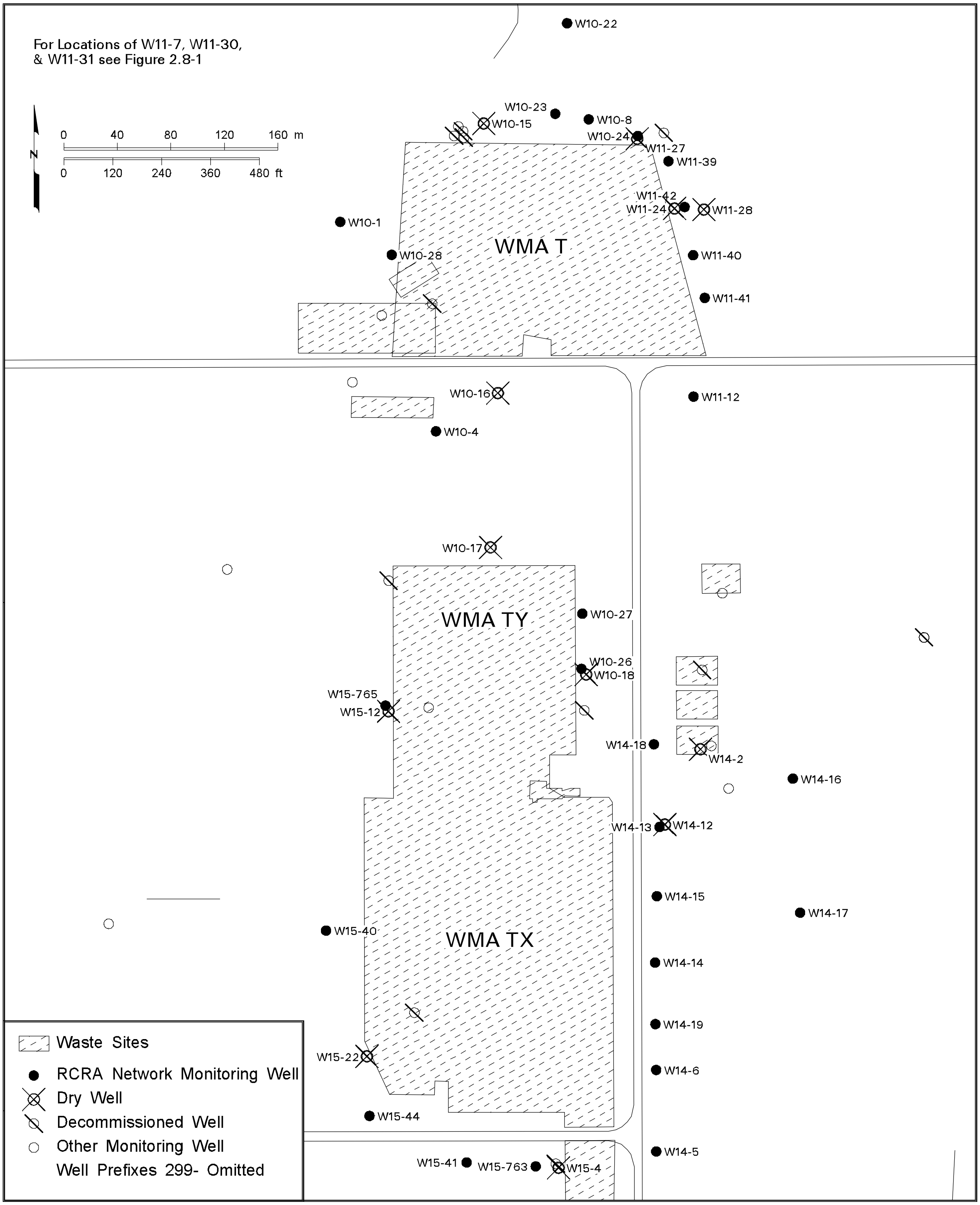


Figure B.19. Groundwater Monitoring Wells at Waste Management Areas S-SX and U



can_gwf04_630 February 12, 2005 11:49 AM

Figure B.20. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY

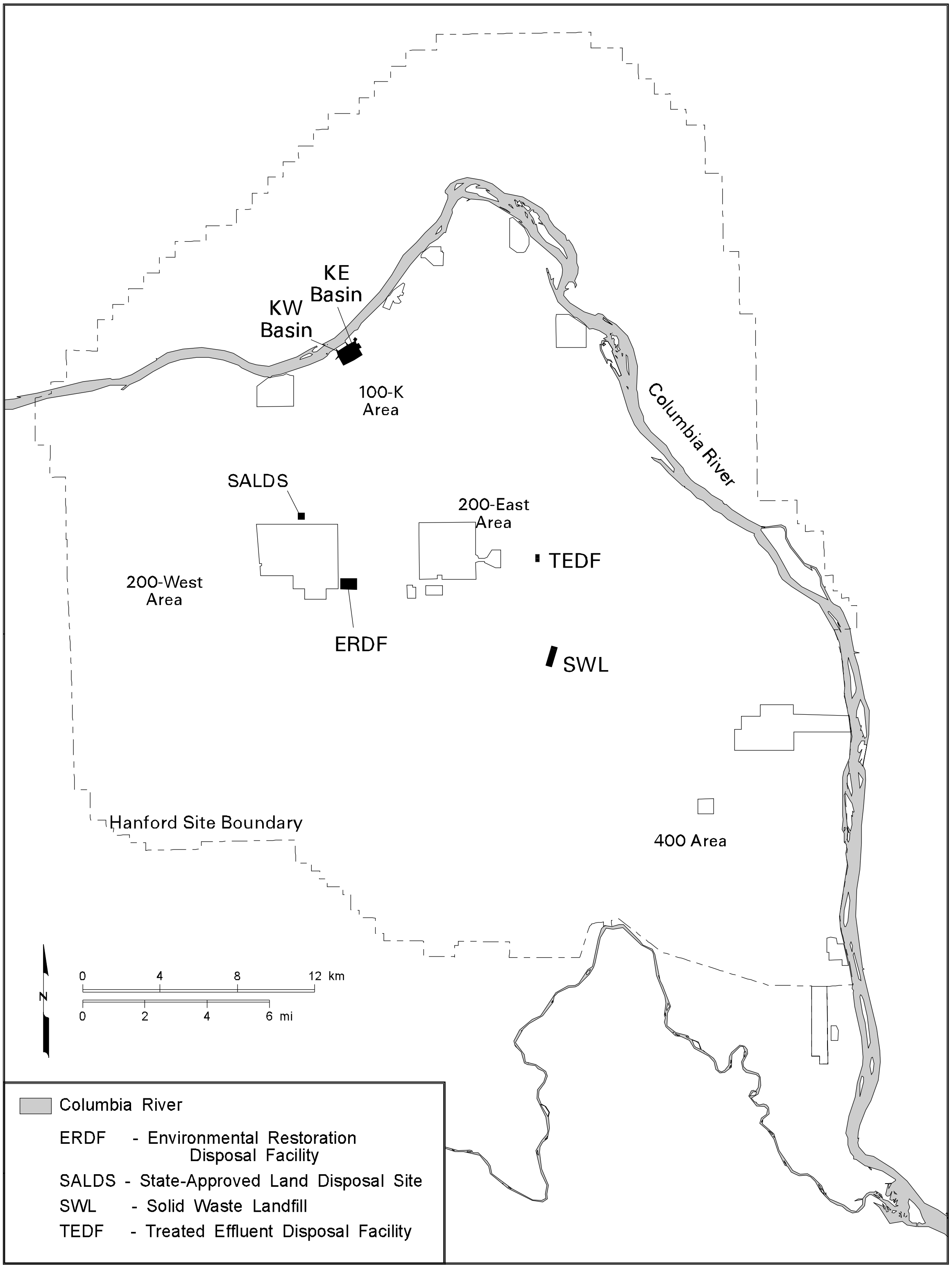
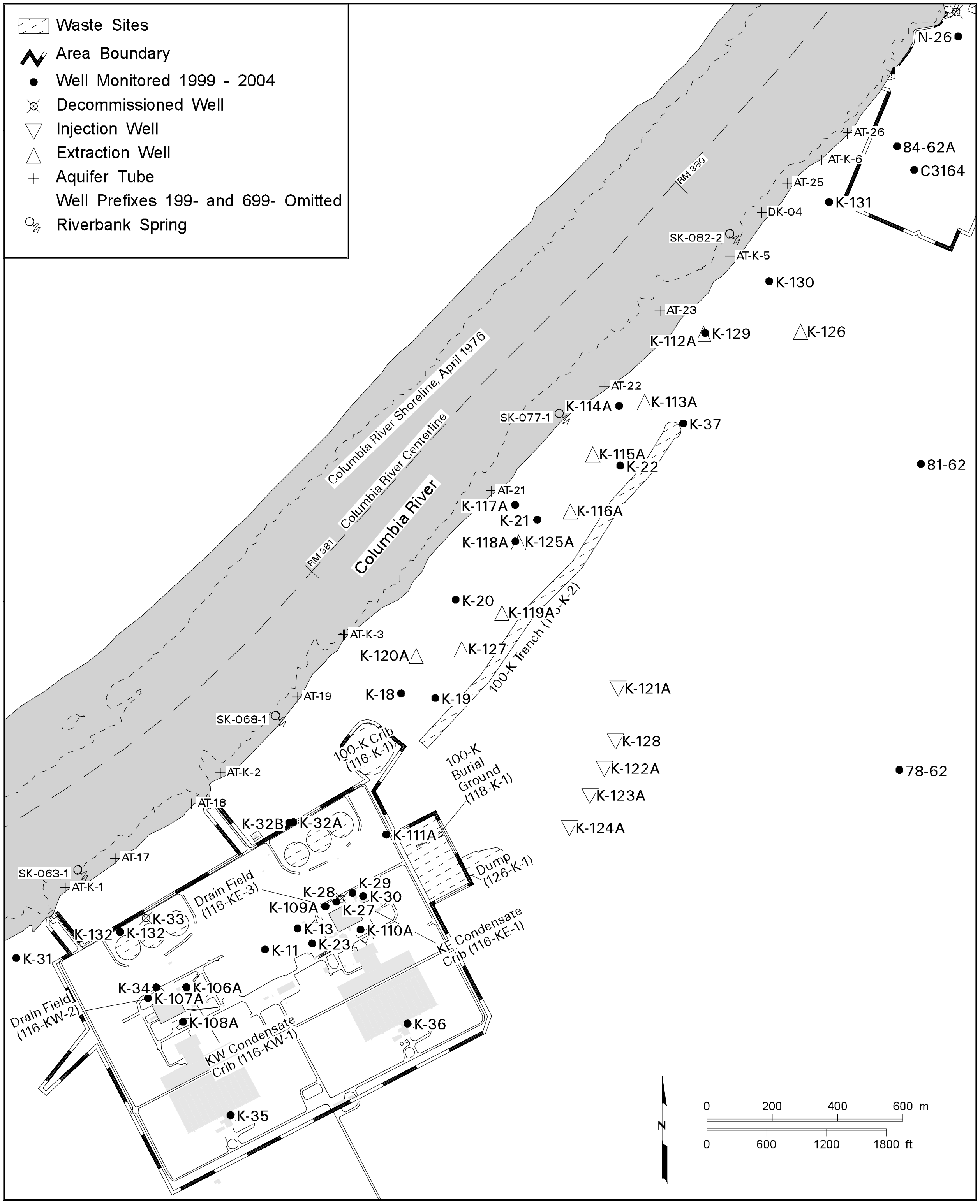
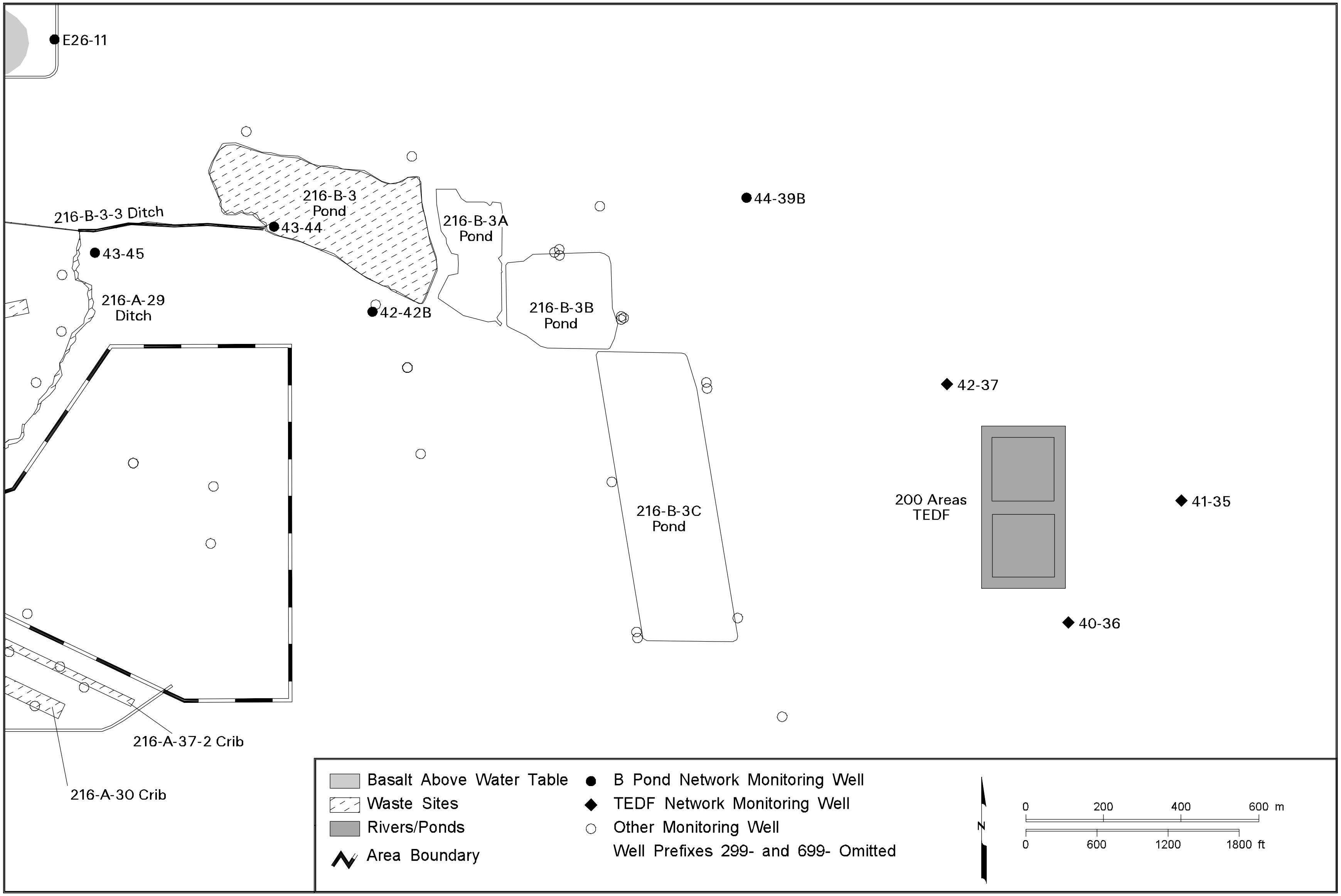


Figure B.21. Regulated Units (other than RCRA units) on the Hanford Site Requiring Groundwater Monitoring



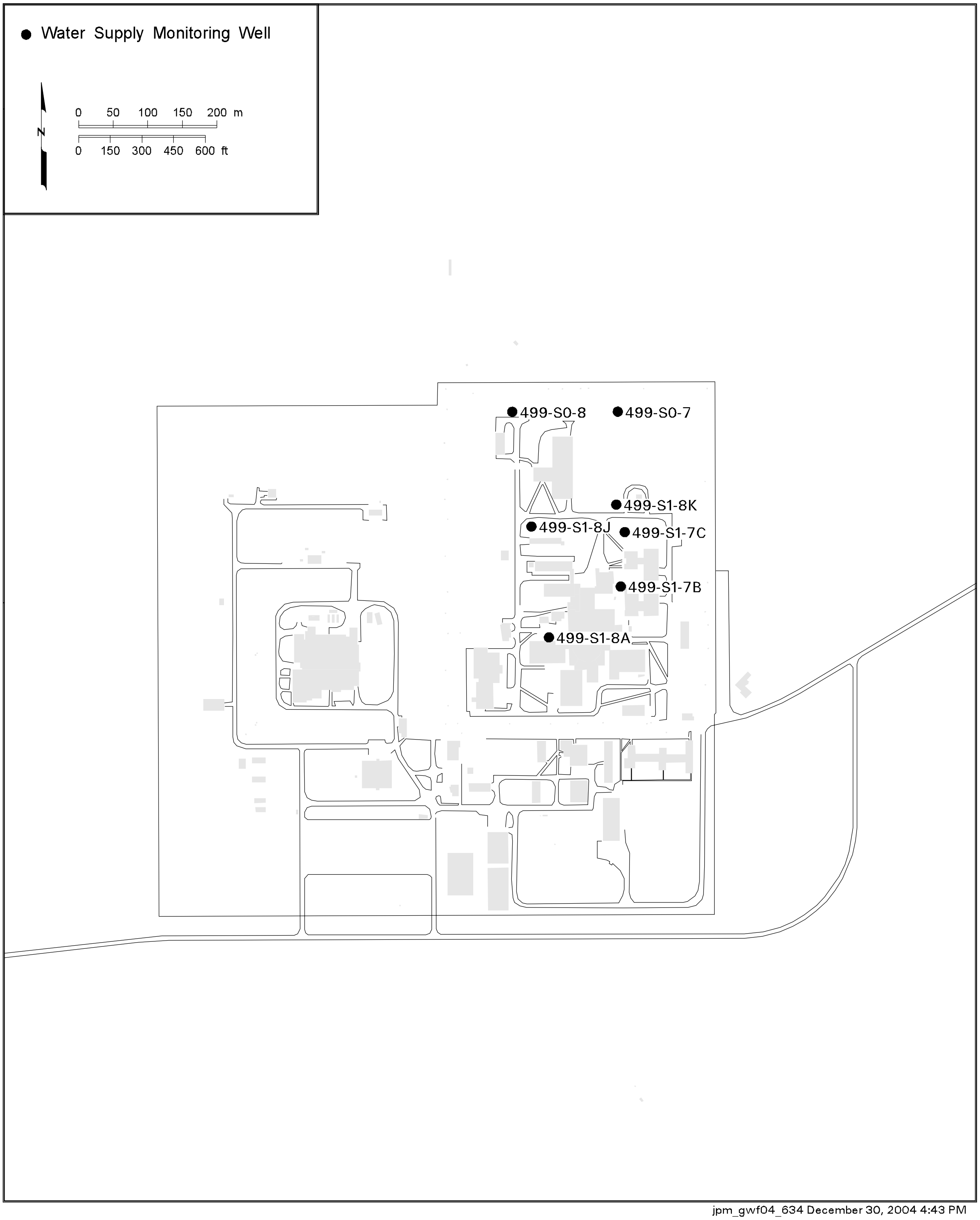
can_gwf04_632 February 28, 2005 8:52 AM

Figure B.22. Groundwater Monitoring Wells at 100-K Basins



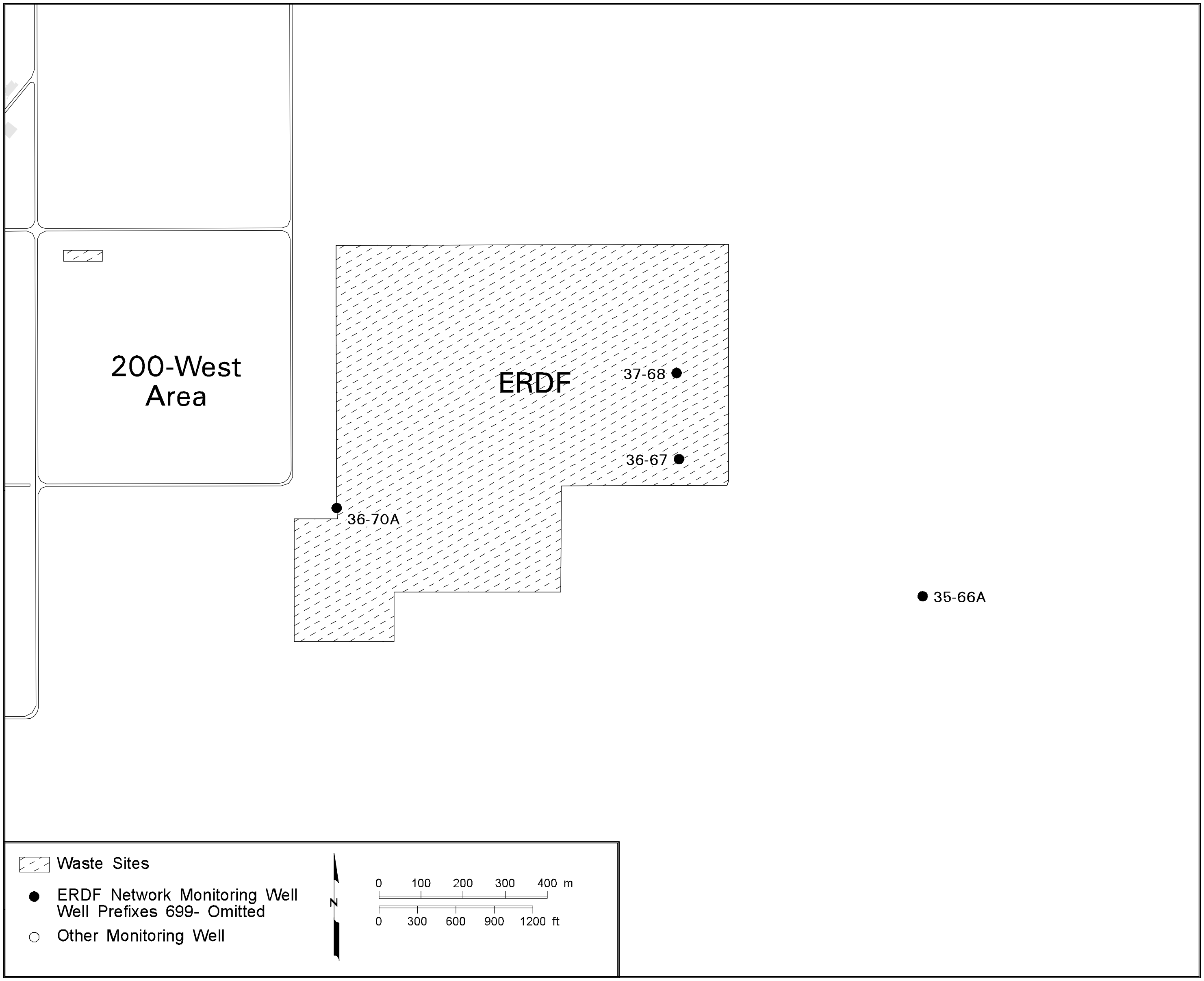
can_gwf04_633 February 22, 2005 7:00 AM

Figure B.23. Groundwater Monitoring Wells at the 200 Area Treated Effluent Disposal Facility



jpm_gwf04_634 December 30, 2004 4:43 PM

Figure B.24. Water-Supply Monitoring Wells in the 400 Area



can_gwf04_635 February 14, 2005 9:29 AM

Figure B.25. Groundwater Monitoring Wells at the Environmental Restoration Disposal Facility

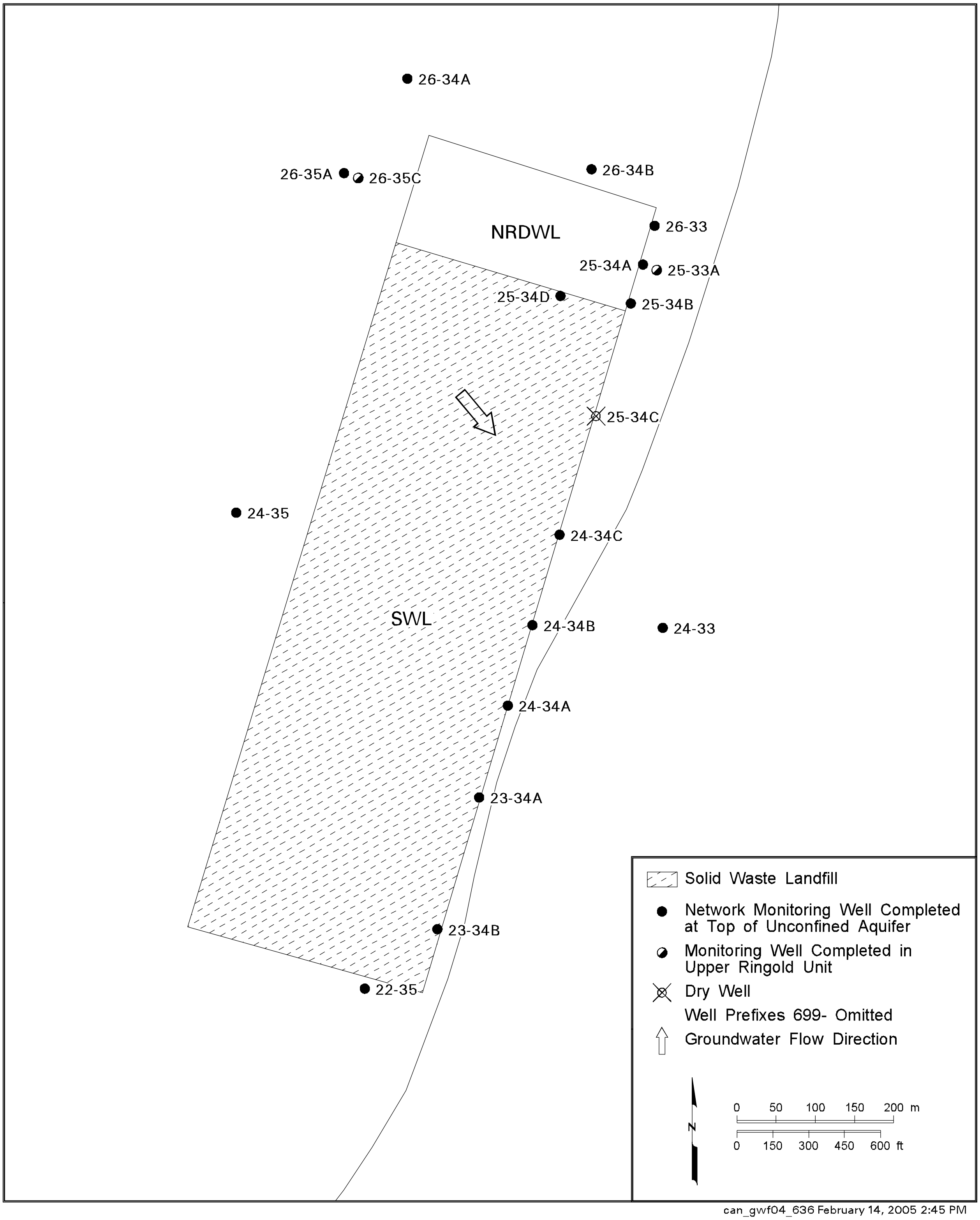
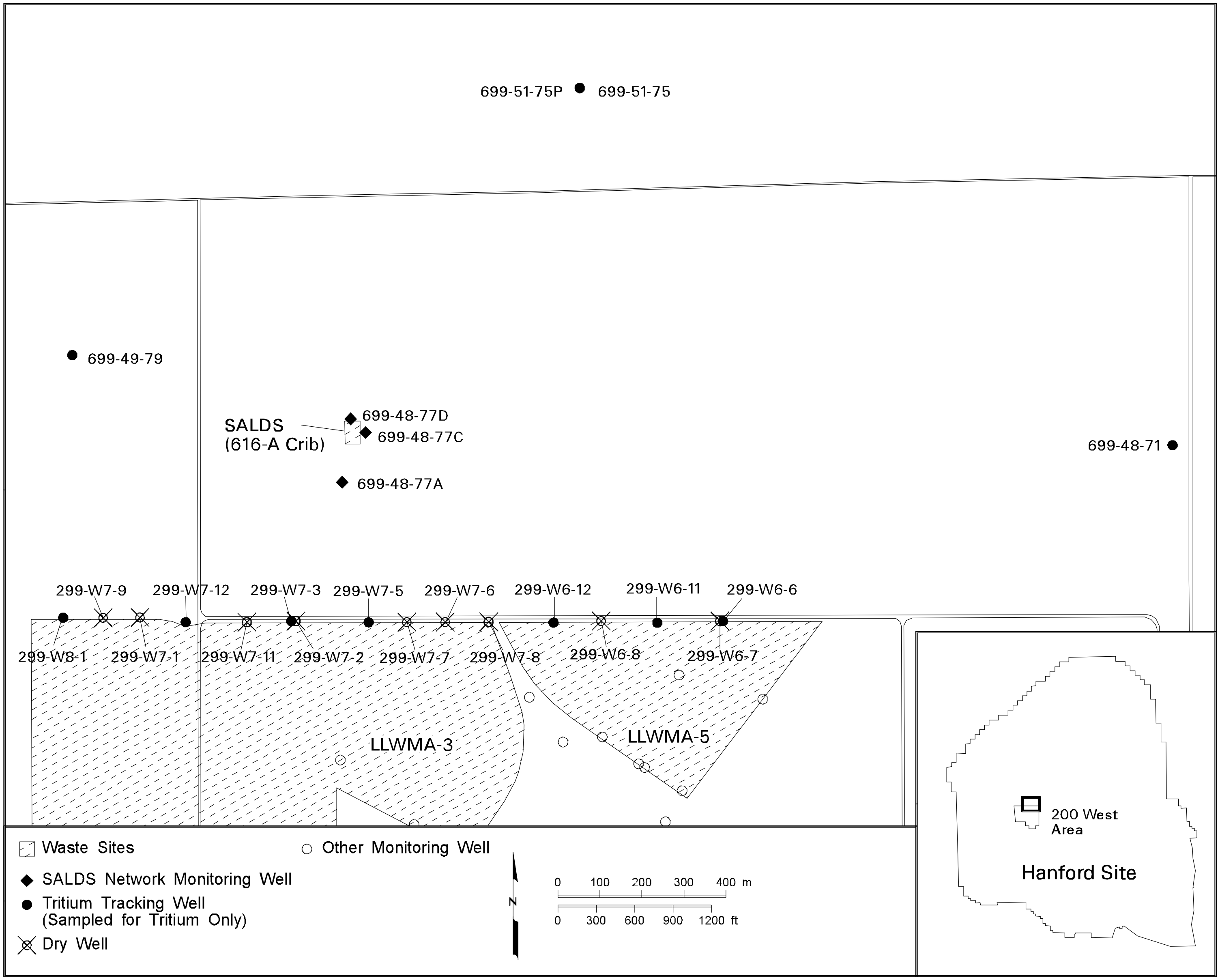


Figure B.26. Groundwater Monitoring Wells at the Solid Waste Landfill



jpm_gwf04_637 February 02, 2005 1:45 PM

Figure B.27. Groundwater Monitoring Wells at the State-Approved Land Disposal Site

Appendix C

Quality Assurance and Quality Control

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Tables

Appendix C

Quality Assurance and Quality Control

C. J. Thompson

This appendix presents fiscal year (FY) 2004 quality assurance/quality control (QA/QC) information for long-term and interim action groundwater monitoring at the Hanford Site. The phrase "long-term monitoring" refers to monitoring performed to meet the requirements of the *Resource Conservation and Recovery Act* (RCRA) and the *Atomic Energy Act of 1954* (AEA). Long-term monitoring also includes monitoring performed at *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) sites with no active groundwater remediation. Pacific Northwest National Laboratory (PNNL) manages long-term monitoring via the Groundwater Performance Assessment Project (groundwater project). Interim action monitoring encompasses monitoring at sites with active groundwater remediation under CERCLA. Fluor Hanford, Inc. provided oversight for interim action groundwater monitoring during FY 2004. For both categories of groundwater monitoring, PNNL managed sample scheduling, sample collection, analytical work, and entry of associated information into the Hanford Environmental Information System (HEIS) database (HEIS 1994).

The QA/QC practices used by the groundwater project assess and enhance the reliability and validity of field and laboratory measurements conducted to support these programs. Accuracy, precision, and detection are the primary parameters used to assess data quality (Mitchell et al. 1985). Representativeness, completeness, and comparability may also be evaluated for overall quality. These parameters are evaluated through laboratory QC checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind standards and blanks, and interlaboratory comparisons. Acceptance criteria have been established for each of these parameters. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence.

The QA/QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (EPA) (EPA 1986a [OSWER-9950.1] and 1986b [SW 846]). U.S. Department of Energy (DOE) Orders and internal requirements provide the guidance for the collection and analysis of samples for other long-term monitoring. The QA/QC practices for the groundwater project are described in the project-specific QA plan (PNNL-15014). Guidance for interim action monitoring QA/QC practices is provided in project-specific documents (e.g., DOE/RL-90-08; DOE/RL-91-03; DOE/RL-91-46; DOE/RL-92-76; DOE/RL-96-07; DOE/RL-96-90; DOE/RL-97-36; DOE/RL-2002-10; DOE/RL-2002-17). A glossary of QA/QC terms is provided in PNNL-13080. Additional information about the QA/QC program and FY 2004 data (e.g., results of individual QC samples and/or associated groundwater samples) is available on request.

C.1 Sample Collection and Analysis

C. J. Thompson and D. L. Stewart

Duratek Federal Services, Inc. conducted groundwater sampling for FY 2004. Their tasks included bottle preparation, sample set coordination, field measurements, sample collection, sample shipping, well pumping, and coordination of purgewater containment and disposal. Duratek's statement of work[a] defines quality requirements for sampling activities. Groundwater project staff review all sampling procedures before the procedures are implemented.

Groundwater project staff periodically reviewed sample collection activities performed by nuclear chemical operators from Fluor Hanford, Inc. under the supervision of Duratek Federal Services, Inc. The purpose of the surveillances was to ensure that samples were collected and submitted to the laboratories in accordance with high-quality standards. Nine surveillances were conducted in the following areas: bottle preparation; sample packaging, shipping, and storage; measurement of groundwater levels; sample collection (two events); water-purification system maintenance;

(a) SOW-409744-A-B3. 2001. Statement of Work between Pacific Northwest National Laboratory and Duratek Federal Services, Inc., Richland, Washington.

decontamination of sampling equipment; training and associated documentation; and quality records management and storage. A few minor procedural deviations were identified. Corrective actions for all of these surveillances have been received and accepted. Three surveillances remain open pending completion of the corrective actions.

During FY 2004, Severn Trent Laboratories, Incorporated, St. Louis, Missouri (STL St. Louis), performed most of the routine analyses of Hanford groundwater samples for hazardous and non-hazardous chemicals. Lionville Laboratory, Incorporated, Lionville, Pennsylvania (Lionville Laboratory), served as a secondary laboratory for chemical analyses of split samples and blind standards.

Severn Trent Laboratories, Incorporated, Richland, Washington (STL Richland) performed the majority of radiological analyses on Hanford groundwater samples. Eberline Services, Richmond, California, also analyzed samples for radiological constituents.

Standard methods from EPA and American Society for Testing and Materials (ASTM) were used for the analysis of chemical constituents. Methods employed for radiological constituents were developed by the analyzing laboratories and are recognized as acceptable within the radiochemical industry. Descriptions of the analytical methods used are provided in PNNL-13080.

C.2 Data Completeness

C. J. Thompson

Data judged to be complete are data that are not suspect, rejected, associated with a missed holding time, out-of-limit field duplicate or field blank, or qualified to indicate laboratory blank contamination. During FY 2004, 87% of the groundwater data (both long-term and interim action monitoring) were considered complete. The percentages of potentially invalid data were 1.4% for field QC problems, 1.9% for exceeded holding times, 0.0% for rejected results, 0.2% for suspect values, and 9.1% for laboratory blank contamination. These values are similar to the percentages observed in FY 2003.

C.3 Field Quality Control Samples

D. S. Sklarew, S. J. Trent, and C. J. Thompson

Field QC samples include field duplicates, split samples, and three types of field blanks. The three types of field blanks are full trip, field transfer, and equipment blanks. Field duplicates are used to assess sampling and measurement precision. Split samples are used to confirm out-of-trend results and for interlaboratory comparisons. Field blanks provide an overall measure of contamination introduced during the sampling and analysis process.

C.3.1 Long-Term Monitoring (Groundwater Performance Assessment Project)

The groundwater project's criteria for evaluating the analytical results of field QC samples are as follows:

- field duplicates – Results of field duplicates must have precision within 20%, as measured by the relative percent difference. Only those field duplicates with at least one result greater than five times the method detection limit or minimum detectable activity are evaluated.
- split samples – Results must have a relative percent difference <20%. Only those results that are greater than five times the method detection limit or minimum detectable activity at both laboratories are evaluated.
- field blanks – For most chemical constituents, results above two times the method detection limit are identified as suspected contamination. However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the method detection limit. Results for metals are flagged if they exceed two times the instrument detection limit. For radiological data, blank results are flagged if they are greater than two times the total minimum detectable activity.

If a field blank does not meet the established criteria, it is assumed that there are potential problems with the data for all associated samples. For full-trip and field-transfer blanks, an associated sample is one that was collected on the same day and analyzed by the same method as a full-trip or field-transfer blank. For equipment blanks, an associated sample is one that has all of the following in common with an equipment blank:

- collection date
- collection method/sampling equipment
- analysis method

Data associated with out-of-limit field blanks are flagged with a Q in the database to indicate a potential contamination problem. A Q is also applied to both duplicate results when their precision exceeds the QC limits.

The percentages of acceptable field blank (4,015/4136 = 97%) and duplicate (4383/4408 = 99%) results evaluated in FY 2004 were high, indicating little problem with contamination and good precision overall. A limited number of split samples were collected during the year; the analyzing laboratories demonstrated reasonable agreement.

Tables C.1 through C.4 summarize the field blank and field duplicate results that exceeded QC limits. To assist with their evaluation, the tables are divided into the following categories, where applicable: general chemical parameters, ammonia and anions, metals, volatile organic compounds, semivolatile organic compounds, and radiological parameters. Constituents not listed in the tables had 100% acceptable field blanks and/or field duplicates.

With the exception of semivolatile organic compounds, all classes of constituents had results that were flagged as potentially contaminated because of out-of-limit field blank results. A few constituents such as chloride, sodium, and sulfate had several quantifiable field blank results, but the concentrations were much lower than the levels of these constituents in almost all groundwater samples.

Compared to FY 2003, the number of field blank results for chloride and fluoride that exceeded the QC limits decreased significantly.

Twelve field blanks results for metals exceeded the QC limits, which is considerably fewer than last year. In general, the blank concentrations were similar to those from last year. Most of the unacceptable results were within a factor of 5 of the instrument detection limits. All of the metals with out-of-limit field blank results had one or more comparable method-blank results, suggesting that some of the elevated field blank values were caused by false detections or laboratory contamination.

Concentrations of eight volatile organic compounds exceeded the QC limits in one or more field blanks. Methylene chloride was the predominant volatile contaminant, accounting for 65% of the out-of-limit results. Levels of acetone were also out-of-limits in twelve field blanks. Laboratory contamination is the suspected source of these common contaminants, because similar concentrations also were measured in several method blanks. Trace levels of several other volatile organic compounds also were measured in field blanks (Tables C.1 through C.3). All these compounds had low frequencies of detection (i.e., <5%) in field blanks, and the overall impact on the data is minor.

Gross beta, tritium, and uranium were the only radiological constituents with out-of-limit field blank results. Although their field blank concentrations were low, they were greater than levels of these constituents in some of the associated groundwater samples. Tritium and uranium were measured in one or more laboratory method blanks at concentrations similar to the field blank values.

Duplicate results were flagged for all constituent classes except general chemistry parameters (Table C.4). Overall, the relative number of flagged duplicate results was very low (<1%), but the percentages of unacceptable results were high for several constituents based on the number of duplicates that met the evaluation criteria. Most of the associated samples in the radiological parameters category were unfiltered; thus, suspended solids in heterogeneous sample fractions may have caused some of the discrepancies in the results. The majority of the out-of-limit duplicate results appear to be anomalous instances of poor precision based on other QC indicators such as the results from the blind standards and laboratory duplicates (discussed in Sections C.5.2 and C.5.3). In several cases, the laboratory was asked to re-analyze or investigate duplicate results with a very high relative percent difference, but the checks did not reveal the source of the problem. Especially poor agreement was observed between a pair of results for zinc (2.7 and 17.1 µg/L) and iodine-129 (16.2 and 26.8 pCi/L). Swapped samples or procedural deviations at the laboratory may have caused the unmatched results.

During the second quarter of FY 2004, four pairs of split samples were collected from well 299-W7-12 (RCRA Low-Level Waste Management Area 3) to investigate previous total organic carbon measurements that showed elevated concentrations. STL St. Louis and Lionville Laboratories analyzed the samples for total organic carbon. Although none of the results was above five times the method detection limit, the laboratories demonstrated reasonable agreement. The average concentration was 525 µg/L for STL St. Louis and 653 µg/L for Lionville. The relative percent difference ranged from 3% to 51%. These results appear to confirm that the previous measurements, which were made when STL St. Louis was having problems with the analysis, were biased high.

C.3.2 Interim Action Monitoring

Trained staff collected samples in accordance with approved procedures. In general, field QC samples consisted of field duplicates, splits, equipment blanks, and trip blanks. Field QC data are evaluated as necessary to make decisions that may modify or terminate a remedial action. In FY 2004, no evaluations were necessary for decision-making purposes.

Field QC data were examined to monitor laboratory operations and to identify potential problem areas where improvements were necessary. Evaluation criteria were essentially the same as those used for the long-term monitoring program identified in Section C.3.1.

For field blank samples, >95% of all reviewed results were returned as non-detected. This is substantially better than FY 2003 results (90% non-detect). This may reflect an overall improvement in sample collection and laboratory performance. Organic compounds showed the greatest inclination to exceed the acceptable QC criteria. Fifty percent of the field blank QC exceedances were due to acetone and methylene chloride. These two compounds are well-known laboratory contaminants, and it is likely that most of the acetone and methylene chloride detections are associated with contamination introduced during analysis of the samples. (Note: The concentration of these organic compounds did not exceed 4 µg/L in any field blank sample.) Evaluation of field blank sample results showed no evidence of unexpected or excessive contamination of blanks in the field. The constituents and levels of contamination found should have no impact on decision making for interim action monitoring. Blank detects are summarized in Table C.5.

Field duplicate results showed ~5% exceeding the criteria used for evaluation. Field duplicate evaluations are summarized in Table C.6. Most of the exceedances (74%) are associated with duplicate results for organic compounds and radiological constituents. The reason for the reduced precision for radiological analytes is not readily apparent, although it might reflect differential entrainment of particulates during sampling or laboratory analytical problems. Exceedance of the criteria for organic analytes is mainly associated with very low-level detections (<1 µg/L) or very high detections where sample dilution was required. In general, field duplicate QC issues are minimal and do not indicate significant laboratory or sample collection problems.

Approximately 10% of split sample results were outside the acceptance limits. Table C.7 summarizes the out-of-limit results. Field analytical and laboratory split samples for hexavalent chromium and sulfate showed the most frequent exceedances of the QC criteria. In most cases, the differences in analyte concentrations are probably associated with differences in analytical protocol and methods between the laboratory and the field test kits. The criteria used to evaluate split samples are likely more restrictive than necessary because they are based on similar criteria for laboratory replicate evaluation (i.e., analysis of multiple aliquots from the same sample container by the same laboratory in the same analytical batch). Evaluation of the split sample data show no significant quality problems exist with either the primary or split laboratories.

Overall, field QC results appear to be good. The evaluation indicates no significant issues between procedures and analyses performed by the laboratories providing services to Fluor Hanford, Inc. The general performance for FY 2004 is similar to or better than the previous year.

C.4 Holding Times

C. J. Thompson

Holding time is the elapsed time period between sample collection and analysis. Samples should be analyzed within recommended holding times to minimize the possibility of changes in constituent concentrations caused by volatilization, decomposition, or other chemical alterations. Samples are also refrigerated to slow potential chemical reactions within the sample matrix. Maximum recommended holding times for constituents frequently analyzed for the groundwater project are listed in Table C.8. Radiological constituents do not have recommended maximum holding times because these constituents are not typically lost under ambient temperatures when appropriate preservatives are used. Results of radionuclide analysis are corrected for decay from sampling date to analysis date.

During FY 2004, recommended holding times were exceeded for 353 out of 7,412 (4.8%) non-radiological sample analysis requests (both long-term and interim action monitoring). A sample analysis request is defined as a sample that is submitted for analysis by a particular analytical method. In general, the missed holding times should not have a significant impact on the data. Results for samples with missed holding times are flagged with an H in the database. STL St. Louis exceeded the holding times for 339 out of 7,218 (4.7%) sample analysis requests, an increase over last year's 1.4%. The constituents with the most missed holding times were anions by EPA method 300.0 (206 samples), phenols (20 samples), total organic carbon (28 samples), and volatile organic compounds (44 samples). STL Richland exceeded holding times for 3 out of 81 hexavalent chromium analyses, but all 69 of the laboratory's coliform analyses were performed within the recommended 24-hour holding time. Lionville Laboratory missed holding times for 11 out of 44 sample analyses. Anions and total organic carbon were the affected constituents.

Several factors caused holding times to be exceeded during FY 2004, including sample shipping delays, re-analyses triggered by QC failures, the need to dilute some samples, and oversight by laboratory staff. Periodically, missed holding times were discussed with the laboratories to help identify areas where improvements are needed.

C.5 Laboratory Performance

C. J. Thompson, D. S. Sklarew, and D. L. Stewart

Laboratory performance is measured by several indicators, including national performance evaluation studies, double-blind standard analyses, laboratory audits, and internal laboratory QA/QC programs. This section provides a detailed discussion of the performance indicators for STL St. Louis and STL Richland. Brief summaries of performance measures for Lionville Laboratory and Eberline Services also are presented throughout this section. The majority of the laboratory's results were within the acceptance limits indicating good performance overall.

C.5.1 National Performance Evaluation Studies

During FY 2004, Environmental Resources Associates and DOE conducted national studies to evaluate laboratory performance for chemical and radiological constituents. STL St. Louis and Lionville Laboratory participated in the EPA sanctioned Water Pollution and Water Supply Performance Evaluation studies conducted by Environmental Resources Associates. STL Richland and Eberline Services took part in DOE's Quality Assessment Program until it ended this year. STL Richland participated in the Environmental Resources Associates' InterLaB RadCheM Proficiency Testing Program; Eberline began participation in this program towards the end of the year. All four laboratories took part in DOE's Mixed Analyte Performance Evaluation Program. Results of those studies related to groundwater monitoring at the Hanford Site are described in this section.

C.5.1.1 Water Pollution and Water Supply Studies

The purpose of water pollution and water supply studies is to evaluate the performance of laboratories in analyzing selected organic and inorganic compounds. An accredited agency such as Environmental Resource Associates distributes standard water samples to participating laboratories. These samples contain specific organic and inorganic analytes at concentrations unknown to the participating laboratories. After analysis, the laboratories submit results to the accredited agency, which uses regression equations to determine acceptance and warning limits for the study participants. The results of these studies, expressed in this report as a percentage of the results that the accredited agency found acceptable, independently verify the level of laboratory performance.

For the three water pollution studies in which STL St. Louis participated this year (ERA WP-109, 111, and 114), the percentage of acceptable results submitted to the groundwater project ranged from 67% to 92% (Table C.9). One of these studies (WP-111) had a limited number of analytes. Of the 40 different constituents with unacceptable results, total Kjeldahl nitrogen (TKN), total cyanide, and tetrachloroethene were out of limits in both studies in which they were analyzed; a number of volatile organic compounds and phenols were out of limits in one out of two studies. The laboratory provided information about possible causes for many of the unacceptable results and suggested corrective actions where appropriate. The constituents that were out of limits last year are mainly within limits this year, with the exception of TKN; however, TKN is not used for Hanford groundwater samples. Overall, the unacceptable results should not have a significant impact on Hanford groundwater samples.

Lionville Laboratory participated in three water supply and three water pollution studies this year (ERA WS-84, 90, and 96 and WP-102, 108, and 114). For the results submitted to the groundwater project, the percentage of Lionville's acceptable results ranged from 91% to 99% (Table C.10). Of the 26 different constituents with unacceptable results, only one was out of limits in more than one study, 1,4-dichlorobenzene was out of limits in two out of six studies. The laboratory provided information about possible causes for the unacceptable results and suggested corrective actions where appropriate. Overall, the unacceptable results should not have a significant impact on Hanford groundwater samples.

C.5.1.2 DOE Quality Assessment and Mixed Analyte Performance Evaluation Programs

DOE's Quality Assessment Program evaluates how laboratories perform when they analyze radionuclides in water, air filter, soil, and vegetation samples. This discussion considers only water samples. The program is coordinated by the Environmental Measurements Laboratory (EML) in New York. The EML provides blind standards that contain specific amounts of one or more radionuclides to participating laboratories. Constituents analyzed can include americium-241, cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, and total uranium. After sample analysis, each participating laboratory forwards the results to the EML for comparison with known values and with results from other laboratories. The EML evaluates the accuracy of the results based on the historical analytical capabilities for the individual analyte/matrix pairs. Using a cumulative normalized distribution, acceptable performance yields results between the 15th and 85th percentiles. Acceptable with warning results are between the 5th and 15th percentile and between the 85th and 95th percentile. Not acceptable results include the outer 10% (<5th percentile or >95th percentile) of historical data (EML-564).

For the two studies conducted this year, QAP59 and QAP60, the percentage of STL Richland's acceptable results ranged from 83% to 91% (Table C.11). The unacceptable results were for gross alpha, gross beta, and strontium-90. Three constituents (13%) had results that were evaluated as acceptable with warning (Table C.11).

The percentage of Eberline Services' results that was acceptable was 100% in both studies (Table C.12). Three constituents had results that were evaluated as acceptable with warning (Table C.12).

The Quality Assessment Program is being terminated by DOE because the mission of EML has been changed to support homeland security. QAP 60 is the last study in the program.

DOE's Mixed Analyte Performance Evaluation Program examines laboratory performance in the analysis of soil and water samples containing metals, volatile and semivolatile organic compounds, and radionuclides. This report considers only water samples. The program is conducted at the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho, and is similar in operation to DOE's Quality Assessment Program discussed above. DOE evaluates the accuracy of the Mixed Analyte Performance Evaluation Program results for radiological and inorganic samples by determining if they fall within a 30% bias of the reference value.

Three studies were available for FY 2004 (MAPEP-02-W10, MAPEP-03-W11, and MAPEP-04-MaW12&GrW12). Four results were unacceptable for STL St. Louis, plutonium-239/240, tritium, 1,3-dichlorobenzene, and 1,4-dichlorobenzene; four other results were acceptable with warning (Table C.11). Four results were unacceptable for STL Richland, americium-241, nickel-63 (two studies), and strontium-90. All results for Eberline Services and Lionville Laboratory were acceptable, though one result for Lionville was acceptable with warning (Table C.12).

C.5.1.3 InterLaB RadCheM Proficiency Testing Program Studies

The purpose of the InterLaB RadCheM Proficiency Testing Program, conducted by Environmental Resources Associates, is to evaluate the performance of laboratories in analyzing selected radionuclides. The program provides blind standards that contain specific amounts of one or more radionuclides in a water matrix to participating laboratories. Environmental Resources Associates standards were prepared for the following radionuclides/parameters: barium-133, cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, iodine-131, radium-226, radium-228, strontium-89, strontium-90, tritium, uranium, and zinc-65. After sample analysis, the results were forwarded to Environmental Resources Associates for comparison with known values and with results from other laboratories. Environmental Resources Associates bases its control limits on the EPA's National Standards for Water Proficiency Testing Studies Criteria Document (NERL-Ci-0045).

In the six studies in which STL Richland participated this year (RAD-53, 54, 55, 56, 57, and 58), 73 constituents were analyzed. Of these, 69 (95%) were acceptable (Table C.11). The unacceptable results were for iodine-131, strontium-89, strontium-90, and tritium.

In the one study in which Eberline Services participated this year (RAD-58), 13 constituents were analyzed. All were acceptable (Table C.12).

C.5.2 Double-Blind Standard Evaluation

The groundwater project forwarded blind QC standards to STL Richland and St. Louis, Lionville Laboratory, and Eberline Services during FY 2004. Blind spiked standards were generally prepared in triplicate and submitted to the laboratories to check the accuracy and precision of analyses. For most constituents, the standards were prepared in a groundwater matrix from a background well. Standards for specific conductance were commercially prepared in deionized water. In all cases, the standards were submitted to the laboratories in double-blind fashion (i.e., the standards were disguised as regular groundwater samples). After analysis, the laboratory's results were compared with the spiked concentrations, and a set of control limits were used to determine if the data were acceptable. Generally, if a result was out of limits, the data were reviewed for errors. In situations where several results for the same method were unacceptable, the results were discussed with the laboratory, potential problems were investigated, and corrective actions were taken if appropriate.

Tables C.13 and C.14 list the number and types of blind standards used in FY 2004 along with the control limits for each constituent. Overall, 90% of the blind spike determinations were acceptable. This is slightly higher than the percentage from FY 2003 (88%), although fewer constituents were evaluated this year. A total of 15 results were out of limits for STL Richland and St. Louis. Total organic halides, cyanide, fluoride, gross alpha, plutonium-239, and tritium were the constituents with out-of-limit results. Lionville Laboratory had nine unacceptable results for total organic carbon. All of Eberline Services' results for gross beta were within the acceptance limits.

Total organic halides results from STL St. Louis were improved over FY 2003, although four results were out of limits. One of the unacceptable results was for a standard spiked with 2,4,5-trichlorophenol. Since the standard was spiked at a low concentration (i.e., approximately five times the method detection limit), the laboratory's recovery of 132% was not unreasonable. All of the unacceptable results for the standards spiked with volatile organic compounds had low recoveries (47% to 62%). PNNL staff performed in-house analyses on splits of the volatile standards and confirmed that the standards were spiked at the proper concentrations. Consequently, the reason for the low bias appears to be volatilization or weak retention of the volatile analytes on the charcoal cartridges used in the analysis. The laboratory investigated the out-of-limit results but was unable to determine the source of error. Low-biased total organic halide results are of concern because of the potential for not detecting halogenated organics at RCRA sites. However, even with a 50% negative bias, detection should occur at concentrations well below the limit of quantitation (discussed in Section C.6).

STL St. Louis had one out-of-limit result for cyanide; the recovery was 9%. Loss of cyanide during the distillation step of the analysis is the suspected cause of the low result.

All of STL St. Louis' first quarter fluoride results were biased high, with recoveries of 130%. PNNL analysis of a duplicate standard suggested that the samples had been spiked at higher concentrations than anticipated. Based on the in-house concentration, STL St. Louis' results would have been acceptable. All of the STL St. Louis' fluoride results from the last three quarters were acceptable.

In general, STL Richland performed well on the analysis of radiological blind standards. Eight results were outside the QC limits. Three of the unacceptable results were for tritium, and all of the results were high by a factor of ~2.5. A calculation or procedural error at the laboratory may have caused the elevated values. Three gross alpha results from the fourth quarter were biased high, with recoveries ranging from 140% to 255%. Additionally, two plutonium-239 results had low out-of-limit recoveries. Reasons for these unacceptable results are unknown.

During December, some special blind standards were submitted to STL Richland to evaluate possible loss of iodine-129 in samples with relatively high levels of technetium-99. Such samples undergo pre-treatment to remove technetium by passing the sample through an extraction disc. The special blind standards were designed to assess whether iodine was also sorbing onto the extraction discs. Two sets of standards were prepared: the first contained ~76 pCi/L of iodine-129, and the second contained ~6,300 pCi/L of technetium-99 in addition to the 76 pCi/L of iodine-129. In both cases, the samples were filtered through the extraction discs prior to analysis. The results from the two groups of standards were very similar, with iodine-129 recoveries ranging from 105% to 113%. Consequently, the data demonstrate that iodine-129 does not appreciably sorb onto the extraction discs.

Over half (i.e., nine out of sixteen) of Lionville Laboratory's total organic carbon results were outside the acceptance limits, and all of the results were biased high. STL St. Louis had acceptable recoveries on splits of these standards, indicating that the samples were spiked correctly. Inadequate removal of inorganic carbon during the analysis is the likely cause of the elevated results. The impact of the out-of-limit results is minimal, because Lionville Laboratory did not analyze many routine groundwater samples for total organic carbon during FY 2004.

Eberline Services analyzed 12 blind standards for gross beta, and all of the results were acceptable.

Fluor Hanford, Inc. sent no blind standards as part of interim action monitoring to the commercial laboratories in FY 2004. The great similarity of matrices between the long-term and interim action monitoring samples and common use of the same laboratories make additional analysis of blind standards redundant.

C.5.3 Laboratory Internal QA/QC Programs

STL Richland, STL St. Louis, Eberline Services, and Lionville Laboratory maintain internal QA/QC programs that generate data on analytical performance by analyzing method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, matrix duplicates, and surrogates (see PNNL-13080 for definitions of these terms). This information provides a means to assess laboratory performance and the suitability of a method for a particular sample matrix. Laboratory QC data are not currently used for in-house validation of individual sample results unless the lab is experiencing unusual performance problems with an analytical method. An assessment of the laboratory QC data for FY 2004 is summarized in this section. STL data are discussed in detail first. Table C.15 provides a summary of the STL QC data by listing the percentage of QC results that were out of limits for each analyte category and QC parameter. Additional details are presented in Tables C.16 through C.19. Constituents not listed in these tables did not exceed STL's QC limits. A brief summary of Lionville Laboratory and Eberline Services data is presented at the end of the section.

Most of this year's laboratory QC results were within acceptance limits, suggesting that the analyses were in control and reliable data were generated. Nevertheless, a number of parameters had unacceptable results.

Evaluation of results for method blanks was based on the frequency of detection above the blank QC limits. In general, these limits are two times the method detection limit for chemical constituents and two times the total propagated error for radiochemistry parameters. For common laboratory contaminants such as 2-butanone, acetone, methylene chloride, phthalate esters, and toluene, the QC limit is five times the method detection limit.

Table C.16 summarizes method blank results from STL Richland and St. Louis. The metals category had the greatest percentages of method blank results exceeding the QC limits. The following parameters had >10% of method blank results outside the QC limits: lithium, zinc, acetone, benzyl alcohol, and diethylphthalate. The out-of-limit method blank results for sodium are not a significant problem because the values are much lower than the levels measured in Hanford Site groundwater. Similarly, the highest method blank results for chloride (0.2 mg/L), sulfate (0.34 mg/L), calcium (1,230 µg/L), magnesium (605 µg/L), and elemental strontium (2.4 µg /L) are typically lower than the respective levels measured in Hanford groundwater. The percentage of out-of-limit method blanks for conductivity, bromide, chloride, fluoride, nitrogen in nitrate, sulfate, iron, lead, sodium, tin, vanadium, methylene chloride, 2,3,4,6-tetrachlorophenol, carbon-14, and uranium decreased significantly compared to last year, while the percentage for lithium, zinc, 1,4-dichlorobenzene, acetone, trichloroethene, benzyl alcohol, diethylphthalate, and strontium-90 increased.

Table C.17 summarizes results for the laboratory control samples from STL Richland and St. Louis. Only volatile organic compounds and semivolatile organic compounds had >2% of their measurements outside the QC limits. Specific compounds with >10% of out-of-limit laboratory control samples included 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, 4-nitrophenol, aldrin, alpha-BHC, beta-BHC, delta-BHC, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, gamma-BHC, heptachlor, heptachlor epoxide, methoxychlor, uranium-234, and uranium-238. In all of these cases except nitrophenol, the number of QC samples analyzed was limited (<20). Most of these constituents are not routinely monitored in Hanford groundwater.

Table C.18 summarizes results for the matrix spikes and matrix spike duplicates from STL Richland and St. Louis. The semivolatile organic compounds, volatile organic compounds, ammonia and anions, and radiochemistry parameters categories had the greatest percentage of matrix spikes/spike duplicates exceeding the QC limits. This represents an increase compared to last year's results for the volatile organic compounds, semivolatile organic compounds and radiochemistry parameters. Fewer than 2% of the matrix spikes or matrix spike duplicates for general chemistry parameters and metals were out of limits; this represents a decrease for the general chemistry parameters compared to FY 2003 results.

Matrix duplicates were evaluated by comparing the relative percent difference to the QC limit for results that were five times greater than the method detection limit or the minimum detectable activity. Table C.19 lists the constituents that exceeded the relative percent difference limits. The semivolatile organic compounds and volatile organic compounds categories had the greatest percentage of matrix duplicates exceeding the QC limits. This represents an increase compared to last year's results for both categories. All other categories had fewer than 2% of their measurements outside the QC limits.

Surrogate data that was out of limits included six compounds for volatile organics and eight for semivolatile organics. For volatile organic compounds, 4.5% of the surrogate results were outside of QC limits; the corresponding percentage for semivolatile organic surrogates was 6.3%.

QC data for Eberline Services and Lionville Laboratory were limited for FY 2004 because these laboratories did not analyze many samples for the groundwater project. Lionville Laboratory analyzed method blanks, laboratory control samples, matrix spikes, and matrix duplicates for total organic carbon, some anions (by ion chromatography) and some metals (by inductively coupled plasma emission spectroscopy). All of the QC data for total organic carbon and the anions were within limits. Method blanks for several metals (barium, calcium, chromium, iron, potassium, magnesium, manganese, sodium, nickel, strontium, zinc) were out of limits at least once. Duplicates for several metals (aluminum, chromium, copper, manganese, nickel, zinc) were also out of limits at least once. Eberline Services QC data were limited to gross alpha, gross beta, radionuclides by gamma spectroscopy, strontium-90, and tritium. All of the QC data except one duplicate for gross beta were within limits.

C.5.3.1 Issue Resolution

Issue resolution forms are documents used to record and resolve problems encountered with sample receipt, sample analysis, missed holding times, and data reporting (e.g., broken bottles or QC problems). The laboratories generate these forms and forward them to the groundwater project as soon as possible after a potential problem is identified. The forms provide a means for the project to give direction to the laboratory on resolution with the issues. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse effect on data integrity. During FY 2004, 108 issue resolution forms were submitted by STL Richland and St. Louis.

Table C.20 indicates the specific issues identified this year and the number of analytical requests that were impacted. The number of analytical requests impacted was small compared to the total number of analytical requests submitted (~13,300, consisting of ~22,900 bottles). Relative to FY 2003, the frequencies of the individual issues increased or remained the same in most categories prior to receipt at the laboratory. Similarly, the frequencies of issues after receipt at the laboratory remained the same with one exception: laboratory QC out of limits. The number of holding time issues was primarily related to delays caused by the need for radiological screens prior to shipment. A small percentage of the holding time issues were related to shipping delays. The QC out of limits were due to analytical problems that occurred with phenols and low level tritium analyses.

C.5.3.2 Laboratory Audits/Assessments

Laboratory activities are regularly assessed by surveillance and auditing processes to ensure that quality problems are prevented and/or detected. Regular assessment supports continuous process improvement. Seven assessments of the commercial analytical laboratories were performed. Four of these audits were conducted by the Department of Energy Consolidated Assessment Program (DOECAP), two audits were conducted by Bechtel Hanford, Inc. (BHI), and one audit was conducted by joint team of BHI and PNNL representatives.

The goal of the DOECAP is to design and implement a program to consolidate site audits of commercial and DOE environmental laboratories providing services to DOE Environmental Management. The specific audit objectives of the DOECAP were to assess the ability of the laboratories to produce data of acceptable and documented quality through analytical operations that follow approved methods and the handling of DOE samples and associated waste in a manner that protects human health and the environment.

The four DOECAP audits were performed at the following laboratories: STL St. Louis, March 30 to April 1, 2004; Eberline Services, May 18 to 20, 2004; Lionville Laboratory, May 4 to 6, 2004; and STL Richland, August 3 to 5, 2004.

The assessment scope of the DOECAP audits included the following specific functional areas: (1) QA management systems and general laboratory practices, (2) data quality for organic analyses, (3) data quality for inorganic and wet chemistry analyses, (4) data quality for radiochemistry analysis, (5) hazardous and radioactive materials management, and (6) verification of corrective-action implementation from previous audit findings.

The purpose of the joint BHI and PNNL assessment (conducted on August 10 to 12, 2004) and the BHI audits (conducted on March 8 and August 15, 2004) was to evaluate the continued support of analytical services to Hanford Site contractors as specified in the statement of work between Fluor Hanford, Inc. and STL and Eberline Services.[(b)] The audit was based on the analytical and QA requirements for both groundwater and multi-media samples as specified in the statement of work. The primary areas of focus were personnel training, procedure compliance, sample receipt and tracking, instrument operation and calibration, equipment maintenance, instrumentation records and logbooks, implementation of STL's QA Management Plan in accordance with Hanford Analytical Services Quality Assurance Document (HASQARD, Volumes 1 and 4, DOE/RL-96-68), and the implementation of corrective actions for deficiencies identified in previous audits.

A total of 26 findings and 41 observations were noted for the 4 DOECAP audits, 11 findings and 6 observations were identified in the joint BHI and PNNL audit, and 5 findings and 19 observations were identified by the BHI only audits. Results of each of these audits are summarized in Table C.21. Corrective actions have been accepted for all audits, and verification of the corrective actions will be performed in future audits. All laboratories have been qualified to continue to provide analytical services for samples generated at DOE sites.

In addition to many of the past audit findings being closed, several proficiencies for all of the laboratories were noted in each audit this year, indicating that the laboratories are improving their processes and continuing to provide quality analytical services. Continued assessments of the laboratories are planned for the upcoming year to further evaluate performance and to ensure those corrective actions for the past findings and observations have been implemented.

C.5.4 Concerns about Aluminum Results

In July, PNNL staff observed an increase in the frequency of detection and the concentrations of aluminum at several wells across the Hanford Site. For example, wells such as 299-E27-4 that previously had a history of non-detected results began having detected results in the range of 70 to 120 µg/L. The problem appeared to begin with samples collected in May and continued through the end of the fiscal year. Although aluminum is not a primary constituent of concern, the results were considered significant because many of the detected values exceeded the lower end of the secondary drinking water standard (50 to 200 µg/L). The questionable data were discussed with the analyzing laboratory (STL St. Louis), and the laboratory was asked if they were aware of any procedural or instrument changes that might be responsible for the data trends. Laboratory staff were not aware of any factors that might explain the anomalous values. Review of the laboratory QC results showed that while aluminum was detected in several method blanks (21%), there did not appear to be an obvious correlation with the elevated sample results. Other laboratory QC parameters such as laboratory control samples and matrix spikes were almost always within the acceptance limits. Moreover, field blank results for aluminum were generally acceptable during the second half of the year, although one from June had a result of 81 µg/L, and one from August had a result of 114 µg/L. In response to PNNL's concerns, the laboratory has performed an extensive cleaning of the laboratory used to prepare samples for metals analysis, and they have replaced overhead ventilation ductwork to reduce the possibility of sample contamination. PNNL has flagged many of the suspect data points in HEIS. In addition, special blind standards and several split samples are planned for FY 2005 to help identify and correct the source of the elevated results.

(b) RFSH-SOW-93-0003, Rev. 6. 1999. *Environmental and Waste Characterization of Analytical Services*. Statement of Work between Fluor Daniel Hanford, Inc. and Severn Trent Laboratories, Richland, Washington, and Eberline Services, Richmond, California.

C.6 Limit of Detection, Limit of Quantitation, and Method Detection Limit

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Detection and quantitation limits are essential to evaluate data quality and usefulness because they provide the limits of a method's measurement. The detection limit is the lower limit at which a measurement can be differentiated from background. The quantitation limit is the lower limit where a measurement becomes quantifiably meaningful. The limit of detection, limit of quantitation, and method detection limit are useful for evaluating groundwater data.

The limit of detection is defined as the lowest concentration level statistically different from a blank (Currie 1988). The concentration at which an analyte can be detected depends on the variability of the blank response. For the purpose of this discussion, the blank is taken to be a method blank.

In general, the limit of detection is calculated as the mean concentration in the blank plus three standard deviations of that concentration (EPA/540/P-87/001, OSWER 9355.0-14). The blank-corrected limit of detection is simply three times the blank standard deviation. At three standard deviations from the blank mean, the false-positive and the false-negative error rates are each ~7% (Miller and Miller 1988). A false-positive error is an instance when an analyte is declared present but is, in fact, absent. A false-negative error is an instance when an analyte is declared absent but is, in fact, present.

The limit of detection for a radionuclide is typically computed from the counting error associated with each reported result (e.g., EPA 520/1-80-012) and represents instrumental or background conditions at the time of analysis. In contrast, the limit of detection and limit of quantitation for the radionuclides shown in Table C.22 are based on variabilities that result from both counting errors and uncertainties introduced by sample handling. In the latter case, distilled water, submitted as a sample, is processed as if it were an actual sample. Thus, any random cross-contamination of the blank during sample processing will be included in the overall error, and the values shown in Table C.22 are most useful for assessing long-term variability in the overall process.

The limit of quantitation is defined as the level above which quantitative results may be obtained with a specified degree of confidence (Keith 1991). The limit of quantitation is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87/001, OSWER 9355.0-14). The blank-corrected limit of quantitation is simply 10 times the blank standard deviation. The limit of quantitation is most useful for defining the lower limit of the useful range of concentration measurement technology. When the analyte signal is 10 times larger than the standard deviation of the blank measurements, there is a 95% probability that the true concentration of the analyte is within ±25% of the measured concentration.

The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero. The method detection limit is determined from analysis of a sample in a given matrix containing the analyte (Currie 1988). The method detection limit is 3.14 times the standard deviation of the results of seven replicates of a low-level standard. Note that the method detection limit, as defined above, is based on the variability of the response of low-level standards rather than on the variability of the blank response.

For this report, total organic carbon, total organic halides, and radionuclide field blank data are available for limit of detection and limit of quantitation determinations. The field blanks are QC samples that are introduced into a process to monitor the performance of the system. The use of field blanks to calculate the limit of detection and the limit of quantitation is preferred over the use of laboratory blanks because field blanks include error contributions from sample preparation and handling, in addition to analytical uncertainties. Methods to calculate the limit of detection and the limit of quantitation are described in detail in Appendix A of DOE/RL-91-03. The results of the limit of detection and limit of quantitation determinations are listed in Table C.23.

Because of the lack of blank data for other constituents of concern, it was necessary to calculate approximate limit of detection and limit of quantitation values by using variability information obtained from low-level standards. The data from the low-level standards are obtained from laboratory method detection limit studies. If low-level standards are used, the variability of the difference between the sample and blank response is increased by a factor of 2 (Currie 1988, p. 84). The formulas are summarized below:

$$\mathrm{MDL} = 3.14 \cdot s$$

$$\begin{aligned}\mathrm{LOD} &= 3\left(\sqrt{2} \cdot s\right)\\ &= 4.24 \cdot s\end{aligned}$$

$$\begin{aligned}\mathrm{LOQ} &= 10\left(\sqrt{2} \cdot s\right)\\ &= 14.14 \cdot s\end{aligned}$$

where s = standard deviation from the seven replicates of the low-level standard.

The results of limit of detection, limit of quantitation, and method detection limit calculations for most non-radiological constituents of concern (besides total organic carbon and total organic halides) are listed in Table C.23. The values in the table apply to STL St. Louis only.

Specific evaluation of detection-limit issues for the interim action groundwater monitoring was not performed for this report. Detection limit issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in FY 2004.

C.6.1 Iodine-129 Detection Issues

Iodine-129 is a challenging radionuclide to monitor due to the need for especially low detection limits. The drinking water standard for iodine-129 is 1 pCi/L, which is the lowest of any radionuclide. STL Richland performed all of the iodine-129 measurements during FY 2004, and in most cases, the laboratory was able to achieve a minimum detectable activity of 1 pCi/L or less. However, ~16% of the results were reported as non-detected at levels up to 7 pCi/L. In FY 2003, the problem was worse, with non-detected values as high as 36 pCi/L. The highest non-detected values were associated with locations having elevated levels of technetium-99 (e.g., wells 299-W14-13 and 299-W14-15). Due to high screening results for these samples (resulting from the technetium-99 concentrations), the laboratory was using a smaller volume for iodine-129 analyses, resulting in a higher effective detection limit. PNNL discussed this problem with the laboratory, and the laboratory has implemented a special preparation step for samples that contain high levels of technetium-99. Such samples are filtered through an extraction disc that removes the technetium, and the filtrate is re-screened and processed for iodine-129 using the full sample volume. Limited data are available since this procedural modification has been employed, and the results have been variable (see Section C.5.2 for an investigation of possible sorption of iodine onto the extraction disc). Obtaining the desired 1-pCi/L detection limit is challenging even for ideal sample matrices, and it is anticipated that detection at these levels will be a continued problem until methodologies improve. PNNL is planning to explore the use of inductively coupled plasma/mass spectroscopy for low-level detection of iodine-129 during FY 2005.

C.7 Conclusions

Overall, assessments of FY 2004 QA/QC information indicate that groundwater monitoring data are reliable and defensible. Sampling was conducted in accordance with reviewed procedures. Few contamination or other sampling-related problems were encountered that affected data integrity. Likewise, laboratory performance was excellent in most respects, based on the large percentages of acceptable field and laboratory QC results. Satisfactory laboratory audits and generally acceptable results in nationally-based performance evaluation studies also demonstrated good laboratory performance. However, the following areas of concern were identified and should be considered when interpreting groundwater monitoring results:

- A few QC samples were probably swapped in the field or at the laboratory based on a small number of unusually high field-blank results and duplicate results with poor precision. The same problem likely occurred for a small number of groundwater samples. Mismatched results for key constituents are identified during data review and flagged when appropriate.

- Several indicator parameters, anions, metals, volatile organic compounds, and radiological parameters were detected at low levels in field and/or laboratory method blanks. The most significant contaminants were 1,4-dichlorobenzene, acetone, aluminum, copper, iron, gross beta, methylene chloride, tritium, and zinc.
- Maximum recommended holding times were exceeded for ~1.4% of groundwater project samples that were analyzed by non-radiological methods. Anions were primarily affected, though the data impacts are considered minor.
- Laboratory performance on blind standards was very good overall: 90% of the results were acceptable. Constituents with out-of-limit results were cyanide (STL St. Louis), fluoride (STL St. Louis), gross alpha (STL Richland), plutonium-239 (STL Richland), total organic carbon (Lionville Laboratory), total organic halides (STL St. Louis), and tritium (STL Richland).

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Table C.1. Long-Term Monitoring Full Trip Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
General Chemical Parameters					
Alkalinity	1	39	2.6	2,400 µg/L	6,000 µg/L
Total organic carbon	4	88	4.6	780 µg/L	790 - 1,000 µg/L
Total organic halides	4	81	4.9	4.4 µg/L	4.6 - 5.8 µg/L
Ammonia and Anions					
Chloride	4	49	8.2	86 - 90 µg/L	98 - 140 µg/L
Nitrogen in nitrate	3	49	6.1	8 - 22 µg/L	13 - 36 µg/L
Sulfate	9	57	15.8	74 - 108 µg/L	260 - 570 µg/L
Metals					
Aluminum	2	43	4.7	68.4 - 191.6 µg/L	81.4 - 114 µg/L
Copper	2	43	4.7	4.8 - 6.4 µg/L	7.4 - 9.7 µg/L
Iron	1	43	2.3	13.8 - 109 µg/L	16.6 µg/L
Sodium	1	43	2.3	163.6 - 324 µg/L	568 µg/L
Zinc	6	43	14.0	3 - 7 µg/L	3.5 - 20.8 µg/L
Volatile Organic Compounds					
1,4-dichlorobenzene	1	13	7.7	0.22 µg/L	0.41 µg/L
Acetone	2	13	15.4	1.05 - 3.3 µg/L	1.6 - 1.9 µg/L
Methylene chloride	3	13	23.1	0.6 - 1.5 µg/L	1.8 - 25 µg/L
Radiological Parameters					
Gross beta	1	28	3.6	3.34 - 5.42 pCi/L[b]	9.81 pCi/L
Tritium	2	36	5.6	10.7 - 674 pCi/L[b]	16.4 - 28.6 pCi/L
Uranium	5	24	20.8	0.00978 µg/L	0.026 - 0.0531 µg/L

(a) Because method detection limits may change throughout the year, some limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

(b) The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

QC = Quality control.

Table C.2. Long-Term Monitoring Field Transfer Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits[a] (µg/L)	Range of Out-of-Limit Results (µg/L)
1,4-Dichlorobenzene	1	93	1.1	0.58	15
4-Methyl-2-pentanone	2	93	2.2	0.38 - 1.8	1.9 - 3.5
Acetone	14	93	15.1	1.05 - 6.5	1.1 - 21
Carbon tetrachloride	3	93	3.2	0.2 - 0.3	0.27 - 1.2
Chloroform	2	93	2.2	0.14 - 0.24	0.26 - 33
cis-1,2-Dichloroethene	1	93	1.1	0.12 - 0.4	0.22
Methylene chloride	49	93	52.7	0.6 - 13	0.87 - 16
Trichloroethene	5	93	5.4	0.12 - 0.32	0.24 - 0.91

(a) Because method detection limits may change throughout the year, some limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

QC = Quality control.

Table C.3. Long-Term Monitoring Equipment Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	QC Limits (µg/L)	Out-of-Limit Results (µg/L)
Ammonia and Anions					
Chloride	1	1	100	43	780
Nitrogen in nitrate	1	1	100	4	16
Metals					
Zinc	1	1	100	1.5	8
Volatile Organic Compounds					
Chloromethane	1	1	100	0.09	0.3

QC = Quality control.

Table C.4. Long-Term Monitoring Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated[(a)]	Number Out of Limits	Percent Out of Limits	Range of Relative Percent Differences[(b)]
Ammonia and Anions					
Chloride	57	57	1	1.8	22.5
Cyanide	18	6	2	33.3	31.8 - 44.0
Fluoride	57	55	2	3.6	24.5 - 34.7
Metals					
Arsenic	18	4	1	25.0	27.7
Vanadium	51	22	2	9.1	21.6 - 22.1
Zinc	51	5	1	20.0	145.5
Volatile Organic Compounds					
Acetone	18	2	2	100.0	28.6 - 162.0
Methylene chloride	54	3	1	33.3	136.8
Tetrachloroethene	54	6	2	33.3	24.0 - 35.6
TPH-Gasoline	6	1	1	100.0	42.4
Trichloroethene	72	16	1	6.3	27.2
Semivolatile Organic Compounds					
TPH-Diesel	6	2	1	50.0	85.7
Radiological Parameters					
Gross beta	87	36	2	5.6	21.9 - 25.8
Iodine-129	24	8	3	37.5	47.6 - 54.0
Tritium	43	29	1	3.4	67.3

(a) Duplicates with both results <5 times the method detection limit or minimum detectable activity were excluded from the evaluation.

(b) In cases where a non-detected result was compared with a measured value, the method detection limit or minimum detectable activity was used for the non-detected concentration.

Table C.5. Interim Action Monitoring Field Blank Detections

Constituent	Number of Detects	Number of Analyses[a]	Percent Out of Limits	Range of QC Limits[a] (µg/L or pCi/L)	Range of Out-of-Limit Results (µg/L or pCi/L)
Anions					
Chloride	1	5	20	43	160
Nitrate	1	5	20	17.7	88.5
Sulfate	1	5	20	0.037	300
Metals					
Aluminum	1	12	8	45.5	117
Beryllium	3	12	25	0.3 - 0.4	0.59 - 1.0
Calcium	1	12	8	111	286
Sodium	1	12	8	94.3	371
Volatile Organic Compounds					
4-Methyl-2-pentanone	1	43	2	0.38	2.4
Acetone	4	43	9	0.21	1.4 - 2.3
Carbon tetrachloride	5	43	12	0.1 - 0.2	0.5 - 0.8
Methylene chloride	13	43	30	0.2 - 0.3	0.4 - 3.6
Radiological Parameters					
Uranium	1	1	100	0.01	0.0235
Tritium	1	5	20	252	276
Field Analyses					
Hexavalent chromium	3	9	33	5	6 - 9
Sulfate	1	7	14	8.3	1,000

(a) Because method detection limits may change throughout the year, some limits are presented as a range.

Table C.6. Interim Action Monitoring Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated[(a)]	Number Out of Limits	Percent Out of Limits	Range of Relative Percent Differences
General Chemical Parameters					
Alkalinity	1	1	0	0	2.2
Ammonia and Anions					
Chloride	24	24	1	4	0 - 21
Cyanide	3	1	1	100	134
Fluoride	24	23	0	0	0 - 19
Nitrate	24	24	0	0	0 - 11
Sulfate	24	24	0	0	0 - 17
Metals					
Aluminum	28	1	0	0	9
Barium	28	18	0	0	0 - 6
Calcium	28	26	0	0	1 - 5
Chromium	28	9	0	0	1 - 8
Cobalt	28	1	0	0	5
Iron	28	2	2	100	22 - 32
Magnesium	28	25	0	0	0 - 4
Manganese	28	6	0	0	1 - 4
Nickel	28	1	0	0	1
Potassium	28	3	0	0	0 - 2
Sodium	28	28	0	0	0 - 4
Strontium	28	28	0	0	0 - 6
Vanadium	28	4	0	0	1 - 10
Zinc	28	5	1	20	2 - 44
Volatile Organic Parameters					
Acetone	12	5	1	25	0 - 153
Carbon disulfide	12	2	2	100	29 - 107
Carbon tetrachloride	12	12	3	25	0 - 65
Chloroform	12	11	0	0	0 - 19
Methylene chloride	12	1	0	0	1
Tetrachloroethene	12	3	3	100	32 - 63
Trichloroethene	12	10	0	0	0 - 15
Radiological Parameters					
Gross beta	10	4	1	25	1 - 24
Iodine-129	9	1	1	100	23
Strontium-90	11	5	1	20	2 - 27
Technetium-99	10	8	1	13	0 - 217
Tritium	21	15	0	0	0 - 12
Uranium	11	11	1	9	0 - 172
Field Analyses					
Hexavalent chromium	48	47	1	4	0 - 43
Sulfate	19	19	0	0	0 - 17

(a) Duplicates with both results <5 times the method detection limit or minimum detectable activity were excluded from the evaluation.

Table C.7. Interim Action Monitoring Interlaboratory Splits Exceeding Quality Control Limits

Constituent	Total Number of Splits	Number of Splits Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Relative Percent Differences
Anions					
Chloride	7	6	0	0	4 - 14
Fluoride	7	1	0	0	16
Sulfate	7	7	0	0	0 - 9
Metals					
Barium	11	9	0	0	0 - 12
Calcium	11	11	0	0	2 - 14
Chromium	11	5	1	20	2 - 22
Magnesium	11	11	0	0	1 - 13
Sodium	11	11	0	0	1 - 8
Strontium	11	11	0	0	1 - 14
Zinc	11	5	1	20	3 - 52
Radiological Parameters					
Gross beta	7	4	0	0	3 - 17
Total beta radiostrontium	6	3	0	0	4 - 11
Tritium	8	6	2	33	12 - 32
Fixed Laboratory-Field Analyses					
Hexavalent chromium	45	44	8	18	0 - 200
Sulfate	11	11	2	18	3 - 30

(a) Split sample pairs with both results <5 times the method detection limit or minimum detectable activity were excluded from the evaluation.

Table C.8. Groundwater Performance Assessment Project Maximum Recommended Holding Times

Method	Constituent	Holding Time
8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction; 40 days after extraction
8081 (SW-846)	Pesticides	7 days before extraction; 40 days after extraction
8082 (SW-846)	Polychlorinated biphenyls	7 days before extraction; 40 days after extraction
8040 (SW-846)	Phenols	7 days before extraction; 40 days after extraction
6010 (SW-846)	Inductively coupled-plasma metals	6 months
7060 (SW-846)	Arsenic	6 months
7131 (SW-846)	Cadmium	6 months
7191 (SW-846)	Chromium	6 months
7421 (SW-846)	Lead	6 months
7470 (SW-846)	Mercury	28 days
7740 (SW-846)	Selenium	6 months
7841 (SW-846)	Thallium	6 months
9012 (SW-846)	Cyanide	14 days
9020 (SW-846)	Total organic halides	28 days
9060 (SW-846)	Total organic carbon	28 days
9131 (SW-846)	Coliform	1 day
120.1 (EPA-600/4-81-004)	Conductivity	28 days
160.1 (EPA-600/4-81-004)	Total dissolved solids	7 days
300.0 (EPA-600/4-81-004)	Bromide	28 days
300.0 (EPA-600/4-81-004)	Chloride	28 days
300.0 (EPA-600/4-81-004)	Fluoride	28 days
300.0 (EPA-600/4-81-004)	Nitrate	48 hours
300.0 (EPA-600/4-81-004)	Nitrite	48 hours
300.0 (EPA-600/4-81-004)	Phosphate	48 hours
300.0 (EPA-600/4-81-004)	Sulfate	28 days
310.1 (EPA-600/4-81-004)	Alkalinity	14 days
350.1 (EPA-600/4-81-004)	Ammonia	28 days
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days

Table C.9. Summary of Severn Trent St. Louis Water Pollution (WP) Performance Evaluation Studies

Accreditation Laboratory	WP-109 April 2004 Acceptable Results/Total	WP-111 June 2004 Acceptable Results/Total	WP-114 September 2004 Acceptable Results/Total
Environmental Resource Associates	241/262[a]	6/9[b]	240/268[c]

(a) Unacceptable results were for total suspended solids, ammonia as N, total Kjeldahl nitrogen, total phosphorus as P, total cyanide, total residual chlorine, total dissolved solids, total solids at 105°C, tetrachloroethene, acenaphthene, 4-chloro-3-methylphenol, 2-chlorophenol, 2,4-dichlorophenol, 2-nitrophenol, pentachlorophenol, 2,4,5-trichlorophenol, and 2,4,6-trichlorophenol.

(b) Unacceptable results were for acidity as CaCO3, volatile solids, and sulfide.

(c) Unacceptable results were for orthophosphate as P, total Kjeldahl nitrogen, total cyanide, fluoride, sodium, chlorobenzene, 2-chloroethylvinylether, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, ethylbenzene, tetrachloroethene, toluene, 1,1,1-trichloroethane, trichloroethene, 2,4,5-T, 2,4,5-TP, naphthalene, boron, and 1,2,4-trichlorobenzene.

Table C.10. Summary of Lionville Laboratory Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies

Accreditation Laboratory	WS-84 September 2003 Acceptable Results/Total	WS-90 March 2004 Acceptable Results/ Total	WS-96 September 2004 Acceptable Results/Total	WP-102 September 2003 Acceptable Results/Total	WP-108 March 2004 Acceptable Results/Total	WP-114 September 2004 Acceptable Results/Total
Environmental Resource Associates	71/75[a]	63/69[b]	68/69[c]	249/271[d]	437/451[e]	455/471[f]

(a) Unacceptable results were for chlorobenzene, 1,4-dichlorobenzene, 1,1,2-trichloroethane, and total xylenes.

(b) Unacceptable results were for nitrate + nitrite as N, 1,2,4-trichlorobenzene, vinyl chloride, chloroethane, chloromethane, and 2,2-dichloropropane.

(c) Unacceptable result was for 1,4-dichlorobenzene.

(d) Unacceptable results were for total hardness ($CaCO_3$), grease and oil (gravimetric), alkalinity as $CaCO_3$; chloride, tetrachloroethene, Aroclor 260, and total organic halides.

(e) Unacceptable results were for fluoride (three results), acenaphthene (two results), bis(2-chloroethoxy)methane (two results), 2,6-dichlorophenol (two results), and benzo(g,h,i)perylene.

(f) Un

Table C.11. Summary of Severn Trent Interlaboratory Performance, FY 2004

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP59, 60) Environmental Measurements Laboratory		
Americium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, tritium, uranium-234, uranium-238, uranium	2[a]	2[b,c]
Strontium-90	2[a]	1[b]
Cesium-134	1[a]	1[b]
Gross alpha, gross beta	1[a]	0[b]
DOE Mixed Analyte Performance Evaluation Program (MAPEP-02-W10, MAPEP-03-W11, MAPEP-04-MaW12&GrW12) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, manganese-54, plutonium-238, plutonium-239/240, strontium-90, technetium-99, uranium-234/233, uranium-238, zinc-65	6[a,d]	6
Americium-241, plutonium-239/240, strontium-90	6[a,d]	5[e,f]
Iron-55	5[a,d]	5
Nickel-63	5[a,d]	3[e]
Tritium	4[a,d]	3[f]
Gross alpha, gross beta	2[a,d]	2
Antimony, arsenic, barium, beryllium, cadmium, copper, lead, nickel, selenium, thallium, vanadium, zinc	3[d]	3
Chromium	2[d]	2
1,2-Dichlorobenzene, 2,4-dimethylphenol, 1,2,4-trichlorobenzene, naphthalene, 4-chloro-3-methylphenol, 2-methylphenol, 2,6-dichlorophenol, 2,6-dinitrotoluene, 2,4-dinitrotoluene, diethylphthalate, phenanthrene, anthracene, pyrene, benzo(a)anthracene, heptachlor, dieldrin	2[d]	2[g]
Nitrobenzene, 2,4-dichlorophenol, hexachlorobutadiene, fluorene, 4-nitrophenol, 1,2,4,5-tetrachlorobenzene, 1,3-dinitrobenzene, benzo(a)pyrene, chrysene, 4,4'-DDT	1[d]	1[g]
1,3-Dichlorobenzene	2[d]	1[f]
1,4-Dichlorobenzene	1[d]	0[f]
ERA InterLaB RadCheM Proficiency Testing Program (RAD 53, 54, 55, 56, 57, 58) Environmental Resource Associates		
Gross alpha	7[a,h]	7[i]
Cesium-134, cesium-137, cobalt-60, gross beta, radium-228	6[a,h]	6[i]
Radium-226, uranium	5[a,h]	5[i]
Strontium-89, strontium-90	5[a]	4[i]

Table C.11. (contd)

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
Zinc-65	4[(a)]	4[(i)]
Tritium	4[(a)]	3[(i)]
Barium-133	3[(a)]	3[(i)]
Iodine-131	3[(a)]	2[(i)]

(a) Results from STL Richland.
(b) Control limits from EML-564.
(c) One result each for americium-241, uranium-234, and uranium was acceptable but outside warning limits.
(d) Results from STL St. Louis.
(e) Result(s) from STL Richland were not acceptable.
(f) Result(s) from STL St. Louis were not acceptable.
(g) One result each for 2,4-dichlorophenol, 4-chloro-3-methylphenol, benzo(a)anthracene, and chrysene was acceptable but outside warning limits.
(h) Some constituents were analyzed more than once in a given study.
(i) Control limits from NERL-Ci-0045.

Table C.12. Summary of Eberline Services and Lionville Laboratory Interlaboratory Performance, FY 2004

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP59, 60) Environmental Measurements Laboratory		
Americium-241, cesium-137, cobalt-60, gross alpha, gross beta, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, uranium	2(a)	2(b,c)
Cesium-134	2(a)	1(b)
DOE Mixed Analyte Performance Evaluation Program (MAPEP-02-W10, MAPEP-03-W11, MAPEP-04-MaW12&GrW12) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, iron-55, manganese-54, nickel-63, plutonium-238, plutonium-239/240, strontium-90, technetium-99, uranium-234/233, uranium-238, zinc-65	3(a)	3
Tritium	2(a)	2
Gross alpha, gross beta	1(a)	1
Antimony, arsenic, barium, beryllium, cadmium, copper, lead, nickel, selenium, thallium, vanadium, zinc	3(d)	3
Chromium	2(d)	2
Silver	1(d)	1
1,3-Dichlorobenzene, 1,2-dichlorobenzene, 2,4-dimethylphenol, 1,2,4-trichlorobenzene, naphthalene, 4-chloro-3-methylphenol, 2-methylphenol, 2,6-dichlorophenol, 2,6-dinitrotoluene, 2,4-dinitrotoluene, diethylphthalate, phenanthrene, anthracene, pyrene, benzo(a)anthracene	2(d)	2(e)
Nitrobenzene, 2,4-dichlorophenol, hexachlorobutadiene, 4-nitrophenol, fluorene, 1,2,4,5-tetrachlorobenzene, benzo(a)pyrene, chrysene	1(d)	1
ERA InterLaB RadCheM Proficiency Testing Program (RAD 58) Environmental Resource Associates		
Barium-133, cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, radium-226, radium-228, strontium-89, strontium-90, tritium, uranium, zinc-65	1(a)	1(f)

(a) Results from Eberline Services.
(b) Control limits from EML-564.
(c) One result each for gross beta, tritium, and uranium was acceptable but outside warning limits.
(d) Results from Lionville Laboratory.
(e) One result for diethylphthalate was acceptable but outside warning limits.
(f) Control limits from NERL-Ci-0045.

Table C.13. Summary of Severn Trent Laboratories Double-Blind Spike Determinations

Constituent	Laboratory	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits[b]	Control Limits[c] (%)
		General Chemical Parameters			
Specific conductance	St. Louis	Quarterly	12	0	±25
Total organic carbon (potassium hydrogen phthalate spike)	St. Louis	Quarterly	16	1	±25
Total organic halides (2,4,5-trichlorophenol spike)	St. Louis	Quarterly	14	1	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	St. Louis	Quarterly	13	4	±25
		Ammonia and Anions			
Cyanide	St. Louis	Quarterly	12	1	±25
Fluoride	St. Louis	Quarterly	12	3	±25
Nitrate as N	St. Louis	Quarterly	12	0	±25
		Metals			
Chromium	St. Louis	Annually	3	0	±20
		Volatile Organic Compounds			
Carbon tetrachloride	St. Louis	Quarterly	12	0	±25
Chloroform	St. Louis	Quarterly	12	0	±25
Trichloroethene	St. Louis	Quarterly	12	0	±25
		Radiological Parameters			
Gross alpha (plutonium-239 spike)	Richland	Quarterly	12	3	±30
Gross beta (strontium-90 spike)	Richland	Quarterly	12	0	±30
Cesium-137	Richland	Annually	3	0	±30
Cobalt-60	Richland	Annually	3	0	±30
Iodine-129	Richland	Semiannually	10	0	±30
Plutonium-239	Richland	Quarterly	12	2	±30
Strontium-90	Richland	Semiannually	6	0	±30
Technetium-99	Richland	Quarterly	12	0	±30
Tritium	Richland	Annually	3	3	±30
Tritium (low level)	Richland	Semiannually	6	0	±30
Uranium-238	Richland	Quarterly	12	0	±30

(a) Blind standards were generally submitted in duplicate, triplicate, or quadruplicate.
(b) Quality control limits are given in PNNL-15014.
(c) Each result must be within the specified percentage of the known value to be acceptable.

Table C.14. Summary of Lionville Laboratory, Inc. and Eberline Services Double-Blind Spike Determinations

Constituent	Sample Frequency	Number of Results Reported[(a)]	Number of Results Outside QC Limits[(b)]	Control Limits[(c)] (%)
		General Chemical Parameters		
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	16	9	±25
		Radiological Parameters		
Gross beta (strontium-90 spike)	Quarterly	12	0	±30

(a) Blind standards were submitted in triplicate or quadruplicate.
(b) Quality control limits are given in PNNL-15014.
(c) Each result must be within the specified percentage of the known value to be acceptable.
QC = Quality control.

Table C.15. Percentage of Out-of-Limit Quality Control Results by Category, Severn Trent Laboratories (Richland and St. Louis)

Quality Control Parameter	General Chemistry Parameters	Ammonia and Anions	Metals	Volatile Organic Compounds	Semivolatile Organic Compounds	Radiological Parameters	Total
Method blanks	0	1.7	2.7	1.2	0.3	0.9	1.3
Laboratory control samples	0	0.2	0.2	2.2	4.0	1.9	1.6
Matrix spikes	1.8	8.6	0.3	8.8	9.3	7.5	5.2
Matrix duplicates	0.2	0.2	0	5.5	21.2	1.2	4.5
Surrogates	--	--	--	4.5	6.3	--	4.9

Table C.16. Method Blank Results, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit[(a)]	Number of Analyses	Concentration Range of Out-of-Limit Results
	General Chemistry Parameters		
Total general chemistry parameters	0	339	--
	Ammonia and Anions		
Total ammonia and anions	1.7	1,133	--
Chloride	2.9	206	0.092 - 0.2 mg /L
Nitrogen in nitrate	0.5	205	0.036 mg /L
Nitrogen in nitrite	0.5	205	0.018 mg/L
Sulfate	5.3	207	0.1 - 0.34 mg/L
	Metals		
Total metals	2.7	1,900	--
Aluminum	8.4	95	61.3 - 297 µg/L
Beryllium	9.5	95	0.79 - 2.0 µg/L
Calcium	1.1	95	1,230 µg/L
Copper	3.2	95	6.5 - 11.9 µg/L
Iron	4.2	95	14.7 - 32.5 µg/L
Lithium	20.0	5	38.1 µg /L
Magnesium	1.1	95	605 µg/L
Manganese	4.2	96	2.4 - 37.6 µg/L
Nickel	1.1	95	28.7 µg/L
Silver	1.1	95	6.3 µg /L
Sodium	2.1	95	359 - 383 µg/L
Strontium	2.1	95	1.8 - 2.4 µg/L
Vanadium	1.1	95	15.4 µg/L
Zinc	14.7	95	3.1 - 13.1 µg/L
	Volatile Organic Compounds		
Total volatile organic compounds	1.2	4,047	--
1,2-Dichloroethane	0.7	148	0.67 µg/L
1,2-Dichloroethene (total)	7.7	13	0.36 µg/L
1,4-Dichlorobenzene	5.1	158	0.27 - 0.37 µg/L
1-Butanol	0.7	136	30 µg/L
Acetone[(b)]	14.9	148	1.1 - 4.4 µg/L
Benzene	0.7	147	0.17 µg/L
Bromomethane	7.7	13	0.74 µg/L
Chloroform	0.7	148	0.16 µg/L
Chloromethane	7.7	13	0.26 µg/L
cis-1,2-Dichloroethene	0.7	149	0.14 µg/L
Methylene chloride[(b)]	4.7	148	0.78 - 2.2 µg/L
Tetrachloroethene	0.7	148	0.19 µg/L
trans-1,2-Dichloroethene	0.7	147	0.22 µg/L
Trichloroethene	2.0	148	0.2 - 0.44 µg/L
	Semivolatile Organic Compounds		
Total semivolatile organic compounds	0.3	1,935	--
4-Nitrophenol	2.1	48	12 µg/L
Benzyl alcohol	28.6	7	7.7 - 7.7 µg/L
Diethylphthalate[(b)]	28.6	7	2 - 2.1 µg/L

Table C.16. (contd)

Constituent	Percent Out of Limit[(a)]	Number of Analyses	Concentration Range of Out-of-Limit Results
	Radiochemistry Parameters		
Total radiochemistry parameters	0.9	1,794	--
Strontium-90	7.1	84	0.724 - 1.25 pCi/L
Tritium	2.5	275	13.5 - 28.0 pCi/L
Uranium	4.2	96	0.0249 - 0.0514 µg/L

(a) Quality control limits are twice the method detection limit.
(b) Quality control limits are 5 times the method detection limit.

Table C.17. Laboratory Control Samples, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	0.0	344
Ammonia and Anions		
Total ammonia and anions	0.2	1,132
Nitrogen in nitrate	0.5	205
Nitrogen in nitrite	0.5	205
Metals		
Total metals	0.2	1,882
Aluminum	3.2	94
Volatile Organic Compounds		
Total volatile organic compounds	2.2	2,849
1,1,1-Trichloroethane	2.0	148
1,1,2-Trichloroethane	6.8	147
1,1-Dichloroethane	2.0	148
1,2-Dichloroethane	4.7	148
1,2-Dichloroethene (total)	7.7	13
1,4-Dichlorobenzene	2.1	143
2-Butanone	0.7	147
4-Methyl-2-pentanone	0.7	147
Acetone	6.8	147
Bromomethane	7.7	13
Carbon tetrachloride	1.9	162
Chloroform	2.7	148
Methylene chloride	1.4	147
Tetrachloroethene	2.7	148
Trichloroethene	4.7	148
Vinyl chloride	2.0	147
Semivolatile Organic Compounds		
Total semivolatile organic compounds	4.0	1,303
2,4-Dinitrophenol	2.2	46
2-Methylphenol	3.7	54
3-+4-Methylphenol	2.0	49
4,4'-DDD	20.0	10
4,4'-DDE	20.0	10
4,4'-DDT	20.0	10
4,6-Dinitro-2-methylphenol	4.3	46
4-Chloro-3-methylphenol	2.2	46
4-Nitrophenol	10.9	46
Aldrin	20.0	10
alpha-BHC	20.0	10
beta-BHC	20.0	10
delta-BHC	20.0	10
Dieldrin	20.0	10
Endosulfan I	40.0	10
Endosulfan II	20.0	10
Endosulfan sulfate	20.0	10
Endrin	30.0	10
Endrin aldehyde	20.0	10
gamma-BHC (lindane)	20.0	10
Heptachlor	20.0	10
Heptachlor epoxide	20.0	10
Methoxychlor	20.0	10
Pentachlorophenol	1.9	54
Phenol	3.4	59

Table C.17. (contd)

Constituent	Percent Out of Limit	Number of Analyses
Radiochemistry Parameters		
Total radiochemistry parameters	1.9	1,299
Cesium-137	5.3	75
Cobalt-60	1.3	75
Europium-152	1.4	74
Gross alpha	4.3	92
Gross beta	1.0	98
Hexavalent chromium	2.1	48
Iodine-129	2.2	93
Neptunium-237	8.3	12
Technetium-99	1.9	107
Tritium	0.7	275
Uranium	1.1	189
Uranium-234	15.4	13
Uranium-238	15.4	13

Table C.18. Matrix Spikes and Matrix Spike Duplicates, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	1.8	165
Total organic carbon	1.3	80
Total organic halides	2.7	74
Ammonia and Anions		
Total ammonia and anions	8.6	560
Chloride	3.1	96
Cyanide	3.4	29
Fluoride	6.3	95
Nitrogen in ammonia	15.4	26
Nitrogen in nitrate	10.3	97
Nitrogen in nitrite	22.1	95
Sulfate	3.0	100
Metals		
Total metals	0.3	4,234
Arsenic	2.3	88
Cadmium	1.4	216
Calcium	1.9	210
Chromium	1.4	214
Potassium	0.5	210
Volatile Organic Compounds		
Total volatile organic compounds	8.8	2,947
1,1,1-Trichloroethane	6.0	150
1,1,2,2-Tetrachloroethane	12.5	16
1,1,2-Trichloroethane	9.3	150
1,1-Dichloroethane	12.7	150
1,1-Dichloroethene	7.1	28
1,2-Dichloroethane	7.9	151
1,2-Dichloroethene (total)	18.8	16
1,2-Dichloropropane	12.5	16
1,4-Dichlorobenzene	8.5	142
2-Butanone	4.7	150
2-Hexanone	12.5	16
4-Methyl-2-pentanone	4.7	150
Acetone	8.7	150
Benzene	5.3	150
Bromodichloromethane	12.5	16
Bromoform	12.5	16
Carbon disulfide	5.3	150
Carbon tetrachloride	28.0	150
Chlorobenzene	18.8	16
Chloroethane	25.0	16
Chloroform	8.0	150
Chloromethane	12.5	16
cis-1,3-Dichloropropene	12.5	16
Dibromochloromethane	12.5	16
Ethylbenzene	9.7	113
Methylene chloride	15.3	150
Styrene	12.5	16
Tetrachloroethene	4.0	150
Toluene	6.0	151
TPH Gasoline	8.8	34
trans-1,3-Dichloropropene	18.8	16
Trichloroethene	2.0	150
Vinyl chloride	5.3	150

Table C.18. (contd)

Constituent	Percent Out of Limit	Number of Analyses
Semivolatile Organic Compounds		
Total semivolatile organic compounds	9.3	2,057
2-(2,4-Dichlorophenoxy)propionic acid	25.0	16
2,3,4,6-Tetrachlorophenol	4.9	61
2,4,5-TP (silvex)	18.8	16
2,4,5-Trichlorophenol	10.1	69
2,4,6-Trichlorophenol	11.6	69
2,4-D	43.8	16
2,4-Dichlorophenol	12.5	80
2,4-Dimethylphenol	10.1	69
2,4-Dinitrophenol	10.1	69
2,6-Dichlorophenol	9.8	61
2-Chlorophenol	11.6	69
2-Methylphenol	11.3	80
2-Nitrophenol	12.5	80
2-secButyl-4,6-dinitrophenol	6.5	77
3+4-Methylphenol	8.3	72
4-(2,4-Dichlorophenoxy)butyric acid	37.5	16
4,4'-DDD	12.5	16
4,4'-DDE	6.3	16
4,4'-DDT	6.3	16
4,6-Dinitro-2-methylphenol	10.1	69
4-Chloro-3-methylphenol	8.7	69
4-Nitrophenol	7.2	69
Aldrin	6.3	16
alpha-BHC	12.5	16
Aroclor 1016	25.0	8
beta-BHC	12.5	16
delta-BHC	6.3	16
Dieldrin	12.5	16
Endosulfan I	12.5	16
Endosulfan II	6.3	16
Endosulfan sulfate	12.5	16
Endrin	12.5	16
Endrin aldehyde	12.5	16
gamma-BHC (lindane)	12.5	16
Heptachlor	6.3	16
Heptachlor epoxide	43.8	16
Methoxychlor	6.3	16
Naphthalene	5.3	19
Oil and grease	9.1	11
Pentachlorophenol	11.3	80
Phenol	18.4	87
TPH Diesel	23.3	30
Radiochemistry Parameters		
Total radiochemistry parameters	7.5	305
Hexavalent chromium	10.8	102
Technetium-99	9.3	108
Uranium	2.2	93

Table C.19. Matrix Duplicates, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total general chemistry parameters	0.2	469
Total organic carbon	0.7	151
Ammonia and Anions		
Total ammonia and anions	0.2	1,669
Chloride	0.3	301
Fluoride	0.3	300
Nitrogen in nitrate	0.7	301
Metals		
Total metals	0.0	2,117
Volatile Organic Compounds		
Total volatile organic compounds	5.5	2,271
1,1,1-Trichloroethane	2.6	116
1,1,2,2-Tetrachloroethane	16.7	12
1,1,2-Trichloroethane	3.4	116
1,1-Dichloroethane	1.7	116
1,1-Dichloroethene	8.6	23
1,2-Dichloroethane	3.4	116
1,2-Dichloroethene (total)	16.7	12
1,2-Dichloropropane	16.7	12
1,4-Dichlorobenzene	2.7	111
2-Butanone	6.0	116
2-Hexanone	25.0	12
4-Methyl-2-pentanone	5.2	116
Acetone	19.8	116
Benzene	1.7	116
Bromodichloromethane	16.7	12
Bromoform	25.0	12
Bromomethane	25.0	12
Carbon disulfide	3.4	116
Carbon tetrachloride	4.9	123
Chlorobenzene	16.7	12
Chloroethane	16.7	12
Chloroform	2.6	117
Chloromethane	16.7	12
cis-1,3-Dichloropropene	25.0	12
Dibromochloromethane	16.7	12
Ethylbenzene	3.5	86
Methylene chloride	4.3	116
Styrene	25.0	12
Tetrachloroethene	2.6	116
Toluene	2.6	116
TPH Gasoline	5.6	18
trans-1,3-Dichloropropene	25.0	12
Trichloroethene	1.7	116
Vinyl chloride	3.4	116
Semivolatile Organic Compounds		
Total semivolatile organic compounds	21.2	1,346
2-(2,4-Dichlorophenoxy)propionic acid	12.5	8
2,2-Dichloropropionic acid	25.0	8
2,3,4,6-Tetrachlorophenol	31.7	41
2,4,5-T	50.0	8
2,4,5-TP (silvex)	12.5	8
2,4,5-Trichlorophenol	23.9	46
2,4,6-Trichlorophenol	23.9	46
2,4-D	37.5	8
2,4-Dichlorophenol	26.4	53

Table C.19. (contd)

Constituent	Percent Out of Limit	Number of Analyses
2,4-Dimethylphenol	23.9	46
2,4-Dinitrophenol	23.9	46
2,6-Dichlorophenol	22.0	41
2-Chlorophenol	26.1	46
2-Methylphenol	28.3	53
2-Nitrophenol	24.5	53
2-secButyl-4,6-dinitrophenol	28.6	49
3,3'-Dichlorobenzidine	20.0	5
3-+4-Methylphenol	29.2	48
4-(2,4-Dichlorophenoxy)butyric acid	25.0	8
4,4'-DDD	18.2	11
4,4'-DDE	18.2	11
4.4'-DDT	18.2	11
4,6-Dinitro-2-methylphenol	23.9	46
4-Chloro-3-methylphenol	23.9	46
4-Chloroaniline	20.0	5
4-Nitrophenol	39.1	46
Aldrin	18.2	11
alpha-BHC	18.2	11
Aroclor 1016	40.0	5
Aroclor 1260	20.0	5
beta-BHC	18.2	11
bis(2-Ethylhexyl)phthalate	8.3	12
delta-BHC	18.2	11
Dicamba	25.0	8
Dieldrin	18.2	11
Endosulfan I	18.2	11
Endosulfan II	18.2	11
Endosulfan sulfate	18.2	11
Endrin	18.2	11
Endrin aldehyde	18.2	11
gamma-BHC (lindane)	18.2	11
Heptachlor	27.3	11
Heptachlor epoxide	18.2	11
Hexachlorocyclopentadiene	40.0	5
Methoxychlor	18.2	11
Naphthalene	16.7	12
Oil and grease	4.8	21
Pentachlorophenol	22.6	53
Phenol	41.1	56
TPH Diesel	6.3	16
Radiochemistry Parameters		
Total radiochemistry parameters	1.2	1,707
Americium-241	12.5	8
Cobalt-60	1.3	77
Gross beta	3.0	99
Iodine-129	6.5	92
Strontium-90	1.2	84
Technetium-99	0.9	108
Tritium	1.3	150
Uranium	2.1	95
Uranium-234	7.1	14
Uranium-235	13.3	15
Uranium-238	6.7	15

Table C.20. Summary of Issue Resolution Forms Received from Severn Trent Laboratories (Richland and St. Louis) for FY 2004

Issue Category	Number of Analyses Impacted Prior to Receipt at the Laboratory	Number of Analyses Impacted After Receipt at the Laboratory
Hold time missed	283	98
Broken bottles	20	
Missing samples	4	
Temperature deviation	3	
pH variance	39	
Bottle size/type (insufficient volume)	6	
Chain of custody forms incomplete	1	
Laboratory QC out of limits	--	220
Analytical preparation deviations	--	17
Method failures/discontinued analyses	--	32

QC = Quality control.

Table C.21. Results of Laboratory Assessments

Laboratory	Audit Team	Findings	Observations	Summary of Results
Severn Trent, Inc. St. Louis, MO	DOECAP	13	19	Findings related to insufficient documentation for proficiency testing, lack of procedures or incomplete procedures or non-compliance with SW-846 methods, inconsistent implementation of procedures, inadequate traceability of acids use for preservation, no separation of rad standards or reference materials from samples, insufficient security for some of the calibration factors used in the LIMS. Observations related to inconsistent general laboratory practices, such are daily recording and monitoring of equipment.
Eberline Services-Richmond, CA	DOECAP	4	8	Findings related to current copies of some procedures not available in the appropriate areas, use of expired flame-sealed check source and background sources, calibration and performance checks not being performed on each day of analyses, waste container being held past the allowable accumulation limits. Observations related to QA management systems and general laboratory practices (i.e., procedures has not been updated to reflect laboratory practice, re-verification of standard solutions, incomplete documentation).
Lionville Laboratory, Inc., Lionville, PA	DOECAP	9	7	Findings related to unclear chain of custody until final disposition of sample, review of control charts not done in a timely manner, personnel qualifications and training requirements not established, overdue method detection limit studies, use of expired standards, inconsistent implementation of procedures and data review, and insufficient preventative maintenance checks and documentation. Observations related to incomplete procedures, lack of procedures, and inconsistent general practices within the laboratory.
Severn Trent, Inc.-Richland, WA	DOECAP	0	7	Six observations related general safety practices used in the laboratory for handling waste and samples and one related to the lack of review of the laboratory policy on "Minimum Detectable Concentration Determination."

Table C.21. (contd)

Laboratory	Audit Team	Findings	Observations	Summary of Results
Severn Trent, Inc.-St. Louis, MO	PNNL/BHI Joint Team	11	6	Findings related to inadequate compliance to STL procedures and Quality Manual (annual determination of method detection limits, internal chain of custody, preventative maintenance), incomplete training documentation, insufficient verification of software changes, insufficient standard operating procedures and document control, ineffective corrective action system, inadequate implementation of the HASQARD requirements in the STL QA Program. Observations related mostly to inconsistent general laboratory practices.
Severn Trent, Inc.-Richland, WA	BHI	3	10	Findings related to lack of verification of corrective actions, lack of employee certification in job descriptions, and non-compliance to procedural deviation quality control acceptance criteria. Observations related to missing information on forms, incomplete training files, incomplete corrective actions, and inconsistent general laboratory practices.
Eberline Services,-Richmond, CA	BHI	2	9	Findings related to lack of documentation for calculation checks and non-compliance to HASQARD requirement for procedures pertaining to functional responsibilities. Observations related to incomplete tracking of samples through sample disposal, not clear roles and responsibilities related to records management, lack of training or assessment documentation, inconsistent general laboratory practices.

BHI = Bechtel Hanford, Inc.
DOECAP = Department of Energy Consolidated Assessment Program.
HASQARD = Hanford Analytical Services Quality Assurance Document (DOE/RL-96-68).
LIMS = Laboratory Information Management System.
PNNL = Pacific Northwest National Laboratory.
QA = Quality assurance.
STL = Severn Trent Laboratories, Incorporated.

Table C.22. Summary of Analytical Laboratory Detection/Quantitation Limits Determined from Field Blanks Data, Severn Trent Laboratories (Richland and St. Louis)

Period(a)	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
		Constituent: Total Organic Carbon (μg/L)			
11/19/02 - 12/17/03	83(b)	112.4	141.6	420(c)	1,420(c)
04/02/03 - 03/11/04	72(b)	174.1	137.0	410	1,370
07/10/03 - 06/08/04	74(b)	199.4	151.9	460	1,520
10/07/03 - 09/27/04	68(b)	207.3	151.2	450	1,510
Summary	68(b)	207.3	151.2	450	1,510
		Constituent: Total Organic Halides (μg/L)			
12/16/02 - 12/17/03	67	0.70	1.54	4.6(c)	15.4(c)
04/02/03 - 03/11/04	65	0.81	1.40	4.2	14.0
07/10/03 - 06/08/04	77	0.92	1.54	4.6	15.4
10/07/03 - 09/27/04	77	0.78	1.27	3.8	12.7
Summary	77	0.78	1.27	3.8	12.7
		Constituent: Cesium-137 (pCi/L)			
12/15/03 - 12/17/03	2	0.04	0.18	0.54(c)	1.81(c)
01/15/04 - 03/11/04	4	0.23	0.87	2.60	8.66
06/01/04 - 06/07/04	4	-0.37	0.48	1.45	4.83
08/02/04 - 09/16/04	3	-0.61	0.28	0.85	2.83
Summary	13	-0.18	0.59	1.77	5.91
		Constituent: Cobalt-60 (pCi/L)			
12/15/03 - 12/17/03	2	1.07	2.25	6.75(c)	22.51(c)
01/15/04 - 03/11/04	4	-0.93	0.53	1.60	5.32
06/01/04 - 06/07/04	4	0.12	0.69	2.06	6.88
08/02/04 - 09/16/04	3	-0.27	1.27	3.81	12.69
Summary	13	-0.15	1.08	3.25	10.83
		Constituent: Europium-152 (pCi/L)			
12/15/03 - 03/11/04	5	-0.52	3.07	9.22(c)	30.73(c)
06/01/04 - 06/07/04	4	-0.15	4.55	13.64	45.46
08/02/04 - 09/16/04	3	1.14	1.10	3.31	11.03
Summary	12	0.02	3.37	10.11	33.70
		Constituent: Europium-154 (pCi/L)			
12/15/03 - 12/17/03	2	3.22	0.40	1.21(c)	4.03(c)
01/15/04 - 03/11/04	4	-2.10	2.58	7.73	25.75
06/01/04 - 06/07/04	4	-1.25	4.27	12.82	42.74
08/02/04 - 09/16/04	3	0.91	4.06	12.17	40.55
Summary	13	-0.33	3.46	10.38	34.60
		Constituent: Europium-155 (pCi/L)			
12/15/03 - 12/17/03	2	-2.53	0.87	2.61(c)	8.70(c)
01/15/04 - 03/11/04	4	0.56	3.26	9.78	32.60
06/01/04 - 06/07/04	4	0.19	2.28	6.83	22.76
08/02/04 - 09/16/04	3	0.74	1.84	5.51	18.35
Summary	13	0.01	2.47	7.41	24.70
		Constituent: Gross Alpha (pCi/L)			
10/01/03 - 12/18/03	12	0.05	0.20	0.60(c)	2.01(c)
01/20/04 - 02/20/04	4	0.08	0.11	0.34	1.15
04/12/04 - 06/08/04	5	0.12	0.06	0.18	0.61
07/08/04 - 09/16/04	6	-0.04	0.10	0.29	0.95
Summary	27	0.05	0.15	0.46	1.54

Table C.22. (contd)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Gross Beta (pCi/L)					
10/01/03 - 12/18/03	11(b)	0.48	0.55	1.65(c)	5.50(c)
01/15/04 - 03/08/04	6	0.85	1.03	3.10	10.33
04/12/04 - 06/08/04	7	0.58	0.79	2.36	7.86
07/08/04 - 09/16/04	7	0.76	0.57	1.72	5.72
Summary	31	0.64	0.72	2.16	7.21
Constituent: Iodine-129 (pCi/L)					
10/01/03 - 12/18/03	7	0.00	0.05	0.14(c)	0.46(c)
01/15/04 - 02/20/04	3	0.05	0.06	0.19	0.64
04/12/04 - 06/01/04	3	0.05	0.03	0.09	0.30
07/08/04 - 09/13/04	5	-0.01	0.04	0.11	0.37
Summary	18	0.02	0.04	0.13	0.45
Constituent: Strontium-90 (pCi/L)					
10/01/03 - 12/15/03	4	0.32	0.27	0.80(c)	2.66(c)
01/15/04 - 03/11/04	3	0.16	0.21	0.63	2.09
04/16/04 - 06/07/04	4	0.27	0.24	0.72	2.39
07/08/04 - 08/11/04	2	0.25	0.10	0.31	1.04
Summary	13	0.26	0.23	0.70	2.32
Constituent: Technetium-99 (pCi/L)					
10/07/03 - 12/17/03	4(b)	1.50	3.95	11.8(c)	39.5(c)
01/15/04 - 03/18/04	8	-0.32	2.99	9.0	29.9
04/12/04 - 06/24/04	6	-0.32	1.89	5.7	18.9
07/21/04 - 09/13/04	6	-0.81	2.90	8.7	29.0
Summary	24	-0.14	2.91	8.7	29.1
Constituent: Tritium (pCi/L)					
10/01/03 - 12/22/03	14	163.4	76.4	229(c)	764(b)
01/15/04 - 03/11/04	8	72.7	52.7	158	527
04/12/04 - 06/24/04	7	33.3	86.9	261	869
07/08/04 - 09/16/04	8	58.7	116.7	350	1,167
Summary	37	96.5	84.5	254	845
Constituent: Tritium – Low-Level Method (pCi/L)					
04/16/04 - 09/16/04	5	10.79	11.54	35(c)	115(c)
Constituent: Uranium (µg/L)					
10/07/03 - 12/18/03	7	0.017	0.018	0.071(d)	0.197(d)
01/15/04 - 03/01/04	5	0.012	0.018	0.065	0.189
04/12/04 - 06/29/04	7	0.007	0.013	0.046	0.138
07/14/04 - 09/16/04	6	0.008	0.015	0.053	0.157
Summary	25	0.011	0.016	0.059	0.171

(a) Time period covered for total organic carbon and total organic halides is a moving average of four quarters.

(b) Excluded outliers.

(c) Limit of detection (blank corrected) equals 3 times the blank standard deviation; limit of quantitation (blank corrected) equals 10 times the blank standard deviation. Numbers are rounded.

(d) Limit of detection equals the mean blank concentration plus 3 standard deviations; limit of quantitation equals the mean blank concentration plus 10 standard deviations. Numbers are rounded.

Table C.23. Summary of Detection and Quantitation Limits, Severn Trent Laboratory (St. Louis)

Method	Constituent	Initial MDL(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
			General Chemical Parameters					
EPA-600/4-81-004, 120.1	Conductivity(b)	0.49	0.662	2.207				
EPA-600/4-81-004, 160.1	Total dissolved solids	3,500	4,726	15,761				
EPA-600/4-81-004, 310.1	Alkalinity	1,200	1,620	5,404				
EPA-600/4-81-004, 410.4	Chemical Oxygen Demand(c)	3,600	4,861	16,211	09/01/2004	7,100	9,587	31,973
EPA-600/4-81-004, 413.1	Oil and grease	920	1,242	4,143	07/14/2004	5,000	6,752	22,516
			Ammonia and Anions					
EPA-600/4-81-004, 300.0	Bromide	42	57	189	04/13/2004	20	27	90
EPA-600/4-81-004, 300.0	Chloride	45	61	203	04/09/2004	43	58	194
EPA-600/4-81-004, 300.0	Fluoride(d)	40	54	180	06/16/2004	10	14	45
EPA-600/4-81-004, 300.0	Nitrogen in Nitrate	11	15	50	04/09/2004	4	5	18
EPA-600/4-81-004, 300.0	Nitrogen in Nitrite(d)	7.4	10.0	33.3	06/16/2004	4	5	18
EPA-600/4-81-004, 300.0	Phosphate	260	351	1171	04/13/2004	23	31	104
EPA-600/4-81-004, 300.0	Sulfate	54	73	243	04/09/2004	37	50	167
EPA-600/4-81-004, 350.1	Nitrogen in ammonia	21.6	29.2	97.3				
SW-846, 9012	Cyanide	4.7	6.3	21.2	3/8/2004	2.5	3.4	11.3
			Metals					
SW-846, 6010	Aluminum(d)	20.3	27.4	91.4	02/09/2004	16.6	22.4	74.8
SW-846, 6010	Antimony(e)	16	22	72	02/09/2004	32.0	43.2	144.1
SW-846, 6010	Barium(e)	6.5	8.8	29.3	02/09/2004	0.754	1.02	3.40
SW-846, 6010	Beryllium(e)	0.17	0.23	0.77	02/09/2004	0.659	0.89	2.97
SW-846, 6010	Cadmium(e)	2	3	9				
SW-846, 6010	Calcium(e)	148	200	666	02/09/2004	20	27	90
SW-846, 6010	Chromium(e)	2	3	9	02/09/2004	7.38	9.97	33.23
SW-846, 6010	Cobalt(e)	4	5	18				
SW-846, 6010	Copper(e)	7.7	10.4	34.7	02/09/2004	4.27	5.77	19.23
SW-846, 6010	Iron(e)	14.5	19.6	65.3	02/09/2004	12.0	16.2	54.0
SW-846, 6010	Lead(e)	9	12	41				
SW-846, 6010	Magnesium(e)	138	186	621	02/09/2004	137.0	185.0	616.9
SW-846, 6010	Manganese(e)	0.79	1.1	3.6	02/09/2004	2	3	9
SW-846, 6010	Nickel(e)	12	16	54	02/09/2004	18.9	25.5	85.1
SW-846, 6010	Potassium(e)	1,330	1,796	5,989	02/09/2004	1,492	2,015	6,719
SW-846, 6010	Silver(e)	6	8	27	02/09/2004	2.2	3.0	9.9
SW-846, 6010	Sodium(e)	140	189	630	02/09/2004	66.4	89.7	299.0
SW-846, 6010	Strontium (elemental)(e)	1.5	2.0	6.8	02/09/2004	0.659	0.89	2.97
SW-846, 6010	Tin(e)	19.8	26.7	89.2				
SW-846, 6010	Vanadium(e)	2.3	3.1	10.4	02/09/2004	7.63	10.30	34.36
SW-846, 6010	Zinc(e)	1.3	1.8	5.9	02/09/2004	2.29	3.09	10.31
SW-846, 7060	Arsenic	1.053	1.42	4.74				
SW-846, 7131	Cadmium	0.078	0.11	0.35				
SW-846, 7191	Chromium	0.364	0.49	1.64				

Table C.23. (contd)

Method	Constituent	Initial MDL(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 7421	Lead	0.622	0.84	2.80				
SW-846, 7470	Mercury	0.1	0.1	0.5				
SW-846, 7740	Selenium	1.652	2.23	7.44				
SW-846, 7841	Thallium	1.298	1.75	5.85				
	Volatile Organic Compounds							
SW-846, 8260	1,1,1,2-Tetrachloroethane(f)	0.04	0.05	0.18	08/12/2004	0.17	0.23	0.77
SW-846, 8260	1,1,1-Trichloroethane(f)	0.17	0.23	0.77	07/06/2004	0.07	0.1	0.3
SW-846, 8260	1,1,2,2-Tetrachloroethane(f)	0.17	0.23	0.77	05/19/2004	0.3	0.4	1.4
SW-846, 8260	1,1,2-Trichloroethane(f)	0.05	0.07	0.23	07/06/2004	0.21	0.28	0.95
SW-846, 8260	1,1-Dichloroethane(g)	0.2	0.3	0.9	07/06/2004	0.12	0.16	0.54
SW-846, 8260	1,1-Dichloroethene(g)	0.16	0.22	0.72	07/10/2004	0.07	0.1	0.3
SW-846, 8260	1,2,3-Trichloropropane(f)	0.15	0.20	0.68	08/12/2004	0.41	0.55	1.85
SW-846, 8260	1,2-Dibromomethane(f)	0.06	0.08	0.27	05/19/2004	0.2	0.3	0.9
SW-846, 8260	1,2-Dichloroethane(g)	0.08	0.1	0.4	07/06/2004	0.21	0.28	0.95
SW-846, 8260	1,2-Dichloroethene (total)(f)	0.17	0.23	0.77	08/12/2004	0.18	0.24	0.81
SW-846, 8260	1,2-Dichloropropane(f)	0.24	0.32	1.08	08/12/2004	0.17	0.23	0.77
SW-846, 8260	1,4-Dichlorobenzene	0.11	0.15	0.50	01/02/2004	0.39	0.53	1.76
SW-846, 8260	1,4-Dioxane	11.1	15.0	50.0	01/02/2004	19	26	86
SW-846, 8260	1-Butanol	4.57	6.17	20.58	01/02/2004	33	45	149
SW-846, 8260	2-Butanone(f)	0.29	0.39	1.31	07/06/2004	0.1	0.1	0.5
SW-846, 8260	2-Hexanone(f)	0.14	0.19	0.63	08/12/2004	0.14	0.19	0.63
SW-846, 8260	4-Methyl-2-pentanone(f)	0.35	0.47	1.58	07/06/2004	0.19	0.26	0.86
SW-846, 8260	Acetone(f)	0.66	0.89	2.97	04/30/2004	0.21	0.28	0.95
SW-846, 8260	Acetonitrile(f)	2.7	3.6	12.2	05/19/2004	0.21	0.28	0.95
SW-846, 8260	Acrolein(f)	2.1	2.8	9.5	05/19/2004	2.8	3.8	12.6
SW-846, 8260	Benzene	0.07	0.09	0.32	12/29/2003	0.11	0.15	0.50
SW-846, 8260	Bromodichloromethane(f)	0.2	0.27	0.90	08/12/2004	0.3	0.4	1.4
SW-846, 8260	Bromoform(f)	0.2	0.3	0.9	08/12/2004	0.3	0.4	1.4
SW-846, 8260	Bromomethane(g)	0.61	0.82	2.75	08/12/2004	0.1	0.1	0.5
SW-846, 8260	Carbon disulfide(g)	0.43	0.58	1.94	07/06/2004	0.06	0.1	0.3
SW-846, 8260	Carbon tetrachloride(f)	0.15	0.20	0.68	07/06/2004	0.1	0.1	0.5
SW-846, 8260	Chlorobenzene(g)	0.08	0.1	0.4	08/12/2004	0.16	0.22	0.72
SW-846, 8260	Chloroethane(g)	0.32	0.43	1.44	08/12/2004	0.1	0.1	0.5
SW-846, 8260	Chloroform(f)	0.07	0.09	0.32	07/06/2004	0.11	0.15	0.50
SW-846, 8260	Chloromethane(f)	0.2	0.3	0.9	05/19/2004	0.09	0.1	0.4
SW-846, 8260	cis-1,2-Dichloroethene(g)	0.06	0.08	0.27	07/6/2004	0.1	0.1	0.5
SW-846, 8260	cis-1,3-Dichloropropene(g)	0.24	0.32	1.08	08/12/2004	0.13	0.18	0.59
SW-846, 8260	Dichlorodifluoromethane(g)	0.32	0.43	1.44	08/12/2004	0.05	0.1	0.2
SW-846, 8260	Ethyl cyanide	1.3	1.8	5.9	01/2/2004	3.6	4.9	16.2
SW-846, 8260	Ethylbenzene(f)	0.14	0.19	0.63	07/12/2004	0.1	0.1	0.5
SW-846, 8260	Methylenechloride(g)	0.3	0.4	1.4	07/06/2004	0.17	0.23	0.77
SW-846, 8260	Styrene(f)	0.07	0.09	0.32	05/19/2004	0.13	0.18	0.59
SW-846, 8260	Tetrachloroethene(f)	0.17	0.23	0.77	07/06/2004	0.08	0.1	0.4

Table C.23. (contd)

Method	Constituent	Initial MDL(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	Tetrahydrofuran	1.74	2.35	7.84	01/02/2004	0.2	0.3	0.9
SW-846, 8260	Toluene(f)	0.12	0.16	0.54	04/29/2004	0.07	0.1	0.3
SW-846, 8260	trans-1,2-Dichloroethene(g)	0.17	0.23	0.77	07/06/2004	0.09	0.1	0.4
SW-846, 8260	trans-1,3-Dichloropropene(f)	0.05	0.07	0.23	05/19/2004	0.12	0.16	0.54
SW-846, 8260	Trichloroethene(f)	0.16	0.22	0.72	04/29/2004	0.09	0.1	0.4
SW-846, 8260	Vinyl acetate	0.2	0.3	0.9	03/27/2004	0.18	0.24	0.81
SW-846, 8260	Vinyl chloride(g)	0.25	0.34	1.13	07/06/2004	0.08	0.1	0.4
SW-846, 8260	Xylenes (total)	0.28	0.38	1.26	01/02/2004	0.82	1.11	3.69
SW-846, 8260	1,4-Dichlorobenzene	0.11	0.15	0.50	01/02/2004	0.39	0.53	1.76
WTPH_Gasoline	TPH, gasoline fraction(f)	0.06	0.08	0.27	07/19/2004	0.029	0.039	0.13
Semivolatile Organic Compounds								
SW-846, 8015	TPH, diesel fraction(f)	60	81	270	4/20/2004	50	68	225
SW-846, 8040	2,3,4,6-Tetrachlorophenol	3.73	5.04	16.80	12/23/2004	4.8	6.5	21.6
SW-846, 8040	2,4,5-Trichlorophenol	2.91	3.93	13.10	12/23/2004	4.6	6.2	20.7
SW-846, 8040	2,4,6-Trichlorophenol	2.65	3.58	11.93	12/23/2004	4.1	5.5	18.5
SW-846, 8040	2,4-Dichlorophenol	2.9	3.92	13.06	12/23/2004	3	4.1	13.5
SW-846, 8040	2,4-Dimethylphenol	3.75	5.06	16.89	12/23/2004	2.8	3.8	12.6
SW-846, 8040	2,4-Dinitrophenol	3.45	4.66	15.54	12/23/2004	3.4	4.6	15.3
SW-846, 8040	2,6-Dichlorophenol	2.66	3.59	11.98	12/23/2004	3.3	4.5	14.9
SW-846, 8040	2-Chlorophenol	2.65	3.58	11.93	12/23/2004	3.2	4.3	14.4
SW-846, 8040	2-Methylphenol (cresol, o-)	2.79	3.77	12.56	12/23/2004	4	5.4	18.0
SW-846, 8040	2-Nitrophenol	2.65	3.58	11.93	12/23/2004	3.2	4.3	14.4
SW-846, 8040	2-secButyl-4,6-dinitrophenol(DNBP)	1.43	1.93	6.44	12/23/2004	4.2	5.7	18.9
SW-846, 8040	3,4 methyl phenol	3.54	4.78	15.94	12/23/2004	2.8	3.8	12.6
SW-846, 8040	4,6-Dinitro-2methyl phenol	4.02	5.43	18.10	12/23/2004	4	5.4	18.0
SW-846, 8040	4-Chloro-3-methylphenol	2.78	3.75	12.52	12/23/2004	2.8	3.8	12.6
SW-846, 8040	4-Nitrophenol	2.81	3.79	12.65	12/23/2004	2.8	3.8	12.6
SW-846, 8040	Pentachlorophenol	2.5	3.38	11.26	12/23/2004	4.3	5.8	19.4
SW-846, 8040	Phenol	3	4.1	13.5	12/23/2004	3	4.1	13.5
SW-846, 8082	Aroclor-1016	0.35	0.47	1.58	05/05/2004	0.22	0.30	0.99
SW-846, 8082	Aroclor-1221	0.35	0.47	1.58	05/05/2004	0.22	0.30	0.99
SW-846, 8082	Aroclor-1232	0.35	0.47	1.58	05/05/2004	0.49	0.66	2.21
SW-846, 8082	Aroclor-1242	0.35	0.47	1.58	05/05/2004	0.2	0.3	0.9
SW-846, 8082	Aroclor-1248	0.35	0.47	1.58	05/05/2004	0.14	0.19	0.63
SW-846, 8082	Aroclor-1254	0.35	0.47	1.58	05/05/2004	0.38	0.51	1.71
SW-846, 8082	Aroclor-1260	0.23	0.31	1.04	05/05/2004	0.19	0.26	0.86
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	0.21	0.28	0.95	01/14/2004	0.4	0.5	1.8
SW-846, 8270	1,2,4-Trichlorobenzene	0.45	0.61	2.03	12/31/2003	0.91	1.23	4.10
SW-846, 8270	1,2-Dichlorobenzene	0.28	0.38	1.26	12/31/2004	1.9	2.57	8.56
SW-846, 8270	1,3-Dichlorobenzene	0.29	0.39	1.31	12/31/2004	1.9	2.57	8.56
SW-846, 8270	2,2'-Oxybis(1-chloropropane)	0.27	0.36	1.22	12/31/2003	1.1	1.49	4.95
SW-846, 8270	2,4,5-Trichlorophenol	0.64	0.86	2.88	12/31/2004	2.4	3.24	10.81
SW-846, 8270	2,4,6-Trichlorophenol	0.44	0.59	1.98	12/31/2004	2.4	3.24	10.81
SW-846, 8270	2,4-Dichlorophenol	0.27	0.36	1.22	12/31/2004	0.91	1.23	4.10

Table C.23. (contd)

Method	Constituent	Initial MDL[(a)] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[(a)] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2,4-Dimethylphenol	5.3	7.2	23.9	12/31/2004	1	1.4	4.5
SW-846, 8270	2,4-Dinitrophenol	1.7	2.3	7.7	12/31/2004	6.7	9.05	30.17
SW-846, 8270	2,4-Dinitrotoluene	0.62	0.84	2.79	12/31/2004	4	5.4	18.0
SW-846, 8270	2,6-Dinitrotoluene	0.68	0.92	3.06	12/31/2004	3	4.1	13.5
SW-846, 8270	2-Chloronaphthalene	0.28	0.38	1.26	12/31/2004	1	1.4	4.5
SW-846, 8270	2-Chlorophenol	0.25	0.34	1.13	12/31/2004	0.92	1.24	4.14
SW-846, 8270	2-Methylnaphthalene	0.37	0.50	1.67	12/31/2004	1.1	1.5	5.0
SW-846, 8270	2-Methylphenol (cresol, o-)	0.24	0.32	1.08	12/31/2004	0.93	1.26	4.19
SW-846, 8270	2-Nitroaniline	0.65	0.88	2.93	12/31/2004	0.71	0.96	3.20
SW-846, 8270	2-Nitrophenol	0.64	0.86	2.88	12/31/2004	1.9	2.6	8.6
SW-846, 8270	3,3'-Dichlorobenzidine	1.3	1.8	5.9	12/31/2004	2.6	3.5	11.7
SW-846, 8270	3-Nitroaniline	0.56	0.76	2.52	12/31/2004	0.85	1.15	3.83
SW-846, 8270	4,6-Dinitro-2methyl phenol	0.53	0.72	2.39	12/31/2004	4	5.4	18.0
SW-846, 8270	4-Bromophenylphenyl ether	0.42	0.57	1.89	12/31/2004	1	1.4	4.5
SW-846, 8270	4-Chloro-3-methylphenol	0.37	0.50	1.67	12/31/2004	0.87	1.17	3.92
SW-846, 8270	4-Chloroaniline	1.1	1.49	4.95	12/31/2004	1.3	1.8	5.9
SW-846, 8270	4-Chlorophenylphenyl ether	0.44	0.59	1.98	12/31/2004	1.1	1.5	5.0
SW-846, 8270	4-Methylphenol (cresol, p-)	7.1	9.6	32.0	12/31/2004	1.5	2.0	6.8
SW-846, 8270	4-Nitroaniline	1	1.4	4.5	12/31/2004	0.84	1.13	3.78
SW-846, 8270	4-Nitrophenol	0.81	1.09	3.65	12/31/2004	3.2	4.3	14.4
SW-846, 8270	Acenaphthene	0.35	0.47	1.58	12/31/2004	1.1	1.5	5.0
SW-846, 8270	Acenaphthylene	0.34	0.46	1.53	12/31/2004	0.99	1.34	4.46
SW-846, 8270	Aniline	0.29	0.39	1.31	12/31/2004	1.1	1.5	5.0
SW-846, 8270	Anthracene	0.39	0.53	1.76	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Benzo(a)anthracene	0.47	0.63	2.12	12/31/2004	1.7	2.3	7.7
SW-846, 8270	Benzo(a)pyrene	1.1	1.5	5.0	12/31/2004	4	5.4	18.0
SW-846, 8270	Benzo(b)fluoranthene	0.83	1.12	3.74	12/31/2004	4.3	5.8	19.4
SW-846, 8270	Benzo(ghi)perylene	1.2	1.6	5.4	12/31/2004	3.1	4.2	14.0
SW-846, 8270	Benzo(k)fluoranthene	1.5	2.0	6.8	12/31/2004	4.8	6.5	21.6
SW-846, 8270	Benzyl alcohol	0.33	0.45	1.49	12/31/2004	1	1.4	4.5
SW-846, 8270	Bis(2-Chloroethoxy)methane	0.37	0.50	1.67	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Bis(2-chloroethyl) ether	0.43	0.58	1.94	12/31/2004	1.1	1.5	5.0
SW-846, 8270	Bis(2-ethylhexyl) phthalate	2.7	3.6	12.2	12/31/2004	3.6	4.9	16.2
SW-846, 8270	Butylbenzylphthalate	0.55	0.74	2.48	12/31/2004	1.8	2.4	8.1
SW-846, 8270	Chrysene	0.6	0.81	2.70	12/31/2004	2	2.7	9.0
SW-846, 8270	Di-n-butylphthalate	0.47	0.63	2.12	12/31/2004	1.7	2.3	7.7
SW-846, 8270	Di-n-octylphthalate	5.1	6.9	23.0	12/31/2004	2.2	3.0	9.9
SW-846, 8270	Dibenz[a,h]anthracene	1.4	1.9	6.3	12/31/2004	2.7	3.6	12.2
SW-846, 8270	Dibenzofuran	0.36	0.49	1.62	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Diethylphthalate	0.24	0.32	1.08	12/31/2004	3.6	4.9	16.2
SW-846, 8270	Dimethyl phthalate	0.68	0.92	3.06	12/31/2004	2.1	2.8	9.5
SW-846, 8270	Fluoranthene	0.44	0.59	1.98	12/31/2004	1.5	2.0	6.8
SW-846, 8270	Fluorene	0.38	0.51	1.71	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Hexachlorobenzene	0.47	0.63	2.12	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Hexachlorobutadiene	0.41	0.55	1.85	12/31/2004	0.91	1.2	4.1

Table C.23. (contd)

Method	Constituent	Initial MDL[(a)] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[(a)] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Hexachlorocyclopentadiene	2.4	3.2	10.8	12/31/2004	2.5	3.4	11.3
SW-846, 8270	Hexachloroethane	0.24	0.32	1.08	12/31/2004	0.8	1.1	3.6
SW-846, 8270	Indeno(1,2,3-cd)pyrene	1.2	1.6	5.4	12/31/2004	2.6	3.5	11.7
SW-846, 8270	Isophorone	0.23	0.31	1.04	12/31/2004	1.1	1.5	5.0
SW-846, 8270	N-Nitroso-di-n-propylamine	0.89	1.20	4.01	12/31/2004	2.4	3.2	10.8
SW-846, 8270	N-Nitrosodimethylamine	0.46	0.62	2.07	12/31/2004	0.73	0.99	3.29
SW-846, 8270	N-Nitrosodiphenylamine	0.45	0.61	2.03	12/31/2004	1.2	1.6	5.4
SW-846, 8270	Naphthalene	0.3	0.4	1.4	12/31/2004	1.1	1.5	5.0
SW-846, 8270	Pentachlorophenol	0.58	0.78	2.61	12/31/2004	3.8	5.1	17.1
SW-846, 8270	Phenanthrene	0.4	0.5	1.8	12/31/2004	1.4	1.9	6.3
SW-846, 8270	Phenol	0.26	0.35	1.17	12/31/2004	0.52	0.70	2.34
SW-846, 8270	Pyrene	0.46	0.62	2.07	12/31/2004	1.7	2.3	7.7

(a) MDLs for many constituents changed during the fiscal year. For th date). In cases where the MDL did not change, no ending values are listed.

(b) µMhos/cm.

(c) Between 05/26/2004 and 09/01/2004, a third MDL (value not shown in table) was in effect for this compound.

(d) Between 04/09/2004 and 06/16/2004, a third MDL (value not shown in table) was in effect for this compound.

(e) Two instruments (standard and trace level) were used for samples analyzed by method 6010. MDL values for the standard instrument were included in this table. MDL values for the trace instrument were typically 2 to 10 times lower, but in s

(f) A third MDL (value not shown in table) was in effect for this compound for part of the fiscal year before the effective date of the ending value.

(g) Two additional MDLs (values not shown in table) were in effect for this compound for part of the fiscal year before the effective date of the ending value.

LOD = Limit of detection.
LOQ = Limit of quantitation.
MDL = Method detection limit.

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