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Hanford Site Groundwater Monitoring for Fiscal Year 2000

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L. F. Morasch
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Prepared for the U.S. Department of Energy
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Abstract

This report was written to describe current groundwater conditions on the Hanford Site and to fulfill regulatory reporting requirements for the period October 1999 through September 2000. It also summarizes the results of groundwater monitoring conducted to assess the effects of groundwater remediation, describes the results of vadose zone monitoring and characterization, and summarizes groundwater modeling activities.

The most extensive contaminant plumes 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. These widespread plumes have ceased spreading, and concentrations are declining in most areas. Carbon tetrachloride, technetium-99, and uranium form plumes beneath the central site that do not reach the Columbia River. Contaminant plumes beneath the former reactor areas near the Columbia River include chromium, strontium-90, and tritium.

Resource Conservation and Recovery Act of 1976 groundwater monitoring continued at 24 waste management areas during fiscal year 2000, including five waste management areas where past leaks from single-shell tanks appear to have contaminated groundwater.

Interim groundwater remediation in the northern Hanford Site continued with the goal of reducing the amount of chromium and strontium-90 reaching the Columbia River. The objective of two interim remediation systems in the central Hanford Site is to prevent the spread of carbon tetrachloride and technetium-99/uranium plumes.

Vadose zone monitoring, characterization, remediation, and several technical demonstrations were conducted in fiscal year 2000. Baseline spectral gamma-ray logging of selected wells in single-shell tank farms was completed. The environmental restoration contractor began characterization of several waste sites in and near the 200 Areas to determine the distribution of contamination in the soil. Soil gas monitoring at the 618-11 burial ground provided a preliminary indication of the location of tritium in the vadose zone and in groundwater. At a vadose zone remediation site in the 200 West Area, soil gas monitoring of carbon tetrachloride continued while the vapor extraction system was shut off. Much of the readily extractable carbon tetrachloride has been removed.

Groundwater modeling efforts focused on (1) identifying and characterizing major uncertainties in the current conceptual model and (2) performing a transient inverse calibration of the existing site-wide model. Specific model applications were conducted in support of the Hanford Site carbon tetrachloride Innovative Treatment Remediation Technology; to support the performance assessment of the Immobilized Low-Activity Waste Disposal Facility; and in development of the System Assessment Capability, which is intended to predict cumulative site-wide effects from all significant Hanford Site contaminants. Groundwater models were used at a local scale to assess and improve the performance of groundwater pump-and-treat systems.

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

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Mary Hartman
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Summary

Over 1.7 trillion liters of liquid waste, some containing radionuclides and hazardous chemicals, have been released to the ground on the Hanford Site since 1944. A portion of these contaminants was held above the water table and some reached groundwater. The U.S. Department of Energy (DOE) monitors groundwater on the Hanford Site to track the spread of these contaminants. Groundwater is being remediated at seven sites that were identified as requiring immediate action.

State and federal regulations require groundwater monitoring for protection of human health and the environment. This report summarizes results of monitoring for fiscal year 2000 and fulfills reporting requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA), specific Washington Administrative Codes, and the *Atomic Energy Act of 1954* as implemented by DOE orders. This report also summarizes results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

Fiscal Year 2000 Highlights

The following highlights represent significant changes or accomplishments for fiscal year 2000.

100 K Fuel Storage Basins: Nuclear fuel elements are stored in water-filled basins in the 100 K Area. Groundwater is monitored to detect new leaks from the basins if they occur. Data for fiscal year 2000 indicated the basins are not currently leaking. DOE began removing the fuel canisters in December 2000.

In Situ Redox Manipulation: Sodium dithionite was injected into 11 wells in the 100 D Area to extend the length of a permeable treatment zone in the aquifer. As groundwater flows through this zone, hexavalent chromium is converted to the non-hazardous trivalent form, which is virtually immobile in groundwater.

Pump-and-Treat Systems: Six interim remedial measures involving pump-and-treat systems continued to operate during fiscal year 2000, with a goal to prevent the worst contaminants from spreading.

Report Objectives

This report is designed to meet the following objectives:

- describe current groundwater conditions
- fulfill federal and state reporting requirements for groundwater monitoring
- summarize the results of groundwater cleanup
- summarize the results of vadose zone monitoring and characterization
- summarize groundwater modeling activities
- summarize the installation, maintenance, and decommissioning of monitoring wells.

Groundwater Monitoring at Single-Shell Tanks: Waste Management Area U began RCRA assessment monitoring. Initial assessment results indicated that chromium, nitrate, and technetium-99 in groundwater may have come from sources within the tank farm. Four other single-shell tank waste management areas continued assessment monitoring with installation of new wells, hydrologic and tracer testing, and additional sampling and analysis to evaluate the rate of contaminant movement and the extent and concentrations of contaminants.

Monitoring Wells: Many 200 Area wells are going dry because the water table is declining. The water table beneath the Liquid Effluent Retention Facility is dropping below the top of the basalt bedrock, and DOE is investigating alternatives to groundwater monitoring. Fifteen new wells were installed for RCRA groundwater monitoring at the single-shell tanks. Seventeen new wells were installed in the 100 Areas for activities related to environmental restoration.

618-11 Burial Ground: Tritium concentrations reached 8 million pCi/L in a downgradient well. Tritium concentrations were much lower in nearby wells, indicating the plume is very small. Soil-gas monitoring helped delineate the distribution of tritium in the vadose zone and groundwater.

System Assessment Capability: The System Assessment Capability is a tool to predict cumulative site-wide effects from all significant Hanford Site contaminants. In fiscal year 2000, the groundwater project compiled historical data to support initial history-matching runs of the model.

Model Calibration: A transient calibration of the site-wide groundwater flow model used information on the rising and falling water table to determine the distribution of aquifer parameters that produces the best match to observed water table changes.

Vadose Zone Characterization at Waste Management Area S-SX: Two slant boreholes were drilled at single-shell tanks Waste Management Area S-SX; one passed under a tank and samples will be analyzed for contaminants in fiscal year 2001. Cone penetrometer work identified a peak in gamma activity above the base of tank S-104.

Geophysical Logging: By the end of fiscal year 2000, baseline spectral gamma logs were completed for all 133 single-shell tanks with capacities of 2 million liters or greater. This characterization serves as a baseline against which future measurements can be compared to aid in identifying tank leaks.

Soil Gas Remediation: Soil gas monitoring at the carbon tetrachloride expedited response action site indicated that much of the readily accessible contamination was removed during soil-vapor extraction operations.

Clastic dike study: A 3-year study of clastic dikes and their influence on vertical movement of moisture and contaminants in the vadose zone began in fiscal year 2000. Results indicate that fine-grained dikes may retard vertical and lateral flow.

Groundwater Flow

The direction of groundwater flow in the uppermost aquifer beneath the Hanford Site is inferred from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants. Movement is generally from recharge areas in the west to discharge areas along the Columbia River. Beneath the reactor areas, groundwater flows generally toward the Columbia River. During periods of low river flow, some of this groundwater appears as seepage along the riverbanks. Inland from the reactors, in the area of the river's horn north of Gable Mountain, flow is toward the northeast and east. Groundwater flowing beneath the 200 West Area moves toward the 200 East Area, where flow becomes southeast. A northward component of flow has carried some contaminants from the northern 200 East Area into the gap between Gable Mountain and Gable Butte, and onto a northwesterly course that leads to the area between 100 B/C and 100 K Areas. As the water-table elevation lowers in the 200 Areas, this northward flow appears to be diminishing. Groundwater enters the 300 Area from the northwest, west, and southwest, and flows to the east toward the Columbia River. Groundwater in the Richland North Area generally flows east from the Yakima River toward the Columbia River.

Water levels continued to decline beneath the central Hanford Site in fiscal year 2000, causing some wells to go dry. Replacement wells were installed at three single-shell tank farms.

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 has decreased significantly, these mounds are disappearing. Water-table elevation maps for 1990 and 2000 are shown in Figure S.1. The 1990 water-table map shows groundwater mounds beneath the 200 West and 200 East Areas, which created radial flow near the mounds and induced northward flow toward the gap between Gable Mountain and Gable Butte. By fiscal year 2000, the mounds had become much less prominent. Water levels east of the 200 East Area have dropped below the top of a fine-grained confining unit, thus creating a barrier to movement in the surrounding unconfined aquifer. Beneath this confining unit, the uppermost aquifer is a transmissive unit in the Ringold Formation. Groundwater flow in this confined aquifer still is influenced by the recharge mound that formerly created an unconfined aquifer above the fine-grained confining unit in the area.

The near cessation of effluent discharge has caused significant changes in the direction and rate of groundwater movement, especially in the 200 Areas. The water table decline continued during fiscal year 2000, causing some monitoring wells to go dry. Replacement wells were installed at locations negotiated between DOE and the Washington State Department of Ecology (Ecology).

The fiscal year 2000 potentiometric map for the upper basalt-confined aquifer is similar to maps in previous reports. The potentiometric map indicates that, south of Umtanum Ridge and Gable Mountain, groundwater generally flows from west to east across the Hanford Site, through the overlying sediment, and into the Columbia River. In the region northeast of Gable Mountain, there is insufficient well coverage to update the map for fiscal year 2000. Earlier maps indicate that groundwater flows southwest and discharges primarily to underlying confined aquifer systems in the Umtanum Ridge/Gable Mountain structural area. Water levels in the central and western portions of the Hanford Site continued to decline in fiscal year 2000, responding to a reduction in artificial recharge to the overlying unconfined aquifer. Water levels in the eastern portion of the Hanford Site continued to increase because of large-scale irrigation activities in areas east of the Columbia River.

The Hanford Groundwater Monitoring Project sampled 669 wells during fiscal year 2000. Tritium, nitrate, and iodine-129 are the most widespread contaminants.

Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Therefore, there is little potential for contaminants to migrate from the unconfined aquifer into the basalt-confined aquifer, where it could move offsite. Downward gradients are measured beneath the western portion of the site, B Pond, and north and east of the Columbia River.

Groundwater Contamination

Monitoring wells were sampled during fiscal year 2000 to satisfy requirements of RCRA, CERCLA, Washington Administrative Code, and DOE orders. There were 669 wells sampled during the period. Sampling of some wells was delayed or cancelled because of issues relating to collection and disposal of secondary sampling waste, such as gloves and tubing. The historical practice of disposing of the secondary waste in regular trash cans was unacceptable. Groundwater sampling was temporarily halted until an acceptable practice of managing the waste was put in place. All secondary waste is now bagged, labeled, and collected in designated drop locations before disposal.

Most of the contamination in the groundwater today resulted from the discharge of high volumes of relatively low-concentration effluents into cribs, ponds, and ditches in the past. Contaminant concentrations in the existing groundwater plumes are expected to decline through radioactive decay, chemical degradation, and dispersion. However, potential sources of new groundwater contamination reside beneath many inactive facilities where contaminants are contained in the vadose zone (e.g., cribs or retention trenches). Increased infiltration of water from man-made or natural sources has been known to mobilize the contamination from the vadose zone to groundwater. In addition, there are a few facilities that are actively storing or disposing of waste: K Basins, underground storage tanks, state-permitted disposal facilities, and solid waste burial grounds. In the past few years, mobile fractions of waste from single-shell tanks and waste in the 618-11 burial ground have been detected in groundwater.

The extent of radiological and chemical contaminant plumes in Hanford Site groundwater are shown in Figures S.2 and S.3. The maps are based on averaged data from wells that monitor near the top of the unconfined aquifer. Contours represent applicable State or Federal standards for drinking water. Groundwater is not a primary source of drinking water on the Hanford Site, but comparison to these standards provides some perspective on contaminant levels. The most extensive plumes are tritium, iodine-129, and nitrate, which all had multiple sources and are very mobile in groundwater. Strontium-90, technetium-99, and uranium exceeded standards in smaller plumes. Carbon tetrachloride and associated organic constituents form relatively large plumes beneath the 200 West Area. Minor radiological contamination included carbon-14 in the 100 K Area. Cesium-137, plutonium, and strontium-90 have exceeded standards in the past near the 216-B-5 injection well in the northern 200 East Area, but the wells were not sampled in fiscal year 2000. DOE derived concentration guide[(a)] levels were exceeded for strontium-90 in the 100 K, 100 N, and 200 East Areas (near the former Gable Mountain Pond). The DOE derived concentration guide for uranium was exceeded near U Plant. The DOE derived concentration guide for tritium was exceeded in single wells that monitor fuel storage basins in the 100 K Area, Waste Management Area TX-TY in 200 West Area, cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant, and the 618-11 burial ground.

In fiscal year 2000, 231 square kilometers of the aquifer were contaminated at levels exceeding drinking water standards. Concentrations of chromium, nitrate, strontium-90, tritium, and uranium exceeded drinking water standards in groundwater discharging to the Columbia River. Contaminant concentrations in river water remained extremely low.

Concentrations of chromium, nitrate, strontium-90, tritium, and uranium exceeded drinking water standards in groundwater discharging to the Columbia River in fiscal year 2000, as they have in the past. However, contaminant concentrations in river water remained extremely low at all locations and were well below standards.

The area of contaminant plumes on the Hanford Site with concentrations exceeding drinking water standards was estimated to be 231 square kilometers in fiscal year 2000. This is ~9% smaller than the estimate for fiscal year 1999. The decrease is primarily due to shrinkage of the 20,000-pCi/L tritium contour at the southern edge of the plume, and a revised interpretation that enlarged the area of low tritium concentrations at the Energy Northwest site. The fiscal year 2000 plumes equate to a volume of ~1.07 billion cubic meters of contaminated groundwater. This volume calculation was based on porosity values of 0.15 for the Ringold gravel/sand and 0.25 for the Hanford and pre-Missoula gravel, and estimated plume thicknesses developed for the System Assessment Capability model. The plumes range from 5 to 30 meters thick, depending on the stratigraphy of the aquifer system. The estimate did not include water in the vadose zone.

Limited data are available on contamination deeper in the Ringold Formation near the 200 Areas. Tritium, technetium-99, carbon tetrachloride, and nitrate have been detected in these deeper units.

Tritium

Tritium is very mobile in groundwater. The largest plume originates in the 200 East Area and extends to the southeast. Levels are generally declining due to radioactive decay.

Tritium was present in Hanford Site waste discharged to the soil and is the most mobile and most widely distributed radionuclide onsite. It has a relatively short half-life (12.3 years). The drinking water standard is 20,000 pCi/L.

The most prominent tritium plume originated in the 200 East Area near the PUREX Plant and is migrating downgradient to the southeast. This plume discharges to the Columbia River from the old Hanford Townsite to the 300 Area.

(a) The DOE derived concentration guide is based on an exposure standard of 100 millirem per year and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios.

Tritium concentrations in seeps or aquifer sampling tubes exceeded drinking water standard near the old Hanford Townsite, where they are greater than 100,000 pCi/L.

Another tritium plume from the 200 East Area has moved northward between Gable Mountain and Gable Butte. A smaller plume between the 200 East and 200 West Areas has its source near the 200 West Area's Reduction-Oxidation (REDOX) Plant. This plume is moving relatively slowly because the aquifer has a relatively low permeability. Additional plumes of tritium originated in the 100 Areas, exceeding the drinking water standard locally.

Tritium exceeded its 2 million pCi/L DOE derived concentration guide in one well in 100 K Area, in one well that monitors Waste Management Area TX-TY, in one well near cribs that received effluent from the PUREX Plant, and in a well monitoring the 618-11 burial ground. Tritium at the 618-11 burial ground was discovered in fiscal year 1999, and included the highest concentration on the site in fiscal year 2000 (8.38 million pCi/L). Recent studies indicate that the extremely high levels have not spread to nearby wells.

The highest tritium concentration measured in fiscal year 2000 was 8 million pCi/L in a well near the 618-11 burial ground. The high concentration is limited to a single well.

Tritium contamination has been detected in confined aquifers beneath the 200 Areas. Concentrations exceeded the drinking water standard in several wells that monitor a confined aquifer in the Ringold Formation near 200 East Area. Levels below the standard were detected in the upper basalt-confined aquifer.

The migration of the 200 East Area tritium plume is illustrated by the historical plume maps in Figure S.4. The maps were made by re-interpreting and manually contouring historical data stored in the Hanford Environmental Information System (HEIS) database. Tritium data were not available for the 100 Areas for the 1970 map. In the past 30 years, the center mass of the main tritium plume has migrated along an arced path from the 200 East Area to the old Hanford Townsite. The tritium plume from the 200 West Area has migrated only slightly because the aquifer is less transmissive in that region.

An extensive tritium plume had already moved southeast from the 200 East Area by 1970, and concentrations >20,000 pCi/L had moved about two-thirds of the way to the Columbia River. In the next ten years, concentrations of 200,000 pCi/L approached the old Hanford Townsite, but this part of the plume had "broken off" from the source in the southeastern 200 East Area. In the southern portion of the Site, the 20,000-pCi/L portion of the plume had apparently flowed around less transmissive sediment beneath the Energy Northwest site. By 1990, the portion of the plume with concentrations >200,000 pCi/L had shrunk. In a small part of the northwestern 200 East Area, concentrations had increased to >200,000 pCi/L. The map for fiscal year 2000 shows that the southward spread continued, with the 20,000 pCi/L contour approaching the 300 Area. The >200,000 pCi/L part of the plume has dissipated, except for one small section near the PUREX plant. Concentrations in the southeastern part of the plume are declining because of dispersion and radioactive decay. The southern margin of the plume appears to have ceased its southward migration in about 1995. Concentrations also have declined in the past 10 years in the northwestern 200 East Area, but a plume with its origins in that region is now migrating north between Gable Mountain and Gable Butte.

Iodine-129

Extensive plumes of groundwater contaminated with iodine-129 exceeded the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area.

Iodine is a fission product and was present in waste related to fuel processing. The presence of iodine-129 in groundwater is significant because of its relatively low 1 pCi/L drinking water standard, its long-term releases from nuclear fuel processing facilities, and its long half-life (16 million years). Iodine-129 is transported in groundwater as the anionic iodide (I^-) species that is very mobile. Waste containing iodine-129 was historically disposed of in the 200 Areas. Extensive plumes exceed the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area. The major plume extends toward the southeast from the 200 East Area. A smaller plume of iodine-129 is moving toward the north between Gable Mountain and Gable Butte. The highest concentration of iodine-129 detected in fiscal year 2000 was 52 pCi/L at Waste Management Area TX-TY.

Riverbank seeps near the old Hanford Townsite contain low levels of iodine-129 (0.4 pCi/L in fiscal year 2000). Data from wells near the river shore and farther inland do not indicate any discernible trend, so concentrations are not expected to increase in the future.

The iodine-129 plume from 200 East Area probably migrated at about the same rate as the tritium plume, but iodine-129 data were not commonly collected until the 1980s. Maps from 1990 and 2000 are shown in Figure S.5. By 1990, the portion of the plume exceeding the 1 pCi/L drinking water standard had traveled more than halfway to the Columbia River. It moved an additional two and a half kilometers between 1990 and 2000. The plume will continue moving toward the river, but concentrations are expected to decline because of dispersion. The plume in the 200 West Area grew only slightly in the past 10 years because the aquifer is less transmissive.

Technetium-99

Technetium-99 was produced as a high-yield fission product and was present in waste streams associated with fuel processing. Technetium-99 is transported in groundwater as an anionic pertechnetate (TcO_4^-) species that is highly mobile. Technetium-99 tended to be associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater on the Hanford Site, so it does not have the same distribution.

Technetium-99 is a mobile contaminant that exceeds the drinking water standard in small plumes. The highest concentration in fiscal year 2000 was in a new well monitoring S-SX single-shell tank farm.

The 200 West Area had the highest technetium-99 concentrations detected in fiscal year 2000 (63,700 pCi/L near the S-SX single-shell tank farms). A plume associated with U Plant is migrating to the east into the 600 Area. A groundwater pump-and-treat system is operating near U Plant to contain the plume. Technetium-99 also is elevated in wells monitored for the B, BX, BY, T, TX, and TY single-shell tank farms. These sites are undergoing RCRA assessment investigations.

Elevated technetium-99 levels apparently associated with the BY cribs (200 East Area) continued to be detected in fiscal year 2000. The maximum annual average near the BY cribs was 10,700 pCi/L.

A small plume of technetium-99 is detected in the 100 H Area near the former 183-H solar evaporation basins. Concentrations vary with river stage. The fiscal year 2000 maximum was 1,070 pCi/L.

Well 299-E33-12, completed in the basalt-confined aquifer near the BY cribs, had technetium-99 at levels above the 900-pCi/L drinking water standard in fiscal year 1998 (average of 1,500 pCi/L, which is within the historical range). However, this well was not scheduled for sampling in fiscal years 1999 or 2000 because a 3-year sampling frequency is sufficient to monitor the steady trend.

Uranium

Uranium contamination on the Hanford Site had numerous potential sources, including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium mobility is dependent on Eh, pH, and the presence of carbonate; its migration is slower than that of tritium and technetium-99. At the Eh/pH conditions found in the unconfined aquifer, uranium(VI) is the most mobile state.

The U.S. Environmental Protection Agency (EPA) proposed a 20 µg/L maximum contaminant level for uranium.[(a)] Uranium was detected at concentrations above this level in the 100 H, 200, and 300 Areas and at the 618-11 burial ground. Contamination in the 100 H and 200 East Areas is very localized.

The highest concentrations detected in fiscal year 2000, which exceeded the DOE derived concentration guides for uranium isotopes, were in the 200 West Area near the 216-U-1, 216-U-2, and 216-U-17 cribs. This plume extends into the 600 Area to the east. Like technetium-99, this plume is the target of a pump-and-treat interim remedial action.

Another area of elevated uranium concentrations is observed in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination is moving from the vicinity of the process trenches toward the southeast. A riverbank seep detected 301 µg/L uranium in fiscal year 2000.

Strontium-90

Strontium-90 was present in waste associated with fuel processing; it was released also by fuel element failures during reactor operations. Strontium-90 has a moderately long half-life (28.8 years).

The most widespread strontium-90 contamination is in the 100 N Area, and is the target of a pump-and-treat interim remedial action. The plume has not changed significantly in 10 years. Concentrations in two near-river wells are very high. Strontium-90 is of concern because of its moderately long half-life (28.8 years) and its potential to concentrate in animal and human bones.

In fiscal year 2000, strontium-90 exceeded the 8 pCi/L drinking water standard in wells in each of the 100 and 200 Areas. Strontium-90 exceeded the 1,000 pCi/L DOE derived concentration guide in wells in the 100 K and 100 N Areas and near the former Gable Mountain Pond. Wells near the 216-B-5 injection well have exceeded the DOE derived concentration guide in the past, but were not sampled in fiscal year 2000.

The most widespread, high strontium-90 concentrations continued to be detected in the 100 N Area, where the distribution of the plume has changed very little over the past 10 years. The goal of a pump-and-treat system in the 100 N Area is to reduce the movement of strontium-90 toward the Columbia River. Near-river wells detected strontium-90 at up to 10,800 pCi/L in fiscal year 2000.

Carbon-14

Carbon-14 exceeded the 2,000 pCi/L drinking water standard in two small plumes near waste disposal facilities adjacent to the KW and KE Reactor buildings where reactor atmosphere gas condensate was discharged to the ground in the past. The maximum concentration in fiscal year 2000 was 35,600 pCi/L, about the same as in recent years.

Cesium-137

Cesium-137 is a high-yield fission product. It was present in waste associated with fuel processing and has been released in reactor areas by fuel element failures. Near the 216-B-5 injection well, the concentration of cesium-137 in groundwater in fiscal year 1999 was 1,840 pCi/L, which is consistent with the historical trend for the well. The well was not sampled in fiscal year 2000 because of waste management issues. The drinking water standard for cesium-137 is 200 pCi/L.

Cesium-137 was present in waste that leaked from underground storage tanks in the past. It is present in the vadose zone near the tanks, but is rarely detected in groundwater.

Cesium-137 is a potential contaminant of concern at the S and SX single-shell tank farms. However, it was not detected in groundwater in fiscal year 2000 in this area. The radionuclide is dominantly sorbed to soil and is not considered a significant groundwater contaminant.

(a) In December 2000, EPA set a new standard for uranium, 30 µg/L. The new standard will be implemented in 2002.

Plutonium

Plutonium was present in waste associated with fuel processing. The DOE derived concentration guide for plutonium-239 is 30 pCi/L. There is no explicit drinking water standard for plutonium-239; however, the maximum contaminant level for gross alpha (15 pCi/L) is applicable. Alternatively, if the DOE derived concentration guide, which is based on a 100 millirem dose standard, is converted to the 4 millirem dose equivalent used for the drinking water standard, 1.2 pCi/L would be the relevant guideline. Plutonium generally binds strongly to sediment, so its mobility in groundwater is limited.

The only significant detection of plutonium in recent years has been associated with the 216-B-5 injection well in the 200 East Area. Typical plutonium-239/240 concentrations detected near this injection well are 60 pCi/L, but the well was not sampled in fiscal year 2000 due to waste management issues.

Nitrate

Nitrate is the widest spread chemical contaminant in groundwater on the Hanford Site. However, the largest portions of the plumes are below the drinking water standard.

Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical processing operations. Septic systems and residual chemicals from pre-Hanford agricultural activities are additional sources of nitrate. Like tritium, nitrate was present in many waste streams and is mobile in groundwater. Additional sources of nitrate are located off the Hanford Site to the south and west.

Nitrate was measured at concentrations greater than the maximum contaminant level (45 mg/L) in wells in all operational areas except 100 B/C. The most extensive plume in the 100 Areas originates in 100 F Area and extends downgradient to the south. This plume was detected in an aquifer sampling tube and a riverbank seep at levels above the maximum contaminant level in fiscal year 2000. The 200 West Area has two main nitrate plumes: one from the vicinity of U Plant extending into the 600 Area, and another near T Plant. Smaller amounts of contamination are found near the Plutonium Finishing and REDOX plants. Waste sites near the PUREX Plant in the 200 East Area contributed to extensive plumes that extend to the southeast, but only proportionally small areas contained nitrate at levels above the maximum contaminant level. This plume extends to wells near the Columbia River at the old Hanford Townsite, where nitrate concentrations are below the maximum contaminant level and are gradually declining. Another plume originates at facilities associated with B Plant and migrates northward.

Two relatively small areas where nitrate is greater than the maximum contaminant level continue to be detected near the 400 Area and Energy Northwest. Nitrate contamination in the Richland North Area apparently has a source off the Hanford Site.

Chromium

Hexavalent chromium may be a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in 100 K, 100 D, and 100 H Areas to reduce the amount of chromium reaching the Columbia River.

A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. Chromium compounds also were used for decontamination in the 100, 200, and 300 Areas and for oxidation-state control in the REDOX Plant processes in the 200 West Area. The hexavalent form of chromium is very soluble in groundwater. The trivalent form is not soluble, so chromium measured in filtered samples is in the more toxic, hexavalent form. Chromium is elevated in each of the 100 Areas, but the major plumes exceeding the 100 µg/L maximum contaminant level are related to past operations in the 100 K, 100 D, and 100 H Areas. Interim actions are under way to pump and treat groundwater in these areas to reduce the amount of chromium reaching the Columbia River.

A plume in the southwestern 100 D Area with maximum concentrations greater than 2,000 µg/L is being treated in situ by a method of reduction/oxidation manipulation. Riverbank concentrations of chromium in the 100 Areas exceeded the maximum contaminant level in the 100 B/C and 100 D Areas in fiscal year 2000.

A chromium plume in the southwestern 100 D Area is being treated in the aquifer to immobilize the contaminant.

Chromium concentrations also exceeded the maximum contaminant level in small plumes or single wells near 200 East and West Area tank farms. Concentrations declined sharply near the 216-S-10 pond and ditch in fiscal year 2000 to levels below the maximum contaminant level. Chromium continued to exceed the maximum contaminant level in one well southwest of the 200 East Area. Other wells in the area also have elevated chromium, though levels are below the maximum contaminant level. The source of this plume has not been identified.

Carbon Tetrachloride

Carbon tetrachloride contamination exceeds the 5 µg/L maximum contaminant level beneath much of the 200 West Area. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume on the Hanford Site. The contamination is principally from waste disposal operations associated with the Plutonium Finishing Plant, where it was used in plutonium processing. Concentrations in the central part of the plume remained above 2,000 µg/L in fiscal year 2000, with the maximum average value at 6,600 µg/L. A groundwater pump-and-treat system is operating in this area to prevent the central portion of the plume from spreading. There appears to be a shift in the maximum concentrations toward the pumping wells.

Groundwater beneath the 200 West Area is contaminated with carbon tetrachloride. A pump-and-treat system prevents the center of the plume from spreading.

The area of the carbon tetrachloride plume in fiscal year 2000 was 9.8 square kilometers. The plume has grown in the past 10 years, as illustrated by maps for fiscal years 1990 and 2000 (Figure S.6). The 1990 map is a reinterpretation of averaged data stored in the HEIS database. The most notable changes were in the southwestern lobe of the plume. These changes probably were related to dissipation of the groundwater mound under U Pond, which formerly prevented southward flow. Carbon tetrachloride concentrations have declined along the western boundary of the 200 West Area as cleaner water flows in from upgradient locations. Meanwhile, the plume spread ~500 to 700 meters to the south over the past decade. The maximum concentration detected northwest of the Plutonium Finishing Plant declined from 8,500 µg/L in fiscal year 1990 to 6,600 µg/L in 2000. The highest concentration near T Plant also declined between 1990 and 2000. This may be due to spreading of the plume to the northeast, as suggested by concentration trends for wells in that area. Concentrations increased in the vicinity of U Plant and its associated disposal cribs. Data are sparse along the eastern side of the plume, but the 5 and 100 µg/L contours appear to have moved farther northeast. The southeastern lobe of the plume also spread slightly, but data are particularly lacking in that area.

In some areas, concentrations of carbon tetrachloride decrease with depth, but data collected in recent years indicate that in other areas carbon tetrachloride is present at higher concentrations deeper in the Hanford/Ringold sediment than at the water table. Therefore, the extent of the plume at the water table may not reflect the extent in deeper parts of the aquifer system.

Chloroform

The 200 West Area chloroform plume is associated with the carbon tetrachloride plume and is believed to be a degradation product of carbon tetrachloride. The maximum annual average value was 96 µg/L, detected in 200 West Area in fiscal year 2000. The maximum contaminant level for chloroform is 100 µg/L (total trihalomethanes).

Trichloroethene

Trichloroethene was used to remove grease. It is present in small plumes in the 100 K, 100 F, 200 West, 300, and Richland North Areas.

Trichloroethene was used on the Hanford Site in the 1960s and 1970s as a degreasing compound. Concentrations of trichloroethene exceeded the 5 µg/L maximum contaminant level in fiscal year 2000 in wells in the 100 K, 100 F, and 200 West Areas. Concentrations declined below the standard in the 300 Area in fiscal year 2000. Trichloroethene typically exceeds the standard in the Richland North Area, but sampling was delayed past fiscal year 2000. Concentrations have been declining in that area because of natural attenuation. Low levels of trichloroethene also were detected in wells near the Solid Waste Landfill, but concentrations were below the maximum contaminant level.

The trichloroethene plume in the 200 West Area extends from the Plutonium Finishing Plant to T Plant. It also exceeds the maximum contaminant level in single-well plumes in other parts of the 200 West Area.

cis-1,2-Dichloroethene

Concentrations of cis-1,2-dichloroethene remained high in a well that monitors the bottom of the unconfined aquifer near the 316-5 process trenches in the 300 Area. The maximum cis-1,2-dichloroethene concentration in this well in fiscal year 2000 was 170 µg/L (maximum contaminant level is 70 µg/L). The source of this constituent is believed to be anaerobic biodegradation of trichloroethene.

Cyanide

Cyanide was associated with waste discharged to the BY cribs near 200 East Area. In groundwater, it exceeded the drinking water standard in two wells in fiscal year 2000 and concentrations are increasing.

Cyanide contamination is present north of the 200 East Area and is believed to have originated from wastes containing ferrocyanide that were disposed in the BY cribs. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Cyanide concentrations exceeded the 200 µg/L maximum contaminant level in two wells in fiscal year 2000, with a maximum value of 411 µg/L, an increase from fiscal year 1999.

Ingestion Risk and Dose Estimate

Groundwater is not a primary source of drinking water for most Hanford Site workers. However, comparison to drinking water standards provides perspective for contaminant levels in groundwater. Drinking water standards use the methods set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 millirem per year from consumption of each individual constituent. Similarly, DOE derived concentration guides provide estimates of radiological concentration that could result in a 100 millirem per year dose as defined in DOE Order 5400.5. However, the potential dose is actually the sum of the doses from the individual constituents. An estimate of this cumulative dose, which could result from consumption of groundwater from different onsite locations, can be calculated from the extent of contamination.

A person's potential dose from drinking contaminated water is the sum of the doses from the individual radionuclides. The highest potential dose estimates on the Hanford Site are restricted to parts of the 100 K, 100 N, and 200 Areas. Groundwater is not used for drinking in these areas.

Figure S.7 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer on the Hanford Site. These estimates were made by adding the effects of all major radionuclides in Hanford Site groundwater: carbon-14, cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium, and uranium. The automatic interpolation process sometimes resulted in peak grid values that were lower than the measured maximum values because it averaged in other lower values. In these cases, the value at the grid node closest to the measured peak value was increased to match the measured peak. Factors to convert activities to ingestion dose equivalents were taken from DOE Order 5400.5.

The dose estimates presented in Figure S.7 show that areas above the 100-millirem per year dose standard are restricted to localized parts of the 100 K, 100 N, and 200 Areas and a location around a single well downgradient of the 618-11 burial ground. Portions of the 100, 200, 300, and 600 Areas exceed 4 millirem per year.[a]

Figure S.8 illustrates the likelihood of a person developing cancer over a lifetime as a result of drinking water contaminated with chemicals and radionuclides at concentrations that have been measured in groundwater across the Hanford Site. Cancer-risk estimates were made by adding concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, cis-1,2-dichloroethene, hexavalent chromium, nitrate, and trichloroethene. The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). Cancer risks exceeding 0.0001 (i.e., 1 in 10,000) are present in portions of the 100, 200, 300, and 600 Areas.

Figure S.9 shows the estimated hazard quotient that would be experienced by an individual drinking water contaminated with chemicals at concentrations that have been measured in groundwater across the Hanford Site. The hazard quotient relates the potential human health hazards associated with exposure to non-carcinogenic substances or carcinogenic substances with systemic toxicity other than cancer (in Hanford Site groundwater, these include hexavalent chromium, nitrate, strontium, and uranium). The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). If the hazard quotient is greater than one, there is a possibility of toxic effects. Values between 1 and 5 are present in the 100 K, 100 D, 100 F, 200 West, and 200 East Areas and from offsite contamination in the Richland North Area. The only locations with hazard quotients above 5 are small portions of the 100 D, 200 West, and 200 East Areas. Values between 1 and 5 are present in the 100 K and 100 F Areas and from offsite contamination in the Richland North Area.

The hazard quotient describes potential health hazards associated with ingesting non-carcinogenic substances. The highest hazard quotient on the Hanford Site is in a small part of the 200 West Area.

Groundwater Remediation

Groundwater remediation conducted in accordance with CERCLA was performed at the following sites:

100-KR-4 Operable Unit, 100 K Area — An interim action to address chromium contamination near the 116-K-2 trench continued in fiscal year 2000. Groundwater is extracted from six wells between the trench and the Columbia River, treated to remove chromium, and injected into wells upgradient of the trench. A capture zone model indicates that part of the plume is not being captured, so a new extraction well is being added. The mass of chromium in the aquifer also is being reduced.

(a) EPA drinking water standards for radionuclides in 40 CFR Part 141 were derived based on a 4 millirem per year 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 area exceeding drinking water standards in Figure S.2 is based on the EPA regulatory requirement. However, the areas in Figure S.7 corresponding to a dose greater than 4 millirem per year were calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (as implemented in DOE Order 5400.5 in 1993). If both dosimetry systems were equivalent, one would expect the area above 4 millirem per year in Figure S.7 to be the same as the area exceeding drinking water standards (see Figure S.2), or to show a slightly larger area exceeding 4 millirem per year (i.e., if two or more radionuclides were individually below the drinking water standards, but added up to exceed 4 millirem per year). In fact, the areas above 4 millirem per year on Figure S.7 are more restricted than the area above the drinking water standard in Figure S.2 because of differences in the dosimetry systems adopted by EPA and DOE.

100-NR-2 Operable Unit, 100 N Area — Groundwater continued to be extracted from wells near the 1301-N liquid waste disposal facility, treated to remove strontium-90, and injected into wells near the 1325-N liquid waste disposal facility. The extraction wells create a hydraulic barrier intended to reduce the volume of contaminated groundwater reaching the Columbia River. However, the system has not reduced the amount of strontium-90 in the aquifer significantly.

100-HR-3 Operable Unit, 100 D Area — An interim action pump-and-treat system continued in fiscal year 2000. The system removes chromium-contaminated groundwater from wells near the Columbia River and pipes it to the 100 H Area for treatment and injection. The hydraulic effects of groundwater extraction are estimated to result in containment of the plume along ~400 meters of shoreline. In a separate chromium plume, an in situ method of redox manipulation was expanded in fiscal year 2000. The project's goal is to create a permeable treatment zone in the subsurface where chemical-reducing agents will turn the highly soluble hexavalent chromium to an insoluble state.

100-HR-3 Operable Unit, 100 H Area — An interim action pump-and-treat system continued in fiscal year 2000. The system removes chromium from wells in the central 100 H Area, treats it to remove chromium, and injects the water into wells in the southwestern part of the area. An additional extraction well began operating in 2000 to improve contaminant capture.

200-UP-1 Operable Unit, 200 West Area — An interim action pump-and-treat system, designed to contain and treat the elevated technetium-99 and uranium, continued to operate in fiscal year 2000. The system also removes carbon tetrachloride and nitrate. Technetium-99 concentrations are below the goal of 9,000 pCi/L in all but one well. Uranium concentrations remained above the goal of 480 μg/L in almost all wells, even after treatment of 420.8 million liters of groundwater and 5 years of operation.

200-ZP-1 Operable Unit, 200 West Area — An interim action pump-and-treat system continued to operate to prevent further movement of carbon tetrachloride, chloroform, and trichloroethene from the high concentration portion of the carbon tetrachloride plume and to reduce contaminant mass. The system appears to be containing and capturing the portion of the plume with the highest concentrations.

Interim Groundwater Remediation

The goal of groundwater treatment systems on the Hanford Site is to prevent the worst contaminants from spreading. Six pump-and-treat systems processed the following volumes of groundwater in fiscal year 2000:

- 100 K (chromium): 285 million liters
- 100 N (strontium-90): 108 million liters
- 100 D (chromium): 136 million liters
- 100 H (chromium): 156 million liters
- 200 West (carbon tetrachloride): 63 million liters
- 200 West (technetium-99, uranium): 63 million liters.

Also, in the 100 D Area an in situ remediation system is immobilizing chromium in the aquifer.

Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

RCRA groundwater monitoring continued at 24 waste management areas. At the end of fiscal year 2000, 15 were being monitored under indicator evaluation programs and do not appear to adversely affect groundwater with hazardous constituents. The others were monitored under assessment or corrective-action programs. The following paragraphs summarize the highlights of RCRA monitoring during fiscal year 2000, including assessment investigations at five single-shell tank waste management areas.

Assessment activities at single-shell tank Waste Management Area T continued with the addition of new wells, hydrologic testing, and sampling and analysis to aid in evaluation of the rate of contaminant transport, the concentration and extent of contamination. Groundwater flow direction maintained a fairly constant direction, slightly north of east, during fiscal year 2000. Relatively high concentrations of nitrate, chromium, and fluoride have been reported in a number of wells as a result of an upgradient contaminant plume moving across the area. Values of nitrate exceeding 1,000 mg/L have been detected in several wells. Samples collected during drilling near the northeastern corner of the waste management area, coupled with chemical data from an existing well, indicate that the top portion of the aquifer is relatively impermeable and contains a high-technetium plume. Deeper portions of the aquifer are more permeable and groundwater is characterized by high nitrate, similar to the upgradient plume.

The water table beneath Waste Management Area T continued to decline in fiscal year 2000. Four new downgradient wells were installed in late fiscal year 2000 and early 2001 to replace dry wells and to account for changes in the direction of groundwater flow.

At Waste Management Area TX-TY, assessment activities continued with the addition of new wells, hydrologic testing, and sampling and analysis to aid in evaluation of the rate of contaminant transport, the concentration and extent of contamination. A plume with high levels of technetium-99 and a separate plume with high concentrations of tritium/iodine-129 and low levels of technetium-99 continued to be detected in the central portion of the waste management area. Tritium concentrations reached 2.9 million pCi/L and iodine-129 reached 48 pCi/L in a downgradient well east of the waste management area. The most likely source for the tritium/iodine-129 plume is the 242-T evaporator, located between the TX and TY tank farms. Increases in technetium-99 concentrations were detected in wells south of the waste management area, indicating the possibility that contaminants are being drawn toward the pump-and-treat system.

The operation of a pump-and-treat system in an area south of Waste Management Area TX-TY has changed the direction of groundwater flow over the past several years. Beneath the southern part of the waste management area, flow is primarily to the south, which may be causing tank-related contaminants to move southward. Five new monitoring wells were installed downgradient of Waste Management Area TX-TY in fiscal year 2000 or early 2001 to account for the changing flow direction and to track the plume farther from the waste management area.

Waste Management Area U was placed in assessment in early fiscal year 2000 because of an exceedance in the indicator parameter specific conductance. It remained in assessment because of elevated concentrations of chromium, nitrate, and technetium-99. Concentrations of these constituents were below drinking water standards, but they were above upgradient concentrations and a plausible upgradient source could not be identified.

The direction of groundwater beneath Waste Management Area U has been strongly influenced by the 200-ZP-1 pump-and-treat operations, particularly in the northern portion of the waste management area. One upgradient well went dry in fiscal year 2000. There are plans to replace this well and to drill several downgradient wells to improve the efficiency of the monitoring network.

RCRA Monitoring

RCRA monitoring at the Hanford Site included

- ▶ 2 sites under corrective action
- ▶ 7 sites under groundwater quality assessments
- ▶ 15 sites under indicator evaluation.

Assessment activities continued at Waste Management Area S-SX with installation of new wells, hydrologic and tracer testing, and additional sampling and analysis to evaluate the rate of contaminant movement and the extent and concentrations of contaminants. The most significant finding during the year was the persistent and gradually increasing trend in technetium-99 in a new well in the southwestern corner of the SX tank farm. Technetium-99 concentrations increased from 39,000 pCi/L on October 1999 to 64,000 pCi/L in June 2000. The contamination is attributed to previous tank waste leaks to the soil in that area. Circumstantial evidence suggests leakage from a nearby water line may be a recent driving force for transport of vadose zone contamination to groundwater. Water lines in this area will be isolated during summer 2001 as one interim corrective measure.

Although the SX tank farm occurrence is the highest technetium-99 concentration detected in groundwater at the Hanford Site, the contaminant plume appears to be localized and moving very slowly (<50 meters per year) to the east-southeast. Other tank waste constituents of concern (strontium-90, cesium-137, neptunium-237, plutonium-239/240, americium-241 and iodine-129) were analyzed in key network wells but all were below detection limits. Based on the groundwater data collected to date, only the more mobile tank waste constituents (e.g., technetium-99, nitrate, hexavalent chromium, tritium) have reached groundwater beneath Waste Management Area S-SX.

Assessment monitoring at Waste Management Area B-BX-BY in fiscal year 2000 continued to indicate the presence of three distinct plumes in the area, based on distinct chemical suites, spatial relationships, historic plume movement, and chemical ratios. Groundwater beneath the BY cribs, north of the waste management area, has the highest level of technetium-99 in the vicinity. This contamination is attributed to discharges to the cribs in the 1950s and forms an extensive plume that now is moving to the south, affecting the groundwater under Waste Management Area B-BX-BY. The highest concentration of nitrate is detected under the 216-B-8 crib, located east of the waste management area. This contamination is believed to be mostly associated with discharges to the crib in the late 1940s. A local low in the basalt bedrock exists in this area, and the contamination may be sitting in a partially stagnant pool. Technetium-99, nitrate, and nitrite have recently increased in wells near the BY tank farm. This contamination may have originated from past leaks within Waste Management Area B-BX-BY.

Assessment studies helped define the direction of groundwater flow in the northern 200 East Area.

Fiscal year 2000 studies, including borescope and trend surface analyses, helped refine the interpretation of the direction of groundwater flow in and near Waste Management Area B-BX-BY. Although the data showed local variability, the overall direction of flow appears to be toward the south beneath the waste management area. In the past, groundwater flowed to the northwest. Three new monitoring wells will be installed in fiscal year 2001.

The former 183-H solar evaporation basins (100 H Area) and the 316-5 process trenches (300 Area) were monitored under final status requirements during fiscal year 2000. Leakage from the 183-H basins in the past has contaminated the groundwater with chromium, nitrate, technetium-99, and uranium at levels exceeding applicable concentration limits. Corrective action is directed by the CERCLA program, and an interim remedial action (pump-and-treat system) for chromium continued in fiscal year 2000. Groundwater monitoring to meet RCRA requirements continues during the remediation.

The 316-5 process trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethene, trichloroethene, and uranium at levels above their respective concentration limits. However, Ecology has not approved the corrective-action monitoring plan, and monitoring continues under the compliance plan. Natural attenuation of the contaminants is the corrective action chosen in the CERCLA record of decision. Groundwater monitoring continues in accordance with RCRA.

The water table beneath the Liquid Effluent Retention Facility is dropping below the top of the basalt bedrock. Effective groundwater monitoring is no longer possible.

Changing water levels have affected the adequacy of some RCRA groundwater monitoring networks. In some areas, flow directions have changed since the networks were designed. In other areas, wells have gone dry because of a declining water table. Dry wells at the 216-S-10 pond and ditch and the 216-U-12 crib have caused their monitoring networks to be considered inadequate, and replacement wells may be required. In the 200 East Area, the Liquid Effluent Retention Facility was monitored by only two downgradient wells in fiscal year 2000 because the water table is dropping to near the bottom of the aquifer. In January 2001, another downgradient well went dry and Ecology directed DOE to cease statistical evaluation of groundwater data for the facility. The adequacy of monitoring networks for

Waste Management Areas A-AX and C are uncertain because of uncertainties in flow direction. Resolution of these uncertainties will be addressed in revised monitoring plans.

Well Installation

In fiscal year 2000, fifteen new wells were installed or begun for RCRA groundwater monitoring. Seventeen new wells were installed in the 100 Areas for activities related to environmental restoration.

Twenty wells were decommissioned (sealed with grout) in fiscal year 2000 because they were no longer used or were in poor condition. Approximately 314 well maintenance activities were carried out during fiscal year 2000. These activities included well or pump repair, cleaning, and maintenance.

Thirty-two new wells were installed or begun in fiscal year 2000 and twenty old wells were sealed.

Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and the effects of remediation systems. Pacific Northwest National Laboratory (PNNL) has responsibility for a site-wide, consolidated groundwater flow and transport model, while Bechtel Hanford, Inc. applies local-scale models to areas of interest for groundwater remediation.

PNNL performed a transient calibration of the site-wide groundwater flow model using historical water-level data. The transient calibration used information on the rising and falling water table to determine the distribution of aquifer hydraulic parameters that produces the best match to observed water table changes.

PNNL also applied the groundwater model to support the Hanford Carbon Tetrachloride Innovative Treatment Remediation Technology Program. This modeling estimated the potential impact of the 200 West Area carbon tetrachloride source on an assumed compliance boundary, ~5,000 meters away. The results of the modeling bracketed the amount of carbon tetrachloride in groundwater that will most likely result in compliance or non-compliance at the boundary.

Groundwater flow and transport calculations supported the performance assessment for the Immobilized Low-Activity Waste Disposal Facility in the 200 East Area. The consolidated site-wide model and supporting local scale models were used to evaluate the impacts from the transport of contaminants at a hypothetical well 100 meters downgradient of the disposal facilities and at the Columbia River.

Computer simulations of groundwater help predict future groundwater conditions and contaminant movement.

The Groundwater/Vadose Zone Integration Project is developing the System Assessment Capability as a tool to predict cumulative site-wide effects from all significant Hanford Site contaminants. Current plans for the groundwater component of the System Assessment Capability are to use a simplified form of the site-wide groundwater model to simulate contaminant transport through the saturated zone. In fiscal year 2000, the groundwater project compiled historical data to support initial history-matching runs of the model.

Bechtel Hanford, Inc. applied groundwater models at local scales to assess and improve the performance of groundwater pump-and-treat systems. These models evaluated system performance and overall progress toward remediation objectives and goals, including evaluating different extraction and injection well configurations, predicting effects of different operational and pumping schedules, assessing extent of hydraulic influence, and evaluating groundwater travel times and extent of the capture zone.

The Groundwater/Vadose Zone Integration Project applied a two-dimensional model for water movement in the zone of interaction between the Hanford Site unconfined aquifer and the Columbia River in the 100 H Area. The model calculated path lines to illustrate the direction and rate of flow within the zone of interaction. Graphics software was then used to animate water movement, showing how the flow field responds to the fluctuating river stage over one complete seasonal cycle of the river. Model results indicate that water in the zone between high and low river stage is a mixture of groundwater and river water, and that contaminant concentrations are likely to be reduced by dilution. Most of the discharge occurs near the shoreline.

Vadose Zone

Subsurface source characterization, vadose zone monitoring, remediation, soil-vapor monitoring, sediment sampling and characterization, and several technical demonstrations were conducted in fiscal year 2000.

Baseline spectral gamma logging of selected wells in single-shell tank farms provides data against which future measurements can be compared to identify tank leaks.

One slant borehole was drilled and sampled in the S and SX single-shell tank farms to study sediment properties, contaminant distribution, and transport mechanisms in the vadose zone. Also, cone penetrometer work identified a peak in gamma-emitting contaminants above the base of tank S-104.

Baseline spectral gamma logging of selected wells in single-shell tank farms was completed. This characterization serves as a baseline against which future measurements can be compared to identify changes in vadose zone contamination, to track movement of gamma-emitting radionuclides, and to identify or verify future tank leaks.

Geologists conducted semi-quantitative mineral analyses of samples from one borehole in the SX tank farm and from four samples designated as “standards” for the Hanford and Ringold Formations at the Hanford Site. The results will help identify mechanisms of contaminant transport in the vadose zone. A state-of-the-art technique was used to determine directly unsaturated hydraulic conductivity of samples from one borehole at the SX tank farm.

DOE began a 3-year study of clastic dikes and their influence on movement of subsurface contamination in fiscal year 2000, using remote sensing and ground penetrating radar. The study is designed to describe the geometric and hydrologic properties of clastic dikes and extrapolate those properties to the subsurface of waste disposal and storage sites.

Characterization activities in support of remediation of the 200-CW-1 Operable Unit indicated that strontium-90 and cesium-137 were the predominant manmade radionuclides in samples from the former Gable Mountain Pond. Strontium-90, cesium-137, and plutonium-239/240 were the predominant manmade radionuclides detected in samples from B Pond. Strontium-90 and cesium-137 were the predominant manmade radionuclides detected in samples from 216-B-2-2 and B-3-3 ditches.

Soil gas monitoring for helium isotopes was performed at the 618-11 burial ground to help determine the distribution of tritium in groundwater and the vadose zone. Results reveal the presence of tritium in the vadose zone and in groundwater.

Four comprehensive data packages were published in fiscal year 2000 to support the 2003 Immobilized Low-Activity Waste Performance Assessment. Those data packages describe the current state of knowledge about the geology, geochemistry, hydrology, and recharge to the vadose zone at two proposed sites for the Immobilized Low-Activity Waste Disposal Facility.

Soil gas was monitored for helium isotopes at the 618-11 burial ground to help define the extent of tritium contamination in groundwater and the vadose zone. The highest concentrations were observed along the north side of the burial ground. The results indicate a vadose zone source of tritium near the northern side of the burial ground and tritium-contaminated groundwater farther from the source area.

Analyses of leachate collected from the Environmental Restoration Disposal Facility show that the liquid collected so far contains no elevated levels of contaminants of concern. Leachate at the Solid Waste Landfill continues to exceed regulatory standards for some constituents, but soil gas monitoring shows no constituents of concern above reporting limits.

Soil gas monitoring at the carbon tetrachloride expedited response action site continued during fiscal year 2000. Results indicate that in many areas much of the readily accessible contaminant mass has been removed, and the supply of additional carbon tetrachloride is limited by desorption and/or diffusion from contaminant sources.

Soil gas monitoring at the carbon tetrachloride remediation site indicates that much of the readily accessible contamination has been removed from the vadose zone by soil-vapor extraction.

Technical demonstrations during fiscal year 2000 were designed to result in new, innovative methods to characterize and monitor the vadose zone. Three technical demonstrations occurred during the fiscal year. First, a small diameter, passive neutron tool was demonstrated to be able to detect subsurface transuranics in the vadose zone under certain conditions. Also, a small diameter spectral gamma logging tool was demonstrated at an environmental remediation site in the 100 Areas. Both tools could result in substantial cost savings over conventional methods of characterization and monitoring. Finally, the Vadose Zone Transport Field Study conducted a series of tests to evaluate how contaminant plumes move in the vadose zone. Nine methods, ranging from electrical resistance to isotopic tracers, were tested. All methods were successful to some degree in identifying changes in subsurface water contents (or pressures) resulting from the test injections.

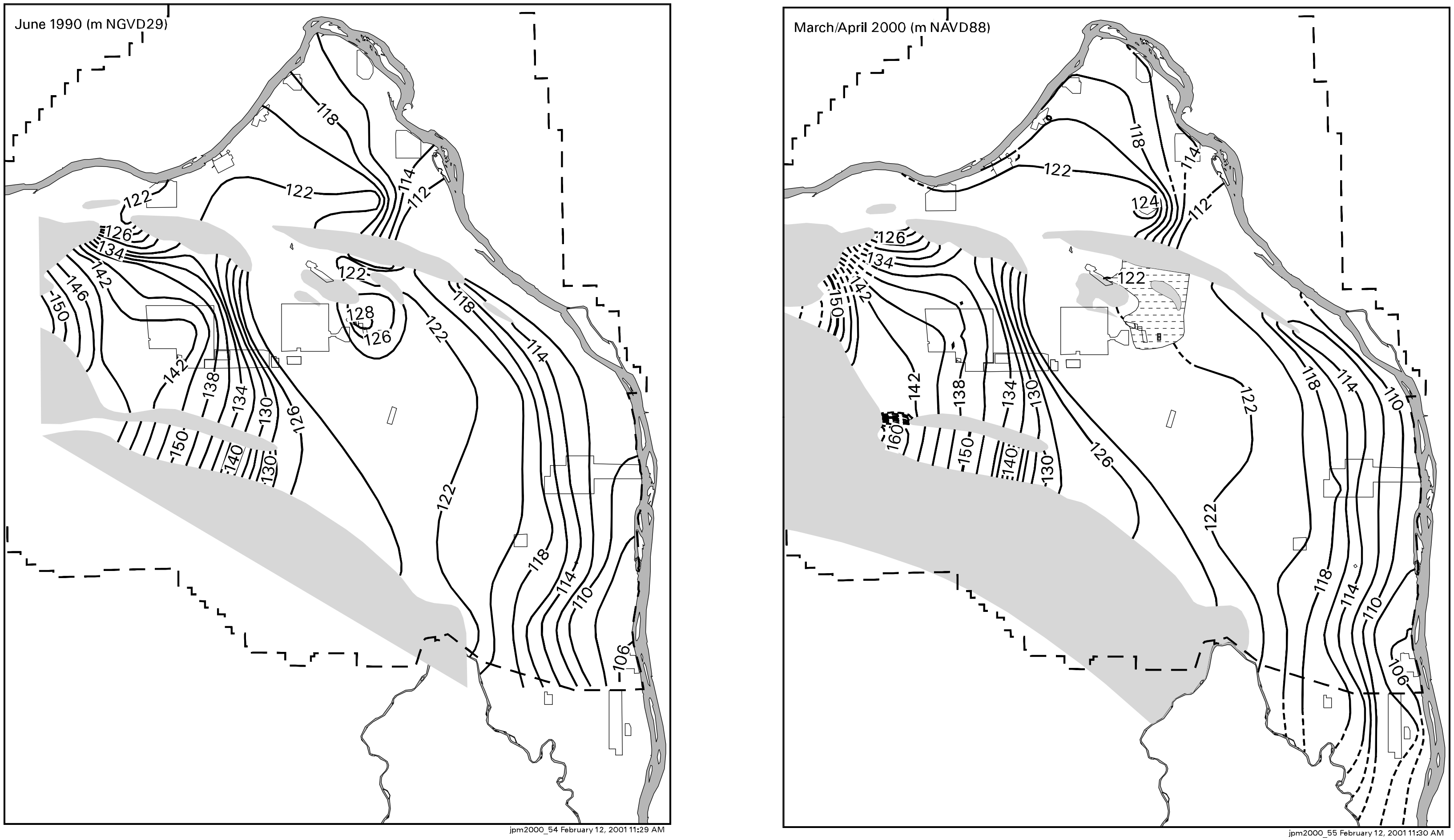

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Figure S.1. Hanford Site Water Table in June 1990 (National Geodetic Vertical Datum of 1929) and March 2000 (North American Vertical Datum of 1988). NGVD29 is ~1 meter lower than NAVD88.

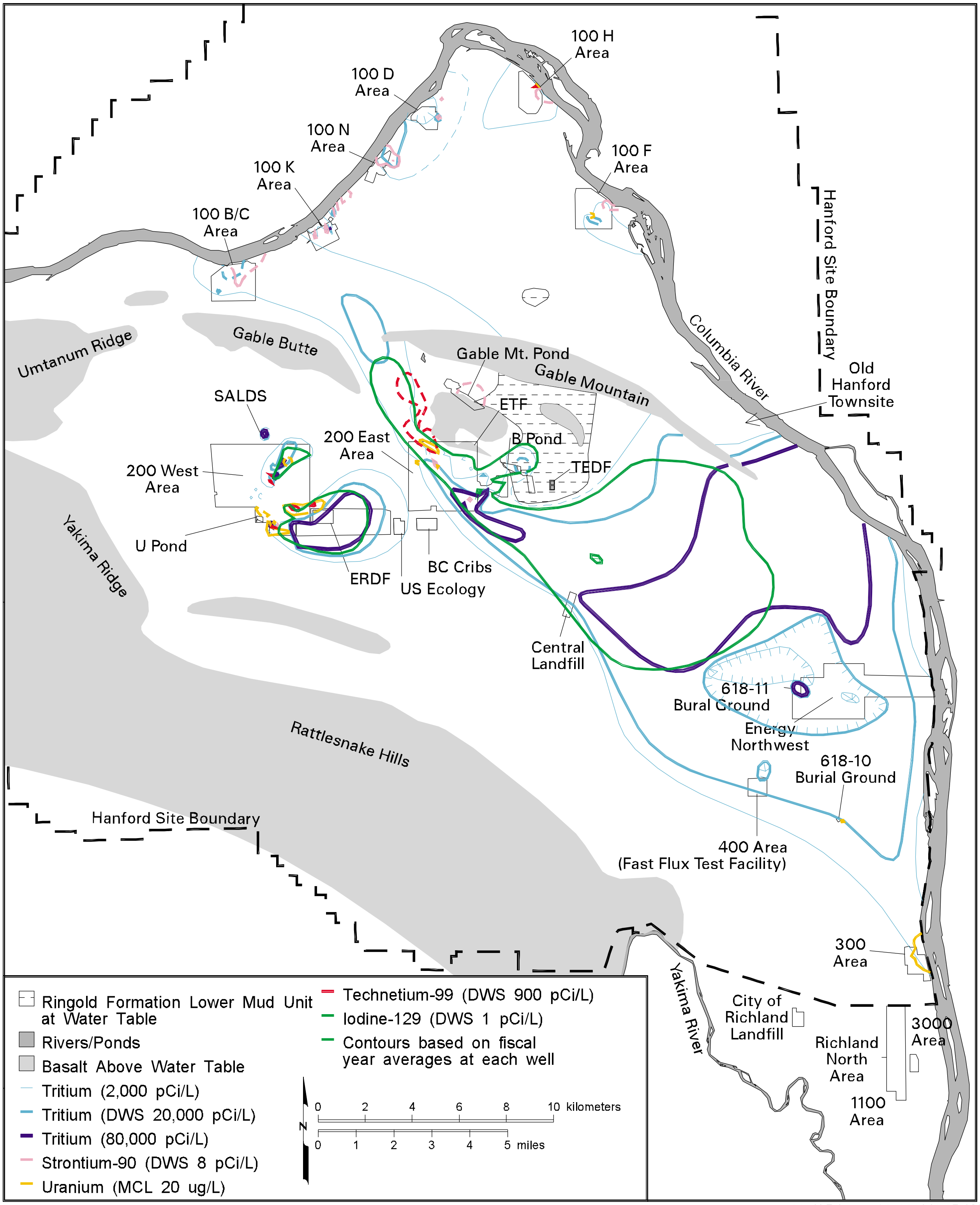

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Figure S.2. Distribution of Major Radionuclides in Groundwater at Concentrations above Maximum Contaminant Levels or Drinking Water Standards, Fiscal Year 2000

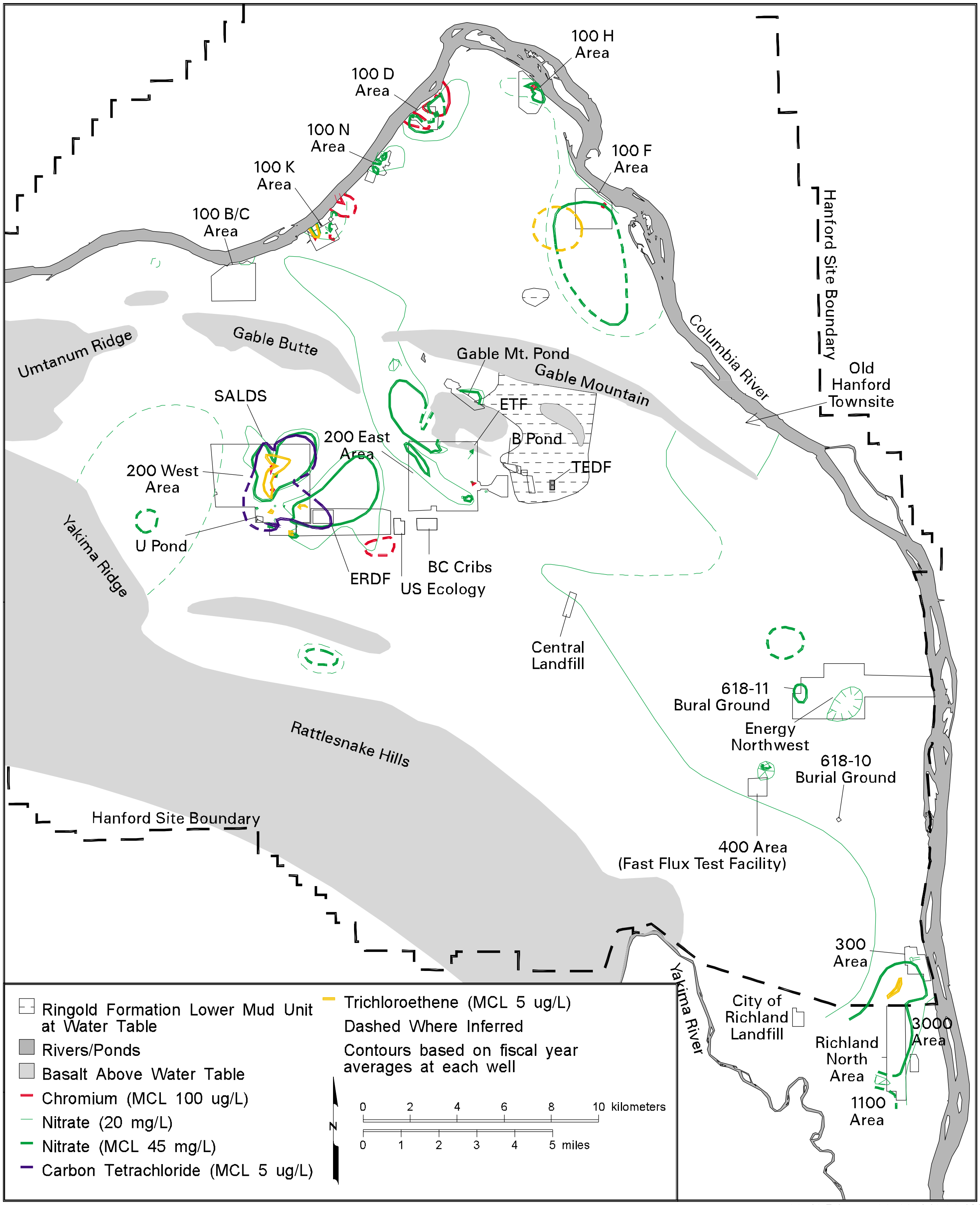

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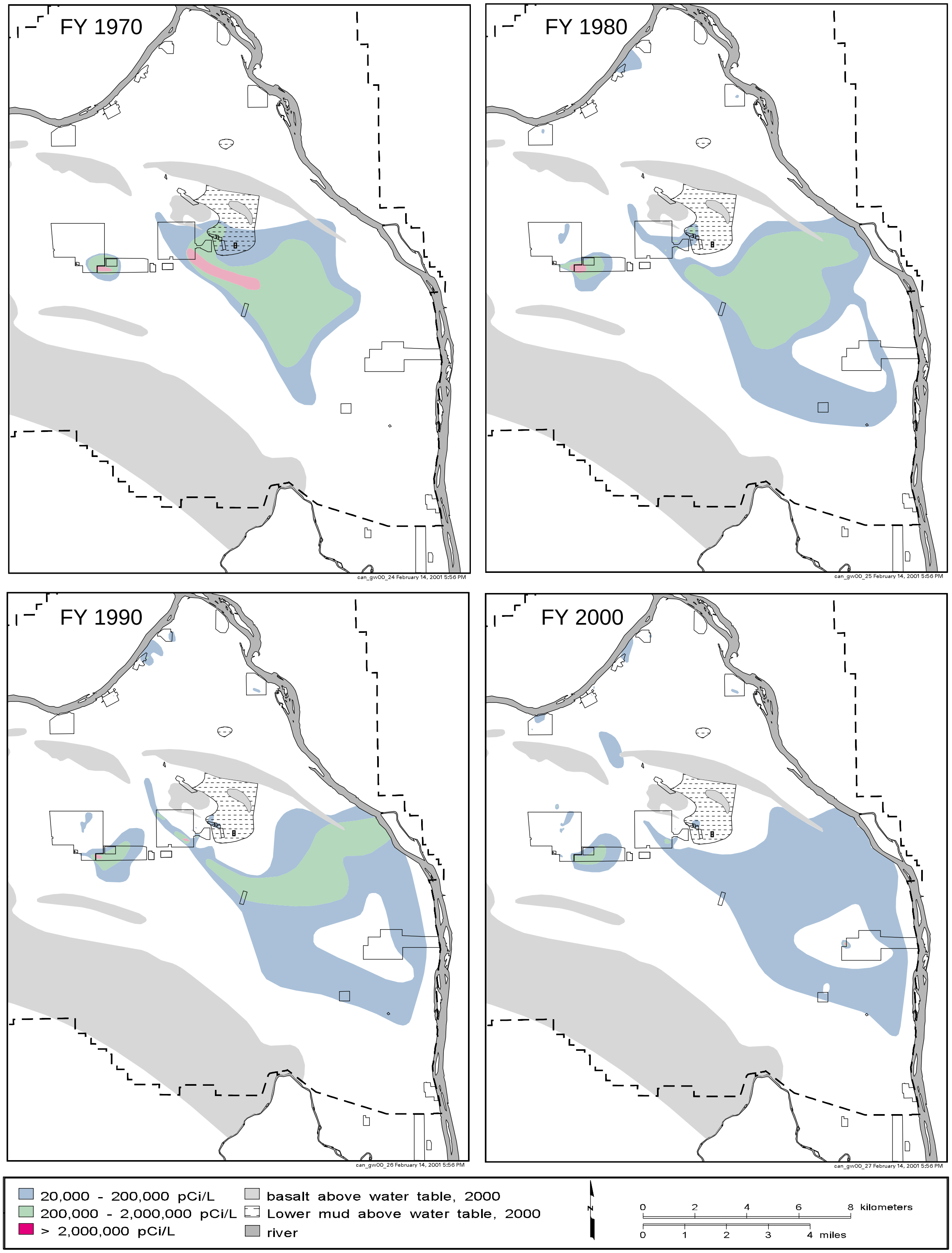
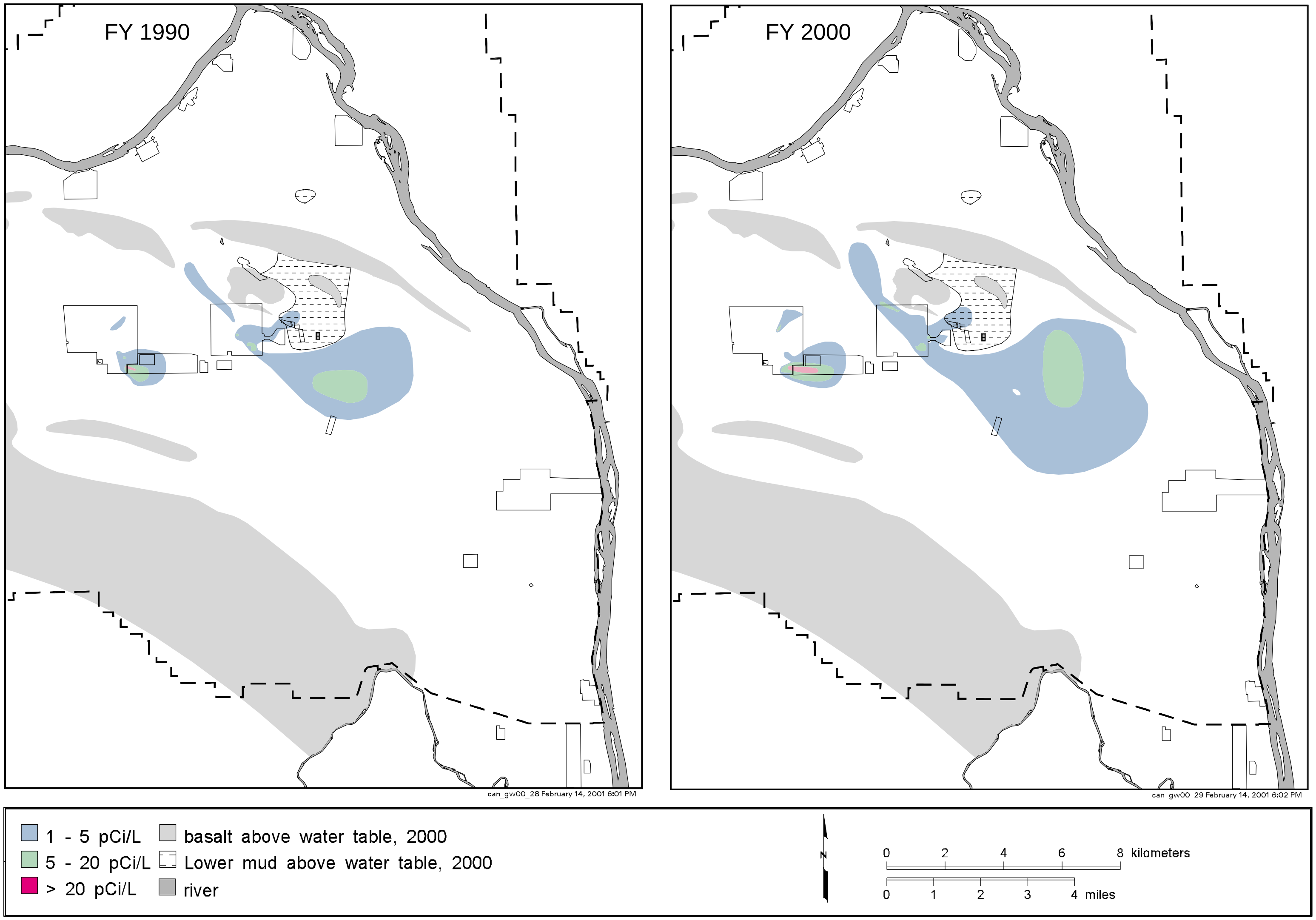
Figure S.3. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations above Maximum Contaminant Levels, Fiscal Year 2000



nacgwf00093 can_gw00_27a February 14, 2001 6:14 PM

Figure S.4. Distribution of Tritium in Groundwater in 1970, 1980, 1990, and 2000



nacgwf00094 can_gw00_29a February 15, 2001 11:56 AM

Figure S.5. Distribution of Iodine-129 in Groundwater in 1990 and 2000

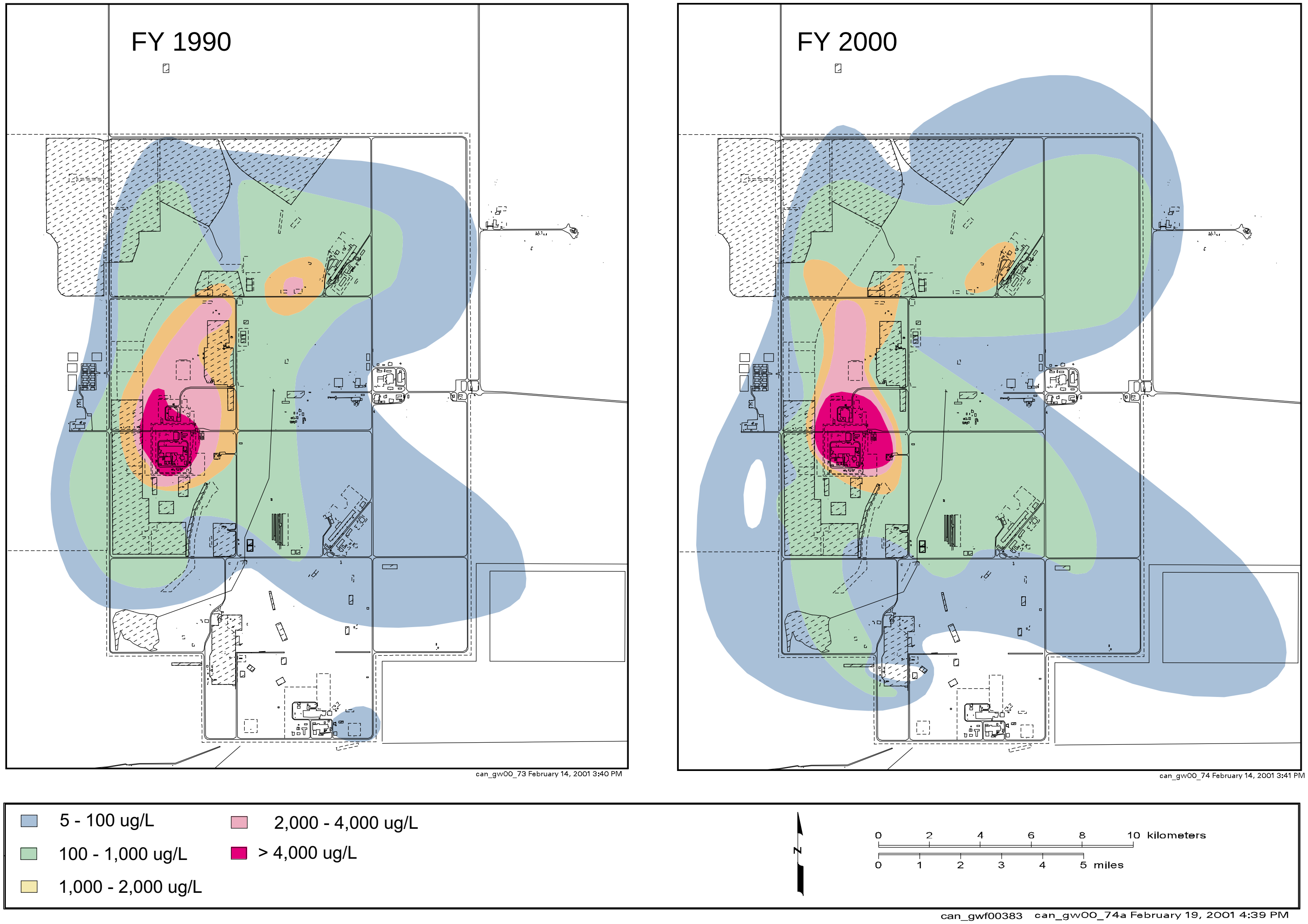
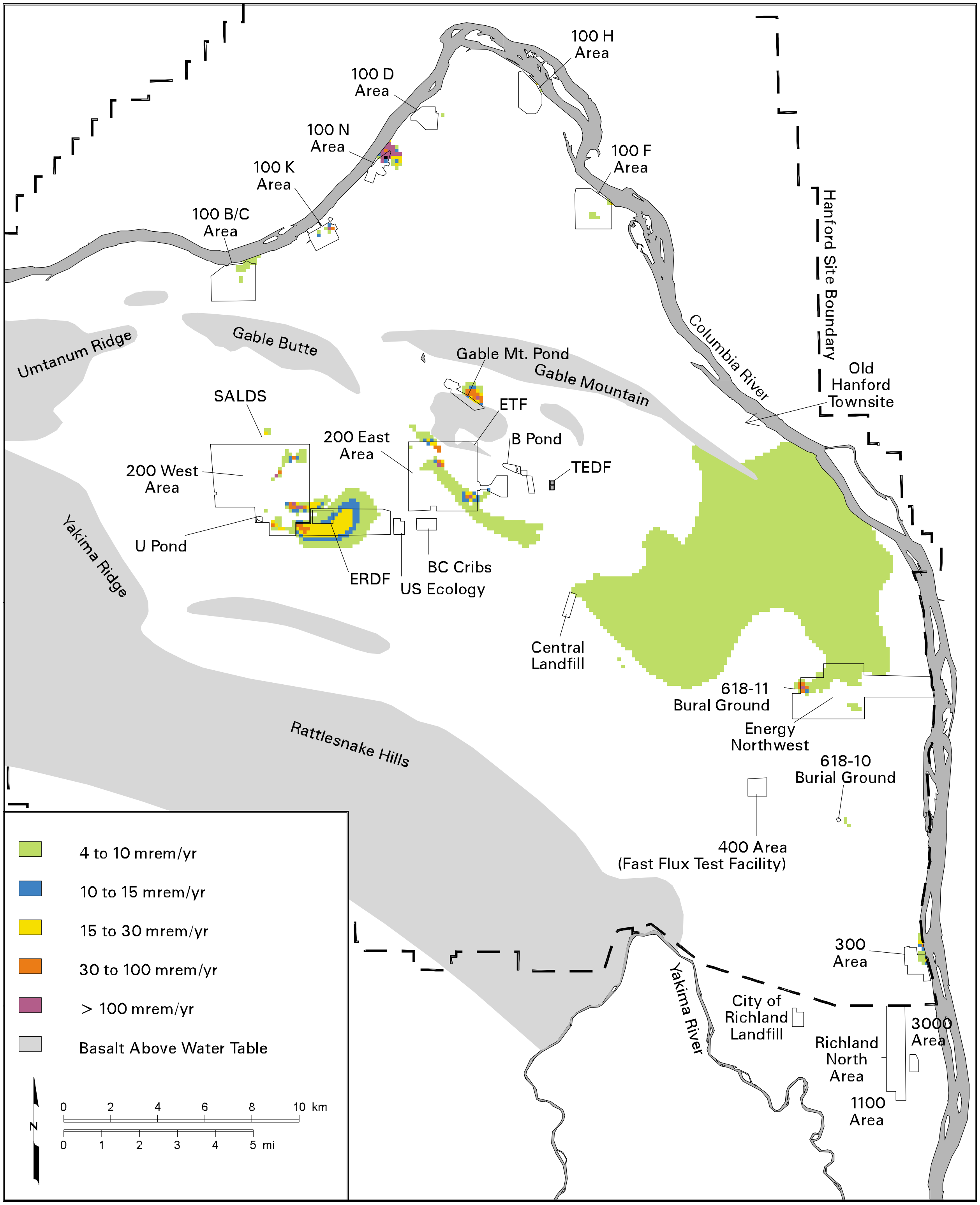
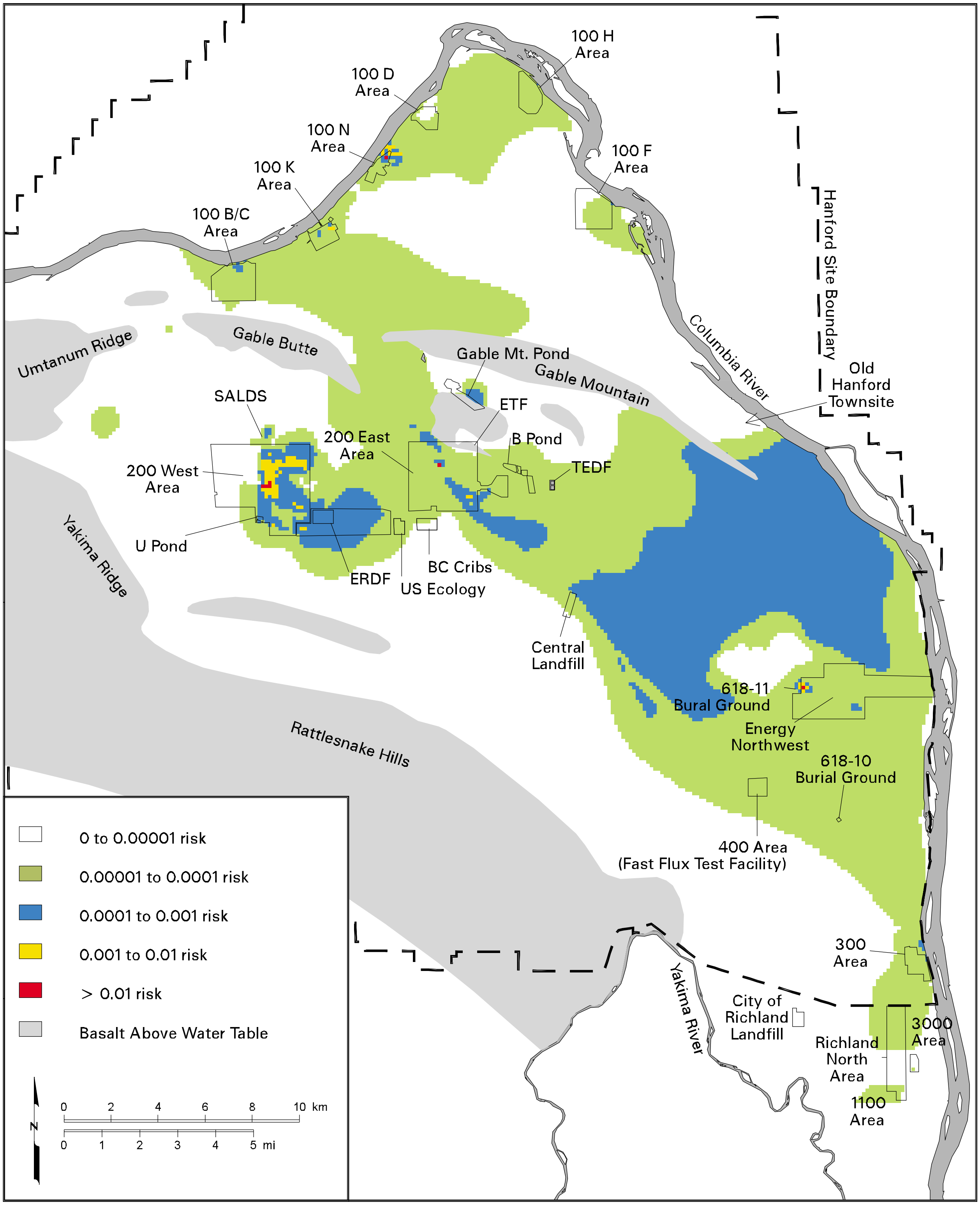


Figure S.6. Distribution of Carbon Tetrachloride in Groundwater in 1990 and 2000



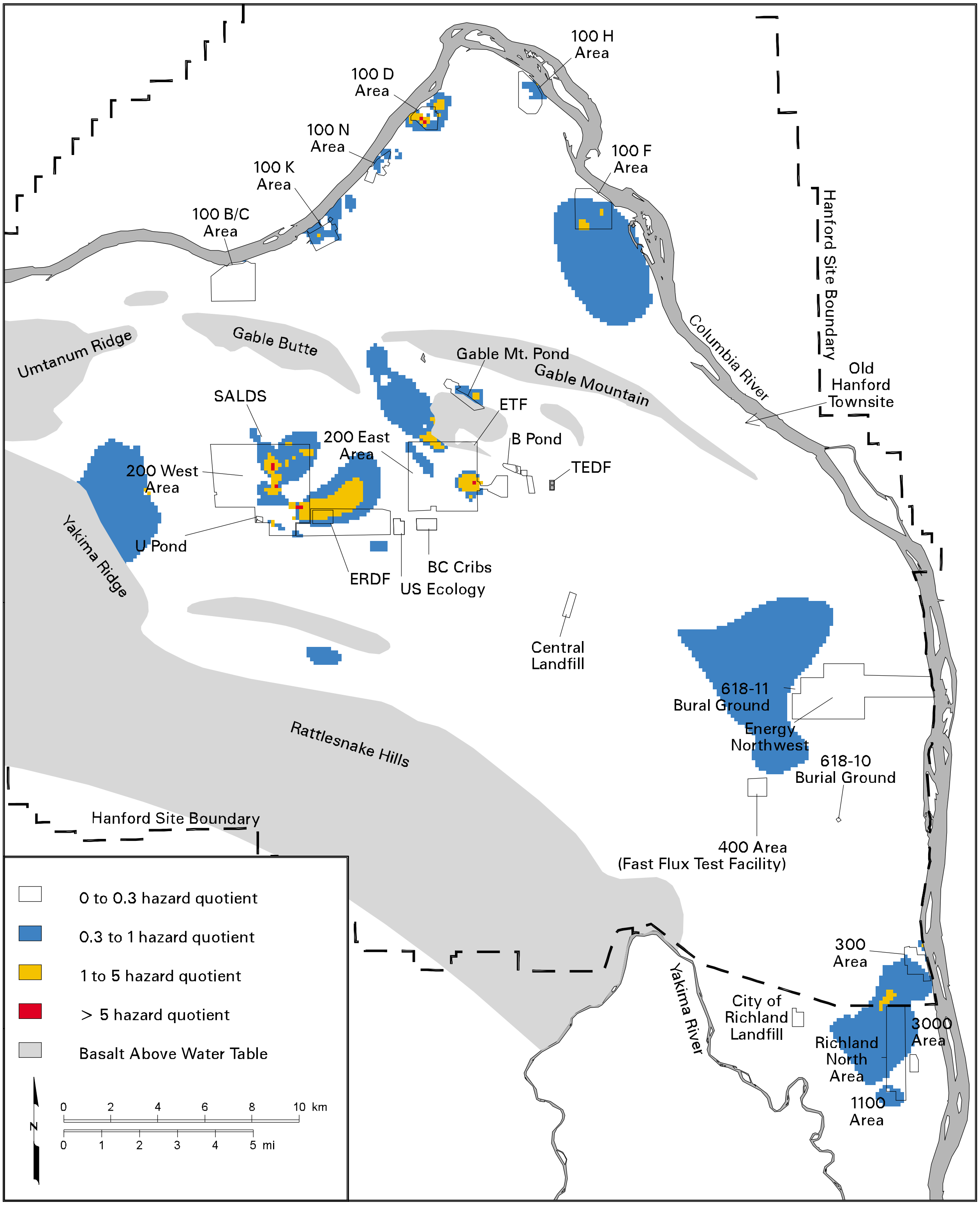
can_pdthorne00_1 February 20, 2001 11:04 AM

Figure S.7. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 2000



can_pdthorne00_2 February 12, 2001 10:42 AM

Figure S.8. Cancer-Risk Estimates from Ingestion of Groundwater, Fiscal Year 2000



can_pdthorne00_3 February 12, 2001 10:42 AM

Figure S.9. Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 2000

Contents

Tables

Figures

1.0 Introduction

The U.S. Department of Energy (DOE) monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the *Atomic Energy Act of 1954*, the *Resource Conservation and Recovery Act of 1976* (RCRA), the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), and Washington Administrative Code. DOE manages these activities through the Hanford Groundwater Monitoring Project, which is conducted by Pacific Northwest National Laboratory.

1.1 Purpose and Scope

M. J. Hartman

This report describes groundwater conditions on the Hanford Site and fulfills regulatory reporting requirements. It also summarizes groundwater remediation, vadose zone studies, and groundwater modeling.

Hanford Site Groundwater Monitoring for Fiscal Year 2000 presents results of groundwater monitoring, vadose zone monitoring and characterization, and groundwater modeling (Figure 1.1-1). This report also summarizes groundwater remediation and well installation activities for the fiscal year. Monitoring results primarily rely on data from samples collected between October 1, 1999, and September 30, 2000. Data received after November 13, 2000, may not have been considered in

Groundwater monitoring helps the U.S. Department of Energy develop solutions to Hanford Site cleanup issues. The protection of the Columbia River corridor is of primary importance. Pictured above is the Hanford Reach, the last free-flowing stretch of the Columbia River.

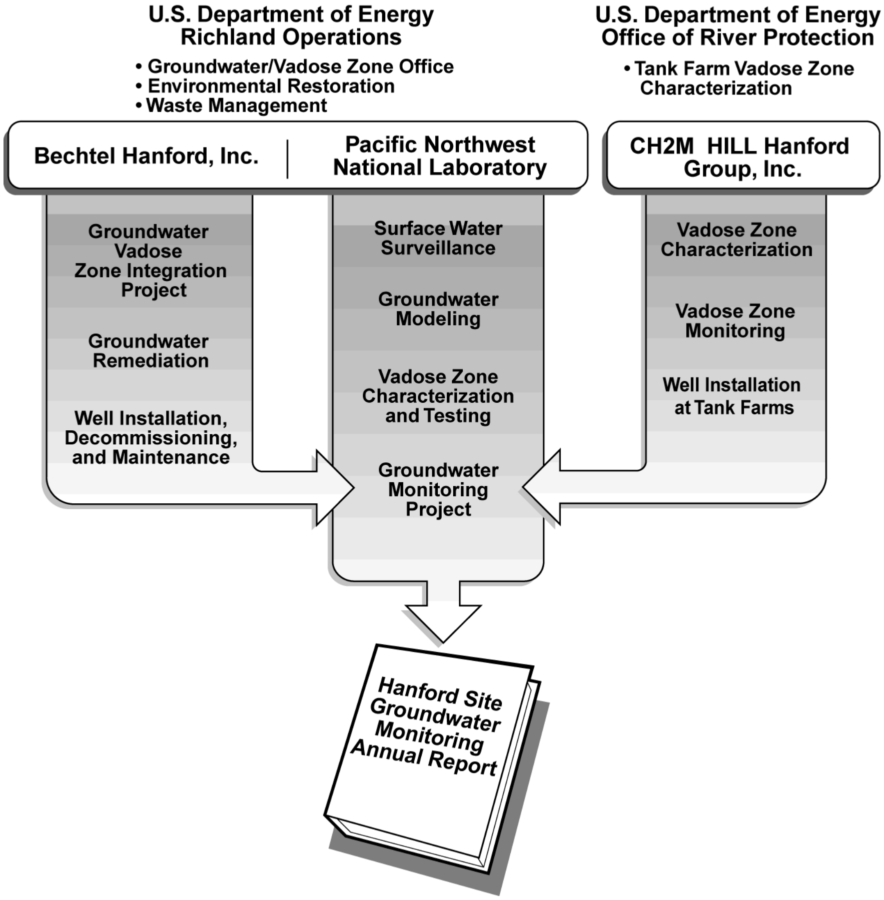


Figure 1.1-1. The Groundwater Monitoring Project Produces the Annual Groundwater Report for the U.S. Department of Energy with Input from Many Contributors

the interpretations. Some wells scheduled for sampling during the fiscal year were delayed until October 2000. Where available, these data are also discussed in this report if they affect interpretations.

This report is designed to meet the following objectives:

- provide a comprehensive report of groundwater conditions on the Hanford Site and adjacent areas
- fulfill the reporting requirements of RCRA, DOE orders, and Washington Administrative Code
- summarize the results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted under CERCLA
- describe the results of vadose zone monitoring and characterization
- summarize groundwater modeling activities
- summarize the installation, maintenance, and decommissioning of Hanford Site monitoring wells.

Environmental restoration work, which includes groundwater remediation and associated monitoring of pumping wells, is the responsibility of Bechtel Hanford, Inc. Vadose zone monitoring and characterization are conducted by Bechtel Hanford, Inc., CH2M HILL Hanford Group, Inc., and Pacific Northwest National Laboratory.

Supporting information for waste units regulated under federal and state requirements are presented in Appendix A. Appendix B describes results of the quality control program.

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). That document is not updated every year because the information does not change significantly from year to year.

As in previous reports, the enclosed computer diskette contains groundwater data for the fiscal year. Large plate maps show the wells used for monitoring, the Hanford Site water table, and the distribution of tritium (the most widespread contaminant) in the uppermost aquifer.

This report, PNNL-13080, and previous year's reports are available on the internet at the groundwater project's web site: http://hanford-site.pnl.gov/groundwater.

1.2 Related Reports

M. J. Hartman

Other reports and databases relating to Hanford Site groundwater in fiscal year 2000 include the following:

- *Hanford Site Environmental Report for Calendar Year 1999* (PNNL-13230) — This annual report summarizes environmental data, describes environmental management performance, and reports the status of compliance with environmental regulations. Topics include effluent monitoring, surface water and sediment surveillance, soil and vegetation sampling, vadose and groundwater monitoring, radiological surveys, air surveillance, and fish and wildlife surveillance.
- Hanford Environmental Information System (HEIS) — This is the main environmental database for the Hanford Site that stores groundwater chemistry and water-level data, as well as other environmental data (e.g., soil chemistry, survey data).
- Quarterly data transmittals — DOE transmits letters quarterly to the Washington State Department of Ecology after groundwater data collected for the RCRA program have been verified and evaluated. These letters describe changes or highlights of the quarter with reference to HEIS for the analytical results.

Abbreviations and Acronyms

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE/RL	U.S. Department of Energy, Richland Operations Office
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
DCG	derived concentration guide
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HEIS	Hanford Environmental Information System
MCL	maximum contaminant level
NAVD88	North American Vertical Datam 1988
PUREX	Plutonium-Uranium Extraction (Plant)
RCRA	*Resource Conservation and Recovery Act*
ROD	Record of Decision
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
WAC	Washington Administrative Code

- *Fiscal Year 2000 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations* (DOE/RL-2000-71) — This report describes results of remediation and monitoring in two groundwater operable units in the 200 West Area.
- *Annual Summary Report Calendar Year 2000 for the 100-HR-3, 100-KR-4, and 100-NR-2 Pump-and-Treat Operations and Operable Units* (DOE/RL-2001-04) — This report describes results of remediation and monitoring in groundwater operable units in the 100 K, 100 N, 100 D, and 100 H Areas.

- *Fiscal Year 2000 Annual Summary Report for the In-Situ REDOX Manipulation Operations* (DOE/RL-2000-74) — This report describes activities related to the remediation system in the southwestern 100 D Area.

1.3 Groundwater/Vadose Zone Integration Project

S. P. Sautter

Radionuclides and Their Half-Lives

Symbol	Radionuclide	Half-Lives
^{3}H	tritium	12.35 yr
^{14}C	carbon-14	5,730 yr
^{60}Co	cobalt-60	5.3 yr
^{90}Sr	strontium-90	29.1 yr
^{99}Tc	technetium-99	2.1×10^{5} yr
^{106}Ru	ruthenium-106	358.2 d
^{129}I	iodine-129	1.6×10^{7} yr
^{137}Cs	cesium-137	30 yr
^{234}U	uranium-234	2.4×10^{5} yr
^{239}Pu	plutonium-239	2.4×10^{4} yr
^{240}Pu	plutonium-240	6.5×10^{3} yr

DOE established the Groundwater/Vadose Zone Integration Project (Integration Project) in late 1997 to create a site-wide approach to protect the Columbia River. In fiscal year 2000, the Integration Project continued to focus on the issues of chemical and radiological contamination in Hanford's groundwater and vadose zone that pose a threat to the Columbia River. The Hanford Groundwater Monitoring Project is under the umbrella of the Integration Project.

In January 2000, DOE instructed the Integration Project to investigate tritium contamination in the groundwater near the 618-11 burial ground, where a groundwater sample from well 699-13-3A, just east of the burial site, showed tritium levels of 8 million pCi/L. Subsequent groundwater samples and soil gas samples collected up- and downgradient from the initial high tritium sample provided a high level of confidence that the plume is localized and the source is likely the waste buried in the 618-11 burial ground (see Sections 2.12.7.3 and 3.2). The investigation will continue into fiscal year 2001.

The Integration Project relies on advances in science and technology to provide new knowledge, data, and tools for Hanford Site cleanup. This new science and technology helps to develop a better understanding of the movement of contaminants through the vadose zone into the groundwater and ultimately into the Columbia River. In fiscal year 2000, staff developed enhanced conceptual and numerical models of the groundwater/river interface in the 100 H Area (see Section 4.3).

After successful demonstration, in situ redox manipulation was deployed to prevent the migration of the harmful chemical hexavalent chromium into the Columbia River at Hanford's 100 D Area (see Section 2.5). Hexavalent chromium may be harmful to young fall Chinook salmon in spawning beds adjacent to the Hanford Site. Crews extended the length of the redox barrier from its demonstration length of 46 meters to 195 meters in fiscal year 2000. Current plans are to complete installation of the barrier by the end of fiscal year 2002. Its final length will be 677 meters.

In fiscal year 2000, the Integration Project released its initial System Assessment Capability, a set of tools to assess future effects from the release of contaminants during past Hanford Site operations or from the existing stored inventory (see Section 4.1). This effort will help DOE decision makers better understand the location, identity, and amount of contaminants in Hanford's vadose zone and groundwater.

Units of Measure

µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
mm/yr	millimeters 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

One of the keys to the success of the Integration Project is the independent peer review of its work. In fiscal year 2000, these peer reviews were completed by a committee from the National Academy of Sciences and the Integration Project's expert panel.

The National Academy of Sciences committee on environmental remediation science and technology at the Hanford Site met three times during the fiscal year. The committee is reviewing and making recommendations to improve the use of science and technology in the Integration Project. This committee will complete its work in fiscal year 2001.

The expert panel provides the Integration Project with ongoing independent advice and recommendations on key programmatic, technical, and administrative issues affecting the project's success. The eight members of the panel are independent of DOE and have a diverse set of technical backgrounds and experience relevant to the cleanup of the Hanford Site. The expert panel met twice during fiscal year 2000 to review progress of the Integration Project and provided a number of recommendations to enhance the project's work.

1.4 Helpful Information

The companion volume to this report, PNNL-13080, describes techniques used to interpret the data and conventions for plotting. Contaminant plume maps in this report show data from fiscal years 1998 and 1999 if there were no new data for a well in fiscal year 2000. Wells that monitor plumes that change slowly are sampled every 3 years, so this convention allows us to see the most recent data. Trend plots in this report use open symbols to show levels of contaminants that were so low the laboratory could not detect them. These results are typically reported as a value that represents the detection limit of the analytical method or instrument and are flagged "undetected" in the database. Analytical results that appear to be erroneous remain on the plots 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 are included in the data files that accompany this report and in the HEIS database.

Nitrate is expressed as the NO_3 ion. Figures showing chromium results include total chromium in filtered samples and hexavalent chromium in filtered or unfiltered samples. Dissolved chromium in Hanford Site groundwater is virtually all hexavalent, so filtered total chromium represents hexavalent chromium.

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
picocuries	1,000	nanocuries
curie	3.7×10^{10}	becquerel
picocurie	0.03704	becquerel
rem	0.01	sievert
°Celsius	(°C x 9/5) + 32	°Fahrenheit

This report compares contaminant concentrations in groundwater with state or federally enforceable "maximum contaminant levels" and other limits for drinking water. Although Hanford Site groundwater is not generally used for drinking, these levels provide a useful indicator to provide perspective on contaminant concentrations.

2.0 Groundwater

Groundwater contamination at the Hanford Site is associated with a number of sources within its active and inactive operational areas. Liquid waste, discharged to the ground since the 1940s, percolated through the soil and in many locations reached the water table. Very little liquid waste is currently disposed to the soil, and cleanup of existing groundwater contamination, by pump-and-treat systems for example, is occurring at some sites.

This section describes groundwater flow and groundwater contamination in each of the major areas on the Hanford Site. Factors that affect the distribution, migration, and concentrations of groundwater contaminants include

- Source history – groundwater contaminants at the Hanford Site originate from hundreds of disposal sites. These sites were used at different periods of time so the plumes were formed and are dissipating in different ways. In addition, plumes originating from many sources are affected by the discharge of uncontaminated or less contaminated water to nearby facilities.
- Stratigraphy – (a) groundwater tends to flow through sediment with higher hydraulic conductivity rather than less permeable units; (b) in some areas, the shallowest aquifer is connected to deeper aquifers, which could allow contaminants to move into deeper aquifers.
- Declining water table – (a) some monitoring wells have gone dry, which affects adequacy of *Resource Conservation and Recovery Act of 1976* (RCRA) or other monitoring; (b) may affect contaminant concentrations, which may vary with depth.
- Well depth – the depth of the well, the length of the screen, and the depth of the pump intake can affect contaminant concentrations in samples if concentrations vary with depth.
- River stage – (a) affects distribution and trends of contaminants at sites near the Columbia River by changing direction of flow; (b) high water may remobilize contaminants from the vadose zone or may dilute contaminants when river water flows into the aquifer.
- Groundwater remediation – (a) extraction and injection wells affect the direction of groundwater flow locally. This affects contaminant distribution and the ability to monitor other sites (e.g., RCRA units); (b) treated water is injected back into the aquifer, but may contain residual contaminants or may dilute local groundwater.

This section discusses these factors, as applicable, for individual areas or waste sites in geographic order (north to south, west to east). The results of the monitoring program are discussed, as much as possible, in relation to source areas. In some cases, several potential sources such as cribs, trenches, or other disposal facilities may contribute to a particular groundwater plume, and their contributions cannot be readily distinguished. Therefore, they are discussed together. Monitoring of specific storage and disposal facilities, such as RCRA units, is reported within the sections on the operational areas. The status of groundwater remediation under RCRA or the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) is discussed in the relevant sections.

Waste sites, hydrogeology, and methods of sampling and analysis are described in *Hanford Site Groundwater: Settings, Sources and Methods* (PNNL-13080). That document also explains how water-level and groundwater chemistry data were interpreted and mapped.

2.1 Overview of Hanford Site Groundwater

J. P. McDonald, M. J. Hartman, and R. E. Peterson

This section provides a broad picture of groundwater flow and contaminant distribution beneath the Hanford Site. Details for specific locations are included in Sections 2.2 through 2.14.

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semi-consolidated sediment of the Hanford and Ringold formations, which were 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.

The Hanford Groundwater Monitoring Project sampled over 650 wells during fiscal year 2000. Tritium, nitrate, and iodine-129 are the most widespread contaminants.

Sampling of some wells was delayed or cancelled because of issues related to collection and disposal of secondary sampling waste such as gloves and tubing. The historical practice of disposing of the secondary waste in regular trash cans was unacceptable. Groundwater sampling was temporarily halted until an acceptable practice of managing the waste was put in place. All secondary waste is now bagged, labeled, and collected in designated drop locations before disposal.

2.1.1 Groundwater Flow

Water-level elevations indicate the potential for groundwater movement, because groundwater flows from areas of high potential (high water-level elevations) to areas of low potential (low water-level elevations). Contour maps indicate the general direction of groundwater movement, because water generally flows perpendicular to the contour lines from high to low potential. Water-level gradients are used to estimate the rate of groundwater flow.

Groundwater monitoring relies on samples from wells across the Hanford Site.

Water-level maps are used to interpret contaminant plume patterns and to support the calibration of groundwater flow models. The Hanford/Ringold aquifer system is the primary focus because it is the most likely groundwater pathway for migration of contaminants off the Hanford Site. However, measurements also are taken annually in the upper basalt-confined aquifer system (Section 2.14) and in the deep basalt aquifers to support groundwater modeling and to provide a data archive in the event that contamination is discovered in these systems. The *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-13021) contains a detailed description of the water-level monitoring activities.

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

The collection of water-level measurements across the Hanford Site during March 2000 was interrupted by a stop work order caused by the waste disposal issues discussed above. Prior to the stop work order, water-level measurements in wells north of Gable Butte and Gable Mountain had been completed. When work resumed, water-level measurements were taken in the remaining wells through mid-April, except those wells associated with sites regulated by the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). Therefore, areas of sparse well coverage occur on the March/April Hanford Site Water-Table Map (Plate 1), particularly near the Plutonium Finishing Plant (200 West Area) and the Horn Rapids Landfill (southwest of the 300 Area). The Hanford Site environmental restoration contractor provided much of the data shown in the vicinity of the pump-and-treat areas from their automated water-level monitoring equipment.

The following sections describe groundwater flow in the unconfined aquifer and changes in the water table during the period from March 1999 to March/April 2000. Flow in a confined aquifer in the Ringold Formation is described in Section 2.9.4. Groundwater flow in the upper basalt-confined aquifer system is discussed in Section 2.14.

2.1.1.1 Current Water Table

Groundwater in the unconfined aquifer flows from areas where the water table is high (west of the Hanford Site) to areas where it is low, near the Columbia River (Figure 2.1-1 and Plate 1). Steep gradients in the western region of the Hanford Site are caused by groundwater recharge and lower hydraulic conductivity than in the eastern region of the site.

Sources of recharge include infiltration of rain and snowmelt at higher elevations, primarily in the Cold Creek and Dry Creek Valleys and the Rattlesnake Hills, as well as irrigation of offsite agricultural land in the Cold Creek Valley. Steep gradients north and east of the Columbia River (see Figure 2.1-1) are attributed to recharge associated with irrigation of agricultural land. Regionally, water-table elevations decrease while approaching the Columbia River from either side, indicating that groundwater flow converges and ultimately discharges to the river.

The water table is relatively flat beneath the 200 East Area. Flow is affected by low permeability sediment at the water table.

Wastewater discharged to the ground on the Hanford Site resulted in groundwater mounding and significantly affected the flow of groundwater. Past discharges at U Pond and lesser discharges to other 200 West Area facilities are still apparent from the shape of the water-table contours passing through the 200 West Area. The steep gradient just east of the 200 West Area results partially from this mounding and partially from the relatively low transmissivity of the aquifer in this region. The hydraulic gradient decreases abruptly between the 200 West and 200 East Areas, corresponding to an increase in transmissivity. The steep gradient between Umtanum Ridge and Gable Butte results partially from recharge coming from Cold Creek Valley, mounding in the 200 West Area, and restriction of the Hanford/Ringold aquifer system by the underlying basalt to a thin, narrow zone in the gap.

The water table in the central portion of the Hanford Site, south of Gable Mountain, is relatively flat because of the presence of highly permeable sediment of the

Hanford formation at the water table. 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. There is a groundwater mound associated with B Pond, where process cooling water and other liquid waste were discharged to the ground up until fiscal year 1997. Currently, the mound occurs mainly within and beneath the Ringold Formation mud units and is considered part of the Ringold Formation confined aquifer (Section 2.9.4).

North of Gable Butte and Gable Mountain, groundwater also generally flows from west to east and discharges to the Columbia River. Recharge to the aquifer in this region comes primarily from the Columbia River west of the 100 B/C Area. Recharge also comes from groundwater flowing north through the gaps between Umtanum Ridge and Gable Butte and between Gable Butte and Gable Mountain.

A local groundwater mound exists ~2 kilometers north of Gable Mountain (between Gable Mountain and the 100 F Area). Long before the Hanford Site was established, Jenkins (1922) reported elevated groundwater levels in this area that have persisted to the present. Data suggest that this mound is associated with a subsurface topographic "high" of Ringold Formation sediment having a low hydraulic conductivity (primarily clay). One possible source of recharge is past seasonal use of the Hanford irrigation canal, which traverses the groundwater mound area and was active between 1908 and 1943. Other potential sources of recharge include upwelling from the upper basalt-confined aquifer system and infiltration from surface runoff. The slow dissipation of the recharge water is attributed to the presence of a significant thickness of clay in the Ringold Formation sediment. There is insufficient information to distinguish whether the groundwater in this area is locally perched or is part of the regional, unconfined flow system.

The elevation of the water table in the region between the Yakima and Columbia Rivers is lower than the Yakima River stage elevation, which is ~122 meters above mean sea level at Wanawish (formerly Horn Rapids) Dam. This implies that infiltration from the Yakima River recharges the Hanford/Ringold aquifer system in this area. During the summer, leakage from the Horn Rapids Ditch and Columbia Canal, which originate from the Yakima River at Wanawish Dam, and irrigation in areas east of the Yakima River also may recharge the Hanford/Ringold aquifer system. Operation of the Richland North Well Field recharge ponds results in a groundwater mound in the Richland North Area.

The water table continued to decline beneath the central Hanford Site in fiscal year 2000, causing some wells in the 200 Areas to go dry.

2.1.1.2 Water-Table Changes from March 1999 to March/April 2000

A contour map of the change in the water table from March 1999 to March/April 2000 is shown in Figure 2.1-2. The water table declined over much of the Hanford Site during this period. This is due to the decline in wastewater discharges to the ground that have occurred since the peak discharge in 1984. Over the 1 year period, the water table declined by an average of 0.13 meter in the 200 East Area and 0.41 meter in the 200 West Area (outside of the 200-ZP-1 and 200-UP-1 Operable Units groundwater pump-and-treat regions).

The water-table elevation increased in a broad region adjacent to the Rattlesnake Hills and Yakima River, as well as in the Cold Creek and Dry Creek Valleys. This may be caused by higher than normal precipitation in fiscal years 1993 through 1997, along with higher than normal Yakima River discharge in fiscal years 1995 through 1998.

North of Gable Butte and Gable Mountain, the water-table change was varied. In general, water levels declined along the river due to a lower river stage during March 2000 as compared to March 1999. Water levels increased slightly in the central portion of this region. Local increases in water levels also occurred in the 100 N, 100 H, and 100 F Areas.

Changes in the water table also occurred beneath active facilities (e.g., the State-Approved Land Disposal Site, near the 200 West Area, and the Richland North Well Field) and within groundwater pump-and-treat areas. These changes are attributed to operation of these facilities. The largest water-level increase in the unconfined aquifer (0.33 meter) occurred in wells 1199-39-15 and 1199-39-16C at the Richland North Well Field, and at well 199-N-28 near the 100-NR-2 Operable Unit groundwater pump-and-treat injection wells in the 100 N Area. The largest water-level decline in the unconfined aquifer (0.75 meter) occurred in well 699-39-79 near the 200-ZP-1 Operable Unit groundwater pump-and-treat injection wells in the 200 West Area.

The major sources of groundwater contamination on the Hanford Site are inactive liquid waste facilities in the 100, 200, and 300 Areas.

2.1.2 Groundwater Contaminants

During fiscal year 2000, Hanford Site staff sampled 669 wells for radiological and chemical constituents. Of the wells sampled, 288 were sampled once, 156 were sampled twice, 80 were sampled three times, 78 were sampled four times, and 67 were sampled more frequently. A number of wells are sampled to meet *Resource Conservation and Recovery Act of 1976* (RCRA) or CERCLA requirements. Well location maps are included in Sections 2.2 through 2.14 and in Appendix A for RCRA units and other sites regulated under the Washington Administrative Code.

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their distribution in the unconfined aquifer are shown in Figures 2.1-3, 2.1-4, and 2.1-5. The distribution of tritium is shown in more detail in Plate 2. The most prominent portions of these plumes are from waste sites in the 200 Areas and spread toward the southeast. Nitrate and tritium also have significant sources in the 100 Areas.

Chromium contamination is widespread in several of the 100 Areas and extends into the surrounding 600 Area. Strontium-90 contamination is present in the 100 Areas, but the plumes are smaller. Other contaminant plumes include

- carbon tetrachloride and associated chloroform and trichloroethene in the 200 West Area
- chromium in the 600 Area south of the 200 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 northwest of the 200 East Area
- uranium in the 300 Area.

Several other constituents are detected outside the boundaries of the operational areas but the contamination is clearly linked to operations in the specific areas and is discussed with the source areas. Table 2.1-1 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants that exceed water quality standards. All analytical results for fiscal year 2000 are included on the data diskette included with this report.

Available data indicate that the vast majority of contamination on the Hanford Site remains near the water table, but information on the depth of the contaminant plumes is lacking for much of the site. Contamination in deeper aquifers of the Hanford/Ringold sediment is discussed for the 200 East Area in Section 2.9.4. Contamination in the upper basalt-confined aquifer is discussed in Section 2.14.

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. Groundwater operable unit boundaries are illustrated in Figure 2.1-6.

A number of Hanford waste sites have specific RCRA monitoring requirements (see Appendix A, Figure A.1). The results of monitoring at these facilities are integrated into the following discussions, and specific RCRA reporting requirements, such as indicator parameter evaluations, are included as needed. Appendix A discusses issues related to regulatory compliance and describes results of statistical evaluations for RCRA monitoring requirements. Appendix A also summarizes analytical results for wells monitoring RCRA- and state-permitted facilities that exceeded maximum contaminant levels or drinking water standards.

2.1.3 Results of Shoreline Monitoring

Groundwater in the unconfined aquifer on the Hanford Site discharges to the Columbia River. Samples at the river shore contained contaminants at levels above drinking water standards. Concentrations in river water remained far below standards.

Groundwater flowing in the uppermost aquifers beneath the Hanford Site ultimately discharges into the Columbia River. A zone of groundwater/river water interaction is created where the approaching groundwater comes under the influence of the river system. Rapidly varying hydraulic gradients, which are caused by river stage fluctuations, and the infiltration of river water into the banks and riverbed sediment, join to create a zone of dynamic physical, chemical, and biological processes. Understanding the features and processes for this zone is essential to estimate and predict contaminant transport.

The principal features and terminology associated with the zone of groundwater/river water interaction are shown in Figure 2.1-7. Contamination transported via groundwater movement typically resides in the uppermost hydrologic unit, i.e., the unconfined aquifer beneath the water table. For contaminant plumes in the 100 Areas, the thickness of this uppermost unit is reasonably well known, so the interface between the contaminated layer and the adjacent river channel can be defined. This knowledge helps identify the riverbed area that is most at risk from contaminated groundwater entering the river.

Monitoring water movement and chemical/radiological characteristics in the zone of interaction requires several approaches. The various facilities and sites available for obtaining observational data are shown in Figure 2.1-7. They include near-river monitoring wells, aquifer sampling tubes, riverbank seepage sites, and riverbed sediment pore water sites. During fall 1997, Environmental Restoration Project staff installed aquifer sampling tubes at ~300-meter intervals along the 100 Areas and downstream near the low river-stage shoreline to the old Hanford Townsite (BHI-01153). One to three polyethylene tubes were installed at various depths at each tube site in an effort to monitor near the water table, at mid-depth in the aquifer, and near the bottom of the aquifer. The tubes were resampled in 1998, 1999, and 2000 to support objectives of the Environmental Restoration Project. The Surface Environmental Surveillance Project and Environmental Restoration Project monitor riverbank seepage annually. River water also is monitored routinely at multiple locations along the shoreline and across several transects of the Columbia River. River water is also routinely monitored at multiple locations along the shoreline and across several transects of the Columbia River.

Groundwater monitoring in the zone of groundwater/Columbia River interaction is accomplished by periodic sampling of (a) aquifer sampling tubes at the low river-stage shoreline, (b) riverbank seepage, and (c) nearshore river water.

Movement patterns vary dramatically in response to daily river stage cycles. At times of very high river stage, flow is reversed and the infiltration of river water is great enough to dilute contaminant concentrations in groundwater approaching the river. To describe these rapid changes, water levels are recorded at hourly intervals using sensors installed in wells and the river. Recently, these data have been used to simulate water movement pathlines perpendicular to the river under the fluctuating river stage (see Section 4.3). This modeling depicts the mixing zone between infiltrating river water and approaching groundwater. Model results also provide new insight on where groundwater discharges to the riverbed, e.g., the bulk of flow discharges relatively close to the shore.

The daily fluctuations of Columbia River flow exert a strong influence on water quality in the aquifer near the river. Contaminants may be diluted significantly prior to their ultimate discharge through the riverbed sediment and into the free-flowing stream.

Because of infiltrating river water, water quality characteristics in the banks and riverbed sediment varies with river stage fluctuations. Specific conductance, which is a measure of the dissolved salts in water, is used to differentiate river water (lower conductance) from groundwater (higher conductance). Investigations to date have revealed that some mixing, and, therefore, dilution of contaminants, invariably occurs at the interface between groundwater and the free-flowing stream of the river. Consequently, the maximum contaminant concentrations observed in near-river wells, aquifer sampling tubes, and riverbank seepage (see Table 2.1-1) may not represent the maximum concentration in groundwater that approaches the river.

Contamination in seeps and aquifer tubes generally agreed with contamination detected in monitoring wells in fiscal year 2000. Tritium exceeded the 20,000 pCi/L drinking water standard at the 100 B and 100 N Area shoreline and at the old Hanford Townsite. Chromium contamination exceeded the 100-µg/L maximum contaminant level in the 100 B and 100 D Areas. Nitrate was elevated in 100 H and 100 F Areas. Strontium-90 was detected in shoreline samples from several of the 100 Areas, and reached 14,700 pCi/L in a near-river well in 100 N Area. Uranium reached 301 µg/L in a seep in the 300 Area. Contaminant concentrations in river water remained extremely low at all locations and remained well below standards in fall 1999 (PNNL-13230).

Table 2.1-1. Maximum Concentrations of Groundwater Contaminants in Fiscal Year 2000

Contaminant (alphabetical order)	DWS or MCL [DCG](a)	Units	100 B/C Section 2.2 Wells	Shore(b)	100 K Section 2.3 Wells	Shore(b)	100 N Section 2.4 Wells	Shore(b)	100 D Section 2.5 Wells	Shore(b)	100 H Section 2.6 Wells	Shore(b)	100 F Section 2.7 Wells	Shore	200 West Section 2.8 Wells
Carbon tetrachloride	5	µg/L													**7,900**
Carbon-14	2,000 [70,000]	pCi/L			**35,600**	639									
Cesium-137	200 [3,000]	pCi/L													undetected
Chloroform	100	µg/L													**250**
Chromium (filtered)	100	µg/L	77	**115**	**474**	76	**122**	34	**2,260**	**641**	**178**	49	**208**	23	**542**
Cobalt-60	100 [5,000]	pCi/L													
Cyanide	200	µg/L													
cis-1,2 Dichloroethene	70	µg/L													
Fluoride	4	mg/L									0.25				**9.8**
Gross alpha	15	pCi/L									**131**				**692**
Gross beta	50	pCi/L	**133**	**67.1**	**22,300**	4.4	**21,500**	**3,680**		10.5	**593**	21	**553**	15.8	**23,000**
Iodine-129	1 [500]	pCi/L													**52**
Manganese (filtered)	50	µg/L					**5,320**								
Nitrate (as NO$_3^-$)	45	mg/L	30	39	**98**	22	**104**	18	**100**	18	**387**	**60**	**144**	**54**	**1,213**
Nitrite (as NO$_2$)	3.3	mg/L							2.3						**36**
Plutonium	NA [30]	pCi/L													undetected
Strontium-90	8 [1,000]	pCi/L	**66**	**17**	***6,970***	ND	***17,700***	***14,700***	**8.5**	4.8	**55**	**9.6**	**265**	1.5	**74.3**
Sulfate	250	mg/L					**370**	38	**744**						
Technetium-99	900 [100,000]	pCi/L									**1,070**				**63,700**
Tetrachloroethene	5	µg/L													
Trichloroethene	5	µg/L			**8**								**18**		**32**
Tritium	20,000 [2,000,000]	pCi/L	**39,900**	**36,600**	**1,360,000**	6,660	**45,000**	**29,100**	**20,000**	15,700	5,580	978	**36,900**	1,450	***2,940,000***
Uranium	20 [790]	µg/L									157		20		***2,100***

Table 2.1-1. (contd)

Contaminant (alphabetical order)	DWS or MCL [DCG][(a)]	Units	200 East Section 2.9 Wells	200 East Section 2.9 Shore[(b)]	400 Section 2.10 Wells	600 Section 2.11 Wells	300 Section 2.12 Wells	300 Section 2.12 Shore[(b)]	618-11 Section 2.12.8 Wells	Richland North Section 2.13 Wells	Basalt-Confined Section 2.14 Wells
Carbon tetrachloride	5	µg/L				1					
Carbon-14	2,000 [70,000]	pCi/L									
Cesium-137	200 [3,000]	pCi/L	122[(c)]								
Chloroform	100	µg/L				7.7					
Chromium (filtered)	100	µg/L	**3,250**			200					
Cobalt-60	100 [5,000]	pCi/L	78.2								
Cyanide	200	µg/L	**411**								
cis-1,2 Dichloroethene	70	µg/L					**170**				
Fluoride	4	mg/L								4.8	
Gross alpha	15	pCi/L	**240**				**60.2**	**228**	**30**	**65.4**	
Gross beta	50	pCi/L	**10,300**	48.6				49	**74**	**46**	
Iodine-129	1 [500]	pCi/L	**12.1**	0.41							undetected
Manganese (filtered)	50	µg/L	141			6.5					
Nitrate (as NO_3^-)	45	mg/L	**562**	36	**92**	**54**	**101**	29	**149**	**203**	11
Nitrite (as NO_2)	3.3	mg/L			0.43				**3.9**		
Plutonium	NA [30]	pCi/L	9.4[(c)]								
Strontium-90	8 [1,000]	pCi/L	***1,210***[(c)]				4.1	0.28			
Sulfate	250	mg/L				55					28
Technetium-99	900 [100,000]	pCi/L	**13,300**	120							
Tetrachloroethene	5	µg/L					0.65				
Trichloroethene	5	µg/L				1.4	3.5			3.7	
Tritium	20,000 [2,000,000]	pCi/L	***2,510,000***	**106,000**	**58,800**	**65,900**	11,600	11,300	***8,380,000***	546	5,770
Uranium	20 [790]	µg/L	**353**				**234**	**301**	**30.8**	13.6	

Note: Table lists highest concentration for fiscal year 2000 in each geographic region. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area.

(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = DOE derived concentration guide. See PNNL-13080 for more information on these standards.

(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 1999. 200 East Area plumes monitored at old Hanford Townsite.

(c) Well typically showing highest concentrations near 216-B-5 injection well not sampled in fiscal year 2000.

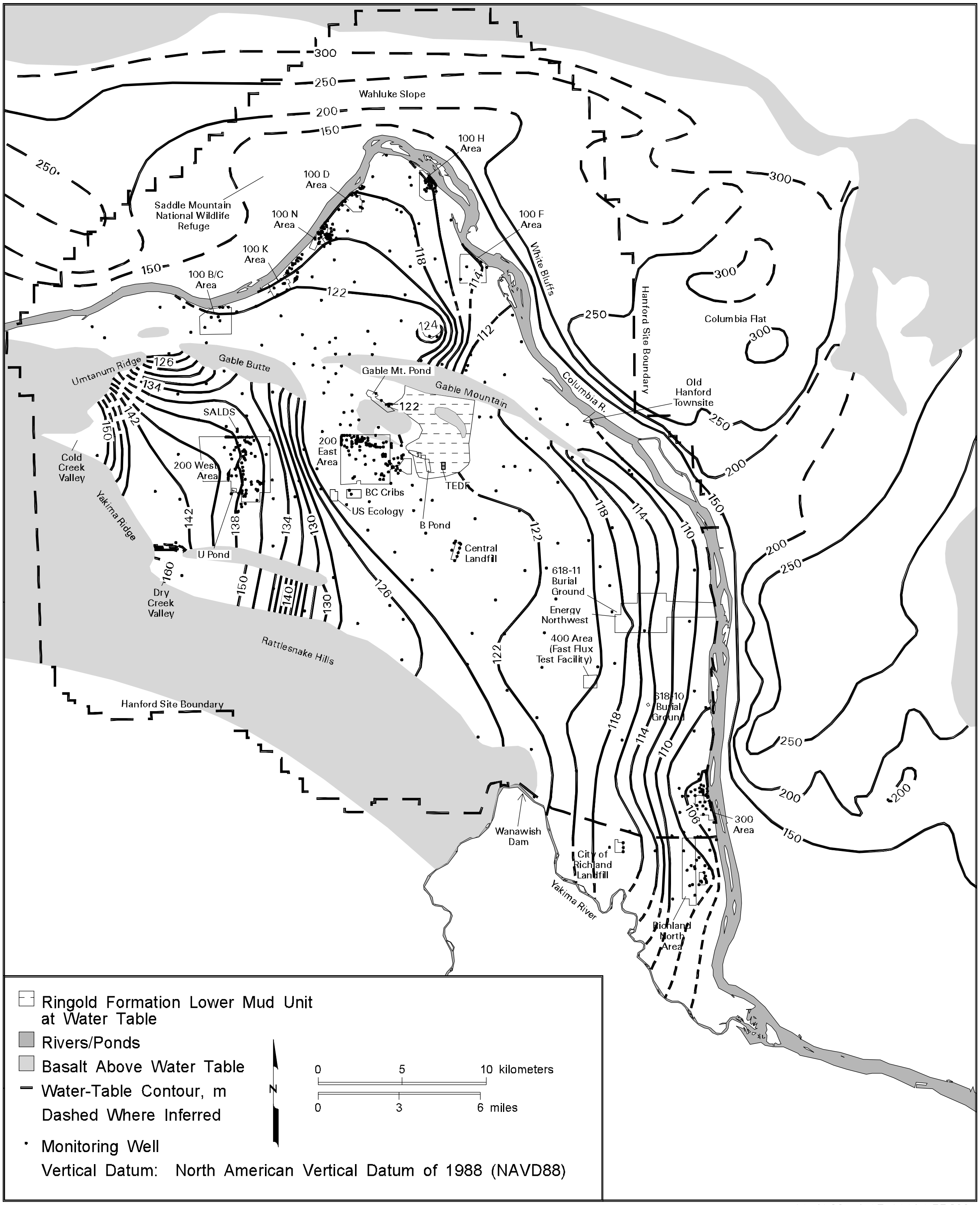


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Figure 2.1-1. Hanford Site and Outlying Areas Water-Table Map, March/April 2000

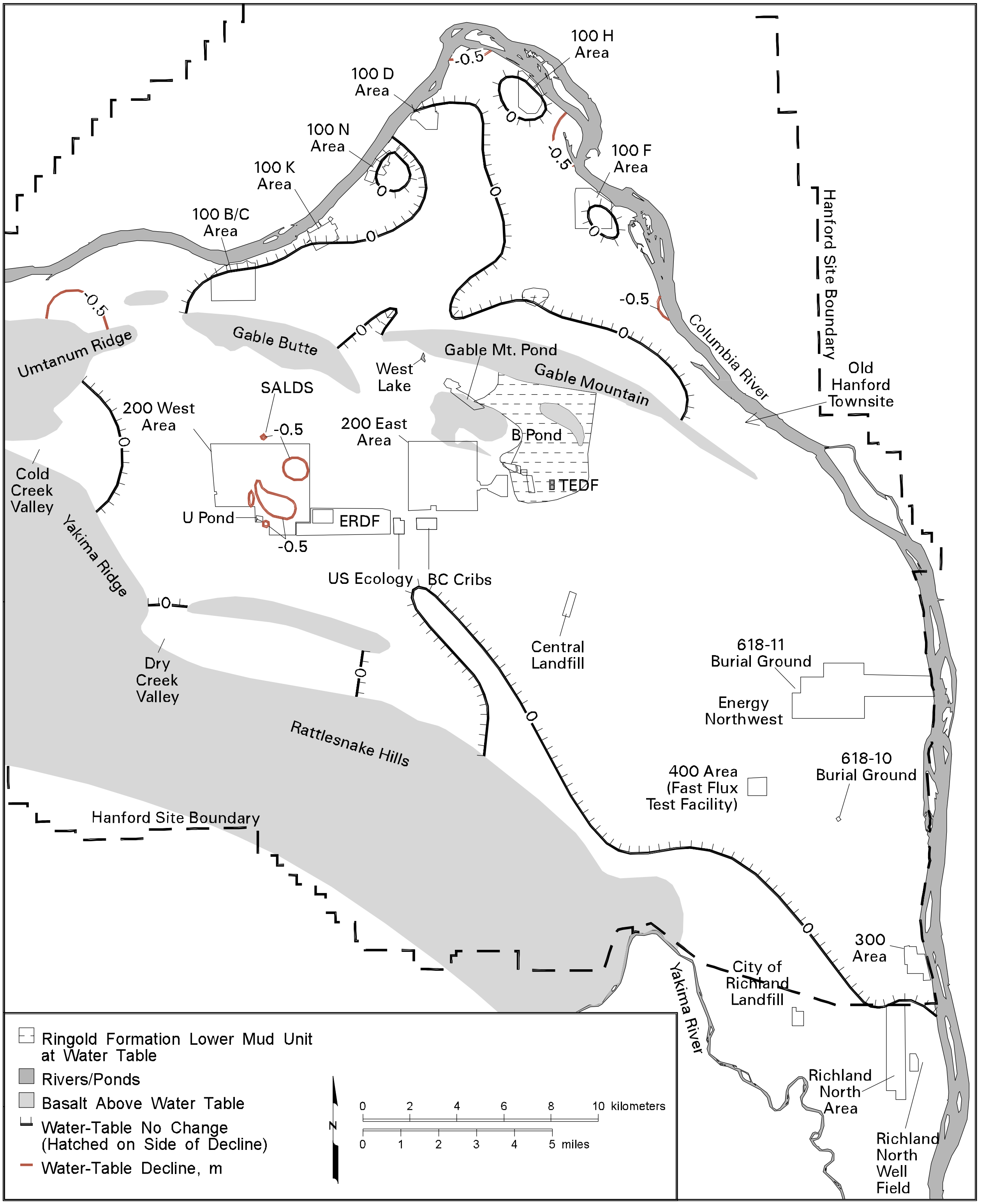

Figure 2.1-2. Changes in Water-Table Elevations between 1999 and 2000

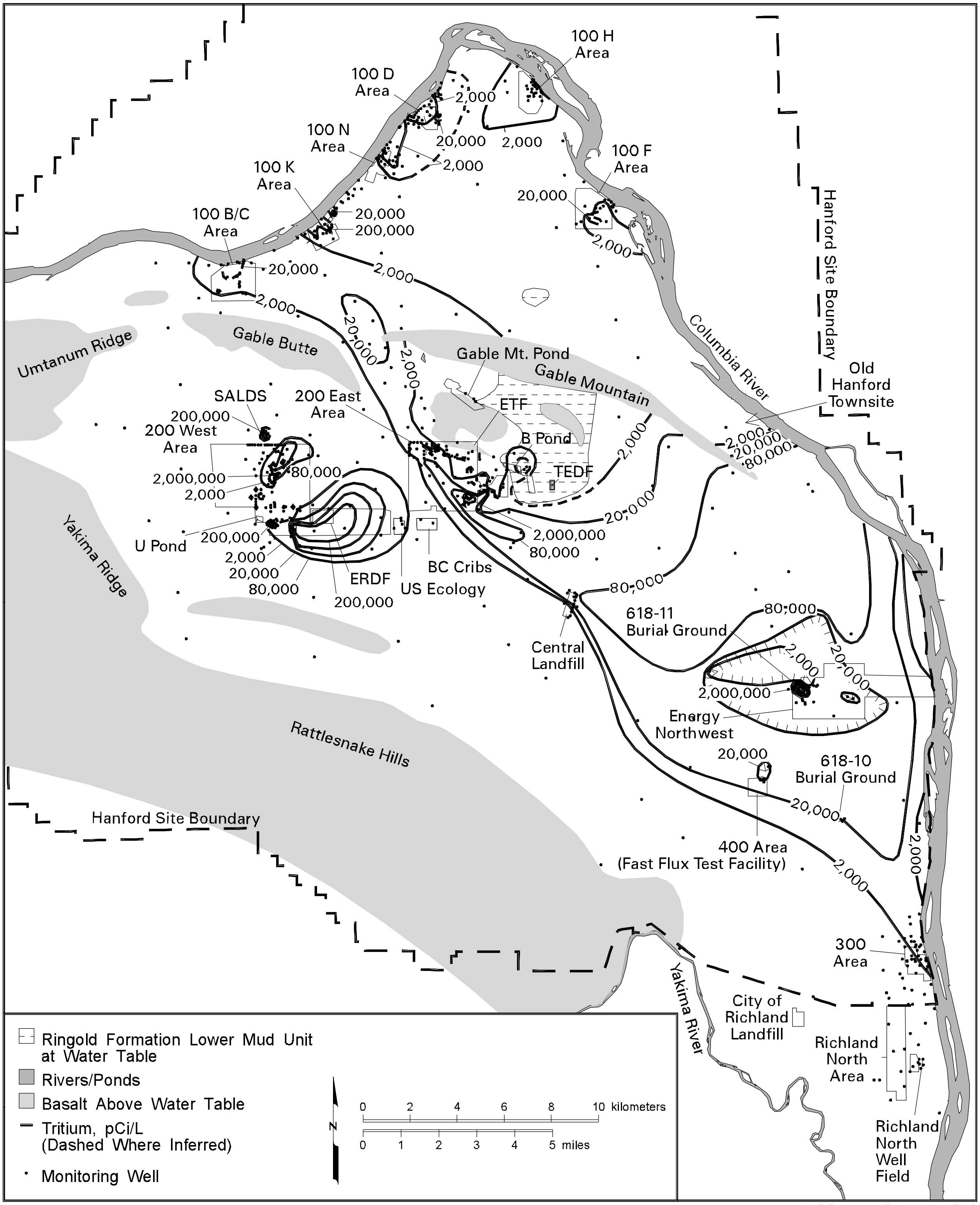

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Figure 2.1-3. Average Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer

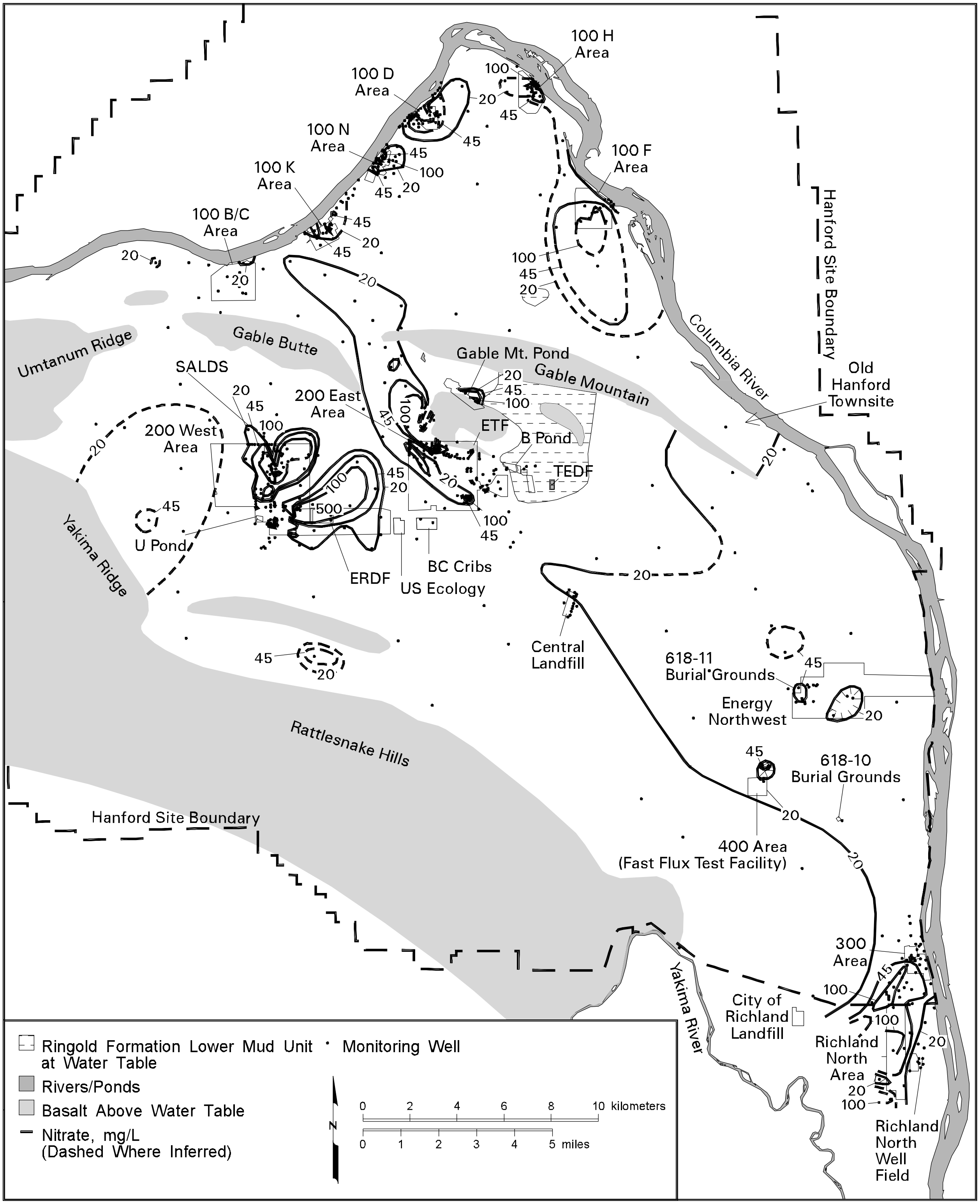

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Figure 2.1-4. Average Nitrate Concentrations on the Hanford Site, Top of Unconfined Aquifer

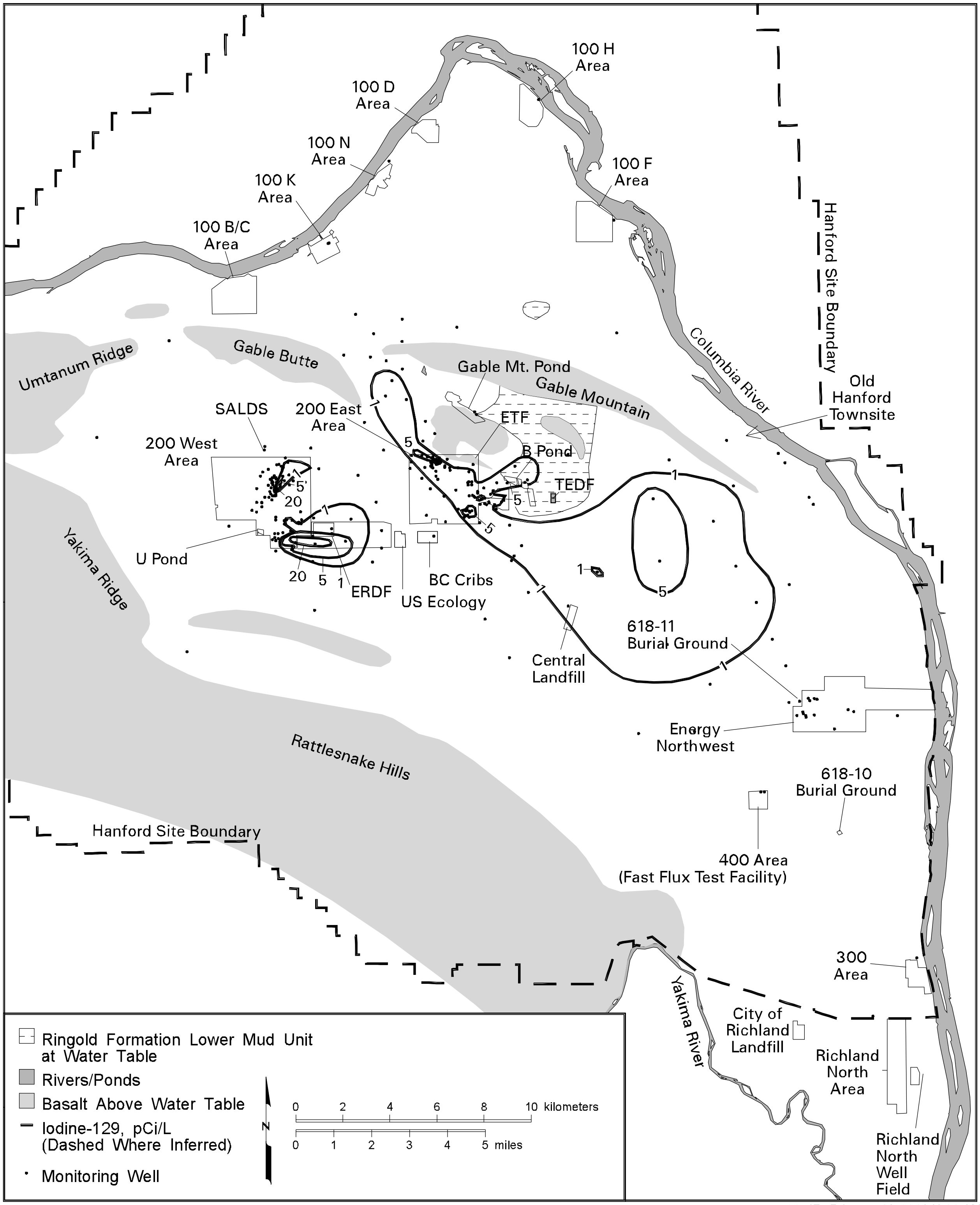

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Figure 2.1-5. Average Iodine-129 Concentrations on the Hanford Site, Top of Unconfined Aquifer

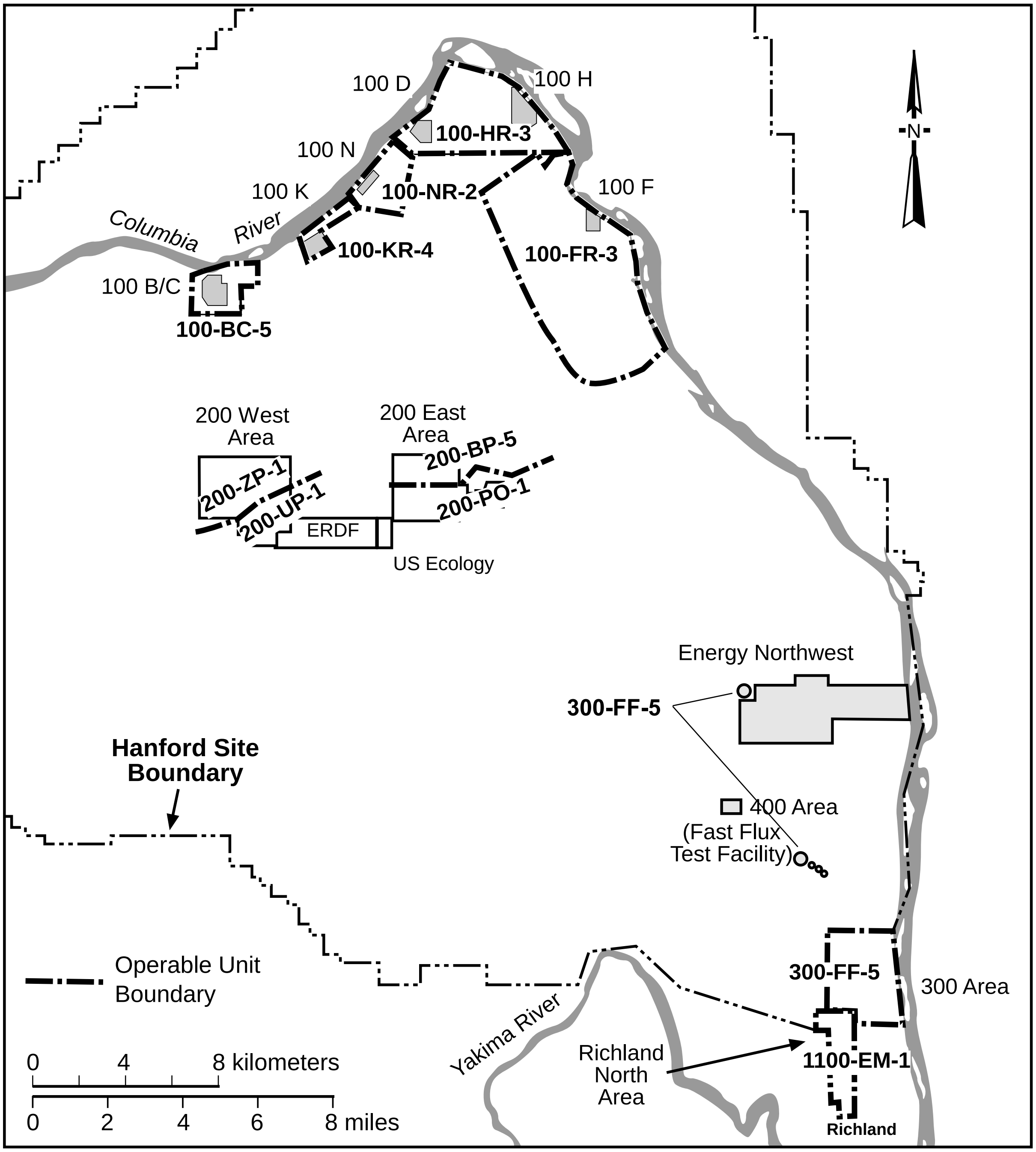

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Figure 2.1-6. Groundwater Operable Units on the Hanford Site

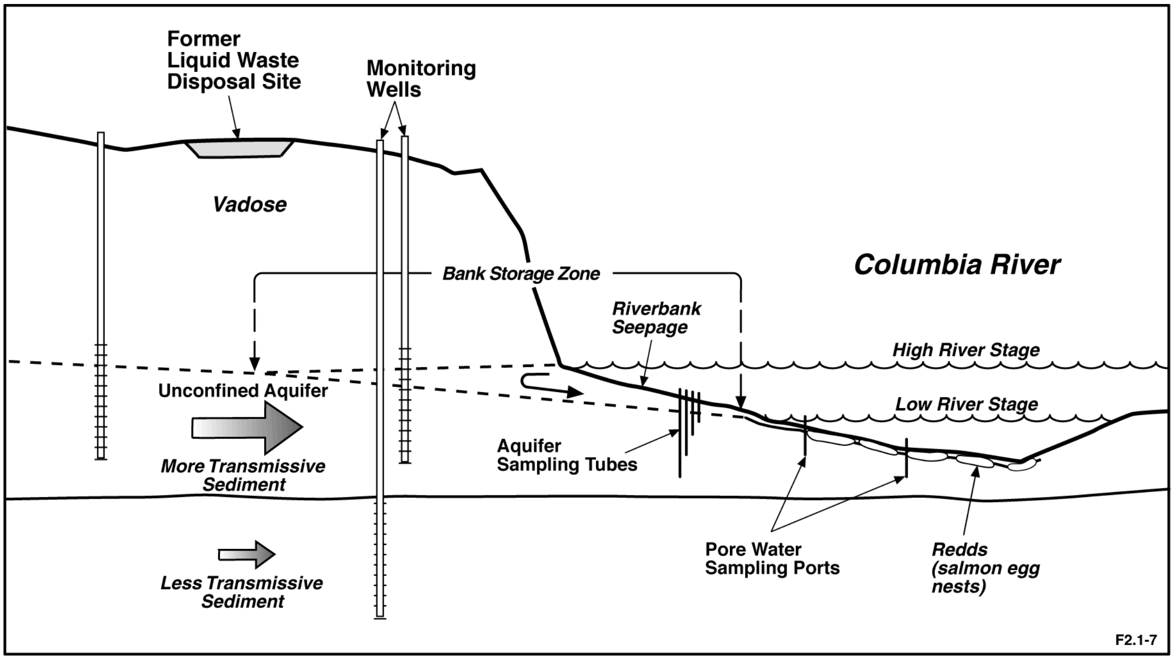


Figure 2.1-7. Principal Features of Groundwater/Columbia River Zone of Interaction

2.2 100 B/C Area

M. D. Sweeney and M. J. Hartman

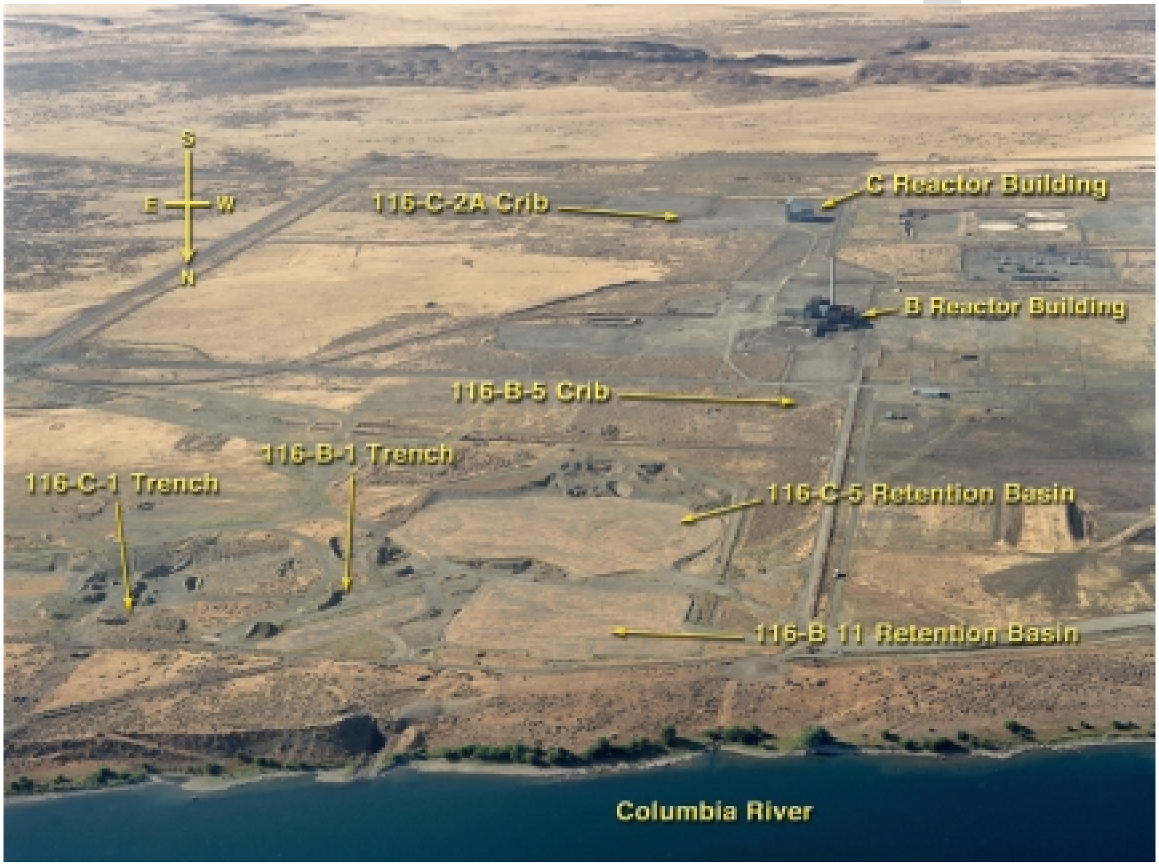
The 100 B/C Area is the reactor area farthest upstream along the Columbia River. B Reactor was placed into service in 1944 and operated until 1968. C Reactor operated from 1952 to 1969. The B and C Reactors used a single-pass system for cooling water (i.e., cooling water passed through the reactor and was discharged to the Columbia River). Groundwater contaminants include strontium-90 and tritium. Chromium and nitrate are elevated locally. Fiscal year 2000 results indicate that contamination concentrations continue to decline throughout the 100 B/C Area. Some monitoring wells (e.g., 199-B3-47) continue to exhibit seasonal variability. Figure 2.2-1 shows the location of monitoring wells in the 100 B/C Area. Some wells in the 600 Area also are monitored near the 100 B/C Area and are shown in Figure 2.2-2.

Strontium-90, tritium, and nitrate exceeded drinking water standards in groundwater at the 100 B/C Area in fiscal year 2000. Concentrations of these contaminants declined in most wells.

Waste site remediation in the 100-BC-5 Area in fiscal year 2000 consisted of backfilling the following sites that were excavated in fiscal year 1999:

116-B-2 trench
116-B-3 crib
116-B-4 crib
116-B-6A and 6B cribs
116-B-9 and 10 French drains
116-B-12 crib
116-B-16 tank
116-C-2A crib
116-C-2B sump
116-C-2C sand filter.

All the open excavations were 4.5 meters deep except for 116-B-6B, 116-B-9, and 116-B-10, which were ~3 meters deep.



Aerial view of the 100 B/C Area, August 2000.

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2.2.1 Groundwater Flow

Groundwater flow within the unconfined aquifer was north toward the Columbia River in March 2000 (see Plate 1). The hydraulic gradient in March 2000 was 0.001 near the Columbia River. The average gradient between C Reactor and the Columbia River was ~0.001 in February 2000. The hydraulic conductivity of the unconfined aquifer in the 100 B/C Area ranges from 4.3 to 17 meters per day (BHI-00917). Using these values and an effective porosity of 0.1 to 0.3, the flow rate ranges from 0.014 to 0.17 meter per day.

2.2.2 Tritium

Tritium exceeded the 20,000 pCi/L drinking water standard in several wells in the north-central 100 B/C Area and in one well near the 118-B-1 burial ground (see Plate 2). Two wells continued to monitor concentrations in excess of the drinking well standard. Two additional wells that also exceeded the standard in fiscal year 1999 were not scheduled for sampling during fiscal year 2000. Well 199-B3-1 dropped below the drinking water standard for the first time since 1998.

Monitoring Objectives in 100 B/C Area

Groundwater monitoring is conducted in the 100 B/C Area triennially to annually to describe the nature and extent of contamination.

Tritium concentrations throughout the 100 B/C Area have decreased in all but one well. Two wells have tritium concentrations that continue to decline, though they still exceed the drinking water standard (Figure 2.2-3). However, these wells are not in close proximity to one another; well 119-B3-47 is located north of the 116-B-1 burial ground and well 119-B8-6 is northeast of the 118-B-1 burial ground (see Figure 2.2-1). Well 699-72-73 (see Figure 2.2-2) has had an increasing trend of tritium concentration since 1996 (Figure 2.2-4). The reported concentration (17,600 pCi/L) remained below the drinking water standard. This well is located ~1,500 meters east of the 100 B/C boundary. Sources for the elevated tritium include the 100 B/C Area or the 200 East Area via Gable Gap.

2.2.3 Nitrate

Nitrate is elevated in a small area near the 116-B-11 retention basin and the 116-B-1 and 116-C-1 trenches. The distribution in fiscal year 2000 did not change significantly. Nitrate concentrations have decreased in all but one well in the 100 B/C Area. There were no wells with concentrations above the 45 mg/L drinking water standard in the reporting period. The only well exceeding the drinking water standard in fiscal year 1999, well 199-B3-47, has reversed its increasing trend (Figure 2.2-5).

2.2.4 Strontium-90

Strontium-90 contamination had sources near the B Reactor building and at retention basins and disposal trenches near the Columbia River. The plume has not changed significantly in recent years.

Five wells in the 100 B/C Area continued to exceed the 8 pCi/L drinking water standard for strontium-90. The contaminant sources are in two distinct regions in the 100 B/C Area, but the contamination has mingled to form a single plume. Three wells are located on the northern boundary near the Columbia River, and the two remaining wells are located near the reactors (see Figure 2.2-1). The trend plots for these wells show that strontium-90 concentrations have changed little in fiscal year 2000 (Figures 2.2-6, 2.2-7, and 2.2-8).

2.2.5 Chromium

Hexavalent chromium concentrations in the 100 B/C Area did not exceed the 100 µg/L maximum contamination level for the reporting period. Wells 199-B3-47 and 199-B5-1 have sporadically exceeded the standard in the past. However, the concentration in well 199-B3-47 has declined, and well 199-B5-1 had no new data in fiscal year 2000. Aquifer tube data (see Section 2.2.6) does indicate that hexavalent chromium is elevated near well 199-B3-47.

2.2.6 Water Quality at Shoreline Monitoring Locations

Groundwater near the Columbia River is sampled annually in the late fall via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline. Seeps are natural areas of groundwater discharge above the water line. Six aquifer tubes and two seeps were sampled in the 100 B/C Area in fiscal year 2000 (Table 2.2-1).

Strontium-90, tritium, and chromium concentrations continued to exceed drinking water standards in groundwater samples at the 100 B/C Area in fiscal year 2000.

Samples from two aquifer tubes exceeded the drinking water standard for strontium-90 in fiscal year 2000, at 15 and 17 pCi/L. The specific conductance of the samples were 403 and 347 µS/cm, indicating the groundwater was relatively undiluted with river water. Tube 06-M is located downgradient of waste sites in the northern 100 B/C Area that have contaminated groundwater with strontium-90. A nearby seep location also had detectable strontium-90 (4.5 pCi/L). Tube 05-M is located farther upstream (see Figure 2.3-1). The concentration in that location indicates that the strontium-90 plume may be slightly larger than previously thought, based on data from monitoring wells alone. However, a seep near tube 05-M had no detectable strontium-90.

Tritium concentrations exceeded the drinking water standards (20,000 pCi/L) in two aquifer tubes that are within the groundwater tritium plume (see Plate 2). The highest concentration was 36,600 pCi/L. One of the seeps also contained a fairly high concentration of tritium (19,600 pCi/L).

Chromium concentrations in one aquifer tube slightly exceeded the maximum contaminant level (see Table 2.2-1). The tube is located near well 199-B3-47, which has had elevated chromium levels in the past.

Nitrate concentrations ranged from 16 mg/L in an upstream tube, to 39 mg/L in a tube near the monitoring wells that typically have elevated nitrate.

Table 2.2-1. Shoreline Monitoring Data for the 100 B/C Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
04-S	Tube	10-Nov-99	363	12	***0.0***	9.0	11,100	16.0
05-M	Tube	09-Nov-99	347	33	17.0	58.3	6,100	18.0
06-M	Tube	10-Nov-99	403	115	15.2	38.2	36,600	39.0
07-D	Tube	09-Nov-99	394	20	***0.0***	25.9	31,600	24.0
11-D	Tube	09-Nov-99	356	12	***0.0***		1,960	
14-D	Tube	02-Nov-99	382	6	***0.1***	67.1	6,510	27.0
SB-038-3	Seep	25-Oct-99	393	17	***0.2***	9.5	19,600	12.8
SB-039-2	Seep	25-Oct-99	253	20	4.5	14.7	4,200	8.0
04-S	River	10-Nov-99	132					
05-M	River	09-Nov-99	121					
06-M	River	10-Nov-99	122					
07-D	River	09-Nov-99	123					
11-D	River	09-Nov-99	122					
14-M	River	02-Nov-99	125					

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore, adjacent to the aquifer sampling tube.

Values in ***bold italics*** are qualified by the laboratory as "undetected." Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 µS/cm.

Data sources: Hanford Environmental Information System and various project records.

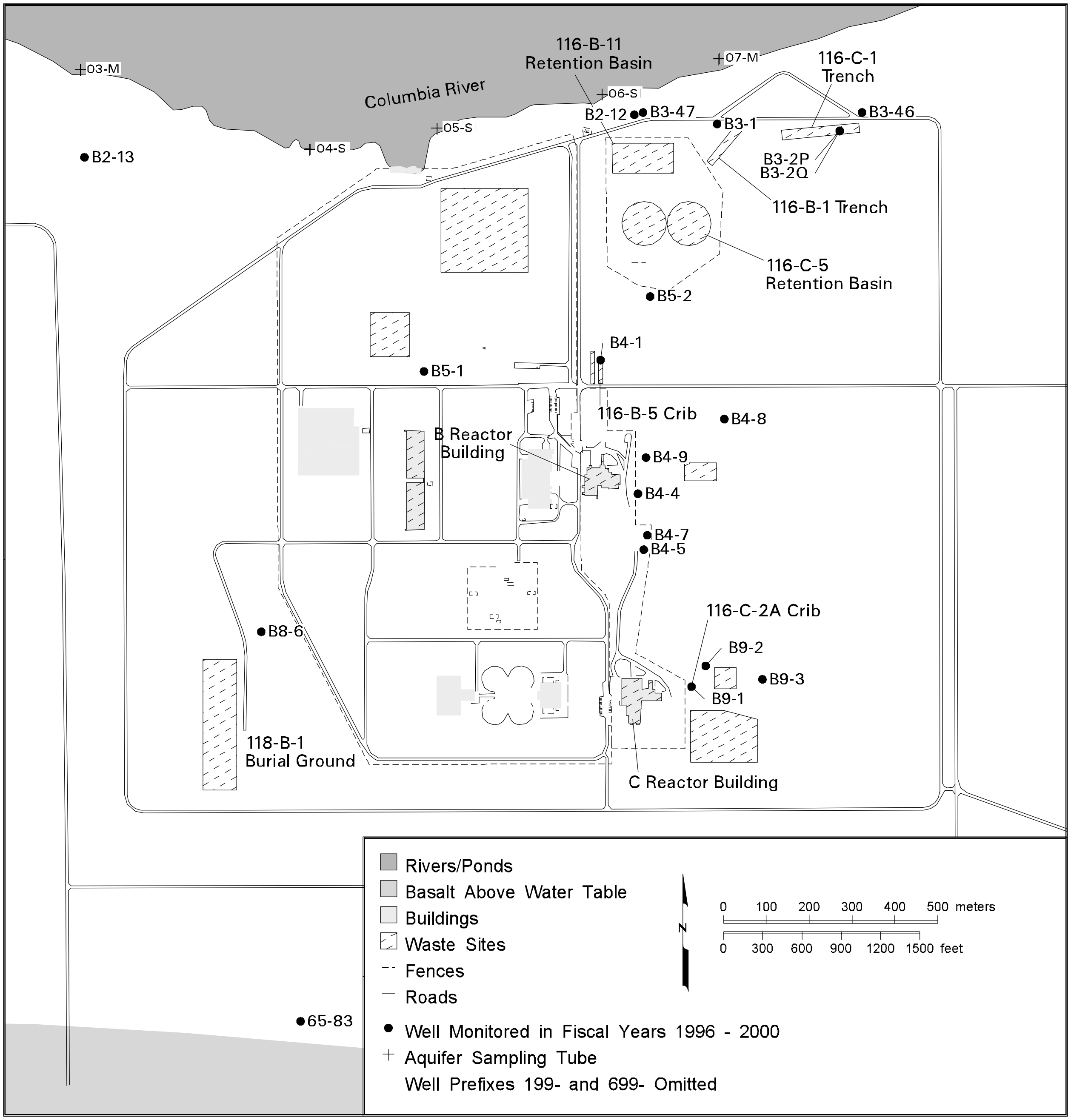

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Figure 2.2-1. Groundwater Monitoring Wells in the 100 B/C Area

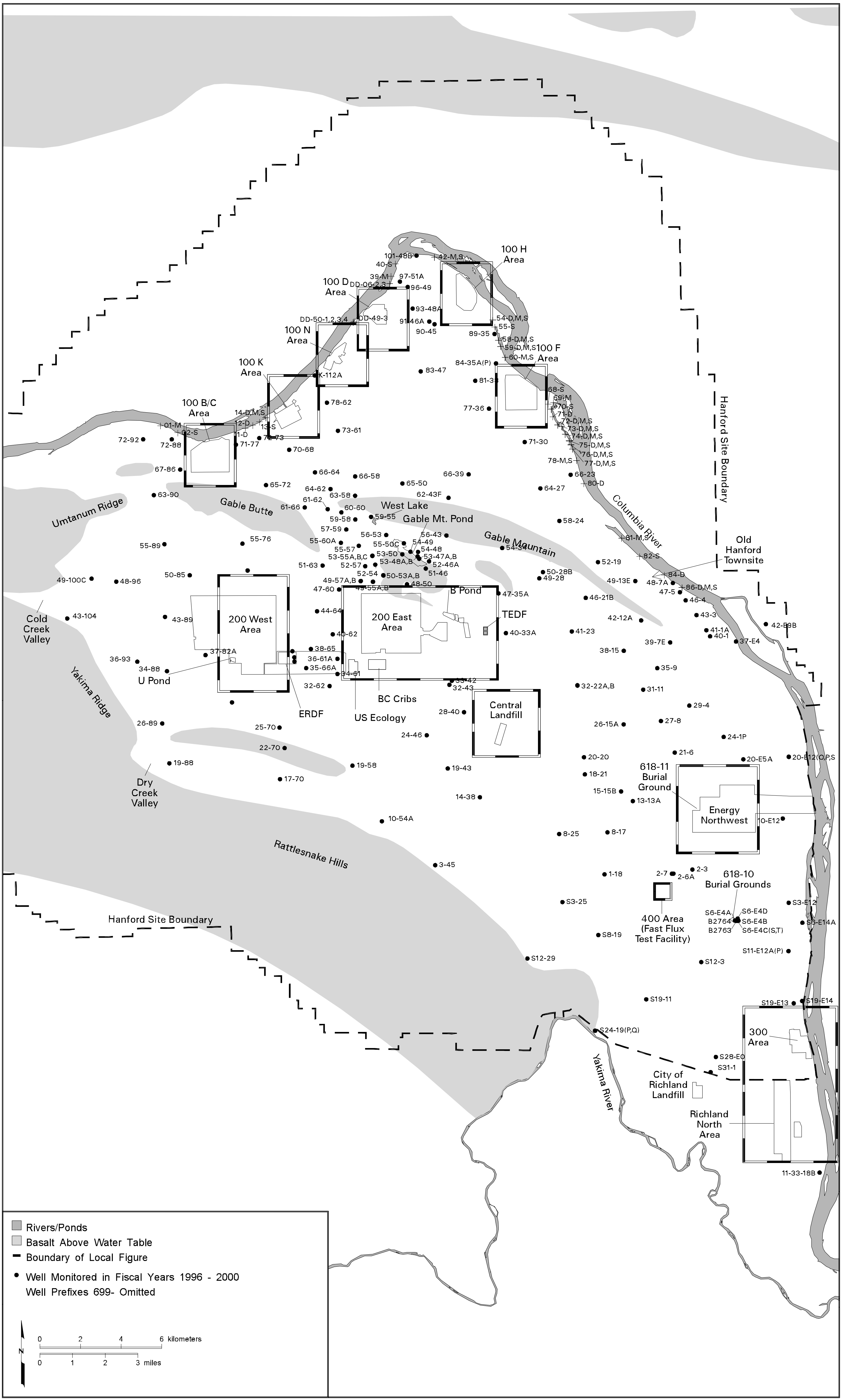

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Figure 2.2-2. Groundwater Monitoring Wells in the 600 Area

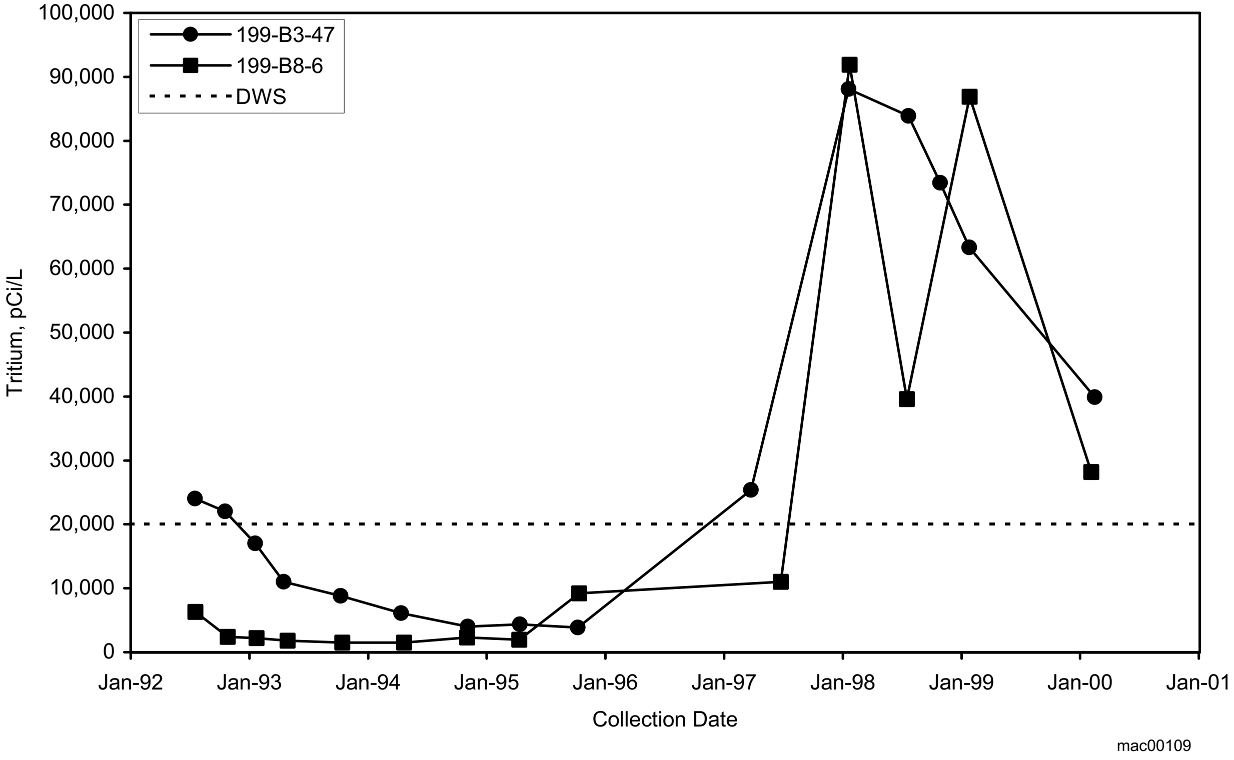

Figure 2.2-3. Tritium in Well 199-B3-47, near the 116-B-11 Retention Basin, and Well 199-B8-6, near the 118-B-1 Burial Ground

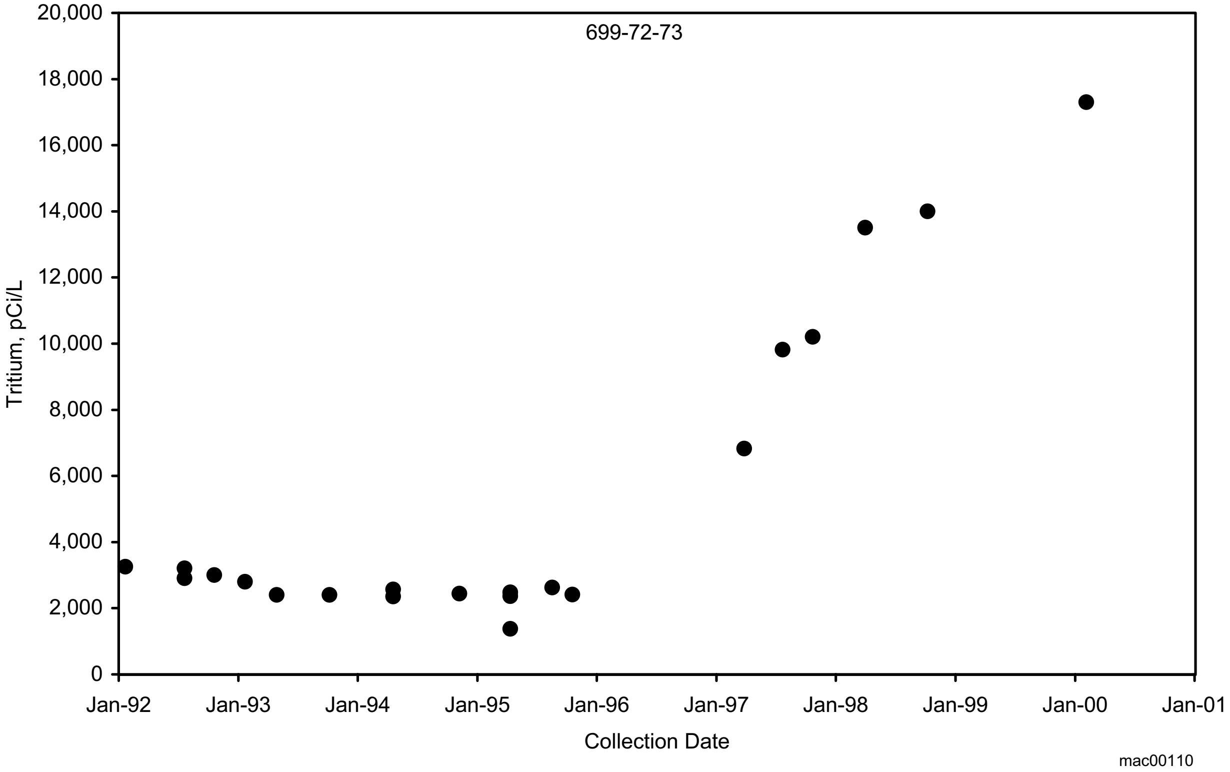

Figure 2.2-4. Tritium in Well 699-72-73 East of the 100 B/C Area

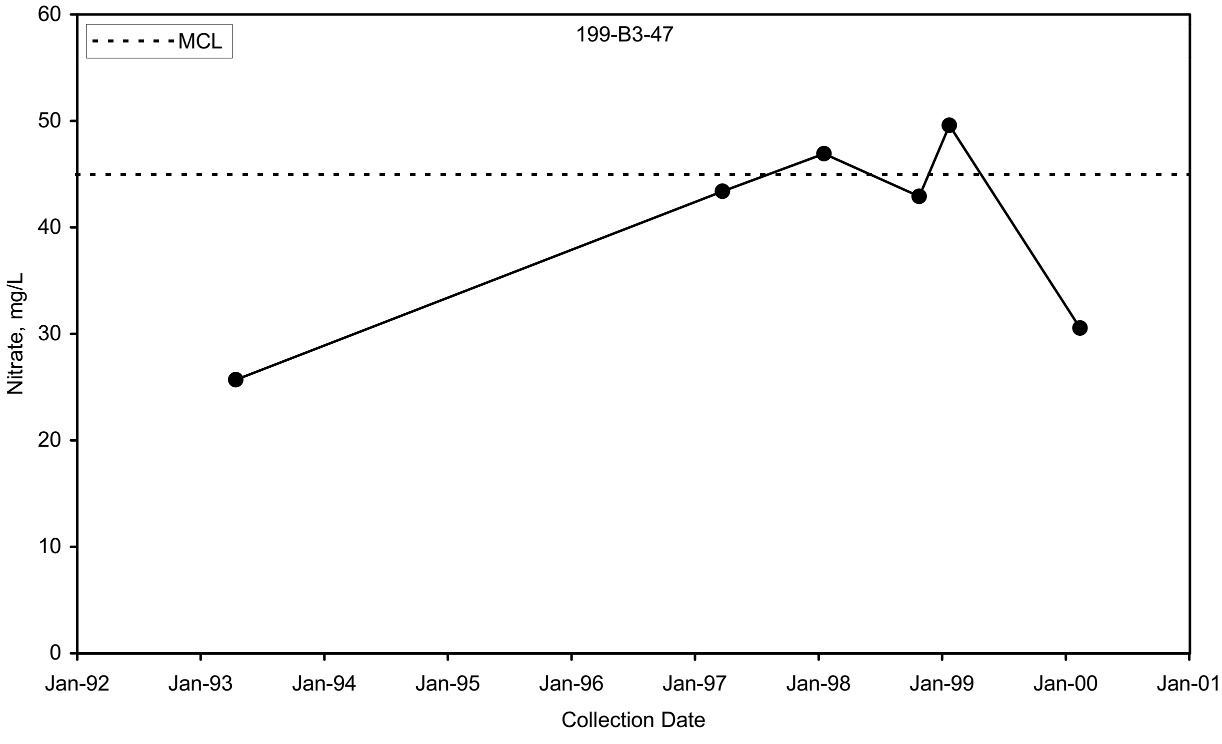

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Figure 2.2-5. Nitrate in Well 199-B3-47 near the 116-B-11 Retention Basin

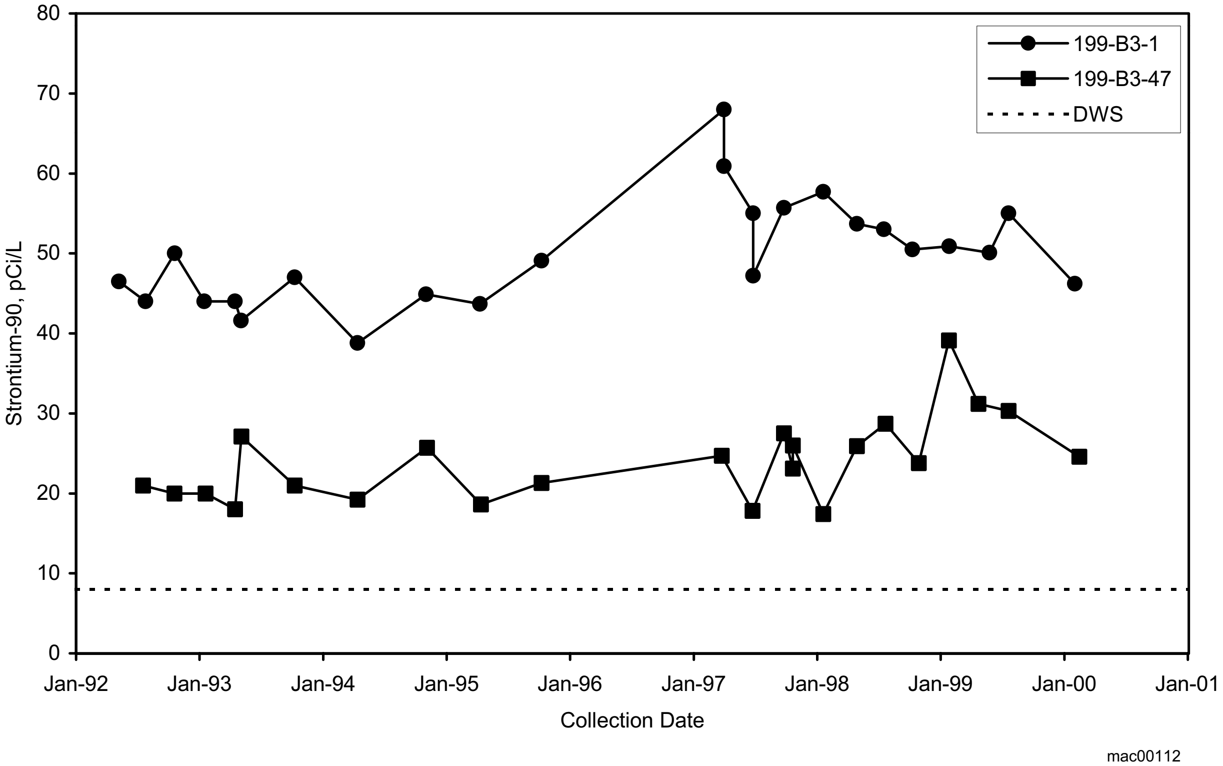

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Figure 2.2-6. Strontium-90 in Wells 199-B3-1 and 199-B3-47 near the 116-B-1 Trench and 116-B-11 Retention Basin

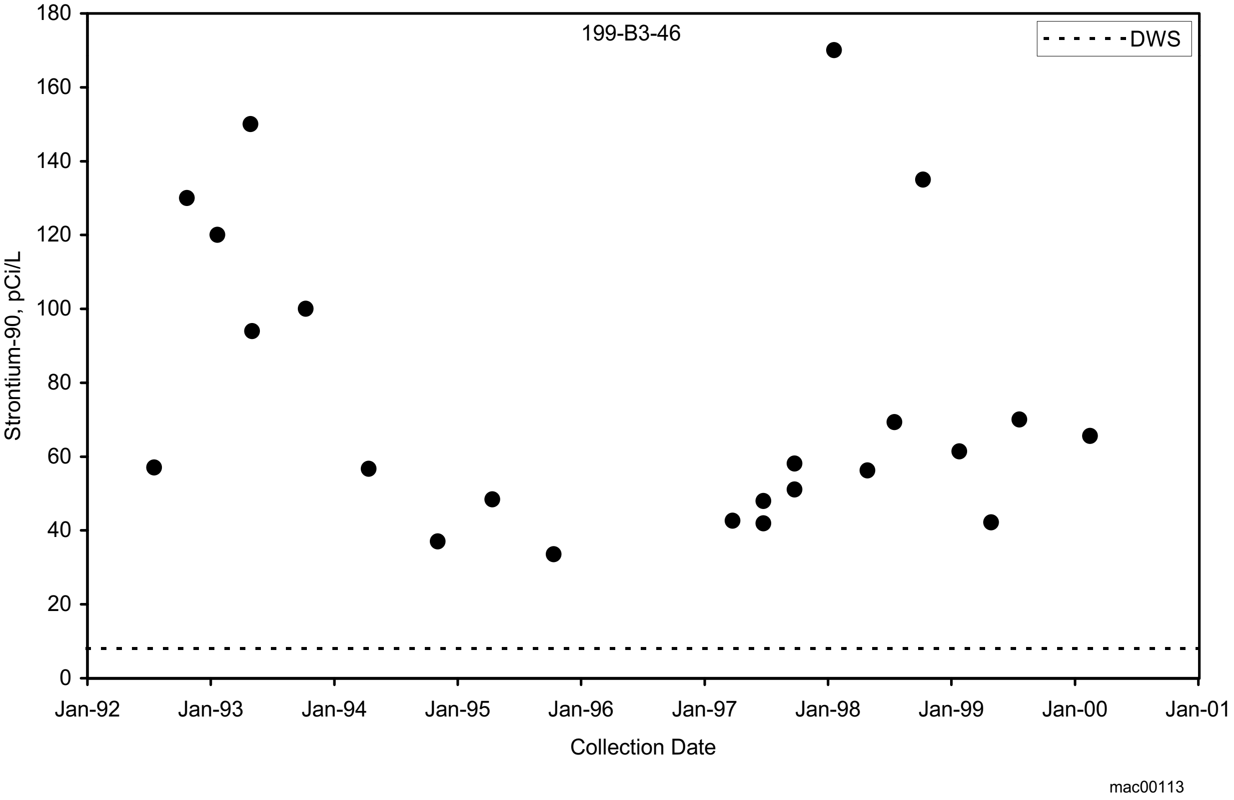


Figure 2.2-7. Strontium-90 in Well 199-B3-46 near the 116-C-1 Trench

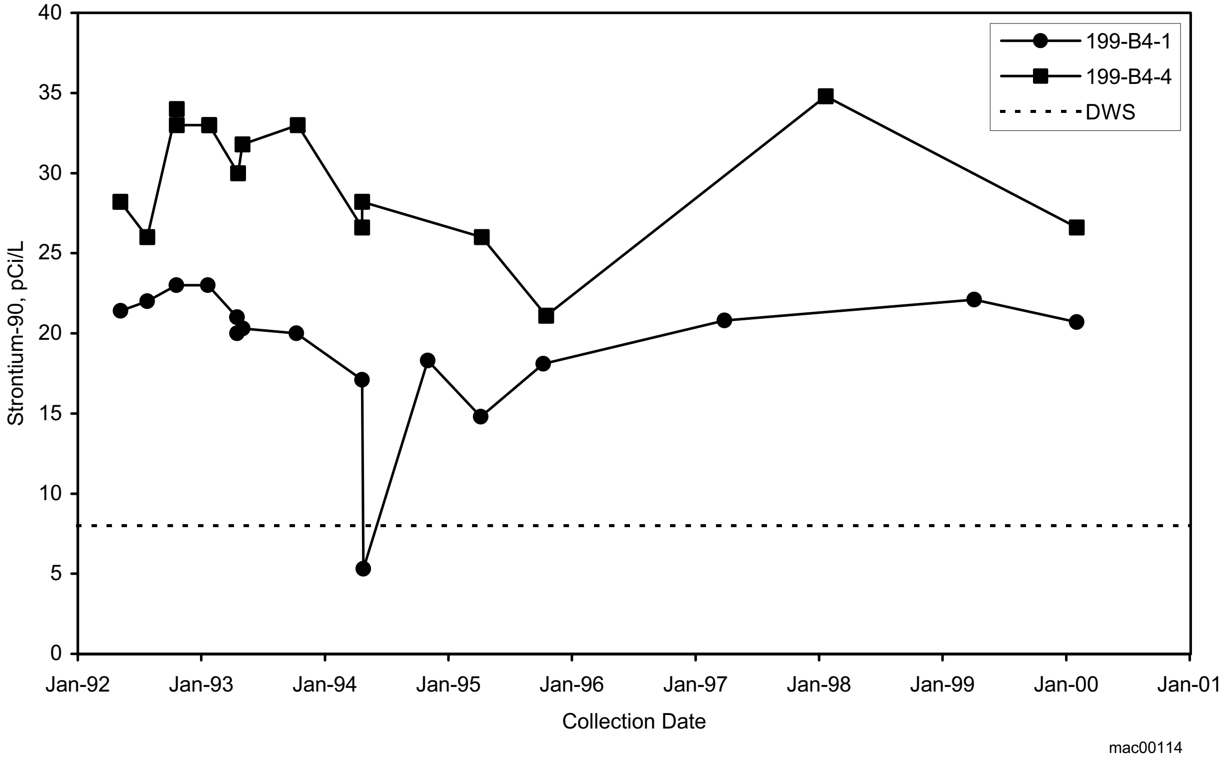


Figure 2.2-8. Strontium-90 in Wells 199-B4-1 and 199-B4-4 near B Reactor

2.3 100 K Area

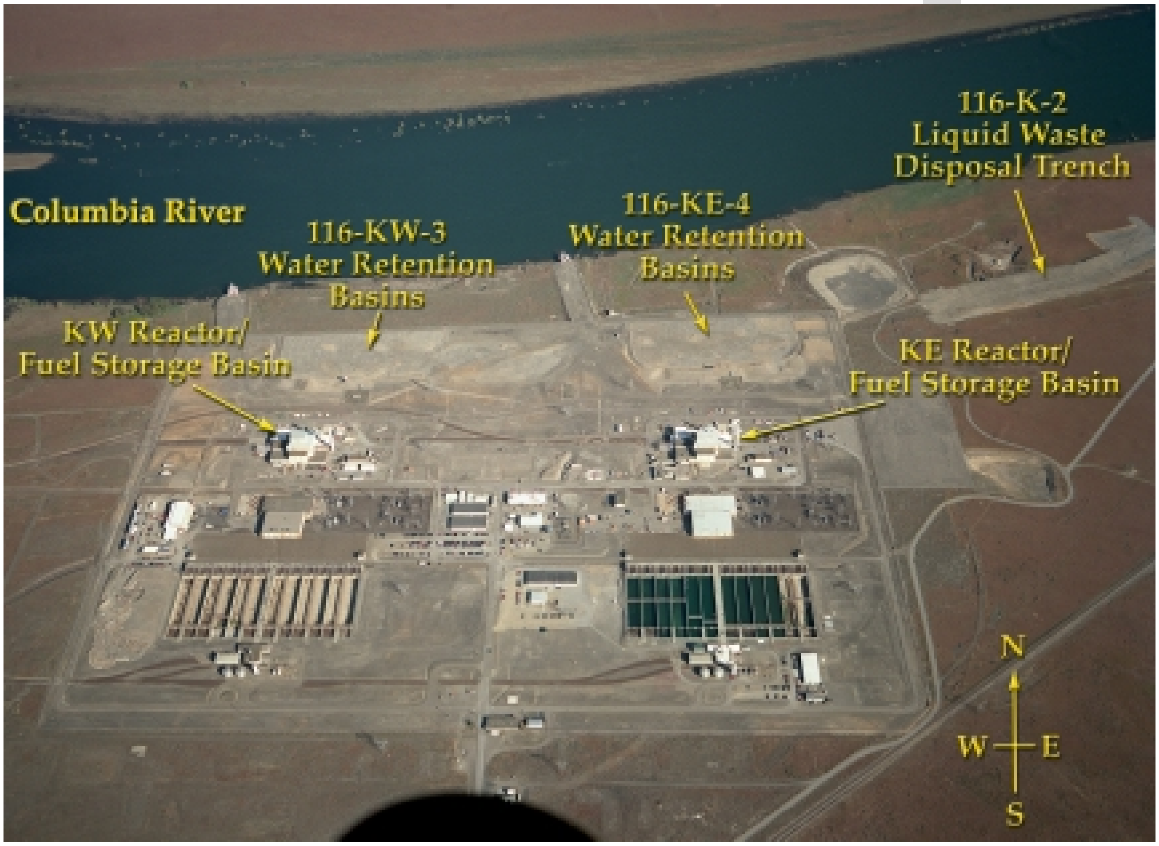
R. E. Peterson and W. J. McMahon

The KE and KW Reactors were the largest of the original group of eight production reactors. They operated between 1955 and 1971. The 116-K-2 liquid waste disposal trench, which received used reactor coolant and decontamination solutions, was the largest soil column disposal facility in the 100 Areas. A photo of the 100 K Area is shown below. Figure 2.3-1 shows the facilities that currently remain in the 100 K Area, former waste disposal sites, monitoring wells, and rivershore monitoring sites.

The principal issues associated with groundwater contamination in the 100 K Area today involve a chromium plume located near the Columbia River; operating facilities that contain highly radioactive spent fuel, shielding water, and sludge; and carbon-14, strontium-90, and tritium contamination from past-practice disposal sites. Several potential sources exist that could contribute additional contamination to the currently mapped groundwater plumes or possibly create new plumes. These sources include locations where the vadose zone contains significant inventories of radionuclides from disposal of liquid waste during the reactor operating years. A second source involves the potential loss of shielding water from two nuclear fuel storage basins, which are located in the KE and KW Reactor buildings.

Principal groundwater issues in the 100 K Area include remediation of a hexavalent chromium plume and potential water loss from fuel storage basins that contain highly radioactive liquid and sludge.

An interim remedial action is in progress to reduce the amount of chromium reaching the Columbia River via groundwater flow. Removing spent nuclear fuel, shielding water, and sludge from the 100 K Fuel Storage Basins is a top priority for the Hanford Site and work is underway.



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Aerial view of the 100 K Area, April 2000.

Information on current groundwater issues at the 100 K Area also is available on the Internet at http://pnl45.pnl.gov/100k or at http://hanford.pnl.gov/groundwater. Background information on the geology of the 100 K Area, regulatory issues, and monitoring methods are described in PNNL-13080. The history of operations and waste sites at 100 K Area is described in the technical baseline report for the 100-KR-4 Operable Unit (WHC-SD-EN-TI-239).

2.3.1 Groundwater Flow

Groundwater movement beneath the 100 K Area is toward the north-northwest, as suggested by contours for the water-table elevation (see Plate 1). A bend in the shape of the contours beneath the KE Reactor suggests a slight westerly flow in that area, perhaps as a consequence of local-scale heterogeneity in aquifer characteristics. In the vicinity of the 116-K-2 liquid waste disposal trench, the extraction and injection of water as part of the interim action pump-and-treat system influences the direction and rate of groundwater movement. Small depressions have developed around each extraction well, as expected, and small mounds have been created around the four injection wells.

Monitoring Objectives in 100 K Area

Groundwater monitoring is conducted in the 100 K Area:

- annually to describe the nature and extent of contamination in support of environmental restoration issues
- monthly near the KE and KW Fuel Storage Basins to detect potential leakage
- various time intervals to evaluate the performance of the pump-and-treat system for chromium.

The unconfined aquifer is contained within the gravelly sediment of Ringold Formation Unit E, which is generally considered a transmissive aquifer. Groundwater flow velocity in this aquifer between the reactors and the Columbia River has been previously estimated to be between 0.01 and 0.4 meter per day (WHC-SD-EN-AP-174). That estimate assumed a hydraulic conductivity in the range 0.95 to 16 meters per day, gradients in the range of 0.003 to 0.005, and an effective porosity of 20%. Recent data suggest that the travel time from the KE Reactor building to a well midway between the reactor and the river is ~6 years, indicating a movement rate of 0.12 meter per day. The evidence for this estimate is a rise in tritium concentrations in well 199-K-32A, which may signal the arrival of a tritium plume created by leakage from the KE Fuel Storage Basin in 1993 (Figure 2.3-2).

Because monitoring wells in the 100 K Area do not provide complete coverage, the configuration of the water table cannot be described with complete certainty for all portions of the area. The general direction of groundwater flow is fairly clear; however, the fine-scale details for direction and rate of flow between known sources and the Columbia River are less well defined. The presence of engineered backfill and heterogeneity in hydraulic properties of the aquifer contributes to uncertainty in describing pathways for contaminant transport. Near the Columbia River, the rate and direction of groundwater flow varies through wide ranges because of changing hydraulic gradients created by the fluctuating river stage.

Although the horizontal movement of groundwater predominates in the flow field, vertical movement also occurs in response to the fluctuating Columbia River stage and possibly the influence of deeper aquifers. The water table typically moves up and down through a range of ~2 meters in 100 K Area wells located within several hundred meters of the river, decreasing to a range of ~0.3 meter in wells located farthest inland (BHI-00917). Water-level fluctuations in wells are even greater during years of extremely high river discharge (e.g., 1996 and 1997). The vertical movement of the water table may cause remobilization of contaminants held in the normally unsaturated vadose zone, as has been demonstrated previously at the 100 K Area (PNNL-12023) and also the 100 N Area (DOE/RL-98-38).

During the operating years 1955 to 1971, a large mound was created beneath the southwestern end of the 116-K-2 liquid waste disposal trench (HW-77170). The mound created a radial flow pattern that modified the flow field beneath the entire

100 K Area and distributed hexavalent chromium and tritium widely throughout the area. The implication of the mound with respect to current groundwater conditions is that residual contaminated moisture from the previously saturated mound areas continues to slowly migrate downward to the water table, thus contributing to groundwater plumes.

In the previous annual report (PNNL-13116), elevated water levels in well 699-78-62, which is located ~1,600 meters inland from the 116-K-2 trench, were cited as evidence for the extent of this mound. Subsequent evaluation of records for this well has revealed that the earlier elevated water levels may be partially a consequence of well construction. Originally, the well monitored a hydrologic unit below the uppermost aquifer, where the hydraulic head is higher. In 1974, the well was reconfigured to monitor the water table. However, gross beta was somewhat elevated in the well during the operating years, and chromium continues to be elevated in the well today. Also, a water table map drawn for 1961 conditions indicates that the mound was recognizable at well 699-78-62 (HW-74095). There is currently no obvious alternative explanation, other than transport via mounding, for why these two reactor effluent indicators are located this far inland from their disposal site.

2.3.2 Chromium

The 100 K Area has three areas of chromium contamination: a plume between the 116-K-2 trench and the Columbia River and two smaller areas of contamination near the reactor buildings.

Chromium was introduced to 100 K Area groundwater from multiple sources. Infiltration of reactor coolant that contained 700 µg/L hexavalent chromium created the most widespread contamination because of mounding beneath the southwestern end of the 116-K-2 liquid waste disposal trench. Additional sources include leakage and/or spillage of sodium dichromate stock solutions near railcar transfer stations, storage tanks, and mixing facilities during the water treatment process. By early 1971, these sources no longer contributed to contamination and the nearly 30 years of groundwater movement since then have allowed the original plumes to disperse. The hexavalent form of chromium is highly soluble in groundwater as chromate (CrO_3^-) and moves at the same speed as groundwater because the anions are not sorbed significantly to the sediment.

The current distribution of chromium in 100 K Area groundwater is shown in Figure 2.3-3. Three areas of concern are apparent: (1) a relatively large area of contamination between the 116-K-2 liquid waste disposal trench and the Columbia River, (2) a smaller area centered on the KW Reactor, and (3) an area near the 183-KE water treatment plant.

The first area is the target plume for interim remedial action using a pump-and-treat system (DOE/RL-99-13). Chromium concentrations in this plume typically range from 75 to 200 µg/L, thus exceeding the 100 µg/L maximum contaminant level for drinking water supplies and the 11 µg/L standard set by Washington State for the protection of freshwater aquatic organisms (WAC 173-201A-040). The chromium concentrations in the six wells used to extract groundwater for treatment are shown in Figures 2.3-4 and 2.3-5. Concentrations in wells located between the extraction wells and the river are shown in Figure 2.3-6. Additional information on the operating characteristics and performance of the interim action pump-and-treatment system that is treating this plume is presented in the section on groundwater remediation (Section 2.3.9).

In the second area of concern, i.e., near the KW Reactor, concentrations in recent years have ranged between 200 and 600 µg/L as illustrated in Figure 2.3-7, though the most recent results suggest a declining trend. The specific source for the chromium in this plume is not known, though the source may be leakage and/or spillage of sodium dichromate stock solution in upgradient areas during the operating years. One potential site is the railcar transfer station and storage tanks located at the southeastern side of the 183-KW water treatment plant. Because of the time that has passed since operations, this plume may represent remobilization of residual vadose zone contamination by more recent infiltration of moisture from the surface. The changing trends in wells 199-K-107A and 199-K-108A, which are located next to the KW Reactor building, suggest plume movement in this area. The most recent decline in chromium concentrations in well 199-K-108A is believed to be the result of dilution caused by infiltration of clean water from the surface (Section 2.3.7).

The western extent of this plume is uncertain because monitoring wells do not cover that area. The plume does not appear to have reached the Columbia River because similar concentrations are not detected in wells 199-K-31 and 199-K-33, which are located between KW Reactor and the Columbia River (see Figure 2.3-7). Also, there is no evidence for elevated chromium in riverbank seepage or aquifer sampling tubes along this segment of 100 K shoreline. The travel time between KW Reactor and well 199-K-33 has been previously estimated at between 1.6 and 4.9 years, depending on the assumed groundwater flow rate (WHC-SD-EN-TI-280). Increasing concentrations first appeared at KW Reactor in mid-1994, so sufficient time has apparently passed for the plume to move downgradient to well 199-K-33, assuming the well is within the flow path. Because a distinct increase in concentrations in the well is not yet apparent, it must be assumed that the well is either not within the flow path, or the travel time estimate is too low.

The third area of chromium contamination appears to have originated at the southeastern end of the 183-KE water treatment plant, near well 199-K-36. High chromium concentrations were previously reported for samples from this well, with a maximum value of 2,710 μg/L on January 16, 1996. Current concentrations are in the range of 250 to 600 μg/L. The source for the chromium is most likely past leaks or spills of sodium dichromate stock solution during railcar transfer operations or from storage tanks located in the area. Subsequent remobilization of residual sodium dichromate held in the vadose zone may have occurred as the result of water leakage from the nearby KE filter plant basins.

2.3.3 Strontium-90

Strontium-90 in groundwater near the KE Reactor originated from past disposal to a nearby waste site. Concentrations vary as a consequence of water movement downward through the contaminated vadose zone.

Strontium-90 is not distributed widely in 100 K Area groundwater, though there are several waste sites where contamination in the vadose zone is expected, thereby creating a potential source for future groundwater contamination. Strontium-90 contamination is anticipated wherever liquid effluents associated with irradiated nuclear fuel were disposed. The principal sites for soil column disposal were the 116-K-2 liquid waste disposal trench and the fuel storage basin drain fields/ injection wells associated with each reactor. The radionuclide is partially adsorbed onto sediment particles in the vadose zone and aquifer; it is considered a moderately mobile radionuclide in groundwater and has a radioactive decay half-life of 29.1 years. The drinking water standard is 8 pCi/L and the U.S. Department of Energy (DOE) derived concentration guideline is 1,000 pCi/L.

Current levels of strontium-90 contamination in groundwater between the 116-K-2 liquid waste disposal trench and the Columbia River range up to a maximum near 50 pCi/L (Figure 2.3-8). The radionuclide is a co-contaminant with chromium in this plume, which is undergoing interim remedial action. However, strontium-90 is not removed by the ion exchange resin that removes chromium from extracted groundwater and is, therefore, returned to the aquifer via the injection wells. Strontium-90 analyses on treated effluent revealed concentrations of 5.27 pCi/L on November 18, 1999, and 4.98 pCi/L on May 16, 2000.

Near the KE Reactor, samples from well 199-K-109A reveal a variable trend in strontium-90 concentrations with the highest values well above the DOE derived concentration guideline. Figure 2.3-9 shows the historical trends, along with data for tritium concentrations. The source for the strontium-90 detected in this well has been previously identified as past-practice disposal to the nearby drain field/injection well (PNNL-12023). This facility (waste site 116-KE-3) received effluent from the KE Fuel Storage Basin that may have contained strontium-90 released from damaged fuel elements, as well as tritium. Recent increased infiltration of water from the surface, caused by leaking fire hydrant lines, apparently remobilized contamination held in the normally unsaturated vadose zone.

Strontium-90 is also elevated somewhat above the drinking water standard near the KW Reactor. Again, the suspected source is the adjacent drain field/injection well (waste site 116-KW-2). Concentration trends are illustrated using gross beta results (Figure 2.3-10) because they are obtained more frequently at these wells. Gross beta activity at this location is caused primarily by strontium-90 from fuel storage basin effluent. The concentration of strontium-90 is approximately one-half that of the gross beta concentration.

2.3.4 Tritium

The distribution of tritium in 100 K Area groundwater is shown in Figure 2.3-11. The principal locations where tritium was (and still may be) introduced to groundwater include

- northeastern side of each reactor building, where condensate from reactor atmosphere gas apparently continues to migrate downward through the soil column beneath the 116-KW-1 and 116-KE-1 cribs (carbon-14 is a co-contaminant with tritium in this effluent).
- former leakage from the KE Fuel Storage Basin with the most recent event occurring in 1993; the plume moved north-northwest past well 199-K-27 and may now be arriving at downgradient well 199-K-32A (see Figure 2.3-2). Tritium trends near the KE and KW Fuel Storage Basins are described in Section 2.3.8.
- past disposal to the 116-K-2 liquid waste disposal trench, which created a mound on the water table; when waste disposal ended in 1971, residual amounts of contaminated moisture remained in the vadose zone.

The tritium distribution map for fiscal year 2000 shows contamination near the 116-K-2 trench as separate from the plume near the reactor buildings.

The cause for the relatively high tritium concentrations detected in the vicinity of pump-and-treat extraction well 199-K-120A (Figure 2.3-12) is not fully understood. One explanation is that residual vadose zone moisture containing tritium from past disposal to the 116-K-2 liquid waste disposal trench continues to feed a small groundwater plume in the vicinity of wells 199-K-18, 199-K-19, and 199-K-120A. An alternative explanation is that the tritium represents shielding water from the KE Basin lost during the period 1976 to 1979, or groundwater from beneath the 116-KE-1 gas condensate crib located on the northeast side of the KE Reactor. However, long-term water-level data do not suggest a gradient directed from the KE Reactor toward well 199-K-120A, so a circuitous route would be required to link the well to those sources.

A field sampling program was conducted during summer 1999 to determine whether a tritium plume in groundwater could be detected by analyzing soil gases sampled from the overlying vadose zone (PNNL-13217). A grid of locations was sampled in the 100 K Area that covered the general area north and east of the KE Reactor. No tritium was detected in the soil moisture samples. Analyses for helium-3 in soil gas, which would indicate the presence of tritium in the underlying groundwater, also did not suggest the presence of a plume.

Tritium in groundwater near the spent nuclear fuel storage basins is monitored as an indicator of potential loss of shielding water. The basins leaked in the past, but there is no evidence of water loss in fiscal year 2000.

2.3.5 Carbon-14

Carbon-14 is present in groundwater in two areas near the KW and KE Reactors. These areas represent the only significant detections of this radionuclide in Hanford Site groundwater.

This radionuclide was present along with tritium in the condensate from reactor atmosphere gas that was disposed to the cribs located on the northeastern side of the KE and KW Reactors (116-KE-1 and 116-KW-1). Carbon-14 disperses more slowly than does tritium because of interaction with carbonate minerals, so the distribution pattern is not coincident with tritium (PNNL-12023). The different geochemical characteristics for carbon-14 and tritium mean that the ratio of the two constituents cannot be used as an exclusive indicator of effluent from the gas condensate cribs.

The highest concentrations of carbon-14 are found in wells near and downgradient of the condensate cribs (see Figure 2.3-11). Figure 2.3-13 illustrates the concentrations found in wells associated with the 116-KE-1 crib and Figure 2.3-14 illustrates concentrations associated with the 116-KW-1 crib. The drinking water standard for carbon-14 is 2,000 pCi/L and the DOE derived concentration guide for this radionuclide is 70,000 pCi/L. The half-life is very long (5,730 years), suggesting that some of the existing plume will eventually be exposed at the Columbia River before it decays, although a portion will likely remain fixed in carbonate minerals.

2.3.6 Nitrate

Nitrate is widely distributed in groundwater beneath all the reactor areas. There are multiple sources that potentially contribute to the plumes, including septic system drain fields and past-practice disposal to the soil column of decontamination solutions, such as nitric acid (WHC-SD-EN-TI-239). The maximum contaminant level for drinking water supplies is 45 mg/L and this level is exceeded in numerous 100 K Area wells. The fiscal year 2000 maximum observed value near the KE Reactor building is ~93 mg/L (well 199-K-30), near the KW Reactor ~90 mg/L (well 199-K-106A), and near the 116-K-2 liquid waste disposal trench ~80 mg/L (wells 199-K-18 and 199-K-19).

Nitrate concentrations increased in the 100 K Area during the late 1990s, but decreased in fiscal year 2000.

Nitrate levels have been gradually rising in numerous wells in the 100 Areas. Arrival of nitrate plumes from distant sources is one explanation for changes observed in the 100 K Area. Groundwater from the 200 East Area has traveled toward the northwest and is now passing to the west of 100 K Area, as indicated by the nitrate plume shown on the site-wide groundwater map (see Figure 2.1-4). Increasing nitrate trends in wells south and west of 100 K Area illustrate the arrival of this plume (Figure 2.3-15). Near the KE Reactor, nitrate concentrations gradually increased during the mid-1990s to slightly over the 45 mg/L drinking water standard (Figure 2.3-16). By 1998 and 1999, this trend reversed itself, and current concentrations are well below that standard. The cause for these trends and the source(s) for the nitrate are not known precisely, though nitrate was introduced to groundwater from multiple sources in the reactor areas, including disposal of various effluents and septic systems.

2.3.7 Other Constituents of Interest

The groundwater constituents described in Sections 2.3.2 through 2.3.6 have been previously identified as contaminants of concern with regard to environmental restoration. Three additional constituents of interest that are detected in several wells in the 100 K Area are discussed in this section, along with a description of two areas where increased infiltration of surface water is suspected.

2.3.7.1 Plutonium

During late May and early April 1999, scientists from Woods Hole Oceanographic Institute completed sampling at wells 199-K-27, 199-K-32A, 199-K-36, and 199-K-110A as part of a plutonium speciation study. The purpose for the research was to study the association of actinides with dissolved organic complexes in subsurface waters. The project was funded by the DOE's Environmental Management Science Program and was a joint effort involving Woods Hole and Pacific Northwest National Laboratory.

The current status of the research was presented in late November 2000 during an Environmental Management Science Program workshop at the Hanford Site. The amount of plutonium detected in groundwater at 100 K Area was extremely small and was reported as number of atoms per liter, which ranges from 100,000 to 10,000,000. The latter value is equivalent to 0.000246 pCi/L, which are the units normally used for environmental monitoring results. Initial results showed that it was possible to differentiate the various sources for plutonium atoms detected in 100 K Area groundwater (e.g., global fallout, KW and KE Reactor fuel, and N Reactor fuel). Analysis of additional samples collected in 1999 are continuing; new samples from 100 N Area groundwater will be collected in spring 2001.

Analysis for plutonium is not routinely performed as part of groundwater monitoring at 100 K Area. The tools and methods used by the researchers to achieve the ultra-low detection levels are not practical for the current monitoring program. Other contamination indicators (e.g., gross alpha) are monitored routinely that would indicate the loss of basin shielding water, which contains plutonium, to the environment.

2.3.7.2 Trichloroethene

This organic constituent is a minor contaminant of concern resulting from the past disposal/spillage of organic solvents. Two wells downgradient of the KW Reactor yielded samples containing trichloroethene at levels above the 5 µg/L maximum contaminant level for drinking water supplies (Figure 2.3-17). Concentrations appear to be decreasing with time.

2.3.7.3 Nickel

Nickel has not been tracked previously as a contaminant of concern for human or ecological health reasons (BHI-00917). However, concentrations in filtered groundwater samples exceed the 100 µg/L maximum contaminant level in wells 199-K-36 and 199-K-110A (Figure 2.3-18). There is no obvious waste site source for nickel contamination and its occurrence is scattered. Nickel appears to be elevated only in relatively new monitoring wells that have stainless steel casings and screens. Therefore, a sampling anomaly is suspected, perhaps the result of corrosion of the stainless steel (Hewitt 1994). Chloride concentrations are well above background in the wells that show elevated nickel, which supports the suggestion of corrosion.

2.3.7.4 Evidence for Infiltration of Surface Water

Infiltration of water from surface sources, such as precipitation or leaking utility lines, may influence contaminant concentrations in the underlying groundwater. During fiscal year 2000, infiltration was suspected near the KW and KE Reactors.

The influence of increased infiltration, because of natural precipitation or leaking underground water lines, has been described previously at several sites at 100 K Area. Continued downward movement of tritium and carbon-14 beneath the KE and KW gas condensate cribs and remobilization of strontium-90 near the KE (and possibly KW) Fuel Storage Basin drain field are two examples where above normal infiltration of clean water from the surface or near surface may play an important role in moving contaminants.

During the past year, groundwater at two additional sites appears to be influenced by the infiltration of clean water through the vadose zone. The most clear indication is groundwater near the southeast corner of the KW Reactor (well 199-K-108A), where the specific conductance and concentration of many constituents began decreasing rapidly in late summer 1999 (Figure 2.3-19). No potential cause for the increased infiltration of clean water has been identified. Because contamination indicators also are decreasing, the overlying vadose zone is believed to be free of contaminants.

Groundwater near the northwest side of KE Reactor also may be influenced by infiltration. In recent months, well 199-K-28 has shown a decreasing trend in specific conductance that suggests dilution by clean water. Although not as clearly defined as at well 199-K-108A, this trend seems to have started during late summer 1999 also.

2.3.8 100-K Fuel Storage Basins Monitoring

Irradiated nuclear fuel from the N Reactor is stored in water-filled basins in the 100 K Area. The shielding water has become highly contaminated and constitutes a potential source for groundwater contamination if a basin leaks. Removal of nuclear fuel from the basins began in December 2000.

The 100-K fuel storage basins are operating facilities that are used to store irradiated fuel elements from the N Reactor. The KE Basin contains ~1,150 metric tons of fuel stored in unsealed canisters, while KW Basin contains ~953 metric tons stored in sealed containers (HNF-SD-SNF-TI-009). Because of the unsealed containers and greater proportion of damaged fuel elements, the KE Basin is the more contaminated facility. A shielding water recirculation system includes exchange resins that remove some of the radionuclides, but concentrations of many fuel degradation products remain very high.

A feasibility study report is available that provides detailed information on the fuel, shielding water, and sludge, along with a description of alternatives for cleanup (DOE/RL-98-66). Following this study, a proposed plan for interim remedial action at the basins was issued for public review and comment (DOE/RL-98-71). Finally, a record of decision was signed that describes the selected remedial action (ROD 1999a). The schedule for activities is described under Tri-Party Agreement Major Milestone M-34-00A (Ecology et al. 1998). Testing of fuel canister handling equipment was completed during summer and fall 2000, and the first canister of fuel was successfully removed from KW Basin in December 2000.

The Hanford Groundwater Monitoring Project provides monitoring services to the Spent Nuclear Fuel Project in support of efforts to detect the loss of basin shielding water. The groundwater project also maintains baseline information on the characteristics of groundwater movement throughout the 100 K Area. A description of the monitoring strategy and data quality objectives for the 100-K fuel storage basins is presented in a groundwater monitoring plan (WHC-SD-EN-AP-174).

2.3.8.1 Groundwater Flow

Travel time for groundwater between the 100-K fuel storage basins and the Columbia River is estimated to be in the range of 5 to 12 years.

The general movement of groundwater beneath the KE and KW Fuel Storage Basins is from the south-southeast to the north-northwest, i.e., toward the Columbia River (see Plate 1). Travel time from the basins to the Columbia River is estimated to be in the range of 5 to 12 years (Section 2.3.1). Several factors may influence the characteristics of groundwater movement beneath the basins, including currently operating facilities that may lose clean water (e.g., fuel storage basin emergency makeup water stored in clearwells) and heterogeneity in the hydraulic properties of the aquifer. The distribution and rate of downward movement of water infiltrating from the surface is influenced by an engineered backfill associated with buildings and pipelines. Infiltration of water is of concern because of the potential to remobilize contamination from former operations that remains in the vadose zone in some areas.

2.3.8.2 Tritium

Tritium is a key constituent for monitoring potential leakage from the KE and KW Fuel Storage Basins. The tritium concentration for KE Basin shielding water is 2,980,000 pCi/L and for KW Basin is 81,700 pCi/L (June 2000 measurements). Additional nearby sources for tritium are past-practice disposal sites located at the eastern side of each reactor building. These soil infiltration sites (typically referred to as cribs or French drains) received condensate from reactor atmosphere gas. The condensate contained significant quantities of tritium and carbon-14. These constituents continue to migrate downward beneath the disposal sites and to contaminate the underlying groundwater.

Figure 2.3-20 shows the tritium concentrations in wells near the KE Basin. The record for these wells, which were constructed in 1980, suggests that the plume from major leakage during the period 1976 through 1979 must have already passed these wells by the time of their installation because there is no indication of a plume. The volume of water lost during that period is estimated at ~57 million liters (WHC-SD-SNF-TI-013) and the tritium concentration in KE Basin water was ~600,000 pCi/L. A subsequent period of documented leakage in 1993 is clearly revealed by the tritium pulse that passed well 199-K-27. That leakage is estimated at ~341,000 liters (WHC-SD-SNF-TI-013), and the basin water concentration at the time was ~3 million pCi/L. (The cause for the 1990 tritium pulse in well 199-K-27 is not known.)

Because of high tritium concentrations in basin shielding water, tritium is used as a key groundwater indicator of water loss from the basins. Groundwater monitoring results for fiscal year 2000 indicated the basins did not leak.

Tritium concentrations in groundwater near the KW Basin are generally lower than near the KE Basin (Figure 2.3-21). There has been no readily identifiable leakage from the KW Basin. The tritium observed in well 199-K-34 is most likely attributable to the KW gas condensate crib.

Concentration trends for tritium in groundwater near the KE and KW gas condensate cribs are included here to illustrate the other major sources for tritium in groundwater near the reactors. Figure 2.3-22 shows the tritium concentrations and specific conductance values for groundwater immediately downgradient of the KE gas condensate crib. The concentrations at that location are believed to represent the downward migration of tritium (and carbon-14) in vadose zone moisture. The strong positive correlation between tritium concentrations and specific conductance values suggests that downward migration is promoted by increased infiltration of water from the surface. The increase in specific conductance in groundwater at the KE gas condensate crib has been attributed to infiltration of precipitation (e.g., snow melt) containing ice control salt (WHC-SD-EN-TI-280).

Figure 2.3-23 shows the same constituents for the KW gas condensate crib. A similar correlation between tritium and specific conductance is absent at this location, and there is currently no clear explanation for the tritium peak (~600,000 pCi/L) that occurred during 1995. Leakage from the KW Basin is not considered a possibility because basin water concentrations were only one-tenth the concentrations observed in the well shown in Figure 2.3-23. Specific conductance at the KW crib is significantly higher than natural background (~650 versus ~350 µS/cm for background).

2.3.9 Groundwater Remediation

A groundwater pump-and-treat system began operating in the 100 K Area in October 1997. The primary purpose for this system is to prevent or reduce the movement of hexavalent chromium from the aquifer to the river, thereby protecting aquatic organisms. The extraction wells are located within a chromium plume located between the 116-K-2 liquid waste disposal trench and the Columbia River. The treatment system removes chromium from the extracted groundwater, and the treated effluent is injected back into the aquifer at an upgradient location. This interim remedial action is described in a record of decision for the 100-KR-4 Operable Unit (ROD 1996b), which also includes remedial actions in the 100 D and 100 H Areas (100-HR-3 Operable Unit).

The goal of the pump-and-treat system in the 100 K Area is to reduce the amount of chromium reaching the Columbia River, where the chemical may adversely affect aquatic organisms.

2.3.9.1 Interim Remedial Action Objectives

The record of decision (ROD 1996b) for interim remedial action contains the following objectives for operating the pump-and-treat system:

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

The record of decision stipulates that the interim action pump-and-treat system will continue to operate until the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. Criteria for ending the operation include (a) sampling results demonstrate that the concentration of hexavalent chromium is below 22 µg/L in the compliance wells, and (b) evidence to conclude that the concentration will remain below the compliance value. Other criteria for terminating pump-and-treat operations involve the effectiveness of the treatment technology and the availability of a superior treatment technique (ROD 1996b).

2.3.9.2 Remediation Progress During Fiscal Year 2000

Progress was made toward achieving the remedial action objectives at the 100-KR-4 Operable Unit in fiscal year 2000. The pumping operation captures groundwater that contains hexavalent chromium at concentrations above the standard for protecting aquatic organisms, thus preventing further transport of the contaminant to exposure sites within the river. Although designed primarily to prevent or reduce the amount of contaminated groundwater that discharges into the Columbia River, the pump-and-treat system also reduces overall contamination in the operable unit by removing contaminant mass from the aquifer. The pump-and-treat program collects data on hydraulic gradients, contaminant levels (including co-contaminants strontium-90, tritium, carbon-14, and nitrate), and treatment system operating parameters. These data are used to evaluate treatment system performance and provide a technical basis for selecting a final remedy for groundwater remediation in the operable unit. A complete description of the progress and effectiveness of the interim remedial action is presented in the annual summary report for calendar year 1999 (DOE/RL-2000-01).

During fiscal year 2000, the pump-and-treat system at 100 K Area extracted 283.5 million liters of groundwater and removed 32.9 kilograms of hexavalent chromium.

During fiscal year 2000, the pump-and-treat system extracted 283.5 million liters of groundwater and removed 32.9 kilograms of hexavalent chromium (Table 2.3-1). Extraction well operating flow rates averaged between 90 and 114 liters per minute for the year, with maximum sustained pumping rates ranging between 140 and 171 liters per minute at the different wells. Average concentrations for hexavalent chromium in groundwater from the extraction wells ranged between 79 and 181 µg/L, with an average treatment system influent concentration of 121 µg/L. The effluent concentration averaged 9 µg/L hexavalent chromium during calendar year 1999 (DOE/RL-2000-01).

2.3.9.3 Influence on Aquifer Conditions

As of December 31, 1999, a total of 79 kilograms of hexavalent chromium has been removed since startup of the pump-and-treat system in October 1997 (DOE/RL-2000-01). An estimate for the total amount of chromium in the plume targeted for remedial action suggests a mass of 250 kilograms (DOE/RL-94-95). Uncertainty in this estimate is primarily associated with the lack of data on the vertical distribution of chromium in the aquifer and the distance inland to which the plume extends. An order-of-magnitude estimate for the rate at which chromium discharges to the Columbia River via groundwater flow is 0.04 kilogram per day (BHI-00469).

This equates to a total mass flux of ~33 kilograms that would have entered the Columbia River during the period October 1997 through December 1999 (821 days) if there were no interim action underway. The total amount of chromium removed by the treatment system to date (79 kilograms) is greater than the flux to the river (33 kilograms) would have been under natural groundwater conditions, i.e., no pump-and-treat system. This implies that the interim action is reducing the amount of hexavalent chromium that would otherwise have discharged into the Columbia River.

The concentration of hexavalent chromium in groundwater from the extraction wells has remained essentially constant or shown a slight but general decline since pumping began ~3 years ago (see Figures 2.3-4 and 2.3-5). However, the concentration has not declined below 22 µg/L, the target concentration listed in the record of decision. Wells 199-K-119A and 199-K-125A reveal a distinct decreasing trend, while wells 199-K-116A and 199-K-120A reveal constant concentrations. An explanation for the slightly increasing trends in two of the extraction wells, i.e., 199-K-115A and 199-K-113A, is not currently evident, though it may be related to changes in plume movement direction as a consequence of the pumping operation.

Concentrations also remained relatively constant or increased slightly over the last 3 years in the compliance wells as illustrated in Figure 2.3-6. Concentrations in each compliance well during late September 2000 are: well 199-K-18 (87 µg/L), well 199-K-20 (108 µg/L), well 199-K-117A (104 µg/L), well 199-K-114A (132 µg/L), and well 199-K-112A (85 µg/L in May 2000).

Because elevated concentrations of hexavalent chromium have persisted in the compliance wells, the annual summary report for the remedial action (DOE/RL-2000-01) recommends continued operation of the pump-and-treat system. Additional planning is underway to convert compliance well 199-K-112A to an extraction well and thereby increase the capture area beyond the northern end of the liquid waste disposal trench. A new monitoring well (199-K-126), which was installed northeast of the trench in 1998 (DOE/RL-97-96), will replace well 199-K-112A as the northern-most compliance well.

The relatively constant or gradually declining concentrations of hexavalent chromium in the extracted groundwater suggest that the pumping operation may require many years of operation to attain the remedial action concentration objective.

2.3.10 Water Quality at Shoreline Monitoring Locations

Groundwater samples are collected annually from aquifer sampling tubes located near the low-river stage shoreline and from riverbank seepage sites during the seasonal low-river stage, which occurs during the fall months. The tubes were resampled in 1998, 1999, and 2000 to support Environmental Restoration Project objectives. (Fall 2000 results were not yet available for this fiscal year 2000 report.) Riverbank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration Project in support of groundwater operable unit investigations. Table 2.3-2 lists the analytical results for key constituents for samples collected during fall 1999 from aquifer sampling tubes, riverbank seepage, and nearshore river water (when available).

Carbon-14, nitrate, chromium, and tritium were detected in aquifer sampling tubes or groundwater seeps discharging to the Columbia River shore in the 100 K Area in fiscal year 2000. Concentrations were all below drinking water standards.

2.3.10.1 Aquifer Sampling Tubes

Samples collected from the tubes during fall 1999 were screened for key 100 K Area contamination indicators (i.e., chromium, strontium-90, gross beta, tritium, carbon-14, and nitrate). Hexavalent chromium concentrations ranged from a high of 76 µg/L downgradient of the 116-K-2 trench (tube 23-D) to lows of less than

10 µg/L (i.e., near the detection limit) in tubes located opposite the K reactor complexes. Strontium-90 was not detected in samples from tubes located downgradient of the 116-K-2 trench and the single gross beta result available for this area also confirms minimal strontium-90. Tritium was measured in tubes downgradient from the 116-K-2 trench at very low concentrations (178 pCi/L in tube 22-D) or not detected. The maximum carbon-14 concentration was 639 pCi/L in a sample collected from tube 17-D downgradient of the KW retention basins. This tube site is also downgradient of well 199-K-33 where samples have contained over 10,000 pCi/L carbon-14. Nitrate was measured in one tube (17-D) opposite the reactors at a concentration well below the drinking water standard.

All of the results from the aquifer sampling tubes, with the exception of those for tube 17-D, reflect dilution by river water, as indicated by the specific conductance of the samples relative to groundwater. Consequently, the groundwater approaching the river may contain contaminants at greater concentrations than those listed in Table 2.3-2.

2.3.10.2 Riverbank Seepage

Samples of riverbank seepage were collected at two locations adjacent to 100 K Area facilities and waste sites during October 1999 (results for sampling conducted in fall 2000 are not yet available). Maximum concentrations for contaminants of concern were: 50 µg/L hexavalent chromium; 6.3 pCi/L gross beta; 6,660 pCi/L tritium; and 22 mg/L nitrate (see Table 2.3-2). Strontium-90 was not detected in seepage and analyses for carbon-14 were not performed during October 1999.

Table 2.3-1. Summary of 100 K Area Pump-and-Treat Performance for Fiscal Year 2000

Well or Sample Location	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped (L)	Average Hexavalent Chromium Concentration (µg/L)	Hexavalent Chromium Mass Removed[a] (kg)
199-K-113A	90	140	38,928,472	79	2.86
199-K-115A	114	157	55,834,721	125	6.72
199-K-116A	110	171	51,837,610	181	9.22
199-K-119A	99	140	45,300,597	117	5.09
199-K-120A	101	163	48,737,995	97	4.52
199-K-125A	101	159	42,910,018	125	5.19
K-Influent	567	765	285,451,725	124	33.6
K-Effluent[b]	567	765	285,451,725	7	--

(a) Total mass removed from 100-KR-4 Operable Unit between October 1, 1997 and December 31, 1999 is 79 kilograms (DOE/RL-2000-01).

(b) Thirty-four of 50 samples of 100-KR-4 effluent were below the chromium detection limit.

Data Source: Project Specific Database for the 100-KR-4 Operable Unit.

Table 2.3-2. Shoreline Monitoring Data for the 100 K Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Carbon-14 (pCi/L)	Nitrate (mg/L)
17-D	Tube	05-Nov-99	427	6				639	15.0
18-S	Tube	05-Nov-99	202	2	***0.1***		***69***	***6***	
22-D	Tube	02-Nov-99	266	50	***0.2***	4.4	178		
23-D	Tube	02-Nov-99	245	76					
SK-063-1	Seep	25-Oct-99	327		***0.0***	6.3	6,660		21.8
SK-082-2	Seep	25-Oct-99	290	50		5.0	4,280		7.2
17-D	River	05-Nov-99	128						
18-S	River	05-Nov-99	120						
22-D	River	02-Nov-99	135						
23-D	River	02-Nov-99	124						

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore, adjacent to the aquifer sampling tube.

Values in ***bold italics*** are qualified by the laboratory as “undetected.” Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350-450 µS/cm.

Data sources: Hanford Environmental Information System and various project records.

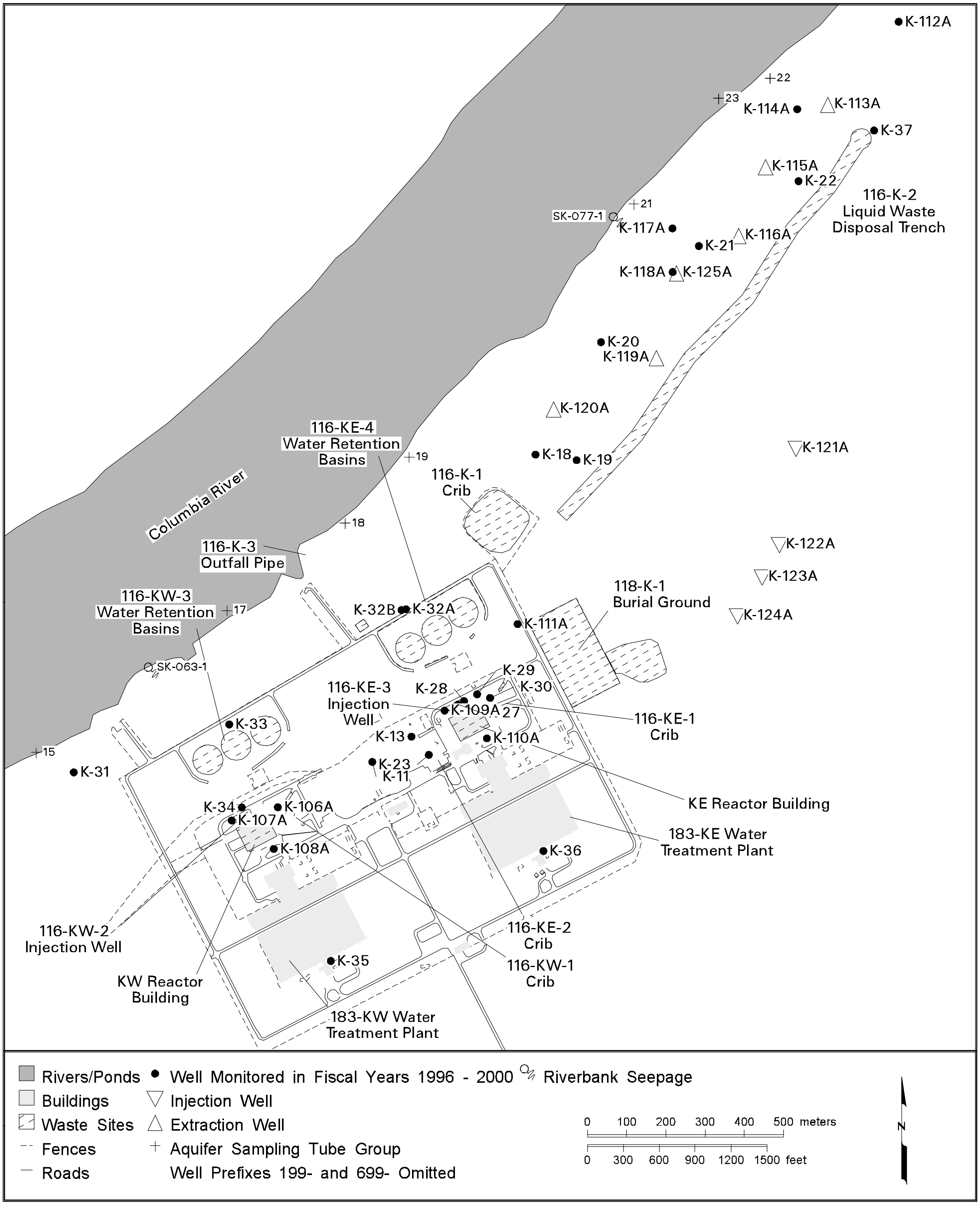

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Figure 2.3-1. Groundwater Monitoring Wells in the 100 K Area

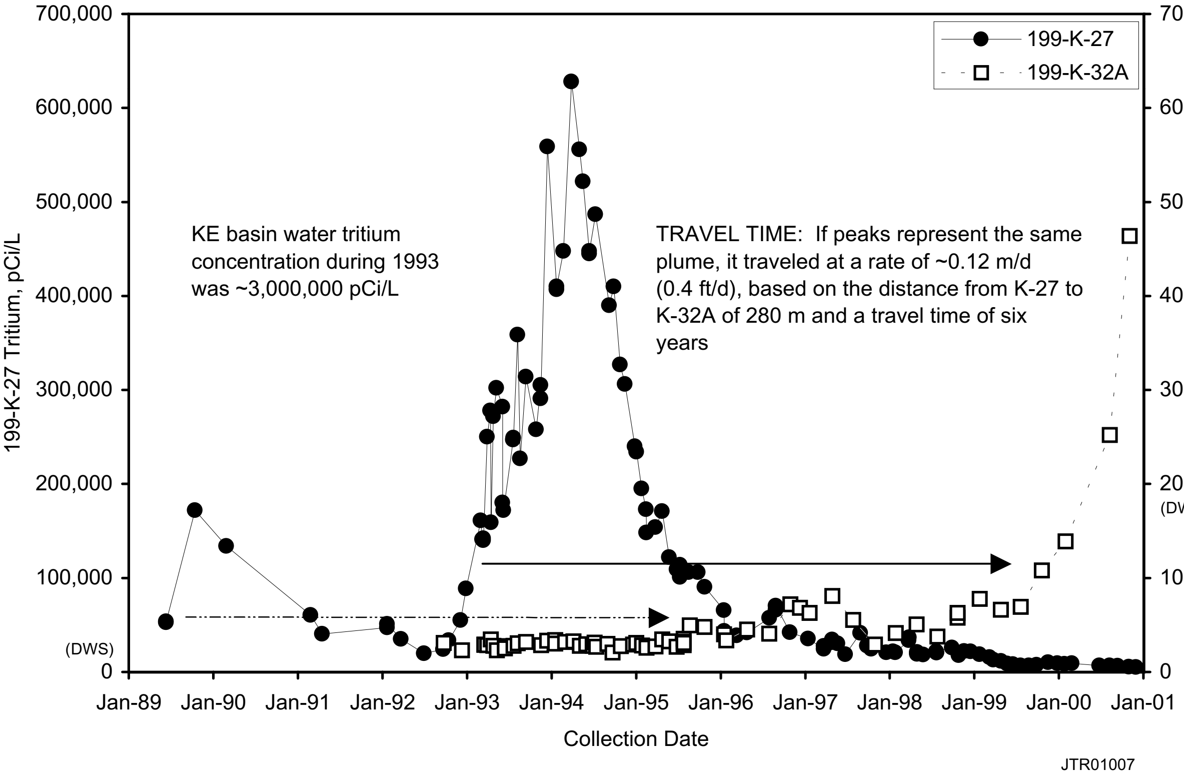

Figure 2.3-2. Tritium Plume Movement from the KE Reactor toward the Columbia River

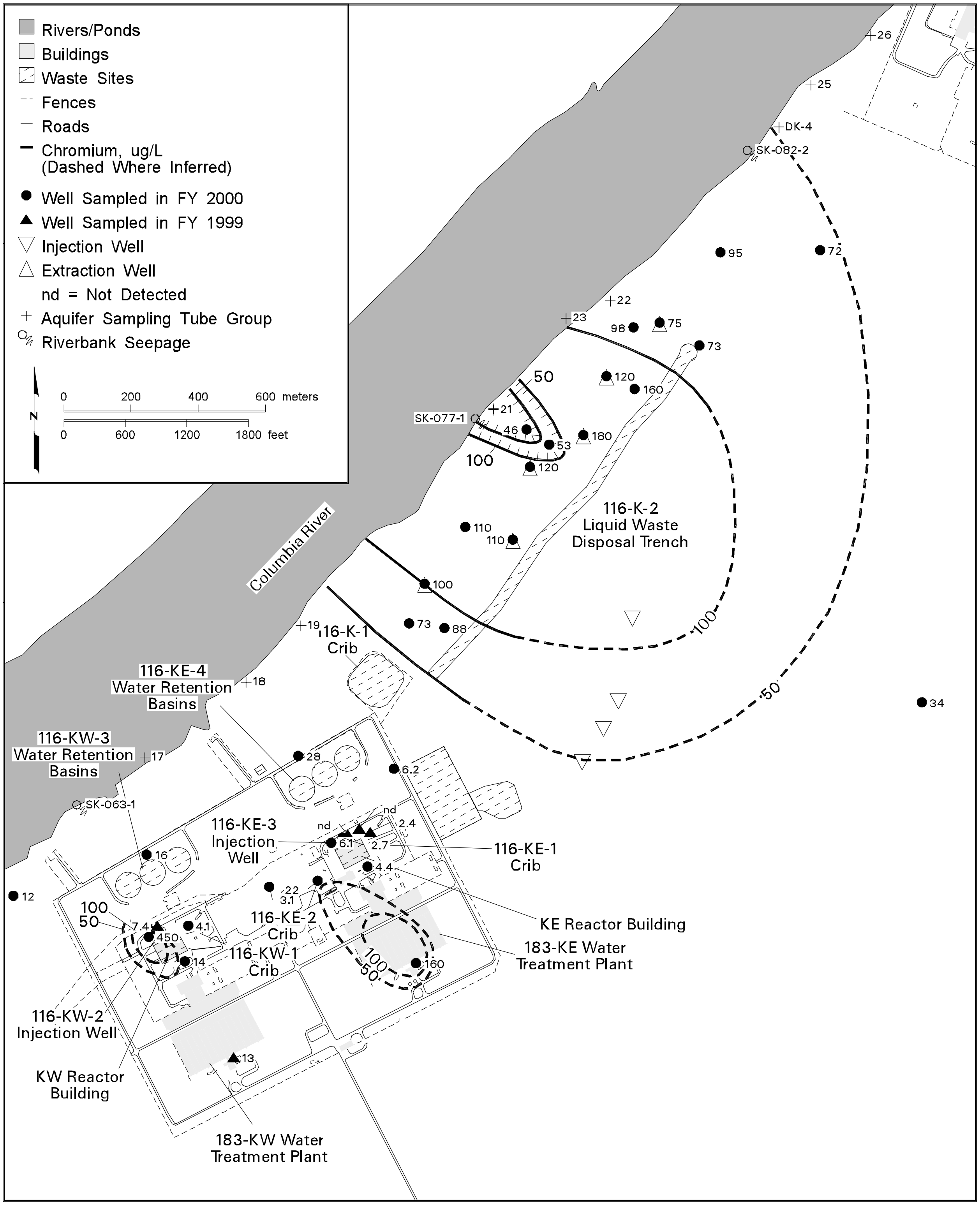

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Figure 2.3-3. Average Chromium Concentrations in the 100 K Area, Top of Unconfined Aquifer

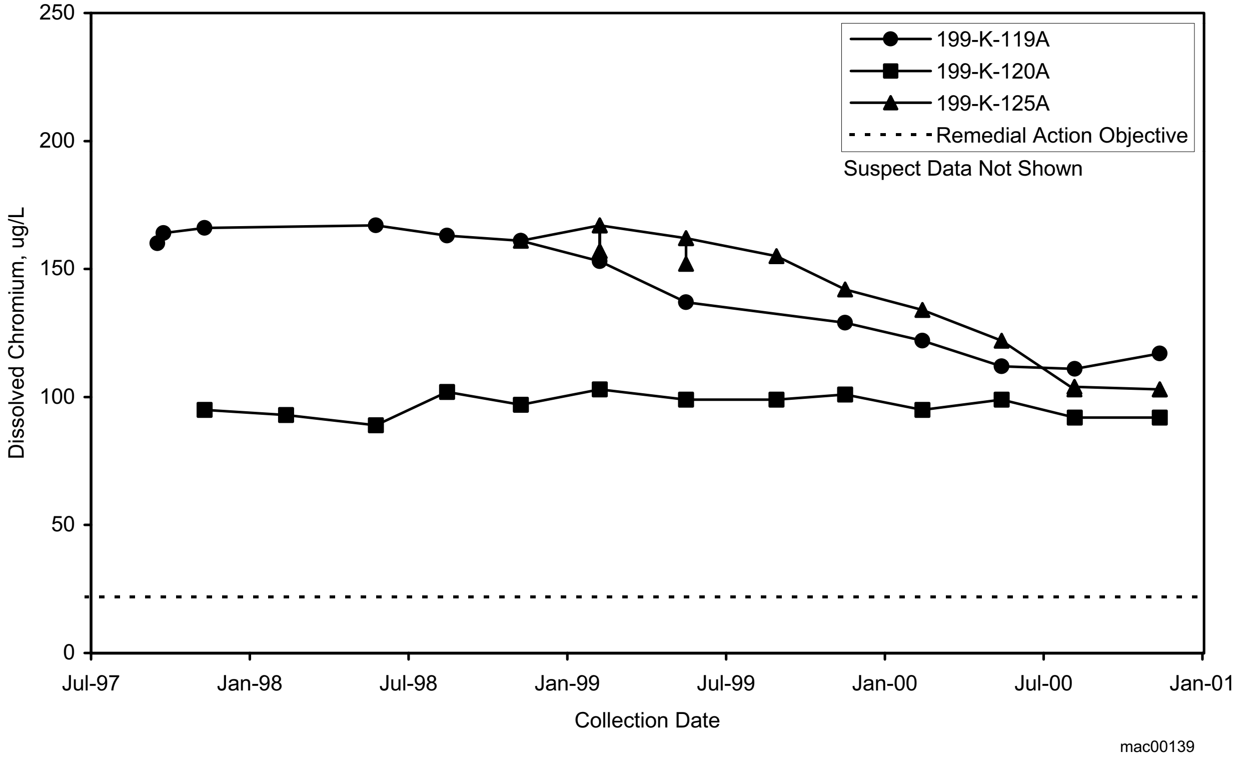


Figure 2.3-4. Chromium in Upstream Extraction Wells at the 100 K Area

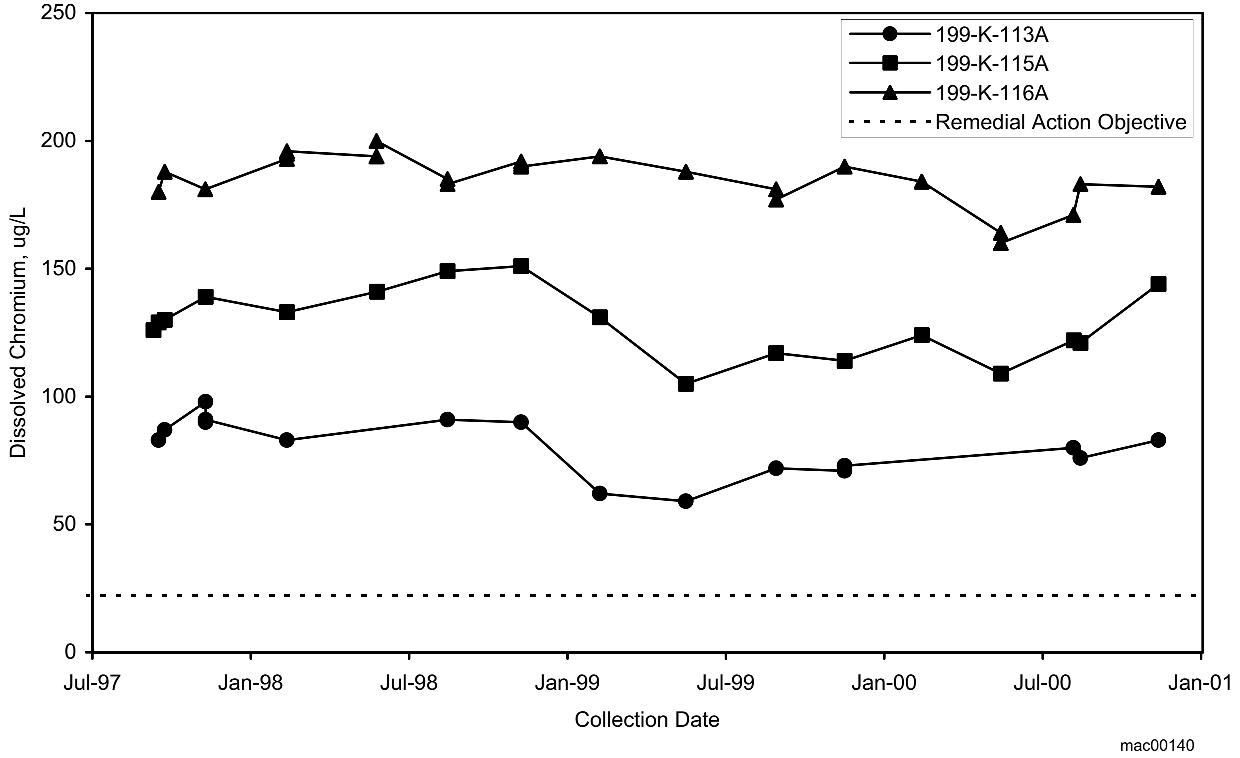
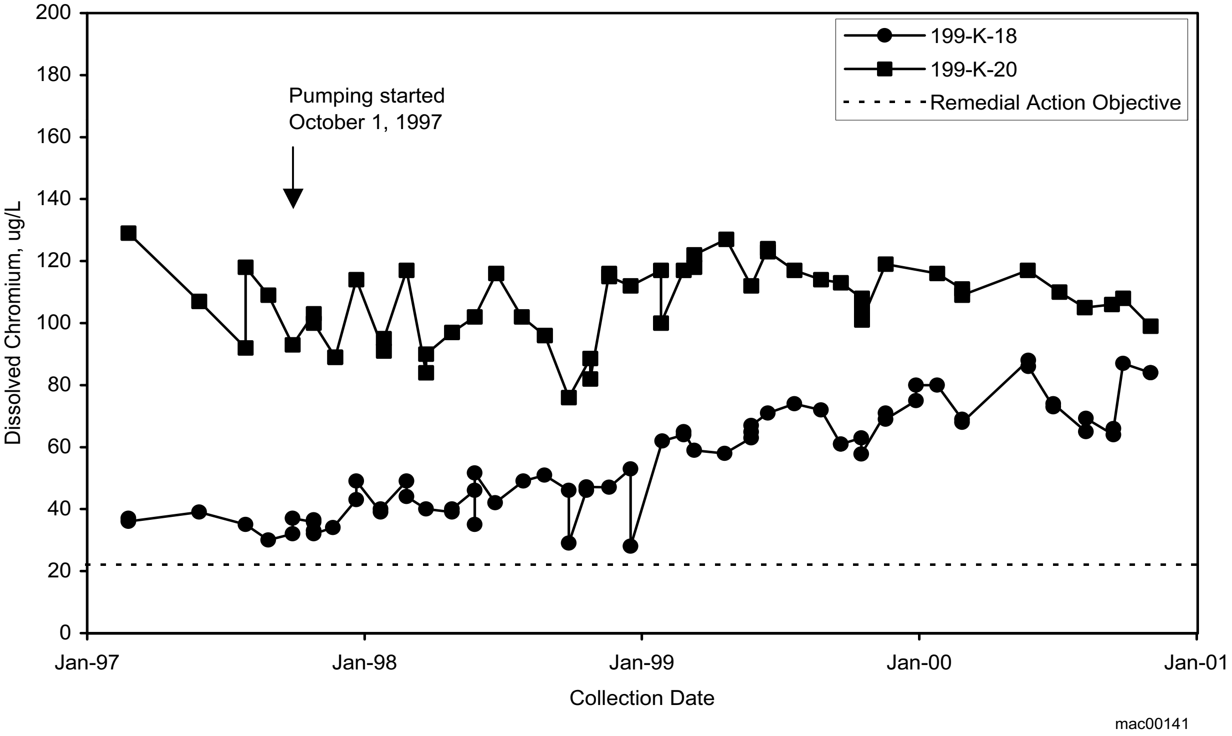


Figure 2.3-5. Chromium in Downstream Extraction Wells at the 100 K Area



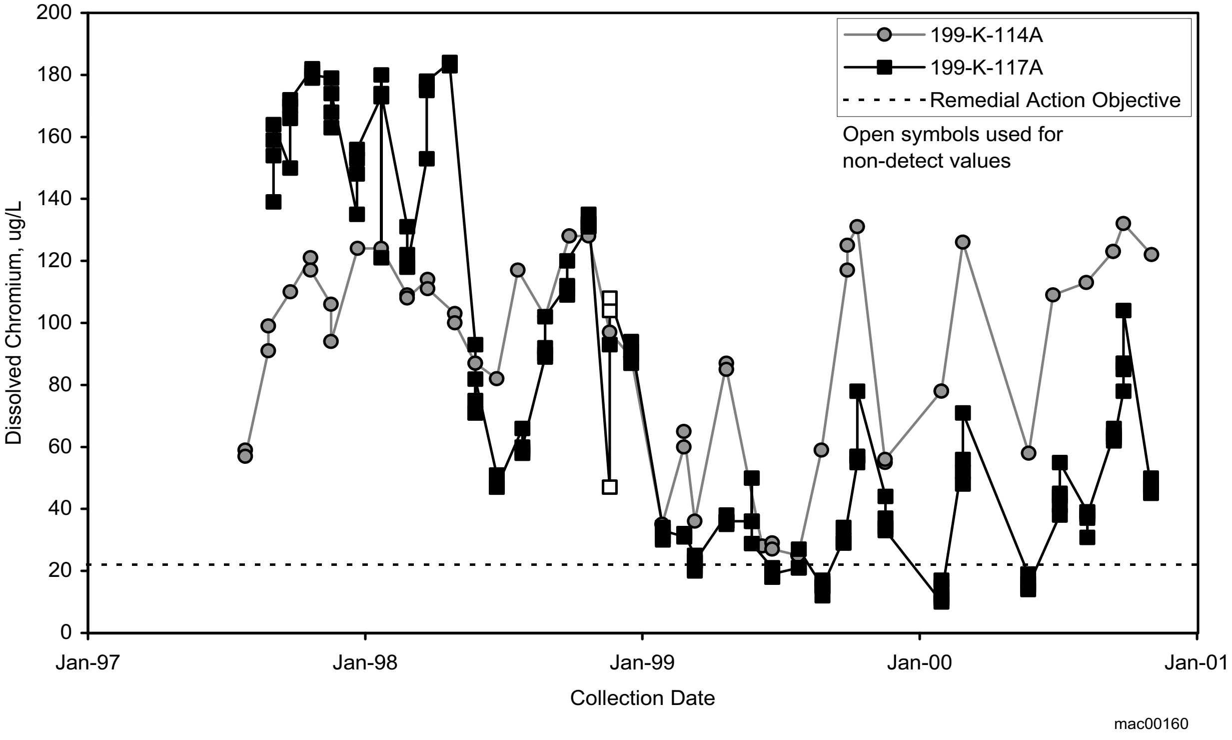


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Figure 2.3-6. Chromium in Groundwater between the Extraction Wells and the Columbia River

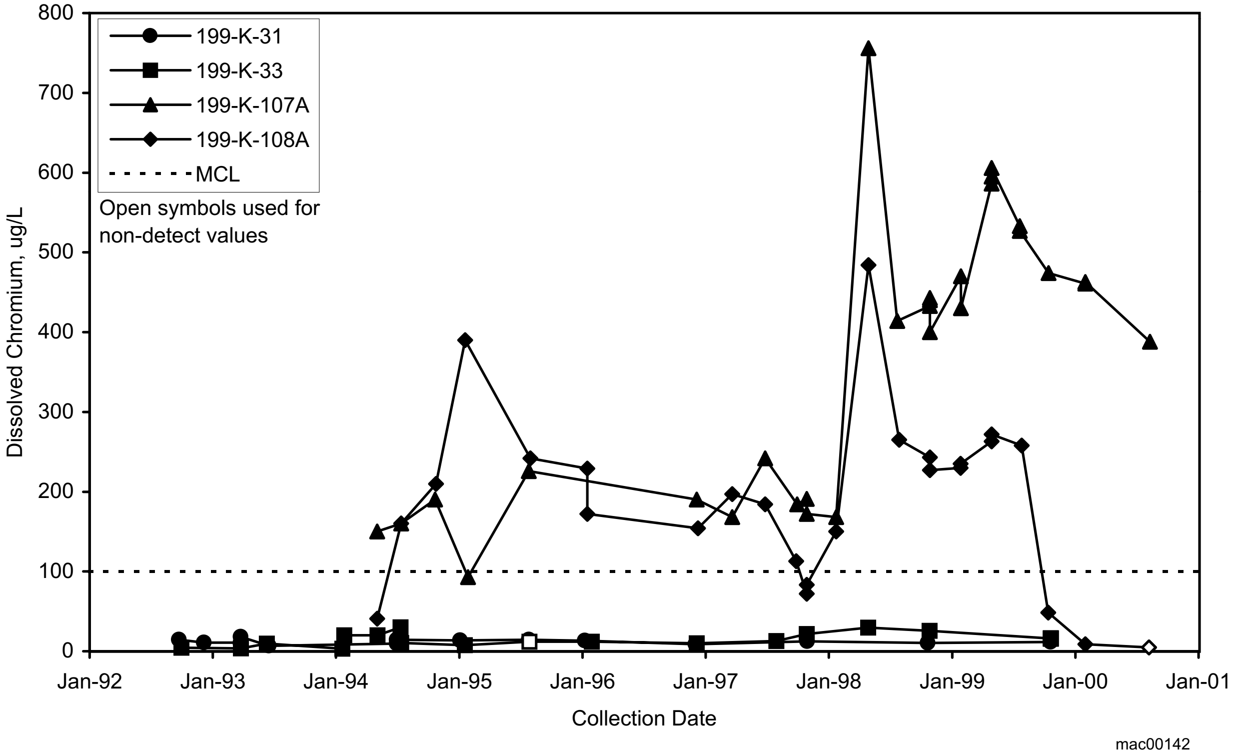

Figure 2.3-7. Chromium in Groundwater near the KW Reactor

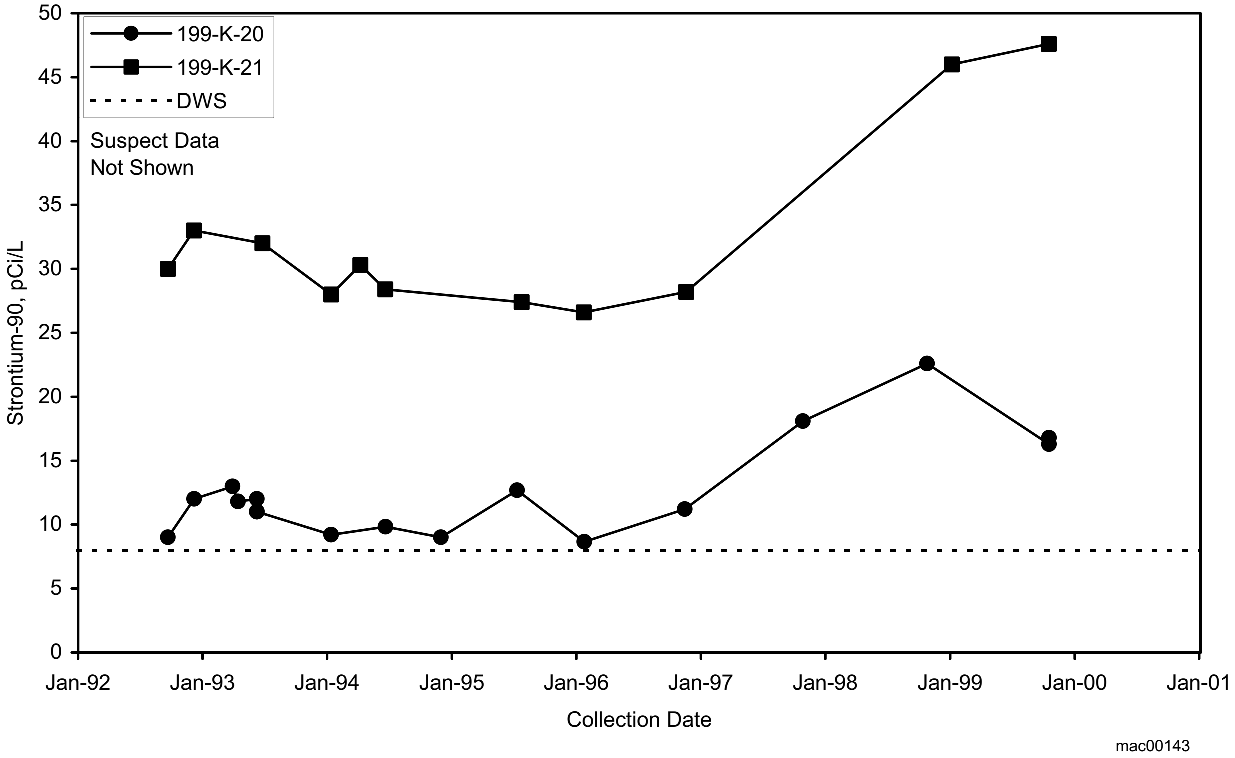

Figure 2.3-8. Strontium-90 in Groundwater near the 116-K-2 Liquid Waste Disposal Trench

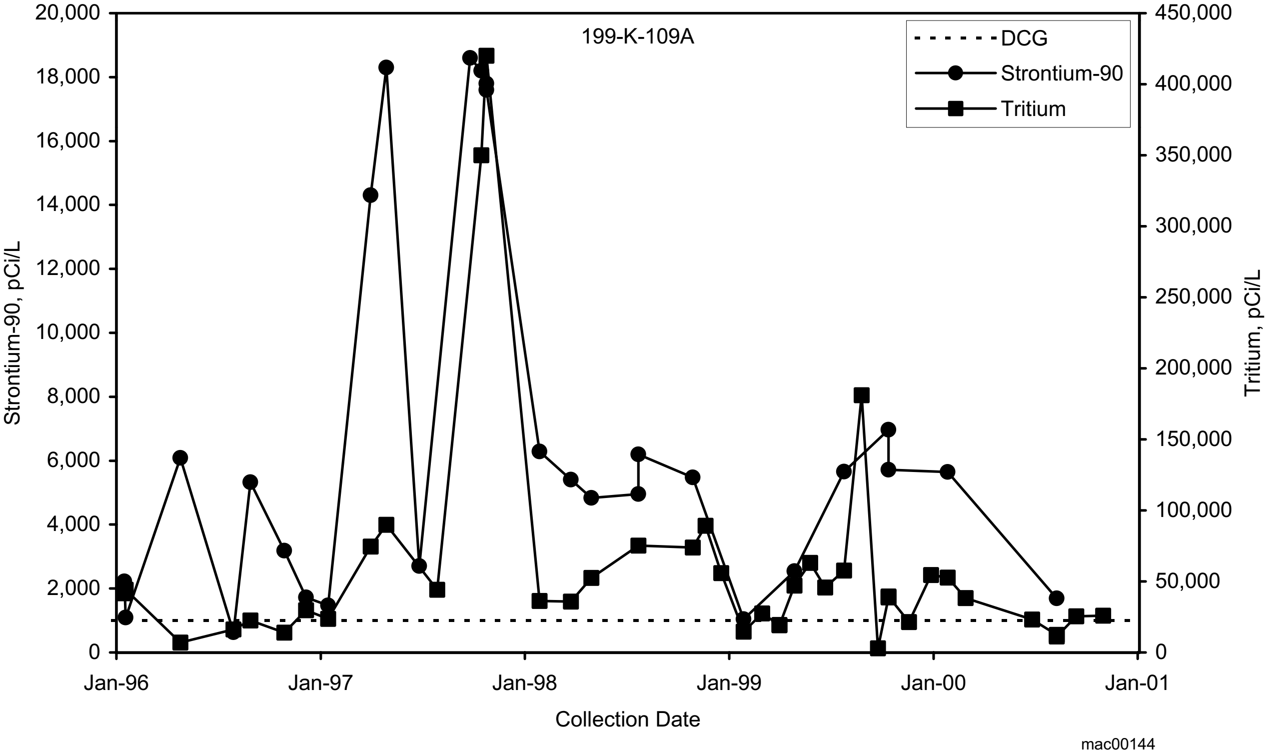

Figure 2.3-9. Strontium-90 and Tritium in Groundwater near the KE Reactor

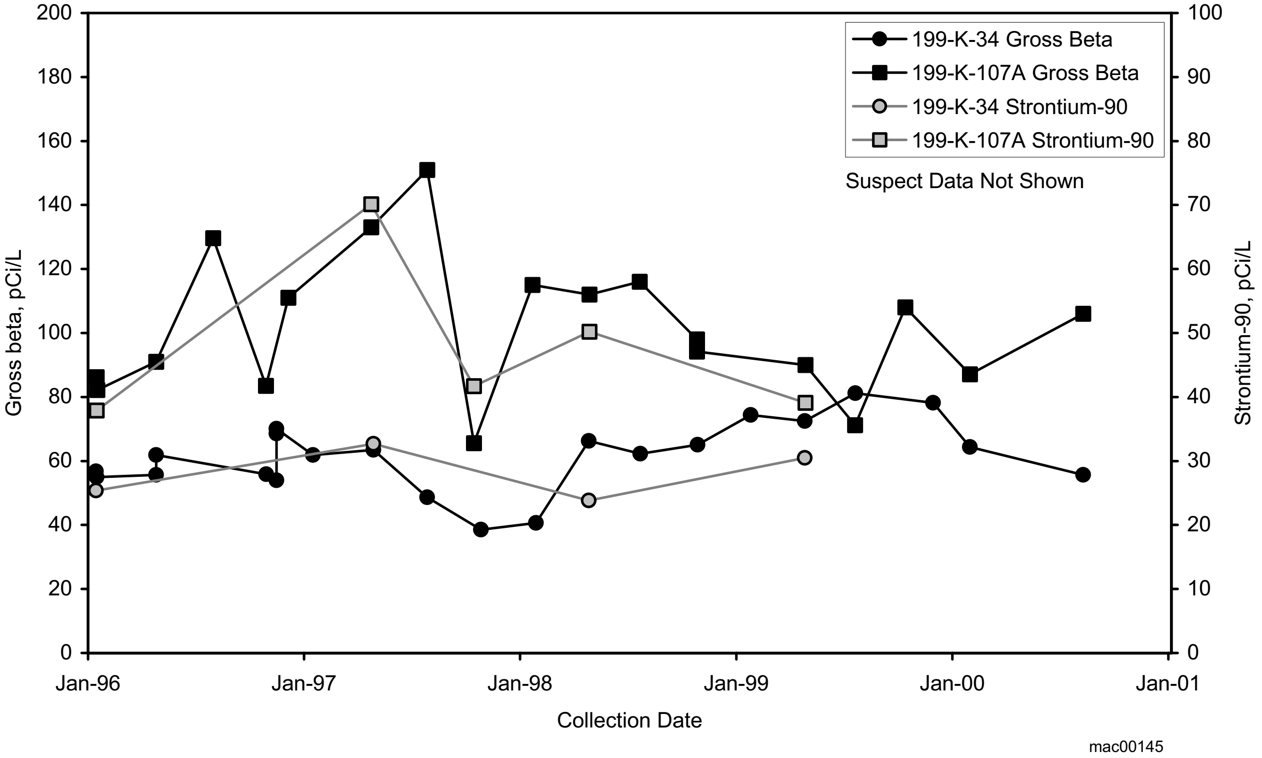

Figure 2.3-10. Gross Beta and Strontium-90 in Groundwater near the KW Reactor

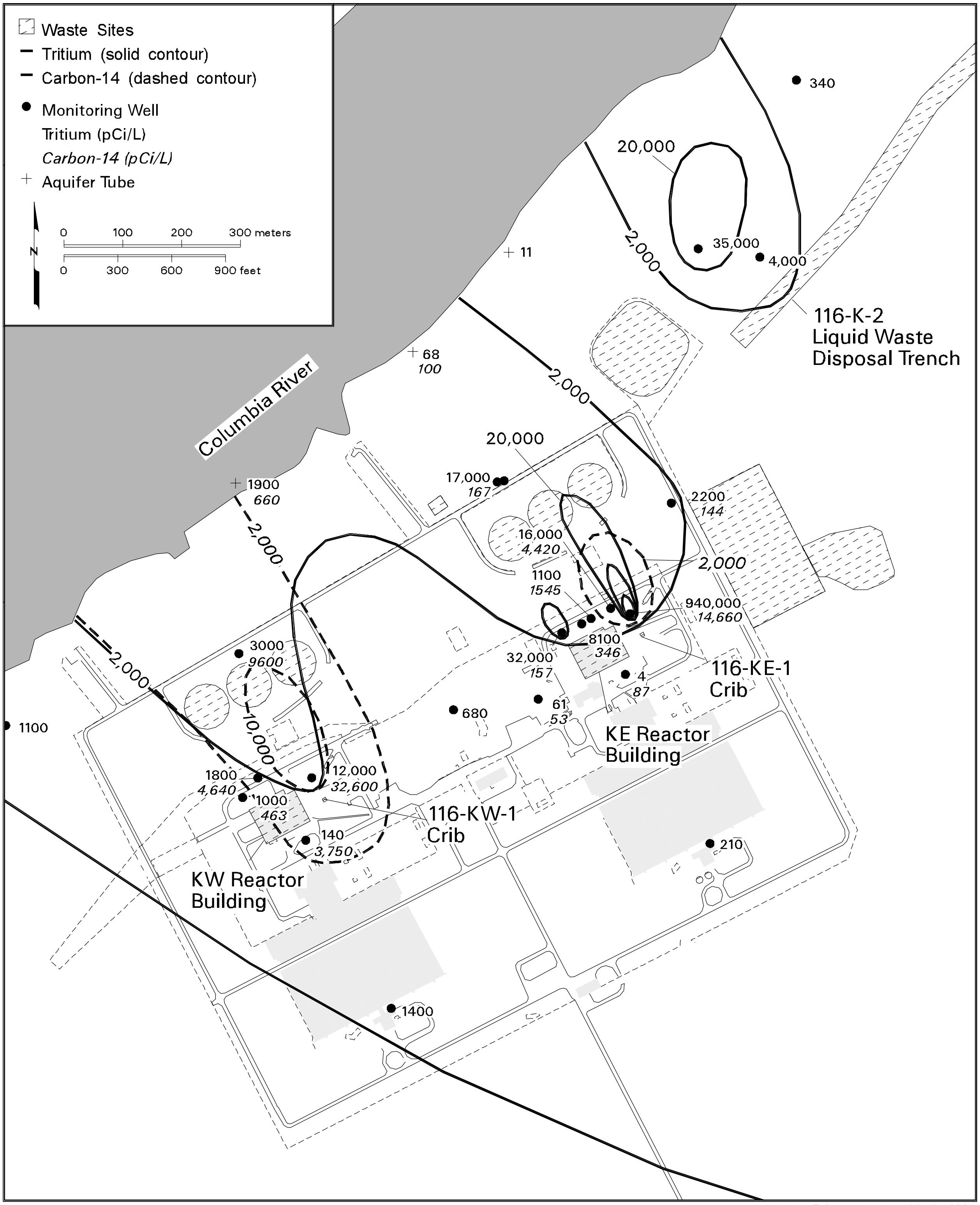

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Figure 2.3-11. Average Tritium and Carbon-14 Distribution in 100 K Area Groundwater

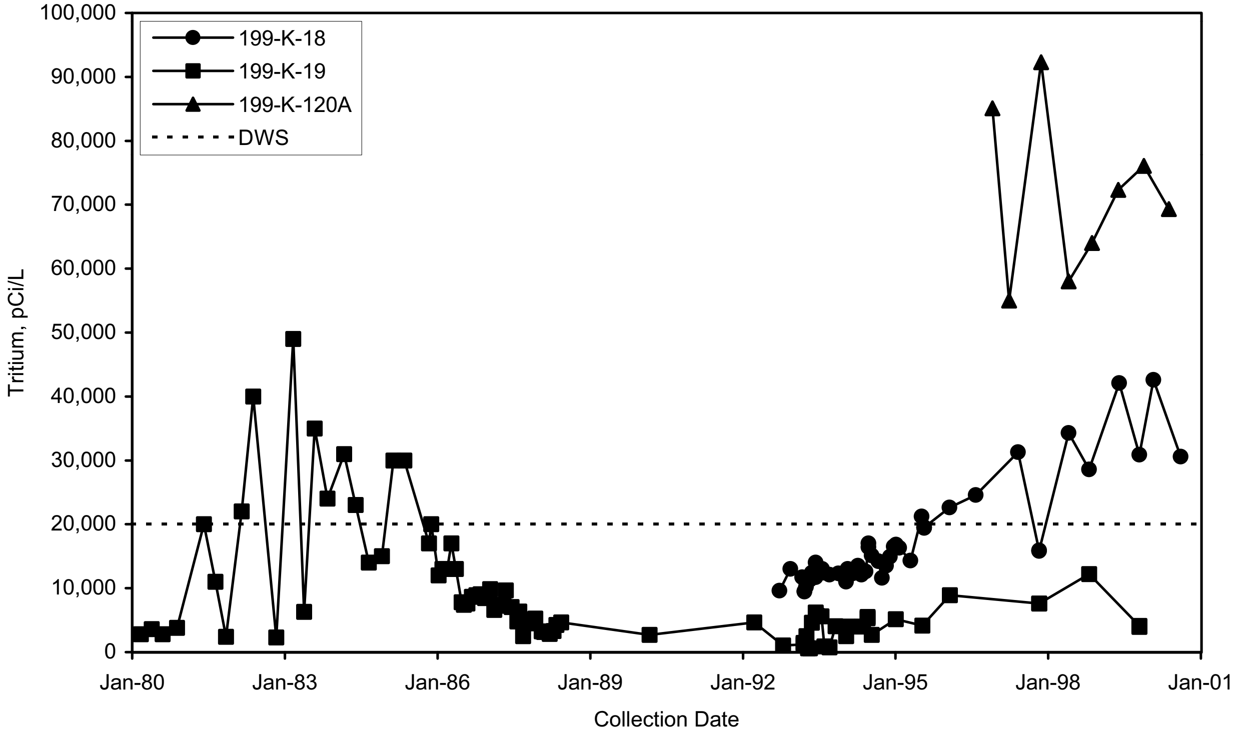

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Figure 2.3-12. Tritium in Groundwater near the 116-K-1 Crib and 116-K-2 Trench

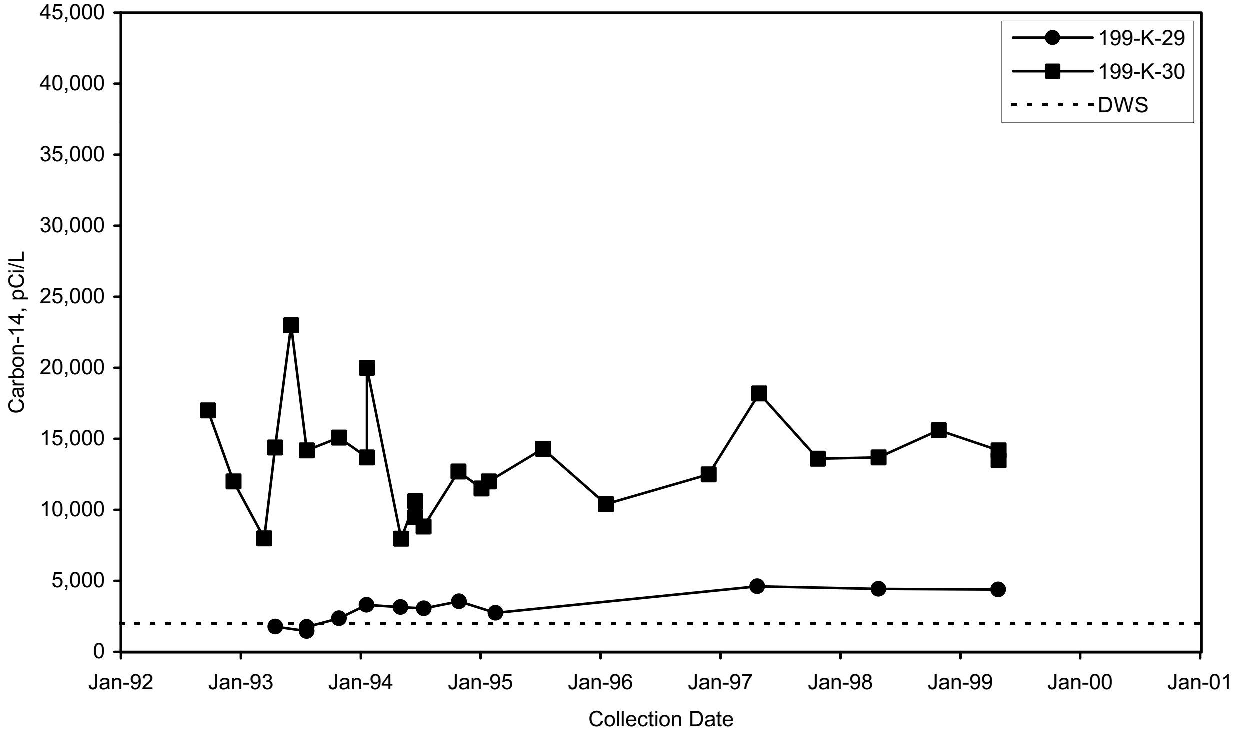

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Figure 2.3-13. Carbon-14 in Groundwater near the KE Gas Condensate Crib

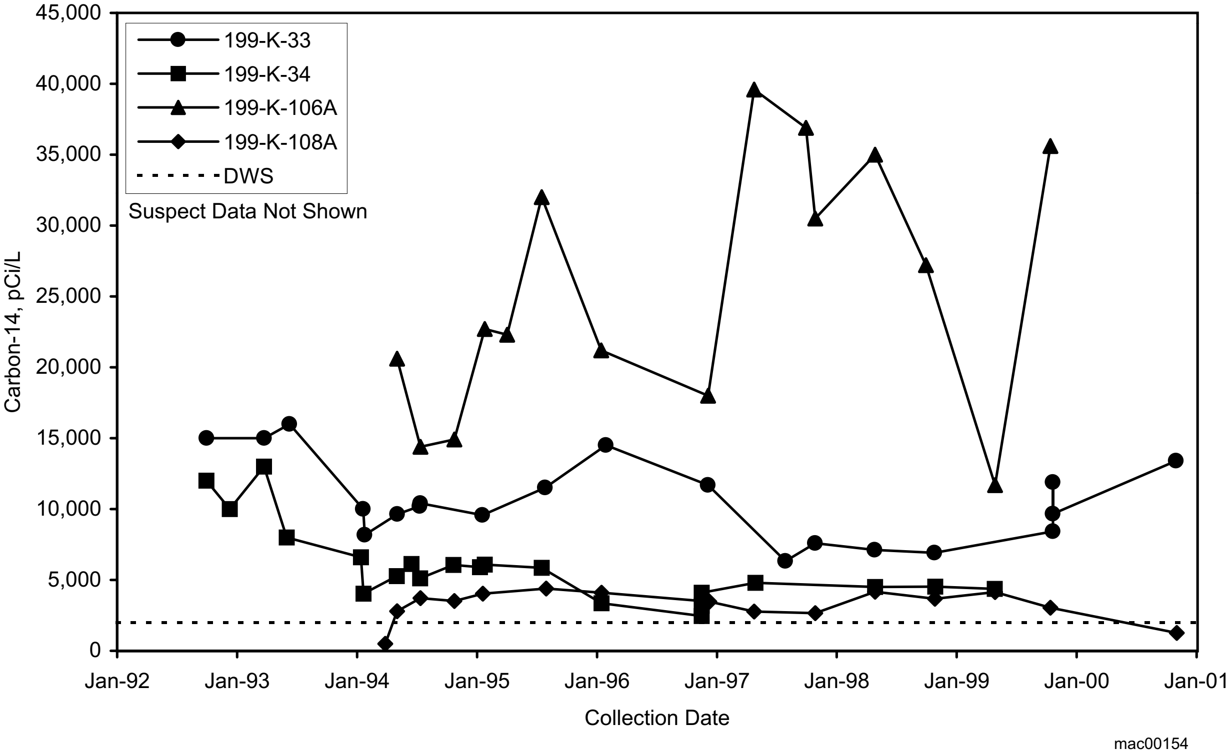


Figure 2.3-14. Carbon-14 in Groundwater near the KW Gas Condensate Crib

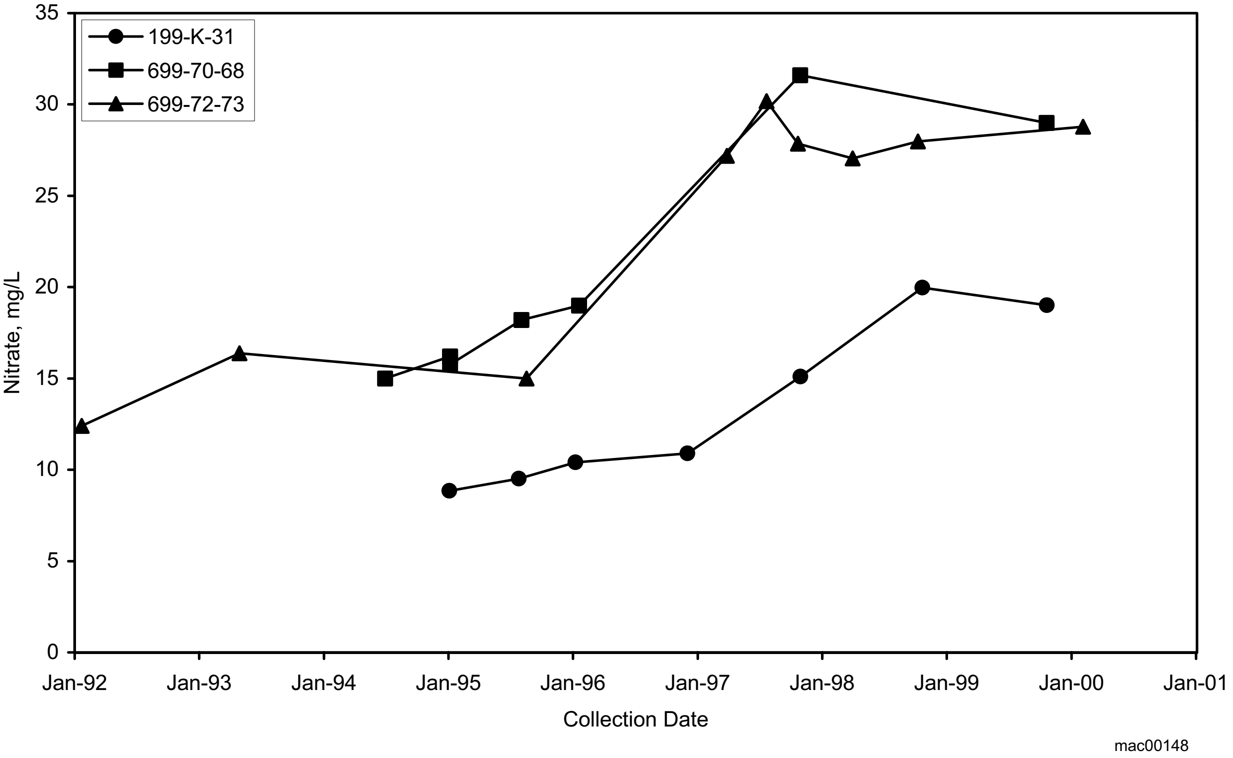


Figure 2.3-15. Nitrate in Groundwater Approaching 100 K Area

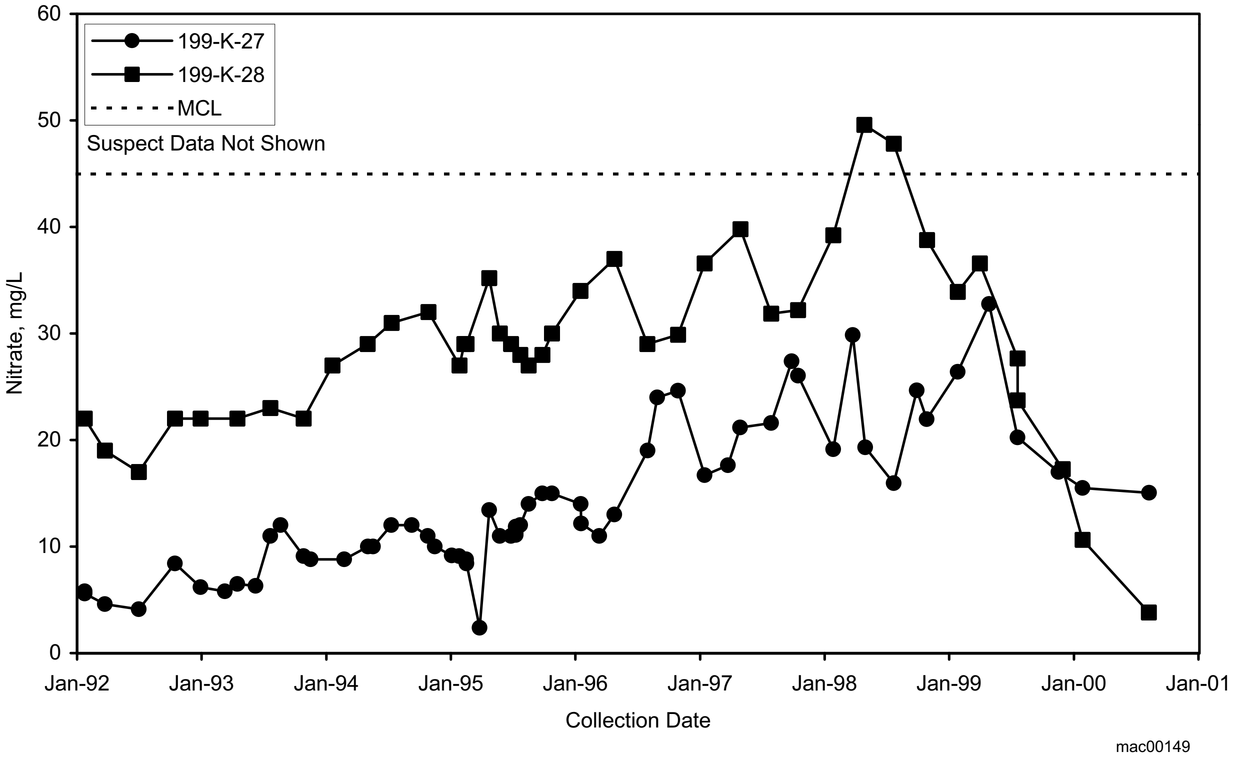


Figure 2.3-16. Nitrate in Groundwater near the KE Fuel Storage Basin

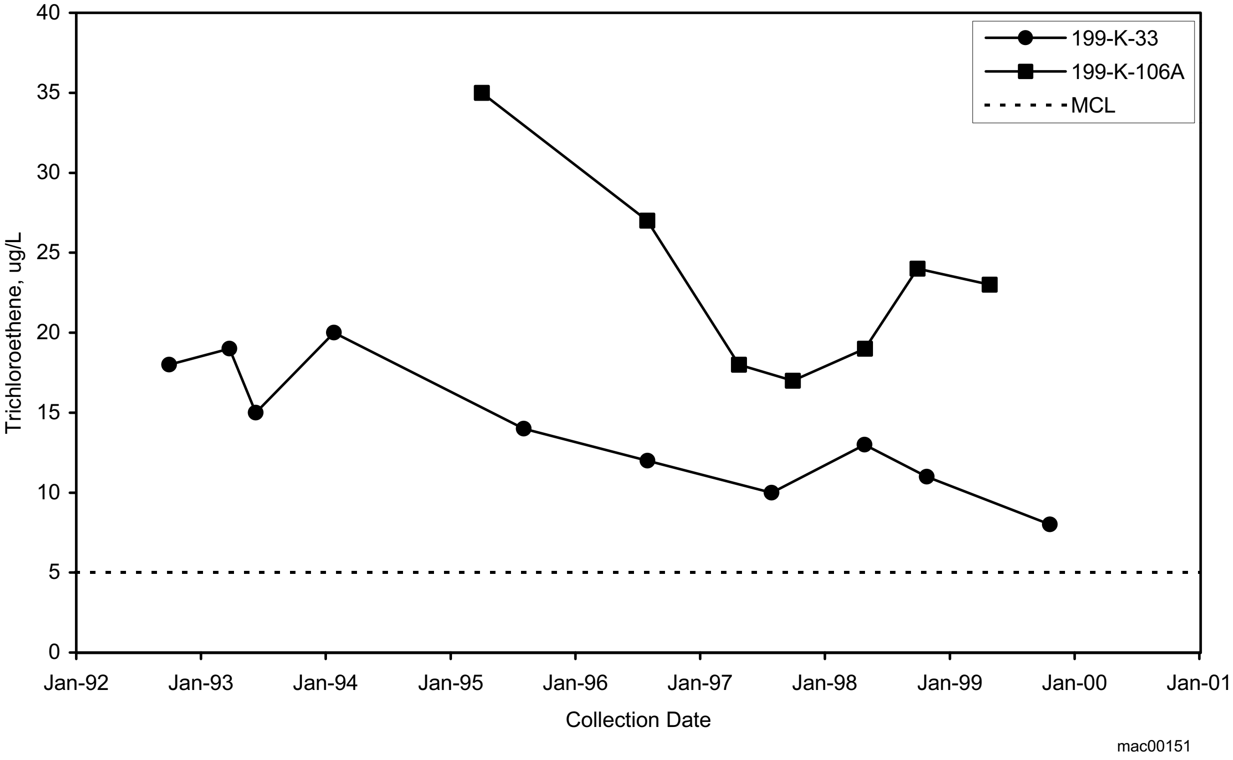


Figure 2.3-17. Trichloroethene in Groundwater near the KW Reactor

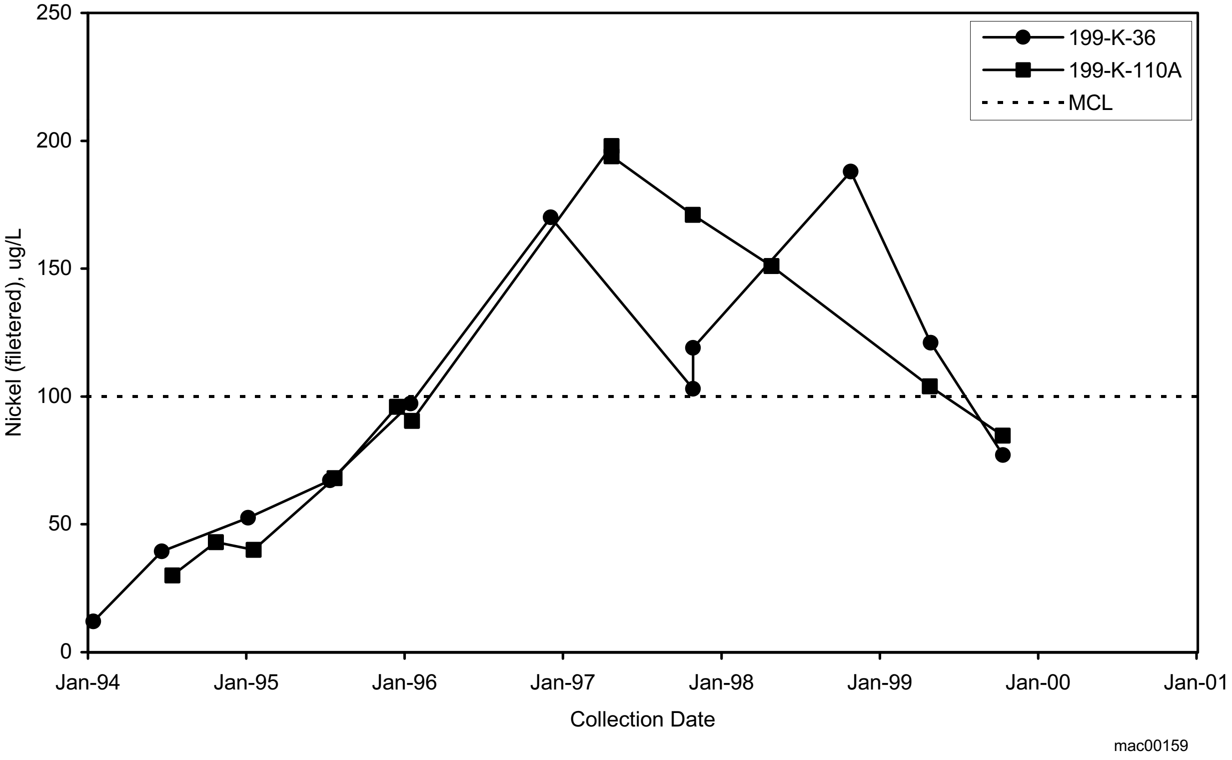


Figure 2.3-18. Nickel in Groundwater at Wells 199-K-36 and 199-K-110A

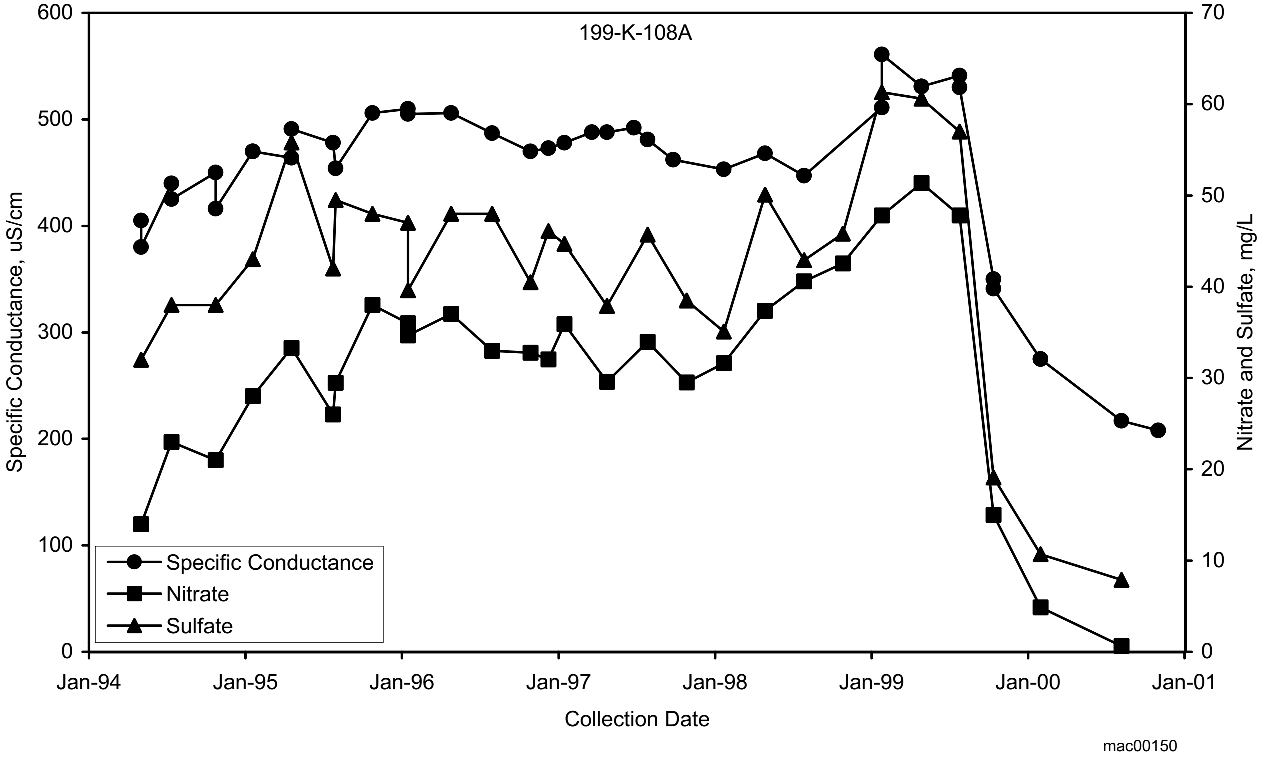


Figure 2.3-19. Concentration Trends near the KW Reactor Indicating Infiltration of Clean Water

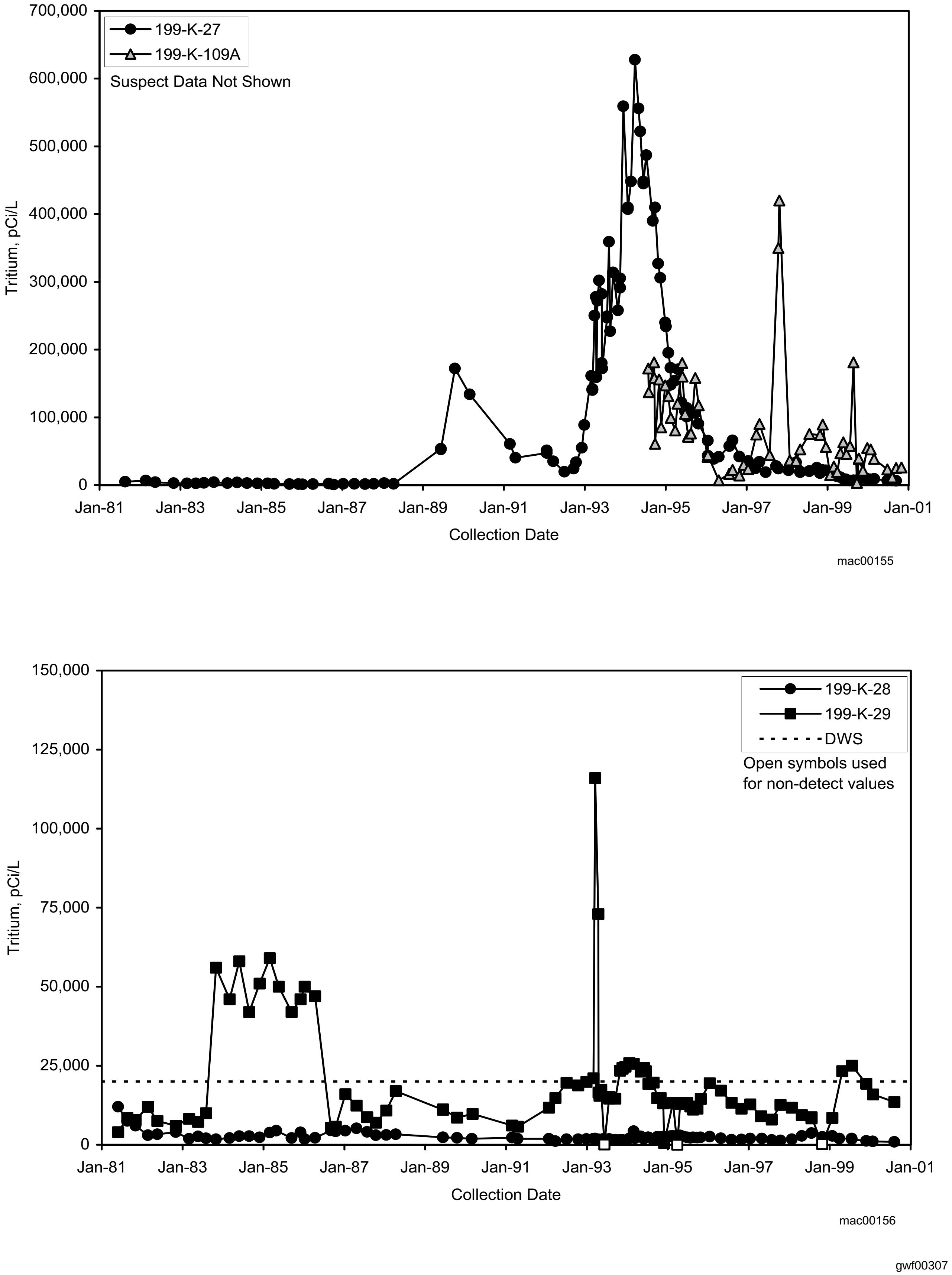


Figure 2.3-20. Tritium in Groundwater near the KE Fuel Storage Basin

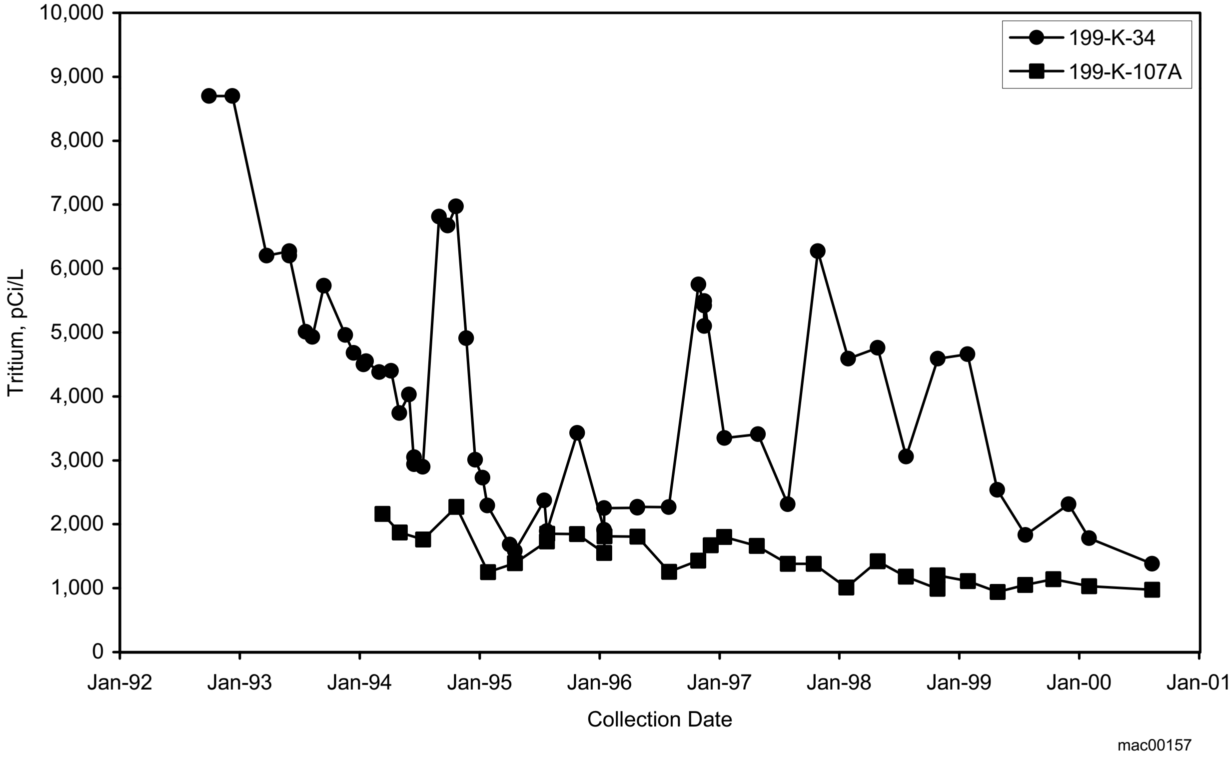


Figure 2.3-21. Tritium in Groundwater near the KW Fuel Storage Basin

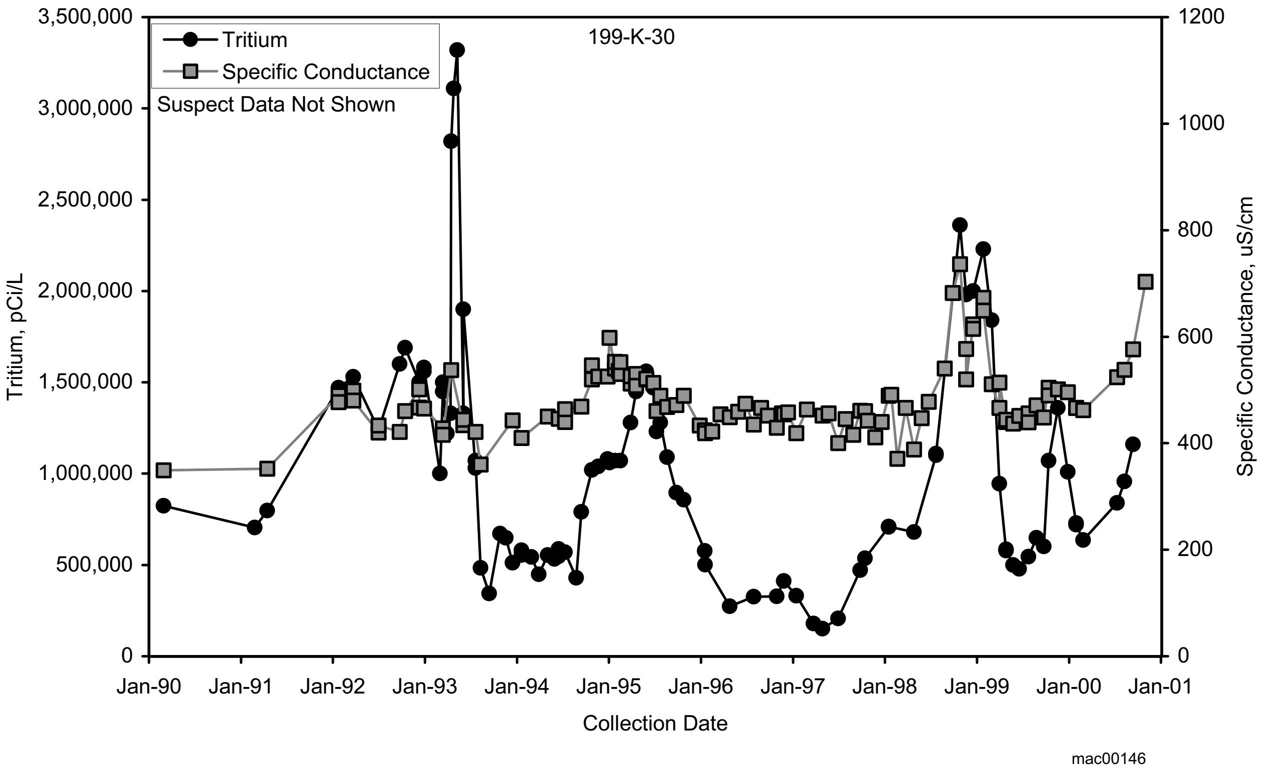


Figure 2.3-22. Tritium and Specific Conductance in Groundwater near the KE Gas Condensate Crib

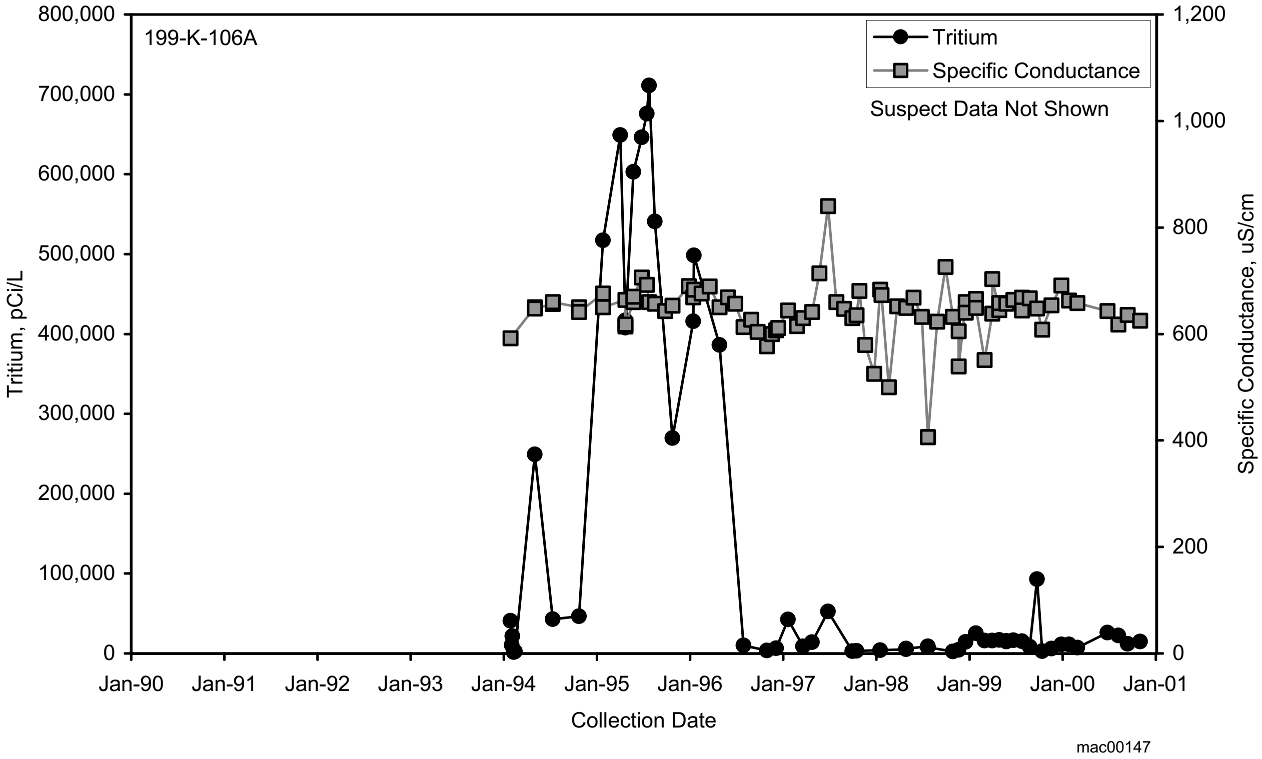


Figure 2.3-23. Tritium and Specific Conductance in Groundwater near the KW Gas Condensate Crib

2.4 100 N Area

M. J. Hartman and W. J. McMahon

The 100 N Area contains a single reactor that operated from 1963 through 1987. The most significant groundwater contamination is associated with the 1301-N and 1325-N liquid waste disposal facilities, which will be remediated in coming years. Other sources of contamination include the 1324-N/NA facilities and various spills or leaks of petroleum products. Waste sites and proposed corrective measures are described in DOE/RL-95-111 and DOE/RL-96-102. Groundwater flow and contamination for each of these contaminant source areas are discussed in the following sections. Facilities and well locations are shown in Figure 2.4-1.

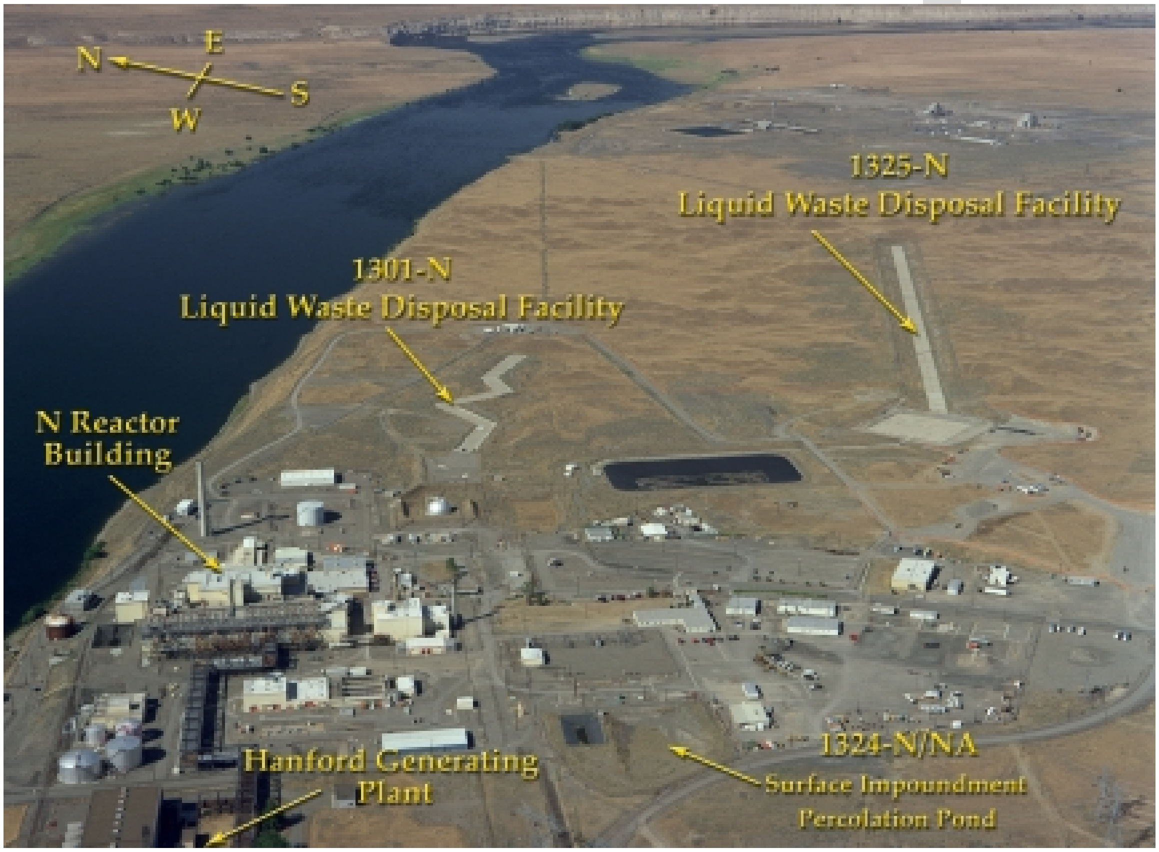
Strontium-90 is the most significant groundwater contaminant in the 100 N Area. It has a relatively low mobility in the aquifer, and the general shape of the plume has not changed in many years.

2.4.1 1301-N and 1325-N Liquid Waste Disposal Facilities

This section describes groundwater flow and contamination beneath the 1301-N and 1325-N facilities. The principal groundwater contaminants are strontium-90 and tritium. Groundwater remediation also is discussed. Fiscal year 2000 data indicate few changes in groundwater quality beneath these facilities compared to previous years.

2.4.1.1 Groundwater Flow

Groundwater generally flows to the northwest, toward the Columbia River, beneath the 1301-N site and toward the north beneath the 1325-N site (see Plate 1).



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Aerial view of the 100 N Area, July 2000.

When the stage of the Columbia River is high, the gradient beneath the 1301-N liquid waste disposal facility reverses, creating a potential for groundwater to flow toward the northeast, approximately parallel to the Columbia River. Estimated flow velocities in March 2000 were 0.07 to 1.3 meter per day at 1301-N and 0.03 to 0.59 meter per day at 1325-N (see Appendix A, Table A.2). The gradient was slightly steeper in March 2000 than in March 1999, so these velocities are higher than last year. Movement of a peak in specific conductance at the 1325-N site in 1997 to 1999 indicated a flow velocity at the middle of the calculated range, 0.3 meter per day.

Extraction of groundwater from wells near the 1301-N facility, and injection of treated water near 1325-N, affect groundwater flow. These effects are clearly visible on the water-table map (see Plate 1) and are discussed in Section 2.4.1.6.

2.4.1.2 Strontium-90

Groundwater beneath the 1301-N and 1325-N facilities is contaminated with strontium-90 at levels up to 18,000 pCi/L (Figure 2.4-2). Contamination is concentrated in an area between the 1301-N facility and the Columbia River. The contours of Figure 2.4-2 take into account the strontium-90 remaining in the treated water that is injected into wells 199-N-29 and 199-N-104A, near the 1325-N facility. The average strontium-90 concentration of the injected water in fiscal year 2000 was 392 pCi/L.

Monitoring Objectives in 100 N Area

Groundwater monitoring is conducted in the 100 N Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of three RCRA sites
- semiannually to monitor trends in variable constituents/wells
- various time intervals to evaluate the performance of a pump-and treat system for strontium-90.

The distribution of strontium-90 near the 1301-N facility has not changed significantly in the last 20 years. Maps for fiscal years 1980 and 1990 are illustrated in Figure 2.4-3. The maps represent new interpretations of data stored in the Hanford Environmental Information System database. There were few wells in 1980, and the interpretation was guided by subsequent data in newer wells. Waste began to be discharged to the 1325-N facility in 1983, and groundwater showed contamination from that site by 1990. The only significant differences in the 1990 and 2000 maps (see Figure 2.4-2) are an increase in strontium-90 concentrations through most of the plume, and the formation of a concentration "sink" near the extraction wells. The extraction wells may be inducing flow from the Columbia River into the aquifer, creating a dilution effect.

The highest concentration of strontium-90 in the 100 N Area in fiscal year 2000, as in previous years, was in well 199-N-67, located near the 1301-N facility (Figure 2.4-4). Strontium-90 concentrations in this part of the plume increased from 1995 to 1998 in response to increasing water levels related to higher than normal river stage. When the water table rose into the former vadose zone, strontium-90 desorbed from sediment grains and entered groundwater. River stages have been closer to average for the years since 1998, and strontium-90 concentrations are declining.

Changes in groundwater chemistry beneath the 1325-N facility appear to have remobilized strontium-90, causing concentrations to increase temporarily.

Near the 1325-N facility in recent years, strontium-90 concentrations have decreased in well 199-N-81 after a peak in 1997 (see Figure 2.4-4). The changes in concentration appear to be related to high-conductance groundwater from the 1324-N/NA site moving through the area and remobilizing the strontium. The potential for this type of chemical interaction was investigated by other researchers in 1993 (Appendix A of WHC-EP-0675). They concluded than ion exchange is the dominant adsorption mechanism for strontium-90 in 100 N Area sediment. With the influx of the higher-conductance groundwater, more calcium is available to exchange with strontium on the sediment grains, thereby releasing the strontium to solution. Trends for specific conductance and calcium are very similar to the strontium-90 trend, suggesting a correlation. Other chemicals associated with the 1324-N/NA site (sulfate, chloride) follow the same trend, supporting the idea that the high-conductance water originated beneath the 1324-N/NA site when flow directions were different than today (see Section 2.4.2 for a discussion of specific conductance and sulfate).

In general, the strontium-90 plume appears to be limited to the upper few meters of the aquifer. Wells 199-N-69 and 199-N-70, completed at the bottom of the upper unconfined aquifer, have no detectable strontium-90, though they are in the heart of the contaminant plume. Well 199-N-80, located near the 1301-N site and completed below a 5-meter-thick clay layer, has also shown undetectable or very low levels (<1 pCi/L) of strontium-90 until September 2000. This sample detected 2.9 pCi/L, which represents a significant increase. Crews will sample well 199-N-80 again in fiscal year 2001 to determine if the detection is repeatable.

2.4.1.3 Tritium

The 1301-N and 1325-N facilities contaminated groundwater with tritium, which forms a widespread plume at levels exceeding the 20,000-pCi/L drinking water standard (see Plate 2). The core of the plume (i.e., the highest concentration) was formerly beneath the 1325-N facility and has migrated to the north and northwest. The highest concentrations of tritium currently are near the Columbia River. Tritium is also present in upgradient wells 199-N-74 and 199-N-52. The current upgradient tritium is believed to have been moved inland by mounding during 1325-N operations.

The tritium plume beneath the 100 N Area continued to shrink in fiscal year 2000 because of migration, dilution, and radioactive decay.

The tritium plume appears to be shrinking, and concentrations are declining in most 100 N Area wells (Figure 2.4-5). The general decline is expected to continue because of plume dilution and radioactive decay.

Unlike strontium-90, tritium concentrations are fairly constant with depth in the aquifer. Tritium concentrations in wells 199-N-69 and 199-N-70, completed at the base of the unconfined aquifer, were about the same as in nearby shallow wells in fiscal year 2000 (20,000 to 24,000 pCi/L). Concentrations are declining at about the same rate as in the shallow wells. Tritium is also elevated in well 199-N-80, monitoring a locally confined aquifer in the Ringold Formation (28,000 pCi/L and declining).

2.4.1.4 Chromium

Only one well in 100 N Area consistently has chromium concentrations above the 100-μg/L maximum contaminant level. Well 199-N-80, which is completed in a thin, confined aquifer in the Ringold Formation typically has chromium concentrations of ~180 μg/L. The well was not sampled in fiscal year 2000 because chromium concentrations are stable. The source for chromium in this deep horizon is unknown. Chromium was disposed of in the 1301-N crib until the early 1970s, and it was identified as a contaminant of potential concern based on soil data (Section 2.5 in DOE/RL-96-39). There are no chromium data from wells that monitored the facility in the early 1970s, and chromium was not detected in significant concentrations in wells near the crib in the 1980s. The presence of chromium in well 699-87-55, which is located east of the northern part of the 1325-N facility, illustrates the possible inland influence of past disposal from the 100 N or 100 D Areas.

2.4.1.5 RCRA Parameters

Monitoring for the *Resource Conservation and Recovery Act of 1976* (RCRA) in fiscal year 2000 indicated the 1301-N and 1325-N facilities are not contaminating groundwater with hazardous constituents. Specific conductance and total organic carbon are elevated in some wells, but reflect contaminants from upgradient sources. Appendix A contains more information about these sites.

The 1301-N and 1325-N RCRA facilities do not appear to have contaminated groundwater with hazardous, non-radioactive constituents.

Specific conductance in 1325-N downgradient well 199-N-41 exceeded the critical mean value in March and September 2000. This well and well 199-N-81 previously exceeded the critical mean value in September 1999. The high specific conductance is believed to originate at an upgradient source (1324-N/NA facility), and passed upgradient well 199-N-74 several years ago (Figure 2.4-6). Because the 1325-N facility is not the source, no assessment is required.

Specific conductance of groundwater near the 1301-N facility is relatively low (200 to 300 μS/cm) compared to typical Hanford Site groundwater because the facility is close to the Columbia River and influenced by low-conductance river water. A plume of high-conductance (500 to 1,000 μS/cm) groundwater from an upgradient source affects groundwater chemistry in downgradient well 199-N-3 and upgradient well 199-N-57.

Since 1997, total organic carbon in well 199-N-3 at the 1301-N facility has increased, and it exceeded the critical mean value in September 2000 (Figure 2.4-7). No organic waste was disposed to the 1301-N facility, and upgradient petroleum waste sites are believed to cause the increase, as discussed in Section 2.4.3.1. Because the 1301-N facility was not the source of contamination, no assessment is required.

Groundwater at the 1301-N and 1325-N facilities is also analyzed for other constituents discharged to these facilities during their use. These analytes include cadmium, chromium, and nitrate (see Appendix A). Cadmium and chromium (in filtered samples) were not detected in significant concentrations in 1301-N or 1325-N downgradient wells. Nitrate was elevated in some of the downgradient wells, as discussed in Section 2.4.3, but the sources are unclear.

2.4.1.6 Groundwater Remediation

The pump-and-treat system at the 100-NR-2 Operable Unit, located along the 1301-N facility, is part of an expedited response action that began operating in 1995. An action memorandum (Ecology and EPA 1994) contains the following objectives that pertain to operation of the pump-and-treat system:

- 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.

Extraction wells between the 1301-N facility and the Columbia River have created a hydraulic sink, reducing the amount of strontium-contaminated groundwater entering the river. The pump-and-treat system is not an efficient way of cleaning up the aquifer.

On September 29, 1999, the U.S. Department of Energy (DOE), Washington State Department of Ecology, and the U.S. Environmental Protection Agency signed an interim record of decision for the 100-NR-1 and 100-NR-2 Operable Units (Ecology 1999). This record of decision specifies the selected remedy and activities for the 100-NR-2 Operable Unit, including continued operation of the pump-and-treat system with the objectives listed above.

The pump-and-treat system made progress toward the remedial action objectives in fiscal year 2000. The extraction wells create a hydraulic sink between the 1301-N 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 controlling the water discharged because of the cyclical river stage and bank storage effects of the Columbia River. A complete description of the progress and effectiveness of the remedial action is presented in DOE/RL-99-79.

During fiscal year 2000, the pump-and-treat system extracted over 108 million liters of groundwater and removed ~0.2 curie of strontium-90 (Table 2.4-1). Combined, the extraction wells delivered an average concentration of 1,994 pCi/L to the treatment system during the fiscal year. After treatment, the effluent contained 392 pCi/L, which was returned to the aquifer through wells 199-N-29 and 199-N-104A.

The pump-and-treat system has not reduced the concentration of strontium-90 in the aquifer, nor has it removed a significant quantity of strontium-90 mass compared to the estimated existing inventory. The distribution of strontium-90 in the aquifer remained essentially unchanged in recent years, with concentrations returning to the levels observed prior to the 1996 and 1997 high water years in the Columbia River.

Since operations began in 1995, the pump-and-treat system has removed 0.9 curie of strontium-90, compared to a total inventory in the aquifer estimated to exceed 75 curies. Current estimates indicate that the pump-and-treat system would have to operate for more than 300 years before the strontium-90 concentrations reach permissible levels (DOE/RL-95-110). Considering the relatively high adsorption characteristic of strontium-90, the fact that the plume geometry has remained virtually unchanged for several years (excepting the flood years), and the high concentrations observed during 1996 to 1997 have not recurred in any of the monitoring wells, the contaminant may be essentially immobile in the aquifer, and there may be much less discharging into the river than previously estimated. For this reason, DOE is investigating and evaluating alternative remediation technologies.

2.4.1.7 Waste Site Remediation

The environmental restoration contractor began excavating the southern one-fourth of the 1325-N trench in July 2000. Soil sampling indicated the rest of the trench is not contaminated. The concrete covers were removed from the contaminated portion of the trench; the covers of the uncontaminated trench were demolished in place. The contaminated sediment was excavated to ~8 meters below the surrounding grade, which is ~15 meters above the water table. Water to control dust was applied as necessary to protect worker health. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to groundwater. The environmental restoration contractor plans to excavate the 1325-N crib in fiscal year 2001.

2.4.2 1324-N Surface Impoundment/ 1324-NA Percolation Pond

This section describes groundwater flow and contamination near the 1324-N/NA RCRA facilities in the southern 100 N Area. Groundwater near these facilities contains high levels of sodium and sulfate, caused by past disposal to the percolation pond.

The 1324-N/NA facility does not appear to have contaminated groundwater with hazardous constituents. However, this site has added non-hazardous constituents, such as sulfate and sodium, to the groundwater.

2.4.2.1 Groundwater Flow

Groundwater flows toward the northwest beneath the 1324-N/NA site, perpendicular to the Columbia River (see Plate 1). The average rate of flow is 0.08 to 1.4 meters per day (see Appendix A, Table A.2). Movement of the sulfate plume between 1990 and 1993 indicated a flow velocity of ~0.5 meter per day (Section 3.2 in DOE/RL-93-88). The gradient in those years was approximately the same as it was in March 2000, so the flow estimate is still valid.

2.4.2.2 RCRA Parameters

RCRA monitoring in fiscal year 2000 indicated the 1324-N/NA site has not contaminated groundwater with hazardous constituents. Since monitoring began in 1988, specific conductance has been elevated at this site primarily because of non-dangerous constituents that were present in the waste, such as sodium and sulfate. No additional assessment is required. Total organic carbon, total organic halides, and pH were all below the critical mean value in downgradient wells. Appendix A contains more information about this site.

2.4.2.3 Sulfate and Specific Conductance

The 1324-NA percolation pond has added non-hazardous constituents, including sulfate and sodium, to groundwater, creating high specific conductance (more than 1,000 µS/cm) (Figure 2.4-8). The plume extends in a wedge shape to the north-northwest, presumably discharging to the Columbia River.

Specific conductance and sulfate have declined from their peaks (Figure 2.4-9). When high conductance waste was being discharged, sulfate concentrations were over 1,500 mg/L. The secondary drinking water standard is 250 mg/L. Sulfate and specific conductance in well 199-N-59 and other downgradient wells remain much higher than in upgradient well 199-N-71.

2.4.3 Other Groundwater Contamination

This section describes miscellaneous contaminants in 100 N Area: petroleum products and nitrate.

2.4.3.1 Petroleum Hydrocarbons

Petroleum hydrocarbons are detected in several locations in the 100 N Area. Wells 199-N-16 and 199-N-18 monitor the most prominent area. Both wells had detectable oil and grease in September 2000 (12 and 23 mg/L). Well 199-N-18 also had total petroleum hydrocarbons (diesel range) at 23 mg/L. Samplers did not see an oil sheen on the tape after measuring water levels, indicating there were no floating petroleum hydrocarbons in the well.

Contamination from old leaks of petroleum products is still present in two wells in the 100 N Area. Samplers did not detect any floating petroleum products in wells in fiscal year 2000.

Groundwater chemistry in the petroleum-contaminated area suggests that bacterial degradation of the product is taking place, creating reducing conditions in the aquifer. Chemical reduction may explain anomalous, low nitrate and high iron and manganese concentrations in wells 199-N-16 and 199-N-18. Dissolved oxygen and oxidation-reduction potential will be measured in fiscal year 2001 to determine if reducing conditions are present.

Oil and grease were previously detected in well 199-N-59, near the 1324-N/NA facility, and total organic carbon was elevated. In fiscal year 2000, oil and grease were undetected and total organic carbon declined to background levels.

2.4.3.2 Nitrate

Nitrate exceeds the 45 mg/L maximum contaminant level in two portions of the 100 N Area, but the sources are unknown (Figure 2.4-10). Virtually the entire area has nitrate at levels above 20 mg/L. The first area with nitrate above the maximum contaminant level is in the southern 100 N Area, near the 1324-N/NA site, and to the north and west of this site. Nitrate or related constituents were not discharged in significant quantities to this facility (DOE/RL-96-39), so the source of contamination is unknown. Nitrate decreased in wells 199-N-59 and 199-N-19 in fiscal year 2000 (Figure 2.4-11).

Well 199-N-2 represents a region of nitrate contamination near the 1301-N facility (see Figure 2.4-11). Several wells near the 1325-N facility, including well 199-N-81, exceeded the maximum contaminant level in 1997 through 1999, but declined to lower levels in fiscal year 2000. No satisfactory explanation has been determined for the recent nitrate peaks. See Section 5.5 of PNNL-12086 for more discussion of elevated nitrate.

Nitrate concentrations declined in many wells in the 100 N Area in fiscal year 2000, but remained above background levels.

Several wells with anomalous, low nitrate values appear to separate the southern part of the plume from the portion near the 1301-N facility. Nitrate has been historically below detection limits in well 199-N-18, which is very unusual in the unconfined aquifer. Nitrate is highly variable in well 199-N-16. Groundwater is not diluted by the Columbia River or leaking utility lines in this area, as evident from the specific conductance, which is >1,000 µS/cm in these wells. Low nitrate may be related to chemical reduction of petroleum hydrocarbons in the aquifer.

2.4.4 Water Quality at Shoreline Monitoring Locations

Water quality near the Columbia River in the 100 N Area is evaluated by sampling wells near the river (199-N-46, 199-N-92A, 199-N-96A, and 199-N-99A) and riverbank seepage. The sampling points are located on the shoreline downgradient of the 1301-N facility (see Figure 2.4-1). Table 2.4-2 lists constituents of interest for the 100 N Area for fall 1999 and fiscal year 2000. The closest aquifer sampling tubes to the 100 N Area are located downstream, between 100 N and 100 D Areas. Aquifer tubes were not installed in the 100 N Area because of the availability of near-river wells and the presence of concrete rubble along the shoreline. Shoreline and river sampling is conducted annually in the fall.

In fiscal year 2000, strontium-90 and tritium concentrations continued to exceed drinking water standards in wells near the Columbia River shore in the 100 N Area.

2.4.4.1 Near-River Wells and Aquifer Sampling Tubes

Strontium-90 concentrations in samples from near-river wells are illustrated with the contaminant plume in Figure 2.4-2. In fiscal year 2000, concentrations ranged from undetected in well 199-N-92A (north of the main plume) to 10,800 pCi/L in well 199-N-46, within the plume. Well 199-N-99A, near the middle of the plume, detected a peak of strontium-90 in 1996 (19,000 pCi/L), after which levels declined. Levels of strontium-90 remain above the 1,000-pCi/L DOE derived concentration guide (1,810 pCi/L in September 2000, about the same as in 1999). The high value in 1996 correlated to a high river stage.

The highest tritium concentration in fiscal year 2000 in a near-river well was 29,300 pCi/L in well 199-N-92A, a typical value for this well. One aquifer tube located between 100 N and 100 D Areas detected tritium at 20,200 pCi/L in November 1999. These concentrations fit the overall distribution of tritium illustrated in Plate 2.

2.4.4.2 Riverbank Seepage

The Sitewide Environmental Surveillance Project collected a sample from one seep along the 100 N Area shoreline in October 1999 (see Table 2.4-2). The sample contained a low level of gross beta, no detectable strontium-90, but relatively high tritium (14,100 pCi/L). Low strontium-90 or gross beta and high tritium concentrations are typical for this seep, because it is located downstream of the main strontium-90 plume. Another seep located in the heart of the strontium-90 plume could not be sampled in fall 1999.

Table 2.4-1. Summary of 100 N Area Pump-and-Treat Performance for Fiscal Year 2000

Well ID or Sample Location	Annual Average Flow Rate (L/min)	Total Volume Pumped (x 10^6 L)	Average Strontium-90 Concentration (pCi/L)	Strontium-90 Mass Removed (Ci)
199-N-75	53	104.5	NS	NA
199-N-103A	61	136.6	NS	NA
199-N-105A(a)	25	0.576	NS	NA
199-N-106A	113	230.6	NS	NA
N-Influent	235	108	1,994	0.2
N-Effluent	235	108	392	NA

(a) Backup extraction well; operated July 31 through August 17.
NA = Not applicable.
NS = Not sampled.
Total strontium-90 removed since startup is ~0.9 curie. Total in aquifer estimated at 75 curies.

Table 2.4-2. Shoreline Monitoring Data for the 100 N Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Sulfate (mg/L)	Nitrate (mg/L)
199-N-46	Well	09-Sep-99	535-557		13,100		9,190		
		28-Mar-00	483		14,700		8,570		
		22-Sep-00	421		10,800		5,490		
199-N-92A	Well	09-Sep-99	183	4.3	***0.29***	2.63	10,300	12.6	10
		26-Sep-00			***0.71***	4.65	29,100		
199-N-96A	Well	09-Sep-99	542-556	***3.2***-4.8	5.9-6.2	18.4-20.1	875-1,150	66.4-68.8	17.3-18.0
		26-Sep-00			9.7	31.7	3,270		
199-N-99A	Well	09-Sep-99	198-206	4.3	1,890	4,080	***4.6***	12.5	4,700
		26-Sep-00			1,810	3,680	6,640		
DD-50-2	Tube	05-Nov-99	278				20,200		
DD-50-3	Tube	05-Nov-99		34				36.0	
SN-NS8-13	Seep	25-Oct-99	263		***0.0***	2.9	14,100	38.1	15.4
DD-50-3	River	05-Nov-99	125						
RN-084	River	10-Sep-99	116		0.2		96	7.5	0.4
RN-089	River	10-Sep-99	116		0.5		50	7.6	0.4
RN-092	River	10-Sep-99	116		1.3		47	7.6	0.4
RN-095	River	10-Sep-99	116		0.3		87	7.5	0.4
RN-098	River	10-Sep-99	117		0.1		112	7.5	0.4

Well = Monitoring well located adjacent to river.
Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore.
Values in ***bold italics*** are qualified by the laboratory as "undetected." Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350-450 µS/cm.
Data from September 1999 (fiscal year 1999) given for wells for comparison with fall 1999 tube, seep, and river data.
Data sources: Hanford Environmental Information System and various project records.

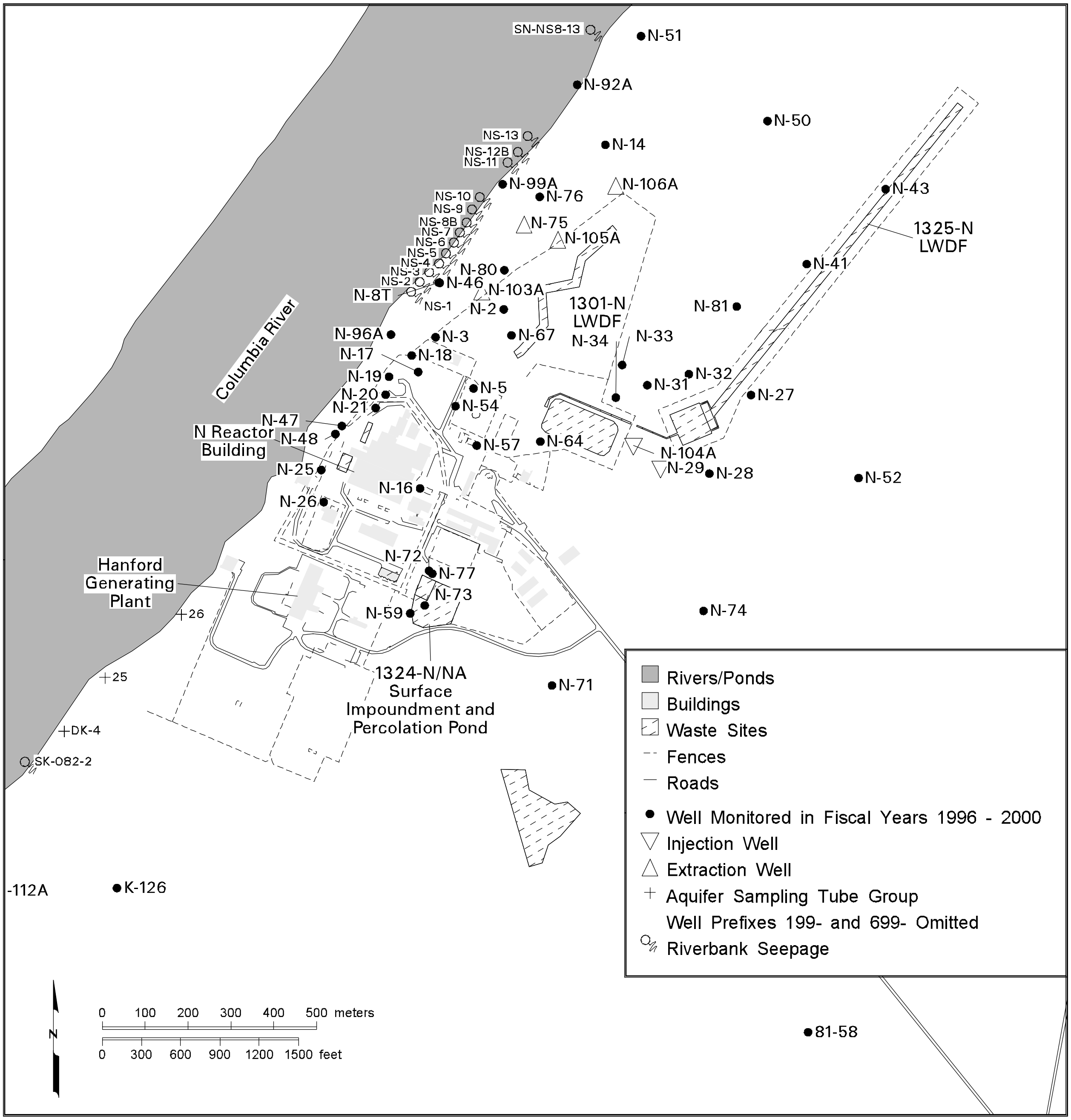

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Figure 2.4-1. Groundwater Monitoring Wells in the 100 N Area

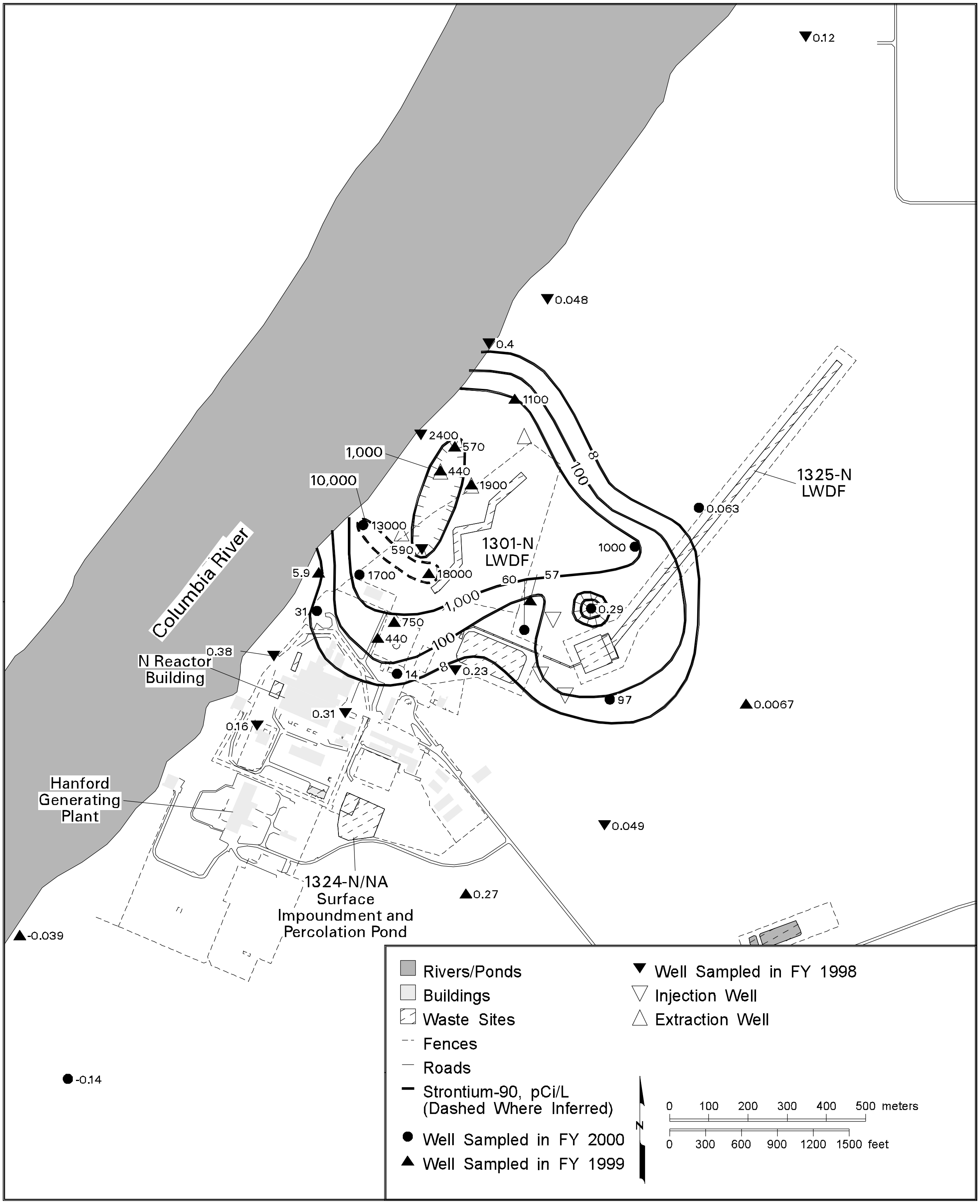

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Figure 2.4-2. Average Strontium-90 Concentrations in the 100 N Area, Top of Unconfined Aquifer

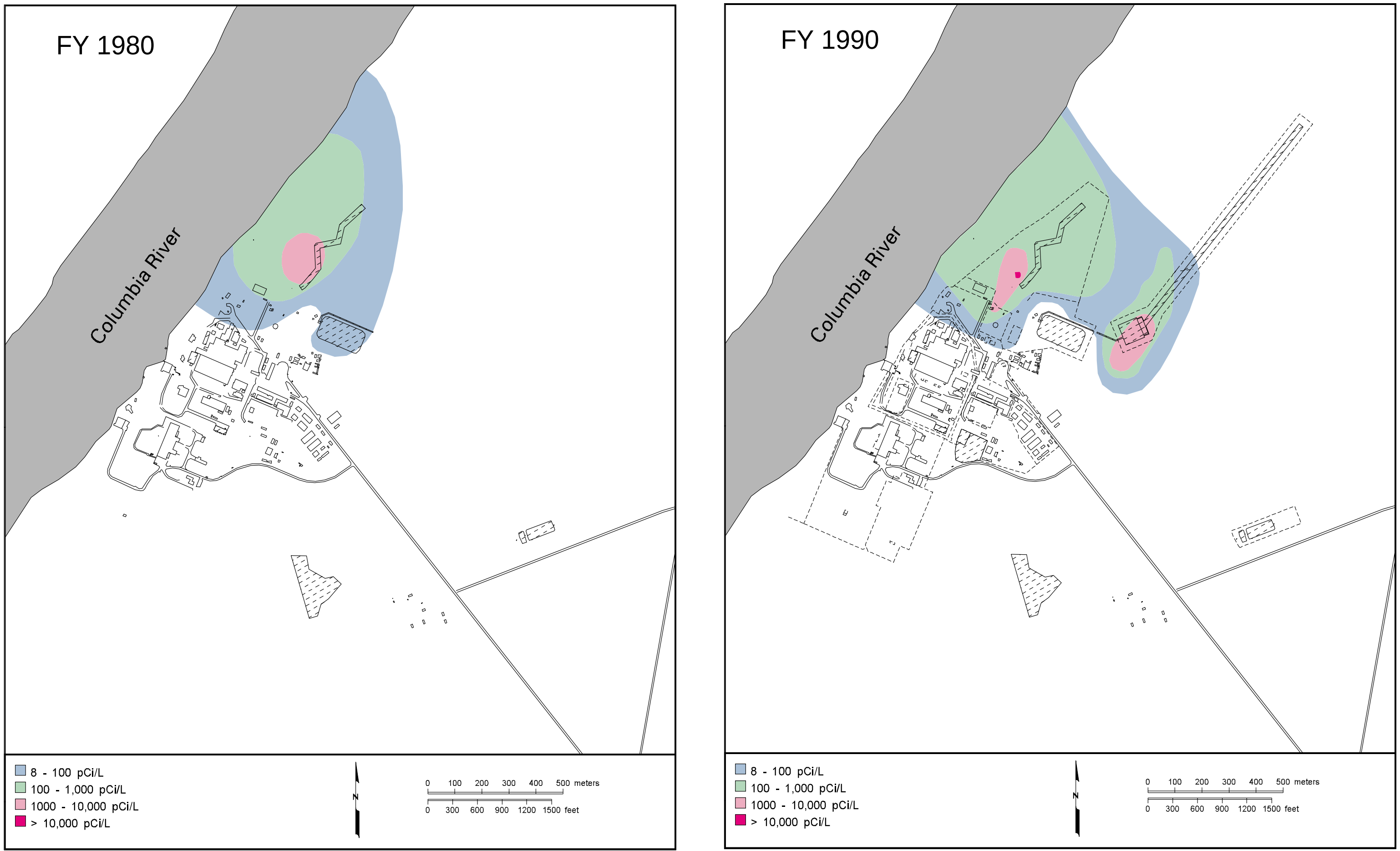

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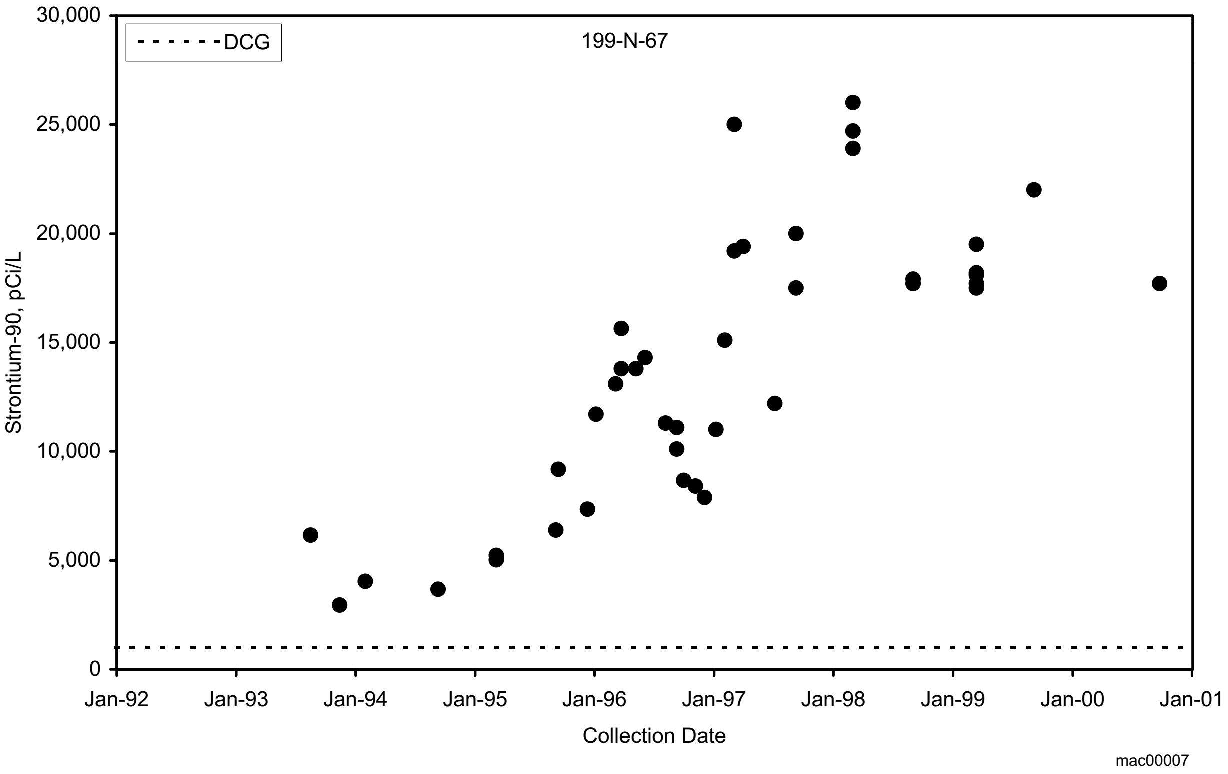
Figure 2.4-3. Average Strontium-90 Concentrations in the 100 N Area, Fiscal Years 1980 and 1990



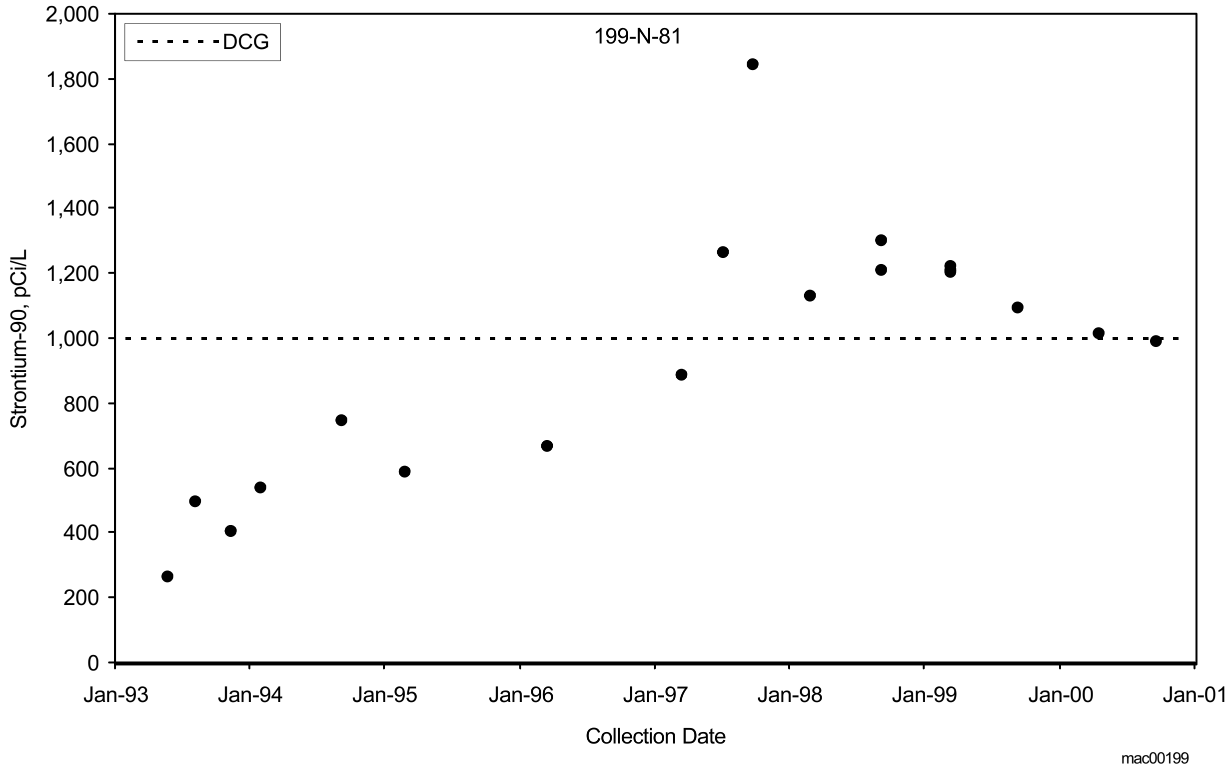


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Figure 2.4-4. Strontium-90 in Well 199-N-67 near the 1301-N Facility and Well 199-N-81 near the 1325-N Facility

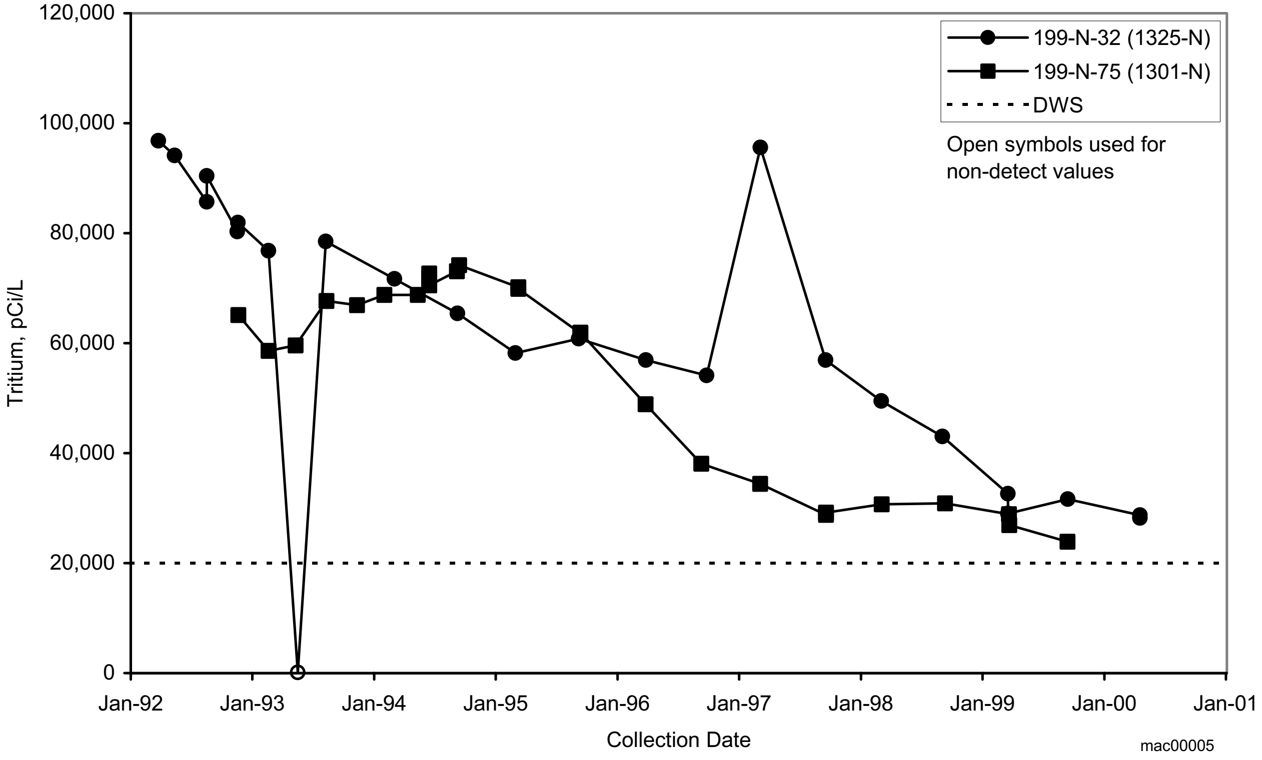

Figure 2.4-5. Tritium in Wells Monitoring 100 N Area

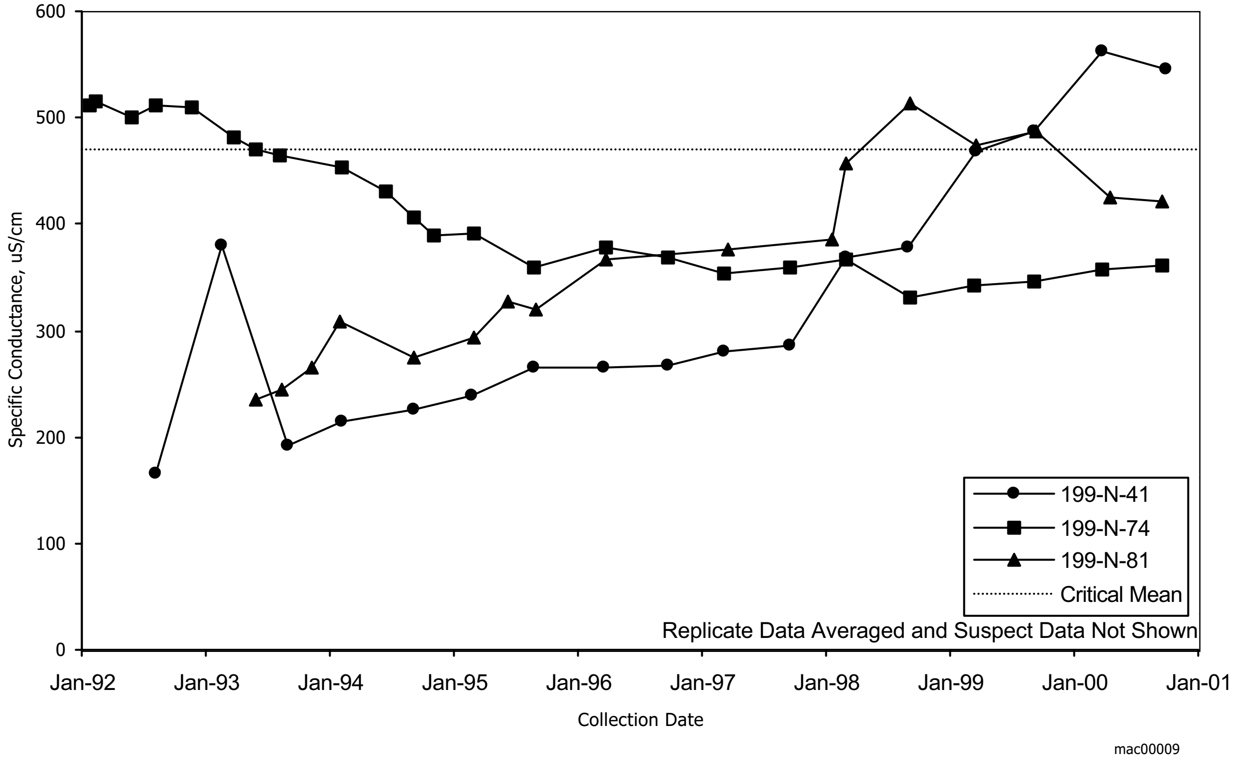

Figure 2.4-6. Specific Conductance in Wells 199-N-41, 199-N-74, and 199-N-81 near the 1325-N Facility

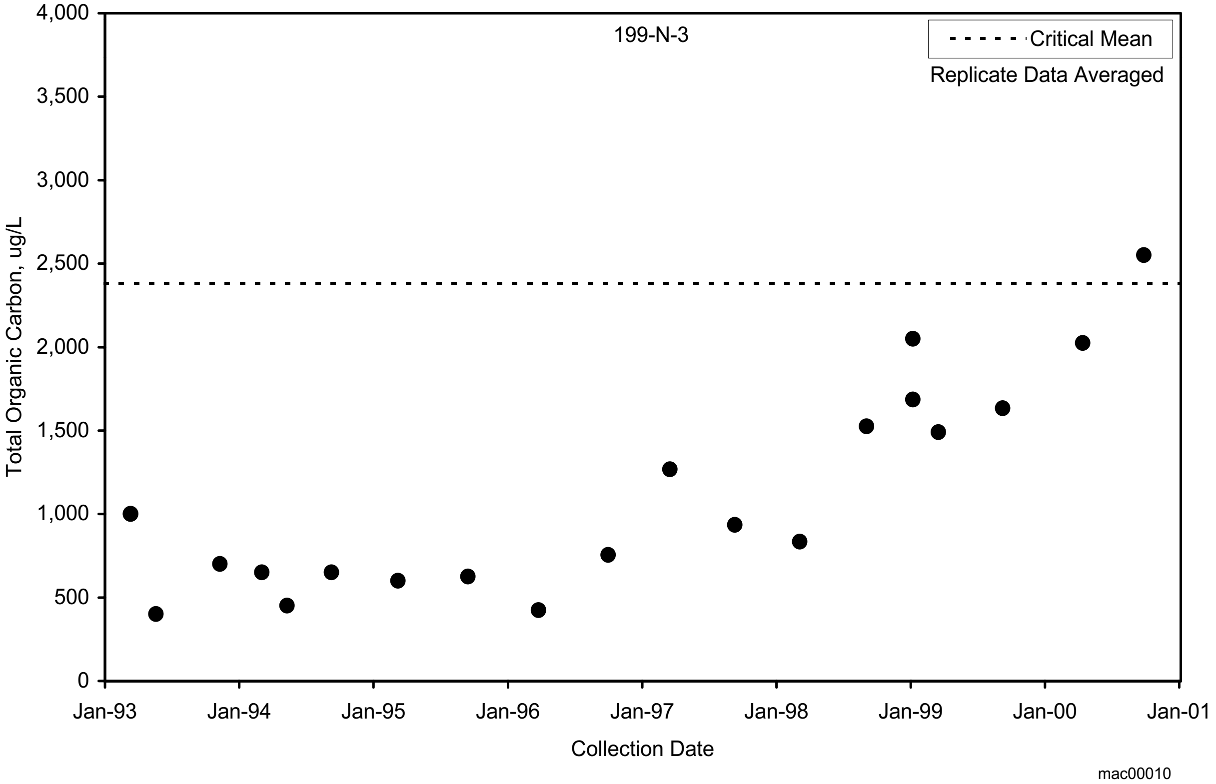

Figure 2.4-7. Total Organic Carbon in Well 199-N-3 near the 1301-N Facility

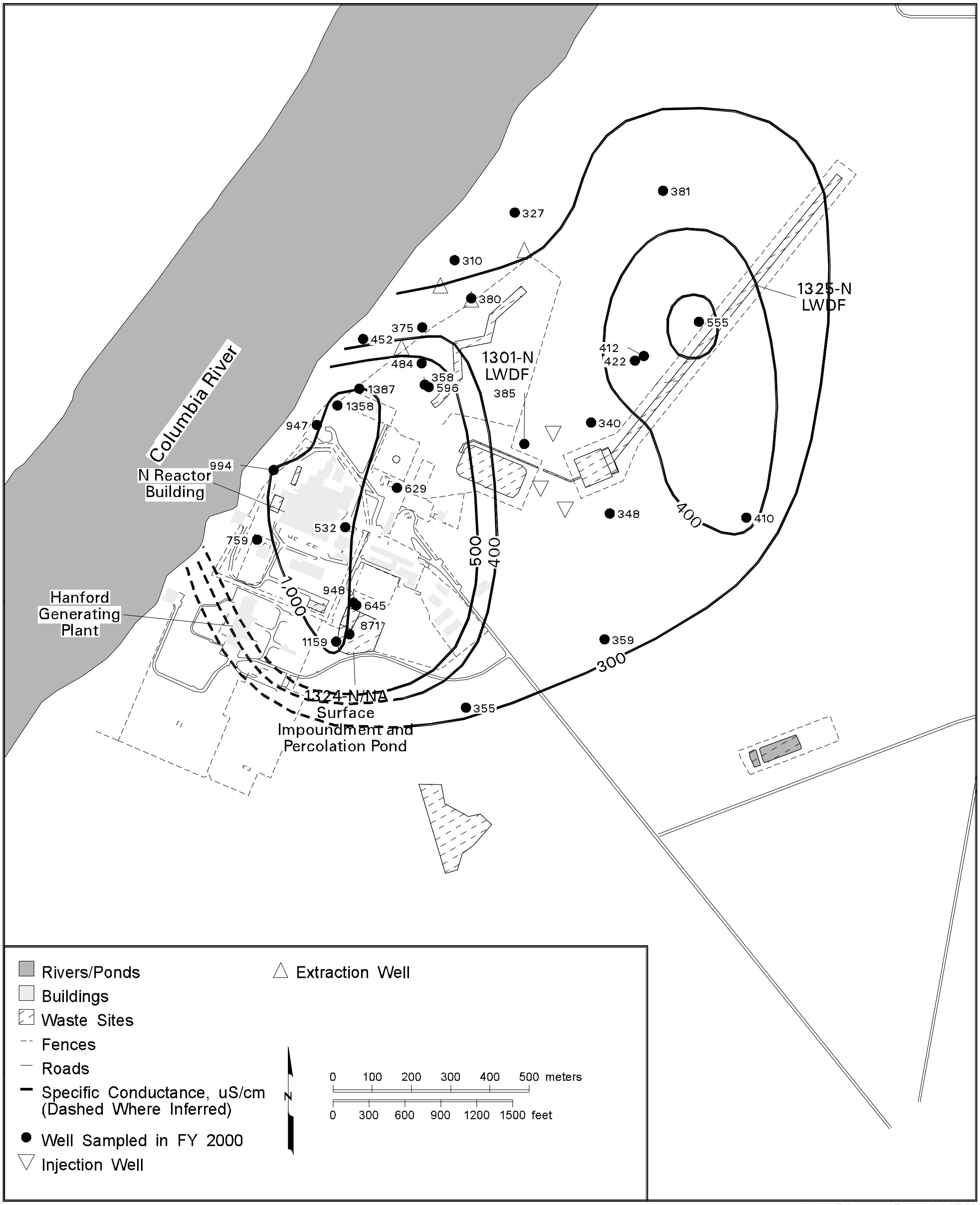

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Figure 2.4-8. Average Specific Conductance in 100 N Area, Top of Unconfined Aquifer

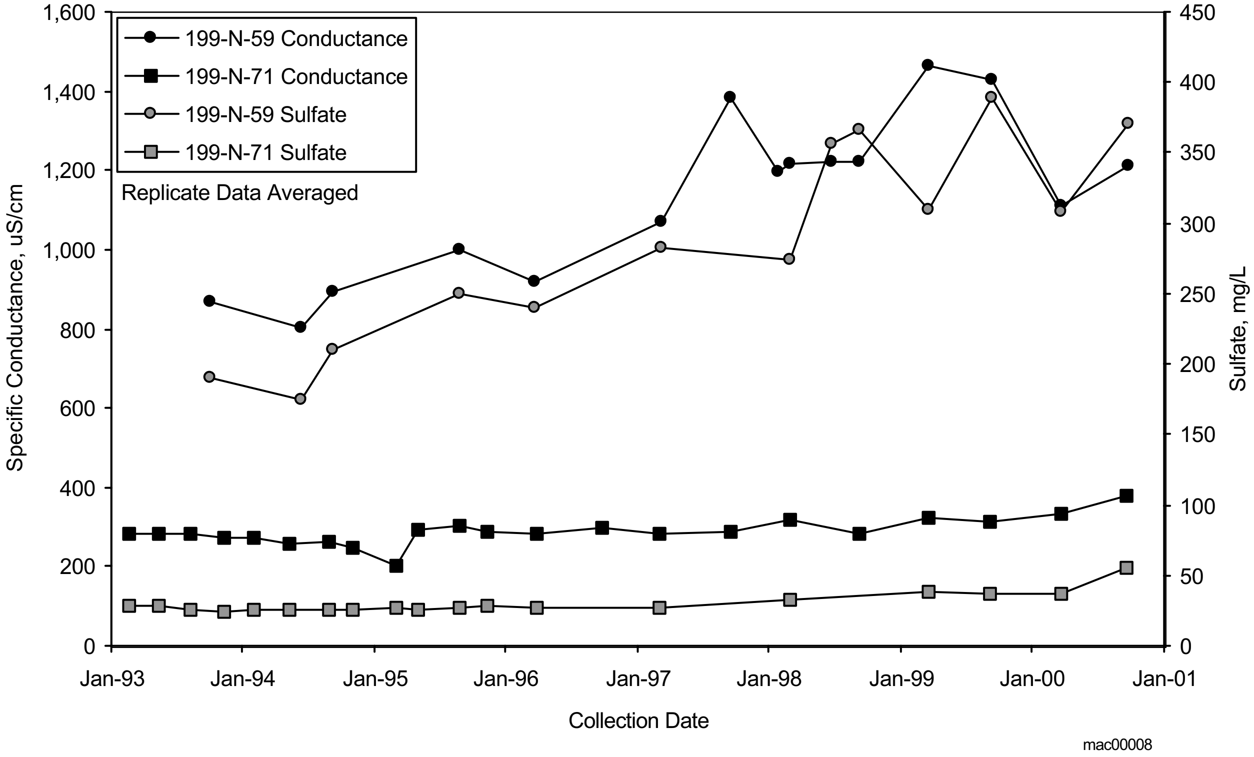

Figure 2.4-9. Specific Conductance and Sulfate in Wells 199-N-59 and 199-N-71 near the 1324-N/NA Facilities

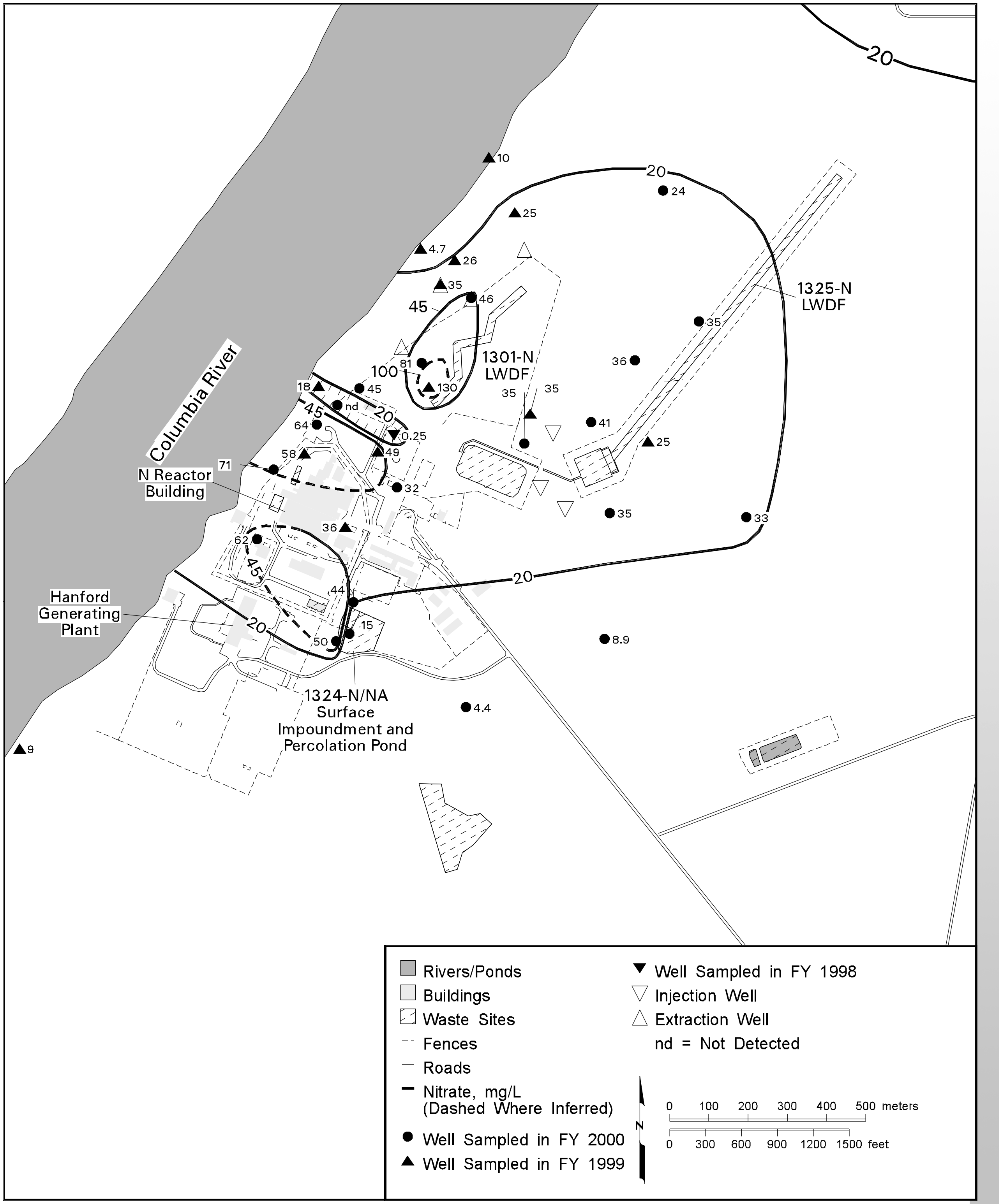

Figure 2.4-10. Average Nitrate Concentrations in the 100 N Area, Top of Unconfined Aquifer

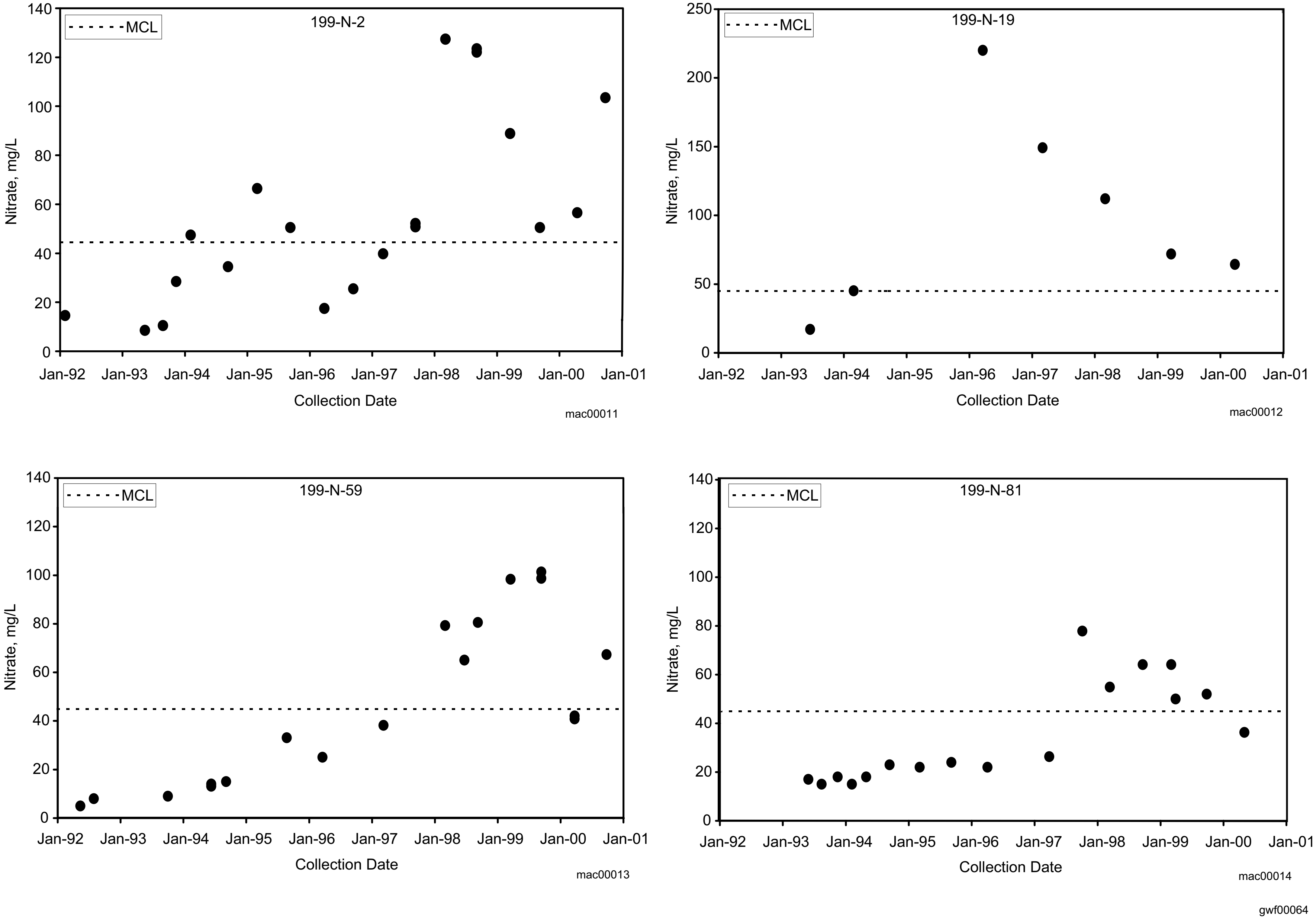

Figure 2.4-11. Nitrate in Wells Monitoring 100 N Area

2.5 100 D Area

M. J. Hartman and W. J. McMahon

The 100 D Area contains two former plutonium production reactors. D Reactor operated between 1944 and 1967 and DR Reactor between 1950 and 1964. Descriptions of operations and associated hazardous waste sites for the 100 D Area are presented in WHC-SD-EN-TI-181. Locations of former waste sites and monitoring wells are shown in Figure 2.5-1.

The presence of hexavalent chromium in groundwater at the 100 D Area is a potential threat to young salmon. The chromium-contaminated groundwater is believed to upwell through the adjacent riverbed gravel used by salmon for spawning habitat. Two remediation systems operate to reduce the amount of chromium entering the Columbia River at 100 D Area.

This section discusses groundwater in four general areas: the northeastern 100 D Area, the former 120-D-1 ponds, the southwestern 100 D Area, and the Columbia River shore.

Hexavalent chromium is the contaminant of greatest concern in the 100 D Area. Two remediation systems help reduce the amount of chromium entering the Columbia River: a pump-and-treat system in the northern 100 D Area and in situ remediating in the southwestern 100 D Area.

2.5.1 D and DR Reactors

This section describes groundwater flow and contamination associated with waste sites near the D and DR Reactors and near retention basins and disposal trenches farther north. The most prevalent contaminant is chromium. Nitrate and tritium are also elevated in broad plumes, while strontium-90 is above drinking water standards locally. A pump-and-treat system in the northern 100 D Area decreases the amount of chromium reaching the Columbia River.

Aerial view of the 100 D Area, August 2000.

00080127-55df

2.5.1.1 Groundwater Flow

Groundwater in the northern 100 D Area flows to the north (see Plate 1). The distribution of contaminant plumes with sources near the reactor buildings confirms this direction of flow. During periods of high river stage in the spring and early summer, groundwater may flow toward the northeast. This effect, which is generally short-lived, is more pronounced in the north and northwest, closer to the Columbia River. Extraction wells 199-D4-53 and 199-D4-54A have created a depression in the water table north of the retention basins (see Plate 1). Groundwater flows radially toward these wells in the immediate vicinity.

Monitoring Objectives in 100 D Area

Groundwater monitoring is conducted in the 100 D Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- quarterly to characterize chromium and sulfate distribution
- quarterly to evaluate the performance of in situ remediation of chromium
- various time intervals to evaluate the performance of a pump-and treat system for chromium.

2.5.1.2 Chromium

The area around the D Reactor building is a primary source for a chromium plume that extends northward toward the river (Figure 2.5-2). The former retention basins and disposal trenches in the north also were contaminant sources. The plume did not change significantly in fiscal year 2000. The center of this plume had annual average concentrations up to 830 µg/L in well 199-D5-14, which is a typical level for the past three years.

Chromium concentrations declined sharply in well 199-D5-15 in fiscal year 1999, and remained low in fiscal year 2000 (Figure 2.5-3). The recent decrease, and a similar dip in the winter of 1996-97, were associated with lower specific conductance. Nitrate and tritium concentrations also declined during these periods (see Figure 2.5-3). These low chromium concentrations may be related to infiltration of fresh water from the surface. The 1996 low was linked to a leaking water line near the well. That line was blocked and is currently not in use. Other wells in the central 100 D Area have low chromium concentrations (see Figure 2.5-2), which are associated with low specific conductance, low nitrate, and low temperature, all suggesting infiltration of water, possibly from the 182-D water reservoir. However, specific conductance and nitrate distributions suggest a separate infiltration source near well 199-D5-15.

A pump-and-treat system in the northern 100 D Area removes chromium-contaminated groundwater to prevent it from reaching the Columbia River (see Section 2.5.1.7). Chromium concentrations vary seasonally, as shown for compliance monitoring wells in Figure 2.5-4. The highest concentrations generally are measured during the late fall and winter months, when the river stage is lowest. The lowest concentrations are measured in late spring and early summer months when runoff caused by snowmelt drains through the Columbia River and its tributaries. The concentrations of chromium measured in well 199-D8-68 varied the most during the past year, from 21 µg/L in June, when the river stage was relatively high, to 323 µg/L in September, when the river stage was lower. Wells 199-D8-69 and 199-D8-70 showed similar patterns, but with less overall variability. None of the wells indicates an increasing or decreasing trend in chromium concentrations over the past four years.

Chromium concentrations in wells near the Columbia River increase when the river stage is low and decrease when the river is high. The data do not show any clear overall trend over the past three years.

Chromium concentrations in the extraction wells also fluctuate with river stage (Figure 2.5-5). The start of pump-and-treat operations coincided with the second consecutive flood stage years in the Columbia River during 1996 and 1997, and chromium concentrations were low during those years. Chromium concentrations increased again in 1998, but have remained lower than they were before the pump-and-treat system began to operate.

2.5.1.3 Nitrate

Nitrate is widely distributed in the 100 D Area at concentrations up to approximately twice the 45 mg/L maximum contaminant level. In fiscal year 2000, the highest nitrate concentrations in the northeastern 100 D Area were near DR reactor (95 mg/L) and D reactor (87 mg/L). Nitrate concentrations have increased in these wells since fiscal year 1999, but long-term trends are variable.

Like chromium and tritium, nitrate concentrations are low in the central 100 D Area, especially downgradient of the 182-D water reservoir. Levels also dropped sharply in well 199-D5-15, near D Reactor, in fiscal year 2000.

2.5.1.4 Tritium

Tritium is above background levels in the eastern 100 D Area (see Plate 2), but concentrations declined below the drinking water standard in fiscal year 2000. Many of the wells in the central 100 D Area continued to have low tritium concentrations (<2,000 pCi/L) as a result of the influence of the Columbia River and artificial recharge with fresh water (see Section 2.5.1.2).

2.5.1.5 Strontium-90

Until its decommissioning in 1999, well 199-D5-12, near D Reactor, consistently had elevated strontium-90 (~30 pCi/L). The contamination was presumably related to past disposal of radionuclide-bearing effluent from the D Reactor fuel storage basin to cribs located nearby. There were no strontium-90 data from nearby wells in fiscal year 2000. Wells 199-D5-14 and 199-D5-16 had no detectable strontium-90 in the past, while well 199-D5-15 had sporadic detections up to 2.4 pCi/L in the mid-1990s. As discussed in Section 2.5.1.2, there is evidence of infiltration of fresh water from an unknown source near well 199-D5-15. To investigate the possibility that this fresh water mobilizes contamination in the vadose zone, strontium-90 will be analyzed in samples from this well in fiscal year 2001.

In the northern 100 D Area, strontium-90 concentrations are above background levels in several wells near the pump-and-treat system but are below the 8-pCi/L drinking water standard with one exception. Well 199-D8-68 has shown widely variable strontium-90 concentrations during its four year history and contained 5 to 8 pCi/L in fiscal year 2000. The overall trend appears to be downward. Other wells in the area have strontium-90 concentrations ranging from undetected to ~2 pCi/L.

2.5.1.6 Waste Site Remediation

Waste sites in the northern 100 D Area, cribs and trenches near D and DR Reactors, and a former sodium dichromate pump station near the 183-D filter plant were remediated in fiscal year 2000 (Table 2.5-1). Remediation consisted of removing and stockpiling clean soil and excavating contaminated soil and debris for disposal. Water (obtained from fire hydrants) was applied as necessary to control dust. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to the groundwater. The ground surface of sites that currently remain open were stabilized with a fixative to control the migration of dust. Some of the excavations were backfilled with clean soil in fiscal year 2000; others will be backfilled in fiscal year 2001.

Contaminated soil from many of the former waste sites in the 100 D Area has been excavated and disposed, reducing the potential for migration of contaminants from the vadose zone into groundwater. The excavated sites include former retention basins, cribs, and process effluent pipelines.

Hexavalent chromium was detected in deep zone soil beneath the former 116-D-7 retention basin, a concrete-lined structure used to hold cooling water from D Reactor before it was released to the Columbia River. To investigate this problem, Pacific Northwest National Laboratory conducted a leach rate study on hexavalent chromium using 116-D-7 soils. The results of this study, summarized in Section 3.1.4 of PNNL-13116, indicated that there is little soluble chromium in the vadose zone sediment beneath the former retention basin.

2.5.1.7 Groundwater Remediation

A pump-and-treat system operates in the 100 D Area as part of an interim action for the 100-HR-3 Operable Unit, primarily to protect aquatic receptors in the river bottom substrate by reducing the discharge of chromium to the Columbia River. The system is located north of the former 116-D-7 and 116-DR-9 retention basins and began operating in July 1997. Groundwater is pumped from extraction wells 199-D8-53 and 199-D8-54A, then is piped to the 100 H Area, where it is treated and discharged.

Interim Remedial Action Objectives

The record of decision (ROD 1996b) contains the following specific remedial action objectives:

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

During fiscal year 2000, the pump-and-treat system removed 22 kilograms of chromium from 100 D Area groundwater.

The record of decision stipulates that the pump-and-treat system continue operating until the selection of the final remedy, or when the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. The system may be shut down when the concentration of hexavalent chromium is below 22 μg/L in the compliance wells (199-D8-68, 199-D8-69, and 199-D8-70), and the data indicate that the concentration will remain low. Other criteria for terminating pump-and-treat operations include the effectiveness of the treatment technology does not justify continued operation or an alternative and superior treatment technique becomes available (ROD 1996b).

Remediation Progress During Fiscal Year 2000

The pump-and-treat system made progress toward achieving the remedial action objectives in 100 D Area during fiscal year 2000. Groundwater that flows beneath the most significant waste sites in this area (retention basins, trenches, and cribs) is prevented from reaching the Columbia River. A complete description of the progress and effectiveness of the remedial action is presented in DOE/RL-2000-01.

Although designed primarily to prevent or reduce the amount of contaminated groundwater discharging into the Columbia River, the pump-and-treat system also is reducing overall contamination in the operable unit by the process of contaminant mass removal. The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and treatment system operation data to assess performance of the treatment system and to provide the basis for selecting the final remedy as part of the record of decision.

During fiscal year 2000, the pump-and-treat system in 100 D Area extracted ~135 million liters of groundwater, removing 22 kilograms of chromium (Table 2.5-2). The withdrawn water was sent to the 100 H Area, where it was treated and injected into the aquifer. A total of ~73 kilograms of hexavalent chromium has been removed from the plume targeted for interim action since startup of the pump-and-treat system in July 1997. This is in addition to the ~30 kilograms removed earlier by the pilot test conducted between August 1992 and August 1994 (DOE/RL-95-83). An estimate for the total amount of chromium in the plume suggests a mass of 590 kilograms (DOE/RL-94-95). This estimate was prepared before the discovery of chromium in the southwestern 100 D Area. Uncertainty in this estimate is associated primarily with the sparse distribution of monitoring wells and the lack of data on the vertical distribution of chromium in the aquifer. The value should be viewed as an order-of-magnitude estimate.

Influence on Aquifer Conditions

Chromium trends in extraction and compliance monitoring wells were discussed in Section 2.5.1.2 and illustrated in Figures 2.5-4 and 2.5-5. Because the concentration of chromium shows a cyclical pattern, an overall trend in concentration over the last 3 years is difficult to identify. The concentration has declined below 22 µg/L in the extraction and compliance wells three times: during summer 1997 (all five wells), summer 1999 (all except compliance well 199-D8-70), and summer 2000 (compliance well 199-D8-68 only). However, the concentration of chromium rebounded above the action level by the following September. Because of the recurring elevated concentration of chromium in the compliance wells, the annual summary report (DOE/RL-2000-01) recommended continued operation of the pump-and-treat system. Contaminant data indicate that many years of pumping may be required before the remedial action objectives have been entirely satisfied.

2.5.2 120-D-1 Ponds

The 120-D-1 ponds (commonly known as D ponds) received effluent from a water treatment plant and related facilities from 1977 until 1994. The site was formerly regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA), but was clean closed in fiscal year 1999. This means that all dangerous waste constituents or residues have been removed and no groundwater monitoring is required for RCRA. Some of the wells near the ponds continue to be monitored for requirements of CERCLA and the *Atomic Energy Act of 1954*.

Groundwater generally flows toward the north beneath D Ponds (see Plate 1). When the stage of the Columbia River is high, flow direction is inferred to be toward the northeast.

The ponds were located over piles of power plant ash, which appear to have created a unique groundwater chemistry. When the ponds were in use, artificial recharge diluted concentrations of metals and anions in groundwater, and these effects extended as far as upgradient well 199-D5-13. Figure 2.5-6 shows changes in major ion chemistry between 1992, when the ponds were in use, and fiscal year 2000, when the effects of dilution had dissipated. In 1992, the chemical signature of downgradient well 199-D8-6 and upgradient wells 199-D5-13 and 199-D5-14 were all very similar, i.e., calcium and sulfate/bicarbonate were the dominant ions. The wells nearer the ponds had lower concentrations of ions as a result of dilution. Fiscal year 2000 data show the chemical signature at upgradient well 199-D5-14 has not changed. Well 199-D5-13 had the same general signature in 2000 as in 1992, but groundwater has become less dilute, as expected. The chemical signature at well 199-D8-6, adjacent to the ponds, has changed dramatically. Calcium, chloride, nitrate, and sulfate all increased to levels higher than at either upgradient well, while bicarbonate decreased sharply. Chloride, nitrate, and sulfate were high in coal ash slurry leachate (WHC-EP-0666), so their presence in groundwater is probably linked to the ash. Nitrate concentrations continued to increase in wells 199-D8-4 and 199-D8-6 in fiscal year 2000, reaching 100 mg/L. These effects are expected to wane in the future, as water drains out of the vadose zone beneath the ash piles.

Ash piles under the former D Ponds have created a unique groundwater chemistry. In fiscal year 2000, calcium, chloride, nitrate, and sulfate were elevated in wells adjacent to the former ponds, while bicarbonate decreased sharply. The groundwater chemistry is probably related to effects of the coal ash.

2.5.3 Southwestern 100 D Area

This section describes groundwater flow and contamination in the southwestern 100 D Area, which contains the highest concentrations of chromium measured in groundwater on the Hanford Site. An innovative technique for groundwater remediation, using principles of reduction and oxidation (redox), is transforming hexavalent chromium to a less toxic, less mobile form (trivalent chromium).

The source of the chromium contamination in the southern 100 D Area is believed to be the former 183-DR filter plant, where chromate was added to water as a corrosion inhibitor. However, recent attempts to locate a vadose zone source of chromium have been unsuccessful (see Section 3.1.3). One of the boreholes drilled during this characterization work was completed as monitoring well 199-D2-8.

2.5.3.1 Groundwater Flow

Based on the water-table map for March 2000 (Plate 1), the direction of groundwater flow was toward the northwest, approximately perpendicular to the Columbia River. This flow direction is present during times of low to average river stage. Field tests in 1997 and 1998 indicate a flow direction to the west-northwest, with a typical flow rate of 0.3 meter per day (PNNL-13349). Flow is temporarily to the northeast when river stage is high.

2.5.3.2 Chromium

The chromium plume in the southwestern 100 D Area is long and thin, oriented perpendicular to the Columbia River (see Figure 2.5-2). The highest average concentrations in fiscal year 2000 remained over 2,000 μg/L in wells 199-D4-15 and 199-D5-43.

A chromium plume in the southwestern 100 D Area contains the highest concentrations of hexavalent chromium anywhere on the Hanford Site. Concentrations continued to exceed 2,000 μg/L in fiscal year 2000. The plume is the target of an in situ remediation technique.

A groundwater cleanup technique called in situ redox manipulation is being used to remediate this chromium plume (see Section 2.5.3.4). Well locations are illustrated in Figure 2.5-7. A chemical solution injected into the aquifer alters sediment chemistry and forms a treatment zone. As groundwater naturally flows through the treatment zone, chromium is immobilized. The technique was tested in fiscal years 1997 through 1999, using five injection wells, and was expanded to ten additional wells in fiscal year 2000. Chromium concentrations are now low in a small area of the plume, and trend plots show the effects of remediation (Figure 2.5-8). Specific conductance trends are also shown in the figure because the injected chemical solution contained high concentrations of sulfate, sodium, and other ions that cause specific conductance to increase.

Wells within the treatment zone (e.g., 199-D4-7, 199-D4-4) showed sharp declines in chromium concentration after injections in 1997 and 1998, and levels remained low through most of fiscal year 2000. However, there was a sharp increase in chromium in well 199-D4-7 in September 2000, which is not understood. Future sampling will determine if the increase was an anomaly or a sign of a larger problem. Similarly, downgradient well 199-D4-6 has had low chromium concentrations since 1998, but concentrations increased from 19 μg/L in July 2000 to 64 μg/L in September 2000. The increase may have been caused by a slight change in flow direction; quarterly monitoring will continue.

New wells 199-D4-38 and 199-D4-39 are located farther downgradient of the treatment zone. Chromium decreased sharply in both wells between March and September 2000, while specific conductance increased. This suggests that the effects of chemical reduction are beginning to extend farther downgradient, as expected. The September decreases were probably not the result of the most recent injections, which occurred in August and September 2000. The wells are ~70 to 80 meters from the injection wells and there would not have been time for the groundwater to travel that far before the samples were collected in late September. It is more likely that the effects of previous injections in 1998 and 1999 are now being detected in these wells. Chromium remained high (745 µg/L) in well 199-D4-23 in September 2000, indicating that reduction effects had apparently not yet reached that well.

Other effects of the redox technique on groundwater chemistry include decreases in dissolved oxygen and nitrate, and increases in aluminum, iron, manganese, and nitrite. Although iron and manganese are elevated in the treatment zone, they are not expected to be mobile downgradient from the zone because they will re-oxidize and become immobile once they contact untreated sediment. Chromium, however, cannot be re-oxidized to its hexavalent state in the natural oxidizing conditions at the 100 D Area.

2.5.3.3 Tritium

Tritium in the southwestern 100 D Area may have migrated from the 100 N Area (see Plate 2). Concentrations in well 199-D3-2 are declining but remained slightly above the drinking water standard in fiscal year 2000 (20,400 pCi/L). The first tritium data from wells 199-D4-19 and 199-D4-20 were also relatively high (15,400 and 17,300 pCi/L, respectively). Tritium concentrations are much lower in the central 100 D Area.

2.5.3.4 Groundwater Remediation

The amended record of decision for the 100-HR-3 Operable Unit includes use of the in situ redox manipulation technique for interim remediation of groundwater (ROD 1999b). The redox system creates a permeable treatment zone in the aquifer by reducing the ferric iron to ferrous iron within the minerals of the sediment. This reduction was accomplished by injecting a chemical-reducing agent, sodium dithionite, into closely spaced wells. After the aquifer sediment was reduced, reagent and reaction products were pumped out of the wells. The reducing conditions remain in the aquifer because of the change in iron chemistry, and the barrier should remain effective for 23 ± 6 years (PNNL-13349). Hexavalent chromium is immobilized by reduction of the soluble chromate ion (hexavalent chromium) to insoluble chromium hydroxide or iron chromium hydroxide (trivalent chromium). This transformation is particularly advantageous because chromium is not easily re-oxidized under ambient environmental conditions and will, thus, remain immobile.

The redox manipulation technique creates a permeable treatment zone in the aquifer. Sodium dithionite was injected into 11 closely spaced wells in fiscal year 2000 to extend the length of the treatment zone. As groundwater flows through this zone, the hexavalent chromium is converted to the trivalent form, which is virtually immobile in groundwater.

Interim Remedial Action Objectives

The objectives of the redox remedial action are the same as for remediation using pump and treat. These objectives are to protect human health and the environment, and include the following three components:

- protection of aquatic receptors in the river substrate from contamination in groundwater entering the Columbia River
- protection of human health by preventing exposure to contaminants in the groundwater
- provide information that will lead to the final remedy.

The goal of this treatment system is to reduce concentrations of hexavalent chromium to 20 µg/L or less in compliance wells. Groundwater monitoring requirements are described in the remedial design report and remedial action work plan (DOE/RL-99-51).

Remediation Progress During Fiscal Year 2000

The redox system was expanded in fiscal year 2000, after successful tests in 1997 through 1999. Crews installed fourteen new injection wells and two downgradient monitoring wells during the year, extending the length of the treatment zone to 195 meters (the zone will continue to be lengthened to 677 meters by 2002). Details on these wells were published in a well completion report (BHI-01381).

Injections and withdrawals through fiscal year 2000 were conducted in the following wells:

- well 199-D4-7: September 29 through October 8, 1997
- wells 199-D4-9, -10, -11, and -12: May 4 through July 23, 1998
- well 199-D4-21: September 28 through October 15, 1999
- wells 199-D4-26, -27, -28, -29, -30, -31, -33, -34, -35, and -36: August 1 through October 8, 2000.

The withdrawn solution from the most recent series of injections was discharged to a lined evaporation pond east of the site.

Influence on Aquifer Conditions

The *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation* (DOE/RL-99-51) describes the groundwater monitoring program that will be used to assess the effectiveness of the treatment system. The monitoring network includes

- ten barrier injection wells to monitor barrier performance
- seven downgradient wells for compliance monitoring. These include wells 199-D4-23, -38, and -39; the others will be installed in the future.
- thirteen wells throughout the southwestern 100 D Area for general plume tracking
- five aquifer sampling tubes and five river substrate tubes to monitor effects at the Columbia River.

The samples are analyzed for hexavalent chromium, specific conductance, dissolved oxygen, and sulfate to monitor the effects of the remedial action.

Additional wells are also sampled for surveillance monitoring (PNNL-11989):

- wells 199-D4-4, -5, -6, and -7 within the treatment zone
- well 199-D4-22 upgradient of the treatment zone
- well 199-D4-23 downgradient of the treatment zone
- additional wells throughout the southwestern 100 D Area for plume tracking.

Chromium distribution and trends were discussed in Section 2.5.3.2 and illustrated in Figure 2.5-8. Chromium concentrations in compliance well 199-D4-39 declined from 769 µg/L in March 2000 to <5 µg/L in September 2000, but it is too early to say whether this is a long-term change. Concentrations also decreased sharply in compliance well 199-D4-38, from 912 µg/L in March 2000 to 370 µg/L in September 2000. Levels did not decline in compliance well 199-D4-23 (745 µg/L in September 2000).

2.5.4 Water Quality at Shoreline Monitoring Locations

Groundwater near the Columbia River is sampled annually in the late fall via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline. Seeps are natural areas of groundwater discharge above the water line. Table 2.5-3 lists constituents of interest for the 100 D Area for fiscal year 2000.

2.5.4.1 Aquifer Sampling Tube Results

Chromium concentrations in the aquifer tubes reflect the distribution of chromium in groundwater (see Figure 2.5-2). Concentrations were lowest in the central shoreline at tube 36-D, with 3 µg/L. The highest concentrations were in the southwestern chromium plume in tube DD-39-3, at 641 µg/L. Shoreline concentrations in this area are expected to decline in the future, as groundwater flows through the redox remediation system toward the river.

Only one aquifer tube in the 100 D Area was sampled for tritium in fiscal year 2000. Tube DD-44-4, in the southwestern part of the area, detected 15,700 pCi/L. The source of the tritium is believed to be the 100 N Area (see Section 2.5.3.3).

One aquifer tube located near the 116-D-7 retention basin was sampled for strontium-90 in fiscal year 2000. Tube DD-17-3 detected 4.8 pCi/L. Monitoring wells in the same area also detect strontium-90 (see Section 2.5.1.5).

Chromium continued to exceed its maximum contaminant level in groundwater samples collected from aquifer sampling tubes and riverbank seeps along the 100 D Area shoreline.

2.5.4.2 Riverbank Seepage Results

Three riverbank seep sites were sampled during fall 1999. Specific conductance ranged from 150 to 271 µS/cm. These relatively low levels suggest that the samples contained substantial river water draining from bank storage.

Chromium concentrations of seep samples ranged from 157 µg/L near the upstream limit of the chromium plume in the southwestern 100 D Area to 17 µg/L downstream near the 100 D Area pump-and-treat compliance wells.

Tritium concentrations ranged from 8,890 pCi/L in the upstream seep, nearest 100 N Area, to undetected in a downstream seep. Strontium-90 was 0.6 pCi/L or lower in the two seeps sampled for this constituent.

2.5.4.3 Special Shoreline Investigations

An investigation of the hydraulic characteristics of the uppermost hydrologic unit at the 100 Area shoreline is currently underway as part of a masters' degree research project.(a) The project is using small diameter well casings driven several meters below the riverbed to obtain hydraulic and water quality data. Tests to determine the hydraulic conductivity, specific discharge, and water chemistry of the subsurface will be performed. The objective is to better define local variability in hydraulic properties, which would contribute to improved understanding of contaminant transport.

(a) Arntzen, E. May 200l. Master's degree research project in progress: "In Situ Hydraulic Testing and Water Quality Sampling in the Hyporheic Zone of the Columbia River, Hanford Reach, Washington." Portland State University, Portland, Oregon.

Table 2.5-1. 100 D Area Waste Sites Remediated in Fiscal Year 2000

Waste Site Designation	Period of Excavation (Fiscal Years)	Backfilled (Fiscal Year)	Approximate Depth of Excavation (meters)
Sites Located in the Northern 100 D Area			
116-D-7 and 116-DR-9 retention basins	1998, 1999	2000	4.6
1607-D2 septic tank and pipeline	1998, 1999	2000	3
116-DR-1 and 116-DR-2 process effluent trenches	1999, 2000	2000	4.6
Process effluent pipelines			
- segment from D Avenue to retention basins	1999, 2000	2000	3.7 to 4.6
- segment from retention basins to river outfall structure	1999, 2000	planned 2001	3.7 to 4.6
100-D-4, D-18, and D-19 sludge trenches	1999, 2000	planned 2001	4.6
Sites Located near D Reactor Building			
100-D-52 dry well	2000	planned 2001	9.1
116-D-3 crib or French drain (also known as 116-D-4)	2000	planned 2001	3
116-D-6 French drain	2000	planned 2001	4.6
116-D-1A and -1B trenches (and co-located 100-D-46 burial ground)	2000	planned 2001	4.6
116-D-2 crib	2000	planned 2001	4.6
116-D-9 crib	2000	planned 2001	4.6
Process effluent pipelines from D and DR reactors to D Avenue, and co-located 100-D-5 and D-6 burial grounds	2000	planned 2001	3 to 5.5
Sites Located near DR Reactor Building			
116-DR-4 crib	2000	2000	4.6
116-DR-6 trench	2000	2000	4.6
116-DR-7 tanks	2000	2000	4.6
Site Located near 183-D Filter Plant			
100-D-12 sodium dichromate pump station	2000	planned 2001	4.6

Table 2.5-2. Summary of 100 D Area Pump-and-Treat Performance for Fiscal Year 2000

Well or Sample Location	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped (x 10^6 L)	Average Chromium Concentration (µg/L)	Chromium Mass Removed (kg)
199-D8-53	135	152	64.2	118	7.13
199-D8-54A	149	154	71.3	214	14.76
Total	--	--	135.6	--	21.89

Data source: Project specific database for the 100-HR-3 Operable Unit.

Table 2.5-3. Shoreline Monitoring Data for the 100 D Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
36-D	Tube	11-Nov-99	311	3				
DD-06-2	Tube	04-Nov-99	208	6				3.0
DD-12-2	Tube	04-Nov-99	193	6				
DD-17-3	Tube	03-Nov-99	288	160	4.8	10.5		
DD-39-3	Tube	08-Nov-99	545	641				
DD-44-4	Tube	04-Nov-99	478	330			15,700	
SD-098-1	Seep	27-Oct-99		17		4.3	8,890	7.9
SD-102-1	Seep	27-Oct-99	271	157	0.4	3.9	***108***	18.2
SD-110-1	Seep	27-Oct-99	150	23	0.6	2.9	272	3.7
36-D	River	11-Nov-99	121					
DD-06-2	River	04-Nov-99	121					
DD-12-2	River	04-Nov-99	121					
DD-17-3	River	03-Nov-99	129					
DD-39-3	River	08-Nov-99	122					
DD-44-4	River	04-Nov-99	125					

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore, adjacent to the aquifer sampling tube.

Values in ***bold italics*** are qualified by the laboratory as “undetected.” Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350-450 µS/cm.

Data sources: Hanford Environmental Information System and various project records.

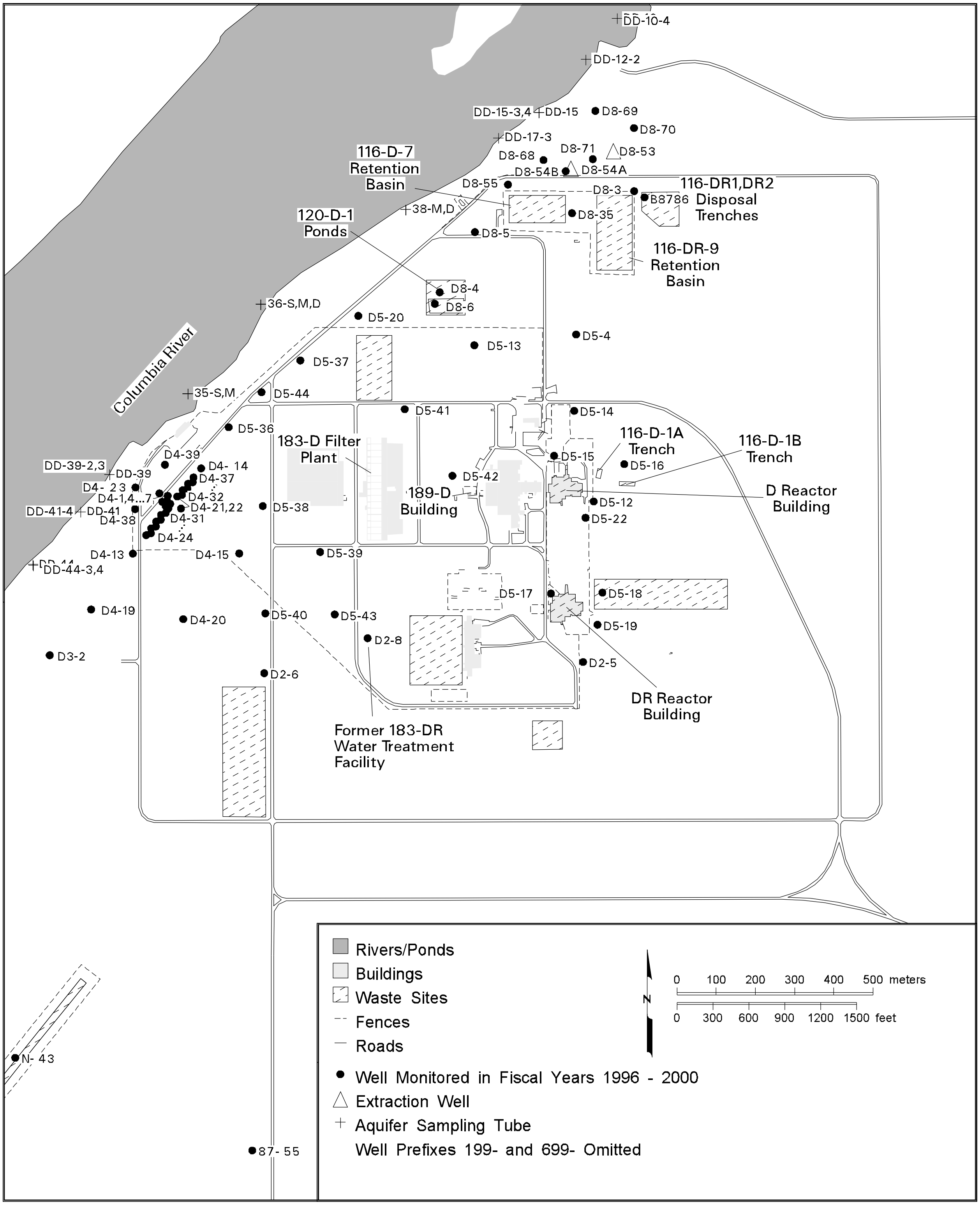

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Figure 2.5-l. Groundwater Monitoring Wells in the 100 D Area

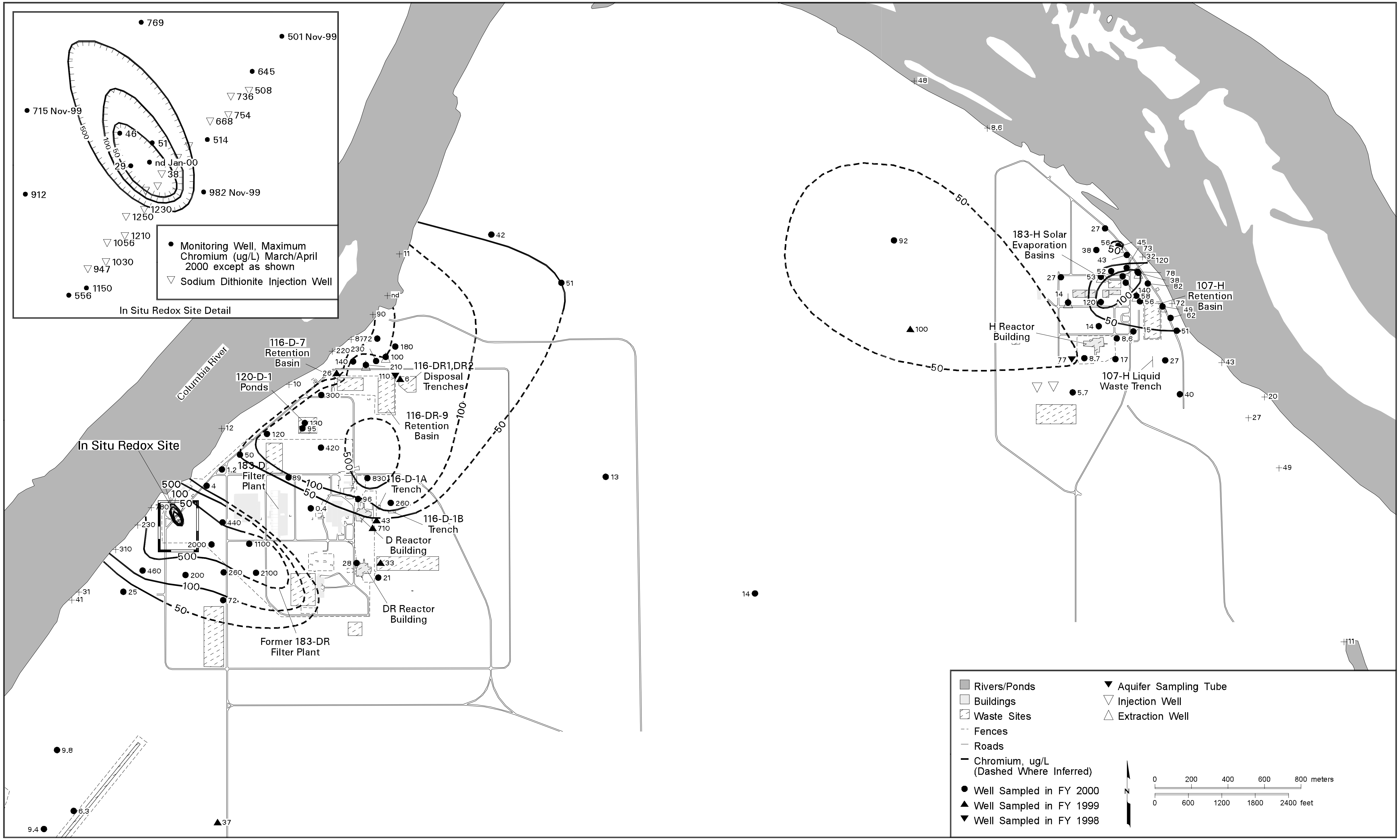

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Figure 2.5-2. Average Chromium Concentration in the 100 D and 100 H Areas, Top of Unconfined Aquifer

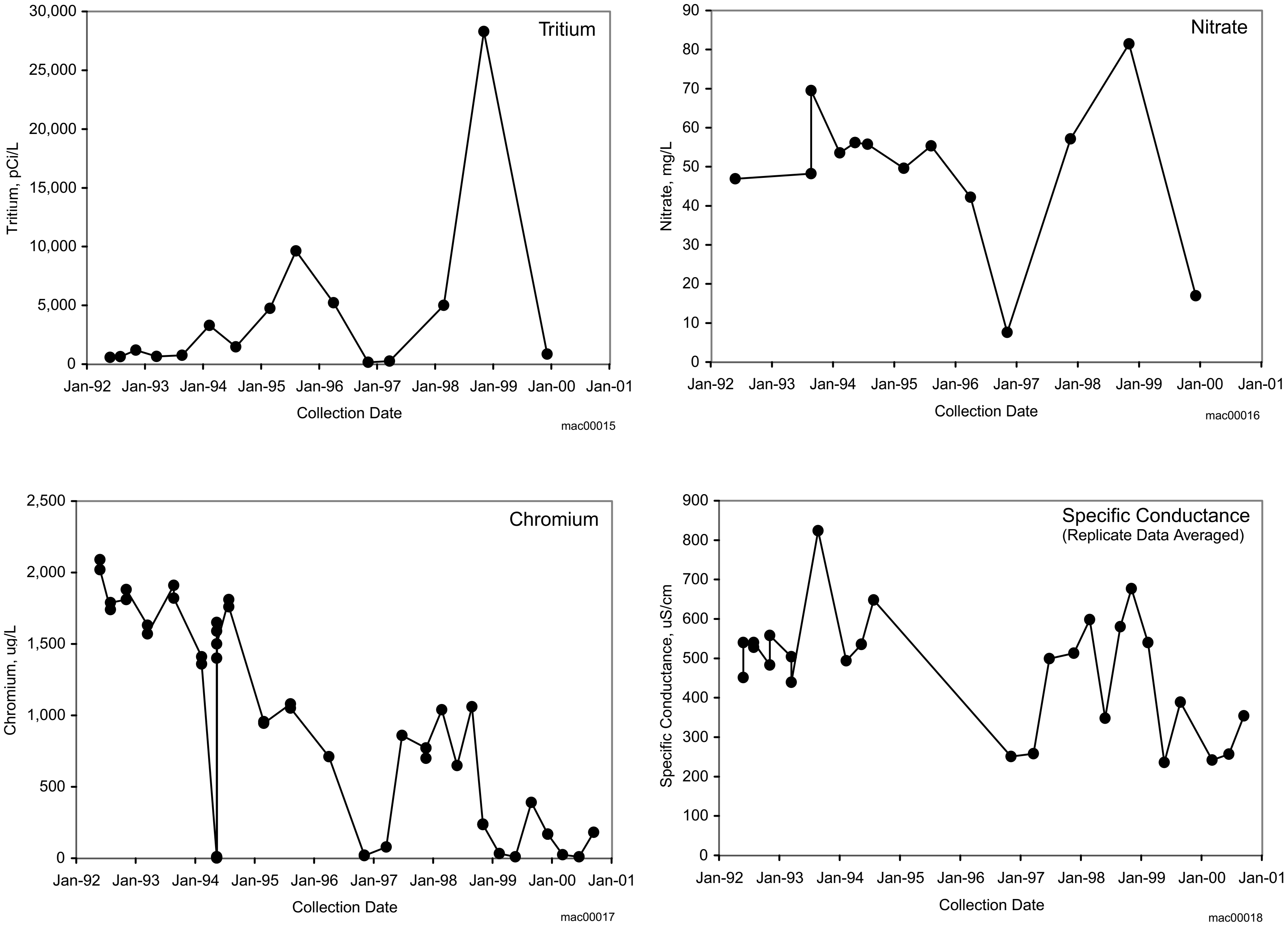

Figure 2.5-3. Tritium, Chromium, Nitrate, and Specific Conductance in Well 199-D5-15 near the D Reactor

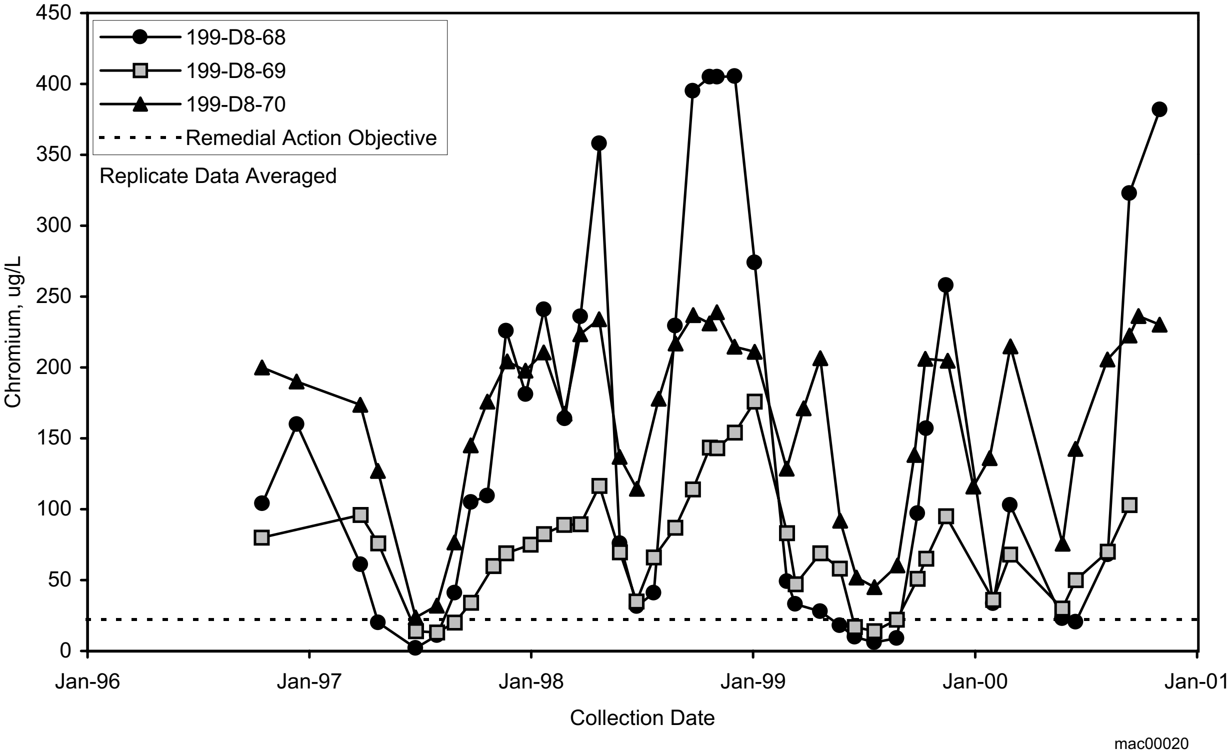

Figure 2.5-4. Chromium in Compliance Wells for the 100-HR-3 Pump-and-Treat System at 100 D Area

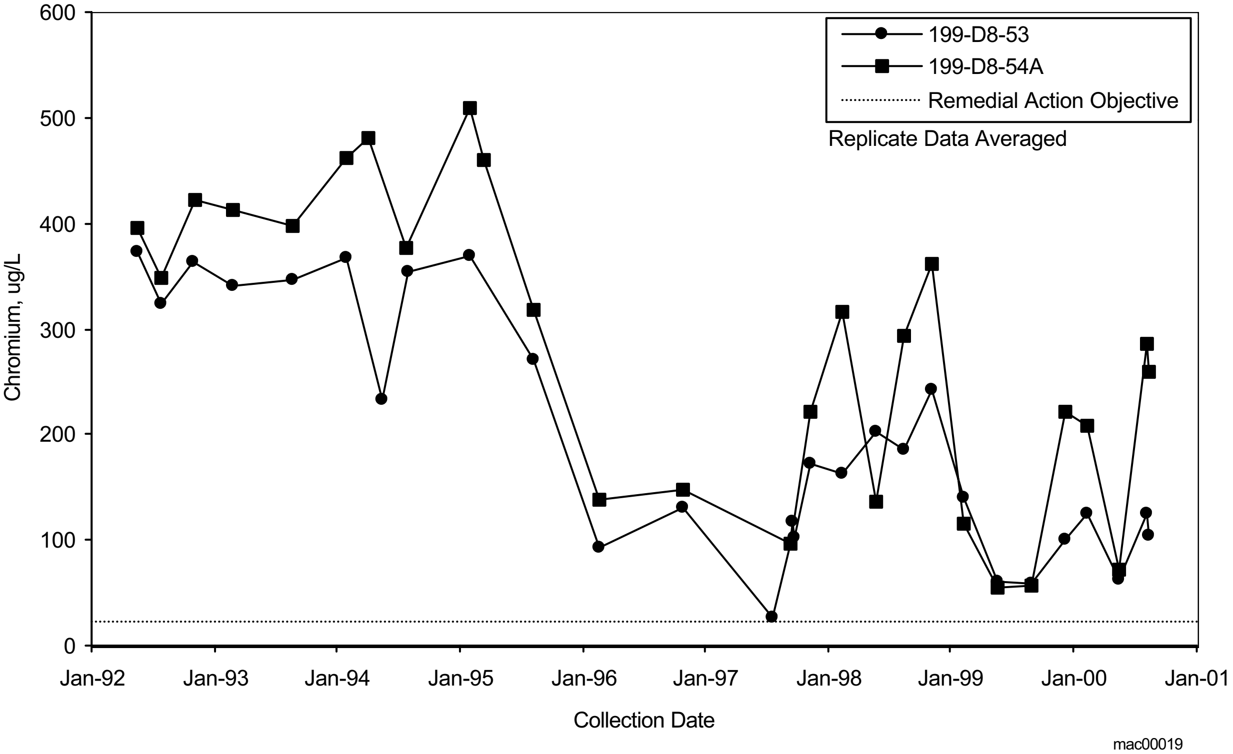

Figure 2.5-5. Chromium in Extraction Wells for the 100-HR-3 Pump-and-Treat System at 100 D Area

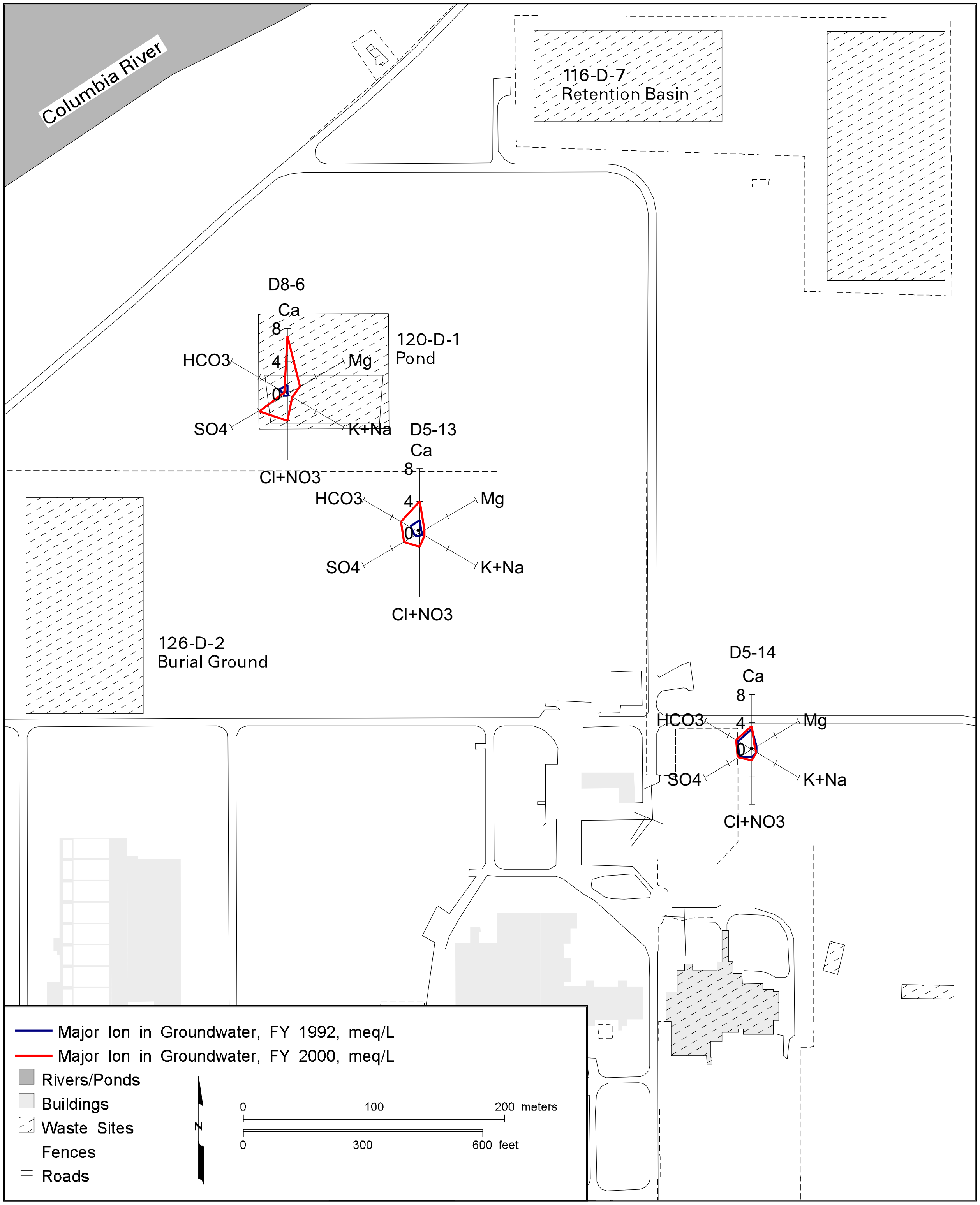

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Figure 2.5-6. Major Ion Chemistry in Wells near the Former 120-D-1 Ponds

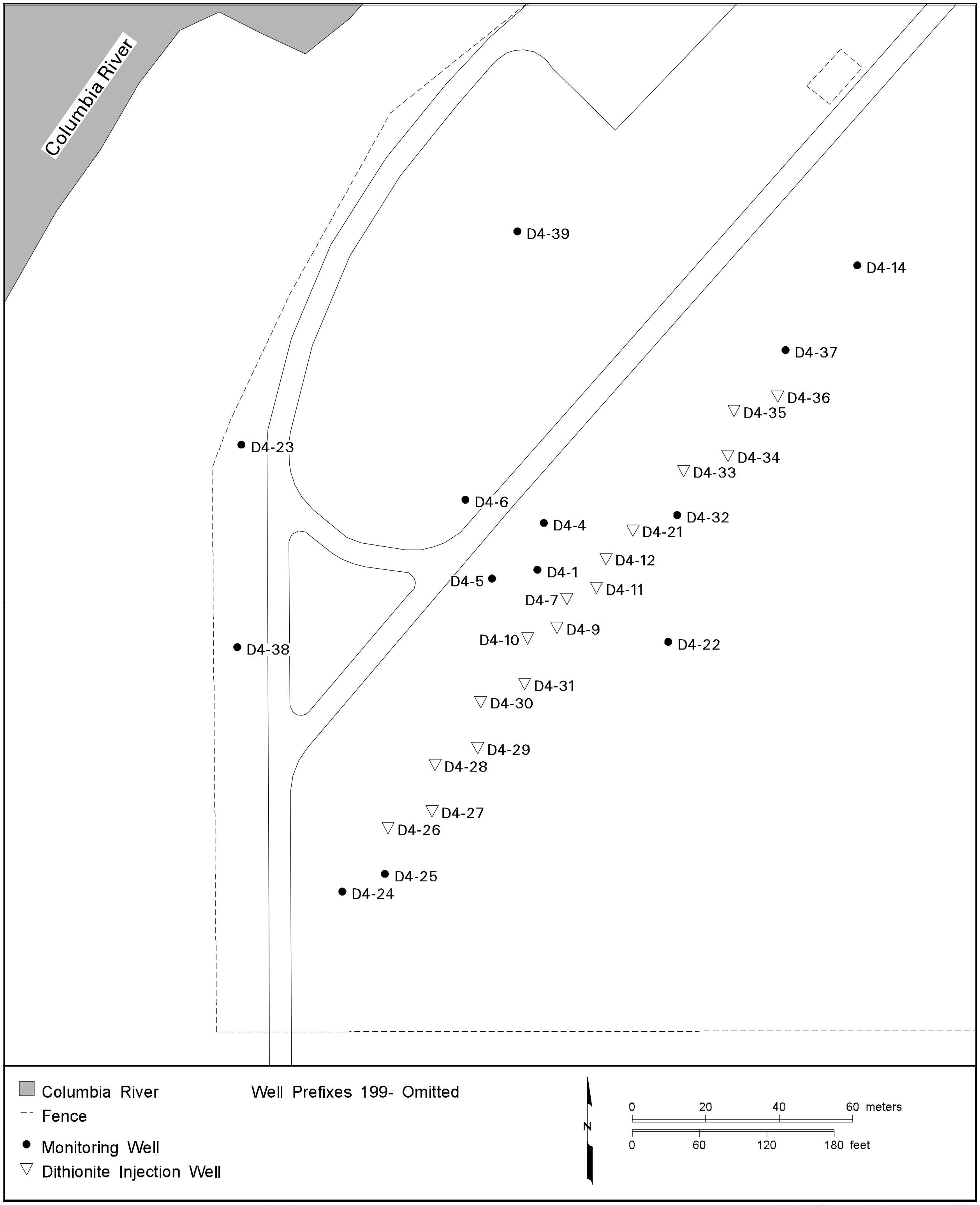

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Figure 2.5-7. Groundwater Monitoring Wells near the Redox Site at 100 D Area

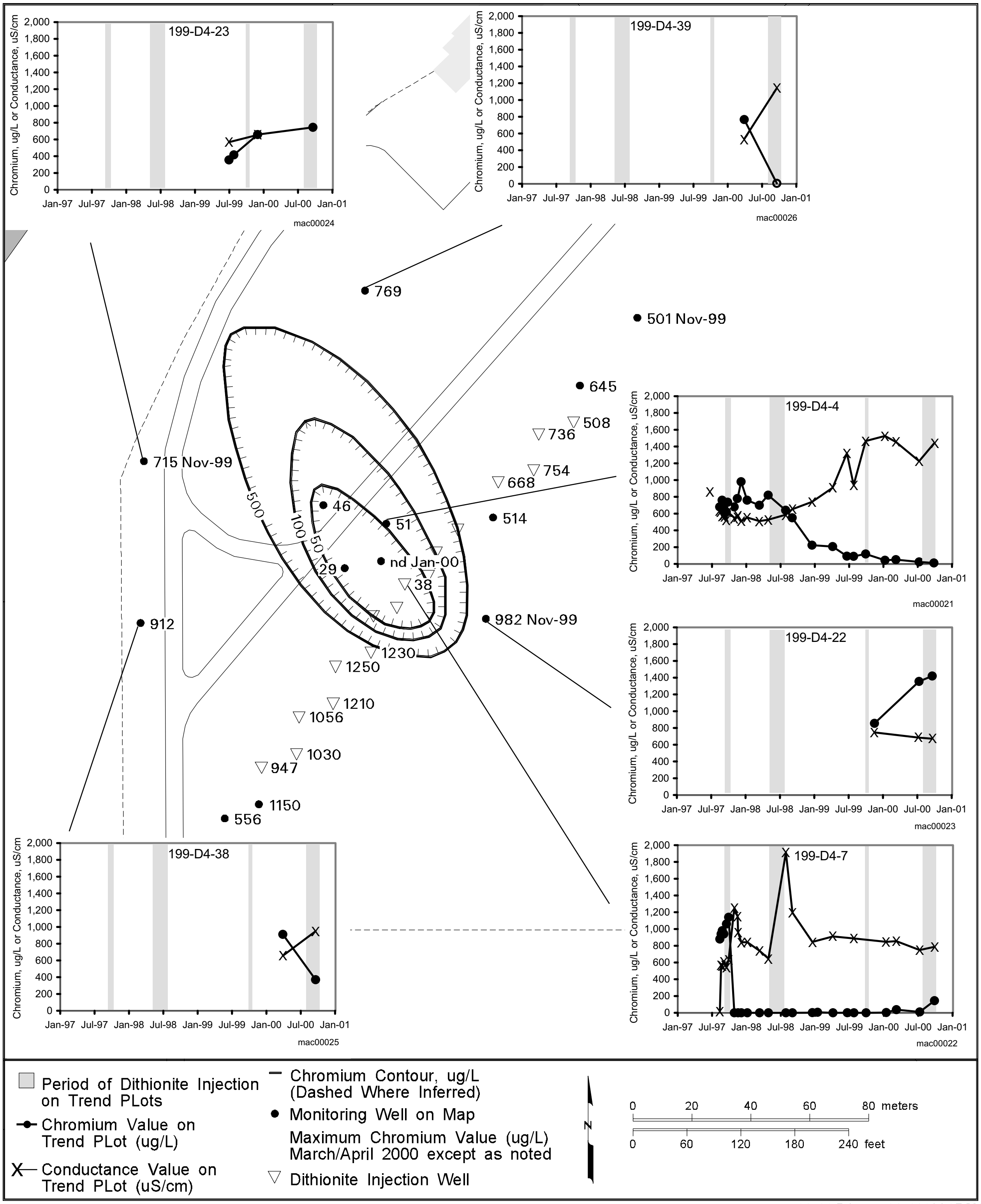

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Figure 2.5-8. Chromium in Wells Monitoring the Redox Remediation Site

2.6 100 H Area

R. E. Peterson, M. J. Hartman, and W. J. McMahon

The H Reactor operated between 1949 and 1965 using a single-pass cooling system. This configuration resulted in large volumes of used coolant being released directly to the Columbia River, following temporary storage in retention basins. The retention basins leaked considerable volumes of coolant, resulting in the formation of mounds on the underlying water table. The mounding caused widespread contamination of the vadose zone by chromium and short-lived radionuclides, and altered the groundwater flow pattern in the area. Coolant that was highly contaminated during periodic fuel element ruptures was discharged to liquid waste disposal trenches located near the retention basins. Starting in 1973, another contributor to groundwater contamination in the 100 H Area was hazardous waste from the 183-H solar evaporation basins, which stored fuel fabrication effluent between 1973 and 1985 (Section 2.6.6). A comprehensive description of 100 H Area operations and waste sites is presented in the technical baseline report for the 100-HR-3 Operable Unit (BHI-00127). Facilities and monitoring wells referred to in the text are shown on Figure 2.6-1. A recent aerial photo of the 100 H Area is shown below.

The presence of chromium in 100 H Area groundwater is a concern because the adjacent riverbed is used by salmon for spawning. Additional groundwater contaminants of interest are nitrate, strontium-90, technetium-99, and uranium.

The presence of chromium in groundwater at the 100 H Area is of concern because of the potential for groundwater to upwell through the adjacent riverbed gravel used by salmon for spawning habitat. Pore water samples collected from gravelly areas used for redds (groups of egg pockets) (BHI-00345) revealed chromium at concentrations above the 11 µg/L standard for protecting aquatic organisms. A pump-and-treat system currently is operating to reduce the rate at which

Aerial view of the 100 H Area, August 2000.

00080127-44df

chromium enters the Columbia River and also the amount of chromium in near-river groundwater (Section 2.6.7).

Excavation of near-surface soil is underway in the 100 H Area to remediate vadose zone contamination beneath the 107-H retention basins, the adjacent liquid waste disposal trench, and associated underground pipelines (Section 2.6.8). These facilities and their underlying soil may contain contaminants that pose a threat to groundwater. The contaminated concrete and soil are being transported to the Environmental Restoration Disposal Facility in the 200 Areas plateau.

The contaminants of potential concern in groundwater beneath the 100 H Area include chemical constituents chromium and nitrate, and radiological constituents strontium-90, technetium-99, tritium, and uranium. Organic constituents are not present at levels of concern. Groundwater approaching the 100 H Area from the west is contaminated by chromium and tritium, which presumably originated from past disposal in the 100 D Area and possibly the 100 N Area. The following sections describe the movement of groundwater beneath the 100 H Area and the contaminants of concern in their order of relative significance to environmental restoration issues.

2.6.1 Groundwater Flow

Groundwater movement beneath the 100 H Area is generally southwest to northeast, toward the Columbia River (see Plate 1). Flow through the sandy/gravelly sediment near the water table is relatively rapid and estimated to be within 0.3 to 2.0 meters per day (DOE/RL-93-43). Groundwater flows generally toward the northeast across the entire horn of the Columbia River north of Gable Mountain, so groundwater approaching the shoreline upstream of 100 H Area and along the area may contain contaminants that originated in the 100 D and 100 N Areas.

Monitoring Objectives in 100 H Area

Groundwater monitoring is conducted in the 100 H Area:

- annually to describe the nature and extent of contamination in support of environmental restoration decisions
- annually to monitor conditions beneath the former 183-H solar evaporation basins, a RCRA site
- semiannually to monitor trends in variable constituents/wells
- various time intervals to evaluate the performance of a pump-and-treat system for chromium.

Daily and seasonal river stage fluctuations create corresponding changes in the elevation of the water table, which causes changes in flow direction and may also influence water quality monitoring results. During periods of high river levels, river water infiltrates the banks along the 100 H Area shoreline, causing variable flow directions and mixing between groundwater and river water. Also, the presence of a preferential pathway, potentially created by a former river channel in the sediment of the unconfined aquifer, promotes groundwater flow that is parallel to the Columbia River. This condition is observed in water-table contour maps drawn for the seasonal high water period during May and June (PNNL-11573) and affects groundwater movement up to a distance of ~300 meters inland. The extraction and injection of groundwater associated with the interim remedial action to address chromium contamination also influence the movement of groundwater in the vicinity of the associated wells. This influence is described in Section 2.6.7.

Groundwater flow modeling conducted at 100 H Area during fiscal year 2000 revealed new information on the water movement beneath the shoreline. The two-dimensional model shows that groundwater flow is deflected slightly downward beneath the bank storage zone, and that discharge from the aquifer into the riverbed occurs relatively close to shore. This new information has implications for near-river monitoring strategies and for conducting aquatic habitat risk assessments. This work is described more completely in Section 4.3.

2.6.2 Chromium

Chromium contamination in 100 H Area groundwater originated from sources within the 100 H Area and from upgradient sources in the 100 D Area (see

Figure 2.5-2). Evidence for this is (1) the direction of groundwater flow inferred from water-table elevation maps and (2) the trends in chromium concentration in wells located along the flow path between 100 D Area and 100 H Area. Several 100 H Area wells show recent changes in chromium that may be associated with the arrival of groundwater from west of the 100 H Area containing chromium and tritium. These include wells near the H Reactor building (Figure 2.6-2). Injection of treated effluent from the chromium pump-and-treat system (Section 2.6.7) may also influence the groundwater flow pattern in that area, thus contributing to the observed changes. Chromium concentrations in 100 H Area groundwater are generally below the 100 μg/L drinking water standard, except for a small area associated with the former 183-H solar evaporation basins. However, the more stringent standard for protection of freshwater aquatic organisms (11 μg/L) is exceeded along a portion of the 100 H Area shoreline. The chromium plume in this area is adjacent to gravelly riverbed areas that are heavily used by salmon for spawning (Dauble and Watson 1997). During previous field studies, samples of pore water were obtained from the spawning gravel in this area and found to contain chromium concentrations as high as 130 μg/L (BHI-00345).

Chromium concentrations exceed standards beneath the 100 H Area. Sources include local waste sites and contaminated groundwater migrating into the area.

Chromium concentrations near the approximate center of the plume generally declined during fiscal year 2000 (Figure 2.6-3). Chromium concentrations in well 199-H4-14 historically have been higher than in surrounding wells, presumably because of sodium dichromate releases at the former water treatment facility located near the well. The increased concentrations that started in 1996 in wells 199-H4-16 and 199-H4-18 may be the result of an unusually high water table during 1996 and 1997, which caused a southward displacement of the contaminant plume located to the north of these wells and associated with the former 183-H solar evaporation basins.

Six wells are currently being used at 100 H Area to extract chromium-contaminated groundwater as part of interim remedial actions, which started in July 1997. These wells are distributed throughout the plume area. Figure 2.6-4 shows chromium concentrations in extracted groundwater from wells nearest the Columbia River. Concentrations in wells located farther inland are shown in Figure 2.6-5. A general decline in concentrations with time is apparent, although concentrations vary appreciably in wells nearest the river, as revealed by trend charts for several compliance monitoring wells (Figure 2.6-6). The performance of this interim remedial action is described more fully in Section 2.6.7.

Several anomalous occurrences of chromium are being tracked. The first involves well cluster 199-H3-2A, 199-H3-2B, and 199-H3-2C. Chromium and other constituents showed an unexplained upward trend in the deeper, and presumably uncontaminated, well 199-H3-2C during 1996 (Figure 2.6-7). Well 199-H3-2C is completed in a confined aquifer beneath the overlying unconfined aquifer, which is monitored by wells 199-H3-2A and 199-H3-2B. In late summer 1996, the water quality observed in well 199-H3-2C became similar to that of water from the shallower wells, as illustrated by the change in chromium concentrations. The change occurred a short time before pumping began in well 199-H3-2A (i.e., July 1997) as part of the interim remedial action for chromium. An explanation for this change has not been identified. However, water quality characteristics in deep well 199-H3-2C appear to be returning to previous, expected conditions during fiscal year 2000.

A second anomaly is found in well 199-H4-12C, which is also completed in a confined unit beneath the unconfined aquifer. This well has shown relatively high chromium concentrations (~300 μg/L) since it was constructed in 1986 (Figure 2.6-8), although no other contamination indicators are present. One potential explanation for these results involves corrosion of the stainless steel well screen (Hewitt 1994; Oakley and Korte 1996). There is no information available to suggest that waste effluents have contaminated this deep aquifer.

2.6.3 Strontium-90

The primary source for strontium-90 contamination currently detected in 100 H Area groundwater is past disposal of contaminated reactor coolant to the 107-H retention basin and 107-H liquid waste disposal trench, which is located nearby. Also, contaminated sludge from the retention basin was placed in an adjacent trench (107-H sludge burial trench), which is located between the basin and the Columbia River. The vadose zone beneath the basin and trenches is potentially contaminated with strontium-90, some of which has dispersed downward and entered groundwater. The upper portion of the vadose zone beneath these facilities was excavated during 1999 and 2000. The contaminated soil was trucked to the Environmental Restoration Disposal Facility in the 200 Areas plateau. Groundwater concentrations for strontium-90 are illustrated by trend charts for three wells located between the former retention basins and the Columbia River (Figure 2.6-9).

Strontium-90 is present in groundwater near the Columbia River in the 100 H Area but was not detected in pore water from the adjacent riverbed sediment.

Samples of pore water from riverbed sediment from a 1995 investigation (BHI-00345) were re-analyzed for strontium-90 during August 1999, and none was detected (see Section 2.6.9.3). A more complete description of the results is presented in PNNL-13177, along with a discussion of strontium-90 in the 100 Areas and its ecological implication.

2.6.4 Tritium

Tritium concentrations in the 100 H Area are below the 20,000 pCi/L drinking water standard (see Plate 2). The highest values observed during fiscal year 2000 were ~5,000 to 6,000 pCi/L in wells at the western boundary of the 100 H Area. During the last several years, tritium appeared to be increasing in concentration at some wells near the H Reactor building (Figure 2.6-10). The increasing trends are believed to represent the arrival of a contaminant plume from sources west of the 100 H Area. The most recent results suggest a reversal to declining concentrations. Upgradient of the wells shown in Figure 2.6-10, tritium concentrations continue to decrease in two wells that monitor groundwater from 100 D and 100 N Area sources. This suggests that the higher concentration core of the plume has passed these wells, and that a continuing decline in concentration beneath the 100 H Area can be expected.

An increase in tritium concentrations started in mid-1996 in well 199-H3-2C, which monitors a semi-confined unit beneath the uppermost unconfined aquifer. This change started a short time before the initial use of adjacent well 199-H3-2A as an extraction well. Concentrations began to rise from low values to a peak of ~3,200 pCi/L, a level similar to that observed in well 199-H3-2A, which is completed near the water table (Figure 2.6-11). The change is significant because well 199-H3-2C monitors a confined aquifer that is considered to be isolated from the overlying unconfined aquifer, and the confined unit is not known to have received any contamination. Other water quality indicators also changed in well 199-H3-2C at the same time (e.g., chromium; see Section 2.6.2), with the characteristics of water from well 199-H3-2C looking similar to those for water from the shallower wells.

2.6.5 Nitrate

During fiscal year 2000, numerous wells in the 100 H Area exceeded the 45 mg/L maximum contaminant level. The highest concentrations occur in groundwater affected by effluent that leaked from the former 183-H solar evaporation basins. Three wells (199-H4-3, 199-H4-4, and 19-H4-9) revealed groundwater concentrations in the range 190 to 387 mg/L during late fall 1999. Figure 2.6-12 shows the historical trends for two of these wells located closest to the former basins. A general increase in nitrate concentration is apparent in the historical trends for 100 H Area wells (and also for wells located in other reactor areas). This trend is illustrated in Figure 2.6-13. The cause for the gradual increase is not known, but has caused several wells to now exceed the maximum contaminant level.

2.6.6 RCRA Monitoring at the Former 183-H Solar Evaporation Basins

Groundwater near the former 183-H solar evaporation basins is monitored to meet RCRA final status monitoring requirements. Hazardous waste was removed from the treatment facility during the late 1980s, followed by decontamination and demolition of the structure, which was completed in 1995 (DOE/RL-97-48). Contaminated soil was then removed, though nitrate and fluoride remained elevated in the remaining soil, thus requiring postclosure groundwater monitoring.

The former 183-H solar evaporation basins are a RCRA site that has contaminated groundwater with chromium, nitrate, technetium-99, and uranium.

Groundwater movement in the vicinity of the basins has been influenced by the interim remedial action under CERCLA that focuses on chromium contamination. While pumping operations are in progress, RCRA monitoring tracks the trends of five contaminants associated with leakage from the basins: chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573). Groundwater monitoring activities associated with RCRA requirements, performance evaluation of the pump-and-treat system, and 100-HR-3 operable unit investigations are fully integrated with respect to sampling schedule and analyses performed.

Groundwater chemistry near these former basins is characterized by elevated levels of chromium, nitrate, sodium, sulfate, technetium-99, and uranium. All of these constituents were present in waste discharged to the basins when they were in use. See Appendix A for supporting information about this RCRA site.

2.6.6.1 Groundwater Flow

As indicated on the March 2000 water-table map (see Plate 1), groundwater beneath the former 183-H solar evaporation basins flows generally to the east-northeast, toward the Columbia River. Technetium-99 and uranium plumes originating at the basins have migrated primarily toward the east. The rate of flow in March 2000 is estimated to be between 0.13 and 3.7 meters per day (see Appendix A, Table A.2).

Groundwater levels associated with the 183-H plume fluctuate with the stage of the Columbia River. These fluctuations are most dramatic in well 199-H4-4 and cause wide variations in water chemistry. Monthly water levels measured in the well ranged in elevation from 114.72 meters in September 2000 to 116.33 meters in May 2000. Periods of high river stage temporarily create a potential for flow toward the south, thus displacing the plume toward the south. Groundwater flow around the former 183-H solar evaporation basins is also influenced by the pump-and-treat system, as discussed in Section 2.6.7.

2.6.6.2 Technetium-99 and Uranium

Groundwater from wells 199-H4-3, 199-H4-4, and 199-H4-9 exceeded the 20 μg/L maximum contaminant level for uranium in fiscal year 2000. The highest concentration was 157 μg/L in well 199-H4-3. Only well 199-H4-3 exceeded the 900 pCi/L drinking water standard for technetium-99, with a groundwater concentration of 1,070 pCi/L detected in November 1999.

Concentrations of technetium-99 and uranium in groundwater downgradient of the former 183-H basins fluctuate with river stage. Near the river, low water levels are usually associated with higher concentrations.

Concentrations of technetium-99 and uranium remain elevated in wells located between the former basins and the Columbia River. These two contaminants are mobile in groundwater (i.e., not adsorbed to sediment). Near the Columbia River, their concentrations vary with changes in elevation of the water table, which responds to fluctuations in river stage. This process is illustrated for well 199-H4-4 in Figure 2.6-14.

Uranium and technetium-99 both increased sharply in well 199-H4-9 during fiscal year 2000 (Figure 2.6-15). The recent values (i.e., 25 μg/L uranium and 616 pCi/L technetium-99) are the highest ever detected at this well for these constituents, except for several outlier results that are not corroborated by high values for co-contaminants. Well 199-H4-9 is located within the influence of the interim remedial action pumping wells, and changes in groundwater movement induced by the pumping may be responsible for the changing trends in the well.

2.6.6.3 Nitrate

Leakage from the former 183-H solar evaporation basins contributed to an existing widespread plume of nitrate. In fiscal year 2000, the highest concentration of nitrate in 100 H Area was detected in downgradient well 199-H4-3 at 384 mg/L (see Figure 2.6-12). Like other basin contaminants, nitrate concentrations in this well fluctuate seasonally, and there is no trend that clearly increases or decreases over the long term. Nitrate concentrations increased sharply in well 199-H4-9 at some point during the last several years, rising from 37 mg/L in June 1997 to 190 mg/L in November 1999 (see Figure 2.6-12). The increase is coincident with similar trend changes for technetium-99, uranium, and chromium.

2.6.6.4 Chromium

Leakage from the former 183-H solar evaporation basins contributed to a widespread plume of chromium (see Figure 2.5-2 and Section 2.6.2). The highest average chromium concentration in the plume attributable to the 183-H source is revealed in well 199-H4-3, with a concentration of 144 μg/L for fiscal year 2000 results.

Past leakage of hazardous waste from the former 183-H basins contributed to the chromium plume beneath the 100 H Area.

Concentrations of chromium, along with other indicators for the 183-H plume, fluctuate with the seasonal river cycle. Near the Columbia River, concentrations typically rise with low river conditions and fall during high river conditions. Chromium concentrations declined sharply in the 1980s, after waste was removed from the basins. The rate of decline slowed during the early-to-mid 1990s and becomes obscured by variations caused by the river cycles. The relationship between chromium concentrations and river conditions is illustrated in Figure 2.6-16, which shows how low chromium concentrations in well 199-H4-4 during fiscal years 1996 and 1997 correspond to periods of high water-table elevations. Since 1997, the water table has been generally lower and chromium concentrations have risen somewhat.

Chromium is gradually declining in well 199-H4-12C (see Figure 2.6-8), though still elevated above background for reasons believed to be unrelated to hazardous waste disposal. This well is completed in a deeper part of the aquifer than the other wells nearby. The well is monitored as part of the RCRA network to ascertain whether pumping the shallow aquifer (i.e., well 199-H4-12A) affects the chromium concentrations detected in the deeper aquifer (PNNL-11573). Concentration trends for the two wells do not suggest a connection. The average concentration for well 199-H4-12C in fiscal year 2000 was ~160 μg/L. Other contaminants that are characteristic of 183-H waste are not elevated; the cause for this chromium is believed to be related to localized conditions around the well screen.

2.6.6.5 Fluoride

Fluoride concentrations in wells downgradient at the former 183-H solar evaporation basins were no higher than in upgradient wells during fiscal year 2000, suggesting no addition of fluoride to groundwater from the vadose zone beneath the footprint of the former basins. This constituent was detected in the vadose zone beneath the basins during remediation activities in 1996, making it a constituent of interest for RCRA postclosure care (DOE/RL-97-48; PNNL-11573). Recent and historical values for fluoride are an order of magnitude lower than the 4 mg/L maximum contaminant level for drinking water supplies.

2.6.7 Groundwater Remediation

A pump-and-treat system began operating in the 100 H Area during July 1997 as an interim remedial action for chromium contamination in groundwater. The primary purpose for this system is to prevent or reduce the movement of hexavalent chromium from the aquifer to the river, thereby protecting aquatic receptors. The extraction network currently includes three wells located within ~50 meters of the river shore, and three additional wells located farther inland. A report is prepared annually that describes the performance of the system for the preceding calendar year (e.g., DOE/RL-2000-01).

The pump-and-treat system in the 100 H Area is reducing the amount of chromium that reaches the Columbia River, where it could potentially harm aquatic organisms. Since 1997, 20 kilograms of chromium have been removed from groundwater.

2.6.7.1 Interim Remedial Action Objectives

The record of decision (ROD 1996b) for the 100-HR-3 Operable Unit contains the following specific remedial action objectives that pertain to operation of the pump-and-treat system that serves the 100 H and 100 D Areas:

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

The record of decision stipulates that the interim action pump-and-treat system continues to operate until the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. Criteria for ending the operation include (a) sampling results indicate that the concentration of hexavalent chromium is below 22 µg/L in the compliance wells and (b) evidence to indicate that concentrations will remain below the compliance value. Other criteria for terminating the pump-and-treat operation involve the effectiveness of the treatment technology and the availability of a superior treatment technique (ROD 1996b).

2.6.7.2 Remediation Progress During Fiscal Year 2000

The pump-and-treat system made progress toward achieving the 100 H Area remedial action objectives during fiscal year 2000. Although designed primarily to prevent or reduce the amount of contaminated groundwater discharging into the Columbia River, the pump-and-treat system also reduces overall contamination in the aquifer by removing contaminant mass. The pump-and-treat monitoring program collects data on water levels, contaminant concentrations, and operating data to assess the performance of the system. These data help to provide a technical basis for selecting a final remedy for environmental restoration of this operable unit.

During fiscal year 2000, the pump-and-treat system extracted over 156 million liters of 100 H Area groundwater and removed ~4.8 kilograms of hexavalent chromium (Table 2.6-1). The average concentration of hexavalent chromium in the groundwater removed was 41.6 µg/L. After treatment, the average effluent concentration was 7 µg/L, with hexavalent chromium being undetected during 34 of the 52 sampling events. The treated effluent was injected back into the aquifer at an upgradient location southwest of the H Reactor.

2.6.7.3 Influence on Aquifer Conditions

A total of ~20 kilograms of hexavalent chromium has been removed from 100 H Area groundwater since startup of the pump-and-treat system in July 1997 (project specific database for the 100-HR-3 operable unit). An order-of-magnitude estimate for the rate at which chromium discharges to the Columbia River via natural groundwater flow (i.e., no pumping operations) is ~0.03 kilograms per day, based on flow modeling work in progress (see Section 4.3.1). This equates to a total mass flux of ~27 kilograms that would have entered the Columbia River via natural groundwater flow during the period July 1997 to December 1999 (913 days). The actual flux is believed to be less because of chromium removal by the pump-and-treat system. Published estimates for the total amount of hexavalent chromium in the plume targeted for remedial action range between 42 and 250 kilograms (WHC-SA-1674-VA; DOE/RL-94-95). Principal contributors to uncertainty in these estimates are the (a) lack of data on the vertical distribution of contamination in the aquifer and (b) difficulty in evaluating the amount of chromium added to the target plume by the arrival of groundwater from west of 100 H Area.

The concentration of chromium typically declines below the 22 µg/L action level in some of the extraction and compliance wells during the early summer months (see Figures 2.6-4, -5, and -6). The concentration subsequently rebounds over the action level by the following September. In September or October 2000, chromium in the compliance wells was measured at 111, 75, 89, and 38 µg/L at wells 199-H4-4, 199-H4-5, 199-H4-63, and 199-H4-64, respectively. Because of the recurring elevated concentrations of hexavalent chromium in the compliance wells, operation of the pump-and-treat system is continuing into fiscal year 2001.

Chromium concentrations in extraction and compliance wells remained above the remedial action objective of 22 µg/L during most of fiscal year 2000. The pump-and-treat system will continue to operate in 2001.

The cyclical pattern for hexavalent chromium concentrations makes it difficult to quantify the effectiveness of the pump-and-treat system in terms of lowered concentrations in the aquifer. The decrease in concentrations detected in some extraction wells (see Figures 2.6-4 and -5) and compliance wells (see Figure 2.6-6) suggests that the concentration in the aquifer is decreasing in some areas. However, the rate of decline is not consistent throughout the entire targeted plume area. The pump-and-treat system does reduce the amount of chromium in the environment, though contaminant monitoring results indicate that many years of pumping may be required before the concentration levels required by remedial action are achieved.

2.6.8 Waste Site Remediation

Remedial actions involving excavation of waste sites in the 100 H Area continued during fiscal year 2000. These activities consisted of excavating contaminated soil and debris for subsequent disposal at the Environmental Restoration Disposal Facility. Where not contaminated, clean overburden soil was removed and stockpiled for refilling excavations. Approximately 450,000 tons of material were removed and disposed in fiscal year 2000.

Water (obtained from fire hydrants) was applied as necessary to control dust during the excavation process. Application of water was held to the minimum amount necessary for worker safety and preventing airborne dispersal of contaminants. Judicious application of water reduced the potential for mobilizing contaminants from the vadose zone to the groundwater. A borehole was drilled within the 116-H-1 waste site to evaluate the vertical extent of contamination and moisture profile. The results indicate that dust control activities do not appear to be mobilizing contaminants to the groundwater. The excavations remained open at the end of fiscal year 2000; they will be backfilled in fiscal year 2001. The waste sites have been stabilized with a soil fixative.

Waste sites excavated in fiscal year 2000 are listed in Table 2.6-2. They include several radioactive disposal sites in the eastern 100 H Area near the Columbia River, two septic tanks in the northern 100 H Area, pipelines from H Reactor to the retention basins, and several drains and trenches near the reactor building.

2.6.9 Water Quality at Shoreline Monitoring Locations

Strontium-90 and nitrate exceeded drinking water standards in aquifer sampling tubes near the Columbia River shore in the 100 H Area during fiscal year 2000.

Groundwater samples are collected annually from aquifer sampling tubes located near the low-river stage shoreline and from riverbank seepage sites during the seasonal low river stage, which occurs during the fall months. The tubes were re-sampled in 1998, 1999, and 2000 to support Environmental Restoration Project objectives. Riverbank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration Project to support investigations of groundwater operable units. Table 2.6-3 lists the analytical results for key constituents in samples collected during fall 1999 from aquifer sampling tubes, riverbank seepage, and near-shore river water (when available).

2.6.9.1 Aquifer Sampling Tubes

Samples from aquifer sampling tubes were collected during the October 1999 and screened for hexavalent chromium, gross beta, nitrate, and strontium-90. Hexavalent chromium concentrations ranged from a high of 49 µg/L at a location just upstream of the 100 H Area, to values in the range 20 to 45 µg/L at tubes located a short distance downstream of 100 H Area and adjacent to the plume targeted for interim remedial action, within the "H slough." These concentrations are consistent with hexavalent chromium concentrations in groundwater samples from nearby monitoring wells. The upstream concentrations represent chromium that has migrated across the tip of the Hanford Site, with a probable source at the 100 D Area.

Gross beta is elevated in one location near the 107-H retention basin, with a value of 21.4 pCi/L, which is consistent with previous years. Strontium-90, the primary source of beta activity, was measured at 9.6 pCi/L in that sample. These concentrations are also consistent with concentrations in samples from groundwater monitoring wells near the 100 H shoreline. Nitrate concentrations ranged from 6 mg/L to 60 mg/L along the 100 H shoreline.

2.6.9.2 Riverbank Seepage

Four riverbank seepage sites were sampled in October 1999 along the 100 H Area shoreline. The seeps were sampled during seasonal low-river discharge conditions, when seepage is least influenced by bank storage of river water and is most representative of groundwater that discharges into the Columbia River. The specific conductance of the collected seep samples ranged from 190 to 240 µS/cm, indicating dilution of groundwater by river water, with the mixture draining back to the river from bank storage.

Chromium concentrations ranged from 9 to 23 µg/L. The highest chromium concentration was detected in a sample from a seep upstream of the 100 H Area, with the source for the chromium most likely to be past disposal in the 100 D Area. Tritium was very low in these samples and ranged from 525 to 978 pCi/L. Nitrate was also low, with values between 5.2 and 14.0 mg/L. As indicated by the relatively low specific conductance values for these seepage samples, the seepage concentrations probably reflect dilution by river water that has infiltrated the bank. Concentrations in the groundwater approaching this section of shoreline are likely to be approximately twice that of the seepage samples.

Table 2.6-1. Performance Parameters for the 100 H Pump-and-Treat System for Chromium, Fiscal Year 2000

	Average Flow (L/min)	Maximum Sustained Flow (L/min)	Total Pumped (L)	Average Concentration (µg/L)	Mass Removed (kg)
199-H3-2A	84	145	36,633,118	8	0.05
199-H4-11	76	91	33,062,962	42	1.16
199-H4-12A	54	57	23,646,725	48	0.96
199-H4-15A	54	58	23,220,922	44	0.86
199-H4-65	45	58	11,534,844	60	0.61
199-H4-7	65	77	28,273,795	49	1.18
Totals			156,372,366		4.81
Averages	63			42	

Table 2.6-2. 100 H Area Waste Sites Excavated Under CERCLA During Fiscal Year 2000

Waste Site Designation	Period of Excavation (Fiscal Year)
Sites Located in Eastern 100 H Area	
116-H-7 retention basin	1999, 2000
116-H-1 trench	1999, 2000
100-H-5 sludge burial ground	1999, 2000
Sites Located in Northern 100 H Area	
1607-H2 and 1607-H4 septic tanks and drain fields	2000
Sites Located near H Reactor	
Reactor process piping	1999, 2000
100-H-1 rod cave	2000
100-H-7 French drain	2000
100-H-17 trench (116-H-2 trench overflow)	2000
100-H-24 substation	2000
100-H-30 sanitary sewer trench	2000
116-H-2 liquid waste disposal trench	2000
116-H-3 French drains	2000

Table 2.6-3. Shoreline Monitoring Data for the 100 H Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
43-D	Tube	27-Oct-99	239	20				12.0
44-D	Tube	27-Oct-99	376	49				
45-D	Tube	27-Oct-99	199	3				
46-D	Tube	25-Oct-99	220	24	2.4	2.2		14.0
47-D	Tube	25-Oct-99	170	20	9.6	21.4		6.0
48-M	Tube	26-Oct-99	491	45	***0.0***	7.5		60.0
49-D	Tube	26-Oct-99	351	30	***0.0***	4.9		29.0
50-M	Tube	26-Oct-99	492	43				55.0
55-S	Tube	26-Oct-99	352	21				21.0
SH-144-1	Seep	27-Oct-99	240	23			978	12.0
SH-145-1	Seep	27-Oct-99	190	17			838	5.2
SH-150-1	Seep	27-Oct-99	200	9			583	7.1
SH-153-1	Seep	27-Oct-99	208	15			525	14.0
43-D	River	27-Oct-99	142					
44-D	River	27-Oct-99	129					
45-M	River	27-Oct-99	122					
46-D	River	25-Oct-99	123					
47-D	River	25-Oct-99	126					
48-M	River	26-Oct-99	132					
49-S	River	26-Oct-99	122					
50-M	River	26-Oct-99	122					

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore, adjacent to the aquifer sampling tube.

Values in ***bold italics*** are qualified by the laboratory as "undetected." Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350-450 µS/cm.

Data sources: Hanford Environmental Information System and various project records.

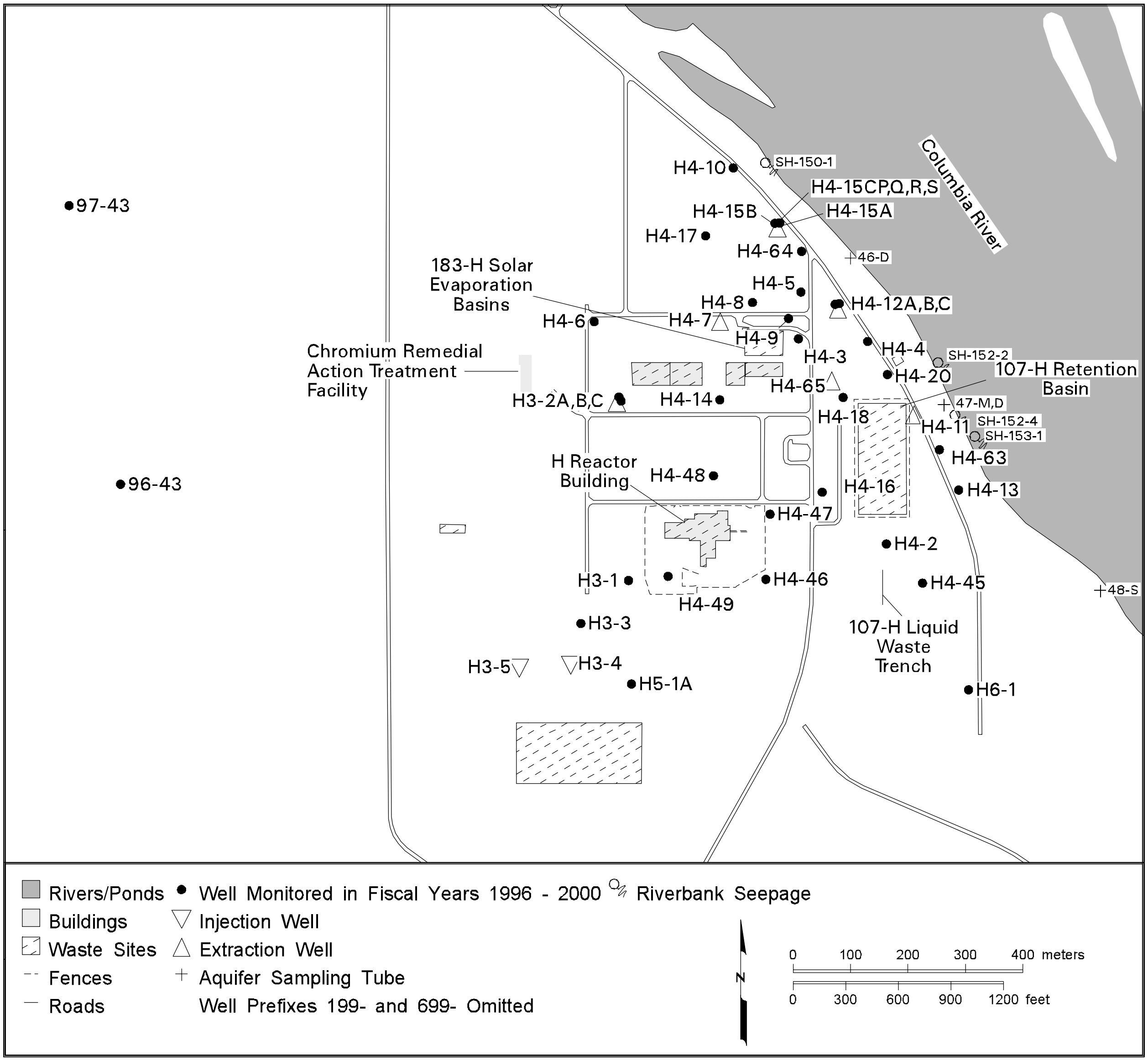

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Figure 2.6-1. Groundwater Monitoring Wells in the 100 H Area

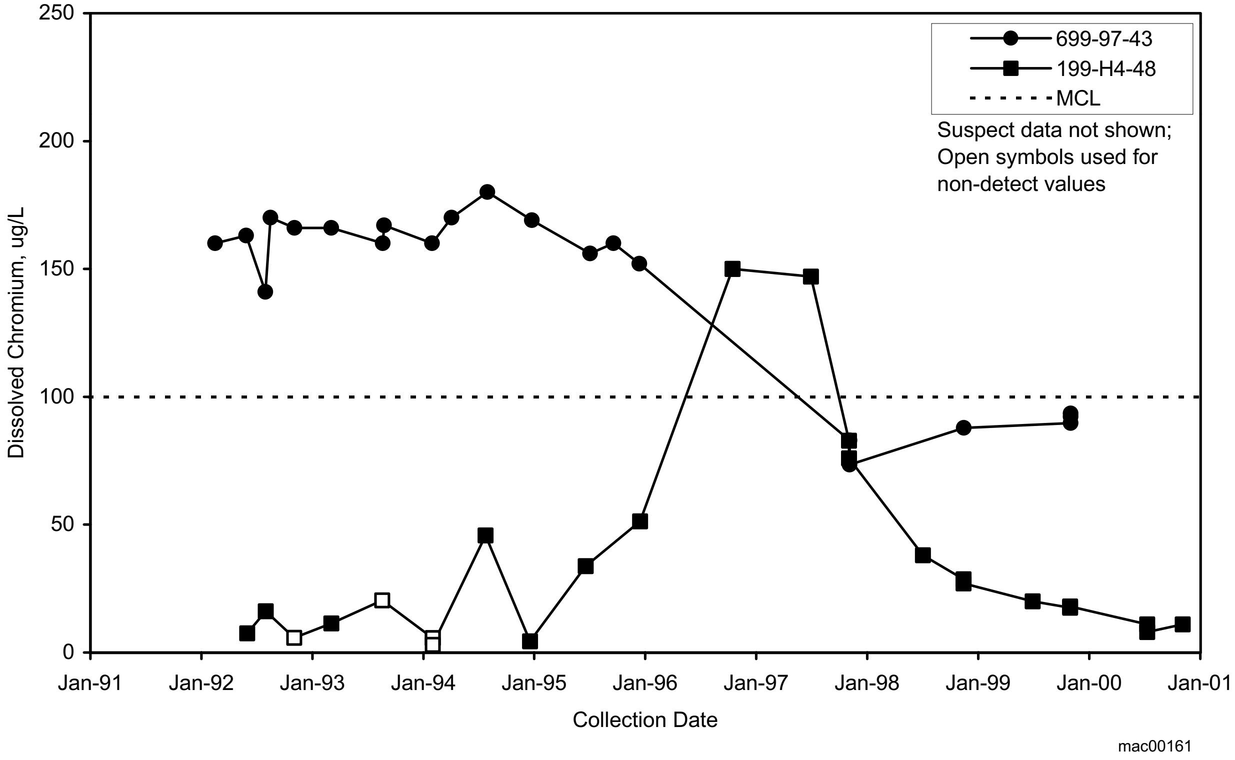

Figure 2.6-2. Chromium in Well 199-H4-48 near H Reactor and Well 699-97-43 Upgradient of 100 H Area

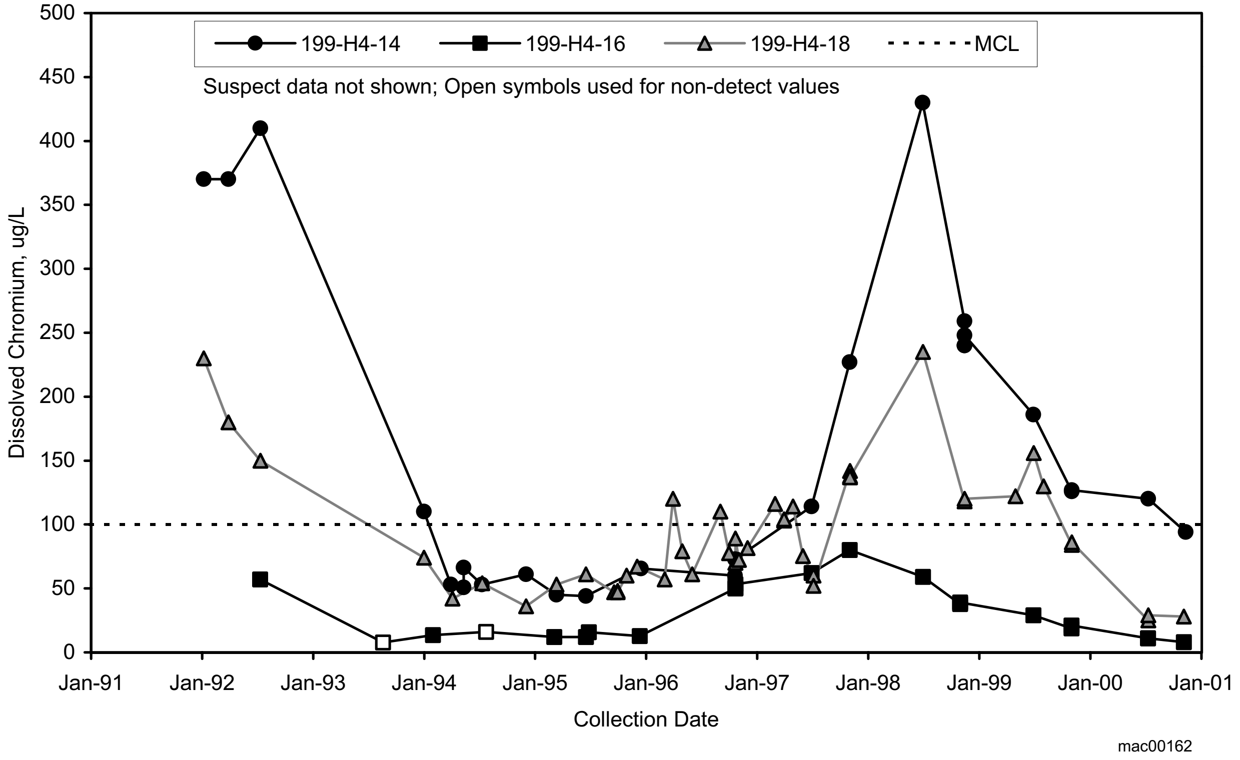

Figure 2.6-3. Chromium in Groundwater in the Center of the 100 H Plume

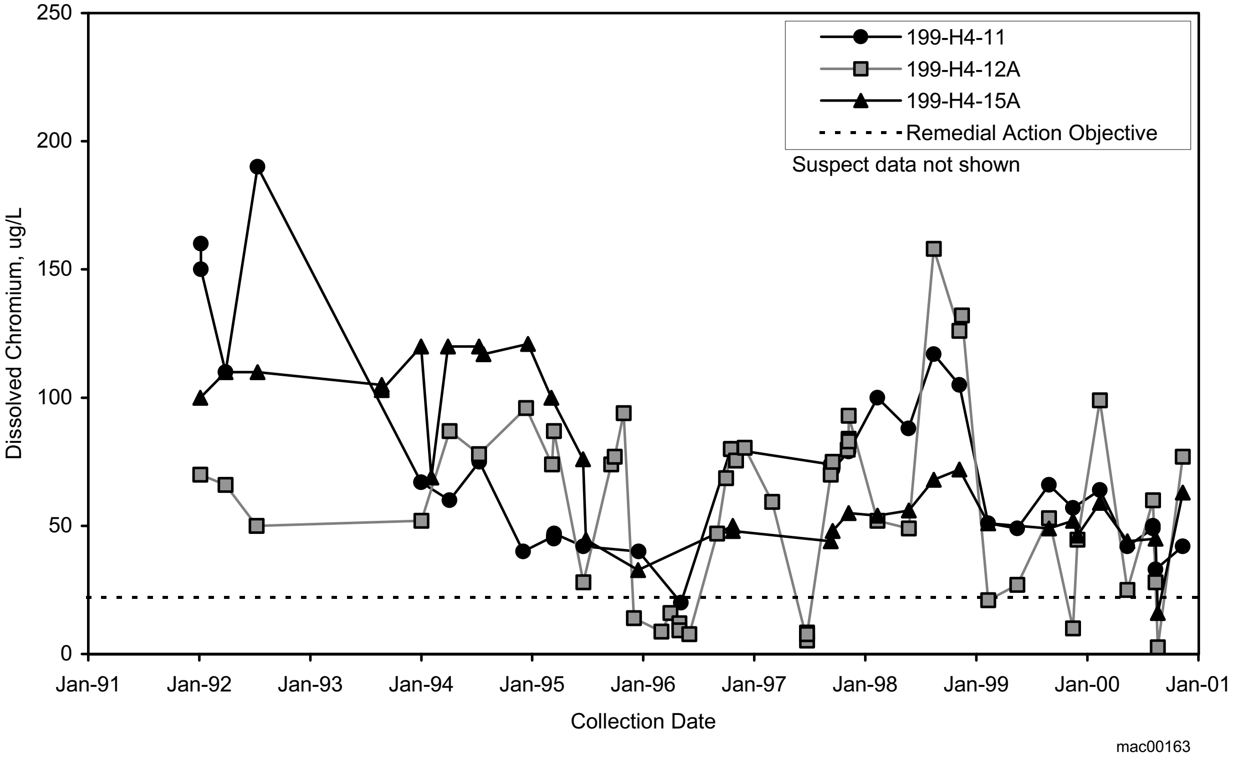

Figure 2.6-4. Chromium in Extraction Wells near the Columbia River at the 100 H Area

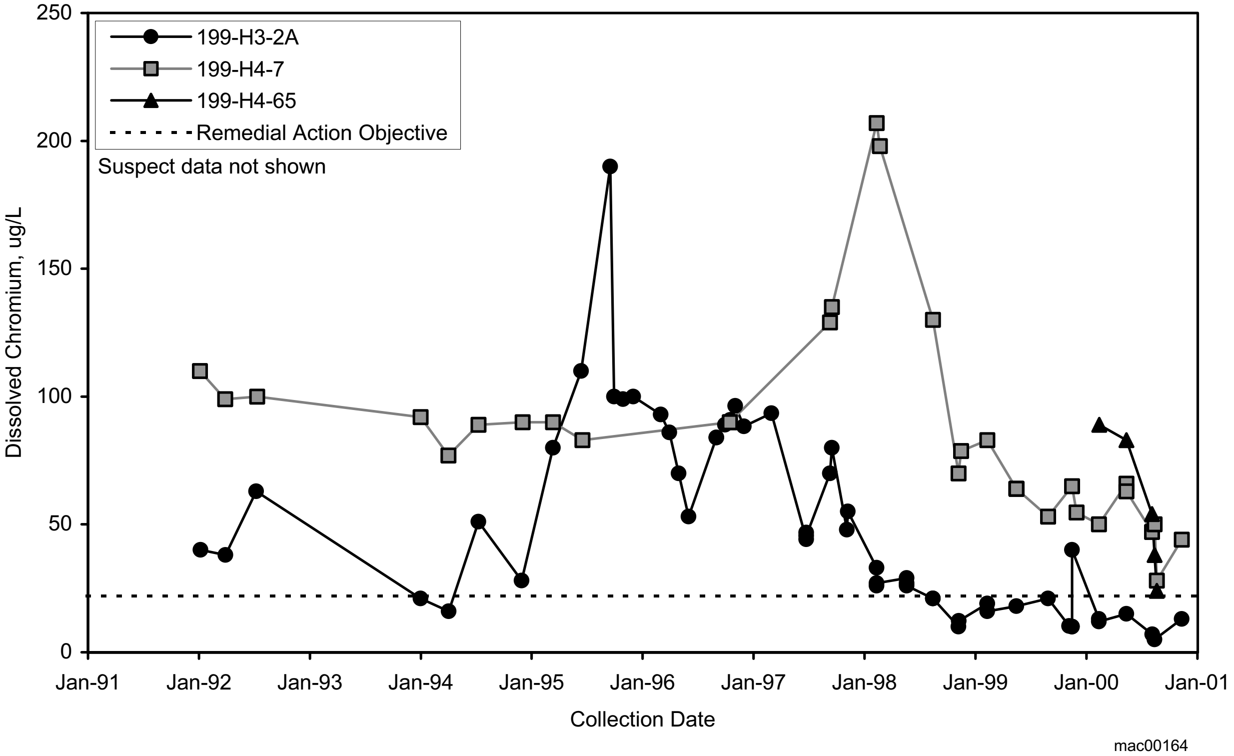

Figure 2.6-5. Chromium in Extraction Wells Located Inland at the 100 H Area

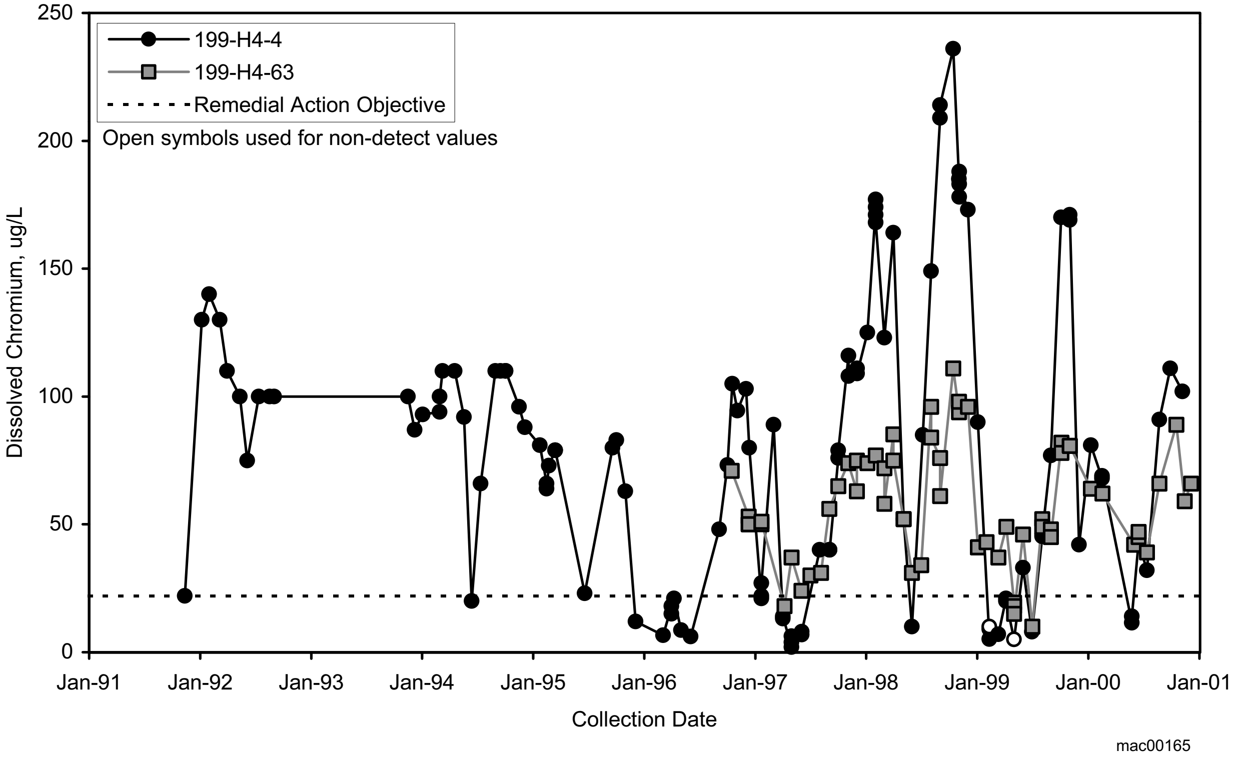

Figure 2.6-6. Chromium in Groundwater at Interim Action Compliance Wells

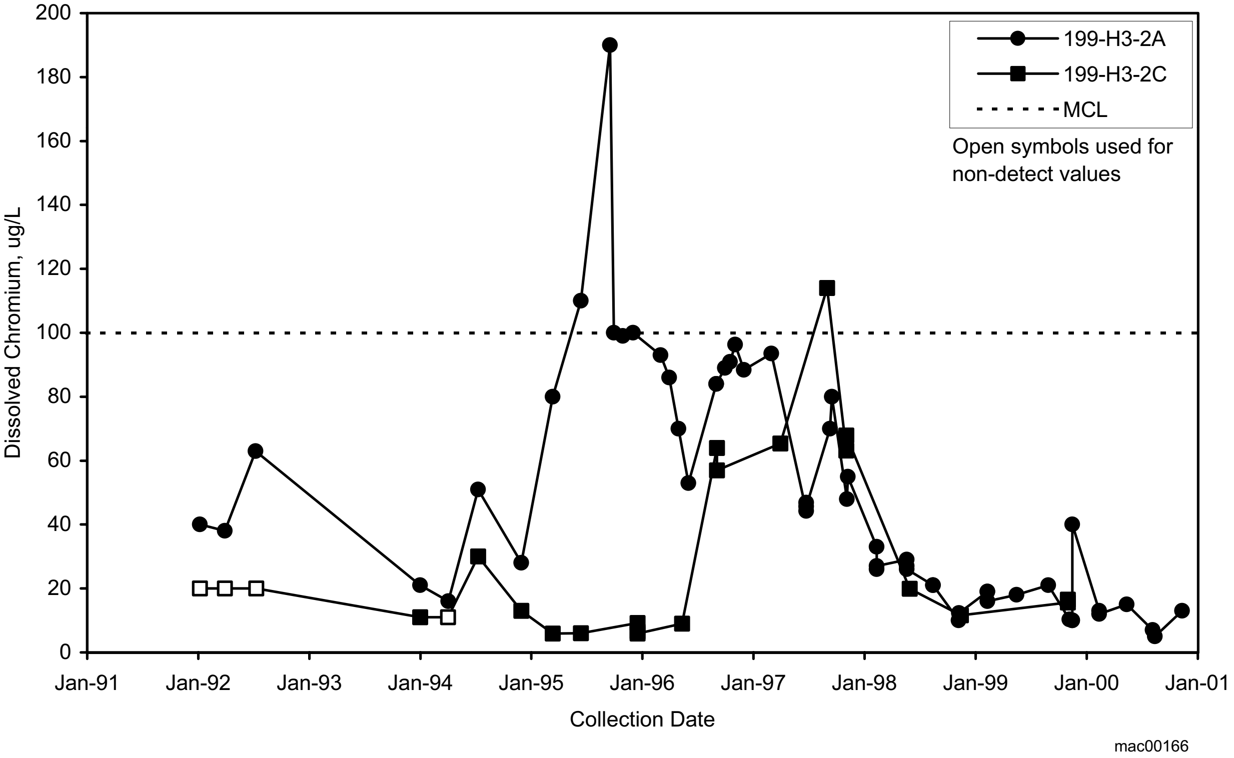

Figure 2.6-7. Chromium in Groundwater at Well Cluster 199-H3-2

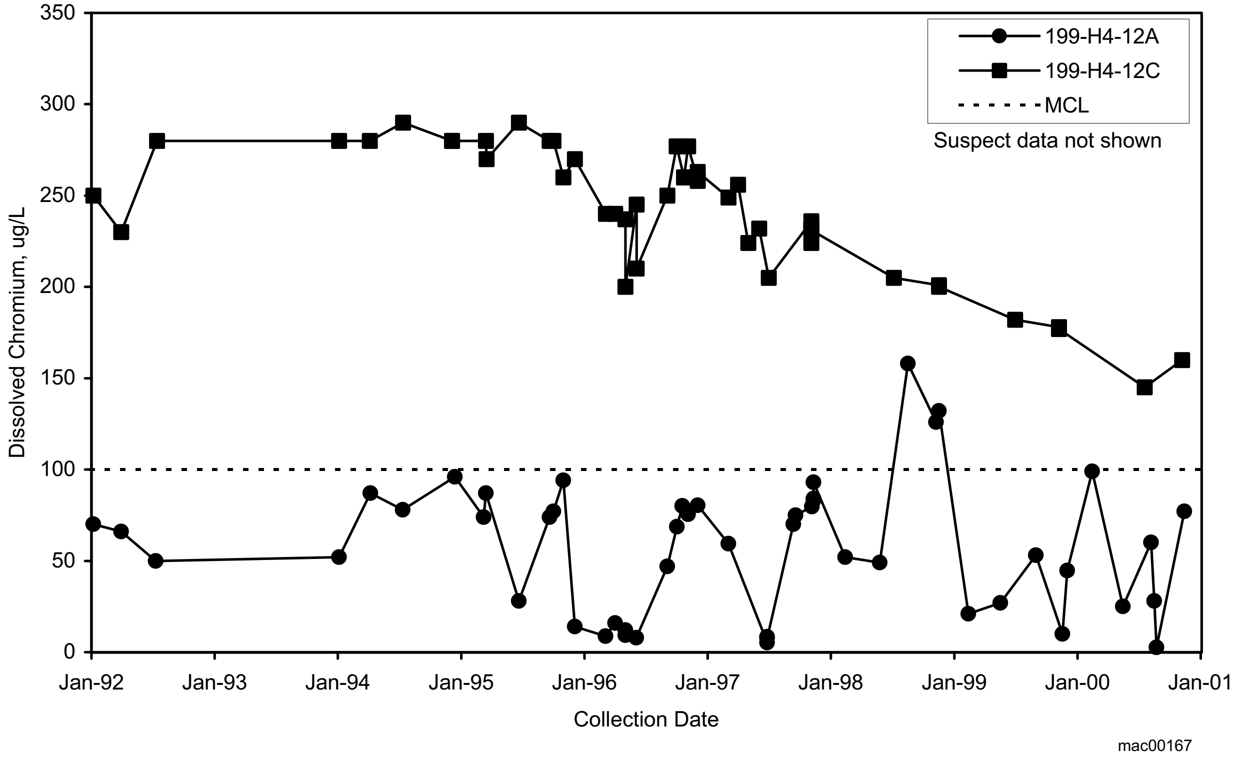

Figure 2.6-8. Chromium in Groundwater at Well Cluster 199-H4-12

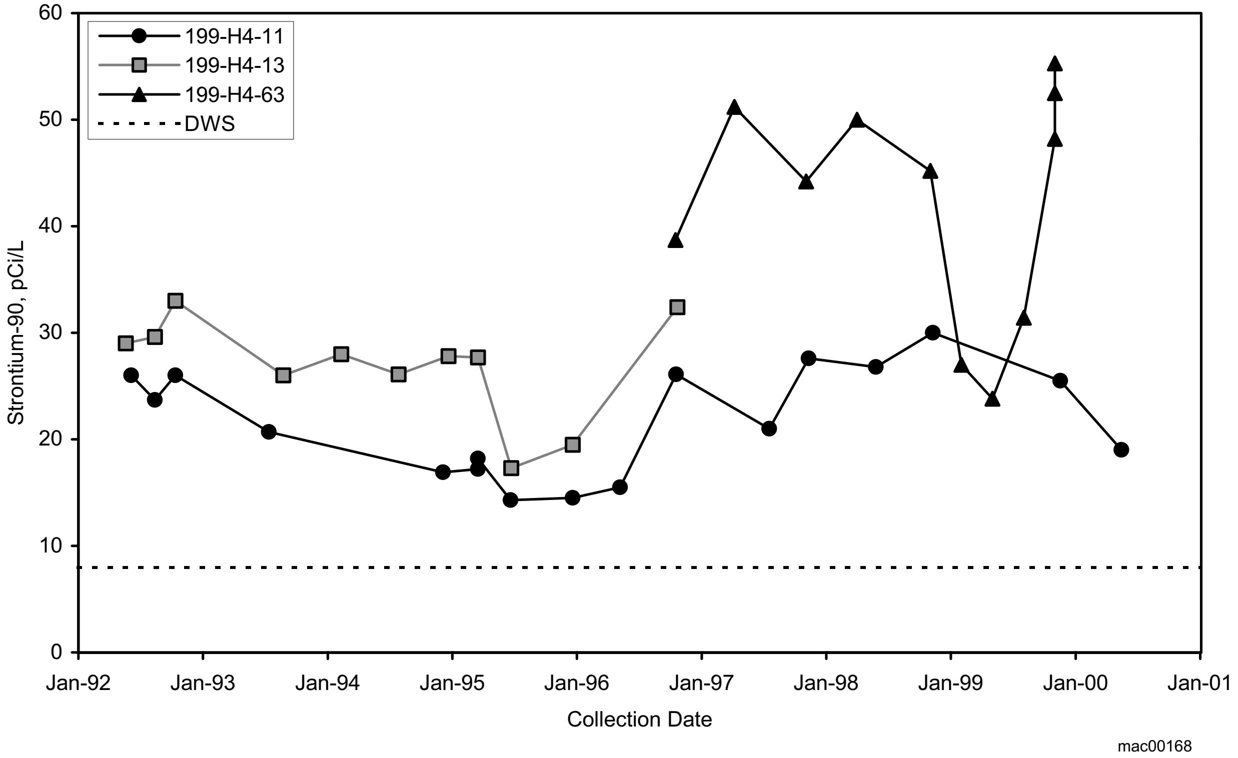

Figure 2.6-9. Strontium-90 in Groundwater between the 107-H Retention Basins and the Columbia River

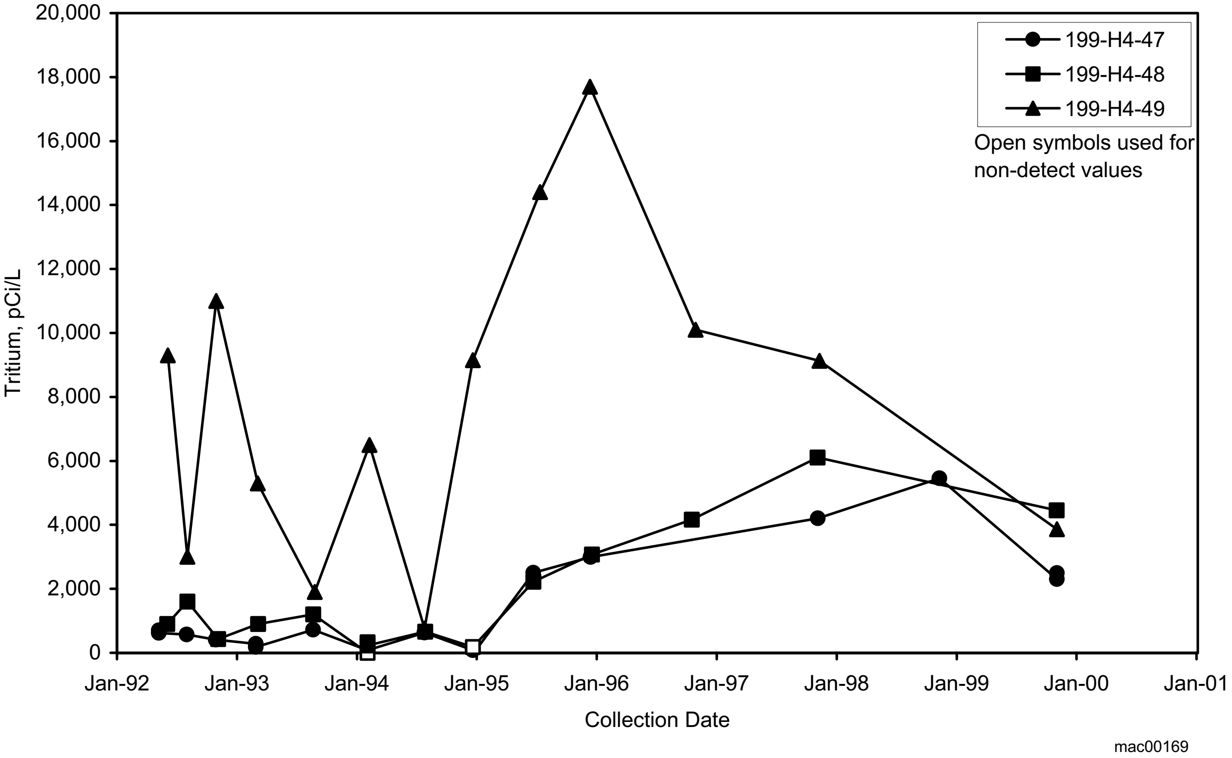

Figure 2.6-10. Tritium in Groundwater at Wells near the H Reactor

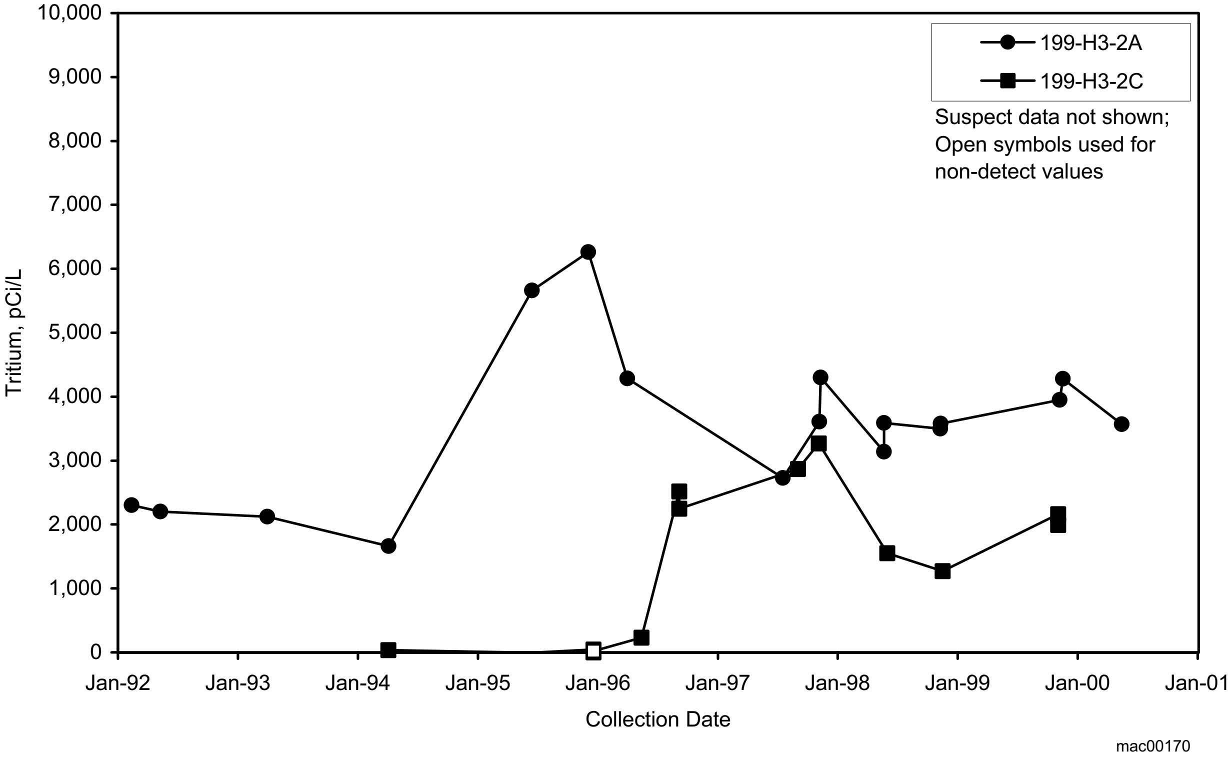

Figure 2.6-11. Tritium in Groundwater at Well Cluster 199-H3-2 near the Western Part of 100 H Area

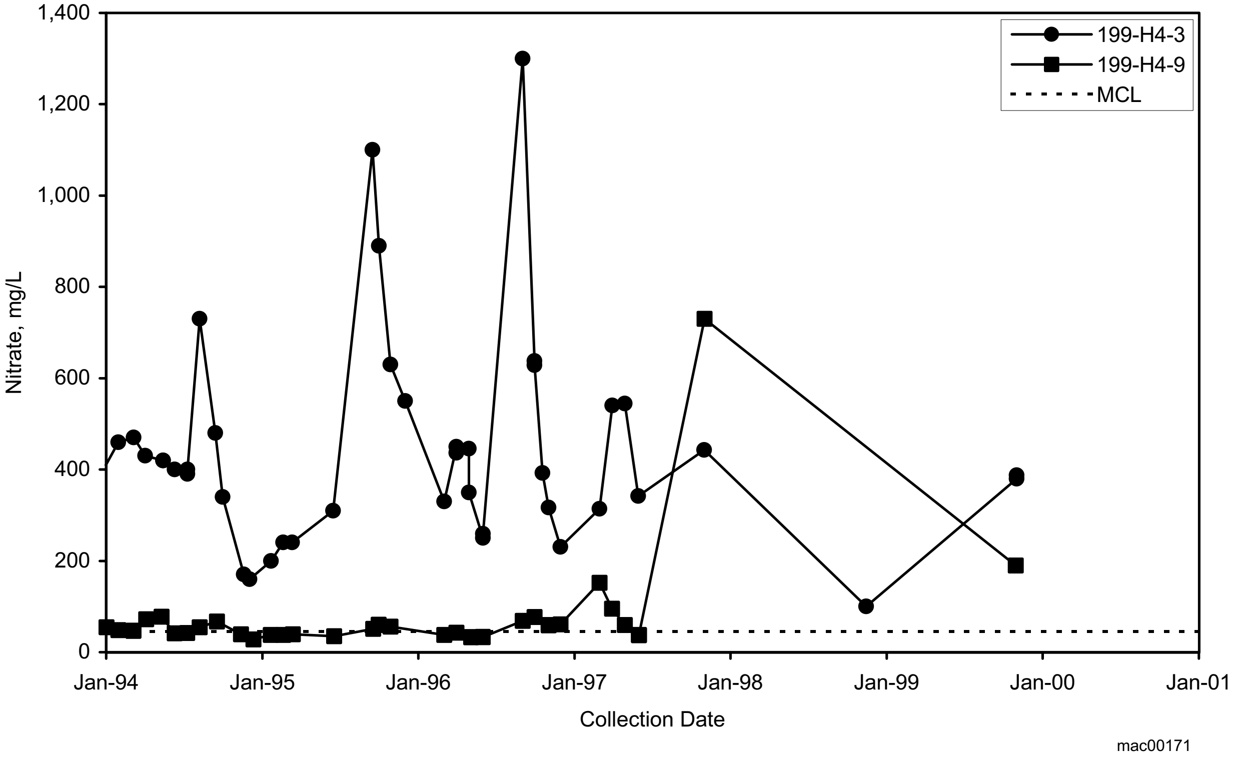

Figure 2.6-12. Nitrate in Groundwater near the Former 183-H Solar Evaporation Basins

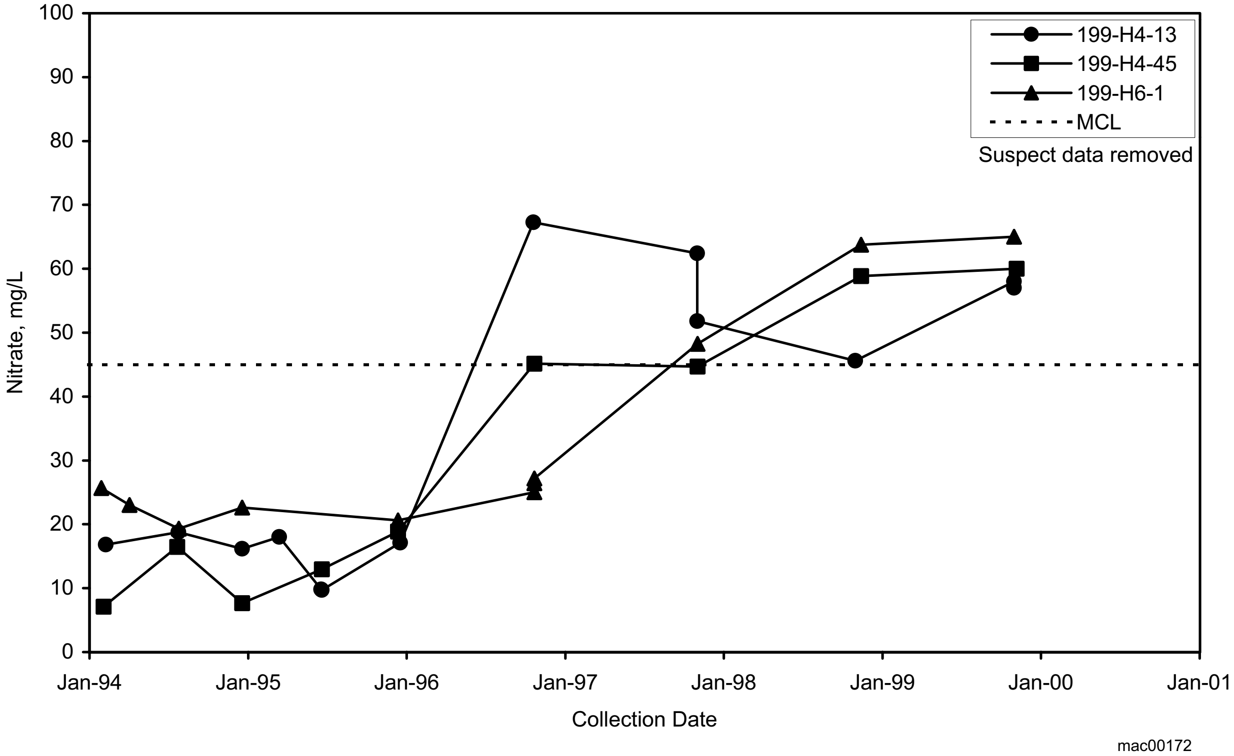

Figure 2.6-13. Example of Increasing Nitrate in Groundwater at 100 H Area Wells

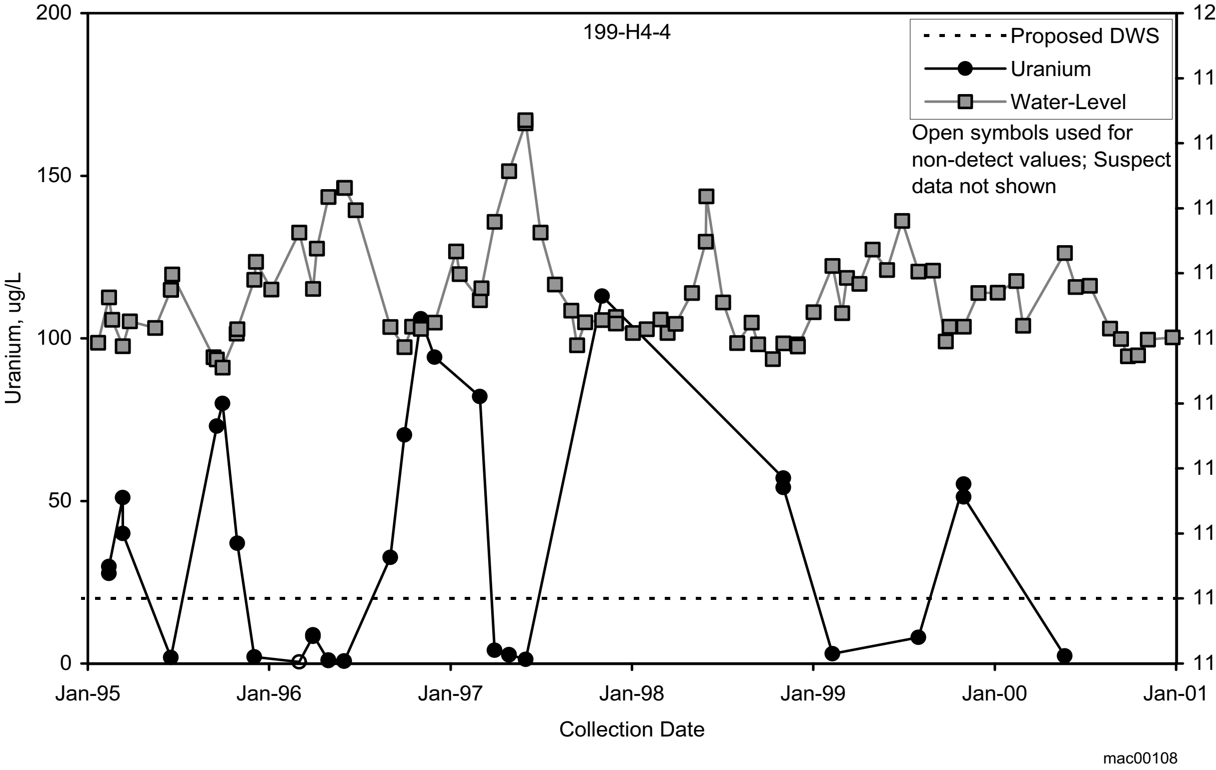

Figure 2.6-14. Uranium in Groundwater near the Former 183-H Solar Evaporation Basins

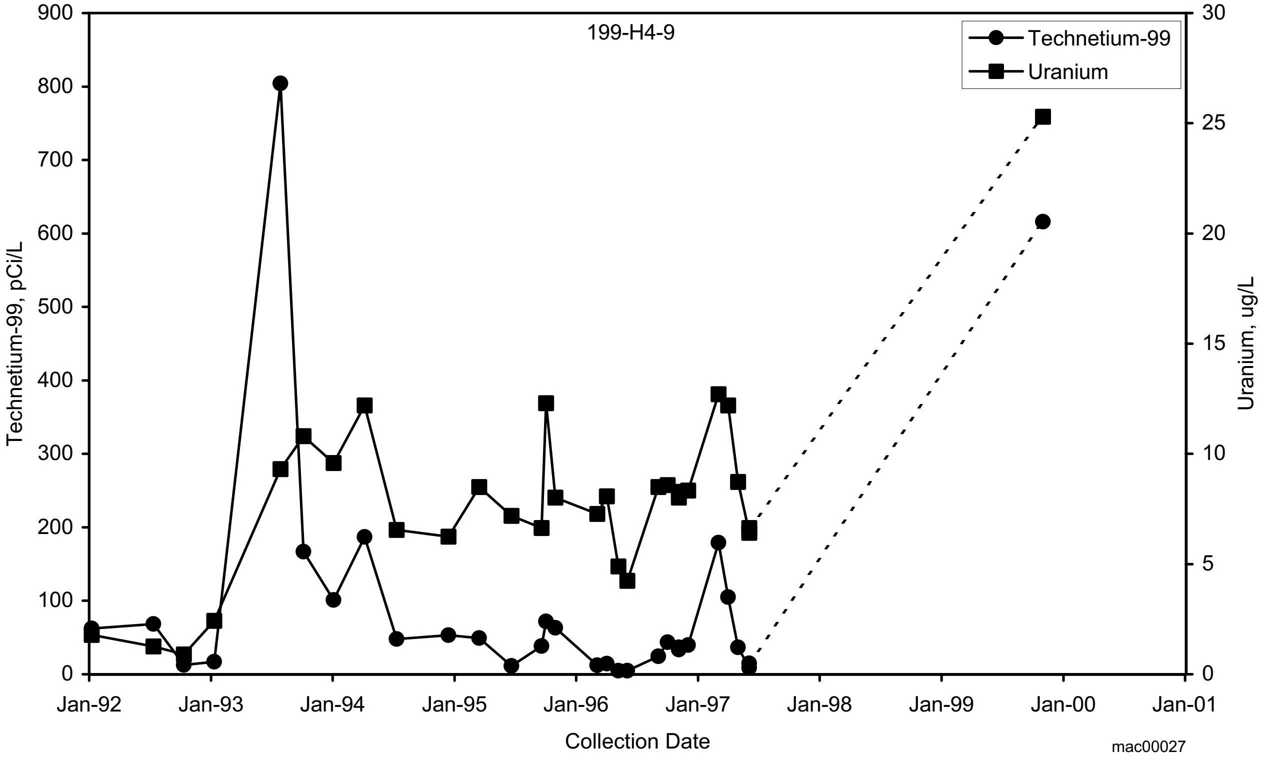

Figure 2.6-15. Technetium-99 and Uranium in Groundwater at Well 199-H4-9 near the Former 183-H Solar Evaporation Basins

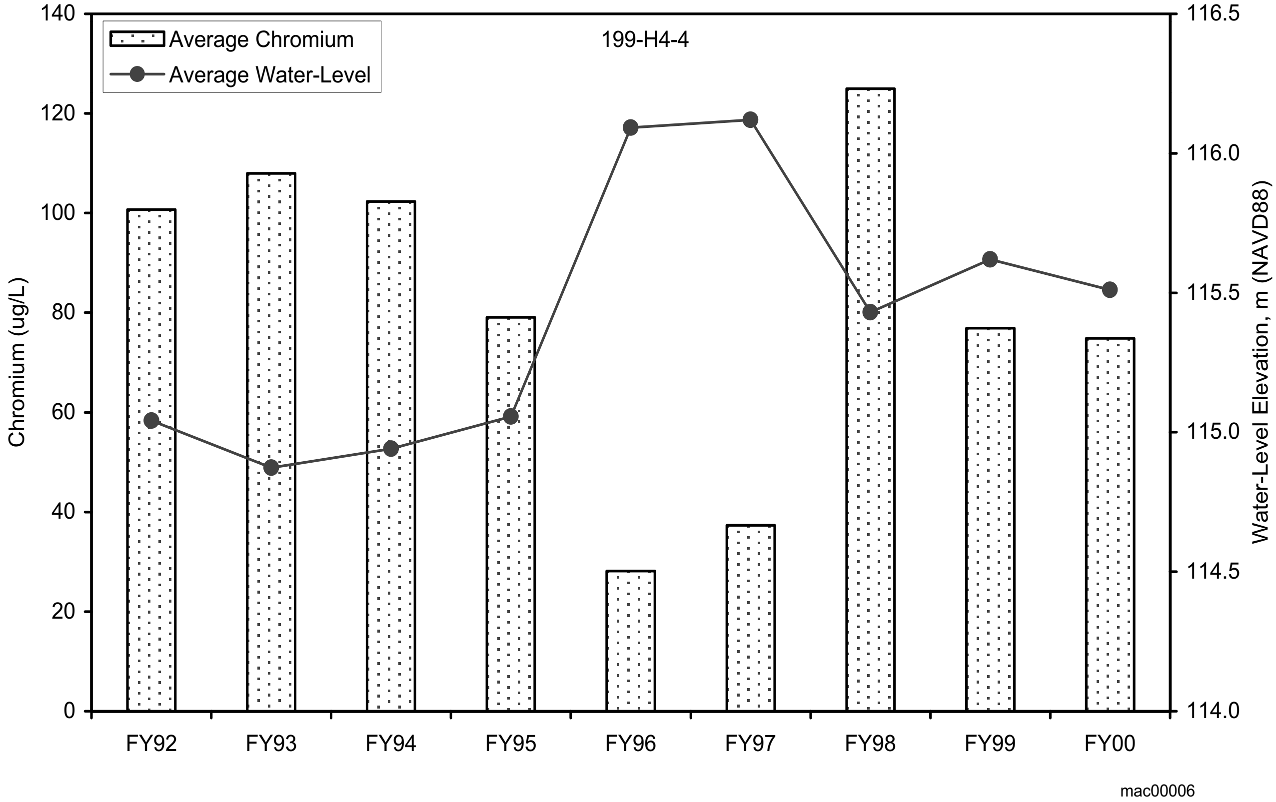

Figure 2.6-16. Chromium Concentrations and Water Levels in Well 199-H4-4 Downgradient of the Former 183-H Solar Evaporation Basins

2.7 100 F Area

M. D. Sweeney and M. J. Hartman

The 100 F Area (Figure 2.7-1) is located the farthest east and downstream of the reactor areas on the Hanford Site. F Reactor operated from 1945 to 1965. Like all of the other Hanford Site reactors except N Reactor, F Reactor was cooled by a single-pass system (i.e., cooling water passed through the reactor and was discharged directly to the Columbia River). Waste sites in the 100 F Area include retention basins for reactor coolant, liquid waste disposal trenches, and French drains. Waste sites are described in DOE/RL-95-54 and DOE/RL-95-92. Groundwater contaminants include nitrate, strontium-90, and tritium. Local contamination with chromium, trichloroethene, and uranium is also detected.

Nitrate exceeds its maximum contaminant level beneath the 100 F Area and in a fairly large plume extending downgradient to the southeast. Chromium, strontium-90, trichloroethene, and tritium exceeded standards in much smaller plumes.

Remedial action of waste sites in the 100 F Area was initiated in fiscal year 2000. These activities consisted of removing and stockpiling clean overburden soil and excavating contaminated soil and debris for disposal at the Environmental Restoration Disposal Facility. Water (obtained from fire hydrants) was applied as necessary to control dust. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to the groundwater. The waste sites that were excavated in fiscal year 2000 include the 116-F-14 retention basins, 1607-F6 septic tank, and 100-F-19 cooling water pipelines.

A small-diameter geophysical investigation was conducted at the 126-F-1 ash pit in fiscal year 2000. The purpose of the investigation was to delineate the extent of radiological contamination in the ash pit, and to demonstrate the efficacy of evaluating shallow contamination by combining cone penetrometers and borehole logging. The results are summarized in Section 3.3.2.

Aerial view of the 100 F Area, August 2000.

2.7.l Groundwater Flow

Groundwater flows toward the east-northeast in the northern 100 F Area and toward the southeast in the southern 100 F Area (see Plate 1). In March 2000, the gradient between wells 199-F5-4 and 199-F8-4 was 0.002. Hydraulic conductivity of the Hanford formation in the 100 F Area ranges from 9.1 to 69 meters per day (BHI-00917). Using these values and an effective porosity of 0.1 to 0.3, the flow rate ranges from 0.06 to 1.4 meters per day toward the southeast.

A plume of groundwater contaminated with tritium, which originates from sources in the 100 F Area, extends to the southeast of the 100 F Area, confirming the southeastern direction of flow. This plume appears to discharge into the river in the vicinity of the 100 F Area slough and some additional but uncertain distance farther downstream. The cause for this preferential pathway may be a buried former river channel that lies parallel to the current channel. Evidence for erosional features on the top of the Ringold Formation (which lies below the water table) was noted during earlier investigations of the hydrogeology of the 100 F Area (see Figure 8 in WHC-SD-EN-TI-221).

2.7.2 Tritium

Tritium concentrations beneath the 100 F Area are generally low except for one well near the 118-F-1 burial ground (see Plate 2). The previously reported value of 16,000 pCi/L for well 199-F8-3 increased to 36,900 pCi/L in November 1999 (Figure 2.7-2). Although the concentration is twice the level of the last sampling event, the increase may represent stabilization of tritium infiltration from the 118-F-1 or 118-F-6 burial grounds, two potential source areas near this well (see Figure 2.7-1). Concentrations of tritium in this well have historically been greater than the 20,000 pCi/L drinking water standard.

2.7.3 Uranium

Monitoring Objectives in 100 F Area

Groundwater monitoring is conducted in the 100 F Area:

- triennially to annually to describe the nature and extent of contamination
- quarterly to monitor trends in variable constituents/wells.

Uranium concentrations did not exceed the proposed 20 μg/L maximum contaminant level for the reporting period. A small plume of uranium, located between the 118-F-1 and 118-F-3 burial grounds, has been detected in the past, but not in fiscal year 2000. Uranium concentrations in well 199-F8-2 were just below the maximum contaminant level in fiscal year 2000. Well 199-F8-1 exceeded the standard in 1997 and reported highest values in the operable unit. This well was decommissioned in 1998. Uranium concentrations in well 199-F8-3 were below the proposed maximum contaminant level, but are increasing. The average concentration of uranium in the 100 F Area is 10.8 μg/L for fiscal year 2000.

2.7.4 Strontium-90

Three wells in the 100 F Area continued to exceed the drinking water standard for strontium-90. Two of these wells, 199-F5-1 and 199-F5-3 (Figure 2.7-3), are near the river ~50 to 100 meters east of the 116-F-2 trench. The third well, 199-F5-46 (Figure 2.7-4), is located ~175 meters west of the 116-F-14 retention basin. Strontium-90 concentrations appear to fluctuate with changing river levels near the 100 F Area.

These wells have been used to track a small strontium-90 plume near the 116-F-14 retention basins and the 116-F-2 trench. The distribution of strontium-90 is nearly the same as in fiscal year 1998 (see Figure 5.8-1 in PNNL-12086). Strontium-90 concentrations have varied considerably since 1996. This may be due to sustained high river levels prior to 1996.

2.7.5 Nitrate

Nitrate exceeds the 45 mg/L maximum contaminant level in a fairly large plume originating in the 100 F Area and extending downgradient to the southeast. Nitrate varies in concentration across the 100 F Area. Eleven wells had concentrations above the maximum contaminant level in fiscal year 2000. Seven of these wells are inside the 100 F Area boundary and have a progressively increasing trend (Figures 2.7-5, 2.7-6 and 2.7-7). They include wells 199-F5-45, 199-F5-46, 199-F5-47, and 199-F5-48 (located south and east of F Reactor), and wells 199-F7-1, 199-F7-2, and 199-F7-3 (located northwest and southwest of F Reactor). Well 699-77-36 is located ~800 meters west of the southwest corner of the 100 F Area boundary (see Figure 2.7-1). The nitrate concentration increase in this well has been substantial (see Figure 2.7-6), growing at an annual rate of 10 to 12 mg/L since 1996.

Nitrate concentrations have increased in many wells in the 100 F Area since the late 1990s. The reason for the increase is unknown.

A slight decline in nitrate concentration has also been detected in three wells sampled during the reporting period (Figure 2.7-8). Although their nitrate concentration exceeds the drinking water standard, their trends have been steadily declining since at least 1998. These wells are located southwest of F Reactor. Well 199-F8-2 is located ~40 meters southeast of the 116-F-7 French drain, well 199-F8-3 is located east of the 188-F-1 burial ground, and well 199-F8-3 is located ~340 meters southeast of the 126-F-1 coal ash pit.

2.7.6 Chromium

Hexavalent chromium was sampled and reported in one well for the reporting period. Well 199-F5-46 reported an increase in hexavalent chromium of more than 100 µg/L from previous sampling (Figure 2.7-9). The concentrations reported in December 1999 (197 and 205 µg/L) and February 2000 (208 µg/L) are higher than the January 1999 sample (91 µg/L). These results also exceed the historical trend since 1997, which varied seasonally at the 75 to 80 µg/L levels. This well is located east of the 100-F-5 French drain.

2.7.7 Trichloroethene

Trichloroethene continued to be detected in the southwestern corner of the 100 F Area and in the adjacent 600 Area. Well 199-F7-1 and 699-77-36 exceeded the 5 µg/L maximum contaminant level during the reporting period. Trichloroethene concentrations have declined slightly in well 199-F7-1 (Figure 2.7-10). Well 699-77-36 (see Figure 2.7-1) reported the same concentration as the last reporting period (18 µg/L). Both wells seem to have a gradual decline overall. The trichloroethene isopleth drawn near well 199-F5-45 in the fiscal year 1999 annual report (PNNL-13116) was removed because the concentration in this well dropped below the maximum contaminant level.

Concentrations of trichloroethene in the southwestern 100 F Area are declining gradually.

2.7.8 Water Quality at Shoreline Monitoring Locations

Groundwater near the Columbia River is sampled annually in the late fall via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline.

Seeps are natural areas of groundwater discharge above the water line. Three aquifer tubes and two seeps were sampled near 100 F Area in fiscal year 2000 (Table 2.7-1).

Nitrate exceeded its maximum contaminant level in a sample from one aquifer sampling tube and one seep on the shore of the Columbia River downgradient of the 100 F Area.

Nitrate concentrations in one aquifer tube and an adjacent seep exceeded the maximum contaminant level. Specific conductance of these samples was about 500 µS/cm, indicating the samples were relatively undiluted groundwater. The tube and seep are located southeast of the 100 F Area, where the groundwater nitrate plume discharges to the Columbia River. Other contaminants were present in very low concentrations at the shoreline.

Table 2.7-1. Shoreline Monitoring Data for the 100 F Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
64-D	Tube	28-Oct-99	210	8				
74-S	Tube	28-Oct-99	309	11				21.0
75-D	Tube	08-Nov-99	509	16	***0.2***			54.0
SF-187-1	Seep	01-Nov-99	167	10	1.5	4.8	***145***	4.3
SF-207-1	Seep	01-Nov-99	505	23	***0.0***	15.8	1,450	51.8
64-D	River	28-Oct-99	121					
74-S	River	28-Oct-99	125					
75-D	River	08-Nov-99	121					
RF-190	River	21-Sep-99	116		0.1		27	0.3

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore, adjacent to the aquifer sampling tube.
Values in ***bold italics*** are qualified by the laboratory as “undetected.” Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 µS/cm.
Data sources: Hanford Environmental Information System and various project records.

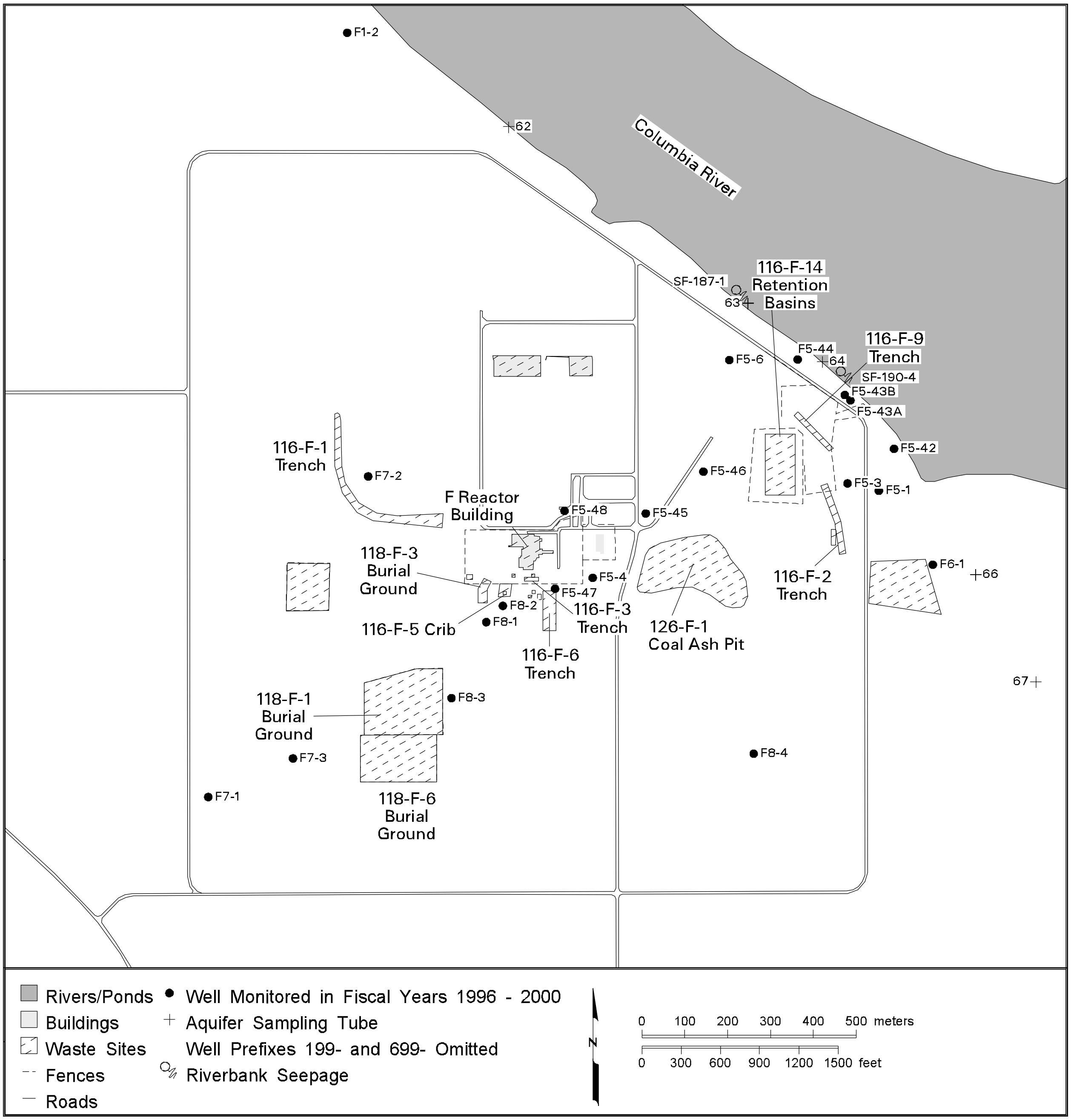

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Figure 2.7-1. Groundwater Monitoring Wells in the 100 F Area

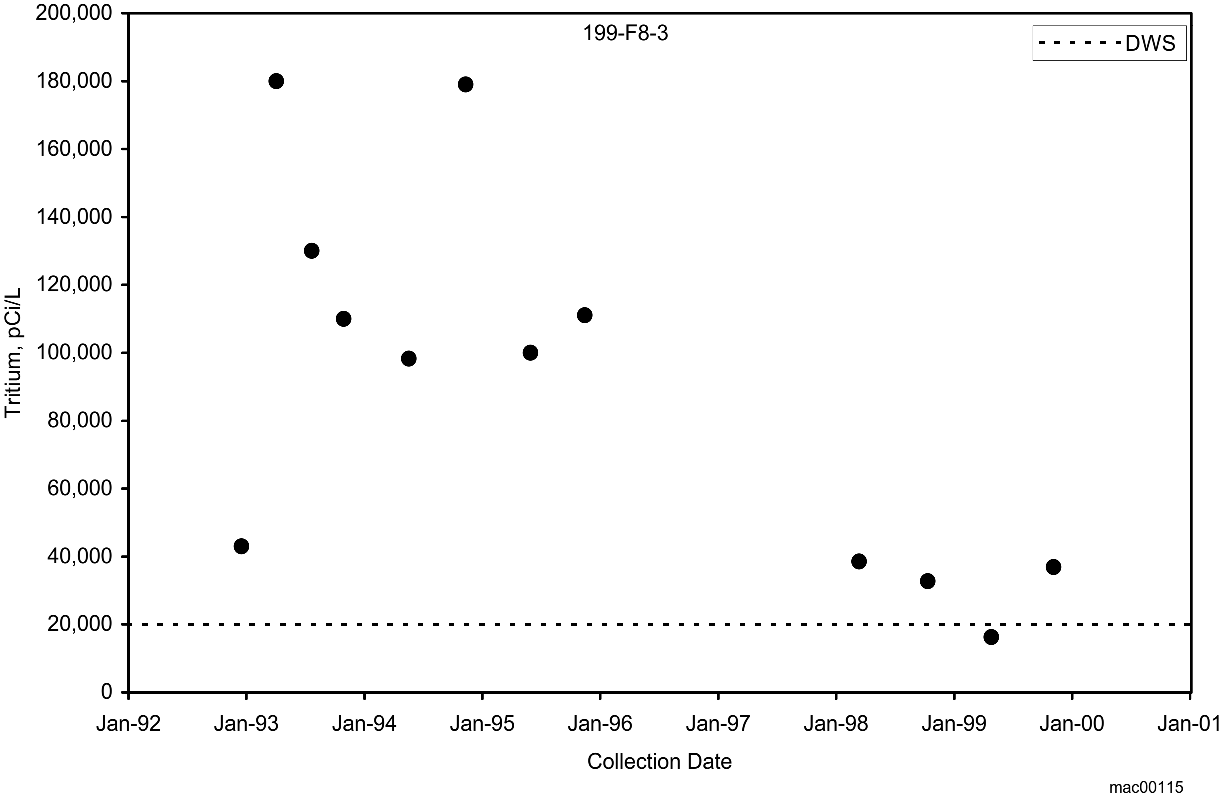

Figure 2.7-2. Tritium in Well 199-F8-3 near the 118-F-1 Burial Ground

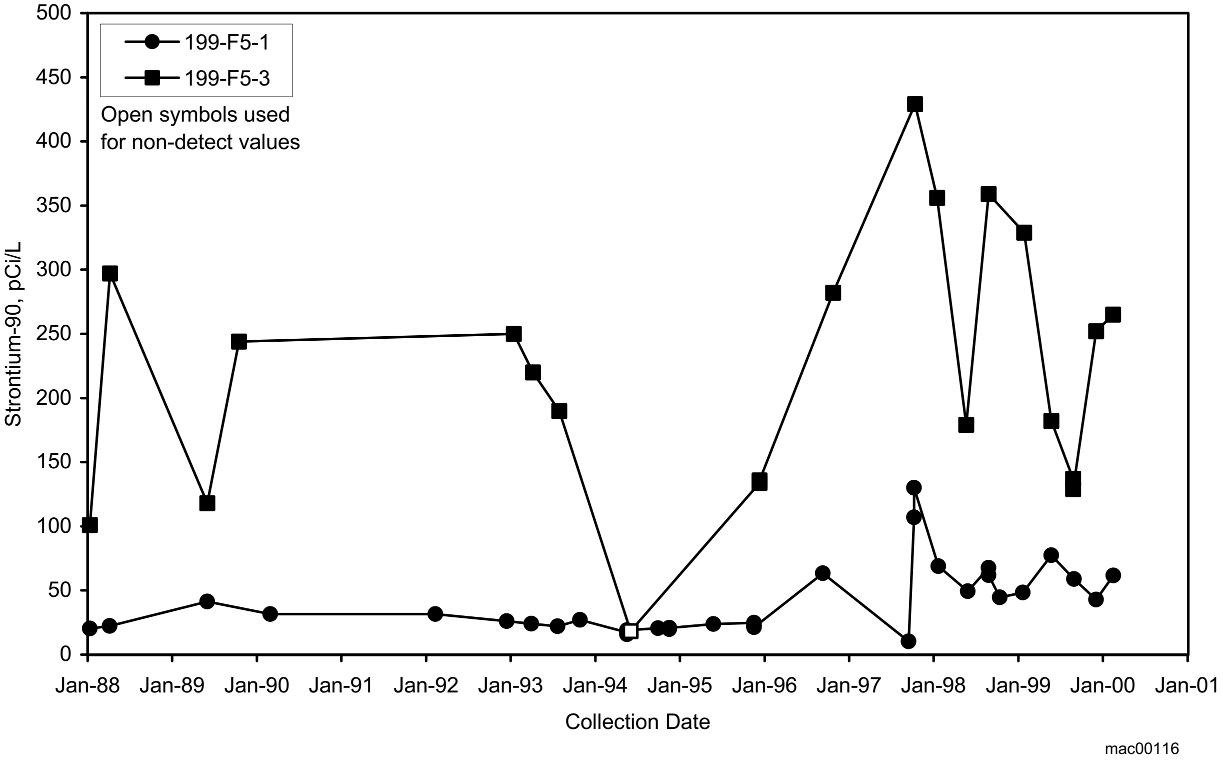

Figure 2.7-3. Strontium-90 in Wells 199-F5-1 and 199-F5-3 near the 116-F-2 Trench

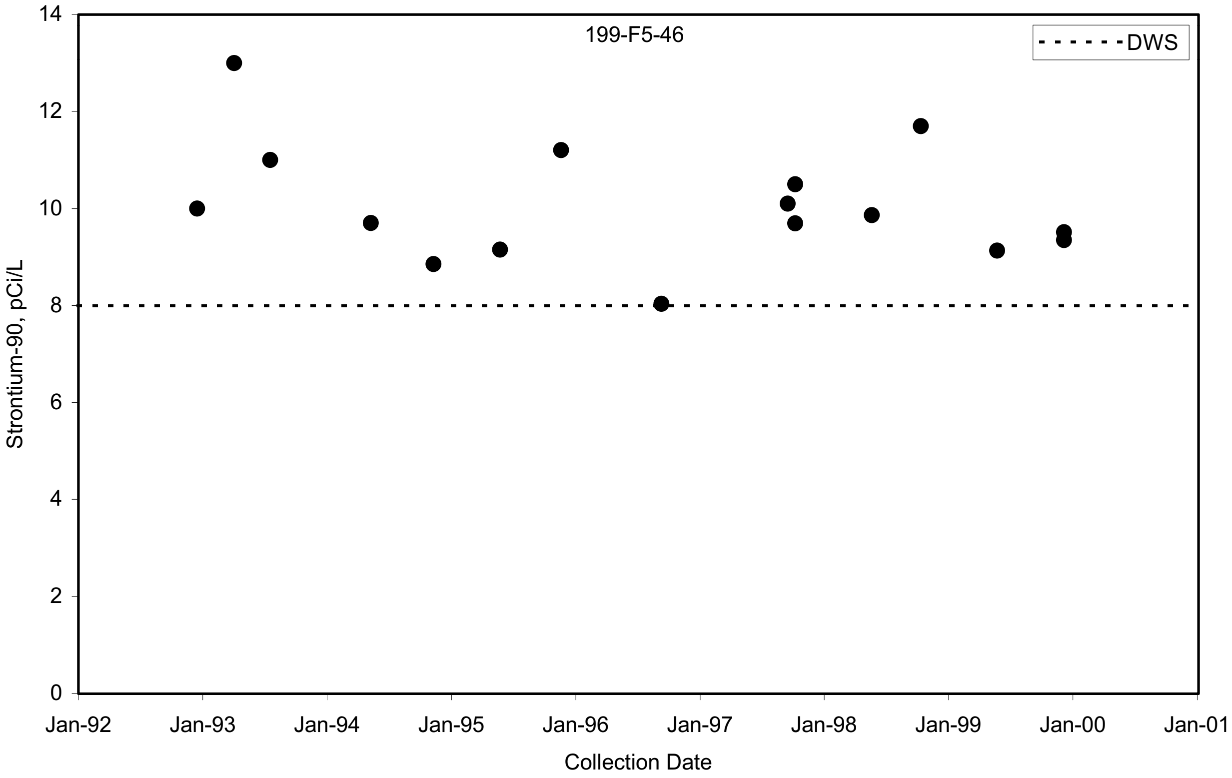

Figure 2.7-4. Strontium-90 in Well 199-F5-46 West of the 116-F-14 Retention Basins

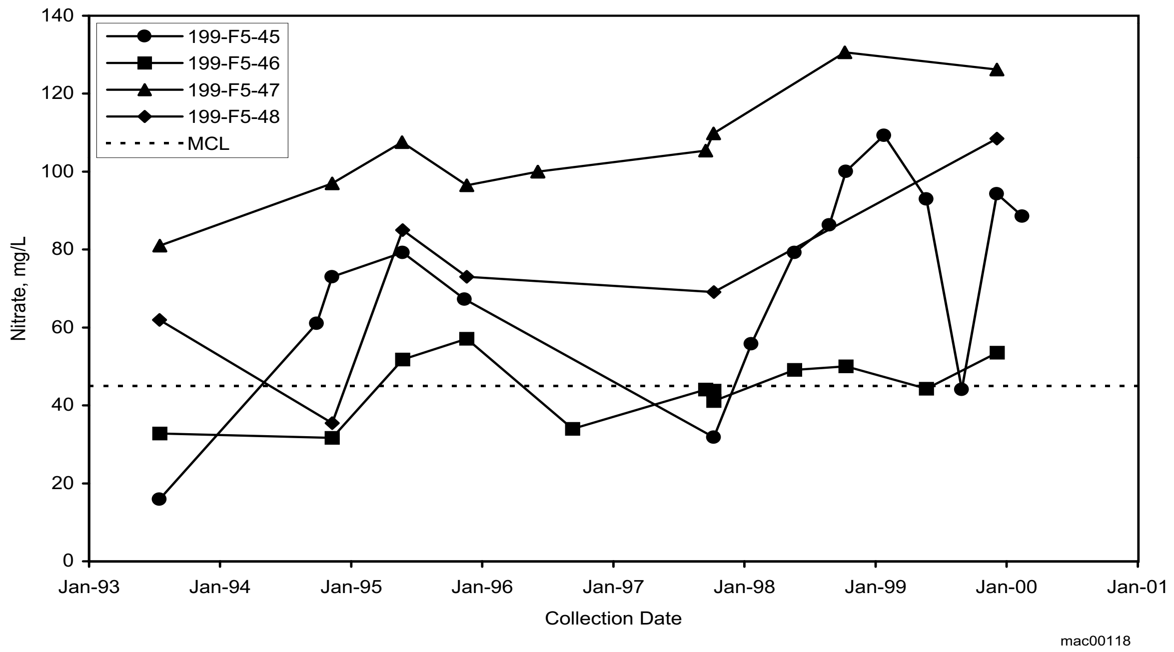

Figure 2.7-5. Nitrate in Wells South and East of F Reactor

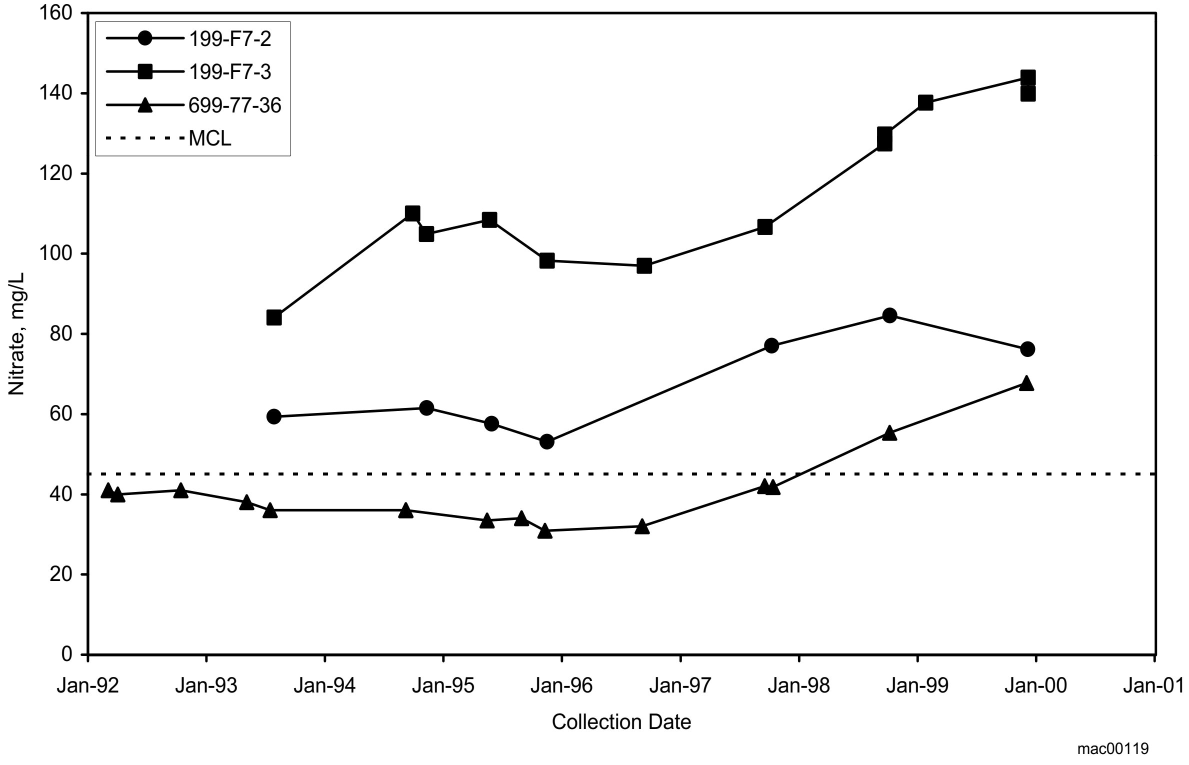

Figure 2.7-6. Nitrate in Wells in the Western 100 F Area

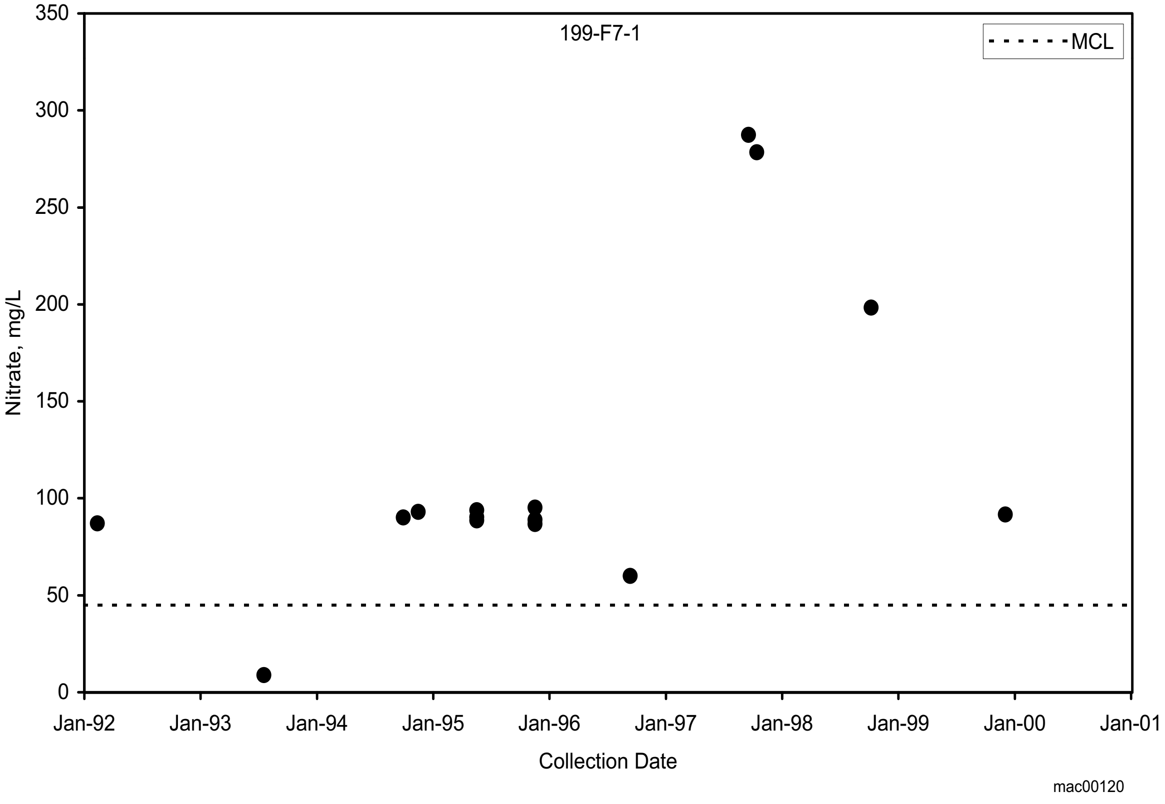

Figure 2.7-7. Nitrate in Well 199-F7-1 in the Southwestern 100 F Area

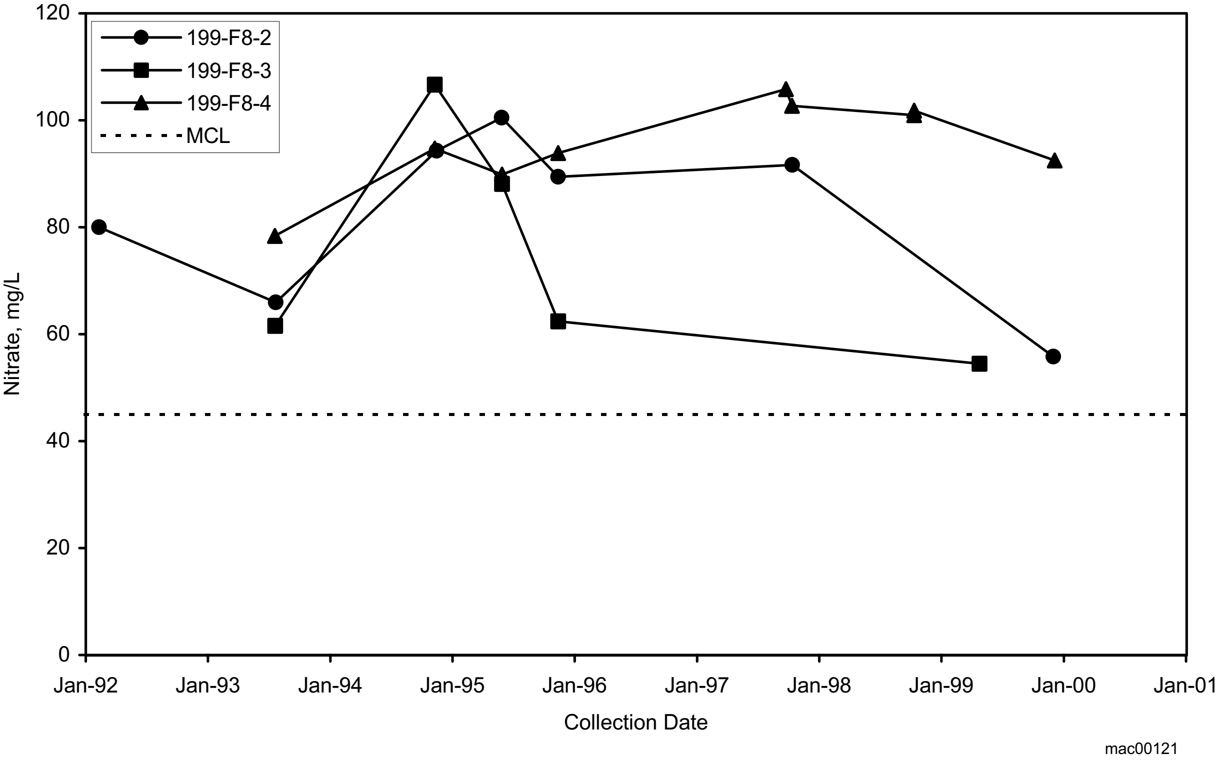

Figure 2.7-8. Nitrate in Wells 199-F8-2, 199-F8-3, and 199-F8-4

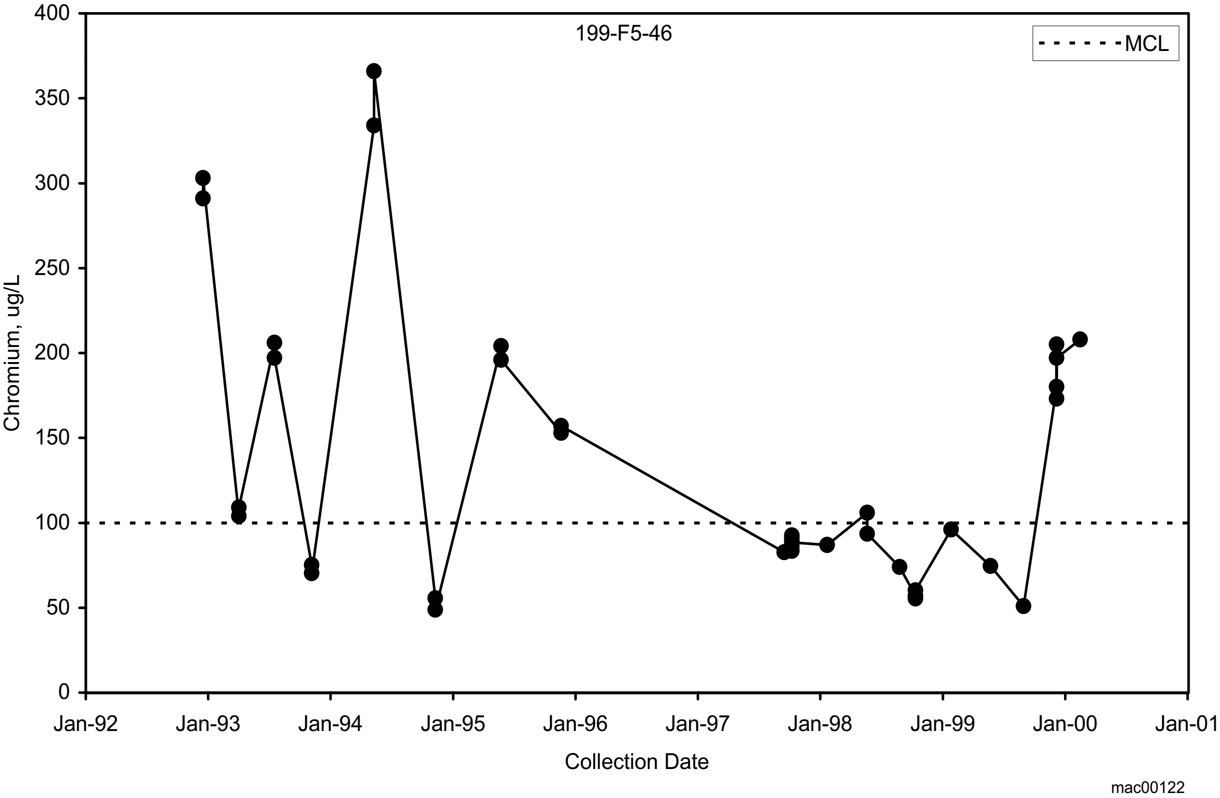

Figure 2.7-9. Chromium in Well 199-F5-46 West of the 116-F-14 Retention Basins

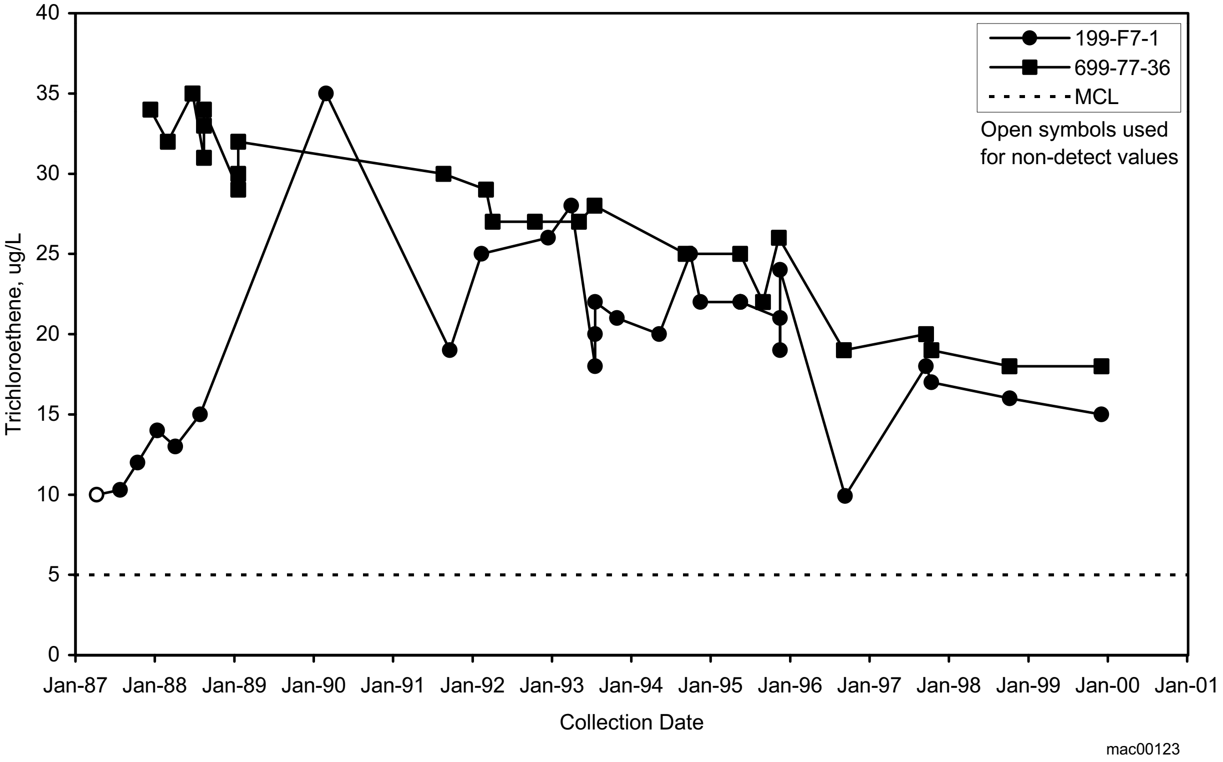

Figure 2.7-10. Trichloroethene in Wells in the Southwestern 100 F Area

2.8 200 West Area

P. E. Dresel, D. B. Barnett, F. N. Hodges, V. G. Johnson, R. B. Mercer, L. C. Swanson, and B. A. Williams

The 200 West Area, located on the central plateau of the Hanford Site, was used to process irradiated reactor fuel to extract and purify plutonium between 1944 and 1987. The extraction took place at the T Plant and later the Reduction-Oxidation (REDOX) Plant. The Plutonium Finishing Plant was used for plutonium purification. U Plant was used to extract uranium from process waste. Currently, the 200 West Area is used for waste management and disposal. Further details are provided in PNNL-13080.

For the purpose of describing groundwater contamination, the 200 West Area can be divided into five major regions:

- Plutonium Finishing Plant
- T Plant
- U Plant
- REDOX Plant
- State-Approved Land Disposal Site.

This section discusses groundwater flow, major contaminants, and specific *Resource Conservation and Recovery Act of 1976* (RCRA) facility monitoring for

Groundwater beneath the 200 West Area is contaminated with widespread plumes of carbon tetrachloride and nitrate. Iodine-129, technetium-99, tritium, uranium, chromium, fluoride, and trichloroethene also are present at levels above their drinking water standards. The eastward spread of contamination from this area is relatively slow because of low-permeability sediment in the aquifer.

Satellite image of the 200 West Area, August 2000.

each region. Where appropriate, groundwater remediation is also discussed. The major contaminant plumes found in 200 West Area are carbon tetrachloride, iodine-129, nitrate, technetium, trichloroethene, tritium, and uranium. Chromium is also found in small, scattered areas. Monitoring well locations in the 200 West Area are shown in Figure 2.8-1.

2.8.1 Plutonium Finishing Plant

The Plutonium Finishing Plant performed the final stages of plutonium purification from 1949 through 1987. The Plutonium Finishing Plant has not been a significant contributor to the major radiological contaminant plumes in groundwater. Migration of plutonium contamination from the vadose zone is of considerable concern because large quantities of plutonium, in the presence of organic complexing agents, were disposed to ground in the area. The formation of plutonium bearing colloids that could enhance mobility is also a concern. No further investigation of the mobility of plutonium was undertaken in fiscal year 2000. Past data suggest minor plutonium groundwater contamination (PNNL-12086), though no new results from fiscal year 2000 indicated the presence of plutonium in 200 West Area groundwater. Carbon tetrachloride and other volatile organic compounds form the major plumes attributable to the Plutonium Finishing Plant. Relatively widespread nitrate contamination is also present.

The only facilities near the Plutonium Finishing Plant with RCRA monitoring requirements are the burial grounds in Low-Level Waste Management Area 4. These are not believed to contribute to groundwater contamination. Remediation of volatile organic compounds in groundwater and the vadose zone is being undertaken in this area using a pump-and-treat system. Large masses of carbon tetrachloride continue to be removed from the vadose zone by vapor extraction, reducing this source of groundwater contamination (see Section 3.2). The groundwater pump-and-treat system removes smaller amounts of carbon tetrachloride as groundwater is withdrawn and re-injected. As a result, significant changes in groundwater flow and contaminant distribution are occurring.

Monitoring Objectives Near Plutonium Finishing Plant

Groundwater monitoring is conducted near the Plutonium Finishing Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of one RCRA waste management area
- semiannually to monitor trends in variable constituents/wells
- various time intervals to evaluate the performance of a pump-and-treat system for carbon tetrachloride.

2.8.1.1 Groundwater Flow

Groundwater near the Plutonium Finishing Plant flows generally from west to east, and is heavily influenced, by the ongoing 200-ZP-1 Operable Unit pump-and-treat activities (see Plate 1). There are six extraction wells trending along an arc from north of the Plutonium Finishing Plant to the east and southeast. There are also 5 injection wells (only 3 are active) located to the southwest of the Plutonium Finishing Plant and to the west of Low-Level Waste Management Area 4. 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. Groundwater flow beneath Low-Level Waste Management Area 4 is discussed in Section 2.8.1.5, and flow beneath the pump-and-treat system is discussed in Section 2.8.1.6.

2.8.1.2 Carbon Tetrachloride

Carbon tetrachloride contamination is present in the unconfined aquifer system beneath most of the 200 West Area and has migrated past the 200 West Area boundary (Figure 2.8-2), covering an area of over 11 square kilometers. The contamination is believed to be from pre-1973 waste associated with the Plutonium Finishing

Plant. The maximum carbon tetrachloride concentration mapped in Figure 2.8-2 in the 200 West Area was in well 299-W15-30, where the concentration was 6,600 µg/L in the only sample taken in fiscal year 2000. This well is located northwest of the Plutonium Finishing Plant and is not near the identified sources of carbon tetrachloride discussed in the following paragraphs. The allowable maximum contaminant level for carbon tetrachloride in drinking water is 5 µg/L.

The major identified sources of carbon tetrachloride are the 216-Z-9 trench, the 216-Z-1A tile field, and the 216-Z-18 crib. The 216-Z-12 crib, the 216-Z-19 ditch, and the 216-T-19 tile field also may have contributed. These sources are shown in Appendix A, Figure A.11. Vadose zone carbon tetrachloride sources are discussed in Section 3.2.

In the center of the plume, the area within the 4,000 µg/L contour has increased during operation of the pump-and-treat system. Concentrations of carbon tetrachloride increased in recent years in the northernmost extraction wells 299-W15-33, 299-W15-34, and 299-W15-35 and nearby monitoring wells such as well 299-W15-1 (Figure 2.8-3) but appear to have leveled off or decreased somewhat in fiscal year 2000. Concentrations in the southern extraction wells 299-W15-32 and 299-W15-36 and nearby monitoring wells declined slowly after the start of pump-and-treat operations but have also leveled off. BHI-01311 discusses in more detail the continued existence of high concentrations in the area of pump-and-treat remediation, which indicates the presence of a continuing source of carbon tetrachloride, such as non-aqueous phase liquid below the water table or continued recharge from the vadose zone. Concentrations are declining around the active injection wells as shown by the depression in the contours in Figure 2.8-2.

The part of the carbon tetrachloride plume with concentrations greater than 1,000 µg/L extends to the north and northeast, reaching the vicinity of Low-Level Waste Management Area 3 and T Plant. Well 299-W10-20, for example, has persistent concentrations of carbon tetrachloride near or above 1,000 µg/L, even though it is not located near any known sources. Other wells in the vicinity also have high carbon tetrachloride values, with the exception of well 299-W10-19, where the concentrations have declined sharply since 1997 (Figure 2.8-4). Well 299-W10-5, located west of Waste Management Area TX-TY was sampled in February 2000 for the first time since 1994 and the carbon tetrachloride concentration increased to 2,500 µg/L.

Carbon tetrachloride concentrations greater than 1,000 µg/L also are found near T Plant northeast of the known carbon tetrachloride sources near the Plutonium Finishing Plant. High concentrations are detected in wells 299-W11-14 (Figure 2.8-5) and 299-W11-7. Concentrations in well 299-W12-1, located in the northeastern corner of the 200 West Area, have increased since 1997 to 140 µg/L in fiscal year 2000 (Figure 2.8-6). Thus, increasing concentrations of carbon tetrachloride continue to move beyond the boundary of the 200 West Area. The carbon tetrachloride plume has been divided into two lobes on its northern boundary, likely because of the discharge of relatively clean water to the 216-T-4-2 ditch. Concentrations of a number of contaminants are increasing in wells near the former ditch since discharges of clean water ceased in 1995.

Carbon tetrachloride contamination beneath the 200 West Area originated primarily in waste sites near the Plutonium Finishing Plant. The central portion of the plume is moving to the north under the influence of remedial action pumping wells.

Carbon tetrachloride concentrations have increased markedly in some wells in the vicinity of Waste Management Area S-SX. For example, concentrations in well 299-W23-15, located directly south of the SX Tank Farm, rose from less than 5 µg/L in fiscal year 1995 to an average of 130 µg/L in fiscal year 2000 (see Figure 2.8-6). The previously low concentrations in this area could have been caused by the discharge of water free of carbon tetrachloride to portions of the 216-U-14 ditch, north of the tank farms, until 1995. This discharge may have affected groundwater flow, so that carbon tetrachloride spread to the east and west of the tank farms. A number of other wells in the area remain low in carbon tetrachloride.

Information on the distribution of carbon tetrachloride in the eastern half of the 200 West Area is very sparse. The original monitoring well network had large gaps in this area and several key wells have gone dry. Whether or not a low concentration area, as shown on the map (see Figure 2.8-2), exists in the east-central part of the 200 West Area is uncertain. This low concentration area may have resulted from past discharges to the 200 West power plant pond and the 216-W laundry waste crib, as is suggested by samples from well 299-W14-10, where carbon tetrachloride was near or below the detection limit. Well 299-W14-10 is an older well that does not appear to have been completed properly to provide representative groundwater samples.

Carbon tetrachloride contamination extends southeast of the Plutonium Finishing Plant to the eastern edge of the Environmental Restoration Disposal Facility. Concentrations in fiscal year 2000 reached the maximum contaminant level of 5 μg/L in well 699-36-67 (see Figure 2.8-6).

Carbon tetrachloride contamination has been detected to depths greater than 60 meters below the water table. In places, contamination at depth extends greater distances laterally than contamination at the water table, as reported previously (PNNL-12086). Little information is available on the distribution of carbon tetrachloride at depth. Available data consist of a few well nests completed at different depths and from depth-discrete samples collected at specific points in older wells with large open intervals. One disadvantage of the depth discrete samples is the potential for vertical mixing within the well or along the annulus. A discussion of depth distribution of carbon tetrachloride is presented in the fiscal year 1998 annual groundwater report (PNNL-12086). A detailed summary of the available data on the depth distribution of carbon tetrachloride has been published in BHI-01311.

2.8.1.3 Chloroform and Trichloroethene

Two sources of chloroform in Hanford Site groundwater are from chlorination of organic matter during purification of potable water and then its subsequent disposal to ground, or from biodegradation of carbon tetrachloride. Biodegradation is believed to be the major source of chloroform in the 200 West Area. The maximum contaminant level for chloroform is 100 μg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. Values for chloroform were all below the maximum contaminant level in fiscal year 2000, with the highest annual average concentration of 96 μg/L in well 299-W14-9.

The distribution of trichloroethene near the Plutonium Finishing Plant is shown in Figure 2.8-7. Disposal of trichloroethene near T Plant also may have contributed to this plume. The maximum annual average trichloroethene found in fiscal year 2000 was 28 μg/L in well 299-W15-7, located near the northern extraction wells for the carbon tetrachloride pump-and-treat system. The maximum contaminant level allowable in drinking water for trichloroethene is 5 μg/L.

2.8.1.4 Nitrate

Waste sites near the Plutonium Finishing Plant have contributed to the large nitrate plume in groundwater beneath the 200 West Area.

The 216-Z-9 trench received an estimated 1.3 million kilograms of chemicals containing nitrate during its operation from 1955 to 1962. Other liquid waste disposal facilities associated with the Plutonium Finishing Plant received smaller but still significant amounts of nitrate. There is, thus, a nitrate plume originating in this area, but additional sources of nitrate from disposal facilities near T Plant also contribute to the contamination. The extent of nitrate in the northern 200 West Area is shown in Figure 2.8-8. The highest nitrate concentrations are associated with facilities near T Plant and are discussed in Section 2.8.2.6.

Nitrate concentrations are increasing in wells downgradient from the injection wells for the 200-ZP-1 pump-and-treat system. This increase is apparently because the injected water was not treated for nitrate removal. Thus, nitrate concentrations in wells 299-W18-23 and 299-W18-26 are now generally greater than the maximum contaminant level, though the values fluctuate in response to varying injection rates (Figure 2.8-9). This nitrate results in an increase in specific conductance of water from wells that are now upgradient of Low-Level Waste Management Area 4, decreasing the usefulness of specific conductance for RCRA detection monitoring.

2.8.1.5 RCRA Parameters for Low-Level Waste Management Area 4

RCRA monitoring at Low-Level Waste Management Area 4 indicates no groundwater contamination from this facility. Monitoring this area is challenging because extraction and injection of groundwater from a nearby remediation system has changed flow directions and contaminant concentrations.

The groundwater flows mainly to the east beneath Low-Level Waste Management Area 4. Groundwater flow is influenced to some extent by the 200-ZP-1 extraction wells to the east and the injection wells to the west of Low-Level Waste Management Area 4.

The groundwater monitoring network remains adequate to detect contaminant releases from Low-Level Waste Management Area 4. The current monitoring network and the constituent list for this area are listed in Appendix A, Table A.19. Samples are collected semiannually in accordance with RCRA interim status regulations. Additional monitoring wells may be necessary to maintain this monitoring network because wells are going dry and flow directions are changing.

Carbon tetrachloride is a major contaminant in most of the monitoring wells surrounding Low-Level Waste Management Area 4. This contamination is related to the widespread plume in the 200 West Area (see Section 2.8.1.2).

Nitrate is also a major contaminant in this area. Wells 299-W15-15, 299-W15-16, 299-W15-18, 299-W18-21, 299-W18-23, and 299-W18-24 exceeded the 45 mg/L maximum contaminant level in fiscal year 2000. With the exception of well 299-W18-21, located at the southwest corner of the waste management area, this contamination is related to the recognized nitrate plume in the 200 West Area and to residual nitrate injected in wells west of the waste management area. The elevated levels of nitrate in well 299-W18-21 appear to be isolated from the main body of this nitrate plume (see Figure 2.8-8). Tritium also is elevated to some degree in well 299-W18-21 and exhibits a similar pattern with respect to the larger tritium plume in the 200 West Area. Whether these elevated constituents indicate a remnant from some other source of contamination or a preferential flow path in this direction is not known.

Comparisons of the upgradient/downgradient values for the indicator parameters are of limited use at Low-Level Waste Management Area 4. The 200-ZP-1 pump-and-treat system and the recent changes in the direction of groundwater flow have both contributed to the difficulties in determining contaminant releases from this facility. There are no indications that Low-Level Waste Management Area 4 has contributed to groundwater contamination (see Appendix A, Section A.7.8).

2.8.1.6 Groundwater Remediation at 200-ZP-1 Operable Unit

Groundwater is pumped out of wells in the carbon tetrachloride plume and treated to remove the contamination. The objective of the interim remedial action is to keep the center of the plume from spreading. In fiscal year 2000, ~300 million liters of groundwater were treated and 1,183 kilograms of carbon tetrachloride were removed.

The pump-and-treat system for the 200-ZP-1 Operable Unit is successfully containing and capturing the high concentration portion of the carbon tetrachloride plume. Contamination in the groundwater was reduced in the area of highest concentration through mass removal; additional information was collected through hydraulic monitoring, contaminant monitoring, and treatment system operation that should support final record of decision development.

The pump-and-treat system for the 200-ZP-1 Operable Unit, located north of the Plutonium Finishing Plant, was implemented as an interim remedial action. The interim action objectives (ROD 1995) are the following:

- prevent further movement of contaminants from the highest concentration area of the plume (i.e., containing carbon tetrachloride inside the 2,000 to 3,000 µg/L contour)

- reduce contamination in the area of highest carbon tetrachloride concentrations
- provide information that will lead to development of a final remedy that will be protective of human health and the environment.

The following information is summarized from DOE/RL-2000-71. The 200-ZP-1 Operable Unit facilities and Phase III extraction, injection, and monitoring well locations are shown in Appendix A, Figure A.12.

History of Operations

The pump-and-treat system was implemented in a three-phase approach. Phase I operations consisted of a pilot-scale treatability test that ran from August 29, 1994, to July 19, 1996. During that period, contaminated groundwater was removed from a single extraction well, treated using granular activated carbon, and returned to the aquifer through an injection well. For more detailed information about operations during the treatability test, refer to DOE/RL-95-30.

Recent data indicate an additional area of high carbon tetrachloride concentrations beneath the Plutonium Finishing Plant. Investigation of this area is planned for 2001.

Phase II operations began August 5, 1996, and ended on August 8, 1997, for transition to Phase III operations. During Phase II, three extraction wells were completed in the top 15 meters of the aquifer. The groundwater was treated using an air stripper followed by granular activated carbon of the air stream and returned to the aquifer through a single injection well.

From August 8 to 28, 1997, well-field piping and treatment equipment were upgraded for Phase III operations, which began August 29, 1997 and continue to the present. During Phase III, six extraction wells were completed in the top 15 meters of the aquifer and five injection wells were installed. The Phase III treatment system uses air stripping combined with vapor-phase, granular activated carbon technology to remove the volatile organic compounds from the contaminated groundwater.

Contaminant Removal

Carbon tetrachloride contamination in the upper part of the aquifer was reduced in the area of highest concentrations through mass removal. Approximately 300.4 million liters of contaminated groundwater were treated in fiscal year 2000 at an average flow rate of 709 liters per minute. Production rates for each of the six extraction wells ranged from 62 to 278 liters per minute. The average influent concentration for the six extraction wells was 4,041 μg/L, an increase over fiscal year 1999 concentrations (3,788 μg/L). Overall, influent concentrations ranged from 3,200 to 4,900 μg/L.

Treatment of the contaminated water resulted in the removal of 1,183 kilograms of carbon tetrachloride in fiscal year 2000. Since initiation of pump-and-treat operations in August 1994, 1.25 billion liters of water have been treated, resulting in removal of 4,570 kilograms of carbon tetrachloride. Table 2.8-1 shows the volumes of treated water and the mass of carbon tetrachloride removed by quarter since inception of operations.

The most significant system shutdown in fiscal year 2000 occurred from December 12, 1999, to January 3, 2000, due to the year 2000 roll-over. Other more minor outages occurred because of scheduled maintenance and the Hanford wildfire (June 29 to July 1, 2000).

Technetium-99 samples were collected again this fiscal year to monitor and ensure that the pump-and-treat system is not being negatively affected by radiological contamination. The origin of technetium-99 may be the 216-T-19 crib area or Waste Management Area TX-TY, located north-northeast of extraction wells 299-W15-34 and 299-W15-35. This area is the nearest known source of technetium-99 in the groundwater. Concentrations at the four northernmost extraction wells ranged from about 30 pCi/L to 224 pCi/L, very similar to the concentration range measured in fiscal year 1999. Near primary injection well 299-W15-29, technetium-99 concentrations results were about 100 pCi/L, which was anticipated based on the average concentrations that pass through the treatment system. None of the results exceed the drinking water standard of 900 pCi/L.

Overall Effectiveness

The highest average fiscal year 2000 concentrations of carbon tetrachloride were measured at the two northernmost extraction wells, 299-W15-33 (5,956 μg/L) and 299-W15-34 (5,517 μg/L) (Figure 2.8-10). Concentrations continued to increase most notably at well 299-W15-34, changing from 4,700 μg/L last fiscal year to 5,517 μg/L this year. The continuing high concentrations at the four northern extraction wells implies that significant carbon tetrachloride and contaminant mass are present beneath the Plutonium Finishing Plant. Table 2.8-2 compares average carbon tetrachloride concentrations at the extraction wells for fiscal years 1997, 1998, 1999, and 2000.

Carbon tetrachloride concentrations were stable at the other two northern extraction wells (299-W15-33 and 299-W15-35), but declined at well 299-W15-32. This well is located on the northwestern side of the 216-Z-9 crib, where the highest volumes of carbon tetrachloride were discharged originally. Figure 2.8-10 and 2.8-11 show the change in carbon tetrachloride concentrations in the extraction wells.

The lowest average concentration of carbon tetrachloride was detected at southernmost extraction well, 299-W15-37 (556 μg/L) (see Figure 2.8-11). This extraction well will be converted to a monitoring well in fiscal year 2001, because of the low concentrations in this area and concerns about spreading the high concentration area of the plume to the southeast. Water-level data and previous modeling results (DOE-RL-99-79) show that this well is not necessary to contain the high concentration area of the plume.

There were no significant changes in chloroform and trichloroethene concentrations in the extraction wells for fiscal year 2000. Chloroform concentrations ranged from 18 to 27 μg/L, while trichloroethene concentrations ranged from 2 to 13 μg/L. All chloroform concentrations were below the drinking water standard of 100 μg/L. The drinking water standard for trichloroethene is 5 μg/L.

As discussed, the influent tank concentrations of carbon tetrachloride increased to an average of 4,041 μg/L. The hydraulic gradient created by the extraction wells is moving significant quantities of dissolved organic mass from the high concentration area of the plume to the extraction wells. Figure 2.8-12 shows the fiscal year 2000 carbon tetrachloride plume map in the area of the remediation system, and Figure 2.8-13 shows the June 1996 baseline plume map.

Several conclusions can be drawn from changes in the carbon tetrachloride plume maps (as presented in DOE/RL-2000-71).

- The plume center (greater than 3,000 μg/L) is moving primarily in a northerly and easterly direction toward the four northernmost extraction wells.
- The area of the 4,000 μg/L contour apparently has increased in size, noted by comparing the fiscal year 2000 plume map with the June 1996 baseline plume map. Spreading of the 4,000 μg/L contour is attributed to the effects of pumping.
- A zone of high carbon tetrachloride concentrations is inferred to be present beneath the Plutonium Finishing Plant. This conclusion is based on the increase in plume size, the continuing high concentrations in the northern extraction wells, and the continuing high concentrations in wells on the west side of the plant. For these reasons, a borehole is planned in fiscal year 2001 to characterize the vadose zone and groundwater beneath the Plutonium Finishing Plant.

The borehole may be converted into a remediation system well to support the soil vapor system, the groundwater pump-and-treat system, or some other technology.

- Concentrations of carbon tetrachloride south and east of injection well 299-W15-29 are decreasing, as demonstrated by the indentation in the 1,000 μg/L contour on Figure 2.8-12. This implies that injection of the treated water is displacing and diluting the plume to the east.

Water-Level Impact and Capture-Zone Analysis

General groundwater flow in the vicinity of the extraction wells is still east-northeast in this area (see Plate 1). Water levels are estimated to be declining at a rate of about 0.4 meters per year (DOE/RL-2000-71). The extraction wells are apparently influencing water levels and flow direction farther north in Waste Management Area TX-TY (see PNNL-13342), Waste Management Area U (to the south), and Low-Level Waste Management Area 4 (to the west).

The entire high concentration area of the plume (greater than 2,000 μg/L) in the immediate vicinity of the Plutonium Finishing Plant was contained hydraulically in fiscal year 2000 (DOE/RL-2000-71), based on the measured radius of influence of the pumping wells across the high concentration area and in monitoring wells situated between the pumping wells. The influence of pumping extends over 124 meters from extraction well 299-W15-33 to the interior of the plume at least to monitoring well 299-W15-31A.

2.8.2 T Plant

T Plant operated from 1944 through 1953 to separate plutonium from irradiated fuel using the bismuth phosphate process. The plant subsequently was converted to an equipment decontamination facility. Chlorinated hydrocarbons (carbon tetrachloride and trichloroethene), iodine-129, nitrate, and tritium form the most extensive contaminant plumes in the vicinity of T Plant. The majority of the chlorinated hydrocarbon contamination appears to originate in the vicinity of the Plutonium Finishing Plant, though there may be a contribution from T Plant facilities. Nitrate contamination appears to originate from both T Plant and Plutonium Finishing Plant facilities. Technetium-99 contamination at levels above drinking water standards is not as extensive, but high levels are found near Waste Management Areas T and TX-TY. In addition, minor chromium, fluoride, and uranium contamination is found near T Plant.

Monitoring Objectives Near T Plant

Groundwater monitoring is conducted near T Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- semiannually to detect the possible impact of one RCRA waste management area
- quarterly to assess contamination from two RCRA waste management areas.

Waste Management Areas T and TX-TY are monitored as RCRA storage, treatment, and disposal facilities. They were both monitored according to interim status assessment requirements in fiscal year 2000. The RCRA groundwater assessments have indicated that Waste Management Areas T and TX-TY are probable sources of some of the groundwater contamination in this vicinity and further assessment is ongoing. Several facilities outside the waste management areas also affected groundwater in this vicinity, so the RCRA assessment must consider those impacts. This section, 2.8.2, is designed to meet the needs for annual reporting of the RCRA assessments. Topical reports will be published at the completion of each stage of the investigation. The specific conclusions of the monitoring regarding the assessment sites are discussed in Sections 2.8.2.11 and 2.8.2.12. Low-Level Waste Management Area 3 was monitored under RCRA interim status detection requirements and is discussed in Section 2.8.2.13.

2.8.2.1 Groundwater Flow

Groundwater in the northern 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 (see Plate 1). The flow direction in this region has changed about 35 degrees over the past decade from a north-northeast direction to a more easterly direction. This is due to decreased effluent discharges to the soil column in the 200 West Area, which is causing flow to return to its pre-Hanford direction.

The water table is influenced locally by the 200-ZP-1 Operable Unit pump-and-treat system. This causes flow in the south-central portion of this region to have a southerly component toward the extraction wells. Also, effluent discharges at the State-Approved Land Disposal Site, just north of the 200 West Area, has resulted in a local groundwater mound beneath this facility. Groundwater flow beneath Waste Management Area T is discussed in Section 2.8.2.11, flow beneath Waste Management Area TX-TY is discussed in Section 2.8.2.12, and flow beneath Low-Level Waste Management Area 3 is discussed in Section 2.8.2.13. Groundwater flow beneath the State-Approved Land Disposal Site is discussed in Section 2.8.5.

2.8.2.2 Tritium

A tritium plume lies beneath much of the northern half of the 200 West Area and extends to the northeast (see Plate 2). The plume geometry suggests the major tritium source is near the TY tank farm, the 242-T evaporator, and associated disposal cribs. Other sources may be present in the vicinity of the T tank farm and associated cribs and trenches. Tritium concentrations remain high in the area immediately east of the TY tank farm. In June 1998, tritium concentration suddenly increased to 3.21 million pCi/L in well 299-W14-2, near the 216-T-28 crib. Since that time, tritium concentrations have been highly erratic in that well, but concentrations increased steadily in nearby wells 299-W14-12 and its replacement well 299-W14-13 (Figure 2.8-14). The March 2000 sample from well 299-W14-13 contained the maximum concentration detected in the 200 West Area in fiscal year 2000, 2,940,000 pCi/L, which is greater than the DOE derived concentration guide. The hydraulic gradient in this vicinity is flat due to the interaction of the regional gradient and the influence of the 200-ZP-1 Operable Unit pump-and-treat system. Condensate from the 242-T evaporator is a likely source of this contamination; however, the cause for the sudden increase is unknown. The erratic concentration trend in well 299-W14-2 suggests that contamination in the vadose zone could be remobilized by a fresh water source such as a leaking water line, but this has not been confirmed.

Waste sites associated with T Plant have contaminated groundwater with tritium. Concentrations have increased sharply in wells near the TY tank farm in the last 3 years, and exceeded 2 million pCi/L in fiscal year 2000.

In an area north of Waste Management Area T, tritium is consistently found at levels much lower than the surroundings, which may be related to past discharge of relatively clean water to the 216-T-4-2 ditch (WHC-EP-0815). Discharge of water to the 216-T-4-2 ditch ceased in 1995 and was followed by an increase in tritium concentrations in nearby wells.

2.8.2.3 Iodine-129

Iodine-129 near T Plant (Figure 2.8-15) coincides generally with the tritium plume. The interpretation of iodine-129 results is somewhat complicated by a number of samples reported with detection limits greater than the 1 pCi/L drinking water standard. High concentrations of iodine-129 were measured in well 299-W14-2 with concentrations ranging from 31.1 to 52.0 pCi/L (average value was 45 pCi/L). Concentrations from this well, like tritium concentrations, fluctuate greatly. High iodine-129 concentrations are also detected in well 299-W14-13, slightly farther south. The T evaporator or cribs which received condensate are likely sources for the iodine-129 contamination.

2.8.2.4 Technetium-99

A technetium-99 plume is present in the T Plant area (Figure 2.8-16), but the concentrations are less than the drinking water standard in most of the area. The two areas with technetium-99 greater than the 900 pCi/L drinking water standard are near the northeastern corner of Waste Management Area T and in Waste Management Area TX-TY. The RCRA assessment concluded that Waste Management Areas T and TX-TY were probably the sources of at least some of this technetium-99 (PNNL-11809). Further details on the technetium-99 contamination are discussed with the tank farm assessment summaries in Sections 2.8.2.11 and 2.8.2.12.

2.8.2.5 Uranium and Gross Alpha

Few analyses for uranium were performed on groundwater samples from the vicinity of T Plant in fiscal year 2000 because most wells showed insignificant levels in previous monitoring. Wells monitored near the single-shell tank farms for RCRA compliance are sampled for gross alpha measurements, which would show an increase if uranium contamination appeared. Uranium was detected above the proposed maximum contaminant level in two wells, located near the T plant. Well 299-W11-14 contained 54.8 µg/L of uranium in the single sample taken in fiscal year 2000, similar to levels found in the past several years. The single sample from well 299-W11-37, located northeast of well 299-W11-14, contained 450 µg/L of uranium. This well had not been sampled for uranium in recent years so a trend cannot be established. The uranium is detected far from major disposal facilities, so the source of the contamination is unknown.

2.8.2.6 Nitrate

Nitrate continued to be present in groundwater at concentrations in excess of the 45 mg/L maximum contaminant level beneath much of the northern part of 200 West Area (see Figure 2.8-8). The maximum concentration in this vicinity in fiscal year 2000 was 1,200 mg/L in well 299-W10-3, located in the western portion of Waste Management Area T, next to the 216-T-7 crib and tile field. The nitrate contamination is more widespread than the iodine-129, technetium-99, or tritium plumes discussed previously. There probably are multiple sources of nitrate in this area, including disposal facilities near the Plutonium Finishing Plant.

High concentrations of nitrate in groundwater continued to be found in wells near T Plant disposal facilities. The maximum value in fiscal year 2000 was 1,200 mg/L.

Nitrate is found at concentrations greater than the maximum contaminant level at considerable depth within the unconfined aquifer near T Plant. For example, 323 mg/L of nitrate was detected in a sample from well 299-W6-3 that is completed approximately 60 meters below the water table. This well is completed above the top of the Ringold lower mud unit.

2.8.2.7 Chromium

Chromium at levels above the 100 µg/L maximum contaminant level in filtered samples is restricted to the immediate vicinity of Waste Management Areas T and TX-TY (Figure 2.8-17). The maximum average annual concentration detected in fiscal year 2000 was 510 µg/L in well 299-W14-13, east of Waste Management Area TX-TY, where concentrations have been generally increasing.

A small chromium plume has been identified in the vicinity of Waste Management Area T. The specific source for this persistent plume has not been identified. Chromium is of interest because it has been identified in tank waste and may help form a signature of mobile tank waste components. However, similar wastes were disposed to cribs and trenches in the immediate vicinity.

2.8.2.8 Fluoride

Fluoride was detected above the 4 mg/L maximum contaminant level near the T Plant waste disposal facilities. The fluoride contamination was found in a number of wells in the vicinity of Waste Management Area T, with well 299-W10-3, located at the northeastern corner of the 216-T-7 crib, having the highest value of 9.8 mg/L. Fluoride may be associated with tank waste from leaks or discharged to the cribs.

2.8.2.9 Chlorinated Hydrocarbons

Although the bulk of the carbon tetrachloride plume in the 200 West Area is known to have originated from liquid waste disposal facilities in the vicinity of the Plutonium Finishing Plant, a second source may exist in the vicinity of T Plant. According to WHC-SD-EN-TI-248, the source could be carbon tetrachloride that was dissolved in the 242-T evaporator overhead and discharged from 1973 to 1976 to the 216-T-19 crib. The carbon tetrachloride distribution in the 200 West Area is shown in Figure 2.8-2. Carbon tetrachloride concentrations in the vicinity of T Plant are highly variable. Of particular interest are relatively low carbon tetrachloride concentrations in the vicinity of the southeastern corner of Waste Management Area TX-TY, where levels are less than 500 µg/L but still above the 5 µg/L maximum contaminant level. This area is within the hydraulic influence of the 200-ZP-1 Operable Unit pump-and-treat system discussed in Section 2.8.1.6. Although data are sparse, there appears to be a generally low carbon tetrachloride concentration area in the east-central part of the 200 West Area.

Trichloroethene also is found at levels above the maximum contaminant level in the vicinity of T Plant but at levels considerably lower than carbon tetrachloride. The area of trichloroethene greater than the maximum contaminant level extends from the Plutonium Finishing Plant northeast through the T Plant vicinity (see Figure 2.8-7). In fiscal year 2000, the 5 µg/L contour does not extend as far to the northeast as was shown in fiscal year 1999.

2.8.2.10 Iron, Manganese, and Nitrite

Wells 299-W11-24 and 299-W11-28, located to the east of Waste Management Area T, have reported high values of iron and manganese in filtered samples. The maximum iron detected in fiscal year 2000 in well 299-W11-28 was 2,350 µg/L, but all other samples ranged from 196 to 251 µg/L. Manganese in well 299-W11-28 reached a fiscal year 2000 maximum level of 494 µg/L. Elevated manganese and iron also were detected in nearby well 299-W11-24. Elevated nitrite was detected at levels (expressed as NO_2^-) up to 36,100 µg/L in well 299-W11-24 and 14,800 µg/L in well 299-W11-28 for fiscal year 2000. The high iron, manganese, and nitrite are indicative of reducing conditions; however, the cause of the reducing conditions is unknown.

2.8.2.11 RCRA Assessment Summary for Waste Management Area T

Waste Management Area T, located in the north-central portion of the 200 West Area, consists of the T tank farm and ancillary equipment (e.g., diversion boxes). Constructed between 1943 and 1944, the tank farm contains twelve 2-million-liter tanks and four 208,000-liter tanks. The tanks began receiving waste in 1944, initially receiving waste mainly from the bismuth phosphate process. During early operations, tank waste was cascaded through sets of three tanks and overflow from the third tank was discharged to the ground in cribs and tile fields to the west of the waste management area. Seven of the tanks in the waste management area are known or suspected to have leaked.

Waste Management Area T was originally placed in 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). This site continued to be monitored under an assessment program in fiscal year 2000. The well and analyte lists for this unit are given in Appendix A, Table A.10.

RCRA Waste Management Area T contains single-shell tank farms that have contaminated groundwater with technetium-99, nitrate, and chromium. Assessment monitoring continued in fiscal year 2000.

Groundwater Flow

The direction of groundwater flow at Waste Management Area T has varied over the life of the facility because of changing effluent discharge patterns within the 200 West Area. The flow direction when the RCRA monitoring network was established was toward the northeast. The groundwater presently flows generally toward the east or slightly north of east, as indicated by the large scale water-table map (see Plate 1). Trend surface analysis of the water table in the vicinity of Waste Management Area T indicated a flow direction of approximately 85 degrees (5 degrees north of east), which agrees with conclusions drawn from water-table maps of the area. Groundwater flow velocities calculated using new values for hydraulic conductivity (PNNL-13378) fall in the range of 0.003 to 0.024 meter per day (Appendix A, Table A.2). This range is in reasonable agreement with velocities of 0.009 to 0.017 meter per day calculated from tracer pumpback tests in well 299-W10-24 (PNNL-13378).

However, locally the direction of groundwater flow may diverge from the regional pattern because variable cementation within the Ringold aquifer may result in preferred groundwater flow paths. The pre-Hanford flow direction in the vicinity of Waste Management Area T is believed to have been from west to east, and it was expected that groundwater flow in this area would eventually move to that direction. However, the change has happened fairly rapidly over the past several years and may have been accelerated by operation of the 200-ZP-1 Operable Unit pump-and-treat system less than 1 kilometer to the south. Results of recent hydraulic testing at Waste Management Area T can be found in PNNL-12057 and PNNL-13378.

Groundwater Contamination

Several contaminants have been detected in the vicinity of Waste Management Area T during fiscal year 2000. High carbon tetrachloride, nitrate, tritium, chromium, fluoride, and trichloroethene are from upgradient sources and are components of a contaminant plume crossing the waste management area from west to east. These contaminants are discussed in previous sections. Technetium-99, chromium, and nitrate may have a local source in or near the tank farm and are discussed here.

Samples collected during drilling near the northeastern corner of Waste Management Area T indicate that the top portion of the aquifer is relatively impermeable and contains a plume high in technetium. Deeper portions of the aquifer are more permeable and groundwater is characterized by high nitrate, similar to a plume from upgradient.

Technetium-99 concentrations began increasing in downgradient well 299-W11-27 in late 1995 and early 1996, soon after effluent discharges to ground stopped in the 200 West Area (Figure 2.8-18). The concentration of technetium-99 peaked at 21,700 pCi/L in February 1997. Technetium-99 subsequently decreased to a low of 6,000 pCi/L when the last sample was taken in March 1999 as water levels dropped in the well. The chemical signature of the contaminants detected in well 299-W11-27 is particularly clear because it is superposed on a very low ionic strength groundwater resulting from leakage along a ~40-centimeter-diameter vitrified clay pipe connecting the 207-T retention basin and the T-4-2 ditch.

Technetium-99 in replacement well 299-W10-24 (see Figure 2.8-18), drilled immediately adjacent 299-W11-27, has ranged between 1,460 and 3,660 pCi/L (1,460 to 2,170 pCi/L during fiscal year 2000) with little apparent trend. As discussed below, this may be because of the longer interval open below the water table in the replacement well. The sampling pump in well 299-W10-24 is set at a depth of ~4.6 meters below the water table.

Technetium-99 concentrations in well 299-W11-23 located east of well 299-W10-27 (see Figure 2.8-18), started to increase in November 1997, reaching a high of 8,540 pCi/L in November 1998. Technetium-99 subsequently dropped to 2,755 pCi/L in March 1999 before increasing to 7,110 pCi/L in August 1999. In fiscal year 2000, technetium-99 concentrations declined to a low of 841 pCi/L in March 2000 and rose to a high of 3,000 pCi/L in August 2000. Very little water remains above the perforated interval in this well and sampling during fiscal year 2000 has been via a KABIS[a] sampler. The detection in well 299-W11-23 is apparently a result of the change in the direction of groundwater flow from northeast to east. Apparently, the plume, that extends northeast from well 299-W11-27 is shifting eastward across well 299-W11-23 (see Figure 2.8-16). The distribution and concentrations of this plume inside the waste management area are unknown at this time.

The recent increase in nitrate concentration in well 299-W11-27 was strongly correlated with the technetium-99 trend (Figure 2.8-19), but this correlation does not carry through to the replacement well 299-W10-24. The concentration of nitrate in well 299-W10-24 is much higher than that in well 299-W11-27, whereas the technetium-99 is lower. Deep aquifer sampling during the drilling of well 299-W10-24 in 1998 indicates the presence of a maximum in nitrate (~500 mg/L) at about 20 meters below the water table, with the deeper groundwater chemically resembling the high nitrate groundwater occurring in other parts of the area (see PNNL-13116). This suggests that the pulse of nitrate and technetium-99 in well 299-W11-27 is a feature of the very top of the aquifer. The groundwater chemistry detected in well 299-W10-24 is apparently a mixture of two sources: the shallow, high-technetium-99 groundwater seen in well 299-W11-27 and the high-nitrate groundwater from depth. The high-nitrate from the lower portion of the screened interval, where the aquifer is more permeable, would dominate the mixture during pumping.

Chromium concentrations in well 299-W11-27 exhibited a peak in fiscal year 1996, reaching 590 μg/L in May 1996 (Figure 2.8-20). Technetium-99 in well 299-W11-27 peaked approximately 9 months later, reaching 21,700 pCi/L in February 1997. The peak for chromium is quite sharp and well defined, while the later peak for technetium-99 is broader and more diffuse.

The contaminant plume initially detected in well 299-W11-27 was quite narrow and moving toward the northeast (PNNL-11809). This plume was not detected in adjacent well 299-W11-23 until groundwater flow changed to a more easterly direction and the existing plume drifted across well 299-W11-23. In well 299-W11-23, chromium and technetium-99 track closely and there is no indication of a lag between the constituents (Figure 2.8-21).

The chromium in replacement well 299-W10-24 is probably related to the regional plume (see Section 2.8.2.7) and is not associated with the shallow contaminant plume intercepted in well 299-W11-27. Tank related contaminants near the northeastern corner of the waste management area appear to be restricted to the upper portion of the aquifer. The lateral extent of contamination is uncertain because of the lack of monitoring wells north and east of the zone of known contamination. However, an intermediate field well is planned for a location ~125 meters east of the northeast corner of the waste management area. The planned well should aid in defining the horizontal extent of contamination.

Monitoring Network

The original RCRA monitoring network for Waste Management Area T, completed in 1992, consisted of one upgradient and three downgradient wells. Three of these wells have subsequently gone dry, as a result of the falling water table in the area, and the fourth will soon be dry. In addition, a change in groundwater flow direction has resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells were used when possible to meet the needs resulting from a declining water table and changing groundwater flow directions; however, new wells are needed for downgradient monitoring and to track the known contaminant plume.

The water table beneath Waste Management Area T continued to decline in fiscal year 2000. Four new downgradient wells were installed in late fiscal year 2000 and early 2001 to replace dry wells and to account for changes in the direction of groundwater flow.

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[a] KABIS is a registered trademark of SIBAK Industries Limited, Peoria, Illinois.

Two new RCRA compliant monitoring wells were drilled in fiscal year 1999. The new wells replace existing groundwater monitoring wells and fill gaps in the downgradient monitoring network caused by changes in the direction of groundwater flow (PNNL-12125). In addition, four new downgradient wells were drilled in late fiscal year 2000 and early fiscal year 2001. These four new wells were completed with 10.7 meter screened intervals to allow for future declines in water-table elevation. The well network is summarized in Appendix A, Table A.10. Plans call for the drilling of an upgradient well, farther downgradient than current waste management area monitoring wells, and a well cluster to sample deeper within the upper part of the unconfined aquifer.

2.8.2.12 RCRA Assessment Summary for Waste Management Area TX-TY

RCRA Waste Management Area TX-TY contains single-shell tank farms that may have contaminated groundwater with technetium-99, chromium, and nitrate. Assessment monitoring continued in fiscal year 2000.

Waste Management Area TX-TY, located in the north-central portion of the 200 West Area, consists of the TX and TY tank farms and ancillary equipment (e.g., diversion boxes). Constructed between 1947 and 1952, the tank farms contains twenty-four 2.9-million-liter tanks. The tanks began receiving waste in 1944, initially receiving principally waste from the bismuth phosphate process. During early operations, tank waste was cascaded through sets of three tanks and overflow from the third tank was discharged to the ground in cribs and tile fields to the west of the waste management area. Twelve of the tanks in the waste management area are known or suspected to have leaked.

Waste Management Area TX-TY was originally placed in assessment monitoring because of elevated specific conductance in downgradient wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132). The area remained in assessment because of contaminants observed in downgradient well 299-W14-12 (PNNL-11809). This site continued to be monitored under an assessment program in fiscal year 2000. The well and analyte lists for this unit are given in Appendix A, Table A.11.

Groundwater Flow

The direction of groundwater flow at Waste Management Area TX-TY has been highly variable over the life of the facility because of changing effluent discharge patterns within the 200 West Area. When the RCRA monitoring network was established, the flow direction was toward the northeast. The pre-Hanford flow direction in the vicinity of Waste Management Area TX-TY is believed to have been from west to east, and it was expected that groundwater flow in this area would eventually return to that direction.

The operation of a pump-and-treat system in an area south of Waste Management Area TX-TY has changed flow directions over the past several years. Beneath the southern part of the waste management area, flow is primarily to the south, which may be causing tank-related contaminants to move southward.

Groundwater flow directions have changed fairly rapidly over the past several years as a result of the 200-ZP-1 Operable Unit pump-and-treat system located immediately south of the waste management area and the decline of the 200 West Area groundwater mound. The current flow direction is generally toward the east in the northern part of the waste management area, toward the southeast in the central part of the waste management area, and toward the south or slightly west of south in the southern part of the waste management area (see Plate 1). Trend surface analysis for water-level measurements at the waste management area indicate a southerly flow direction throughout, which varies from the indications based on water-table maps. The apparent reasons for this discrepancy are the limited spatial extent of available water-level measurements and the fact that the water table beneath the waste management area is not planar as a result of the large cone of depression immediately south of the waste management area. Locally, flow directions may diverge from the regional pattern because variable cementation within the Ringold aquifer may result in preferred groundwater flow paths. Results of recent hydraulic testing at Waste Management Area T can be found in PNNL-12072 and PNNL-13378. Groundwater flow velocities calculated using new values for hydraulic conductivity (PNNL-13378) fall in the range of 0.003 to 0.026 meter per day (Appendix A, Table A.2).

Groundwater Contamination

A number of contaminants were detected in the vicinity of Waste Management Area TX-TY during fiscal year 2000. High carbon tetrachloride is from upgradient sources and was discussed in previous sections of this chapter. Technetium-99, chromium, nitrate, tritium, and iodine-129 may also have a local source and are discussed in more detail in the following paragraphs.

Contaminant levels (chromium, cobalt-60, iodine-129, nitrate, technetium-99, and tritium) were elevated in well 299-W14-12 when first sampled in 1992 and remained high for several years. Technetium-99 had a high value of 13,300 pCi/L in November 1992 (Figure 2.8-22). Contaminant concentrations dropped sharply, along with falling water levels in 1995 to 1996 and remained at relatively low levels during 1997 to 1998. In late 1998, contaminant levels began to increase and continued that trend until the last sampling of the well in January 1999 prior to the well going dry. Technetium-99 concentrations in replacement well 299-W14-13 also exhibit an upward trend reaching a maximum of 7,400 pCi/L in March 2000 (see Figure 2.8-22).

Chromium was a prominent co-contaminant in downgradient well 299-W14-12, reaching 600 μg/L in November 1992 (Figure 2.8-23). Subsequently chromium decreased, reaching a low of 5 μg/L before increasing to 46 μg/L before the well went dry. Chromium continued to increase in replacement well 299-W14-13, reaching 538 μg/L in March 2000. Although both chromium and technetium-99 were increased in concentration in well 299-W14-12 prior to it going dry, the chromium remained below 50 μg/L. Well 299-W14-13 has much higher chromium concentrations relative to the technetium-99 indicating a different source for the contamination.

Technetium-99 levels have increased in well 299-W15-4 since the initiation of the 200-ZP-1 Operable Unit pump-and-treat operations (see Section 2.8.1) south of the waste management area (Figure 2.8-24). Concentrations increased to 982 pCi/L in July 1999 but dropped to 641 pCi/L in October 1999. Well 299-W15-4, originally constructed to monitor the 216-T-19 crib, is directly south of the waste management area in a direct flow path between the waste management area and the nearest extraction well. This waste management area is the possible source of the technetium-99 detected in well 299-W15-4. This small increase is important for evaluating the impact of the pump-and-treat remediation on contaminants in the T Plant area and for potential future impact of increasing technetium-99 on the operation of the pump-and-treat system. Technetium-99 in well 299-W15-22, located in the southwestern corner of Waste Management Area TX-TY, increased significantly in 1998 before the well went dry. Technetium-99 concentrations reached 3,680 pCi/L in May 1998 and 2,940 pCi/L in August 1998. More recently, technetium-99 concentrations in new well 299-W15-41, located between wells 299-W15-4 and 299-W14-22, have ranged between 847 and 1,980 pCi/L in fiscal year 2000. These values suggests that the remediation may be having a significant impact on the distribution of contaminants under and around the waste management area and that technetium-99 may be drawn from beneath the area into the pump-and-treat system. Technetium-99 reached a concentration of 286 pCi/L in extraction well 299-W15-32 in fiscal year 1999 (see Section 2.8.1.7, PNNL-13116). The fiscal year 2000 concentration in this well was 224 pCi/L. This well is located east of the Plutonium Finishing Plant at the 216-Z-9 trench. Technetium-99 (206 pCi/L) also was detected in fiscal year 2000 in extraction well 299-W15-35, located ~225 meters south of the tank farm.

Nitrate was a major constituent of the contaminant plume first detected in well 299-W14-12, peaking at 530 mg/L in November 1992. Nitrate concentrations dropped to 190 mg/L in May 1997 and subsequently rose to 580 mg/L in January 1999. Nitrate concentrations have remained high, with a maximum concentration of 436 mg/L in January 2000. Nitrate shows a high correlation with technetium-99 and apparently is from a similar source.

Tritium and iodine-129 were important constituents of the contaminant plume initially detected in well 299-W14-12 (Figure 2.8-25). Tritium peaked at 585,000 pCi/L in February 1995 and iodine-129 peaked at 64 pCi/L in September 1993. Both constituents decreased to lows in 1997, with tritium reaching 53,800 pCi/L in August 1997 and iodine-129 reaching 2 pCi/L in February 1997. Both constituents started to increase in well 299-W14-12 in 1998, with tritium reaching 1,170,000 pCi/L and iodine-129 reaching 32 pCi/L in January 1999, the last sampling of the well. Tritium and iodine-129 continued to increase in replacement well 299-W14-13, with tritium reaching 2,940,000 pCi/L in March 2000 and iodine-129 reaching 48 pCi/L in August 2000. A key to the behavior of tritium and iodine-129 is the detection of a contaminant plume in non-RCRA well 299-W14-2 that consists predominately of tritium and iodine-129, with relatively low concentrations of technetium and nitrate. After the initial detection in June 1998, when a tritium concentration of 3,210,000 pCi/L and an iodine-129 concentration of 81 pCi/L were reported, tritium concentrations ranged from 233,000 pCi/L to 1,970,000 pCi/L and iodine-129 concentrations ranged from 17 to 59 pCi/L. The most likely source of the contaminants detected in well 299-W14-2 is condensate leaked from the T evaporator located between the TX and TY tank farms. It is also likely that condensate from evaporator leaks has been a major contributor to tritium and iodine-129 contamination detected in wells 299-W14-12 and 299-W14-13.

A plume with high concentrations of tritium/iodine-129 and low levels of technetium-99 appears to have a source from the 242-T evaporator.

The direction of groundwater flow in the vicinity of well 299-W14-12 was toward the northeast when monitoring was initiated. Flow is currently toward the southeast. Thus, it seems likely that well 299-W14-13 intersects a technetium-99 plume that is distinct from the technetium-99 plume first sampled by well 299-W14-12. Groundwater flow directions indicate that the source for the initial plume was within the TX tank farm. The present direction of groundwater flow indicates a source for the current plume somewhere within the TY tank farm. A third plume, consisting primarily of tritium and iodine-129 from the 242-T evaporator, is superimposed on the two tank waste plumes. Sampling in wells 299-W14-12 and 299-W14-13 indicate considerable complexity in the vertical distribution of contaminants in the vicinity of the wells. This complexity is increased by the observed strong vertical hydraulic gradient in well 299-W14-13 (PNNL-13378). In a lateral direction, the extent of the contaminant plumes is bounded by wells 299-W14-2 and 299-W14-14. At present, the downgradient extent is uncertain; however, the completion of two intermediate wells ~100 meters east of well 299-W14-13 should help define the downgradient extent of contaminants.

Monitoring Network

The original RCRA monitoring network for Waste Management Area TX-TY, completed in 1992, consisted of one upgradient and three downgradient wells. Three of these wells have subsequently gone dry, as a result of the falling water table in the area, and the fourth will be dry soon. In addition, a change in direction of groundwater flow has resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells were used when possible to adjust a declining water table and changing groundwater flow directions; however, new wells are needed for downgradient monitoring and for tracking the known contaminant plume.

Five new monitoring wells were installed downgradient of Waste Management Area TX-TY in fiscal year 2000 or early 2001 to account for the changing flow direction and to monitor contaminants farther from the waste management area.

Four new RCRA compliant monitoring wells were drilled in fiscal year 1999 to replace existing groundwater monitoring wells and to fill gaps in the downgradient network resulting from changes in the direction of groundwater flow. In late fiscal year 2000 and early fiscal year 2001, five new downgradient wells were drilled. Three, including a replacement for well 299-W15-4, were installed along the southern margin of the waste management area, and two intermediate field wells were installed farther downgradient. All wells have been completed with 10.7-meter screened intervals to allow for future declines in water-table elevation. The current monitoring network is summarized in Appendix A, Table A.11. Plans call for drilling wells at three downgradient locations, including two clusters of wells to monitor deeper portions of the unconfined aquifer and one upgradient well to replace well 299-W15-12.

The 200-ZP-1 pump-and-treat operation has significantly altered the direction of groundwater flow at the waste management area. This change in direction affects the migration paths of contaminants from the waste management area and the efficiency of the groundwater monitoring network to detect contaminants. Water-table maps indicating new flow directions and modeling to estimate the efficiency of the network in detecting contaminants have been carried out. As a result of these studies, a number of new wells have been drilled and several additional wells, including well clusters completed at different depths, have been proposed. In addition to increased monitoring efficiency, the new wells will allow the construction of more accurate water-table maps in the vicinity of the waste management area; well clusters will allow evaluation of potential vertical groundwater gradients resulting from pump-and-treat activities. Ongoing evaluation will be used to indicate whether further study or additional wells are required.

2.8.2.13 RCRA Parameters for Low-Level Waste Management Area 3

RCRA monitoring at Low-Level Waste Management Area 3 indicates no groundwater contamination from this facility.

The groundwater monitoring network for Low-Level Waste Management Area 3 is sampled semiannually. Appendix A, Table A.16 lists current monitoring wells and the constituents. Several monitoring wells are approaching the end of their useful life span. Sampling events at wells 299-W9-1 and 299-W7-10 were unsuccessful in October 2000 because of falling water levels. The current network configuration adequately monitors this disposal area. However, additional wells are being planned to augment this monitoring network and provide coverage as the groundwater flow direction continues to change.

Groundwater Flow

The groundwater flow direction in this area continues to shift to the east. In the past, the flow direction was predominately to the north and slightly north-northeast. With the decline of the groundwater mounds in the 200 West Area the flow direction is returning to the pre-Hanford conditions and is currently east northeast. This shift is expected to continue until the flow direction is to the east.

Extent of Contamination

There are no indications that Low-Level Waste Management Area 3 has contributed to groundwater contamination. None of the upgradient/downgradient comparison values for the indicator parameters (pH, specific conductance, total organic carbon, and total organic halogen) were exceeded in this reporting period. The allowed maximum contaminant levels for nitrate and carbon tetrachloride are consistently exceeded at Low-Level Waste Management Area 3. These constituents are not related to the disposal of wastes in this facility rather they are attributed to contaminant plumes originating to the south of Low-Level Waste Management Area 3. Trichloroethene continues to slightly exceed the 5 µg/L maximum contaminant level in well 299-W10-21.

2.8.3 U Plant

U Plant was built to recover plutonium using the bismuth phosphate process but was never used for that purpose. It was used for recovery of uranium from bismuth phosphate process waste from 1952 until approximately 1962.

A groundwater contaminant plume, containing iodine-129, nitrate, trichloroethene, technetium-99, and uranium, originates from U Plant disposal facilities and extends beyond the 200 West Area fence line to the east. The 216-U-1 and 216-U-2 cribs are the major sources of the plume. Waste from these cribs is believed to have been remobilized by disposal of acidic waste to the 216-U-16 crib (WHC-EP-0133). Additional sources of contaminants include the 216-U-17, 216-U-8, and 216-U-12 cribs.

Monitoring Objectives Near U Plant

Groundwater monitoring is conducted near U Plant:

- triennially to annually to describe the nature and extent of contamination
- quarterly to assess the impact of two RCRA waste management areas
- various time intervals to evaluate the performance of a pump-and-treat system for technetium-99 and uranium.

Interim action remediation using a groundwater pump-and-treat system is taking place in the vicinity of U Plant. Because of the effects of remediation and past injection of treated water into the aquifer, the plume maps in this report are somewhat generalized in the area of system influence. This section discusses the contamination from the facilities in the vicinity of U Plant and includes the contamination being remediated in accordance with CERCLA and the specific reporting requirements for RCRA monitoring at the 216-U-12 crib and Waste Management Area U single-shell tank farm.

2.8.3.1 Groundwater Flow

Groundwater flow in the vicinity of U Plant in the 200 West Area is primarily toward the east (see Plate 1). The flow direction has changed only slightly (5 to 10 degrees), from east-southeast to a more easterly direction, over the past decade. This is because many of the former liquid effluent disposal sites in the 200 West Area are to the west of U Plant. Groundwater flow in this area is not significantly influenced by the pump-and-treat system at the 200-UP-1 Operable Unit. This is because there is only a single extraction and a single injection well, compared to the six extraction and three injection wells at the 200-ZP-1 Operable Unit pump-and-treat system. Groundwater flow beneath the 216-U-12 crib is discussed in Section 2.8.3.7, flow beneath Waste Management Area U is discussed in Section 2.8.3.8, and flow at the 200-UP-1 Operable Unit pump-and-treat system is discussed in Section 2.8.3.9.

2.8.3.2 Uranium

The highest concentrations of uranium in Hanford Site groundwater in fiscal year 2000 were detected near U Plant in wells downgradient from the 216-U-1 and 216-U-2 cribs and adjacent to the 216-U-17 crib (Figure 2.8-26). Uranium concentrations in wells near the 216-U-1 and 216-U-2 cribs showed a large pulse of uranium in 1986. Trends in uranium concentrations in well 299-W19-3, immediately downgradient from the cribs, are shown in Figure 2.8-27. The uranium levels in this well decreased considerably since the maximum measured in 1986. Uranium in fiscal year 2000 was 1,080 µg/L, a decline from the 1999 concentration of 1,990 µg/L.

Waste sites associated with U Plant have contaminated groundwater with uranium at the highest concentrations currently detected on the Hanford Site. The maximum concentration in fiscal year 2000 was 2,100 µg/L in a well near the 216-U-17 crib. Levels have declined significantly since 1986.

The maximum annual average uranium concentration detected near U Plant in fiscal year 2000 was 1,900 µg/L in well 299-W19-20, located near the pump-and-treat extraction well (see Figure 2.8-26). The uranium concentrations for several wells in the U Plant vicinity constitute dose values greater than the DOE derived concentration guide dose level. Assuming natural isotopic abundance, a uranium concentration of 790 µg/L represents the 100 mrem/yr dose equivalent for ingestion of drinking water.

The uranium distribution in the vicinity of the 216-U-17 crib has been affected by pump-and-treat remediation (discussed in Section 2.8.3.9). The remediation system affected the direction of groundwater flow, both through the pumping and the past injection of treated groundwater upgradient of the pumping well. Because injection ceased in March 1997, its effect on the uranium distribution is decreasing. As expected, uranium concentrations decreased downgradient of the injection well and increased near the pumping well as the plume is drawn toward the pumping well. In fiscal years 1999 and 2000, however, high concentrations of uranium were detected near the former injection well. This suggests that uranium contamination is moving into the area from upgradient and also may be rebounding from termination of the injection.

2.8.3.3 Technetium-99

Technetium-99 typically followed uranium throughout much of the fuel cycle. Thus, a sizable technetium-99 plume is associated with the 216-U-1, 216-U-2, and 216-U-17 cribs in essentially the same location as the uranium plume (Figure 2.8-28). The distribution of technetium-99 in this vicinity is complex, in part because of the operation of the pump-and-treat system that re-injected treated water until March 1997. The maximum annual average technetium-99 concentration associated with this plume in fiscal year 2000 was 19,400 pCi/L, found in well 299-W19-36. This well is the former injection well, and concentrations are increasing as the treated water moves downgradient. Technetium-99 concentrations in most wells in the central part of the plume have declined during the period of pump-and-treat operations.

Technetium-99 is a major contaminant of concern associated with uranium in groundwater beneath the U Plant area.

Technetium-99 concentrations also declined in downgradient well 699-38-70 (Figure 2.8-29). The data indicate that the technetium-99 plume has split into two lobes, one contained by the pump-and-treat system and a lower concentration portion downgradient of the capture zone.

Technetium-99 remains slightly elevated in wells downgradient of Waste Management Area U, when compared to upgradient wells. However, levels are below the drinking water standard. The concentrations in most downgradient wells declined to values between 200 and 300 pCi/L. In new well 299-W19-41, however, concentrations of technetium-99 averaged 620 pCi/L during fiscal year 2000.

2.8.3.4 Nitrate

Near U Plant, nitrate contamination at levels greater than the maximum contaminant level is considerably more widespread than technetium-99 or uranium (Figure 2.8-30). This reflects the multiple sources of nitrate in the area. In particular, the 216-U-12 crib contributed to nitrate levels above the maximum contaminant level. Nitrate sources near the REDOX Plant have also contributed to contamination in this vicinity (see Section 2.8.4.5).

Nitrate concentrations in the vicinity of the 216-U-17 crib are among the highest on the Hanford Site but are not typically monitored because nitrate is not a performance indicator for the pump-and-treat system. The maximum nitrate concentration detected in fiscal year 2000 was 860 mg/L in well 299-W19-20. The nitrate source is believed to be past disposal to the 216-U-1 and 216-U-2 cribs, the same as the technetium-99 and uranium source.

2.8.3.5 Iodine-129

Iodine-129 was found above the drinking water standard in the immediate vicinity of the 216-U-1 and 216-U-2 cribs (Figure 2.8-31). The iodine-129 concentration detected in well 299-W19-3 was 4.82 pCi/L. Downgradient, the iodine-129 plumes from U Plant operations merge with, and become indistinguishable from, the REDOX Plant plume (see Section 2.8.4.2).

2.8.3.6 Trichloroethene

Trichloroethene is found at levels greater than the maximum contaminant level of 5 μg/L in the vicinity of the technetium-99 and uranium plume. Well 299-W19-35 was the only well that contained trichloroethene at levels greater than the maximum contaminant level, with a fiscal year average concentration of 13 μg/L. Thus, there does not appear to be a significant ongoing source of trichloroethene in this area.

2.8.3.7 RCRA Assessment Summary for 216-U-12 Crib

RCRA groundwater monitoring continued in an assessment program in fiscal year 2000. The results and findings of the assessment monitoring program are presented in PNNL-11574. The elevated levels of specific conductance in the downgradient wells are attributed to calcium and nitrate. Technetium-99 has been detected in downgradient monitoring wells since monitoring began, indicating that the crib was the source. These findings indicated that the crib contributed to groundwater contamination and must remain in interim status assessment monitoring. The objective of the assessment monitoring is to evaluate the flux of constituents into the groundwater beneath the crib and monitor the known constituents until a corrective action is defined or final status monitoring plan is implemented for the crib.

Declining water levels in the 200 West Area reduced the monitoring network from the original five wells to just two downgradient wells. This included one new well that was installed in September 1998. The two remaining downgradient wells, 299-W22-79 and 699-36-70A (see Appendix A, Figure A.7), are sampled quarterly for the constituents of interest. Washington State Department of Ecology (Ecology) and the U.S. Department of Energy (DOE) agreed in the form of a Tri-Party Agreement interim milestone M-24-00L that new wells would not be added during calendar year 2000 because of higher priorities at other sites.

The 216-U-12 crib is a RCRA facility that has contributed to groundwater contamination in the U Plant area. Nitrate and technetium-99 are elevated in downgradient wells. Concentrations of these contaminants are declining.

New well 299-W22-79 is located approximately halfway between downgradient wells 299-W22-41 and 299-W22-42, both of which went dry and were last sampled in March 1999. Well 299-W22-79 was installed to replace 299-W22-42. Well 299-W22-40 was removed from the network in the first quarter of 1999 after it went dry. Well 299-W22-40 will not be replaced because it was not located directly downgradient of the crib, and no contaminants were detected in the well. The upgradient well 299-22-43 was last sampled in January 2000 before it went dry.

Based on regional groundwater elevations, the direction of groundwater flow continues east-southeast to east. New wells will be located appropriately to maximize the downgradient coverage of the 216-U-12 crib.

Groundwater flow rates have not changed significantly since last year and range between 0.1 and 0.3 meter per day (Appendix A, Table A.2).

Site-specific parameters selected for the interim status quality assessment monitoring include gross beta, iodine-129, nitrate, technetium-99, and tritium (see Appendix A, Table A.15). The crib is the source of elevated nitrate and technetium-99 that were detected in downgradient wells 299-W22-41, 299-W22-42, 299-W22-79, and 699-36-70A.

The regional nitrate and technetium-99 plumes are a series of smaller plumes with sources from several cribs (216-U-1, 216-U-2, 216-U-8, and 216-U-12) in the U Plant area. Iodine-129 and tritium were detected repeatedly in several monitoring wells downgradient from the 216-U-12 crib, but the sources appear to be the REDOX Plant effluent disposal cribs that are upgradient of the 216-U-12 crib. These plumes are discussed further in Section 2.8.4.

Nitrate continued to be detected at levels greater than the 45 mg/L maximum contaminant level in all the downgradient wells. However, the concentration trend in the nitrate has been downward (Figure 2.8-32). Technetium-99 followed a trend similar to nitrate. Technetium-99 activities ranged from 33.30 to 126 pCi/L in downgradient wells, which is well below the 900 pCi/L drinking water standard (Figure 2.8-33). Technetium-99 concentration trends are declining in wells near the crib.

During fiscal year 2000, the center of the tritium plume appears to have moved farther east, away from the crib. The tritium has a source upgradient of the 216-U-12 crib. Tritium concentrations remained above the 20,000-pCi/L drinking water standard in downgradient well 699-36-70A during fiscal year 2000. The most recent concentrations are 17,000 and 72,600 pCi/L reported in downgradient wells 299-W22-79 and 699-36-70A, respectively.

Iodine-129 is elevated above the 1 pCi/L drinking water standard in wells 299-W22-79 and 699-36-70A. Iodine-129 in these wells is 2.66, and 12.9 pCi/L, respectively. The iodine-129 source is upgradient of the 216-U-12 crib.

2.8.3.8 RCRA Assessment Summary for Waste Management Area U

RCRA Waste Management Area U was placed in assessment in early fiscal year 2000 because of an exceedance in the indicator parameter specific conductance. The area remained in assessment because of elevated concentrations of chromium, nitrate, and technetium-99.

Waste Management Area U, located in the central portion of the 200 West Area, consists of the U Tank Farm and ancillary equipment (e.g., diversion boxes). Constructed between 1943 and 1944, the tank farm contains twelve 2-million-liter tanks and four 208,000-liter tanks. The tanks began receiving waste in 1946, initially receiving waste mainly from the bismuth phosphate process.

Waste Management Area U was placed in assessment status in fiscal year 2000 because recalculation of the critical mean for specific conductance lowered the trigger value from 533 to 273 µS/cm. Specific conductance values for downgradient well 299-W19-41 exceeded this new critical mean, triggering the assessment process. The lowering of the critical mean is a result of lower upgradient values and less variability in upgradient value, apparently resulting from the stabilization of groundwater flow directions at the waste management area.

DOE notified Ecology of the exceedance in February 2000 and an assessment plan was prepared (PNNL-13185). Subsequently, a first determination assessment report was prepared (PNNL-13282) that reached the conclusion that chromium, technetium-99, and nitrate contamination cannot be explained by an upgradient source and that the waste management area is contaminating groundwater.

Groundwater Flow

Groundwater flow directions at Waste Management Area U have been variable over the life of the facility because of changing effluent discharge patterns within the 200 West Area. Groundwater flowed toward the northeast when the RCRA monitoring network was established. Prior to establishment of the Hanford Site, groundwater in the vicinity of Waste Management Area U is believed to have flowed from west to east, and it was expected that groundwater flow in this area would eventually move to that direction. However, groundwater flow directions have changed over the past several years as a result of the 200-ZP-1 Operable Unit pump-and-treat system located immediately to the north of the waste management area.

Presently, groundwater flows generally toward the east in most of the waste management area but has a component toward the north or northeast in the northern part of the waste management area (see Plate 1). This component is a result of extraction at well 299-W15-37. This extraction well was shut down and converted to a monitoring well in early fiscal year 2001. The waste management area is outside of the capture zone of this well, but near enough to experience deflection of groundwater flow paths.

Groundwater flow beneath the northern part of Waste Management Area U is deflected to the north, toward remediation pumping wells.

Locally, flow directions may diverge from the regional pattern because variable cementation within the Ringold aquifer may result in preferred groundwater flow paths. Groundwater flow velocities calculated using new values for hydraulic conductivity (PNNL-13378) fall in the range of 0.006 to 0.14 meter per day (Appendix A, Table A.2). This range is in reasonable agreement, though slightly lower, with velocities of 0.149 to 0.181 meter per day calculated from tracer pumpback tests in well 299-W19-41 (PNNL-13378).

Groundwater Contamination

Waste Management Area U was placed in assessment monitoring as a result of relatively elevated specific conductance in downgradient well 299-W19-41 (Figure 2.8-34). The elevated specific conductance in well 299-W19-41 is a result of higher non-hazardous constituents, principally sodium, chloride, bicarbonate, calcium, and magnesium. However, it is apparently indicative of enhanced infiltration of surface water along the southern margin of the waste management area. Infiltration may mobilize waste constituents within the vadose zone in that area.

Technetium-99, though usually below the drinking water standard of 900 pCi/L, has been consistently present in downgradient wells while virtually absent from upgradient wells (Figure 2.8-35; see also Figure 2.8-28). There is no apparent upgradient source for the technetium-99 detected in the downgradient wells; therefore, it was concluded the technetium-99 is a result of groundwater contamination from within the waste management area.

Chromium increased along with technetium-99 and nitrate in well 299-W19-41, reaching 38 μg/L in August 1999. A spike in chromium concentrations detected in upgradient well 299-W18-25, shortly before it went dry, apparently was related to corrosion products in the well and cannot explain the chromium observed in well 299-W19-41.

Monitoring Network

The original RCRA groundwater monitoring network established at Waste Management Area U consisted of two upgradient and three downgradient wells (see Appendix A, Table A.12). One pre-RCRA well (299-W19-12) is used for indication only to fill a gap between RCRA wells 299-W19-41 and 299-W19-42. Three of the RCRA wells were constructed with 4.6-meter screened intervals and two with 10.7-meter screened intervals. Two of the three wells with the shorter screened intervals have gone dry, and the third will likely be dry within a year. The two that have gone dry were replaced with new wells with 10.7-meter screened intervals.

Planning calls for three additional downgradient wells and one upgradient well to replace well 299-W18-25, which is dry. Planning for two wells along the northern boundary of the waste management area is on hold because of the shutdown of the 200-ZP-1 extraction well, located northwest of the waste management area. The well was shut down on January 17, 2001. Ongoing weekly water-level measurements to evaluate the affect on groundwater flow directions will continue, and a decision regarding the proposed wells along the northern boundary of the waste management area will be made after flow directions have stabilized.

2.8.3.9 Groundwater Remediation at 200-UP-1 Operable Unit

Groundwater in the U Plant area is pumped and treated to shrink the highest-concentration portions of the uranium and technetium-99 plumes. The system operates as an interim action until a final remedy is selected.

The goal of the pump-and-treat system at the 200-UP-1 Operable Unit is to reduce contamination in the highest concentration area of the plumes, reduce human health risks through mass removal, hydraulically contain the contaminant plume, and provide information to support a final remedy decision. At the end of fiscal year 2000, technetium-99 remained above the 9,000 pCi/L remediation goal in one monitoring well. Uranium concentrations generally remained above the 480 μg/L remediation goal in almost all wells. However, the loss of many of the monitoring wells the last several years due to declining water levels has created a situation where the contaminant plumes can no longer be tracked accurately. For more detailed information about operations during fiscal year 2000, refer to DOE/RL-2000-71.

Interim Remedial Action Objectives

The pump-and-treat system for this operable unit is located southeast of U Plant (221-U) (see Appendix A, Figure A.10). The interim action objectives (ROD 1997) are the following:

- reduce contamination in the areas of highest concentration of technetium-99 and uranium to below 10 times (480 μg/L) the cleanup level under the *Model*

Toxics Control Act (WAC-173-340) for uranium, and 10 times (9,000 pCi/L) the drinking water standard for technetium-99

- reduce potential adverse human health risks through reduction of contaminant mass
- prevent further movement of these contaminants from the highest concentration area
- provide information that will lead to the development and implementation of a final remedy that will protect human health and the environment.

History of Operations

A previous pump-and-treat system operated in 1985 near the 216-U-1 and 216-U-2 cribs to reduce elevated uranium concentrations. For a discussion of this operation, refer to WHC-EP-0133.

The current system was constructed to contain the highest concentration portion of the technetium-99 and uranium plume. Early operations consisted of a treatability test conducted from March 1994 to September 1995. Phase I pump-and-treat operations began September 1995 and consisted of one extraction well and one injection well. This system operated until February 7, 1997. Groundwater was treated onsite using an ion-exchange medium, and treated water was injected upgradient from the extraction well.

On February 25, 1997, an interim action record of decision (ROD 1997) was issued that initiated Phase II for the pump-and-treat system at the 200-UP-1 Operable Unit. The selected remedy consisted of pumping the highest concentration zone of the technetium-99 and uranium groundwater plumes, using the same extraction well and transporting the contaminated groundwater to the Effluent Treatment Facility in the 200 East Area. Since March 1997, contaminated groundwater was pumped from the extraction well, transported in an 11-kilometer pipeline to the Effluent Treatment Facility in the 200 East Area for treatment, and then sent to the State-Approved Land Disposal Site north of the 200 West Area for disposal. Secondary contaminants (carbon tetrachloride and nitrate) are also present and are being removed.

Contaminant Removal

Approximately 63.2 million liters of contaminated groundwater from the 200-UP-1 system were treated at the Effluent Treatment Facility in fiscal year 2000. A total volume of 420.8 million liters have been treated since startup in fiscal year 1994. The average extraction flow rate was 180 liters per minute. The amount of contamination removed this fiscal year is summarized in the following list:

- Technetium-99
  - 67.3 grams removed since startup (March 1994)
  - 5.6 grams removed during fiscal year 2000
- Uranium
  - 114.8 kilograms removed since startup (March 1994)
  - 13.6 kilograms removed during fiscal year 2000
- Carbon tetrachloride
  - 17.4 kilograms removed since startup (March 1994)
  - 1.66 kilograms removed during fiscal year 2000
- Nitrate
  - 15,576 kilograms removed since startup (March 1994)
  - 2,807 kilograms removed during fiscal year 2000.

Table 2.8-3 shows the amount of contamination removed since startup of operations.

Carbon tetrachloride concentrations again decreased while groundwater was transported along the 11-kilometer pipeline between the extraction well in the 200 West Area to the Effluent Treatment Facility in the 200 East Area. The dissolved carbon tetrachloride outgasses and is lost to the atmosphere. Given the volume of groundwater pumped in fiscal year 2000 (76.2 million liters), the estimated amount of carbon tetrachloride mass lost to the atmosphere was 5.7 kilograms. This loss is in addition to the mass removed during treatment.

Overall Effectiveness

As of July 2000, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained. However, they were not remediated to the levels required by the interim action objectives as shown in Table 2.8-4 (ROD 1997). Significant progress was made to reduce the size and concentration of the technetium-99 plume. Less progress has been made to remediate the uranium plume because of its tendency to sorb to the soil.

The 200-UP-1 pump-and-treat system has made significant progress in reducing the size and concentration of the technetium-99 plume. Less progress has been made in remediating uranium because of its tendency to sorb to the soil.

The following conclusions were drawn from these plume maps and from information contained in DOE/RL-2000-71.

Technetium-99

- Remediation has reduced the highest concentrations around the extraction well from 9,000 pCi/L in July 1999 to 6,000 pCi/L in January/February 2000. Note that the January/February 2000 (900 pCi/L) plume (Figure 2.8-36) covers about the same areal extent as the June 1995 (9,000 pCi/L) plume (Figure 2.8-37).
- Technetium-99 concentrations exceeded the remediation criterion of 9,000 pCi/L in only monitoring well 299-W19-36. The technetium-99 concentration in this well was 25,400 pCi/L (±2,600 pCi/L) in January 2000 and was on an upward trend. This well is the former injection well.
- The northwest high concentration portion of the technetium-99 plume will not reach the extraction well for 1 to 2 years under the natural groundwater gradient. For this reason, another extraction well may be installed in this area next fiscal year.

Uranium

- Uranium concentrations were above the 480 μg/L remedial action objective only in monitoring well 299-W19-20 where it was measured at 1,900 μg/L in January 2000 (Figure 2.8-38). However, six out of seven wells that had uranium concentrations above the remedial action objective a couple of years ago, have subsequently gone dry (see Table 2.8-4). At that time, they were still above the remediation goal. Consequently, it presently cannot be determined whether uranium concentrations are above or below the remedial action objective.
- Uranium concentrations were stable in five of nine wells, i.e., there is less than 20% variation during fiscal year 2000 when compared to average 1999 concentrations.
- Uranium concentrations decreased from fiscal year 1999 to fiscal year 2000 in three wells, 299-W19-20, 299-W19-30, and 299-W19-37. The decrease in well 299-W19-20 probably can be attributed to remediation efforts, and movement of the plume under the hydraulic effect of the extraction well. The lower concentrations in wells 299-W19-30 and 299-W19-37 probably indicates that groundwater diluted by former injection well 299-W19-36 has reached these wells and is causing concentrations to decline.

- Total uranium concentrations are increasing in monitoring well 299-W19-36, the former injection well. The slow increase in uranium concentrations compared to technetium-99 is probably because of the tendency of uranium to sorb to soil. The January/February 2000 concentration was 170 µg/L, considerably below the 480 µg/L remedial action objective.

In summary, most of the high concentration portion of the technetium-99 plume in the southeastern 200-UP-1 Operable Unit has been remediated to below the 9,000 pCi/L remedial action objective. An area of high concentration in the northwestern portion of the plume is present near former injection well 299-W19-36. Technetium-99 concentrations reached 25,400 pCi/L (±2,600 pCi/L) in January 2000 and appear to be on an upward trend.

Uranium concentrations are above the 480 µg/L remedial action objective in only one well, 299-W19-20, near extraction well 299-W19-39, however, many monitoring wells have gone dry as discussed below. Total uranium in 299-W19-36 was 170 µg/L in January 2000, with concentrations increasing as the groundwater diluted by previous injection of treated groundwater moves downgradient.

Water-Level Impact and Capture-Zone Analysis

The rate of water-level decline at 200-UP-1 Operable Unit apparently has slowed over the past five years from a maximum of 0.69 meter per year to a present rate of 0.40 meter per year (DOE-RL-2000-71). Additional monitoring wells went dry this year: 299-W19-23, 299-W19-26, and 299-W19-38. Well 299-W19-20 is now sampled with a KABIS sampler because of low water levels. The well network is now reduced to seven monitoring wells, with only three wells in the interior of the plume where samples can be obtained. Table 2.8-4 lists the wells that are now dry, those that can still be monitored for water levels, and the dates the wells were last sampled.

Three wells monitoring the progress of the 200-UP-1 pump-and-treat system went dry in fiscal year 2000. Only three wells currently monitor the interior of the plume.

The radius of influence of the extraction well is estimated at about 155 meters, essentially unchanged from fiscal years 1998 or 1999. The extraction well appears to be capturing the targeted plume area based on drawdowns observed in observation wells located outside of the targeted remediation area, previous modeling results (DOE/RL-2000-71), and the low concentrations of contaminants in downgradient well 299-W19-40. However, the limited monitoring network is not robust enough to allow confirmation that interior plume concentrations are below the remedial action objectives.

2.8.4 REDOX Plant

The REDOX Plant was used for separating plutonium from irradiated fuel from 1951 through 1967. Groundwater plumes, originating in the vicinity of the REDOX Plant and its associated waste storage and disposal facilities, include chromium, iodine-129, nitrate, technetium-99, trichloroethene, tritium, and uranium at levels above the maximum contaminant levels/drinking water standards. Strontium-90 was not detected at levels above the drinking water standard in this area in fiscal year 2000. Two facilities in this vicinity, Waste Management Area S-SX and 216-S-10 pond and ditch, have RCRA monitoring requirements. Other facilities appear to have produced the major part of the groundwater contamination, though high concentrations of technetium-99 and other contaminants are attributed to leaking tanks or associated piping in Waste Management Area S-SX.

Monitoring Objectives Near REDOX Plant

Groundwater monitoring is conducted near the REDOX Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of one RCRA waste management area
- quarterly to assess contamination from one RCRA waste management area.

2.8.4.1 Groundwater Flow

The direction of groundwater flow in the southern portion of the 200 West Area is principally toward the east (see Plate 1). Over the past decade, flow in this area has changed (by about 30 degrees) from a southeasterly direction to mostly east in response to decreased effluent discharges in the 200 West Area. Groundwater flow beneath Waste Management Area S-SX is discussed in Section 2.8.4.8, and flow beneath the 216-S-10 pond and ditch is discussed in Section 2.8.4.9.

2.8.4.2 Tritium

A tritium plume extends eastward from the vicinity of the REDOX Plant in the southern 200 West Area (see Plate 2). The eastern part of the plume curves to the north, but the tritium concentrations in the northern part of this plume are declining, as illustrated by the tritium trend plot for well 699-38-65 (Figure 2.8-39).

Waste sites associated with the REDOX plant have contributed to tritium, iodine-129, technetium-99, uranium, chromium, and trichloroethene plumes in groundwater. Movement of these plumes is relatively slow because of the low-permeability sediment in the area.

The tritium plume from the southern 200 West Area extends to US Ecology's low-level radioactive waste disposal facility. The maximum tritium concentration (annual average of 5,600 pCi/L) detected in groundwater at that facility in fiscal year 2000 was in well 699-35-59 (US Ecology well 13). Tritium concentrations in that well, located on the western (upgradient) side of the facility, have increased slowly due to transport from the 200 West Area. These data were provided by US Ecology and are not included on the diskette included with this report.

Movement of this tritium plume is expected to be slow because of the low-permeability sediment at the 200 West Area and the dissipation of the groundwater mound beneath the 200 West Area since the reduction of effluent discharge. Data for the past several years indicate that the extent of the plume has not changed greatly.

Tritium was found above the drinking water standard upgradient of the REDOX Plant near the 216-S-25 crib and Waste Management Area S-SX. The source of tritium in this area is attributed to the past-practice disposal sites (e.g., 216-S-4, 216-S-21, 216-S-25 cribs). Tritium concentrations in well 299-W23-9, located near the 216-S-25 crib, have risen in recent years but have not reached the levels seen in the late 1980s. The tritium pulse seen since 1995 in well 299-W22-46 may be the downgradient expression of the discharge from the 216-S-25 crib (Figure 2.8-40).

2.8.4.3 Iodine-129

An iodine-129 plume from the 200 West Area extends into the 600 Area to the east and coincides with the tritium plume originating near the REDOX Plant (see Figure 2.8-31). This iodine-129 plume and the iodine-129 contamination originating farther north near U Plant appear to combine downgradient and become indistinguishable at the current level of monitoring detail. The maximum iodine-129 concentration detected in this plume in fiscal year 2000 was 34 pCi/L in well 699-35-70. Iodine-129 concentrations in this well have not changed significantly in the last decade. However, well 299-W22-9, which previously had the maximum iodine-129 concentrations, could not be sampled due to declining water levels.

2.8.4.4 Technetium-99

Technetium-99 continued to be found at levels above the drinking water standard in three small plumes located near Waste Management Area S-SX (Figure 2.8-41). Evidence from recent years suggests that multiple sources of technetium-99 in the Waste Management Area S-SX tank farm contribute to groundwater contamination (PNNL-11810). Past data suggest that the 216-S-13 crib may have contributed to the technetium-99 detected further downgradient of Waste Management Area S-SX. Well 299-W22-21, located next to the 216-S-13 crib, can no longer be sampled due to the declining water table. Therefore, there is a scarcity of wells to track the migration of technetium-99 downgradient of Waste Management Area-S-SX. Technetium-99 in the vicinity of Waste Management Area S-SX is discussed in Section 2.8.4.8.

2.8.4.5 Nitrate

Nitrate was detected in fiscal year 2000 above the maximum contaminant level in two small plumes in the vicinity of the REDOX Plant. The first plume is located near the 216-S-20 crib, which received laboratory waste from the 222-S Building (see Figure 2.8-30). Lower concentrations of nitrate also are associated with the tritium and iodine-129 plumes extending to the east of the REDOX Plant.

Nitrate was detected above the maximum contaminant level in well 299-W23-9 near the 216-S-25 crib and extends past Waste Management Area S-SX (see Figure 2.8-30). Nitrate appears to be associated with the technetium-99 plumes in this vicinity. In particular, 510 mg/L of nitrate was detected in new well 299-W23-19, located in the southwestern corner of Waste Management Area S-SX. Nitrate levels are considerably lower in wells downgradient of the tank farm.

2.8.4.6 Chromium

Chromium declined to levels below the maximum contaminant level for the first time since the start of the monitoring in well 299-W26-7, the upgradient well for the 216-S-10 pond and ditch (Section 2.8.4.9). The source of the chromium contamination has not been determined, but it is possibly related to the 216-S-10 pond or to earlier disposal to upgradient facilities (termed the "REDOX swamp" in some early reports).

There may be a relationship between the chromium detected in well 299-W26-7 and chromium detected farther downgradient, south of the 200 East Area (discussed in Section 2.11.5).

2.8.4.7 Trichloroethene

A small trichloroethene plume, with concentrations just above the maximum contaminant level, is found east of the REDOX Plant. Trichloroethene was not detected at levels above the maximum contaminant level in this vicinity in fiscal year 1999. In fiscal year 2000, trichloroethene was measured at 9 μg/L in well 299-W22-20. The 216-S-20 crib is a likely source of the trichloroethene plume.

2.8.4.8 RCRA Assessment Summary for Waste Management Area S-SX

Waste Management Area S-SX continued to be monitored under a RCRA assessment program in fiscal year 2000. Assessment findings from November 1997 through June 2000 were published in PNNL-13441. The groundwater assessment is being conducted concurrently with the vadose zone characterization work for the RCRA field investigation (HNF-5058). The initial results of the vadose zone characterization investigation, together with the groundwater pathway evaluation, are scheduled for release in April 2001. The RCRA field investigation report will be used to support decisions concerning the need for a corrective measures study and possible mitigating actions that could be taken to reduce groundwater contamination from this waste management area. The site map for this waste management area (Appendix A, Figure A.4) and a table (Appendix A, Table A.3) of wells and associated analytes exceeding contaminant standards are included Appendix A.

At RCRA Waste Management Area S-SX, the most significant finding during fiscal year 2000 was the persistent and gradual increase in technetium-99 concentration in a new well in the southwestern corner of the SX tank farm. Technetium-99 concentrations reached 64,000 pCi/L, the highest levels detected in Hanford Site groundwater in fiscal year 2000. The contamination is attributed to previous leaks of tank waste to the soil in that area.

Groundwater Flow

Estimates of the rate of groundwater flow , using travel times for tritium between upgradient and downgradient 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 (PNNL-12114). Calculated Darcy flow rates (see Appendix A, Table A.2) based on new hydraulic conductivity and tracer test data obtained in fiscal year 2000, also suggest even lower flow rates (0.013 to 0.049 meter per day).

The water table is gradually declining at the rate of ~0.6 meter per year, which probably accounts for the gradual change in flow direction from 1990 to the present. For example, trend surface analysis of the water-table elevations in the network wells indicates that the flow direction has shifted from a southeasterly direction to almost due east at the present time (PNNL-13441). The flow direction inferred from water-table elevation contours suggests a southeasterly flow over the larger area around the waste management area (see Plate 1). This apparent discrepancy may in part be due to localized aquifer inhomogeneities in the vicinity of the waste management area.

Assuming the contaminant-based flow rate estimates noted above are the most representative, the average arrival time from the center of Waste Management Area S-SX to the nearest downgradient RCRA monitoring wells is ~3 to 6 years at 25 meters per year or 1.5 to 3 years at 50 meters per year. At 50 meters per year, it would take over 20 years for a contaminant plume to migrate from within Waste Management Area S-SX to the nearest downgradient 200 West Area fence line and much longer to reach the Columbia River. The apparent slow travel time in this location is attributed to the low permeability of the semi-cemented Ringold Formation in this part of the 200 West Area.

Groundwater Contamination

The general distributions of contaminant plumes in the vicinity of Waste Management Area S-SX were discussed earlier in this section. Contaminants have tended to migrate to the east-southeast as also suggested by the water-table contours for this area (see Plate 1). The new wells installed in late 1999 provide additional information concerning both areal and vertical extent of contamination, in addition to estimates of the extent of groundwater contamination based on the somewhat limited number of near-field monitoring wells in the area (PNNL-13441).

The constituents of interest for this waste management area were identified previously based on process knowledge and results of in-tank sampling and analysis. The radioactive constituents with greatest concentrations in the tanks are cesium-137 and strontium-90. The more mobile components of the waste that have been identified in groundwater beneath this waste management area include technetium-99 as pertechnetate, chromate, nitrate, and tritium. While upgradient sources exist because of past-practice discharges to adjacent cribs (216-S-25 crib), tank farm waste input can be distinguished from upgradient sources by isotopic and chemical ratios (PNNL-12114; HNF-4936; PNNL-13441). For example, ratios of technetium-99 to nitrate in upgradient wells are very low compared to ratios in downgradient wells (~0.01 versus ~0.1 respectively, PNNL-13441).

The occurrence of chromium, nitrate, and technetium-99 (Figure 2.8-42) in groundwater at the SX tank farm is consistent with the high percentage of these mobile constituents in the water extracts from contaminated soil samples near tanks SX-108, -109 and -115 (see Tables 3.2-2 and 3.2-3, PNNL-13116). While a direct link between the above tank sources and groundwater cannot be made at this time, the high percentage of water extractable chromium, nitrate, and technetium-99 in soil samples suggests there is potential for transport of this type of waste through the vadose zone to groundwater. In contrast, cesium-137 is not detected in groundwater. This is consistent with a low percentage of this radionuclide in the water-leach fraction of contaminated sediment from borehole 41-09-39 (PNNL-13116). The existence of old water lines that are still pressurized and pass near some of these sources lends credibility to the speculation that a local artificial source of recharge water may exist near certain tank leak sites and serves as a driving force to carry tank waste contaminants down to the water table (PNNL-11810). Isolation or capping of remaining old pressurized water lines is scheduled for summer of 2001.

Table A.3 in Appendix A lists contaminant concentration exceedances for Waste Management Area S-SX. A complete discussion of contaminant concentrations is provided in the updated assessment report (PNNL-13441). Highlights of concentration trends for key contaminants of concern are summarized as follows.

Technetium-99. The most significant trend during fiscal year 2000 was the persistent upward trend of technetium-99 in well 299-W23-19. This well is located immediately adjacent to tank SX-115 where a documented release to the soil column occurred in the 1960s. The technetium-99 concentration increased from a low of 39,000 pCi/L in October of 1999 to a maximum of 72,000 pCi/L in December 2000. Technetium-99 levels in well 299-W22-46 (Figure 2.8-43) and well 299-W22-50, east-southeast of the tank SX-115, appear to persist (3,000 to 5,000 pCi/L), suggesting a longer-term release source than previously observed in other wells in the waste management area network. Another notable change is the rising concentrations of chromium, nitrate, and technetium-99 in downgradient well 299-W22-45 at the SX tank farm (see Figure 2.8-42). Based on the location of this well, and inferred flow directions, this new contaminant occurrence represents a different vadose zone source, possibly originating in the northeastern area of the SX tank farm. The well is located downgradient from diversion boxes and valve pits that were sources of surface spills in the past. Single-shell tanks are less likely sources in this area than the ancillary waste systems because of the direction of groundwater flow. Technetium-99 in a new downgradient well (299-W22-48) at the S tank farm also seemed to increase gradually during the year and exceeded the drinking water standard of 900 pCi/L, reaching a maximum of 1,290 pCi/L in June 2000.

Based on the groundwater data collected to date, only the more mobile tank waste constituents (e.g., technetium-99, nitrate, hexavalent chromium, tritium) have reached groundwater beneath Waste Management Area S-SX.

Cesium-137 and Strontium-90. Except for one isolated detection of strontium-90 in new well 299-W22-50, cesium-137 and strontium-90 were not detected in the monitoring well network for Waste Management Area S-SX during fiscal year 2000 (the isolated detection of strontium-90 in the above well was attributed to the introduction of surface contamination into the well during removal and replacement of the sample pump for hydraulic and tracer tests). Evaluation of historical and recent groundwater data (HNF-4936) showed that results for these two constituents of interest were at or below the routine detection limits (~10 pCi/L for cesium-137 and ~1 pCi/L for strontium-90) and were within the 95% confidence limits for field trip blank results.

Transuranics. Some special analyses were conducted for transuranics in water samples from the well with the highest technetium-99 (well 299-W23-19). Results for neptunium-237, plutonium-238, plutonium-239, and americium-241 were all non-detect (<0.1 pCi/L versus the drinking water standard of ~1 pCi/L for these alpha emitting radionuclides). Since these long-lived alpha emitters have been found in groundwater as colloidal phases at other DOE sites (e.g., Kaplan et al. 1994; Kersting et al. 1999), it might be expected the same type of occurrence could be present at Hanford. However, if colloidal phases are present, they must be at lower concentrations than the detection limit used for the above analyses; or colloidal phases do exist but have not yet reached the water table. Investigation of this possibility is underway as part of the Environmental Management Science Program studies being conducted near this tank farm.

Monitoring Network

Six new wells were drilled in calendar year 2000. Two new wells replaced the upgradient wells going dry and four were added to enhance downgradient spatial coverage and to evaluate the downgradient extent of contamination at the south end of this waste management area. Three additional new downgradient wells are planned for fiscal year 2001. When all the currently planned wells are installed, the theoretical detection efficiency will be >95% (PNNL-13441).

Indications from the discrete depth sampling conducted in fiscal year 1999 suggest the maximum concentrations of tank farm related contaminants occur near the top (upper 5 meters) of the aquifer at Waste Management Area S-SX (PNNL-13441). Thus, the 5-meter and 9-meter screen lengths used in the new wells should intercept the highest concentrations that occur in the aquifer beneath this waste management area.

New well 299-W23-21 (upgradient replacement well for the SX tank farm) was cored to the Plio-Pleistocene Unit (~40 meters below ground surface). Investigators from the Environmental Management Science Program will use the core samples to clarify contaminant sorption mechanisms and moisture movement through the vadose zone in the vicinity of single-shell tank farms (see Section 3.1). The information acquired will also help to better define the stratigraphy in this corner of the waste management area. One important finding during the coring was the discovery of free water or "perched water" at ~24 meters below ground surface. This occurrence suggests a local source of artificial recharge, possibly a leaking water line.

2.8.4.9 RCRA Parameters for 216-S-10 Pond and Ditch

The inactive 216-S-10 pond and ditch was monitored semiannually under RCRA interim status indicator evaluation (see Appendix A, Tables A.1 and A.13). None of the indicator parameter concentrations in downgradient monitoring wells exceeded critical mean values during fiscal year 2000 (see Appendix A, Table A.3). A site-specific constituent, chromium, which had been elevated above the 100 μg/L maximum contaminant level in past years, has dramatically declined during fiscal year 2000 to less than 20 μg/L in upgradient well 299-W26-7 (Figure 2.8-44). Because the upgradient well is located immediately adjacent to the 216-S-10 pond (see Appendix A, Figure A.6), the elevated chromium could have been from an upgradient source or from the pond. A new monitoring plan will be prepared to reclassify this well as a downgradient well and replace it with a new upgradient well in calendar year 2001. Further description of the chromium plume is presented in Section 2.8.4.6.

RCRA monitoring at the 216-S-10 pond and ditch provides no evidence of groundwater contamination from this facility. Chromium concentrations in the upgradient well declined dramatically in fiscal year 2000.

The water table continued to decline in the 200 West Area during fiscal year 2000. One new well, 299-W26-13, was installed downgradient near the northeastern corner of the 216-S-10 pond due to the loss of down gradient monitoring wells 299-W26-9 and 299-W26-10 (PNNL-13198). This continuing decline reduced the 216-S-10 monitoring network from one upgradient and three downgradient wells to just one upgradient well (299-W26-7) and two downgradient well (299-W26-12 and new well 299-W26-13). RCRA interim status monitoring requirements specify that a minimum of one upgradient and three downgradient monitoring wells are needed to monitor the site. As a result, at least one additional well is needed to bring the monitoring network back into compliance with RCRA regulations. If well 299-W26-7 is designated as a downgradient well, one upgradient well needs to be constructed. Ecology has deferred the installation of the proposed new well indefinitely.

Background values of contaminant indicator parameters for the facility have been recalculated based on one upgradient well (299-W26-7). Based on regional groundwater elevations, the groundwater flow direction continues toward the east-southeast to east. The indicator parameters provide no evidence of contamination from the 216-S-10 pond and ditch.

Groundwater flow rates have not changed significantly since last year and range between 0.047 and 0.33 meter per day, primarily due to the variable gradient across the pond and ditch (Appendix A, Table A.2).

Sample results that exceeded drinking water standards and maximum contaminant levels this year are presented in Appendix A, Table A.3.

2.8.5 State-Approved Land Disposal Site

The State-Approved Land Disposal Site is used to dispose treated water that occasionally contains tritium. During fiscal year 2000, tritium concentrations in most of the wells near the site declined.

The Hanford Site 200 Areas Effluent Treatment Facility processes contaminated liquids from Hanford Site facilities. The clean water generated by these processes is occasionally enriched in tritium and is discharged to the 200 Area State-Approved Land Disposal Site. This site is regulated by State Waste Discharge Permit ST-4500 (Ecology 2000), which is administered under WAC 173-216. Groundwater monitoring for tritium and other constituents is required by the state-issued permit at 22 wells surrounding the facility (Figure 2.8-45).

During fiscal year 2000, discharge volume to the facility totaled ~71.3 million liters. Over 340 million liters of effluent have been discharged since the State-Approved Land Disposal Site began operating in 1995. The quantity of tritium disposed to the site during fiscal year 2000 totaled slightly more than 16.44 curies. This brings the total inventory disposed since 1995 to slightly over 320 curies.

In August 2000, a new state waste discharge permit was signed with Ecology, allowing operation of the facility to continue through August 2005. In support of the permit, a revised groundwater monitoring plan (PNNL-13121) was prepared during fiscal year 2000. A discussion of fiscal year 2000 groundwater monitoring results in presented in PNNL-13329 and is summarized below.

2.8.5.1 Groundwater Flow

Water levels measured during fiscal year 2000 indicate that a small groundwater mound persists in the vicinity of the State-Approved Land Disposal Site (Plate 1). Hydrographs of wells near the 200 West Area, immediately south of the disposal site (Figure 2.8-46), indicate a potential for flow in that direction from the disposal site. The center of the mound is not necessarily located at well 699-48-77A; its shown location is partially an artifact of well coverage at the State-Approved Land Disposal Site and is an approximate location, with the actual center probably located somewhere between well 699-48-77A and the facility. Interpreted flow paths (or the potential for flow) of groundwater in the vicinity of the State-Approved Land Disposal Site indicate that effluent from the site could eventually affect groundwater quality at wells to the south of the facility. Exactly how far south the effluent from State-Approved Land Disposal Site could actually flow before turning east is not known and will ultimately depend on the interplay between discharge volumes and aquifer properties. Importantly, downgradient well 699-51-75 is currently in an optimum location for the interception and efficient tracking of tritium in a regionally downgradient direction from the State-Approved Land Disposal Site. The hydrographs (see Figure 2.8-46) also illustrate the general decline of head in the aquifer due to the cessation of 200 West Area disposal practices.

The hydraulic gradient near the State-Approved Land Disposal Site was approximately 0.002, as measured between wells 699-48-77A and 699-48-77D in March 2000 (Appendix A, Table A.2). The gradient is probably somewhat higher closer to well 699-48-77A, which is the approximate location where effluent from the State-Approved Land Disposal Site infiltrates.

2.8.5.2 Extent of Contamination

During fiscal year 2000, average tritium concentrations in most wells in the State-Approved Land Disposal Site tritium tracking network declined from average concentrations measured in fiscal year 1999 (see Figure 2.8-45). Wells in the southeast portion of the network, such as well 299-W6-7, still reflect the decay of the tritium plume originating from the northeast portion of the 200 West Area. Exceptions occurred in well 699-48-77C, which displayed delayed penetration of the effluent to the deeper levels in the aquifer, and possibly in well 299-W7-3 where tritium from the State-Approved Land Disposal Site may have appeared for the first time (1,400 pCi/L in August 2000). Well 299-W7-7 has not produced a detectable result since early 1997, but produced a result (300 pCi/L) marginally above detection in August 2000. Tritium in well 299-W6-11 was slightly higher in the fiscal year 2000 sample (6,000 pCi/L) than in the fiscal year 1999 sample (5,700 pCi/L), but this single result is of insufficient magnitude to suggest that the overall downward trend in this well is reversing. Well 299-W8-1 is nearly 1 kilometer away from the facility, and is thus far unaffected by discharges to the State-Approved Land Disposal Site. This well produced one marginally-detectable tritium result of 220 pCi/L (minimum detectable activity = 184 pCi/L) in July 1999, and a result of 290 pCi/L in April of 2000. However, both of these results were followed by results below detection. Also, this well has historically produced higher results prior to operation of the State-Approved Land Disposal Site. This well was removed from its status as an upgradient background well when the new permit went into effect in August 2000.

Trend plots for tritium in wells nearest to the State-Approved Land Disposal Site (Figure 2.8-47) showed the concentrations declining in wells 699-48-77A and 699-48-77D, but continuing to rise in the deeper well 699-48-77C. The well is completed ~20 meters deeper in the aquifer and tritium levels have risen since 1998, as a delayed response to disposal.

In addition to tritium, groundwater from the wells nearest to the State-Approved Land Disposal Site (699-48-77A, 699-48-77C, and 699-48-77D) and well 299-W8-1 were analyzed for a list of 16 constituents required by the State Waste Discharge Permit ST-4500 Special Condition S1 (A). Enforcement limits were set for most of these constituents [acetone, ammonia, benzene, cadmium (total), chloroform, copper (total), lead (total), mercury (total), pH, sulfate, tetrahydrofuran, total dissolved solids]. Gross alpha, gross beta, strontium-90, and tritium are not assigned enforcement limits but are monitored and reported.

Of the 12 constituents with permit limits, all were below the enforcement limits for groundwater during fiscal year 2000.[a] Acetone, ammonia, benzene, mercury, and tetrahydrofuran results were all below detection limits in all four wells for all of fiscal year 2000.

Chloroform was below detection in all wells except 299-W8-1, where it was below the assigned confidence level for quantitation, as determined by the laboratory. These results are a departure from fiscal year 1999 when all but well 699-48-77D produced chloroform results above detection.

Fiscal year 2000 maxima for gross alpha and gross beta results were all within Hanford Site background ranges for these two indicators (WHC-EP-0595; DOE/RL-96-61), and generally lower than corresponding results from fiscal year 1999. The highest gross alpha result for fiscal year 2000 of 2.2 pCi/L was recorded for well 699-48-77C in February 2000. A gross beta result of 77 pCi/L was reported for well 699-48-77A in February 2000, but a duplicate analysis on that same date produced a result of only 1.6 pCi/L.

Strontium-90 is the only radionuclide (other than tritium) that is specifically monitored at the State-Approved Land Disposal Site, and was detected in all three nearby wells and well 299-W8-1 during fiscal year 2000. This is a departure from fiscal year 1999, when wells 299-W8-1 and 699-48-77A produced no detections of strontium-90. Nevertheless, concentrations of this radionuclide remain low, with the highest in fiscal year 2000 measured in well 299-W8-1 at 5.4 pCi/L. The earliest reported strontium-90 detections predate the arrival of the tritium plume, so the contamination is not from the State-Approved Land Disposal Site.

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[a] Period reported is October 1, 1999 through August 31, 2000.

Other constituents illustrate the leaching effects of State-Approved Land Disposal Site effluent on natural soil components, and later dilutive effects in groundwater. Concentrations of sulfate in State-Approved Land Disposal Site wells illustrates this leaching effect (Figure 2.8-48). As with tritium, sulfate was first noticed in wells completed at the water table (699-48-77A and 699-48-77D), then a subdued, delayed response was observed in deeper well 699-48-77C. Similar trends emerge for concentrations of calcium, chloride, conductivity, and total dissolved solids in the same wells. In wells 699-48-77A and 699-48-77C, all six parameters appear to have fallen below the initial background concentrations of these in groundwater. Concentrations that are more characteristic of the dilute effluent from the State-Approved Land Disposal Site have replaced the natural levels to a minor degree.

Assuming that the detection of tritium in well 299-W7-3 is from the State-Approved Land Disposal Site, the occurrence and distribution of tritium in the aquifer agrees well with numerical model predictions of 1997 (PNNL-11665). The model indicated that tritium would first arrive at the 200 West Area northern boundary in 2000, and would then be detectable in as many as three wells along this boundary. In this model, well 299-W7-3 is barely outside the area of the predicted plume, with wells 299-W7-5, 299-W7-6, and 299-W7-7 lying inside the 500 pCi/L portion (lowest practically detectable) portion of the plume. The fact that tritium arrived as predicted in year 2000 very near the predicted locations, and within a factor of 2 of predicted concentrations, represents excellent performance by the model, and suggests that the effects of tritium disposal to groundwater are being accurately anticipated.

Table 2.8-1. Volume of Groundwater Treated and Mass of Carbon Tetrachloride Removed Since Startup of Operations at the 200-ZP-1 Operable Unit

Reporting Period	Liters Treated	Mass of Carbon Tetrachloride Removed (kg)
August 1994 - July 1996	26,676,000	75.85
August 1996 - September 1996	33,232,327	60.96
October 1996 - December 1996	44,583,715	143.54
January 1997 - March 1997	69,869,604	237.2
April 1997 - June 1997	41,877,094	140.8
July 1997 - September 1997	62,469,305	228.8
October 1997 - December 1997	81,629,000	245.7
January 1998 - March 1998	72,791,000	279.5
April 1998 - June 1998	90,842,900	348.9
July 1998 - September 1998	90,899,200	338.1
October 1998 - December 1998	83,552,570	315.57
January 1999 - March 1999	77,079,156	310.2
April 1999 - June 1999	90,657,196	337.8
July 1999 - September 1999	88,657,486	323.7
October 1999 - December 1999	53,073,724	201.8
January 2000 - March 2000	90,498,074	370.0
April 2000 - June 2000	74,312,707	307.8
July 2000 - September 2000	82,096,586	303.7
Total	1,254,797,644	4,569.9

Table 2.8-2. Average Carbon Tetrachloride Concentrations for Each of the Extraction Wells and the Influent Tank at the 200-ZP-1 Operable Unit, Fiscal Year 2000

Well Name[(a)]	FY 2000 Min. Value (µg/L)	FY 2000 Max. Value (µg/L)	FY 1997 Mean Concentration (µg/L)	FY 1998 Mean Concentration (µg/L)	FY 1999 Mean Concentration (µg/L)	FY 2000 Mean Concentration (µg/L)	Overall Change
299-W15-33	4,500	7,100	5,058	6,000	6,218	5,956	Stable
299-W15-34	4,400	6,700	2,900	3,770	4,700	5,517	Increasing
299-W15-35	2,800	4,900	3,351	3,660	3,858	3,842	Stable
299-W15-32	3,500	4,700	7,120	6,560	5,023	4,224	Lower
299-W15-36	1,400	2,300	2,820	2,040	1,697	1,779	Stable
299-W15-37	320	1,600	280	235	358	556	Increasing
Influent Tank	3,200	4,900	3,270	3,530	3,788	4,041	Increasing

(a) Wells listed from north to south.

Table 2.8-3. Quantity of Treated Groundwater and Contaminant Mass Removed Since Initiation of 200-UP-1 Pump-and-Treat Operations

Reporting Period	Liters Treated	Mass Technetium-99 Removed (g)	Mass Total Uranium Removed (g)	Mass Carbon Tetrachloride Removed (g)	Mass Nitrate Removed (kg)
March 1994 - November 1994(a)	3,898,550	3.41	4,422	Not reported	N/A
December 1994 - August 1995	11,391,491	7.79	9,831	992	N/A
September 1995 - November 1995	17,198,571	3.95	3,895	630	N/A
December 1995 - March 1996	31,311,340	9.05	9,105	1,609	N/A
April 1996 - June 1996	22,459,108	5.40	6,845	1,569	N/A
July 1996 - September 1996	22,370,327	4.01	5,134	2,790	N/A
October 1996 - December 1996	20,300,000	3.33	5,607	2,980	N/A
January 1997 - February 1997(b)	2,667,600	0.83	963	73	N/A
February - March 30, 1997	Shut down	N/A	N/A	N/A	N/A
March 31 - September 30, 1997	32,414,481	5.6	11,000	888	2,260
October 1 - December 31, 1997	20,390,054	3.31	6,300	572	1,530
January 1 - March 31, 1998	19,791,765	2.08	4,900	460	1,070
April 1 - June 30, 1998	33,538,750	3.58	8,680	907	2,150
July 1 - September 30, 1998	26,346,466	1.57	3,750	296	900
October 1 - December 31, 1998	22,174,396	1.49	4,910	341	979
January 1 - March 31, 1999	23,720,542	1.89	4,450	601	1,050
April 1 - June 30, 1999	24,369,400	2.29	5,400	600	1,400
July 1 - September 30, 1999	23,206,922	2.14	5,940	460	1,430
October 1 - December 31, 1999	14,858,190	1.25	3,080	286	681
January 1 - March 31, 2000	14,636,480	1.29	3,100	352	645
April 1 - June 30, 2000	18,295,080	1.63	4,050	527	806
July 1 - September 30, 2000	15,439,630	1.45	3,410	494	675
Total	420,779,143	67.34	114,772	17,427	15,576

(a) Data from the treatability test as reported in *Treatability Report for the 200-UP-1 Operable Unit - Hanford Site* (DOE/RL 95-02).

(b) Estimated values based on 189 L/min flow, running 24 hours/day, at 97.5% efficiency.

NA = Not applicable.

Table 2.8-4. Status of Wells in the 200-UP-1 Operable Unit Monitoring Network at the End of Fiscal Year 2000

Well Name	Available Water[a] (m)	Sample Dry Date[b]	Water Level Monitoring Dry Date	Uranium Concentration (μg/L)[c]	Technetium-99 Concentration (pCi/L)[c]	Date Sampled
299-W19-19	None	5/99	5/99	**1,400**	**16,700**	8/18/1995[d]
299-W19-20	1.20	9/02	12/03	**1,780**	6,820	2/1/2000
299-W19-23	None	8/99	7/00	**570**	4,650	7/19/1999
299-W19-24	None	4/99	6/00	**1,450**	6,675	4/14/1999
299-W19-25	None	10/97	2/98	**944**	**12,990**	3/22/1994[e]
299-W19-26	None	5/00	8/00	**690**	**9,720**	7/19/1999
299-W19-28	None	10/99	11/99	**550**	2,510	4/9/1999
299-W19-29	None	10/99	2/01	**1,335**	**25,050**	7/14/1999
299-W19-30	None	6/00	10/00	280	2,770	10/5/2000
299-W19-34A	14.70	Beyond 2010	Beyond 2010	2.3	123	2/2/2000
299-W19-35	5.22	Beyond 2010	Beyond 2010	34	540	2/1/2000
299-W19-36	9.86	Beyond 2010	Beyond 2010	170	**25,400**	1/24/2000
299-W19-37	3.62	10/07	9/09	180	1,073	2/2/2000
299-W19-38	0.39[c]	10/00	10/01	213	750	1/26/2000
299-W19-39	7.87	Beyond 2010	Beyond 2010	160	1,660	2/2/2000
299-W19-40	2.26	8/06	8/06	140	352	1/24/2000

All future dry dates assume the present water table decline rate of 0.4 m/yr stays constant.
Bold numbers designate values that exceed the interim remedial measure (ROD 1997) remedial action objectives of 9,000 pCi/L for technetium-99 and 480 μg/L for uranium.

(a) The water that is above the bottom of the screen.
(b) Wells are " sample dry" when a sample can no longer be take from the water remaining, which is at approximately 0.4 meter.
(c) The values listed are averaged if more than one sample was taken on the same day. Values are for the date last sampled.
(d) Sample date is for most recent sample analyzed for uranium. Most recent sample date for technetium-99 is December 30, 1994, and most recent sample date for carbon tetrachloride is August 16, 1995.
(e) Sample date is for most recent sample analyzed for uranium and technetium-99. Most recent sample date for carbon tetrachloride is April 14, 1994.
(f) A pump is lodged in the bottom of this well, reducing the actual length of available well screen.

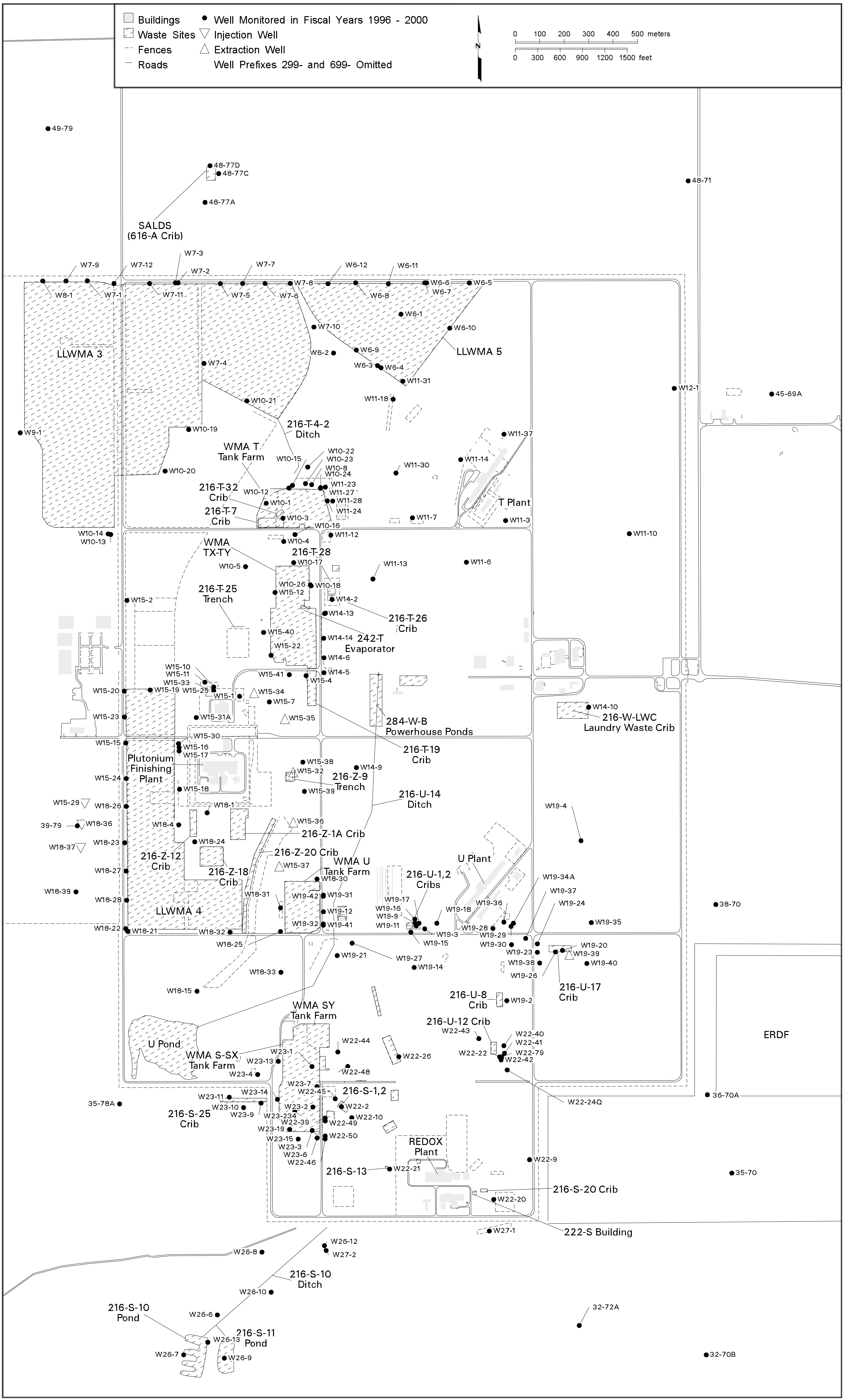

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Figure 2.8-1. Groundwater Monitoring Wells in the 200 West Area

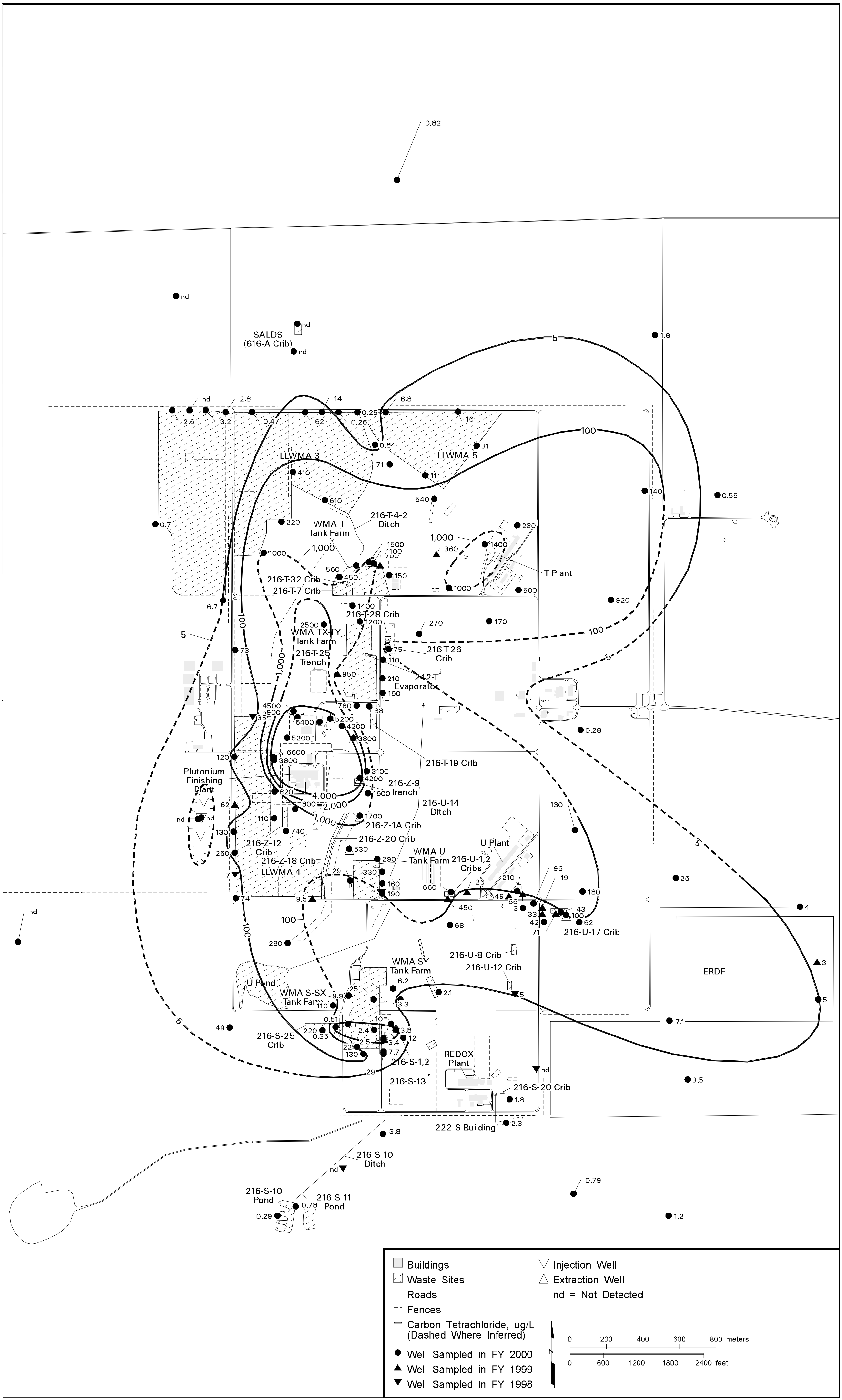

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Figure 2.8-2. Average Carbon Tetrachloride Concentrations in 200 West Area, Top of Unconfined Aquifer

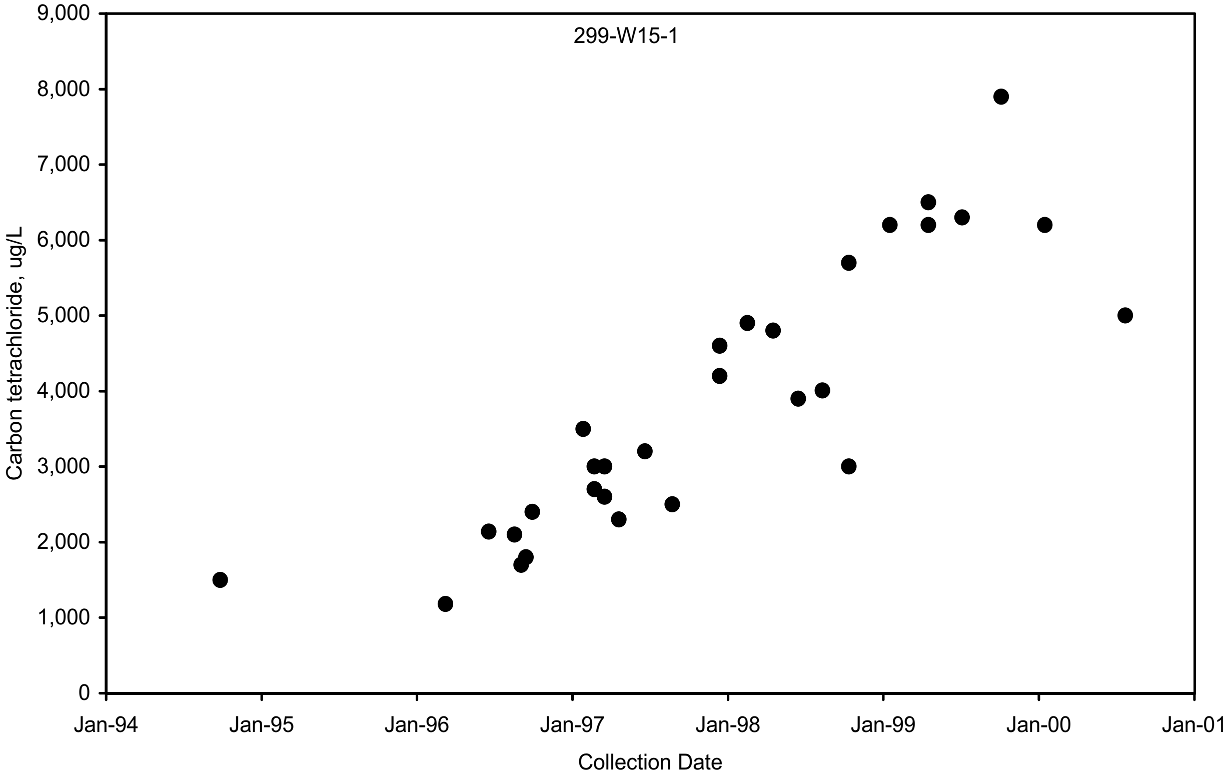

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Figure 2.8-3. Carbon Tetrachloride in Well 299-W15-1 near the Northern Extraction Wells

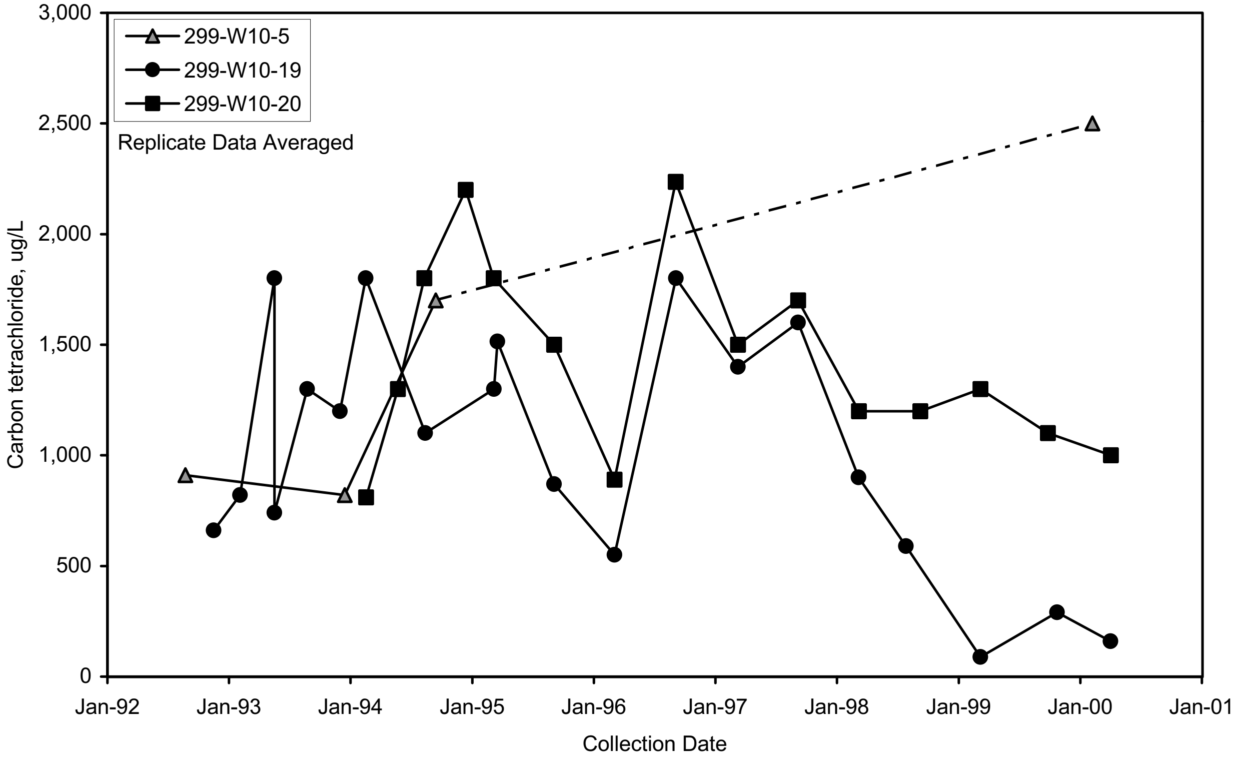

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Figure 2.8-4. Carbon Tetrachloride in Wells 299-W10-19, 299-W10-20, and 299-W10-5 in the Northwestern 200 West Area

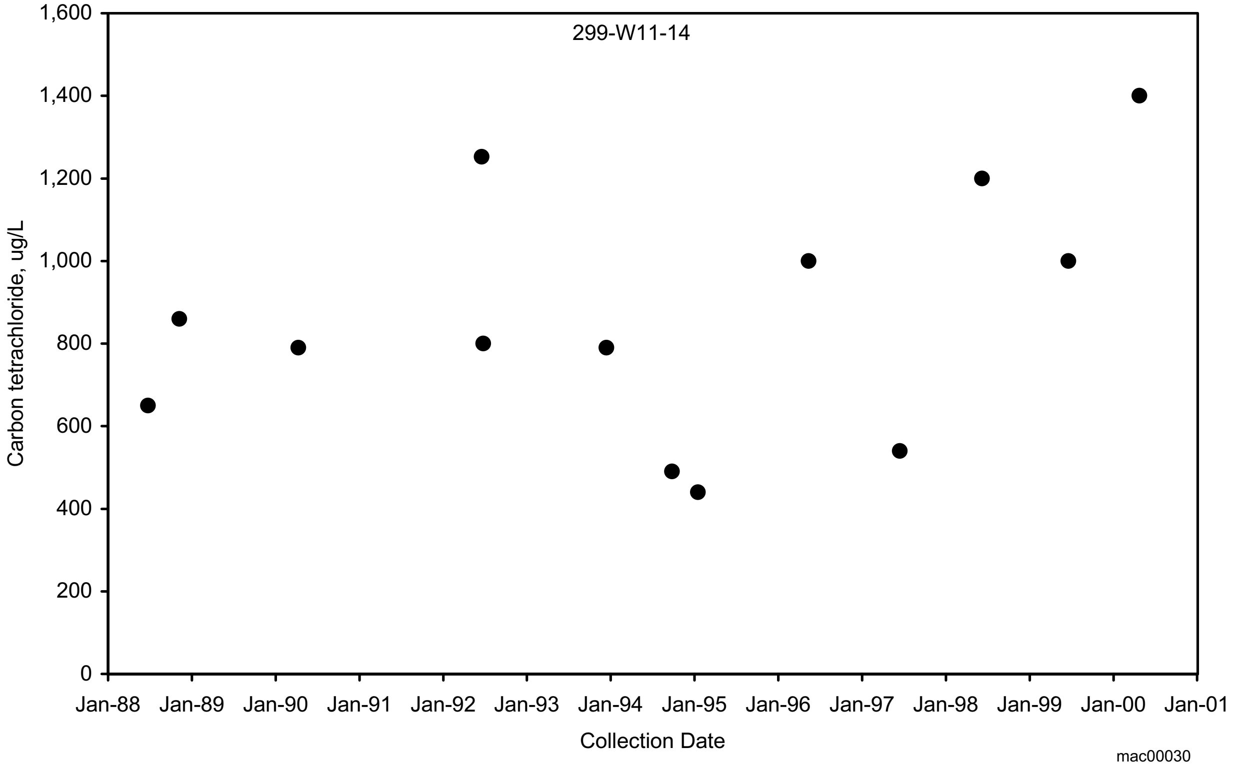

Figure 2.8-5. Carbon Tetrachloride in Well 299-W11-14 in the Northeastern 200 West Area

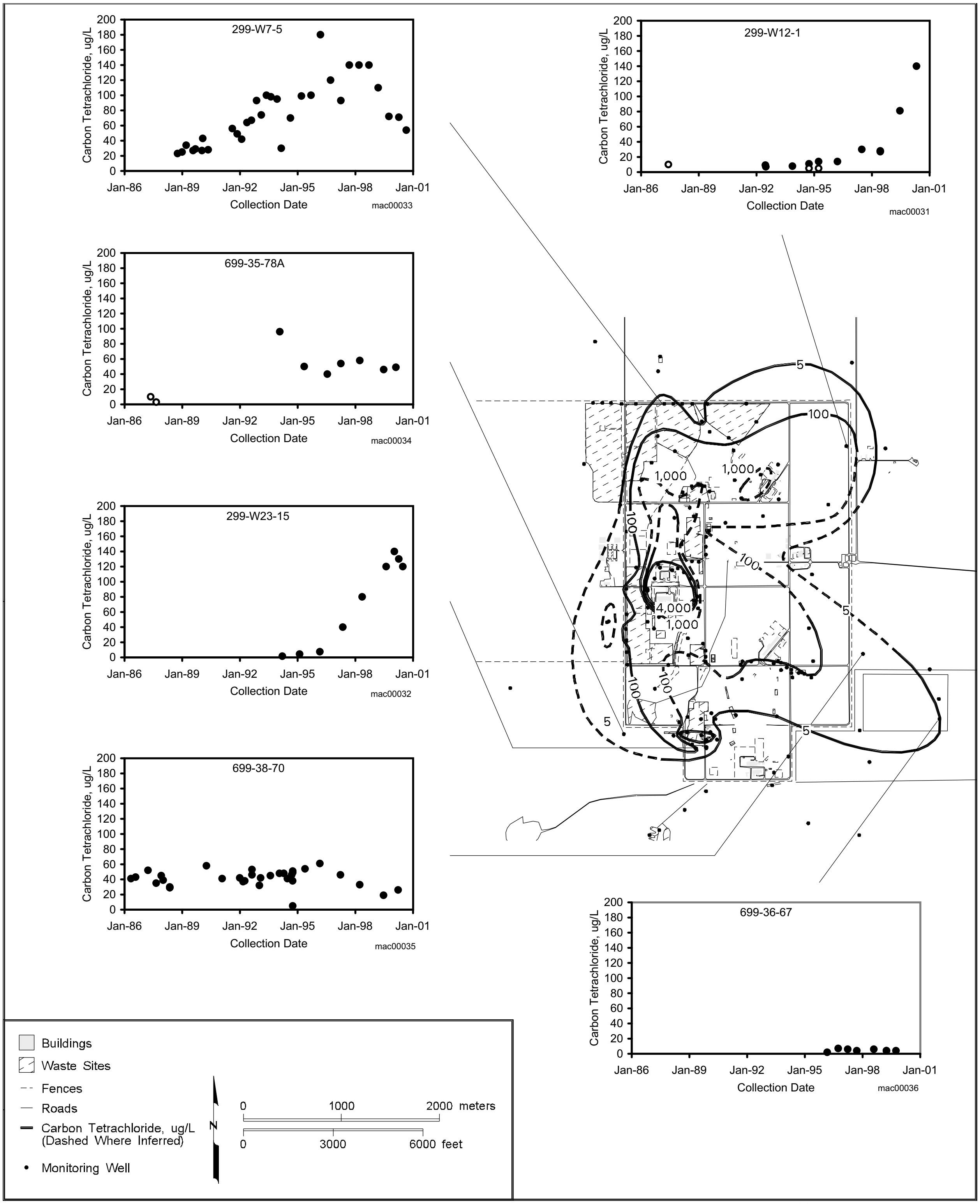

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Figure 2.8-6. Carbon Tetrachloride Concentrations in Wells Monitoring 200 West Area, Top of Unconfined Aquifer

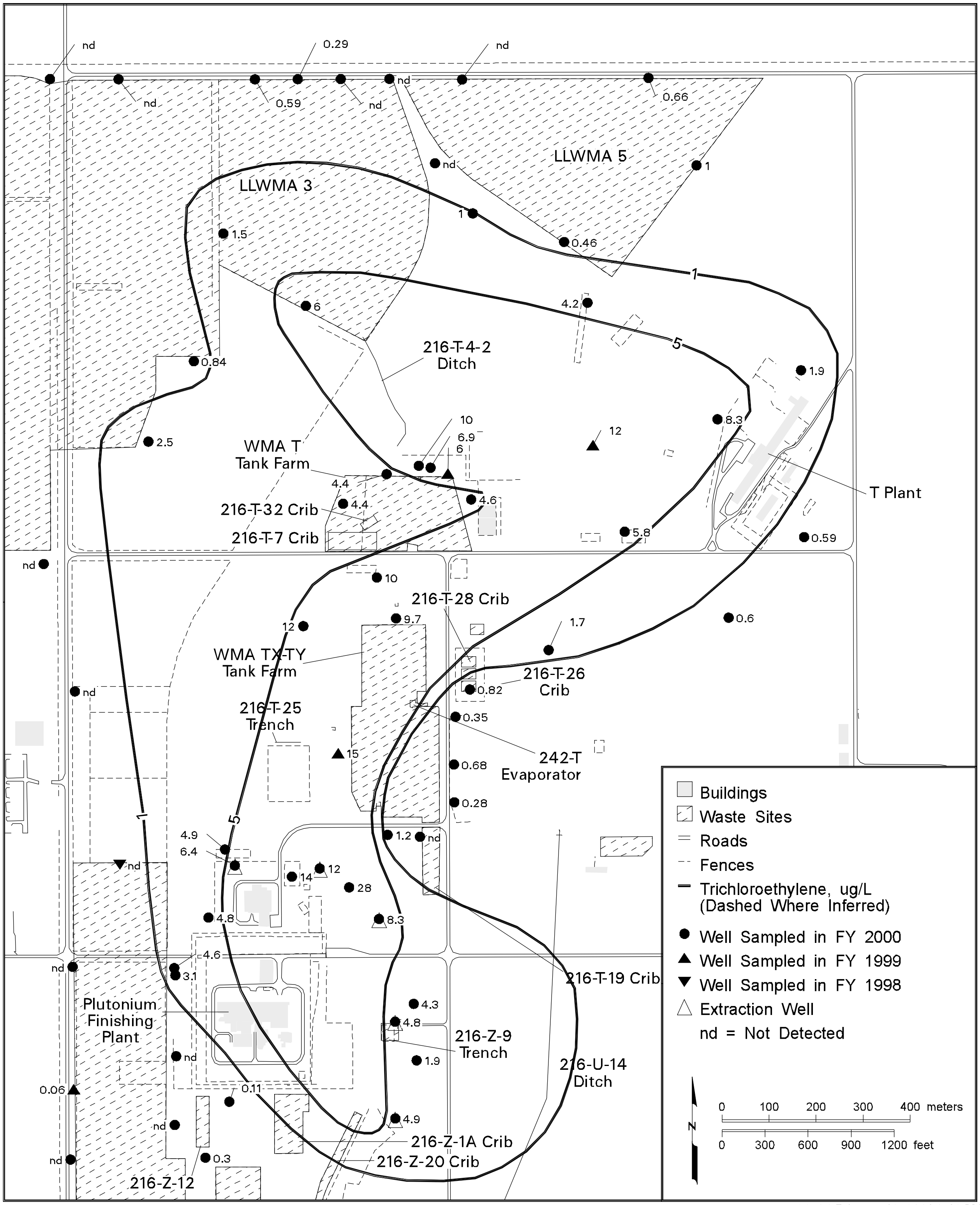

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Figure 2.8-7. Average Trichloroethene Concentrations in Central and Northern 200 West Area, Top of Unconfined Aquifer

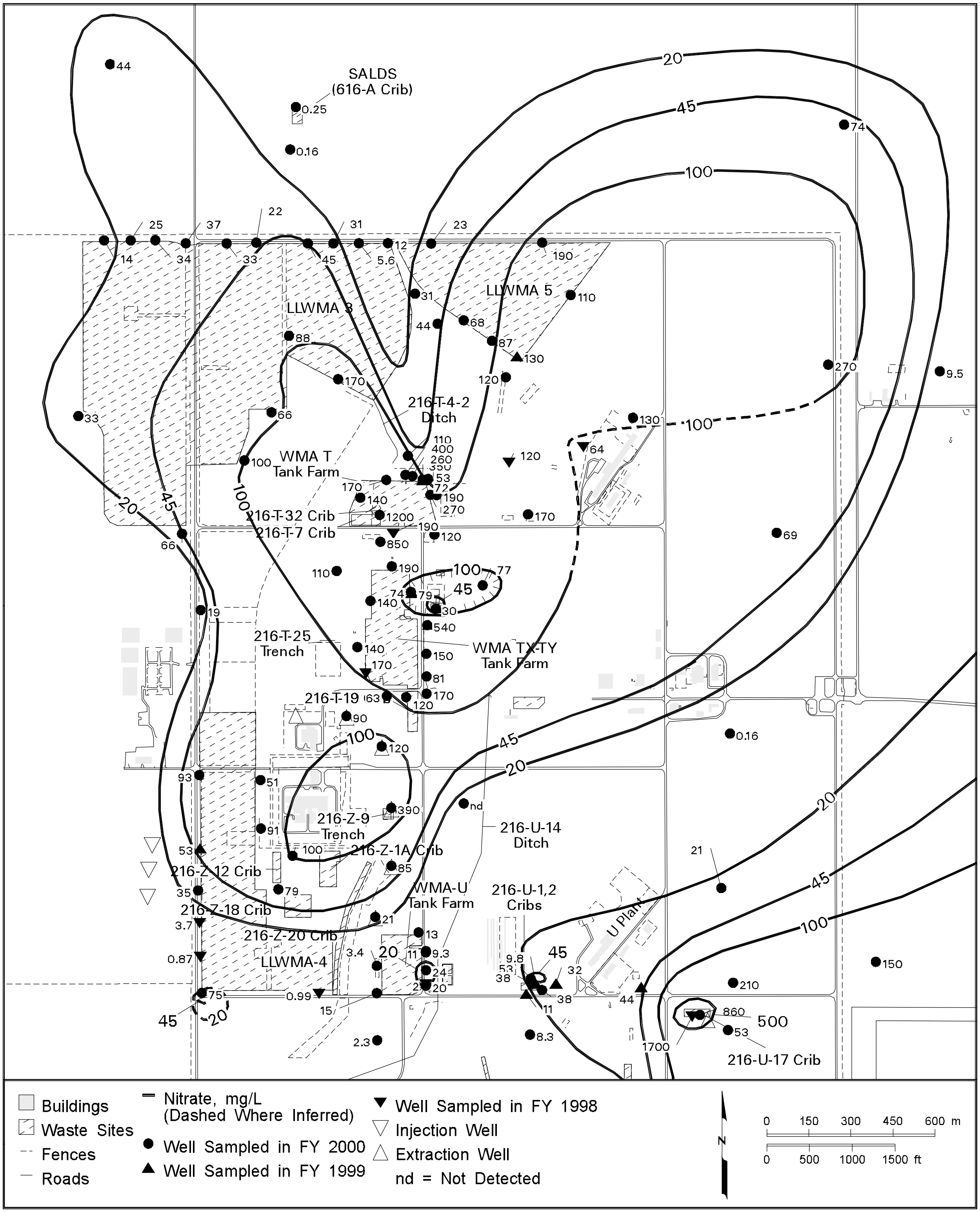

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Figure 2.8-8. Average Nitrate Concentrations in the Central and Northern 200 West Area, Top of Unconfined Aquifer

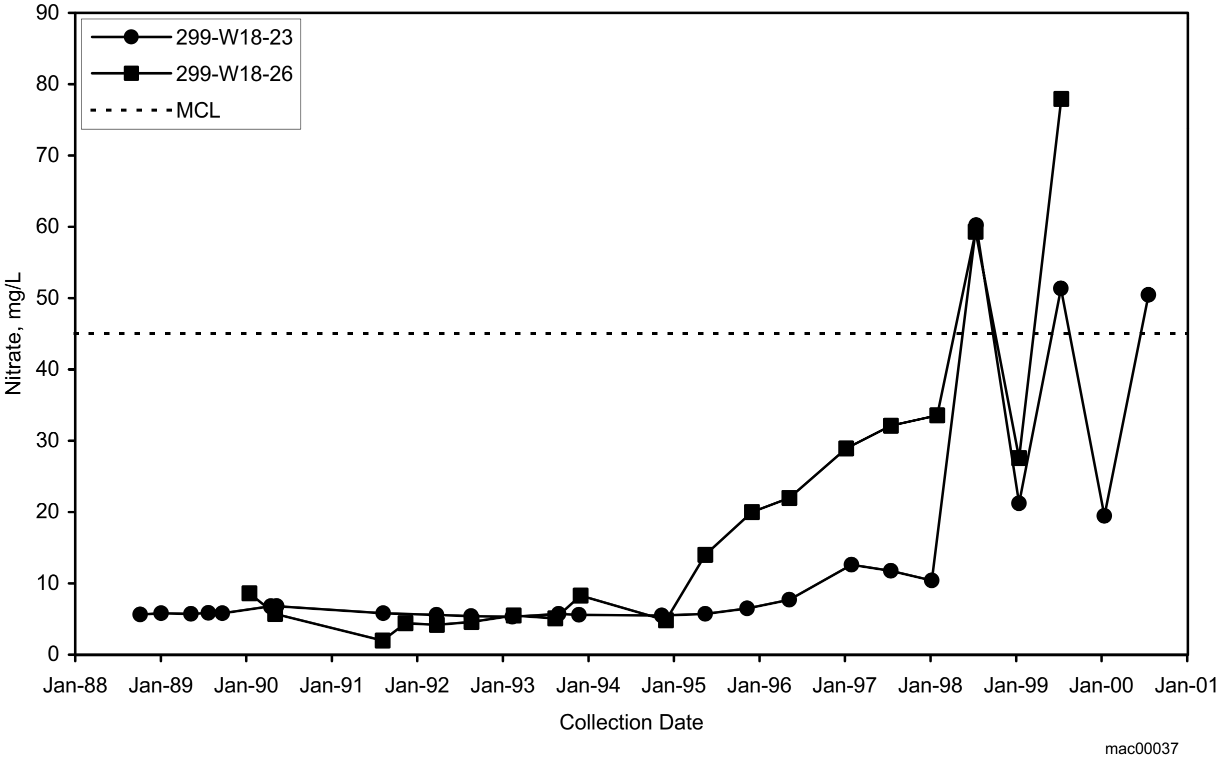

Figure 2.8-9. Nitrate in Wells 299-W18-23 and 299-W18-26 in the Western 200 West Area

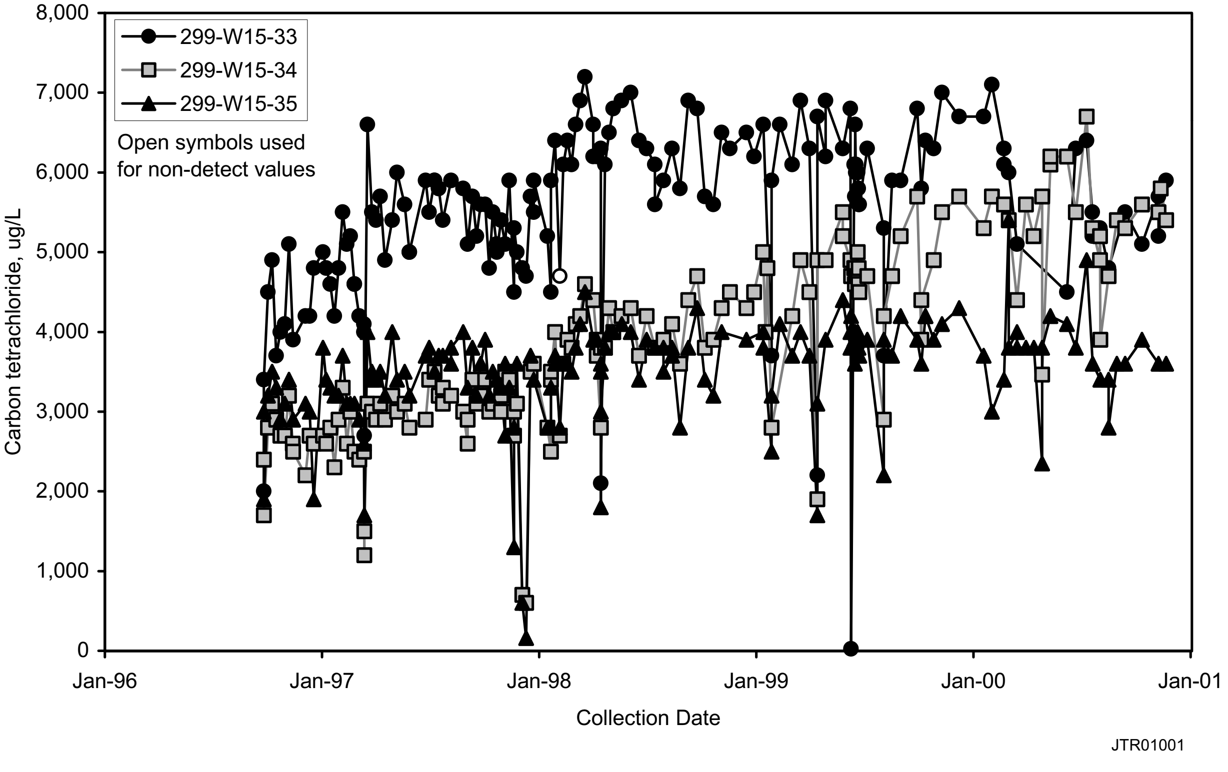

Figure 2.8-10. Carbon Tetrachloride in Northern Extraction Wells for the 200-ZP-1 Pump-and-Treat System

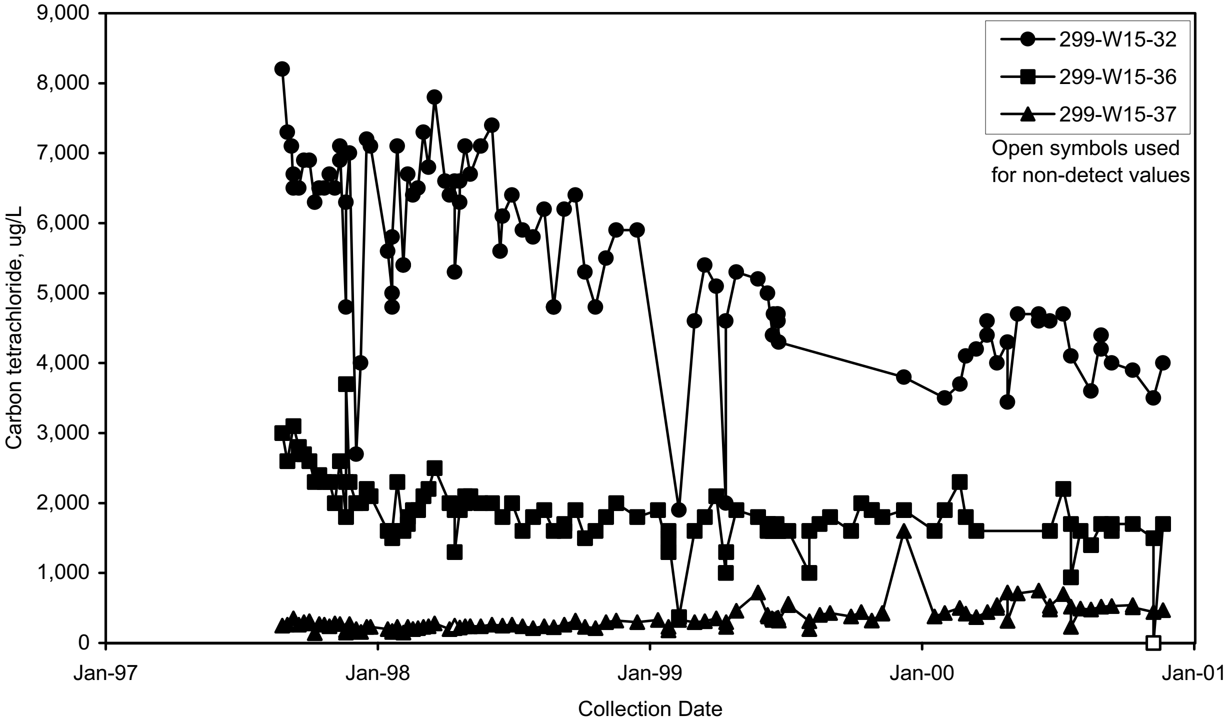

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Figure 2.8-11. Carbon Tetrachloride in Southern Extraction Wells for the 200-ZP-1 Pump-and-Treat System

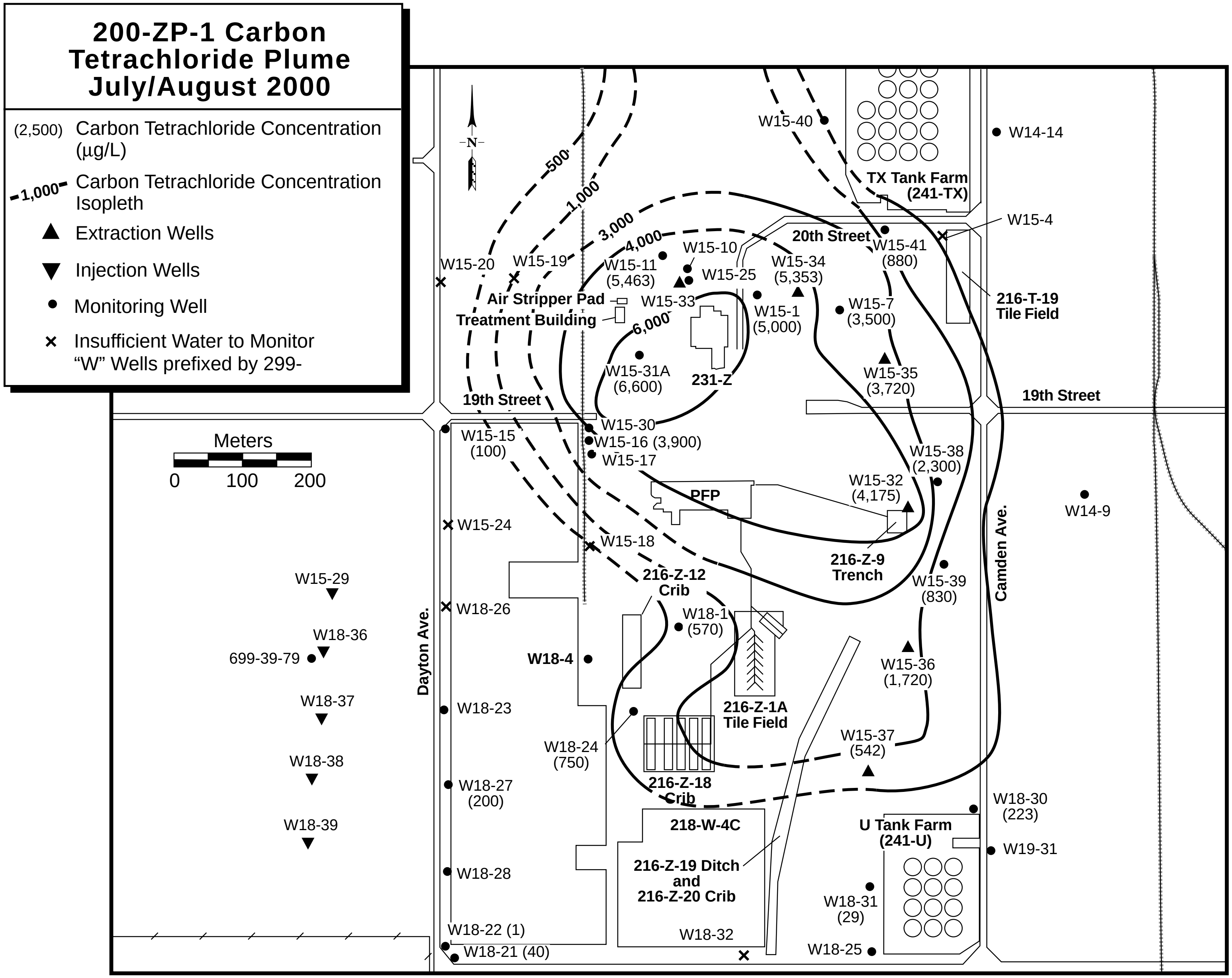

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Figure 2.8-12. Carbon Tetrachloride Plume at the 200-ZP-1 Operable Unit Remediation Area, July/August 2000 (DOE/RL-2000-71)

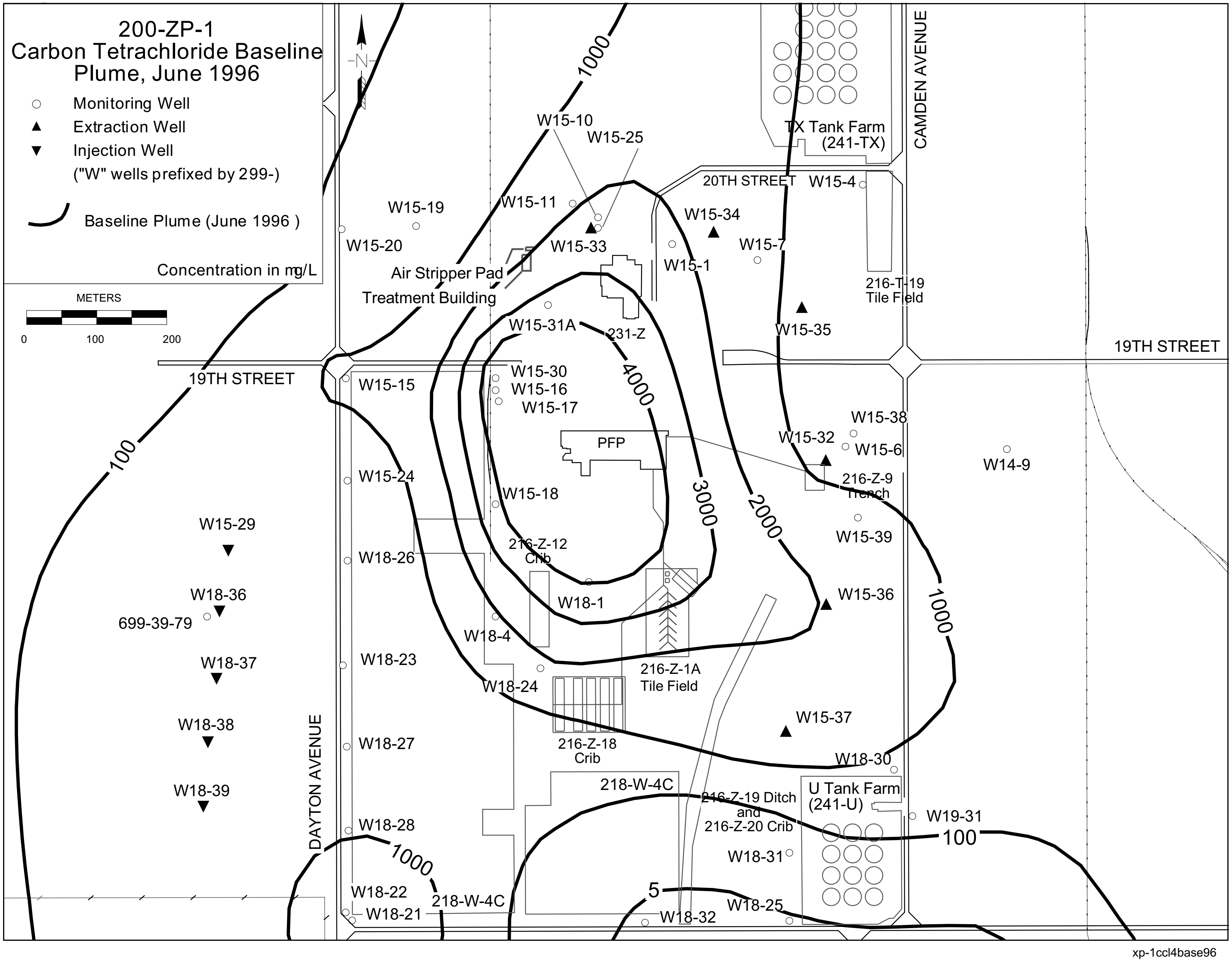

Figure 2.8-13. Carbon Tetrachloride Plume at the 200-ZP-1 Operable Unit Remediation Area, June 1996 (DOE/RL-2000-71)

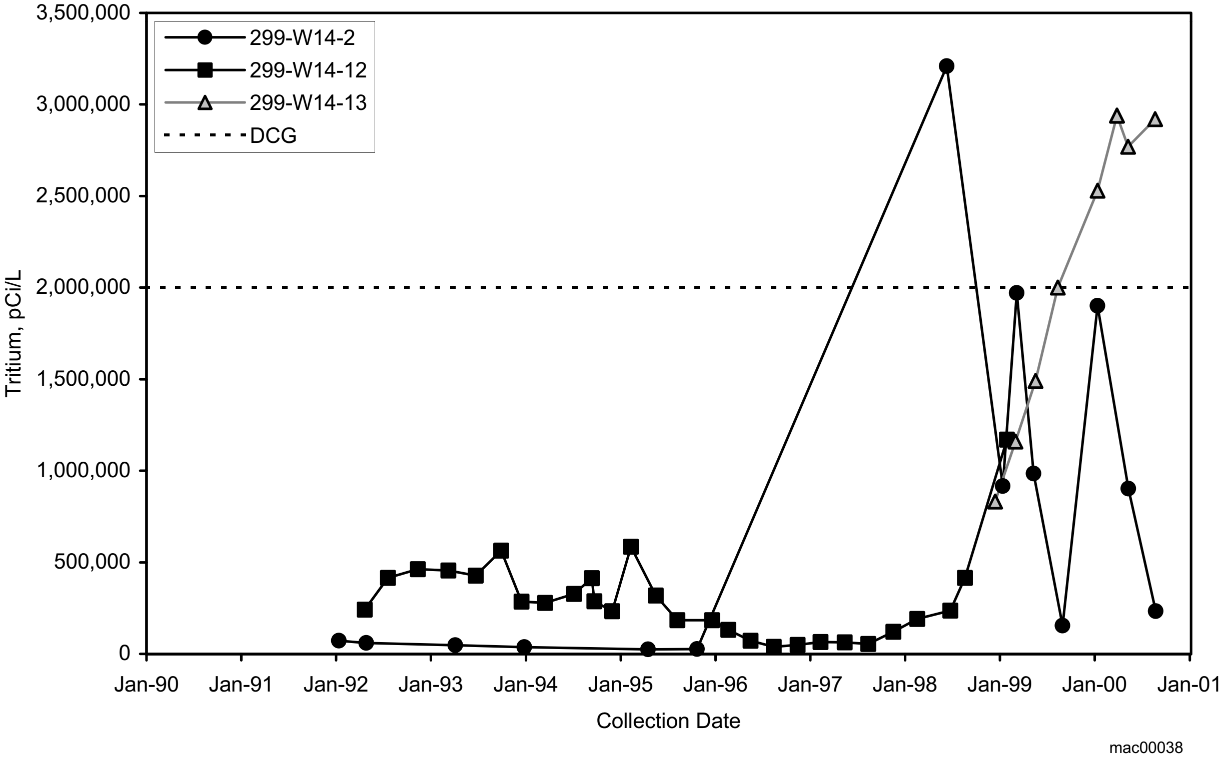

Figure 2.8-14. Tritium in Wells 299-W14-2, 299-W14-12, and 299-W14-13 East of TY Tank Farm

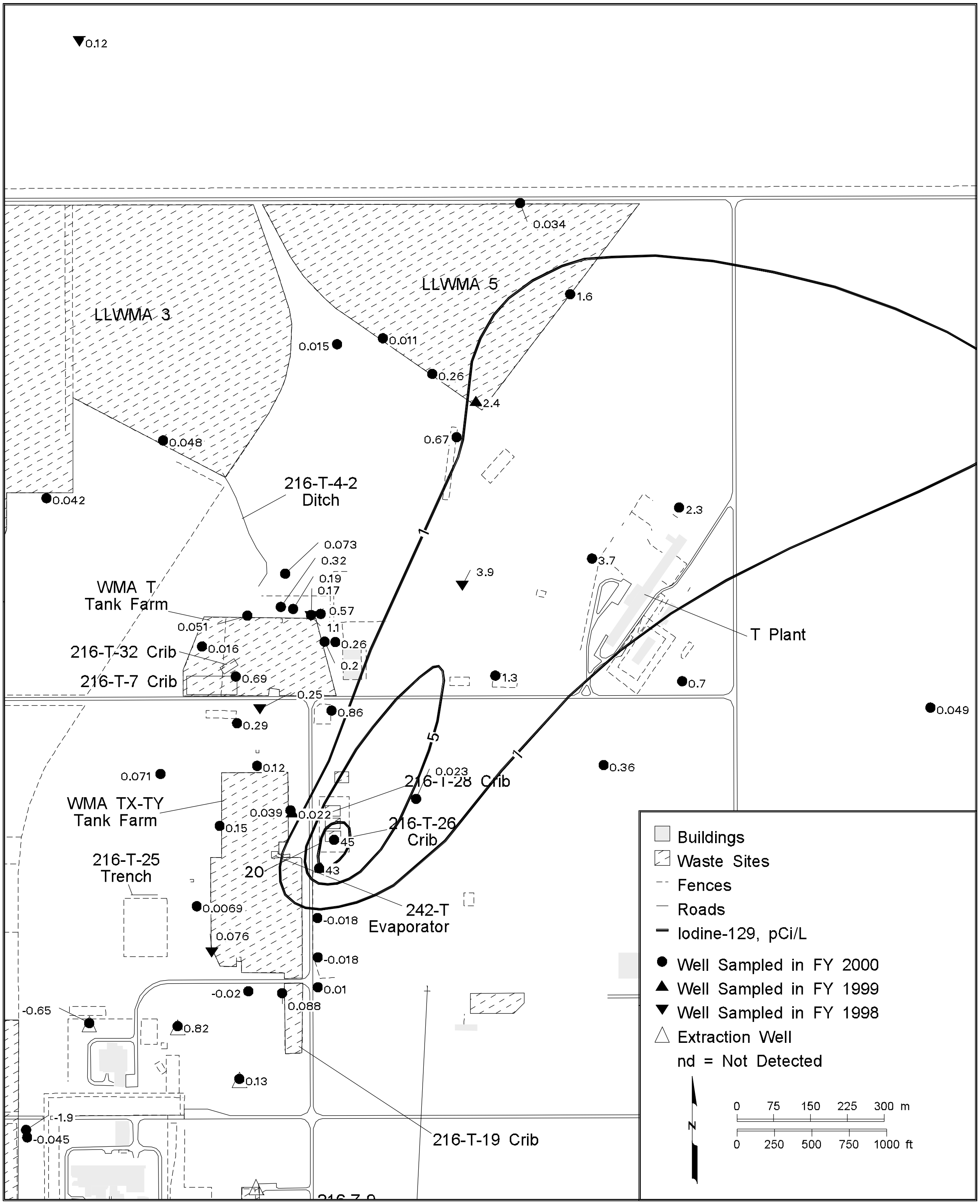

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Figure 2.8-15. Average Iodine-129 Concentrations in the Northern 200 West Area, Top of Unconfined Aquifer

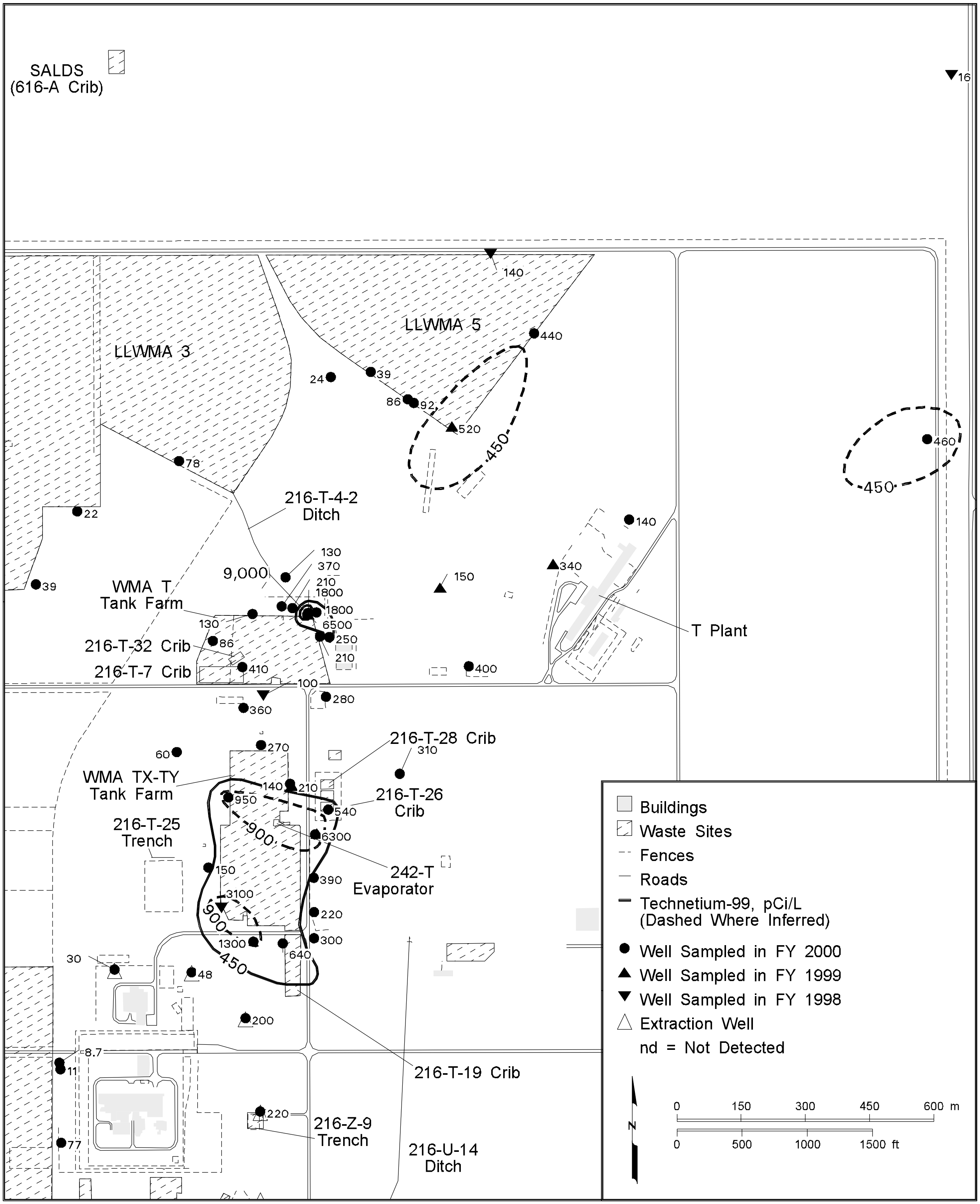

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Figure 2.8-16. Average Technetium-99 Concentrations in the Northern 200 West Area, Top of Unconfined Aquifer

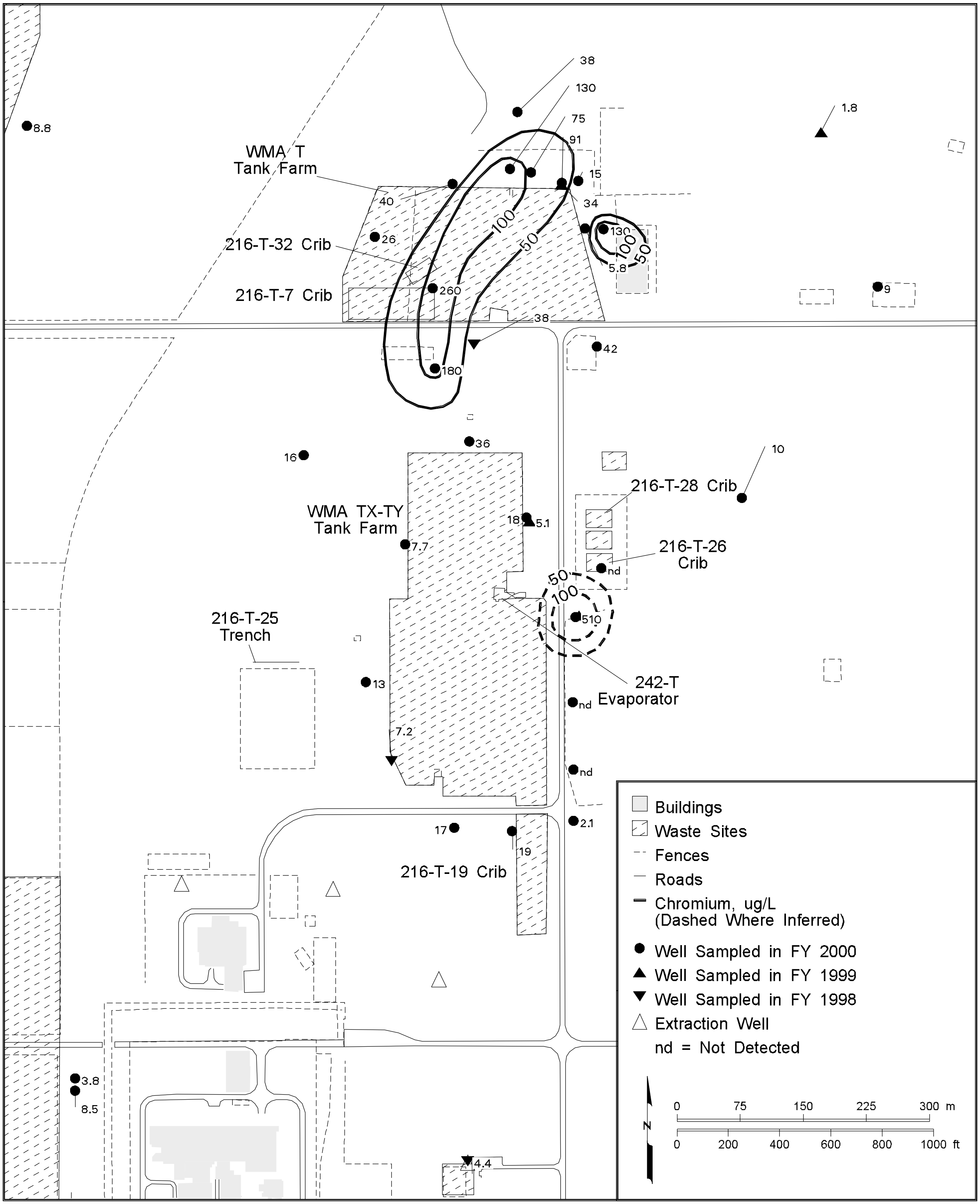

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Figure 2.8-17. Average Dissolved Chromium Concentrations near Waste Management Areas T and TX-TY, Top of Unconfined Aquifer

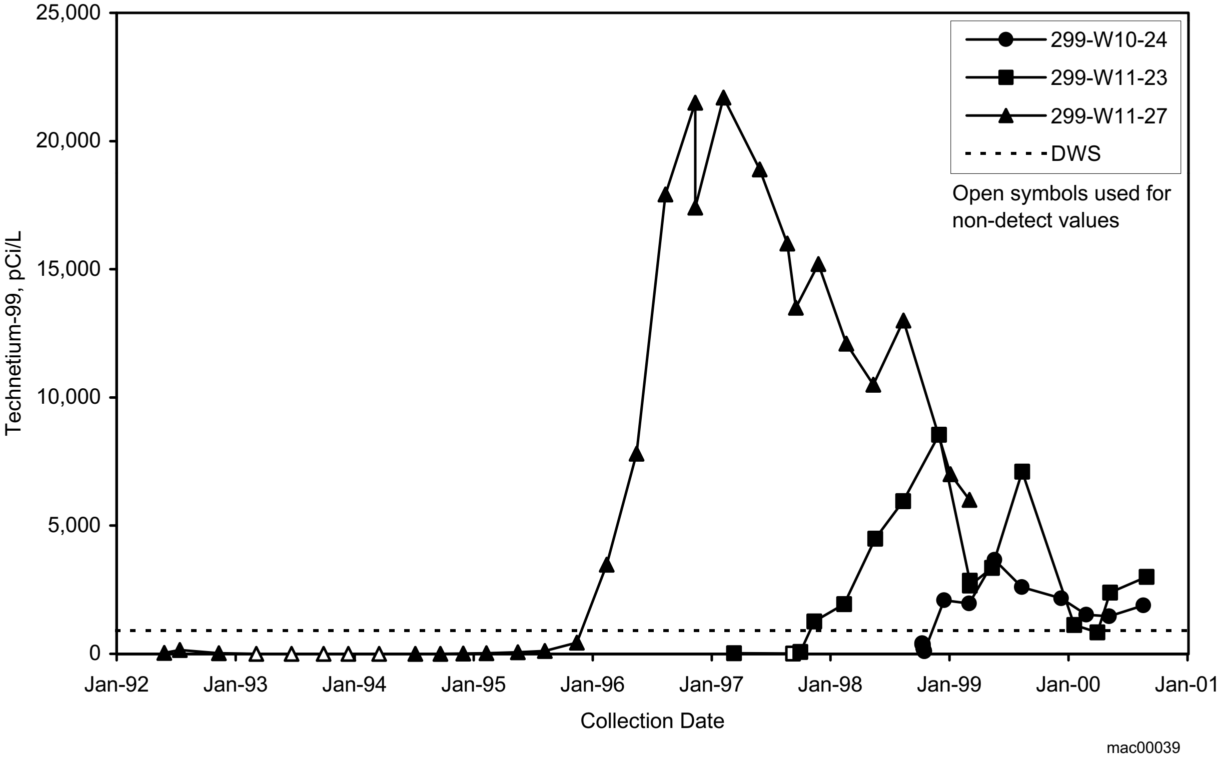

Figure 2.8-18. Technetium-99 in Wells 299-W11-27, 299-W11-23, and 299-W10-24 North of T Tank Farm

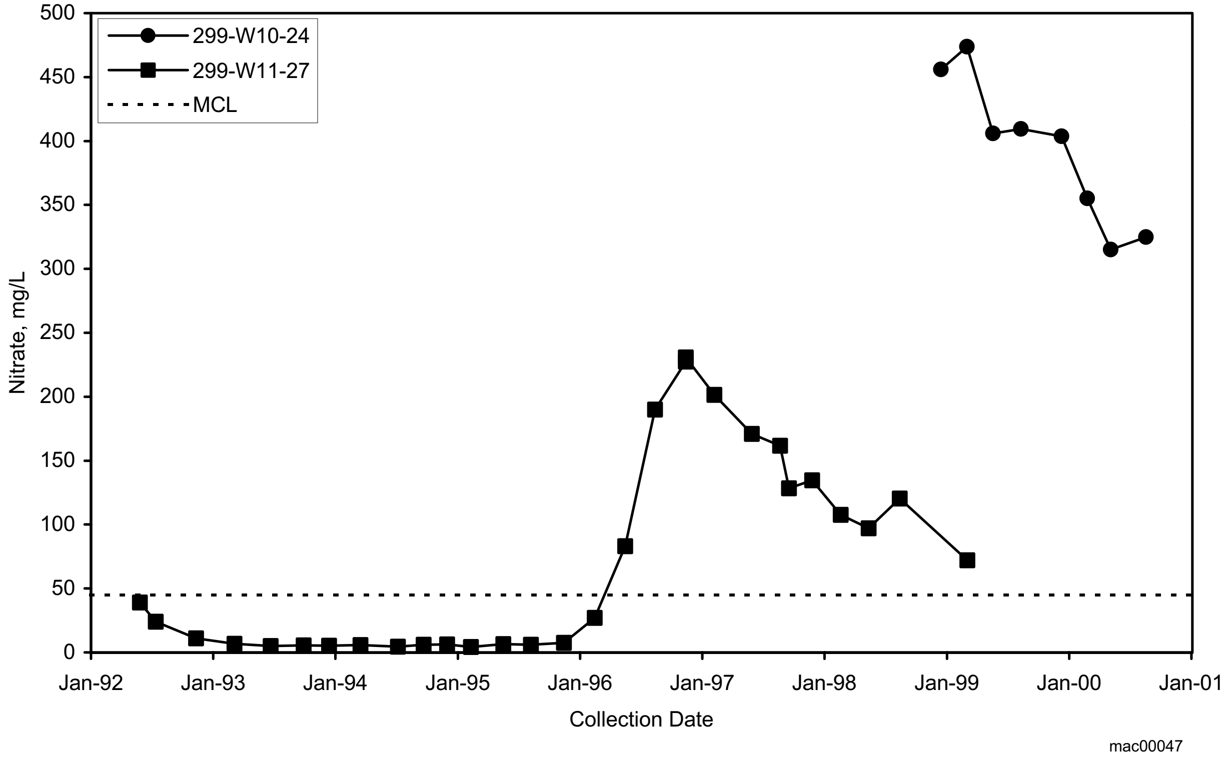

Figure 2.8-19. Nitrate in Wells 299-W11-27 and 299-W10-24 North of T Tank Farm

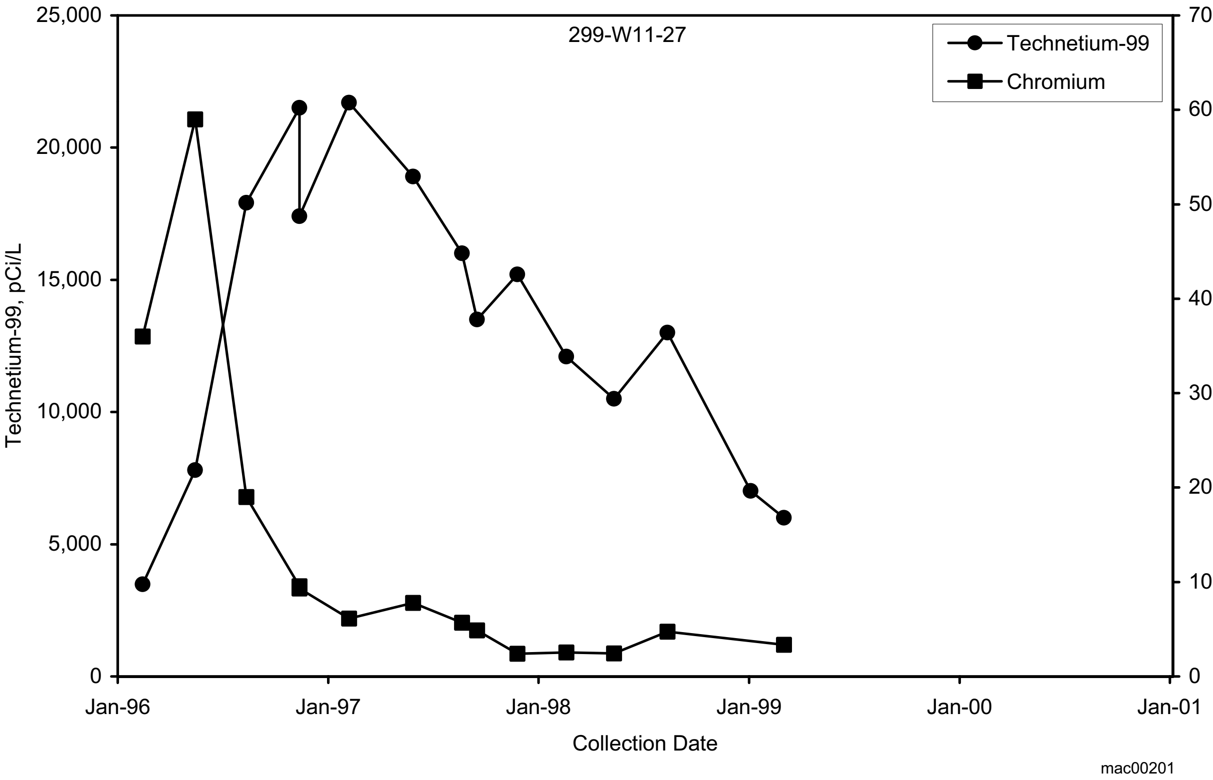

Figure 2.8-20. Technetium-99 and Chromium in Well 299-W11-27 Northeast of Waste Management Area T

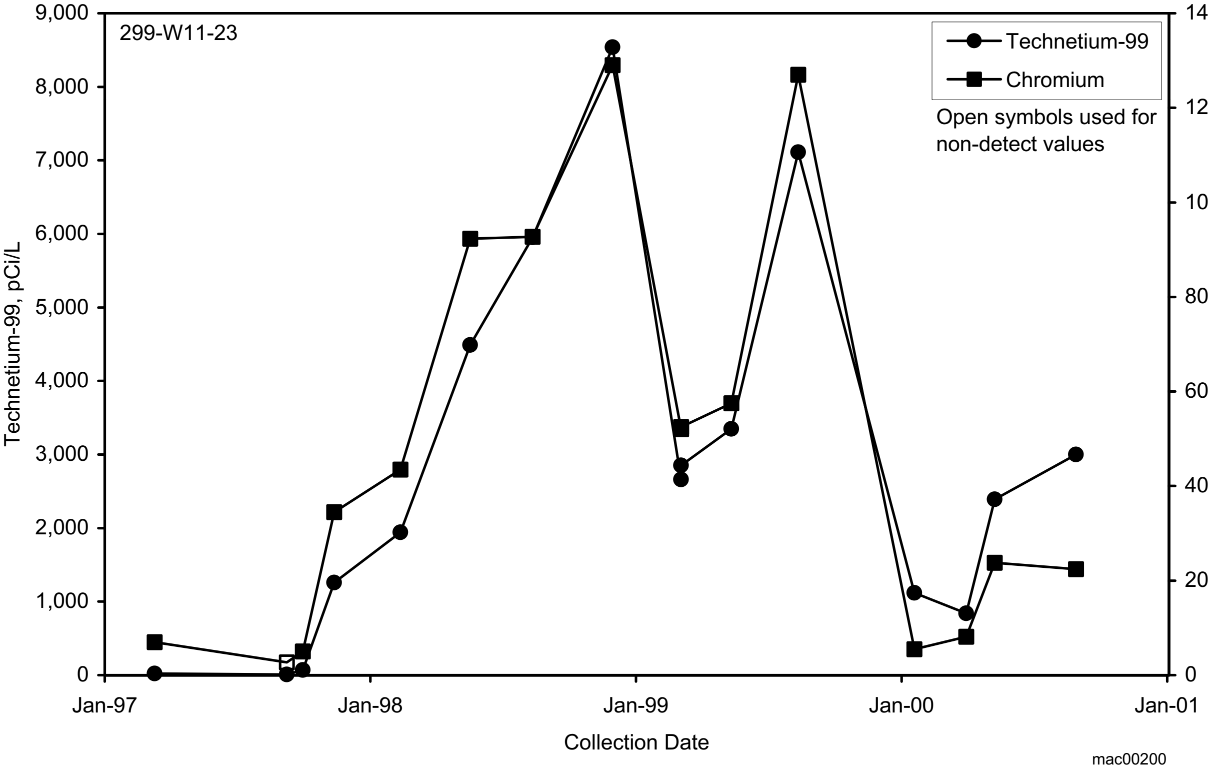

Figure 2.8-21. Technetium-99 and Chromium in Well 299-W11-23 Northeast of Waste Management Area T

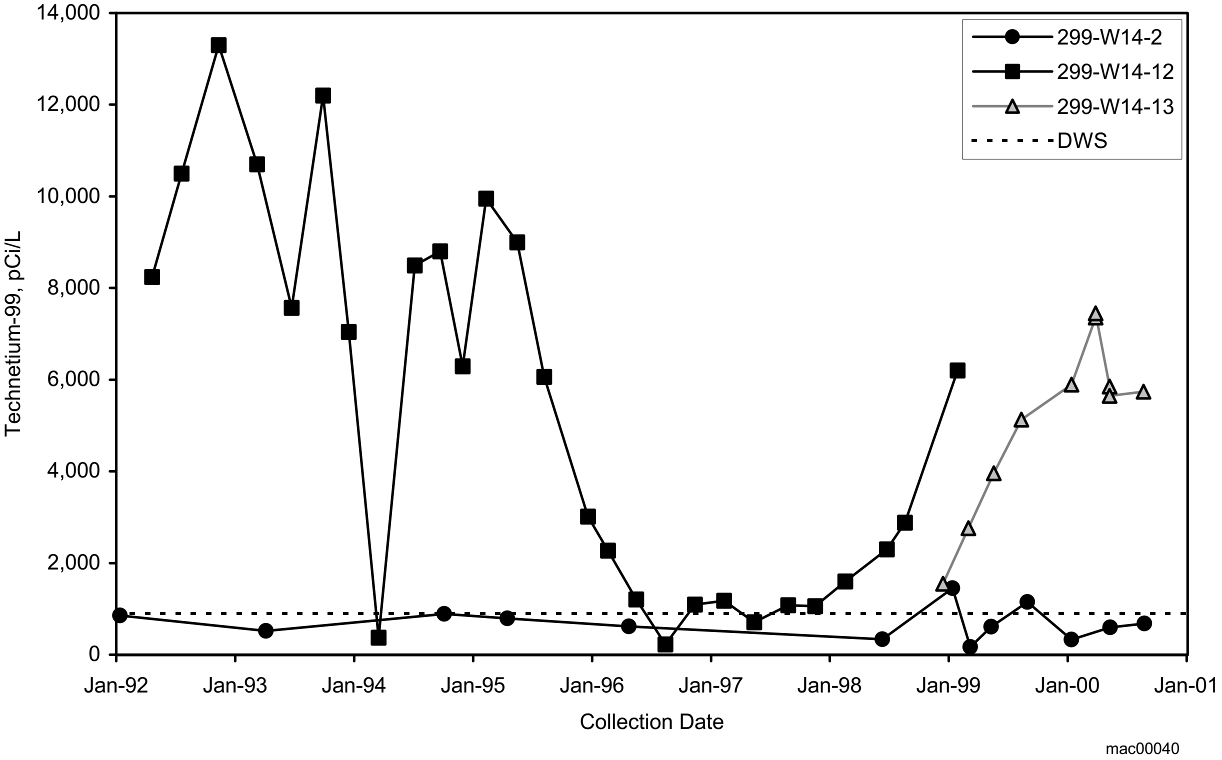

Figure 2.8-22. Technetium-99 in Wells 299-W14-2, 299-W14-12, and 299-W14-13 East of TX-TY Tank Farms

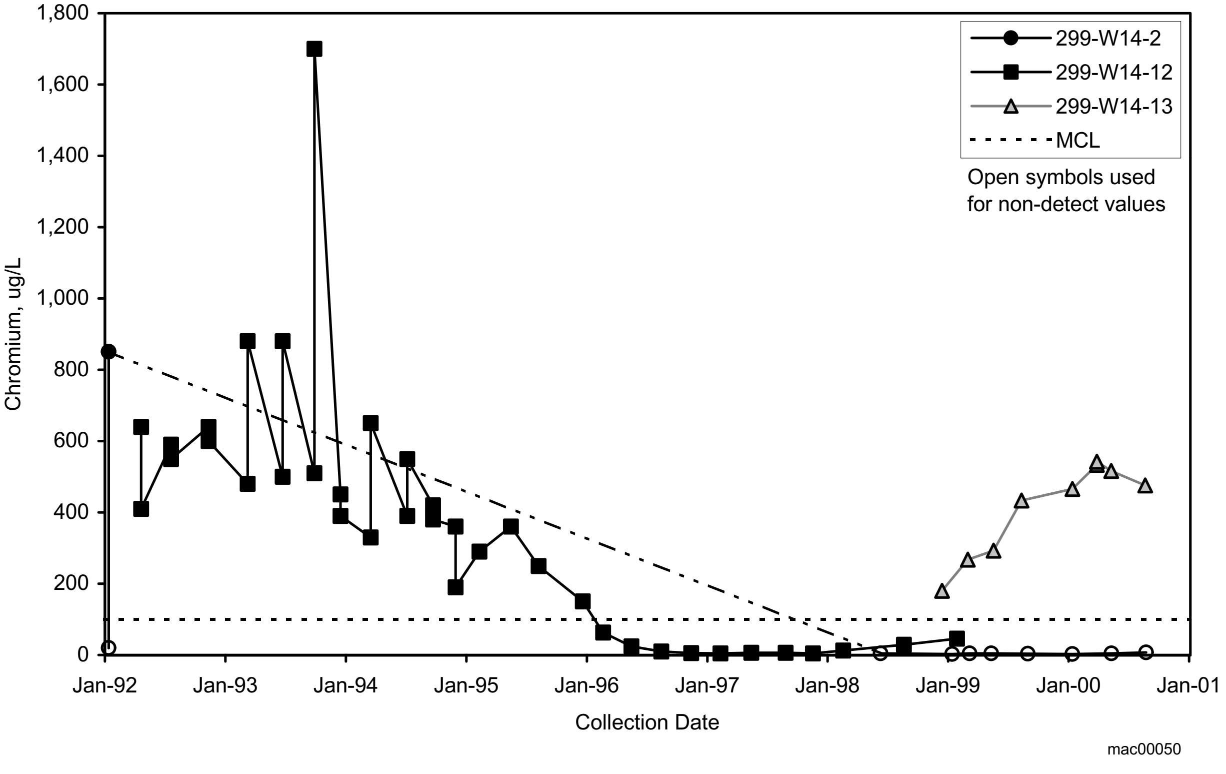

Figure 2.8-23. Chromium in Wells 299-W14-2, 299-W14-12, and 299-W14-13 East of TX-TY Tank Farms

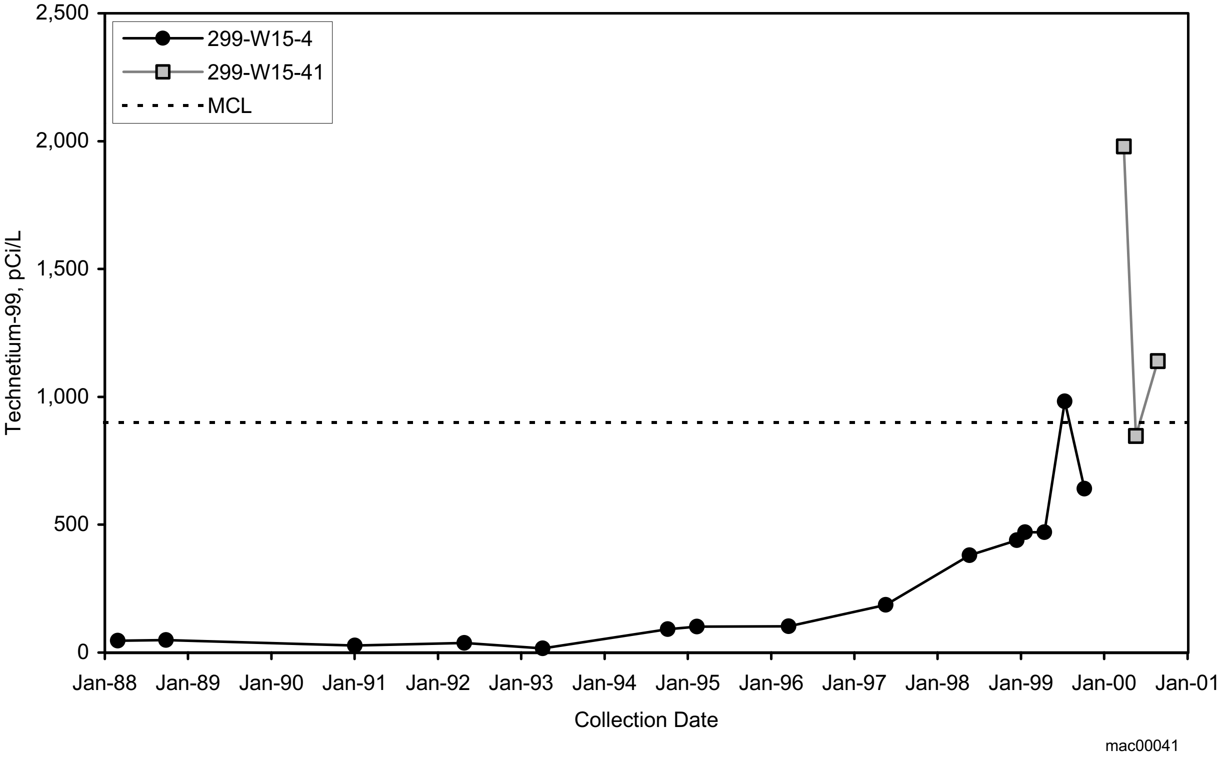

Figure 2.8-24. Technetium-99 in Wells 299-W15-4 and 299-W15-41 South of TX-TY Tank Farms

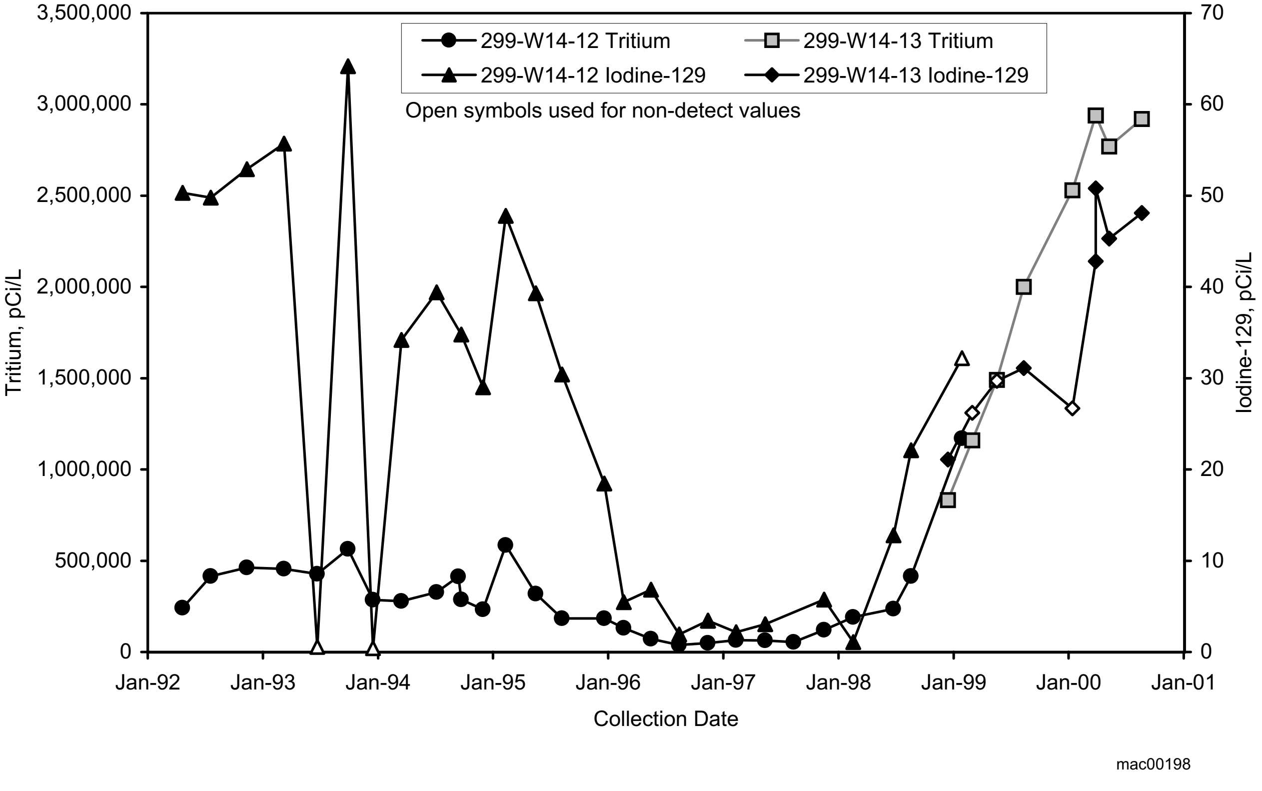

Figure 2.8-25. Tritium and Iodine-129 in Wells 299-W14-12 and 299-W14-13 East of Waste Management Area TX-TY

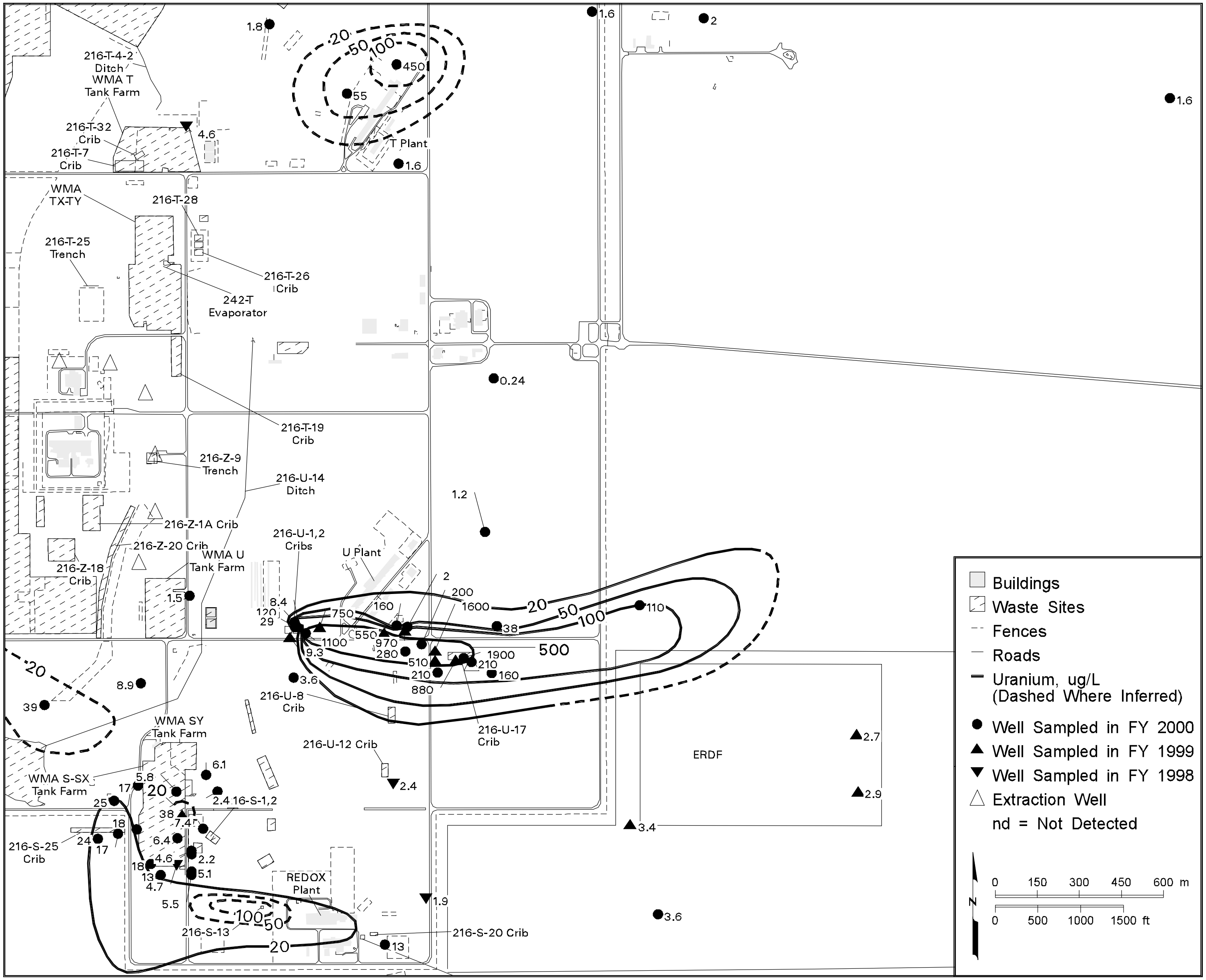

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Figure 2.8-26. Average Uranium Concentrations in the Eastern 200 West Area, Top of Unconfined Aquifer

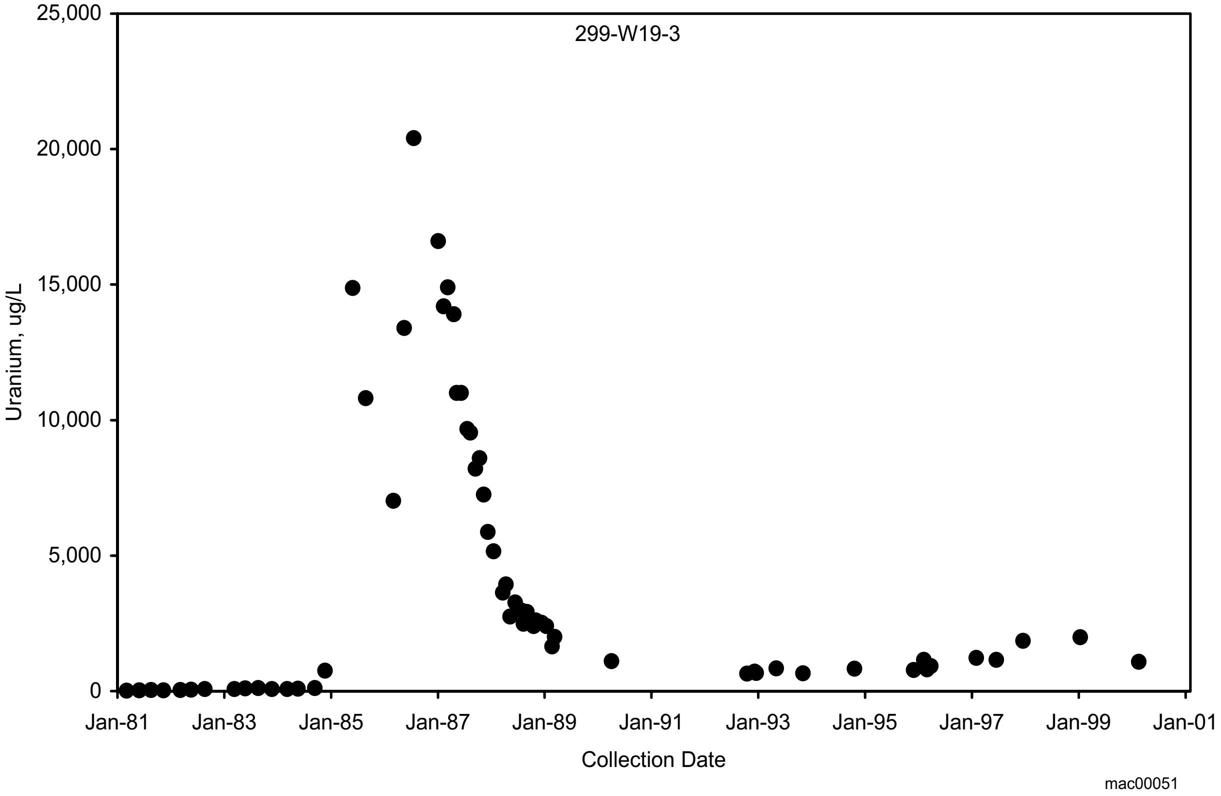

Figure 2.8-27. Uranium in Well 299-W19-3 near the 216-U-1 and 216-U-2 Cribs

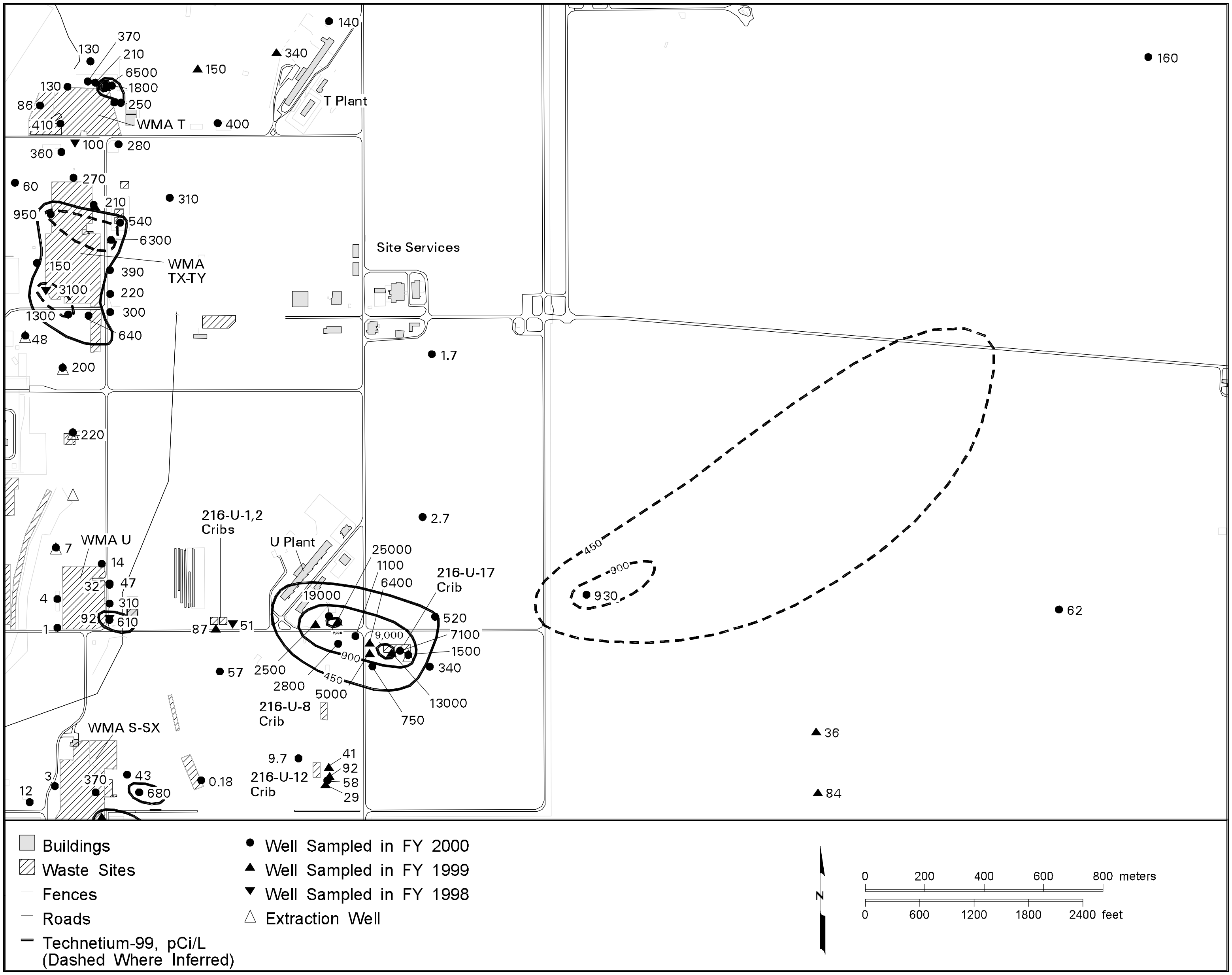

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Figure 2.8-28. Average Technetium-99 Concentrations in the Eastern 200 West Area, Top of Unconfined Aquifer

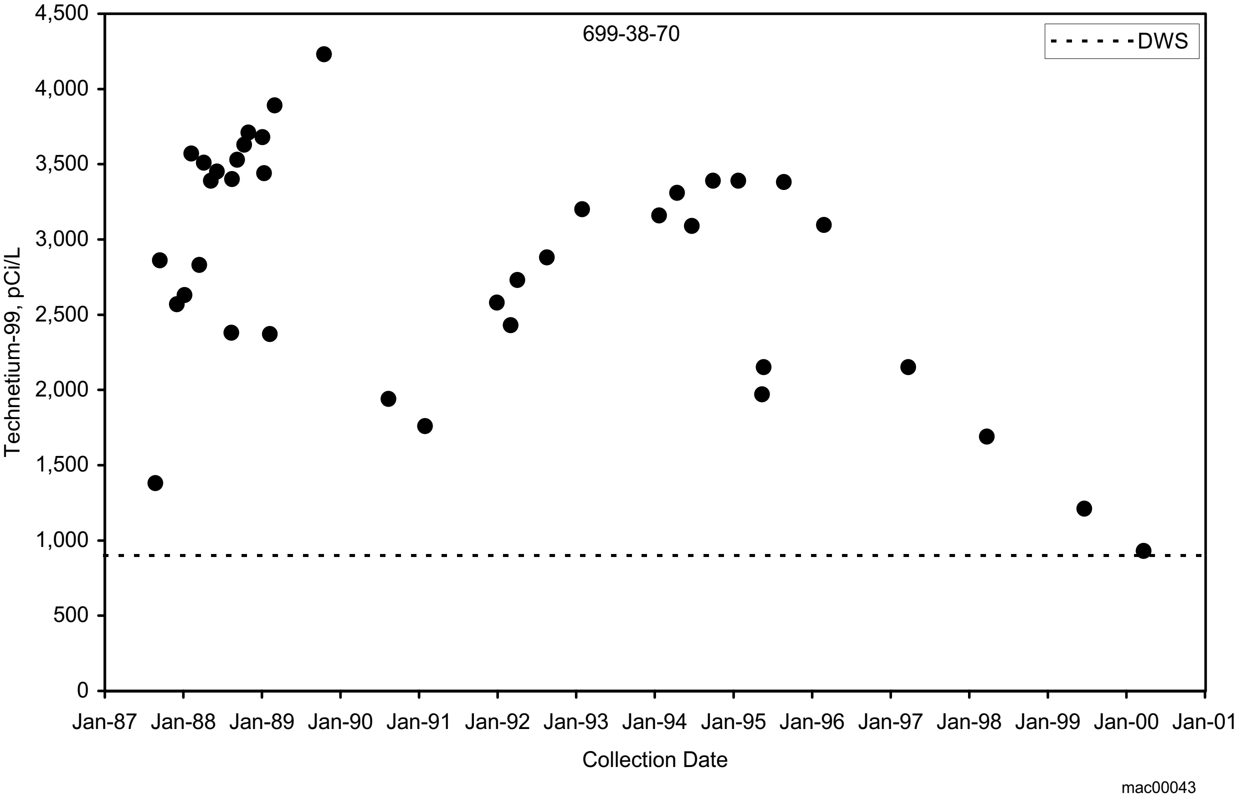

Figure 2.8-29. Technetium-99 in Well 699-38-70 East of U Plant

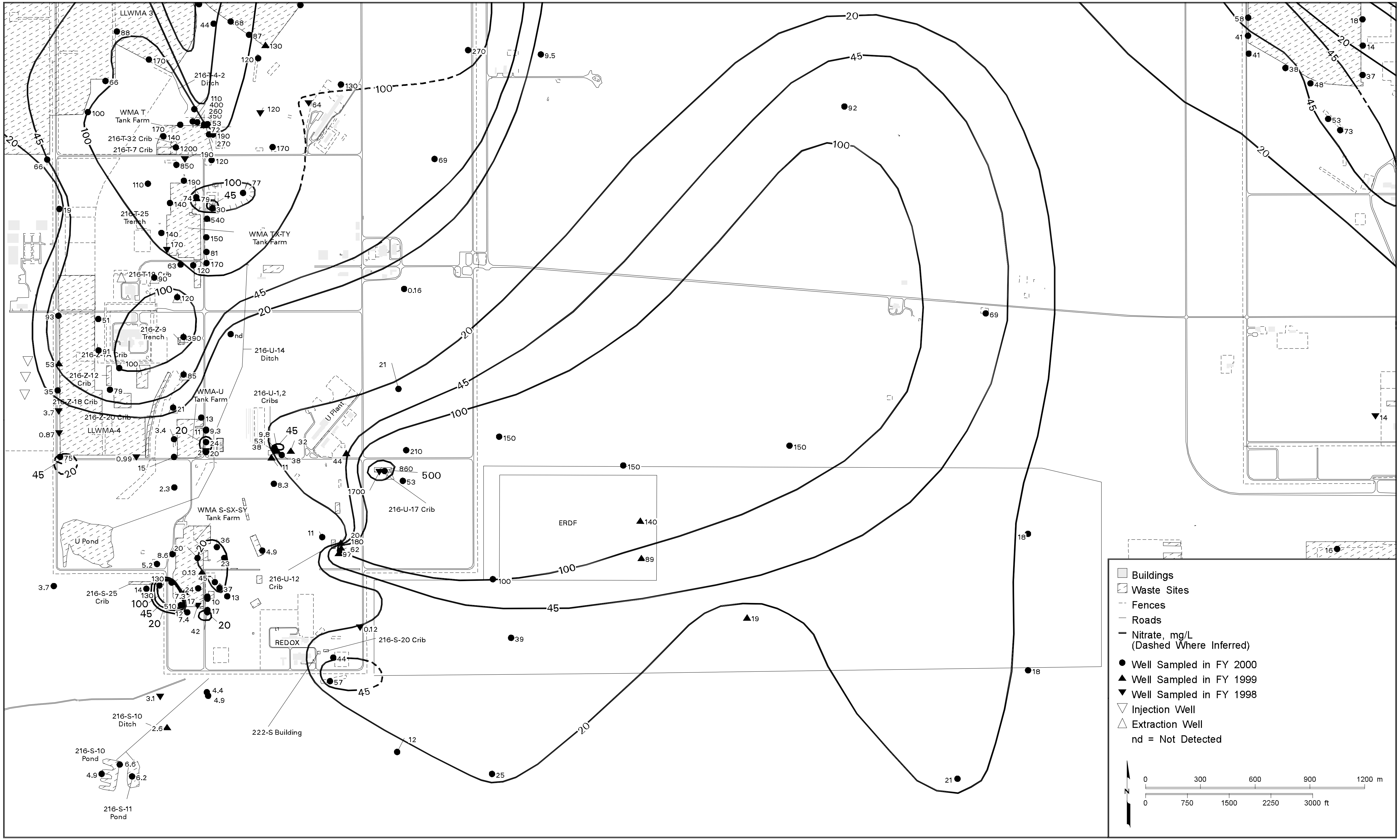

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Figure 2.8-30. Average Nitrate Concentrations in the Southern and Eastern 200 West Area, Top of Unconfined Aquifer

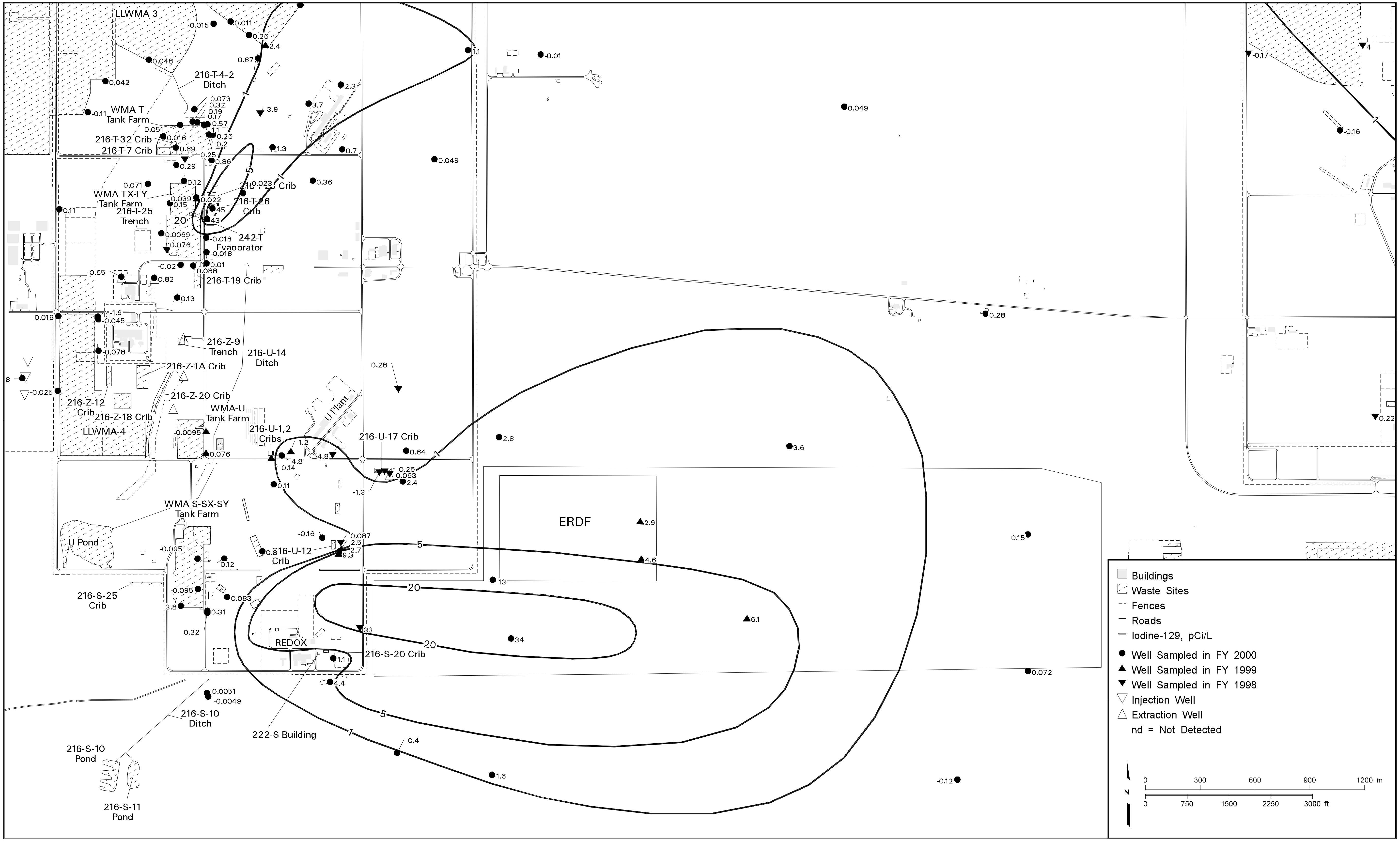

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Figure 2.8-31. Average Iodine-129 Concentrations in the Southern and Eastern 200 West Area, Top of Unconfined Aquifer

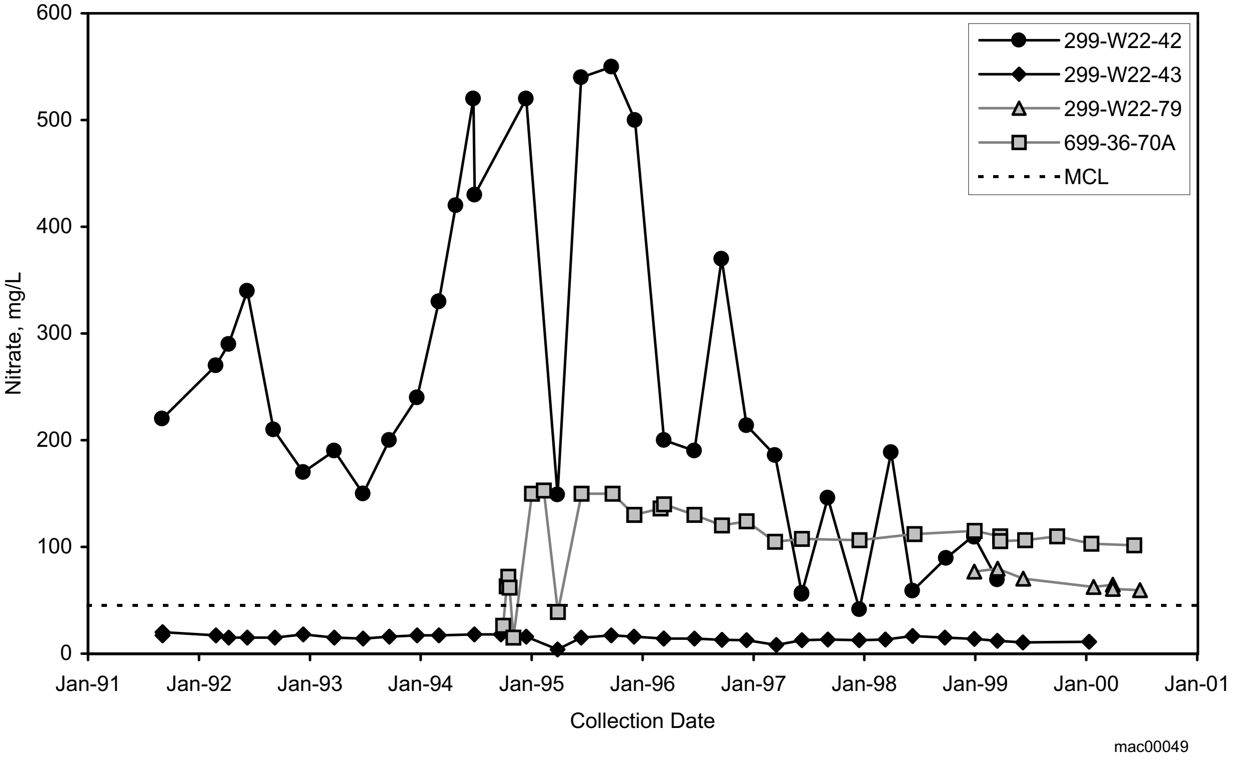

Figure 2.8-32. Nitrate in Wells near the 216-U-12 Crib

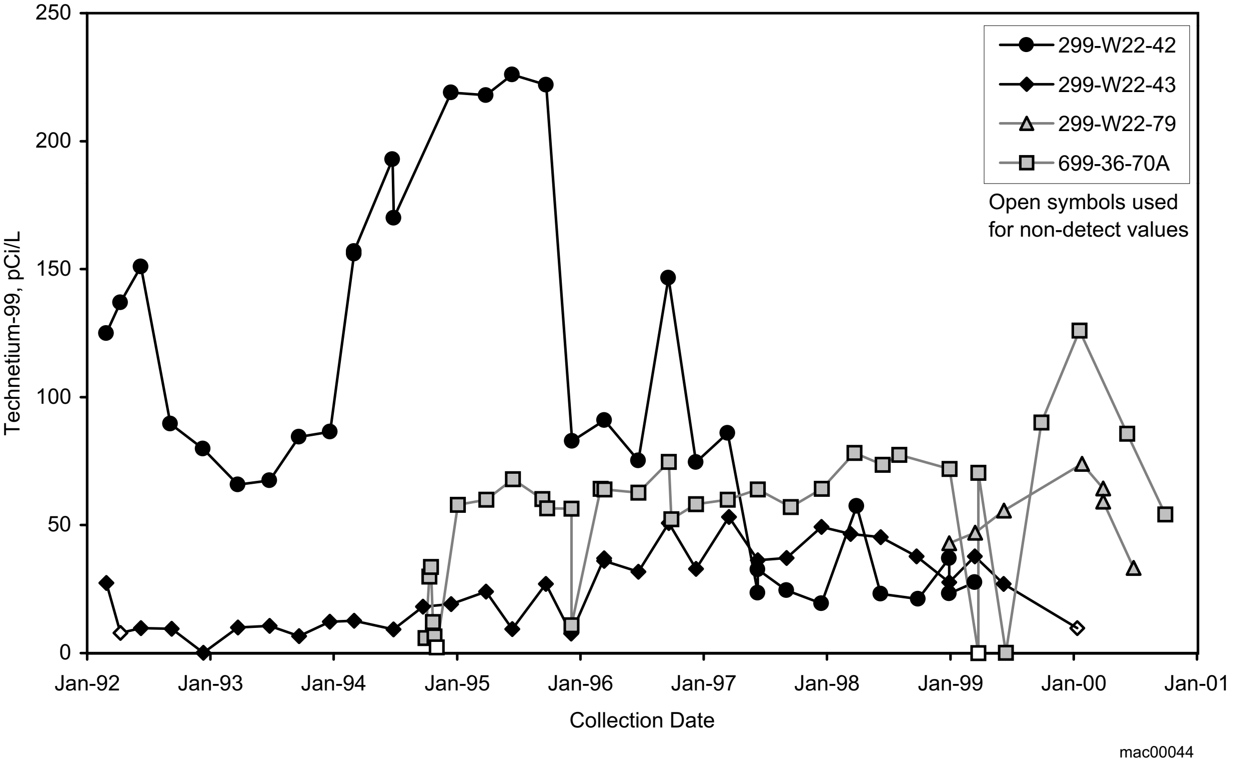

Figure 2.8-33. Technetium-99 in Wells near the 216-U-12 Crib

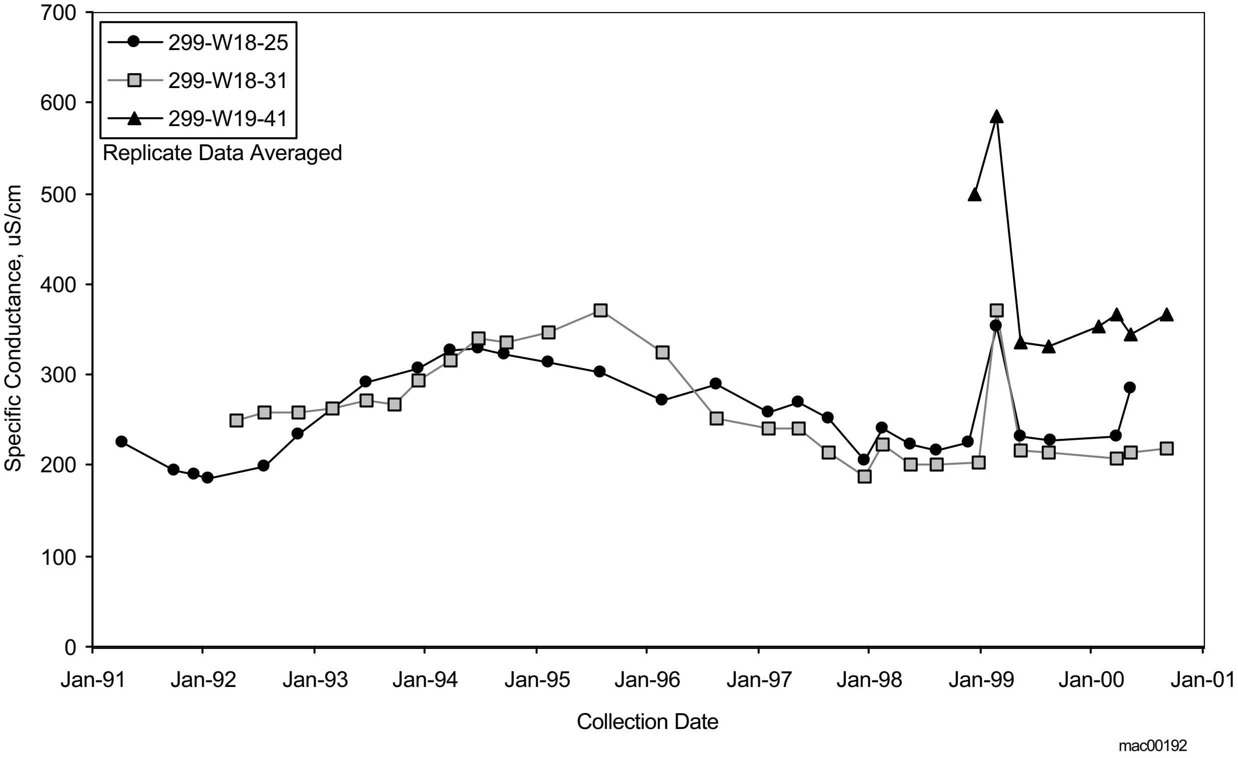

Figure 2.8.34. Specific Conductance in Waste Management Area U Downgradient Well 299-W19-41 and Upgradient Wells 299-W18-25 and 299-W18-31

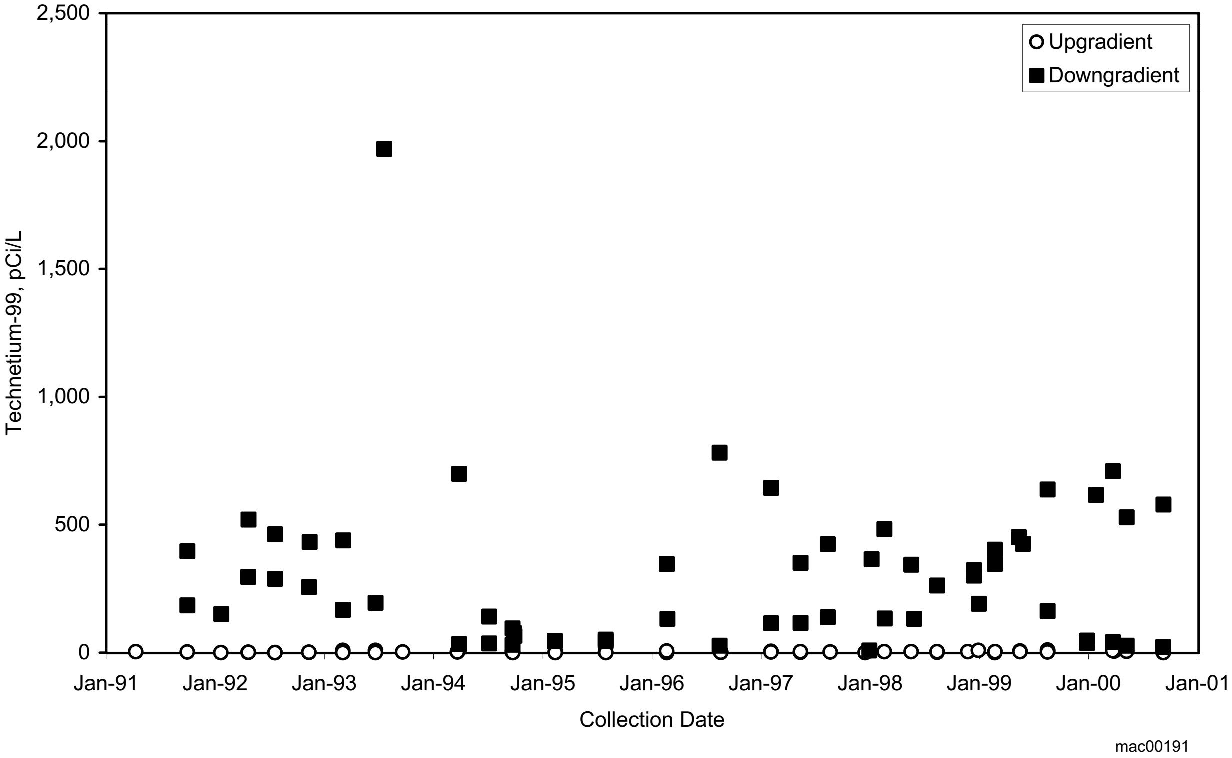

Figure 2.8-35. Technetium-99 in Waste Management Area U Downgradient Wells 299-W19-12, 299-W19-31, 299-W19-32, 299-W19-41, 299-W19-42 and Upgradient Wells 299-W18-25 and 299-W18-31

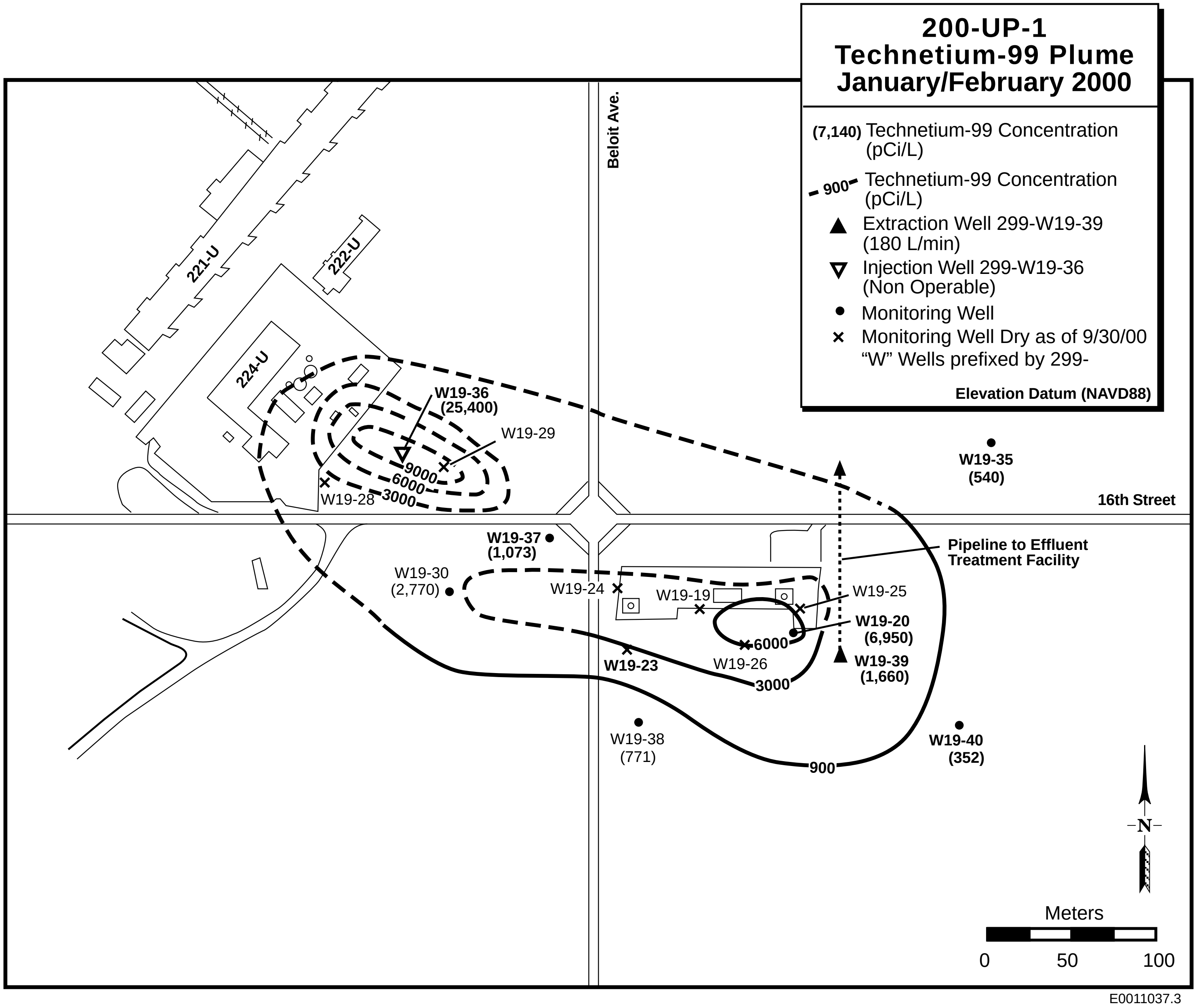

Figure 2.8-36. Technetium-99 Plume at 200-UP-1 Operable Unit, January/February 2000 (DOE/RL-2000-71)

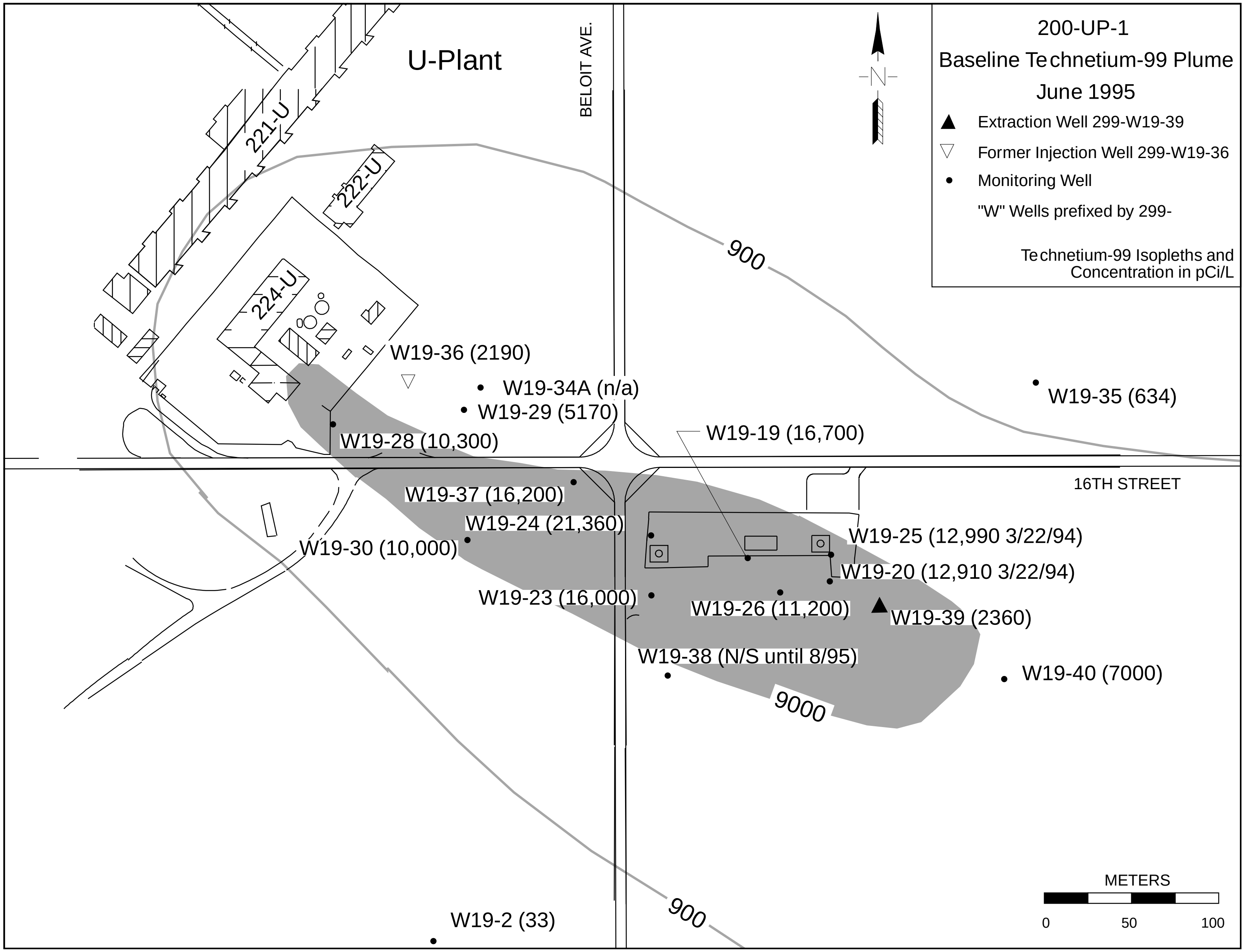

Figure 2.8-37. Technetium-99 Baseline Plume at 200-UP-1 Operable Unit, June 1995 (DOE/RL-99-79)

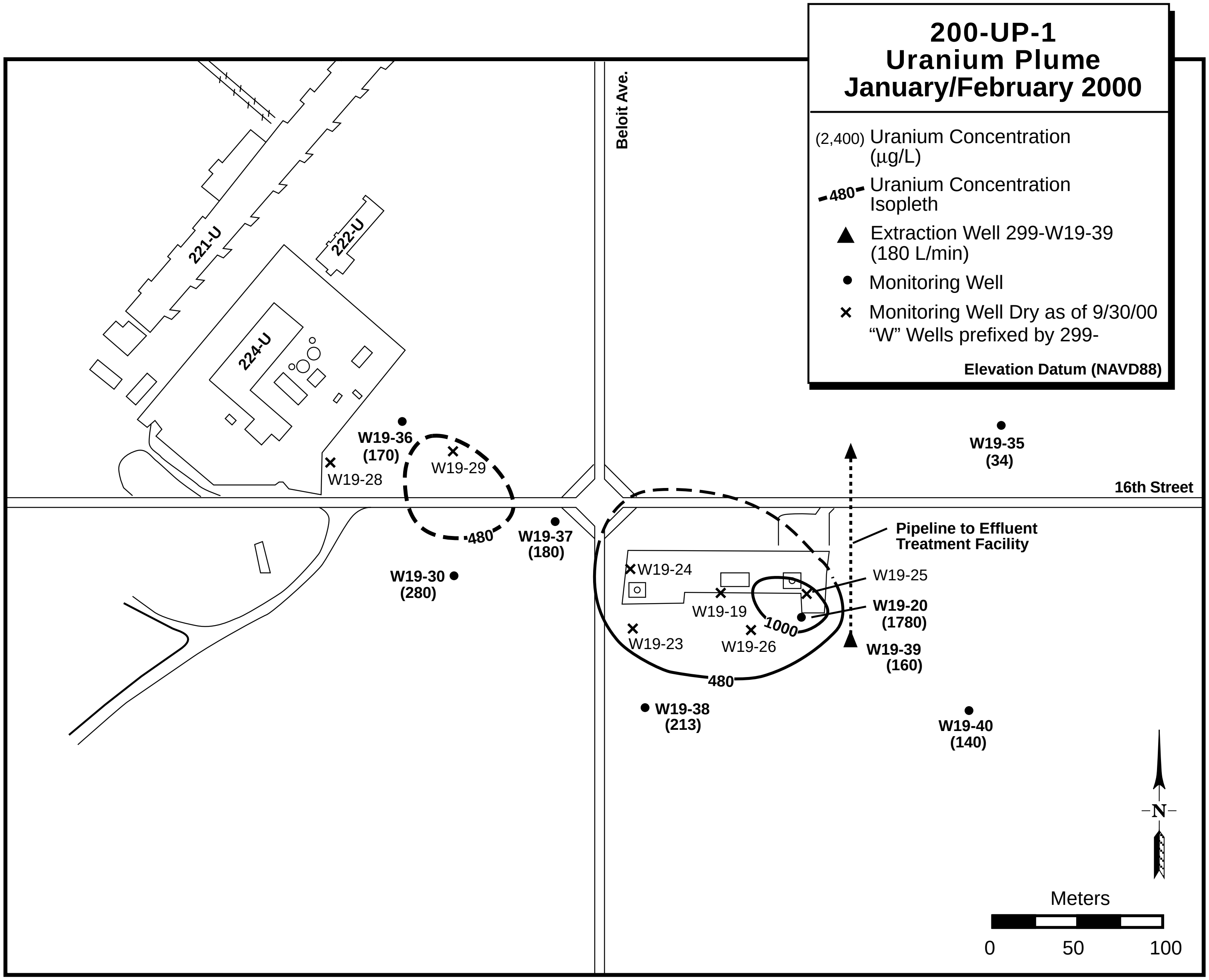

Figure 2.8-38. Uranium Plume at 200-UP-1 Operable Unit, January/February 2000 (DOE/RL-2000-71)

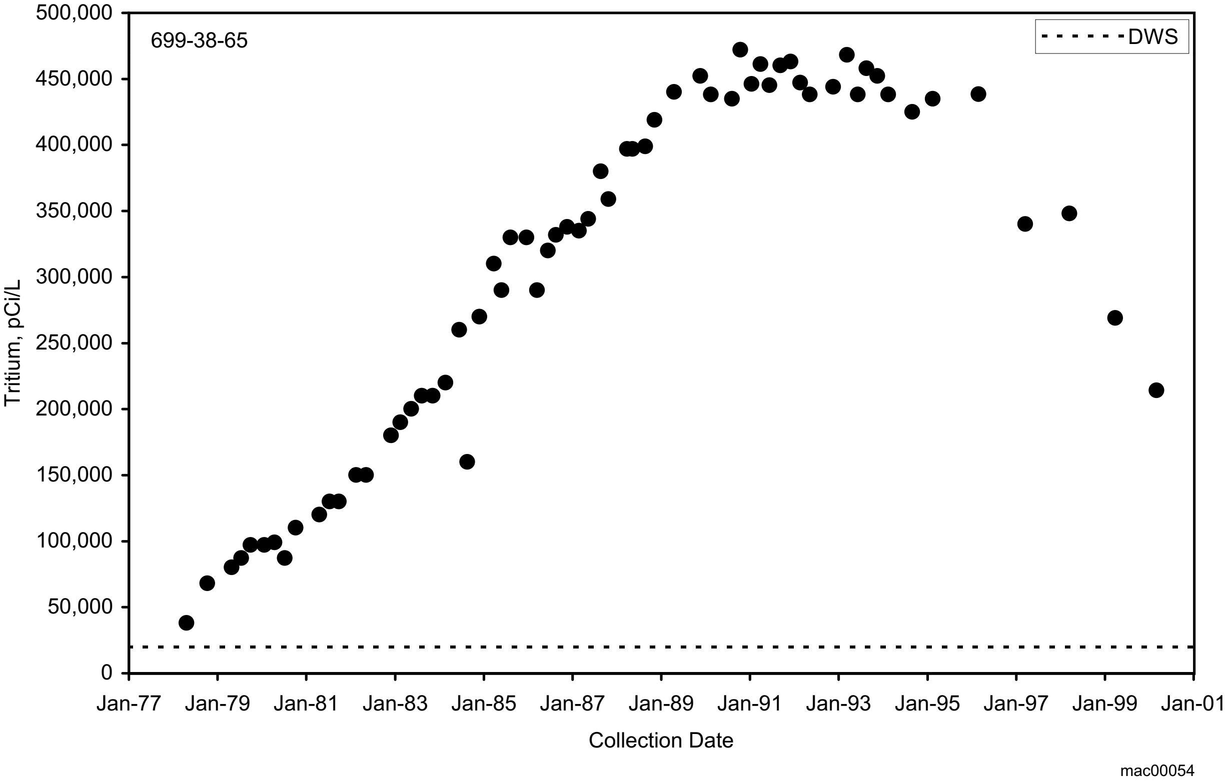

Figure 2.8-39. Tritium in Well 699-38-65 East of 200 West Area REDOX Plant

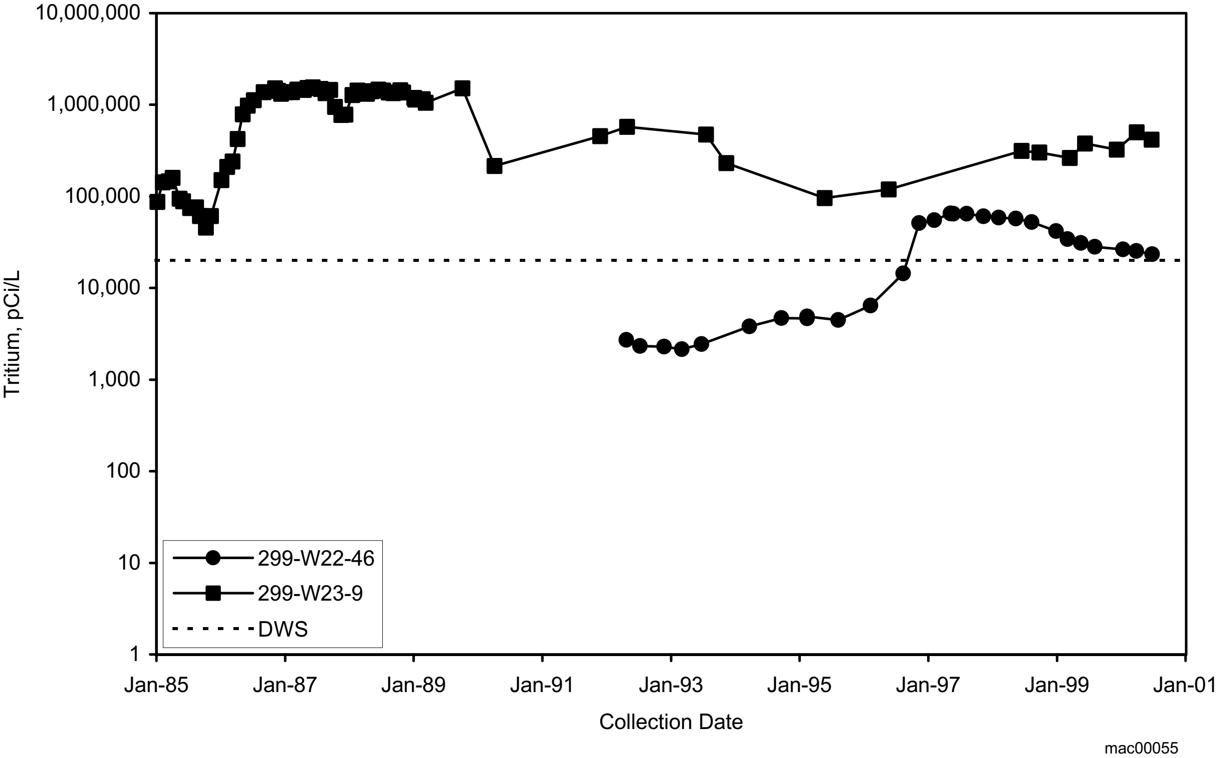

Figure 2.8-40. Tritium in Wells 299-W23-9 and 299-W22-46 near the 216-S-25 Crib and S-SX Tank Farms

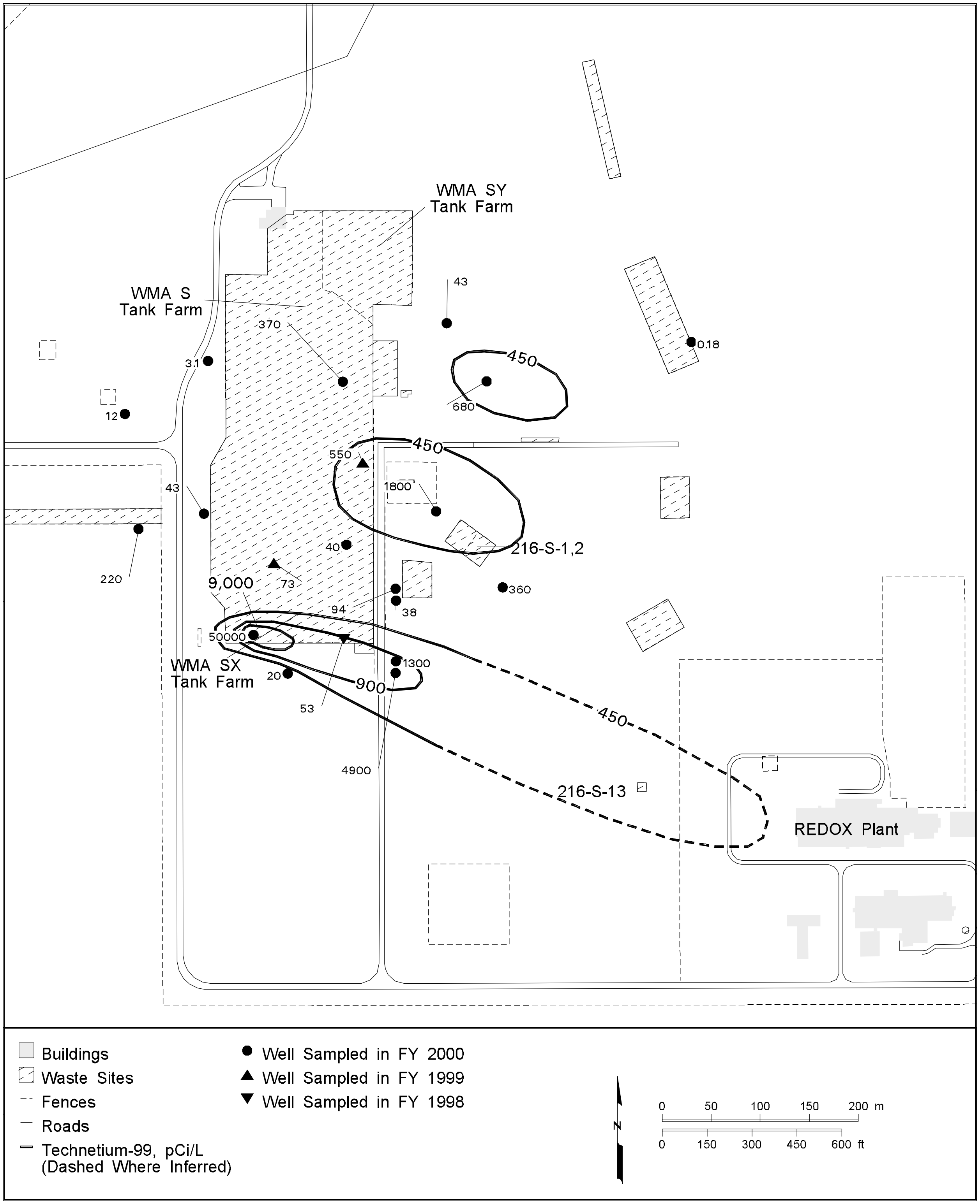

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Figure 2.8-41. Average Technetium-99 Concentrations near the S-SX Tank Farms, Top of Unconfined Aquifer

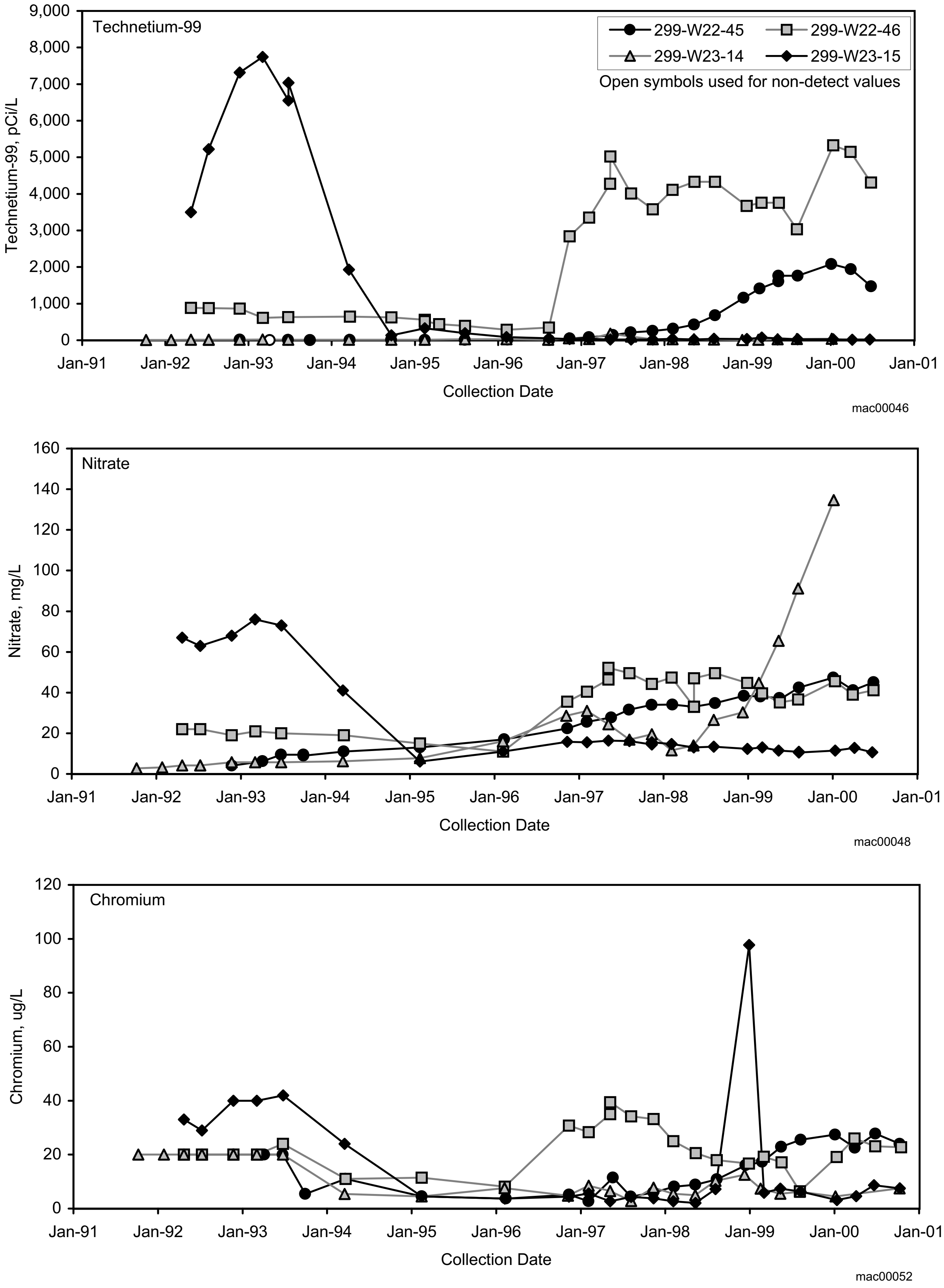

Figure 2.8-42. Technetium-99, Chromium, and Nitrate in Wells at Waste Management Area S-SX

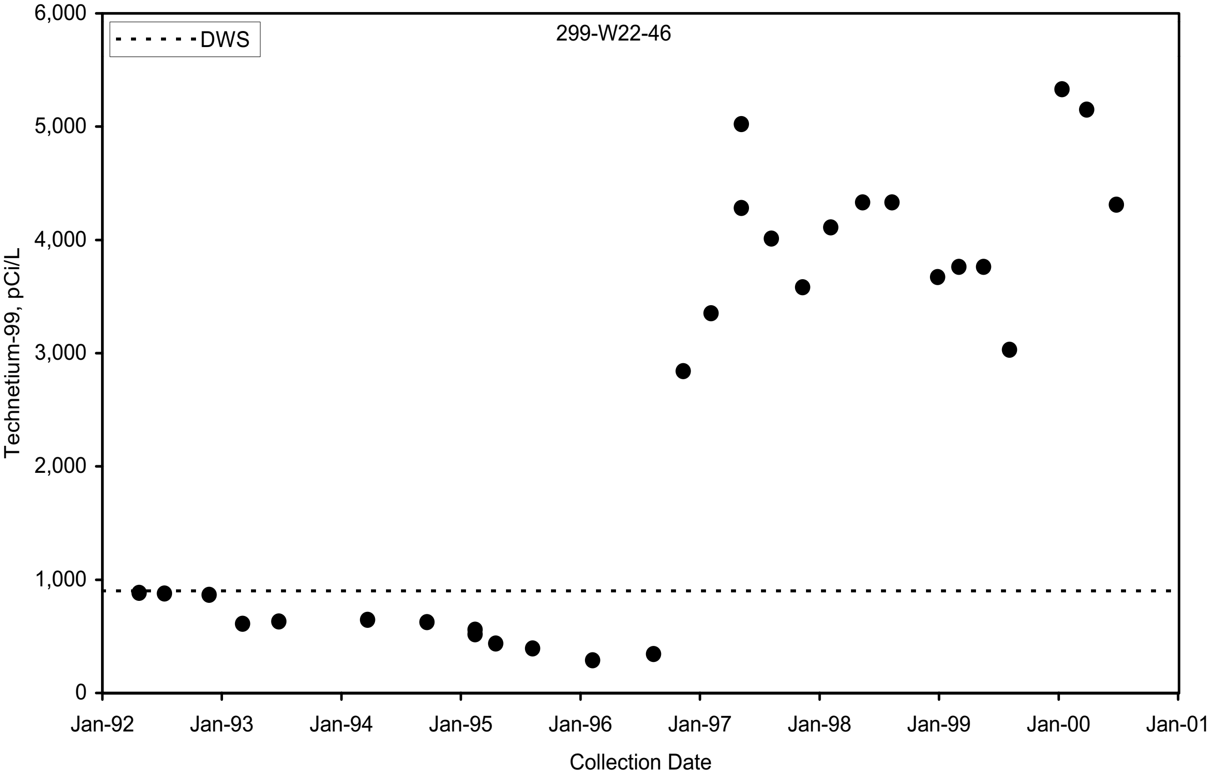

Figure 2.8-43. Technetium-99 in Well 299-W22-46 Southeast of Waste Management Area SX

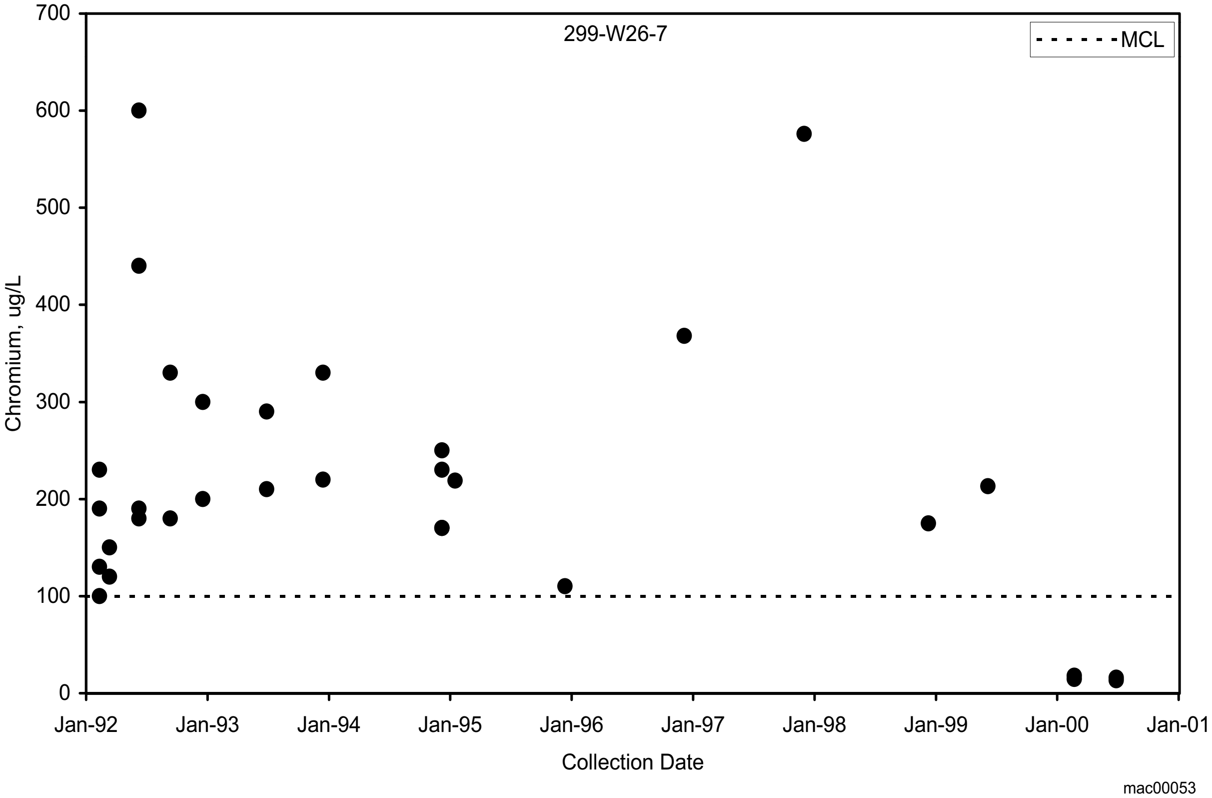

Figure 2.8-44. Chromium in Well 299-W26-7 Monitoring 216-S-10 Pond and Ditch

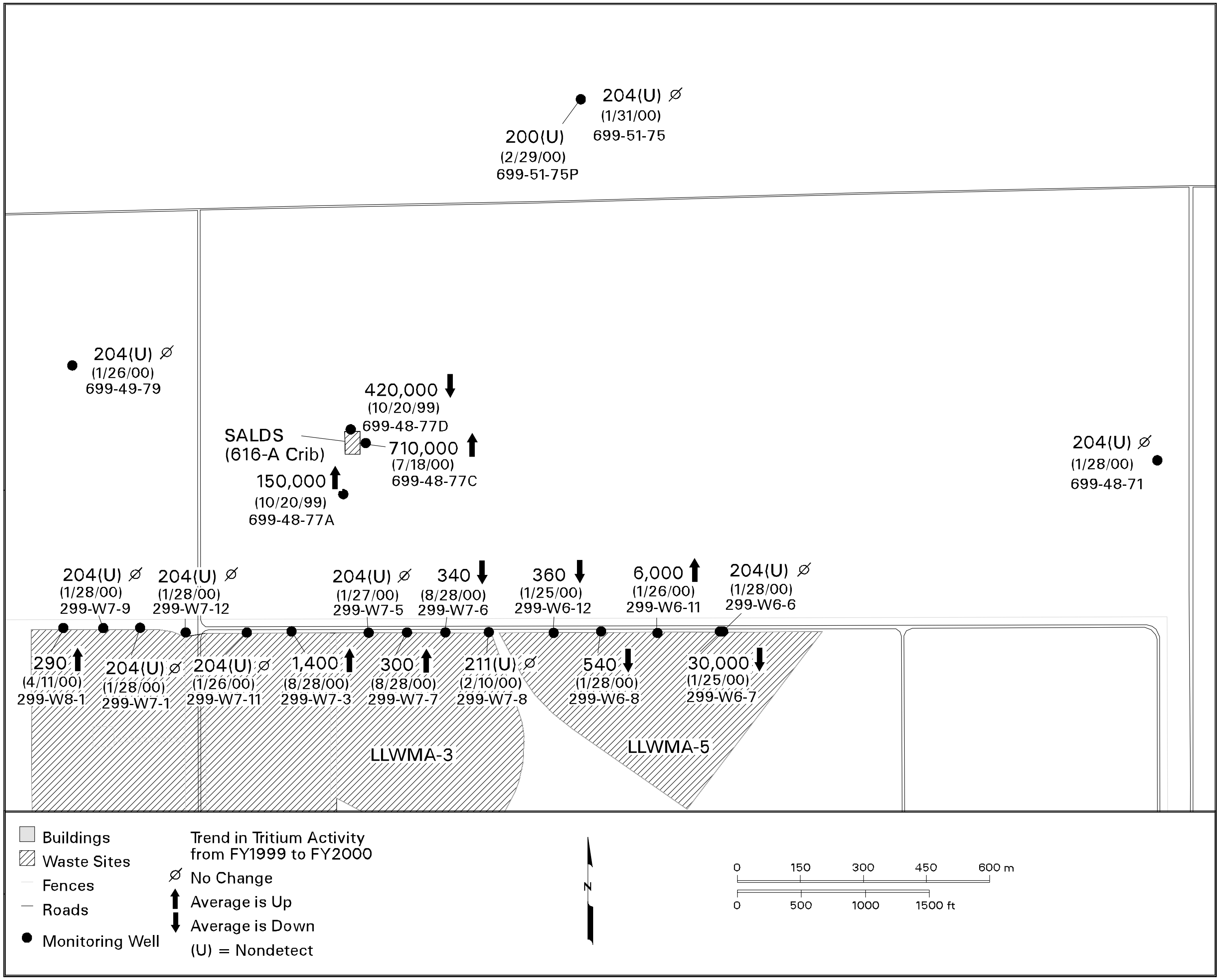

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Figure 2.8-45. Groundwater Monitoring Wells at the State-Approved Land Disposal Site Showing Maximum Tritium Concentrations for Fiscal Year 2000, Indicating Date of Measurement and Change from Fiscal Year 1999

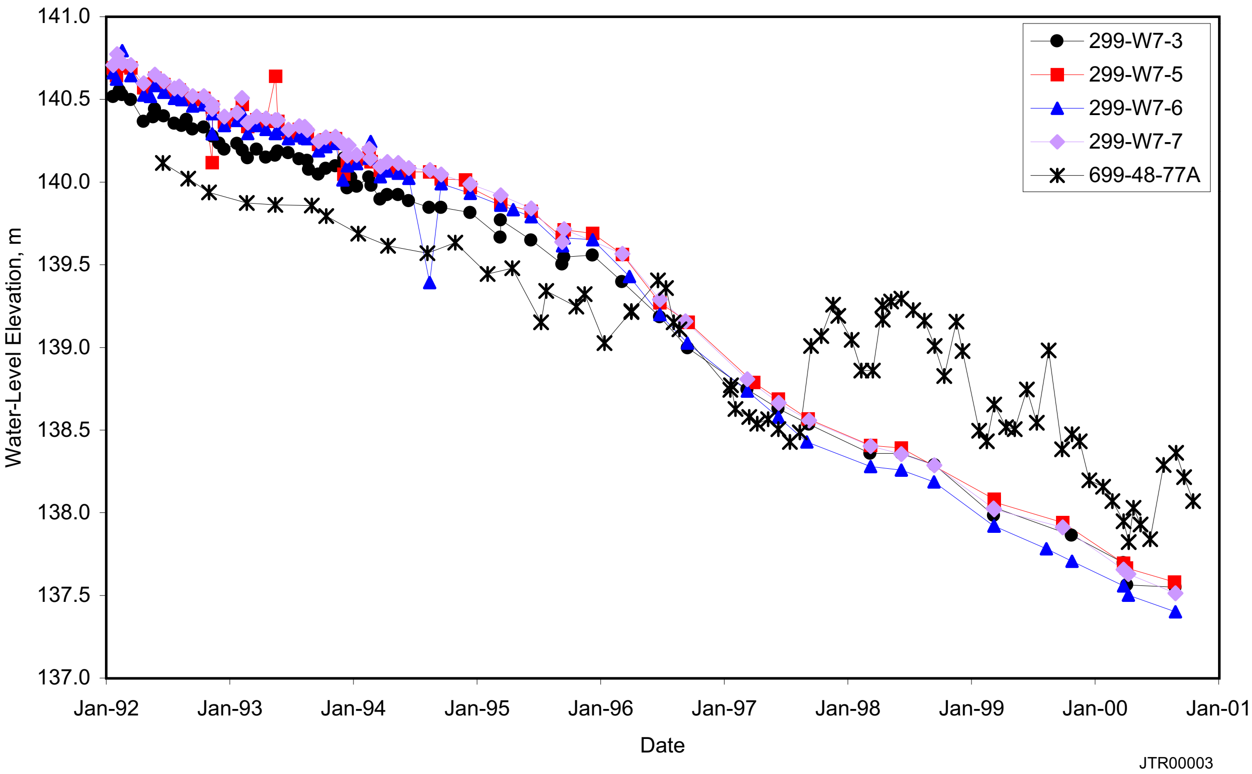

Figure 2.8-46. Water Levels at Tritium Tracking Wells South of the State-Approved Land Disposal Site Compared to Well 699-48-77A

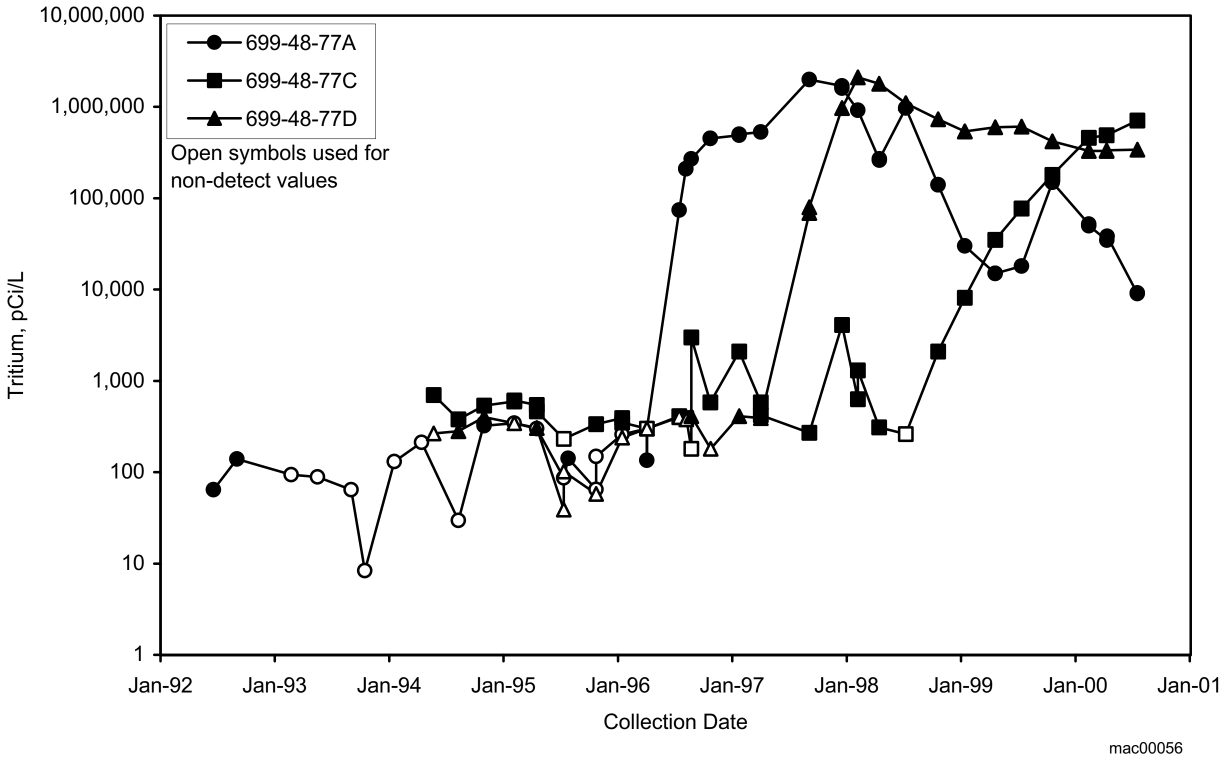

Figure 2.8-47. Tritium Concentration Trends in Wells Nearest to the State-Approved Land Disposal Site through August 2000. Well 699-48-77C is completed ~20 meters deeper in the aquifer than wells 699-48-77A and 699-48-77D.

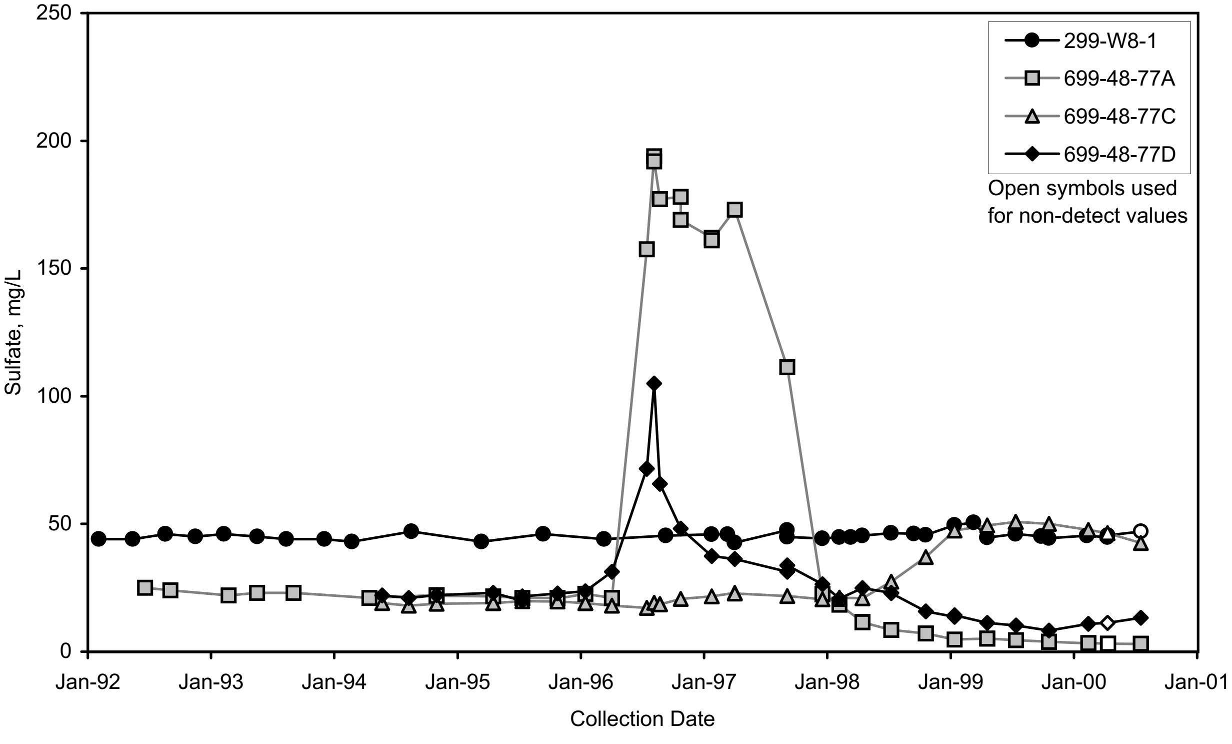

Figure 2.8-48. Sulfate in Wells Nearest to the State-Approved Land Disposal Site and Well 299-W8-1

2.9 200 East Area

J. W. Lindberg, P. E. Dresel, D. B. Barnett, J. P. McDonald, R. B. Mercer, S. M. Narbutovskih, R. E. Peterson, M. D. Sweeney, and B. A. Williams

The 200 East Area, located on the central plateau of the Hanford Site, was used for processing irradiated reactor fuel to extract plutonium between 1944 and 1990. The extraction took place at the B Plant and later at the Plutonium-Uranium Extraction (PUREX) Plant. Currently, the 200 East Area is used for waste management, storage, and disposal. Further details are provided in PNNL-13080.

For the purpose of describing groundwater contamination, the 200 East Area is divided into two parts:

- the B Plant area in the northwestern and northern parts of the 200 East Area
- the PUREX Plant area in the southeastern and eastern parts of the 200 East Area.

The vast majority of the 200 East Area groundwater contamination has its source in these two areas. This chapter includes a discussion of the tritium, nitrate, iodine-129, and technetium-99 plumes, which extend northwest and southeast of the 200 East Area. These plumes have sources within the 200 East Area. Shoreline monitoring at the old Hanford Townsite for tritium and other constituents from the 200 East Area also are discussed in this section. Contamination at Gable Mountain Pond and the 216-B-3 pond (B Pond) is considered under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) to be part of a 200 East Area operable unit so they also are discussed here. A section on contamination in the confined aquifer in the Ringold Formation near B Pond is also included.

Waste sites in the 200 East Area produced the most widespread contaminant plumes in Hanford Site groundwater: tritium, iodine-129, and nitrate. Locally, cyanide, strontium-90, technetium-99, and uranium also are present at levels above their drinking water standards. The aquifer is very permeable and groundwater moves quite rapidly toward the southeast.

Satellite image of the 200 East Area, August 2000.

The discussion in this section is divided into two parts representing these two areas within the overall 200 East Area. Within each section, the general groundwater flow, major contaminants, and specific *Resource Conservation and Recovery Act of 1976* (RCRA) facility monitoring are discussed. The major groundwater contaminants of the 200 East Area are tritium, iodine-129, technetium-99, uranium, strontium-90, plutonium, and nitrate.

2.9.1 B Plant

This section describes the area associated with facilities surrounding B Plant including waste storage and disposal facilities north of the plant. B Plant was used to recover plutonium from irradiated fuel using the bismuth phosphate process from 1945 to 1956. Contamination in the B Plant area is the result of waste disposal to the soil at a variety of locations. Throughout the active life of B Plant, the waste that was disposed to these facilities included effluent from process streams, chemicals, cooling water, and condensate. Due to similarity in the chemical makeup of some of the waste, it is difficult to assign specific groundwater contaminants to individual waste sites. Certainly there are instances where general contaminants can be assigned to waste facilities. The broadly distributed groundwater plumes throughout the eastern Central Plateau, however, are the result of disposal to unspecified waste units within the B Plant area and adjacent PUREX complex (Section 2.9.2). Monitoring wells within the 200 East Area are shown in Figure 2.9-1.

Significant waste sources in this vicinity include the BY cribs, the 216-B-5 injection well, and several RCRA treatment, storage and disposal facilities. The RCRA facilities include low-level burial grounds Waste Management Areas 1 and 2, the 216-B-63 ditch, and the tank farm facilities at Waste Management Area B-BX-BY. Of the RCRA facilities, only the Waste Management Area B-BX-BY tank farm is monitored under a groundwater assessment plan because it is believed to have contaminated groundwater with hazardous constituents. Much of the detailed information on contaminant distributions in this area was collected as part of the RCRA assessment for the tank farms, and this section is written to support the annual reporting requirements of RCRA regulations. Because of the multiple sources in the area, several of which have affected the groundwater in the immediate vicinity of the tank farm, the groundwater flow and contaminant distributions will be discussed in a general sense first. Then specific conclusions related to the tank farm assessment and other RCRA detection monitoring will be discussed.

Monitoring Objectives at B Plant

Groundwater monitoring is conducted near B Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- semiannually to detect possible impact of three RCRA waste management areas
- quarterly to assess contamination from one RCRA waste management area.

2.9.1.1 Groundwater Flow

The small differences in water-table elevation across the B Plant area and the northwestern part of the 200 East Area make it difficult to determine the direction of groundwater flow from water-table maps. Therefore, several other techniques are used to examine groundwater flow in this region. The results based on these techniques are compared for consistency with each other and with groundwater flow theory. The techniques used to determine groundwater flow within the B Plant area consist of plume maps and contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells.

In pre-Hanford times, groundwater in the B Plant area is believed to have flowed toward the southeast. Newcomb et al. (1972) presented a water-table map of the Hanford Site for January 1944 that was "…reconstructed empirically from a few known levels." HW-51277 also presented a January 1944 Hanford Site water-table map based on "scanty data." BNWL-B-360 expanded on the work by Newcomb et al. (1972) and HW-51277 by incorporating back extrapolated data from well hydrographs in a January 1944 water-table map. All three of these maps show the pre-Hanford flow direction in the northwestern corner of the 200 East Area as being to the southeast or east-southeast.

Considering the hydrogeologic framework of the 200 East Area and vicinity (described in PNNL-12261), the direction of groundwater flow prior to establishment of the Hanford Site was probably to the southeast. Currently, groundwater entering the vicinity of 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 northwest across a buried anticline and through the gap between Gable Butte and Gable Mountain (i.e., Gable Gap). The location of the flow divide (i.e., the stagnation point) depends on the relative ability of each pathway to transmit water. The more water that can be transmitted across the buried anticline and through Gable Gap, the farther southeast will be the stagnation point. The less water that can be transmitted, the farther northwest the stagnation point. The pre-Hanford water-table elevation in the 200 East Area vicinity was ~120 meters in the North American Vertical Datum of 1988 (NAVD88) (Newcomb et al. [1972], HW-51277, and BNWL-B-360 all show a January 1944 water-table elevation for the 200 East Area of about 390 feet in the National Geodetic Vertical Datum of 1929, which converts to 119.9 meters NAVD88). Wells drilled to basalt in the vicinity of the buried anticline show basalt elevations from 119 to 122 meters NAVD88. Therefore, it is likely that a significant portion of the buried anticline was present above the water table in pre-Hanford times, and quite possibly the northwestern flow pathway was entirely blocked by this anticline. In this situation, groundwater can only exit the 200 East Area vicinity to the southeast. Even if the northwestern pathway was not entirely blocked, the aquifer above the anticline would be quite shallow and not very transmissive; therefore, the stagnation point would be very near this anticline resulting in southeast flow beneath the B Plant area.

The water-table gradient in the B Plant area is very slight, making it difficult to determine the direction of groundwater flow. A colloidal borescope was used in fiscal year 2000, indicating a generally southward flow direction in much of the area. Historically, groundwater flowed toward the northwest in this area when the water table was higher than it is today.

During Hanford operations, a significant quantity of liquid effluent was discharged to the soil column in the 200 East Area, causing the water table to rise. The water-table elevation in the B Plant area peaked at about 124.7 meters NAVD88 in the late 1980s. During Hanford operations, groundwater flow in the B Plant area was to the northwest. This is known because contaminant plumes that originate in the B Plant area, such as tritium and technetium-99, have migrated toward the northwest. This means that the stagnation point was located somewhere to the south or southeast of the B Plant area. The stagnation point migrated in this direction because the water-table rise allowed for more water to be transmitted along the northwestern flow pathway.

The decline in liquid effluent discharges to the soil, especially at B Pond, is expected to cause groundwater flow in the B Plant area to reverse direction and resume its pre-Hanford flow toward the southeast. The near cessation of liquid effluent disposal to the soil is causing the water table to decline (the water-table elevation in the 200 East Area for March/April 2000 is ~122.7 meters, NAVD88). The water table may be higher than in pre-Hanford times, due to increased irrigation recharge in areas west of the Hanford Site (primarily Cold Creek Valley). However, it is still expected that the water table will decline significantly and that the flow will approximate the pre-Hanford condition. In this case, the northwestern pathway will be largely blocked by the buried anticline and will not transmit a significant quantity of water. Therefore, the stagnation point is expected to migrate to the northwest. As the divide moves through the B Plant area, a reversal in the direction of groundwater flow will occur.

Colloidal Borescope

A colloidal borescope was used in fiscal year 2000 to determine local flow directions as planned in the current assessment document guiding work for Waste Management Area B-BX-BY (PNNL-13023). This tool uses a small borehole camera, a flux-gate compass, a light for illumination, and a set of magnifying lenses to track particles moving through the well (Kearl and Roemer 1998). A video frame grabber is used to digitize each individual video frame. Specialized software compares two frames, matching the movement of a particle and determining the direction and rate of particle movement. In previous studies using the colloidal borescope, at least two hours of data displaying a steady flow direction is required to identify a reliable flow direction through a well (Kearl 1997).

Colloidal borescope investigations were conducted in fifteen wells in the northwestern 200 East Area. Several general conclusions can be made about the aquifer based on the results of this study. The groundwater flow rate is greater in the southern part of Waste Management Area B-BX-BY than it is near the BY cribs and the northeastern corner of Low-Level Waste Management Area 1. Second, the flow direction in the southern part of Waste Management Area B-BX-BY appears to be more consistent throughout the test period than in the north where the direction appeared to vary slightly over the two-hour tests.

Borescope data from wells in the southwestern corner of Waste Management Area B-BX-BY (299-E33-334 and 299-E33-335) formed a well defined steady flow direction. These records were collected for about two hours and define azimuthal directions of 125 and 165 degrees (35 degrees south of east to 15 degrees east of south), respectively. Data from wells at the northeastern and southeastern corners of Low-Level Waste Management Area 1 (299-E33-34 and 299-E28-27) displayed some variability in the direction. Although not as steady, azimuthal directions were estimated as 220 and 130 degrees. The flow observed as the particles moved across the viewing screen at well 299-E33-34 was slower than at wells 299-E33-334 and 299-E33-335. East of the BY cribs in well 299-E33-39, flow was swirling at the depth of 69 meters. Additional data and from the borescope studies will be published in a separate document in fiscal year 2001.

Figure 2.9-2 summarizes results of the borescope study. This figure also shows the local relief of the basalt and the estimated region (tan) where basalt was above the water table in pre-Hanford times. The extent of the pre-Hanford unconfined aquifer is shown in blue. Borescope results are shown with red arrows. Black arrows illustrate the results from the KV flow meter study conducted in 1994 when the water table was about half a meter higher (BHI-00442). The KV flow meter discerns temperature variations across a flow zone delineating advective flow. In the two wells where both types of meters were used (northern part of Waste Management Area B-BX-BY), results between the two studies agreed that the flow direction is primarily to the south. In Low-Level Waste Management Area 1, the borescope provided less definitive results.

In summary, the colloidal borescope results show a generally southward flow direction in the northern part of the study area; however, considerable variation is observed in flow direction between wells and measured flow directions varied during the course of the tests. In the southern part of the study area, flow measurements were more consistent between wells and consistent within the time of measurement at each well, showing flow to the southeast.

Trend Surface Analysis

The trend surface analysis results for the 216-B-63 trench indicate that groundwater flow is to the southwest beneath this site, while groundwater flow beneath Low-Level Waste Management Area 1 is toward the northwest. (The latter estimate does not agree with results of the borescope study.) Water-level trend surface analyses were conducted using a plane fit to a set of water-level elevation measurements using least squares regression. A sensitivity analysis was conducted to identify outlying measurements by systematically removing each measurement from the analysis and evaluating the change in the orientation of the fitted plane. Those wells having a significant effect were removed from the final analysis. To detect any systematic bias in the data and to verify the assumption that the data can be represented by a plane, the wells to be analyzed were typically divided into two spatial groups and assessed separately in addition to assessing all the wells together. Also, the analysis conducted for the 216-B-63 trench corrected for barometric pressure fluctuations, while the analysis for Low-Level Waste Management Area 1 did not remove these effects. More details on the trend surface analysis method, including its application to the 216-B-63 trench, can be found in PNNL-13078.

Contaminant Based Estimates

Determining groundwater movement by examining changes in the concentration of groundwater contaminants over time is complicated in the B Plant area, because there are numerous different sources of contamination and the plumes that result overlap to a significant extent. However, some insight into groundwater movement can be obtained by examining this data. Constituents typically used to track groundwater flow in this region are tritium, technetium-99, iodine-129, and nitrate because they are not significantly affected by interactions with the geologic medium. Although this section will not attempt to discuss the groundwater sampling data in detail, a few observations are noted. For instance, contamination from the B Plant area is known to occur to the north and northwest of the 200 East Area, which means that groundwater at some time in the past moved in this direction. Recent sampling data at Waste Management Area B-BX-BY suggest that technetium-99 and nitrate are rising in a southerly direction, a result that is consistent with a current flow having a southerly component. However, another significant constituent in this region is uranium, which occurs in a northwest-southeast orientation. Although uranium does interact with the geologic medium, retarding its transport, one could still interpret the distribution of uranium, by itself, as indicating northwest flow. The movement of contaminants beneath Low-Level Waste Management Area 1, especially tritium and nitrate, are generally interpreted as supporting northwest flow. To date, the direction of groundwater flow beneath the 216-B-63 trench cannot be determined using sampling data.

Conceptual Model

Considering the available information on groundwater flow in the B Plant area, the following preliminary conceptual model has emerged. The generally southerly flow in the northern part of Waste Management Area B-BX-BY (based on borescope data) and flow to the southwest at the 216-B-63 trench (based on trend surface analysis) is a direct result of the declining water table, as groundwater flows in a perpendicular direction away from the southeast-northwest buried anticline. Because the aquifer is thin in these areas, the transmissivity of the aquifer (i.e., its ability to transmit water) is small. Farther down dip, the saturated thickness and thus, the transmissivity, increases sharply, so the flow lines refract across this boundary and flow becomes southeast. The stagnation point, which was present to the southeast of the B Plant area during Hanford waste disposal operations, is migrating to the northwest in response to the declining water table because less water is being transmitted through Gable Gap. Currently, this stagnation point occurs within the B Plant area somewhere between Waste Management Area B-BX-BY and Low-Level Waste Management Area 1, or perhaps within the southeastern half of Low-Level Waste Management Area 1. The water-level surface analysis performed at Low-Level Waste Management Area 1 found that the water-table gradient is more shallow and the flow direction more variable in the southeastern half of this site than in the northwestern half. These observations are consistent with the southeastern half of Low-Level Waste Management Area 1 being closer to a stagnation point.

This conceptual model is preliminary and uncertain. The elevation of the basalt across the buried anticline is not well known because wells drilled to basalt in this area are sparse. It is possible that a significant gap was eroded into this anticline, and its presence remains undiscovered. If this were the case, the groundwater flow to the northwest would be much more transmissive than is currently recognized, so the stagnation point would not be expected to migrate very far to the northwest. Further, determining the direction of groundwater flow in the 200 East Area using constituent sampling data is difficult. There may be other explanations for this data that are inconsistent with the conceptual model, such as other sources affecting the groundwater or overlapping plumes. In particular, water-line leaks may locally affect flow direction and contaminant distribution. Therefore, efforts to verify this conceptual model and better understand groundwater flow in the B Plant area will continue.

2.9.1.2 Tritium

Tritium contamination is widespread throughout the northwestern part of the 200 East Area. The contamination extends north through the gap between Gable Mountain and Gable Butte and southeast toward the PUREX Plant (see Plate 2). Tritium contamination from B Plant has declined greatly because of natural decay. The highest concentrations are in the southern part of the area and represent contamination from the PUREX Plant that moved to the northwest under past flow conditions. Given the widespread, low-level nature of the contamination, it is likely that a number of waste disposal facilities contributed to the plume.

A number of waste sites in the B Plant area contributed to a plume of tritium. One part of this plume has moved north between Gable Mountain and Gable Butte. Concentrations are declining naturally.

Although tritium concentrations in the B Plant area have declined since 1990, one well in the vicinity of the 216-B-5 injection well had concentrations of tritium greater than the drinking water standards in fiscal year 2000. Well 299-E28-24 contained 22,900 pCi/L of tritium in May 2000. Another well contained tritium at levels above the drinking water standard in fiscal year 1999 but was not sampled in fiscal year 2000 due to waste management issues.

Another pulse of tritium at levels above the drinking water standard can be found between Gable Mountain and Gable Butte (see Plate 2). Monitoring well 699-61-62 continued to decline with a maximum average concentration for fiscal year 2000 of 34,700 pCi/L. This tritium is the result of flow through the gap under earlier flow conditions.

The assessment program for Waste Management Area B-BX-BY monitors tritium trends in the surrounding region. For wells north and west of Waste Management Area B-BX-BY, tritium levels tend to be high in the north and decrease to the south. The maximum tritium value in this region is 17,300 pCi/L in well 299-E33-26, located between the BY cribs and Low-Level Waste Management Area 1 (Figure 2.9-3). It appears that tritium currently trends similarly in this well and in well 299-E33-7 (at the BY cribs), which may imply groundwater flow from the northeast.

On the western side of the BX tank farm, tritium rose sharply from values below 2,000 pCi/L in early 1999 to around 8,000 pCi/L by August 2000 in the wells shown in Figure 2.9-4. However, well 299-E33-42 and other wells located farther north do not show this increasing trend. Tritium concentrations in well 299-E33-28, located farther west, on the eastern side of Low-Level Waste Management Area 1 are also increasing. Tritium increased in these wells at essentially the same time. The source of the tritium has not been established.

2.9.1.3 Iodine-129

Contamination from iodine-129 is present throughout the B Plant area. Like the tritium plume, the iodine-129 plume extends to the northwest through the Gable Mountain/Gable Butte gap and southeast toward the PUREX Plant (Figures 2.1-5 and 2.9-5). Iodine-129 concentrations range up to 6.6 pCi/L in well 299-E33-34. Iodine-129 concentrations have increased slowly in that well. A band of elevated iodine-129 concentrations (<5 pCi/L) extends from the vicinity of the 216-B-63 trench, through Waste Management Area B-BX-BY, to the northeastern corner of Low-Level Waste Management Area 1. Interpretation of the iodine-129 configuration in this area is complicated by elevated detection limits that result from interference by technetium-99. In addition, the current laboratory reporting system produced some values reported as non-detect at levels greater than the 1 pCi/L drinking water standard.

Several wells between Gable Mountain and Gable Butte were sampled for iodine-129 to define the northern plume and to track the movement of this plume out of the 200 Areas (see Figure 2.9-5). The most recent results for these wells were below detection limits, but concentrations were at or above the drinking water standard occasionally in the past. The well data indicate that the iodine-129 plume is not spreading to the northern 600 Area through the gap between Gable Mountain and Gable Butte. This suggests the direction of groundwater flow may have changed due to declining water levels in the 200 East Area. However, it is also possible that the iodine-129 is diluted by other water as flow converges toward the gap.

2.9.1.4 Technetium-99

A plume of technetium-99 (drinking water standard 900 pCi/L) extends from the area of Waste Management Area B-BX-BY to beyond the 200 East Area boundary to the northwest (Figure 2.9-6). The larger part of the plume is to the north and is interpreted to represent early releases of technetium-99 from the BY cribs. Detection of technetium-99 at levels lower than the 900 pCi/L drinking water standard north of the Gable Mountain/Gable Butte gap indicates that technetium-99 has moved north, into, and through the gap.

Interpretation of the details of the technetium-99 plume north of the 200 East Area is complicated by the variable concentrations seen in wells that are relatively close together. For example, concentrations of technetium-99 less than the drinking water standard were consistently detected in well 699-49-55A since the early 1990s (47 pCi/L in fiscal year 2000), while well 699-49-57A has higher and increasing concentrations (2,800 pCi/L in fiscal year 2000). Well 699-52-57, located north of well 699-49-57A, had consistently low technetium-99 concentrations (less than 90 pCi/L) throughout the 1990s; however, the water table fell below the screen in 1999 so the well can no longer be sampled. The representativeness of the data from well 699-52-57 is somewhat suspect due to the shallow penetration into the aquifer. Technetium-99 was not routinely measured in groundwater prior to the late 1980s, limiting the information on the historical trends. Thus, there is considerable uncertainty in the precise extent of technetium-99 contamination.

The assessment program for Waste Management Area B-BX-BY tracks the technetium-99 plume. Very high levels of technetium-99, along with cobalt-60, cyanide, and nitrate were found north of the 200 East Area in well 699-50-53A in the late 1980s (Figure 2.9-7). As the water table began to drop in 1988 (Figure 2.9-8), contaminant levels decreased, indicating that the plume had moved out of this area. Technetium-99 levels rose again to almost 10,000 pCi/L during pump-and-treat operations, which began in this well in early 1995. The technetium-99 was removed locally from this well. Since that time, technetium-99 concentrations in this well have been low as the aquifer has grown thinner. In fact, the aquifer above the basalt surface in this area is presently only a few centimeters thick.

One major source of technetium-99 contamination was the BY cribs. Sources within Waste Management Area B-BX-BY also may have contributed. The plume moved toward the north in the past, and now may be moving to the south.

In the early 1990s, rising technetium-99 concentrations were seen in the BY crib area in wells 299-E33-7 and 299-E33-38 (see Figure 2.9-7). During late 1997 and 1998, the technetium-99 concentration was higher in well 299-E33-7 than in well 299-E33-38. In early 1999, the trends for both wells began to track together.

Possible explanations for this increase include movement of the contaminant plume back into the 200 East Area from the north and/or an increase in transport of contamination from the vadose zone.

Technetium-99 generally decreases from north to south along the western side of Waste Management Area B-BX-BY and on the eastern side of Low-Level Waste Management Area 1. This distribution suggests that the plume is moving toward the south, which agrees with results of in situ flow meters, nitrate trends and hydrographs from this region. Concentrations are increasing with time in these wells. Technetium-99 levels also are increasing for the first time in wells 299-E33-33 and 299-E33-36, both located southeast of Waste Management Area B-BX-BY. This increase in technetium-99 may indicate arrival of the plume from that direction.

Near the 216-B-8 crib, technetium-99 concentrations are not increasing. This suggests that the nitrate increase seen at the 216-B-8 crib is part of a different group of contaminants from a different source than the BY cribs.

2.9.1.5 Uranium

Uranium contamination in the B Plant area is limited to three isolated areas:

- wells monitoring Waste Management Area B-BX-BY and surrounding cribs
- wells near the 216-B-5 injection well
- wells at the 216-B-62 crib (299-E28-21 and 299-E28-18).

Uranium was associated with technetium-99 in the B Plant area. However, it moves more slowly in groundwater.

Although the trend decreased slightly since 1998, many wells in all three of these areas exceeded the 20 µg/L proposed drinking water standard during fiscal year 2000.

Waste Management Area B-BX-BY and Surrounding Cribs

The origin of uranium contamination in the vicinity of Waste Management Area B-BX-BY is somewhat problematic. Currently, the highest uranium concentrations are found to the east of the BY tank farm (Figure 2.9-9). The contamination is restricted to a narrow northwest-southeast band with the highest concentration detected in fiscal year 2000 in well 299-E33-44, with an annual average concentration of 290 µg/L. Unfortunately, historical data are not available for this well, which was drilled in 1998, or for well 299-E33-9, located within the BY tank farm. Concentrations began increasing in approximately 1993 in wells 299-E33-13 and 299-E33-18, located east of the BY cribs and north of the B tank farm, respectively. The later decline in well 299-E33-13 is likely due to a westward shift in groundwater flow. Uranium concentrations rose in well 299-E33-26 located in the northwestern end of the plume. Uranium concentrations farther west, in well 299-E33-34, have risen by a factor of ~5 since 1995, but the increase leveled off in the past 3 years. Although uranium is generally increasing in well 299-E33-38, in the southern part of the BY cribs, only low concentrations have been found in well 299-E33-7, located in the northern part of the BY cribs. Section 2.9.1.10 includes additional discussion of uranium at Waste Management Area B-BX-BY.

The uranium data seem somewhat at odds with the technetium-99 trends. Uranium transport is somewhat retarded in groundwater with respect to the water velocity, yet concentrations are just beginning to increase in wells along the western edge of Waste Management Area B-BX-BY. The lack of uranium in the northern part of the BY cribs indicates that the uranium is not moving into the area from the north or northwest and that the uranium sources are distinct from the source of the majority of the technetium-99. As discussed in Section 2.9.1.10, at least some of this uranium likely is from past releases from Waste Management Area B-BX-BY.

216-B-5 Injection Well

Uranium contamination is associated with the strontium-90, cesium-137, and plutonium contamination found at the 216-B-5 injection well. The highest uranium concentration detected in fiscal year 2000 was 69 μg/L in well 299-E28-23, located only ~1 meter from the injection well.

216-B-62 Crib

Uranium was detected consistently at levels slightly above the proposed drinking water standard 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 uranium at the 216-B-62 crib in fiscal year 2000 was 28 μg/L in well 299-E28-18. Uranium also was found along the western side of Low-Level Waste Management Area 1. In fiscal year 2000, only well 299-E32-2 had an average concentration that reached the proposed drinking water standard. The uranium detected near Low-Level Waste Management Area 1 probably originated at the 216-B-62 crib.

2.9.1.6 Nitrate

A nitrate plume originating in the 200 East Area extends beyond the boundary fence line, extending northwest to the Columbia River (Figures 2.9-10 and 2.1-4). The plume within the 200 East Area has two parts: (1) a western plume that extends from B Plant to the northwest and (2) an eastern plume extending from the BY and surrounding cribs toward the north and northwest. The two plumes 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 allowable maximum contaminant level for drinking water (45 mg/L).

The western part of the nitrate concentration, extending from B Plant, appears to be a portion of a larger plume extending from the PUREX Plant. 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 have sources in the vicinity of the BY cribs and other nearby liquid waste disposal facilities. As discussed in Section 2.9.1.10, some nitrate also may be associated with past releases from tank farms. High concentrations of nitrate are associated with the technetium-99, cobalt-60, and cyanide plume originating from the BY cribs. This source is a major contributor to the contamination extending to the northwest. The highest nitrate concentrations measured in fiscal year 2000, however, were found in well 299-E33-16, near the 216-B-8 crib, where the fiscal year 2000 average concentration was 550 mg/L (Figure 2.9-11). The ratio of technetium-99 to nitrate in well 299-E33-16 is low compared to the ratio of technetium-99 to nitrate in wells near the BY cribs, indicating an additional nitrate source in the area. Multiple nitrate sources also are indicated by the nitrate and technetium-99 trends in well 699-50-53A, north of the 200 East Area. Prior to 1997, nitrate and technetium-99 tracked closely in this well (Figure 2.9-12). Since that time, the nitrate increased while the technetium-99 remained low or only increased slightly. The fiscal year 2000 average nitrate concentration in well 699-50-53A was 160 mg/L.

2.9.1.7 Cyanide and Cobalt-60

Cyanide and cobalt-60 continue to be detected in a number of wells in the vicinity of B Plant. Cobalt-60 is not considered a significant threat due to its relatively short half-life (5.3 years), and because it is currently only found at levels less than the 100 pCi/L drinking water standard. Cyanide is also a minor contaminant but is found at levels above the 200 μg/L allowable maximum contaminant level for drinking water. These species are useful, however, in distinguishing contaminant groups and contaminant sources. Cyanide and cobalt-60 are generally found together in this vicinity.

The maximum cyanide concentration in this area in fiscal year 2000 was 411 μg/L in the February 2000 sample from well 299-E33-38, located in the southern part of the BY cribs (the annual average concentration for this well was 285 μg/L). Cyanide contamination in this well, and others in the vicinity, is increasing along with the technetium-99 and nitrate. Thus, the cyanide also appears be from past discharge of ferrocyanide waste to the BY cribs.

The highest cobalt-60 values in fiscal year 2000 also were detected in wells monitoring the BY cribs, and the cribs are believed to be the source of the contamination. The highest cobalt-60 concentration was in well 299-E33-7, located in the northern part of the BY cribs, where the May 2000 result was 78.2 pCi/L and the annual average was 66 pCi/L.

2.9.1.8 Strontium-90 and Cesium-137

The 216-B-5 injection well created a small plume containing cesium-137, plutonium, and strontium-90.

Several wells in the vicinity of B Plant have trends indicating historical concentrations of strontium-90. The highest levels are near the 216-B-5 injection well. 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 fiscal year 1999. 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. In past years, one well near the 216-B-5 injection well had concentrations of cesium-137 greater than the drinking water standard (200 pCi/L). Due to waste management issues, most of these wells near the 216-B-5 injection well were not sampled in fiscal year 2000. The fiscal year 2000 sample from well 299-E28-24 contained 50.4 pCi/L of strontium-90, similar to previous years.

2.9.1.9 Plutonium

Plutonium-239 and -240 were detected in past years in samples taken from several wells near the 216-B-5 injection well. In fiscal year 2000, 9.35 pCi/L of plutonium were detected in a sample from well 299-E28-23. Due to waste management issues, the wells near the 216-B-5 injection well were not sampled in fiscal year 2000.

2.9.1.10 RCRA Assessment Summary for Waste Management Area B-BX-BY

RCRA Waste Management Area B-BX-BY contains single-shell tank farms that may have contaminated groundwater with nitrate, uranium, and technetium-99.

Underground single-shell tank farms B, BX, and BY, located in the northwestern part of the 200 East Area, comprise Waste Management Area B-BX-BY (see Appendix A, Figure A.14). In 1996, the waste management area was placed in a groundwater quality assessment program, based on specific conductance values that were elevated above the critical mean in downgradient well 299-E33-32 (PNNL-13022). Nitrate, along with associated calcium and sodium, is the apparent cause of the elevated specific conductance. Elevated concentrations of technetium-99 are associated with the nitrate. The monitoring frequency was increased in 1996 from semiannual to quarterly. In addition, outlying wells were added to the sampling schedule to provide additional coverage for the numerous past-practice liquid effluent discharge facilities located around the waste management area. This additional coverage was needed to identify non-tank farm sources that may have caused the increase in groundwater contamination. Also with the uncertainty in the flow direction, additional coverage was needed to assure that any contamination from the site would be detected.

During 1997, nitrate, technetium-99, and uranium concentrations rose above the drinking water standards of 45 mg/L, 900 pCi/L, and 20 μg/L, respectively, in well 299-E33-41. This well is located between the B and the BX tank farms. An assessment report (PNNL-11826) concluded 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 this well by recent fresh water flooding.

Although concentrations of nitrate and technetium-99 were rising in the groundwater along the western side of the waste management area, the source could not be identified. A further determination is being conducted to identify the source of this contamination and to determine the rate and extent of groundwater contamination at Waste Management Area B-BX-BY (PNNL-13022). Two wells were installed in fiscal year 1999 and three more will be drilled during fiscal year 2001 along the southern and southwestern side of the waste management area.

Groundwater Flow

The hydraulic gradient is nearly flat across Waste Management Area B-BX-BY (see Plate 1), making it difficult to determine upgradient versus downgradient wells from water-level measurements. This difficulty was exacerbated by numerous uncertainties in estimating water-level elevations. These include measurement errors, small errors in well elevation survey data, pressure effects associated with changing weather conditions, small deviations from vertical of the borehole, and lateral changes in sediment grain size distribution across a site causing slight undulations in the water table. Each of these sources of uncertainty can affect the water elevation in a well resulting in incorrect interpretation of flow direction and gradient (PNNL-13022; PNNL-13023; PNNL-13116). Unless these errors are identified, minimized, or corrected, estimates of the direction of groundwater flow from water elevations alone are ambiguous when applied to a region as small as Waste Management Area B-BX-BY (PNNL-13022). Flow estimates based on water levels are being supplemented with other techniques (see Section 2.9.1.1).

Another issue that confuses the determination of local groundwater flow is related to decreasing water elevations. Most of the region under Waste Management Area B-BX-BY and the BY cribs had little or no unconfined groundwater prior to Hanford operations in the mid-1940s. The unconfined aquifer beneath the BY cribs was formed by rising water levels related to intentional and unintentional releases of waste liquids to the ground. As can be seen in Figure 2.9-8, the water table may drop at least 3 meters if it returns to its pre-Hanford level. The unconfined aquifer in the northern part of the site is only 2 meters thick in some areas. This thin aquifer is located on a hummocky basalt surface with structural relief that varies from 1.5 to 3.4 meters. Consequently, local flow paths in this area might vary greatly as the water flows between basalt highs. Some water may even be trapped in local depressions in the basalt, causing quasi-stagnant conditions.

The average flow rate, estimated using a form of the Darcy equation, was calculated to be 0.8 meter per day in fiscal year 2000 (see Appendix A, Table A.2). This equates to 292 meters of groundwater movement per year. This estimate has a high degree of uncertainty because the gradient across the site is so difficult to determine. This high flow velocity has implications when determining the optimal frequency for groundwater sampling. Because the waste management area is less than 292 meters across, contamination related to leaking tank waste might move through the area in less than a year. Given the rapid movement of contaminants in the past at well 299-E33-41, semiannual or even quarterly sampling may not be sufficient to clearly identify and differentiate tank-related waste from background contamination related to the surrounding cribs, trenches, and reverse wells (PNNL-11810; PNNL-11826).

Groundwater Contamination

Assessment studies at Waste Management Area B-BX-BY have identified three distinct groups of contaminants based on spatial relationships, historic plume movement, knowledge of process chemistry, and characteristic chemical ratios of contaminant concentrations.

1. **Uranium, Technetium-99, Nitrate, and Nitrite**. These contaminants are located at the BY tank farm. Past releases from the waste management area are one possible source of this contamination. Further assessment to evaluate this plume is ongoing.
2. **Technetium-99, Nitrate, Cobalt-60, and Cyanide**. The plume represented by these contaminants extends under the BY cribs, south through Waste Management Area B-BX-BY, and west to the northeastern corner of Low-Level Waste Management Area 1. Some of the wells associated with this plume also contain uranium, though that may be from a separate source. The contaminants in this group are attributed to releases from the BY cribs in the 1950s.
3. **Technetium-99, Nitrate, and Slightly Elevated Chromium**. These contaminants are associated with the 216-B-8 crib.

Technetium-99, nitrate, and nitrite have recently increased in wells near the BY tank farm. This contamination may have originated from past leaks within Waste Management Area B-BX-BY.

The first group is discussed in this section because its source may be within Waste Management Area B-BX-BY, probably from past events. Groups 2 and 3 were discussed in Sections 2.9.1.4 through 2.9.1.7. A full analysis and interpretation of the groundwater chemical trends, plume movement, and associated sources will be presented in a detailed topical report scheduled for completion in fiscal year 2002.

Although the inorganic constituents in tank waste at Waste Management Area B-BX-BY are numerous, the main tank constituents known to be mobile and used for tracking tank-related waste are nitrate and associated anions, technetium-99 (as TcO_4^-), and, to some degree, uranium. Groundwater samples also are analyzed for cobalt-60 and cyanide because both constituents can be mobile, are present in some tank waste, have been disposed in the immediate area, and have a history of being found in the groundwater at this site.

Nitrate and technetium-99 concentrations have increased recently in wells near the BY tank farm. Low levels of cyanide also have been detected recently. However, the high uranium concentrations found at the BY tank farm and to the east have remained almost steady for about two years. Nitrite is detected only in wells in the immediate vicinity of this tank farm.

Nitrate concentrations in the central region of Waste Management Area B-BX-BY increased in 1999 and 2000 (Figure 2.9-13). Concentrations in well 299-E33-44, located east of the BY tank farm, increased from 109 mg/L in 1999 to 180 mg/L in August 2000. Nitrate levels are comparable and increasing in well 299-E33-18, located north of the B tank farm. Nitrate concentrations are much lower in well 299-E33-41, south of well 299-E33-44, increasing from about 20 mg/L in 1999 to 35 mg/L in August 2000. Technetium-99 concentrations also increased in fiscal year 2000 (Figure 2.9-14). The figure compares rising technetium-99 concentrations between well 299-E33-38, located at the BY cribs, with concentrations in wells 299-E33-44 and 299-E33-41, on the eastern side of the BY tank farm. Cyanide concentrations also increased on the east side of the BY tank farm. These increases in technetium-99, nitrate and cyanide may be related to contaminant migration southward from the BY cribs. This would agree with flow directions shown in Figure 2.9-2.

Uranium trends are relatively flat and do not reflect the sharp increases seen in nitrate, technetium-99 and cyanide. Uranium travels at a slower rate than the more mobile contaminants, but the general trends should be reflected in the uranium at a later time. This was shown with the high pulses of technetium-99 contamination detected in well 299-E33-41 in 1997 (PNNL-11793). These same pulses for uranium were detected in well 299-E33-41 about six months later.

Increasing uranium west of Waste Management Area B-BX-BY (e.g., wells 299-E33-26, 299-E33-31, and 299-E33-42; Figure 2.9-15) suggests that uranium may be migrating toward the west from the waste management area. Alternatively, the increasing uranium seen in wells 299-E33-31 and 299-E33-42 may be related to movement from the BY cribs region.

The group of contaminants in the central part of the waste management area also has high levels of nitrite. The concentration of nitrite in processing waste is often equal to that of nitrate; however, the nitrite is usually oxidized to nitrate before it can be detected in groundwater. Although the presence of nitrite might suggest a recent release from the waste management area, the lack of cyanide and the high levels of uranium indicate that the source of the contamination is probably metal waste associated with the 1951 overflow leak and/or the leak associated with the BX-102 tank. The BY tank farm is located over a structural low in the basalt, and, thus, most of the contamination at this site may be in this pocket.

The history of effluent discharges to the ground in and around Waste Management Area B-BX-BY has resulted in complex patterns of groundwater contamination with possible interactions between multiple plumes. As discussed above, the highest level of technetium-99 is located under the BY cribs to the north and is attributed to discharges to the cribs in the mid-1950s. The technetium-99 is associated with moderately high concentrations of nitrate and with low concentrations of cyanide and cobalt-60. This contamination forms an extensive plume that now is moving generally to the south and affecting the groundwater under Waste Management Area B-BX-BY. The highest concentration of nitrate is under the 216-B-8 crib located east of the waste management area. Low levels of technetium-99 and chromium are also found in that area. This waste is believed to be associated with the original discharge to the crib in the late 1940s. A local low in the basalt basement exists in this area, and, thus, this contamination may be in a partially stagnant pool that is either not moving or is moving very slowly. At this time, there is no clearly identified groundwater contamination from the waste management area although the waste management area may have contributed to uranium, nitrite, and other contamination in the vicinity of the BY tank farm. The Waste Management Area B-BX-BY will continue in assessment with quarterly monitoring of the groundwater. Three new wells are scheduled for installation in fiscal year 2001.

2.9.1.11 RCRA Parameters for the 216-B-63 Trench

Groundwater monitoring continues to provide no evidence that dangerous non-radioactive constituents from the 216-B-63 trench have entered groundwater. The RCRA interim status indicator parameters are pH, specific conductance, total organic carbon, and total organic halides (40 CFR 265.92[b][3]). Included in the analysis list for this trench are a gamma scan, alkalinity, gross beta, and turbidity. The statistical analyses presented in Appendix A revealed no exceedances in pH, specific conductance, total organic carbon, or total organic halides.

RCRA monitoring at the 216-B-63 trench continued to provide no evidence that it has contaminated groundwater.

Groundwater analysis continues to indicate an increase in concentrations of calcium, magnesium, sodium, and sulfate in several wells. The rate of change in concentration, however, has slowed and may indicate that groundwater chemistry has stabilized beneath the trench. The constituent concentrations do not exceed maximum contaminant levels.

The current network is composed of six wells drilled specifically to monitor this trench. The network also includes five upgradient wells drilled to monitor the low-level burial grounds located just north of the trench and one upgradient well drilled to monitor Waste Management Area B-BX-BY. The network currently is considered adequate but will be re-evaluated as water levels and groundwater gradient change with time.

2.9.1.12 RCRA Parameters for Low-Level Waste Management Areas 1 and 2

The two low-level burial grounds in the 200 East Area, Low-Level Waste Management Area 1 and Low-Level Waste Management Area 2, are monitored under interim status detection monitoring.

Low-Level Waste Management Area 1

The well network for groundwater monitoring at Low-Level Waste Management Area 1 continues to meet all RCRA requirements. Sampling is done semiannually at seventeen monitoring wells for the constituents listed in Appendix A. Appendix A also contains a list of the monitoring wells used in this network. Water levels continue to decline in the 200 East Area; however, none of the monitoring wells at Low-Level Waste Management Area 1 are expected to go dry within the next 10 years.

Specific conductance continued to exceed the upgradient/downgradient comparison value in well 299-E33-34 in this reporting period. The major contributor to this exceedance was nitrate at levels more than five times the 45 mg/L maximum contaminant level. Nitrate levels in nearby wells 299-E32-10 and 299-E33-28 have also exceeded the maximum contaminant level. The source of the nitrate contamination is assumed to be from the cribs to the east of Low-Level Waste Management Area 1. Elevated nitrate is also present in wells on the south and west sides of Low-Level Waste Management Area 1 with values exceeding the maximum contaminant level in wells 299-E28-26, 299-E32-2, 299-E32-3, 299-E32-6, and 299-E32-7. These high levels have been associated with the nitrate plume originating south of Low-Level Waste Management Area 1.

RCRA monitoring at Low-Level Waste Management Areas 1 and 2 indicates no groundwater contamination from this facility.

Technetium-99 also was elevated in the northeast corner of Low-Level Waste Management Area 1. Well 299-E33-34 had values over 5,000 pCi/L in August 2000 and the trend continues to be upward. This technetium-99 is believed to originate at the BY cribs to the east.

There are no indications that Low-Level Waste Management Area 1 has contributed to groundwater contamination.

The groundwater gradient in the northern part of the 200 East Area is extremely small and determining the direction of groundwater flow is difficult. Based on contaminant plume data and trend surface analysis, the flow direction is assumed to be to the northwest. Preliminary trend surface analysis indicates a north-northwest flow direction. Conflicting data from flow meter studies, however, shows flow to the southwest or southeast (see Figure 2.9-2). Additional work needs to be done to better understand the flow regime in this area.

Low-Level Waste Management Area 2

Indicator parameters of contamination were compared semiannually in compliance with RCRA interim status regulations at this facility. The groundwater monitoring network continues to provide adequate coverage; however, if the decline in water levels in the area continues at the current rate, additional wells are expected to go dry in the next few years. Additional wells may be required in some instances, but many of the monitoring wells in this network are completed at or near the top of basalt. Alternative methods to monitor this waste management area may be necessary to determine contaminant releases.

There is no evidence of groundwater contamination from Low-Level Waste Management Area 2. The upgradient/downgradient comparison value for specific conductance is consistently exceeded in upgradient well 299-E34-7. The major causes of the increased conductivity are sulfate, nitrate, and calcium. Nitrate exceeded the 45 mg/L maximum contaminant level in this well. There are no apparent sources of sulfate or nitrate in Low-Level Waste Management Area 2 near well 299-E34-7.

The quadruplicate averages for total organic carbon at well 299-E34-7 greatly exceeded the established upgradient/downgradient comparison value in this reporting period. Additional analyses for volatile organic and semi-volatile organic compounds were all below detection limits except for bis(2-ethylhexyl)phthalate, which was less than the practical quantitation limit. The cause of this increase is being investigated.

The groundwater flow at Low-Level Waste Management Area 2 is influenced by the basalt subcrop beneath the north and east portions of the burial ground. The direction of groundwater flow is assumed to be toward the west.

2.9.2 PUREX Plant

Numerous disposal facilities received waste from PUREX Plant operations. In particular, numerous cribs to the south and east of the PUREX building affected groundwater quality over a large area of the site. The most extensive and significant contaminants are iodine-129, nitrate, and tritium. Three cribs (216-A-10, 216-A-36B, and 216-A-37-1) are at least partially responsible for the significant contamination and were monitored in accordance with RCRA in fiscal year 2000. Monitoring results indicate that the impact to groundwater originates from other facilities as well. These other facilities are located generally northeast and east of the plant, and are being addressed under the CERCLA/RCRA past-practice process. The 216-A-29 ditch, B Pond, and high-level waste tanks in Waste Management Areas A-AX and C also are monitored in accordance with RCRA. However, to date there is no evidence to indicate that groundwater at these sites has been contaminated with RCRA-regulated waste.

Monitoring Objectives at PUREX Plant

Groundwater monitoring is conducted near PUREX Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- semiannually to detect possible impact of five RCRA waste management areas
- quarterly to assess contamination from one RCRA waste management area
- quarterly or semiannually to detect possible impact of the Treated Effluent Disposal Facility.

2.9.2.1 Groundwater Flow

Groundwater beneath the PUREX Plant occurs in an unconfined aquifer and two confined aquifers overlying basalt bedrock. However, none of these aquifers is continuous across the entire PUREX area. Groundwater flow in this system is influenced by a northwest-to-southeast high conductivity channel, Ringold Formation mud units, the May Junction fault, and past disposal of liquid effluents at B Pond, all of which interact to produce a complex flow system. The hydrogeology of this area is discussed in detail in PNNL-12261.

Groundwater flow in the central and eastern portion of the PUREX area is depicted in Figure 2.9-16. The Ringold Formation mud units occur in the eastern and southern portion of this area, and their lateral extent is depicted in Figure 2.9-16 as the confined aquifer boundary. The confined aquifers occur within permeable layers between the mud units. These muds extend above the water table in the B Pond vicinity, but dip to the south below the water table. Therefore, the unconfined aquifer is not present in the B Pond vicinity. The high conductivity channel, formed by cataclysmic Pleistocene flooding, occurs over much of the 200 East Area, and extends to the southeast over the top of the mud units. The north-south May Junction fault occurs east of B Pond and the Treated Effluent Disposal Facility.

As is the case over much of the 200 East Area, differences in water-table elevation in the PUREX Plant area are small, making it difficult to determine the groundwater flow direction from water-table maps. Therefore, flow in the unconfined aquifer is determined using water-level measurements in conjunction with contaminant movement as depicted on plume maps and concentration trend plots. Unconfined groundwater entering the 200 East Area from the west divides the flows to the Columbia River along two separate paths: one to the southeast and one to the northwest through the gap between Gable Butte and Gable Mountain. The flow is currently thought to divide in the northwestern corner of the 200 East Area (see Section 2.9.1.1). Therefore, flow within the southern part of the PUREX Plant area is believed to be southeast within the unconfined aquifer. This is confirmed by the migration of contaminant plumes from the PUREX cribs. In the northern part of the PUREX Plant area, flow is believed to have a significant southerly component, as groundwater must flow south around the mud units that are located in the B Pond vicinity.

Past disposal of liquid effluents at B Pond has resulted in high water level within the underlying confined aquifers (see Figures 2.9-16 and 2.9-17). The May Junction fault is believed to act as a barrier to groundwater flow in these aquifers, causing flow to occur largely to the southwest and south. This water is believed to discharge to the unconfined aquifer in the 200 East Area where it then migrates to the southeast. The rate and direction of groundwater flow beneath the individual waste facilities within the PUREX Plant area varies and is discussed is the following sections on RCRA monitoring. Groundwater flow within the confined aquifers is discussed more fully in Sections 2.9.2.11, 2.9.2.13, and 2.9.4.1.

2.9.2.2 Tritium

The highest tritium concentrations in the 200 East Area continued to be found in wells near cribs that received effluent from the PUREX Plant (see Plate 2). Concentrations of more than 2 million pCi/L (the DOE derived concentration guide) were detected only in well 299-E17-9 next to the 216-A-36B crib (Figure 2.9-18). The maximum concentration detected in this well in fiscal year 2000 was 2.51 million pCi/L, which is down from the highest fiscal year 1999 reported value of 3.87 million pCi/L. Tritium concentrations that exceed the 20,000-pCi/L drinking water standard continued to be found in many wells affected by cribs near the PUREX Plant.

Prior to fiscal year 1998, tritium levels measured in well 699-37-47A, near the southeastern corner of the 200 East Area and completed in 1996, remained below 20,000 pCi/L (the drinking water standard). In 1998, tritium concentration rose to 36,000 pCi/L (Figure 2.9-19). The rise in tritium concentration was probably due to the reduction in wastewater discharged in the vicinity of B Pond. Well 699-37-47A is very near the mixing area of groundwater from the northwest that has higher tritium concentration and groundwater from the B Pond area that has lower tritium levels. As the influence of wastewater in the B Pond area continued to shrink, the mixing area for groundwater from the two sources (near well 699-37-47A) became more dominated by groundwater from the northwest that has higher tritium concentration. Since 1998, tritium levels in well 699-37-47A have dropped from 36,000 to 22,000 pCi/L in April of 2000.

Waste sites associated with the PUREX Plant have contaminated groundwater with tritium, nitrate, and iodine-129. These contaminants are very mobile and have moved to the southeast and east, toward the Columbia River. Tritium concentrations declined in most wells within the plume.

The movement of the widespread tritium plume (see Plate 2), extending from the southeast portion of the 200 East Area to the Columbia River, was consistent with patterns noted in fiscal year 1999 (see Section 2.9.2.2 of PNNL-13116). Separate tritium pulses associated with the two periods of PUREX Plant operations contributed to the plume. The first pulse, which resulted from discharges during 1956 to 1972, can be detected near the Columbia River (e.g., well 699-40-1, Figure 2.9-20). Elevated tritium concentrations measured immediately downgradient from the 200 East Area (within the 80,000 pCi/L contour) represent the second pulse associated with the restart of operations between 1983 and 1988. In the area immediately downgradient of the cribs, where concentrations are greater than

200,000 pCi/L, tritium is naturally attenuating as a result of radioactive decay and dispersion combined with the decreasing source that resulted from the termination of operations. Figure 2.9-21 clearly shows the arrival of the plume in early 1987 at well 699-24-33, near the Central Landfill, long after the passage of the plume from the earlier operation. The tritium concentrations in this well during the passage of the first pulse were at least three times the maximum concentrations in the second pulse. Thus, the second pulse is expected to have a significantly lower impact than the first pulse downgradient toward the Columbia River. The overall decline in tritium concentrations throughout this plume indicates that the greatest impact expected at the Columbia River has already occurred.

The zone of lower tritium concentration near Energy Northwest (see Plate 2) 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 ground is discussed in Section 2.12.

2.9.2.3 Iodine-129

The highest iodine-129 concentrations (drinking water standard of 1.0 pCi/L) detected in the 200 East Area in fiscal year 2000 were near the PUREX Plant cribs (see Figures 2.9-22 and 2.1-5). The maximum concentration of iodine-129 detected in fiscal year 2000 was 12.1 pCi/L in 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 well 299-E17-9 (Figure 2.9-23). The iodine-129 plume extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes (see Figures 2.1-3 and 2.1-4).

The portion of the iodine-129 plume that exceeds the drinking water standard is smaller than tritium and has not reached the Columbia River.

2.9.2.4 Nitrate

High nitrate concentrations continued to be found near liquid waste disposal facilities that received effluent from PUREX Plant operations, and the concentrations are deceasing steadily with time. The maximum nitrate concentration detected near the PUREX Plant in fiscal year 2000 was 150 mg/L in well 299-E17-9, which is adjacent to the 216-A-36B crib. The extent of the nitrate plume that originates from the 200 East Area (see Figure 2.1-4) is nearly identical to that of the tritium plume. However, the area with nitrate greater than the 45 mg/L (the maximum contaminant level) is considerably more restricted than the area with tritium above the drinking water standard (20,000 pCi/L). Nitrate at levels above the maximum contaminant level north of the 400 Area, within the area impacted by PUREX operations, is attributable to 400 Area disposal (see Section 2.10.2).

Nitrate originating at the PUREX site forms a broad plume, but most of the plume is below the maximum contaminant level.

2.9.2.5 Strontium-90

A single well (299-E17-14), near the 216-A-36B crib, had a concentration above the drinking water standard (8.0 pCi/L) for strontium-90 (a beta emitter) in fiscal year 2000. The maximum strontium-90 concentration detected in fiscal year 2000 was 19.1 pCi/L, which is slightly higher than the maximum concentration during fiscal year 1999 (17.2 pCi/L). The impact is localized because of the lower mobility of strontium-90 compared to iodine-129, nitrate, and tritium. This result is consistent, in part, with a gross beta (drinking water standard of 50 pCi/L) concentration of 62.5 pCi/L in the same well. Strontium-90 was detected at four other wells near the 216-A-10 and 216-A-36B cribs during fiscal year 2000. The concentrations in these four wells have been stable since 1994.

The 62.5 pCi/L result for gross beta at well 299-E17-14 during fiscal year 2000 is more than can be accounted for from the 19.1 pCi/L result for strontium-90 in the same well. If the only beta emitter present were strontium-90, gross beta would be ~30 pCi/L. Therefore, the 62.5 pCi/L must include another beta emitter. The higher result for gross beta is probably due to technetium-99 (also a beta emitter). The last technetium-99 result from well 299-E17-14 was 209 pCi/L in fiscal year 1994. Technetium-99 is no longer routinely sampled at well 299-E17-14 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.

2.9.2.6 Manganese

Manganese concentrations continued to decrease in fiscal year 2000 in well near the 216-A-37-1 crib in two wells (299-E25-17 and 299-E25-19) after a fiscal year 1998 peak. The concentration increased in early fiscal year 1998 to levels not reached since 1993 and continued to rise throughout the remainder of the year (Figure 2.9-24). The concentration continued to increase to a maximum of 64 µg/L at well 299-E25-19 in October 1998 and then began to decrease. After January 1999, the concentration of manganese remained below the secondary maximum contaminant level (50 µg/L). The source of the increased levels of manganese is unknown but presumed to be the 216-A-37-1 crib because it is not detected at this level in the upgradient well.

2.9.2.7 RCRA Assessment Summary for the PUREX Cribs

Groundwater downgradient of the 216-A-10, 216-A-36B, and 216-A-37-1 cribs continued to be monitored under a groundwater quality assessment program. These cribs and other waste sites not regulated under RCRA all contributed to the widespread tritium, iodine-129, and nitrate plumes.

The PUREX cribs (216-A-10, 216-A-36B, and 216-A-37-1) are monitored in interim status to assess groundwater quality (see Appendix A). Groundwater flow for the two western cribs (216-A-36B and 216-A-37-1) is most likely toward the southeast. The flow rate is difficult to determine because the water table is so flat that the hydraulic gradient is difficult to determine. Similarly, the eastern crib (216-A-37-1) is within the area of a flat water table, and the hydraulic gradient is difficult to determine there also. Formerly, groundwater flowed mainly to the southwest at the 216-A-37-1 crib when the B Pond was in full operation. But with the decreased discharges to the B Pond, the flow may revert to more of a southerly or southeasterly direction.

The 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 PUREX cribs difficult. During fiscal year 2000, the constituents exceeding drinking water standards in at least one well at the PUREX cribs are as follows (see Appendix A, Table A.28):

- gross beta (one well only, 299-E17-14)
- iodine-129
- nitrate
- strontium-90
- tritium.

Although the concentrations of sulfate and chloride do not exceed drinking water standards, they have increased sharply in wells monitoring the PUREX cribs during the period 1998 through 2001. The reason for these rises in sulfate and chloride concentrations is unknown.

The far-field monitoring well network of the PUREX cribs is integrated with the well network for the 200-PO-1 Operable Unit and the site surveillance well network downgradient of the 200 East Area. These well networks monitor the approximate area of the Hanford Site covered by the tritium plume (above 2,000 pCi/L) from the 200 East Area. Besides the tritium plume, this area also contains the iodine-129 and nitrate plumes. The data from RCRA monitoring of the PUREX cribs are integrated into the assessment of the overall extent of contamination for these constituents (Sections 2.9.2.2 through 2.9.2.6).

2.9.2.8 RCRA Parameters for Waste Management Area A-AX

RCRA Waste Management Area A contains single-shell tank farms. Monitoring data in fiscal year 2000 did not indicate any impact to groundwater.

This section provides information on the current nature of unconfined groundwater in the immediate vicinity of Waste Management Area A-AX. The most recent description of stratigraphy for this site can be found in PNNL-13023. Waste Management Area A-AX is regulated under RCRA, and groundwater monitoring is under interim status, indicator-evaluation requirements (WAC 173-303 and by reference 40 CFR 265.92). RCRA monitoring began in 1992.

Groundwater Flow

The interpretation of groundwater flow direction or rate has not changed since fiscal year 1999. A flat water table in the vicinity of Waste Management Area A-AX coupled with suspected errors in multiple elevation surveys and borehole deviations in monitoring wells causes uncertainty in interpreting the rate and direction of groundwater flow. However, the well hydrographs suggest an easterly flow direction in the vicinity of Waste Management Area A-AX (Figure 2.9-25). Wells located to the west tend to show higher water-table elevations than those east of the site (see Appendix A, Figure A.13).

The estimated flow rate at Waste Management Area A-AX is 1 to 2 meters per day (see Appendix A, Table A.2) depending on hydraulic conductivity value used in the Darcy equation. Using these estimates of flow rate, the average distance of groundwater flow at the site is 376 to 719 meters per year, reflecting the highly transmissive sediment in the aquifer.

The existing well network at Waste Management Area A-AX was designed for a southwest groundwater flow. Because more recent interpretations suggest that the flow direction has changed to a more easterly direction (see Section 2.9.1.1), the well network will have to be changed.

Groundwater Chemistry

Concentrations of indicator parameters have not exceeded the critical means at Waste Management Area A-AX since 1992. Groundwater monitoring to date provides no evidence that the site has contaminated groundwater.

Specific conductance values generally ranged from 257 to 340 μS/cm during fiscal year 2000 (Figure 2.9-26), reflecting changes in sulfate and nitrate concentrations. These values are well below the critical mean of 534.9 μS/cm. Figures 2.9-27 and 2.9-28 show trend plots for sulfate and nitrate, comparing contaminant levels in selected RCRA groundwater monitoring wells. The specific conductance changes that occurred at Waste Management Area A-AX are generally dominated by sulfate except for well 299-E24-20. For most of the wells, sulfate (maximum contaminant level 250 mg/L) concentration ranges from 34 to 38 mg/L, which is close to the Hanford Site background values reported in WHC-EP-0595 (~14 to 60 mg/L). Sulfate concentrations above background values were identified in two wells, 299-E25-40 and 299-E25-41, where values reach ~72 mg/L.

Nitrate values currently range from ~4 to 12 mg/L, which falls within the ranges of background values of 3 to 12 mg/L for the Hanford Site (WHC-EP-0595) except for one well. Nitrate concentrations in well 299-E24-20 are ~38 mg/L, which is above the maximum background value of 12 mg/L (see Figure 2.9-28). This well is located south of the 244-AR vault. Nitrate values rose from 6 mg/L in February 1996 to 38 mg/L in June 2000. Although there is no elevated technetium-99 associated with this increase in nitrate, there is a distinct correlation with tritium (Figure 2.9-29). Values rose from ~7,200 pCi/L in June 1999 to ~9,200 pCi/L in February 2000. Most tritium values at the waste management area range from 3,300 to 5,300 pCi/L. The drinking water standards for tritium and nitrate are 20,000 pCi/L and 45 mg/L, respectively. Without more complete knowledge of the local direction of groundwater flow, it is not possible to speculate on the source of this isolated, elevated nitrate. However, nitrate concentrations were above 60 mg/L in early 1992. The current elevated nitrate may be this same pocket of nitrate moving back through the well.

One well monitored for Waste Management Area A-AX appears to have a corroding screen, which increases concentrations of chromium, nickel, and manganese in groundwater samples.

In a filtered sample from well 299-E24-19, chromium was detected at a new maximum of 3,250 µg/L in February 2000 (Figure 2.9-30). This well historically has high concentrations of chromium, nickel, and manganese. The maximum contaminant level for these metals are 100 µg/L for chromium and nickel and 50 µg/L for manganese. Color changes (green and yellow) in the sampled groundwater are frequently reported at the well site during sampling. Because there are no other constituents associated with the groundwater at this well, and the change in color occurs during well purging, it is likely that the elevated metals concentration is a result of screen corrosion.

To test the well corrosion theory, special sampling was conducted in June 2000 sampling event to investigate the change in color versus the chromium content. A plot of the data is shown in Figure 2.9-31. The results show, as purging began, the chromium content rapidly elevated to a maximum of 4,200 µg/L between 8.5 and 9 minutes. The sample's yellow color increased in intensity with the brightest or most intense yellow corresponding with the maximum chromium content. As the purge continued, the concentration of chromium sharply declined. If the chromium flowed with the groundwater over an extended distance from the well screen, the chromium content would not have decreased as the purge progressed. This study provides further support for the premise that the elevated metals historically found in the groundwater at this well are related to corrosion of the screen. Further studies are planned including testing of an alternate hypothesis where, under short purging conditions, the chromium enters the well from a small or limited area, but with extended purges, chromium is pulled in from other producing zones.

Technetium-99 concentrations (drinking water standard 900 pCi/L) remained low during fiscal year 2000, with the high at 72.9 pCi/L at well 299-E25-41. There does not appear to be any correlation of technetium-99 with other contaminants in the area.

2.9.2.9 RCRA Parameters for Waste Management Area C

RCRA Waste Management Area C contains single-shell tank farms. Monitoring data in fiscal year 2000 did not indicate any impact to groundwater with dangerous waste constituents.

This section provides information on the nature of the uppermost aquifer (unconfined) in the immediate vicinity of Waste Management Area C. Waste Management Area C is regulated under the RCRA, and groundwater monitoring is under interim status, indicator-parameter evaluation requirements (WAC 173-303 and by reference 40 CFR 265.92). RCRA monitoring to date provides no evidence that Waste Management Area C has contaminated groundwater.

Groundwater Flow

Figure 2.9-32 shows hydrographs for four of the five wells at Waste Management Area C used to monitor the water table. Water-table elevations at well 299-E27-7 are generally higher (upgradient), lower at well 299-E27-13 (downgradient), and intermediate at wells 299-E27-12 and 299-E27-14 (see Appendix A, Figure A.13 for well locations). These hydrographs suggest that the flow direction is toward the southwest, which is consistent with the regional water-table map (Plate 1). The hydrograph for the fifth well (299-E27-15) was not shown because the well is suspected of deviating from vertical causing erroneous depth-to-water measurements.

The existing groundwater monitoring well network was designed to sample groundwater flow toward the west (WHC-SD-EN-AP-012). However, the monitoring plan for this site has recently been revised (PNNL-13024) and recommends flow meter studies to help confirm the rate and direction of groundwater flow. If the flow direction is found to be other than southwest or west, the well network will be redesigned to accommodate the revised flow direction.

Average groundwater flow rates calculated using the Darcy equation range from 0.7 to 1.3 meters per day (see Appendix A, Table A.2). The flow rate is equal to 267 to 534 meters per year.

Currently, the aquifer thickness penetrated in WAC 173-160 compliant wells at the Waste Management Area C ranges from 2.4 to 3.2 meters. Well 299-E27-7, which is not WAC 173-160 compliant, is open over an interval of 14.3 meters. The rate of water table decline beneath Waste Management Area C increased from 0.09 meter per year in June 1997 to ~0.3 meter per year in March 1999. If this rate continues, downgradient well 299-E27-13 may go dry in six or seven years because its well screen penetrates less than 3 meters of aquifer.

Groundwater Chemistry

During fiscal year 2000, critical means (or range for pH) were not exceeded for the four indicator parameters pH, electrical conductivity, total organic carbon, and total organic halides). However, there have been small increases in some contaminant levels in recent years (1994 to 1999).

Technetium-99 (drinking water standard 900 pCi/L) concentrations have increased in all wells at Waste Management Area C since 1997. The greatest increase was detected in well 299-E27-14 (Figure 2.9-33), which had a maximum value of 709 pCi/L in December 1999. The increase in technetium-99 seems to correspond to rising chloride, nitrate, sodium, and sulfate concentrations in Waste Management Area C wells. However, the nitrate and sodium levels rose only through June 1999 in well 299-E27-14 (Figure 2.9-34). After September 1999, they began to decrease. These changes in concentration levels may be due to chemical differences within a larger, regional plume.

Groundwater monitoring during and after sluicing waste from tank C-106 did not indicate any leakage from the sluicing activities.

From November 1998 to October 1999, sluicing operations were performed in tank C-106. Before, during, and after the in-tank sluicing, Waste Management Area C network wells were temporarily monitored monthly and later bi-monthly to provide additional coverage to increase the ability to detect a leak related to sluicing operations. The period of sluicing (November 1998 to October 1999) is marked in Figure 2.9-33 by the two vertical lines. As can be seen, technetium-99 began rising in well 299-E27-14 prior to the sluicing operations, so it is unlikely that the sluicing operations are responsible for the rise in technetium-99. During the sluicing, the vadose zone was monitored also, and leakage was not detected.

Specific conductance has risen to levels as high as 400 µS/cm in wells 299-E27-7 and 299-E27-14 (Figure 2.9-35). This rise in specific conductance may be due to general increases in levels of ionic chemistry. Well 299-E27-7 recently has begun to show low levels of cyanide at 15 µg/L. Scavenging with ferrocyanide occurred in tanks at Waste Management Area C. Well 299-E27-7 is still considered an upgradient well. It is unclear if well 299-E27-14 is upgradient or cross gradient. It may be necessary to recalculate the specific conductance critical mean for this site, which is currently 553.5 µS/cm, because there is an upgradient source causing an increase in specific conductance.

There does not appear to be other tank-related waste in the groundwater at Waste Management Area C. Tritium levels are low, generally less than 1,500 pCi/L, except at well 299-E27-7 where values rose from about 600 to 2,500 pCi/L during the late 1990s. Currently, the trend remains steady near 2,480 pCi/L.

2.9.2.10 RCRA Parameters for the 216-A-29 Ditch

RCRA groundwater monitoring at the 216-A-29 ditch in fiscal year 2000 showed no evidence of contamination from the site.

The 216-A-29 ditch is a RCRA disposal facility in the 200 East Area, which is monitored under an interim status detection program (40 CFR 265 Subpart F; WAC 173-303-400[3]). To date, there is no evidence that the site has contaminated groundwater with regulated constituents. At one time, the site was in assessment monitoring status because of high specific conductance, which was caused by sulfate from the site. However, sulfate is non-hazardous. With time, sulfate and specific conductance returned to lower levels, and the site returned to detection monitoring.

The direction of groundwater flow beneath the ditch is west-southwest (S60°W), based on tritium and nitrate plume maps (Plates 2 and Figure 2.1-4, respectively) and on water-level elevations in the monitoring wells. The tritium plume map (see Plate 2) shows that the flow direction swings to the southeast as groundwater flows to the southeast corner of the 200 East Area. The calculated gradient is ~0.0004 for the entire length of the ditch and the flow rate is ~0.03 to ~0.09 meter per day (see Appendix A, Table A.2). This estimate of flow rate is lower than the nearby Waste Management Areas A-AX and C because of the much lower estimate of hydraulic conductivity.

The water table beneath the ditch has steadily declined since discharges to the B Pond system were terminated. Figure 2.9-36 shows the water levels are continuing to decline in wells monitoring the head and discharge ends of the ditch. The change in water-table elevation resulted in a flattened water table at the head end of the ditch and a drop in gradient at the discharge end.

There were no exceedances of contaminant indicator parameters during fiscal year 2000. Water-level measurements were taken during routine sampling throughout the year. Although groundwater levels continue to decline regionally, there is sufficient water in network wells for groundwater monitoring purposes.

2.9.2.11 RCRA Parameters for B Pond

RCRA groundwater monitoring at B Pond in fiscal year 2000 showed no evidence of contamination from the site.

An interim status RCRA facility, the B Pond system originally consisted of a main pond, three expansion ponds, and portions of several ditches leading to the main pond (see Figure 2.9-1 and Appendix A, Figure A.16). Currently, only the main pond and an adjacent portion of the 216-B-3-3 ditch are regulated as a RCRA treatment, storage, and disposal facility.

The B Pond system was placed into assessment in 1990 because of elevated total organic carbon and total organic halides in groundwater from two wells. Following the initial excursion, occurrences of elevated results for total organic carbon and total organic halides were isolated and generally declining with time. Groundwater quality assessment that concluded in 1996 (PNNL-11604) determined that no specific compounds could be identified in sufficient concentration or with consistency that would allow correlation to elevated total organic carbon and total organic halides.

The groundwater monitoring well network in this area was more extensive in the past when groundwater was interpreted to flow “radially” away from the facility, and the now clean-closed expansion ponds were still part of the regulated facility. The entire historical network and fiscal year 2000 network is shown in Appendix A, Figure A.16. In March 2000, changes in the well network were made to accommodate changes in the water table and potential groundwater flow directions.

Groundwater Flow

Groundwater flow beneath the B Pond, which was historically described as “radial,” has now become less defined. Currently, flow appears to be from northeast to southwest across the main pond, and is changing rapidly because of declines in the water table and the shifting patterns of drainage in the aquifer.

In fiscal year 2000, groundwater flow rate was estimated at 0.01 to 7.7 meters per day (Appendix A, Table A.2). This range in flow velocities reflects the significant differences in hydraulic conductivities between the relatively permeable Hanford formation gravel and sand, and the less conductive Ringold Formation sediment.

Actual flow may be extremely limited in a southeastern direction (toward the Treated Effluent Disposal Facility) as indicated by tritium concentrations and ionic balances in groundwater in this area (Figure 2.9-37). Tritium concentrations in this area are well below background levels for surface water (e.g., Columbia River) and the unconfined aquifer elsewhere (less than 9 pCi/L in fiscal year 2000). Major ion proportions, which are sodium bicarbonate dominated, also indicate a more highly evolved groundwater chemistry than typical for the unconfined Ringold aquifer. These two circumstances suggest groundwater in this area is very “old” and was virtually unaffected by B Pond discharges; hence, flow in this direction is limited.

Groundwater is considered to flow more readily southwestward out of the confined portions of the aquifer into unconfined Hanford formation aquifer beneath the southwest extremity of the main pond and the 216-B-3-3 ditch (see Figure 2.9-16 and Section 2.9.4). This groundwater then encounters a highly conductive northwest-southeast channel in the Hanford formation gravel and flows southeastward, eventually flowing over the top of the same layer (Ringold lower mud unit) that confines groundwater in the east and southeast portions of the B Pond facility. This is possible because the strata dip south in this area.

A downward gradient is indicated between shallow and deep well pairs in the network. Head measurements from March 2000 indicated a downward-directed gradient of 0.03 and 0.04 in well pairs 699-42-42B/699-43-42J and 699-43-41E/699-43-41G, respectively (see Appendix A, Figure A.16). The downward potential is most likely a result of the groundwater mound beneath the facility.

Wells continue to go dry in the monitoring network at B Pond because of the subsiding effects of historical discharges. Some wells are predicted to have less than 3 years of life. Wells that might have been useful in the current network, such as 699-44-43B and 699-44-42, are already unusable. The rate of water level decline has slowed, however, since 1998.

Groundwater Quality

Chemical parameters sought in B Pond groundwater analyses, which represent both site-specific concerns and regulatory requirements, are listed in Appendix A, Table A.29.

Results for total organic halides, total organic carbon, pH, and conductivity are compared semiannually with calculated background critical means. Because the critical means are below the limits of quantitation for total organic halides and total organic carbon, results from downgradient wells are compared to the limits of quantitation. No critical means or limits of quantitation were exceeded by results in downgradient B Pond wells during fiscal year 2000.

Nitrate displays upward trends in some wells (Figure 2.9-38), but concentrations are all well below the drinking water standard, and most are near or below Hanford Site background as calculated by DOE/RL-96-61. The wells shown in Figure 2.9-38 are still monitored periodically by site-wide groundwater surveillance.

Specific conductance in some wells (Figure 2.9-39) also displayed a recent recovery. This recovery is interpreted as groundwater returning to equilibrium with the aquifer solids. Past discharges at B Pond mostly diluted the groundwater, artificially depressing specific conductance. This parameter remains below Hanford Site-wide background levels for groundwater in several B Pond wells.

Samples are taken for the radionuclide indicators gross alpha and gross beta because some radionuclides may reside in the soil or groundwater beneath the facility. No trends are apparent in any wells in the B Pond network sampled for these parameters.

Arsenic, iodine-129, nitrate, and tritium are considered of slight potential concern in the B Pond area, but are part of broader Hanford Site-wide groundwater contamination in the same area. Hence, analyses for these parameters are deferred to site-wide surveillance sampling in the appropriate B Pond wells.

A "contained-in" analysis for hydrazine in groundwater is now underway to determine if this U.S. Environmental Protection Agency (EPA)-listed waste is present in groundwater in the B Pond region. Since monitoring began at B Pond, only one result for hydrazine has been definitively above detection in analyses of groundwater. This was a result of 36 µg/L in well 699-42-40B in December 1989. Hydrazine is highly unstable in oxidizing environments, and it is unlikely that any detectable quantities remain. The evaluation of this constituent is not expected to have an effect on groundwater monitoring strategy at B Pond.

Soil analyses for radionuclides and hazardous constituents concluded in early fiscal year 2000 revealed only slight contamination in the soil beneath the main pond and 216-B-3-3 ditch (BHI-01367). The results of this investigation indicate that cadmium, cesium-137, copper, lead, mercury, silver, and strontium-90 are present in concentrations marginally above background in soil beneath the main pond and 216-B-3-3 ditch. However, historical concentrations of these constituents (or their indicators) in groundwater have been, with few exceptions, below detection or Hanford Site background levels.

2.9.2.12 RCRA Parameters for the Liquid Effluent Retention Facility

RCRA groundwater monitoring at the Liquid Effluent Retention Facility indicates the site has not affected groundwater. The unconfined aquifer is thinning in the area, and effective groundwater monitoring is no longer possible.

Groundwater monitoring at the Liquid Effluent Retention Facility has been guided by the conditions set forth by the operating permit. 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. A variance was granted by the Washington State Department of Ecology (Ecology) 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. Ecology has suspended groundwater monitoring statistical analyses at the Liquid Effluent Retention Facility effective January 14, 2001.

The direction of groundwater flow beneath the facility is generally to the southwest, based on regional water-table contours (Plate 1).

Groundwater monitoring shows no evidence that regulated groundwater constituents from the Liquid Effluent Retention Facility have entered the groundwater.

Two additional exceedances of the critical mean for specific conductance were identified during the reporting period. The first exceedance involved wells 299-E35-2 and 299-E26-10. The second exceedance involved only well 299-E26-10. The elevations were identified in the past and were associated with an increasing trend in specific conductance in all downgradient wells. The exact nature of the elevation is unknown, but there is speculation that decreasing effluent discharges to B Pond and a return to natural groundwater conditions may be factors. The lack of elevated tritium concentrations in the downgradient wells supports the conclusion that the Liquid Effluent Retention Facility is not the source of the increase. Tritium has been a principle component of effluent stored in the Liquid Effluent Retention Facility basins. Also, the rise in specific conductance concentration began before the basins stored waste.

2.9.2.13 200 Areas Treated Effluent Disposal Facility

Located southeast of the B Pond RCRA site, the 200 Areas Treated Effluent Disposal Facility has been in operation since June 1995. Groundwater monitoring beneath the facility began in late 1992, initially as an unofficial part of the B Pond RCRA monitoring. Three wells were installed in 1992 for the express purpose of monitoring groundwater at the Treated Effluent Disposal Facility (see Appendix A, Figure A.16).

The state waste discharge permit (ST-4502), which sets discharge and groundwater monitoring parameters, was revised in May 2000, and extends the operating period through May 18, 2005. A revised groundwater monitoring plan (PNNL-13032) accompanies this renewed permit.

Discharges originate from the 200 Areas facilities and consist of clean water and Columbia River water. During fiscal year 2000, ~514 million liters of effluent were discharged to the Treated Effluent Disposal Facility.

The three monitoring wells at the Treated Effluent Disposal Facility (see Appendix A, Figure A.16) are sampled quarterly for a list of constituents specified by the state waste discharge permit (see Appendix A, Table A.41).

The Ringold confined aquifer (uppermost aquifer), which consists of Ringold units 9A-9C (PNNL-12261), is ~35 meters thick beneath the Treated Effluent Disposal Facility (see Section 2.9.4). Groundwater occurs under confining pressure in the uppermost aquifer beneath the Treated Effluent Disposal Facility. The confining unit consists of the Ringold Formation unit 8 (lower mud unit), which is ~26 meters thick near well 699-40-36. Effluent from the Treated Effluent Disposal Facility flows readily downward through the unsaturated Hanford formation gravel, and is then diverted from the uppermost aquifer by the relatively-impermeable lower mud unit silt and clay stratum. The effluent is thought to then flow generally south along the top of this unit before entering the unconfined Hanford formation aquifer some distance south of the Treated Effluent Disposal Facility.

Since late 1995, hydrographs of the Treated Effluent Disposal Facility wells (Figure 2.9-40) reveal only the continuing decline in hydrostatic pressure from the discontinuation of B Pond discharges. Upgradient well 699-43-37 has experienced the most pronounced decline, probably because of its proximity to the source of the B Pond hydraulic mound. No obvious features in the hydrographs can be related to Treated Effluent Disposal Facility operation, which began in April 1995.

The direction of groundwater flow, or the potential for flow beneath the Treated Effluent Disposal Facility in the confined Ringold aquifer, is south-southwest. Calculations of groundwater flow rate (see Appendix A, Table A.2) from March 2000 measurements, indicate an average linear flow velocity of ~0.004 meter per day. However, groundwater chemistry and recent hydrostratigraphic research suggest that actual flow may be at a very low rate (see Section 2.9.4). Major ion proportions and tritium concentrations of less than 9.0 pCi/L in this aquifer near Treated Effluent Disposal Facility and eastern portions of B Pond (see Figure 2.9-37) support this inference. The results of monitoring suggest that groundwater has been isolated from Hanford Site influences and may be relatively old compared with groundwater elsewhere in the uppermost aquifer.

The results of monitoring at the Treated Effluent Disposal Facility indicate that groundwater has been isolated from Hanford Site influences.

A list of six constituents are evaluated quarterly and compared with permit enforcement limits. No enforcement limits were exceeded during fiscal year 2000. In fact, none of these parameters have exceeded enforcement limits or practical quantitation limits since monitoring of Treated Effluent Disposal Facility wells began in 1992 (2+ years prior to operation). Most results for anions, metals, and radionuclide indicators have been near or below Hanford Site-wide background levels calculated by WHC-EP-0595 and DOE/RL-96-61.

Because there was no unconfined aquifer beneath the facility before operation began, wells were installed in the confined Ringold aquifer, even though they are isolated from the effects of operation. Hence, the objective of groundwater monitoring at the Treated Effluent Disposal Facility is to demonstrate that the uppermost aquifer remains unaffected by discharges to the facility.

2.9.3 Gable Mountain Pond (216-A-25 Pond)

Gable Mountain Pond is located in the area between the 200 East Area and Gable Mountain. Beneath the south portion of the pond, basalt bedrock is above the water table. Beneath the north portion of the pond, the groundwater flow direction is probably to the west based on the water-table map.

The former Gable Mountain Pond contaminated groundwater north of the 200 East Area with strontium-90 and nitrate.

Between July 1999 and January 2000, contamination was characterized at Gable Mountain Pond as part of the 200-CW-1 Operable Unit remedial investigation (BHI-01367). The results of the vadose zone characterization are summarized in Section 3.1.4. Although significant amounts of cesium-137 and strontium-90 were detected in vadose zone sediment, the cesium-137 remains higher in the profile and strontium-90 is the most significant groundwater contaminant. The drinking water standard for strontium-90 is 8.0 pCi/L and the DOE derived concentration guide is 1,000 pCi/L. Strontium-90 in the Gable Mountain Pond area apparently resulted from the discharge of waste to that pond during its early use. Wells completed above the basalt in the vicinity of this pond are becoming difficult to sample because of declining water levels.

Strontium-90 concentrations reversed a rising trend over the last few years in several wells near Gable Mountain Pond. Strontium-90 was detected in groundwater at levels above the DOE derived concentration guide in one well in fiscal year 2000 (Figure 2.9-41). The concentration in the sample from that well, 699-53-47A was 1,210 pCi/L, considerably higher than the 1999 sample, although concentrations were also above the DOE derived concentration guide in 1997 and 1998 (Figure 2.9-42).

Nitrate continued to be detected in wells monitoring Gable Mountain Pond at levels above the maximum contaminant level in fiscal year 2000 (see Figure 2.9-10). Well 699-53-47A contained 106 mg/L of nitrate, which was the maximum detected in Gable Mountain Pond vicinity. In fiscal year 1999, 402 mg/L of nitrate was detected in well 699-53-48B, which was not sampled this year.

2.9.4 Confined Aquifer in the Lower Ringold Formation

PNNL-10886 subdivided the Ringold Formation into six hydrogeologic units (units 4 through 9). The Ringold Formation confined aquifer consists of the lowermost hydrogeologic unit (unit 9), which consists of fluvial sand and gravel overlying the uppermost basalt flow. It is confined by hydrogeologic unit 8, also referred to as the lower mud sequence, which is the thickest and most laterally continuous mud unit beneath the Hanford Site. The base of the aquifer is the dense interior of the uppermost basalt flow. Previous studies have often included portions of the Ringold confined aquifer when describing and mapping the unconfined aquifer. Interpretations prior to 1999 generally did not differentiate these aquifers and did not attempt to distinguish the groundwater results (i.e., contaminant-plume and potentiometric-surface mapping) for the separate aquifers. Recent re-evaluation of hydrostratigraphy in the 200 East Area and vicinity attempt to refine the interrelationships between confined and unconfined aquifers, and explain nuances in groundwater chemistry between these two systems (PNNL-12261).

An aquifer confined beneath mud units in the Ringold Formation is present near the 200 East Area. Groundwater flow in this area is influenced by a recharge mound related to past discharges to B Pond.

The Ringold confined aquifer is known to be in communication with the unconfined aquifer in the 200 East Area, where they are adjacent to the unconformity created by erosion and subsequent deposition of the Hanford formation (PNNL-12261). Currently, there is no monitoring network designed specifically to monitor conditions within the Ringold confined aquifer. Most of the wells that monitor the Ringold confined aquifer are located east and south of 200 East Area. Therefore, this section focuses on that region.

2.9.4.1 Groundwater Flow

The groundwater project has constructed a preliminary potentiometric surface for a portion of the confined aquifer in the Ringold Formation (see Figure 2.9-17). This map is incomplete and subject to uncertainty because only a few wells are monitored within 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. In the central portion of the aquifer, groundwater flow is to the northeast. In addition, a groundwater mound is present northeast of B Pond as a remnant of past wastewater discharges to this facility. This mound causes groundwater to flow southwest beneath B Pond. A stagnation point is believed to exist to the south of B Pond, where the groundwater flow divides and flows toward the 200 East Area and toward the east. Therefore, groundwater flow converges on the 200 East Area where the confining mud unit (unit 8) is absent, and flow discharges to the unconfined aquifer. After discharging to the unconfined (mostly Hanford formation) aquifer to the southwest of the B Pond system (see Section 2.9.2.11), groundwater from the confined Ringold Formation is interpreted to flow generally southeastward, eventually flowing over the top of the same unit (Ringold lower mud) that confines groundwater near the Treated Effluent Disposal Facility and B Pond area. This is possible because of the southerly dip of the suprabasalt strata.

With the exception of the area immediately around B Pond, there appears to be an upward gradient between unit 9 and the Hanford formation near the 200 East Area in a region where the confining unit (unit 8) is absent (Figure 2.9-43*).* Well 299-E25-28 is completed within hydrogeologic unit 9 of the Ringold Formation (below the water table), and well 299-E25-34 is completed across the water table within the overlying Hanford formation (unit 1). This figure shows that hydraulic heads are apparently slightly higher in well 299-E25-28, and supports the inference that groundwater discharging from the confined aquifer in the vicinity of the 200 East Area may recharge the overlying unconfined aquifer.

The contours on Figure 2.9-17 are similar to the potentiometric surface for the upper basalt-confined aquifer (see Section 2.14). Hydraulic head and flow patterns in the central portion of the Hanford Site are very similar in both aquifers. Hydraulic heads differ in the western portion of the aquifers (~3 to 4 meters of head difference in the northern part of the 200 West Area) where a downward hydraulic gradient exists. Hydraulic heads are also interpreted to diverge to the east, and an upward hydraulic gradient is expected in the vicinity of the Columbia River.

Water levels over much of this aquifer declined during the period from March 1999 to March/April 2000, except for along the southern boundary where water levels increased slightly. These changes are similar to the water-level changes in the overlying unconfined aquifer (see Section 2.1.1.2). The declining water levels are due to the near cessation of wastewater disposal to the soil column at Hanford, while the increases along the south boundary are due to increased recharge from the elevated areas west and southwest of the site.

2.9.4.2 Contaminant Distribution

Most of the available chemical data from the Ringold confined aquifer are from wells on the 200 Areas plateau. This is believed to be the only area where contamination can migrate from the unconfined aquifer into the confined aquifer. However, groundwater chemistry data for the Ringold confined aquifer are limited because of the lack of well completions in the aquifer.

Tritium concentrations are elevated in the Ringold confined aquifer. The contaminated water flows to the southwest where it rejoins the unconfined aquifer.

The primary factors contributing to the observed groundwater chemistry are the hydrostratigraphy and groundwater flow patterns. The ion chemistry and tritium concentrations corroborate the interpretation of groundwater flow described in Section 2.9.2.13. Because groundwater flow in the unconfined aquifer is isolated from flow in the Ringold confined aquifer (except within the erosional unconformity), the groundwater chemistry must be evaluated for each aquifer independently.

Figure 2.9-37 illustrates proportions of major dissolved ions and shows the extent of tritium penetration into the confined aquifer east of the 200 East Area. The figure illustrates that groundwater chemistry correlates with groundwater flow paths in the unconfined aquifer and in the Ringold confined aquifer (unit 9). The major ion chemistry of groundwater in the Ringold confined aquifer, adjacent to the aquifer juncture, is of the calcium-bicarbonate type and has elevated tritium activities similar to groundwater in the unconfined aquifer (see Figure 2.9-37). South and east of B Pond toward the May Junction Fault, groundwater in the Ringold confined aquifer has lower tritium concentrations and is of the sodium-bicarbonate type. Tritium concentrations and other chemical data (see PNNL-13032) indicate that groundwater in the Ringold confined aquifer has not been displaced or diluted by wastewater associated with 200 East Area operations.

Tritium was present in discharges to B Pond, which is located directly above the erosional juncture that allows communication between the unconfined and confined aquifers. During active disposal, groundwater mounding increased the driving head and forced groundwater and any associated contamination into the confined aquifer. The groundwater moved laterally within the confined aquifer as long as the head remained high from the overlying groundwater mound. When disposal to B Pond decreased in the late 1980s and then ceased in 1997, water levels and tritium concentrations in the unconfined aquifer decreased significantly. In the case of tritium, decay has contributed significantly to the decline in concentrations. The reduced head has created an upward gradient between the confined and unconfined aquifers. Horizontal flow is toward the southwest, so the high concentrations of tritium in the confined aquifer are expected to move toward the unconfined aquifer.

2.9.5 Water Quality at Shoreline Monitoring Locations (Old Hanford Townsite)

Groundwater from the 200 East Area flows to the southeast and east, eventually discharging to the Columbia River. One of the major discharge areas is the old Hanford Townsite. Fiscal year 2000 samples from riverbank seeps contained tritium at levels above the drinking water standard and had low levels of technetium-99 and iodine-129. All contaminants in river samples were below drinking water standards.

The major plumes of groundwater contamination (tritium, nitrate, and iodine-129) from the 200 East Area enter the Columbia River at the old Hanford Townsite and elsewhere along the Columbia River to the south. Because of this known groundwater contamination entering the Columbia River along this stretch, groundwater samples are collected annually from riverbank seepage sites and aquifer sampling tubes located near the shoreline during the seasonal low river stage, which occurs during the fall months. Riverbank seepage is monitored by the Surface Environmental Surveillance Project and aquifer tubes are monitored under the Environmental Restoration Project, the latter in support of groundwater operable unit investigations. Three seepage sites were sampled during fiscal year 1999; no aquifer tubes were sampled. Table 2.9-1 lists the analytical results for key constituents for samples collected from riverbank seepage and from nearshore river water along the old Hanford Townsite shoreline. There are no known local sources for these key constituents, which are believed to have migrated to the old Hanford Townsite area from the 200 East Area (PNL-8167).

The samples from riverbank seepage had a specific conductance of 345 to 408 µS/cm, indicating that the samples were primarily groundwater, with little dilution by river water in bank storage. The three seepage sites are located near Hanford River Marker #28, with the closest groundwater monitoring wells being 699-45-2, 699-44-4, and 699-46-2. These seepage sites have been monitored for numerous years and have revealed increasing concentration trends for gross beta, tritium, technetium-99, and iodine-129 since 1994 (PNNL-13230). The increasing trends are not reflected in nearby groundwater monitoring wells, where concentrations for these constituents have remained relatively constant or declined in recent years (see Figure 2.9-20).

Gross beta measurements in the seeps range between 22 and 49 pCi/L, which is slightly below the 50-pCi/L drinking water standard. Technetium-99 and iodine-129 are detected in the samples, but at very low concentrations. Tritium is present in the 75,000 to 106,000 pCi/L range, which is above the 20,000 pCi/L drinking water standard. These concentrations are consistent with the groundwater plume that reaches the river along this shoreline. Nearshore river water samples show low concentrations, which are several orders of magnitude below groundwater concentrations. Nitrate in seepage is in the range 22 to 36 mg/L, again, well below the 45 mg/L drinking water standard.

Table 2.9-1. Analytical Results for Key Constituents Collected from Riverbank Seepage and from Nearshore Columbia River Water

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)
SHTS-UR28-2	Seep	01-Nov-99	358		57.4	21.9	75,000	0.41	22.1
SHTS-28-2	Seep	01-Nov-99	408		120.0	48.6	106,000	0.23	35.8
SHTS-DR28-2	Seep	01-Nov-99	345		88.0	26.9	86,100	0.17	29.6
RHTS-260	River	21-Sep-99	118	0.06			28		0.3
RHTS-270	River	21-Sep-99	118	0.09			30		0.3
RHTS-287	River	21-Sep-99	117	0.06			46		0.3
RHTS-290	River	21-Sep-99	117	0.06			51		0.3
RHTS-300	River	21-Sep-99	119	***0.06***			33		0.3

The numbers in the location name refer to Hanford River Marker locations (e.g., RHTS-260 indicates nearshore river water at marker location 26.0).
Seep = Natural riverbank seepage site.
River = River water collected near the shore.
Values in ***bold italics*** are qualified by the laboratory as "undetected." Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350-450 µS/cm.
Data sources: Hanford Environmental Information System and various project records.

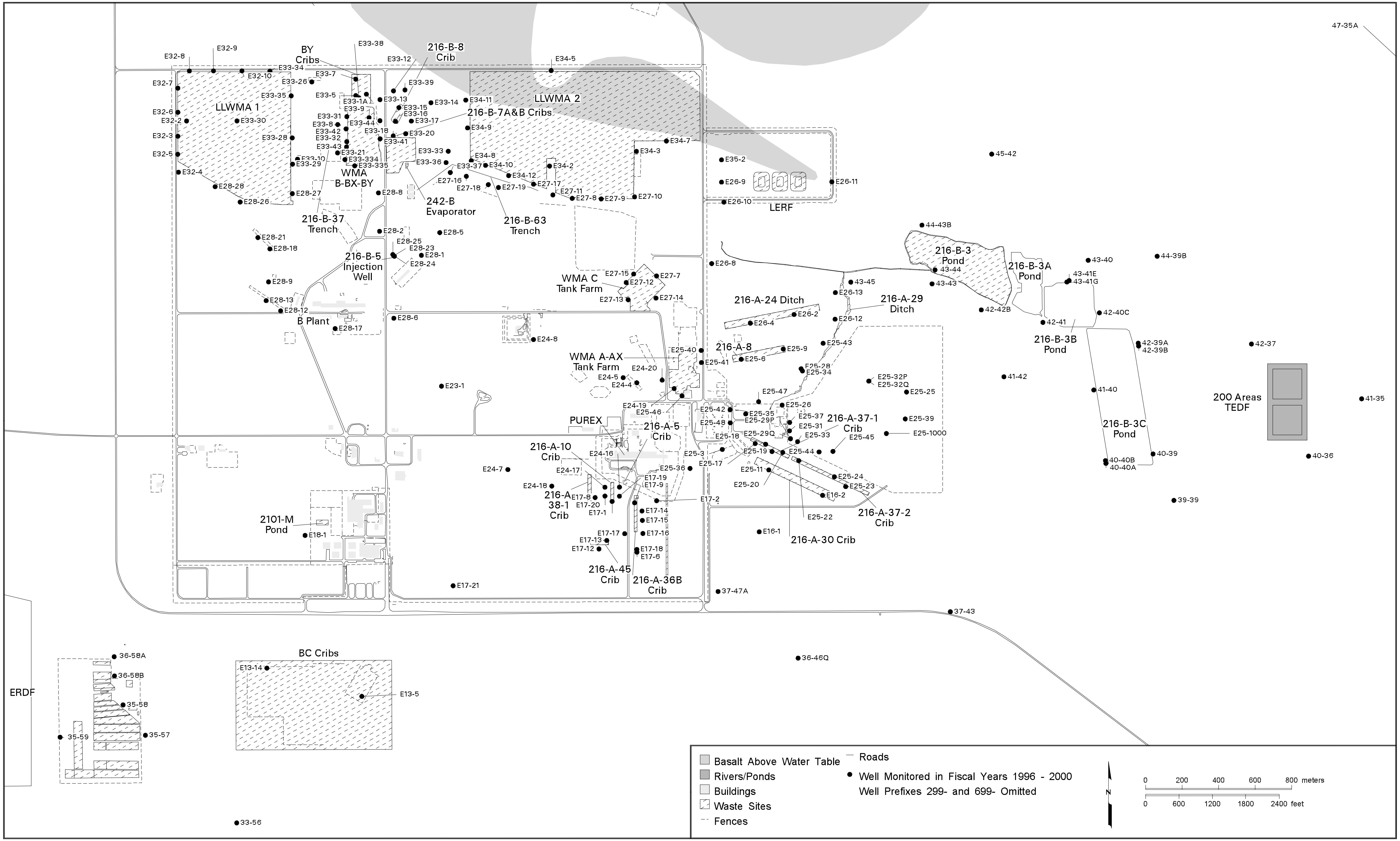

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Figure 2.9-1. Groundwater Monitoring Wells in the 200 East Area

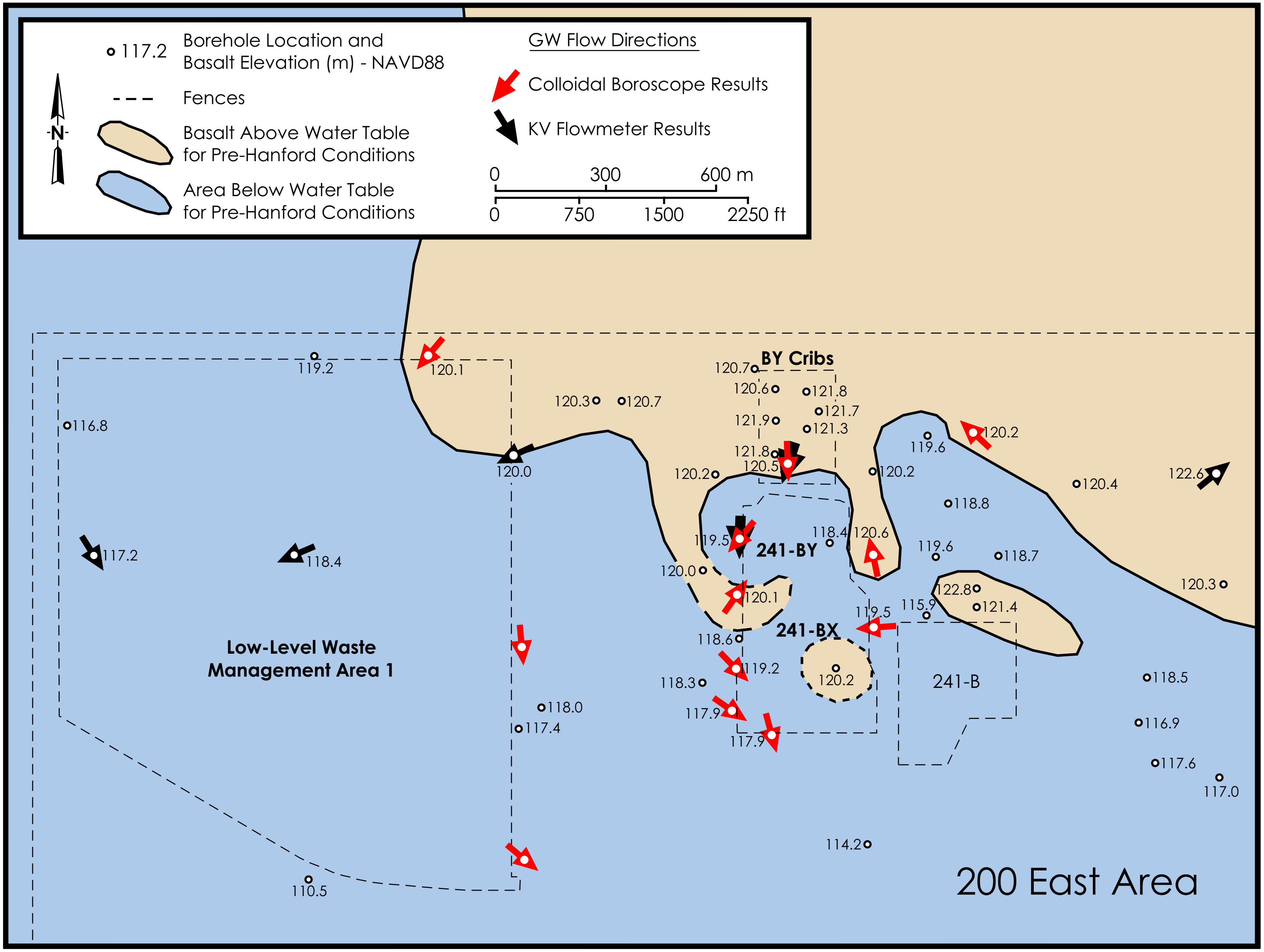

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Figure 2.9-2. Groundwater Flow Directions in the Northern 200 East Area, Based on Flow Meter Studies

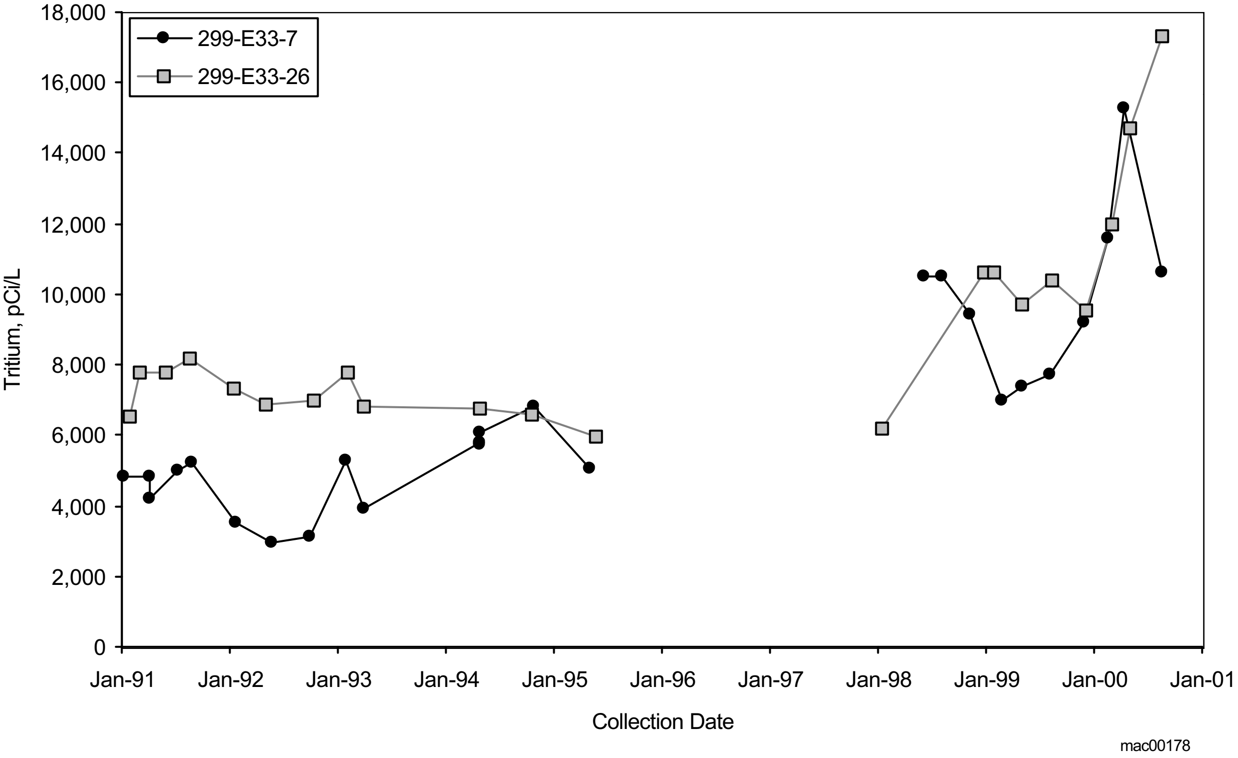

Figure 2.9-3. Tritium in Well 299-E33-7 at the BY Cribs and Well 299-E33-26 West of BY Cribs

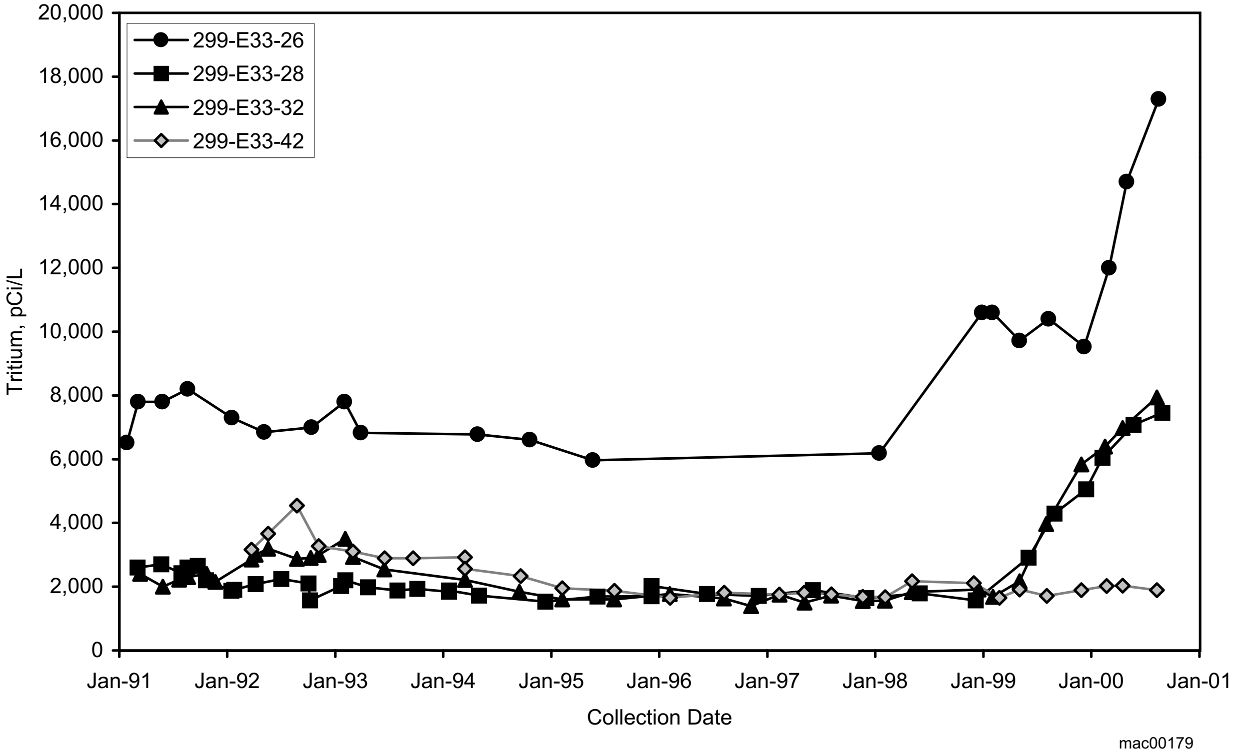

Figure 2.9-4. Tritium in Wells 299-E33-28, 299-E33-32, 299-E33-42, and 299-E33-43 at Waste Management Area B-BX-BY

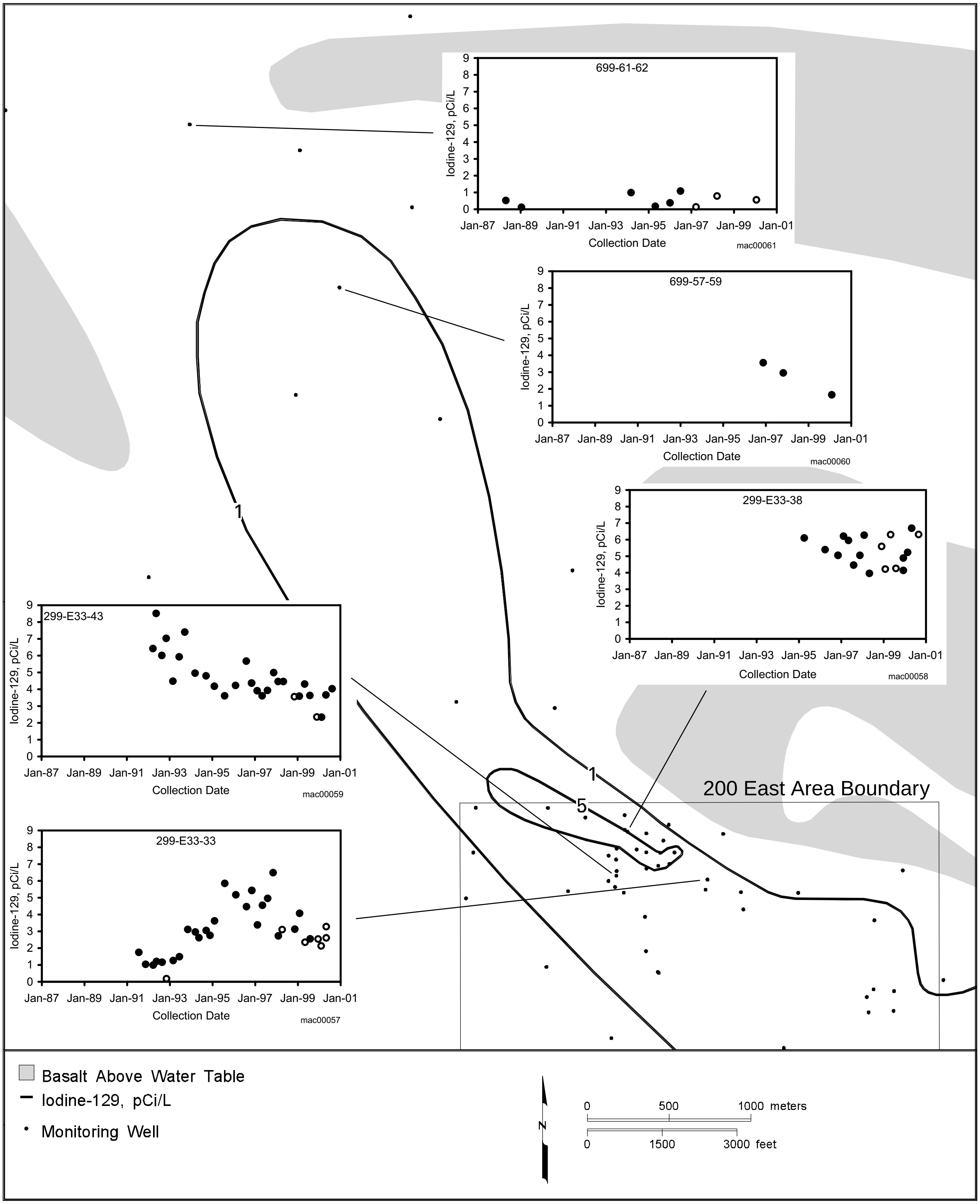

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Figure 2.9-5. Average Iodine-129 Concentrations in the Northern Part of the 200 East Area, Top of Unconfined Aquifer

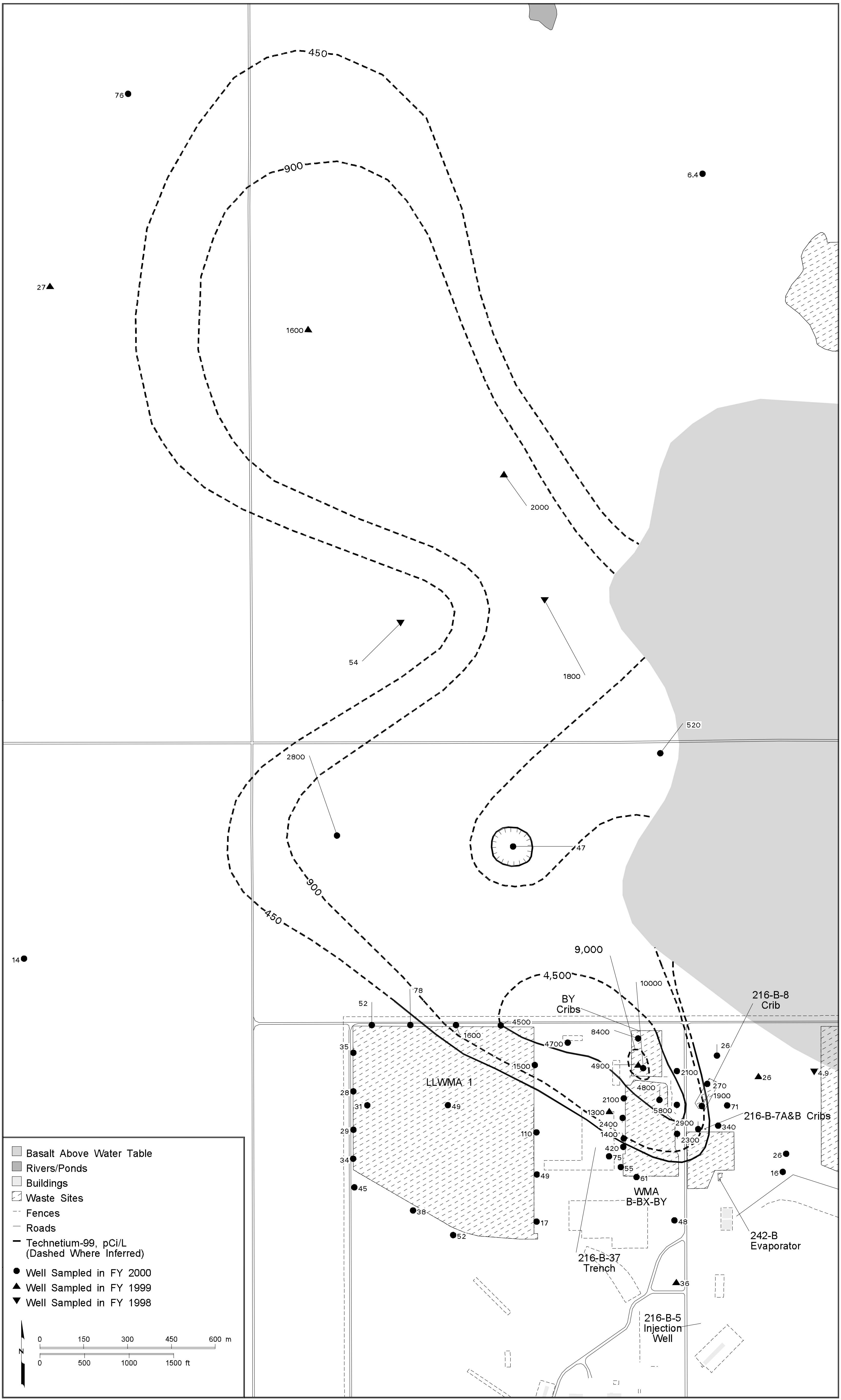

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Figure 2.9-6. Average Technetium-99 Concentrations in the Northern 200 East Area, Top of Unconfined Aquifer

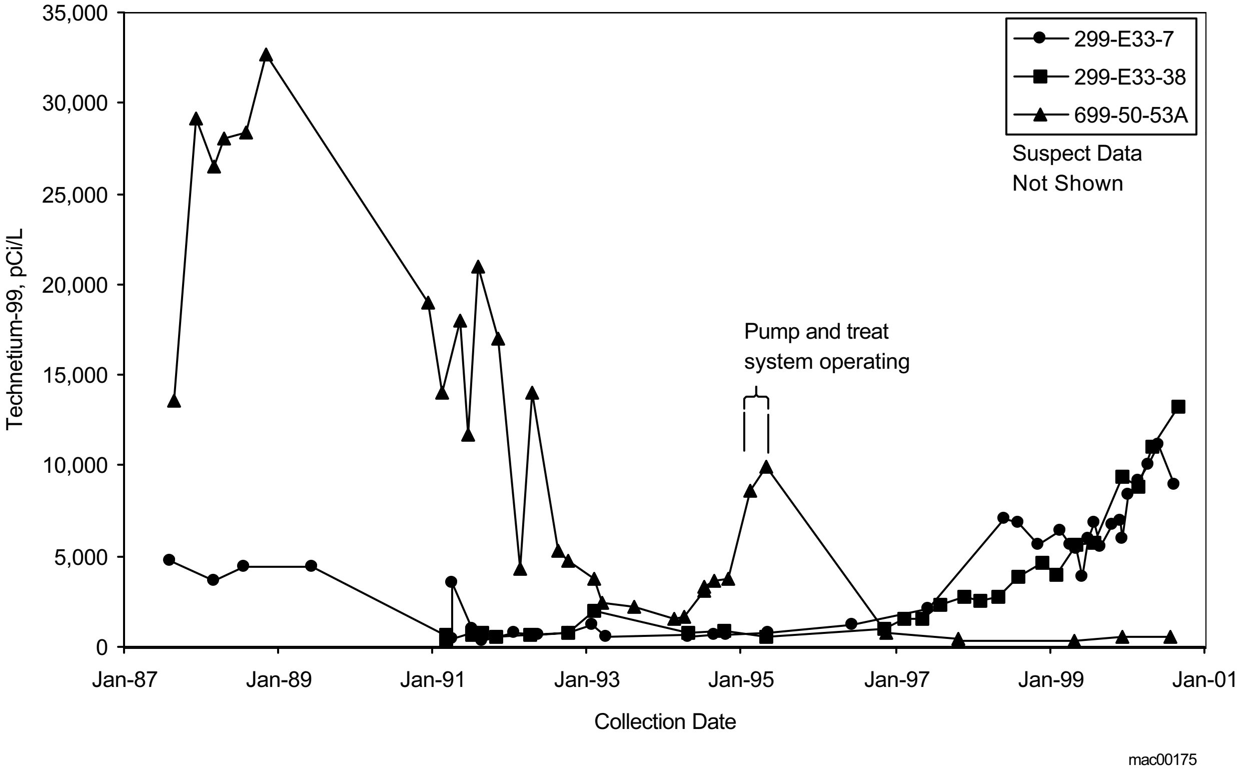

Figure 2.9-7. Technetium-99 in Wells 299-E33-7 and 299-E33-38 at the BY Cribs and Well 699-050-53A North of 200 East Area

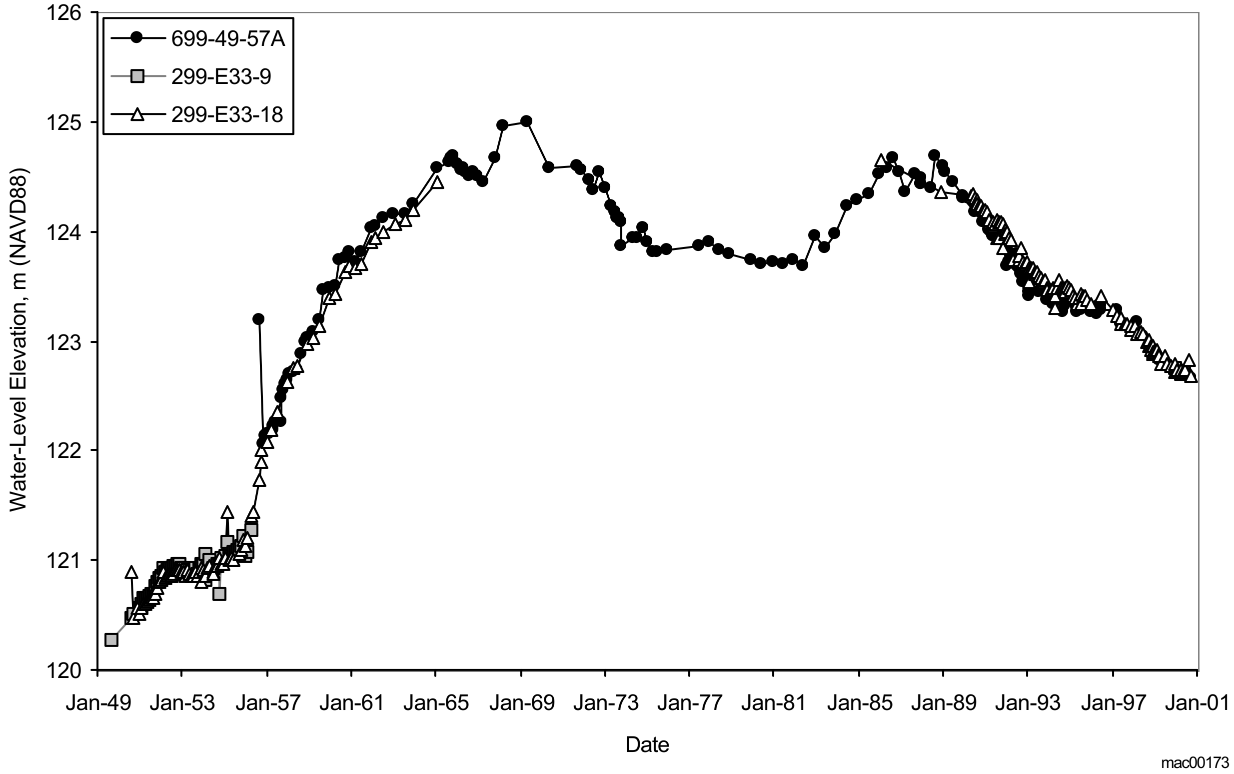

Figure 2.9-8. Water Levels in Wells 699-49-57A, 299-E33-9, and 299-E33-18 at Waste Management Area B-BX-BY

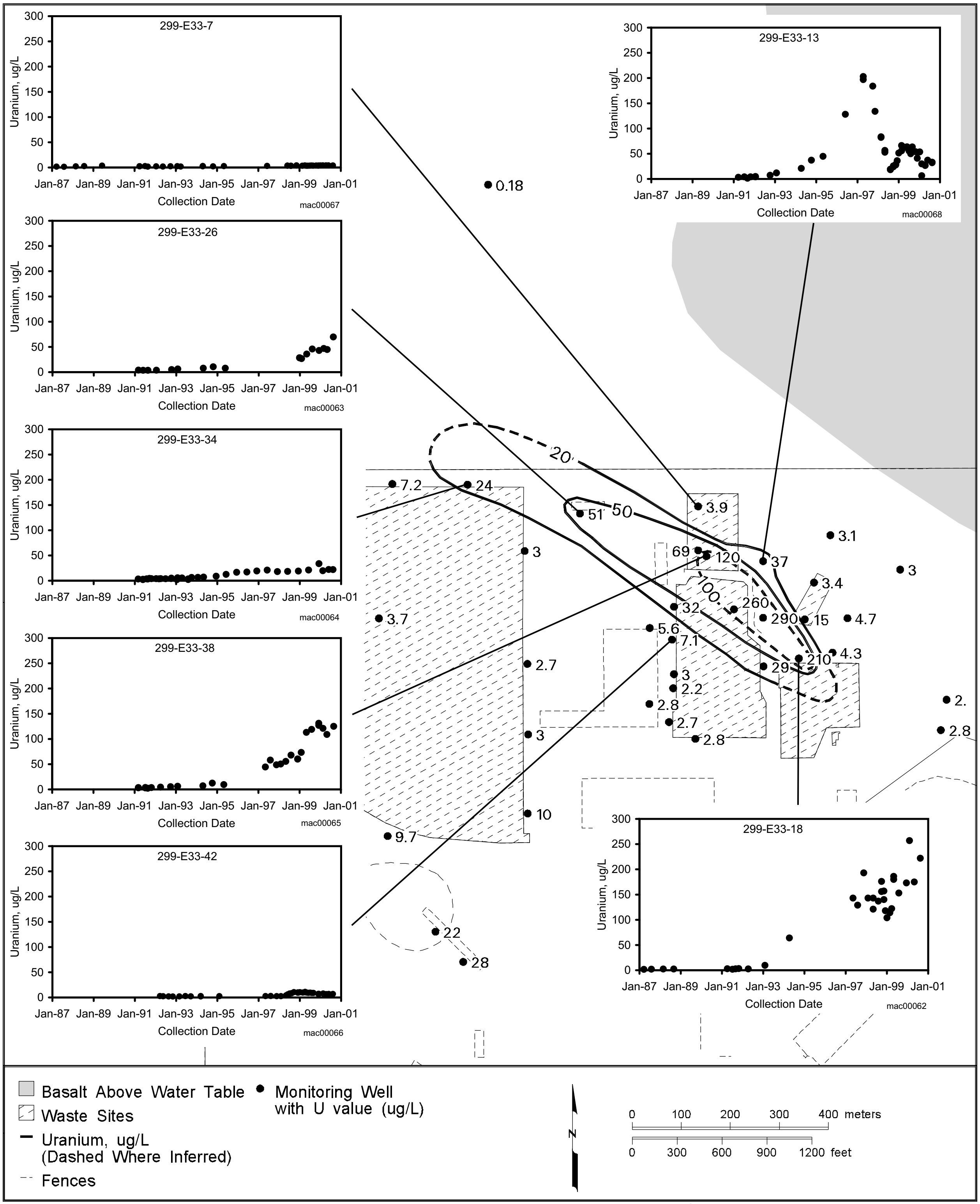

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Figure 2.9-9. Average Uranium Concentrations in the Vicinity of BY Cribs, Top of Unconfined Aquifer

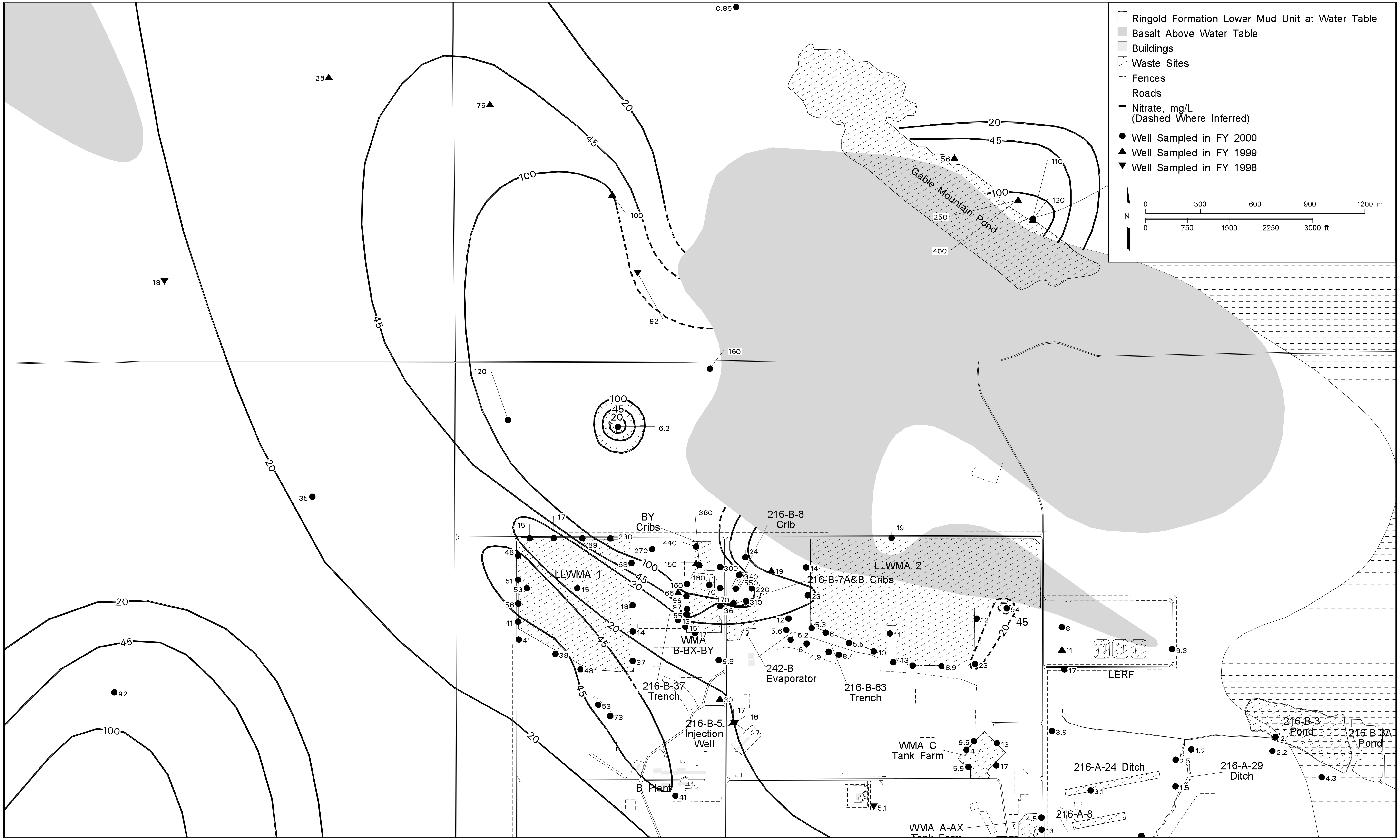

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Figure 2.9-10. Average Nitrate Concentrations in the 200 East Area, Top of Unconfined Aquifer

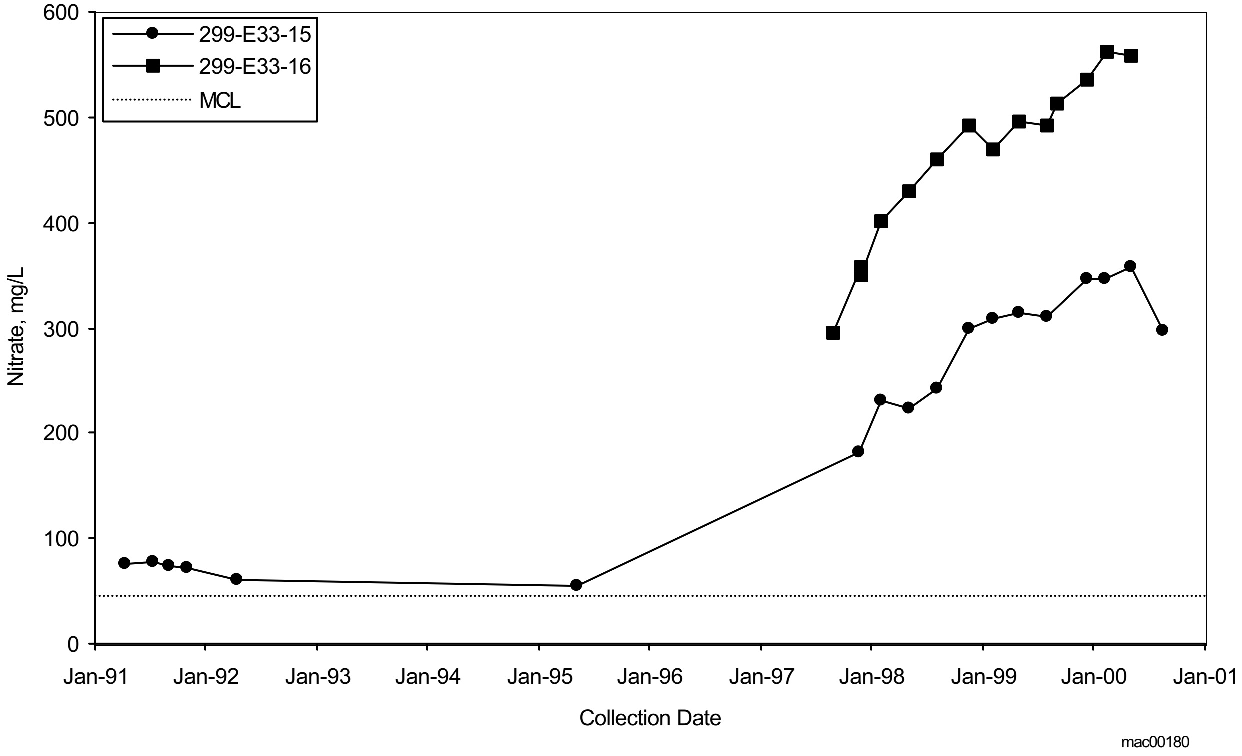

Figure 2.9-11. Nitrate in Wells 299-E33-15 and 299-E33-16 Monitoring 216-B-8 Crib

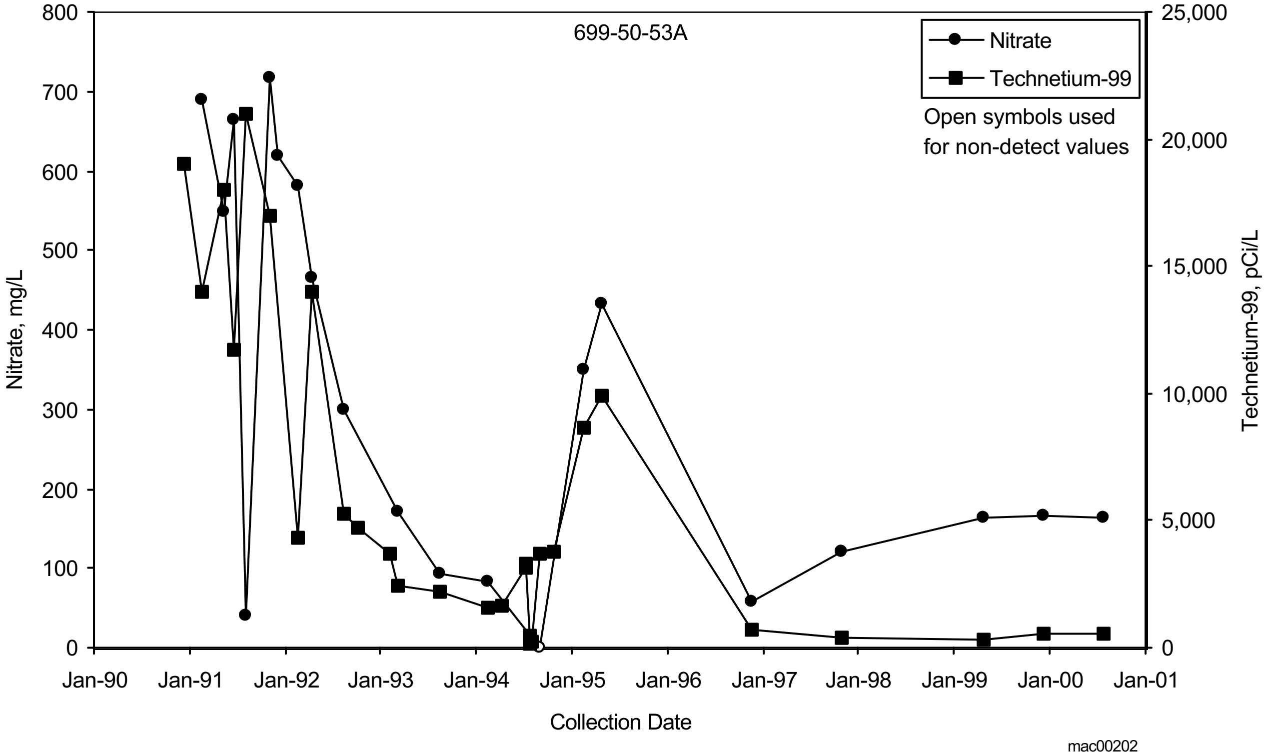

Figure 2.9-12. Nitrate and Technetium-99 in Well 699-50-53A North of the 200 East Area

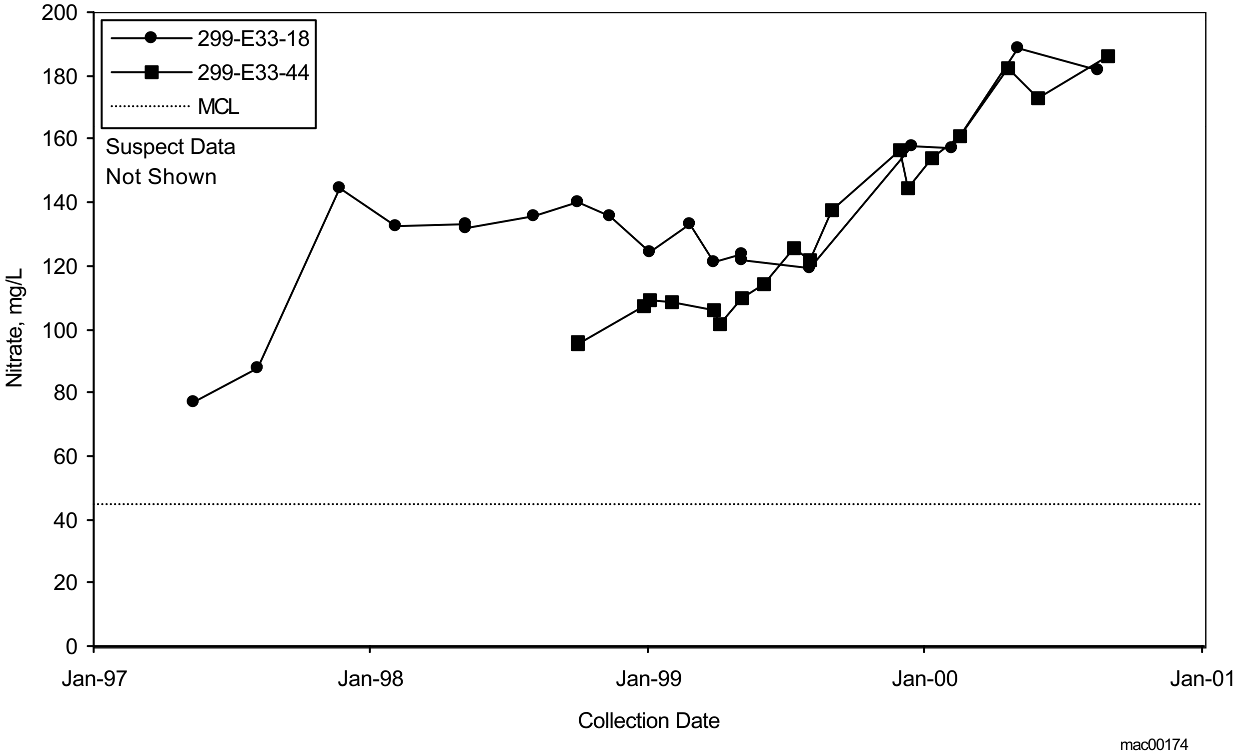

Figure 2.9-13. Nitrate in Wells 299-E33-18 and 299-E33-44 Monitoring Waste Management Area B-BX-BY

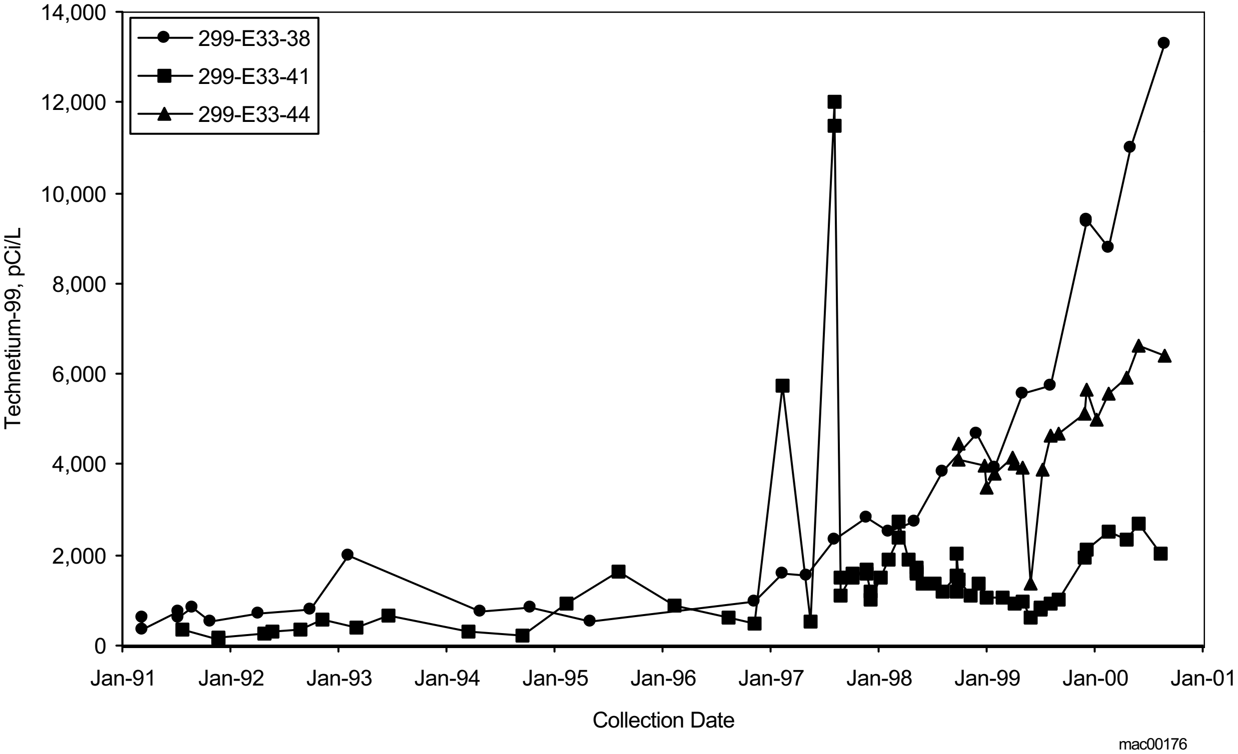

Figure 2.9-14. Technetium-99 in Well 299-E33-38 at the BY Cribs and Wells 299-E33-41 and 299-E33-44 at Central Waste Management Area B-BX-BY

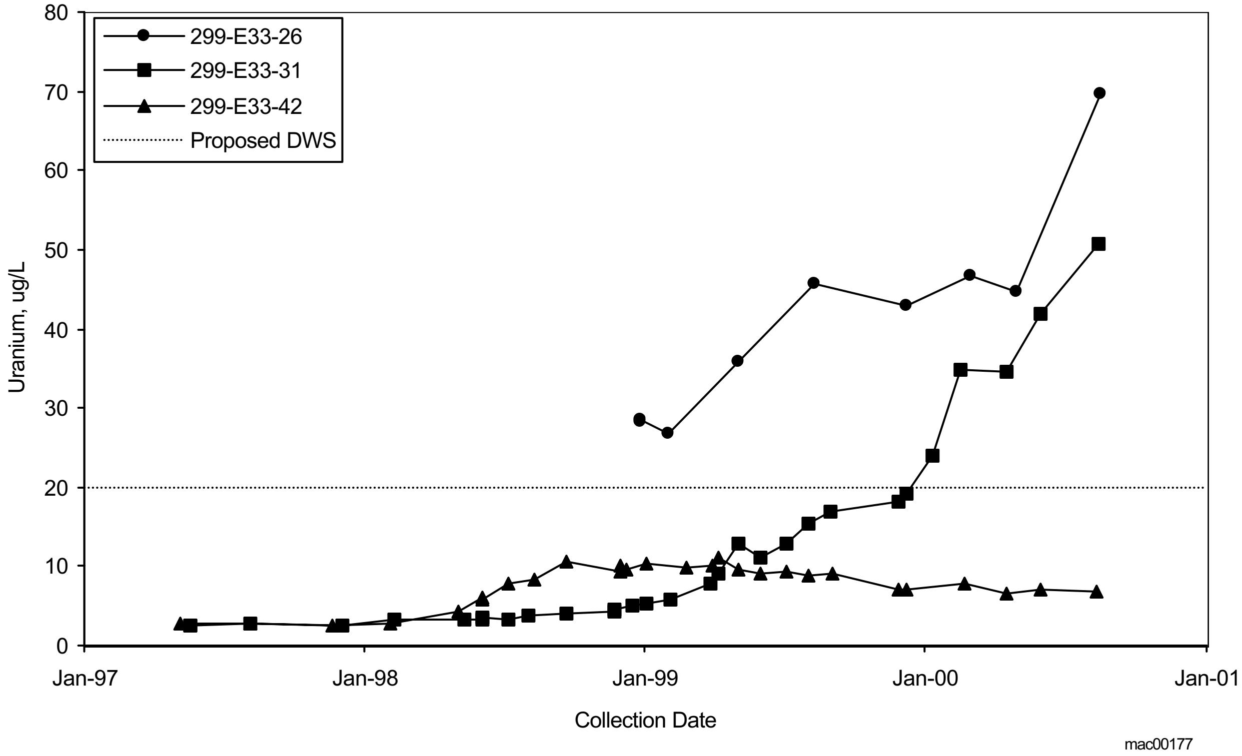

Figure 2.9-15. Uranium in Wells 299-E33-26, 299-E33-31, and 299-E33-42 West of Waste Management Area B-BX-BY

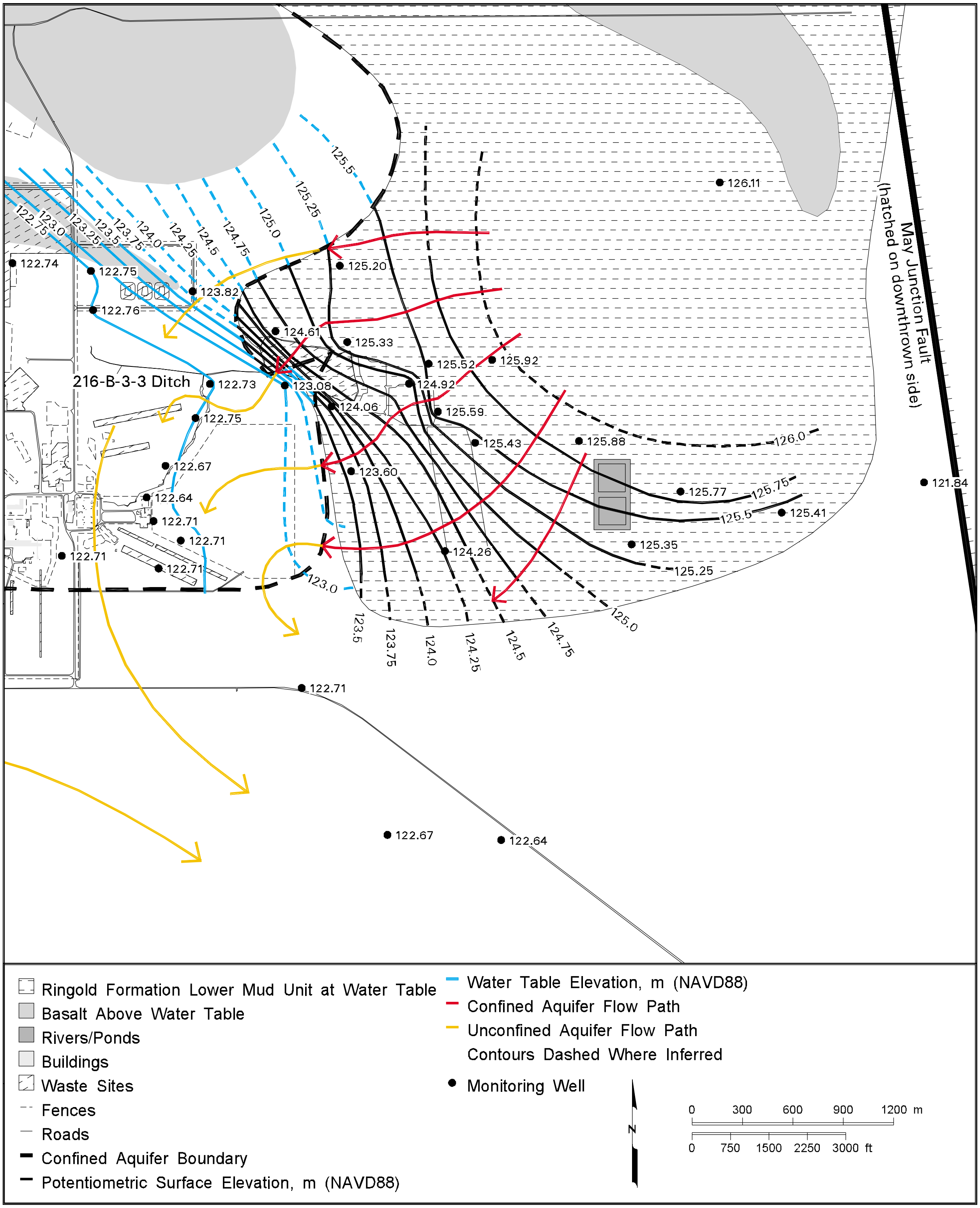

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Figure 2.9-16. March 2000 Water-Table Map for the Confined and Unconfined Aquifers near B Pond (PNNL-12261)

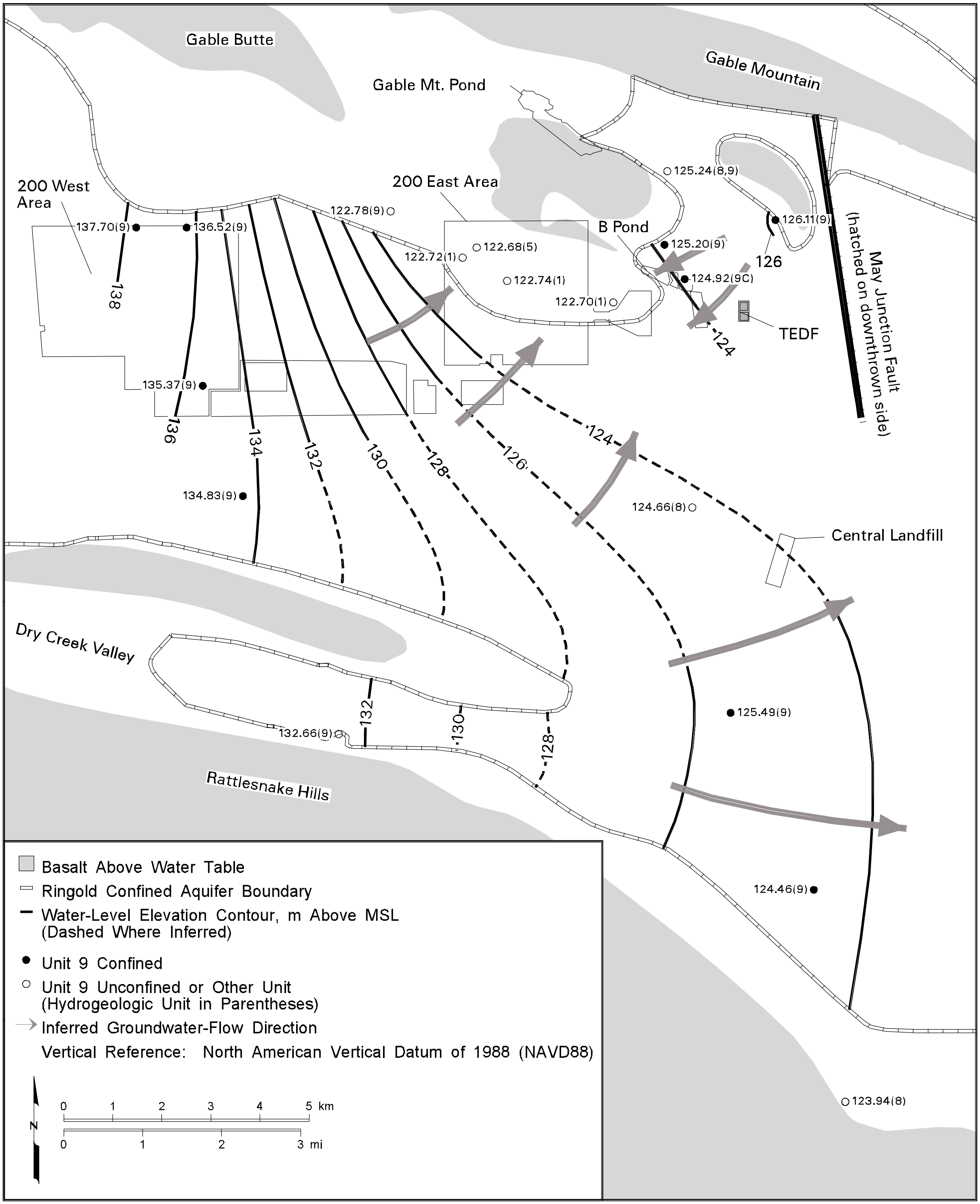

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Figure 2.9-17. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March/April 2000

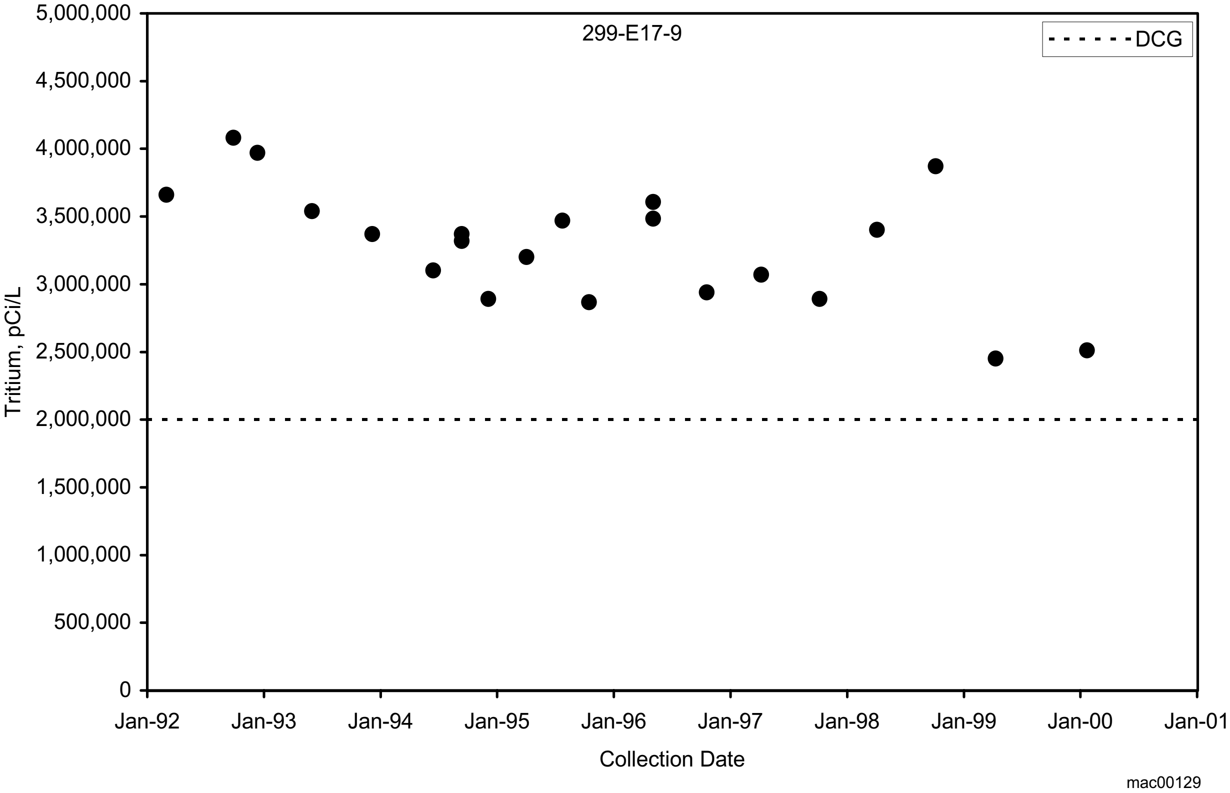

Figure 2.9-18. Tritium in Well 299-E17-9 at the 216-A-36B Crib

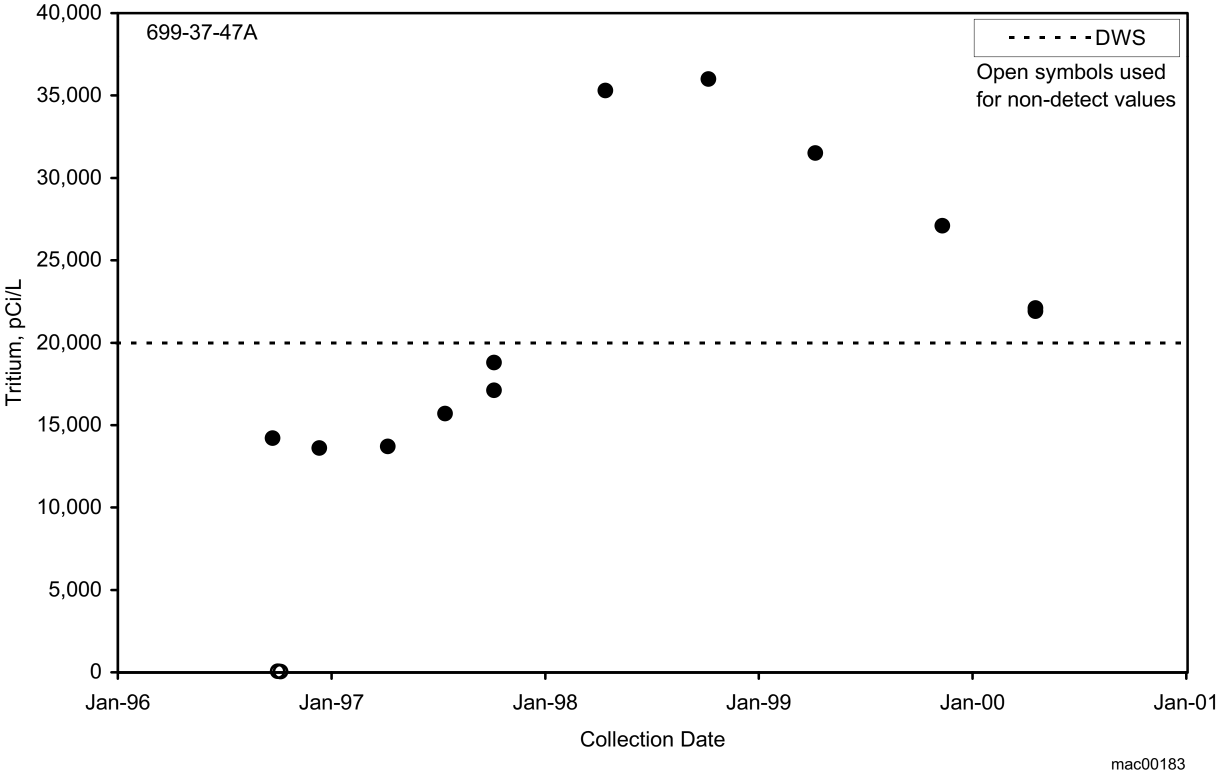

Figure 2.9-19. Tritium in Well 699-37-47A in the Southeastern 200 East Area

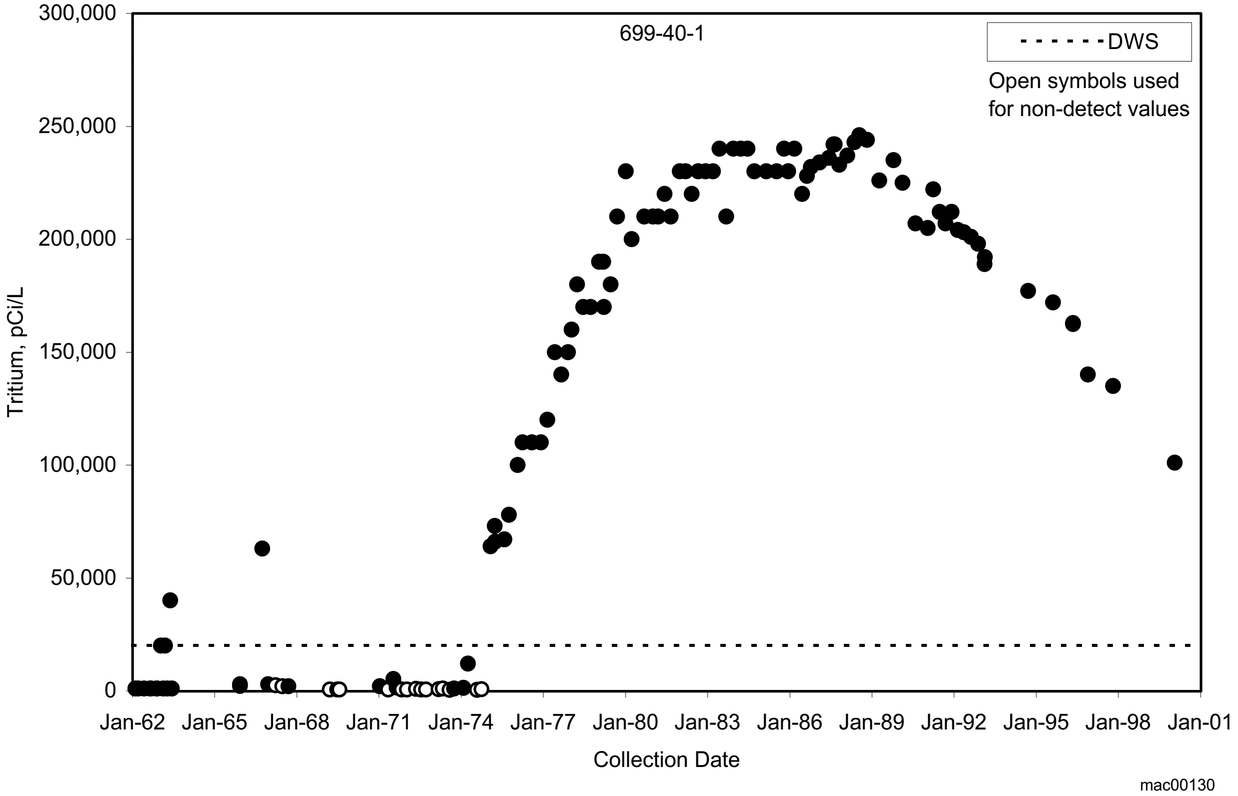

Figure 2.9-20. Tritium in Well 699-40-1 in the 600 Area near the Old Hanford Townsite

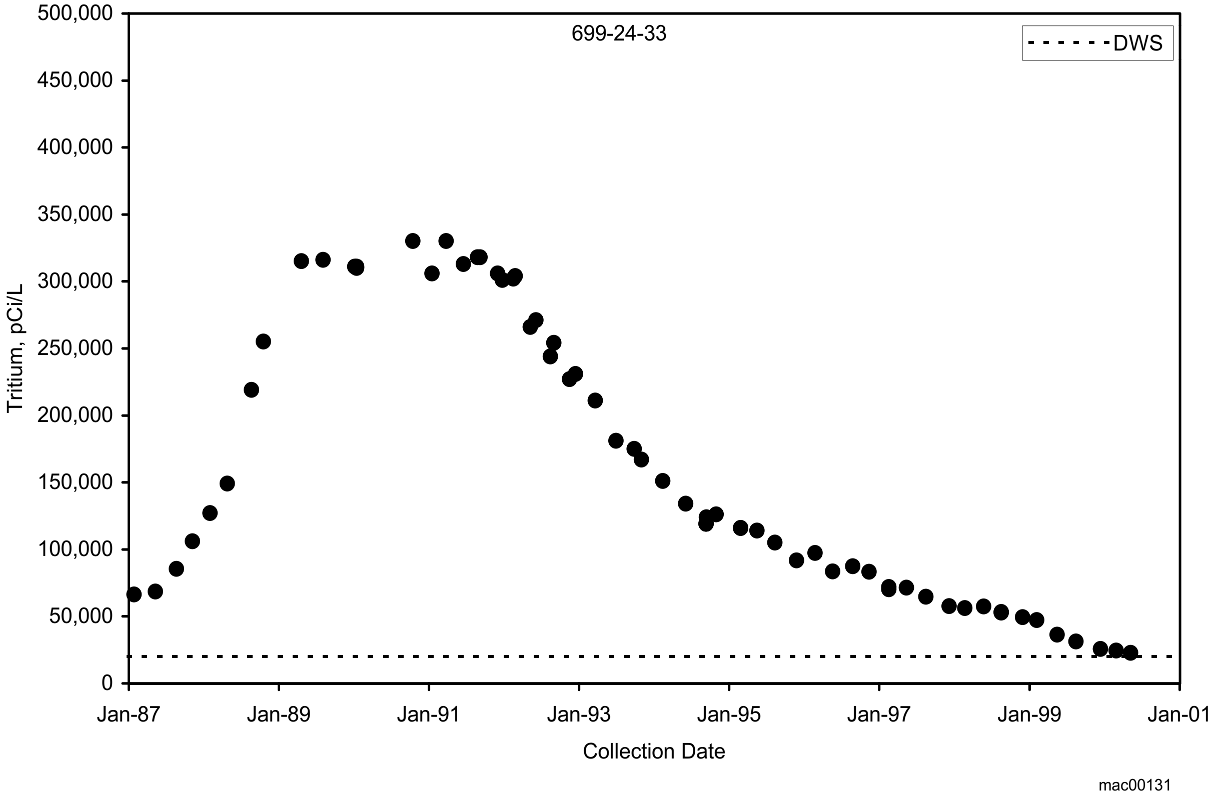

Figure 2.9-21. Tritium in Well 699-24-33 near the Central Landfill

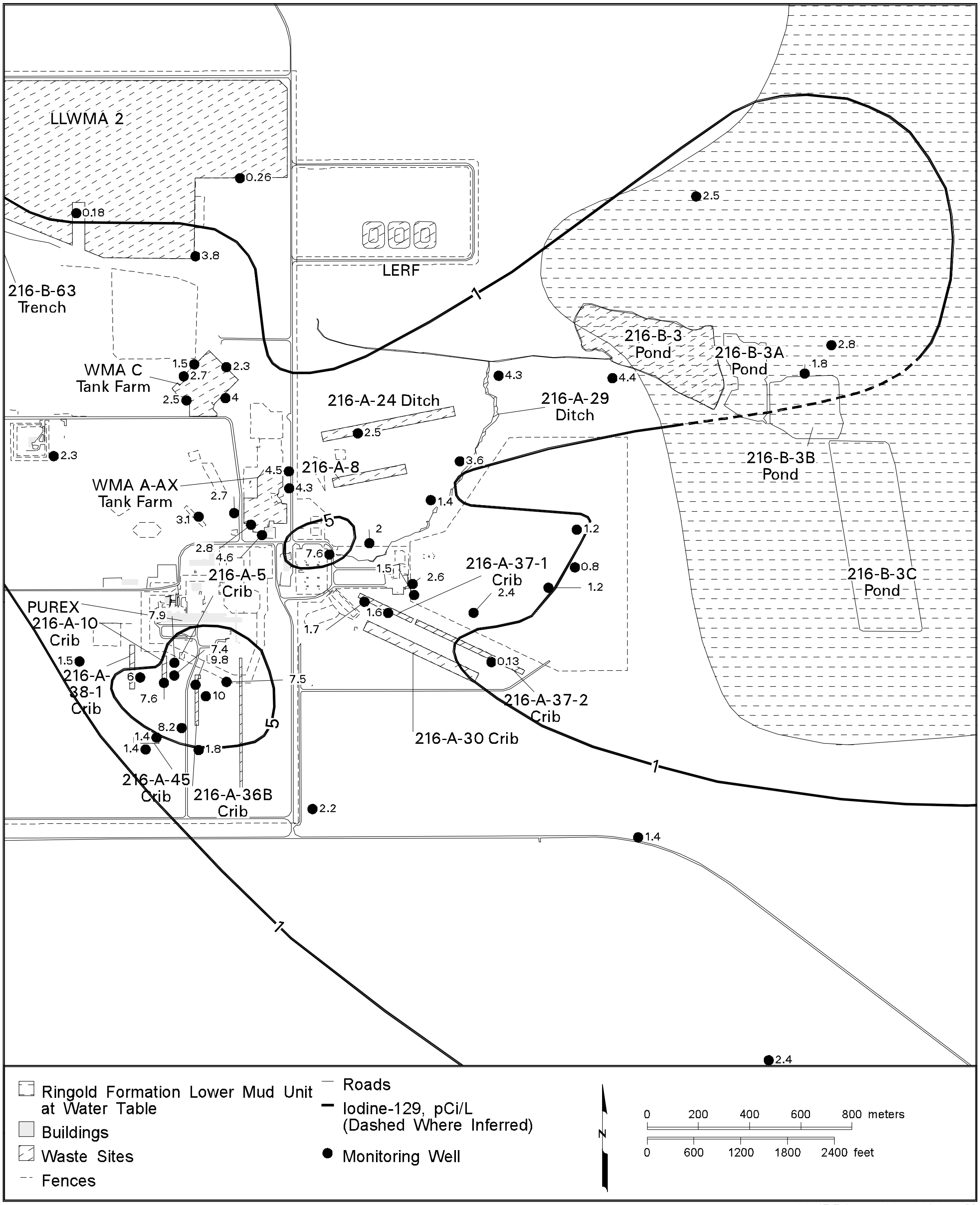

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Figure 2.9-22. Average Iodine-129 Concentrations near the PUREX Plant, Top of Unconfined Aquifer

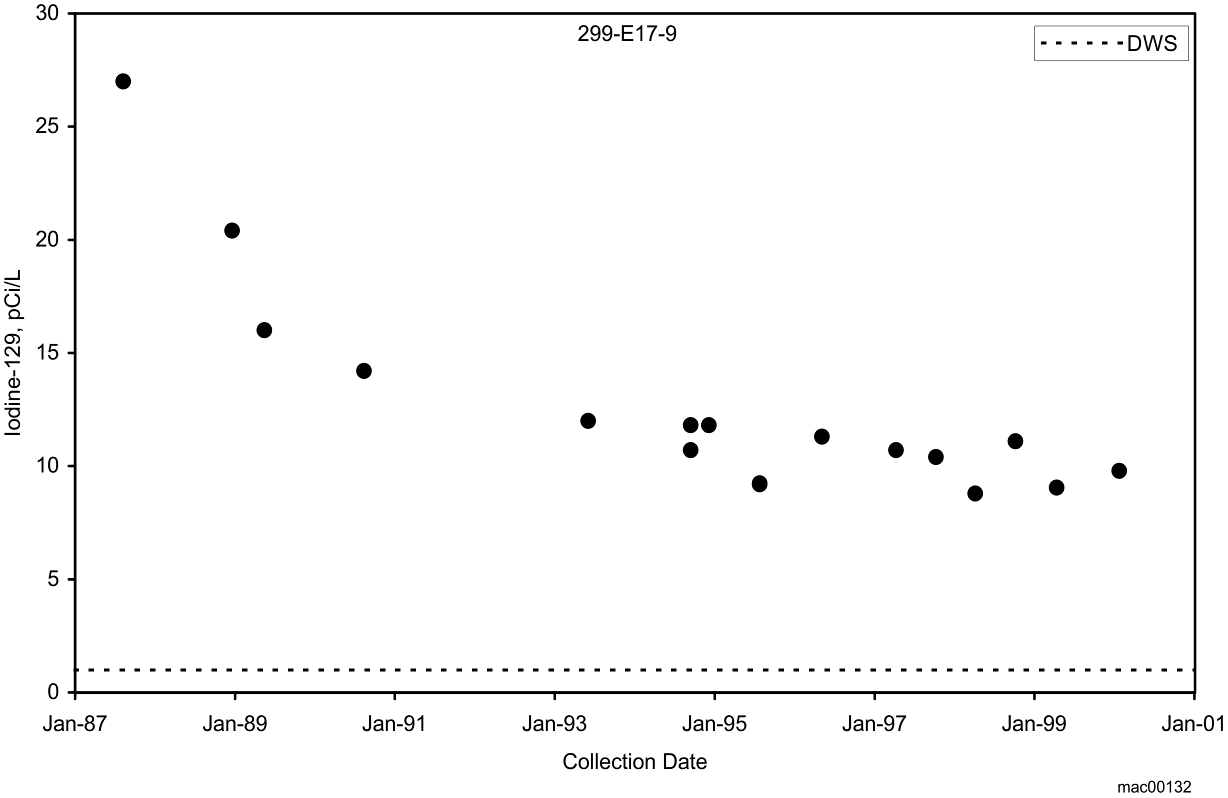

Figure 2.9-23. Iodine-129 in Well 299-E17-9 at the 216-A-36B Crib

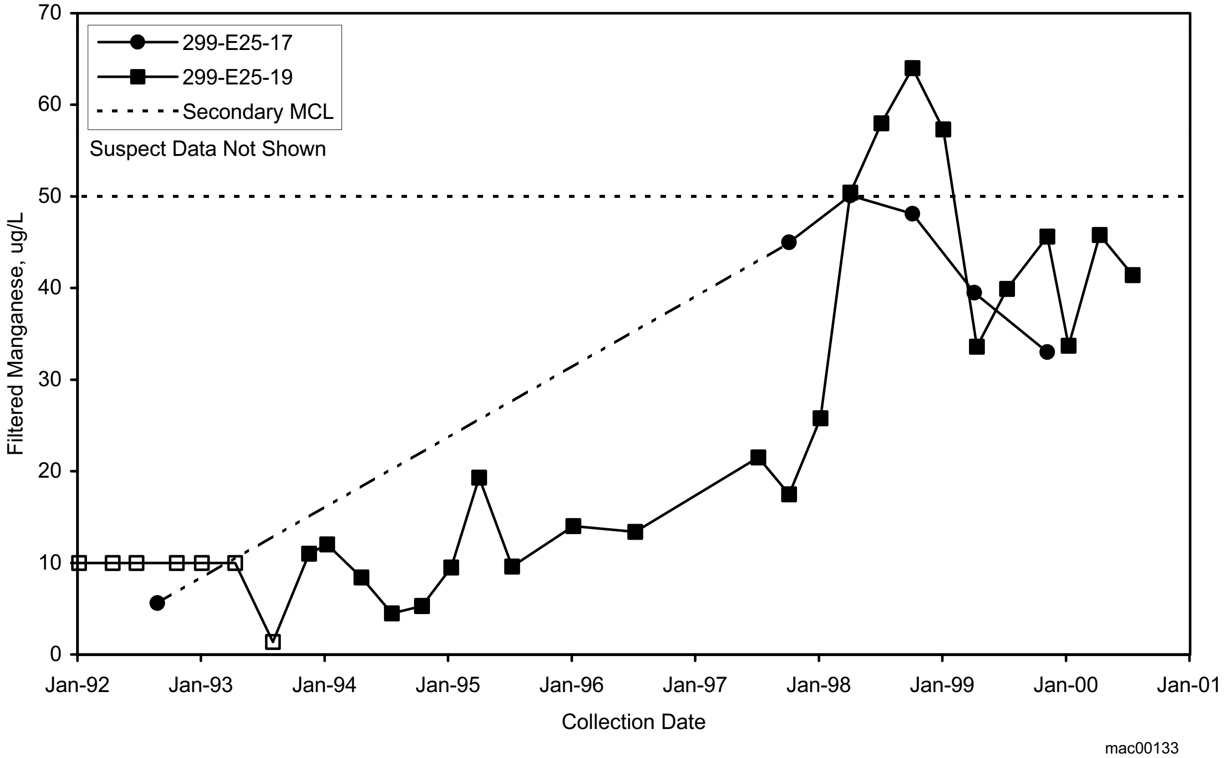

Figure 2.9-24. Manganese at the 216-A-37-1 Crib

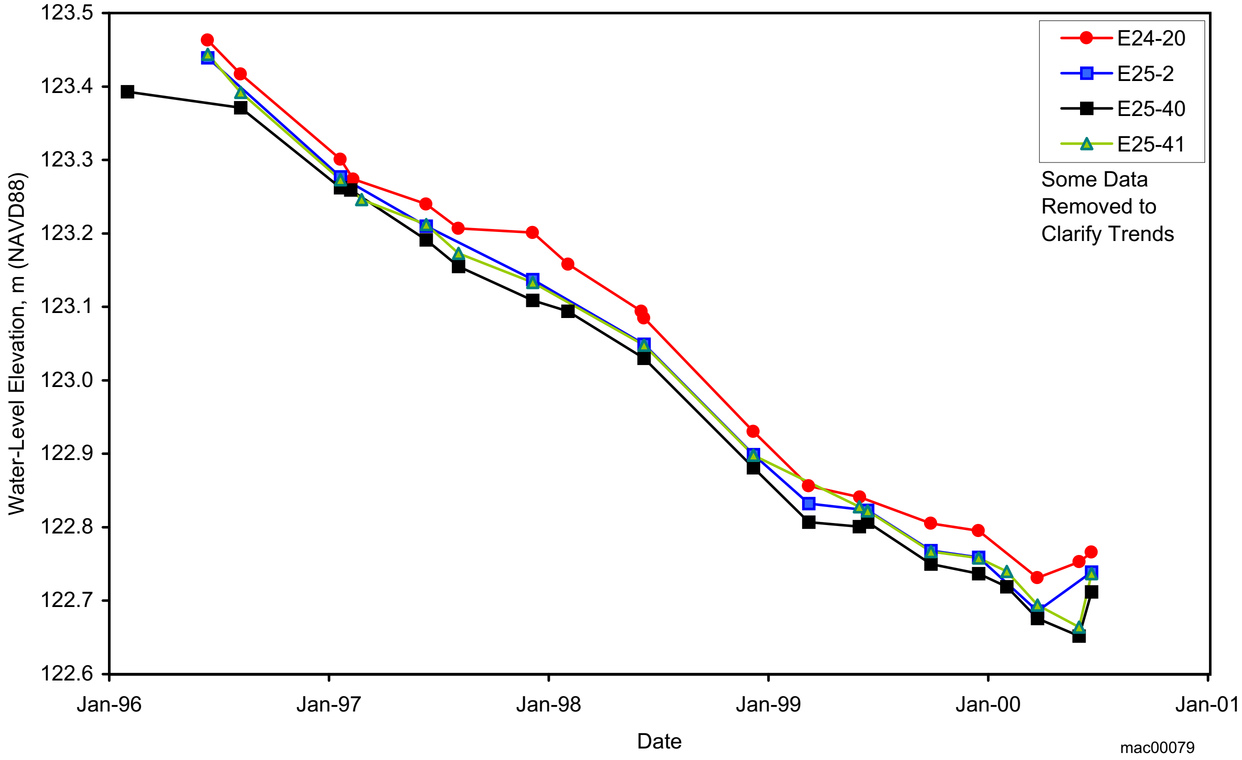

Figure 2.9-25. Water Levels in Wells at Waste Management Area A-AX Tank Farm

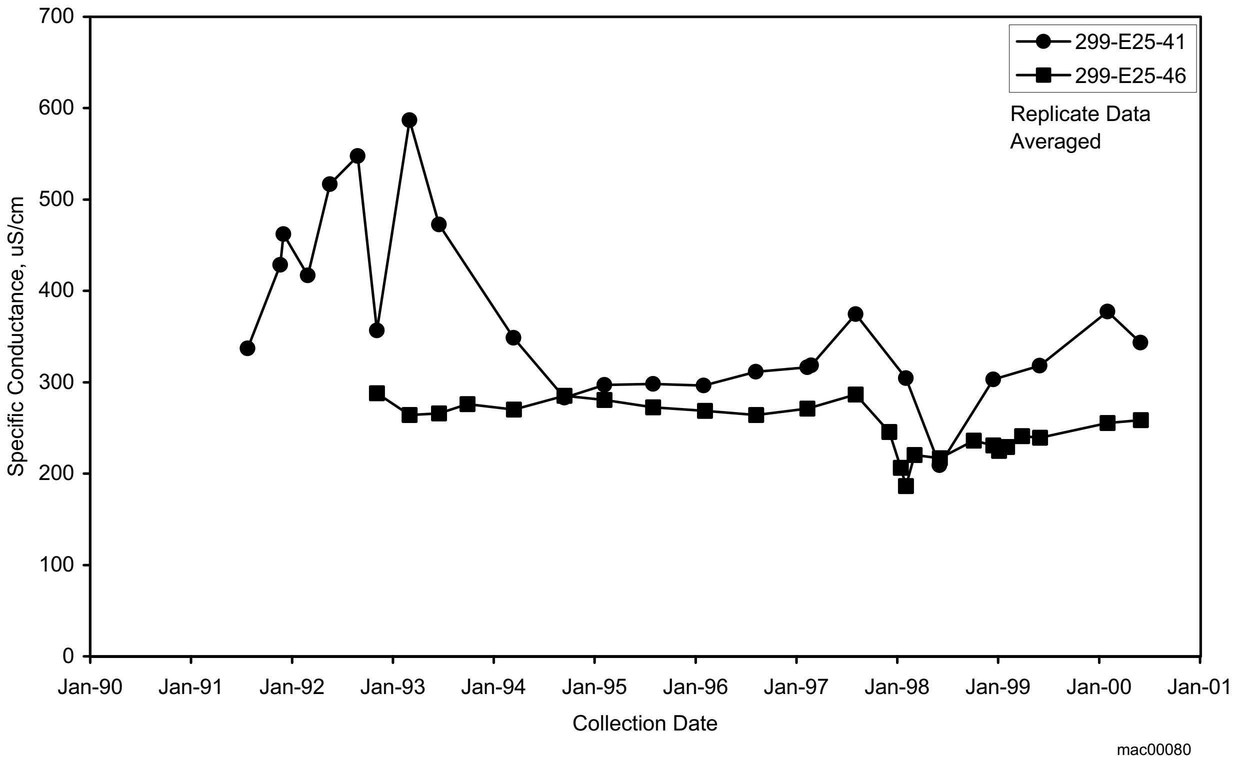

Figure 2.9-26. Specific Conductance in Wells at Waste Management Area A-AX

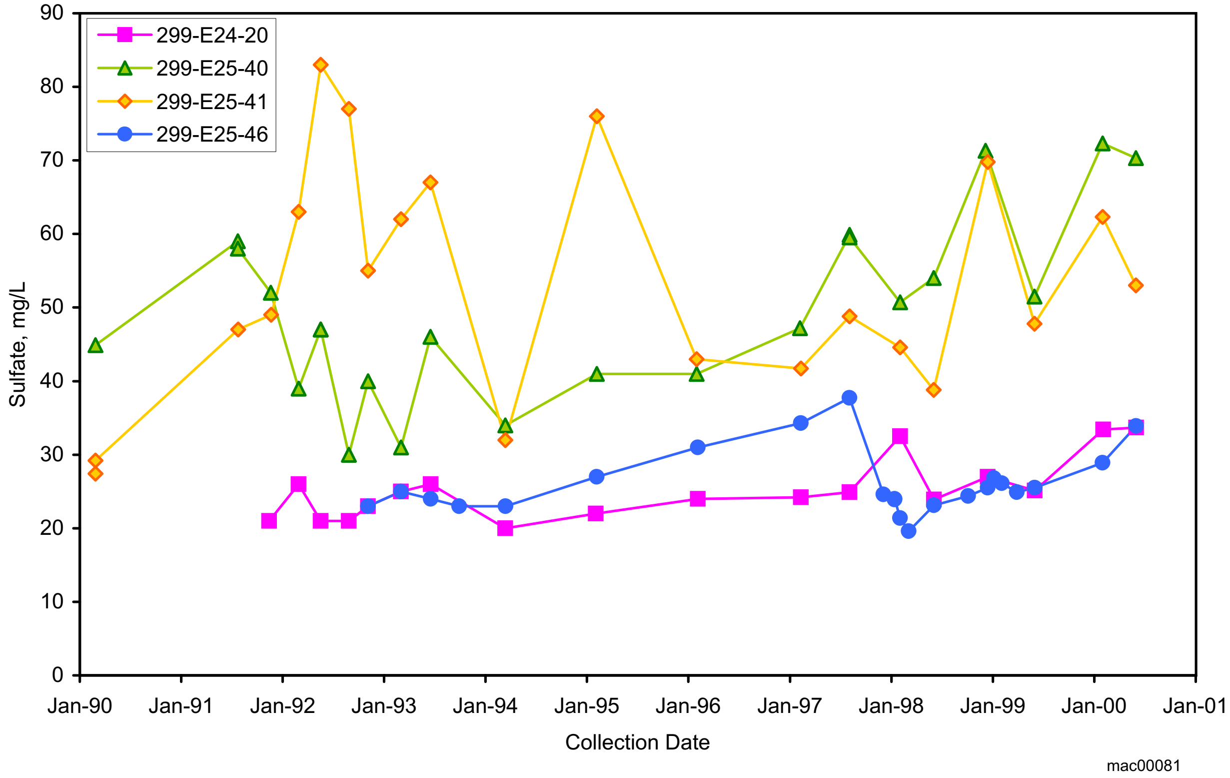

Figure 2.9-27. Sulfate in Wells at Waste Management Area A-AX

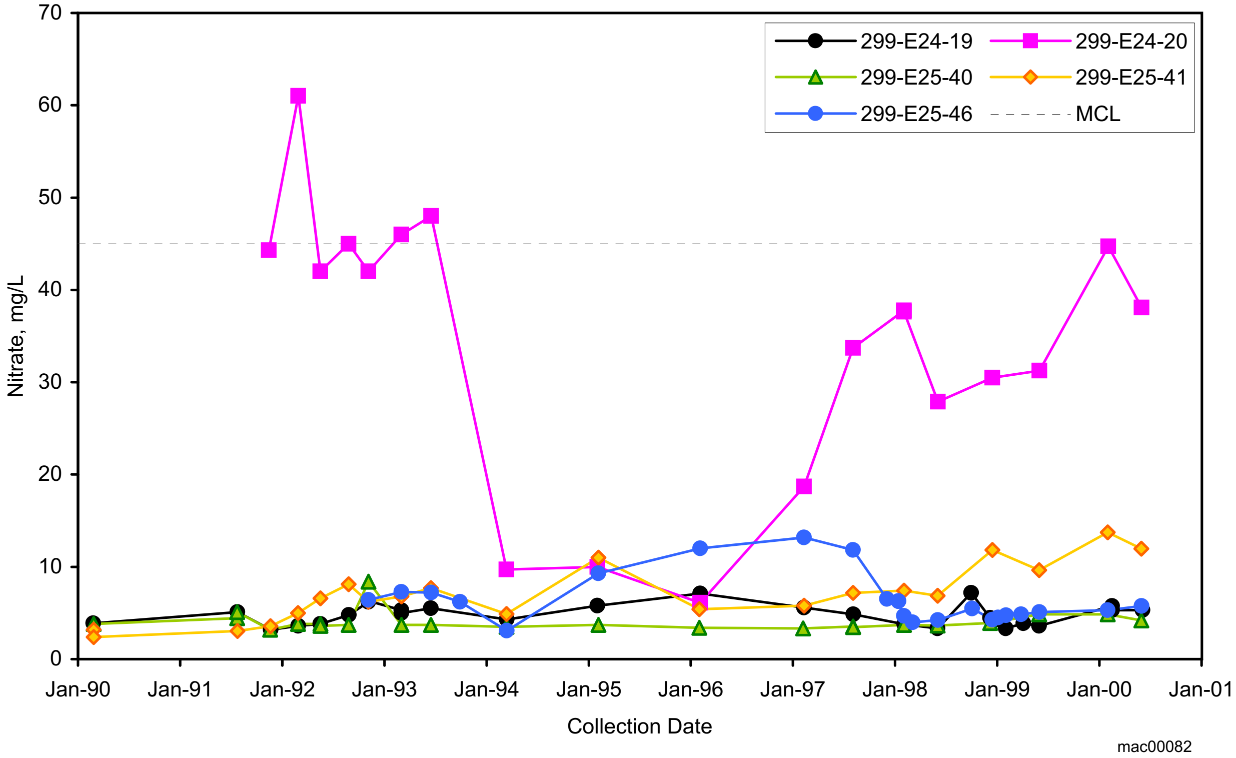

Figure 2.9-28. Nitrate in Well 299-E24-20 at Waste Management Area A-AX

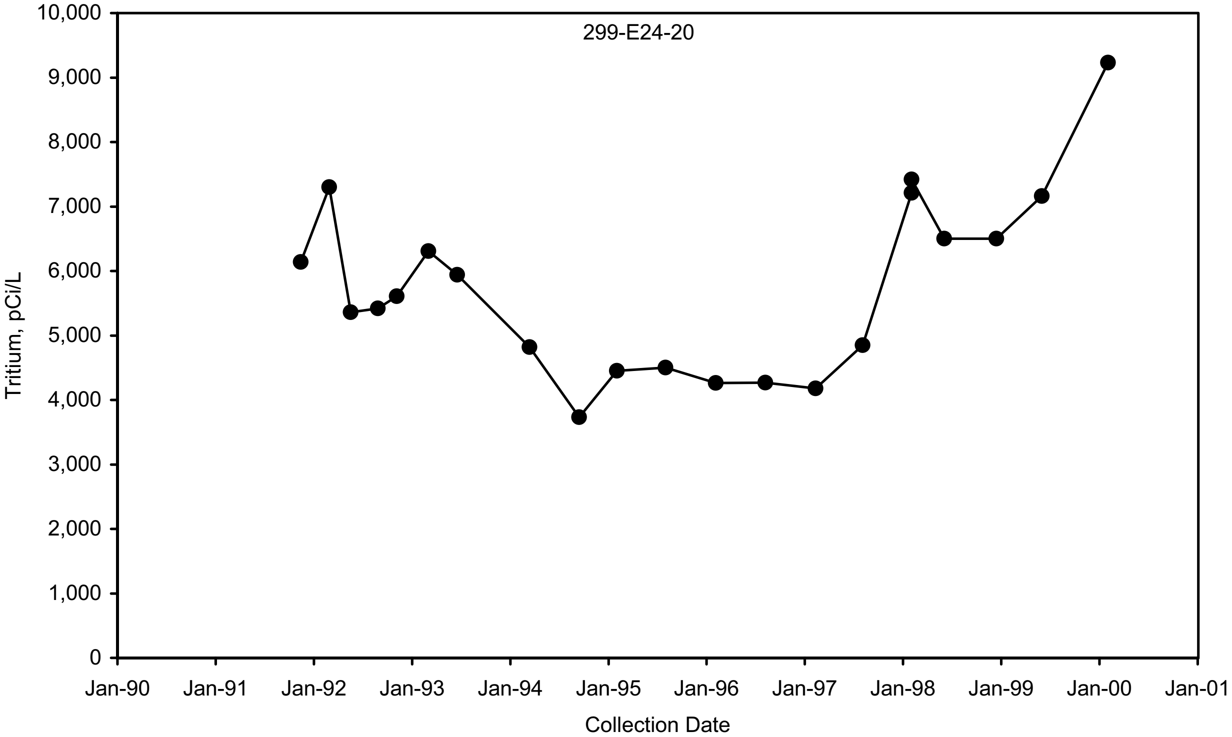

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Figure 2.9-29. Tritium in Well 299-E24-20 at Waste Management Area A-AX

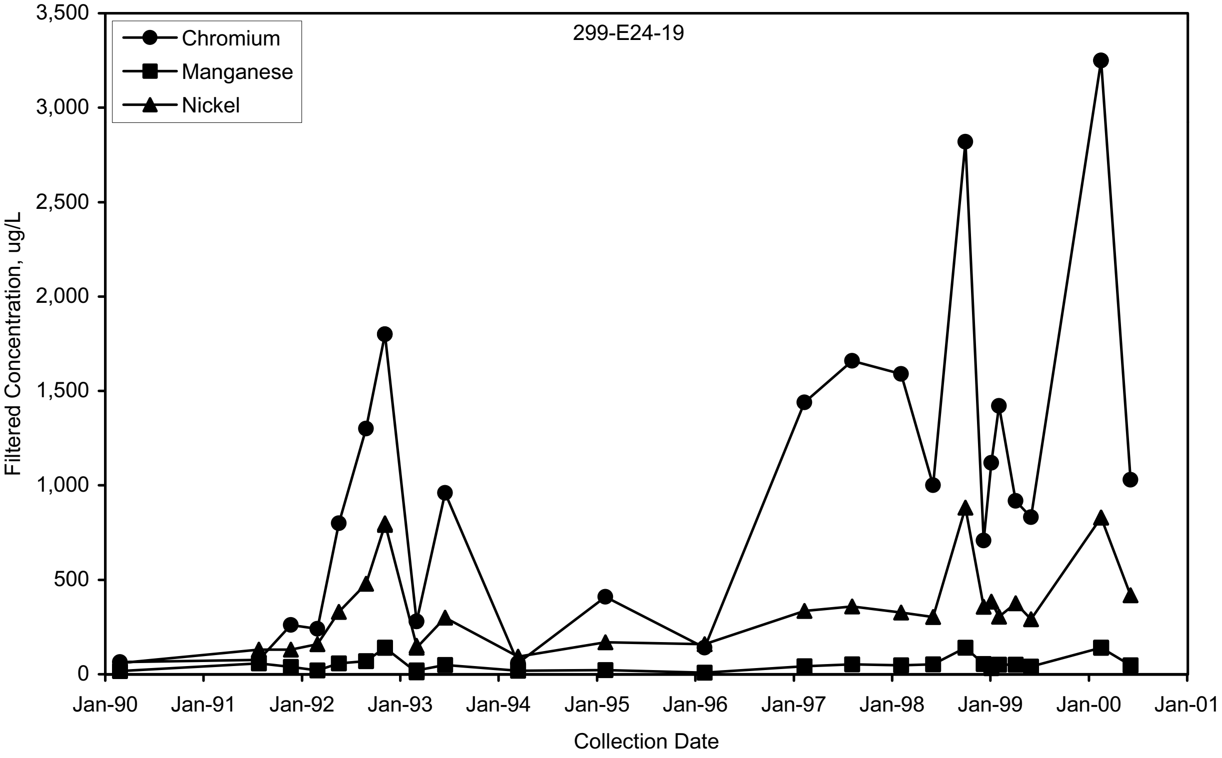

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Figure 2.9-30. Chromium, Manganese, and Nickel in Well 299-E24-19 at Waste Management Area A-AX

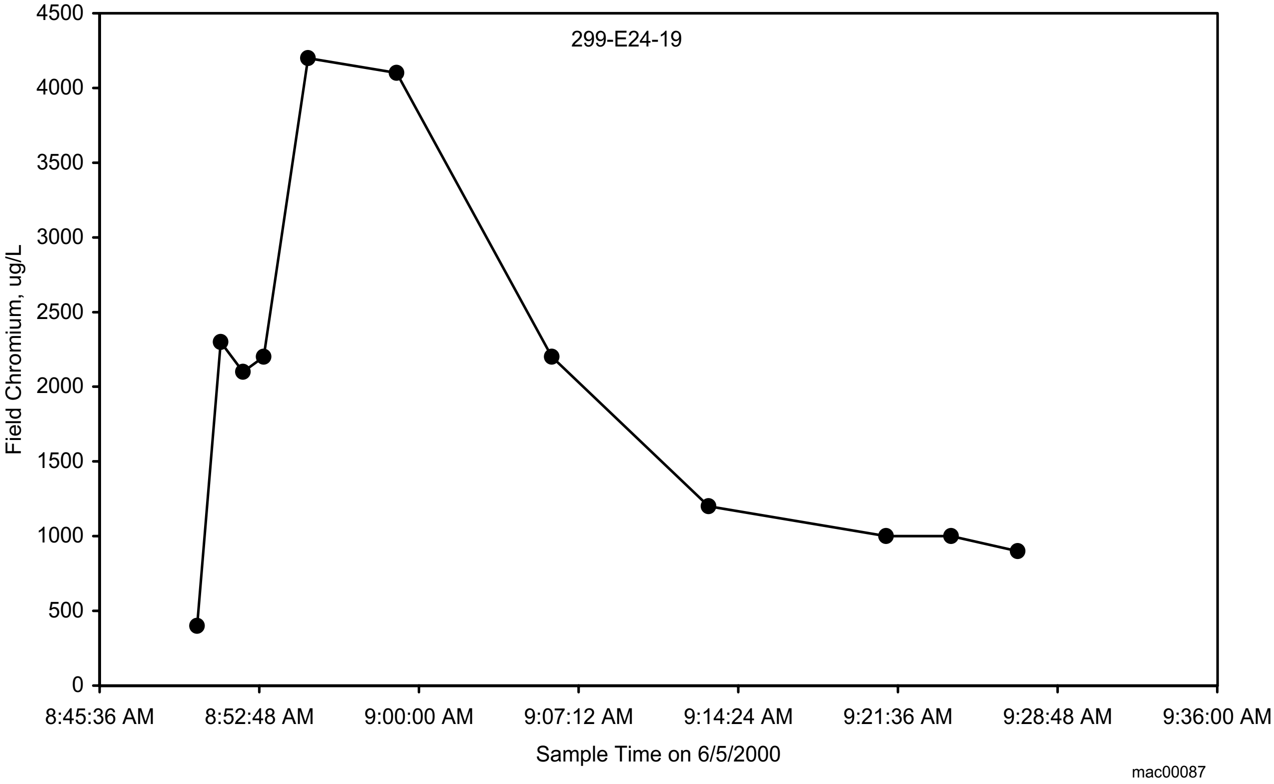

Figure 2.9-31. Chromium in Well 299-E24-19 during a Purging Test

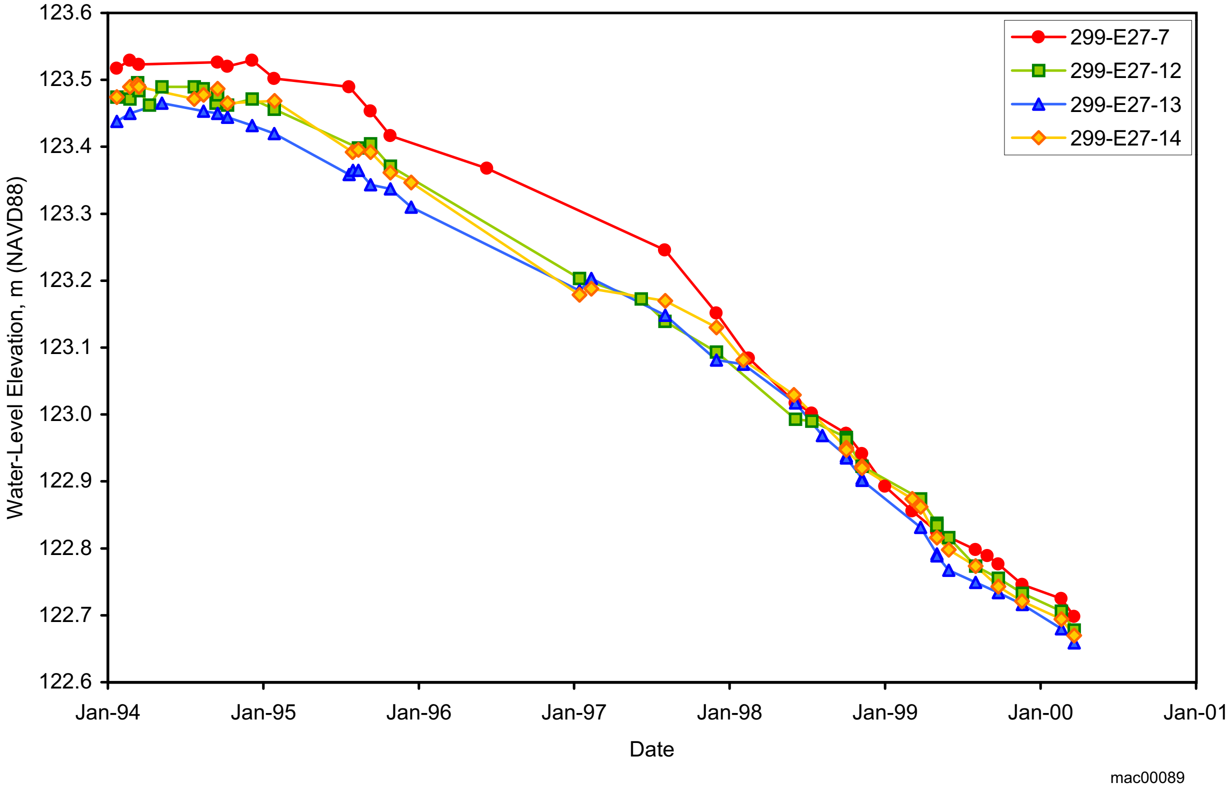

Figure 2.9-32. Water-Level Elevations in Wells at Waste Management Area C. All data referenced to NAVD88 datum; spurious data have been removed.

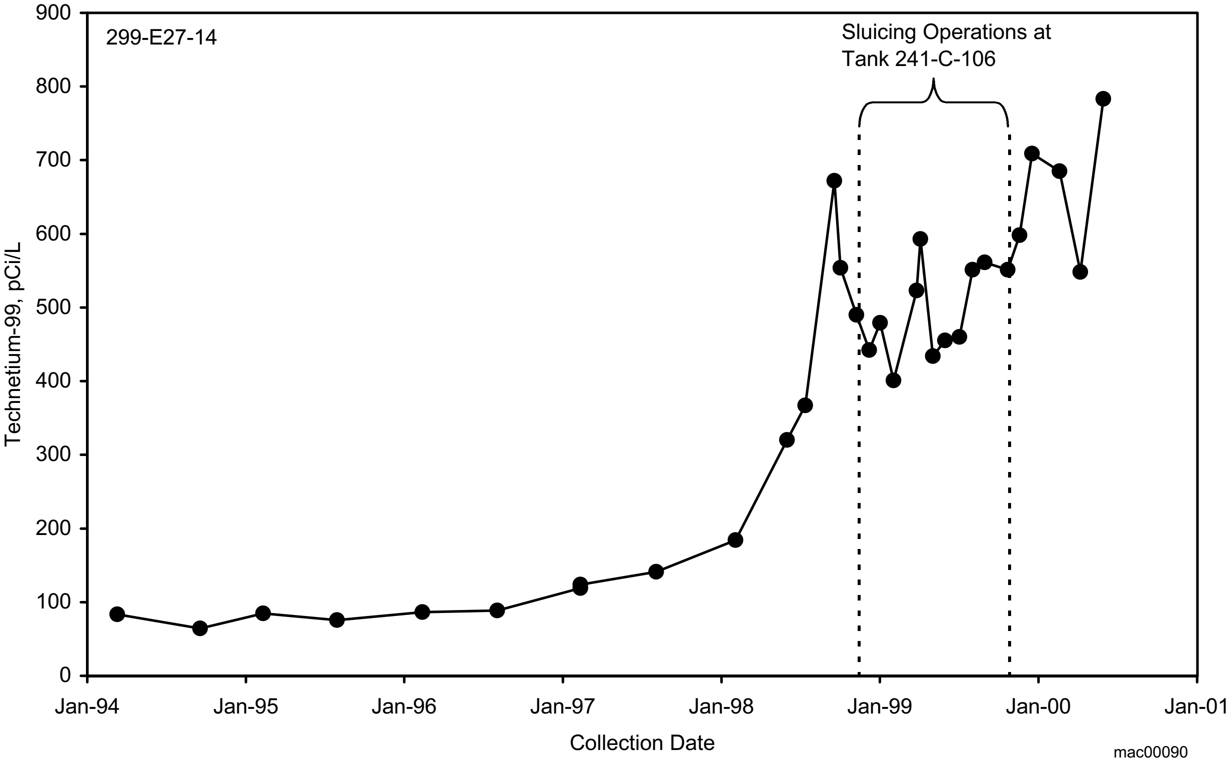

Figure 2.9-33. Technetium-99 in Well 299-E27-14 at Waste Management Area C, Showing Initiation and End of Sluicing

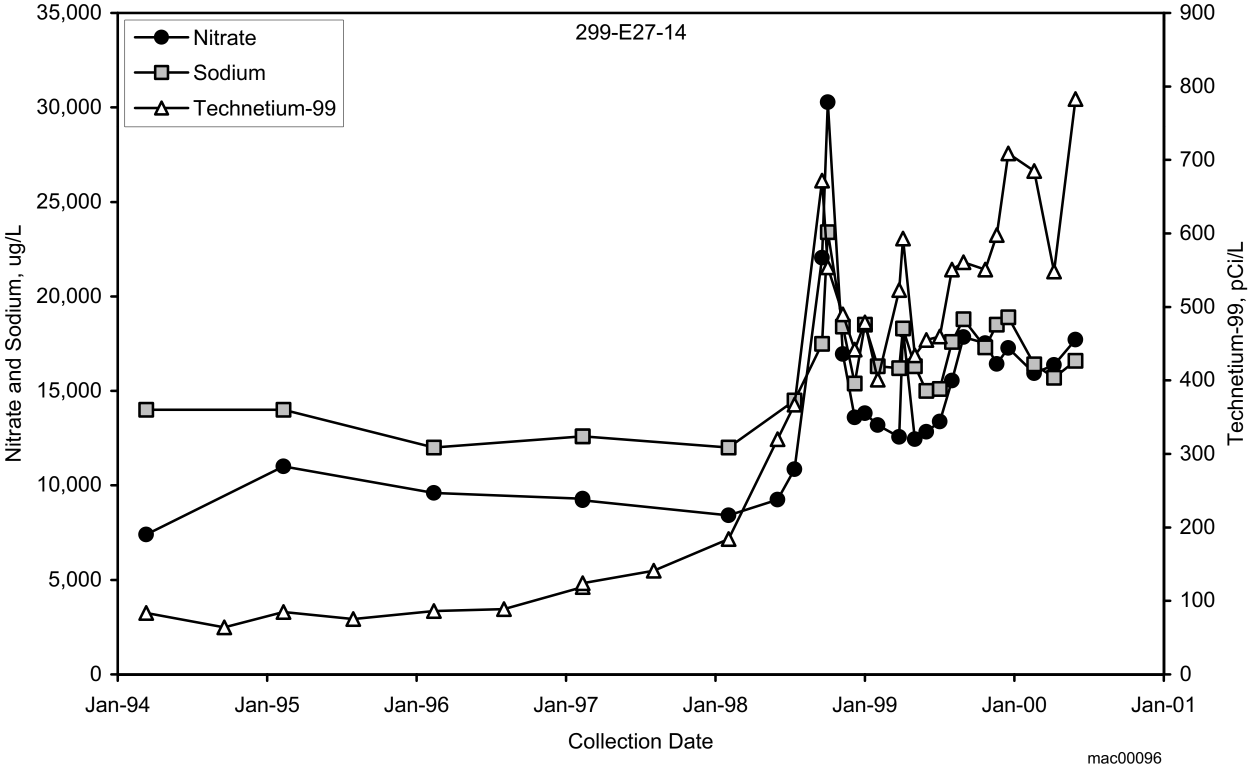

Figure 2.9-34. Technetium-99, Nitrate, and Sodium in Well 299-E27-14 at Waste Management Area C

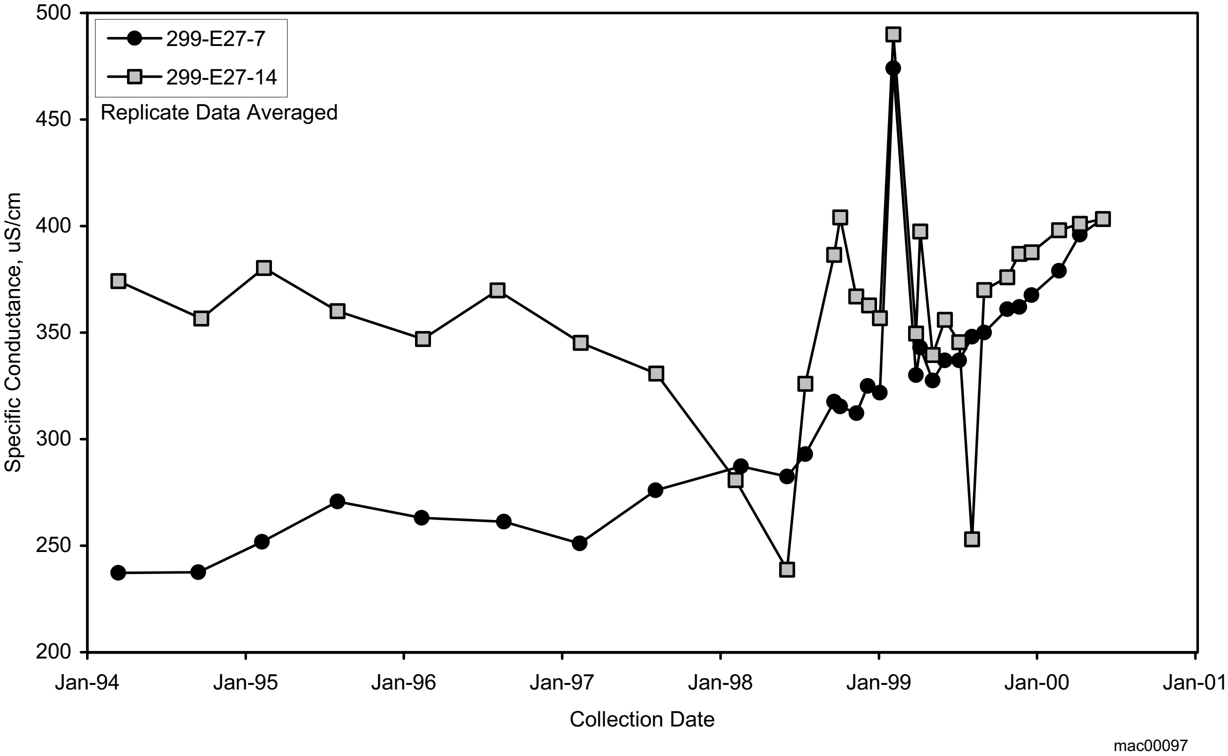

Figure 2.9-35. Specific Conductance at Waste Management Area C

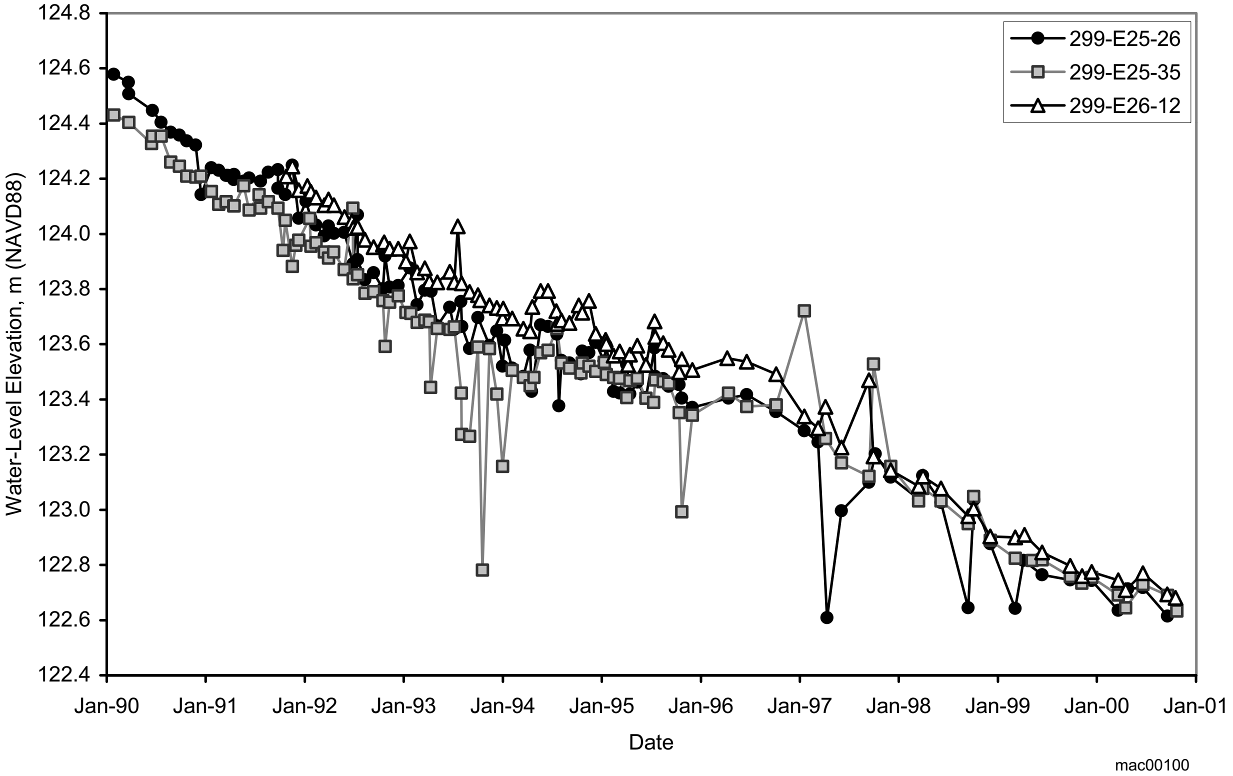

Figure 2.9-36. Water Levels in Wells at the 216-A-29 Ditch

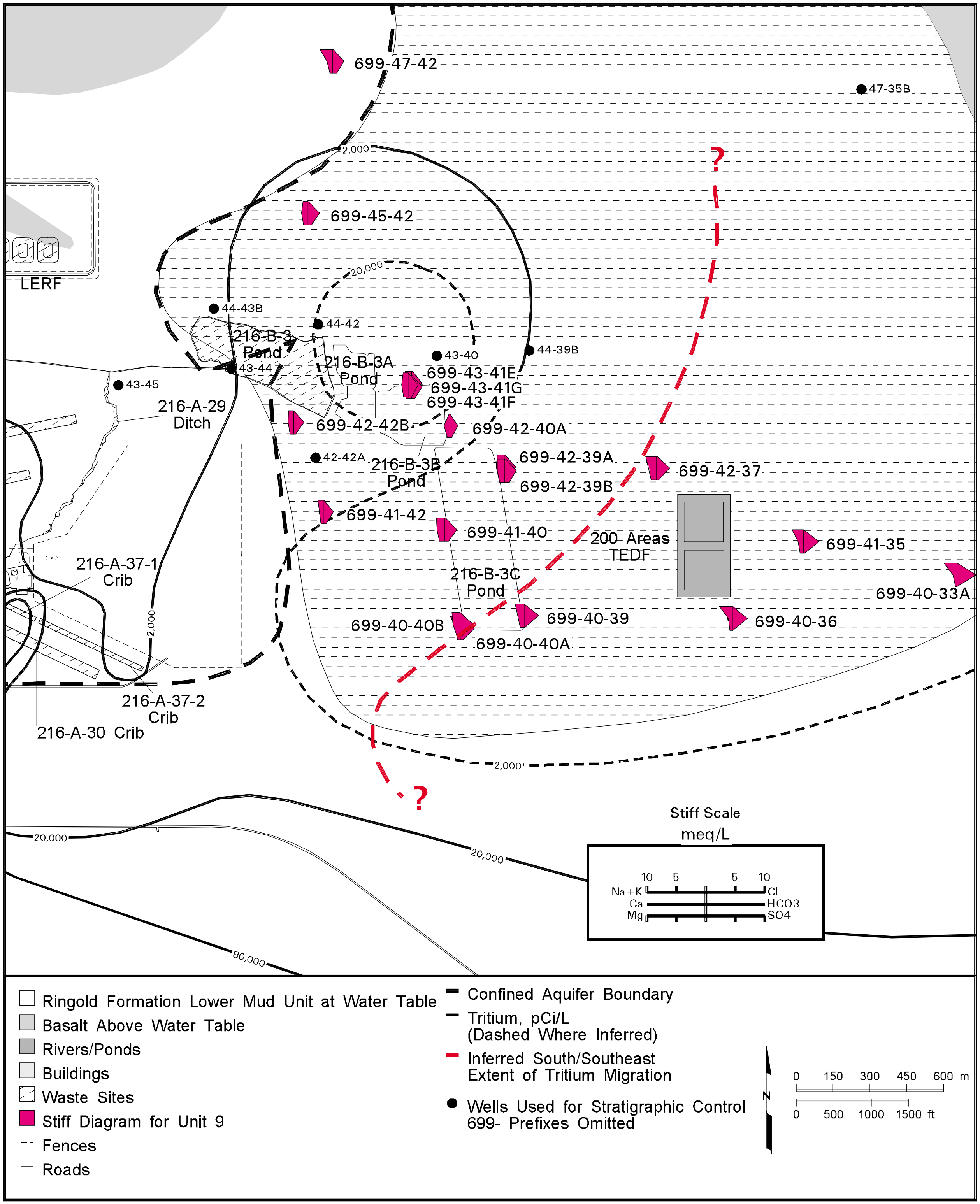

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Figure 2.9-37. Major Ion Chemistry in Wells Completed in the Confined Aquifer in the Vicinity of B Pond (PNNL-12261)

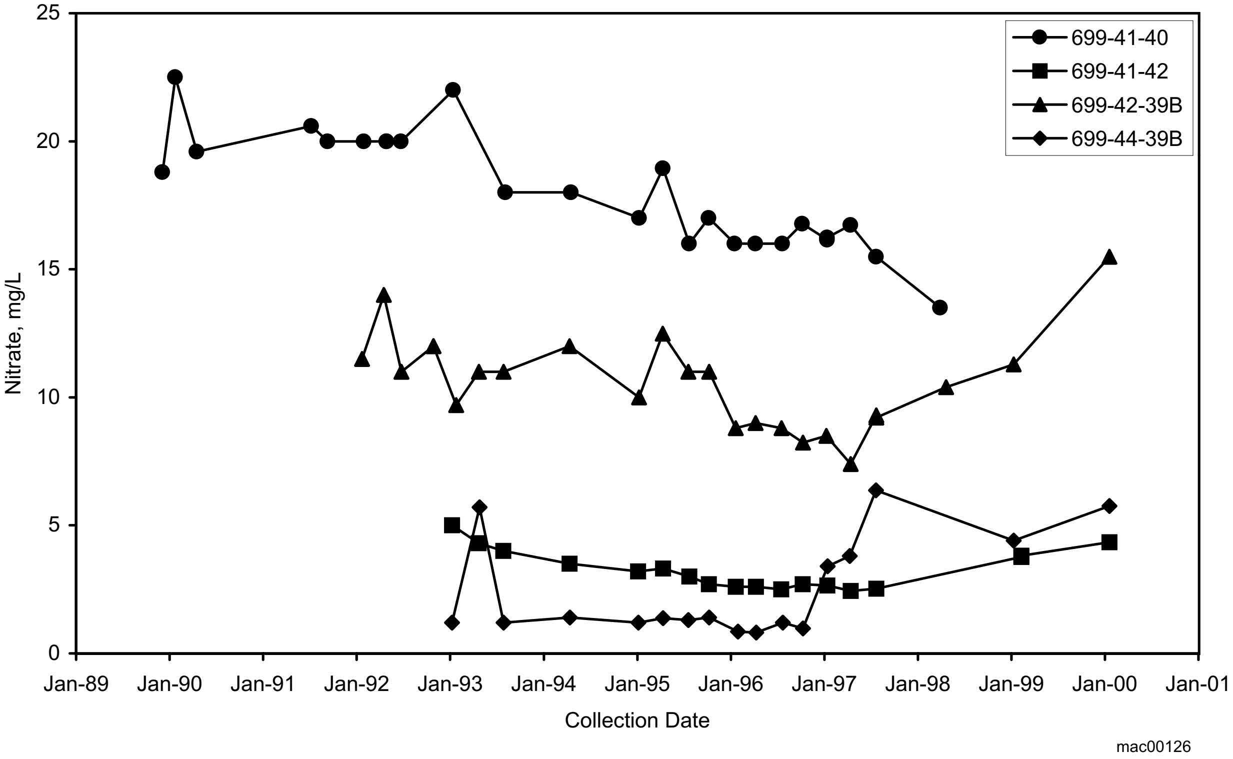

Figure 2.9-38. Nitrate Concentrations at B Pond in Wells Illustrating Significant Trends

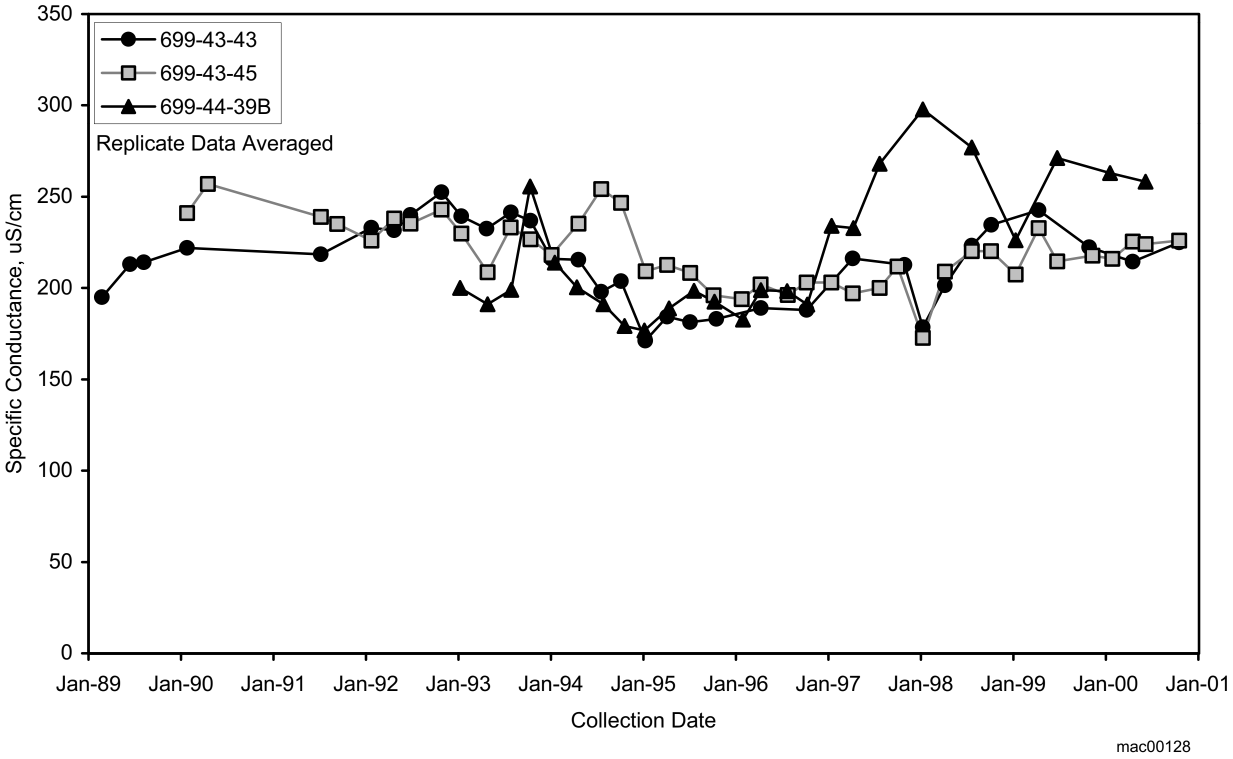

Figure 2.9-39. Specific Conductance in Wells Monitoring B Pond

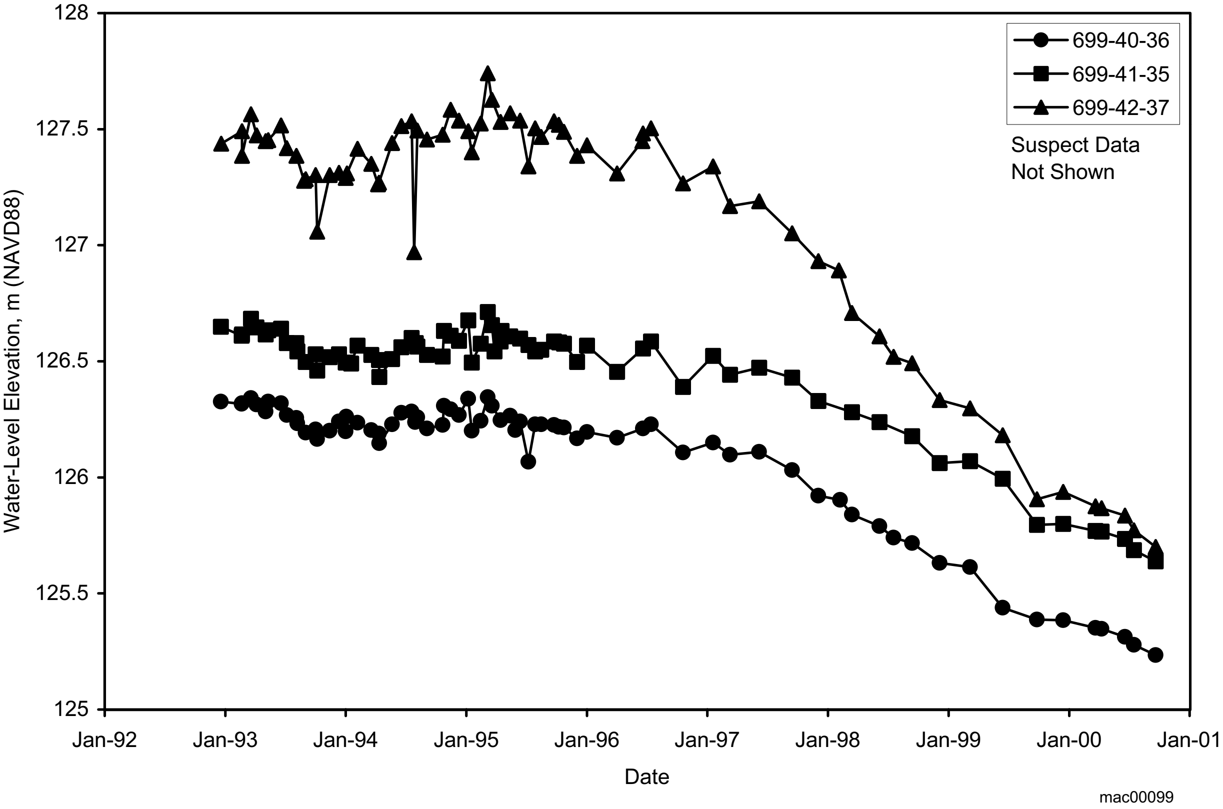

Figure 2.9-40. Water Levels in Wells at the Treated Effluent Disposal Facility

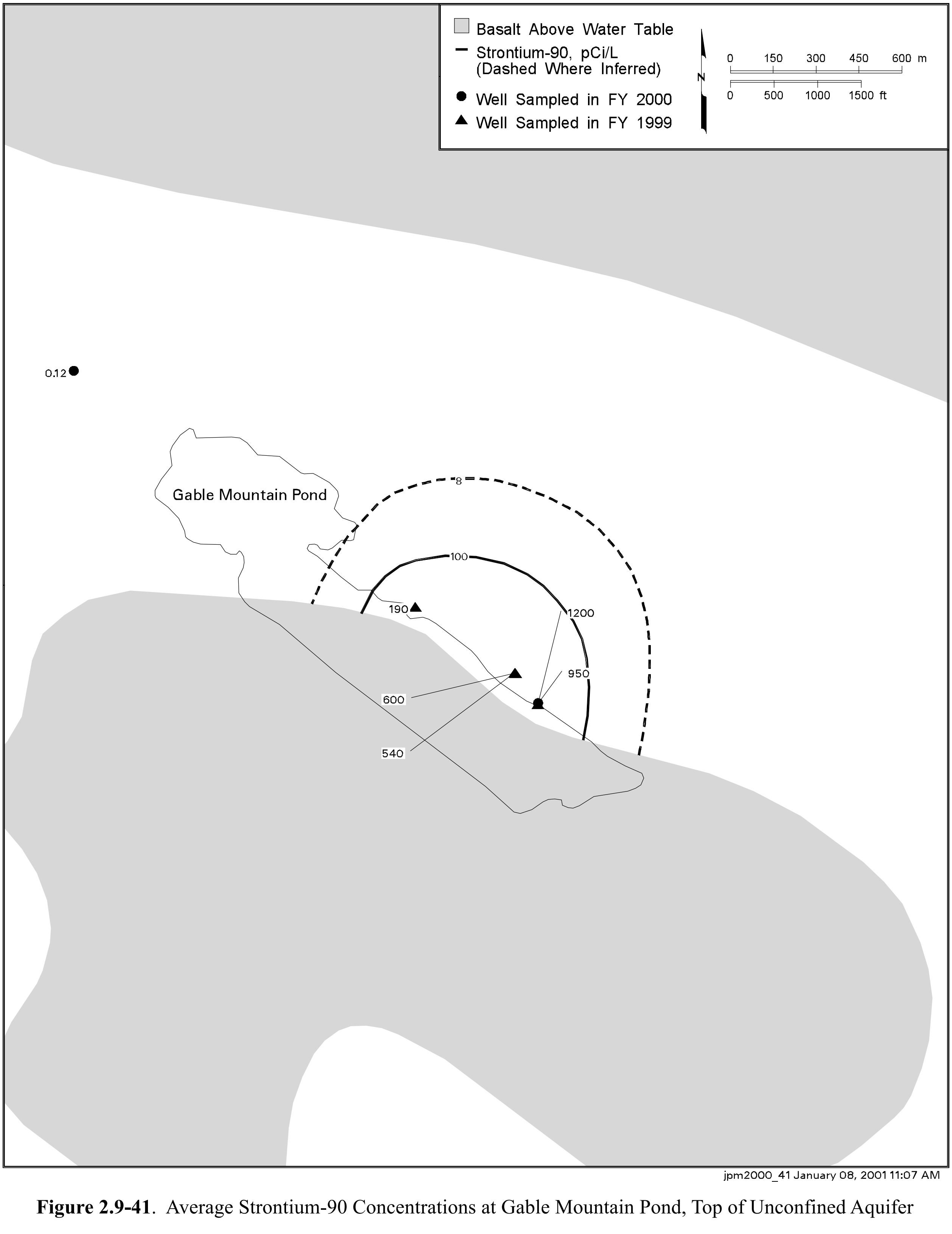

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Figure 2.9-41. Average Strontium-90 Concentrations at Gable Mountain Pond, Top of Unconfined Aquifer

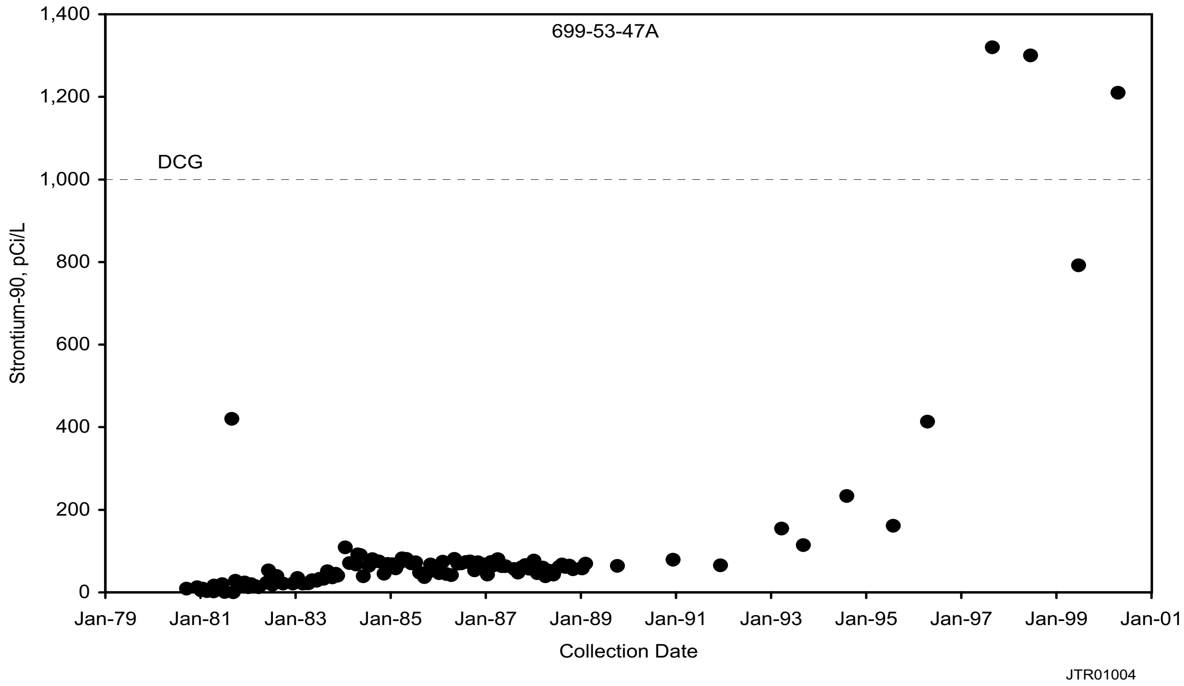


Figure 2.9-42. Strontium-90 in Well 699-53-47A near Gable Mountain Pond

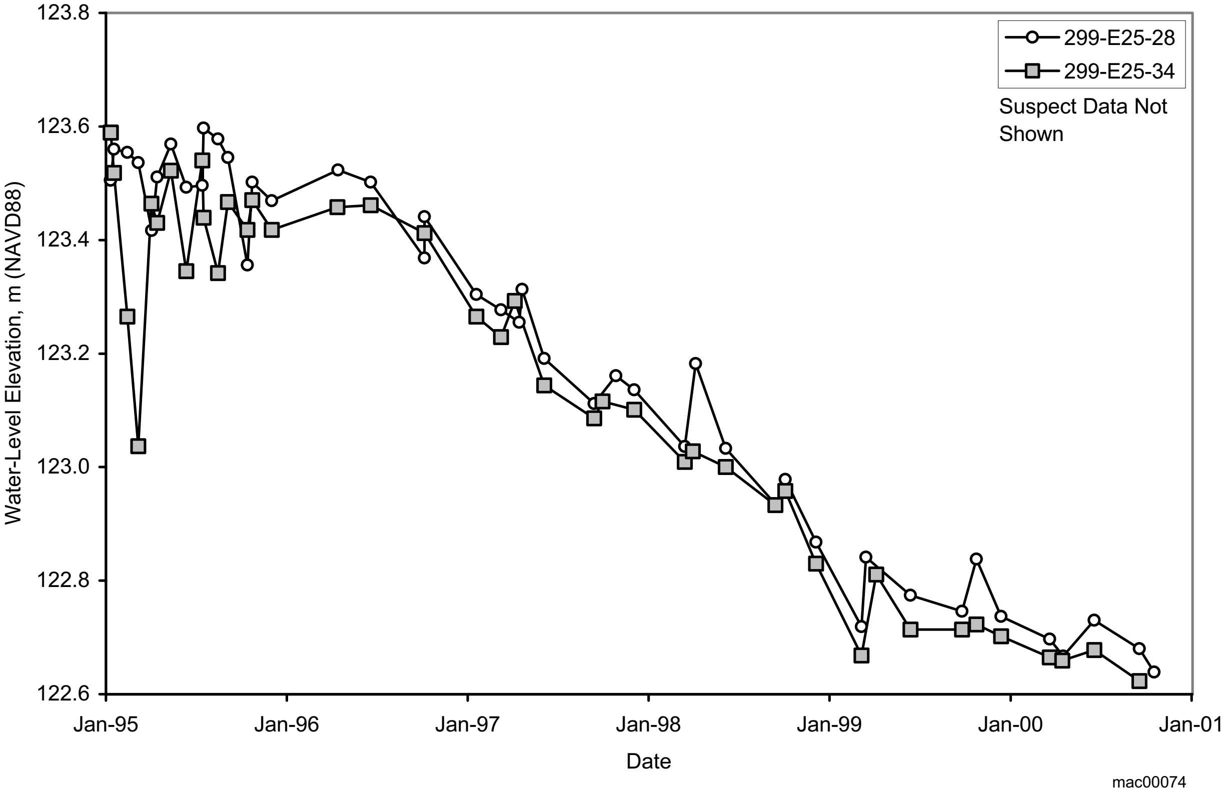


Figure 2.9-43. Water Levels in Well 299-E25-28 in Ringold Formation Unit 9 and Well 299-E25-34 in the Unconfined Aquifer

2.10 400 Area

E. C. Thornton

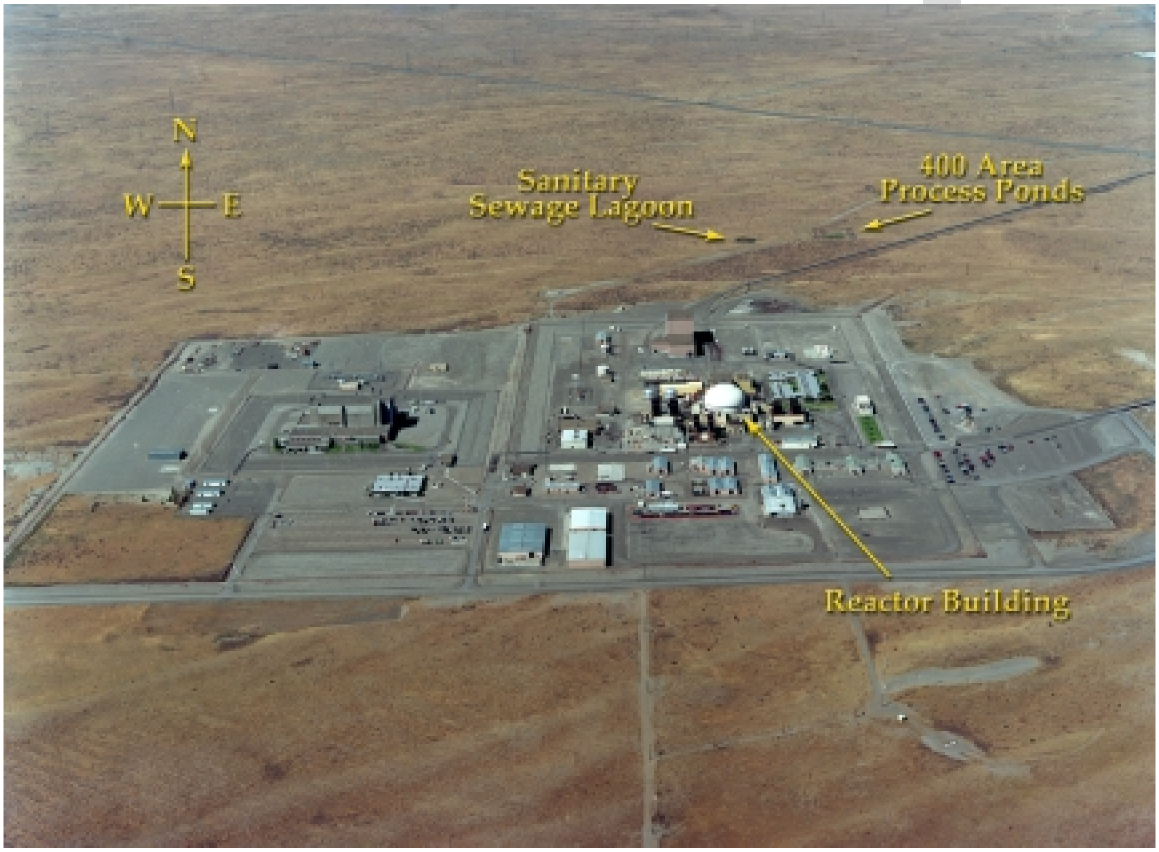
The 400 Area on the Hanford Site is the location of the Fast Flux Test Facility, a liquid sodium-cooled reactor that is currently being held on standby. In November 2000, the U.S. Department of Energy (DOE) announced its preferred alternative for the department's nuclear research and civilian isotope production does not include restart of the Fast Flux Test Facility. The record of decision (66 FR 7877) was signed after a month-long public comment period. Detailed planning has begun for the final deactivation of the facility.

Assessment efforts associated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* 300-FF-2 Operable Unit will extend to include groundwater contamination in the 400 Area. Primary groundwater monitoring activities in the 400 Area include monitoring of the 4608 B/C ponds (also called the 400 Area process ponds) for compliance with a waste discharge permit and monitoring of the 400 Area water supply, which is provided by wells completed in the unconfined aquifer system. Monitoring is also conducted to provide information needed to describe the nature and extent of site-wide contamination. The location of groundwater monitoring wells in the 400 Area is shown in Figure 2.10-1.

Wells in the 400 Area supply water and serve for emergency backup use. The wells are monitored monthly to ensure that tritium levels remain low.

2.10.1 Groundwater Flow

The Hanford Site water-table map (see Plate 1) shows the groundwater contours for the 400 Area. The water-table map indicates that flow is generally from



Aerial view of the 400 Area, August 1996.

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west to east 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.

2.10.2 Nitrate and Nitrite

Nitrate is the only groundwater contaminant attributable to 400 Area operations. The contamination is believed to have come from a sanitary sewage lagoon that is no longer in use.

Nitrate is the only significant contaminant attributable to 400 Area operations and has been detected at elevated levels in one of the wells (699-2-7) downgradient to the process ponds. Elevated nitrate concentrations up to 92 mg/L (45 mg/L maximum contaminant level) were found in well 699-2-7 during fiscal year 2000 and are attributed to a sanitary sewage lagoon formerly located immediately west and upgradient of the process ponds (Figures 2.10-2 and 2.10-3) and later to a drainfield associated with septic tanks located southwest of the ponds. Groundwater samples associated with this well are also frequently elevated with respect to nitrite (Figure 2.10-4), which may have been generated by reduction of nitrate to nitrite due to the natural breakdown of nitrate in the aquifer. All nitrite values are below the 3.3-mg/L maximum contaminant level, however. Disposal to the lagoon was discontinued in 1983 or 1984 and to the drainfield in April 1997. Thus, groundwater contamination from these sources is expected to diminish with time. Nitrate and nitrite concentrations in samples obtained from the new downgradient well 699-2-6A were not significantly elevated relative to the upgradient well 699-8-17.

2.10.3 Tritium

Elevated levels of tritium (Figure 2.10-5) associated with the groundwater plume from the vicinity of the Plutonium-Uranium Extraction Plant in the 200 East Area were identified in 400 Area wells as in previous years. The lower concentrations of tritium north of the 400 Area are probably related to discharge at the process ponds. This source of groundwater contamination is 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. The tritium concentrations in wells 499-S0-7, 499-S0-8, and 499-S1-8J are compared in Figure 2.10-6 to that of the 400 Area drinking water supply. Tritium was found at levels at or below the 20,000 pCi/L drinking water standard in samples from well 499-S0-7 during fiscal year 2000. Samples collected from well 499-S0-8 exceeded the drinking water standard during the latter part of fiscal year 1999, but all samples collected during fiscal year 2000 were well below the drinking water standard. All samples collected from well 499-S1-8J in fiscal year 2000 were below the drinking water standard.

Tritium remained below the 20,000-pCi/L drinking water standard and the 4 mrem/yr dose equivalent in the drinking water supply, sampled at a tap for all sampling events in fiscal year 2000 (see Figure 2.10-6). Nitrate remained below the maximum contaminant level in fiscal year 2000 for the water-supply wells. Data from fiscal year 2000 and earlier from 400 Area and surrounding wells indicates no other constituents are present at levels above their maximum contaminant levels or drinking water standards.

Monitoring Objectives in 400 Area

Groundwater monitoring is conducted in the 400 Area:

- triennially to annually to describe the nature and extent of contamination
- quarterly to detect possible impacts of 400 Area process ponds
- monthly to monitor tritium trends in drinking water wells.

2.10.4 400 Area Process Ponds

The 400 Area process ponds are regulated under a WAC 173-216 state waste discharge permit, which was issued on August 1, 1996, and modified on February 10, 1998. This permit defines groundwater enforcement limitations for the facility. Groundwater monitoring is provided by upgradient well 699-8-17 and downgradient wells 699-2-6A and 699-2-7, and is undertaken quarterly per the requirements presented in Appendix A, Table A.42. Groundwater quality met permit conditions in fiscal year 2000.

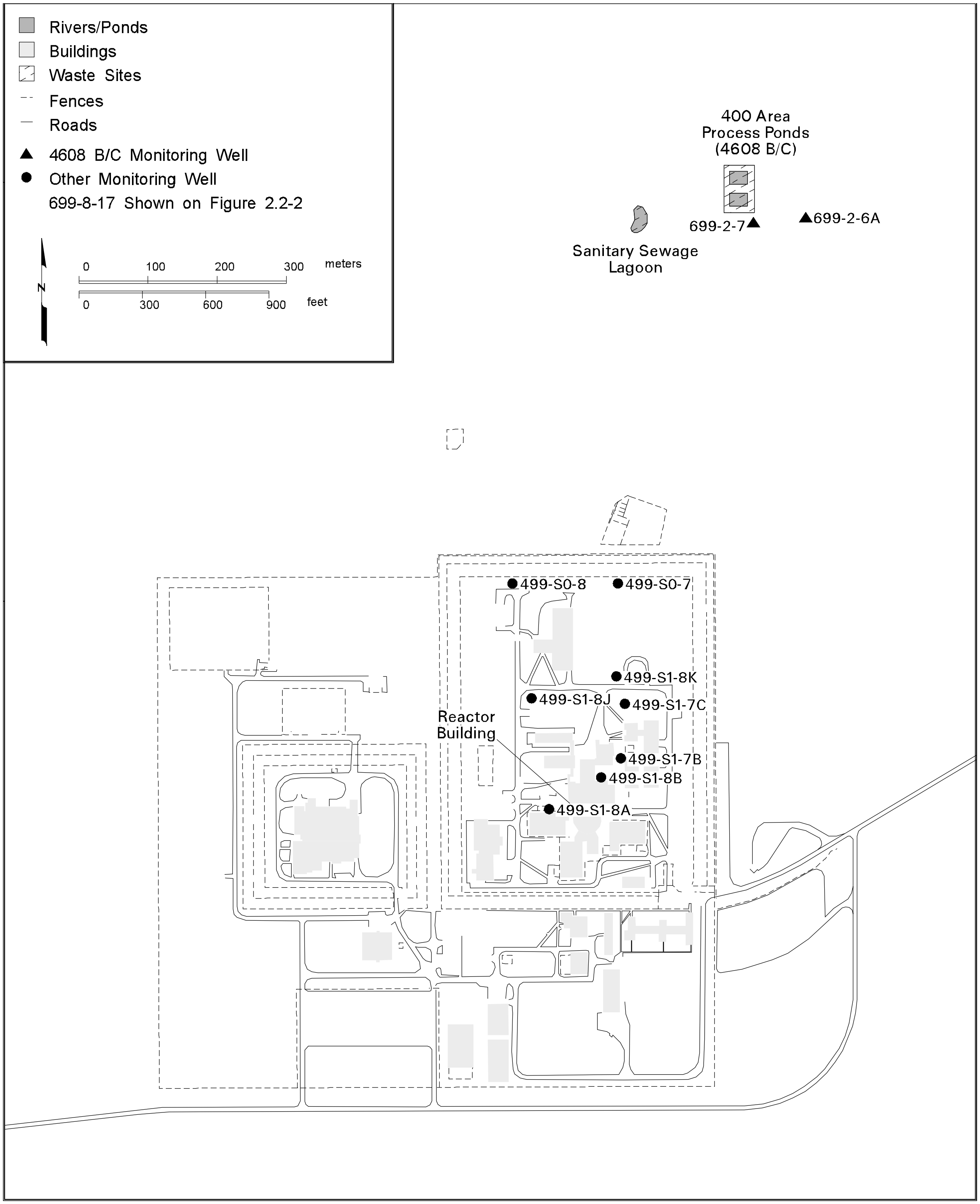

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Figure 2.10-1. Groundwater Monitoring Wells in the 400 Area

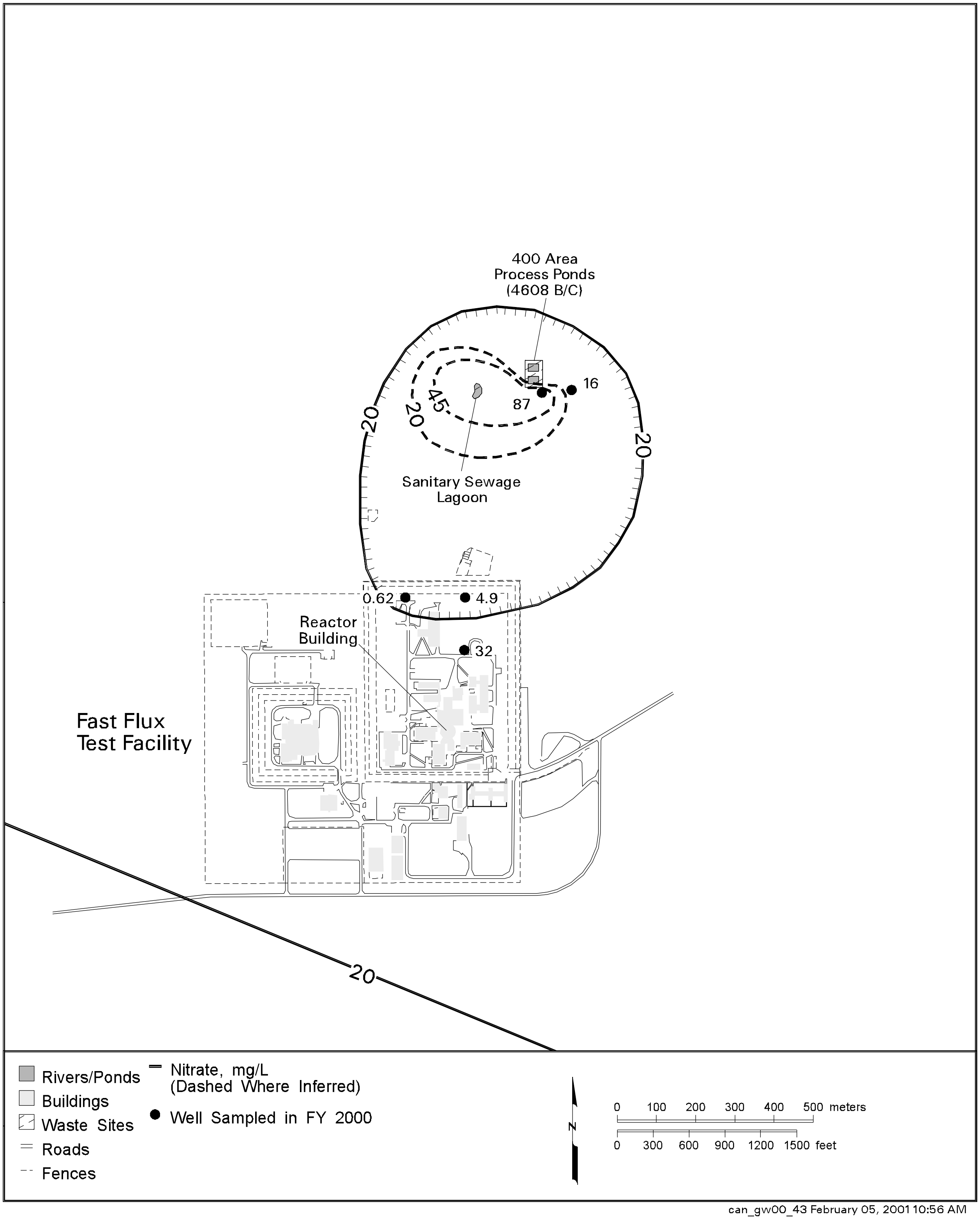

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Figure 2.10-2. Average Nitrate Concentrations in the 400 Area, Top of the Unconfined Aquifer

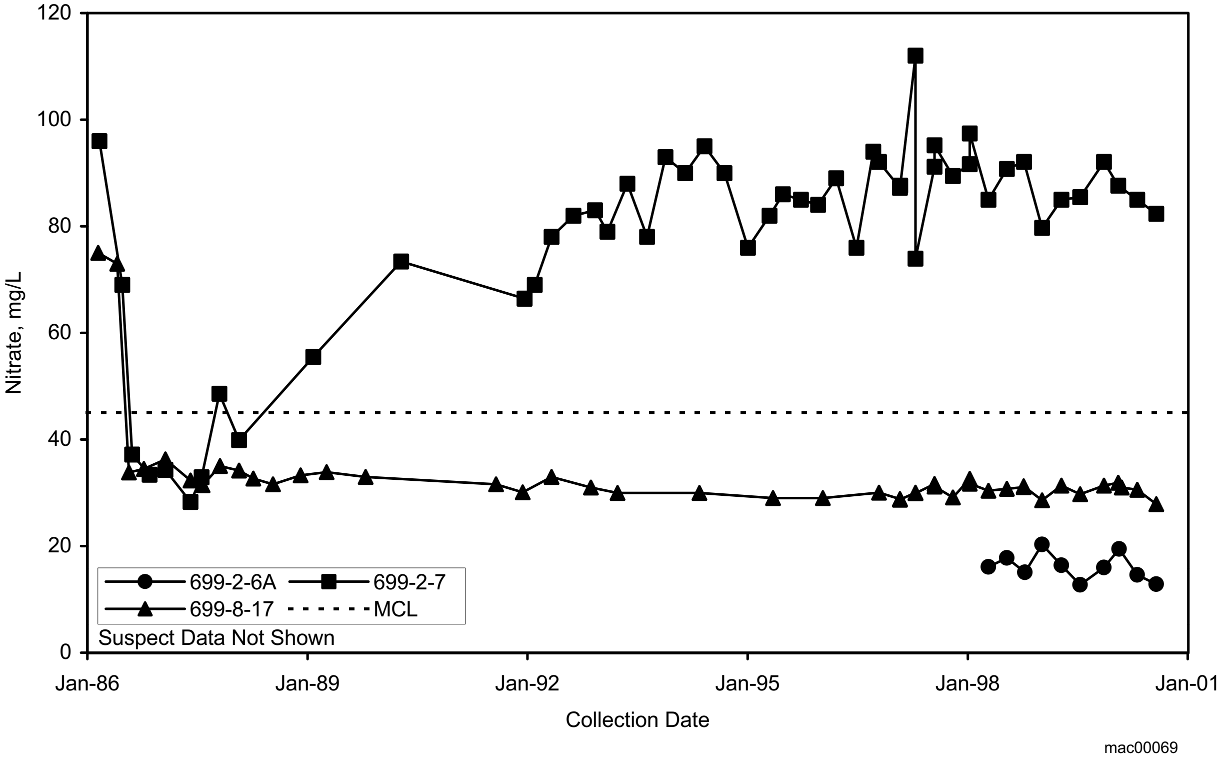

Figure 2.10-3. Nitrate in Wells Monitoring the 400 Area Process Ponds

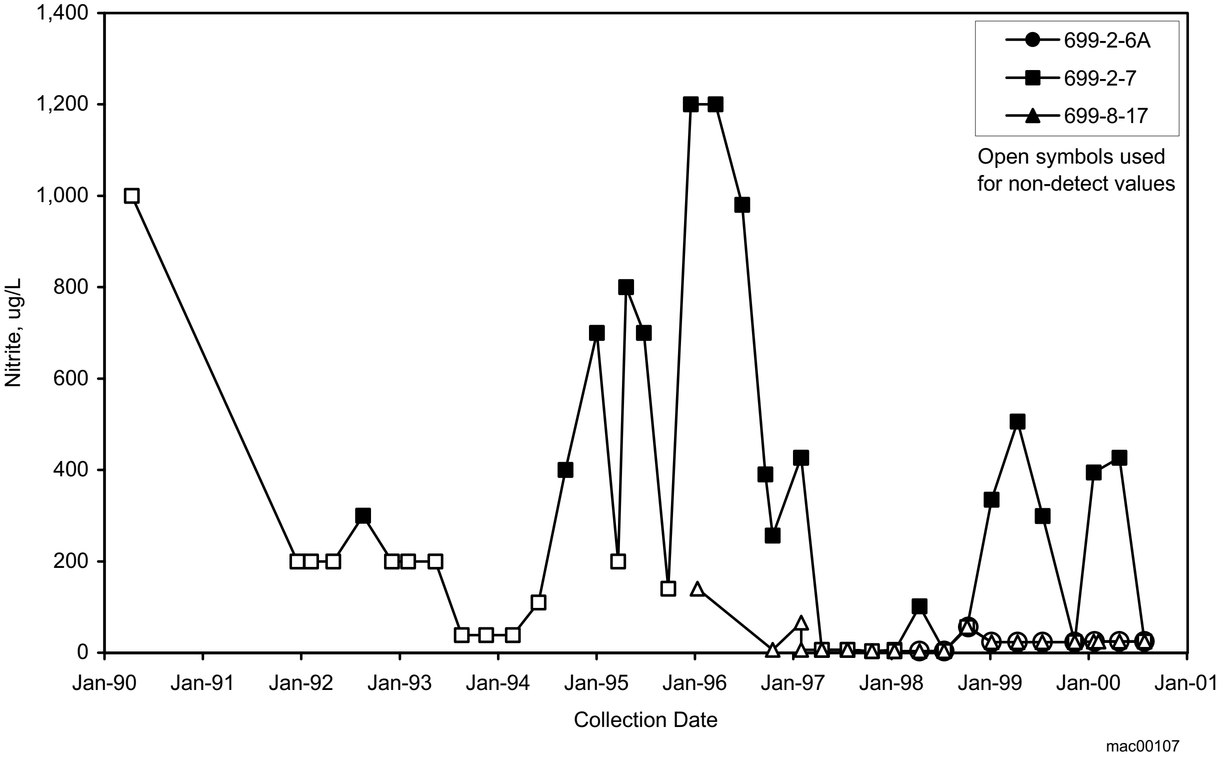

Figure 2.10-4. Nitrite in Wells Monitoring the 400 Area Process Ponds

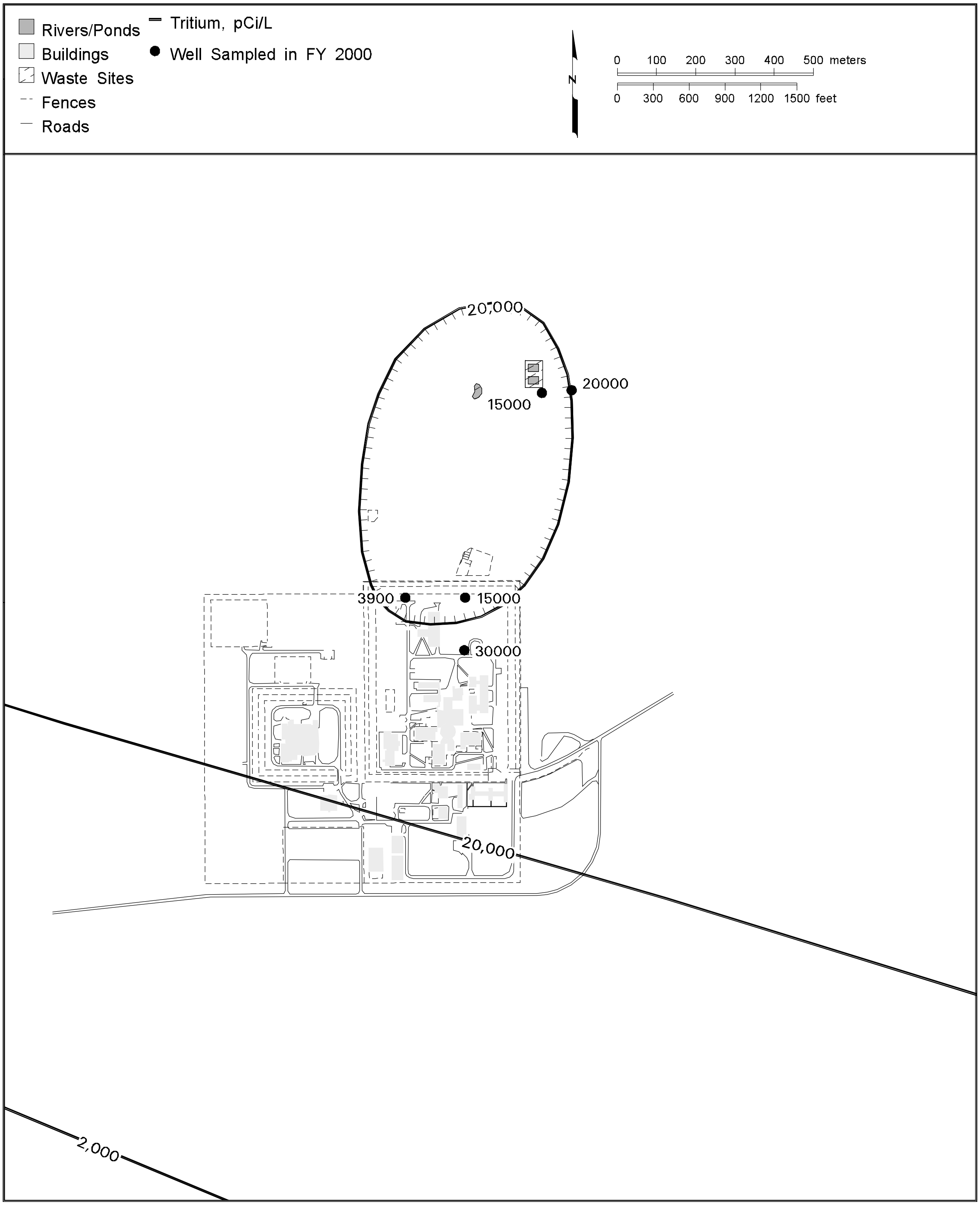

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Figure 2.10-5. Average Tritium Concentrations in 400 Area, Top of Unconfined Aquifer

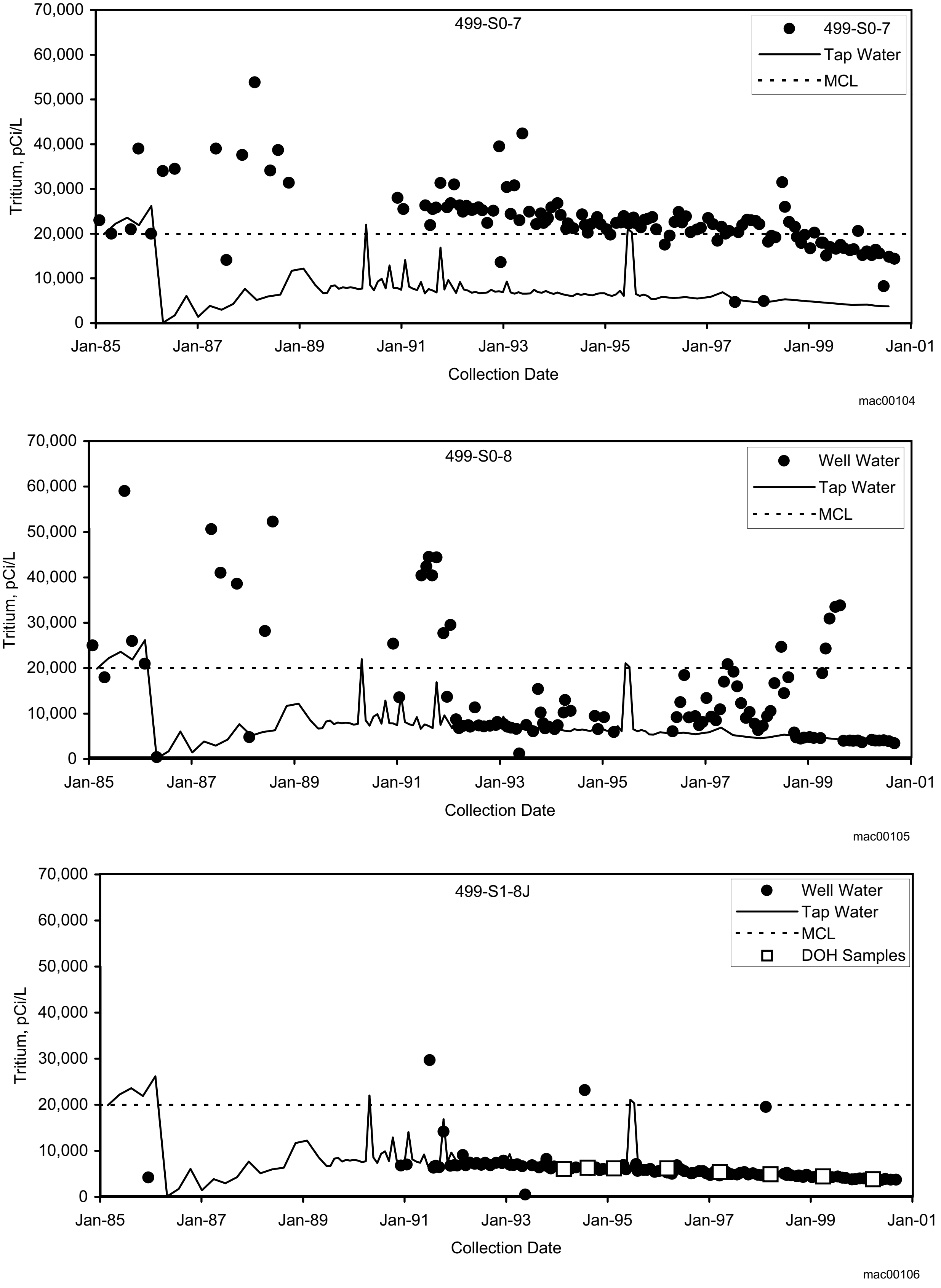

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Figure 2.10-6. Comparison of Tritium Concentrations in 400 Area Drinking Water System

2.11 600 Area

J. W. Lindberg and P. E. Dresel

This section discusses groundwater contamination in the 600 Area including the Nonradioactive Dangerous Waste Landfill, Solid Waste Landfill, western 600 Area, and the 200-PO-1 Operable Unit. Other facilities located in the 600 Area are described in the sections relating to their operable units (i.e., 618-10, 618-11, 316-4 are in Section 2.12; Gable Mountain Pond in Section 2.9; PUREX cribs plumes in 2.9).

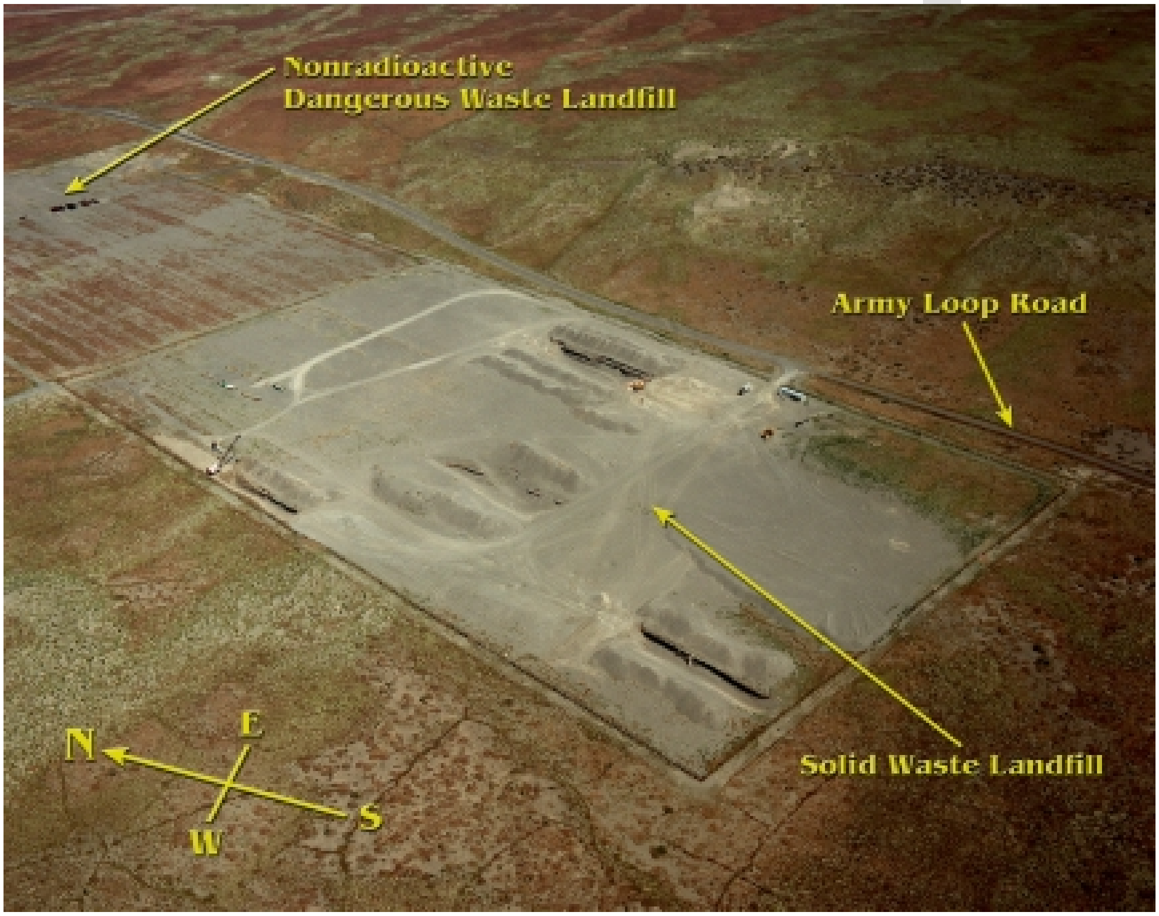
Most of the groundwater contaminants in the 600 Area originated at waste sites in other areas.

2.11.1 Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill is a *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal facility regulated under an interim status, indicator parameters program. The Nonradioactive Dangerous Waste Landfill and the adjacent Solid Waste Landfill make up what is known as the Central Landfill.

2.11.1.1 Groundwater Flow

Groundwater flow beneath the Central Landfill in fiscal year 2000 was the same as in recent years. The direction and rate of groundwater flow at the Central Landfill are difficult to determine from water-table maps because of the extremely low hydraulic gradient. The best indicators of flow direction are the major plumes of



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Aerial view of the Central Landfill, June 1991.

iodine-129, nitrate, and tritium. These plumes flow to the southeast (~125 degrees east of north; see Section 17.0 in DOE/RL-91-03) in the vicinity of the Central Landfill. The decrease in nitrate and tritium concentrations across the Central Landfill indicates the rate of groundwater flow is ~6 meters per day. For more information on groundwater flow rate and flow direction, see Appendix A, Table A.2.

Water-level data from one well pair, sampling the top of the unconfined aquifer and the top of the Ringold Formation, indicate that the vertical gradient within the upper portion of the aquifer is negligible. The well pairs (and water-level elevations) are 699-26-35A (163.360 meters) and 699-26-35C (163.368 meters).

2.11.1.2 RCRA Parameters for the Nonradioactive Dangerous Waste Landfill

RCRA monitoring at the Nonradioactive Dangerous Waste Landfill in fiscal year 2000 indicated the site has not had a significant impact on groundwater.

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. Chlorinated hydrocarbons are monitored because they may represent groundwater contamination originating from this landfill. Tritium and nitrate are present in groundwater and have sources in the 200 East Area (see Section 2.9.2). The groundwater quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate) are monitored but are either not detected or not found in concentrations significantly above background concentrations. None of the groundwater quality parameters exceed maximum contaminant levels.

Wells at the Nonradioactive Dangerous Waste Landfill (Figure 2.11-1) are sampled on a semiannual basis in February and August. The second sampling (August 2000) was delayed beyond the end of the fiscal year.

The values for RCRA indicator parameters did not exceed their critical means (i.e., critical range) in fiscal year 2000.

During fiscal year 2000, six chlorinated hydrocarbons were detected in Nonradioactive Dangerous Waste Landfill wells, but none at concentrations greater than the practical quantitation limit. They include 1,1,1-trichloroethane, 1,1-dichloroethane, 1,4-dichlorobenzene, methylene chloride, tetrachloroethene, and trichloroethene. The source of the chlorinated hydrocarbons could be either from the Solid Waste Landfill (to the south) or the Nonradioactive Dangerous Waste Landfill. For example, tetrachloroethene is present in vadose zone vapor beneath the Solid Waste Landfill (PNL-7147) and also is the principal vadose zone vapor contaminant around the chemical disposal trenches at the Nonradioactive Dangerous Waste Landfill (see Section 5.2 of DOE/RL-93-88). It is possible that both of these sources contribute to the contamination.

Monitoring Objectives in 600 Area

Groundwater monitoring is conducted in the 600 Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect possible impacts of the Nonradioactive Dangerous Waste Landfill RCRA Site
- quarterly to detect possible impacts of the Solid Waste Landfill.

Tritium and nitrate were detected in all Nonradioactive Dangerous Waste Landfill wells. Concentrations increase from the southwestern wells, lowest concentrations, to the northeast where concentrations are highest. The Nonradioactive Dangerous Waste Landfill is on the edge of the major tritium and nitrate plumes from the 200 East Area (Plate 2 and Figures 2.1-3 and 2.1-4). Both tritium and nitrate concentrations in the network wells at this landfill are decreasing with time.

2.11.2 Solid Waste Landfill

The Solid Waste Landfill is regulated by the Washington State Department of Ecology under WAC 173-304, *Washington Solid Waste Regulations.* WAC 173-304 parameters and site-specific parameters (including chlorinated hydrocarbons, gross alpha, gross beta, and tritium) are analyzed on groundwater samples collected quarterly, though the fourth quarter samples were not collected in time to be included in fiscal year 2000. Groundwater flow was described in Section 2.11.1.1. The location of wells at the Solid Waste Landfill is shown in Figure 2.11-1.

The Solid Waste Landfill has had little negative impact on Hanford Site groundwater, except minor chlorinated hydrocarbon contamination below drinking water standards but above WAC 173-200 levels, which are lower and applicable to the Solid Waste Landfill. Some downgradient wells show higher specific conductance, lower pH, and higher sulfate than upgradient wells. This apparently is a result of high concentrations of carbon dioxide in the vadose zone resulting from the degradation of sewage material beneath the Solid Waste Landfill (see Section 5.3 of DOE/RL-93-88; PNL-7147; and WHC-SD-EN-TI-199).

2.11.2.1 WAC 173-304 Parameters

Each WAC 173-304 parameter is discussed separately below. See Appendix A, Table A.46 for a complete list of all results for required constituents at the Solid Waste Landfill during fiscal year 2000.

- Temperature – Average values for replicate temperature determinations measured during sampling in downgradient wells ranged from 17.4 to 19.6°C. All measurements were below the background threshold value of 20.7°C. See Appendix A, Table A.47 for a total list of fiscal year 2000 background threshold values for WAC 173-304 required parameters.
- Specific conductance – Specific conductance measurements on samples from all of the Solid Waste Landfill downgradient wells exceeded the background threshold value of 583 µS/cm. The range in downgradient wells was 626 to 862 µS/cm. Five of the eight downgradient wells also exceeded the 700 µS/cm maximum contaminant level (WAC 246-290-310) in fiscal year 2000.
- Constituent pH – Average values for replicate pH measurements in downgradient wells ranged from 6.5 to 7.3. Reported results were lower than the background threshold range (6.68 to 7.84) in three downgradient wells (699-23-34A, 699-24-34A, and 699-24-34B).
- Total organic carbon – The average of replicates for total organic carbon concentration in downgradient wells ranged from 235 to 550 µg/L. None of the reported values exceeded the 1,168 µg/L background threshold value.
- Chloride – Chloride concentrations in downgradient wells ranged from 5,300 to 7,200 µg/L. The 7,820 µg/L background threshold value was not exceeded.
- Nitrate – Nitrate concentrations in the downgradient wells ranged from 11.1 to 18.6 mg/L. Neither the 29.0 mg/L background threshold value nor the 45.0 mg/L maximum contaminant level were exceeded in any downgradient well. The source of nitrate at the Solid Waste Landfill is from upgradient sources in the 200 East Area (see Figure 2.1-4).
- Nitrite and ammonium – Nitrite and ammonium concentrations in all downgradient wells were less than the method detection levels, 24.3 µg/L for nitrite and 36.6 µg/L for ammonium.
- Sulfate – Reported sulfate concentrations in downgradient wells ranged from 38.9 to 54.9 mg/L. Reported results from two wells (699-22-35 and 699-23-34B) exceeded the background threshold value of 47.2 mg/L. None of the samples exceeded the 250.0 mg/L standard (WAC 173-200).
- Filtered iron – Reported values for filtered iron ranged from 24.7 to 121.0 µg/L in downgradient wells. None of the reported values exceeded the 160 µg/L background threshold value.
- Filtered zinc – Reported values for filtered zinc ranged from less than 3 to 24.5 µg/L in downgradient wells. None of the reported values exceeded the background threshold value of 34.9 µg/L.

The Solid Waste Landfill is regulated under state law. Groundwater monitoring has detected only very low levels of chlorinated hydrocarbons.

- Filtered manganese – Reported values for filtered manganese ranged from less than 1.1 to 6.5 µg/L in downgradient wells. None of the reported values exceeded the background threshold value of 10.0 µg/L.
- Chemical oxygen demand – Six of the eight downgradient wells and both upgradient wells had reported values of chemical oxygen demand ranging from 5,000 to 18,000 µg/L from samples collected in December 1999 or March 2000. The other two downgradient wells had reported results less than the 3,100 µg/L method detection level during all three of the sampling periods (December 1999 and March 2000). None of the wells had reported results above the 3,100 µg/L method detection level in samples collected in May 2000. Therefore, the results above the 3,100 µg/L method detection level in December 1999 and March 2000 are probably laboratory errors. The background threshold value was 10,000 µg/L.
- Coliform bacteria (most probable number) – The reported values for coliform bacteria were all non-detections (i.e., zero colonies per 100 milliliters), and therefore, the background threshold value of 16 colonies per 100 milliliters was not exceeded in any downgradient wells.

2.11.2.2 Site-Specific Parameters

Site-specific parameters at the Solid Waste Landfill include chlorinated hydrocarbons, gross alpha, gross beta, and tritium. Slightly elevated concentrations of chlorinated hydrocarbons continued to be detected at the Solid Waste Landfill during fiscal year 2000. Two samples exceeded the groundwater criteria set forth in WAC 173-200. The range of reported concentrations of chlorinated hydrocarbons in given in Table 2.11-1.

Chlorinated hydrocarbons were detected in all of the Solid Waste Landfill monitoring wells, including the upgradient wells. The chlorinated hydrocarbons detected were

1,1,1-trichloroethane
1,1-dichloroethane
1,4-dichlorobenzene
carbon tetrachloride
chloroform
tetrachloroethene (PCE)
trichloroethene.

Of those detected, only 1,1-dichloroethane and tetrachloroethene exceeded the WAC 173-200 concentration limits (1.0 µg/L and 0.8 µg/L, respectively). These results were consistent in all the upgradient and downgradient wells at the Solid Waste Landfill for at least one of the three sampling periods during fiscal year 2000. None of the reported results exceeded the maximum contaminant levels for any of the detected chlorinated hydrocarbons. The results reported for detected chlorinated hydrocarbons are, in general, lower in concentration than the reported results for fiscal year 1999. During fiscal year 1999, eight chlorinated hydrocarbons were detected, and all but two had concentrations exceeding the WAC 173-200 concentration limits.

The most likely cause of the widespread chlorinated hydrocarbon contamination at the Solid Waste Landfill, including upgradient wells and the adjacent Nonradioactive Dangerous Waste Landfill, is the dissolution of vadose zone vapors into groundwater. However, the source of the vapors is uncertain. The most probable source is chlorinated hydrocarbons dissolved in liquid sewage waste that was discharged to trenches at the site.

Gross alpha and gross beta were detected in most of the upgradient and downgradient wells at the Solid Waste Landfill. However, neither exceeded the drinking water standards, 15 pCi/L for gross alpha and 50 pCi/L for gross beta. The range of reported gross alpha values was less than the method detection limit of 2.08 pCi/L to 9.33 pCi/L. The range for reported gross beta was 9.98 to 18.90 pCi/L. These reported values are slightly above Hanford Site background, are similar to reported values in previous years, and are probably from 200 East Area sources. Background wells for the Solid Waste Landfill have similar reported levels.

Tritium, which has a source in the 200 East Area (see Section 2.9.2.2; Plate 2; and Figure 2.1-3), is generally highest in concentration in the northeast and lowest to the southwest, corresponding to position on the edge of the major plume emanating from the 200 East Area. Although the overall levels are decreasing gradually with time, four Solid Waste Landfill monitoring wells (including one upgradient well) have tritium levels that remain greater than the 20,000 pCi/L drinking water standard. The maximum concentration level reported during fiscal year 1998 was 91,400 pCi/L, during 1999 was 73,700 pCi/L, and during 2000 was 55,400 pCi/L.

2.11.3 Central 600 Area

Chromium is frequently detected in filtered samples south of the 200 East Area. Concentrations in well 699-32-62 of 200 µg/L were above the maximum contaminant level in fiscal year 2000. The chromium concentrations have declined slowly since it was first analyzed in 1992. The sources and extent of this contamination are uncertain; however, chromium is detected in several other wells in this area. Early disposal to the vicinity of the 216-S-10 pond and ditch is one possible source. The extent of chromium contamination to the south of well 699-32-62 is particularly poorly defined.

2.11.4 Western 600 Area

The western 600 Area is the area of the Hanford Site west of the 200 West Area and south of the Columbia River. This area includes the portion of the Hanford Site near the southwestern part of the site along Rattlesnake Ridge.

Nitrate exceeds the maximum contaminant level in two wells in the western Hanford Site. This contamination has sources off the Site.

Nitrate was detected at levels above the maximum contaminant level in two wells in the western part of the 600 Area in fiscal year 2000 (see Figure 2.1-4). Nitrate concentrations in these wells have changed little over the past decade. Well 699-36-93, located west (upgradient) of the 200 West Area, contained 47 mg/L of nitrate in the fiscal year 2000 sample. Nitrate concentrations in this well rose during the 1980s and only declined slightly during the 1990s. Well 699-17-70 (54 mg/L), located 6 kilometers south-southeast of the 200 West Area contained 53 mg/L of nitrate. Nitrate upgradient of the 200 West Area and in well 699-17-70 north of the Rattlesnake Hills appears to have a source off the Hanford Site, possibly related to agricultural activity. An extension of Yakima Ridge, south of the 200 West Area, forms a partial hydraulic barrier for the unconfined aquifer system, and hydraulic head is considerably higher south of the ridge (see Plate 1). For this reason and the lack of other Hanford Site contaminants such as tritium, nitrate in well 699-17-70, south of the ridge, is not believed to result from Hanford Site activities.

2.11.5 200-PO-1 Operable Unit

The 200-PO-1 Operable Unit encompasses the area bounded by the 2,000 pCi/L isopleth of the major Hanford Site tritium plume originating from the 200 East Area and extending east and southeast to the Columbia River (see Plate 2). This area also contains the far-field well network of the PUREX cribs RCRA facility (see

Section 2.9.2.7). The purpose of the 200-PO-1 Operable Unit and PUREX cribs well networks is to monitor the extent and concentration of the three major plumes of groundwater contamination extending east and southeastward from the 200 East Area. The three major plumes are tritium, nitrate, and iodine-129 (see Figures 2.1-3, 2.1-4, and 2.1-5). They are described with their source areas in Section 2.9.2.

Table 2.11-1. Ranges of Chlorinated Hydrocarbon Concentrations (µg/L) in Groundwater at the Solid Waste Landfill, December 1999 to May 2000

Constituent	Limit (µg/L)	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A
Carbon tetrachloride	WAC 0.3	<0.32 - **1.0**	<0.32	<0.32	<0.32	<0.32
Chloroform	WAC 7.0	<0.38 - 1.3	<0.38 - 0.92	<0.38 - 1.0	<0.38 - 0.91	<0.38
1,1-Dichloroethane	WAC 1.0	**1.2 - 2.8**	0.94 - **2.3**	**1.0 - 2.2**	0.63 - **1.8**	0.67 - **1.7**
1,2-Dichloroethane	WAC 0.5	<0.34	<0.34	<0.34	<0.34	<0.34
1,4-Dichlorobenzene	WAC 4.0	<0.1	0.13 - 0.83	<0.11 - 0.87	<0.1	<0.1
cis-1,2-Dichloroethene	MCL 70	<0.33	<0.33	<0.33	<0.33	<0.33
trans-1,2-Dichloroethene	MCL 100	<0.43	<0.43	<0.43	<0.43	<0.43
Tetrachloroethene	WAC 0.8	**1.0 - 1.7**	**1.6 - 2.3**	**0.96 - 1.4**	**2.0 - 2.4**	**1.9 - 2.1**
Total organic halides	NA	5.9 - 13.3	4.9 - 10.4	4.4 - 10.4	4.3 - 9.1	4.3 - 11.5
Trichloroethene	WAC 3.0	0.54 - 1.4	0.55 - 1.4	0.43 - 1.1	0.78 - 1.4	0.78 - 1.2
1,1,1-Trichloroethane	WAC 200	4.1 - 6.4	2.9 - 4.1	3.4 - 4.4	2.3 - 2.9	3.0 - 3.3
1,1,2-Trichloroethane	MCL 5.0	<0.19	<0.19	<0.19	<0.19	<0.19

Constituent	Limit (µg/L)	699-24-34B	699-24-34C	699-24-35	699-25-34C	699-26-35A
Carbon tetrachloride	WAC 0.3	<0.32	<0.32	<0.32	<0.32	<0.32 - **0.85**
Chloroform	WAC 7.0	<0.38	<0.38 - 0.92	<0.38	<0.38 - 0.95	<0.38 - 0.94
1,1-Dichloroethane	WAC 1.0	0.71 - **1.8**	0.39 - **1.8**	<0.36 - **1.4**	<0.36 - **1.4**	<0.36 - **1.3**
1,2-Dichloroethane	WAC 0.5	<0.34	<0.34	<0.34	<0.34	<0.34
1,4-Dichlorobenzene	WAC 4.0	<0.1	<0.1 - 0.38	<0.1	<0.1	<0.1
cis-1,2-Dichloroethene	MCL 70	<0.33	<0.33	<0.33	<0.33	<0.33
trans-1,2-Dichloroethene	MCL 100	<0.43	<0.43	<0.43	<0.43	<0.43
Tetrachloroethene	WAC 0.8	**1.9 - 2.2**	**1.9 - 2.5**	**0.98 - 1.1**	**1.0 - 1.6**	**0.7 - 1.0**
Total organic halides	NA	4.3 - 7.3	4.3 - 7.4	4.3 - 18.4	4.3 - 10.7	4.3 - 8.9
Trichloroethene	WAC 3.0	0.68 - 1.2	0.47 - 1.4	<0.26 - 0.94	0.45 - 1.3	<0.26 - 0.98
1,1,1-Trichloroethane	WAC 200	2.4 - 2.8	1.6 - 3.2	1.9 - 2.6	0.7 - 2.0	0.87 - 2.0
1,1,2-Trichloroethane	MCL 5.0	<0.19	<0.19	<0.19	<0.19	<0.19

(a) WAC = Washington Administrative Code.
MCL = Maximum contaminant level.
NA = Not applicable.
Values in **bold** type equal or exceed WAC 173-200-40.

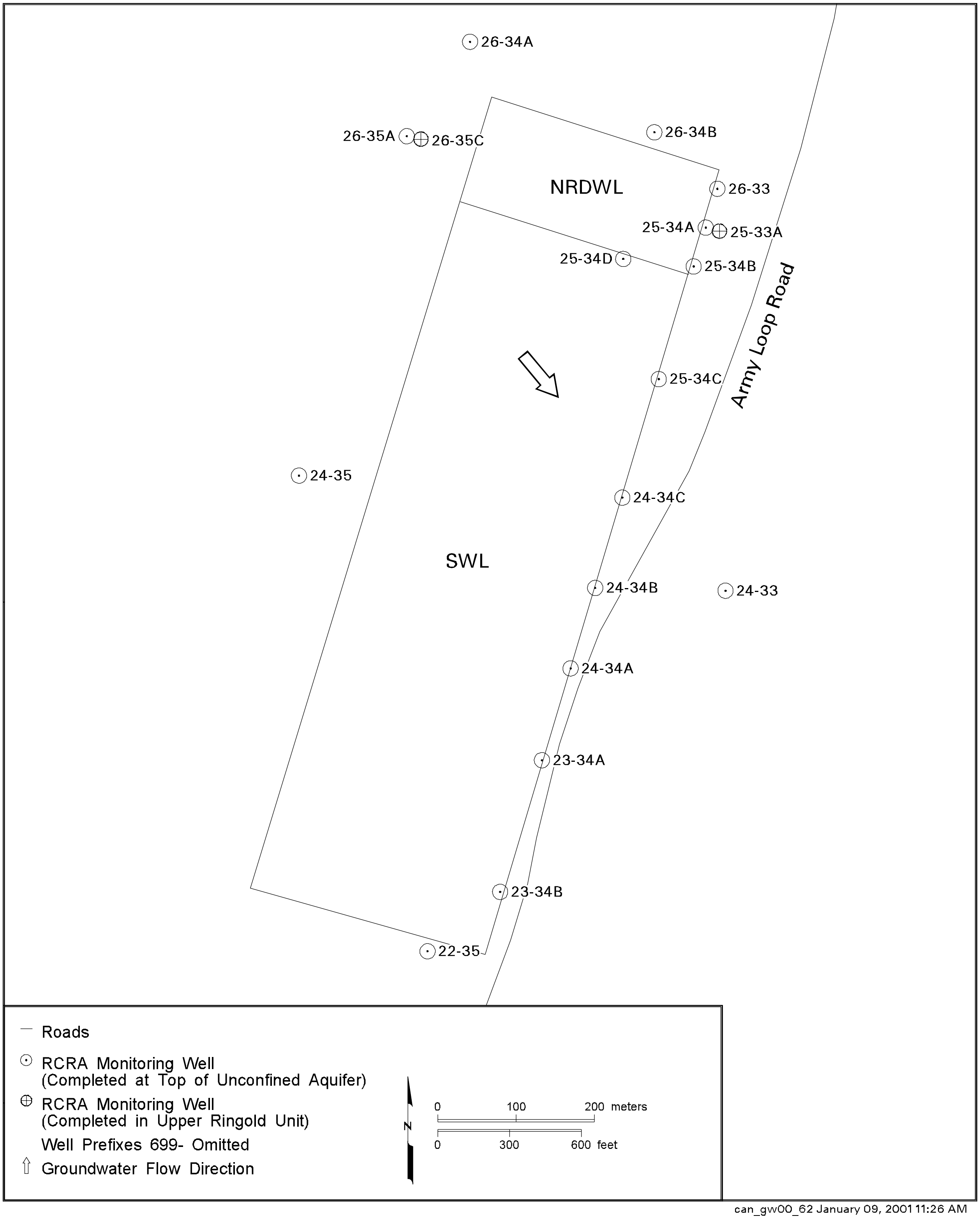

Figure 2.11-1. Groundwater Monitoring Wells in the Central Landfill and Vicinity. The Nonradioactive Dangerous Waste Landfill (NRDWL) and Solid Waste Landfill (SWL) comprise the Central Landfill.

2.12 300 Area

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This discussion on the 300 Area is mainly about the 300 Area proper, which includes one *Resource Conservation and Recovery Act of 1976* (RCRA) site (316-5 process trenches) and one groundwater operable unit (300-FF-5). The chapter also includes smaller areas to the north of the 300 Area that are included in the 300-FF-5 Operable Unit. These satellite areas to the north include the 618-11 burial ground, the 618-10 burial ground, and the 316-4 crib discussed in Sections 2.12.7.2 and 2.12.7.3.

Uranium is the major contaminant of concern in the 300 Area. Tritium contamination from the 200 East Area affected the 300 Area at levels less than the drinking water standard of 20,000 pCi/L (see Section 2.13). The 10,000 pCi/L isopleth line extends through the 300 Area and shows little change since fiscal year 1999. Tritium contamination and how it affects the 300 Area is discussed in Sections 2.9.2.2 and 2.13.2. Additional constituents detected during fiscal year 2000 include cis-1,2-dichloroethene, nitrate, strontium-90, and trichloroethene. Figure 2.12-1 shows the locations of groundwater monitoring wells in the 300 Area and Richland North Area. Major contaminants of concern at the 618-10 burial ground and 316-4 crib include uranium, various hydrocarbons, and tributyl phosphate. At the 618-11 burial ground, the major contaminant of concern is tritium.

Uranium in the 300 Area and tritium at the 618-11 burial ground are the major groundwater contaminants of concern in the 300-FF-5 Operable Unit.

2.12.1 Groundwater Flow

The primary influence on water-table elevation in the 300 Area is the fluctuation in Columbia River stage. Changes in river-stage elevation can be correlated to

Aerial view of the 300 Area, July 2000.

changes in water-level elevations at wells as far as ~360 meters from the river (PNL-8580). During fiscal year 2000, river-stage fluctuations were typical for an average year, and the water-table elevations and corresponding configuration of the water-table map for March 2000 (see Plate 1) were similar to March water-table maps of previous years. This configuration indicates a slight increase over low river stage. The bend in water-table contours near the river indicates a potential for flow out of the river into the aquifer, which occurs when river stage increases.

Monitoring Objectives in 300 Area

Groundwater monitoring is conducted in the 300 Area:

- annually to describe the nature and extent of contamination
- annually to determine if contaminants in the groundwater operable unit are reducing in concentration
- semiannually to determine if contaminants at one RCRA site are reducing in concentration.

Water-table contours in the vicinity of the 300 Area are somewhat concentric indicating that the 300 Area is a low point, or “sink,” in the local unconfined aquifer. Groundwater enters the 300 Area from the northwest, west, and southwest, flows through the 300 Area, and then into the Columbia River. In the immediate vicinity of the 316-5 process trenches, the flow direction was southward during March 2000 based on the water-table contours. Flow rate there was 0.2 to 60 meters per day (see Appendix A, Table A.2) based on the March 2000 gradient and calculated hydraulic conductivity from aquifer tests (PNL-6716). The southward flow direction is a response to the slight increase in river stage. Average river stage would produce a more southeasterly flow in the vicinity of the 316-5 process trenches.

2.12.2 Uranium

The uranium distribution in the 300 Area is shown in Figure 2.12-2. The highest uranium concentrations are found in the northern part of the 300 Area, downgradient from the 316-5 process trenches and near the 316-1 process pond. Because the 316-1 process pond is downgradient of the process trenches, it is difficult to determine the relative contribution of each facility to the contamination. However, the maximum uranium concentration (20 μg/L proposed drinking water standard) detected in the 300 Area during fiscal year 2000 was 234 μg/L at well 399-3-1 in the September sample. (The highest level reported on Figure 2.12-2 is 322 μg/L at well 399-2-2 for a sample collected in August of 1999.) The line of wells from 399-1-17A to 399-3-1 has the highest levels of uranium in the 300 Area, and this alignment is close to the average groundwater flow direction from the 316-5 process trenches. This alignment suggests that the 316-5 process trenches are a major source of the uranium contamination.

Figure 2.12-3 shows the historical trend for uranium in well 399-1-17A, which is the well closest to the inflow portion of the 316-5 process trenches. Uranium concentrations dropped dramatically in 1991 as a result of the expedited response action, which removed much of the contaminated sediment in the trenches. However, uranium concentrations began to rise sharply again when the process trenches discharges ceased in December 1994, presumably due to the lack of dilution by the large quantities of process water (5.7 to 9.5 million liters per day). (Note: In the last few years of operation, the 316-5 process trenches were discharging mostly steam condensate and cooling water with little or no uranium contamination.) In fiscal years 1996 and 1997, the rise continued, though not at the rapid rate it did in fiscal year 1995. Since 1997, the average uranium levels appear to be dropping slightly.

The 316-5 process trenches and 316-1 process pond were waste sites that contaminated groundwater with uranium. The sites have been excavated and contaminant concentrations in groundwater have declined in recent years.

Figure 2.12-3 also shows a yearly cycle for uranium concentration. The peak each year is in the spring with the lowest concentration each year in the fall or early winter. This yearly cycle or yearly fluctuation is caused by high Columbia River stages, which mobilize more uranium from the lower vadose zone in spring and less during low flow stages in fall or early winter.

In previous years, another zone of elevated uranium in 300 Area groundwater was found near the 324 Building, immediately west of well 399-3-11. However, in recent years, the elevated zone of uranium has moved downgradient (southeast) (see Figure 2.12-2). Uranium concentrations in well 399-3-11 have declined since 1996 (Figure 2.12-4). At the same time, well 399-4-9, downgradient from well 399-3-11, showed a corresponding increase in uranium concentration over the same years (74 to 130 μg/L) (see Figure 2.12-4). In fiscal years 1999 and 2000, the reported concentrations of uranium at well 399-3-11 were 44.4 and 28.3 μg/L, while the reported concentration at the downgradient well 399-4-9 continued to rise to 163 μg/L in fiscal year 1999. In fiscal year 2000, well 399-4-9 was not sampled. Apparently, the uranium high near the 324 Building has moved with the groundwater flow to a downgradient position along the Columbia River near well 399-4-9. However, there still appears to be a limited source of uranium near the 324 Building (possibly the 307 trenches [316-3] that were retired in the 1960s).

2.12.3 Strontium-90

Strontium-90 (8-pCi/L drinking water standard) continues to be detected at well 399-3-11 near the 324 Building. However, the more recently measured concentrations are not as high as those recorded in December 1995 sampling (8.7 pCi/L). Since December 1995, strontium-90 concentration has varied between 3 and 8 pCi/L. During fiscal years 1999 and 2000, the recorded values were 4.0 and 4.1 pCi/L. Although there may have been a release of strontium-90 in the vicinity of the 324 Building, the reported concentration of 8.7 pCi/L in December 1995 was the only result greater than the drinking water standard since 1986. The source of the strontium-90 is unknown, but it may be the retired (and reclaimed) 307 trenches (316-3) located immediately north of the 324 Building.

In previous years, it was reported that the detected strontium-90 recorded at well 399-3-11 may have been due to strontium-90 sorbed to sediment that was sampled along with the groundwater in the bailer-derived groundwater samples at well 399-3-11. However, among the samples collected in fiscal year 2000 was a filtered sample. The results show that the filtered sample had a similar result (4.02 pCi/L), and sorbed sediment cannot be the cause of the detected strontium-90.

2.12.4 Chlorinated Hydrocarbons

Trichloroethene was detected at 19 wells in the 300 Area in fiscal year 2000. However, none of the reported results was at or above the maximum contaminant level of 5.0 μg/L. The highest concentration reported during fiscal year 2000 (3.5 μg/L) was at well 399-1-16B near the 316-5 process trenches.

There are two "plumes" of trichloroethene in the 300 Area:

- a localized plume confined to one well pair (wells 399-1-16A and 399-1-16B) downgradient of the process trenches
- a plume extending into the 300 Area from the southwest (Figure 2.12-5).

The 316-5 process trenches contaminated groundwater with trichloroethene. Concentrations are declining naturally, and were below the maximum contaminant level in fiscal year 2000.

The plume downgradient of the 316-5 process trenches (wells 399-1-16A and 399-1-16B) had the highest concentration of trichloroethene in the lower portion of the uppermost aquifer. The concentration in well 399-1-16B was 2.2 to 3.5 μg/L during fiscal year 2000. Concentration of trichloroethene has decreased steadily in this well since 1997 (Figure 2.12-6). Trichloroethene also was detected in the well screened at the water table (well 399-1-16A), but concentrations were much lower during fiscal year 2000 (in the range of 0.37 to 0.65 μg/L). Trichloroethene detected in well 399-1-16A may actually be a portion of the second plume of trichloroethene from the southwest.

The other plume of trichloroethene , the one extending into the 300 Area from the southwest (see Figure 2.12-5), is detected at wells screened at the water table. The highest concentration in this plume within the 300 Area during fiscal year 2000 was at well 399-4-1 where the reported result was 2.3 µg/L and holding steady (Figure 2.12-7). The only identified source of trichloroethene in this plume is from offsite, southwest of the Horn Rapids Landfill (see also Section 2.13.4).

A plume of cis-1,2-dichloroethene was detected at five 300 Area wells, but the reported concentrations exceeded the 70 µg/L drinking water standard only in well 399-1-16B. The source of cis-1,2-dichloroethene is probably the 316-5 process trenches and potentially as a degradation product of trichloroethene. The concentration was at its maximum during fiscal years 1997 and 1998 and decreased slightly during fiscal year 2000 (Figure 2.12-8). During fiscal year 2000, the concentration at well 399-1-16B ranged from 110 to 170 µg/L.

A plume of tetrachloroethene (i.e., PCE) was detected in the 300 Area during fiscal year 1998, but it has dissipated and was virtually undetected in fiscal year 2000. Its source was in the vicinity of the 316-5 process trenches and extended southeast toward the Columbia River. The plume continued during fiscal year 1999, but the concentration within the plume decreased dramatically. The maximum reported value at well 399-1-17A, immediately downgradient of the process trenches, was 38 µg/L in fiscal year 1998. The maximum value at the same well in fiscal year 1999 was 4.0 µg/L. The plume maximum during fiscal year 1999 was 7.0 µg/L at well 399-1-16A, but the yearly average was only 1.8 µg/L. During fiscal year 2000, tetrachloroethene was detected at only one well (399-1-17A immediately downgradient of the process trenches) with a reported value of 0.65 µg/L.

2.12.5 Nitrate

Nitrate above background levels (WHC-EP-0595, Table A-1-2) is detected in all wells sampled in the 300 Area (Figure 2.12-9). However, only two of those wells reported nitrate concentrations greater than the 45 mg/L drinking water standard. The wells that reported concentration greater than the drinking water standard were well 399-5-1 (100.0 mg/L) and well 699-S27-E14 (60.6 mg/L) in the southwestern and southern portions of the 300 Area, respectively. The source of the nitrate is probably offsite industry and agriculture (see also Section 2.13).

2.12.6 RCRA Summary for the 316-5 Process Trenches

The 316-5 process trenches are a RCRA site that has contaminated groundwater and is monitored under a corrective-action program. The corrective action is deferred to the CERCLA operable units and involves natural attenuation of the contaminants.

Since December 1996, the 316-5 process trenches have been monitored by a RCRA final status corrective-action network. Corrective action is in conjunction with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (see Sections 2.12.7 and 2.12.8). The purpose of groundwater monitoring is to examine the trend of the constituents of concern to determine if they decreased in concentration as expected. Eight wells are monitored for uranium and volatile organics (including as a minimum, the contaminants of concern, trichloroethene, cis-1,2-dichloroethene, and tetrachloroethene) (see also Appendix A, Table A.48).

During fiscal year 2000, uranium remained above the proposed drinking water standard (20 µg/L) in the three downgradient wells that monitor the upper portion of the unconfined aquifer, near the water table. Those three wells are 399-1-10A, 399-1-16A, and 399-1-17A. Well 399-1-16B had cis-1,2-dicloroethene levels above the maximum contaminant level (70 µg/L). Trichloroethene and tetrachloroethene exceeded maximum contaminant levels in previous years. During fiscal year 2000, trichloroethene was detected but did not exceed maximum contaminant levels, and tetrachloroethene was no longer detected. For more information about uranium and the volatile organics, see Sections 2.12.2 and 2.12.4.

2.12.7 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units

In June 2000, the U.S. Environmental Protection Agency developed an *Explanation of Significance Difference to the 300-FF-5 Record of Decision* (EPA 2000) that expands the scope of the 300-FF-5 record of decision (ROD 1996a) to include groundwater beneath all 300-FF-2 waste sites and burial grounds as well as 300-FF-1 waste sites. (Note: An "explanation of significant difference" is an EPA document explaining why and how previous decisions in CERCLA documents are changed.) Therefore, the original 300-FF-5 boundary as it was defined in the 1996 record of decision (ROD 1996a) was expanded to include the 618-10 burial ground and 316-4 crib (between the 300 Area and Energy Northwest) and 618-11 burial ground (immediately west of Energy Northwest). The explanation also requires an update to the operations and maintenance plan (DOE/RL-95-73) to ensure that adequate groundwater monitoring requirements are in place. The Explanation of Significance Difference did not make any fundamental changes to the 1996 remedy selection decision. Figure 2.12-10 shows the location of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units; 618-10 burial ground; 316-4 crib; and 618-11 burial ground

2.12.7.1 Waste Site Remediation

In fiscal year 2000, the 300-FF-1 Remedial Action Project completed excavation and hauling of contaminated waste from the South Process Pond (316-1) and completed excavation and hauling of contaminated soil and debris from Landfills 1A and 1B. Also, the remaining stockpiled soil from Landfill 1D was hauled away.

2.12.7.2 618-10 Burial Ground and 316-4 Crib

This burial ground and adjacent crib are southeast of the 400 Area, adjacent to Route 4S. Based on water-table contours, groundwater flow is to the east (see Plate 1). This site was investigated as part of a CERCLA limited field investigation for the 300-FF-2 Operable Unit (DOE/RL-96-42). In fiscal year 1995, high levels of uranium, 768 µg/L unfiltered, were detected in well 699-S6-E4A that is immediately adjacent to the crib. The presence of hydrocarbon contamination was detected also in well 699-S6-E4A and included

- 104 mg/L total petroleum hydrocarbon
- ~770 to 1,800 µg/L alkane and assorted decanes
- ~3,200 µg/L unknown volatile organic compounds.

Groundwater samples from a well near the 618-10 burial ground and 316-4 crib contain elevated levels of uranium and petroleum products. Contaminant concentrations are declining.

Subsequently, tributyl phosphate was detected in well 699-S6-E4A. Well locations near the 618-10 burial ground and 316-4 crib are shown in Figure 2.12-11. The CERCLA investigation included re-configuration of well 699-S6-E4A and sampling of two cone penetrometer borings near this well. The conclusions in DOE/RL-96-42 were that uranium and hydrocarbon groundwater contamination are probably localized in the area of well 699-S6-E4A. The source of such contamination is primarily the crib, with possibly some contribution from the burial ground. There are no monitoring wells located immediately downgradient of the 618-10 burial ground.

Uranium in well 699-S6-E4A declined slightly from previous years with a fiscal year 2000 average value of 36 µg/L (Figure 2.12-12). This uranium is highly depleted in uranium-234 and uranium-235 (Table 2.12-1). Although details of the disposal to the burial ground and crib have not been researched, the waste is known to have come from 300 Area operations, and depleted uranium is known to have been used there. The presence of a low concentration of uranium-236 suggests that a component of the uranium has been irradiated in a reactor.

Tributyl phosphate concentrations reported in well 699-S6-E4A have been erratic, with 200 µg/L detected in the January 2000 sample (Figure 2.12-13). The reasons for the erratic concentrations have not been established but may be related to the petroleum hydrocarbons detected in the past. A sample collected August 30, 2000, indicated the presence of oil and grease at 3.1 mg/L.

During fiscal year 1996, well 699-S6-E4C was re-configured to provide two deep, depth-discrete, monitoring intervals within the Hanford/Ringold aquifer system that, in conjunction with shallow monitoring wells 699-S6-E4B and 699-S6-E4D, provide information on the vertical distribution of contaminants at this location. Previously the well was an 8-inch-diameter carbon steel pipe perforated from 14 to 80 meters below ground surface. The two new monitored intervals are at 26 meters (699-S6-E4CS) and at 50 meters (699-S6-E4CT) below the water table, and each interval (26 and 50 meters) is sampled by a piezometer that is open for 2 meters. Tritium concentrations at the water table in fiscal year 2000 were 20,400 pCi/L in well 699-S6-E4D. Tritium concentrations at 26 meters below the water table declined to 387 pCi/L in fiscal year 2000 from 27,800 pCi/L shortly after reconfiguration in fiscal year 1996. Tritium was not detected at the 50-meter level in fiscal year 2000. This suggests that the earlier value resulted from intercommunication down the well bore prior to reconfiguration. These results indicate that the highest concentrations of tritium are near the water table and concentrations decrease with depth.

2.12.7.3 618-11 Burial Ground

In January 1999, a sample from well 699-13-3A was analyzed for tritium for the first time. This well is located along the eastern (downgradient) fence line of the 618-11 burial ground, and the sample contained 1.86 million pCi/L of tritium (see Figure 2.12-11). This value is far higher than data found from the surrounding wells. The value was confirmed by re-analysis. The January 2000 sample contained 8.1 million pCi/L of tritium. This is the highest concentration of tritium detected on the Hanford Site in recent years. A special investigation of the groundwater at the 618-11 burial ground began in fiscal year 2000 to define the source of the high tritium results. The most recent groundwater sample from well 699-13-3A was collected on August 29, 2000, and the tritium results ranged from 6,720,000 to 8,380,000 pCi/L.

Tritium concentrations reached 8 million pCi/L in a well downgradient of the 618-11 burial ground. This contamination was only recently discovered, and the site was investigated further in fiscal year 2000. The high-level contamination is not present in nearby monitoring wells, strongly suggesting a source within the burial ground.

This burial ground is located west of the Energy Northwest reactor complex in the eastern 600 Area. The burial ground was active from 1962 to 1967 and received a variety of low and high activity waste from the 300 Area. The Waste Information Data System description of this site identified contaminants of concern (i.e., cesium, cobalt-60, curium, plutonium, strontium, uranium, and zirconium). Other contaminants that might be encountered include aluminum-lithium, beryllium, carbon tetrachloride, hydrogen gas, sodium-potassium eutectic, and thorium.

The water-table gradient in the vicinity of the 618-11 burial ground is nearly due east. However, the Hanford formation sediment thins to the east of the burial ground until less permeable Ringold Formation sediments are present at the water table (PNNL-13080). These lithologic changes suggest that groundwater flow may not be due east, but may divert to the northeast or southeast. The presence of low permeability sediment is believed to explain the area of low tritium concentrations in this region.

The Phase I investigation of the elevated tritium levels downgradient from the 618-11 burial ground consisted of sampling existing wells in the vicinity of the burial ground and re-evaluating historical data for the area (PNNL-13228). The extremely high tritium values seen in well 699-13-3A were not found in any other nearby wells, strongly suggesting a source within the burial ground (Figure 2.12-14). No radionuclides have been detected at levels above drinking water standards in this well except for the tritium discussed above. Gross alpha measurements have all been less than 10 pCi/L. Gross beta measurements in well 699-13-3A are generally less than 40 pCi/L but have shown an increasing trend (Figure 2.12-15). A split of the August 29, 2000, sample sent to ThermoRetec laboratory for gross beta analysis was reported to contain 74 pCi/L gross beta. This result did not agree with duplicates analyzed by Severn Trent Laboratories, which reported 30 and 31 pCi/L gross beta. Nitrate was detected in well 699-13-3A at levels greater than the maximum contaminant level with a fiscal year 2000 average of 90.3 mg/L. Other wells in the region monitoring the 200 East nitrate plume have reported nitrate concentrations in the 20 to 45 mg/L range. However, the immediate area near well 699-13-3A (Energy Northwest) had reported nitrate concentrations at 90 mg/L or greater in previous years. No other constituents have been detected at levels above primary maximum contaminant levels in well 699-13-3A. Low levels of technetium-99 were detected in well 699-13-3A, but the levels were consistent with the regional plume.

A single reported uranium result from well C3079 had a reported value of 30.8 µg/L for a sample collected in August 2000. This result is consistent with the gross alpha result of 20.8 pCi/L from a groundwater sample collected from the same well at the same time. Although there are no other uranium results from this well, gross alpha was also reported earlier (February 2000) at 22.5 pCi/L. These gross alpha and uranium results from well C3079 do not constitute a definite trend for uranium contamination at this site, but the information available to date indicate that uranium monitoring should continue.

Potential tritium source materials and source locations within the 618-11 burial ground have not been identified. Possible source materials include fission products and activation products from nuclear operations. In particular, there is a possibility that the tritium is related to tritium production research carried out at the Hanford Site in the 1960s. Although that link has not been established, the hypothesis is consistent with what is known about the research and about burial ground operations.

Subsequent Phase II investigation of the burial ground began in late summer 2000. Soil gas monitoring points were installed at the burial ground perimeter and downgradient. The results of the soil gas monitoring are discussed in Section 3.2.1. In brief, the monitoring points were sampled to measure the soil gas helium-3/helium-4 ratios. Helium-3 is the stable decay product of tritium. If elevated helium-3 relative to the atmospheric helium-3/helium-4 ratio are detected, it indicates the presence of a nearby tritium source. The source may be a groundwater plume or vadose zone contamination.

The helium-3 survey detected elevated ratios of helium-3/helium-4 along the eastern and northern sides of the burial ground. Helium-3/helium-4 ratios along the south side and in the western corners of the burial ground were near atmospheric. Elevated ratios were also detected to the east of the burial ground. These relationships confirm that the 618-11 burial ground provides a local source of tritium.

In early fiscal year 2001, two borings were drilled to collect water samples at locations of elevated helium-3/helium-4 ratios. The first boring (well number C3264) was placed along the northern boundary of the burial ground where the maximum ratio was detected. Although the helium-3/helium-4 ratio was 62.54, the groundwater sample indicated only 6,500 pCi/L of tritium. This strongly suggests that the elevated helium-3 results from vadose zone transport from buried tritium-bearing waste. The peak ratio is near a series of caissons used for disposal of highly radioactive waste and, thus, these are considered to be possible sources.

The second boring (well number C3265) was drilled approximately 50 meters east of well 699-13-3A. The groundwater sample collected at this location contained 1.5 million pCi/L of tritium. Technetium-99 levels were somewhat elevated at 330 pCi/L but were below the drinking water standard. Further steps to delineate the groundwater tritium plume are being discussed for fiscal year 2001.

2.12.8 Water Quality at Shoreline Monitoring Locations

Groundwater samples are collected annually from riverbank seepage sites during the seasonal low river stage, which occurs during the fall months. Riverbank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration Project in support of the 300-FF-5 Operable Unit investigations. Table 2.12-2 lists the analytical results for key constituents for samples collected during November 1999 from riverbank seepage and during September 1999 from nearshore river water.

Two riverbank seeps along the 300 Area contained uranium at levels exceeding the maximum contaminant level. Concentrations in river samples were far below that level.

Samples of riverbank seepage were collected at two locations along the 300 Area shoreline during fiscal year 2000. The first location (S300-42-2) is adjacent to well 399-1-10, near the former process trenches, and the second (S300-DR42-2) is ~550 meters downstream from the first location, close to wells 399-2-1 and 399-2-3. The specific conductance for the two sites was 403 and 455 μS/cm, respectively, indicating that the seepage samples consisted primarily of groundwater, with little addition of bank storage river water. These seepage sites have been tracked for many years and historical trends of specific conductance are highly variable, with no distinct increase or decrease indicated (PNNL-13230).

The principal contaminant of concern, uranium, was measured at 114 μg/L at location S300-42-2 and 301 μg/L at downstream location S300-DR42-2. Gross alpha measurements reflect the uranium concentrations in these samples. Nearshore river water samples collected at several points along the 300 Area shoreline did not reveal similar elevated values of uranium, with river water results ranging from 0.4 to 0.7 μg/L.

Gross beta measurements at the seeps approach the 50 pCi/L drinking water standard, which is slightly higher than in previous years. Tritium concentrations are approximately one-half the 20,000 pCi/L drinking water standard. Tritium is measurable in nearshore river water, but is a factor of ten or more lower than in the seeps. Nitrate is below the 45 mg/L drinking water standard in the seeps, and nearly undetectable in river water near the shore.

Table 2.12-1. Well 699-S6-E4A Uranium Isotopic Measurements by Inductively Coupled Plasma/Mass Spectrometry (sampled January 25, 1999)

Analyte	Result
U-234 µg/L	3.27E-03
U-235 µg/L	5.16E-01
U-236 µg/L	1.34E-03
U-238 µg/L	9.83E+01
U-234 atom %	3.37E-05
U-235 atom %	5.29E-03
U-236 atom %	1.37E-05
U-238 atom %	9.95E-01
U-234 enrichment	-38.8%
U-235 enrichment	-26.6%

Table 2.12-2. Shoreline Monitoring Data for the 300 Area, Fiscal Year 2000

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Uranium (µg/L)	Gross Alpha (pCi/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
S300-42-2	Seep	1-Nov-99	403	113.9	98.6	0.21	48.9	10,300	25.8
S300-DR42-2	Seep	1-Nov-99	455	300.9	228.0	0.28	35.6	11,300	29.0
R300-415	River	16-Sep-99	118	0.6		0.07		128	0.4
R300-421	River	16-Sep-99	122	0.6		0.07		306	0.7
R300-425	River	16-Sep-99	143	0.7		0.08		1,090	2.3
R300-429	River	16-Sep-99	117	0.5		0.07		132	0.4
R300-431	River	16-Sep-99	118	0.4		0.07		82	0.4

Seep = Natural riverbank seepage site.
River = River water collected near the shore.
Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 µS/cm.
Data sources: Hanford Environmental Information System and various project records.

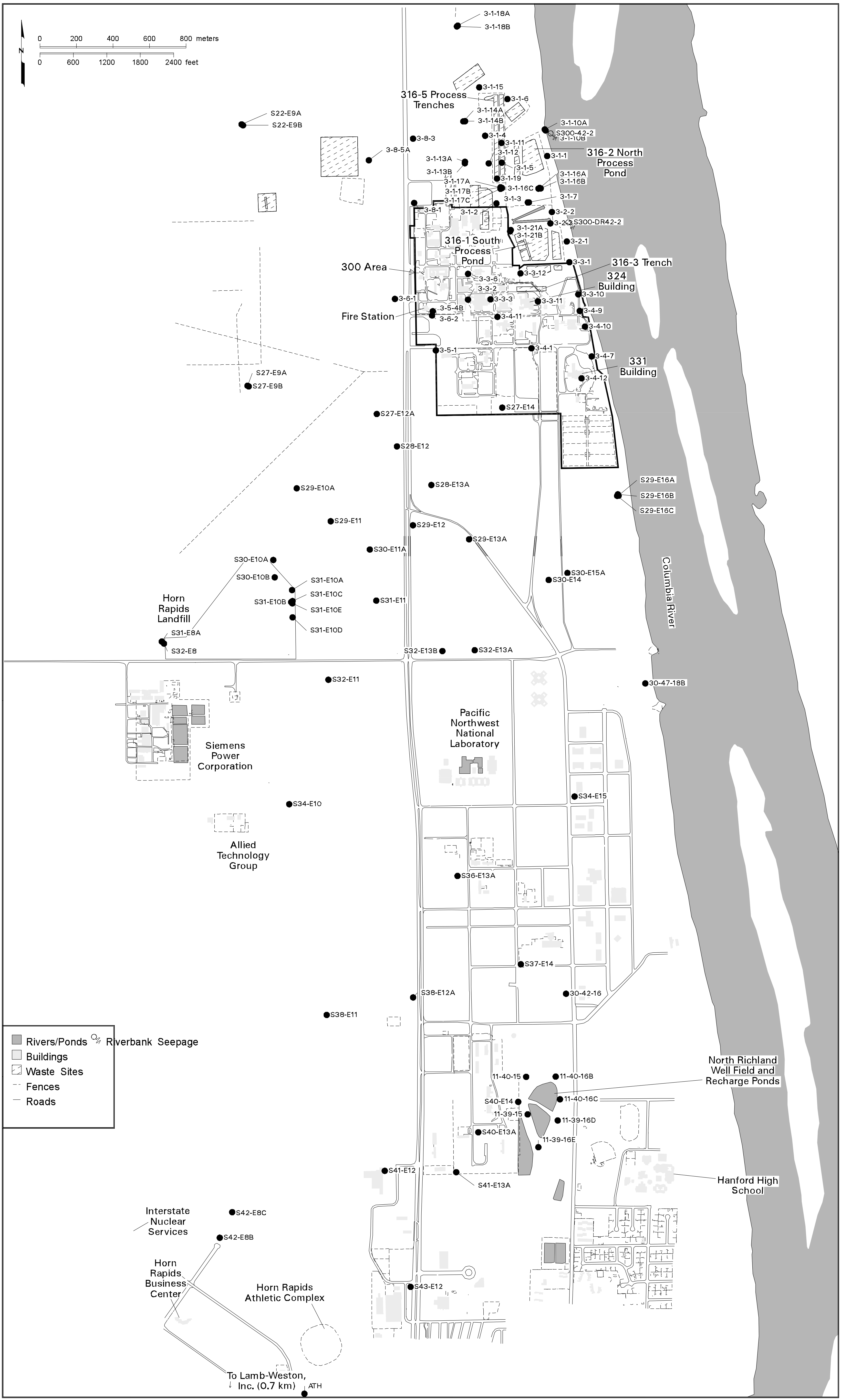

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Figure 2.12-1. Groundwater Monitoring Wells in the 300 and Richland North Areas

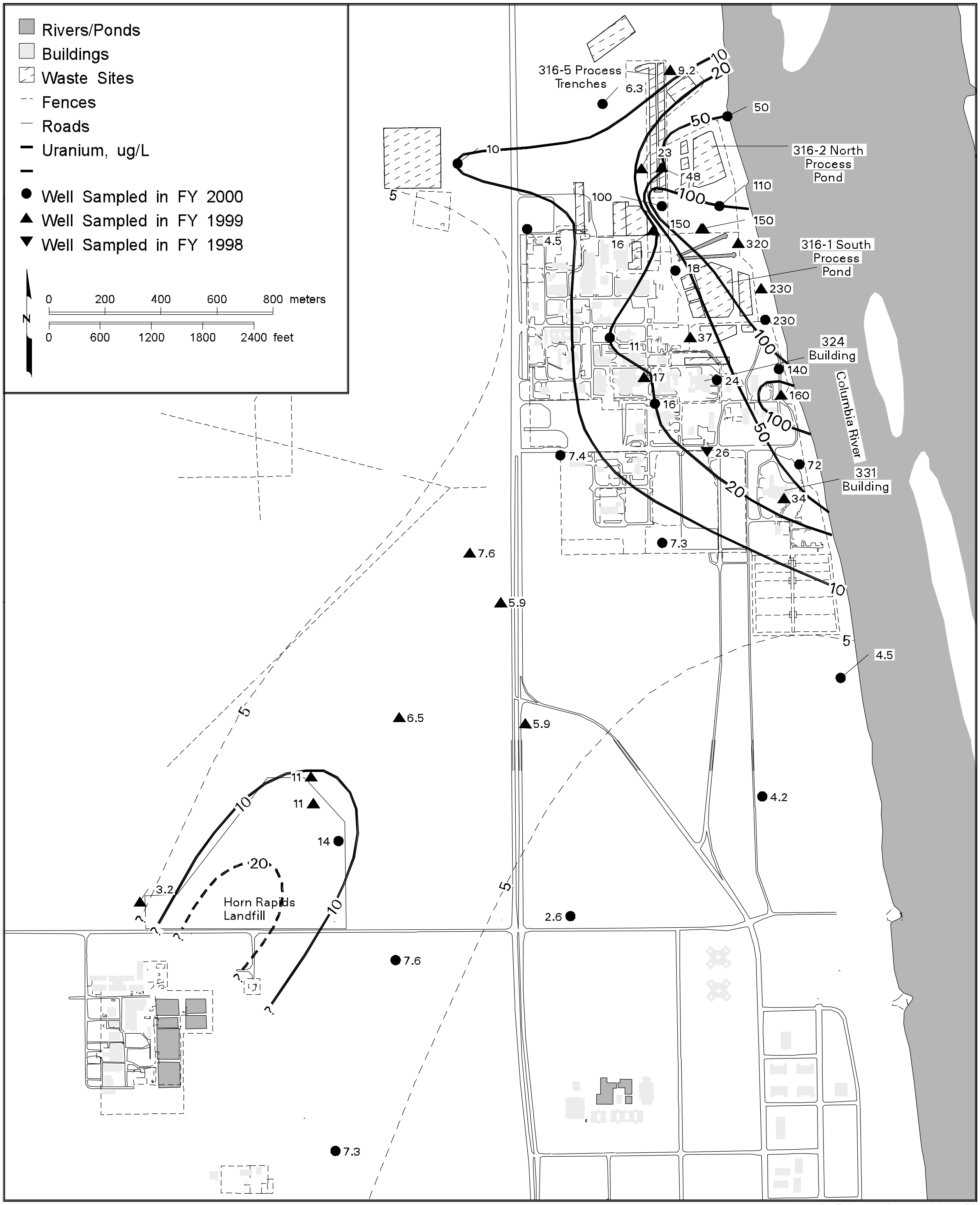

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Figure 2.12-2. Average Uranium Concentrations in Groundwater at the 300 and Richland North Areas, Top of Unconfined Aquifer

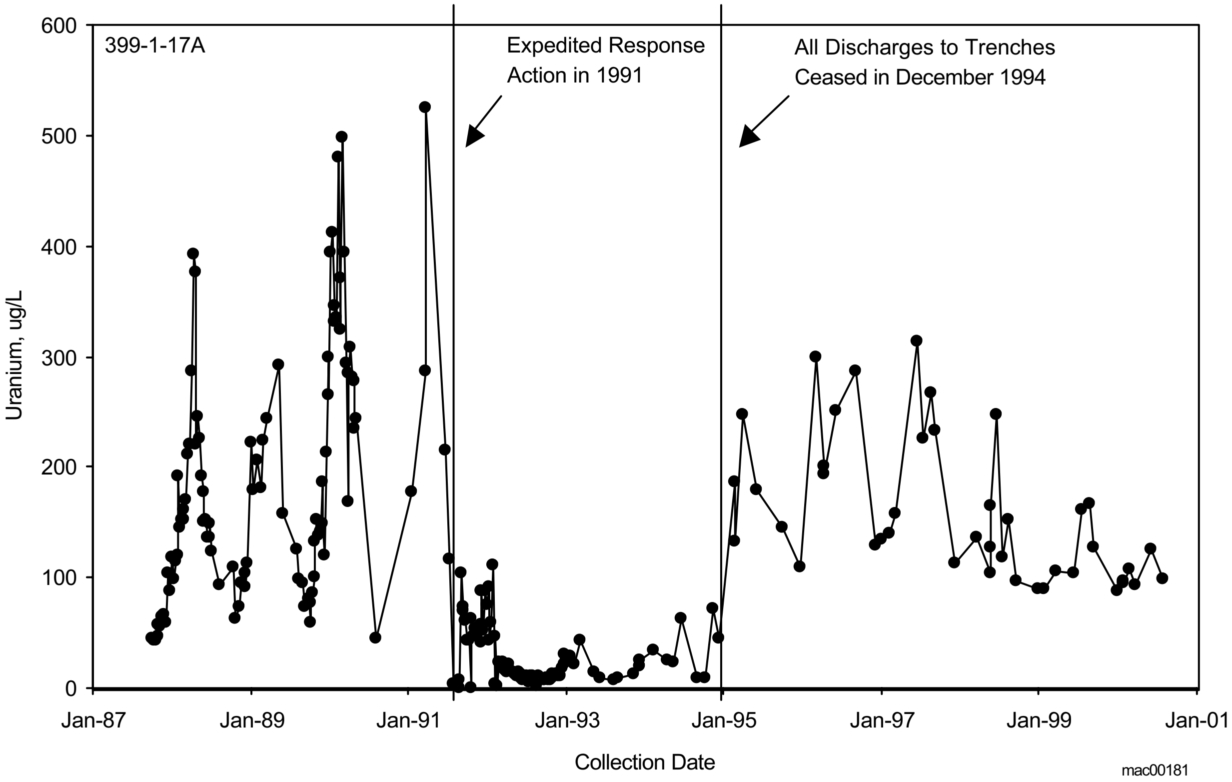

Figure 2.12-3. Uranium in Well 399-1-17A near the 316-5 Process Trenches

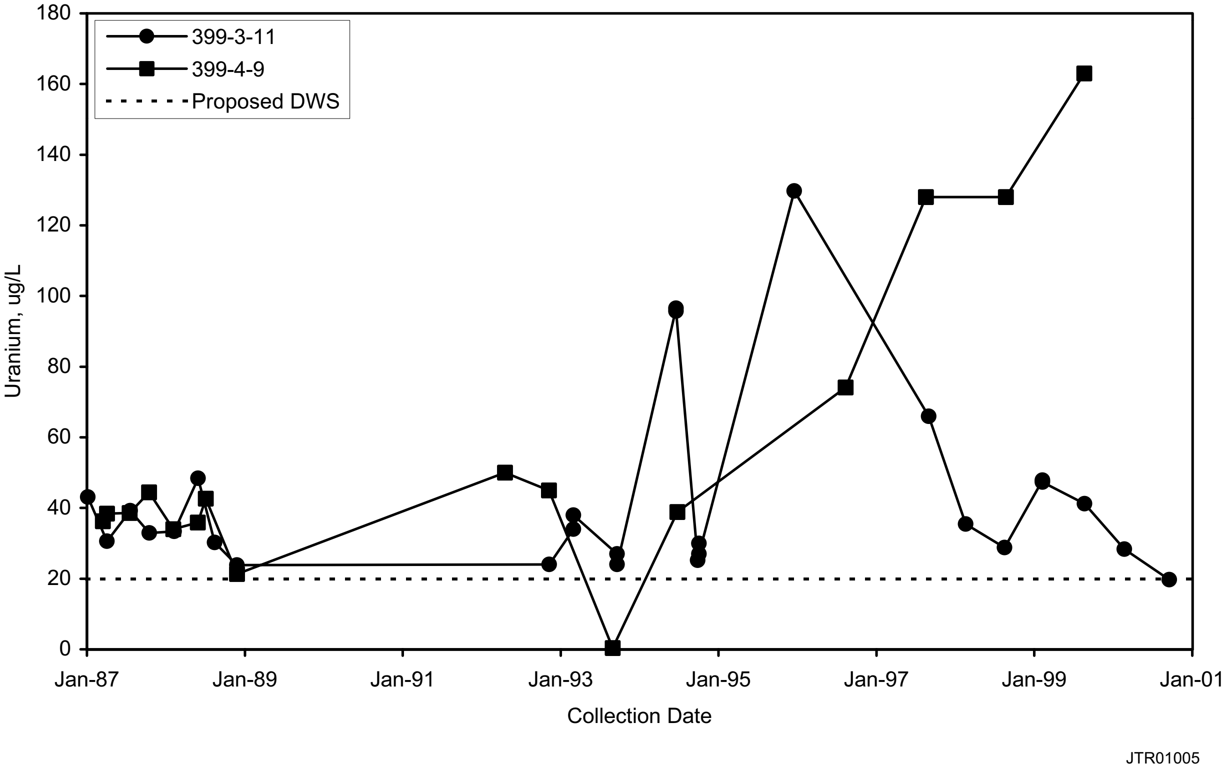

Figure 2.12-4. Uranium in Wells 399-3-11 and 399-4-9 near the 324 Building

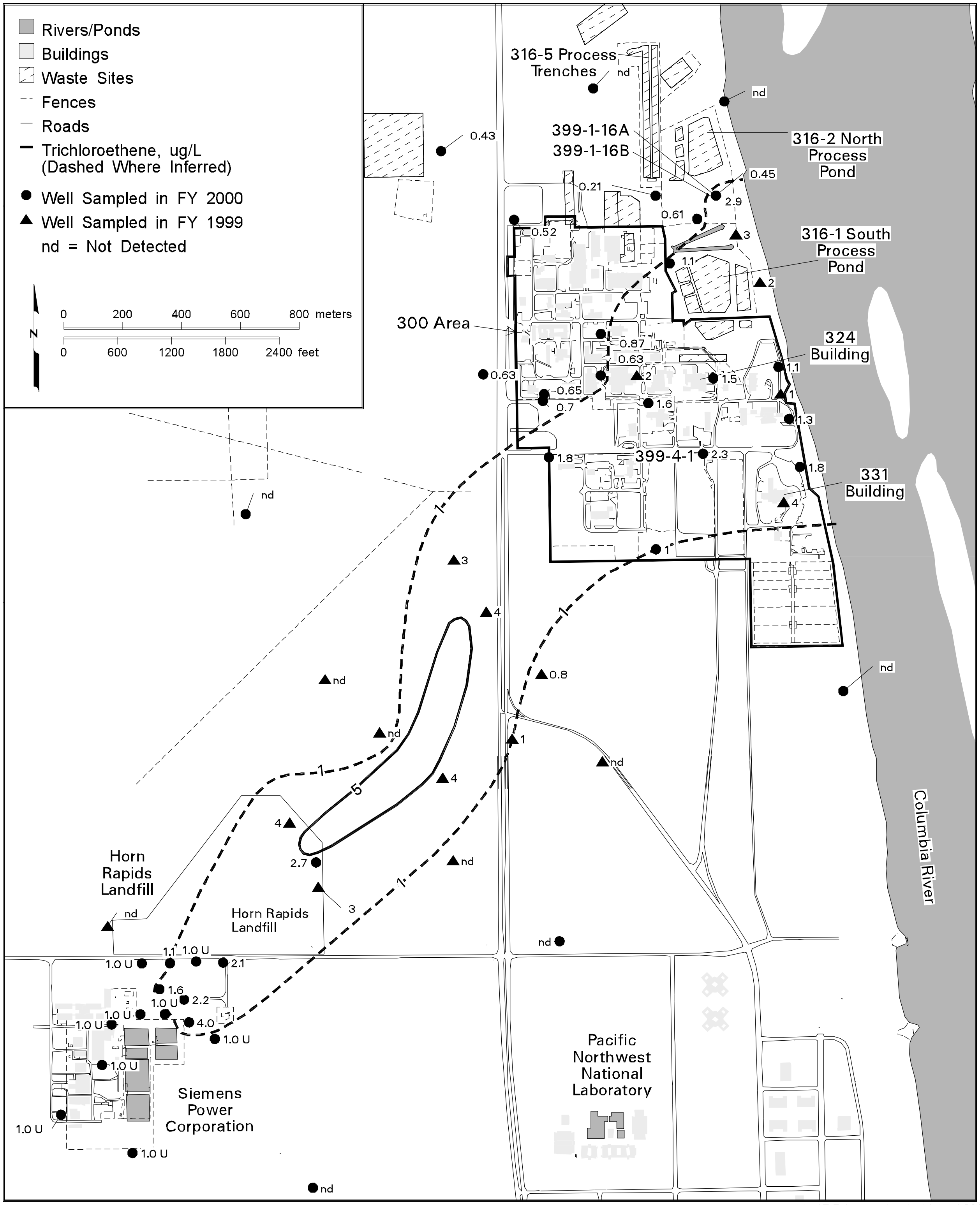

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Figure 2.12-5. Average Trichloroethene Concentrations in the 300 and Richland North Areas, Top of the Unconfined Aquifer

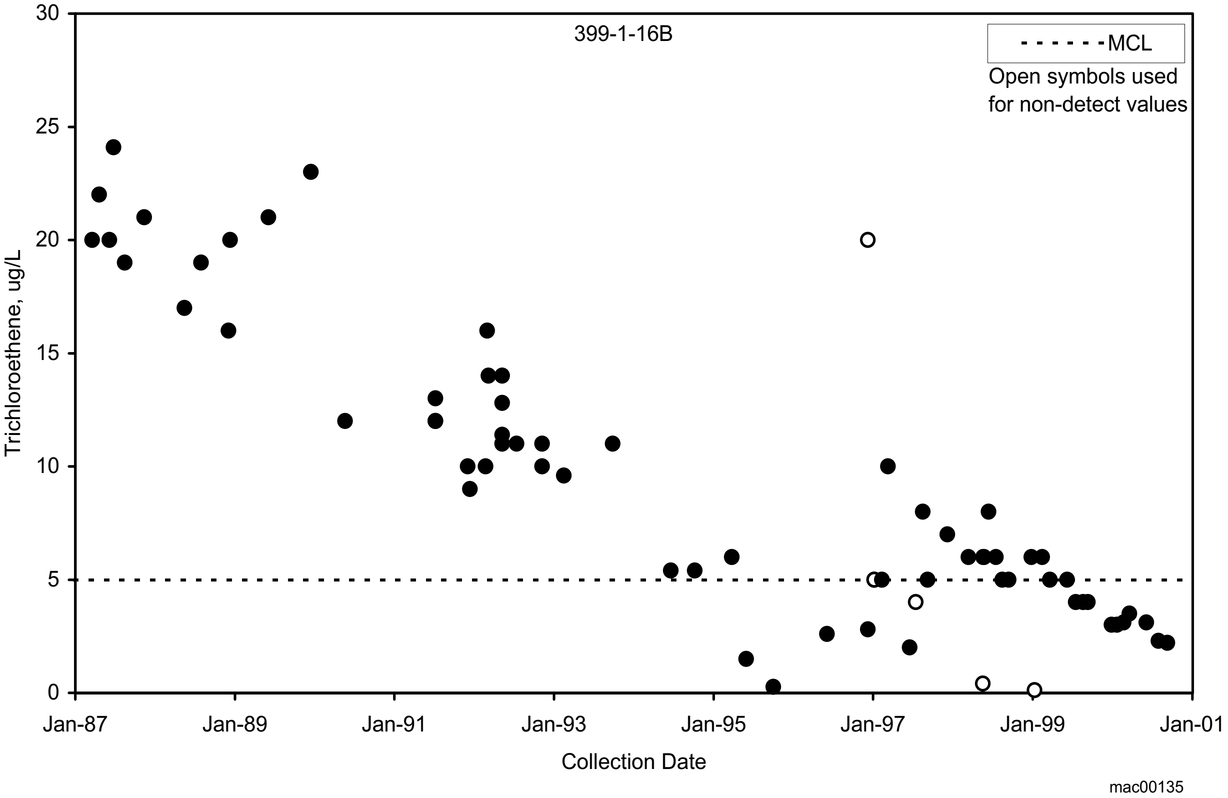

Figure 2.12-6. Trichloroethene in Well 399-1-16B near the 316-5 Process Trenches

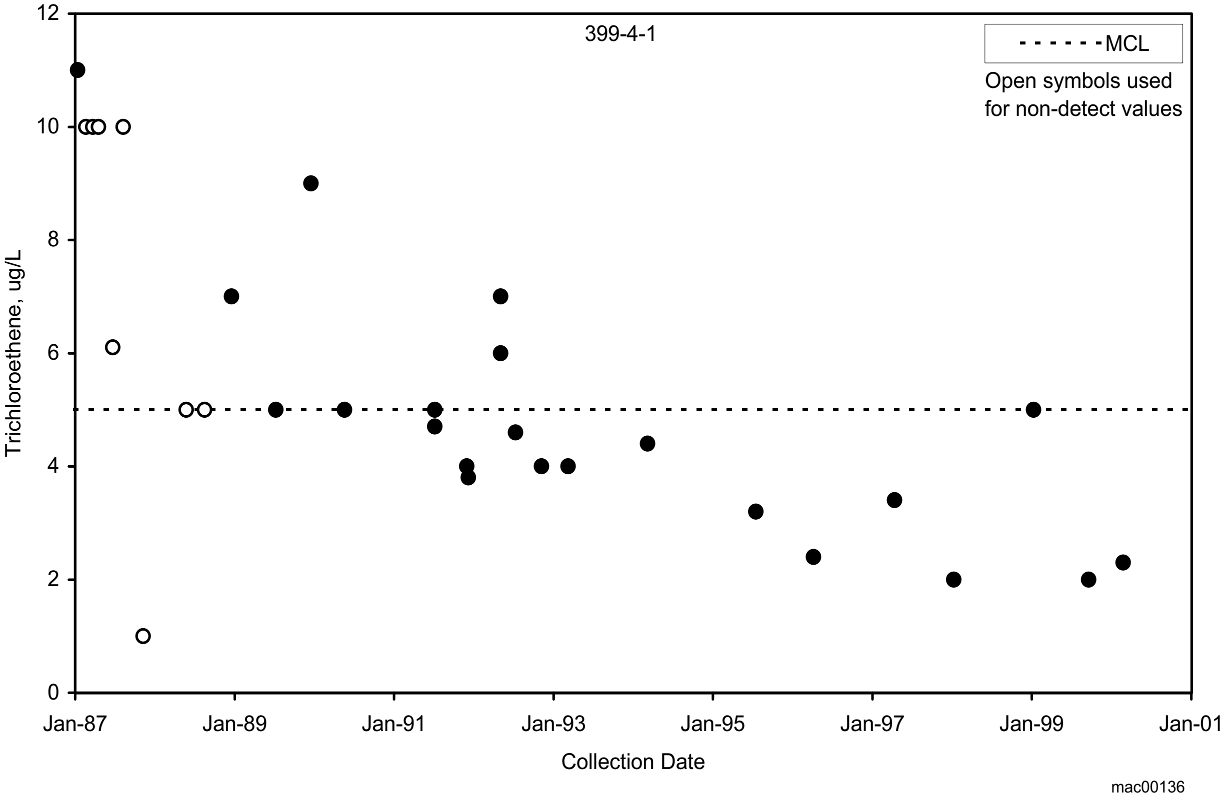

Figure 2.12-7. Trichloroethene in Well 399-4-1 in the Southern 300 Area

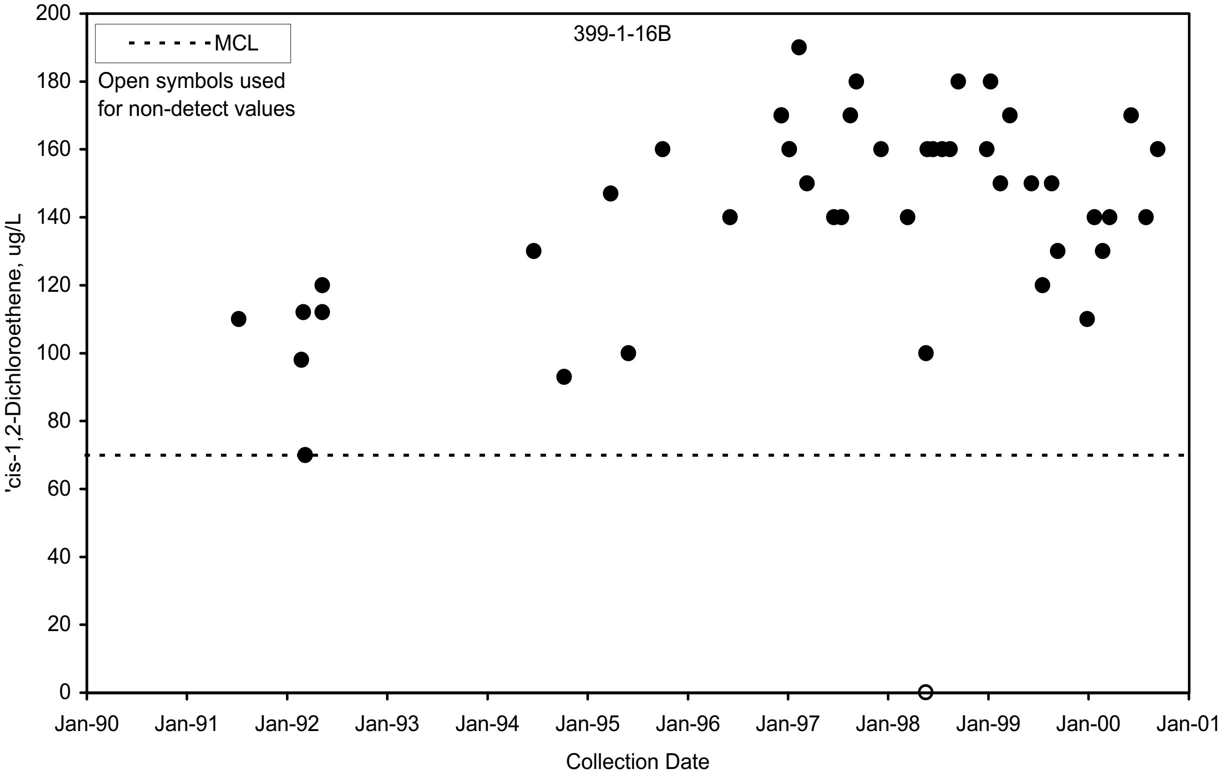

Figure 2.12-8. cis-1,2-Dichloroethene in Well 399-1-16B near the 316-5 Process Trenches

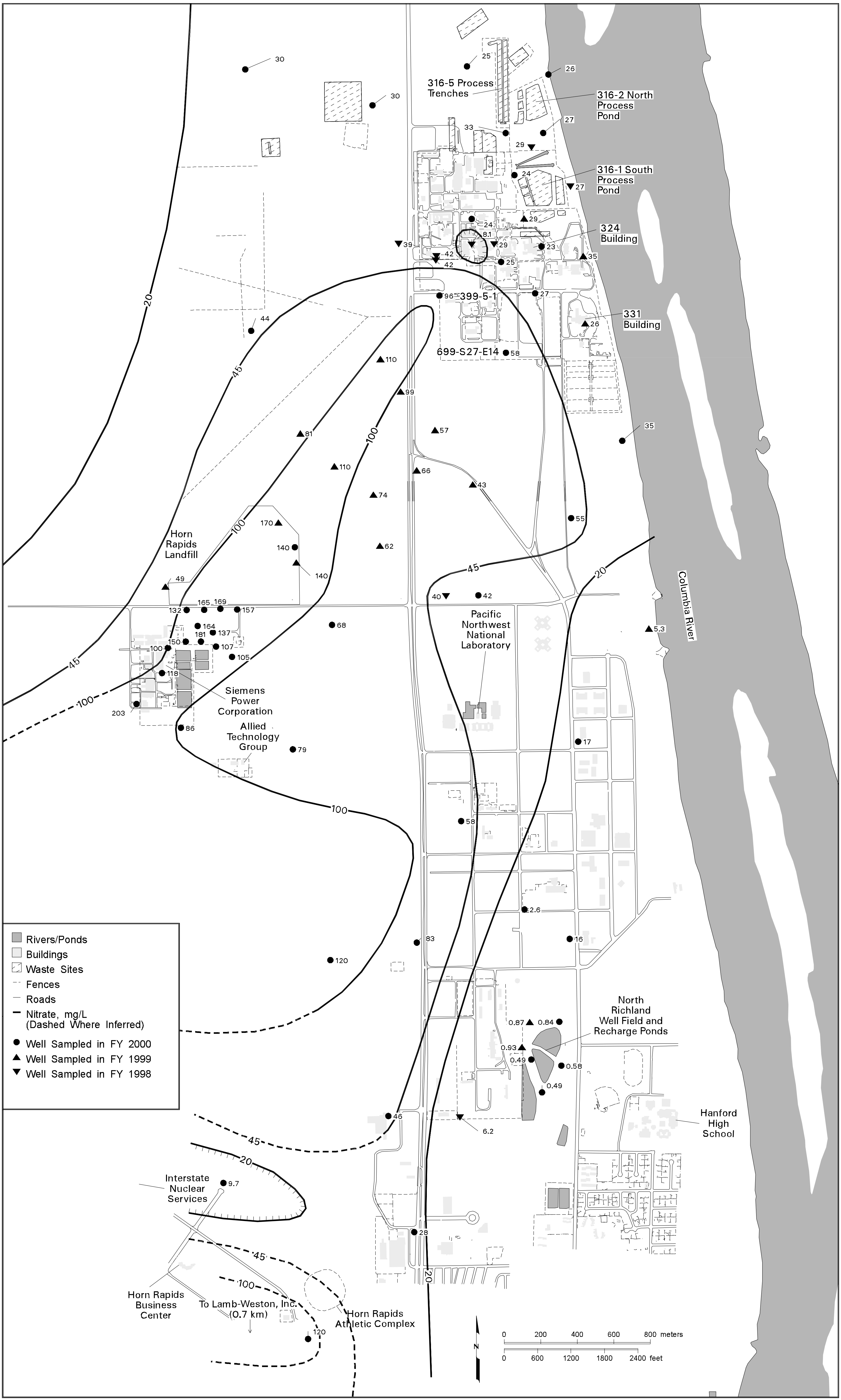

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Figure 2.12-9. Nitrate in Wells at the 300 Area and Richland North Area

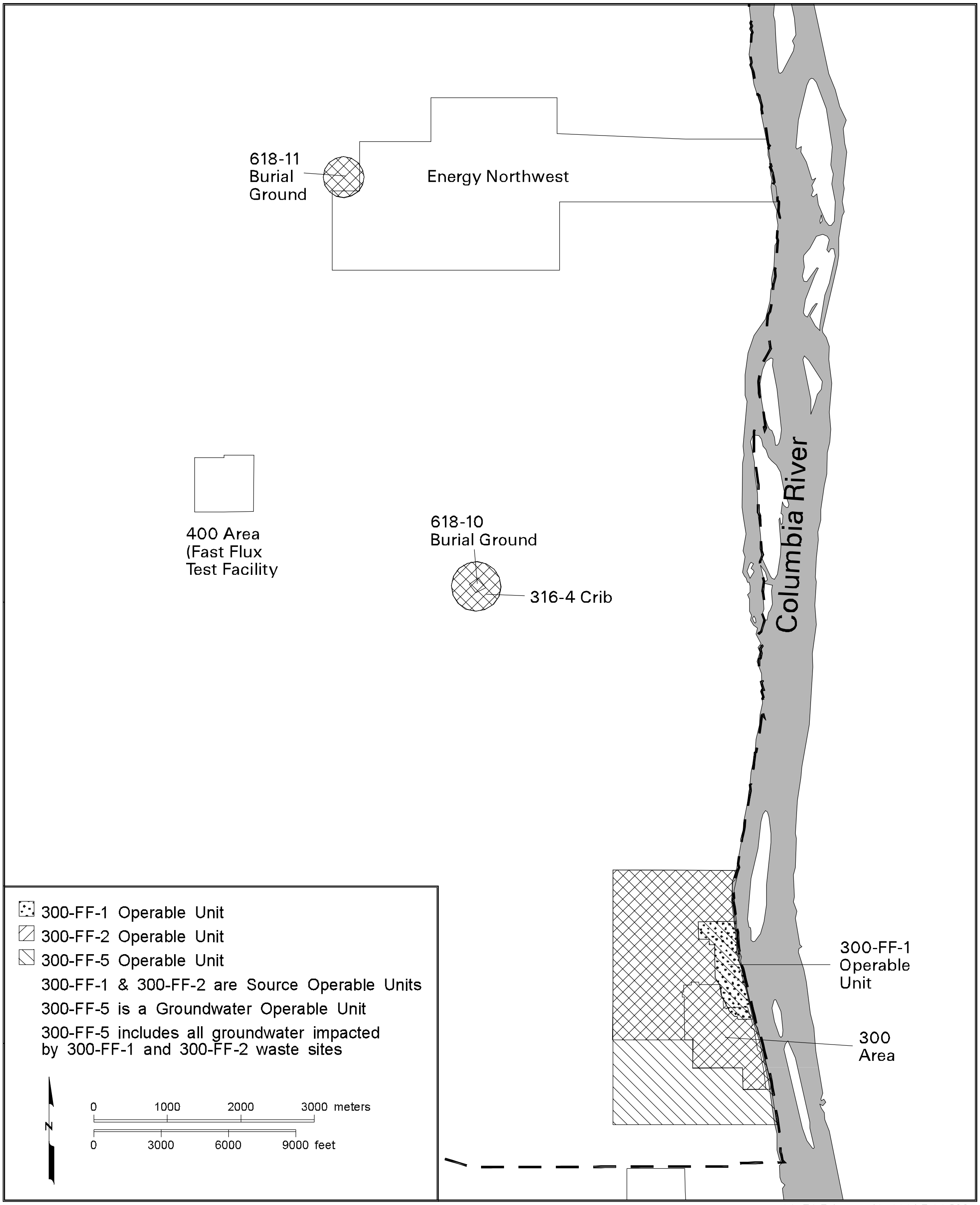

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Figure 2.12-10. Locations of the 300-FF-1, 300-FF-2, 300-FF-5 Operable Units; 618-10 Burial Ground; 316-4 Crib; and 618-11 Burial Ground

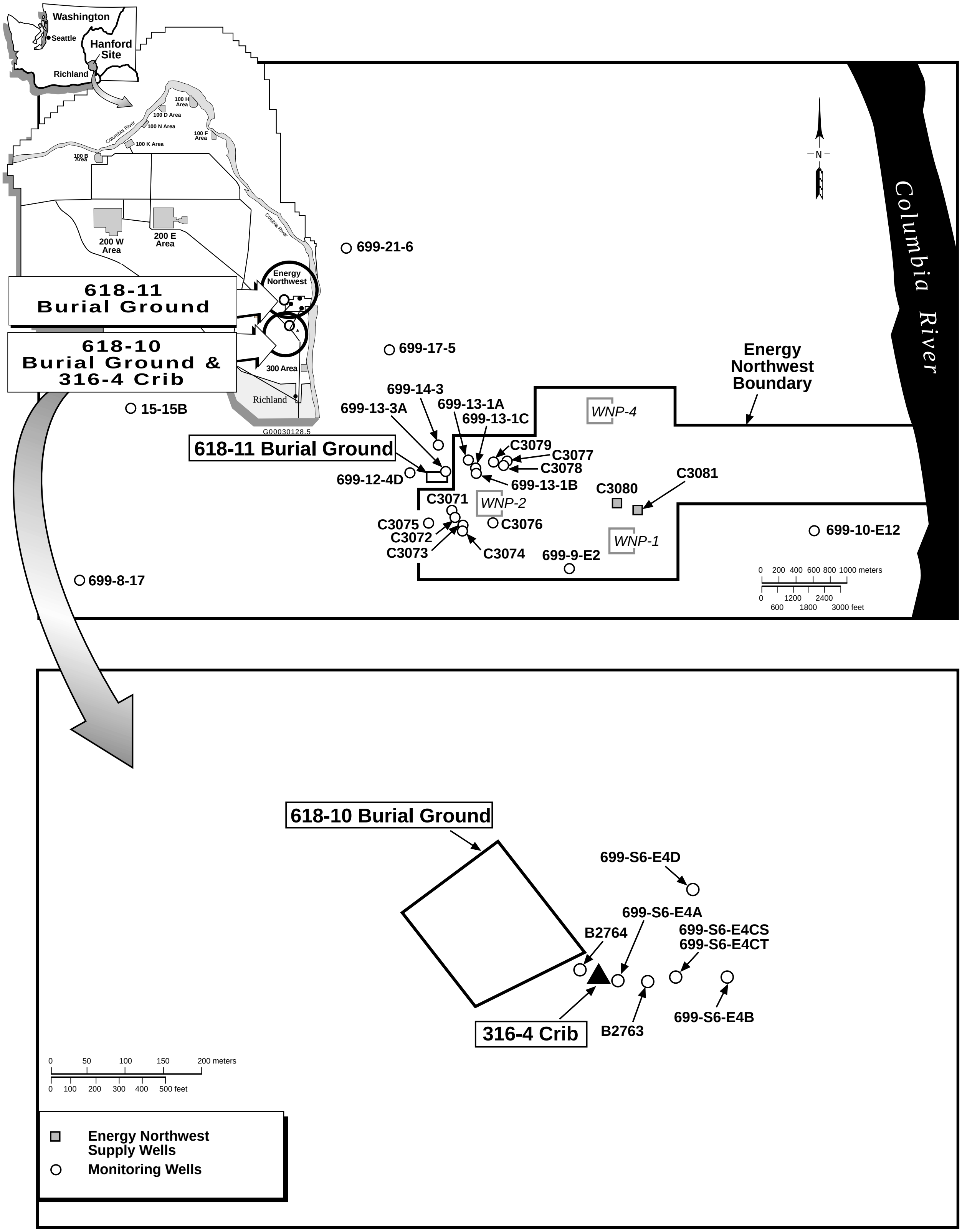

Figure 2.12-11. Groundwater Monitoring Wells near the 618-11 Burial Ground

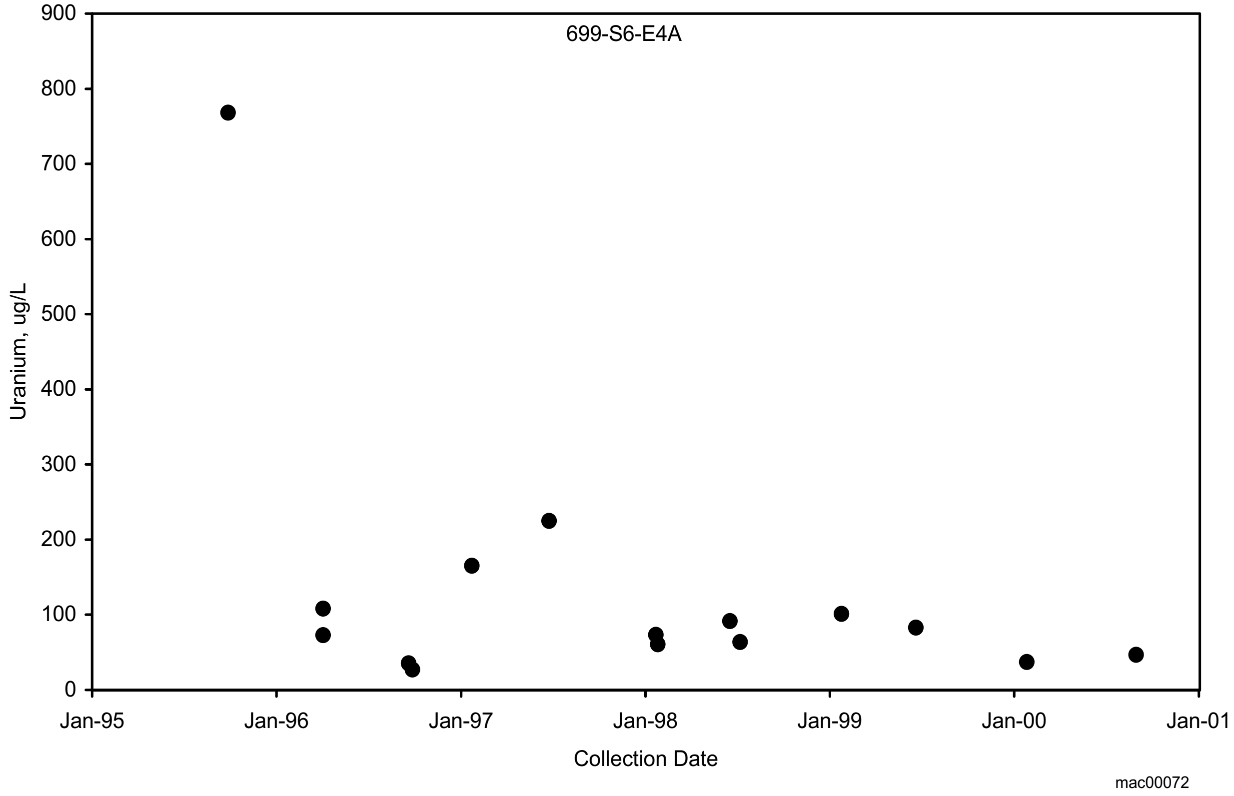

Figure 2.12-12. Uranium in Well 699-S6-E4A near the 618-10 Burial Ground

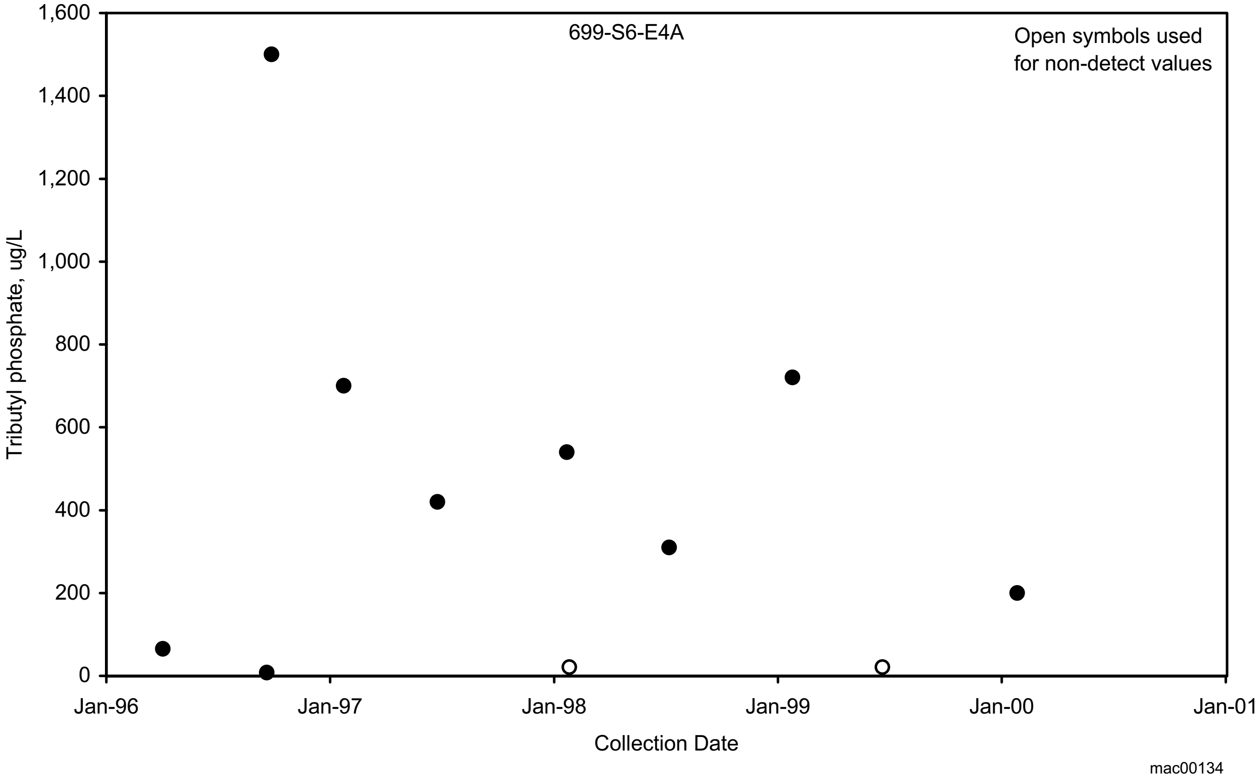

Figure 2.12-13. Tributyl Phosphate in Well 699-S6-E4A near the 618-10 Burial Ground

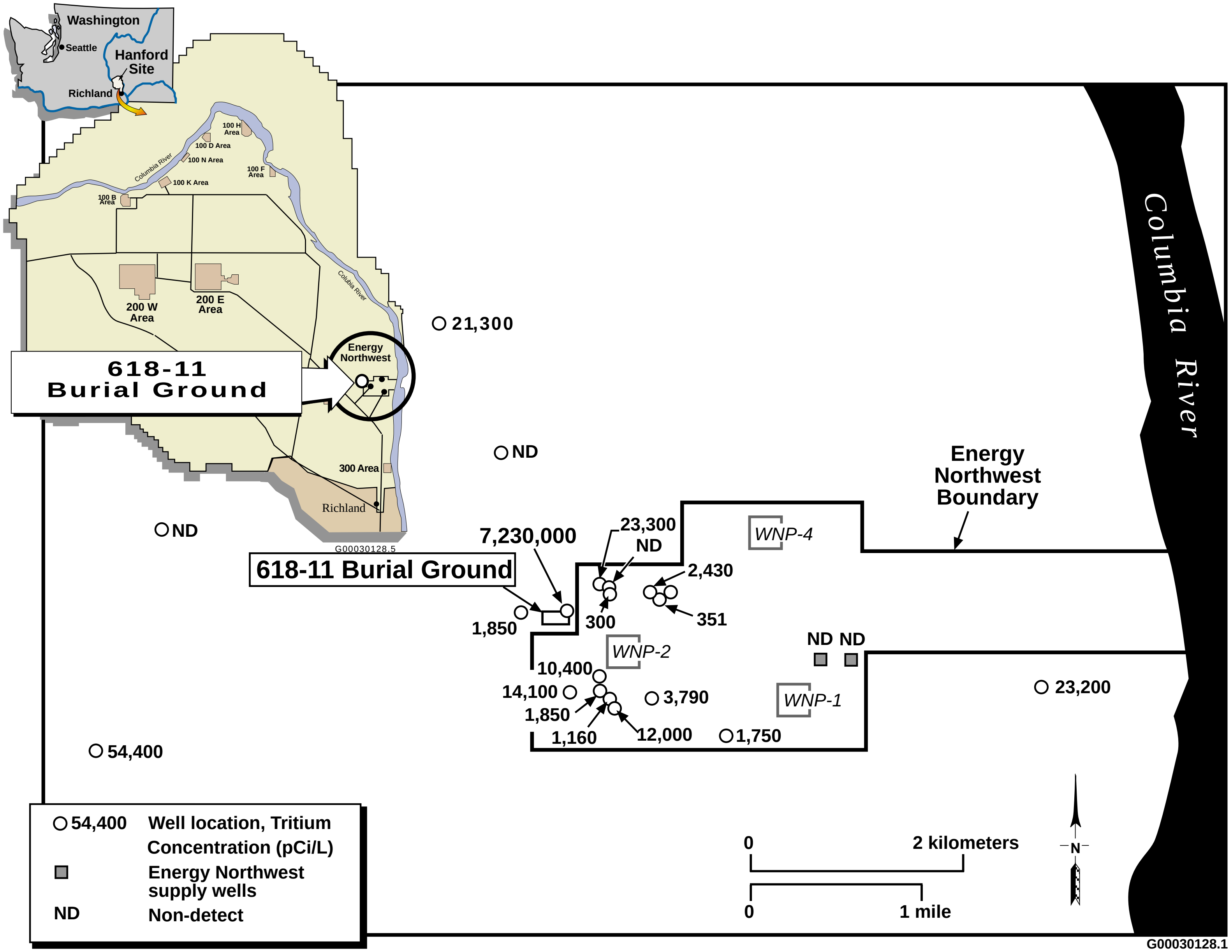

Figure 2.12-14. Tritium Concentrations for February 2000 Sampling near the 618-11 Burial Ground (from PNNL-13228)

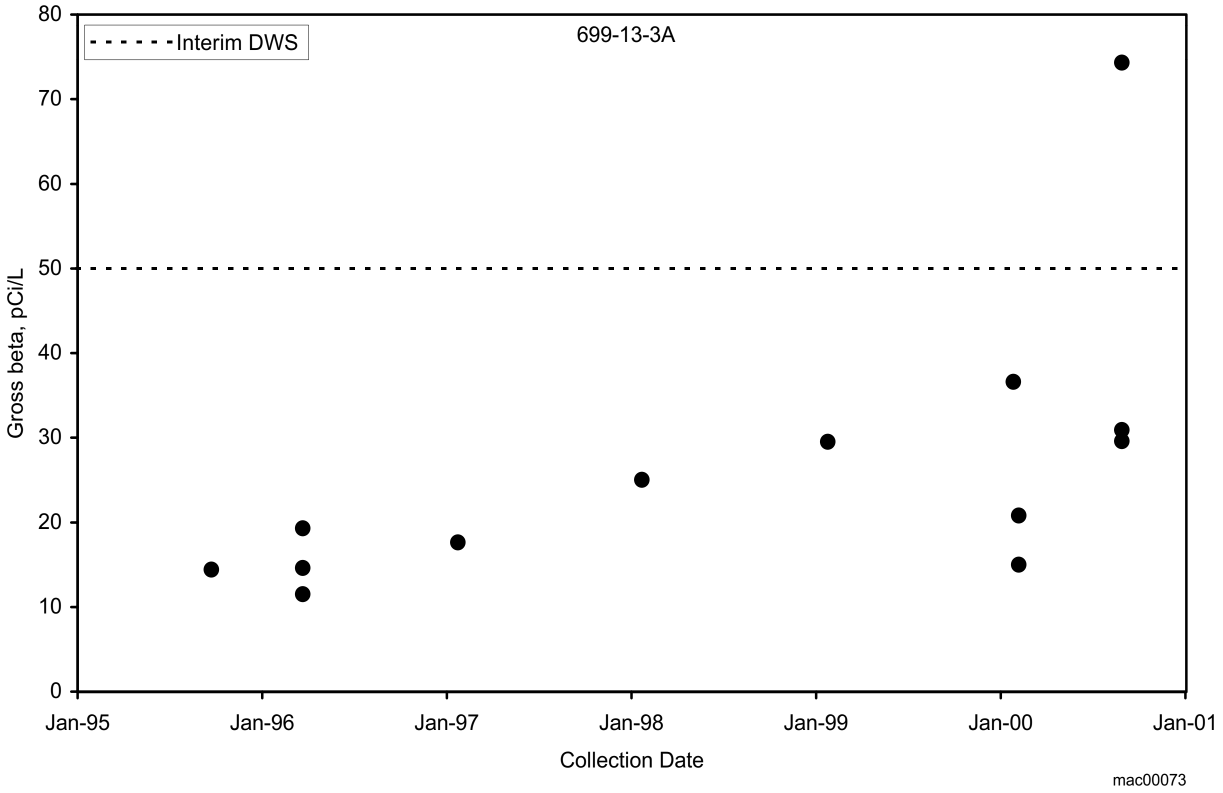

Figure 2.12-15. Gross Beta Concentrations in Well 699-13-3A near the 618-11 Burial Ground

2.13 Richland North Area

D. R. Newcomer

The Richland North Area is located in the southern part of the Hanford Site (see Figure 2.12-1). For this report, the Richland North Area is defined as the former 1100 and 3000 Areas, that part of the 600 Area adjacent to the 300 Area, and parts of nearby Richland between the Yakima and Columbia Rivers. Ownership of the 1100 Area was transferred from the U.S. Department of Energy (DOE) to the Port of Benton in 1998. Ownership of the 3000 Area was transferred from DOE to the Port of Benton in 1996.

The area near the city of Richland's North Well Field is monitored closely to detect the possible impact of the tritium plume from the 200 Areas. Monitoring in fiscal year 2000 gave no indication that the tritium plume is migrating southward. Although tritium levels are far below the drinking water standard, frequent monitoring will continue.

2.13.1 Groundwater Flow

Figure 2.13-1 shows the March 2000 water-table elevations and illustrates water-level-elevation trends for selected areas of the Richland North Area. Groundwater

Aerial view of city of Richland's North Well Field, 1983.

in the Richland North Area generally flows eastward from the Yakima River and discharges to the Columbia River (see Plate 1). In the northern part of the Richland North Area, groundwater flows northeast and converges with groundwater entering the 300 Area before discharging to the Columbia River. In the southern part of the Richland North Area, groundwater flow from the east is diverted around a recharge mound before discharging to the Columbia River.

Monitoring Objectives in Richland North Area

Groundwater monitoring is conducted in the Richland North Area:

- triennially to annually to describe the nature and extent of contamination
- annually to detect the impact of contamination from off the Hanford Site
- annually or more frequently to ensure the safety of the city of Richland's North Well Field.

Recharge from the Yakima River has a regional effect on groundwater flow and is the primary source of groundwater in the Richland North Area. A higher elevation in Yakima River stage than the water table implies that Yakima River water infiltrates and recharges the unconfined aquifer. Leakage from canals and ditches originating from the Yakima River during the summer months is also a source of groundwater recharge.

The city of Richland's North Well Field, in the south-central portion of the Richland North Area, is the primary local influence on changes in groundwater elevation in this area. The groundwater mound in this area continued to be maintained with at least a 2:1 ratio of recharge to discharge at the well field during fiscal year 2000. Groundwater levels in much of the area near the well field increased between March 1999 and April 2000 (see Figure 2.13-1). The maximum increase was 0.3 meter at the well field. The effect of the increase is illustrated by hydrographs of wells near the well field (see Figure 2.13-1). The rise in the water table between March 1999 and April 2000 is the result of an increase in net recharge at the well field and recharge pond system.

Irrigation of agricultural fields in the area between the Yakima River and the former 1100 Area has affected groundwater levels in the Richland North Area. Agricultural irrigation supplied primarily by the Columbia River recharges the unconfined aquifer between the Yakima and Columbia Rivers. This seasonal effect is illustrated from the hydrograph of well 699-S43-E7A in the southern part of the Richland North Area (see Figure 2.13-1) and by water-level fluctuations in well SPC-GM-2 upgradient of Siemens Power Corporation in the northern part of the Richland North Area (Figure 2.13-2). Water levels have increased in wells west of the Richland North Area near the southern boundary of the Hanford Site. These levels are illustrated by the hydrograph for one of these wells in Figure 2.13-3.

2.13.2 Tritium

The southern portion of the 200 Area tritium plume extends into the 300 Area and continues to raise concern over its potential impact to the city of Richland's North Well Field (Figure 2.13-4). Figure 2.13-4 shows that tritium concentrations decrease from greater than 10,000 pCi/L to less than 100 pCi/L in a southwesterly direction across the 300 Area. The tritium contours across the 300 Area changed little since fiscal year 1999. Tritium trends in many wells in and around the 300 Area have begun to show stable levels within the last few years. This is illustrated by the trend plots for wells 699-S19-E13 and 399-1-17A in Figure 2.13-4, which show stable tritium levels since 1995.

South of the 300 Area, slightly elevated levels of tritium occur in wells near the city of Richland's recharge ponds (see Plate 2). However, these levels are far below the 20,000 pCi/L drinking water standard. A tritium sampling investigation in 1999 and 2000 indicated that there is no statistical difference between most of the tritium results detected in groundwater in this area and tritium in Columbia River water. Columbia River water, which shows slightly elevated tritium levels near the shoreline, is piped to the recharge pond system. Thus, a likely source of the elevated tritium levels is recharge of Columbia River water discharged to the ponds.

The tritium sampling investigation also showed that tritium is not migrating in groundwater from the Hanford Site tritium plume to the well field. Several factors limit the migration of the tritium plume into the Richland North Area.

- Groundwater generally flows from west to east between the Yakima River and the Columbia River.
- Artificial recharge from agricultural irrigation west of the Richland North Area contributes to the eastward flow.
- Flow is directed outward from the groundwater mound 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 2.13-1 and Plate 1). Thus, there is no indication that the tritium plume is migrating southward and affecting the well field.

2.13.3 Nitrate

Nitrate contamination migrates to the Richland North Area from industrial and agricultural activities off the Hanford Site. Concentrations generally continued to increase in fiscal year 2000.

The nitrate distribution in groundwater is shown in Figure 2.12-9. Nitrate contamination that is found in the Richland North Area is likely the result of industrial and agricultural uses off the Hanford Site. In fiscal year 2000, nitrate concentrations continued to increase in a number of wells. The nitrate plume generally has migrated east toward the Columbia River.

Concentrations above the 45 mg/L maximum contaminant level are found over much of the Richland North Area. Some of the highest nitrate levels occur both upgradient and downgradient of Siemens Power Corporation. Nitrate data for Siemens Power Corporation wells are reported in EMF-1865, Addenda 19 and 22. The highest nitrate concentrations were found to occur southwest (upgradient) of Siemens Power Corporation. The maximum average concentration was 203 mg/L immediately upgradient of Siemens Power Corporation. This nitrate is likely the result of agriculture to the west and southwest. As shown in Figure 2.12-9, many of the wells downgradient of the Horn Rapids Landfill were not sampled in fiscal year 2000. The sampling of the wells was delayed from fiscal year 2000 to fiscal year 2001 because of issues associated with disposal of sample-related waste on the Hanford Site.

The shape of the plume (as defined by the 100 mg/L contour) near Siemens Power Corporation and the Horn Rapids Landfill indicates that nitrate in these areas continues to migrate in a northeastern direction toward the 300 Area. This flow diagram generally is consistent with the water-table map in Plate 1, which also shows a northeastern flow direction. However, the water-table map represents a single month of time, whereas, the plume distribution represents the net effect of groundwater flow over a longer period. One effect on groundwater flow in the area downgradient of the Horn Rapids Landfill is groundwater level changes in response to seasonal river stage fluctuations.

Nitrate levels continued to be elevated in an area northwest of the North Richland well field and recharge ponds during fiscal year 2000. These elevated levels are illustrated by the trend plots in Figure 2.13-5. The most likely source of these elevated nitrate levels is agriculture circles to the west. The shape of the plume indicates that the eastward migration of nitrate is being diverted around the groundwater mound that is in the vicinity of the recharge ponds (see Plate 1). 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.

2.13.4 Trichloroethene

Trichloroethene contamination occurs in the Richland North Area beneath the Horn Rapids Landfill and offsite in Siemens Power Corporation wells (see Figure 2.12-5). The distribution of trichloroethene shows that the plume has an elongated configuration similar to the 100 mg/L nitrate contour discussed in Section 2.13.3. This configuration indicates a northeast flow direction around the city of Richland's North Well Field recharge ponds and toward the 300 Area. However, concentrations have decreased in essentially all the plume area near the Horn Rapids Landfill. Trichloroethene concentrations decreased by more than an order of magnitude in this area since monitoring began in 1990 (Figure 2.13-6). The decreased concentrations in the majority of wells downgradient of the Horn Rapids Landfill suggests that some elements of natural attenuation (e.g., volatilization through passive pumping) may be reducing the plume mass. For a discussion of trichloroethene in the 300 Area, see Section 2.12.4. In fiscal year 2000, trichloroethene concentrations ranged from less than detection to 2.7 μg/L downgradient of the landfill. The sampling for trichloroethene in several of the wells was delayed from fiscal year 2000 to fiscal year 2001 because of issues associated with disposal of sample-related waste on the Hanford Site.

Trichloroethene contamination in Richland North Area has sources off the Hanford Site. Concentrations are naturally declining.

Average trichloroethene concentrations continued to be less than 5 μg/L in all Siemens Power Corporation wells during fiscal year 2000 (EMF-1865, Addenda 19 and 22). The maximum average trichloroethene concentration was 3.7 μg/L. The past use of solvent to install and maintain process lagoon liners at Siemens Power Corporation is the only potential source of trichloroethene identified in the Richland North Area (DOE/RL-92-67).

Vinyl chloride and 1,1-dichloroethene concentrations, breakdown products of trichloroethene, continued to be close to or less than their respective minimum detection limits for those wells sampled in fiscal year 2000.

2.13.5 Gross Alpha and Uranium

Elevated levels of gross alpha and uranium occur downgradient of Siemens Power Corporation near the inactive Horn Rapids Landfill. The highest gross alpha level was an average of 65 pCi/L in well SPC-GM-8 during fiscal year 2000. Most of the downgradient Siemens Power Corporation wells showed average gross alpha levels that were above the 15 pCi/L maximum contaminant level. It is probable that the gross alpha levels are largely attributed to uranium because Siemens Power Corporation manufactures nuclear fuel pellets and assemblies for commercial nuclear power plants. If gross alpha is attributed to uranium with natural isotopic abundances, then 65 pCi/L gross alpha is equivalent to 94 μg/L uranium, which is above the 20 μg/L proposed maximum contaminant level for uranium. Siemens Power Corporation is not required to analyze samples collected from their wells for uranium.

Relatively low levels of uranium, ammonia, and fluoride detected near the inactive Horn Rapids Landfill are from sources off the Hanford Site.

The distribution of uranium near the Horn Rapids Landfill is shown in Figure 2.12-2. The map shows a small plume of uranium with levels less than the 20 μg/L proposed maximum contaminant level near the landfill. However, uranium concentrations have increased in wells downgradient of the landfill since approximately 1995. Uranium concentrations ranged up to an average of 13.6 μg/L, with the highest concentration immediately downgradient of the Horn Rapids Landfill in well 699-S31-E10B. An example of these increases is shown in the trend plot in Figure 2.13-7. At this time, the landfill is not considered a source of the uranium contamination in groundwater because no known uranium sources exist in the landfill. The source of the uranium is probably from off the Hanford Site.

Gross alpha levels, which generally mimic trends in the uranium concentrations, also increased in wells downgradient of the Horn Rapids Landfill. In these wells, gross alpha levels ranged up to an average of 27.4 pCi/L.

2.13.6 Other Constituents

Ammonia, fluoride, and gross beta are found at low levels in wells near Siemens Power Corporation.

Ammonia – Concentrations of ammonia in the Siemens Power Corporation wells generally remained steady in fiscal year 2000 (EMF-1865, Addenda 19 and 22). The highest average concentration detected was 17.5 mg/L (as NH_3) in well SPC-GM-10. 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 downgradient Siemens Power Corporation wells. The fact that ammonia is found in the groundwater suggests that relatively high concentrations reached the soil column.

Fluoride – Three downgradient Siemens Power Corporation wells (SPC-GM-5, SPC-GM-8, and SPC-GM-10) continued to show fluoride concentrations above the 4 mg/L maximum contaminant level in fiscal year 2000 (EMF-1865, Addenda 19 and 22). The highest average concentration was 4.8 mg/L in well SPC-GM-10. Average fluoride concentrations in onsite wells for this area continued to be less than 1 mg/L.

Gross Beta – Gross beta continued to be detected in wells downgradient of Siemens Power Corporation during fiscal year 2000 (EMF-1865, Addenda 19 and 22). The highest average gross beta measurement in fiscal year 2000 was 45 pCi/L in well SPC-GM-8. The highest average gross beta measurement in onsite groundwater was 22.3 pCi/L (well 699-S31-E10B). Low levels of technetium-99, detected near the Horn Rapids Landfill, may be related to the gross beta measurements.

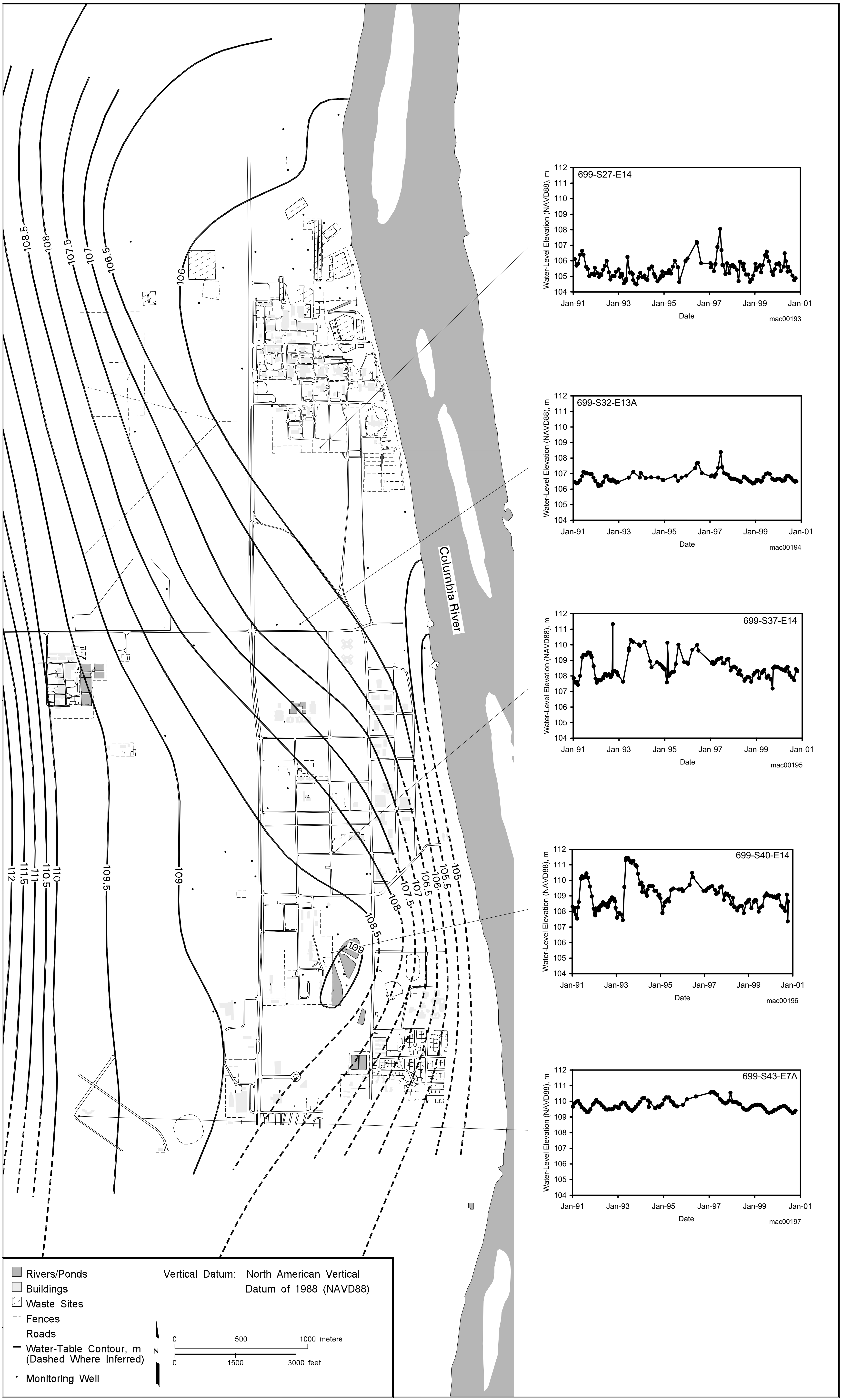

Figure 2.13-1. Water Levels in Wells Monitoring the Richland North Area, April 2000

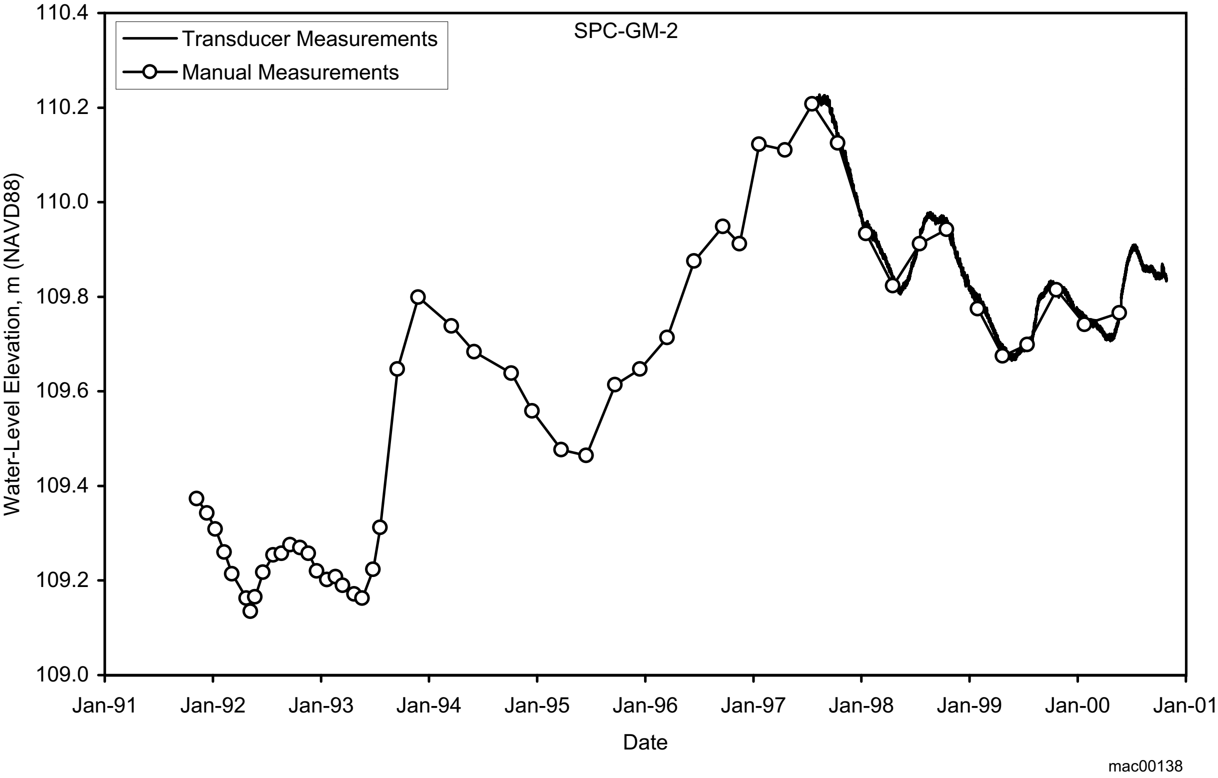

Figure 2.13-2. Water Levels in Well SPC-GM-2 at Siemens Power Corporation (manual measurements taken from Siemens quarterly reports, e.g., EMF-1865)

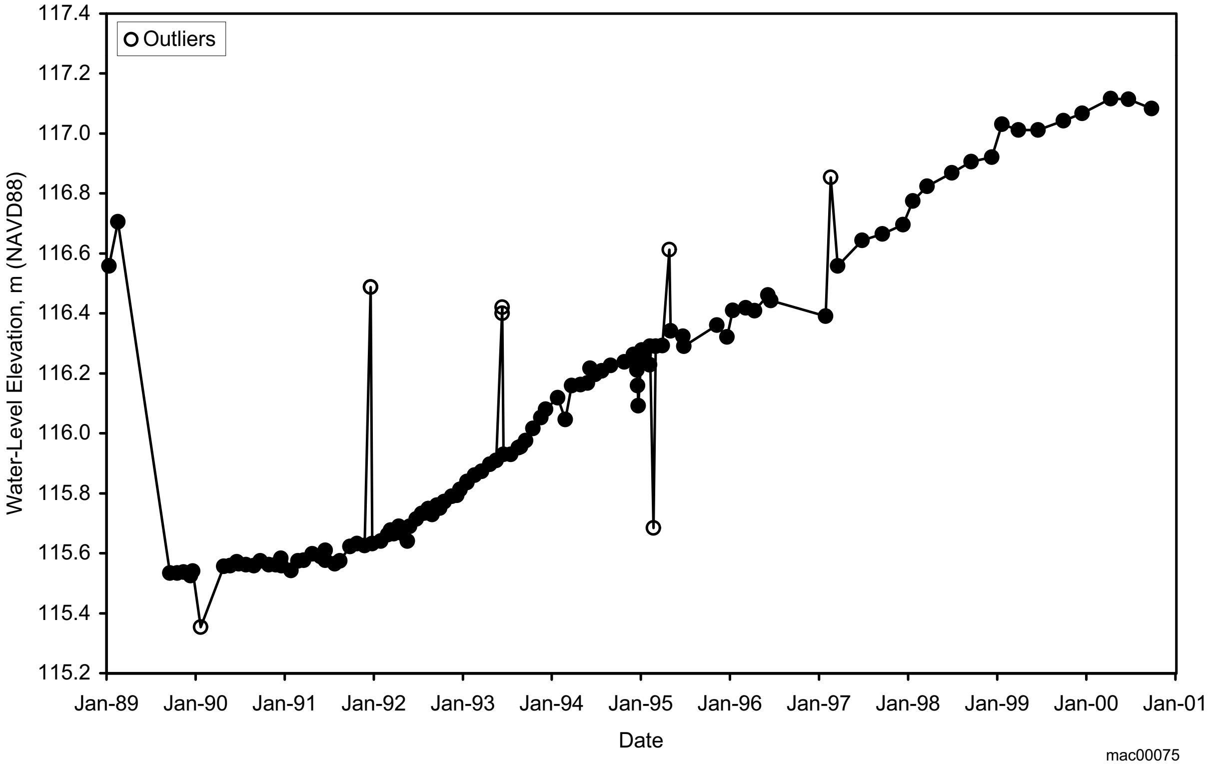

Figure 2.13-3. Water Levels in Well 699-S31-1 West of Richland North Area

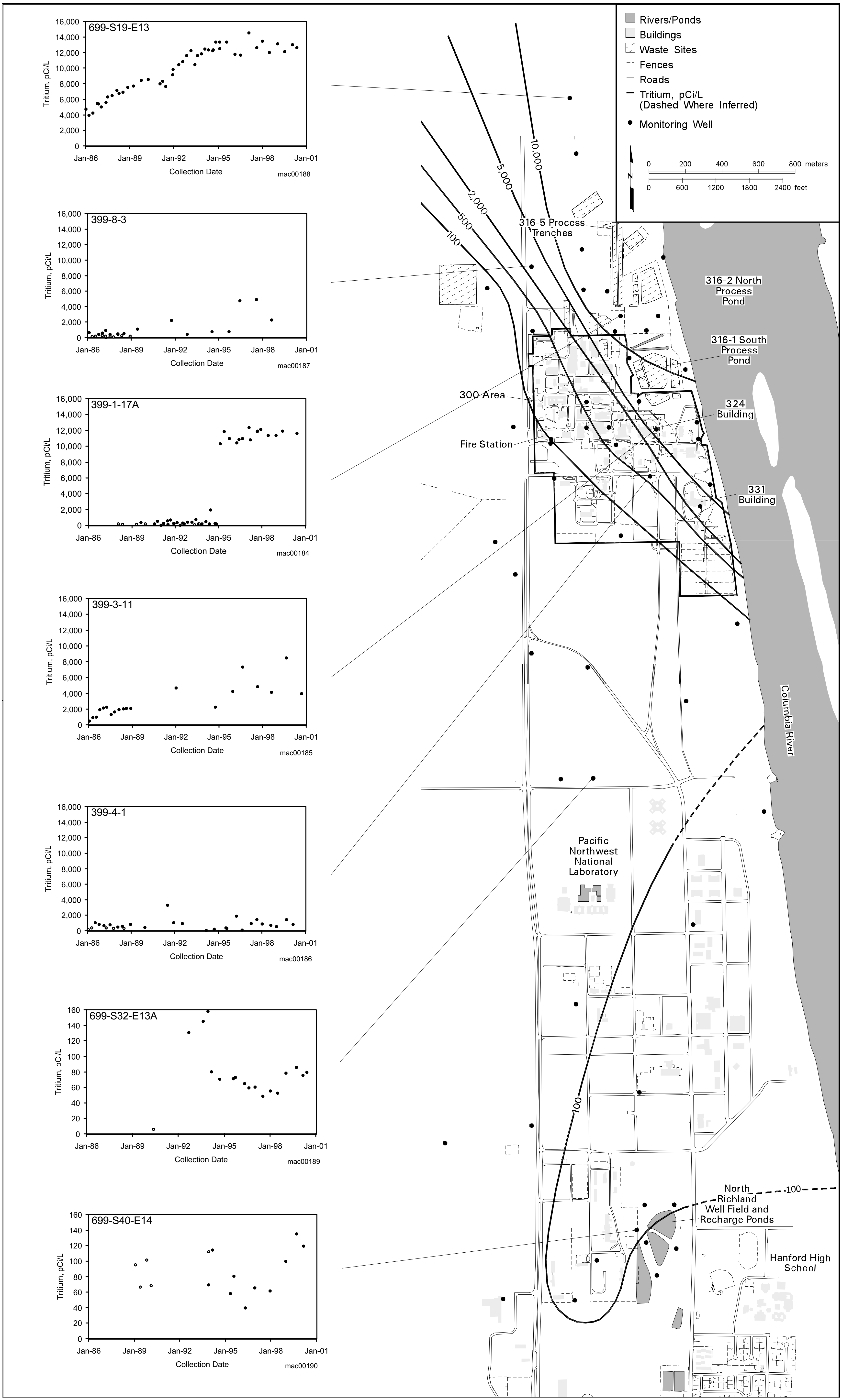

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Figure 2.13-4. Tritium Concentrations in Groundwater at 300 and Richland North Areas, Top of Unconfined Aquifer

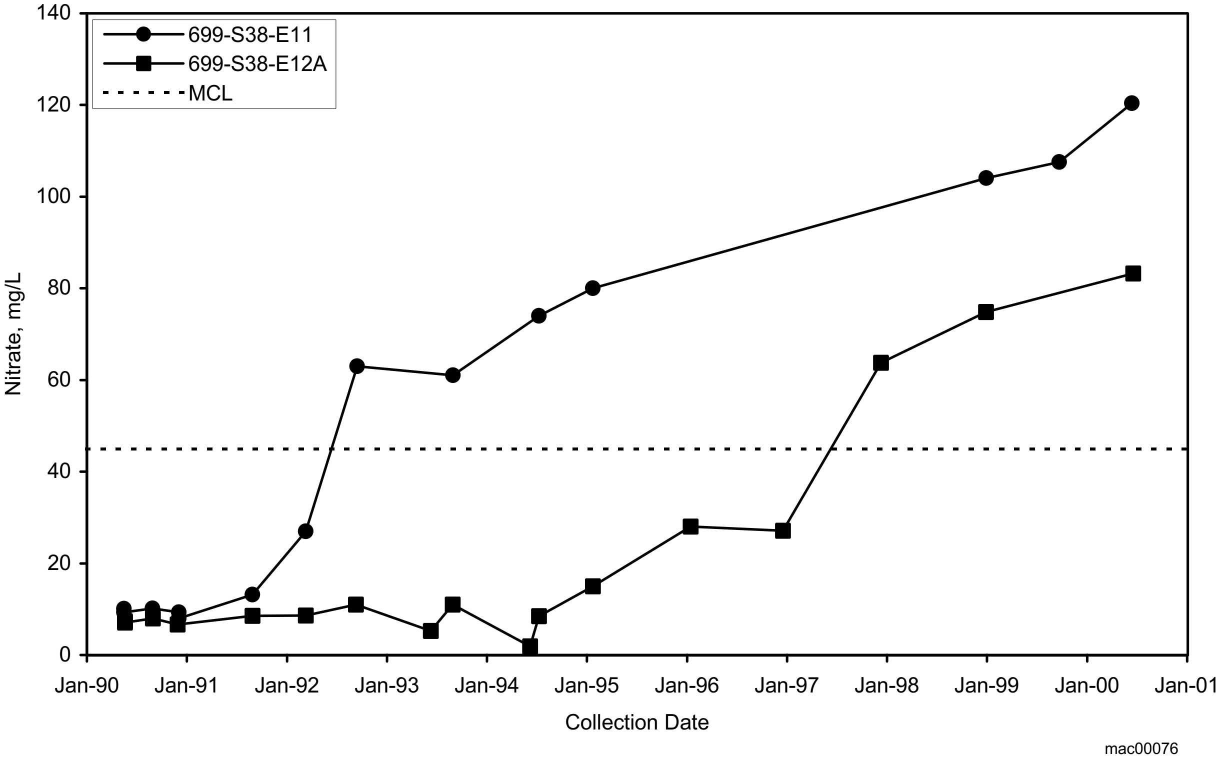

Figure 2.13-5. Nitrate in Wells 699-S38-E11 and 699-S38-E12A Northwest of the City of Richland's North Well Field

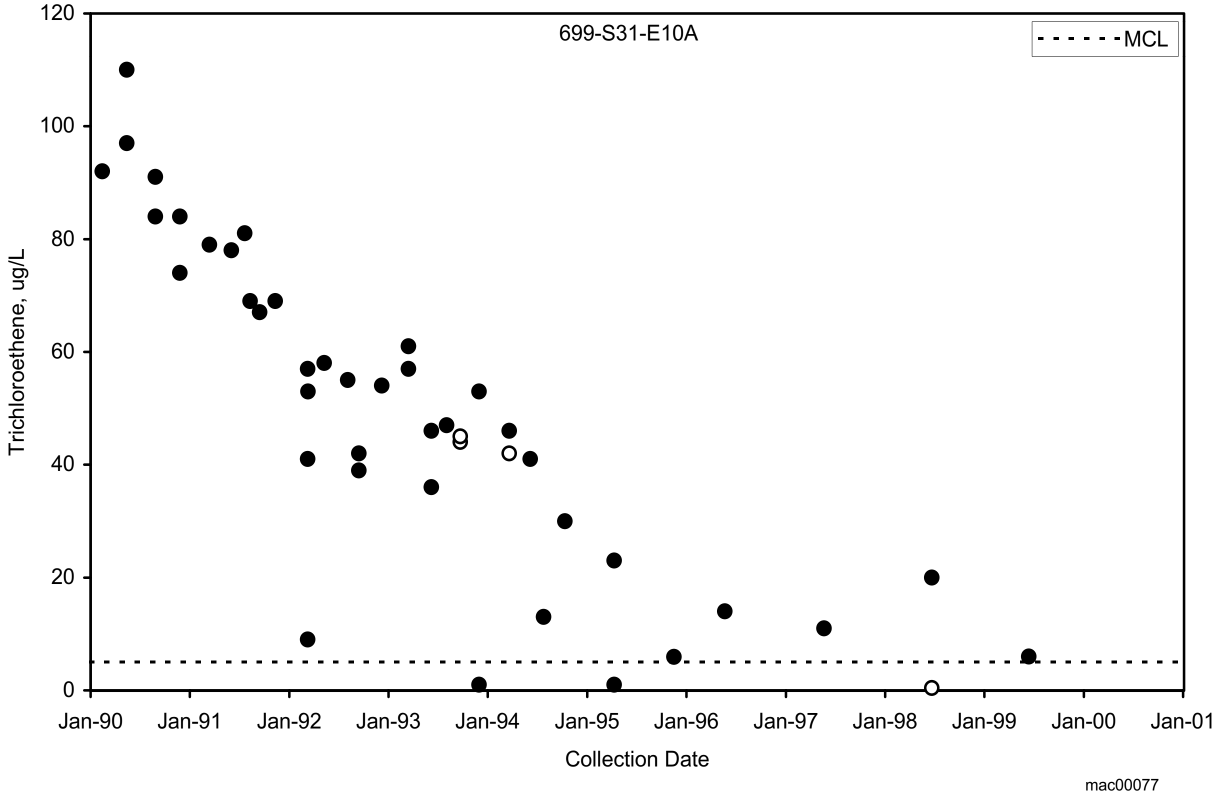

Figure 2.13-6. Trichloroethene in Well 699-S31-E10A, Horn Rapids Landfill

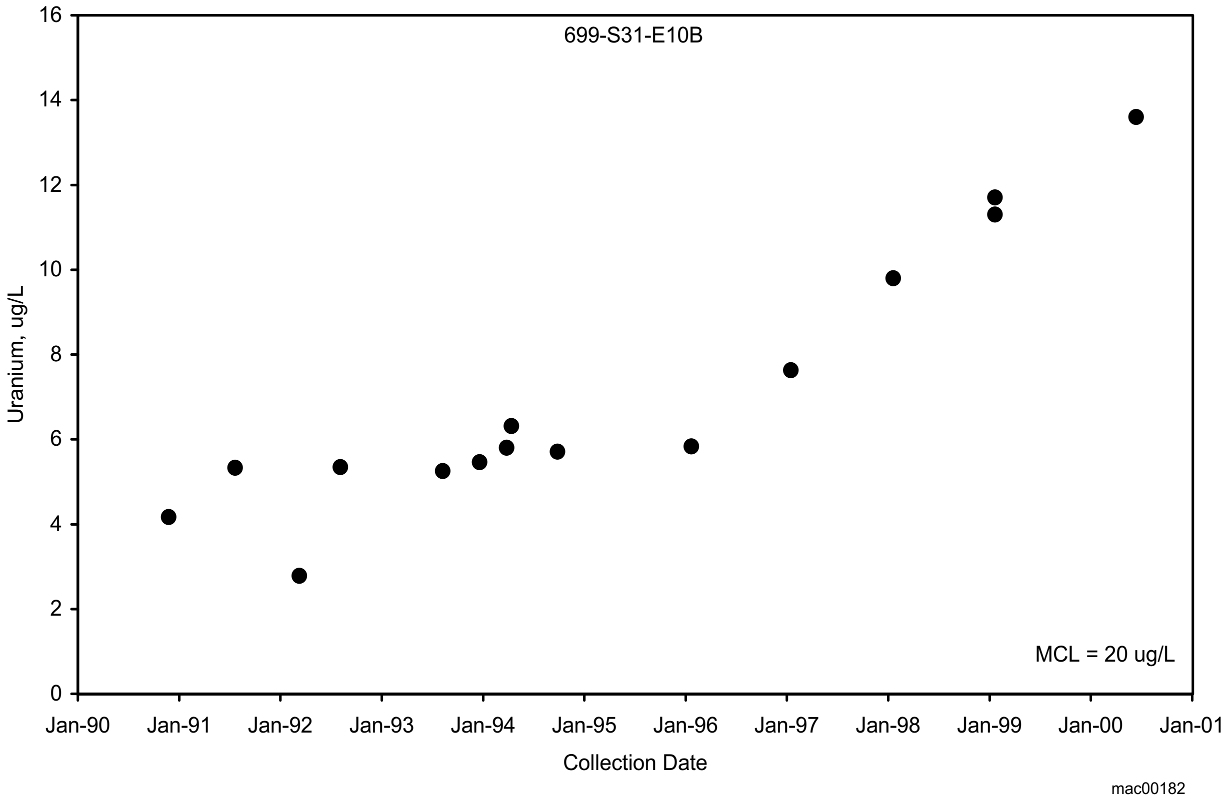

Figure 2.13-7. Uranium in Well 699-S31-E10B, Horn Rapids Landfill

2.14 Upper Basalt-Confined Aquifer

D. B. Barnett and J. P. McDonald

Monitoring groundwater within the upper basalt-confined aquifer is important because of the potential for

- downward migration of contamination from the unconfined aquifer system
- migration of contamination off the southern portions of the Hanford Site
- migration of contamination onto the Hanford Site from offsite sources.

The upper basalt-confined aquifer is much less contaminated than the overlying unconfined aquifer.

Approximately 40 wells, with sampling schedules from annually to triennially, are used to monitor the upper basalt-confined aquifer (Figure 2.14-1). During fiscal year 2000, eight wells were sampled in selected areas to aid in determining the potential for hazardous and radionuclide contamination within the upper basalt-confined aquifer.

Since 1995, the frequency of sampling in most wells in the network has been reduced because there are few areas of concern for contamination or migration to occur in the upper basalt-confined aquifer.

2.14.1 Groundwater Flow

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and intercalated sedimentary interbeds within the upper Saddle Mountains Basalt (see Section 3.1.1 of PNNL-13080).

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In the area of Gable Mountain, shown above, erosion into the basalt has resulted in isolated communication between the unconfined aquifer and the upper basalt-confined aquifer.

The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge Interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey Interbed, which is present only in the southern portion of the site. An interflow zone occurs within the Elephant Mountain member of the upper Saddle Mountains Basalt, and may also 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. 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.

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 ground surface. Recharge also may occur through the Hanford/Ringold aquifer system, where a downward hydraulic gradient exists between the Ringold Formation confined and upper basalt-confined aquifers. Recharge may also occur from deeper basalt aquifers where an upward gradient is present. The Columbia River represents a regional discharge area for this aquifer system, at least in the southern portion of the site. Discharge also occurs to the overlying Hanford/Ringold aquifer system, where an upward hydraulic gradient is present. 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.

Confined groundwater generally flows from west to east beneath the Hanford Site, eventually discharging to the Columbia River through the unconfined aquifer.

The groundwater project measures hydraulic heads annually in the upper basalt-confined aquifer system. Figure 2.14-2, constructed by manual contouring, presents an approximation of the March/April 2000 potentiometric surface for this aquifer system south of Gable Butte and Gable Mountain. The region to the north was not contoured because of insufficient well control. Measurements in the Rattlesnake Ridge Interbed (23 wells), the Levey Interbed (2 wells), and the Elephant Mountain Interflow zone (1 well) were primarily used to construct this map. Additional measurements in the upper Saddle Mountains Basalt (9 wells) were used for general contouring. A consistent 2-meter contour interval is used for the March/April 2000 potentiometric surface map, so this version differs from the maps presented in previous years when a variable contour interval was used. The monitoring well network used for hydraulic head monitoring is presented in PNNL-13021.

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. The elevated regions to the west and southwest of the site are believed to be recharge areas for this aquifer system, and the Columbia River represents a discharge area. The Yakima River may also be a source of recharge.

In the vicinity of the 200 East Area, the potentiometric surface in Figure 2.14-2 is similar to the potentiometric surface for the Ringold Formation confined aquifer (compare with Figure 2.9-17). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding (RHO-BWI-LD-5), which facilitates aquifer intercommunication in this area and probably explains the similarity in hydraulic heads. 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 (compare the water-level elevations on Figure 2.14-2 with those on Plate 1). Therefore, it is likely the upper basalt-confined aquifer system discharges to the overlying Hanford/Ringold aquifer system in this region.

Water-table and potentiometric surface maps of the upper basalt-confined aquifer system (see Figure 2.14-2), the unconfined aquifer (see Figure 2.1-1 and Plate 1), and the Ringold Formation confined aquifer (see Figure 2.9-17) indicate that a downward hydraulic gradient from the Hanford/Ringold aquifer system to the upper basalt-confined aquifer occurs in the western 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. In the vicinity of B Pond, however, head decline within the Hanford/Ringold aquifer system may soon lead to a reversal of the vertical hydraulic gradient. Comparison of heads between well 699-42-40C and adjacent wells completed in the unconfined aquifer indicate that the vertical head gradient between this aquifer and the upper basalt-confined aquifer system has diminished in recent years and is now virtually nil. This is in contrast to historical conditions that indicated a pronounced downward gradient between these two aquifers, presumably due to the effects of the B Pond mound. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the Hanford/Ringold aquifer system.

Water levels in the central and western portion of the Hanford Site declined over the period from March 1999 to March/April 2000, whereas water levels in the eastern portion of the site increased during this period. Water levels in the 200 East Area and to the immediate north and east (near B Pond) continue to show a decline; ranging from no change to -0.34 meter over the 12-month period. Water levels near the 200 West Area also continue to show a decline with a range of -0.17 to -0.29 meter. These declines are a 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 maximum hydraulic head effects of the groundwater mound associated with B Pond have apparently shifted to the northeast since periodic monitoring of the upper basalt-confined aquifer system began in 1991. Figure 2.14-3 shows a trend plot of hydraulic head at well 699-42-40C (located at B Pond and formerly the approximate center of the groundwater mound) and well 699-51-36B (the current approximate center of the groundwater mound). This figure shows that water levels beneath B Pond peaked higher and earlier and are now declining more rapidly than the water level at well 699-51-36B. This more rapid decline beneath B Pond causes the apparent shift in the groundwater mound.

The hydrogeology of the Hanford/Ringold aquifer system in the vicinity of the 200 East Area was extensively investigated in PNNL-12261. This report concluded that the May Junction Fault, located east of B Pond and running north-south, controls groundwater movement from the 200 East Area by impeding the movement of groundwater toward the east. A similar effect may also occur in the upper basalt-confined aquifer system, which would explain why the apparent shift in the B Pond mound is eastward.

2.14.2 Groundwater Quality

The upper basalt-confined aquifer is affected by contamination far less than the overlying unconfined aquifer system. Lower groundwater flow rates (see Section 2.14.1) probably restrict migration of any contamination that reaches the upper basalt-confined aquifer.

Most wells sampled in fiscal year 2000 were analyzed for iodine-129, nitrate, and tritium because these constituents are the most widespread in the unconfined system, the most mobile in groundwater, and serve as potential early-warning indicators. Radioactivity indicators such as gross alpha and gross beta, and specific radionuclides were also sought in areas perceived as higher risk for this type of contamination, primarily because of contamination recognized in the overlying unconfined aquifer.

Tritium is detected in several confined-aquifer wells. The highest concentration measured in fiscal year 2000 was 5,770 pCi/L in a well near B Pond.

Nitrate concentrations were up slightly to significantly in six of seven wells sampled for this constituent in fiscal year 2000 (Figure 2.14-4). The highest concentration (11 mg/L) occurred in well 699-50-53B. This well also displays a slight upward trend in concentrations of this constituent since 1991 when monitoring of the well began. Well 299-E26-8, with a nitrate concentration of 4 mg/L, also displayed an irregular upward trend since 1996, when the concentration was measured at only 0.4 mg/L.

Tritium concentrations were either down or unchanged (mostly non-detect) in all but one well (Figure 2.14-5). In well 299-E26-8, tritium concentration was 20.8 pCi/L, up from non-detection in 1998. Well 699-42-40C, which is completed beneath B Pond in the Rattlesnake Ridge Interbed, historically had the highest tritium concentration of any well completed in the upper basalt-confined aquifer. The well produced concentrations as high as 8,000 pCi/L in 1993 and 1996. Tritium concentration has declined steadily since 1996, with a fiscal year 2000 concentration of 5,770 pCi/L.

Iodine-129 concentrations were either down or unchanged (all non-detect) in all seven wells sampled for this constituent during fiscal year 2000. Well 699-56-53 was sampled for iodine-129 for the first time, but the concentration was below detection.

Sulfate concentration has climbed gradually in well 699-42-40C since 1992. In fiscal year 2000, sulfate concentrations were at 28 mg/L, up from 25 mg/L in 1992. Conversely, the trend of sulfate concentration has steadily declined in wells 699-42-E9B and 699-13-1C since 1991 and 1992, respectively. The highest concentration (~44 mg/L) occurred in well 699-42-E9B in 1991, but fell to 18 mg/L by fiscal year 2000. Sulfate concentrations average ~26 to 28 mg/L in both the upper basalt-confined aquifer and the overlying unconfined aquifer on and near the Hanford Site, with a wide range of concentrations in the upper basalt-confined system (PNL-10817; DOE/RL-96-61). The cause(s) of the trends in wells 699-42-E9B and 699-13-1C is problematic, but may be the result of dilution imparted by the overlying unconfined aquifer and the many surface activities (e.g., irrigation) that directly affect it.

Well 699-13-1C was sampled for selected radionuclides and indicators for the first time in fiscal year 2000. These initial results and results for the other wells sampled during fiscal year 2000, are indicated in Figure 2.14-6 near the location of the well on the map. No trends emerge as a result of fiscal year 2000 radionuclide and gross beta/gross alpha results in the upper basalt-confined aquifer wells, and most results were below detection limits. Well 199-H4-2 was also sampled for gross alpha and gross beta for the first time in fiscal year 2000, yielding a non-detect and 10.5 pCi/L, respectively.

In February 2000, conductivity was down dramatically in well 699-13-1C at 330 µS/cm from 1,015 µS/cm in October 1995. This change appears to be mostly a result of lower anion concentrations, primarily sulfate and nitrate.

The February 2000 analysis of groundwater from well 699-13-1C indicated a sodium concentration of 53,300 µg/L. Sodium had not been analyzed in this well since October 1992, when it was at a concentration of 5,300 µg/L.

The causes of changes in constituent concentrations, such as sulfate levels in wells 699-42-40C and 699-13-1C, are uncertain. In some cases, flaws in well completions may be allowing localized communication with the unconfined aquifer, or intercommunications with other units within the upper basalt-confined aquifer. Alternatively, these changes may represent more widespread effects within the upper basalt-confined aquifer. Resolution of this problem and others, such as uncertainty in water levels may remain difficult with the limited number of wells available for monitoring in the upper basalt-confined aquifer.

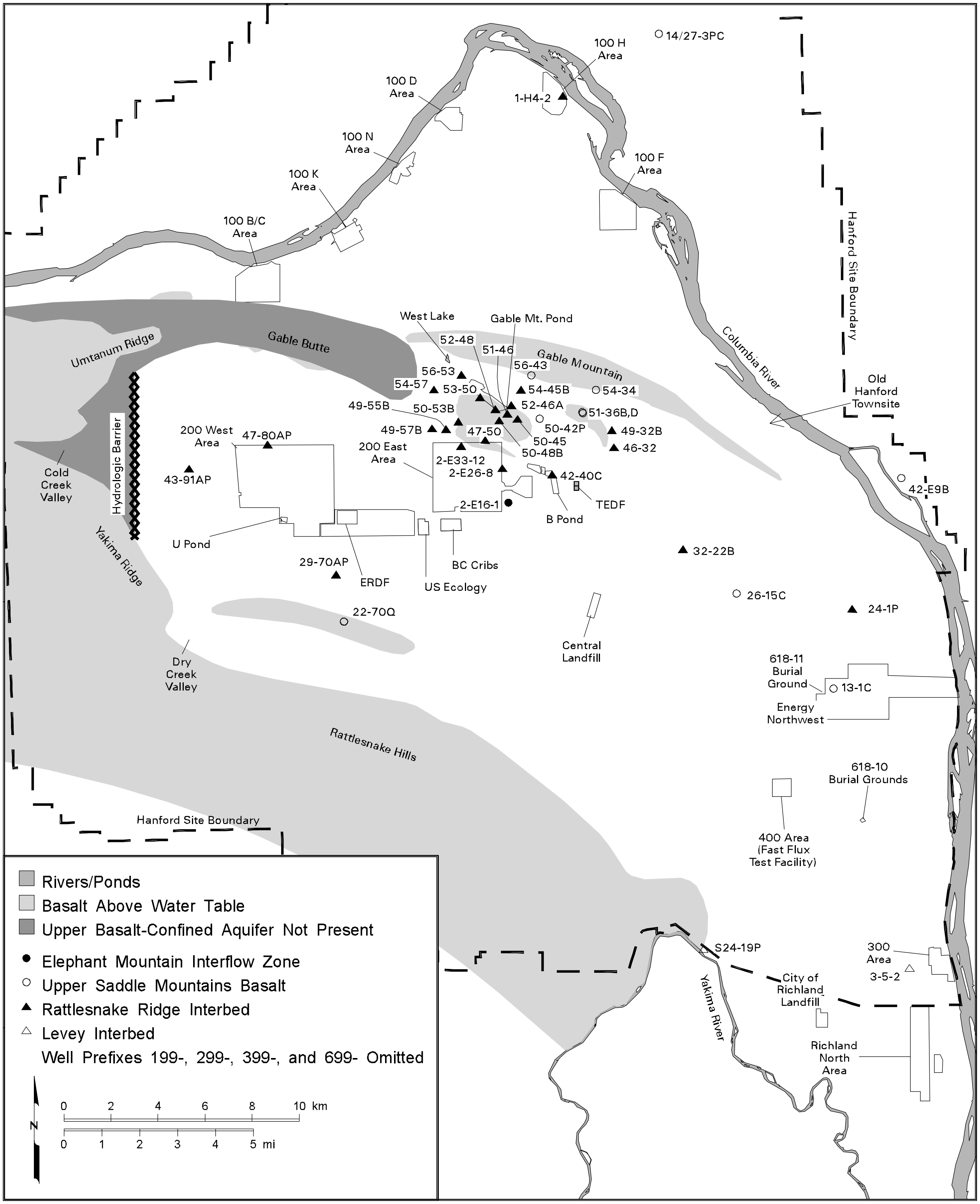

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Figure 2.14-1. Groundwater Monitoring Wells in the Upper Basalt-Confined Aquifer on the Hanford Site

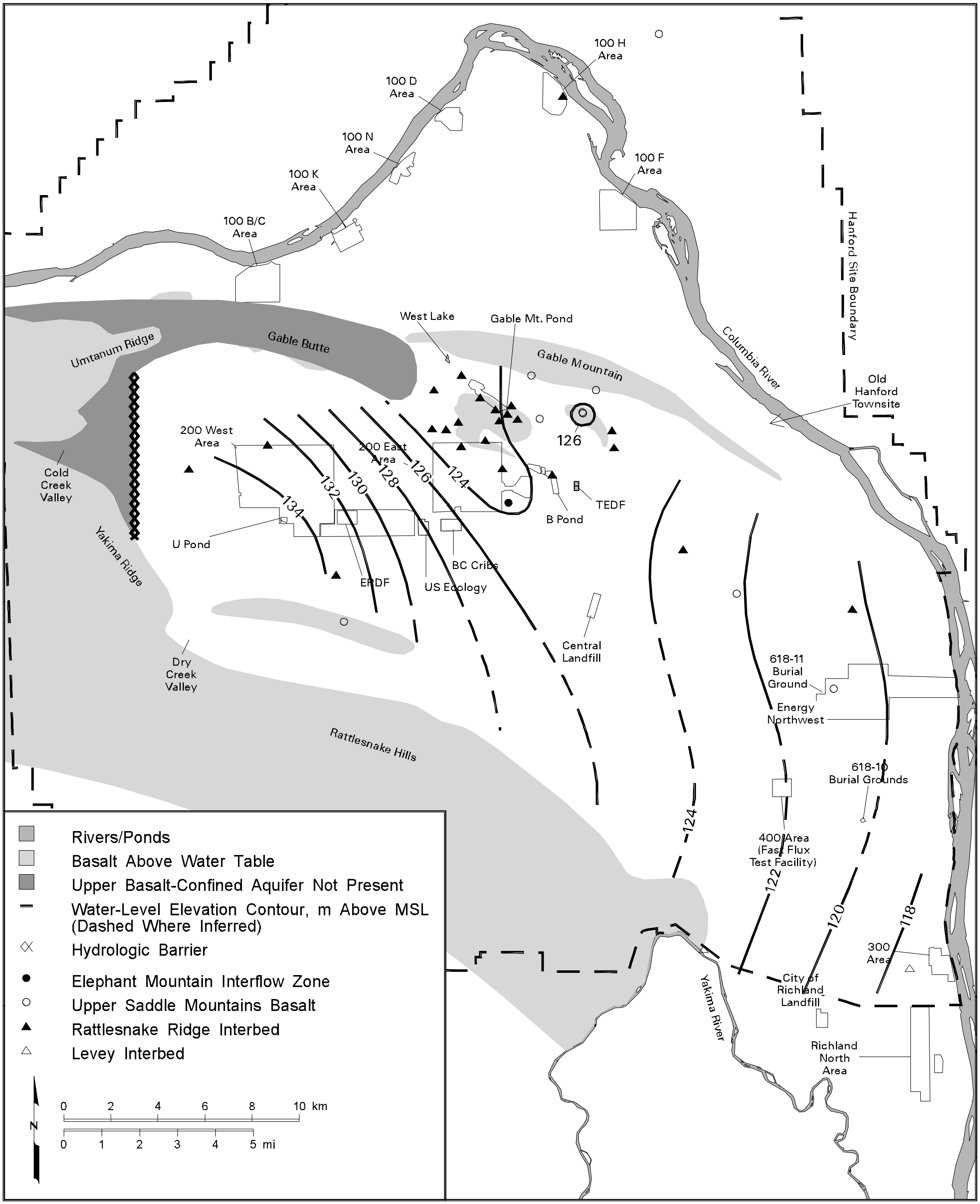

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Figure 2.14-2. Potentiometric Map of Upper Basalt-Confined Aquifer System, March/April 2000

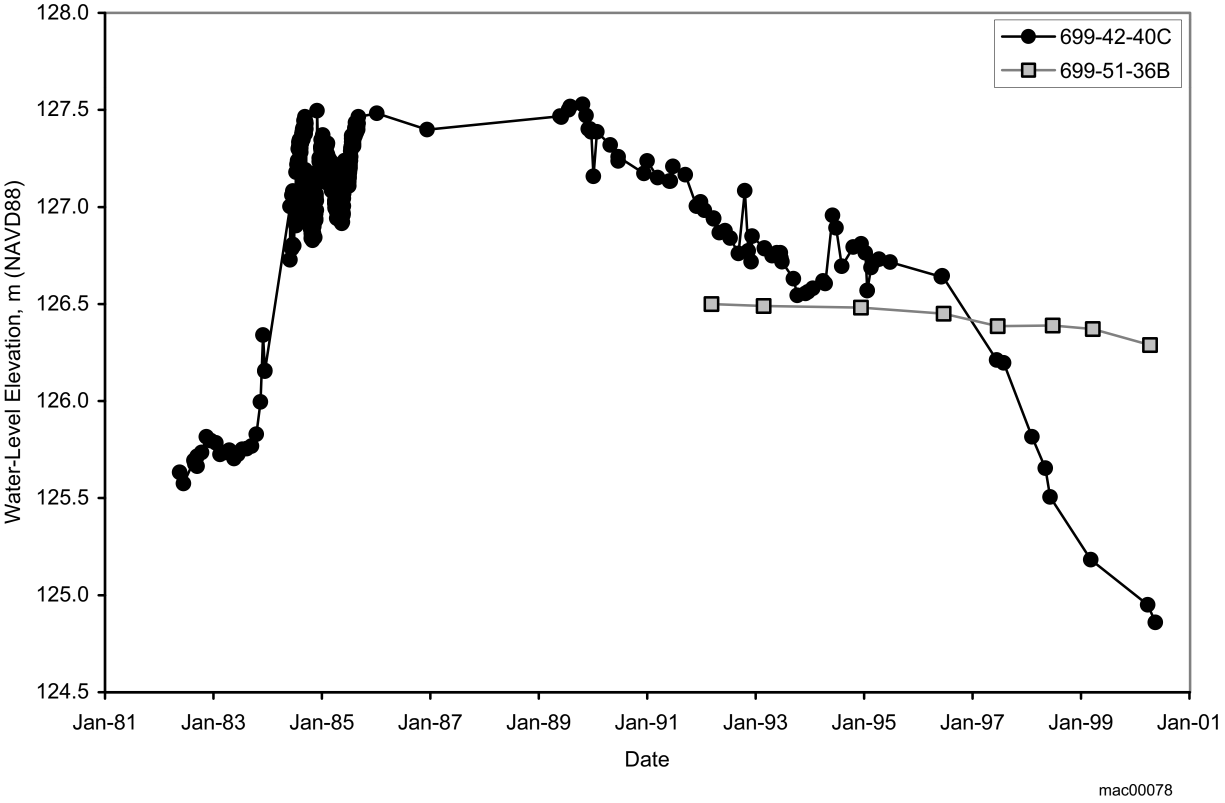

Figure 2.14-3. Water Levels in Upper Basalt-Confined Aquifer in Well 699-42-40C near B Pond and Well 699-51-36B North of B Pond

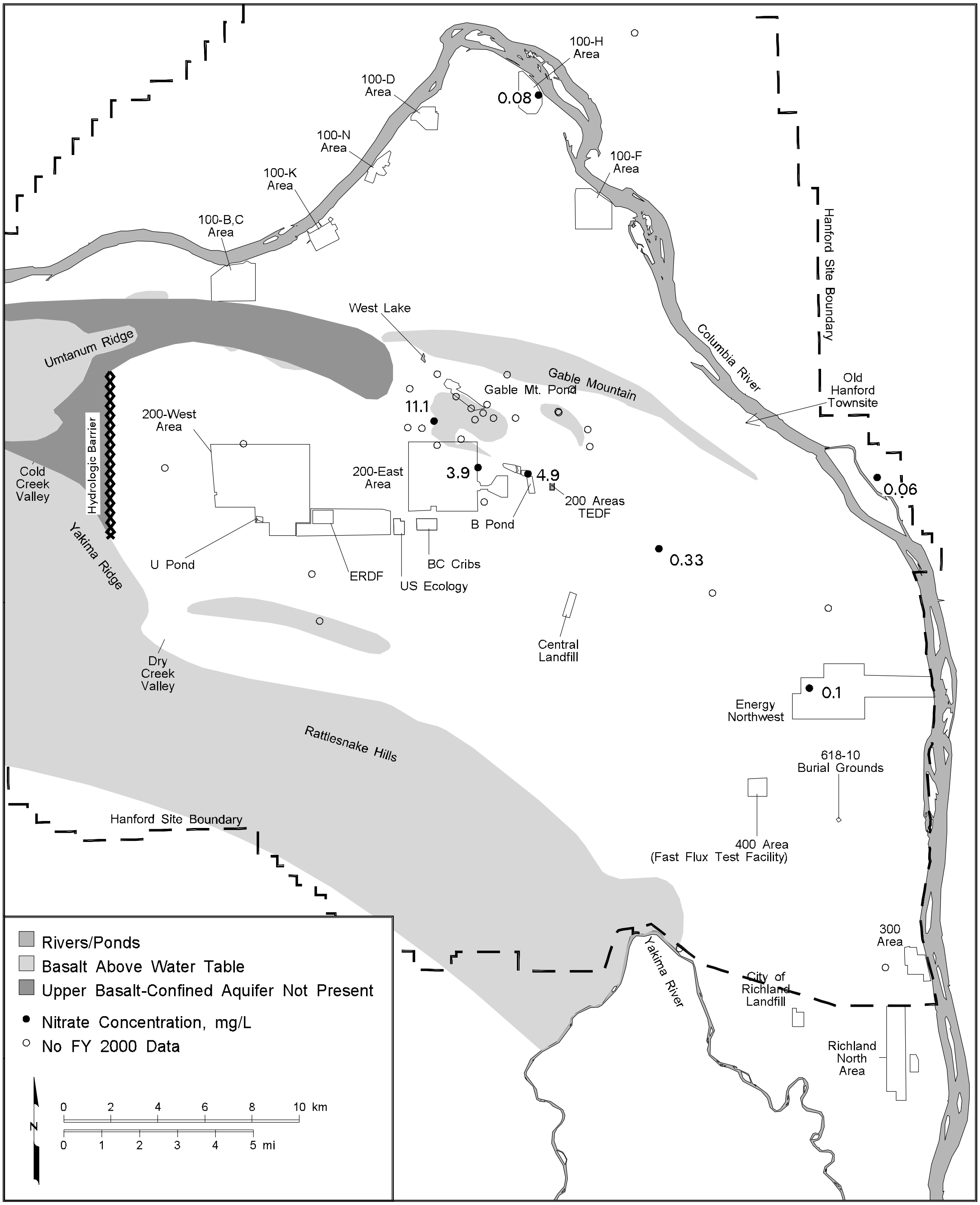

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Figure 2.14-4. Highest Results for Nitrate Detected in Upper Basalt-Confined Aquifer Monitoring Wells, Fiscal Year 2000

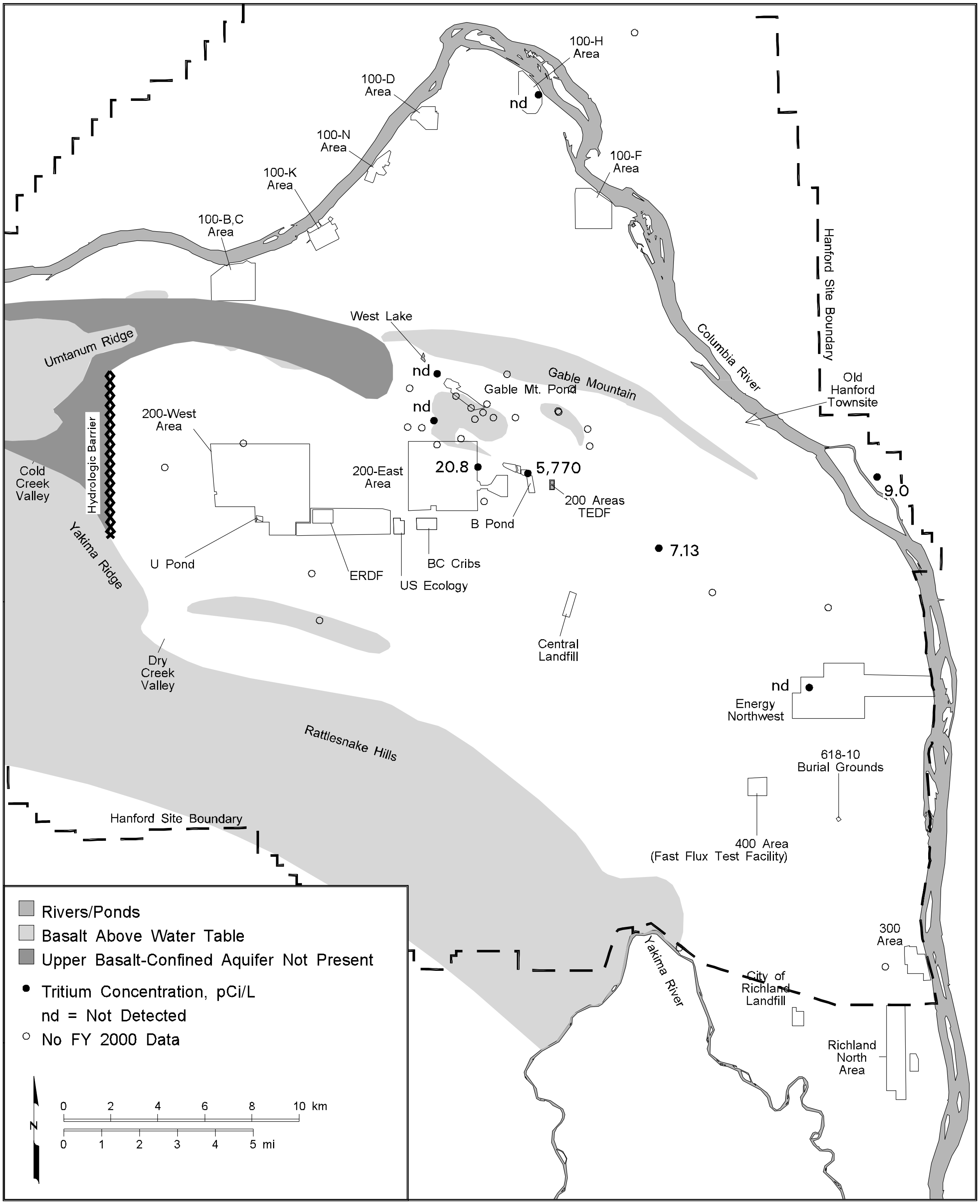

Figure 2.14-5. Highest Results for Tritium Detected in Upper Basalt-Confined Aquifer Monitoring Wells, Fiscal Year 2000

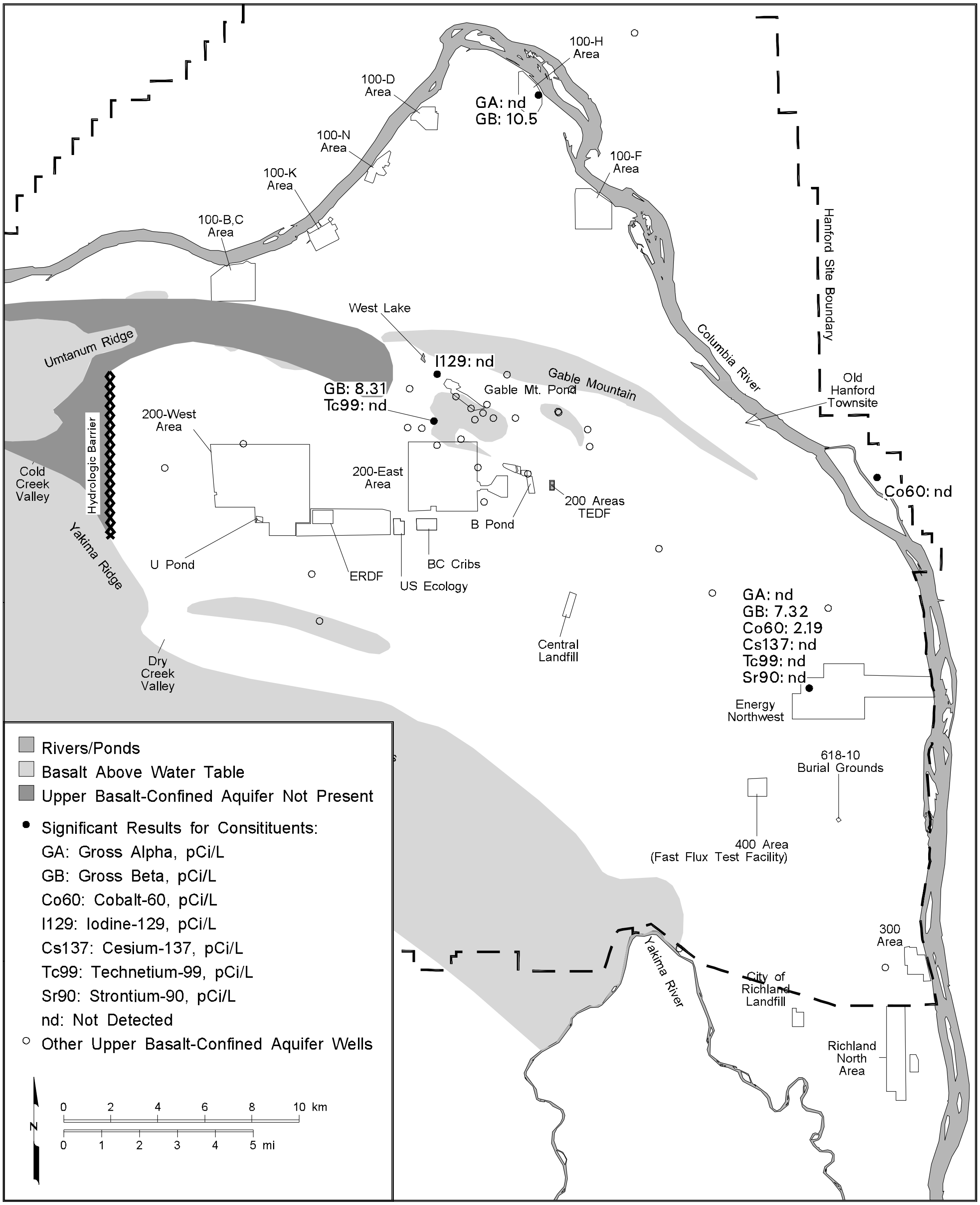

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Figure 2.14-6. Highest Results for Selected Radionuclides Detected in Upper Basalt-Confined Aquifer Monitoring Wells, Fiscal Year 2000

3.0 Vadose Zone

D. G. Horton

Radioactive and hazardous wastes in the soil column from past intentional liquid waste disposals, unplanned leaks, solid waste burial grounds, and underground tanks at the Hanford Site are potential sources of continuing and future vadose zone and groundwater contamination. Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in fiscal year 2000 to better understand the distribution and mechanisms that control the movement of subsurface contamination. This chapter summarizes major findings from those efforts, focused primarily on vadose zone soil contamination associated with reactor operations, past single-shell tank leaks, and liquid disposal to ground as a result of spent fuel processing. This chapter also summarizes three fiscal year 2000 technical demonstrations that could lead to new and improved methods to characterize and monitor the vadose zone.

An overview of the major soil column sources of groundwater contamination is provided in PNNL-13080. This chapter discusses vadose zone contamination that could impact groundwater in the future. Much of the evidence for continuing impact on groundwater from vadose zone contamination is discussed in Section 2.0. 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 fiscal year 2000 vadose zone results are summarized here but the bulk of the data interpretation on impact to groundwater is presented and discussed in Section 2.0.

3.1 Vadose Zone Characterization

D. G. Horton

This section describes significant vadose zone characterization activities that occurred during fiscal year 2000. During the year, one new characterization borehole was drilled and sampled in the SX single-shell tank farm to better understand sediment properties, contaminant distribution, and transport mechanisms operating in the vadose zone. During fiscal year 2000, baseline spectral gamma logging of selected wells in single-shell tank farms was completed. The logging was follow-up to the baseline characterization effort that occurred in all single-shell tank farms between 1995 and 1999.

The goal of vadose zone characterization is to improve understanding of contaminant distribution and movement above the water table. This is accomplished through drilling, sampling, geophysics, and laboratory tests.

Also in fiscal year 2000, semi-quantitative mineral analyses were completed of samples from one borehole in the SX tank farm and four samples designed to be "standards" for the Hanford and Ringold Formations at the Hanford Site. Such analyses have not been done previously at the Hanford Site and will help interpret mechanisms of contaminant transport in the vadose zone.

A 3-year U.S. Department of Energy (DOE) Environmental Management Science Program study of clastic dikes and their influence on movement of subsurface contamination began in fiscal year 2000. The study is designed to describe the geometric and hydrologic properties of clastic dikes and extrapolate those properties to the subsurface of waste disposal and storage sites.

Vadose zone characterization activities were done at four sites in the 200 Areas to support remediation of sites that received cooling water waste (200-CW-1 Operable Unit) and at one site in the 100 DR Area to support chromate remediation using in situ gaseous reduction technology.

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Two slant boreholes were constructed in and near Waste Management Area S-SX. The first was a demonstration borehole to develop operational and safety procedures for the second slant borehole in the tank farm.

Finally, four comprehensive data packages were published in fiscal year 2000 to support the 2005 Immobilized Low-Activity Waste Performance Assessment. Those data packages describe the current knowledge about the geology, geochemistry, hydrology, and recharge to the vadose zone at the proposed Immobilized Low-Activity Waste Disposal Facility site.

3.1.1 Characterization of the Vadose Zone Beneath Single-Shell Tanks

Vadose zone characterization activities at single-shell tank farms in fiscal year 2000 were concentrated at the S and SX tank farms. Several characterization efforts were begun and most are ongoing, so complete results will not be available until next year. However, some borehole logging results from new boreholes and some laboratory measurements of sediment mineralogy and hydrologic properties were completed and became available during fiscal year 2000. Also, spectral gamma-ray logging of high-count-rate zones in 51 boreholes and logging of selected depths in 88 other boreholes was done in all single-shell tank farms in fiscal year 2000.

3.1.1.1 River Protection Project Vadose Zone Activities

D. A. Myers

The River Protection Project operated by CH2M HILL Hanford Group conducted a series of investigations at the S and SX tank farms during fiscal year 2000. In October 1999, well 299-W19-23, located 3 meters southwest of tank SX-115, was completed as a groundwater monitoring well and brought into the *Resource Conservation and Recovery Act of 1976* (RCRA) assessment program for Waste Management Area S-SX. Analyses of sediment samples collected during the drilling of this well have been conducted throughout the year. The preliminary results of these analyses will become available in fiscal year 2001.

In January and February, a cone penetrometer was used adjacent to tanks S-102 and S-104. In addition to standard tip sleeve measurements, the cone penetrometer tools included a sodium-iodide based spectral gamma sonde. Ten pushes were made with the logging sonde and three pushes were made to obtain samples from zones identified by the spectral gamma tool as containing significant contamination. The cone penetrometer work identified a gamma peak above the base of tank S-104 and below the elevation of several spare inlet ports that had been built in the tank. Tank S-104 had been overfilled during its operating history, and the possibility exists that losses from this tank may have been through the spare access ports. The cone penetrometer work lends support to this hypothesis, though it does not eliminate the possibility that the tank itself may have suffered a loss of integrity.

A new slant drilling and sampling technique was deployed at the SX tank farm.

The major activity conducted in and near the Waste Management Area S-SX was the construction of two slant boreholes that were extended into the lower Hanford formation or Plio-Pleistocene Unit. The first of these boreholes was constructed south of the SX tank farm as a demonstration of a new drilling and sampling approach and to train tank farm personnel before deploying the system inside the farm. A heavy-wall drill pipe with a diameter of 18 centimeters was driven into the ground using a pile driving unit inclined 30 degrees from vertical (Figure 3.1-1). The leading end of this drill string was designed to be removable, so that a split spoon sampler could be driven ahead of the disturbed region of the borehole. A special, lead-shielded sampler also was designed so that highly radioactive soil samples could be retrieved with minimal risk to the workers. The sampler was tested to assure its ability to collect and retract a useful sample. Upon completion of the demonstration and training effort, the rig was set up inside the farm for the second hole. During the test and demonstration, ground acceleration measurements were taken to provide data for analysis of the drilling technique impact on the sidewalls and base of the tanks.

The second hole was aligned to pass beneath tank SX-108, through a zone of highly contaminated soil and "bottom-out" in the Plio-Pleistocene Unit at a vertical depth of 45 meters, ~3 meters due south of the tank center. Figure 3.1-2 shows the projection of the borehole relative to the geologic formations and the tank. Seventeen sample depths were identified based on the geology and geophysical logs of nearby drywells. The configuration of the drilling machine limited sampling intervals to no more frequent than 1.5 meters. Samples were successfully collected from 16 of the 17 preselected locations. Sampling was initiated, after a check of borehole position, at the approximate contact of the tank farm backfill and the underlying undisturbed soils. The second sample to be attempted was lost, probably due to the coarse nature and dryness of the soil that allowed them to fall from the sampler. All other samples were recovered and sent for laboratory analysis; the complete results of those analyses will be available in fiscal year 2001 and will be summarized in the next annual report.

Upon completion, this borehole was logged and then decommissioned. Both spectral gamma and downhole temperature logs were obtained, and Figure 3.1-3 shows the logging results. The figure shows good correlation between the available laboratory results and the geophysical logs. Samples from this borehole have provided the highest levels of soil contaminant concentrations recovered from Hanford Site tank farms to date.

3.1.1.2 Characterization of Borehole 41-09-39 at Single-Shell Tank SX-109

H. T. Schaef, D. G. Horton, and D. A. Myers

Borehole 41-09-39 is located adjacent to single-shell tank SX-109 in the SX tank farm in the Hanford Site's 200 West Area. The borehole was originally constructed in 1996 to a depth of 40 meters in order to determine the distribution of cesium-137 at depths of 24 to 40 meters below ground surface. The borehole was deepened in 1997 and temporarily completed as a monitoring well to allow collection of groundwater samples. The borehole was decommissioned in 1999 to eliminate it as a potential pathway for contaminants to reach groundwater. As part of the decommissioning effort, sidewall samples were collected at previously unsampled portions of the borehole and submitted for chemical, radiological, and mineralogical analyses.

Summaries of the results of chemical and radiological testing on samples from borehole 41-09-39 were reported in 1999 and 2000 (PNNL-12086; PNNL-13116). This section summarizes the results of mineralogical testing that became available in late fiscal year 2000. These analyses are the first reported semi-quantitative mineral abundances from radionuclide contaminated sediment at the Hanford Site. The results will help interpret experimentally derived distribution coefficients and cation exchange capacities and will help understand the distribution of radiocontaminants in the subsurface.

Results of mineralogical testing of samples from a borehole in the SX tank farm will help scientists understand the distribution of radionuclides underground.

X-ray diffraction analyses were done on five samples from borehole 41-09-39. All samples were from the Hanford formation. Samples were prepared for analysis according to the methods of Jackson (1974), Drever (1973), and Moore and Reynolds (1989). Semi-quantitative mineral abundances were determined for both the bulk sample and the <2 µm size fraction. Semi-quantitative measurements of mineral phases were done according to Brindley (1980) using the relationship of x-ray intensity and mass attenuation to weight fraction of unknown phases. Mass attenuation coefficients for both pure minerals and for the unknown samples were measured according to Brindley (1980).

X-ray diffraction analysis of the bulk samples from five depths in borehole 41-09-39 show that the sediment is about 35 to 50 wt. % quartz and about 25 to 55 wt. % feldspars with lesser amounts of mica and chlorite. Plagioclase feldspar is 2 to 10 times more abundant than is potassium feldspar. Minor amounts of amphibole and calcite also were detected in the bulk sediment. Table 3.1-1 shows the bulk mineral composition of the samples from borehole 49-09-39.

Mineral quantities in the <2 μm size fraction are shown in Table 3.1-2. The data show that the <2 μm fraction is dominated by four clay minerals: illite, smectite, chlorite, and kaolinite. Minor amounts of quartz and feldspar and trace amounts of amphibole were identified in some samples (abundances of amphibole were not determined). Overall, illite is the dominant mineral in the <2 μm fraction ranging from 20 to 35 wt. % of the samples. Smectite ranged from 5 wt. % to as much as 20 wt. % of the samples and chlorite made up between about 10 and 30 wt. % of the samples. Minor amounts of kaolinite (<10 wt. %) were detected in all samples and quartz and feldspars made up about 5 to 20 wt. %.

The bulk mineralogy determined by this study is similar to that determined by Tallman et al. (RHO-ST-23) for samples from the southern part of 200 West Area. However, the x-ray diffraction work of Tallman et al. was qualitative and no absolute mineral abundances were given. Tallman et al. (RHO-ST-23) did estimate mineral abundances obtained by electron microprobe.

3.1.1.3 Baseline Spectral Gamma-Ray Logging at Tank Farms

P. D. Henwood and R. G. McCain

Since 1995, baseline vadose zone characterization in single-shell tank farms has been conducted by the DOE Grand Junction Office (DOE-GJO) and its subcontractor, MACTEC-ERS. By the end of fiscal year 2000, the baseline data had been reported in tank summary data reports for all 133 single-shell tanks with capacities of 2 million liters or greater (100-series tanks), and in tank farm reports for each of the 12 single-shell tank farms. Since the original baseline data were acquired, additional data have been collected, new analysis techniques have been developed, and additional insights into the nature and distribution of contamination in the vadose zone have been gained. An addendum to each tank farm report was prepared during fiscal year 2000 to present these additional data and to report revised interpretations of subsurface contaminant distribution. With submittal of these reports, the baseline characterization was completed.

Spectral gamma logging is a geophysical method that can identify radionuclides through the sides of boreholes or wells. By the end of fiscal year 2000, baseline logging had been completed for the single-shell tank farms. The baseline data provide a comparison for future logs to determine if contamination is moving.

The purpose of the baseline characterization was to identify the nature and extent of contamination associated with gamma-emitting radionuclides in the tank farms using data collected from existing boreholes. This work serves as a baseline against which future measurements can be compared to identify changes in the vadose zone, to track gamma-emitting radionuclide contaminant movement, and to aid in identifying or verifying future tank leaks. During fiscal year 2001, a monitoring program for selected boreholes around single-shell tanks will be established, and the baseline logging effort will be extended to existing boreholes near liquid waste disposal sites across the Hanford Site. Results of the Tank Farms Vadose Zone Characterization Program are posted on the Internet at: http://www.doegjpo.com/programs/hanf/HTFVZ.html.

Spectral Gamma Logging Methods

Two borehole logging trucks were specially fabricated for the baseline logging project. Log data in the form of gamma spectra were collected using a high-purity germanium semiconductor detector with 35% relative efficiency. This combination of detector and logging truck is referred to as the spectral gamma logging system. The spectral gamma logging system is able to quantify radionuclide concentrations from background levels up to several thousand picocuries per gram. Frequently, zones of more intense radiation are encountered in which the detector becomes saturated and ineffective. In order to provide data in these high-rate zones, an additional detector, called the high-rate logging system, was developed and deployed in 1999.

The high-rate logging system uses the same logging trucks and electronics system as the spectral gamma logging system. The high-rate logging system, however, has a smaller detector and two shields that allow measurement of cesium-137 concentrations up to about 100 million pCi/g. High-rate logging operations were completed in fiscal year 2000. The spectral gamma logging system and high-rate logging system data were collected in accordance with procedures documented in MAC-VZCP 1.7.10-1 and analyzed in accordance with MAC-VZCP 1.7.9.

A new high-rate logging system was developed to measure cesium-137 in highly contaminated zones.

The spectral gamma-ray logging system was initially calibrated at the DOE-GJO Borehole Calibration Facility (GJPO-HAN-1). Continuing calibration measurements were made at the Hanford Site calibration facilities, and the most recent calibration (February 2000) is documented in GJO-HAN-30. The base calibration of the high-rate logging system was conducted at the Hanford Site in 1999 and is documented in GJO-HAN-29.

Additional Data and Analysis

Logging was conducted using the high-rate logging system in all borehole intervals where the original baseline spectral gamma logging system indicated zones of detector saturation resulting from very high gamma fluxes. However, the high-rate logging system is significantly more sensitive to cesium-137 relative to other radionuclides such as cobalt-60 or europium-152/154, and cesium-137 is the primary radionuclide measured in high-rate zones. In addition, the relative degree of uncertainty for measurements made with this system is significantly greater than that for the spectral gamma logging system. An example of high-rate data using various shield configurations is plotted along with the spectral gamma logging system data for borehole 30-05-07 in the C tank farm in Figure 3.1-4. As shown in the figure, the final baseline consists of a composite of spectral gamma logging system and high-rate logging system data.

Other data collected since the original tank farm reports were issued include repeat logging measurements acquired up to 4 years after the initial baseline data were collected. Boreholes were selected for repeat logging primarily to check for possible contaminant movement over time. To compare the original baseline and the repeat logging data, baseline data were adjusted for radionuclide decay. An example of a repeat logging event from a borehole in the C tank farm is depicted in Figure 3.1-5. This figure presents data indicating downward movement of cobalt-60 contamination.

A data analysis method known as shape factor analysis has been introduced since the first tank farm report was issued. This method is used to discriminate between contamination on the inside or outside of the borehole casing, uniformly distributed contamination in the formation, or a discrete contaminant source at a distance from a borehole. Depth intervals in which contamination was localized to the borehole were removed from the data sets used to create visualizations of subsurface contamination. Figure 3.1-4 shows intervals of contamination that have been removed as a result of this type evaluation. Removal of these intervals led to significant modifications to the original visualizations presented in the tank farm reports. Addenda were issued during fiscal year 2000 for each tank farm report that presented additional information from shape factor analyses and revised visualizations.

Antimony-125, cesium-137, cobalt-60, europium-152, uranium-235, uranium-238, and possibly strontium-90 have been detected in tank farms using the spectral gamma logging systems. The visualizations are intended to provide the reader with an understanding of how gamma-emitting contaminants that have leaked from tanks may be distributed in the vadose zone sediment. A valuable attribute of the visualizations is that they can be used to define areas of concern in which to focus future characterization, monitoring, and remediation efforts. Figure 3.1-6 presents an example of a revised data visualization that includes high-rate logging data and excludes contamination localized to a borehole.

Results

Results of baseline logging conducted from 1995 to 1999 for single-shell tanks were reported in prior groundwater monitoring reports. Results also were reported in individual tank summary data reports and tank farm reports (http://www.doegjpo.com/programs/hanf/HTFVZ.html). Conclusions reported in those documents have not changed substantially as a result of incorporating shape factor analysis and high-rate logging data. Inclusion of the high-rate logging data in the interpreted data set used to create the three-dimensional visualizations had a relatively minor impact on the spatial distribution of the contaminant plumes, but had a substantial impact on the estimated total curie activity within the plume volume. Although evaluation of shape factor results and other data provided a justification for eliminating many contamination intervals in some boreholes, most intervals of significant contamination remain and only relatively low-concentration “ghost” plumes were eliminated from the visualizations.

High-rate logging provides an improved basis to estimate the volume of contaminated soil in the vadose zone. It also provides a method for future comparisons of contaminant movement in highly contaminated zones.

High-rate logging data were collected in 51 boreholes in the Hanford Site tank farms. Of these 51 boreholes, 39 exhibited high gamma flux zones below the operating level of the tanks. The remaining 12 zones were at depths above the tank operating level and were typically associated with contamination related to tank farm infrastructure, such as buried transfer lines, that is not related to tank leaks. The maximum concentration measured in any zone was about 100 million pCi/g. The acquisition of high-rate logging data completed the baseline characterization of tank farms and allowed determination of maximum concentrations in contamination plumes. This capability provides an improved basis to estimate the volume of contaminated soil and contaminant inventory in the vadose zone. It also provides a method for future quantitative comparisons of contaminant movement in high gamma flux zones by repeated logging through time.

Repeat log data were collected with the spectral gamma logging system in all tank farms from selected depth intervals in 88 boreholes. The log intervals measured in 80 of the boreholes were below the operating level of the tanks. Data acquired in 22 borehole intervals below the operating levels of the tanks indicated possible concentration increases that would suggest the possibility of continued contaminant movement through the vadose zone from tanks that had leaked in the past.

Routine gross gamma logging of boreholes surrounding single-shell tanks was discontinued in 1994, and there has been no comprehensive monitoring effort since that time. However, a comprehensive, routine logging program will be established in fiscal year 2001 for selected boreholes in the tank farms. The results of the baseline logging, the high-rate logging, and the repeat logging will be used to prioritize future vadose zone monitoring at the single-shell tank farms.

3.1.2 Hydrogeologic Influence of Clastic Dikes on Vadose Zone Transport

C. J. Murray, D. G. Horton, G. W. Gee, and A. L. Ward

A 3-year study of clastic dikes and their influence on vertical movement of moisture and contaminants in the vadose zone began in fiscal year 2000. The study is funded by the DOE's Environmental Management Science Program. The goal is to describe the geometry and hydrologic properties of clastic dikes and dike networks and extrapolate those properties to the vadose zone beneath waste storage and disposal facilities.

Clastic dikes are common sedimentary structures in the vadose zone at the Hanford Site (BHI-01103). The dikes consist of vertical to subvertical structures that are often contorted and irregular, and cross-cut the normal subhorizontal sand and silt beds of the Hanford formation (Figure 3.1-7). Clastic dikes generally are composed of multiple layers including an outer skin of silt/clay and coarser grained infilling layers. The dikes vary in width from less than 1 centimeter to more than 2 meters and have vertical extents that range from less than 1 meter to more than 50 meters, with a large number greater than 20 meters. In plan view, clastic dikes often form 4- to 8-sided polygons arranged in a network. Previous investigators have proposed that the dikes may provide a preferential path for contaminated water leaking from waste tanks to move through the thick unsaturated zone to the unconfined aquifer. However, there is insufficient evidence to determine if that speculation is accurate.

In 2000, the project used remote sensing and ground-penetrating radar surveys to describe the large-scale distribution of the clastic dikes along Army Loop Road in the 600 Area and at the 216-S-16 pond. Figure 3.1-8 shows the dikes at the two sites as mapped into a Geographic Information System (GIS) from air photographs. The GIS then was used to extract the lengths, area of the polygons, and azimuth of the dikes and simple statistical analyses were made. In addition, four field traverses were made across the dike swarm and the widths of dikes crossed during the traverses were measured. The edges of the dikes were interpreted to be the boundaries where the density of vegetation changed. (Vegetation is thicker on the dikes than on the host soil because the dikes tend to hold more moisture.) Figures 3.1-9 through 3.1-12 show the distribution of the measured properties. The mean length of the dikes is 62 meters, and the average width of the surface expression of the dikes is just over 2 meters. The rose diagram (Figure 3.1-12) indicates a slight preferential orientation to the dikes in the network, with many of the dikes occurring in two conjugate sets. Those sets have north, northwest-south, southeast and north, northeast-south, southwest orientations.

The influence of clastic dikes on subsurface moisture movement was the subject of research in fiscal year 2000. Researchers used air photographs and surface geophysical methods to determine the size, shape, and orientation of the dikes.

Surface ground-penetrating radar surveys were conducted at three areas: square grid surveys at the Army Loop Road site and at the 216-S-16 pond, and a 6.9 kilometer traverse in the 600 Area (see Figure 3.1-8). The surveys were to aid mapping the dikes and to detect smaller dikes not visible on air photos or the ground surface. In general, the data quality at the 216-S-16 pond was not good because numerous diffractions in the data interfered with deeper reflections. Those diffractions are probably from cobbles and boulders exposed at the surface and buried in the ground. The data quality of the Army Loop Road survey and the 6.9 kilometer traverse were significantly better. Figures 3.1-13 and 3.1-14 show examples from the ground-penetrating radar survey at Army Loop Road. Figure 3.1-13 shows four northeast-southwest profiles. The white area at ~30 meters distance in the northeast-southwest direction on each traverse is a clastic dike. Figure 3.1-14 is a three-dimensional view of the same area. The white area along the plot's surface corresponds to the subsurface expression of a clastic dike. A second dike can be seen at ~10 meters on the east-west face of the plot. The second dike intersects the first dike near the center of the diagram.

The ground-penetrating radar survey and the air photo and field mapping were used to select a site to trench across a clastic dike. In August 2000, a clastic dike at the 216-S-16 pond was trenched with a backhoe to a depth of ~3.5 meters (Figure 3.1-15). The exposed clastic dike is in the sand-dominated facies of the Hanford formation. The dike is ~0.7 meter thick at the bottom of the trench but becomes extremely narrow (~8 to 10 centimeters) within ~1 meter of the surface. The narrow portion of the dike appears to be reactivation of the dike along an older dike surface.

In the exposures made by the lower two lifts, the host material is very different on each side of the dike (see Figure 3.1-15). The material to the west of the dike (to the left in Figure 3.1-15) is medium to coarse-grained plane laminated sand containing some silt and sand rip-up clasts. The material to the east of the dike consists of finer grained, silty fine to medium sand. In addition, a clastic sill (a structure similar to a clastic dike but concordant with horizontal bedding) is exposed east of the dike, near the base of the trench. The sill is seen in Figure 3.1-15 as the ~8-centimeters-thick, fine-grained unit to the right of the dike in the lower part of the trench. The heterogeneities within both the host sediment and within the dike complicate comparison of physical property data from samples of dike and host.

The trench was dug in four lifts. After each lift, except the first, the dike and host sediment were characterized by air permeability measurements and infrared imagining. In addition, samples were taken for moisture analyses, grain size distribution, and mineralogy (x-ray diffraction).

Figure 3.1-16 shows two composite photographs of the lowest level in the trench. The lower photo is a normal photograph and the upper photo is infrared. The contrast in the infrared photo is due to variation in the moisture content of the sediment; darker colors indicate more moisture. The dark vertical band on the left side of the infrared photo is the clastic dike and the dark horizontal band is the clastic sill. An attempt will be made to calibrate the infrared data to the air permeability moisture data.

Several hundred air permeability measurements were obtained from the exposures in the trench. Figure 3.1-17 shows the distribution of the results. The dike and sill exposed in the trench tend to be finer-grained than the host material and, therefore, have a higher moisture content and lower permeability than the host material. Figure 3.1-18 shows a box plot comparing the moisture content in the dike and host materials. Moisture content was determined gravimetrically from samples collected at the trench.

Results of dye tracer tests in a partially excavated clastic dike suggested that fine-grained dikes may retard vertical and lateral flow rather than act as conduits to flow.

Samples were collected from the dike and host sediment to compare the mineralogy and grain size distribution between the dike and host sediment. Qualitative x-ray diffraction analysis of 21 samples showed that the mineral composition of both the dike and the host sediment is dominated by quartz and plagioclase feldspar. Lesser amounts of pyroxene, mica, chlorite and amphibole are also present in most samples. Calcite was identified in only three samples. No apparent differences were found in the mineral composition between the dike and host sediment.

Nineteen samples were submitted for analysis of particle size distribution. In general, the samples from the dike tend to be much finer grained than do samples of host sediment.

In addition to the above tests, drip-irrigation and dye-tracer studies were done at the excavation. Vertical time-domain reflectometry probes, 0.25 meter long, were driven into the exposed horizontal face at 0.15 meter back from the exposed vertical face (Figure 3.1-19). These probes were spaced every 0.3 meter along the traverse. Horizontal probes, 0.5 meter long, were driven into the exposed vertical face in a grid with spacings of 0.3 meter horizontally and 0.15 meter vertically. A drip irrigation system with lines spaced ~5 centimeters apart was used to uniformly deliver known amounts of water.

There were five injections of water applied totaling 738 liters. Brilliant Blue dye was mixed with the water for the last injection. Figure 3.1-20 shows the distribution of soil moisture three days after the first injection. The figure shows that the wetting front appears deeper in the dike than in the relatively coarser grained host sediment. This is, in part, due to capillary wicking of the finer sediment in the dike. The water was applied so that the soil remained unsaturated; therefore, capillary wicking was quite important. After nearly a week, the entire exposed face on the west of the dike was visibly wet to a depth of greater than 1 meter, while on the east side the sediment appeared to be uniformly wet to a depth of ~75 centimeters, or ~20 centimeters below the bottom the horizontal clastic sill.

Several parameters were measured during the experiment. Volumetric water content was monitored along the surface and the cut face. Soil-water pressure head was monitored with tensiometers along the bench surface and field-saturated conductivity was measured every 0.15 meter along the bench surface using a tension infiltrometer. In addition, soil samples were collected on a 15-by-15 centimeter grid on the cut face to analyze for particle-size distribution.

Figure 3.1-21 shows the distribution of dye 1 day after injection and 8 days after prewetting was initiated. The dye injection preferentially infiltrates the coarser-grained parts of the dike and the coarse-grained host sediment. The dye trace results suggest that clastic dikes containing fine sediment may actually retard vertical flow rather than act as conduits to fluids applied at the upper surface of the dike. Also, it suggest that such features may act as cutoff walls, limiting the spread of fluids, which otherwise could move significant distances laterally in response to large scale anisotropic features such as graded horizontal layering, typical of most Hanford sediment.

Figure 3.1-22 shows an example of the water content for three different sediment materials. The data show that the fine-grained material of the dike had the highest water content whereas the coarse-grained host sediment west of the dike (to the left on Figures 3.1-15 and 3.1-20) had the lowest water content. The finer-grained host material, to the east of the dike, had intermediate water content. Figure 3.1-23 shows water content and saturated hydraulic conductivity along a surface traverse on October 1, 2000. The clastic dike is easily seen on the water content and hydraulic conductivity profiles to lie between 1 to 3 meters distance from the left (west face), where a maximum in water content and a minimum in field-saturated hydraulic conductivity is detected. The maximum in water content at ~5 meters distance is not due to the dike; however, it may be due to structures not exposed but near the surface of the cut face.

The trench and dike studies done in fiscal year 2000 are preliminary tests to prepare for larger scale studies to be done in fiscal year 2001. The main test to be done in the future is a large-scale infiltration test. The infiltration test and geostatistical techniques will be used to integrate all data and construct quantitative hydrofacies models of the dike and enclosing sediment.

3.1.3 Characterization of the 183-DR Site to Support In Situ Gaseous Reduction Demonstration

E. C. Thornton, T. J Gilmore, K. B. Olsen, R. Schalla, and K. J. Cantrell

In fiscal year 2000, both field and laboratory investigations were conducted to support an in situ gaseous reduction technology demonstration in the 100 DR Area. In situ gaseous reduction technology is being developed for remediation of hexavalent chromium at soil waste sites. The technology involves injecting a mixture of hydrogen sulfide gas and nitrogen or air into chromate contaminated soil through a borehole. The mixture is drawn through the soil by a vacuum applied to extraction wells located around the injection well. Hexavalent chromium is reduced to the trivalent oxidation state as the gas mixture contacts the contaminated soil. The result is immobilization and detoxification of the chromium.

A large plume of groundwater contaminated with chromate exists at the former 183-DR water treatment facility (see Figure 2.5-1 for location). The shape of the plume suggests that the source is the 183-DR site. If a vadose zone source of hexavalent chromium can be identified and treated, the groundwater plume will eventually dissipate. However, no vadose zone source of hexavalent chromium was found during this characterization.

Researchers drilled boreholes in the 100 D Area to locate a vadose zone source of hexavalent chromium, which is present in the underlying groundwater. No highly-contaminated sediment was found. Laboratory tests showed that chemical reduction of chromium by hydrogen gas during drilling does not explain the lack of chromium in the vadose zone.

3.1.3.1 Vadose Zone Sampling and Analysis

Two trenches were excavated and two boreholes drilled to evaluate the distribution of hexavalent chromium in the vadose zone at the former 183-DR water treatment facility (Figure 3.1-24). Borehole C3040 was drilled to a depth of 30.7 meters and borehole C3041 was drilled to 26.3 meters. Borehole C3040 was completed as groundwater monitoring well 199-D2-8.

The stratigraphy encountered during drilling was capped by 5 to 7 meters of backfill consisting of miscellaneous construction material. Hanford formation sandy gravel and silty sandy gravel occurs between depths of ~5 to 15.3 meters. Some sand layers were encountered within the coarser grained sediment. The Ringold Formation was encountered at ~15.3 meters and continued to total depth in both boreholes.

Fifty samples from the trenches were analyzed for hexavalent chromium with generally no significant concentrations detected. One sample from an area of discolored soil contained a trace of hexavalent chromium. Ten of the soil samples were analyzed for total metals by x-ray fluorescence. Most were uncontaminated with a total chromium concentration near background at 20 to 30 ppm. The discolored sample from a depth of 1 meter contained ~650 ppm total chromium and was depleted in iron, manganese, and calcium and slightly enriched in lead. A second sample from a depth of 4.5 meters had similar chemical characteristics and total chromium content of 43 ppm, slightly above background. The high level of total chromium in the discolored samples suggests that chromium-bearing solutions may have entered the soil. Hexavalent chromium was apparently reduced to trivalent chromium upon entering the soil and precipitated as trivalent chromium phases. The reaction could have been promoted by acidic solutions, which would tend to accelerate reduction by ferrous-iron or organic matter and may also account for the slight orange discoloration of the soil.

Essentially no significant chromium contamination was found in samples from the two boreholes. One sample from borehole C3040, collected between a depth of 20.7 and 20.8 meters, contained total chromium at 132.8 ppm and hexavalent chromium at 130 ppb.

3.1.3.2 Laboratory Treatment Testing

Drilling at several Hanford Site locations has generated hydrogen gas (Bjornstad et al. 1994). This appears to occur due to reduction of water attributed to either broken basalt cobbles exposing ferrous-iron or to metal shavings from the drill bit or drive casing. Hexavalent chromium in the vadose zone may be reduced because of hydrogen generation or by direct reduction by basalt or metal shavings. The split spoon sediment samples collected at the 183-DR site were collected ahead of the drive casing so that reduction of hexavalent chromium by broken rock or metal shavings would not be expected. However, this does not preclude diffusion of hydrogen ahead of the drive casing.

To test this hypothesis, two columns were packed with hexavalent chromium contaminated soil from the 183-KW site. A 4% hydrogen gas in nitrogen gas was passed through one of the columns at a flow rate of 100 cc/min for more than

29 hours. The treated and untreated columns were then leached with deionized water and the leachate analyzed for hexavalent chromium. No significant difference in hexavalent chromium concentration was detected indicating that hydrogen gas did not reduce any of the chromate present in the treated column. Therefore, reduction of hexavalent chromium by hydrogen gas in the vadose zone during drilling is probably not an important process and the cored sediment from the 183-DR site was not significantly altered by the drilling process.

Gas treatment tests also were completed on the <0.9 centimeter fraction of soil collected during trench excavations at the 183-DR site. The purpose of these tests was to determine the amount of treatment gas consumption by the soil matrix and to obtain information about the specific reactions between hydrogen sulfide/nitrogen and hydrogen sulfide/air gas mixtures and soil components. Mixtures of 200 ppm hydrogen sulfide in nitrogen and in air were used in two column treatment tests. Both tests were run until 80% breakthrough was achieved. The consumption ratio of hydrogen sulfide to soil by mass was determined to be 0.001 for the hydrogen sulfide/nitrogen gas mixture and 0.0003 for the hydrogen sulfide/air mixture. However, the >0.9 centimeter fraction of the soil was removed before packing the columns. This gravel-size material would likely consume less hydrogen sulfide on a mass basis because of the lower specific surface area. A breakthrough of less than 80% should also be adequate for reduction of hexavalent chromium at the site because the rate of this reaction appears to be fast (i.e., most of the treatment gas is consumed by slower reactions of hydrogen sulfide with soil iron oxides). Thus, a consumption ratio of about 0.0001 should be adequate for the application of in situ gaseous reduction at the 183-DR site.

The time required to achieve treatment during an in situ gaseous reduction demonstration at the 183-DR site can be estimated on the basis of the mass associated with the treatment zone, the mass of hydrogen sulfide required per unit mass of soil, and the concentration and flow rate of treatment gas through the site. Assuming the zone for treatment is 4.5 meters thick and 18.3 meters in diameter, the volume of soil involved is 1,200 cubic meters. Based on a bulk density of about 1.6 g/cc measured in laboratory column tests, ~1.9 million kilograms of soil is in the treatment zone. If a gas consumption ratio of 0.0001 is adequate to treat hexavalent chromium, then ~192 kilograms of hydrogen sulfide will be needed. If the treatment gas is injected into the site as a 200 ppm hydrogen sulfide mixture at a flow rate of 94 liters per second, the time required to achieve a moderate level of breakthrough is roughly 78 days. However, because the treatment time required is inversely proportional to gas concentration and flow rate, the time needed for treatment could be reduced by increasing the hydrogen sulfide concentration in the injection gas or by injecting at a higher flow rate.

Because field characterization at the 183-DR site did not locate a vadose zone source of hexavalent chromium, it is not possible to proceed with an in situ gaseous reduction demonstration at this time. Such a demonstration awaits the discovery of a vadose zone source of hexavalent chromium contamination in the Hanford Site 100 Areas.

3.1.4 Characterization at 200-CW-1 Operable Unit

C. S. Cearlock, K. M. Singleton, M. E. Todd, and D. B. Barnett

Bechtel Hanford, Inc. and CH2M HILL Hanford, Inc. characterized the contaminant distribution at four inactive waste sites in fiscal year 2000 as part of the remedial investigation for the 200-CW-1 Operable Unit (BHI-01367). The waste sites were 216-B-2-2 ditch, 216-B-3-3 ditch, 216-B-3 pond (Main B Pond), and 216-A-25 pond (Gable Mountain Pond). Characterization was accomplished by geologic and geophysical logging, analysis of soil physical properties, and sampling and analysis for chemical and radiochemical constituents. The data collected will be used to evaluate remedial actions for 24 other analogous sites. This section summarizes the results of the study. A complete description of characterization activities can be found in BHI-01367.

Samples were collected for laboratory analyses from 29 test pits and two boreholes. Test pits were excavated by backhoe after removing the uppermost 0.3 to 0.6 meters of topsoil. Twenty-one test pits were excavated to 7.6 meters and the remaining eight test pits to less than 7.6 meters because basalt bedrock or manmade structures were encountered or because of unsafe conditions. Two hundred and ten samples were collected from the test pits including 38 quality control samples. Generally, continuous samples were collected from the bottom to 3 meters below the bottom of the waste sites and at 1.5 meter intervals from 3 meters below bottom to total depth (7.6 meters).

Boreholes were drilled by cable tool and sampled by split spoon methods. The depths of the borings ranged from 11.3 to 53.9 meters below ground surface. Shallow sample intervals were similar to those in the test pits. Deeper samples were generally reduced to 7.6 to 15.2 meters intervals below a depth of 7.6 meters in boreholes. Twenty-five samples were collected from the boreholes including eight quality control samples.

Data collected from four inactive waste sites in the 200 Areas will be used to evaluate remedial actions for 24 similar sites.

Borehole geophysical logging was performed on two new boreholes (B8757 and 699-43-44) and three existing groundwater monitoring wells (699-53-47A, 699-54-49, and 699-55-50) adjacent to Gable Mountain Pond. Spectral gamma and neutron-neutron moisture surveys were run in new boreholes drilled through B Pond and Gable Mountain Pond. Only spectral gamma surveys were performed in existing wells. Small-diameter geophysical logging was also conducted at B Pond and the 216-B-2-2 Ditch using the Geoprobe™.[a] Details of this investigation are presented in BHI-01352 and summarized in Section 3.3.2 of this report.

Prior to drilling or excavating, ground penetrating radar surveys were conducted at all four waste sites to search for buried manmade objects and to delineate the site boundaries. The bottoms of both Gable Mountain Pond and B Pond were mapped and several cross sections were made. The ground penetrating radar surveys were not effective in delineating the boundaries of the ditches because there was not sufficient contrast between the fill material in the ditches and the surrounding host material in the banks.

Several metals and anions were found to exceed background levels but most were well below *Model Toxics Control Act* cleanup levels for direct contract. With several exceptions, there were variations in spatial distributions of contaminants with respect to position in the ponds and ditches. As might be expected, higher concentrations tended to be found in the interior of ponds and at the head end of ditches. Also, the highest concentrations of contaminants were in the pond and ditch bottom sediment and concentrations tended to decrease rapidly with depth. Details are provided in BHI-01367 and summarized in the following sections.

3.1.4.1 Gable Mountain Pond

Gable Mountain Pond is a 28.7 hectare natural depression south of Gable Mountain. Gable Mountain Pond routinely received cooling water and other low-level radioactive effluent from several facilities between 1957 and 1987 (DOE/RL-99-07). The pond received 307 billion liters of liquid waste.

(a) Geoprobe is a registered trademark of Geoprobe Systems, Salinas, Kansas.

Figure 3.1-25 shows the location of the 16 test pits and one borehole (B8757) used for characterization at Gable Mountain Pond. The lithology beneath the pond consists of the Elephant Mountain Member of the Columbia River Basalt Group between 0.9 to 9.3 meters below ground surface. The basalt is overlain by sediment typical of the Hanford formation up to ~4 meters depth. Overlying the Hanford formation are 1.5 meters or less of pond sediment. The sediment consists of wind blown silty sand, silty clay, sandy silt, and fine to very fine sand. This zone also contains plant material, red and yellow staining, and elevated beta-gamma activity (BHI-01367).

Overlying the pond sediment, and extending to the surface, are backfill materials consisting of sandy gravel to silty sandy gravel with an upper 0.3 to 0.9 meter zone of silty sand to sandy silt. Much of this upper fine-grained zone may be wind deposited.

Barium, beryllium, nickel, and vanadium were detected in most samples from Gable Mountain Pond near or below the Hanford Site background concentrations (see DOE/RL-92-24 for background values of non-radionuclide constituents). Total chromium, copper, lead, and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* (WAC-173-340) Method B cleanup levels for direct contact (BHI-01367). Four samples contained cadmium at concentrations up to 1.7 mg/kg exceeding the state background level of 1.0 mg/kg. Twelve samples contained arsenic at greater than the Hanford Site background value of 6.5 mg/kg with a maximum concentration of 33.8 mg/kg.

Strontium-90 and cesium-137 were detected in sediment samples from the former Gable Mountain Pond. Cesium-137 concentrations were highest near the pond bottom, while strontium-90 concentrations were higher at greater depths.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 25% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367). The maximum anion concentrations were found typically in the pond bottom samples and concentrations decreased with depth.

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

Strontium-90 and cesium-137 were the predominant manmade radionuclides detected in samples from Gable Mountain Pond with maximum concentrations of 58.8 and 7,180 pCi/g, respectively. Figure 3.1-26 shows the distribution of these radioisotopes. High concentrations of cesium-137 generally were associated with sediment from the pond bottom and were one to two orders of magnitude higher than concentrations 0.3 to 0.6 meter deeper. Strontium-90 concentrations tended to increase with depth, and the greatest concentrations were found in the deepest sample from some test pits. Also, strontium-90 concentrations tended to be higher in the interior of the pond than near the edges.

In addition to cesium-137 and strontium-90, europium-154 was identified in three test pits at a maximum concentration of 3.37 pCi/g and americium-241 was identified in two test pits at a maximum concentration of 1.28 pCi/g. Technetium-99 was identified in one sample at an estimated concentration of 0.458 pCi/g (BHI-01367).

The only manmade radionuclide identified by spectral gamma-ray logging of borehole B8757 at Gable Mountain Pond was cesium-137. The main zone of contamination was relatively thin, between a depth of 3.5 and 3.8 meters below ground surface with a maximum concentration of 573 pCi/g. This correlates well with data from a nearby test pit (pit GP-2 on Figure 3.1-25), where the maximum cesium-137 concentration of 7,180 pCi/g was also found at a depth of 3.7 meters.

Moisture content in borehole B8757, determined by neutron logging, was between 2% and 15%. Values greater than about 9% are from zones where water or bentonite was introduced during drilling. The higher, natural moisture content near 9% correlates to an increase in the silt content from about 5% to 25% and to the thin zone of cesium-137 concentration at a depth of 3.7 meters (BHI-01367).

3.1.4.2 B Pond (216-B-3 Pond)

B Pond is located adjacent to the northeast corner of the 200 East Area. Throughout its operational lifetime, B Pond has varied in size from about 5.7 to 18.6 hectares (DOE/RL-99-07). B Pond received an estimated 240 billion liters of effluent between 1945 and 1991. The effluent consisted mostly of cooling water and steam condensate.

Figure 3.1-27 shows the location of the five test pits and one borehole (699-43-44, B8758) at B Pond. The lowermost lithology in borehole 699-43-44 is the Elephant Mountain Member of the Columbia River Basalt Group. The top of basalt is at 63.6 meters below ground surface. Overlying the basalt is the lower mud unit of the Ringold Formation consisting of very well sorted, compacted silt and clay. Overlying the Ringold Formation at 53.7 meters is a lower gravel sequence of the Hanford formation. The gravel sequence is 25.9 meters thick and consists of sandy gravel to gravelly sand. A 26.8 meters thick, Hanford formation sand-dominated sequence extends to 5.8 meters below ground surface. The sand sequence is described as salt and pepper sand on the geologist's log. An upper gravel-dominated sequence of the Hanford formation overlies the sand sequence. The upper gravel sequence is similar in composition to the lower gravel sequence.

Overlying the Hanford formation are 0.6 to 1.5 meters of pond sediment. The sediment consists of wind blown silt and silty sand with up to 75% silt. The pond sediment also contains plant material and exhibits red and yellow staining and elevated beta-gamma activity (BHI-01367).

Overlying the pond sediment, and extending to the surface, are 1.7 to 3.7 meters of backfill material. Backfill is thickest near the center of the pond and thins toward the edges. The backfill consists of sandy gravel to silty sandy gravel in the lower part and silty sand to sandy silt in the upper part.

Cesium-137, plutonium-239/240, and strontium-90 were detected in sediment samples from B Pond. Most of the cesium and plutonium were found near the pond bottom and strontium-90 was found deeper.

Arsenic, barium, beryllium, chromium, nickel, and vanadium were detected in most samples from B Pond near or below the Hanford Site background concentrations. Copper and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367). Seven samples contained cadmium at concentrations up to 7.3 mg/kg and exceeding the state background level of 1.0 mg/kg. Lead concentrations ranged from 2 to 573 mg/kg of which only the highest concentration exceeded the *Model Toxics Control Act* cleanup level of 253 mg/kg. Four samples contained silver between 0.29 and 9.6 mg/kg with only the highest concentration exceeding the 8 mg/kg *Model Toxics Control Act* cleanup level. Eleven samples contained mercury between 0.05 and 11.9 mg/kg. The maximum concentrations of cadmium, lead, silver, and mercury were in samples of the pond bottom sediments.

The anions chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 10% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367). The maximum anion concentrations were found typically in the pond bottom samples and concentrations decreased with depth.

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup levels for direct contact.

Cesium-137, plutonium-239/240, and strontium-90 were the predominant man-made radionuclides detected in samples from B Pond. The maximum concentration of strontium-90 was 99.9 pCi/g, the maximum cesium-137 was 1,000 pCi/g, and the maximum plutonium-239/240 was 27.5 pCi/g. Americium-241 was found in three test pits with concentrations between 0.083 and 4.96 pCi/g. Figure 3.1-28 shows the distribution of these radioisotopes. The maximum concentrations of cesium-137, plutonium-239/240, and americium-241 generally were associated with the sediment from the bottom of B Pond and were one to two orders of magnitude higher than concentrations 1.5 to 1.8 meters deeper. Strontium-90 concentrations tend to increase with depth in the test pits, and the maximum strontium-90 concentration was at the bottom of test pit BP-1. In borehole 699-43-44, strontium-90 was not detected below 15.2 meters. As at Gable Mountain Pond, concentrations of radioisotopes in B Pond samples tended to be higher in the interior of the pond than near the edges (BHI-01367).

The only manmade radionuclide identified by spectral gamma-ray logging of borehole 699-43-44 at B Pond was cesium-137 between 1.2 and 2.4 meters below ground surface. Concentrations ranged between 0.9 and 21 pCi/g.

Moisture content in borehole 699-43-44, determined by neutron logging, was between 2% and 3%. Three zones of elevated moisture content were noted and these correlated with silt rich zones indicated on the geologist's log (BHI-01367).

Distribution of radionuclides beneath the former 216-B-2-2 ditch indicates that most contamination remains at the end where waste flowed into the ditch.

3.1.4.3 216-B-2-2 Ditch

The 216-B-2-2 ditch carried effluent to B Pond between 1963 and 1970. The ditch has since been backfilled. Three test pits were excavated up to 7.5 meters deep at the 216-B-2-2 ditch for characterization. Figure 3.1-29 shows the location of the pits. Excavation of the test pits showed that fill material, consisting of silty sandy gravel with minor sand layers, extends from the surface to a depth of 1.8 to 2.7 meters. The bottom of the ditch is represented by less than 1.8 meters of silty sandy gravel and silty sand with localized reddish stains. Hanford formation sediment consisting of silty sandy gravel to sandy gravel extends from the ditch bottom to the base of the test pits (BHI-01367).

Arsenic, barium, beryllium, cadmium, chromium, copper, and vanadium were detected in most samples from the test pits near or below the Hanford Site background concentrations. Lead and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* Method B cleanup levels for direct contact. Mercury and silver were detected in bottom sediment from the ditch in test pit TP-1 (see Figure 3.1-29 for location) at 0.93 and 8.4 mg/kg, respectively. Nickel was found at the slightly elevated concentration of 44.8 mg/kg at 0.6 meter below the ditch bottom in test pit TP-1.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 10% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367).

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

The polychlorinated biphenol (PCB) Aroclor-1260 was identified between 2.4 and 4.6 meters below ground surface and between 1.3 and 33 mg/kg in test pit TP-1. Also, 6.5 mg/kg of diesel organics were found in a sample from the ditch bottom in pit TP-1, and waste oil constituents were found at three locations between concentrations of 78 and 1,100 mg/kg.

Cesium-137 and strontium-90 were the predominant manmade radionuclides detected in samples from 216-B-2-2 ditch with maximum concentrations of 721 and 12,100 pCi/g, respectively. The highest concentrations of cesium-137 and strontium-90 were in a sample of the ditch bottom in test pit TP-1 and were one to two orders of magnitude greater than concentrations 0.3 to 0.6 meter deeper. Small amounts of americium-241 and europium-154 were found in test pit TP-1 and 0.064 pCi/g plutonium-238 was in one sample from pit TP-3 (BHI-01367). Test pit TP-1 is the nearest pit to the head end of the 216-B-2-2 ditch. The distribution of radionuclides among the three test pits suggests that most contamination remains at the head end of the ditch.

3.1.4.4 216-B-3-3 Ditch

The 216-B-3-3 ditch began carrying effluent to B Pond in 1970. Five test pits were excavated at the 216-B-3-3 ditch. Figure 3.1-27 shows the location of the pits. Excavation of the test pits showed that fill material, consisting mostly of silty sandy gravel, extends from the surface to a depth of ~1.8 meters. The bottom of the ditch is represented by the contact of fill material with up to 3 meters of gravel and sand containing as much as 20% silt. A layer of plant debris up to 0.15 meter thick was found in this zone. Sediment typical of the Hanford formation extends from a depth of ~3 meters to the base of the pits (BHI-01367).

Barium, beryllium, cadmium, chromium, nickel, vanadium, and zinc were detected near or below the Hanford Site background concentrations in most samples from the 216-B-3-3 ditch. Lead, copper, and silver were found above Hanford Site background levels but less than *Model Toxics Control Act* Method B cleanup levels for direct contact. The highest concentration of mercury was 0.51 mg/kg in test pit BP-9, and arsenic was 14.7 mg/kg in pit BP-6.

Cesium-137 and strontium-90 were the predominant radionuclides in samples from the former 216-B-3-3 ditch. The highest concentrations were near the ditch bottom.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 5% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367).

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

The PCBs Aroclor-1254 and Aroclor-1260 were identified in three of five test pits. Aroclor-1254, up to 38 μg/kg, was in samples from pit BP-9 and Aroclor-1260, between 35 and 440 μg/kg, was identified in pits BP-6 and BP-7A. At all three locations, the highest concentrations of PCBs were found in the ditch bottom sediment. Waste oil was found in pit BP-9 with the maximum concentration of 78 mg/kg in ditch bottom sediment.

Cesium-137 and strontium-90 were the predominant manmade radionuclides detected in samples from 216-B-3-3 ditch with maximum concentrations of 188 and 9.79 pCi/g, respectively, in test pit BP-7A. The highest concentrations of cesium-137 and strontium-90 were in samples of ditch bottom sediment (except in pit BP-9) and were one to two orders of magnitude greater than concentrations 0.3 to 0.6 meters deeper. Plutonium-239/240 was found in all test pits with concentration between 0.032 to 5.73 pCi/g. There were no significant concentrations of manmade radionuclides found deeper than 4.6 meters below the ground surface (BHI-01367).

3.1.5 Immobilized Low-Activity Waste

D. G. Horton

The Office of River Protection is responsible for safely disposing of the portion of single- and double-shell tank waste that is classified as low-activity waste. The current plan is to vitrify the waste and bury the low activity portion as solid waste in shallow, near-surface facilities. The Hanford Immobilized Low-Activity Tank Waste Performance Assessment is currently underway to assess the performance of the disposal facilities. The goal is to provide a reasonable expectation that the disposal of the waste protects the general public and environmental resources. Fifteen data packages were issued in fiscal year 2000 to support the 2001 Immobilized

Low-Activity Waste Performance Assessment (HNF-5636). Four of those data packages pertain directly to the vadose zone and are summarized in this section. Those four are

- Geologic Data Package for 2001 Immobilized Low-Activity Waste Performance Assessment (PNNL-12257)
- Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment (PNNL-13033)
- Geochemistry Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment (PNNL-13037)
- Far-Field Hydrology Data Package for Immobilized Low-Activity Tank Waste Performance Assessment (HNF-4769).

3.1.5.1 Geology

Geologic information was compiled for two proposed Immobilized Low-Activity Waste disposal sites. The first site is the area of the former grout treatment facility east of the 200 East Area. The second is an area in the south-central part of the 200 East Area. Data were compiled from both surface and subsurface sources including published geologic maps, driller's and geologist's logs, archived samples, and geophysical logs. Uncertainty in the data is mainly related to borehole information. Variations in sampling and drilling techniques cause some correlation uncertainties across the sites.

Earth science data was assembled in fiscal year 2000 to support the Immobilized Low-Activity Waste disposal Performance Assessment.

The information consists of tables of geologic contacts from all wells and boreholes associated with the two sites. From this information, cross sections, structure contour maps, and fence diagrams were made depicting the subsurface lithology, stratigraphy and structure. The seismicity of the areas was also discussed. Few earthquakes have occurred in the area and most were less than coda magnitude 3.0 (coda magnitude is a local magnitude that approximates the Richter magnitude).

The data supplied in the geology data package are used to construct conceptual models considered in the remaining three data packages.

3.1.5.2 Recharge

Estimates of recharge rates were made for both current conditions and long-term scenarios involving the shallow land disposal of immobilized low-activity waste to support the 2001 Performance Assessment. The Performance Assessment requires recharge estimates for the surface cover, the cover sideslope, the immediately surrounding soil, and a degraded cover. The following discussion is from PNNL-13033.

Table 3.1-3 gives the recharge estimates for the best estimate case and upper and lower bounding cases. The best estimate case is the situation for which all disposal facility features function as expected, a shrub-steppe plant community surrounds the site, the climate is the same as today, and no irrigated farming occurs at the site. The lower bounding case assumes the same conditions as the best estimate case but with the lowest possible recharge. The upper bounding case assumed the best estimate case conditions with the exception of either erosion of part of the surface cover or sand deposition on the surface cover and a sparse shrub-steppe cover on the surround soil. The recharge estimates for each case were derived from lysimeter and trace data and from modeling analyses.

The most important feature of the disposal facility is expected to be a modified RCRA Subtitle C cover. This uses a 1-meter-thick silt loam over sand and gravel layers to create a capillary break. A 0.15-meter-thick asphalt layer underlies the sand and gravel to promote lateral drainage. Sideslopes are expected to be sandy gravel at a 1:10 (vertical to horizontal) slope.

A recharge rate of 0.1 mm/yr is estimated for the surface cover (PNNL-13033). Although the cover design goal is 0.05 mm/yr, the rate of 0.1 mm/yr is used because it is closer to actual rates measured with lysimeters. Modeling results showed that erosion of the top 20% of the cover or deposition of 20 centimeters of sand on the cover did not impair performance.

A recharge rate of 50 mm/yr is estimated for the sideslope which is lower than the 75 mm/yr used in the 1998 Performance Assessment. For a soil type known as the Rupert sand with shrub-steppe plant community, an estimate of 0.9 mm/yr is given, which is lower than the 3 mm/yr rate used in the 1998 Performance Assessment. For a soil type known as the Burbank loamy sand with the same plant community, an estimated rate of 4.2 mm/yr is given. Finally, a recharge rate of 55.4 mm/yr is given for Hanford formation sediment during construction. Neither the Burbank loamy sand or the Hanford formation were considered in the 1998 Performance Assessment.

Modeling sensitivity tests showed that the cover limited recharge to less than 0.1 mm/yr regardless of plant type, the presence of plants, or any reasonable climate change. However, recharge rates into the Rupert sand and the Burbank loamy sand increased when the vegetation type or the climate were changed. A complete description of the work can be found in PNNL-13033.

3.1.5.3 Geochemistry

The geochemical properties of the materials comprising the Immobilized Low-Activity Waste Disposal Facility, the disturbed region around the facility, and the physically undisturbed sediments below the facility were estimated to support the Immobilized Low-Activity Waste 2001 Performance Assessment. The geochemical parameters that were estimated are the distribution coefficient (K_d), which is used to quantify adsorption, and the solution concentration limit, used to quantify solubility. A complete discussion of the estimates and their sources can be found in PNNL-13037 from which the following summary was taken.

Best estimates were made for K_ds and solution concentration limits for each of five expected environments in the disposal system. One of the five environments was a concrete vault. The current design for the disposal facility does not include the vault. The five environments and the geochemical characteristics used to evaluate K_ds are shown in Table 3.1-4.

Most probable “empirical” K_d values and/or solubility values, reasonable lower-bounding estimates, and a likely range of values are given in PNNL-13037 for each radionuclide considered in the 1998 Performance Assessment in each geochemical environment. Where possible, estimates were based on specific Hanford Site experiments. Literature or offsite data were used where no site-specific data were available. Attempts were made to chose literature values that were appropriate for the Hanford Site. In a few cases, no data were available and estimates were based on “expert judgement.”

K_ds for the radionuclides in the gravel-dominated environment were corrected for gravel content. The correction was based on the assumption that the gravel fraction had no sorption capacity and was made according to $K_{dgc} = (1\text{-}g)K_d$ where K_{dgc} is the gravel-corrected distribution coefficient, g is the weight fraction of gravel in the sample, and K_d is the measured or literature value from samples containing no gravel. The correction provides more conservative K_ds for the Immobilized Low-Activity Waste Performance Assessment than do uncorrected values.

The conservative K_ds are reasonable lower-bounding values that consider conditions that may enhance radionuclide transport. The lower value from the range of values was usually taken as the reasonable conservative K_d. The best estimates were selected as the central value of the available data and on expert judgement. Supporting references for the selection of all values are given in PNNL-13037.

3.1.5.4 Hydrology

The hydrologic data needed to perform far-field vadose zone flow and transport modeling for the Immobilized Low-Activity Waste Performance Assessment were compiled in fiscal year 2000. This section summarizes the content of the material in the data package. The actual data along with discussions of the data are presented in HNF-4769.

The hydrologic data package presented results of previously determined laboratory measurements of physical and hydraulic properties measured from core samples of the Hanford formation sand-dominated sequence obtained at the Immobilized Low-Activity Waste Disposal Facility in south-central 200 East Area and samples of the Hanford formation gravel-dominated sequence obtained from the 100 Areas and extrapolated to the disposal site. Laboratory measurements were compiled for moisture retention, particle-size distribution, saturated and unsaturated hydraulic conductivity, and bulk density.

The numerical models of flow and transport of fluids and contaminants in the unsaturated zone require hydraulic properties scaled to discrete grid blocks (scales on the order of meters). The laboratory measured hydraulic properties were obtained from core samples and are applicable to scales of a few centimeters. Therefore, hydraulic parameter estimates need to be upscaled from the laboratory scale to the field scale. The hydrologic data package presents the methodology and results of upscaling the flow parameters of moisture retention and saturated and unsaturated hydraulic conductivity and the transport parameters of bulk density, diffusivity, and macrodispersivity. Upscaled parameters are presented for both the sand-dominated and the gravel-dominated sediments of the Hanford formation.

The data package presents a method to estimate uncertainties in model predictions of far-field hydrologic behavior. Uncertainty estimates on model predictions include (1) variations in model configurations, (2) uncertainties in the calculated mean solution for concentration, and (3) variance around the calculated mean solution for concentration. Variations in model configuration include variations in stratigraphy, presence of discontinuities such as clastic dikes, the degree of homogeneity in the stratigraphy, and the orientation of the sedimentary layers (dip). Uncertainties in the calculated mean solution for concentration include the variations in the conceptual model mentioned above and sensitivity of the model predictions due to variations in upscaled input parameters.

Uncertainties in far-field hydrologic behavior predicted by the numerical models will be calculated as part of the Immobilized Low-Activity Waste Performance Assessment.

Well characterized Hanford Site sediment is available for future research.

3.1.6 Characterization of Standard Hanford and Ringold Formation Samples

H. T. Schaef

Pacific Northwest National Laboratory, Bechtel Hanford Inc., and CH2M HILL Hanford Group collected large quantities of Ringold Formation from outcrop and Hanford formation from outcrop and core in fiscal year 1999. The purpose of the samples was to serve as well characterized "standards" to be made available to researchers throughout the Hanford Site, the DOE complex, and academia that wish to study problems associated with the Hanford Site.

Characterization was conducted throughout fiscal year 2000 and included determination of

- water content
- particle size distribution

- particle density
- calcium carbonate and organic carbon content
- bulk chemical composition
- cation exchange capacity
- pore water composition
- 1:1 water extract pH and cation, anion, and trace element compositions
- nitric acid extract compositions
- mineralogy of the bulk sample and the silt and clay fractions.

The results of the analyses will help researchers select samples for future laboratory studies of Hanford Site environmental problems and will help those researchers in interpretation of analytical results. The results also yield well characterized samples of Hanford Site sediment for future experiments. A comprehensive description of all data and a detailed discussion of laboratory results will be published in fiscal year 2001. This section summarizes only the mineralogy results because those data became available in fiscal year 2000 and are among the first semi-quantitative mineral compositions determined from samples of Ringold and Hanford formations. The detailed mineralogy will help researchers explain sorption and desorption phenomena and contaminant transport through the vadose zone.

3.1.6.1 The Samples

Three surface outcrops were sampled on or adjacent to the Hanford Site: the 218-E-12B burial ground (submarine pit), the Environmental Restoration Disposal Facility, and the White Bluffs east of the Columbia River in Franklin County. Only samples from the 218-E-12B burial ground and the White Bluffs have been characterized. The White Bluffs' sample consisted of three 19-liter buckets of lacustrine, laminated silt from the Upper Ringold Formation. Samples from the 218-E-12B burial ground were (1) pebbly sand (hereafter termed Hanford coarse sand) representing the sand-dominated facies of the Hanford formation and (2) silty, fine sand (called the Hanford fine sand) representing the silt-dominated facies of the Hanford formation.

A fourth sample was obtained for characterization. That sample was a composite of sediment from core sleeves obtained between 19 and 30 meters depth during drilling of borehole 299-W22-50 located east of the SX tank farm. The borehole sample was a slightly silty medium to fine sand (called the borehole fine sand in this description) of the Hanford formation sand-dominated facies and represents the fine-grained strata underlying many of the single-shell tanks in 200 West Area.

All samples were air dried and homogenized prior to any testing. Samples were stored in 19-liter buckets and each time an aliquot of sample was needed, the entire bucket was spread on a tarp and re-homogenized.

Semi-quantitative mineralogy of the four "standard" samples was determined by x-ray diffraction. Standard sample preparation methods were used (Jackson 1974; Drever 1973). Semi-quantitative measurements of mineral phases were done according to Brindley (1980) using the relationship of x-ray intensity and mass attenuation to weight fraction of unknown phases. This involved measurement of the mass attenuation coefficients for both pure minerals and for the unknown samples. This approach has not been used previously for samples collected at the Hanford Site and should provide quantitative data on mineral abundances for the Hanford and Ringold Formations. Semi-quantitative analyses were done on the bulk sediment samples and on the separated ≤ 2 µm size fractions (clay fractions) of the samples.

3.1.6.2 Summary of Results

X-ray diffraction analysis of the bulk sediment shows that the samples are mostly quartz (30 to 80 wt. %) and plagioclase feldspar (5 to 20 wt. %), with minor amounts of potassium feldspar (<10 wt. %) and amphibole. Calcite was identified in the Ringold Formation sediment at <5 wt. %. Mica and/or clay minerals are evident in the bulk sample but were not quantified. Mica and chlorite are more abundant in the Ringold Formation silt than in the Hanford formation sediments. Table 3.1-5 shows the semi-quantitative mineralogy for the four analyzed samples.

The <2 µm size fraction of all four samples is dominated by four clay minerals: illite, smectite, chlorite, and kaolinite (Hanford formation samples only). Minor amounts of quartz, feldspars, and amphibole are also present.

The semi-quantitative mineralogy of the samples is given in Table 3.1-6. The data show that smectite is the dominant mineral in the <2 µm fraction (30 to 40 wt. %). Illite concentrations range from 15 to 40 wt. % and chlorite occurs between ~15 and 20 wt. %. Minor kaolinite was identified in all three samples from the Hanford formation but was not identified in the Ringold Formation sample. Quartz and feldspars make up about 5 to 10 wt. % of the <2 µm fraction of all four samples. The total weight percent for the <2 µm fractions ranged from about 75 to 80 wt. % to about 105 wt. % (Table 3.1-6).

In addition to the x-ray diffraction analyses, some transmission electron microscopy was done on the samples. The analyses show that the mineral 10 Å is illite and not strictly detrital muscovite. This distinction is important when considering the nature and types of cation exchange sites available for contaminant sorption. The cation exchange capacity of muscovite mica is about 10 meq/100g whereas that of illite is 10 to 40 meq/100g; thus, illite has the greater capacity to sorb some contaminants.

Table 3.1-1. Semi-Quantitative Mineral Abundances in Bulk Samples from Borehole 41-09-39 (wt. %)

Sample (depth in m)	Sample Description	Quartz	Potassium Feldspar	Plagioclase Feldspar	Calcite
17	Hanford formation sand-dominated sequence	50	5	50	ND
22.5	Hanford formation gravel-dominated sequence	50	5	25	ND
24	Hanford formation gravel-dominated sequence	35	5	55	ND
27.4	Hanford formation fine sand and silt sequence	50	15	25	<5
33	Hanford formation fine sand and silt sequence	45	5	40	<5

ND = Not detected.

Table 3.1-2. Semi-Quantitative Mineral Abundances in the <2 µm Size Fraction of Samples from Borehole 41-09-39 (wt. %)

Sample (depth in m)	Quartz	Feldspar	Smectite	Illite	Chlorite	Kaolinite
17	5	<5	20	35	30	10
22.5	10	10	5	30	20	10
24	10	<5	10	20	15	5
27.4	<5	<5	15	20	10	10
33	5	<5	20	20	10	10

Table 3.1-3. Recharge Estimates for the Best Estimate Case and Reasonable Bounding Cases during Each Period of Interest to the Immobilized Low-Activity Waste Performance Assessment (from PNNL-13033)

		Estimated Recharge Rates for the Best Estimated Case (and Reasonable Bounding Cases) (mm/yr)		
		Time Period of Recharge Evaluation		
Surface Feature	Pre-Hanford Site	During Disposal Operations	During Surface Cover Design Life	After Surface Cover Design Life
Modified RCRA Subtitle C Cover	NA	NA	0.1 (0.01, 4.0)	0.1 (0.01, 4.0)
Cover Sideslope	NA	NA	50 (4.2, 86.4)	50 (4.2, 86.4)
Rupert Sand	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)
Burbank Loamy Sand	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)
Hanford formation	NA	55.4 (50, 86.4)	NA	NA

NA = Not applicable.

Table 3.1-4. Five Conceptual Geochemical Environments Associated with the Immobilized Low-Activity Waste Disposal Facility (from PNNL-13037)

Zone	Solid Phases	Aqueous Phase	Appropriate Geochemical Parameters
Near field	Glass, secondary phases from glass degradation, backfill, engineered barrier materials	Glass leachate: high pH, high ionic strength, high high radionuclide concentrations	K_d Solubility constraints
Degraded concrete vault	Three assemblages based on concrete age: fresh concrete with pH = 12.5, moderately aged concrete with pH ~10.5, and completely aged concrete with pH ~8.5	Three leachate chemistries controlled by different aged concrete: pH values of 12.5, 10.5, and 8.5 to match solid phases; generally high ionic strength and high radionuclide concentration	K_d Solubility constraints
Chemically impacted far field in Hanford formation sand sequence	Sand-dominated sequence altered because of contact with moderately caustic aqueous phase	pH 8 to 11, ionic strength 0.01 to 0.1 low radionuclide concentration	K_d
Chemically impacted far field in Hanford formation gravel sequence	Gravel-dominated sequence altered because of contact with moderately caustic aqueous phase	pH 8 to 11, ionic strength 0.01 to 0.1 low radionuclide concentration	K_{dgc}
Far field in a Hanford formation gravel sequence	Unaltered Hanford formation gravel sequence	Unaltered Hanford Site groundwater with trace of radionuclides	K_{dgc}

Table 3.1-5. Semi-Quantitative Mineralogy of the Bulk Samples (wt. %)

Sample	Quartz	Plagioclase Feldspar	Potassium Feldspar	Calcite
Ringold Formation silt	30	5	5	<5
Hanford formation coarse sand	55	15	5	ND
Hanford formation fine sand	80	20	10	ND
Borehole fine sand	50	20	10	ND

ND = Not detected.

Table 3.1-6. Semi-Quantitative Mineralogy of the <2 μm Size Fractions (wt. %)

Sample	Quartz	Feldspar	Smectite	Illite	Chlorite	Kaolinite	Total
Ringold Formation silt	10	<5	35	35	20	nd	105
Hanford formation coarse sand	5	<5	30	15	15	5	75
Hanford formation fine sand	5	<5	30	15	15	10	80
Borehole fine sand	5	<5	30	40	20	5	105

Figure 3.1-1. Slant Borehole Drilling Rig Set Up in the SX Tank Farm

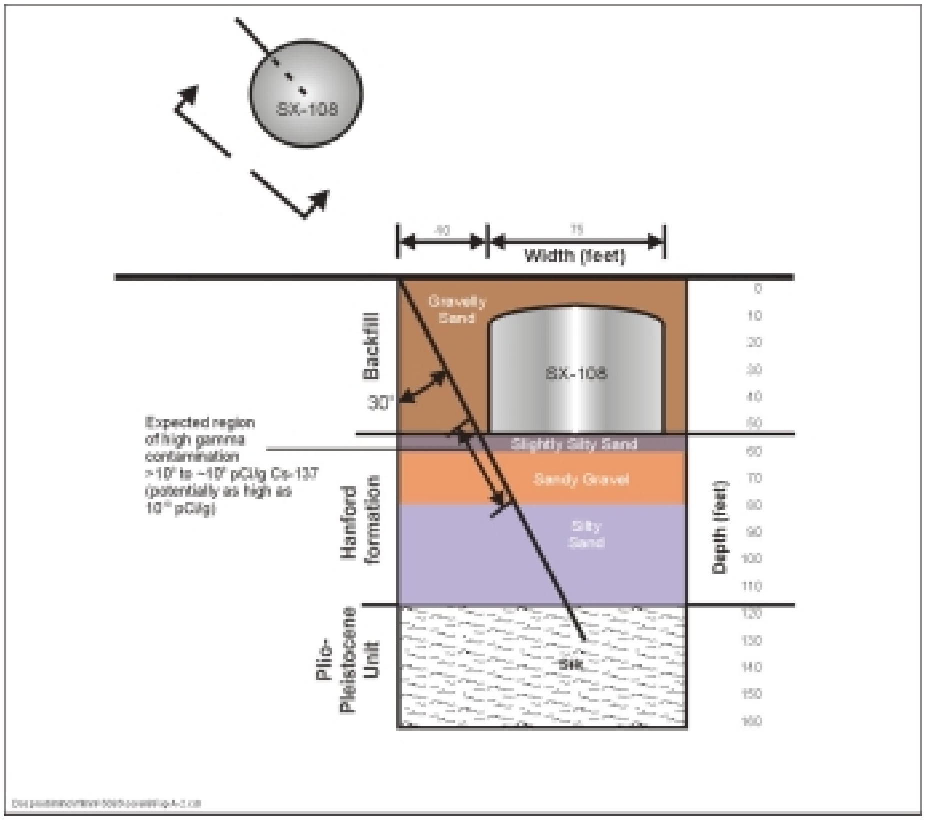


Figure 3.1-2. Layout of the Proposed Sampling Locations beneath Tank SX-108

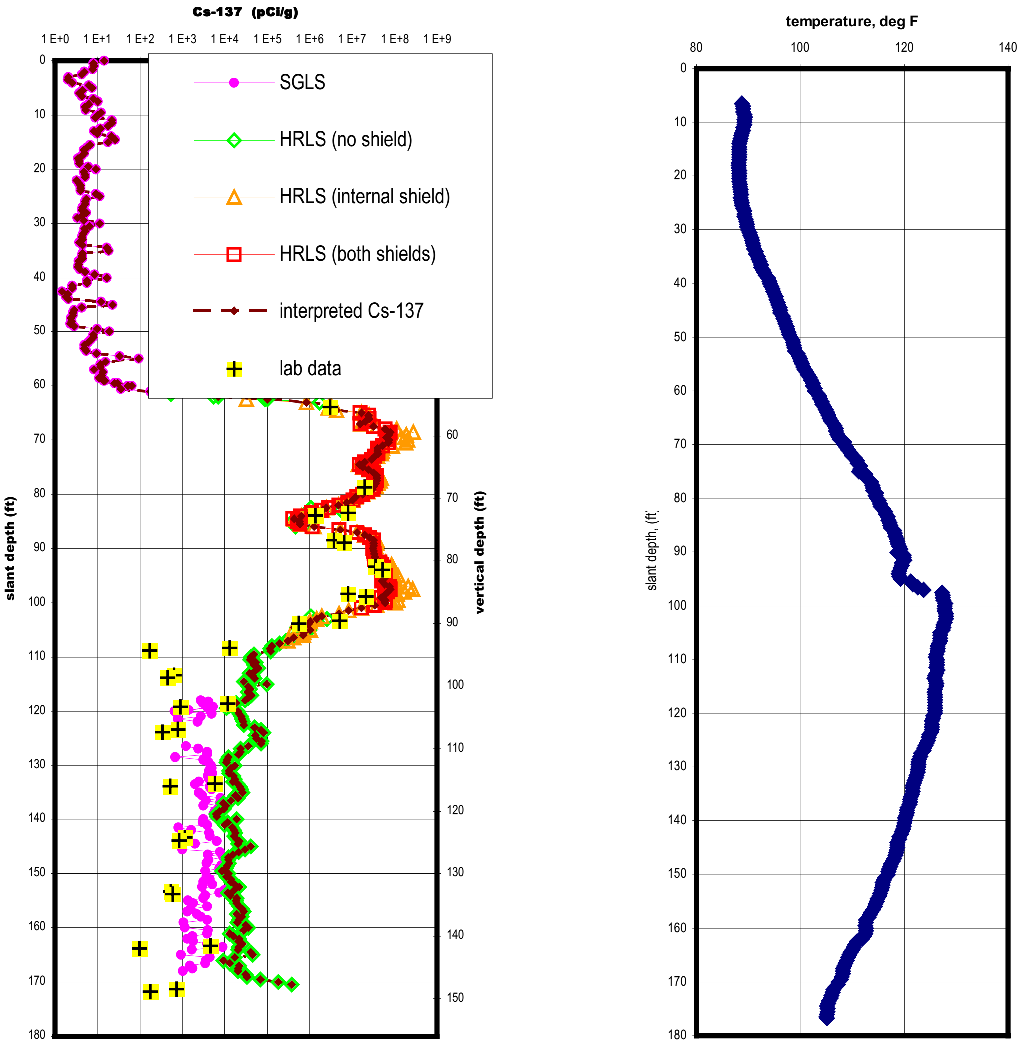


Figure 3.1-3. Borehole Logs Taken in Slant Borehole at Tank SX-108

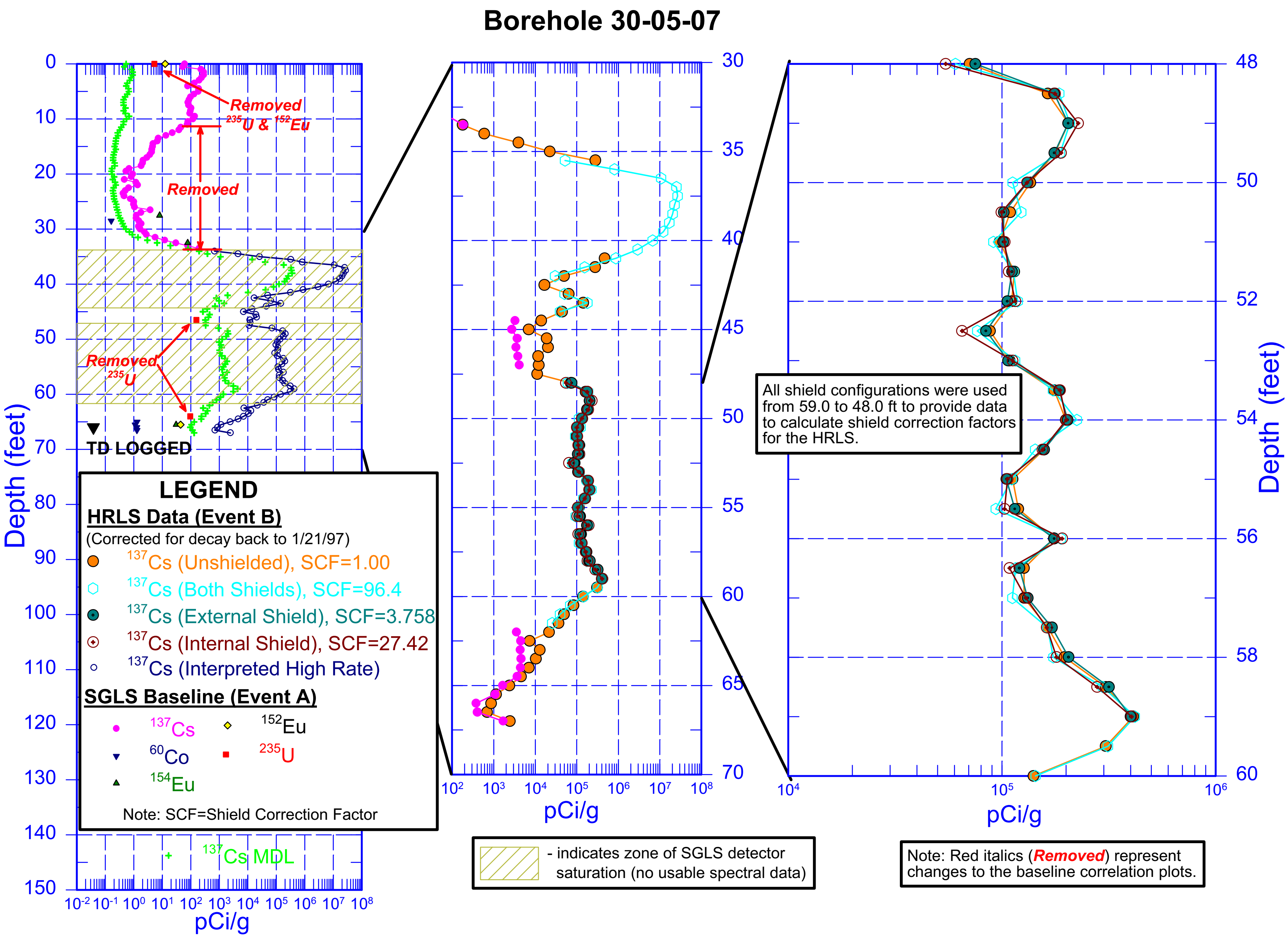


Figure 3.1-4. Example of High-Rate Logging System Data

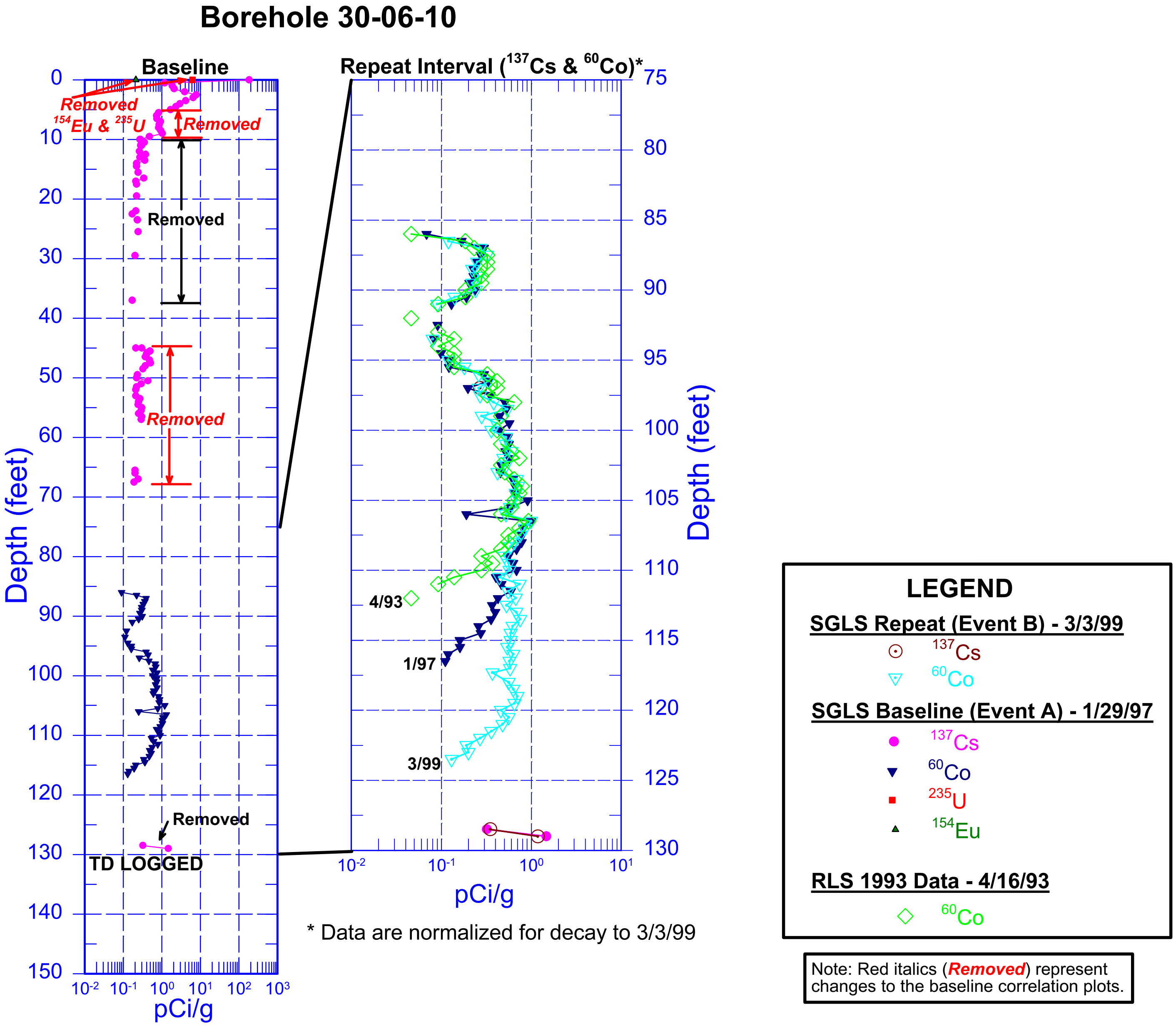


Figure 3.1-5. Example of Repeat Logging Data Compared to Baseline Data

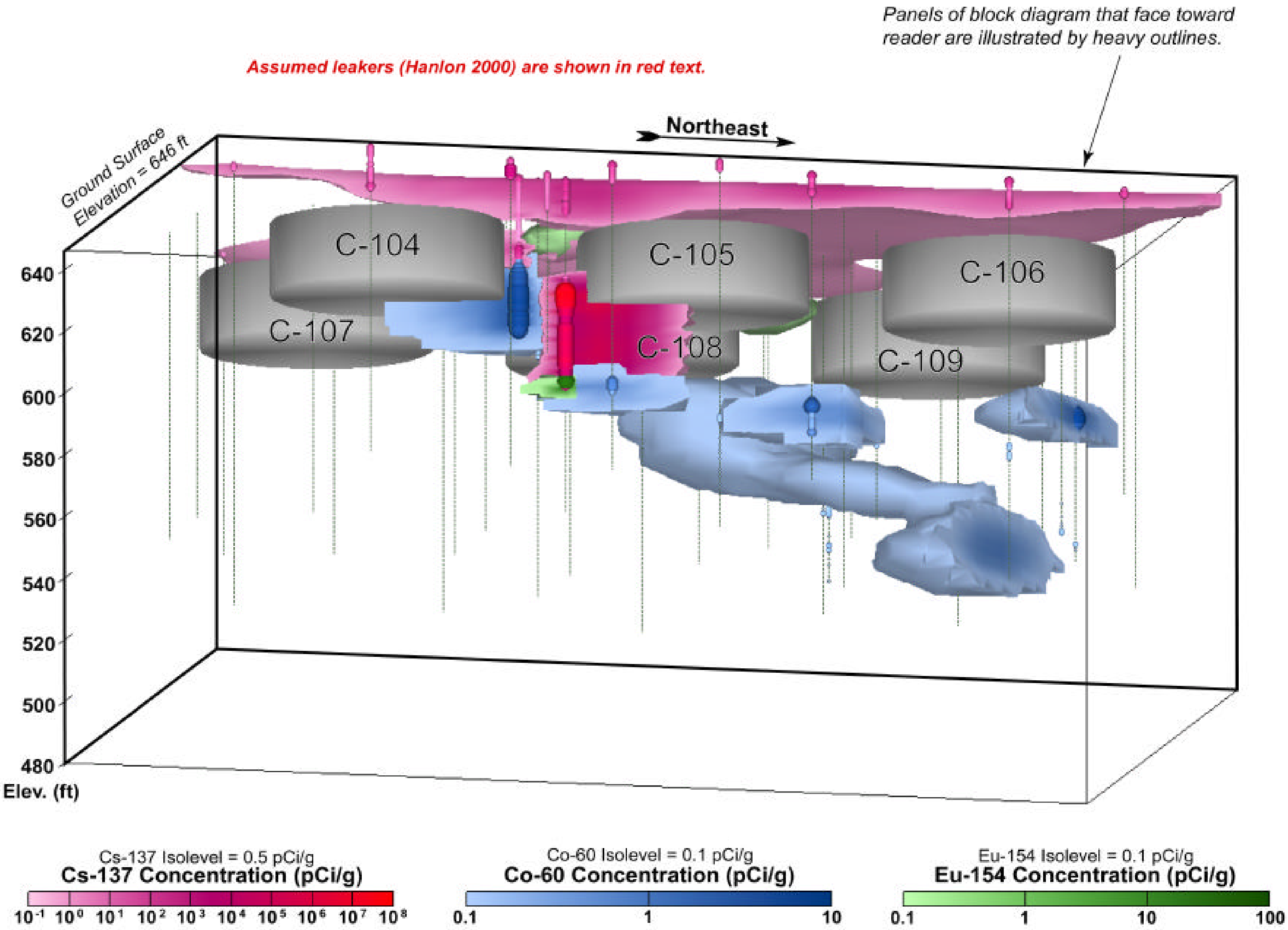


Figure 3.1-6. Example of a Revised Visualization

Figure 3.1-7. Photograph of Clastic Dikes in the Hanford Formation at the Environmental Restoration Disposal Facility (from BHI-00230)

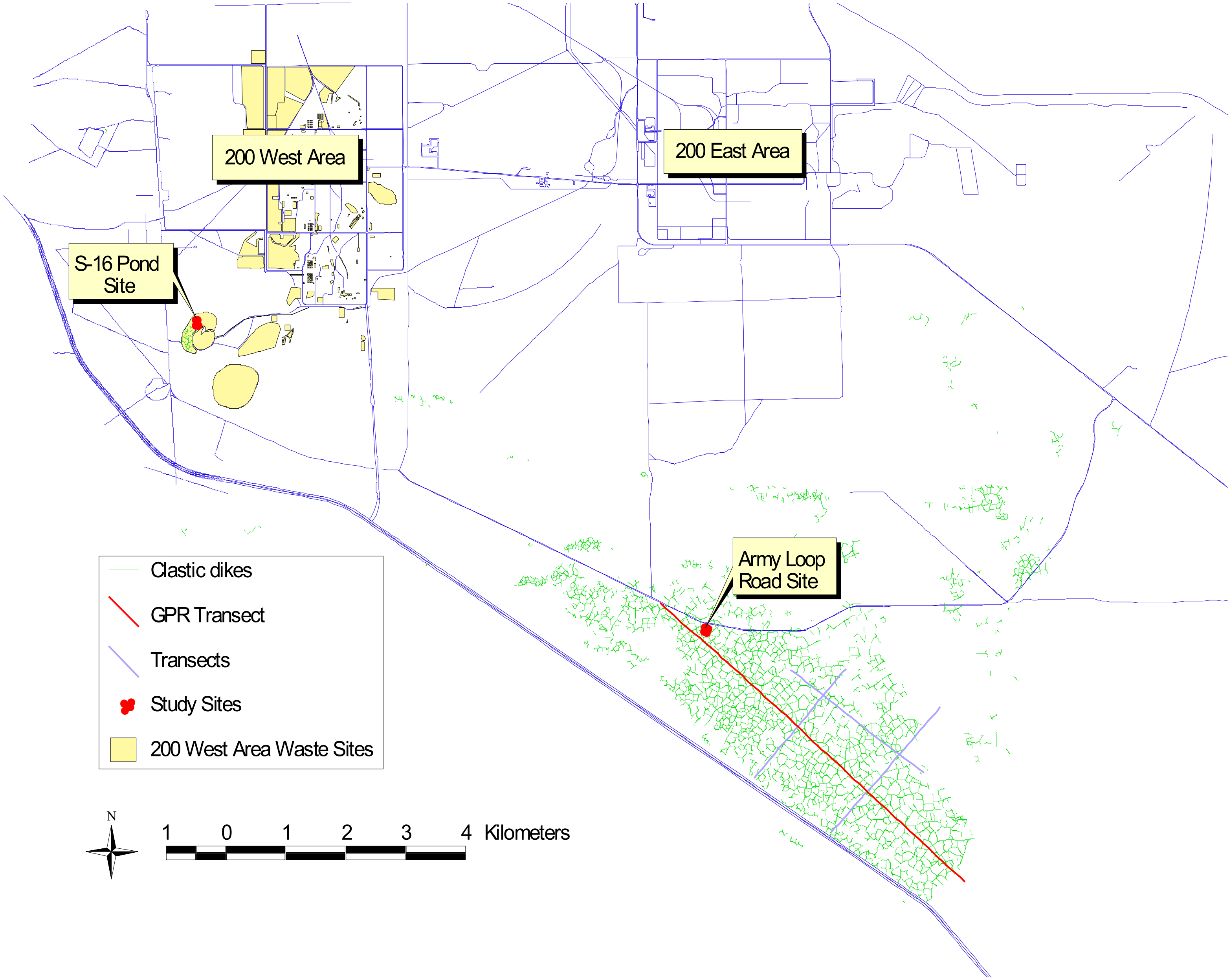


Figure 3.1-8. Distribution of Clastic Dikes at the Army Loop Road Site and the 216-S-16 Pond

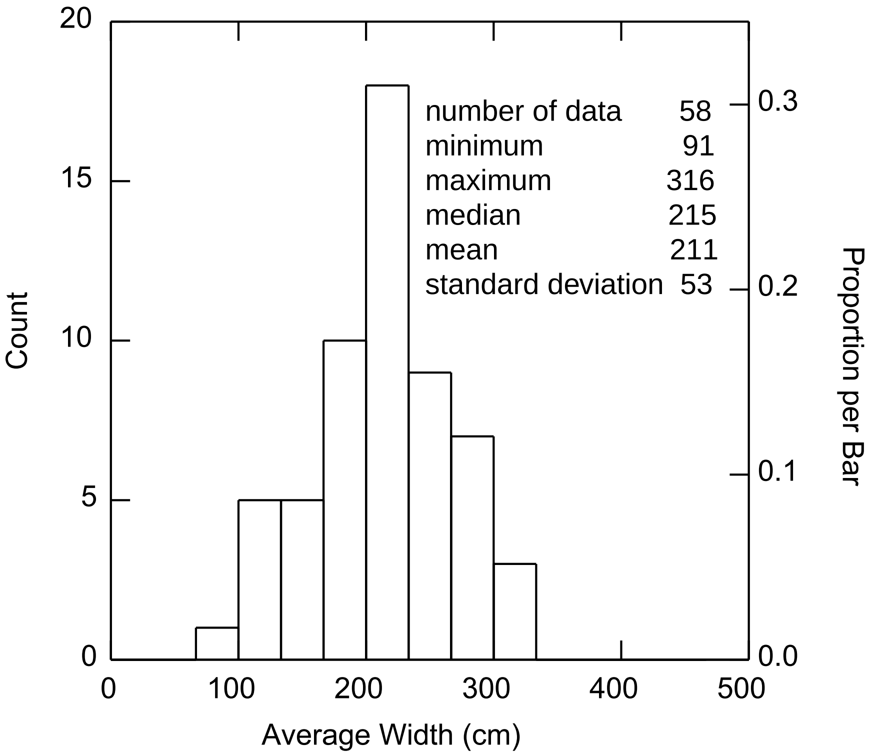


Figure 3.1-9. Distribution of Widths of Clastic Dikes at the Army Loop Road Site

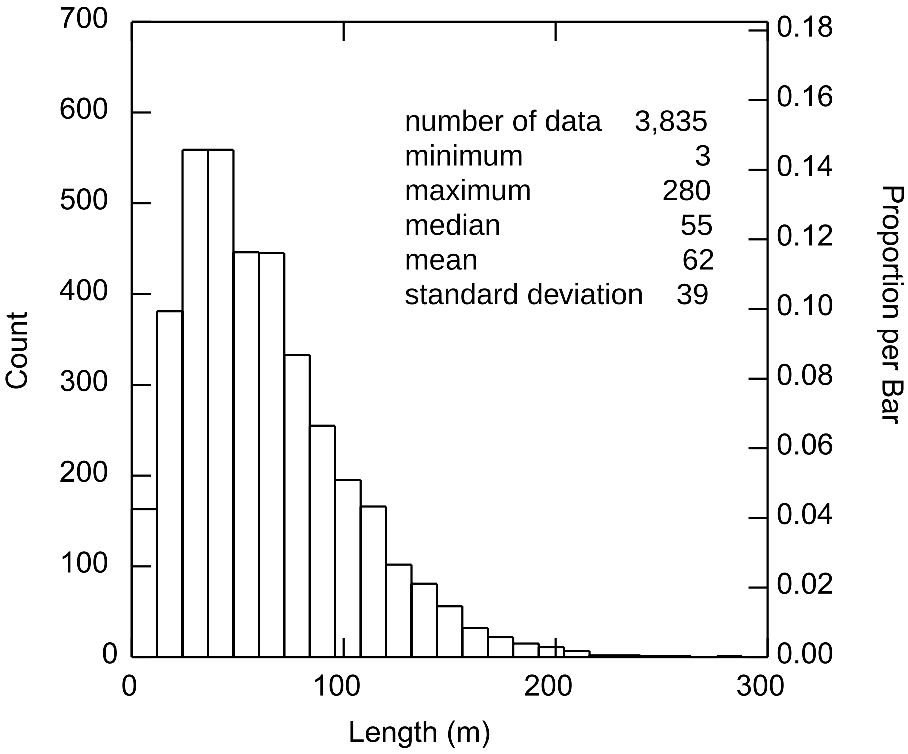


Figure 3.1-10. Distribution of Lengths of Clastic Dikes at the Army Loop Road Site

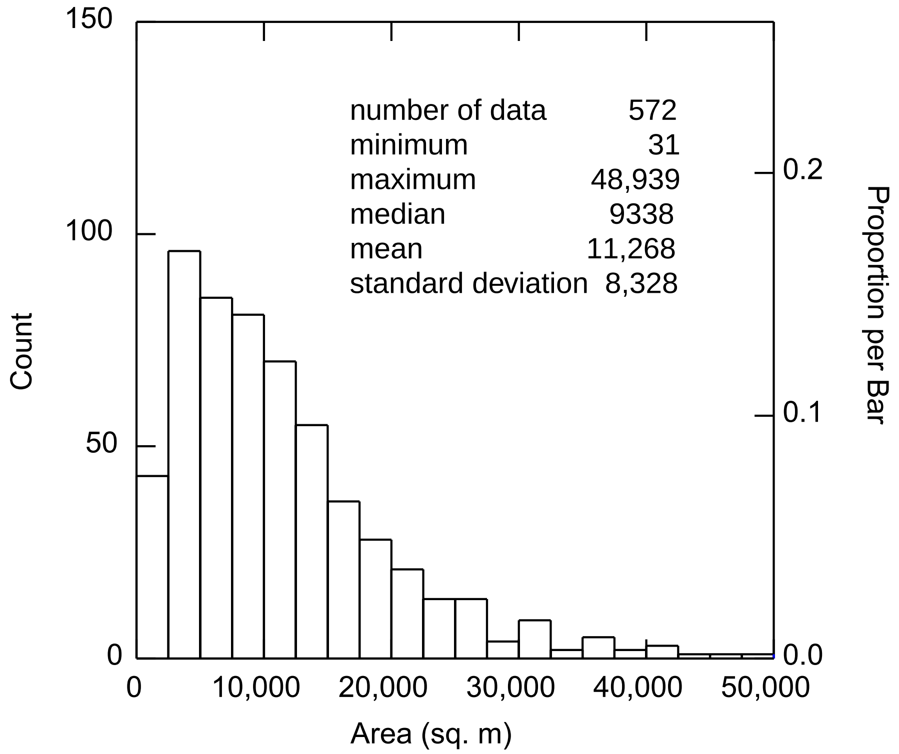


Figure 3.1-11. Distribution of Polygon Areas of Clastic Dikes at the Army Loop Road Site

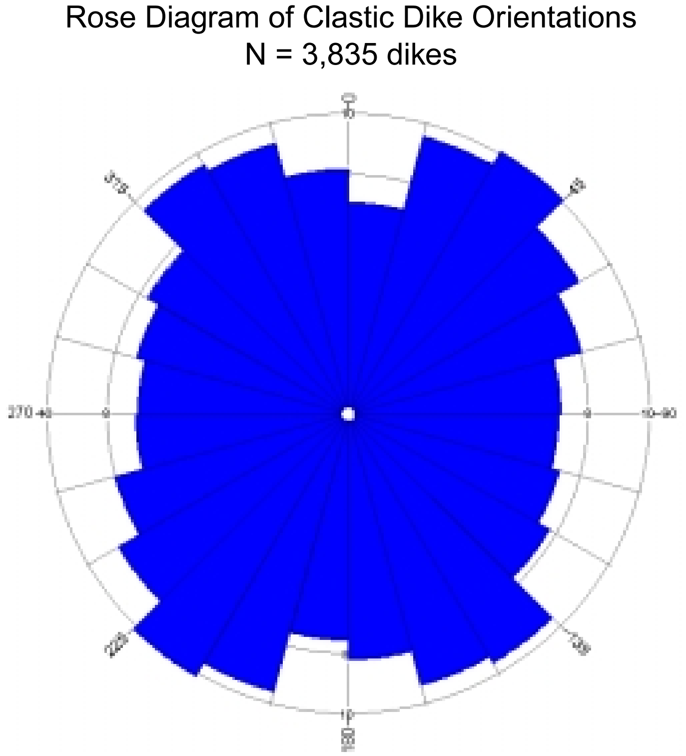


Figure 3.1-12. Distribution of Clastic Dike Azimuth at the Army Loop Road Site

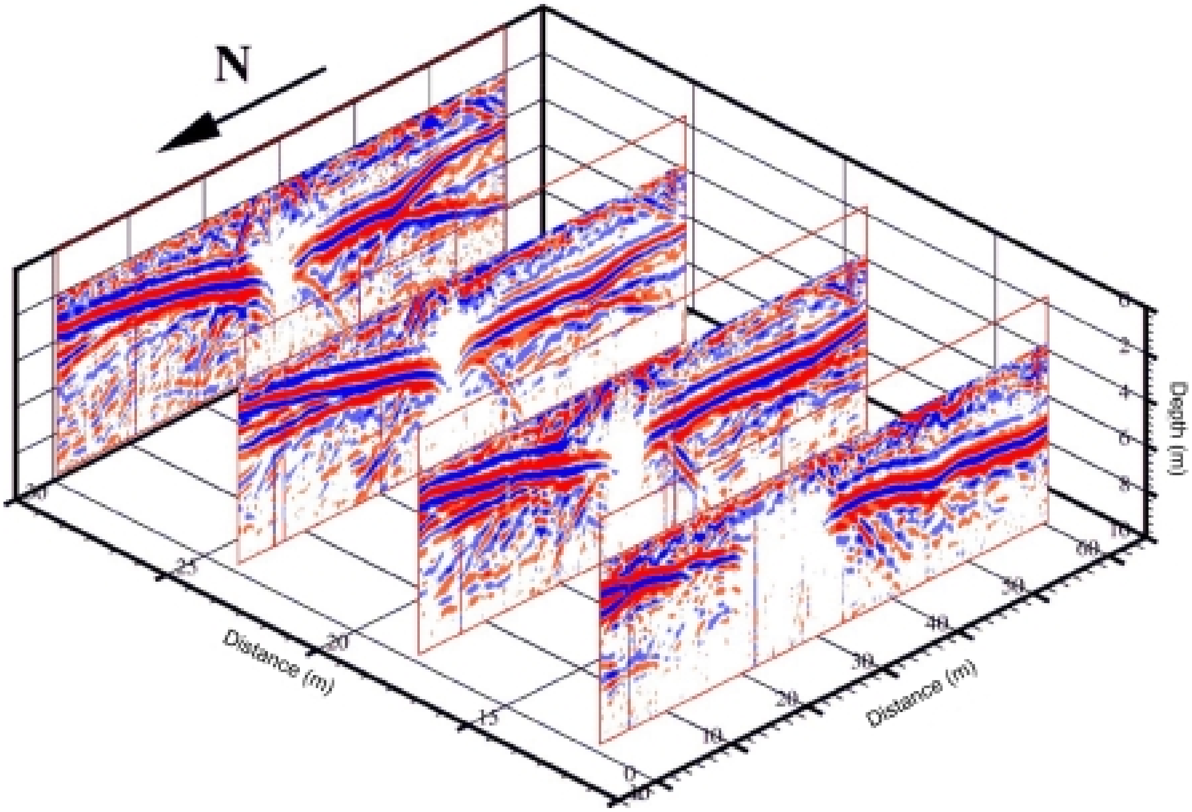


Figure 3.1-13. Fence Diagram of the Northeast-Southwest Army Loop Road Profiles

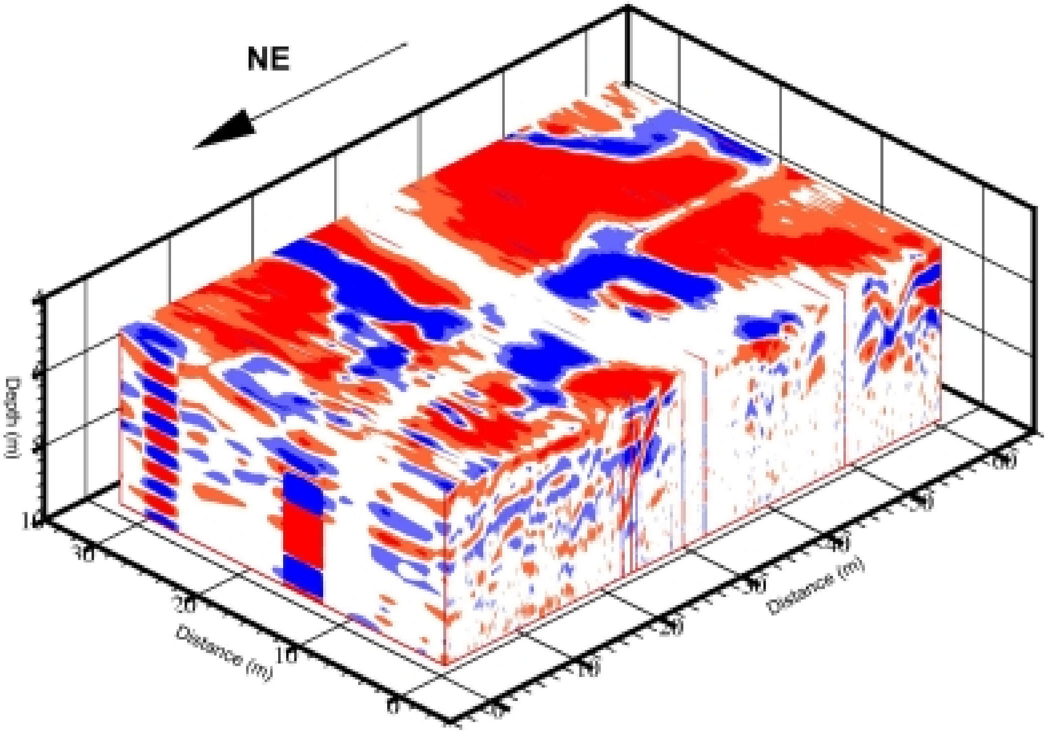


Figure 3.1-14. Three-Dimensional Diagram of the Data from the Army Loop Road Survey

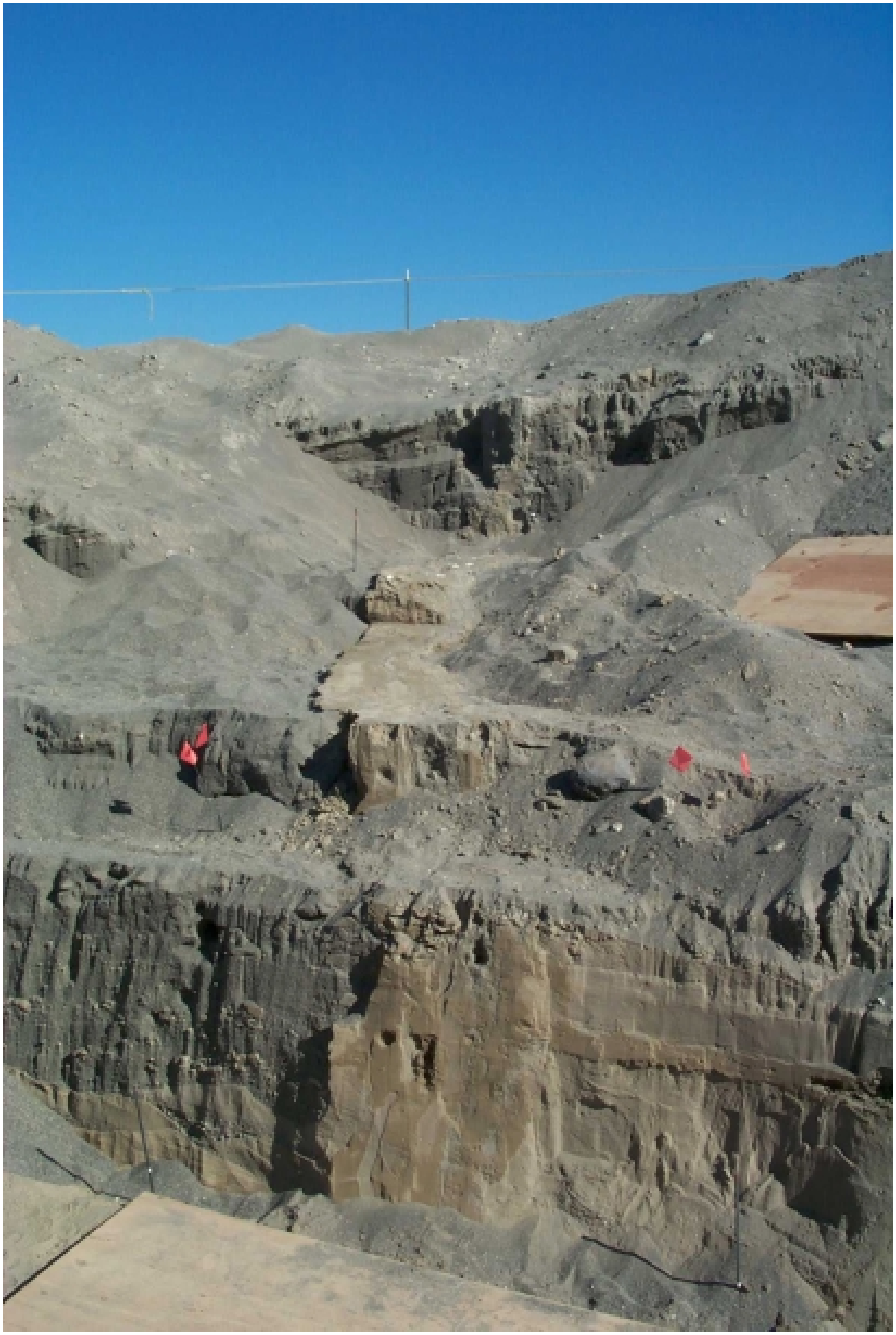


Figure 3.1-15. Clastic Dike Exposed in Trench at 216-S-16 Pond. The dike is approximately 0.7 meter wide at the bottom of the trench.

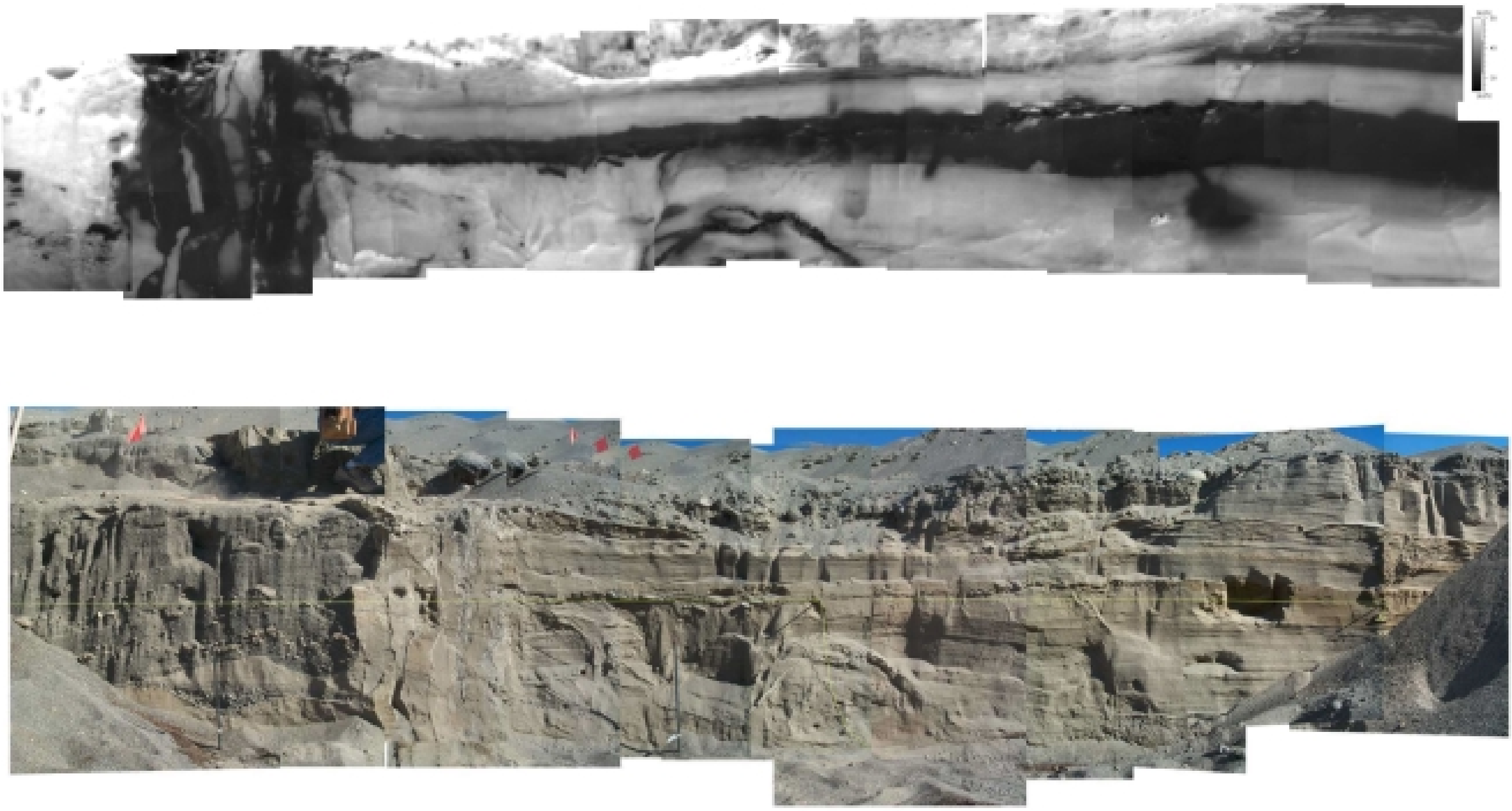


Figure 3.1-16. Composite Photographs of the Lower Part of the Trench at the 216-S-16 Pond. The upper photo is an infrared image and the lower photo is a normal photograph.

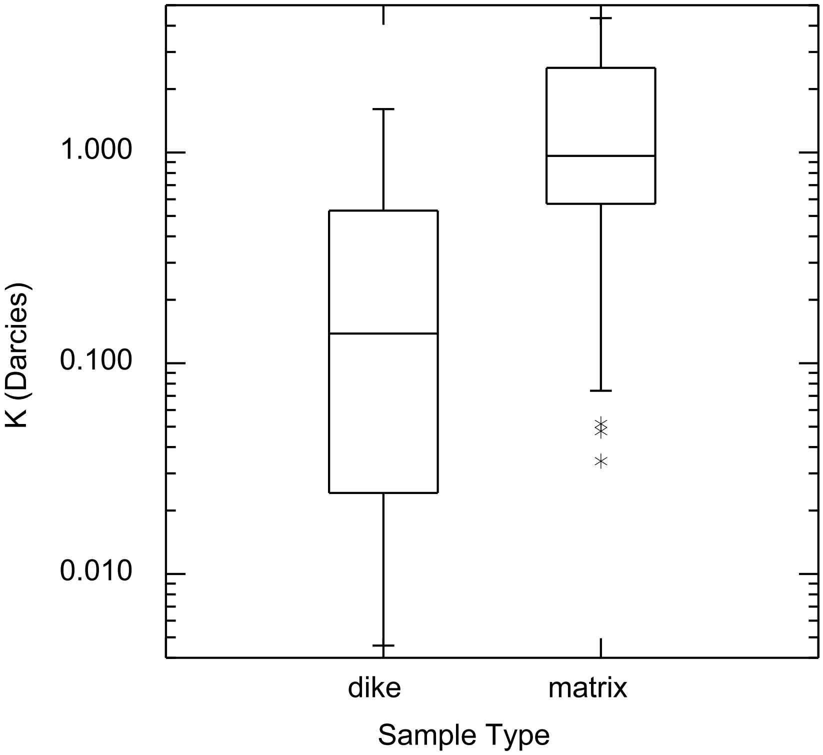


Figure 3.1-17. Air Permeability Data from Dike and Host Sediment at 216-S-16 Pond

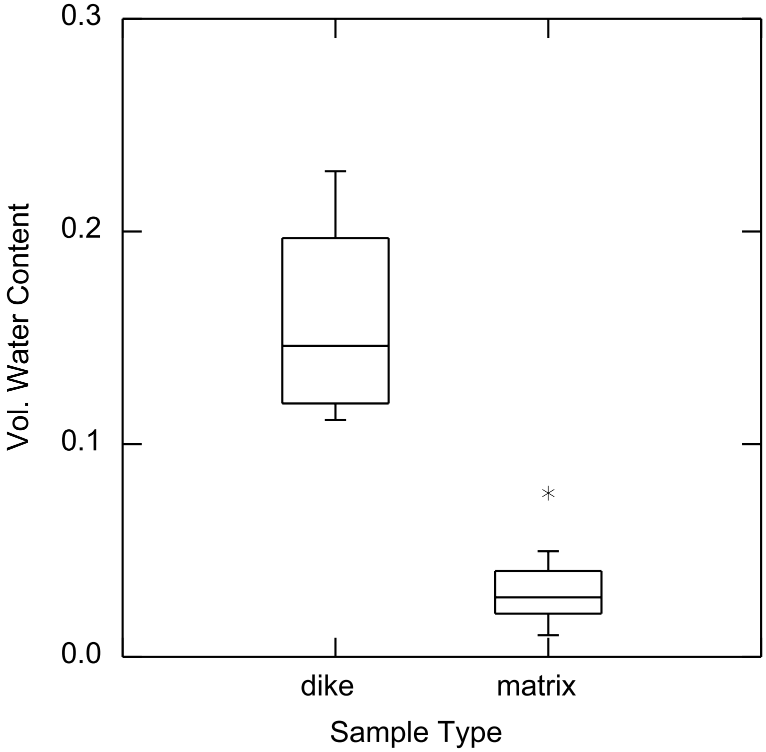


Figure 3.1-18. Gravimetric Water Content of Samples Collected from the Dike and Host Sediment at 216-S-16 Pond

Figure 3.1-19. Instrumentation Installed at the 216-S-16 Pond Clastic Dike Trench

Figure 3.1-20. Distribution of Soil Moisture Three Days after the first Injection of Water

Figure 3.1-21. Dye and Water Distribution in Clastic Dike and Adjacent Host Sediment 1 Day after Dye Injection and 8 Days after Prewetting

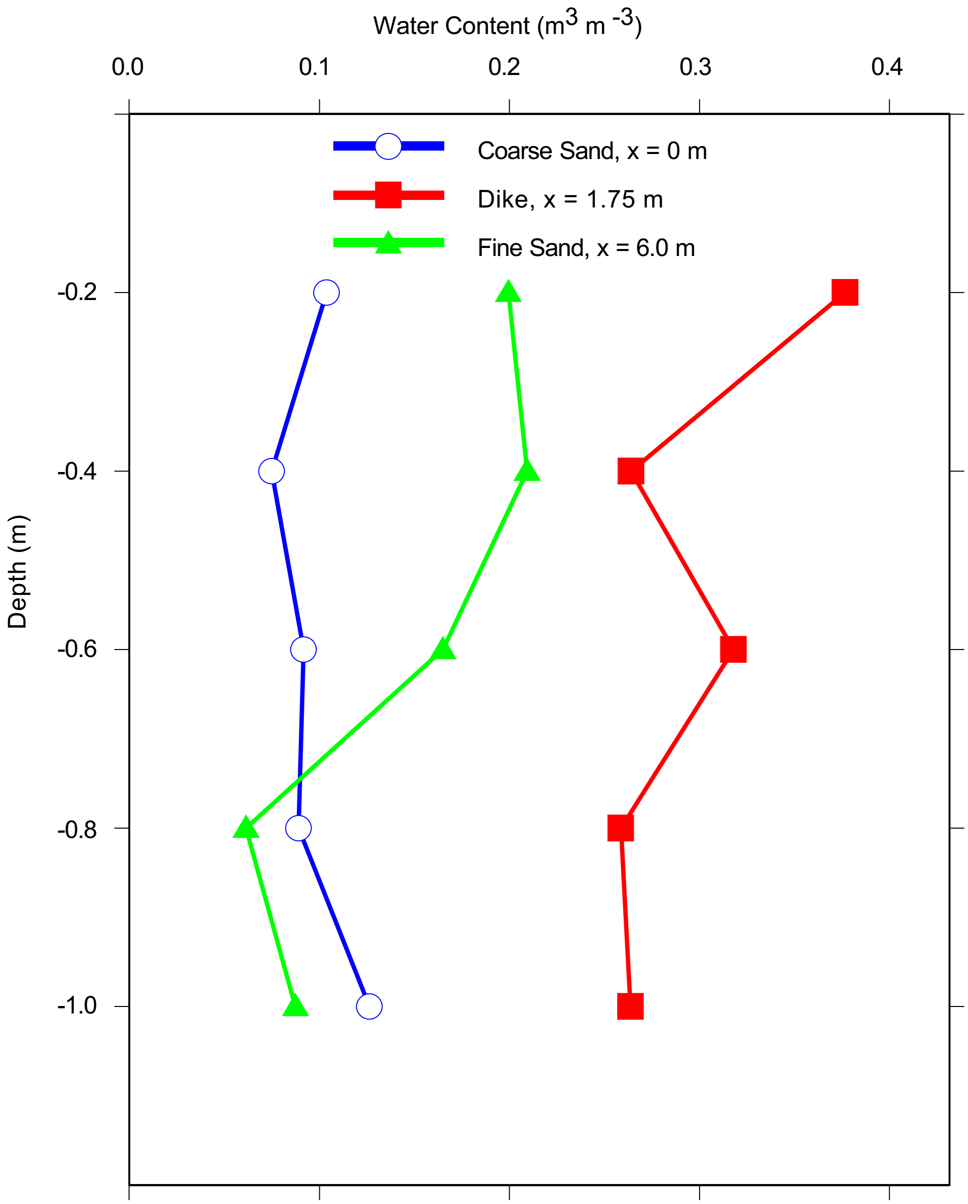


Figure 3.1-22. Water Content versus Depth for the Dike and Host Sediment in the Trench at the 216-S-16 Pond after the last Water Injection

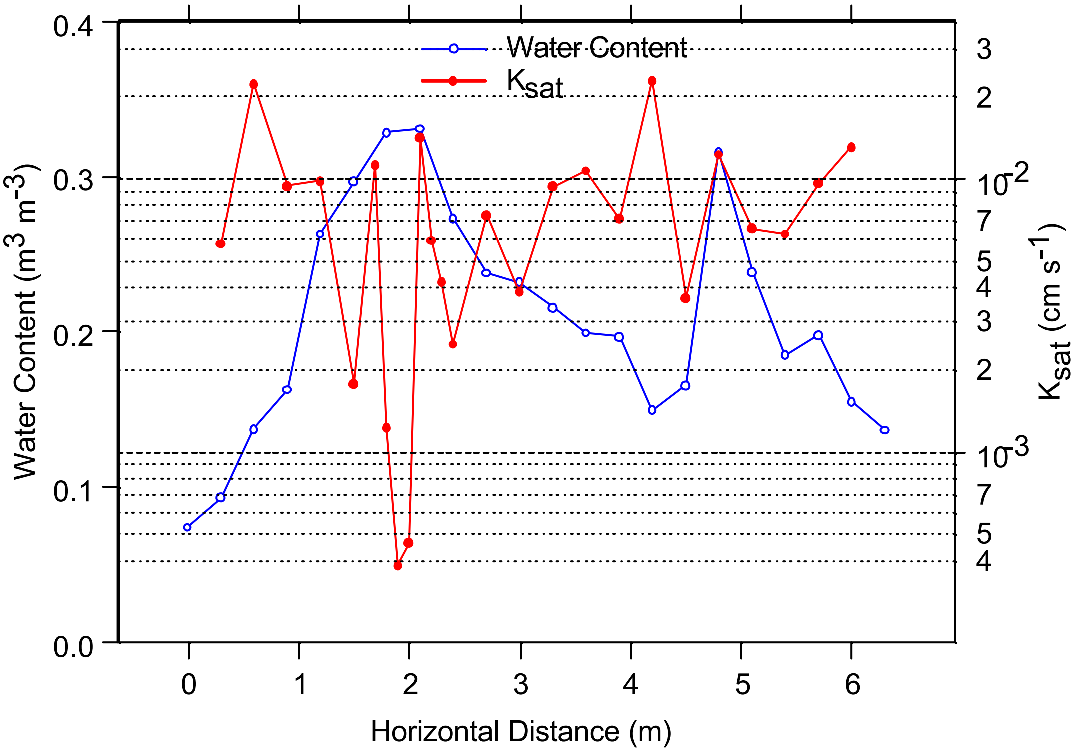


Figure 3.1-23. Water Content and Saturated Hydraulic Conductivity as Measured along a Surface Traverse across the Clastic Dike at the Trench near the 216-S-16 Pond, October 1, 2000

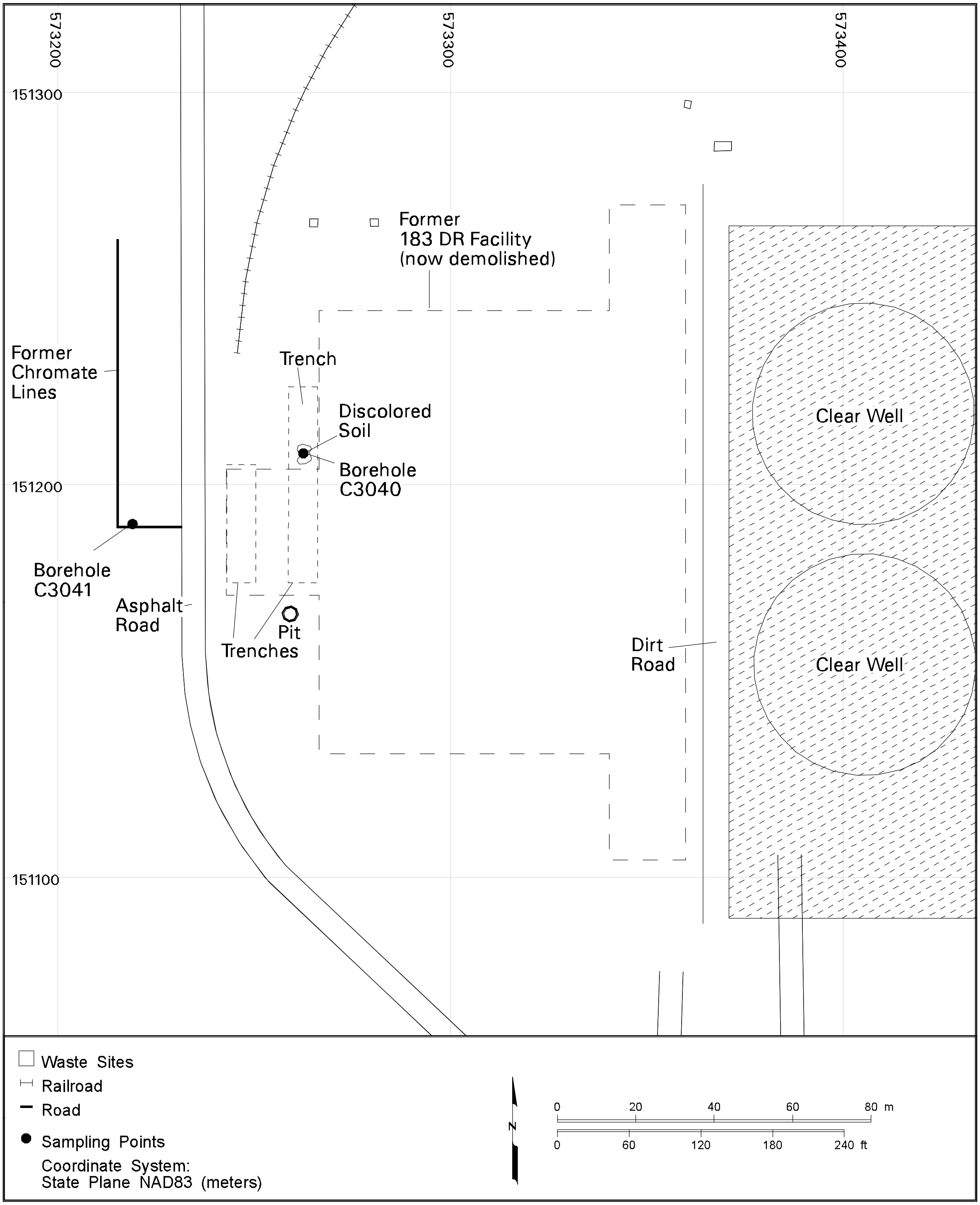
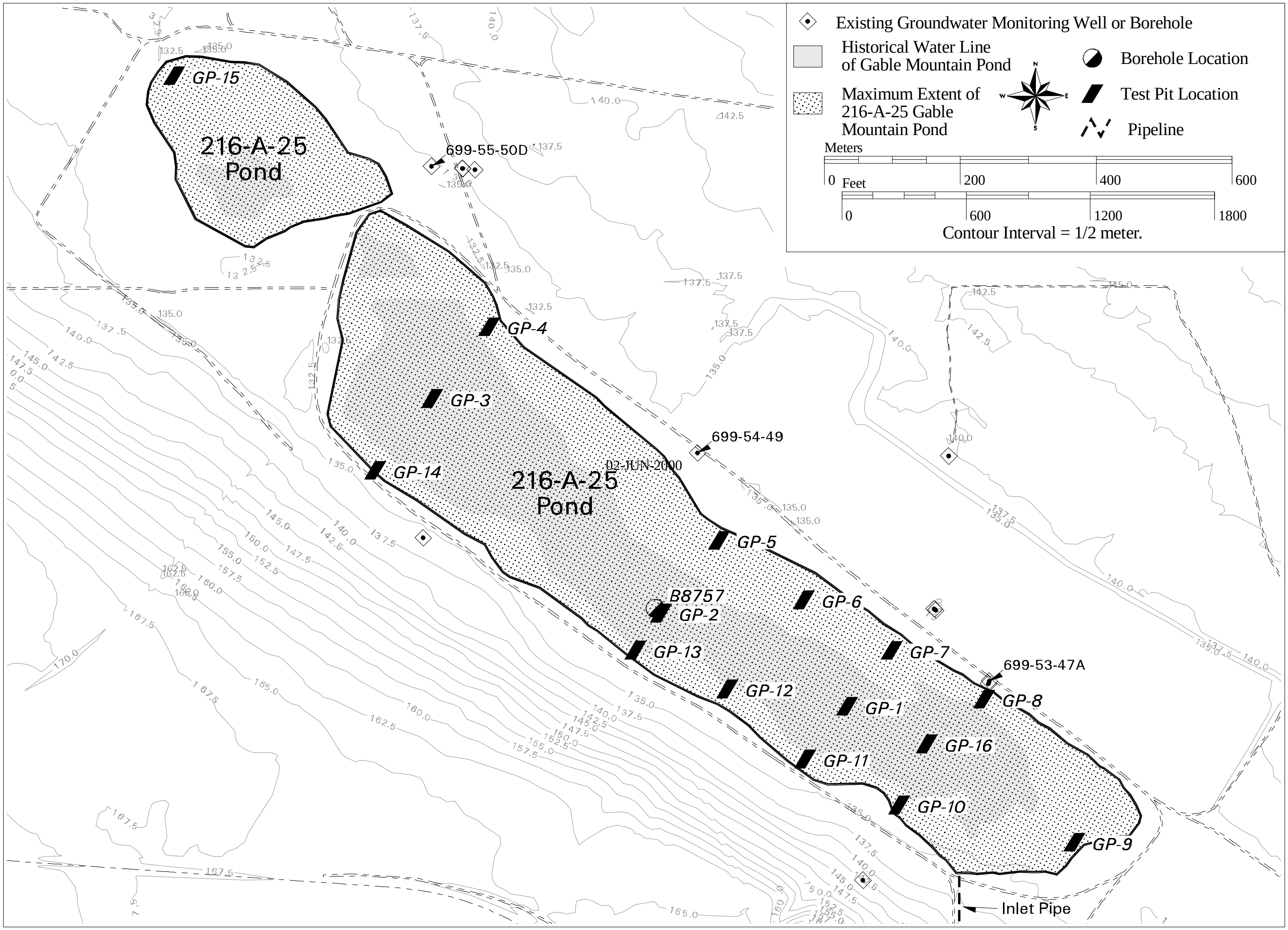


Figure 3.1-24. Location of Boreholes C3040 and C3041 and Excavation Trenches at the Former 183-DR Water Treatment Facility



BHI:maa 1/20/00 /home/maaye/amls/figure6borehole.aml Database:

Figure 3.1-25. Location of the Test Pits and Borehole B8757 at Gable Mountain Pond (from BHI-01367)

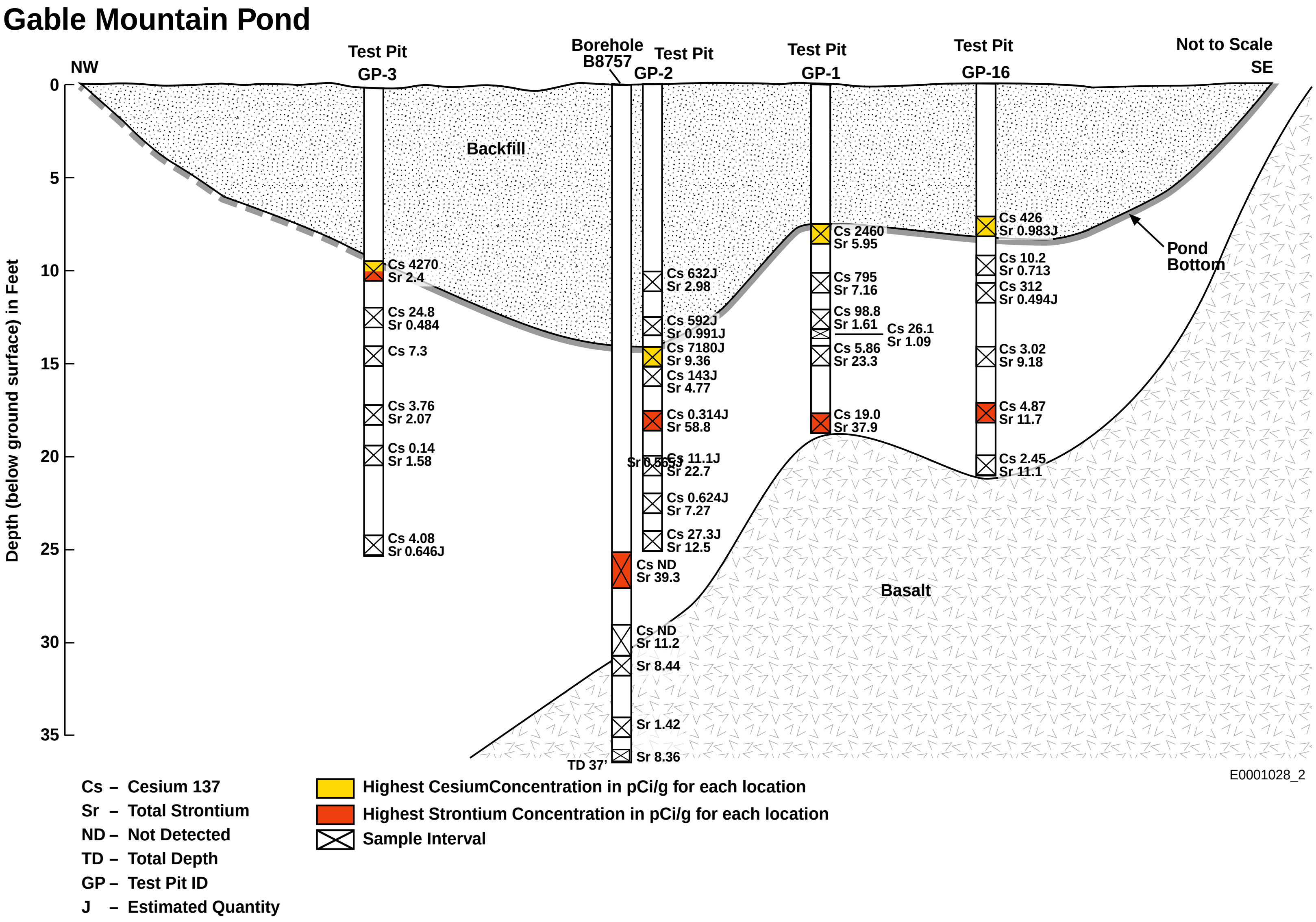
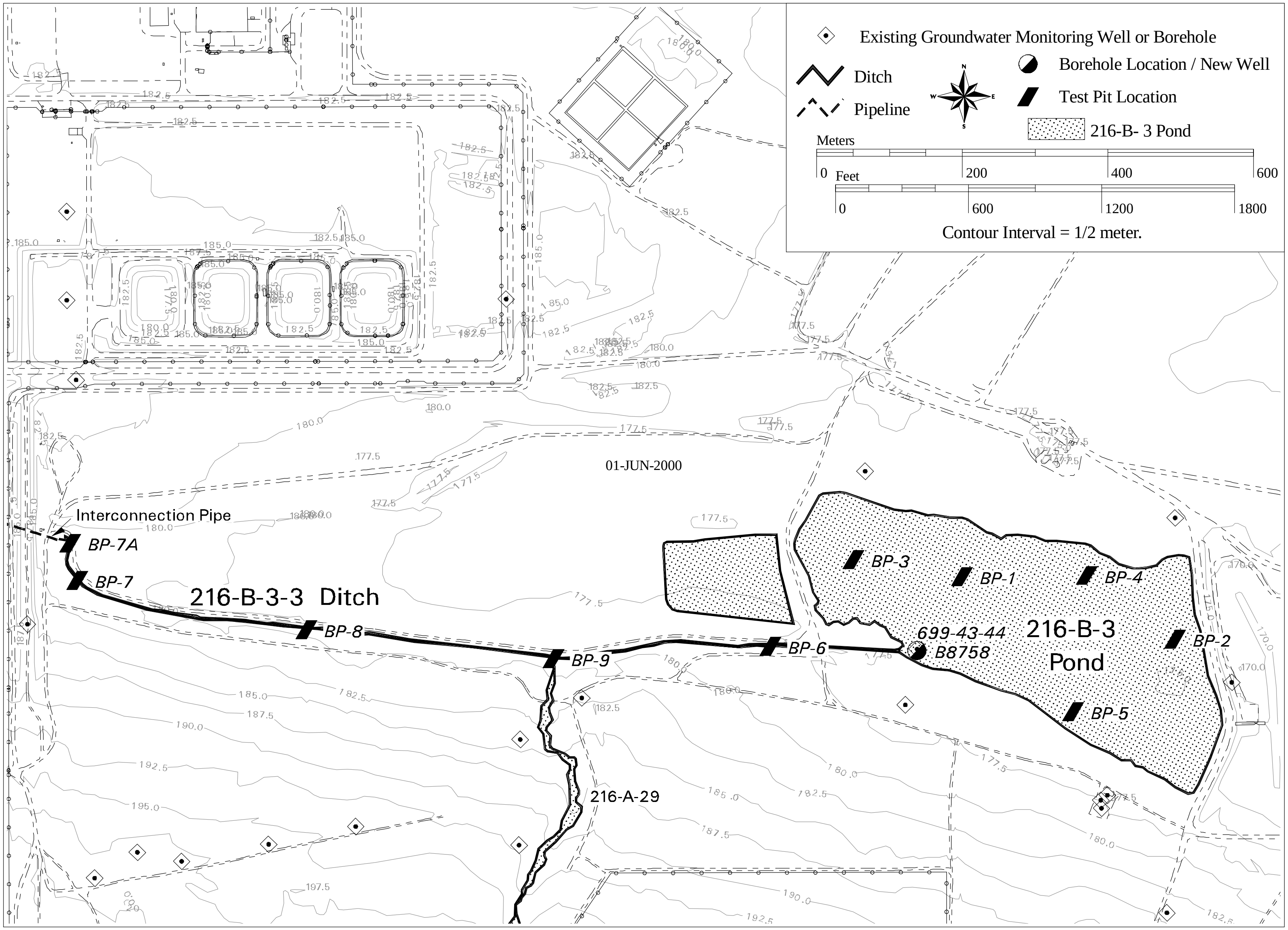


Figure 3.1-26. Cross Section of Gable Mountain Pond showing the Distribution of Cesium-137 and Strontium-90 (from BHI-01367)



BHI:maa 1/20/00 /home/maaye/amls/figure5borehole.aml Database:

Figure 3.1-27. Location of the Test Pits and Boreholes 699-43-44 (B87758) at B Pond and Test Pits at 216-B-3-3 Ditch (from BHI-01367)

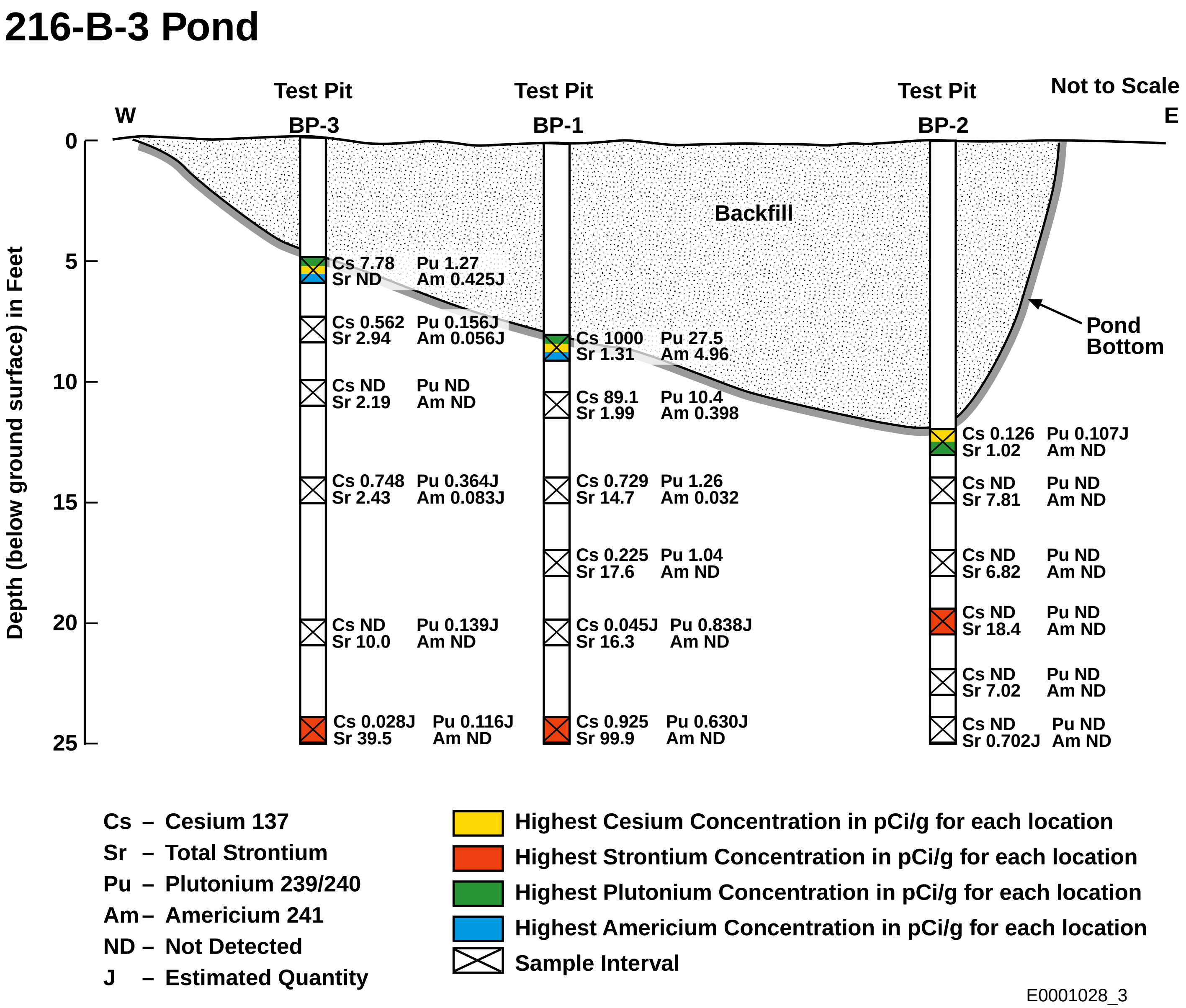
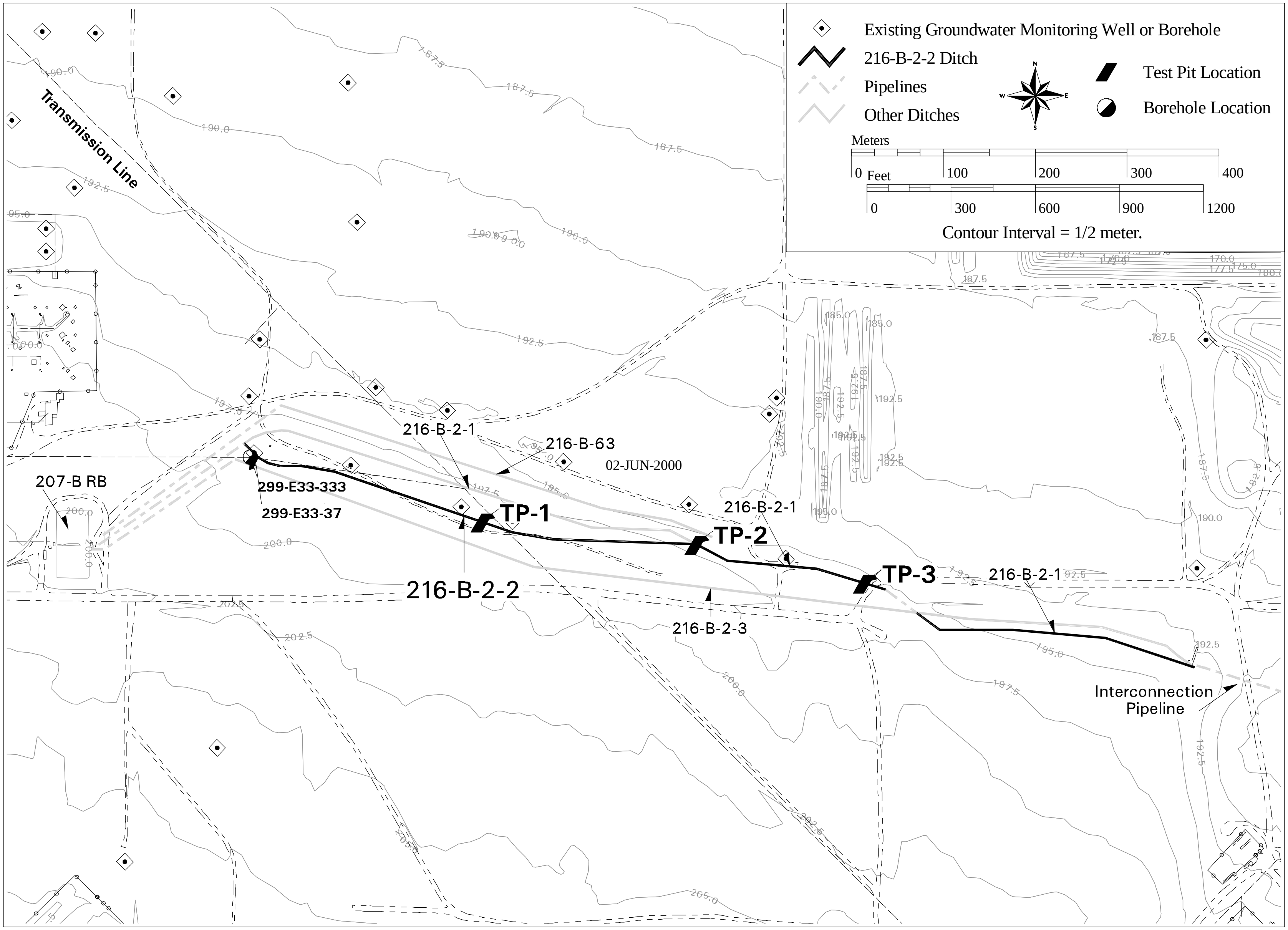


Figure 3.1-28. Cross Section of B Pond showing the Distribution of Radionuclides beneath the Pond (from BHI-01367)



BHI:maa 1/20/00 /home/maaye/amls/borehole_new.aml Database:

Figure 3.1-29. Location of the 216-B-2-2 Ditch Test Pits (from BHI-01367)

3.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four sites at the Hanford Site in fiscal year 2000. Leachate and soil gas monitoring continued at the Solid Waste Landfill and the Environmental Restoration Disposal Facility and historical results from the 3-year period 1996 to 1999 were summarized for the Environmental Restoration Disposal Facility. Also, soil gas monitoring at the carbon tetrachloride expedited response action site continued during fiscal year 2000. Finally, soil gas monitoring was done at the 618-11 burial ground in response to elevated levels of tritium discovered during 2000.

This section summarizes the vadose zone monitoring efforts that occurred during the past fiscal year.

Vadose zone monitoring in fiscal year 2000 included soil gas monitoring for helium isotopes, carbon tetrachloride, and other organic contaminants, and leachate monitoring at landfills.

3.2.1 Helium-3/Helium-4 Ratios in Soil Gas as an Indicator of Subsurface Tritium Contamination at the 618-11 Burial Ground Site

K. B. Olsen, P. E. Dresel, J. C. Evans, G. W. Patton, J. V. Borghese, R. W. Ovink, and J. M. Faurote

A groundwater sample collected in January 2000 from well 699-13-3A (see Figure 2.12-11), located along the eastern fence line of the 618-11 burial ground,

Groundwater samples from well 699-13-3A contained elevated tritium concentrations. (Photo taken April 2000) contained 8.1 million pCi/L of tritium. This is the highest concentration of tritium detected at the Hanford Site in recent years. An investigation to determine the extent of the groundwater contamination was begun in fiscal year 2000. As part of the investigation, a soil gas survey was begun at the burial ground in the summer of 2000 to determine the distribution of tritium. Section 2.12.7.3 discusses the results of the groundwater investigation at the 618-11 burial ground. This section summarizes the soil gas investigation.

Samples of soil gas collected at the 618-11 burial ground were analyzed for helium-3 concentrations in an effort to locate tritium contamination in the subsurface. The technique is based on the decay of tritium, with a half-life of 12.32 years. Tritium decays to the stable, inert isotope helium-3. As tritium decays, its daughter isotope, helium-3, begins to build up in the vadose zone and groundwater at the rate of tritium decay. The helium-3 then diffuses away from the source and toward the surface. Throughout this process, helium-3 acts as a non-reactive tracer moving through the vadose zone. The soil gas monitoring at the 618-11 burial ground was based on the detection of helium-3 in the soil gas to identify vadose or groundwater sources of tritium in the subsurface environment.

3.2.1.1 Soil Gas Sampling and Analysis

Tritium decays into an isotope of helium. By monitoring helium isotopes in soil gas, researchers can locate underlying sources of tritium without drilling deeply into waste sites. In fiscal year 2000, helium isotope data helped locate a potential source of tritium within the 618-11 burial ground.

Fifty-four soil gas sampling points were installed north and east of the 618-11 burial ground and up to 120 meters to the east of well 699-13-3A (Figure 3.2-1). All sampling points were completed at 6 meters below ground surface. Soil gas sampling points were installed using a truck mounted Geoprobe™[a] system equipped with a 1.25-inch-diameter probe and a detachable steel tip. Each sampling location was allowed to equilibrate for at least 24 hours before soil gas samples were collected. All samples were collected with the aid of a flexible diaphragm pump.

Fifty milliliter samples were collected for analysis of helium-3/helium-4 ratios from each sampling location near 618-11 burial ground. (Helium-4 is the stable form of helium and does not change, whereas helium-3 increases as tritium decays. Thus, an increase in the helium-3/helium-4 ration indicates an increase in tritium.) After collection, soil gas samples were sent to the University of Rochester for rare gas analysis. Helium isotope ratios and concentrations were analyzed on a rare gas mass spectrometer. All helium-3/helium-4 ratios were reported relative to the atmospheric ratio (R_A), using air helium as the absolute standard.

Two groundwater samples were also collected to determine tritium concentrations; one sample was collected from the area with the highest helium-3/helium-4 ratio on the north side of the burial ground, and the second was collected ~60 meters to the east of well 699-13-3A (see Figure 3.2-1).

3.2.1.2 Results and Discussion

The results of soil gas analyses of samples from the west and south sides of the 618-11 burial ground were near background (that is, near the value of ambient air normalized to 1.0). Helium-3/helium-4 ratios from samples from the north and east sides of the burial ground, however, were larger than ambient air indicating tritium decay. The largest value was 62.5 times greater than the atmospheric ratio (see Figure 3.2-1). The largest values were about midway between the east and west ends of the burial ground, north of a series of disposal caissons. A groundwater grab sample collected from a well near the maximum helium-3/helium-4 value contained only 6,500 pCi/L tritium, however. This suggests that the helium-3/helium-4 enrichment resulted from a vadose zone source or tritium in the area. The area of high helium-3/helium-4 may represent a “halo” of elevated helium-3 in the vadose zone surrounding the tritium source within the burial ground.

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[a] Geoprobe is a registered trademark of Geoprobe Systems, Salinas, Kansas.

A second area of elevated helium-3/helium-4 occurs at the northeastern corner of the burial ground with a maximum ratio of 10.9. A groundwater sample has not been collected at this location. If the helium-3 at this location is from tritium in groundwater, then the concentration of tritium in groundwater can be estimated at about 24 million pCi/L based on scaling the concentration of tritium in groundwater at well 699-13-3A (~8 million pCi/L) (see Figure 3.2-1 for location of well) and the helium-3/helium-4 directly adjacent to the well (3.69).

A tritium concentration of 1.5 million pCi/L was measured in a groundwater sample collected from a borehole ~80 meters east of well 699-13-3A. This value is consistent with the helium-3/helium-4 ratio (1.37) that would be predicted by the scaling the values given in the above paragraph.

Fiscal year 2001 studies are planned to further define the extent of the groundwater tritium plume. Helium-3/helium-4 ratios from additional soil gas monitoring points will be used to determine locations for collection of groundwater samples.

3.2.2 Leachate Monitoring at the Environmental Restoration Disposal Facility

J. M. Faurote

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility to dispose of radioactive, hazardous or dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. In fiscal year 2000, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during the first four years of operation (BHI-01382). Part of the published results contains laboratory analyses of leachate collected from beneath the facility. This section discusses those results.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200 East and 200 West Areas (Figure 2.2-2), the facility is currently operating two trenches covering 10.3 hectares. Each trench is lined to collect leachate resulting from water added as a dust suppressant and precipitation. The liner is sloped to a sump and the leachate is pumped from the sump to tanks. After about 757,080 liters of leachate are collected, samples are taken and analyzed. Analyses are made for 41 volatile organics, 64 semi-volatile organics, 23 metals, and 9 radionuclides (gross alpha and gross beta analyses are also done). The number of samples depends on the amount of leachate collected.

Leachate from the Environmental Restoration Disposal Facility contained no elevated levels of contaminants of concern.

The purposes of the data are to provide an inventory to the Effluent Treatment Facility, where the leachate is disposed, and to determine whether additional analytes should be added to the groundwater-monitoring list.

Analyses of leachate collected from the Environmental Restoration Disposal Facility show that the liquid collected so far contains no elevated levels of contaminants of concern (BHI-01382). Small levels of common laboratory organics used during analyses are present. A few analytes showed statistically significant increases in groundwater samples since operations began. However, leachate samples contain no constituents of concern for groundwater and no leachate has been released to the soil column at the Environmental Restoration Disposal Facility. Thus, increases in groundwater contaminants must be due to another source.

3.2.3 Leachate and Soil Gas Monitoring at the Solid Waste Landfill

R. A. Del Mar and D. G. Horton

The Solid Waste Landfill is a land disposal facility in the center of the Hanford Site (labeled as Central Landfill on Figure 2.2-2). The Solid Waste Landfill began operation in 1973; it received non-hazardous, non-radioactive sanitary waste generated from site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an "interim cover" was placed over all trenches. Current monitoring at the Solid Waste Landfill includes leachate, soil gas, and groundwater. Recent groundwater monitoring results are discussed in Section 2.11.2. This section summarizes the leachate and soil gas results reported by DynCorp Environmental Programs and Compliance to the U.S. Department of Energy (DOE).[a,b]

One of the double trenches in the Solid Waste Landfill overlies a lined, basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. The lysimeter covers an area of about 88 square meters. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump (BHI-01063). Leachate is only collected from under two of more than 90 buried trenches and the trench is one of the newer trenches built after implementation of regulations restricting land disposal practices. Therefore, the analytical results from the lysimeter may not reflect leachate draining from most trenches.

None of the contaminants of concern detected in leachate for the Solid Waste Landfill have been detected in groundwater.

Figure 3.2-2 shows the volume of leachate collected since routine monitoring began in 1997. The volume collected is consistent with expected infiltration rates at the Solid Waste Landfill. Table 3.2-1 shows analytical results for several key indicator parameters, metals, anions, and organics in leachate samples during fiscal year 2000. The data show that some indicator parameters and some organic and metal constituents continue to be above the groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290).

The most notable change in the leachate between the second and third quarters of fiscal year 2000 was a statistically significant increase in total organic halide from 586 to 945 µg/L. The only specific organic halide detected was 1,4-dichlorobenzene at 6 and 4 µg/L for the first and second quarters, respectively. These small concentrations can not account for the total organic halide values and the source for the total organic halide is unknown.

The increase in pH from 6.14 during the second quarter of fiscal year 2000, which is below the groundwater quality criteria of 6.5, to 7.43 during the third quarter suggests that the second quarter's low pH was an anomalous value. A pH of 7.43 is within the normal range for historical measurements.

Figures 3.2-3 and 3.2-4 show historic trends for several key organic compounds and metals in leachate from the Solid Waste Landfill. None of the contaminants of concern thus far detected in the leachate has been detected at significant levels in the groundwater (see Section 2.11.2).

(a) Letter report FH-0001763 from D. S. Kelly, Fluor Hanford, Inc. to S. H. Wisness, DOE/RL, *Submittal of Solid Waste Landfill Leachate, Soil Gas, and Groundwater Monitoring Results from Fourth Quarter, Calendar Year 1999*, dated May 3, 2000.

(b) Letter report FH-0002667 from D. S. Kelly, Fluor Hanford, Inc. to S. T. Burnum, DOE/RL, *Submittal of Solid Waste Landfill Leachate, Soil Gas, and Groundwater Monitoring Results from First and Second Quarters, Calendar Year 2000*, dated September 20, 2000.

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 ~2.7 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 first three quarters of fiscal year 2000.

3.2.4 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay and L. C. Swanson

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 and the Washington State Department of Ecology authorized DOE to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) expedited response action. The primary focus in the following discussion is on fiscal year 2000 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720 and Section 3.2 in PNNL-13116.

The 14.2 m^3/min soil-vapor extraction system operated from March 29 through June 28, 1999, at the 216-Z-9 well field and from June 30 through September 30, 1999, at the combined 216-Z-1A/-12/-18 well field (see PNNL-13080 for location maps of the well fields). The system was maintained in standby mode in fiscal year 2000. Soil vapor monitoring during non-operation of the soil-vapor extraction system has been in progress since July 1999. The 28.3 and 42.5 m^3/min soil-vapor extraction systems also were maintained in standby mode during fiscal years 1999 and 2000.

Remediation efforts this fiscal year were directed toward monitoring carbon tetrachloride concentrations during non-operation of the soil-vapor extraction system, passive soil-vapor extraction, and continuation of the carbon tetrachloride innovative technology remediation demonstration program.

3.2.4.1 Soil-Vapor Extraction

As of September 1999, ~76,500 kilograms of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1992 (Table 3.2-2). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at well field 216-Z-1A/-12/-18 and 22% of the mass at well field 216-Z-9. 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 (BHI-00720; WHC-SD-EN-TI-101).

Soil-vapor extraction is estimated to have removed up to 22% of the carbon tetrachloride at some past-practice disposal facilities.

3.2.4.2 Monitoring at Off-Line Wells and Probes

During fiscal year 2000, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Plio-Pleistocene 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 assess whether non-operation of the soil-vapor extraction system is allowing carbon tetrachloride to migrate out of the vadose zone. The maximum concentration detected near the ground surface (between 2 and 10 meters below ground surface) was 9.4 ppmv. Near the groundwater, at a depth of 58 meters below ground surface, the maximum concentration was 20.4 ppmv.

Soil-vapor concentrations were also monitored above and within the Plio-Pleistocene Unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. (The Plio-Pleistocene Unit is a geologic strata that may be a confining layer to carbon tetrachloride vapors.) The maximum concentration detected near the Plio-Pleistocene Unit (between 25 and 41 meters below ground surface) was 442 ppmv in well 299-W15-217 (35 meters below ground surface) at the 216-Z-9 site. During monitoring in fiscal years 1997, 1998, and 1999, the highest carbon tetrachloride concentrations were also detected in this well.

At the 216-Z-1A/-12/-18 well field, the maximum carbon tetrachloride concentration detected near the Plio-Pleistocene Unit was 248 ppmv in well 299-W18-167 (37 meters below ground surface) in the 216-Z-1A tile field. The highest concentrations detected during the fiscal years 1998 and 1999 were detected at well 299-W18-158L also within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in fiscal year 2000 appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. This view is supported because carbon tetrachloride concentrations did not increase significantly at the near-surface probes monitored in fiscal year 2000. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations have not increased significantly near the water table since that time.

3.2.4.3 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, while 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 systems were installed at the end of fiscal year 1999 at eight boreholes that are open near the vadose-groundwater interface at the 216-Z-1A/-12/-18 well field. The passive systems are outfitted with a check valve that only allows soil-vapor flow out of the borehole (i.e., one way movement), and a canister holding granular activated carbon that adsorbs carbon tetrachloride 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.

Passive soil-vapor extraction was used to remove carbon tetrachloride from the vadose zone at the Plutonium Finishing Plant.

Three of eight boreholes are instrumented to measure hourly air pressure differentials between the ground surface and the bottom of the borehole, carbon tetrachloride concentrations, temperature, and flow rates. These data can be used to calculate an hourly estimate of the amount of mass removed from the well. The granular activated carbon in all eight boreholes is sampled monthly and analyzed quarterly using laboratory analytical services. The granular activated carbon samples provide a passive, time-integrated measure of the amount of mass removed through the well.

At the two instrumented boreholes near 216-Z-1A tile field, 299-W18-6L and 299-W18-252L, the peak carbon tetrachloride concentration was 69.2 ppmv. Well 299-W18-247L located at the southeastern corner of the 216-Z-18 crib had a peak concentration of 8 ppmv. Flow rates measured at the wells ranged from 0 to as high as 0.3 cubic meters per minute.

3.2.4.4 Innovative Technology Remediation Demonstration Program

DOE began an Innovative Technology Remediation Demonstration Program for carbon tetrachloride in January 1999. The program is evaluating innovative technologies for characterization and remediation of carbon tetrachloride in Hanford soil and groundwater considering cost, performance, and regulatory issues. During fiscal year 2000, the program evaluated characterization technologies that might detect the presence of dense, non-aqueous phase liquids in the vadose zone and groundwater. (Carbon tetrachloride in pure form is a dense non-aqueous phase liquid.) Groundwater modeling was performed during fiscal year 2000 to support evaluation of innovative technologies to remediate the carbon tetrachloride groundwater plume (Section 4.1.3). The Innovative Technology Remediation Demonstration Program will continue into fiscal year 2001.

Table 3.2-1. Fiscal Year 2000 Leachate Monitoring Results from the Solid Waste Landfill

	Results				
Parameter	First Quarter	Second Quarter	Third Quarter	GWQC(a)	MCL(b)
pH	7.6	**6.14**	7.43	6.5 - 8.5	NA(c)
Conductivity (µS/cm)	**2,000**	**1,970**	**1,943**	NA	700
Sulfate (mg/L)	8	8	7.7	250	250
Chloride (mg/L)	238.9	223.5	188.3	250	250
Total dissolved solids (mg/L)	**1,300**	**1,288**	**1,297**	500	NA
Arsenic (µg/L)	**19.2**	**17.5**	**13**	0.05	50
Barium (µg/L)	458	444	384	1,000	2,000
Manganese (µg/L)	**2,480**	**2,480**	**2,310**	50	50
Nickel (µg/L)	**208**	**179**	**191**	NA	100
Cadmium (µg/L)	<0.5	0.45	0.29	10	5
Copper (µg/L)	7.97	4.05	2.78	1,000	NA
Selenium (µg/L)	3.65	2.79	2.48	10	50
Zinc (µg/L)	1,490	649	448	5,000	5,000
1,4-Dioxane (µg/L)	**180**	**150**	**57**	7	NA
1,4-Dichlorobenzene (µg/L)	**6**	**6**	**4**	4	NA
Total organic halides (µg/L)	742	586	945	NA	NA
Acetone (µg/L)	12	8	19	NA	NA
Methyl ethyl keytone (µg/L)	<3.1	<3.1	12	NA	NA
Tetrahydrofuran (µg/L)	22	24	21	NA	NA
Liquid volume (L)	483	398	344	NA	NA

Bold indicates values that exceeded groundwater quality criteria or maximum contaminant level.

(a) Groundwater quality criteria from WAC 173-200.

(b) Maximum contaminant level from WAC 246-290.

(c) NA = Not available.

Table 3.2-2. Carbon Tetrachloride Inventory in Primary Disposal Sites

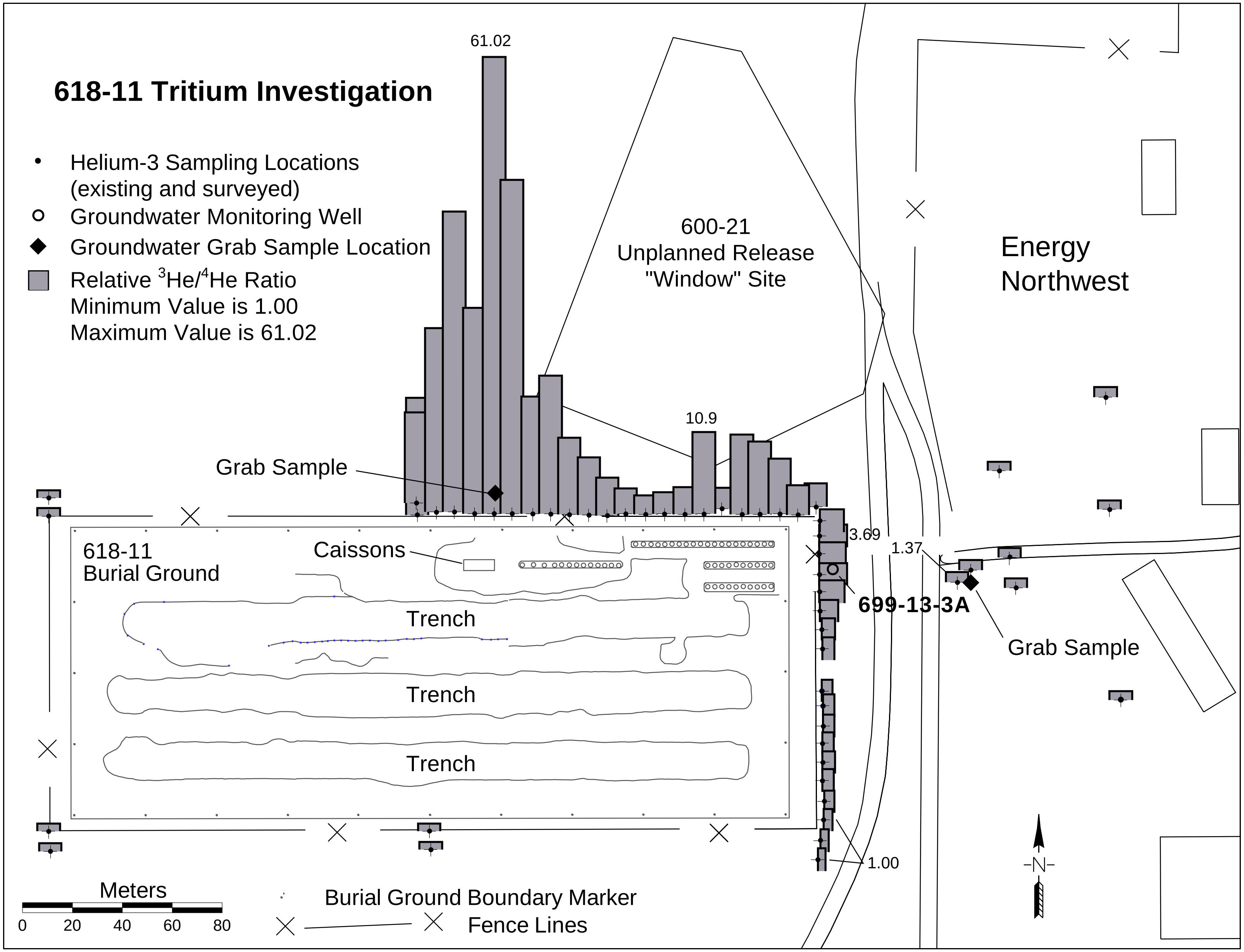
Well Field	Estimated Mass Discharged 1955 to 1973(a) (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990(b) (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 1999(c) (kg)
216-Z-1A	270,000	56,700	23,511(d)
216-Z-9	130,000 to 480,000	27,300 to 100,800	52,949
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	76,460

(a) Based on DOE/RL-91-32.

(b) Based on WHC-SD-EN-TI-101.

(c) Based on BHI-00720.

(d) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.



wdw00050/can_kolsen00_03

Figure 3.2-1. Relative Helium-3/Helium-4 Ratios at Soil Gas Sampling Locations around the 618-11 Burial Ground

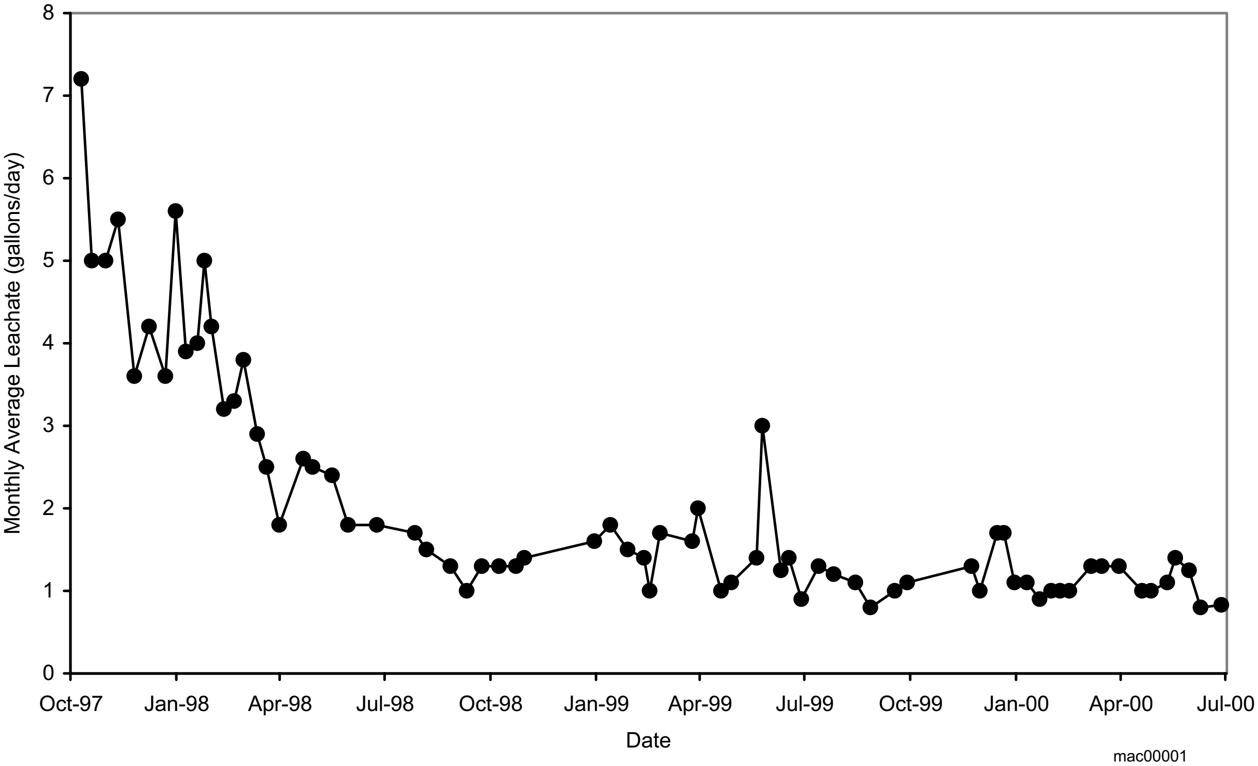


Figure 3.2-2. Trend Plot of Leachate Pumped from the Solid Waste Landfill Lysimeter (modified from DynCorp Environmental Programs and Compliance)

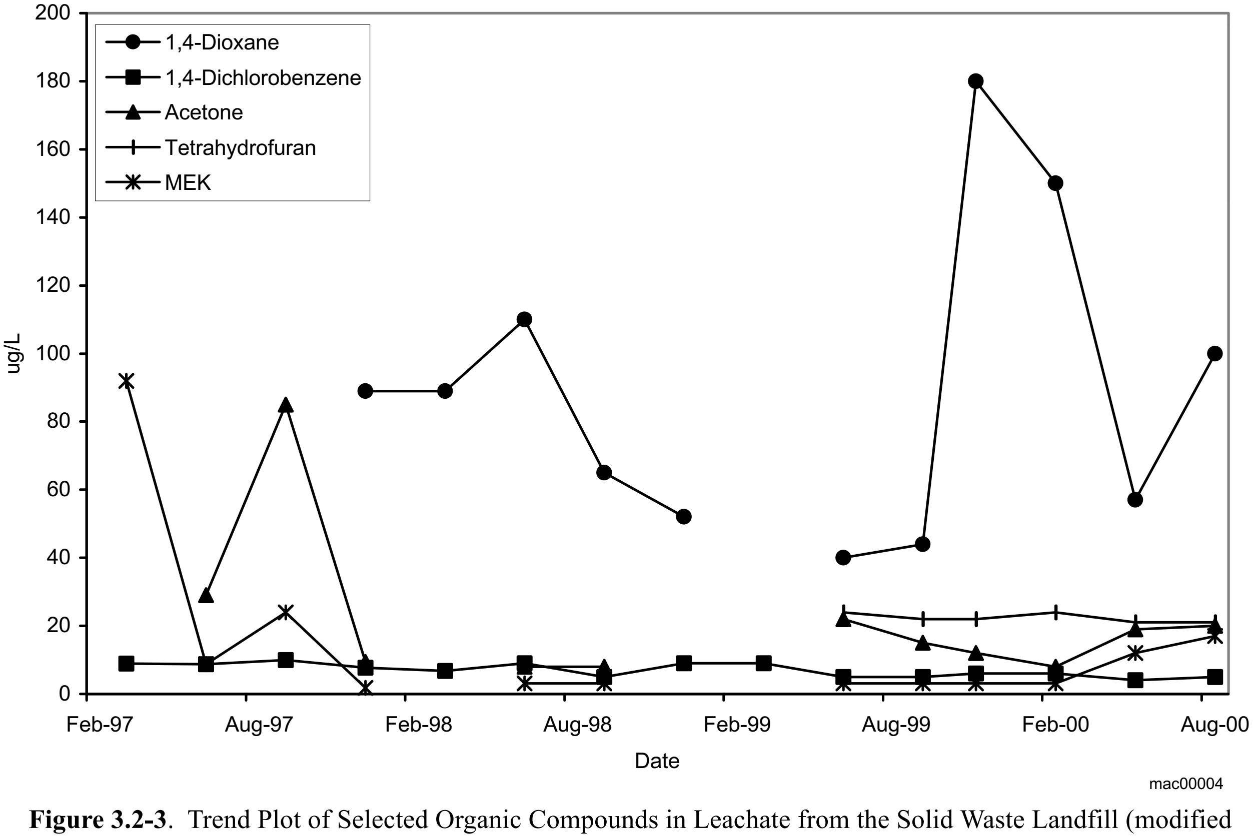


Figure 3.2-3. Trend Plot of Selected Organic Compounds in Leachate from the Solid Waste Landfill (modified from letter report FH-0002667)

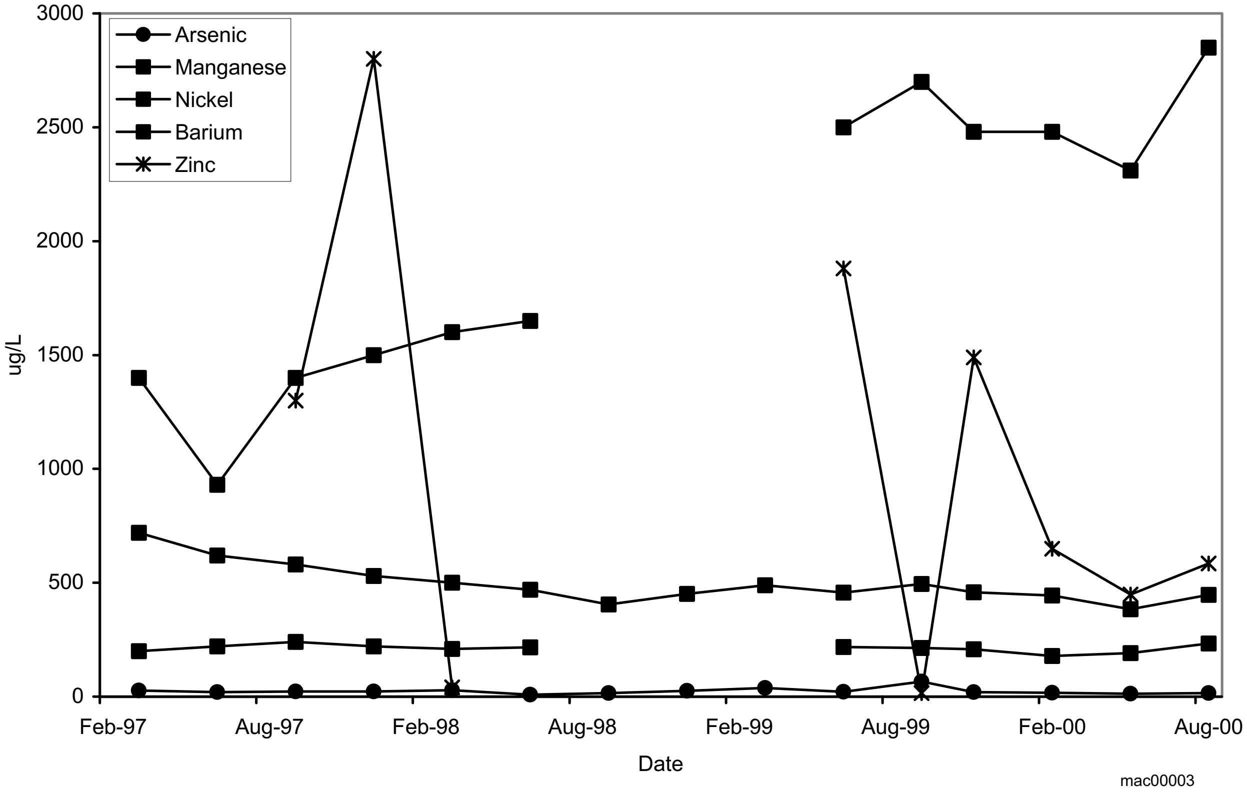


Figure 3.2-4. Trend Plot of Selected Metals in Leachate from the Solid Waste Landfill[(a)] (modified from letter report FH-0002667)

(a) Modified from letter report FH-0002667 from D. S. Kelly, Fluor Hanford, Inc. to S. T. Burnum, DOE/RL, *Submittal of Solid Waste Landfill Leachate, Soil Gas, and Groundwater Monitoring Results from First and Second Quarters, Calendar Year 2000*, dated September 20, 2000.

3.3 Technical Demonstrations

D. G. Horton

This section summarizes the activities and results of technical demonstrations done at the Hanford Site in fiscal year 2000. Technical demonstrations are designed to result in new, innovative methods for clean up and monitoring at the Hanford Site. Three technical demonstrations occurred during the fiscal year. First, a small-diameter, passive neutron tool was demonstrated to be able to detect subsurface transuranics in the vadose zone under certain conditions. Also, a small-diameter spectral gamma logging tool was demonstrated at an environmental remediation site in the 100 Areas. Both tools could result in substantial cost savings over conventional methods of characterization and monitoring.

Technical demonstrations are designed to result in new, innovative methods for clean up and monitoring at the Hanford Site. Three technologies were demonstrated in fiscal year 2000.

The Vadose Zone Transport Field Study conducted a series of tests in fiscal year 2000 to evaluate how contaminant plumes move in the vadose zone. Several geophysical methods to monitor the movement were tested. The fiscal year 2000 tests are the first of four field tests to be conducted at the Hanford Site.

3.3.1 Demonstration of a Passive Neutron Tool to Detect Transuranic-Contaminated Soil

R. G. Bauer, R. R. Randall, and R. K. Price

Bechtel Hanford, Inc., CH2M HILL Hanford, Inc., Three Rivers Scientific, and Pacific Northwest Geophysics evaluated the ability of a passive neutron tool to detect transuranic radionuclide contaminated soil in the subsurface in fiscal year 2000. The demonstration was done in two boreholes that penetrated transuranic contaminated sediment at the 216-Z-1A tile field in the 200 West Area. The tile

A small-diameter spectral gamma logging tool was demonstrated at the 100 Areas.

field and boreholes were chosen for the demonstration because a 1998 examination of spectral gamma-ray logs from one of the boreholes reveled several intervals with a 2.223-MeV photo peak that was not associated with naturally occurring or man-made radionuclides (PNNL-11978). Subsequent analysis showed that the photo peak was due to the gamma ray emitted by hydrogen when a thermal energy neutron is captured. This indicated the presence of a thermal neutron flux and hydrogen. The neutron flux was the result of alpha particles interacting with oxygen in the soil and the hydrogen was from the polyvinyl chloride casing in the borehole. The alpha particles were from high concentrations of transuranic radionuclides (plutonium-239, americium-241, and neptunium-237). Other investigations (Kos et al. 2000) found that transuranic concentrations >100 nCi/g were necessary to generate elevated passive neutron fluxes.

The demonstration had three objectives:

- test a small-diameter, bismuth-germanate gamma-ray detector designed for use with a small-diameter gamma logging system and small-diameter Geoprobe™[a] hydraulic driver
- determine whether the passive neutron detector could detect transuranic-contaminated soil at or near the 100 nCi/g threshold concentration
- determine whether a relationship exists between different transuranic radionuclides and neutron detector response in soil matrices.

A small diameter passive neutron logging tool was successfully demonstrated in a highly contaminated zone.

The gamma-logging instrument used in the demonstration was a bismuth-germanate scintillator, housed in a probe 3.8 centimeters in diameter and 0.658 meter long. The passive neutron-logging instrument was a helium-3 detector, housed in a 3.8 centimeter by 0.57 meter probe. The data collection time at each 0.15-meter depth was 100 seconds.

Boreholes 299-W18-149 and 299-W18-167 were selected for logging. Borehole 299-W18-149 was chosen because it contains a known passive neutron flux and has a large range of transuranic concentration from 150 to 8,300 nCi/g plutonium-239 and 10 to 900 nCi/g americium-241 through a depth of 3.66 meters (PNNL-11978). Borehole 299-W18-167 was chosen because concentrations of transuranic radionuclides were potentially below the detection limit of the small-diameter tools (maximum concentrations of 20 nCi/g plutonium-239 and 130 nCi/g americium-241) and the ratio of americium-241:plutonium-239 varies significantly between boreholes 299-W18-167 and 299-W18-149 (7:1 and 1:8, respectively).

3.3.1.1 Results

The logging results show that the efficiency of the bismuth-germanate detector was sufficient to detect transuranic radionuclides at threshold levels equivalent to the high purity germanium detector used to log the boreholes in 1998 for a gross gamma determination. Figure 3.3-1 shows logs from borehole 299-W18-149. Track 1 compares the bismuth germanate and high purity germanium gross gamma logs. Track 2 compares the bismuth germanate gross gamma log with the 1998 high purity germanium log of plutonium-239. The high purity germanium detector reached sufficiently high dead-time levels (>30%) between 3.5 and 4.0 meters. The electronics associated with the bismuth-germanate detector are faster responding and do not experience as much dead time (<18%). The bismuth germanate gross gamma response is scaled by a factor of 1.12 for comparison with the high purity germanium. Thus, the count rate from the small-diameter bismuth germanate is only 12% less than the count rate from the high purity germanium instrument, which was a 35% efficient detector.

(a) Geoprobe is a registered trademark of Geoprobe Systems, Salinas, Kansas.

The neutron count rate for the small-diameter passive neutron detector is shown in Figure 3.3-1, Track 3. The range of passive neutron and transuranic radionuclide concentrations is large in borehole 299-W18-149 and the magnitude of the neutron count rate is a function of the concentrations. The neutron measurements in borehole 299-W18-149 indicate an upwardly biased passive neutron detector response. This is noted by comparing the low transuranic radionuclide concentrations from 2.7 to 3.2 meters and from 7 to 7.6 meters (see Figure 3.3-1, Track 2) with the much higher passive neutron count (see Figure 3.3-1, Track 3) over the same intervals. The difference in passive neutron count rate is most likely due to neutron streaming in the air-filled borehole. (Neutron streaming is the result of the lack of scattering and attenuation of neutrons in the air, which causes a stream of neutrons up and down the borehole. The result is a detectable flux of neutrons above and below the zone containing the transuranic radionuclides.)

Figure 3.3-2 contains borehole logs from 299-W18-167. The scaling factor for Figure 3.3-2, Track 1 used to compare the bismuth germanate and high purity germanium gross gamma logs is 1.2. The comparison of the bismuth germanate gross gamma log to the americium-241 concentration is shown in Figure 3.3-2, Track 2. The 1998 high purity germanium log from this borehole identified a thin zone at 17.5 meters (57.5 feet) that is represented by the maximum sample point in the plot.

The neutron count rate shown in Figure 3.3-2, Track 3 shows much lower count rates than those encountered in borehole 299-W22-149, and the background streaming in the air-filled borehole is lower. The estimated total concentration of transuranic radionuclides is approximately 150 nCi/g. The passive neutron detector response shown in Figure 3.3-2, Track 3 indicates successful detection of transuranic concentrations just above 100 nCi/g. The vertical depth resolution is less for the neutron signal than for the gross gamma signal due to streaming in the borehole.

The bismuth germanate and high purity germanium data from borehole 299-W18-149 were analyzed to determine the dependence of the passive neutron response to increasing concentrations of transuranic radionuclides. The large range from depths of 4 to 7.9 meters was used of the analysis. Figure 3.3-3 contains a plot of passive neutron and total transuranic concentrations for each depth interval in the 4 to 7.9 meters range. The observed scatter in the data is caused largely by the streaming of neutrons in the air-filled borehole and is not caused by instrument error.

The least squares fit of these data generates an exponential function of total transuranic concentration to passive neutron count rate that is depicted by the solid line in Figure 3.3-3. Thus, the dependence of the neutron count rate is exponential to the total transuranic concentration. The intercept is near 1 count/second for the neutron count rate, which represents the minimum observable count rate in the data and is not the detection threshold. The neutron streaming makes the minimum detection threshold higher in this borehole than in borehole 299-W18-167, where concentrations of transuranic radionuclides were much lower. Thus, when high concentrations of transuranic radionuclides are encountered, higher detection thresholds will result, as expected.

3.3.1.2 Conclusions

The initial evaluation to detect transuranic radionuclides with a small-diameter geophysical logging system gross gamma probe and a passive neutron detector was successful. Two objectives of the evaluation were met:

- A small-diameter geophysical logging system passive gamma probe for detection of transuranic-contaminated soil was demonstrated.

- The passive neutron detector was demonstrated to detect transuranic-contaminated soil at or near the 100 nCi/g concentration during the logging of borehole 299-W18-167.

A third objective to determine whether a relationship exists between different transuranic radionuclide concentrations and neutron detector response was not accomplished because there were significant differences between the two boreholes that were logged. These differences introduced too many variables to support a baseline comparison of neutron responses from americium-241 and plutonium-239.

The efficiency of the bismuth-germanate detector gamma probe is comparable to the gross gamma efficiency of the high purity germanium logging instrument used in the 1998 logging of the 216-Z-1A tile field boreholes. The small-diameter geophysical logging system gross gamma probe with the bismuth-germanate detector has an improved lower-level gamma energy detection threshold and is able to detect transuranic radionuclides. However, any gamma emitting radionuclide will affect the detected gamma activity whereas only transuranic radionuclides (through alpha-neutron reaction) can affect the passive neutron detector response.

3.3.2 Small-Diameter Geophysical Logging System Demonstration

K. A. Bergstrom, T. H. Mitchell, R. R. Randall, and R. K. Price

The results of a small-diameter geophysical logging system demonstration became available in fiscal year 2000. The system was designed to collect information on the distribution of subsurface gamma-emitting radionuclides. The purpose of the demonstration was to collect information to reduce remediation costs by minimizing the amount of excavated soils from the 126-F-1 ash pit in the Hanford Site's 100 F Area (see Figure 2.7-1 for location of the ash pit). Complete results of the demonstration can be found in BHI-01352. This section summarizes those results.

The successful demonstration of a small diameter gamma-ray tool can lead to substantial reductions in remediation costs.

A truck mounted Geoprobe hydraulic driver was used for the demonstration. The logging sonde was 2.12 centimeters in diameter, 20.5 centimeters long, and contained a cesium iodide scintillator crystal. The sonde was lowered inside the push rods and measurements were taken at intervals of 15 centimeters with a count time of 200 seconds. Data were collected with a 512-channel pulse height analyzer for subsequent processing. The detector was calibrated in the Hanford Site borehole calibration models. The minimum detection limit for cesium-137 was about 4 pCi/g and for cobalt-60 about 0.5 pCi/g.

The small-diameter geophysical logging system was used to geophysically log 42 probe holes at the 216-B-2-2 ditch, 216-B-3 pond (B Pond), and the 126-F-1 ash pit. Holes created during geophysical logging were decommissioned according to Washington State Department of Ecology guidelines (WAC 173-160) by sealing with grout.

Prior to taking the small-diameter geophysical logging system to the 126-F-1 ash pit, the system was tested at the 216-B-2-2 ditch and B Pond. The objective was to test the system at known waste sites and to evaluate the Geoprobe's push capabilities under a variety of geologic conditions and with different rod sizes. Three rod sizes were used: 57 millimeters, 51 millimeters, and 45 millimeters. Each of the rod sizes was successful, and depths in excess of 6 meters were achieved in the sandy soil at 216-B-2-2 ditch and B Pond. The small rods had the most curvature problems and all broken rods occurred with the intermediate rod size. Straightness was tested by lowering steel pipes into the Geoprobe rods.

Five small-diameter geophysical logging system probe holes were logged at B Pond. The rods were pushed to depths between 4.75 and 7.87 meters. Cesium-137 was the only manmade radionuclide identified. Cesium-137 was primarily in a narrow zone approximately 2.5 to 3.5 meters below the ground surface. This agrees with laboratory data collected from another study (see Section 3.1.4). The maximum cesium-137 concentration was 488 pCi/g.

Five small-diameter probe holes were logged at the 216-B-2-2 ditch. The ditch had been covered previously with fill material, and its exact location was not known. The objective was to locate the ditch. The five holes were equally spaced at 3 meters along a line across the projected location of the ditch. Only one probe hole encountered contamination. Cesium-137 was identified at 2.3 meters below ground surface with a concentration of 11.53 pCi/g. A test pit was excavated at the site, and subsequent results suggest the pit was located in the ditch (BHI-01367).

The 126-F-1 ash pit is a solid waste site that received large amounts of coal ash sluiced with raw Columbia River water. The initial remedial action for the site was planned to remove and dispose of 287,904 cubic meters of contaminated material (BHI-01352). The site was contaminated by leaks from reactor effluent lines in the 1940s. Most of the contamination is believed to be contained north of an earthen dike built in the late 1940s. Forty-two small-diameter geophysical logging system probe holes along seven profiles were made in and adjacent to the ash pit in an attempt to better delineate contamination and potentially reduce the amount of material needing to be removed. All probe holes are believed to have penetrated through the ash and entered native soils. This is based on refusal of the push rods to extend deeper into the soil at approximately the same elevation at most probe holes. Refusal is believed to be due to a horizontally pervasive soil layer.

The small-diameter geophysical logging system demonstration identified cesium-137 and cobalt-60 in the northern part of the ash pit but found no contamination in the southern part. Based on the results of the investigation, a new volume of 148,000 cubic meters is estimated to be contaminated. This is a reduction of about 50% and can result in substantial cost savings to the 126-F-1 ash pit remediation project.

The successful demonstration of the small-diameter geophysical logging system shows that the system can enhance characterization and remediation of radionuclide contaminated waste sites at a significant reduction in cost over more conventional methods such as excavation of test pits and installation of boreholes. The technique also has potential use in determining whether pipelines have leaked and in long-term monitoring to assess the effectiveness of remedial activities.

3.3.3 Vadose Zone Transport Field Studies: Summary of Fiscal Year 2000 Activities

G. W. Gee and A. L. Ward

Vadose Zone Transport Field Studies shed light on the movement of contaminant plumes.

The scope of the Vadose Zone Transport Field Studies is to conduct a series of tests at the Hanford Site to evaluate how contaminant plumes move in the vadose zone. Planned experiments include two flow and transport tests at an uncontaminated site to simulate a tank leak, followed by two flow and transport tests in deeper Hanford formation sediment. The goal is to identify dominant transport processes, quantify parameters in the Hanford subsurface, and generate accurate and reliable databases for validation of three-dimensional numerical models of vadose zone flow and transport. These studies pertain to current data gaps related to mobile contaminants by making in situ measurements of subsurface moisture using qualified and reliable monitoring technologies. The resulting information is intended to reduce uncertainty in conceptual models of vadose zone flow and transport and to improve transport predictions at tank farms and other waste disposal sites. During fiscal year 2000, the first of four planned field tests was completed at an uncontaminated site. This section provides a summary of the fiscal year 2000 field test. The section refers to detailed companion reports by national laboratories and contractors that collaborated on the fiscal year 2000 effort. These companion contractor reports can be found on the Vadose Zone Transport Field Studies website at: http://etd.pnl.gov:2080/vadose/.

3.3.3.1 Objectives

The objectives of the Vadose Zone Transport Field Studies are to conduct controlled transport experiments at well-instrumented field sites at the Hanford Site to:

- identify mechanisms controlling transport in soil typical of Hanford's waste disposal sites
- reduce uncertainty in conceptual models
- develop a detailed and accurate database of hydraulic and transport parameters for validation of three-dimensional numerical models
- identify and evaluate advanced, cost-effective characterization methods and to assess changing conditions in the vadose zone.

3.3.3.2 Fiscal Year 2000 Test Activities

The emphasis of the Vadose Zone Transport Field Studies is to perform tests that delineate the dominant transport processes in the Hanford Site vadose zone. This includes assessment of focused flow induced by both manmade and natural features such as buried tanks or clastic dikes. The field tests are designed on a sufficiently large scale that the data can be used to verify transport predictions. Testing is approached in two phases:

1. characterization of background site conditions
2. characterization that will occur during and after the actual transport tests including assessment of the physical and chemical properties that may affect vadose zone transport processes.

A test site was selected at the 299-E24-111 experimental test well (RHO-ST-46P) located in the 200 East Area where an extensive amount of characterization has already been completed (RHO-ST-46P; NUREG/CR-5996; PNL-10860). Ward and Gee (PNNL-13263) provide details of the site selection process. Figure 3.3-4 shows the test site location relative to the location of the proposed Immobilized Low-Activity Waste Disposal Facility.

Figure 3.3-5 shows the site during instrument installation and sampling on May 31, 2000. The picture was taken from the east side of the test site looking across the bare soil of the 216-A-38 crib past the Sisson and Lu test site to the adjacent shrub-steppe vegetation in the background. The drill rig used to place advanced tensiometers and to provide core samples is shown at the left of the picture. The pink pin flags on the ground in the central part of the picture mark locations where surface electrodes were placed for geophysical logging measurements.

Figure 3.3-6 shows a plan view of the well configuration at the test site, including the location of new instrumentation and boreholes installed during the collection of soil cores. The injection well used in the fiscal year 2000 test is located adjacent to H2 and there are thirty-two 0.15-meter-diameter, schedule 40 steel cased observation wells. The details of the well placements and array configurations are provided in PNNL-13263.

3.3.3.3 Selection of Subsurface Monitoring Methods

More than 20 technologies were screened to identify those that could be used alone or in conjunction with others to reduce the uncertainty in plume delineation. With this objective in mind, a short list of possible technologies was identified based on the following criteria:

- the ability to identify key geologic features controlling water movement with a vertical resolution of 0.1 meter or better and a horizontal resolution of 1 meter or better
- the ability to locate wetting fronts and a change in water content of 0.01 $m^3\ m^{-3}$ or better with a repeatability of at least 0.01 $m^3\ m^{-3}$
- the ability to determine the shape and extent of non-gamma-emitting contaminant plumes or their surrogates
- the ability to function and produce useful results in culturally noisy environments.

The nine technologies resulting from the screening process included neutron moisture logging, advanced tensiometry/suction lysimetry, electrical resistance tomography, cross hole radar tomography, cross hole seismic tomography, cross hole electromagnetic induction, and high-resolution resistivity. Additional methods included tracers (including isotopes) and coring. The details of each of the nine methods selected and the collaborators who helped deploy the selected methods are listed in the Vadose Zone Transport Field Studies test plan (PNNL-13263).

Neutron probes were used in the past to monitor water content at the Sisson and Lu injection site (RHO-ST-46P; NUREG/CR-5996; PNL-10860). These probes are also used routinely to monitor field water contents at the Hanford Site. For the fiscal year 2000 study, water content was the primary variable measured. Water content, as determined by neutron probe logging, was also selected as the primary standard against which the other geophysical methods could be compared. Details of the calibration of neutron probes for monitoring water content at the Sisson and Lu site is provided in PNL-10860.

3.3.3.4 Test Activities

After baseline data from all methods were obtained, a series of five injections occurred. Injections began on June 1, 2000, when 4,000 liters of water were injected into the 5-meter-deep injection well over a 6-hour period. Subsequent injections occurred weekly for a period of 5 weeks. Neutron logging of 32 steel-cased wells (surrounding the injection well) occurred before the initial injection and followed each of the five injections within a day, with the exception of the injection that occurred on June 26, 2000. On that day, a wildfire burned on the Hanford Site so that neutron logging occurred on July 7, 2000. One additional 4,000 liter injection was made on September 18, 2000. This injection was made in order to obtain in situ hydrologic properties using a combination of pressure measurements and neutron probe water content measurements at the same depth.

Reports for each of the methods are provided in the companion collaborator reports displayed on the Vadose Zone Transport Field Study web page that can be found at http://etd.pnl.gov:2080/vadose/.

3.3.3.5 Preliminary Modeling of Fiscal Year 2000 Vadose Zone Transport Field Studies Injection Test

The fiscal year 2000 test was simulated using STOMP (Subsurface Transport Over Multiple Phases) a multiphase (unsaturated) flow and transport code developed at Pacific Northwest National Laboratory (PNNL). A conditional simulation of the five injections was made using methods developed by Rockhold et al. (1999).

The simulations were conditioned on the initial water contents and the water retention characteristics of Hanford Site soils that are similar, but not identical, to those soils found by Sisson and Lu (RHO-ST-46P).

The model results describe the general flow depths and directions of the plume but do not completely describe the extent of the lateral spreading of the plume. The improved and more site-specific hydraulic property data collected during the field test may be helpful in improving the prediction of the lateral spreading. These estimates will be updated in fiscal year 2001.

3.3.3.6 Summary

PNNL and collaborators conducted the first of four field tests at the 299-E24-111 injection site in the 200 East Area of the Hanford Site in fiscal year 2000. Nine methods were tested to document a vadose zone plume produced from injecting a total of 20,000 liters of Columbia River water into a 5-meter-deep injection well, in five increments of 4,000 liters each over a period of 5 weeks. Water contents, obtained by neutron probe logging techniques, were used as baseline measurements upon which other geophysical measurements were compared. Prior to completing the test, the development of the water plume was simulated using conditional simulation techniques (Rockhold et al. 1999). The conditional simulation relied on estimates from hydrologic characterization of a limited number of samples previously taken from the site. While the computational results were in qualitative agreement with field measurements, they did not predict the observed lateral extent of the plume.

Researchers used various geophysical techniques, lysimeters, tracer tests, core samples, and a computer model to study the movement of contaminated liquid through the vadose zone. Each of nine methods tested was successful to some degree. Future work will build upon these results.

All methods were successful to some degree in identifying changes in subsurface water contents (or pressures) resulting from the five injections. Electrical resistance tomography showed promise in delineating the shape of the entire plume. However, the interpretation of signal responses was difficult, mostly because of interference between the electrical signal and the dense “forest” of more than 35 steel-cased wells. Apparent changes in electrical resistivity were observed at depths of 18 meters but on closer inspection, real changes were confined largely to depths of 6 and 12 meters in conformance with water content changes observed by neutron probe logging.

Cross-borehole radar was successful in identifying a section of the plume, and provided a very good time lapse of the redistribution of one injection. The results compared well with neutron probe logging; however, the results were limited by the relatively narrow spacing with plastic access tubes. Tests with electromagnetic induction and high-resolution resistivity were marginally successful in showing changes in electrical properties but the surface measurements were unable to provide sufficient vertical resolution to identify the depth of penetration of the wetting front, an important parameter for plume migration investigations. Seismic monitoring was successful in delineating stratigraphy at the site. Peak concentrations of isotopic tracers (e.g., deuterium) sampled from vertical cores matched well with the bromide tracer data taken from adjacent cores and indicated the peak concentrations of the tracer plume. Isotopic tracer distributions also confirmed that none of the new water injected penetrated the impeding layer at the 12-meter depth. Advanced tensiometers were only marginally successful in delineating the pressure profiles due to a series of pressure transducer failures in about half of the units. The nonfunctioning tensiometers are currently being repaired.

Work in fiscal year 2001 will focus on a thorough analysis of the data collected in fiscal year 2000 and another series of field experiments. Thus far, the use of mathematical models has been limited to the forward prediction of wetting front distributions using conditional simulations. In the first quarter of fiscal year 2001, the scope of the modeling component will be expanded to obtain effective flow and transport parameters using two-dimensional inverse procedures with STOMP.

Field activities will focus on using the most successful geophysical techniques and isotopic tracers in a series of hyper-saline (≥1 molar concentration) transport experiments. A series of injections will be made in a fashion similar to the fiscal year 2000 experiments and the salt plume tracked with selected geophysical tools and coring.

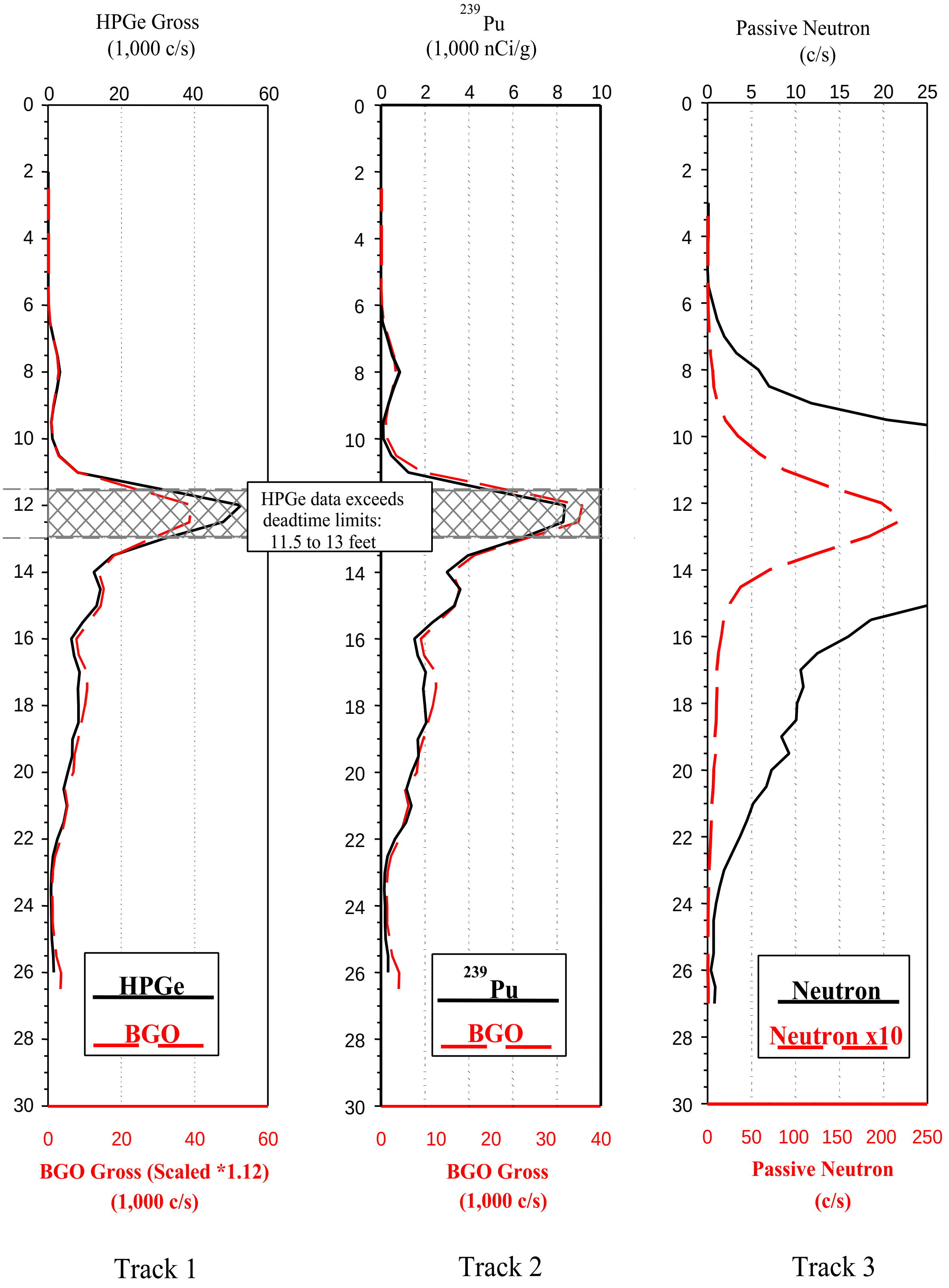


Figure 3.3-1. Small Diameter Log Data compared to 1998 High-Purity Germanium Data for Borehole 299-W18-149

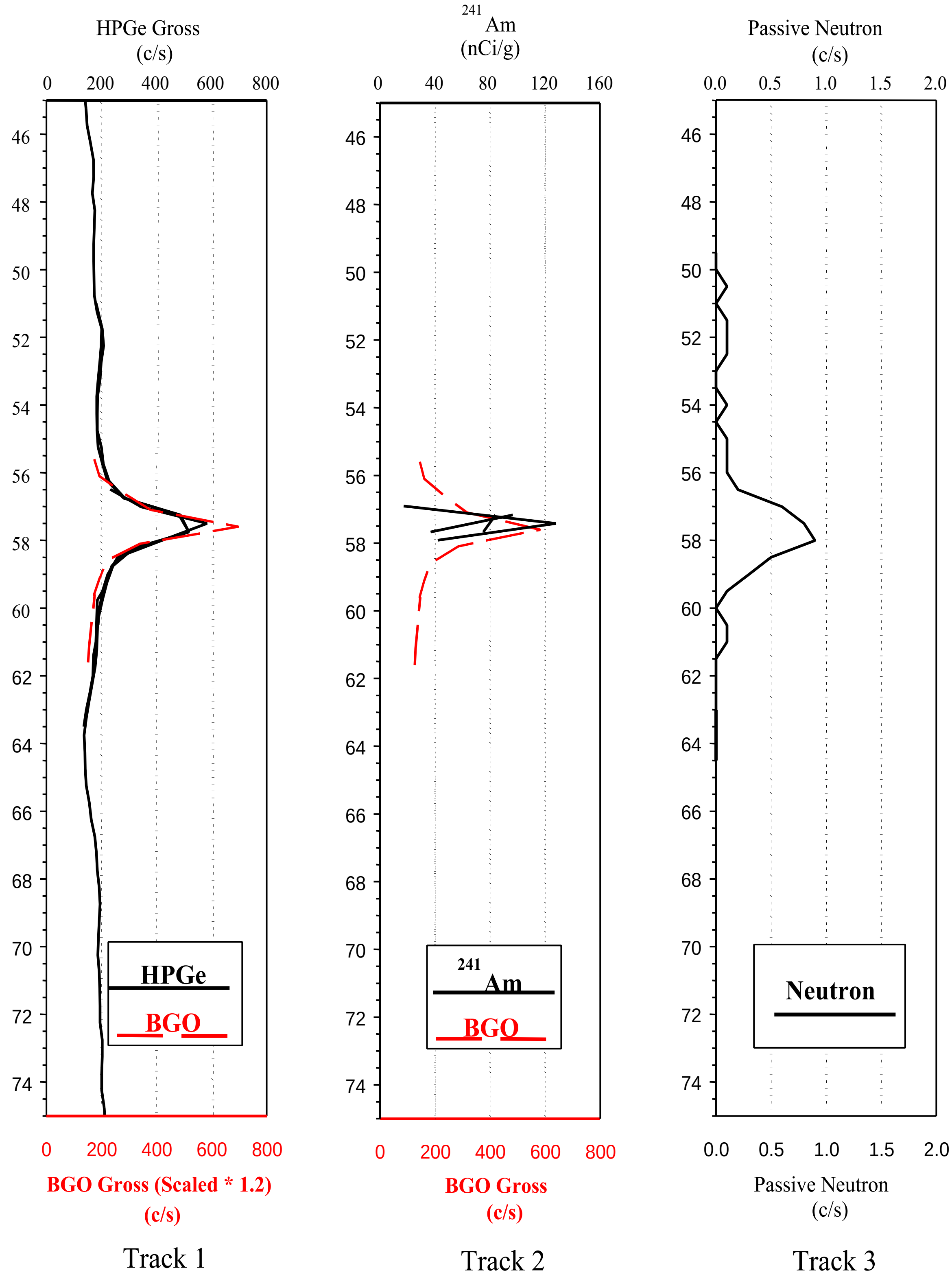


Figure 3.3-2. Small Diameter Log Data compared to 1998 High-Purity Germanium Data for Borehole 299-W18-167

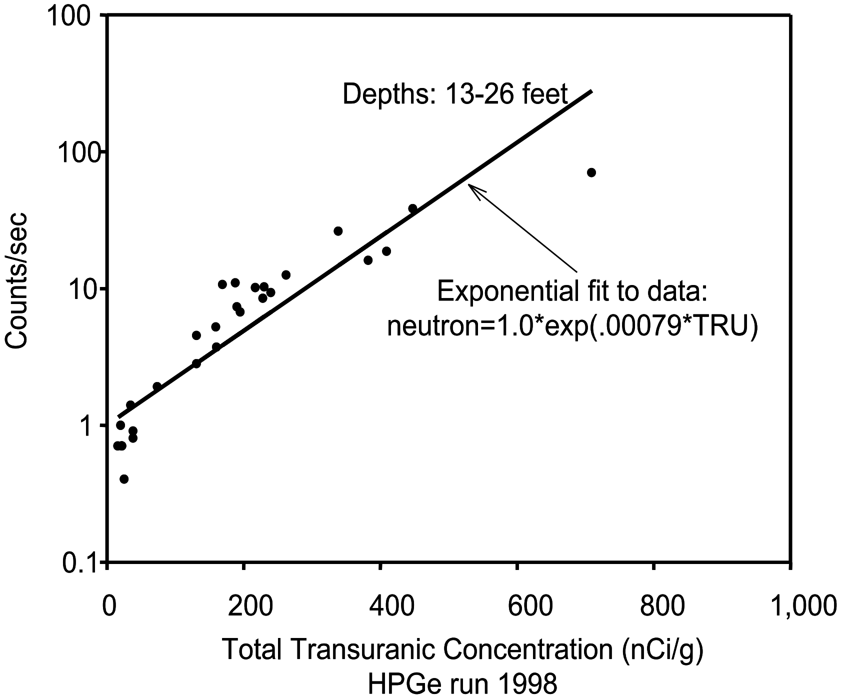


Figure 3.3-3. Data from Borehole 299-W18-149 showing the Passive Neutron Response to Total Transuranic Radionuclides

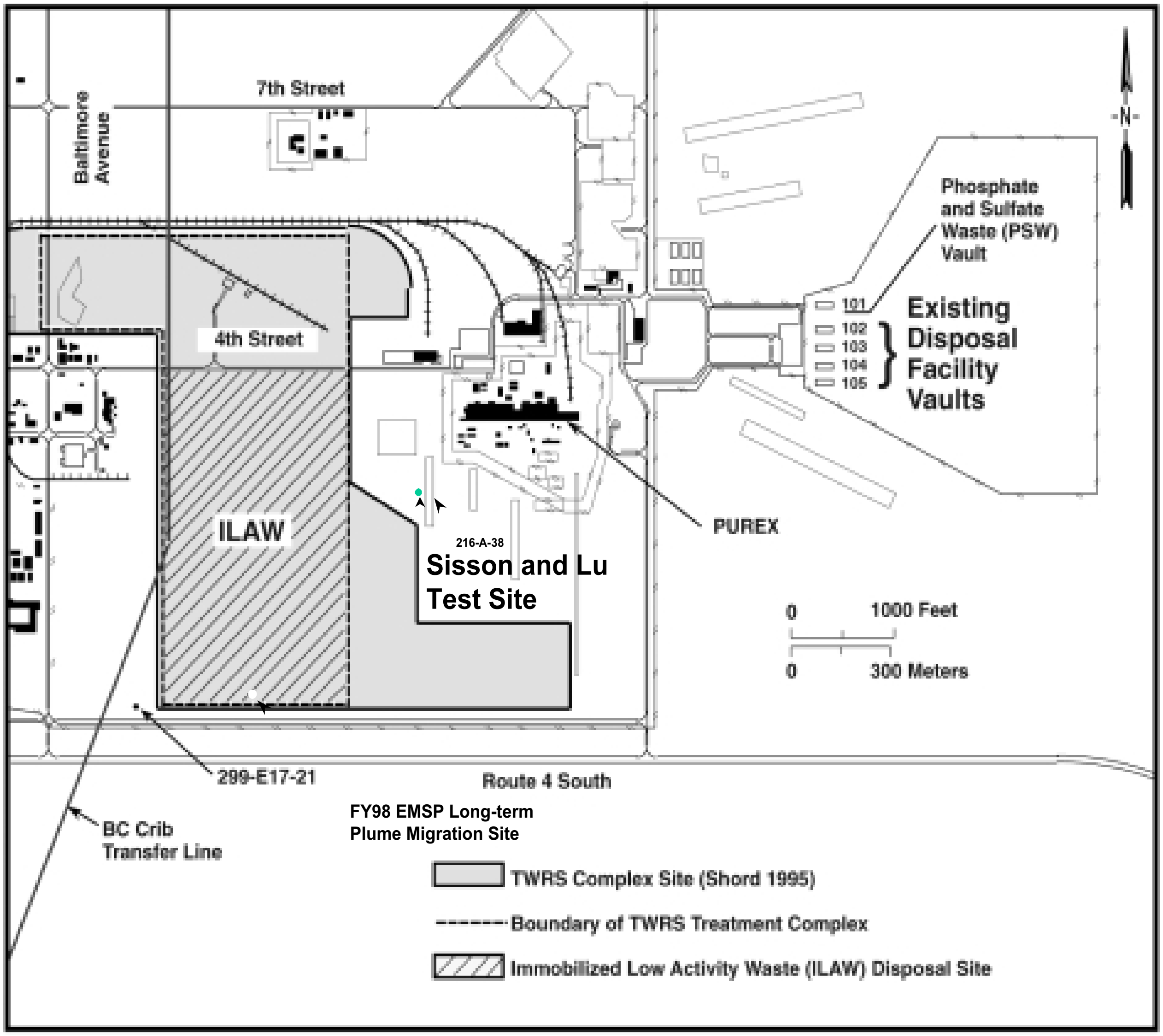


Figure 3.3-4. Schematic of Test Site Location. The site was used by Sisson and Lu (RHO-ST-46P) to conduct the first controlled vadose zone transport study at the Hanford Site and is now designated as 299-E24-111, Experimental Test Well Site, in the Hanford Waste Information Data System (WIDS).

Figure 3.3-5. Instrumentation and Sampling of the Vadose Zone Transport Field Study Test Site on May 31, 2000

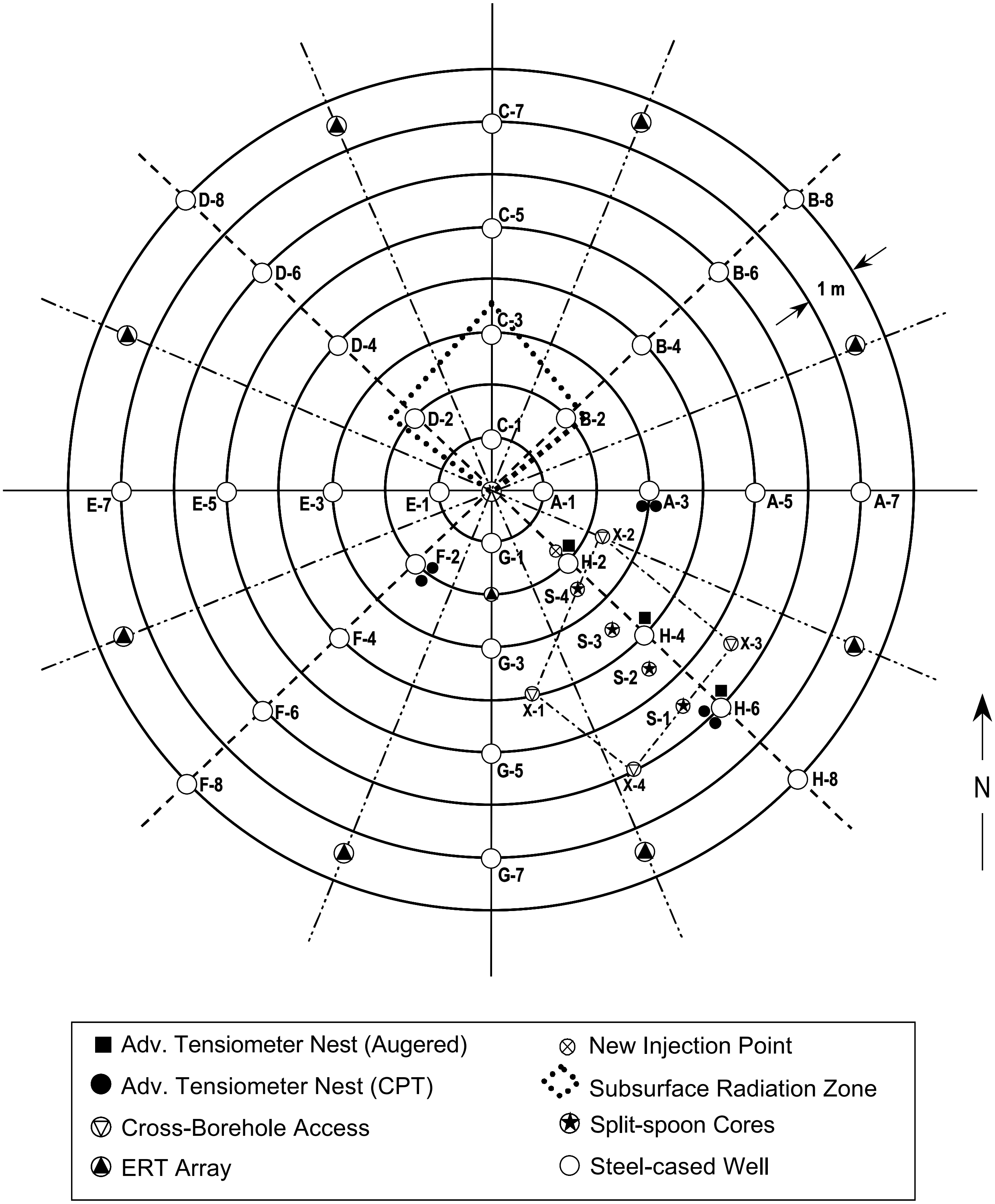


Figure 3.3-6. Plan View of Fiscal Year 2000 Test Site Showing Locations of Access Tubes, Vertical Electrode Arrays, Injection, and Core Sampling Points

4.0 Groundwater Modeling

Groundwater modeling is conducted to predict future groundwater conditions and the movement of contaminants through groundwater to the accessible environment. The Hanford Groundwater Monitoring Project consolidates groundwater modeling activities that address site-wide problems to eliminate redundancies and promote consistency. Section 4.1 provides information on the ongoing consolidation process and specific applications of the consolidated groundwater flow and transport model. Other groundwater models are used for problems at a local scale (i.e., less than about 10 kilometers) and for specific applications that are not suitable for the consolidated model. Section 4.2 describes local-scale modeling performed by the environmental restoration contractor to design and evaluate pump-and-treat systems for the remediation of contaminated groundwater. These models were used to describe the capture and injection zones for extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat systems at different times. Section 4.3 describes local-scale modeling of groundwater movement in the zone of interaction between the Hanford Site unconfined aquifer and the Columbia River at the 100 H Area. The model calculates groundwater pathlines to illustrate the direction and rate of flow within the zone of interaction near the river.

Computer simulations of groundwater help predict future groundwater conditions and contaminant movement to the environment. One site-wide model and several local-scale models were used in fiscal year 2000.

4.1 Consolidated Site-Wide Groundwater Model

P. D. Thorne and S. K. Wurstner

Until recently, multiple versions of site-wide groundwater flow and contaminant transport models were maintained and used by contractors at the Hanford Site. In response to both internal and external recommendations, the U.S. Department of Energy (DOE) initiated a site-wide groundwater model consolidation process in 1998. Additional information on the consolidation process is available in last year's annual groundwater report (PNNL-13116) and in DOE/RL-2000-11.

A major objective of the consolidation process is to strengthen the technical basis of groundwater flow and transport predictions for the Hanford Site by identifying and quantifying uncertainty. The method proposed to estimate uncertainty is to develop alternative conceptual models that encompass the identified uncertainties, then apply a transient inverse calibration to each model based on historical observations of water-level changes and contaminant movement. In fiscal year 2000, the consolidation effort focused on (1) identifying and characterizing major uncertainties in the current conceptual model and (2) performing a transient inverse

Groundwater models were used at a local scale to assess and improve the performance of groundwater pump-and-treat systems designed to contain contamination within the unconfined aquifer system.

calibration of the existing site-wide model. These two activities are summarized in the following subsections, followed by descriptions of three applications of the existing consolidated groundwater model.

Objectives of Hanford Site Groundwater Model

A computer model of Hanford Site groundwater must be able to

- predict impact of Hanford activities on groundwater
- assess performance of waste-disposal facilities
- predict movement of contaminants
- evaluate remediation strategies.

4.1.1 Addressing Uncertainty in the Consolidated Groundwater Model

Public and external review of prior site-wide groundwater models have helped identify components of the current conceptual model whose uncertainty warrant further investigation (DOE/RL-2000-11). Three categories of uncertainty in hydrologic modeling are (1) uncertainty resulting from natural variability, (2) uncertainty in the model structure, and (3) uncertainty in the model parameters. Alternative implementations of the conceptual model can be developed and run and results compared to quantify the sources of uncertainty resulting from model structure. Model structure includes the definition of boundary conditions, identification of hydrogeologic units, and hydraulic property zonation (i.e., delineation of areas with consistent hydraulic properties). The following components of uncertainty in model structure were identified:

- interaction of the unconfined aquifer system with the uppermost basalt-confined aquifers
- additional recharge from surface runoff along basalt subcrops (Gable Butte and Gable Mountain, Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills)
- low-frequency recharge events originating in upland areas west and southwest of the Hanford Site
- transient nature of the Columbia and Yakima Rivers
- the effect of irrigation north and east of the Columbia River
- processes (e.g., direct evaporation, vadose zone transport, etc.) that delay and/or reduce the volume of artificial recharge from major wastewater discharges
- distribution and extent of major hydrogeologic units, particularly low permeability mud units within the Ringold Formation
- the effect of geologic faults within the unconfined aquifer system
- the effect of alternative zonation patterns of hydraulic properties based on interpretation of past geologic despositional history and major geologic facies and sediment characteristics
- the effect of alternative methods for incorporating dispersion in regional contaminant transport.

4.1.2 Transient Calibration of the Consolidated Model

PNNL performed a transient calibration of the site-wide groundwater flow model using historical water-level data. The transient calibration used information on the rising and falling water table to determine the distribution of aquifer hydraulic parameters that produces the best match to water-table changes.

During fiscal year 2000, a transient calibration of the site-wide groundwater flow model was performed using over 100,000 hydraulic head measurements taken in about 1,200 wells at the Hanford Site since 1943. Details on the methodology and results of this calibration are presented in PNNL-13447. Prior to 1990, water-table elevations increased significantly because of wastewater discharged from Hanford Site operations. Since 1990, the water table has declined because these discharges were largely curtailed. The transient calibration used this information to determine the distribution of aquifer hydraulic parameters that produces the best match to observed changes in the water table. The inverse calibration was performed using UCODE, a universal inverse modeling code developed jointly by the U.S. Geological Survey and International Groundwater Modeling Center of the Colorado School of Mines. The transient calibration improved the ability of the model to simulate historical water-table changes over the entire Hanford Site, particularly near major wastewater discharge facilities in the 200 West Area. However, estimates of the hydraulic parameter, specific yield, which is related to the storage capacity of the aquifer, were not consistent with other data. The transient calibration may have produced incorrect specific yield estimates because the flow of water between the unconfined aquifer system and the underlying basalt-confined aquifer is not accounted for in the current model. The interaction between the aquifer systems will be included in a future version of the consolidated groundwater model.

4.1.3 Modeling to Support the Innovative Treatment Remediation Technology Project

Groundwater modeling was performed in support of the Hanford Site carbon tetrachloride Innovative Treatment Remediation Technology Project. As a first step toward implementing innovative technologies to remediate this carbon tetrachloride source, this modeling was performed to estimate the potential impact at an assumed compliance boundary, which is ~5,000 meters from the source. The primary results of the modeling gave upper and lower estimates for the amount of carbon tetrachloride that will most likely result in groundwater concentrations being over 5 µg/L at the boundary. The relative influence of the various modeling parameters was also examined.

Groundwater modeling provided an indication of the potential impact of the 200 West Area carbon tetrachloride source at an assumed compliance boundary, ~5,000 meters away from the source. The model gave upper and lower estimates for the amount of carbon tetrachloride that will most likely result in groundwater concentrations being over 5 µg/L at the boundary.

The modeling was based on the assumption that ~750,000 kilograms of carbon tetrachloride were discharged to the soil in the Z crib area. Previous work has shown that of this 750,000 kilograms, about 65% cannot be accounted for. Therefore, modeling was performed using 65%, 30%, 10%, and 1% of the 750,000 kilograms as possible source amounts of carbon tetrachloride that could reach the groundwater. Approximately 1 to 2% of the original carbon tetrachloride inventory currently exists in the distal plume based on averaged carbon tetrachloride groundwater measurements. The modeling simulations conducted for this study examined the migration of carbon tetrachloride from the source area to the compliance boundary.

The carbon tetrachloride transport was conservatively simulated within a stream tube 1,000 meters wide by 5,000 meters long under one-dimensional groundwater flow conditions. Regional flow modeling results using the Hanford Site consolidated groundwater model flow grid provided groundwater velocity estimates for the simulation. The modeling produced 1,000 Monte Carlo simulations that were analyzed to provide an estimate of the portion of the source area needing remediation. Selected simulations were then modeled with the three-dimensional sitewide consolidated model to check the one-dimensional model results.

The conclusions drawn from the modeling are:

- If 1% of the discharged carbon tetrachloride is all that ever reaches the groundwater, then it is likely the highest concentration of carbon tetrachloride to arrive at the compliance boundary will not exceed the compliance concentration of 5 µg/L. However, it is possible the compliance concentration would be exceeded if the actual aquifer porosity, sorption coefficient, and natural attenuation rate for carbon tetrachloride correspond to the lower values used in this study.
- If 10% or more of the discharged carbon tetrachloride reaches the groundwater, then it is likely that the concentration of carbon tetrachloride eventually arriving at the compliance boundary will exceed the compliance concentration unless source removal efforts are used.
- There is a breakpoint between 1% and 10% of the discharged inventory that defines the amount of carbon tetrachloride in the source at which source removal would be required to avoid exceeding the compliance concentration at the compliance boundary.

- Because source inventory remaining appears to be the quantity driving the amount of site cleanup required for compliance, source inventory characterization is needed to resolve compliance issues.

4.1.4 Modeling to Support an Assessment of the Immobilized Low-Activity Waste Disposal Facility

Groundwater flow and transport calculations were done to support the performance assessment of the Immobilized Low-Activity Waste Disposal Facility (Bergeron and Wurstner 2000). Vitrified waste from Hanford's waste tanks will be buried at this site in the southern 200 East Area. The consolidated site-wide model and supporting local scale models were used to evaluate the impact from the transport of contaminants through groundwater to a hypothetical well 100 meters downgradient of the disposal facilities and to the Columbia River. These models generated well-intercept factors, or dilution factors, from a given areal flux of a hypothetical contaminant released to the unconfined aquifer from the Immobilized Low-Activity Waste Disposal Facility for two waste-disposal options: (1) a remote-handled trench concept and (2) a concrete-vault concept. The well-intercept factor is defined as the ratio of the concentration at a well location in the aquifer to the concentration in infiltrating water entering the aquifer. These well-intercept factors are being used in conjunction with calculations of released contaminant fluxes through the vadose zone (see Section 3.1.5) to estimate the potential impacts from radiological and hazardous chemical contaminants within the Immobilized Low-Activity Waste Disposal Facility at compliance points.

Groundwater flow and transport calculations supported the performance assessment for the Immobilized Low-Activity Waste Disposal Facility in the 200 East Area. Results were used to evaluate the impact from the transport of contaminants at a hypothetical well 100 meters downgradient of the disposal facilities and at the Columbia River.

Transport model calculations for a base case considered a six trench configuration representing a remote-handled trench concept and were based on local-scale flow conditions postulated after site closure. These conditions were developed based on boundary conditions provided by the steady-state simulation of post-Hanford flow conditions performed with the site-wide consolidated model.

Regional and local-scale flow model results for the base case showed that groundwater beneath the Immobilized Low-Activity Waste Disposal Facility moves in a southeasterly direction and then in an easterly direction for ~15 kilometers before reaching the Columbia River. For the six remote-handled trench configuration examined in the base case, predicted concentration profiles reach steady state within about 10 years after the start of source release at the water table.

Concentration levels, based on an assumed infiltration rate of 4.2 mm/yr and an input concentration of 1 Ci/m^3 at the source release area, reach a maximum value of 1.1×10^{-3} Ci/m^3 at a hypothetical well 100 meters downgradient of the site and reach 7.8×10^{-4} Ci/m^3 at a well 1 kilometer downgradient. For the assumed recharge rate (4.2 mm/yr), the calculated well-intercept factors would be 1.1×10^{-3} at the 100 meter well and 7.8×10^{-4} at the 1 kilometer well.

Uncertainties in the following key factors affecting calculated well-intercept factors were investigated with sensitivity analyses:

- source-release area at the water table
- vertical position of the post-closure water table and the associated direction of groundwater flow
- lateral position of the Hanford-Ringold formation contact
- hydraulic properties of Hanford and Ringold formation sediment.

Results of these analyses suggested that calculated well-intercept factors are linearly related to the source-release area over the range of assumed surface areas of release. Calculated well-intercept factors were also affected by the long-term predicted position of the water table and the resulting estimated distribution of hydraulic properties underlying the Immobilized Low-Activity Waste Disposal Facility. The proposed location of the disposal facility is underlain by an ancestral channel of the Columbia River that is filled with highly permeable sediment of the Hanford formation. For the predicted water-table position used in this analysis, the current interpretation places the contact between the Hanford formation and the underlying, less permeable, Ringold Formation along the southern edge of the proposed disposal facility area.

Assumptions made about long-term regional natural recharge rates and boundary conditions are uncertain and can also change the predicted position of the water table and the position of the contact between the Hanford and Ringold Formation sediments. Higher assumed rates of recharge can increase the water-table elevation and saturate more of the Hanford formation, leading to lower calculated well-intercept factors (i.e., higher levels of dilution) for releases from the Immobilized Low-Activity Waste Disposal Facility.

4.1.5 Modeling to Support the System Assessment Capability (Rev. 0)

The System Assessment Capability is being developed under the Groundwater/Vadose Zone Integration Project as a tool to predict cumulative site-wide effects from all significant Hanford Site contaminants. The tool includes components for waste site inventories; release mechanisms; transport through the vadose zone, groundwater, and Columbia River; and impact on human health, the environment, local economies, and cultures. The initial implementation of the System Assessment Capability, called SAC (Rev. 0), will demonstrate whether an assessment with the proposed scope and at the scale of the Hanford Site and Columbia River can be performed and yield the desired information. It is considered a proof-of-principle assessment. A detailed description of the System Assessment Capability is provided in BHI-01365.

The System Assessment Capability is a tool to predict cumulative site-wide effects from all significant Hanford Site contaminants. In fiscal year 2000, the groundwater project compiled historical data to support initial history-matching runs of the model.

Current plans call for the groundwater component of the SAC (Rev. 0) to use a simplified implementation of the consolidated site-wide groundwater model to simulate contaminant transport through the saturated zone. A simplified model is needed to reduce run times so that many different realizations (i.e., cases with varying parameter values) can be modeled for each contaminant. The different realizations will address uncertainty in the inventories and selected analysis parameters. Contaminant inputs to the groundwater component will come from the vadose zone component and, in the case of injection wells, directly from the waste inventory component. During fiscal year 2000, historical data were compiled to support initial history-matching runs of the groundwater component and the entire System Assessment Capability tool. History matching comparisons of the full consolidated model and the simplified version will demonstrate whether the simplified model is accurate enough to meet the objectives of the System Assessment Capability.

4.2 Modeling to Support Pump-and-Treat Operations

W. J. McMahon

Groundwater models were used at a local scale in operable units in the 100 and 200 Areas to assess and improve the performance of groundwater pump-and-treat systems designed to contain contamination within the unconfined aquifer system. These models evaluated system performance and overall progress toward remediation objectives and goals, including evaluating different extraction and injection well configurations, predicting effects of different operational and pumping schedules, assessing extent of hydraulic influence, and evaluating groundwater travel times and extent of the capture zone.

Modeling was conducted using Micro-FEM©, a two-dimensional finite-element code with a finite difference algorithm to calculate flow in the third dimension. The MicroFEM© model was used to evaluate the hydraulic effects of the remedial action sites in the 100 K, 100 N, 100 D, 100 H, and 200 West Areas that are addressing the following contaminants of concern:

- 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.

Groundwater remediation at each of the operable units listed above is described in the appropriate subsections of Chapter 2. Additional information on pump-and-treat operations and figures showing the modeled capture zones are presented DOE/RL-99-97 and DOE/RL-2000-01.

4.2.1 Model Results for 100-KR-4, 100-HR-3, and 100-NR-2 Operable Units

Modeling the pump-and-treat systems in the 100 Areas has helped determine optimal locations for pumping wells to improve plume capture.

Numerical modeling for these pump-and-treat operations provides a quantitative method to evaluate the hydraulic capture and optimize the pumping rates of the pump-and-treat system wells. The models are intended to provide a relative measure of system performance. The models use steady state analysis to evaluate the pump-and-treat systems, thus omitting changes caused by the fluctuating river stage. To compensate and ensure a conservative and reasonable evaluation of the pump-and-treat system performance, the analyses were conducted using boundary conditions representative of the November/December time frame. The November/December time frame corresponds to the low flow time of year in the Columbia River, when the sustained groundwater discharge to the river is greatest. During other times of the year, when the river stage is higher, the extraction wells intercept a higher percentage of the flow, but some of that water may have originated from the river or outside the targeted plume area. Evaluating the hydraulic capture of the pump-and-treat systems during the period of the highest sustained groundwater flow to the river provides the most reliable and defensible assessment of the pump-and-treats' performance. For additional discussion on the 100-KR-4 and 100-HR-3 models, refer to DOE/RL-2001-01. For additional discussion on the 100-NR-2 model, refer to DOE/RL-99-79.

Results of the modeling indicated that pump-and-treat extraction wells intercepted groundwater flowing through ~76% the targeted area in the 100-KR-4 Operable Unit (DOE/RL-2001-01). Because of the persistently high chromium concentration levels in compliance well 199-K-112A and the location of this well outside of the overall capture zone, that well is being equipped to become an extraction well. The well is expected to begin operating in 2001. Optimizing the pumping rates and adding well 199-K-112A increases the capture to ~84%. Much of the uncaptured groundwater passing through the targeted plume area occurs in a culturally sensitive area. The decision to add wells to the network must balance the benefits of improved capture with the consequences of disturbing the sensitive area.

The 100-HR-3 Operable Unit includes both 100 D and 100 H Areas. At 100 D Area, the model results indicated that the extraction wells intercepted groundwater passing through more than 90% of the original targeted plume area. The extraction wells remove groundwater with relatively high concentrations that originated from the retention basins, trenches, and cribs. However, the depiction of the chromium plume geometry at 100 D Area has undergone great change during the last few years, and the plume may extend more laterally than initially shown (DOE/RL-96-84). Methods to address the larger plume are currently being evaluated. At 100 H Area, the model results indicated that the extraction wells intercepted groundwater passing through ~86% of the original targeted plume area (DOE/RL-2001-01). The report predicted capture through ~98% of the original targeted plume area when extraction well 199-H4-65 began operating, which occurred in January 2000.

At the 100-NR-2 Operable Unit during the same time, the model results indicated that the pump-and-treat system was reducing the net groundwater flow to the Columbia River through the targeted plume area by ~96% (DOE/RL-99-79). This estimate was developed using the steady state groundwater flow and contaminant transport model developed for the performance evaluation report (DOE/RL-95-110). The model results indicated a 96% reduction in strontium-90 exiting the river boundary along the river when the extraction wells were operating compared to modeled no-action conditions. Analysis of drawdown and flow field data included in the performance evaluation report showed good agreement between the measured and modeled results. Flow line analysis using measured water level data showed no flowlines bypassing the extraction wells. Therefore, it was concluded that the system performed according to the model predictions. No data or analyses since then appear to alter that conclusion. The current modeling is intended to show that the current flow lines have not changed from those presented in the performance evaluation report.

4.2.2 Model Results for 200-UP-1 Operable Unit

Numerical modeling for this pump-and-treat operation was performed to evaluate effectiveness in containing the targeted area of the technetium-99 and uranium plumes and to track the progress of remediation. The model was developed during the design phase of the pump-and-treat and then revised when the injection well went off-line in 1997. Comparisons of the model results to measured data were presented in DOE/RL-98-38. The purpose of the modeling was to demonstrate, in conjunction with the measured drawdown, water level, and contaminant data, that the pump-and-treat system achieved the remedial action objectives to contain the targeted plume area and prevent its migration.

The modeling results indicated that the steady state capture flow lines extend outside and contain the entire targeted area of the plume (see DOE/RL-99-79). Thus, the one extraction well 299-W19-39 appears capable of capturing and containing the entire high concentration area of the technetium-99 and uranium plumes. The model results have also been used to track the progress of the pump-and-treat system by estimating the area where groundwater has been removed by the extraction well. By the end of September 2000, the extraction well had removed at least one pore volume from the entire targeted plume area. The plume capture efficiency was ~55%, which is the ratio of the amount of water removed from the target area of the plume to the total amount of water removed from the aquifer. Groundwater remediation at the 200-UP-1 Operable Unit is described in more detail in Section 2.8.3.9. For additional discussion on the 200-UP-1 model, refer to DOE/RL-98-38 and DOE/RL-99-79.

Modeling results for 200 West Area pump-and-treat systems indicates that they are capturing the portions of the plumes for which they were designed.

4.2.3 Model Results for 200-ZP-1 Operable Unit

Numerical modeling also was performed to evaluate the remedial action at this pump-and-treat operation. The modeling results show the capture flow lines of the extraction wells extending outside the targeted carbon tetrachloride plume area and converging into the areas between the wells (DOE/RL-99-79). Thus, modeling indicates that the pump-and-treat extraction wells contain the entire high concentration (greater than 4,000 µg/L) area of the plume. The numerical modeling predictions indicate that pump-and-treat operations have removed 1 pore volume of water from the upper 15 meters of the aquifer from an area of ~163,400 square meters around the northernmost extraction wells. The three southernmost extraction wells began operating in 1997, and the modeling results indicate that wells 299-W15-32, 299-W15-36, and 299-W15-37 have removed 1 pore volume of water from an area of ~20,500, ~35,800, and ~24,000 square meters, respectively, around those wells. Groundwater remediation at the 200-ZP-1 Operable Unit is described in more detail in Section 2.8.1.6. For a more detailed description of 200-ZP-1 modeling, refer to BHI-00952-02 and DOE/RL-99-79.

4.3 Modeling of Groundwater Movement Near the Columbia River

M. P. Connelly

A two-dimensional model for water movement in the zone of interaction between the Hanford Site unconfined aquifer and the Columbia River was prepared during fiscal year 2000 within the Groundwater/Vadose Zone Integration Project (Science and Technology Task HVSTP1 XS10). The model calculates pathlines to illustrate the direction and rate-of-flow within the zone of interaction, using Pacific Northwest National Laboratory's "Subsurface Transport Over Multiple Phases" (STOMP) code (PNNL-11218). Graphics software was then used to animate water movement, to show how the flow field responds to the fluctuating river stage over one complete seasonal cycle of the river. Visualizing the patterns of groundwater flow in the zone of interaction helps to understand where contaminants enter the river bed and how they are diluted by river water entering the aquifer at high river stage.

Near the Columbia River, river water infiltrates the banks and mixes with groundwater that approaches the channel. A two-dimensional model for water movement in this zone of interaction was developed for the 100 H Area.

The model was developed for the zone of interaction at the 100 H Area. A three-dimensional spatial framework was constructed using existing geologic information, land topography, and river channel bathymetry estimated from unpublished U.S. Army Corps of Engineers data collected in 1986. A cross section oriented perpendicular to the river was then selected to best represent the zone of interaction. Hourly water-level data from several monitoring wells and the 100 H river station were compiled for 1998, which represents a typical water year, and used to calculate the flow field, assuming published values for aquifer hydraulic properties.

4.3.1 Model Features

Figure 4.3-1 shows one hourly frame of the animation and provides an example of the abundant information generated by the model. Each frame contains four subpanels. The numbers in the following text refer to the yellow-shaded text on this figure. Note: The entire animation sequence is available on CD-ROM upon request to the Groundwater/Vadose Zone Integration Project.

Panel 1 – The uppermost panel on Figure 4.3-1 is a portion of the modeled area that shows the near-river groundwater flow field at the time indicated (1a). The left vertical axis is elevation in meters and the horizontal axis is distance in meters. Colored areas (1b) describe pore water velocities and white arrows (1c) indicate the direction of water flow. Lines of equal hydraulic potential are shown as black contours (1d) and hydraulic head elevations as numbers in white inset boxes (1e). The top of the unconfined aquifer (i.e., water table) is shown by the dark blue line (1f) above the flooded contours. The capillary fringe is portrayed by the light blue lines (1g) that indicate the percentage of pore space that is saturated.

The Columbia River (1h) rises and falls during the animation. Red lines (1i) show the path followed by a hypothetical water parcel from its starting point to the currently-displayed flow field. Red marker boxes indicate 4-week intervals of travel. Well 199-H4-63, which is used for calibrating the model, is shown by the black vertical line (1j). Gray vertical lines and the gray line stair-stepping along the riverbed represent planes across which water volume flux is calculated.

<u>Panel 2</u> – The lower left panel is an exaggerated representation of the near-river water pathlines that are shown in Panel 1. The water table, indicated by the dark blue line (2a), rises and falls with the river stage (2b). Colors are used to indicate time along the pathlines (2c) during the course of the simulation.

<u>Panel 3</u> – The middle right panel contains a table listing calculated water volumes that are passing through the various flux planes shown in Panel 1. Cumulative fluxes are shown for flow toward the river, for flow into the aquifer during periods of high stage, and the net flux to the river. The flux calculation assumes a cross-sectional slice that is one meter in width.

<u>Panel 4</u> – The lower right panel is a trend chart that shows the transient boundary conditions for the calculations. The magenta line (4a) represents the water level at the inland boundary (i.e., well 199-H4-49). The dark blue line (4b) represents the boundary condition applied at the nodes located directly below the river. The daily average water level for the Columbia River is also included as a light blue line (4c). The vertical green line (4d) shows the time frame for which the groundwater flow field is being calculated.

4.3.2 Model Results

Pathlines for water movement from the aquifer through the zone of interaction are deflected downward near the river as a consequence of river water moving into the bank during high stage. This suggests that water beneath the riparian zone (i.e., shoreline area between high and low river stage) is a mixture of groundwater and river water, and that contaminant concentrations are likely to be reduced by dilution. This conclusion is supported by abundant observational data on riverbank seepage (WHC-EP-0609), which appears in the riparian zone during low river stage. Also, the pathlines clearly reveal that collecting samples from the upper portion of the aquifer near the shoreline will produce different information compared to samples collected from relatively greater depths.

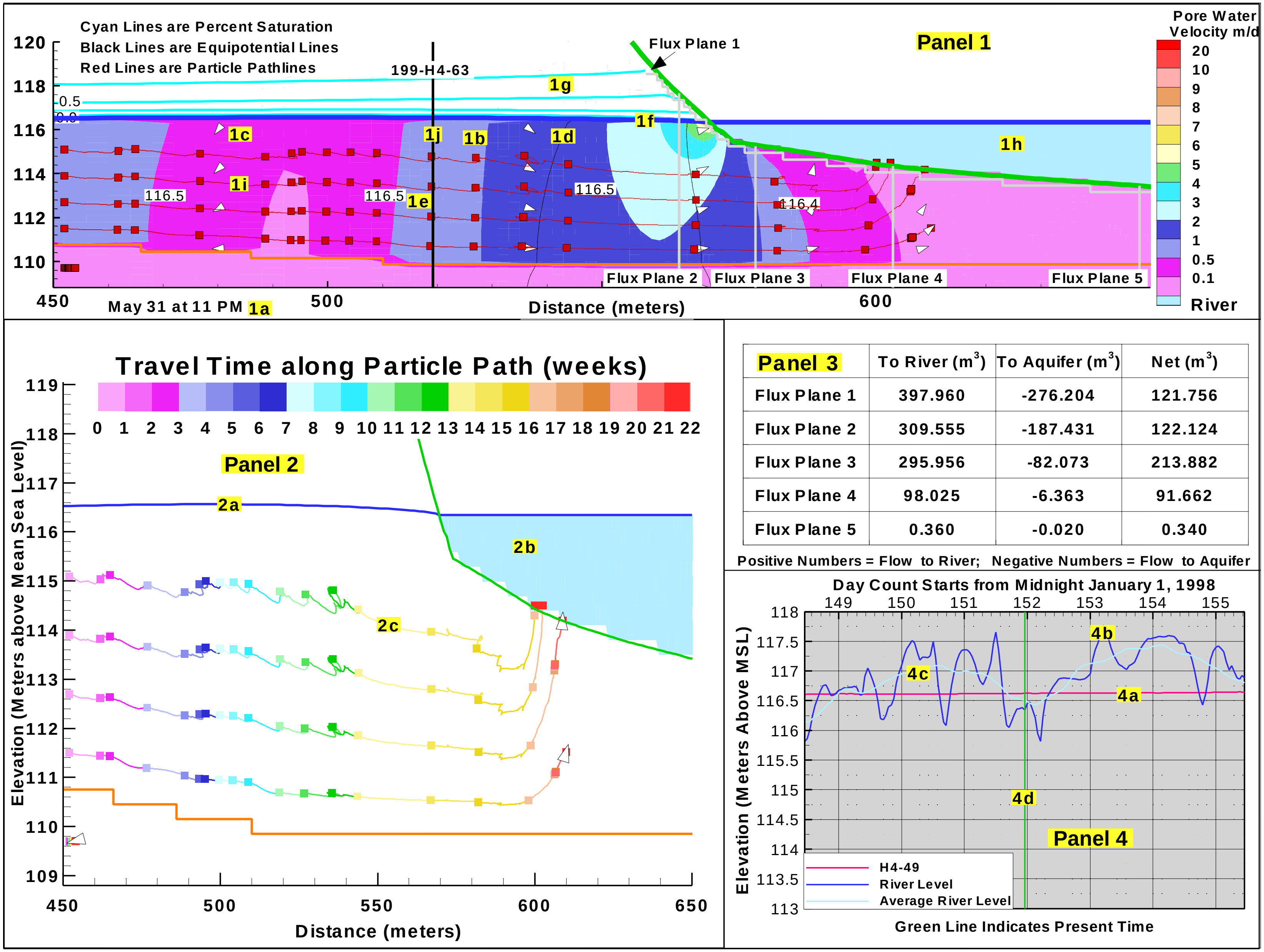
Locations where pathlines are most focused entering the riverbed are relatively close to shore, i.e., within 35 meters, compared to the ~475-meter width of the main channel at the 100 H cross section location. Thus, the area of riverbed that is subject to the influx of contamination from the Hanford Site unconfined aquifer is relatively small compared to the total area of riverbed.

Water volume flux calculations reveal that infiltration of river water into the banks is a significant component of the total volume flux to the riverbed near the shore. Relatively large volumes of water move in and out of the near-river unconfined aquifer on a daily and seasonal basis as a consequence of the river stage fluctuations. The increased flux across vertical planes located just offshore indicates the addition of river to the flow field beneath the shoreline.

Model results show how infiltrating river water may dilute contaminants in groundwater. Results also indicate that most groundwater discharge occurs near the shoreline of the Columbia River, rather than farther out in the river channel.

The two-dimensional model was run using (a) transient river boundary conditions and (b) a steady-state condition, which simplifies the calculations. The two options produce dramatically different information with regard to the pathlines for water movement, where groundwater is likely to emerge in the river, and the volume flux of water. The flow field simulation emphasizes that flow modeling based on steady-state conditions or a time-weighted averages is generally not appropriate for examining flow in the near-river unconfined aquifer at local scales, e.g., scales relevant to benthic habitat investigations.

The two-dimensional animation of water movement in the near-river unconfined aquifer clearly demonstrates the strong influence exerted by fluctuations in the Columbia River stage. The rise and fall of the river cause the direction and rate of groundwater flow to constantly change, with complete reversals in direction of flow and pore water velocities varying from no motion up to 10 meters per day. The dynamic nature of this flow field has implications for monitoring strategies, environmental restoration remedial actions, and river impact assessments.



Panel 3	To River (m^3)	To Aquifer (m^3)	Net (m^3)
Flux Plane 1	397.960	-276.204	121.756
Flux Plane 2	309.555	-187.431	122.124
Flux Plane 3	295.956	-82.073	213.882
Flux Plane 4	98.025	-6.363	91.662
Flux Plane 5	0.360	-0.020	0.340

Positive Numbers = Flow to River; Negative Numbers = Flow to Aquifer

Figure 4.3-1. Graphical Display of Output from Zone-of-Interaction Water Movement Model

5.0 Well Installation, Maintenance, and Decommissioning

R. B. Mercer, B. A. Williams, and J. E. Auten

This section describes well installation, maintenance, and decommissioning activities conducted on the Hanford Site during fiscal year 2000.

5.1 Well Installation

The Hanford Groundwater Monitoring Project defines needs for new monitoring wells in a description of work between Pacific Northwest National Laboratory and Bechtel Hanford, Inc. Each year, the groundwater project installs new wells to maintain network compliance with the *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring requirements and U.S. Department of Energy (DOE) orders. These compliance issues include ongoing RCRA facility groundwater assessments, 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, and vertical characterization of groundwater contamination. The environmental restoration contractor also determines its needs for new wells annually.

Over 300 wells were repaired or cleaned, and 20 wells were decommissioned in fiscal year 2000.

Each year DOE and the Washington State Department of Ecology (Ecology) approve RCRA wells through a process that integrates data quality objectives. This process integrates the data needs of various Hanford Site projects in the proposed wells (i.e., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* and Tank Waste Remediation System). New wells needed to monitor environmental restoration projects are approved using a data quality objective process with DOE, Bechtel Hanford, Inc., and the lead regulator (U.S. Environmental Protection Agency or Ecology).

Thirty-two new groundwater monitoring wells were installed on the Hanford Site during fiscal year 2000.

Milestone M-24-00L (Ecology et al. 1998) required the installation of ten new RCRA groundwater monitoring wells by December 31, 2000. Milestone M-24-00M required five additional RCRA wells by April 30, 2001. Table 5.1-1 lists all new wells installed for fiscal year 2000. Well data packages will be published in fiscal year 2001 with more detailed information about these new wells, including the detailed geologic and geophysical descriptions and a complete set of sampling data results. One well, 299-W11-38 (not included in Table 5.1-1), was abandoned during drilling because of construction problems. Well 299-W11-42 (C3242) was installed as a replacement. Seventeen new wells were installed in the 100 D Area for activities related to environmental restoration (see Table 5.1-1).

5.2 Well Maintenance

Well Installation

Thirty-two new wells were installed on the Hanford Site in fiscal year 2000:

- 15 for RCRA monitoring
- 17 for CERCLA investigations or remediation.

Maintenance of groundwater wells is performed to meet regulatory requirements as part of a scheduled preventive maintenance cycle (routine) or in response to problems identified in the field (non-routine). Non-routine maintenance includes both surface and subsurface tasks. Surface tasks include conducting field inspections, well labeling, maintenance and replacement of locking well caps, casing repairs, and diagnosis and repair of surface electrical and pump-discharge deficiencies. Subsurface tasks include repairing and replacing sampling pumps; performing camera surveys; brushing casing perforations or screens; developing wells to improve yield, recovery, and sample quality; or removing sediment accumulation. Routine maintenance is performed 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:

- removal of groundwater sampling pump system and/or aquifer testing instrumentation/equipment
- inspection and repair or replacement of sampling pump system and/or aquifer testing instrumentation/equipment
- brushing/cleaning of well casing perforations/well screen
- removing debris and fill material
- developing the well
- performing borehole video camera survey
- reinstallation of sampling and/or aquifer-testing instrumentation/equipment
- documenting well conditions and maintenance activities.

Non-routine tasks are performed in response to a problem identified in the field. Non-routine maintenance tasks are varied and dependent on the specific problem encountered at a well.

A summary of maintenance activities by regulatory program is presented in Table 5.2-1.

5.3 Well Decommissioning

Decommissioning activities result in the permanent removal of a well from service and from the Hanford Site well inventory. Well decommissioning is performed in accordance with Ecology standards (WAC 173-160). A well becomes a candidate for decommissioning if its use has been permanently discontinued; if its condition is so poor that its continued use is impractical; or it poses an environmental, safety, or public health hazard. Decommissioning involves backfilling a well with impermeable material to prevent vertical movement of water or contaminants.

Wells that present the risk of being immediate hazards to the public health or safety are categorized into basic risk groups (high, medium, and low). These categories identify wells that have the potential to provide preferential pathways that allow movement of contaminants deeper into the subsurface strata. Well classifications and decommissioned wells are shown in Figure 5.3-1.

At this time, well decommissioning is generally driven by the long-range environmental restoration schedule (DOE/RL-96-105). Twenty Hanford Site wells were decommissioned during fiscal year 2000 (Table 5.3-1). Wells decommissioned to date on the Hanford Site are illustrated also in Figure 5.3-1.

Table 5.1-1. Well Installations for Fiscal Year 2000

Well Number	Well ID	Program	Project
199-D4-24	B8975	CERCLA	100 D ISRM
199-D4-25	B8976	CERCLA	100 D ISRM
199-D4-26	B8977	CERCLA	100 D ISRM
199-D4-27	B8978	CERCLA	100 D ISRM
199-D4-28	B8979	CERCLA	100 D ISRM
199-D4-29	B8980	CERCLA	100 D ISRM
199-D4-30	B8981	CERCLA	100 D ISRM
199-D4-31	B8982	CERCLA	100 D ISRM
199-D4-32	B8983	CERCLA	100 D ISRM
199-D4-33	B8984	CERCLA	100 D ISRM
199-D4-34	B8985	CERCLA	100 D ISRM
199-D4-35	B8986	CERCLA	100 D ISRM
199-D4-36	B8987	CERCLA	100 D ISRM
199-D4-37	B8988	CERCLA	100 D ISRM
199-D4-38	B8989	CERCLA	100 D ISRM
199-D4-39	B8990	CERCLA	100 D ISRM
199-D2-8	C3040	CERCLA	100 D ISRM*
299-W23-20	C3112	RCRA	S-SX tank farms
299-W23-21	C3113	RCRA	S-SX tank farms
299-W14-15	C3114	RCRA	TX-TY tank farms
299-W22-80	C3115	RCRA	S-SX tank farms
299-W11-39	C3117	RPP/RCRA	T tank farm
299-W11-40	C3118	RCRA	T tank farm
299-W11-41	C3119	RCRA	T tank farm
299-W14-16	C3120	RCRA	TX-TY tank farms
299-W14-17	C3121	RCRA	TX-TY tank farms
299-W15-763	C3339	RCRA	TX-TY tank farms
299-W22-81	C3123	RCRA	S-SX tank farms
299-W22-82	C3124	RCRA	S-SX tank farms
299-W10-27	C3125	RCRA	TX-TY tank farms
299-W22-83	C3126	RCRA	S-SX tank farms
299-W11-42	C3242	RCRA	T tank farm

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
ISRM = In situ redox manipulation.
RCRA = *Resource Conservation and Recovery Act of 1976.*
RPP = River Protection Program.
*Originally drilled for the In Situ Gaseous Reduction Project, completed as a CERCLA monitoring well.

Table 5.2-1. Well Maintenance Summary

Program	Routine	Nonroutine
RCRA	32	31
CERCLA	108	70
Surveillance	57	23
LTMC	1	2
Total	198	126

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
LTMC = Long-Term Monitoring - CERCLA.
RCRA = *Resource Conservation and Recovery Act of 1976.*

Table 5.3-1. Wells Decommissioned in Fiscal Year 2000

Well Name	Well ID	Location	Date
299-W10-3	A4897	200 West	July 28, 2000
299-W10-12	A4889	200 West	July 18, 2000
B8909	B8909	100 N	February 18, 2000
199-N-43	A5831	100 N	February 23, 2000
199-N-109A	B2740	100 N	February 24, 2000
199-N-107A	B2736	100 N	February 28, 2000
199-N-108A	B2750	100 N	February 29, 2000
199-N-23	A4672	100 N	March 1, 2000
199-N-55	A4698	100 N	March 3, 2000
199-N-54	A4697	100 N	March 3, 2000
199-N-20	A4670	100 N	March 3, 2000
199-N-17	A4666	100 N	March 3, 2000
199-N-65	A4709	100 N	March 7, 2000
199-N-45	A5832	100 N	March 7, 2000
199-N-5	A5814	100 N	March 9, 2000
199-N-4	A4687	100 N	March 10, 2000
199-N-35	A5829	100 N	May 15, 2000
199-N-55	A4698	100 N	May 28, 2000
299-W15-13	A4918	200 West	June 19, 2000
299-W10-11	A4888	200 West	June 27, 2000

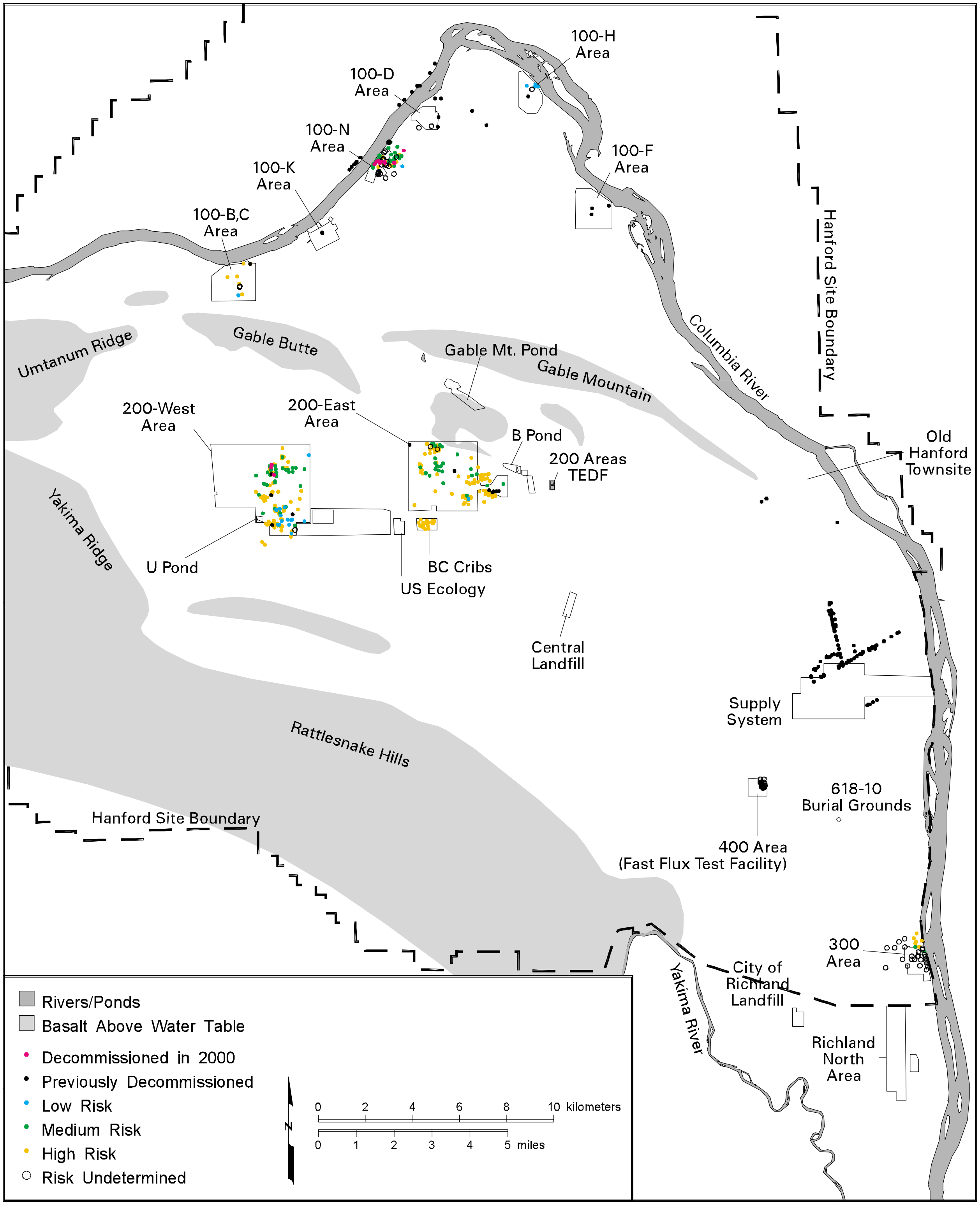


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Figure 5.3-1. Classification of Wells for Decommissioning

6.0 References

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Appendix A

Supporting Information

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Appendix A

Supporting Information

M. J. Hartman

This appendix lists supplemental information for waste disposal facilities on the Hanford Site requiring groundwater monitoring and regulated under the Washington Administrative Code (WAC) (Figure A.1). Most of these are regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA) (WAC 173-303), on which this appendix is focused. Three treated effluent disposal facilities (WAC 173-216), one solid waste landfill (WAC 173-304), and various groundwater operable units (*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA]) are also included. Exceedance of drinking water standards and U.S. Department of Energy (DOE) derived concentration guides are also discussed for each geographic region. Information required by the regulations (e.g., assessing the adequacy of the monitoring networks) is included for each RCRA unit.

Table A.1 lists the monitoring status for RCRA facilities at the end of fiscal year 2000. Estimates of groundwater velocity, and supporting data, are shown for RCRA sites in Table A.2. Table A.3 lists wells exceeding drinking water standards for each regulated unit during fiscal year 2000.

The supplemental information includes tables of wells, constituents, and statistical evaluations (Table A.4 through A.48) and maps of well locations (Figures A.2 through A.22). The tables provide references to applicable monitoring plans.

A.1 100 B/C Area

The 100 B/C Area continued to be monitored in accordance with CERCLA (100-BC-5 Operable Unit) and the *Atomic Energy Act of 1954*. Sampling schedules and analyte selection are coordinated to meet the requirements of both regulations. The CERCLA well network and constituent list are documented in Federal Facility Agreement and Consent Order Change Control Form No. M-15-99-03, dated July 14, 1999 and in the *Groundwater Sampling and Analysis Plan for the 100-BC-5 Operable Unit* (PNNL-13326).

Monitoring wells in the 100 B/C Area are sampled biannually or annually. Strontium-90 and tritium exceeded their drinking water standards locally in fiscal year 2000. Gross beta also exceeded its standard, corresponding to the wells with high strontium-90. No radiological contaminants were detected at levels above the DOE derived concentration guides.

A.2 100 K Area

Regulatory compliance issues related to groundwater in the 100 K Area include monitoring associated with the KE and KW Fuel Storage Basins and CERCLA environmental restoration activities, which include a pump-and-treat system for chromium contamination in groundwater.

A.2.1 KW and KE Fuel Storage Basins

Groundwater monitoring in fiscal year 2000 revealed no evidence of current leakage from either of these basins. DOE monitors groundwater around these facilities to ensure compliance with requirements for nuclear fuel and waste storage facilities (DOE Order 5400.1 [IV]9b). The Hanford Site environmental monitoring plan describes the regulatory basis for monitoring these facilities (DOE/RL-91-50). The implementation of these monitoring and reporting requirements is contained in a groundwater monitoring and assessment plan (WHC-SD-EN-AP-174).

A.2.2 100-KR-4 Operable Unit

The environmental restoration contractor continued to operate a pump-and-treat system to treat chromium contamination in 100 K Area groundwater during fiscal year 2000 (DOE/RL-2000-01). The system is an interim remedial action stipulated by a 1996 record of decision (ROD 1996a).

The objectives of the pump-and-treat system as listed in the record of decision are to

- protect aquatic receptors in the Columbia River bottom substrate from contaminants in groundwater entering the Columbia River
- protect human health by preventing exposure to contaminants in the groundwater
- provide information leading to a final remedy for groundwater in the 100-KR-4 Operable Unit.

The performance evaluation and annual summary reports (e.g., DOE/RL-2000-01) indicate that the pump-and-treat system reduces contaminant flux to the Columbia River by creating a hydraulic barrier that extends along the length of the liquid waste disposal trench, which is the presumed source for chromium. The extraction wells capture contaminants moving with groundwater between the trench and the river, thus reducing the mass of chromium that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data all serve to provide the decision basis for the future final remedy. Additional information on groundwater conditions and remediation activities in the 100 K Area is presented in Section 2.3 of the main text.

CERCLA characterization of groundwater contamination also continued during fiscal year 2000. The groundwater monitoring schedule consists predominantly of annual sampling of wells, with analyses for anions, metals, and radiological indicators (BHI-00916). The list of wells, frequency of sampling, and analyses to be performed are described in National Priorities List Agreement/Change Control Form No. 108, dated November 20, 1996. DOE/RL-96-90 and DOE/RL-96-84 describe sampling and monitoring required as part of the interim action.

A.2.3 Drinking Water Standards and DOE Derived Concentration Guides

During fiscal year 2000, groundwater in wells downgradient of the KW and KE Reactors exceeded the drinking water standards for tritium (20,000 pCi/L), strontium-90 (8 pCi/L), gross beta (50 pCi/L), carbon-14 (2,000 pCi/L), and nitrate (45 mg/L). Chromium exceeded the 100-µg/L maximum contaminant level near the KW and KE Reactors, and near the liquid waste disposal trench (waste site 116-K-2). Trichloroethene exceeded the 5-µg/L maximum contaminant level in one well downgradient of the KW Reactor.

Strontium-90 exceeded the 1,000 pCi/L DOE derived concentration guide in well 199-K-109A, which is located near a liquid waste infiltration site associated with the 105-KE Fuel Storage Basin (waste site 116-KE-3). Tritium did not exceed the 2 million pCi/L DOE derived concentration guide in groundwater from any 100 K Area wells in fiscal year 2000.

A.3 100 N Area

Regulatory compliance of the groundwater in the 100 N Area includes RCRA monitoring and CERCLA environmental restoration activities.

A.3.1 RCRA Units

The 1301-N, 1324-N/NA, and 1325-N liquid waste disposal facilities are monitored in accordance with RCRA interim status indicator evaluation programs (40 CFR 265; WAC 173-303-400). The closure plans for these facilities were incorporated into a modification of the Hanford Site RCRA Permit in 1999 (Ecology 1994). Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 Operable Units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

During fiscal year 2000, 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 (Table A.4 and Figure A.2). The critical mean values for indicator parameters are presented in Tables A.5 through A.7.

At the 1301-N facility, the average total organic carbon concentration in downgradient well 199-N-3 exceeded the critical mean value in September 2000. DOE notified Washington State Department of Ecology (Ecology) of a previous exceedance in this well in February 1999. Because no organic constituents of concern have been identified in 1301-N waste or sediment, the contamination is assumed to have come from another source, and the site remains in indicator evaluation status.

Average specific conductance values in wells 199-N-59, 199-N-72, and 199-N-73 downgradient of the 1324-N/NA site continued to exceed the critical mean value in fiscal year 2000. A groundwater quality assessment indicated that the high specific conductance is caused by the non-hazardous constituents sulfate and sodium (WHC-SD-EN-EV-003). Because an assessment has already been completed and non-hazardous constituents caused the high conductance, no further action was needed.

Average specific conductance values in downgradient well 199-N-41 at the 1325-N facility continued to exceed the critical mean value in March and September 2000. This was a continuation of a previous exceedance in 1999. DOE notified Ecology of that previous exceedance, and submitted an assessment report that concluded the exceedance was caused by past discharges of non-hazardous constituents to an upgradient facility.

Of the dangerous waste constituents or byproduct discharged to these facilities, only nitrate exceeded the maximum contaminant level, and the sources are unclear (see Section 2.4.3 of main text). The 1301-N and 1325-N facilities have contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities. The 1324-N/NA site has contaminated groundwater with sulfate and sodium, which are not dangerous waste constituents. Table A.3 lists constituents that exceeded drinking water standards in fiscal year 2000.

The current well networks adequately monitor the 100 N Area RCRA sites, and there are no plans to modify the networks in fiscal year 2001.

A.3.2 100-NR-2 Operable Unit

A pump-and-treat system for strontium-90 continued to operate in 100 N Area in fiscal year 2000. The environmental restoration contractor operates the system in response to an action memorandum[a] and a record of decision signed in September 1999 (Ecology 1999).

The goals of this pump-and-treat system are to

- reduce strontium-90 contamination 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 system met these goals in fiscal year 2000 (see Section 2.4.1 of the main text). The pump-and-treat operation is successfully intercepting and capturing groundwater containing elevated concentrations of strontium-90, and reduces the amount of contamination discharging into the Columbia River. The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and treatment system operation data to assess treatment system performance and to provide the basis for selecting the final remedy.

National Priorities List Agreement/Change Control Form No. 113, dated March 25, 1997, specifies performance monitoring requirements for the N Springs pump-and-treat system. The basic requirement is to sample the process influent and effluent streams monthly for strontium-90 analysis and to place the analytical results in a database to which the regulator has access. An update to the original monitoring plan (i.e., BHI-00164) identifies and summarizes all current groundwater monitoring being conducted in the 100 N Area (BHI-01165).

The remedial investigation for the 100-NR-2 Operable Unit also collected groundwater data in fiscal year 2000. Monitoring results, along with information gained by operating the pump-and-treat system, will be used to support

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(a) Letter from D. Butler (Washington State Department of Ecology) and R. F. Smith (U.S. Environmental Protection Agency) to R. Izatt (U.S. Department of Energy, Richland Operations Office, Richland, Washington) dated September 23, 1994, “Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy, Hanford Site, Richland, Washington.”

selection of a final remediation alternative for the operable unit. Federal Facility Agreement and Consent Order Change Control Form No. M-15-96-08, signed on October 9, 1996, lists the wells and analyses to be performed to satisfy groundwater monitoring requirements for the 100-NR-2 Operable Unit (CERCLA) and the 1301-N, 1325-N, and 1324-N/NA facilities (RCRA).

The Sitewide Environmental Surveillance Project collects riverbank seepage annually. Authority for this activity comes from DOE orders for environmental monitoring. The results are presented in an annual report (e.g., Section 4.2 in PNNL-13230). The Near-Facility Environmental Monitoring Program, which is also mandated primarily by DOE orders, conducts additional groundwater and surface water monitoring. Samples are collected from 13 near-river well casings, which have been driven into the shoreline gravels, and also from a near-river monitoring well. The monitoring supports activities for waste management and environmental restoration and helps determine the effectiveness of effluent treatment and control practices. Results are presented annually (e.g., HNF-EP-0573-6).

A.3.3 Drinking Water Standards and DOE Derived Concentration Guides

Strontium-90 continued to exceed the 1,000 pCi/L DOE derived concentration guide in wells 199-N-14, 199-N-46, and 199-N-67. Nitrate, strontium-90 (and gross beta), and tritium continued to exceed maximum contaminant levels or drinking water standards in the 100 N Area. Radium-226 exceeded its drinking water standard in well 199-N-32, but the result is believed to be erroneous and is being investigated.

A.4 100 D Area

CERCLA and the *Atomic Energy Act of 1954* govern groundwater monitoring in the 100 D Area. CERCLA environmental restoration activities include remedial investigations and performance monitoring associated with the groundwater interim action pump-and-treat system.

A.4.1 100-HR-3 Operable Unit

The extraction well network in the northern region of the 100 D Area continued to operate through fiscal year 2000. The purpose for the interim remedial action is to decrease the amount of hexavalent chromium that is entering the Columbia River via groundwater. The key documents that pertain to this interim action are the record of decision to proceed (ROD 1996b) and the performance monitoring plan (DOE/RL-96-84).

The specific objectives of the pump-and-treat system are to

- protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River
- protect human health by preventing exposure to contaminants in the groundwater
- provide information leading to a final remedy.

The performance evaluation and annual summary reports (DOE/RL-2000-01) indicated that the pump-and-treat system reduces contaminant flux to the Columbia River by creating a hydraulic barrier. The extraction wells capture and remove contaminants from the groundwater passing under the water sites that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data collected in support of the project all serve to provide the decision basis for the future final remedy. The pump-and-treat system is discussed in more detail in Section 2.5 of the main text.

The U.S. Environmental Protection Agency (EPA), Ecology, and DOE signed an amended record of decision for the 100-HR-3 Operable Unit in October 1999 (ROD 1999). The amendment adds a requirement for implementing in situ redox manipulation to remediate the chromium plume in the southwestern 100 D Area. The goal of this treatment system is to reduce concentrations of hexavalent chromium to 20 µg/L or less in compliance wells. A design report/work plan defines groundwater monitoring requirements (DOE/RL-99-51). The system made progress toward remedial action objectives in fiscal year 2000. Additional wells were installed for injection/withdrawal and compliance monitoring, and a series of injections/withdrawals was conducted in ten of the wells (see Section 2.5 in the main text).

Groundwater monitoring in other 100-HR-3 wells in 100 D Area also continued during fiscal year 2000. The list of wells to be sampled and the analyses to be performed have been agreed on and are described in National Priorities List

Agreement/Change Control Form No. 107, dated November 20, 1996. Most wells are sampled annually, and the samples are analyzed for anions, metals, and radiological indicators. DOE/RL-96-90 and DOE/RL-96-84 describe monitoring required as part of the interim action.

A.4.2 Drinking Water Standards and DOE Derived Concentration Guides

Nitrate and chromium exceeded the maximum contaminant levels during fiscal year 2000 in a fairly broad part of the 100 D Area. Strontium-90 slightly exceeded the 8 pCi/L drinking water standard in one well in the northern 100 D Area. Tritium contamination that migrates from the 100 N Area is present in the southwestern 100 D Area at the 20,000 pCi/L drinking water standard. Cadmium slightly exceeded its 5 µg/L maximum contaminant level in one well that is affected by the redox remediation system. No radiological constituents exceeded the DOE derived concentration guides.

A.5 100 H Area

RCRA and CERCLA govern groundwater monitoring in the 100 H Area. Environmental restoration activities under CERCLA include remedial investigations and performance monitoring associated with the groundwater interim action pump-and-treat system.

A.5.1 183-H Solar Evaporation Basins

This RCRA unit continued to be monitored under a final status corrective-action program during fiscal year 2000 (WAC 173-303-645). The unit was incorporated into the Hanford Site RCRA Permit (Ecology 1994) in 1998. 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 (PNNL-11573; Table A.8 and Figure A.3). 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 wells were sampled in November 1999.

The current monitoring network was designed to accommodate groundwater flow imposed by the pump-and-treat system. The network remains adequate, and no changes are planned for fiscal year 2001.

A.5.2 100-HR-3 Operable Unit

The extraction and injection well networks in the 100 H Area continued to operate through fiscal year 2000. The purpose for the interim action is to reduce the amount of hexavalent chromium that is entering the Columbia River via groundwater movement. The key documents that pertain to this interim action are the record of decision to proceed (ROD 1996a) and the remedial action work plan (DOE/RL-96-84).

The specific objectives of the pump-and-treat system are to

- protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River
- protect human health by preventing exposure to contaminants in the groundwater
- provide information leading to a final remedy.

The performance evaluation and annual summary reports (e.g., DOE/RL-2000-01) indicated that the pump-and-treat system reduces contaminant flux to the river by creating a hydraulic barrier. The extraction wells and treatment system capture and remove contaminants from the groundwater that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data all serve to provide the decision basis for the future final remedy. The interim action is discussed in more detail in Section 2.6 of the main text.

Groundwater monitoring in other 100-HR-3 wells in the 100 H Area also continued during fiscal year 2000. The list of wells to be sampled and the analyses to be performed were agreed on and are described in National Priorities List Agreement/Change Control Form No. 107, dated November 20, 1996. Most wells are sampled annually, and the samples are analyzed for anions, metals, and radiological indicators. During fall 1999, aquifer sampling tubes and riverbank seepage were sampled. DOE/RL-96-90 and DOE/RL-96-84 describe additional monitoring that is required as part of the interim action.

A.5.3 Drinking Water Standards and DOE Derived Concentration Guides

Chromium and nitrate exceeded maximum contaminant levels throughout the 100 H Area in fiscal year 2000. Uranium, technetium-99, gross alpha, and gross beta exceeded standards in a few wells near the former 183-H solar evaporation basins. Strontium-90 exceeded its drinking water standard near the former 107-H retention basins. No radiological constituents exceeded the DOE derived concentration guides.

A.6 100 F Area

CERCLA (100-FR-3 Operable Unit) and the *Atomic Energy Act of 1954* govern groundwater monitoring in the 100 F Area. The CERCLA monitoring network and constituent list are documented in Federal Facility Agreement and Consent Order Change Control Form No. M-15-99-02, dated July 14, 1999 and in the *Groundwater Sampling and Analysis Plan for the 100-FR-3 Operable Unit* (PNNL-13327). The Hanford Groundwater Monitoring Project coordinates sampling schedules and analyte selection to meet the requirements of both regulations. Wells are sampled biannually to quarterly.

Nitrate exceeds its maximum contaminant level beneath most of the 100 F Area and downgradient. Chromium, gross beta, strontium-90, trichloroethene, and tritium also exceeded standards locally. One well had uranium concentrations at the 20-μg/L standard. No radiological constituents exceeded the DOE derived concentration guides.

A.7 200 West Area

RCRA, CERCLA, and state dangerous waste regulations govern groundwater monitoring in the 200 West Area. Groundwater is monitored at eight RCRA sites and two groundwater operable units.

A.7.1 Waste Management Area S-SX

This RCRA site continued to be monitored under an interim status assessment program during fiscal year 2000. DOE initiated the assessment program in response to a directive from Ecology in 1996. The directive cited anomalous trends in technetium-99 and high specific conductance as primary reasons for the assessment. An assessment plan was submitted in August 1996 (WHC-SD-EN-AP-191). A report on the results of the assessment (PNNL-11810) concluded that this waste management area contributed to groundwater contamination. Accordingly, investigation of the rate and extent of the contamination is required. For this purpose, an updated assessment plan (PNNL-12114) was prepared in 1999. Findings for the period November 1997 through June 2000 are documented in PNNL-13441.

Monitoring wells sampled during the report period and constituents analyzed are listed in Table A.9. Three new wells were installed in 1999 and six in 2000 to improve spatial coverage and to replace wells going dry. Technetium-99, nitrate, and chromium, mobile tank farm contaminants with the highest concentrations, occur in downgradient wells (299-W23-19, 299-W22-45, 299-W22-46, and 299-W22-50, Figure A.4) at the SX tank farm. The highest concentrations in the network occur in well 299-W23-19 located adjacent to tank SX-115 in the southwest corner of the SX tank farm. This area appears to be the source of the downgradient occurrences of elevated technetium-99 and nitrate in wells 299-W22-46 and 299-W22-50. The moderately elevated carbon tetrachloride in well 299-W23-15, as well as the lower concentrations in other network wells (Table A.9), are attributed to past-practice upgradient sources (e.g., Plutonium Finishing Plant cribs, ditches and trenches). The nearby upgradient crib, 216-S-25, is a major source of tritium and nitrate that passes beneath the southern end of this waste management area.

The rate and direction of groundwater flow (see Table A.2) and the extent of contamination at Waste Management Area S-SX are discussed further in Section 2.8 of the main text, and in the updated assessment report for this waste management area (PNNL-13441). Results of the groundwater quality assessment for this RCRA unit will be used together with the vadose zone findings from the RCRA Field Investigation/Corrective Measures Study to support a risk assessment (DOE/RL-99-36) of hypothetical exposure pathways. If there is a determination of substantial risk, a decision to acquire additional data may be made and/or near-term mitigating actions may be taken (DOE/RL-99-36). The field investigation report (TPA Milestone M-45-55-T01, Ecology et al. 1998), which includes the preliminary risk assessment, is due in fiscal year 2001. Ecology will decide the endpoints for both soil and groundwater investigations using the risk assessment results (DOE/RL-99-36). Groundwater monitoring must continue, however, at least until closure of the facility. Groundwater monitoring results will verify the efficacy of any near-term mitigation or corrective action, document groundwater quality conditions during the tank waste retrieval phase, and verify the overall success of cleanup and closure of the S and SX tank farms. The same process will be followed in the other tank farm waste management areas, but at later dates.

A.7.2 Waste Management Area T

This RCRA site continued to be monitored under an interim status assessment program during fiscal year 2000 (Table A.10 and Figure A.5). Waste Management Areas T and TX-TY began assessment monitoring in 1993 because of high specific conductance in downgradient wells (WHC-SD-EN-AP-132). Assessment findings (PNNL-11809) indicated that contaminants in well 299-W10-15 are a result of sources outside the waste management area. There is strong evidence, however, that contaminants detected in well 299-W11-27, which include chromium, cobalt-60, nitrate, technetium-99, and tritium, are a result of sources within the waste management area; therefore, assessment work has continued. The plume detected in well 299-W11-27 has reached well 299-W11-23, located to the east of 299-W11-27, apparently as a result of changed groundwater flow direction at Waste Management Area T.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8. Four new wells were drilled during fiscal year 2000 to improve network coverage.

A.7.3 Waste Management Area TX-TY

This RCRA unit continued to be monitored under an interim status assessment program during fiscal year 2000 (Table A.11 and see Figure A.5). Waste Management Area TX-TY began assessment monitoring in 1993 because of high specific conductance in wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132). The exceedance in well 299-W14-12 was accompanied by elevated cobalt-60, iodine-129, technetium-99, and tritium. Assessment results (PNNL-11809) indicated that contaminants in well 299-W10-17 are a result of sources outside the waste management area. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the waste management area, though upgradient sources are also possible. Because there was no direct evidence for upgradient sources, assessment continues at the site.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8. Five new wells were drilled during fiscal year 2000 to improve network coverage.

A.7.4 Waste Management Area U

This RCRA unit was monitored under an interim status assessment program in fiscal year 2000 (Table A.12 and see Figure A.4). The average specific conductance value in downgradient well 299-W19-41 exceeded the critical mean in August 1999, triggering assessment monitoring. DOE transmitted an assessment monitoring plan to Ecology in March 2000 (PNNL-13185). Results of initial assessment studies were published in July 2000 (PNNL-13282). The report concluded that there is evidence that both upgradient sources and sources within the waste management area contributed to the elevated nitrate observed in monitoring wells. Chromium and technetium-99 are believed to originate within the southern portion of the waste management area. Thus, assessment monitoring will continue.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site are discussed in Section 2.8.

A.7.5 216-S-10 Pond and Ditch

During fiscal year 2000, this facility continued to be monitored semiannually under a RCRA interim status indicator evaluation program (Table A.13 and Figure A.6). Statistical evaluation of indicator parameter data from downgradient wells indicates that the site is not contaminating groundwater. Critical mean values are listed in Table A.14. The direction of groundwater flow and estimated flow rate are listed in Table A.2.

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Chromium, which was elevated above the 100 μg/L standard in upgradient well 299-W26-7 since 1992, averaged less than 20 µg/L in fiscal year 2000. This rapid decline will be tracked in subsequent sampling events to determine the validity of these values. Because the upgradient well is located adjacent to the 216-S-10 pond (see Figure A.6), it is unclear if the elevated chromium was from an upgradient source or from past discharges to the pond. To assess the chromium source further, a proposal is being drafted to reclassify this well as a downgradient well and replace it with a new upgradient well in calendar year 2001.

One new downgradient well, 299-W26-13, was installed in late 1999 and added to the monitoring network in 2000. This well was added as a replacement for well 299-W26-9, which is now dry. The new well is located downgradient near the northeastern corner of the 216-S-10 pond. Currently, the 216-S-10 pond and ditch are monitored by one upgradient well and two shallow downgradient wells because other network wells have gone dry. The groundwater monitoring network is not in compliance with RCRA interim status monitoring requirements. Also, at the current rate of water table decline in the 200 West Area, it is projected that downgradient well 299-W26-12 will go dry in early 2001 and that upgradient well 299-W26-7 will go dry in 2002. Ecology has temporarily agreed to the reduced network and has deferred all proposals to install new wells at the 216-S-10 pond and ditch indefinitely.

A.7.6 216-U-12 Crib

This RCRA unit continued to be monitored under an interim status assessment program in fiscal year 2000. Assessment monitoring began in 1993 because of high specific conductance in two downgradient wells (299-W22-41 and 299-W22-42) (WHC-SD-LEF-EV-001). In fiscal year 2000, network monitoring wells were sampled quarterly for constituents of interest (Table A.15 and Figure A.7).

Based on the results of the assessment investigation (PNNL-11574), the site remains in interim status assessment monitoring because of continued elevated levels of nitrate and technetium-99. Site-wide surveillance monitoring evaluates the extent of these plumes. The objective of RCRA assessment monitoring, rather than delineating the existing plumes, is focused on (1) determining whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; (2) monitoring the known constituents until a near-term interim corrective action is defined; and (3) monitoring until a final status plan is implemented. The rate and direction of groundwater flow (see Table A.2) and the extent of contamination at this site are discussed in Section 2.8.

The crib will not receive additional effluents and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final status regulations in 2005.

Currently, the 216-U-12 crib is monitored by only two downgradient wells (299-W22-79, and 699-36-70A). Declining water levels have rendered upgradient well 299-W22-43 dry in the past year (last sampled during January 2000) and downgradient wells 299-W22-41 and 299-W22-42 went dry in 1999. The groundwater monitoring network is not adequate for RCRA interim status monitoring. Ecology has agreed temporarily to the reduced network and has deferred proposals for additional upgradient and downgradient wells indefinitely.

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Specific conductance (the contaminant indicator for the crib) in downgradient well 299-W22-79 has been below the 457.8 µS/cm critical mean value since 1998 but nitrate, the primary constituent responsible for the elevated specific conductance, remains above the 45-mg/L drinking water standard. Both specific conductance and nitrate remain above the critical mean and drinking water standard, respectively in far field well 699-36-70A.

A.7.7 Low-Level Waste Management Area 3

This RCRA site continued to be monitored under interim status indicator evaluation requirements. Groundwater monitoring wells were sampled twice in fiscal year 2000 (Table A.16 and Figure A.8). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Critical mean values for specific conductance were exceeded in samples collected from upgradient well 299-W10-13 in fiscal year 2000. The upward trend was noted and reported earlier, and is caused by increases in sulfate and nitrate concentrations from upgradient sources. Other contamination indicator parameters were not exceeded in any wells monitoring this waste management area. Tables A.17 and A.18 list critical mean values. Contaminant concentrations that exceeded drinking water standards are listed in Table A.3.

The network continues to monitor this waste management area adequately. Several of the groundwater monitoring wells are approaching the point where representative sampling will no longer be possible because of the declining water table. No additional wells were installed in calendar year 2000. Additional wells are proposed for calendar year 2001, but are subject to funding priorities and negotiations with Ecology.

A.7.8 Low-Level Waste Management Area 4

Wells were sampled semiannually for contamination indicator parameters in accordance with RCRA interim status regulations (Table A.19 and Figure A.9). Downgradient well 299-W15-16 continued to exceed the critical mean for total organic halides. This well was at one time an upgradient monitoring well and is still affected by contamination from other sources. DOE reported the exceedance to EPA and Ecology in August 1999. Critical mean values are listed in Table A.20. Contaminant concentrations that exceeded drinking water standards are listed in Table A.3.

This monitoring network is marginally adequate to detect releases from Low-Level Waste Management Area 4. Additional monitoring wells may be necessary in the future, as the water level continues to decline and to provide greater downgradient coverage.

A.7.9 200-UP-1 Operable Unit

The environmental restoration contractor continued to operate a pump-and-treat system in fiscal year 2000 (Figure A.10).

The interim action objectives (ROD 1997) include the following:

- reduce contamination in the areas of highest concentration of technetium-99 and uranium to below 10 times (480 mg/L) the cleanup level under the *Model Toxics Control Act* (WAC 173-340) for uranium, and 10 times (9,000 pCi/L) the maximum contaminant level for technetium-99
- reduce potential adverse human health risks through reduction of contaminant mass
- prevent further movement of these contaminants from the highest concentration area
- provide information that will lead to the development and implementation of a final remedy that will be protective of human health and the environment.

As of September 2000, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained. However, they were not remediated to the levels required by the interim action objectives (ROD 1997). The remedial action made progress in reducing the size and concentration of the technetium plume, particularly near extraction well 299-W19-39 where concentrations are less than the remediation objective of 9,000 pCi/L. Near the former injection well, 299-W19-36, technetium-99 concentrations have actually increased to over 25,000 pCi/L. Less progress has been made in remediating the uranium plume because of its tendency to sorb to the soil. The slower response to remediation may also indicate that more uranium is present in the aquifer than originally estimated. Section 2.8.3 of the main text discusses groundwater remediation in more detail.

A.7.10 200-ZP-1 Operable Unit

The pump-and-treat system continued to operate in fiscal year 2000 (Figure A.11). The purpose of the pump-and-treat system is to prevent further movement of groundwater contamination from the high concentration portion of the carbon tetrachloride plume and to reduce contaminant mass (ROD 1995). Section 2.8.3 of the main text discusses groundwater remediation in more detail.

The interim action objectives (ROD 1995) include the following:

- prevent further movement of contamination from the highest concentration area of the plume (i.e., containing carbon tetrachloride inside of 2,000 to 3,000 μg/L contour)
- reduce contamination in the area of highest carbon tetrachloride concentrations
- provide information that will lead to development of a final remedy that will be protective of human health and the environment.

The 200-ZP-1 pump-and-treat system made measurable progress toward meeting its specific objectives in fiscal year 2000. However, the central portion of the carbon tetrachloride plume has expanded to the extraction wells. Spreading of the high concentration area is attributed to the effects of pumping. This situation implies that more carbon tetrachloride mass is present beneath the Plutonium Finishing Plant than originally anticipated. Additional investigative work is needed to characterize contamination in this area. Section 2.8.1.7 of the main text discusses groundwater remediation in more detail.

A.7.11 State-Approved Land Disposal Site

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 for tritium only is conducted in 17 wells near the facility (Table A.21 and Figure A.12). The permit stipulates requirements for groundwater monitoring and establishes enforcement limits for concentrations of 16 constituents in 3 additional wells immediately surrounding the facility (see Table A.21).

During fiscal year 2000, average tritium concentrations in most wells declined from 1999 averages. One exception is deep well 699-48-77C, where tritium results reached a maximum value of 710,000 pCi/L as a result of the delayed penetration of effluent deeper into the aquifer. In August 2000, well 299-W7-3, along the northern boundary of the 200 West Area, may have detected tritium from the State-Approved Land Disposal Site for the first time. One sample showed 1,400 pCi/L tritium, but a duplicate sample showed no detectable tritium. The discrepancy is being investigated. No permit enforcement limits were exceeded during fiscal year 2000. Evaluation of the well network indicates that well coverage is currently adequate to satisfy groundwater monitoring requirements.

A.7.12 Environmental Restoration Disposal Facility

This facility is a landfill authorized by CERCLA that is designated to meet RCRA requirements of Subpart N, 40 CFR 264. The groundwater monitoring network consists of one upgradient and three downgradient wells that are sampled semiannually (Table A.22). In addition, the facility has a system to collect and remove leachate that helps evaluate whether the liner system is performing within design standards. The sampling plan for groundwater monitoring is documented in BHI-00873, and results for calendar years 1996 through 1999 are published in BHI-01382.

Monitoring wells for this facility were sampled in September 2000. Sampling in March 2000 was cancelled because of issues relating to disposal of sampling-related waste.

A.7.13 Drinking Water Standards and DOE Derived Concentration Guides

The highest tritium concentration in the 200 West Area (2,940,000 pCi/L) exceeded the DOE derived concentration guide in fiscal year 2000 in well 299-W14-13, located near Waste Management Area TX-TY and associated facilities. Concentrations in this well have exceeded the DOE derived concentration guide in every sample since January 2000. A nearby well has exceeded the guide level in the past, but was slightly below it in fiscal years 1999 and 2000 (1,900,000 pCi/L). Total uranium analyses of samples from wells 299-W19-3 and 299-W19-20, near U Plant, indicate the DOE derived concentration guides for uranium-234 and uranium-238 were exceeded. Gross alpha, gross beta, iodine-129, technetium-99, and tritium were found at levels above the drinking water standards in some of the wells in the 200 West Area. Strontium-90 exceeded the 8 pCi/L drinking water standard in well 299-W22-10, located east of the S-SX tank farm. Uranium was found at levels above its proposed maximum contaminant level. Carbon tetrachloride, chromium, fluoride, nickel, nitrate, nitrite, and trichloroethene were detected at levels above the maximum contaminant levels.

A.8 200 East Area

Regulatory compliance issues related to groundwater in the 200 East Area include monitoring for RCRA and CERCLA requirements. There is also one state regulated disposal unit in this region.

A.8.1 Waste Management Area A-AX

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 2000. Wells were sampled twice for indicator and site-specific parameters (Table A.23 and Figure A.13). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to those established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during fiscal year 2000. Table A.24 lists critical mean values and Table A.3 summarizes results exceeding drinking water standards.

Table A.2 includes current estimates of the direction and rate of groundwater flow. Because of uncertainty in flow directions, the well network for this site may not be adequate for RCRA monitoring. The aquifer ranges from 2.2 to 4.2 meters thick in RCRA network wells. The rate of water-table decline was 9.1 centimeters per year in 1997, and increased to 30.5 centimeters per year in 1999. The rate of decline decreased to 12.9 centimeters per year in 2000. If this rate continues, the RCRA compliant wells at Waste Management Area A-AX will remain usable for at least 15 to 20 years.

A.8.2 Waste Management Area B-BX-BY

RCRA assessment monitoring continued at this waste management area in fiscal year 2000. Exceedances of the critical mean value for specific conductance in February 1996 at well 299-E33-32 initiated assessment monitoring. An assessment monitoring plan (WHC-SD-ENV-AP-002) was issued in September 1996, followed by an assessment investigation. An assessment report released in February 1997 (PNNL-11826) concluded that tank waste from this waste management area had reached the groundwater. An updated assessment plan (PNNL-13022) was issued in 2000 that provided guidance for further determination of other contaminant sources. This latest plan also guides investigation of the rate of movement and extent of groundwater contamination at this site (see Section 2.9 and Table A.2). Wells were sampled quarterly, and in some cases, bimonthly, in fiscal year 2000 In fiscal year 2001, near-field wells will be sampled quarterly and far-field wells semiannually.

For fiscal year 2000, iodine-129, nitrate, technetium-99, and uranium exceeded maximum contaminant levels or drinking water standards in RCRA compliant wells, with corresponding exceedances of gross beta and gross alpha standards (see Table A.3). Section 2.9.1 discusses contaminant trends.

Originally, the RCRA groundwater monitoring network was designed for groundwater flow toward the northwest, based on regional plume maps. This method was used to determine flow direction because the water table is almost flat in the immediate area of the farms. Assessment studies are attempting to better determine the approximate flow direction (see Table A.2 and Section 2.9.1 of the main text). Although water levels are declining through this area and the aquifer ranges from 2 to 3 meters thick in RCRA-compliant wells, it is anticipated that these wells can be used for at least 5 years.

In fiscal year 2000, the monitoring network was modified to include far-field wells (Table A.25 and Figure A.14). Some of these wells are RCRA compliant, while others are older wells installed to monitor past-practice waste disposal sites. The choice of monitoring wells was reviewed quarterly to track contamination moving through the site. Two new wells, 299-E33-334 and 299-E33-335, were installed in fiscal year 1999 on the southwestern corner of BX Tank Farm in support of the assessment work. A discussion of results from monitoring these wells can be found in Section 2.9.1. Three new wells will be drilled in fiscal year 2001 to provide monitoring coverage southeast of the site. Contaminant migration and results from colloidal borescope investigations indicate a southeast flow direction out of the southern boundary of the waste management area. Thus, additional well coverage is required (see Section 2.9.1).

A.8.3 Waste Management Area C

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 2000. Wells were sampled every other month to continue to assess the potential impact of waste removal and sluicing of tank contents. This site will be monitored quarterly in fiscal year 2001 to track rising nitrate, sulfate, and technetium-99 concentrations currently detected in upgradient wells. In addition, the required detection sampling was conducted twice for indicator and site-specific parameters (Table A.26 and see Figure A.13). Indicator parameter data from upgradient wells were statistically evaluated. Values from downgradient wells were compared to values established from the upgradient wells. The indicator parameters (specific conductance, pH, total organic carbon, and total organic halides) did not exceed critical mean values during fiscal year 2000. Table A.27 lists critical mean values and Table A.3 summarizes results exceeding drinking water standards.

Currently, the well network for this site appears to comply only marginally with the required placement of groundwater monitoring wells because of changes and uncertainty in the direction of flow (see Section 2.9.2 and Table A.2).

A.8.4 PUREX Cribs

The 216-A-10, 216-A-36B, and 216-A-37-1 cribs continued to be monitored under a RCRA assessment program in fiscal year 2000 (Table A.28 and Figure A.15). The sites are monitored as a single waste management area because they have similar hydrogeology and waste constituents. The groundwater monitoring plan (PNNL-11523) was changed from an indicator parameter evaluation program to a groundwater quality assessment program in 1997 because of evidence of contamination. Combining these cribs into one RCRA groundwater monitoring area saves sampling and analysis costs because the number of near-field wells is reduced.

Two of the near-field monitoring wells were not sampled at times during fiscal year 2000 because of deteriorating well conditions, and they will need to be replaced. The two wells needing replacement are 299-E17-9 near the 216-A-36B crib and 299-E25-17 near the 216-A-37-1 crib. Neither of these wells meet the requirements of WAC 173-160 as resource protection wells. Well 299-E17-9 can be replaced by the existing well 299-E17-16, which meets the requirements of WAC 173-160 and is in an advantageous downgradient position. However, well 299-E17-9 consistently had reported tritium values that exceeded any other well in the 200 East Area, and the replacement well does not detect such high concentrations. Well 299-E25-17 can be replaced by well 299-E25-18, but well 299-E25-18 does not meet the requirements of WAC 173-160, and it is located on the immediate northeast side (possibly upgradient) of the 216-A-37-1 crib. It will function as a temporary replacement well for 299-E25-17 until new wells are installed near the 216-A-37-1 crib.

Many of the far-field wells that formerly were sampled annually are now sampled every 3 years. These wells track the extent and flow rate of the extensive iodine-129, nitrate, and tritium plumes that change very little in a 3-year period. This change was incorporated in two updates of the groundwater monitoring plan along with corrections to outdated procedural references (PNNL-11523).

The rate and extent of contamination are discussed in Section 2.9.2 of the main text. Knowledge of the groundwater flow direction and flow rate in the southeastern portion of the 200 East Area did not change significantly during fiscal year 2000 (see Table A.2). Therefore, the combined near-field and far-field monitoring well networks are generally adequate to continue to monitor both the extent and rate of flow of the contaminant plumes emanating from the PUREX cribs.

During fiscal year 2000, iodine-129, gross beta, nitrate, strontium-90, and tritium continue to exceed drinking water standards or maximum contaminant levels in areas downgradient of the PUREX cribs (see Table A.3). Tritium exceeded the DOE derived concentration guide of 2,000,000 pCi/L at well 299-E17-9 near the 216-A-36B crib. Strontium-90, a beta emitter, and gross beta exceeded the drinking water standards only in well 299-E17-14, which is also near the 216-A-36B crib. Manganese was elevated in previous year in wells downgradient of the 216-A-37-1 crib. During fiscal year 2000, it continued to be detected downgradient of the 216-A-37-1 crib, but did not exceed the 50-µg/L maximum contaminant level. Iodine-129, nitrate, and tritium are major plumes that extend beyond the near-field monitoring well network at the PUREX cribs. These more extensive plumes are monitored by the far-field monitoring well network.

A.8.5 216-B-3 Pond

In fiscal year 2000, groundwater monitoring at the 216-B-3 pond (B Pond) continued under an interim status indicator evaluation program. The current network includes eight downgradient wells and one upgradient well (Table A.29 and Figure A.16). One new well was drilled near the end of fiscal year 1999 that was added to the network during fiscal year 2000. The network is designed to intercept contamination potentially entering groundwater from the vadose zone near the facility (e.g., well 699-44-39B) and contamination potentially entering groundwater from the vadose zone near the facility (e.g., well 699-42-42B). With the addition of the new well in 2000, the network is adequate to detect potential contamination from the facility.

Statistical evaluations of indicator parameters in fiscal year 2000 indicated the site has not adversely affected groundwater quality. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal 2000. Table A.30 lists critical mean values.

A.8.6 216-A-29 Ditch

This RCRA unit continued to be monitored under an interim status indicator evaluation program in fiscal year 2000 (Table A.31 and see Figure A.15). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Average specific conductance values at downgradient wells 299-E25-35 and 299-E25-48 exceeded the critical mean value and were linked to increases in sulfate, nitrate, calcium, and sodium from upgradient sources. The exceedances were reported previously and indicator evaluation monitoring will continue, because the 216-A-29 ditch was not the source of the elevated specific conductance. Replicate averages for other contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 2000. Critical mean values are listed in Table A.32. The current network is adequate for detection monitoring.

A.8.7 216-B-63 Trench

In fiscal year 2000, RCRA monitoring continued to provide no evidence that dangerous non-radioactive constituents from the site have entered groundwater. The well network was sampled twice for the indicator parameters pH, specific conductance, total organic carbon, and total organic halides (Table A.33 and Figure A.17). All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 2000. Critical mean values are listed in Table A.34. The network is considered adequate.

A.8.8 Liquid Effluent Retention Facility

This RCRA facility is subject to final status monitoring and is included in the Hanford Site RCRA Permit (Ecology 1994). Until the final status plan is approved by the regulators, groundwater is monitored under the interim status plan (WHC-SD-EN-AP-024). Critical mean values are listed in Table A.36.

In fiscal year 2000, groundwater monitoring provided no evidence that dangerous, non-radioactive constituents from the site have entered the groundwater. The RCRA indicator parameters are pH, specific conductance, total organic carbon, and total organic halides (Table A.35 and Figure A.18). Average values of specific conductance in two downgradient wells (299-E26-10 and 299-E35-2) exceeded the critical mean value in fiscal year 2000. The exceedances were part of a continuing trend, which was reported in March 1999. The Liquid Effluent Retention Facility was not the source of the high specific conductance and detection monitoring will continue.

During fiscal year 2000, the Liquid Effluent Retention Facility was monitored by one upgradient and two downgradient wells because the other downgradient well went dry in 1999. The water table is dropping below the top of the basalt in the area so the unconfined aquifer is disappearing. In September 1999, Ecology directed DOE to continue monitoring using three wells for 18 months. In January 2001, another downgradient well went dry. Ecology directed DOE to cease statistical evaluation of groundwater data at the facility.

A.8.9 Low-Level Waste Management Area 1

Groundwater monitoring under interim status requirements continued at this RCRA site in fiscal year 2000. The well network was sampled twice for indicator and site-specific parameters (Table A.37 and Figure A.19). Downgradient monitoring well 299-E33-34 continued to exceed the critical mean for specific conductance in samples taken in fiscal year 2000. This exceedance is related to the nitrate plume and not Low-Level Waste Management Area 1. DOE submitted a letter of notification to Ecology on March 18, 1999. Because no waste has been placed in the northern portion of this site and there is a known nitrate plume from an upgradient source, no further action is necessary. Critical mean values are listed in Table A.38. Results exceeding drinking water standards are listed in Table A.3.

The groundwater monitoring network for Low-Level Waste Management Area 1 is adequate for the RCRA requirements. No new wells are planned for this area.

A.8.10 Low-Level Waste Management Area 2

This RCRA site continued in RCRA interim status indicator evaluation in fiscal year 2000. Wells were sampled twice for indicator and site-specific parameters (Table A.39 and see Figure A.17). Statistical evaluations for this area determined that upgradient well 299-E34-7 continued to exceed the critical mean for specific conductance. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.6 meter of water remaining in this well, which is completed at the top of basalt, and the increase may be related to the basalt chemistry. This well also exceeded the comparison value for total organic carbon in both sampling events in fiscal year 2000. All results of volatile and semi-volatile organic analyses from this well were less than detection limits except bis (2-Ethylhexyl) phthalate at 1.7 µg/L. This does not explain the elevated total organic carbon. Additional investigations are being planned. Table A.40 lists the critical mean values based on data from the upgradient wells. Table A.3 summarizes constituents exceeding drinking water standards.

The monitoring network for Low-Level Waste Management Area 2 is adequate to detect releases from the facility. However, the continued water-level decline may cause additional wells to go dry. Monitoring wells in this area are all completed at the top of basalt and if more wells become dry, alternatives to groundwater monitoring may be required to detect contamination from this facility.

A.8.11 200 Areas Treated Effluent Disposal Facility

A state waste discharge permit (WAC 173-216) governs groundwater sampling and analysis in the three monitoring wells at this facility (Table A.41 and see Figure A.16). The constituent list and frequency of sampling are specified in the permit. A groundwater monitoring plan (PNNL-13032) describes details of the monitoring program. Wells were sampled quarterly during fiscal year 2000.

No permit criteria for constituents in groundwater were exceeded in fiscal year 2000. The groundwater monitoring network demonstrates that effluent from the facility is not taking a direct route to the uppermost aquifer and differentiates the effects of the Treated Effluent Disposal Facility from those of B Pond. The well configuration is currently adequate for this purpose.

A.8.12 200-PO-1 Operable Unit

This groundwater operable unit, which encompasses the area of the tritium plume southeast of the 200 East Area, has the same monitoring objectives as monitoring for the *Atomic Energy Act of 1954* (surveillance) and RCRA (PUREX cribs assessment). See Section A.8.4 for additional discussion.

A.8.13 200-BP-5 Operable Unit

This groundwater operable unit, which encompasses the northern portion of 200 East Area, has the same monitoring objectives as the *Atomic Energy Act of 1954* (surveillance). See Section A.8.14 for additional discussion.

A.8.14 Drinking Water Standards and DOE Derived Concentration Guides

Tritium was detected at levels above the 2 million pCi/L DOE derived concentration guide at one well south of the PUREX Plant. Tritium contamination at levels above the 20,000 pCi/L drinking water standard was found in a number of wells in the 200 East Area, mainly in the southeast portion of the area near the PUREX Plant. Strontium-90 concentrations exceeded the 1,000 pCi/L DOE derived concentration guide in a well near the former Gable Mountain Pond, and exceeded the 8 pCi/L drinking water standard near the 216-B-5 injection well and in one well south of the PUREX Plant. The following constituents also were detected at levels above standards in the 200 East Area: cyanide, gross alpha, gross beta, iodine-129, nitrate, technetium-99, and uranium.

A.9 400 and 600 Areas

This section discusses compliance issues for the 400 Area process ponds, 400 Area water supply wells, Nonradioactive Dangerous Waste Landfill, and Solid Waste Landfill.

A.9.1 400 Area

The 4608 B/C ponds (also called the 400 Area process ponds), are regulated under WAC 173-216. The permit, issued on August 1, 1996, and modified on February 10, 1998, defines groundwater enforcement limits (Table A.42 and Figure A.20). Groundwater quality met permit conditions in fiscal year 2000.

The water supply in the 400 Area, which comes from wells, is also monitored to maintain compliance with drinking water standards. Tritium was detected at levels above the 20,000-pCi/L standard in the backup water supply wells for this area. Because the backup water supply wells are seldom used, however, the monthly water supply sampling indicates that tritium in the drinking water is maintained at a level below the 4 mrem/yr dose equivalent standard.

A.9.2 Nonradioactive Dangerous Waste Landfill

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 2000 (Table A.43 and Figure A.21). Statistical evaluations indicated the site has not adversely affected groundwater quality. However, average values of specific conductance in downgradient wells 699-25-34A, 699-25-34B, and 699-25-34D are increasing and approaching the critical mean. Table A.44 lists critical mean values.

Groundwater flow direction and rate did not change significantly during fiscal year 2000 (see Table A.2), and the wells in the network are still functioning. Therefore, the monitoring well network is adequate to fulfill the needs of the current groundwater monitoring plan.

A.9.3 Solid Waste Landfill

State dangerous waste regulations (WAC 173-304) govern groundwater monitoring at this landfill. The final closure plan for the site has been implemented. Wells are sampled quarterly for constituents specified in WAC 173-304 plus the site-specific constituents chlorinated hydrocarbons, gross alpha, gross beta, and tritium (Table A.45 and see Figure A.21).

Statistical evaluations of the constituents specified in WAC 173-304 for landfills (Tables A.46 and A.47) revealed that three exceeded their background threshold levels (or range) during fiscal year 2000:

1. Specific conductance exceeded its 583 µS/cm threshold level in all eight of the downgradient wells in the monitoring network.
2. Sulfate exceeded its 47.2 mg/L threshold level in two of the eight downgradient wells.
3. Reported results for pH were lower than the background threshold range (6.68-7.84) in three downgradient monitoring wells.

Tritium exceeded its drinking water standard at many of the monitoring wells on the eastern side of the landfill, but the source is upgradient. Three chlorinated hydrocarbons exceeded WAC 173-200 groundwater quality criteria in at least one well of the monitoring network. They are as follows, with the numbers of wells having exceedances and the WAC limit:

- 1,1-dichloroethane (10) (1.0 µg/L)
- carbon tetrachloride (2) (0.3 µg/L)
- tetrachloroethene (10) (0.8 µg/L).

Gross alpha and gross beta did not exceed the drinking water standards, 15 pCi/L for gross alpha and 50 pCi/L for gross beta.

The monitoring network for the Solid Waste Landfill has two upgradient wells and eight downgradient wells and is adequate for meeting the requirements of WAC 173-304.

A.9.4 Drinking Water Standards and DOE Derived Concentration Guides

No radionuclides exceeded DOE derived concentration guides in the 600 Area. Contamination from other operational areas affected the 600 Area at levels that exceeded the drinking water standards or maximum contaminant levels, as discussed in Chapter 2. Nitrate concentrations that exceeded the maximum contaminant level were found upgradient of the operational areas and probably result from offsite agriculture.

In the 400 Area, nitrate exceeded the 45 mg/L maximum contaminant level and tritium from upgradient sources exceeded the drinking water standard.

A.10 300 and Richland North Areas

Groundwater in these areas is monitored for one RCRA site and the 300-FF-5 and 1100-EM-1 groundwater operable units.

A.10.1 316-5 Process Trenches

This RCRA site continued to be monitored with a final status corrective-action network. The objective of groundwater monitoring during the corrective-action period is to monitor the trend of the constituents of concern to confirm that they are naturally attenuating, as expected by the CERCLA record of decision for the 300-FF-5 Operable Unit (ROD 1996b). A proposed groundwater monitoring plan for corrective action calls for samples from the same wells as in the compliance monitoring plan, but with fewer independent samples from each well during each sampling period (i.e., four to one). The proposed plan was the Combined Shewhart-CUSUM Control chart statistical approach (Westgard et al. 1977; Lucas 1982). Also, each well showing an exceedance of one of the constituents of concern will be sampled quarterly to better follow the trends of contaminant concentration. The other wells in the network will continue to be sampled semiannually. The proposed plan is still being reviewed by the regulator.

Until the proposed plan is implemented, the final status compliance monitoring program (WHC-SD-EN-AP-185) remains in effect (Table A.48 and Figure A.22). This plan calls for four independent groundwater samples from each network well (eight) during each semiannual sampling period (i.e., 64 well trips per year). The monitoring network for the 316-5 process trenches includes two wells upgradient and six wells downgradient. One of the upgradient wells and three of the downgradient wells monitor the bottom of the unconfined aquifer, and one upgradient and three downgradient wells monitor the unconfined aquifer near the water table. The monitoring network has eight wells and is adequate to ensure that the 316-5 process trenches complies with a RCRA final status corrective-action network and the current groundwater monitoring plan (WHC-SD-EN-AP-185).

Uranium and cis-1,2-dichloroethene continued to exceed concentration limits specified in the permit (see Table A.3). Uranium and gross alpha exceeded maximum contaminant levels in one or more wells monitoring near the water table (see Table A.3). In one downgradient well that monitors the base of the unconfined aquifer, cis-1,2-dichloroethene exceeded the maximum contaminant level.

A.10.2 300-FF-5 Operable Unit

Groundwater in this operable unit is monitored to assess whether the contaminants of concern (uranium, trichloroethene, and cis-1,2-dichloroethene) are naturally diminishing over time. The remedial action is an interim action that involves imposing restrictions on the use of the groundwater until these contaminants meet health-based criteria (ROD 1996b). This is an interim action because there are other constituents (e.g., tritium) migrating into the unit that have not yet been fully addressed and because a portion of the unit is overlaid by uncharacterized waste sites in the 300-FF-2 Operable Unit. A final action decision for the 300-FF-5 Operable Unit will be made after these issues have been resolved .

An operation and maintenance plan for the 300-FF-5 Operable Unit (DOE/RL-95-73) identifies tasks necessary to verify the effectiveness of the remedial action. The plan describes the monitoring program and administrative tasks that are part of the remedial action. The routine operation and maintenance activities include groundwater and river monitoring.

The constituents of concern actually increased in concentration in the groundwater of the 300-FF-5 Operable Unit immediately after discharges from the process sewers to the 316-5 process trenches stopped. The previously lower concentrations in the groundwater were apparently due to the dilution of the constituents by the large quantities of relatively clean waste cooling water. When the trenches ceased to be used and the dilution no longer occurred, the concentrations rose to the high levels discovered in 1995-1997. More recently the constituents of concern have begun to decrease in concentration, as was predicted (ROD 1996a).

In June 2000, EPA developed an explanation of significant difference to the 300-FF-5 operable unit that expands the scope of the 300-FF-5 groundwater operable unit to include groundwater beneath all 300-FF-2 waste sites and burial grounds. That is, the original 300-FF-5 boundary as it was defined in the 1996 ROD (ROD 1996a), was expanded to include the 618-10 burial ground and 316-4 crib (between the 300 Area and Energy Northwest) and 618-11 burial ground immediately west of Energy Northwest. The explanation of significant difference also requires an update to the operations and maintenance plan (DOE/RL-95-73) to ensure that adequate groundwater monitoring requirements are in place. The explanation of significant difference did not make any fundamental changes to the 1996 remedy selected.

Although there are no wells located immediately downgradient of the 618-10 burial ground, there are several wells in the immediate area including one well completed at multiple depths. During fiscal year 2000, uranium concentrations declined slightly from previous years with a fiscal year 2000 average value of 36 µg/L. Also, tributyl phosphate and tritium were detected. Tributyl phosphate concentrations were erratic with a high of 200 µg/L detected in January 2000. The tritium concentration at the water table was 20,400 pCi/L which is consistent with the regional tritium plume. For more information on the 618-10 burial ground and 316-4 crib, see Section 2.12.

The discovery of high levels of tritium in well 69-13-3A (1.9 million pCi/L in January 1999; 8.1 million pCi/L in January 2000) resulted in a two-phase study during fiscal year 2000 to determine the source and extent of the anomalous tritium plume. The most recent groundwater sample from well 699-13-3A (August 29, 2000) had tritium ranging from 6.7 million to 8.4 million pCi/L. Results of Phase I showed that the extremely high levels of tritium found in well 699-13-3A were not found in any other nearby wells, strongly suggesting a source with the 618-11 burial ground. No radionuclides were detected at levels above drinking water standards in well 699-13-3A except for the tritium. However, a single uranium result from nearby well C3079 was 30.8 µg/L (drinking water standard 20 µg/L). Nitrate was detected in well 699-13-3A at levels greater than the maximum contaminant level (45 mg/L) with a fiscal year 2000 average of 90 mg/L. No other non-radioactive constituents were detected at levels above primary maximum contaminant levels. The studies to determine the source and extent of the extremely high tritium near the 618-11 burial ground will continue in fiscal year 2001 (see Section 2.12 for more on the studies near the 618-11 burial ground).

A.10.3 1100-EM-1 Operable Unit

The 1100-EM-1 Operable Unit contains the inactive Horn Rapids Landfill. Results of the CERCLA investigation for this operable unit are presented in the final remedial investigation study (DOE/RL-92-67, Draft B) and the record of decision (ROD 1993). The selected remedy for groundwater is monitored natural attenuation of volatile organic compounds, with institutional controls on drilling of new water supply wells. Monitoring includes analysis for trichloroethene, its breakdown products (vinyl chloride and 1,1-dichloroethene), and nitrate in wells downgradient of the Horn Rapids Landfill, as recommended in the sampling plan (PNNL-12220). Sampling of wells in the 1100-EM-1 Operable Unit network was delayed from fiscal year 2000 to early fiscal year 2001 because of issues associated with disposal of sampling-related waste.

Trichloroethene was not measured at the point of compliance wells 699-S27-E12A, 699-S28-E13A, and 699-S29-E13A because the sampling was delayed into fiscal year 2001. These wells form a line downgradient of the Horn Rapids Landfill that is approximately perpendicular to the prevailing path of the trichloroethene plume.

Although not specified in the record of decision, chromium is monitored annually in one well downgradient of the 1171 Building. The concentration of unfiltered chromium in this well decreased from the maximum contaminant level of 100 µg/L in fiscal year 1999 to 42 µg/L in fiscal year 2000. Filtered chromium continued to be much less than the maximum contaminant level and was less than the minimum detection limit of 3 µg/L in fiscal year 2000.

A.10.4 Drinking Water Standards and DOE Derived Concentration Guides

Tritium was the only radiological constituent detected above the DOE derived concentration guide in 300-FF-5 Operable Unit groundwater during fiscal year 2000. Tritium concentrations were over 8 million pCi/L at well 699-13-3A near the 618-11 burial ground (to the northwest of the 300 Area). Uranium exceeded the proposed maximum contaminant level in much of the eastern part of the 300 Area. In the deeper part of the unconfined aquifer system, one well (399-1-16B) had levels of cis-1,2-dichloroethene above the maximum contaminant level (70 μg/L). Trichloroethene was also detected in the deeper part of the unconfined aquifer system at well 399-1-16B, but it did not exceed the maximum contaminant level. Trichloroethene was also detected in other wells in the upper portion of the unconfined aquifer of the central and southern parts of the 300 Area. The source is from outside the 300 Area to the southwest. Nitrate exceeded its maximum contaminant level at two wells in the southern portion of the 300 Area.

In the Richland North Area, fluoride and nitrate were detected in groundwater at concentrations above their respective maximum contaminant levels. High levels of gross alpha suggest that uranium may also have been above its standard during fiscal year 2000. Likely sources of these constituents include offsite industry and agriculture.

A.11 References

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Table A.1. RCRA Interim and Final Status Groundwater Monitoring Projects, September 2000

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
1301-N LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
1324-N/NA LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
1325-N LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
183-H solar evaporation basins, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1994(c)
WMA S-SX, October 1991		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA T, February 1990		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA TX-TY, September - October 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA U, October 1990		X, 2000				40 CFR 265.93(b) WAC 173-303-400	TBD(c,j)
216-S-10 pond and ditch, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2003(c)
216-U-12 crib, September 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	2005(c)

Table A.1. (contd)

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated	Indicator Parameter Evaluation[a]	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
LLWMA 3, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[d,e]
LLWMA 4, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[d,e]
WMA A-AX, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD[c,i]
WMA B-BX-BY, February 1990		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD[c,i]
WMA C, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD[c,i]
PUREX cribs[f] 1988		X, 1997				40 CFR 265.93(d) WAC 173-303-400	2005[c]
216-B-3 pond, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
216-A-29 ditch, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
216-B-63 trench, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
LERF, July 1991			X, 1998[g]			40 CFR 265.93(b) WAC 173-303-400	1998[d]
LLWMA 1, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[f,g]
LLWMA 2, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[f,g]

Table A.1. (contd)

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated (associated [CERCLA] groundwater operable units)	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
NRDWL, October 1986	X					40 CFR 265.93(b) WAC 173-303-400	2006(c)
316-5 process trenches, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1996(c,h)

(a) Specific parameters (pH, specific conductance, total organic carbon, and total organic halides) used to determine if a facility is affecting groundwater quality. Exceeding the established limits means that additional evaluation and sampling are required (i.e., groundwater quality assessment). An X in the assessment column indicates whether an evaluation was needed or an assessment was required.
(b) Monitored according to interim status plan as specified in closure plans.
(c) Closure/postclosure plan; TSD unit will close under WAC 173-303-610.
(d) Part B permit; TSD unit scheduled to operate under final status regulations beginning in year indicated.
(e) Facility Part B permit and final status groundwater monitoring plan contingent on completion of solid waste environmental impact statement.
(f) 216-A-10, 216-A-36B, and 216-A-37-1 combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim status groundwater quality assessment requirements.
(g) Will monitor groundwater under interim status until final status groundwater monitoring plan is approved.
(h) Closure plan pending Ecology approval.
(i) Unscheduled.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.
LERF = Liquid effluent retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste disposal facility.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PUREX = Plutonium-uranium extraction (plant).
RCRA = *Resource Conservation and Recovery Act of 1976*.
TBD = To be determined.
TSD = Treatment, storage, or disposal (unit).
WMA = Waste management area.

Table A.2. 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
1301-N LWDF	NW	0.07 to 1.3	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0035	Gradient calculated between wells 199-N-66 and 199-N-2.
1324-N/NA	NW	0.08 to 1.4	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0039	Gradient calculated between wells 199-N-72 and 199-N-26.
1325-N LWDF	N	0.03 to 0.59	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0016	Gradient calculated between wells 199-N-28 and 199-N-81.
183-H solar evaporation basins	E	0.13 to 3.7	Darcy	15 to 140 (PNL-6728)	0.1 to 0.3	0.0026	Gradient calculated between wells 199-H3-2A and 199-H4-5. Flow meter in wells 199-H4-7 and 199-H3-2A (Section 3.3 in DOE/RL-96-01).
		0.65 to 4.9	Flow meter				
WMA S-SX	E	0.013	Darcy	1.8 (PNNL-13441)	0.26	0.00180	New well 299-W22-48; only approximately one-third of the well screen transmitted water.
	E	0.031	Darcy	5.2 (PNNL-13441)	0.35	0.00206	New well 299-W22-50; run #1.
	E	0.049	Darcy	5.2 (PNNL-13441)	0.22	0.00206	New well 299-W22-50; run #2.
		0.07 to 0.14	Contaminant travel time (PNNL-12114)				Average gradient calculated from wells 299-W23-13 and 299-W22-45 at S Tank Farm and wells 299-W23-14 and 299-W22-39 at SX Tank Farm.
WMA T	E	0.003 to 0.024	Darcy	1 to 2.4 (PNNL-13378)	0.1 to 0.3	0.001	
WMA TX-TY	E (north half) S or SW (south half)	0.003 to 0.026	Darcy	0.88 to 2.6 (PNNL-13378)	0.1 to 0.3	0.001	
WMA U	E	0.006 to 0.14	Darcy	1.2 to 9.5 (PNNL-13378)	0.1 to 0.3	0.0015	
216-S-10 pond	ESE	0.047 to 0.33	Darcy	10 (WHC-SD-EN-DP-052) 12 to 150 (BNWL-1709)	0.1 to 0.3	0.0014 to 0.0033	Gradient increases to the south. Gradients calculated between wells 299-W26-8 and average of wells 299-W26-10 and 299-W26-12 (north) and wells 299-W26-7 and 299-W26-9 (south).
216-U-12 crib	ESE, changing to E	0.07 to 0.3	Darcy	4.2 to 5.4 (PNNL-13378)	0.1 to 0.3	0.0047	Gradient calculated using water-table contours.
LLWMA 3	ENE	0.0001 to 0.14	Darcy	0.02 to 9.8 (PNL-6820)	0.1 to 0.3	0.0014	

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity(a)	Gradient(b)	Comments
LLWMA 4	E to ENE	0.2 to 0.7	Darcy	24 (PNL-6820)	0.1 to 0.3	0.003	
SALDS	NE	0.03 to 0.3	Darcy	3.5 to 36.3 (WHC-SD-C018H-RPT-003)	0.25(c)	0.002	Gradient was calculated between wells 699-48-77A and 699-48-77D.
WMA A-AX	E	1.0 to 2.0	Darcy	1,981 to 2,519 (WHC-SD-EN-TI-019)	0.2 to 0.3	0.00016	Gradient calculated between wells 299-E25-41 and 299-E24-20. Flow direction inferred from hydrographs but is uncertain.
WMA B-BX-BY	SW (north half) SE (south half)	0.8	Darcy	1,615 (WHC-SD-EN-TI-019)	0.3	~0.00014	Gradient calculated between wells 299-E33-33 and 299-E33-42. Flow directions verified with direct in situ measurements.
WMA C	SW	0.7 to 1.3	Darcy	1,067 to 2,073 (WHC-SD-EN-TI-019)	0.3	0.00020	Gradient calculated between wells 299-E27-7 and 299-E27-13. Flow direction inferred from hydrographs, but is uncertain.
PUREX cribs	SE	See comment	Plume maps	NA	NA	See comment	Gradient too low to determine flow direction or rate.
216-B-3 pond	SW	0.01 to 7.7	Darcy	1 to 640 (WHC-SD-EN-EV-002, PNL-10195)	0.25	~0.003	Gradient calculated between wells 699-44-42 and 699-43-45.
216-A-29 ditch	WSW	~0.03 to ~0.09	Darcy	18 (WHC-SD-EN-DP-047)	0.1 to 0.3	~0.0004	
216-B-63 trench	SW	0.01 to 0.1	Darcy	52 to 200 (WHC-SD-EN-EV-002)	0.1 to 0.3	~0.00004	
LERF	W	0.04 to 6.0	Darcy	6.1 to 120 (PNNL-11620)	0.1 to 0.3	0.002 to 0.005	
LLWMA 1	NW	≤0.5	Darcy	73 to 760 (PNL-6820)	0.1 to 0.3	≤0.00006	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
LLWMA 2	W	~0.06 to ~0.8	Darcy	430 to 2,000 (PNL-6820)	0.1 to 0.3	~0.00004	Gradient calculated between wells 299-E27-16 and 299-E27-9.
200 Area TEDF	SW	0.004	Darcy	1.1 (WHC-SD-EN-ES-004)	0.25(c)	~0.001	

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity(a)	Gradient(b)	Comments
NRDWL	125° E of N (based on plume maps)	0.035 to 0.305	Darcy	518 to 1,524 (WHC-EP-0021)	0.1 to 0.3	0.00002	
SWL	125° E of N (based on plume maps)	0.043 to 0.256	Darcy	640 to 1,280 (PNL-6820)	0.1 to 0.3	0.00002	
316-5 process trenches	SE	31 (DOE/RL-89-14)	Movement of PCE spill				
	S	0.2 to 60	Darcy	150 to 15,000 (PNL-6716)	0.1 to 0.3	0.0004	Gradient from Plate 1.

(a) Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system.
(b) March 2000 unless noted otherwise.
(c) RHO-ST-42, RHO-RE-ST-12, PNNL-11801.

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 = Tetrachloroethylene.
RCRA = *Resource Conservation and Recovery Act of 1976*.
SWL = Solid Waste Landfill.
WMA = Waste management area.

Table A.3. Monitoring Results Exceeding Maximum Contaminant Levels or Drinking Water Standards (Regulated units listed in alphanumeric order)(a)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
1301-N						
Gross beta, pCi/L	N	199-N-2	Down	1	532	50
	N	199-N-3	Down	3	3,900	50
Nitrate, µg/L	N	199-N-105A	Down	1	45,596.04	45,000
	N	199-N-2	Down	2	10,4029.8	45,000
Strontium-90, pCi/L	N	199-N-2	Down	1	269	8
	N	199-N-3	Down	3	2,310	8
	N	199-N-34	Up	1	59.9	8
	N	199-N-57	Up	1	13.8	8
Tritium, pCi/L	N	199-N-2	Down	1	39,500	20,000
	N	199-N-34	Up	1	22,000	20,000
1324-N/NA						
Nitrate, µg/L	N	199-N-59	Down	1	67,287.36	45,000
1325-N						
Antimony, µg/L	Y	199-N-41	Down	1	29.2	6
Gross beta, pCi/L	N	199-N-81	Down	1	1,900	50
Radium-226, pCi/L	N	199-N-32	Down	2	102	5
Strontium-90, pCi/L	N	199-N-28	Down	1	96.8	8
	N	199-N-81	Down	2	1,010	8
Tritium, pCi/L	N	199-N-28	Down	1	24,000	20,000
	N	199-N-32	Down	3	28,700	20,000
	N	199-N-81	Down	1	22,300	20,000
183-H Solar Evaporation Basins						
Chromium, µg/L	N	199-H4-12C	Down	1	234	100
	N	199-H4-3	Down	2	151	100
	Y	199-H4-12C	Down	1	178	100
	Y	199-H4-3	Down	2	142	100
Gross alpha, pCi/L	N	199-H4-3	Down	2	131	15
Gross beta, pCi/L	N	199-H4-3	Down	2	593	50
Hexavalent chromium, µg/L	Y	199-H4-12C	Down	2	177	100
	Y	199-H4-3	Down	4	153	100
Nitrate, µg/L	N	199-H4-12A	Down	1	59,761.8	45,000
	N	199-H4-3	Down	2	387,345	45,000
	N	199-H4-7	Down	2	52,600	45,000
Technetium-99, pCi/L	N	199-H4-3	Down	1	1,070	900
Uranium, µg/L	N	199-H4-3	Down	1	157	20
216-A-29 Ditch						
None						
216-B-3 Pond						
Antimony, µg/L	Y	299-E32-4	Up	1	25.7	6
216-B-63 Ditch						
Antimony, µg/L	Y	299-E27-11	Up	1	51.8	6
	Y	299-E33-36	Down	1	47.2	6
Iodine-129, pCi/L	N	299-E33-36	Down	3	3.67	1
216-S-10 Pond						
Nickel, µg/L	Y	299-W27-2	Down	2	180	100

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
216-U-12 Crib						
Carbon tetrachloride, µg/L	N	699-36-70A	Down	1	7.1	5
Iodine-129, pCi/L	N	699-36-70A	Down	1	12.9	1
Nitrate, µg/L	N	299-W22-79	Down	4	64,631.28	45,000
	N	699-36-70A	Down	2	103,144.4	45,000
Tritium, pCi/L	N	299-W22-79	Down	2	20,500	20,000
	N	699-36-70A	Down	3	81,200	20,000
316-5 Trenches						
cis-1,2-dichloroethene, µg/L	N	399-1-16B	Down	7	170	70
Gross alpha, pCi/L	N	399-1-17A	Down	2	60.2	15
Uranium, µg/L	N	399-1-10A	Down	6	53.4	20
	N	399-1-16A	Down	6	131	20
	N	399-1-17A	Down	7	126	20
400 Area						
Antimony, µg/L	N	699-2-6A	Down	1	46.6	6
Nitrate, µg/L	N	699-2-7	Down	4	92,077.44	45,000
Tritium, pCi/L	N	699-2-6A	Down	1	20,400	20,000
	N	699-8-17	Up	2	58,800	20,000
Liquid Effluent Retention Facility						
Gross alpha, pCi/L	N	299-E35-2	Down	1	26.3	15
Low-Level Waste Management Area 1						
Antimony, µg/L	Y	299-E28-27	Up	1	88.3	6
	Y	299-E32-4	Up	1	25.7	6
	Y	299-E33-29	Up	1	88.1	6
	Y	299-E33-35	Up	1	60.7	6
Gross alpha, pCi/L	N	299-E33-34	Down	1	17.1	15
Gross beta, pCi/L	N	299-E32-10	Down	3	571	50
	N	299-E33-34	Down	4	2,400	50
	N	299-E33-35	Up	4	549	50
Nitrate, µg/L	N	299-E28-26	Up	3	48,252.12	45,000
	N	299-E32-10	Down	3	96,504.24	45,000
	N	299-E32-2	Down	3	57,105.72	45,000
	N	299-E32-3	Down	3	66,844.68	45,000
	N	299-E32-6	Down	3	57,105.72	45,000
	N	299-E32-7	Down	3	49,137.48	45,000
	N	299-E33-34	Down	4	262,066.6	45,000
	N	299-E33-35	Up	4	71,714.16	45,000
Technetium-99, pCi/L	N	299-E32-10	Down	2	1,610	900
	N	299-E33-34	Down	4	5,320	900
	N	299-E33-35	Up	4	1,710	900
Uranium, µg/L	N	299-E33-34	Down	3	33.7	20
Low-Level Waste Management Area 2						
Antimony, µg/L	Y	299-E27-11	Down	1	51.8	6
Nitrate, µg/L	N	299-E34-7	Up	2	95,618.88	45,000
Low-Level Waste Management Area 3						
Carbon tetrachloride, µg/L	N	299-W10-13	Up	2	7.4	5
	N	299-W10-19	Up	2	290	5
	N	299-W10-20	Up	1	1,000	5
	N	299-W10-21	Up	1	610	5
	N	299-W6-2	Down	2	80	5
	N	299-W7-4	Down	1	410	5

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
	N	299-W7-5	Down	2	71	5
	N	299-W7-7	Down	2	16	5
Nickel, µg/L	Y	299-W7-1	Down	1	112	100
Nitrate, µg/L	N	299-W10-13	Up	2	68,172.72	45,000
	N	299-W10-19	Up	2	69,058.08	45,000
	N	299-W10-20	Up	1	102,701.8	45,000
	N	299-W10-21	Up	1	166,890.4	45,000
	N	299-W6-2	Down	1	47,366.76	45,000
	N	299-W7-4	Down	1	88,093.32	45,000
	N	299-W7-5	Down	1	51,350.88	45,000
Trichloroethene, µg/L	N	299-W10-21	Up	1	6	5
Low-Level Waste Management Area 4						
Antimony, µg/L	Y	299-W15-15	Up	1	56.5	6
Cadmium, µg/L	Y	299-W15-17	Down	1	6.2	5
Carbon tetrachloride, µg/L	N	299-W15-15	Up	7	160	5
	N	299-W15-16	Down	5	5,400	5
	N	299-W15-17	Down	2	8.5	5
	N	299-W15-18	Down	2	1,000	5
	N	299-W18-21	Up	4	130	5
	N	299-W18-23	Up	2	170	5
	N	299-W18-24	Down	5	1,000	5
Gross alpha, pCi/L	N	299-W18-21	Up	1	15.8	15
Nitrate, µg/L	N	299-W15-15	Up	3	97,389.6	45,000
	N	299-W15-16	Down	3	54,892.32	45,000
	N	299-W15-18	Down	1	90,749.4	45,000
	N	299-W18-21	Up	2	84,551.88	45,000
	N	299-W18-23	Up	1	50,465.52	45,000
	N	299-W18-24	Down	3	79,682.4	45,000
Nonradioactive Dangerous Waste Landfill						
Tritium, pCi/L	N	699-26-33	Down	1	65,900	20,000
Plutonium-Uranium Extraction (PUREX) Cribs						
Gross beta, pCi/L	N	299-E17-14	Down	5	62.5	50
Iodine-129, pCi/L	N	299-E17-1	Down	3	8.48	1
	N	299-E17-14	Down	5	12.1	1
	N	299-E17-18	Down	1	2.05	1
	N	299-E17-19	Down	2	7.6	1
	N	299-E17-9	Down	1	9.79	1
	N	299-E24-16	Down	4	9.13	1
	N	299-E25-31	Up	1	3.19	1
Nitrate, µg/L	N	299-E17-1	Down	3	81,895.8	45,000
	N	299-E17-14	Down	5	112,883.4	45,000
	N	299-E17-19	Down	1	46,924.08	45,000
	N	299-E17-9	Down	1	149,625.8	45,000
Strontium-90, pCi/L	N	299-E17-14	Down	5	19.1	8
Tritium, pCi/L	N	299-E17-1	Down	3	680,000	20,000
	N	299-E17-14	Down	5	789,000	20,000
	N	299-E17-18	Down	2	145,000	20,000
	N	299-E17-19	Down	2	690,000	20,000
	N	299-E17-9	Down	1	2,510,000	20,000
	N	299-E24-16	Down	4	308,000	20,000
	N	299-E24-18	Up	2	98,700	20,000
	N	299-E25-19	Down	4	208,000	20,000
	N	699-37-47A	Down	3	27,100	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS$^{(b)}$ Level
State-Approved Land Disposal Site						
Carbon tetrachloride, µg/L	N	299-W6-12	Down	1	6.8	5
	N	299-W6-7	Down	1	16	5
	N	299-W7-5	Down	2	71	5
	N	299-W7-7	Down	2	16	5
Chromium, µg/L	N	699-48-77A	Down	2	450	100
Gross beta, pCi/L	N	699-48-77A	Down	1	77	50
Nickel, µg/L	Y	299-W7-1	Down	1	112	100
Nitrate, µg/L	N	299-W6-6	Down	1	52,678.92	45,000
	N	299-W6-7	Down	1	18,8581.7	45,000
	N	299-W7-5	Down	1	51,350.88	45,000
	N	699-48-71	Down	1	73,927.56	45,000
Tritium, pCi/L	N	299-W6-7	Down	2	30,000	20,000
	N	699-48-77A	Down	6	150,000	20,000
	N	699-48-77C	Down	4	710,000	20,000
	N	699-48-77D	Down	5	420,000	20,000
Solid Waste Landfill						
Tritium, pCi/L	N	699-24-33	Down	3	25,700	20,000
	N	699-24-34C	Down	3	26,400	20,000
	N	699-25-34C	Down	3	45,900	20,000
	N	699-26-35A	Up	3	55,400	20,000
Waste Management Area A-AX						
Chromium, µg/L	Y	299-E24-19	Down	3	3,250	100
Iodine-129, pCi/L	N	299-E24-19	Down	1	3.09	1
	N	299-E25-40	Up	1	4.51	1
	N	299-E25-41	Up	1	4.34	1
	N	299-E25-46	Down	1	4.56	1
Nickel, µg/L	Y	299-E24-19	Down	3	830	100
Waste Management Area B-BX-BY						
Antimony, µg/L	Y	299-E28-27	Down	1	88.3	6
	Y	299-E32-4	Down	1	25.7	6
	Y	299-E33-15	Down	1	25.2	6
	Y	299-E33-29	Down	1	88.1	6
	Y	299-E33-35	Down	1	60.7	6
	Y	299-E33-36	Up	1	47.2	6
Cyanide, µg/L	N	299-E33-38	Down	4	411	200
	N	299-E33-7	Down	3	386	200
Gross alpha, pCi/L	N	299-E33-13	Down	7	28.8	15
	N	299-E33-18	Down	4	154	15
	N	299-E33-26	Down	4	38.7	15
	N	299-E33-31	Down	3	31.7	15
	N	299-E33-34	Down	1	17.1	15
	N	299-E33-38	Down	5	101	15
	N	299-E33-41	Down	3	38.7	15
	N	299-E33-44	Down	7	240	15
	N	299-E33-9	Down	3	191	15
Gross beta, pCi/L	N	299-E32-10	Down	3	571	50
	N	299-E33-13	Down	9	913	50
	N	299-E33-15	Down	4	103	50
	N	299-E33-16	Down	3	559	50
	N	299-E33-18	Down	3	1,100	50
	N	299-E33-20	Down	3	92.5	50
	N	299-E33-26	Down	4	1,990	50
	N	299-E33-31	Down	7	884	50
	N	299-E33-32	Down	6	597	50
	N	299-E33-34	Down	4	2,400	50

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS$^{(b)}$ Level
	N	299-E33-35	Down	4	549	50
	N	299-E33-38	Down	5	4,910	50
	N	299-E33-41	Down	6	946	50
	N	299-E33-42	Down	6	974	50
	N	299-E33-43	Down	4	200	50
	N	299-E33-44	Down	7	2,890	50
	N	299-E33-7	Down	8	3,680	50
	N	299-E33-9	Down	3	2,210	50
	N	699-49-57A	Down	4	1,050	50
	N	699-50-53A	Down	1	110	50
Iodine-129, pCi/L	N	299-E33-13	Down	1	3.76	1
	N	299-E33-16	Down	3	7	1
	N	299-E33-26	Down	3	7.25	1
	N	299-E33-31	Down	1	3.95	1
	N	299-E33-32	Down	1	4.4	1
	N	299-E33-334	Down	1	4.03	1
	N	299-E33-335	Down	1	4.14	1
	N	299-E33-36	Up	3	3.67	1
	N	299-E33-38	Down	4	6.69	1
	N	299-E33-41	Down	1	3.54	1
	N	299-E33-42	Down	1	4.95	1
	N	299-E33-43	Down	3	4.03	1
	N	299-E33-44	Down	1	4.94	1
	N	299-E33-9	Down	2	6.21	1
Nitrate, µg/L	N	299-E28-26	Down	3	48,252.12	45,000
	N	299-E32-10	Down	3	96,504.24	45,000
	N	299-E32-2	Down	3	57,105.72	45,000
	N	299-E32-3	Down	3	66,844.68	45,000
	N	299-E32-6	Down	3	57,105.72	45,000
	N	299-E32-7	Down	3	49,137.48	45,000
	N	299-E33-13	Down	9	335,994.1	45,000
	N	299-E33-15	Down	4	357,685.4	45,000
	N	299-E33-16	Down	3	562,203.6	45,000
	N	299-E33-17	Down	4	254,098.3	45,000
	N	299-E33-18	Down	4	188,581.7	45,000
	N	299-E33-20	Down	3	321,828.4	45,000
	N	299-E33-26	Down	3	271,362.8	45,000
	N	299-E33-31	Down	7	223,996.1	45,000
	N	299-E33-32	Down	6	108,456.6	45,000
	N	299-E33-34	Down	4	262,066.6	45,000
	N	299-E33-35	Down	4	71,714.16	45,000
	N	299-E33-38	Down	5	460,387.2	45,000
	N	299-E33-41	Down	1	45,153.36	45,000
	N	299-E33-42	Down	6	115,096.8	45,000
	N	299-E33-43	Down	2	91,192.08	45,000
	N	299-E33-44	Down	7	186,368.3	45,000
	N	299-E33-7	Down	8	522,362.4	45,000
	N	299-E33-9	Down	3	181,056.1	45,000
	N	699-49-57A	Down	4	128,819.9	45,000
	N	699-50-53A	Down	2	166,890.4	45,000
Technetium-99, pCi/L	N	299-E32-10	Down	2	1,610	900
	N	299-E33-13	Down	9	2,540	900
	N	299-E33-16	Down	3	2,030	900
	N	299-E33-18	Down	4	3,150	900
	N	299-E33-26	Down	4	6,310	900
	N	299-E33-31	Down	7	2,740	900
	N	299-E33-32	Down	6	1,790	900
	N	299-E33-34	Down	4	5,320	900
	N	299-E33-35	Down	4	1,710	900
	N	299-E33-38	Down	5	13,300	900
	N	299-E33-41	Down	6	2,700	900
	N	299-E33-42	Down	6	2,710	900
	N	299-E33-44	Down	7	6,640	900

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
	N	299-E33-7	Down	8	11,200	900
	N	299-E33-9	Down	3	6,080	900
	N	699-49-57A	Down	4	2,930	900
Uranium, µg/L	N	299-E33-13	Down	8	54.2	20
	N	299-E33-18	Down	4	257	20
	N	299-E33-26	Down	4	69.6	20
	N	299-E33-31	Down	5	50.6	20
	N	299-E33-34	Down	3	33.7	20
	N	299-E33-38	Down	5	131	20
	N	299-E33-41	Down	5	61	20
	N	299-E33-44	Down	7	353	20
	N	299-E33-9	Down	3	303	20
	Y	299-E33-13	Down	1	29.9	20
Waste Management Area C						
Gross beta, pCi/L	N	299-E27-14	Up	5	192	50
	N	299-E27-7	Up	2	93.9	50
Iodine-129, pCi/L	N	299-E27-12	Down	1	2.72	1
	N	299-E27-13	Down	1	2.52	1
	N	299-E27-14	Up	1	3.97	1
Waste Management Area S-SX						
Antimony, µg/L	Y	299-W22-44	Down	1	42.8	6
	Y	299-W22-46	Down	1	26.4	6
	Y	299-W22-49	Down	1	44.3	6
	Y	299-W22-50	Down	1	88.6	6
	Y	299-W23-13	Up	1	30	6
	Y	299-W23-9	Down	1	31.7	6
Carbon tetrachloride, µg/L	N	299-W22-44	Down	5	8.6	5
	N	299-W22-45	Down	3	12	5
	N	299-W22-46	Down	3	30	5
	N	299-W22-48	Down	1	5.6	5
	N	299-W22-49	Down	2	6	5
	N	299-W22-50	Down	5	23	5
	N	299-W23-1	Down	1	25	5
	N	299-W23-13	Up	2	11	5
	N	299-W23-15	Down	3	140	5
	N	299-W23-19	Down	4	30	5
	N	299-W23-4	Up	3	130	5
Gross alpha, pCi/L	N	299-W22-50	Down	1	20.9	15
Gross beta, pCi/L	N	299-W22-45	Down	3	768	50
	N	299-W22-46	Down	3	1,830	50
	N	299-W22-48	Down	2	555	50
	N	299-W22-50	Down	4	1,420	50
	N	299-W23-1	Down	1	110	50
	N	299-W23-19	Down	4	23,000	50
	N	299-W23-9	Down	1	56.6	50
Nitrate, µg/L	N	299-W22-45	Down	2	47,366.76	45,000
	N	299-W22-46	Down	1	45,596.04	45,000
	N	299-W22-50	Down	1	57,991.08	45,000
	N	299-W23-14	Up	1	134,574.7	45,000
	N	299-W23-19	Down	6	562,203.6	45,000
	N	299-W23-9	Down	3	165,562.3	45,000
Nitrite, µg/L	N	299-W23-19	Down	4	5,485.182	3,300
Technetium-99, pCi/L	N	299-W22-45	Down	3	2,080	900
	N	299-W22-46	Down	3	5,330	900
	N	299-W22-48	Down	1	1,290	900
	N	299-W22-50	Down	3	4,240	900
	N	299-W23-19	Down	5	63,700	900

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS[(b)] Level
Tritium, pCi/L	N	299-W22-39	Down	3	28,500	20,000
	N	299-W22-46	Down	3	26,400	20,000
	N	299-W22-49	Down	3	23,900	20,000
	N	299-W22-50	Down	3	31,400	20,000
	N	299-W23-14	Up	1	208,000	20,000
	N	299-W23-19	Down	4	95,800	20,000
	N	299-W23-9	Down	3	502,000	20,000
Uranium, µg/L	N	299-W23-19	Down	1	23.6	20
	N	299-W23-4	Up	3	25.3	20
	N	299-W23-9	Down	1	20.5	20
Waste Management Area T						
Antimony, µg/L	Y	299-W10-1	Down	1	51.6	6
	Y	299-W10-4	Down	1	45.7	6
	Y	299-W10-8	Down	1	64	6
Cadmium, µg/L	Y	299-W6-10	Down	1	7.3	5
Carbon tetrachloride, µg/L	N	299-W10-1	Down	1	450	5
	N	299-W10-12	Down	2	610	5
	N	299-W10-19	Down	2	290	5
	N	299-W10-20	Down	1	1,000	5
	N	299-W10-21	Down	1	610	5
	N	299-W10-23	Down	1	1,500	5
	N	299-W10-4	Down	2	1,400	5
	N	299-W10-8	Down	1	1,100	5
	N	299-W11-28	Down	1	150	5
	N	299-W11-7	Down	1	1,000	5
	N	299-W6-2	Down	2	80	5
	N	299-W6-4	Down	1	11	5
Chromium, µg/L	Y	299-W10-23	Down	3	135	100
	Y	299-W10-3	Down	1	257	100
	Y	299-W10-4	Down	4	186	100
Fluoride, µg/L	N	299-W10-12	Down	3	5,000	4,000
	N	299-W10-24	Down	3	4,600	4,000
	N	299-W10-4	Down	1	4,200	4,000
	Y	299-W10-3	Down	1	9,800	4,000
Gross beta, pCi/L	N	299-W10-23	Down	3	97.7	50
	N	299-W10-24	Down	4	568	50
	N	299-W10-4	Down	4	103	50
	N	299-W10-8	Down	3	63.7	50
	N	299-W11-12	Down	4	64.3	50
	N	299-W11-23	Down	3	1,480	50
	N	299-W11-24	Down	1	78.3	50
	N	299-W11-28	Down	3	85.9	50
	N	299-W11-7	Down	2	81.1	50
	N	299-W6-10	Down	2	97.2	50
	Y	299-W10-3	Down	1	129	50
Nitrate, µg/L	N	299-W10-1	Down	2	143,871	45,000
	N	299-W10-12	Down	3	187,696.3	45,000
	N	299-W10-19	Down	2	69,058.08	45,000
	N	299-W10-20	Down	1	102,701.8	45,000
	N	299-W10-21	Down	1	166,890.4	45,000
	N	299-W10-22	Down	4	124,835.8	45,000
	N	299-W10-23	Down	3	423,202.1	45,000
	N	299-W10-24	Down	4	403,724.2	45,000
	N	299-W10-4	Down	4	1,049,152	45,000
	N	299-W10-8	Down	5	298,809	45,000
	N	299-W11-12	Down	4	127,934.5	45,000
	N	299-W11-23	Down	4	64,631.28	45,000
	N	299-W11-24	Down	4	353,258.6	45,000
	N	299-W11-28	Down	4	255,869	45,000
	N	299-W11-7	Down	2	177,514.7	45,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS[b] Level
	N	299-W6-10	Down	2	113,326.1	45,000
	N	299-W6-2	Down	1	47,366.76	45,000
	N	299-W6-4	Down	1	86,765.28	45,000
	N	299-W6-9	Down	2	71,271.48	45,000
	Y	299-W10-3	Down	1	1,212,943	45,000
Nitrite, µg/L	N	299-W11-24	Down	4	36,129.94	3,300
	N	299-W11-28	Down	1	14,780.43	3,300
Technetium-99, pCi/L	N	299-W10-24	Down	4	2,170	900
	N	299-W11-23	Down	2	3,000	900
Trichloroethene, µg/L	N	299-W10-21	Down	1	6	5
	N	299-W10-23	Down	1	10	5
	N	299-W10-4	Down	2	11	5
	N	299-W10-8	Down	1	6.9	5
	N	299-W11-7	Down	1	5.8	5
Tritium, pCi/L	N	299-W10-23	Down	3	21,100	20,000
	N	299-W11-12	Down	4	69,500	20,000
	N	299-W11-24	Down	2	25,000	20,000
	N	299-W11-28	Down	4	34,100	20,000
	N	299-W6-10	Down	2	39,700	20,000
	Y	299-W10-3	Down	1	23,600	20,000
		Waste Management Area TX-TY				
Antimony, µg/L	Y	299-W10-26	Down	1	61.6	6
	Y	299-W14-13	Down	1	27.1	6
Carbon tetrachloride, µg/L	N	299-W10-17	Down	1	1,200	5
	N	299-W14-13	Down	1	110	5
	N	299-W14-14	Down	2	270	5
	N	299-W14-2	Down	1	75	5
	N	299-W14-6	Down	1	160	5
	N	299-W15-4	Down	1	88	5
Chromium, µg/L	Y	299-W14-13	Down	5	542	100
Gross beta, pCi/L	N	299-W10-17	Down	4	73.7	50
	N	299-W14-13	Down	5	2,110	50
	N	299-W14-14	Down	4	131	50
	N	299-W14-2	Down	2	214	50
	N	299-W14-5	Down	3	68.1	50
	N	299-W14-6	Down	3	64.6	50
	N	299-W15-12	Down	2	272	50
	N	299-W15-4	Down	1	225	50
Iodine-129, pCi/L	N	299-W14-13	Down	4	50.8	1
	N	299-W14-2	Down	3	52	1
Nitrate, µg/L	N	299-W10-17	Down	3	263,837.3	45,000
	N	299-W10-26	Down	5	80,125.08	45,000
	N	299-W14-13	Down	4	436,039.8	45,000
	N	299-W14-14	Down	4	212,486.4	45,000
	N	299-W14-5	Down	3	180,170.8	45,000
	N	299-W14-6	Down	3	82,781.16	45,000
	N	299-W15-12	Down	2	173,087.9	45,000
	N	299-W15-4	Down	1	121,737	45,000
	N	299-W15-40	Down	3	149,625.8	45,000
Nitrite, µg/L	N	299-W14-2	Down	1	5,912.172	3,300
Technetium-99, pCi/L	N	299-W14-13	Down	6	7,450	900
	N	299-W15-12	Down	2	963	900
Trichloroethene, µg/L	N	299-W10-17	Down	1	9.7	5
Tritium, pCi/L	N	299-W14-13	Down	5	2,940,000	20,000
	N	299-W14-2	Down	3	1,900,000	20,000
	N	299-W15-12	Down	1	20,700	20,000
	N	299-W15-4	Down	1	25,600	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS[(b)] Level
Waste Management Area U						
Carbon tetrachloride, µg/L	N	299-W18-30	Down	6	420	5
	N	299-W18-31	Up	1	29	5
	N	299-W19-12	Down	1	160	5
	N	299-W19-41	Down	1	190	5
	N	299-W19-42	Up	2	340	5
Gross beta, pCi/L	N	299-W19-12	Down	3	99.7	50
	N	299-W19-41	Down	4	206	50
Nickel, µg/L	Y	299-W18-25	Up	3	176	100

(a) Samples collected between October 1, 1999 and September 30, 2000. Primary maximum contaminant levels and drinking water standards. Excludes data flagged as undetected, rejected, or suspect.

(b) MCL = Maximum contaminant level.
DWS = Drinking water standard.

Table A.4. Monitoring Wells and Constituents for 100 N Area Units (adapted from WHC-SD-EN-AP-038, Rev. 2)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
1301-N Liquid Waste Disposal Facility				
199-N-2^{64}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-3^{64}	Top of unconfined	Semiannual	Semiannual	PRE
199-N-34^{83}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-57^{87}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-105A^{95}	Unconfined	Semiannual	--	RCRA(a)
1324-N/NA Liquid Waste Disposal Facilities				
199-N-59^{87}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-71^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-72^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-73^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-77^{92}(b)	Bottom of unconfined	Semiannual	Semiannual	RCRA
1325-N Liquid Waste Disposal Facility				
199-N-28^{83}(b)	Top of unconfined	Semiannual	Quarterly	PRE
199-N-32^{83}	Top of unconfined	Semiannual	Semiannual	PRE
199-N-41^{84}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-74^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-81^{93}	Top of unconfined	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)
- Total organic carbon
- Total organic halides

Site-Specific Parameters

- Alkalinity(c)
- Anions(c)
- Gross alpha(d)
- ICP metals (filtered)(c)
- Turbidity

(a) Extraction well; screened over entire thickness of aquifer.
(b) Used for supplemental information; no statistical evaluations.
(c) Annually for 1301-N and 1325-N liquid waste disposal facilities.
(d) Gross alpha required for wells 199-N-59 and 199-N-77 only.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.5. Critical Mean Values for the 1301-N Liquid Waste Disposal Facility[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	10	9	4.7815	537.69	237.05	1,726.5	1,726.5
Field pH	10	9	5.2912	7.969	0.356	[5.99, 9.94]	[5.99, 9.94]
Total organic carbon, µg/L	10	9	4.7815	623.625	350.836	2,383.0	2,383.0
Total organic halides,[b] µg/L	9	8	5.0420	6.162	3.377	24.1	24.1

(a) Based on semiannual sampling events from September 1997 to September 1999 for upgradient wells 199-N-57 and 199-N-34.

(b) Excluding suspect data collected on September 30, 1997 from well 199-N-57.

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 A.6. Critical Mean Values for 1324-N/NA Liquid Waste Disposal Facilities[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	305.25	18.694	471.6	471.6
Field pH	5	4	9.7291	8.162	0.095	[7.15, 9.17]	[7.15, 9.17]
Total organic carbon,[b] µg/L	5	4	8.1216	237.25	180.157	1,840.1	1,840.1
Total organic halides, µg/L	5	4	8.1216	7.334	2.286	27.7	27.7

(a) Based on semiannual sampling events from September 1997 to August 1999 for upgradient well 199-N-71.

(b) 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 16 comparisons.

Table A.7. Critical Mean Values for the 1325-N Liquid Waste Disposal Facility(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	349.75	13.621	470.9	470.9
Field pH	5	4	9.7291	8.163	0.149	[6.57, 9.76]	[7.46, 8.79](b)
Total organic carbon, µg/L	5	4	8.1216	307.5	156.774	1,702.3	1,702.3
Total organic halides, µg/L	5	4	8.1216	6.185	2.375	27.3	27.3

(a) Based on semiannual sampling events from September 1997 to September 1999 for upgradient well 199-N-74.
(b) Values calculated using data collected from August 1995 to September 1999 because the critical range calculated using limited data is too large to be meaningful.
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 A.8. Monitoring Wells and Constituents for the Former 183-H Solar Evaporation Basins (adapted from PNNL-11573)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
199-H4-3^{74}	Top of unconfined	Annual	Semiannual	PRE
199-H4-7^{86}(a)	Top of unconfined	Annual	Semiannual	RCRA
199-H4-12A^{86}(a)	Top of unconfined	Annual	Semiannual	RCRA
199-H4-12C^{86}	Mid-depth unconfined	Annual	Semiannual	RCRA

Dangerous Waste Constituents

- Chromium (filtered)
- Nitrate
- Fluoride
- Technetium-99
- Uranium

Site-Specific Parameters

- Alkalinity
- Anions
- ICP metals (filtered)
- pH
- Specific conductance
- Turbidity

(a) Extraction well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.9. Monitoring Wells and Constituents for Waste Management Area S-SX (adapted from PNNL-12114)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W22-39^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-44^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-45^{92}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-46^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-48^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-49^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-50^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-80^{00}(a)	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-1^{52}(b)	Top of unconfined	Quarterly	Quarterly	PRE
299-W23-2^{54}(b)	Top of unconfined	Quarterly	Quarterly	PRE
299-W23-4^{56}	Top of unconfined	Quarterly	Quarterly	PRE
299-W23-9^{72}	Top of unconfined	Quarterly	Quarterly	PRE
299-W23-13^{90}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-14^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-15^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-19^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-20^{00}(a)	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-21^{00}(a)	Top of unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters(c)	
pH	Alkalinity	Strontium-90
Specific conductance	Anions	Technetium-99
Total organic carbon	Gamma scan (cesium-137)	Total dissolved solids
Total organic halides	Gross alpha	Tritium
	Gross beta	Turbidity
	Hexavalent chromium	Uranium
	ICP metals (filtered)	Volatile organic compounds

(a) New wells replacing wells that are nearly dry. Will be sampled beginning fiscal year 2001.
(b) Dry well. Last sampled in June 2000.
(c) Constituent list varies by well.

Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.10. Monitoring Wells and Constituents for Waste Management Area T (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-AP-132)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W6-2^{87}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W6-4^{91}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W6-9^{92}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W6-10^{92}	Unconfined	Semiannual	Semiannual	RCRA
299-W10-1^{47}	Unconfined	Semiannual	Semiannual	PRE
299-W10-3^{51}	Unconfined	(b)	--	PRE
299-W10-4^{52}	Unconfined	Quarterly	Quarterly	PRE
299-W10-8^{73}	Top of unconfined	Quarterly	Quarterly	PRE
299-W10-12^{74}	Top of unconfined	Semiannual(c)	Quarterly	PRE
299-W10-19^{92}(a)	Top of unconfined	Semiannual	Quarterly	RCRA
299-W10-20^{93}(a)	Top of unconfined	Semiannual	Quarterly	RCRA
299-W10-21^{93}(a)	Top of unconfined	Semiannual	Quarterly	RCRA
299-W10-22^{94}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-23^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-24^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W11-7^{51}	Unconfined	Semiannual	Semiannual	PRE
299-W11-12^{53}	Unconfined	Quarterly	Quarterly	PRE
299-W11-23^{73}	Top of unconfined	Quarterly	Quarterly	PRE
299-W11-24^{73}	Top of unconfined	Quarterly	Quarterly	PRE
299-W11-28^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W11-30^{92}	Unconfined	Semiannual	Semiannual	RCRA
299-W11-31^{92}(a)	Top of unconfined	Semiannual	Quarterly	RCRA
299-W11-41^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W11-42^{00}	Unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Site-Specific Parameters(d)

Alkalinity
Anions
Gamma scan (cesium-137, cobalt-60)
Gross alpha
Gross beta
ICP metals (filtered)
Iodine-129
Strontium-90
Technetium-99
Total dissolved solids
Tritium
Turbidity
Volatile organic compounds

(a) Wells used for expanded assessment monitoring.
(b) Sampled once before decommissioning.
(c) Sampled twice before decommissioning.
(d) Constituent list varies by well.

Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.11. Monitoring Wells and Constituents for Waste Management Area TX-TY (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-AP-132)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W10-17^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W10-26^{99}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-2^{55}	Unconfined	Quarterly	Quarterly	PRE
299-W14-5^{74}	Unconfined	Quarterly	Quarterly	PRE
299-W14-6^{74}	Unconfined	Quarterly	Quarterly	PRE
299-W14-13^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-14^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-15^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W15-4^{56}	Unconfined	Dry(a)	NA	PRE
299-W15-12^{73}	Unconfined	Dry(b)	NA	PRE
299-W15-40^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W15-41^{00}	Unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Iodine-129
Specific conductance	Anions	Strontium-90(c)
Total organic carbon	Gamma scan (cesium-137, cobalt-60)	Technetium-99
		Total dissolved solids
	Gross alpha	Tritium
	Gross beta	Turbidity
	ICP metals (filtered)	Volatile organic compounds(c)

(a) Well is dry; last sampled October 1999.
(b) Well is dry; last sampled May 2000.
(c) Limited wells.

Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
NA = Not applicable.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.12. Monitoring Wells and Constituents for Waste Management Area U (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W18-25^{90}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W18-30^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W18-31^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W19-12^{83}(a)	Top of unconfined	Quarterly	Quarterly	PRE
299-W19-41^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W19-42^{99}	Top of unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Phenols(c)
Specific conductance	Anions	Technetium-99
Total organic carbon	Gamma scan(b)	Total dissolved solids
Total organic halides	Gross alpha	Tritium
	Gross beta	Turbidity
	ICP metals (filtered)	Volatile organic compounds(d)

(a) Used for supplemental information; no statistical evaluations.
(b) Wells 299-W19-41 and 299-W19-42 only.
(c) Annually.
(d) Beginning September 2000.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.13. Monitoring Wells and Constituents for the 216-S-10 Pond and Ditch (adapted from WHC-SD-EN-AP-018)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W26-7^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W26-9^{90}	Top of unconfined	Dry(a)	NA	RCRA
299-W26-12^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W26-13^{99}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W27-2^{92}(b)	Base of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Hexavalent chromium (filtered)
Specific conductance	Anions	ICP metals (filtered)
Total organic carbon	Gross alpha	Phenols
Total organic halides	Gross beta	Turbidity

(a) Well dry; last sampled December 1999.
(b) Used for supplemental information; no statistical evaluation.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
NA = Not applicable.
RCRA = Well constructed to RCRA standards.

Table A.14. Critical Mean Values for the 216-S-10 Pond and Ditch[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	276.6	5.504	322.0	322.0
Field pH	5	4	9.0292	8.101	0.089	[7.22, 8.98]	[7.22, 8.98]
Total organic carbon,[b] µg/L	5	4	7.5288	274.45	111.93	1,197.6	1,197.6
Total organic halides, µg/L	5	4	7.5288	5.584	2.175	23.5	23.5

(a) Data collected from December 1996 to December 1997 for upgradient well 299-W26-7, except for total organic carbon that was collected from December 1995 to December 1997.
(b) 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 12 comparisons.

Table A.15. Monitoring Wells and Constituents for the 216-U-12 Crib (adapted from WHC-SD-EN-AP-019 and WHC-SD-EN-AP-108)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W22-43^{90}	Top of unconfined	Dry[a]	Quarterly	RCRA
299-W22-79^{98}	Top of unconfined	Quarterly	Quarterly	RCRA
699-36-70A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity[b]	Iodine-129[c]
Specific conductance	Anions	Technetium-99
Total organic carbon	Gross alpha	Total dissolved solids[b]
Total organic halides	Gross beta	Tritium
	ICP metals (filtered)[b]	Turbidity

(a) Well is dry; last sampled January 2000.
(b) Analyzed annually.
(c) Analyzed semiannually.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.16. Monitoring Wells and Constituents for Low-Level Waste Management Area 3 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W6-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-3^{87}	Deep unconfined	Semiannual	Semiannual	RCRA
299-W7-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-5^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-6^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-8^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-9^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-10^{90}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-11^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-12^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W8-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W9-1^{87}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-13^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-14^{87}(b)	Deep unconfined	Semiannual	Semiannual	RCRA
299-W10-19^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-20^{93}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-21^{93}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Mercury (filtered)
Specific conductance	Anions	Phenols
Total organic carbon	Gross alpha	Tritium
Total organic halides	Gross beta	Turbidity
	ICP metals (filtered)	Volatile organic compounds
	Lead (filtered)	

(a) Wells dry early fiscal year 2001.
(b) Used for supplemental information; no statistical evaluations.
Bold italic = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

Table A.17. Critical Mean Values for Low-Level Waste Management Area 3 (area not affected by upgradient contamination)[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	9	8	5.3168	445.472	24.948	585.3	585.3
Field pH	9	8	5.9119	8.287	0.226	[6.88, 9.69]	[6.88, 9.69]
Total organic carbon,[(b,c)] µg/L	8	7	5.7282	169.062	49.945	472.5	1,168.3
Total organic halides, µg/L	8	7	5.7282	9.10	7.137	52.5	52.5

(a) Data collected from December 1994 to September 1995 for upgradient wells 299-W9-1 and 299-W10-13. Critical means calculated for area not impacted by upgradient source of contamination.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.
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 A.18. Critical Mean Values for Low-Level Waste Management Area 3 (area affected by upgradient contamination)[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	11[(b)]	10	5.0494	561.296	54.4	848.2	848.2
Field pH	15	14	4.8656	8.059	0.316	[6.47, 9.65]	[6.47, 9.65]
Total organic carbon,[(c,d)] µg/L	15	14	4.4995	336.917	126.77	926.0	1,168.3
Total organic halides, µg/L	13[(b)]	12	4.7168	784.492	374.522	2,617.7	2,617.7

(a) Data collected from March 1997 to March 1998 for upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21. Critical means calculated for area impacted by upgradient source of contamination.
(b) Excluded outliers.
(c) Critical means calculated from values reported below vendor's specified method detection limit.
(d) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.
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 A.19. Monitoring Wells and Constituents for Low-Level Waste Management Area 4 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W15-15^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W15-16^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W15-17^{87}(a)	Deep unconfined	Semiannual	Semiannual	RCRA
299-W15-18^{87}	Top of unconfined	Semiannual(b)	Semiannual	RCRA
299-W18-21^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W18-22^{87}(a)	Deep unconfined	Semiannual	Semiannual	RCRA
299-W18-23^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W18-24^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W18-26^{89}(b)	Top of unconfined	Dry	Dry	

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Mercury (filtered)
Specific conductance	Anions	Phenols
Total organic carbon	Gross alpha	Technetium-99(c)
Total organic halides	Gross beta	Tritium
	ICP metals (filtered)	Turbidity
	Iodine-129(c)	Volatile organic compounds
	Lead (filtered)	

(a) Used for supplemental information; no statistical evaluations.
(b) Well dry July 2000.
(c) Selected wells.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.20. Critical Mean Values for Low-Level Waste Management Area 4(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	12	11	4.5481	378.917	75.969	738.5	738.5
Field pH	12	11	4.9785	7.918	0.112	[7.34, 8.50]	[7.34, 8.50]
Total organic carbon,(b) µg/L	12	11	4.5481	486.875	219.649	1,526.7	1,526.7
Total organic halides, µg/L	12	11	4.5481	272.480	199.772	1,218.2	1,218.2

(a) Based on semiannual sampling events from July 1997 to January 1998 for upgradient wells 299-W15-15, 299-W18-21, and 299-W18-23.
(b) Critical means calculated using data 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 24 comparisons.

Table A.21. Monitoring Wells, Constituents, and Enforcement Limits for the State-Approved Land Disposal Site (adapted from WHC-SD-C018H-PLN-004, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W6-6	Top of unconfined	Annual	Annual	RCRA
299-W6-7	Top of unconfined	Annual	Annual	RCRA
299-W6-8	Top of unconfined	Semiannual	Semiannual	RCRA
299-W6-11	Top of unconfined	Annual	Annual	RCRA
299-W6-12	Top of unconfined	Annual	Annual	RCRA
299-W7-1	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-3	Top of unconfined	Annual	Annual	RCRA
299-W7-5	Top of unconfined	Annual	Annual	RCRA
299-W7-6	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-7	Top of unconfined	Annual	Annual	RCRA
299-W7-8	Top of unconfined	Annual	Annual	RCRA
299-W7-9	Top of unconfined	Annual	Annual	RCRA
299-W7-11	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-12	Top of unconfined	Annual	Annual	RCRA
299-W8-1(a)	Top of unconfined	Quarterly	Monthly	RCRA
699-48-71	Unconfined	Annual	Annual	PRE
699-48-77A(a)	Ringold unit E; upper	Quarterly	Monthly	RCRA
699-48-77C(a)	Ringold unit E; mid to lower	Quarterly	Monthly	RCRA
699-48-77D(a)	Ringold unit E; upper	Quarterly	Monthly	RCRA
699-49-79	Top of unconfined	Annual	Annual	PRE
699-51-75	Top of unconfined	Annual	Annual	PRE
699-51-75P	Lower unconfined	Annual	Annual	PRE

Constituent	Enforcement Limit (μg/L)	Constituent	Enforcement Limit (μg/L)
Acetone	160	Lead, total	50
Ammonia	1,100	Mercury, total	2
Benzene	5	pH	6.5 - 8.5 pH units
Cadmium, total	10	Strontium-90	Monitor only
Chloroform	6.2	Sulfate	250,000
Copper, total	70	Tetrahydrofuran	100
Gross alpha	Monitor only	Total dissolved solids	500,000
Gross beta	Monitor only	Tritium	Monitor only

(a) Monitored for full constituent list. Other wells analyzed for tritium only.

Bold italic = Upgradient well.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.22. Monitoring Wells and Constituents for the Environmental Restoration Disposal Facility (adapted from BHI-00873)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-35-66A^{57}	Top of unconfined	Semiannual	Semiannual	PRE
699-36-67^{96}	Top of unconfined	Semiannual	Semiannual	RCRA
699-36-70^{94}	Top of unconfined	Semiannual	Semiannual	RCRA
699-37-68^{96}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	ICP metals (filtered)
Specific conductance	Anions	Iodine-129
Turbidity	Arsenic (filtered)	Radium
	Carbon-14	Technetium-99
	Carbon tetrachloride	Total dissolved solids
	Gross alpha	Total organic halides
	Gross beta	Uranium

Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.23. Monitoring Wells and Constituents for Waste Management Area A-AX (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E24-19^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E24-20^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-40^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-41^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-46^{92}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Phenols(a)
Specific conductance	Anions	Strontium-90(a)
Total organic carbon	Gross alpha	Technetium-99
Total organic halides	Gross beta	Total dissolved solids
	ICP metals (filtered)	Tritium(a)
	Iodine-129(a)	Turbidity
	Low-level gamma	Uranium

(a) Annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.24. Critical Mean Values for Waste Management Area A-AX[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	6[(b)]	5	6.8688	313.50	29.838	534.9	534.9
Field pH	8	7	6.0818	8.066	0.182	[6.89, 9.24]	[6.89, 9.24]
Total organic carbon, µg/L	8	7	5.4079	724.375	168.522	1,691.0	1,691.0
Total organic halides,[(c)] µg/L	8	7	5.4079	2.552	0.791	7.1	7.1

(a) Based on semiannual sampling events from February 1998 to June 1999 for upgradient wells 299-E25-40 and 299-E25-41.
(b) Outlier excluded.
(c) 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 20 comparisons.

Table A.25. Monitoring Wells and Constituents for Waste Management Area B-BX-BY (adapted from PNNL-13022)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
		Near-Field Wells		
299-E28-8^{57}	Unconfined	Quarterly	Quarterly	PRE
299-E33-7^{55}	Unconfined	Bimonthly	Bimonthly	PRE
299-E33-9^{49}	Unconfined	Quarterly	Quarterly	PRE
299-E33-13^{53}	Unconfined	Bimonthly	Bimonthly	PRE
299-E33-15^{53}	Unconfined	Quarterly	Quarterly	PRE
299-E33-16^{53}	Unconfined	Quarterly	Quarterly	PRE
299-E33-17^{53}	Unconfined	Quarterly	Quarterly	PRE
299-E33-18^{50}	Unconfined	Quarterly	Quarterly	PRE
299-E33-20^{56}	Unconfined	Quarterly	Quarterly	PRE
299-E33-21^{57}	Unconfined	Quarterly	Quarterly	PRE
299-E33-31^{89}	Unconfined	Bimonthly	Bimonthly	RCRA
299-E33-32^{89}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-33^{89}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-36^{90}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-38^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-39^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-41^{91}	Unconfined	Bimonthly	Bimonthly	RCRA
299-E33-42^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-43^{91}	Unconfined	Bimonthly	Bimonthly	RCRA
299-E33-44^{98}	Unconfined	Bimonthly	Bimonthly	RCRA
299-E33-334^{00}	Unconfined	Bimonthly	Bimonthly	RCRA
299-E33-335^{00}	Unconfined	Bimonthly	Bimonthly	RCRA
		Far-Field Wells(a)		
299-E28-27^{87}	Unconfined	Semiannual	Quarterly	RCRA
299-E33-26^{69}	Unconfined	Quarterly	Quarterly	PRE
299-E33-28^{87}	Unconfined	Semiannual	Quarterly	RCRA
299-E33-29^{87}	Unconfined	Semiannual	Quarterly	RCRA
299-E33-34^{90}	Unconfined	Semiannual	Quarterly	RCRA
299-E33-35^{90}	Unconfined	Semiannual	Quarterly	RCRA
699-49-55A^{61}	Unconfined	Quarterly	Quarterly	PRE
699-49-57A^{56}	Unconfined	Quarterly	Quarterly	PRE
699-50-53A^{55}	Unconfined	Quarterly	Quarterly	PRE
		Supplemental Far-Field Wells(a)		
299-E28-26^{87}	Unconfined	Variable	Quarterly	RCRA
299-E28-28^{90}	Unconfined	Variable	Quarterly	RCRA
299-E32-2^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-3^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-4^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-5^{89}	Unconfined	Variable	Semiannual	RCRA
299-E32-6^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-7^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-8^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-9^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-10^{92}	Unconfined	Variable	Annual	RCRA
299-E33-30^{87}	Unconfined	Variable	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters(b)	
pH	Alkalinity	Low-level gamma (cobalt-60)
Specific conductance	Anions (nitrate, nitrite)	Strontium-90
Total organic carbon	Cyanide	Technetium-99
Total organic halides	Gross alpha	Total dissolved solids
	Gross beta	Tritium
	ICP metals (filtered)	Turbidity
	Iodine-129	Uranium

(a) Far-field wells sampled routinely; supplemental wells sampled periodically for key constituents only.
(b) Constituent list varies by well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.26. Monitoring Wells and Constituents for Waste Management Area C (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency[(a)]	Water-Level Measurement	Well Standard
299-E27-7$^{82(b)}$	Top of unconfined	Semiannual	Semiannual	PRE
299-E27-12^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-13^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-14^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-15^{89}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Phenols
Specific conductance	Anions	Strontium-90
Total organic carbon	Cyanide	Technetium-99
Total organic halides	Gross alpha	Total dissolved solids
	Gross beta	Total uranium
	ICP metals (filtered)	Tritium
	Iodine-129	Turbidity
	Low-level gamma	

(a) Bimonthly for limited constituent list.
(b) Used for supplemental information; no statistical evaluation.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.27. Critical Mean Values for Waste Management Area C[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4[(b)]	3	11.9838	349.812	15.202	553.5	553.5
Field pH	6	5	7.6037	8.345	0.072	[7.76, 8.93]	[7.76, 8.93]
Total organic carbon,[(c)] µg/L	5[(b)]	4	8.1216	516.25	128.871	1,662.9	1,662.9
Total organic halides,[(c)] µg/L	6	5	6.5414	3.021	1.076	10.6	10.6

(a) Based on semiannual sampling events from February 1997 to June 1999 for upgradient well 299-E27-14.
(b) Outliers removed.
(c) 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 16 comparisons.

Table A.28. Monitoring Wells and Constituents for PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1 (adapted from PNNL-11523)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
Upgradient Wells				
299-E24-18^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-31^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
Near-Field Wells – 216-A-10 Crib				
299-E17-1^{55}	Top of unconfined	Semiannual	Semiannual	PRE
299-E17-19^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E24-16^{88}	Top of unconfined	Quarterly	Quarterly	RCRA
Near-Field Wells – 216-A-36B Crib				
299-E17-9^{68}	Top of unconfined	Semiannual[(a)]	Semiannual	PRE
299-E17-14^{88}	Top of unconfined	Quarterly	Quarterly	RCRA
299-E17-18^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
Near-Field Wells – 216-A-37-1 Crib				
299-E25-17^{76}	Top of unconfined	Semiannual[(a)]	Semiannual	PRE
299-E25-19^{76}	Top of unconfined	Quarterly	Quarterly	PRE
699-37-47A^{96}	Top of unconfined	Semiannual	Semiannual	RCRA
Far-Field Wells				
57 wells	Unconfined	Triannual[(b)]	Triannual[(b)]	RCRA, PRE

Contamination Indicator Parameters	Site-Specific Parameters	
pH[(c)]	Alkalinity	ICP metals (filtered)
Specific conductance[(c)]	Ammonium ion	Iodine-129[(c)]
	Anions[(c)]	Phenols
	Arsenic (filtered)	Strontium-90
	Gross alpha	Tritium[(c)]
	Gross beta	Turbidity[(c)]

(a) Wells became unsampleable in fiscal year 2000.
(b) Some far-field wells sampled annually.
(c) Far-field wells analyzed for these constituents only.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
PUREX = Plutonium-uranium extraction (plant).
RCRA = Well constructed to RCRA standards.

Table A.29. Monitoring Wells and Constituents for the 216-B-3 Pond (adapted from WHC-SD-EN-AP-013)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E26-11^{89}	Top of uppermost	Semiannual	Semiannual	RCRA
299-E32-4^{87}	Top of uppermost	Semiannual	Quarterly	RCRA
699-40-39	Lower uppermost	Semiannual	Semiannual	RCRA
699-41-42^{92}	Top of uppermost	Semiannual	Quarterly	RCRA
699-42-39B^{91}	Lower uppermost	Semiannual	Quarterly	RCRA
699-42-42B^{88}	Top of uppermost	Semiannual	Quarterly	RCRA
699-43-41G^{91}	Lower uppermost	Semiannual	Quarterly	RCRA
699-43-44^{99}	Bottom of uppermost	Semiannual	Semiannual	RCRA
699-43-45^{89}	Top of uppermost	Semiannual	Quarterly	RCRA
699-44-39B^{92}	Top of uppermost	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Anions(a)	Iodine-129(b)
Specific conductance	Arsenic(b)	Nitrate(b)
Total organic carbon	Gross alpha	Phenols(a)
Total organic halides	Gross beta	Tritium(b)
	ICP metals (filtered, unfiltered)(a)	Turbidity

(a) Analyzed annually.
(b) Constituents of sitewide concern, selected wells analyzed under surveillance monitoring.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.30. Critical Mean Values for the 216-B-3 Pond(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	15	14	4.4995	417.667	7.215	451.2	451.2
Field pH	15	14	4.8656	7.704	0.262	[6.39, 9.02]	[6.39, 9.02]
Total organic carbon,(b,c) μg/L	15	14	4.4995	174.150	123.011	745.8	1,168.3
Total organic halides,(b) μg/L	14	13	4.5978	3.980	2.242	14.7	14.7

(a) Based on semiannual sampling events from January 1994 to January 1997 for upgradient well 299-E32-4.
(b) Critical means calculated from values reported below vendor’s specified method detection limit.
(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.
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 A.31. Monitoring Wells and Constituents for the 216-A-29 Ditch (adapted from PNNL-13047)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E25-26^{85}	Upper unconfined	Semiannual	Quarterly	RCRA
299-E25-28$^{86(a)}$	Deep unconfined	Semiannual	Quarterly	RCRA
299-E25-32P^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-34^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-35^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-48^{92}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E26-12^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E26-13^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
699-43-43^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
699-43-45^{89}	Top of unconfined	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Phenols
Specific conductance	Anions	Turbidity
Total organic carbon	ICP metals (filtered)[(b)]	
Total organic halides		

(a) Used for supplemental information; no statistical evaluations.
(b) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.32. Critical Mean Values for the 216-A-29 Ditch[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.9757	207.50	22.003	347.0	347.0
Field pH	8	7	6.6987	8.364	0.238	[6.68, 10.05]	[7.26, 9.39][(b)]
Total organic carbon, µg/L	8	7	5.9757	467.03	150.309	1,419.7	1,419.7
Total organic halides, µg/L	8	7	5.9757	4.951	1.985	17.5	17.5

(a) Data collected from January 1998 to October 1998 for upgradient wells 699-43-43 and 699-43-45.
(b) Values calculated using data collected from October 1997 to April 1999 (wells 699-43-43 and 699-43-45) because the critical range calculated using only four quarters of data is too large to be meaningful.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 36 comparisons.

Table A.33. Monitoring Wells and Constituents for the 216-B-63 Trench (adapted from WHC-SD-EN-AP-165)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E27-8^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-9^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-11^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-16^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-17^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-18^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-19^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-33^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-36^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-37^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-8^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity(a)	ICP metals (filtered)(a)
Specific conductance	Anions(a)	Phenols(a)
Total organic carbon	Gross alpha	Turbidity
Total organic halides	Gross beta	

(a) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.34. Critical Mean Values for the 216-B-63 Trench(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	18(b)	17	4.371	360.889	23.830	467.9	467.9
Field pH	20	19	4.572	8.029	0.179	[7.19, 8.87]	[7.19, 8.87]
Total organic carbon, µg/L	20	19	4.267	474.375	200.588	1,351.5	1,351.5
Total organic halides, µg/L	20	19	4.267	3.520	1.549	10.3	10.3

(a) Based on semiannual sampling events from November 1997 to April 1999 for upgradient wells 299-E27-8, 299-E27-9, 299-E27-11, 299-E27-17, and 299-E34-10.
(b) Excluded outliers.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table A.35. Monitoring Wells and Constituents for the Liquid Effluent Retention Facility (adapted from WHC-SD-EN-AP-024)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E26-9^{87}	Top of unconfined	Dry	Semiannual	RCRA
299-E26-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E26-11^{89}	Top of unconfined	Quarterly	Semiannual	RCRA
299-E35-2$^{87(a)}$	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

- pH
- Specific conductance
- Total organic carbon
- Total organic halides

Site-Specific Parameters

- Alkalinity(b)
- Ammonium(b)
- Anions(b)
- Gross alpha(b)
- Gross beta(b)
- ICP metals (filtered)(b)
- Phenols(b)
- Temperature
- Turbidity
- Volatile organic compounds

(a) Well dry January 2001.
(b) Analyzed annually.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.36. Critical Mean Values for the Liquid Effluent Retention Facility(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	386.094	2.707	419.0	419.0
Field pH	4	3	13.745	8.162	0.104	[6.56, 9.76]	[6.56, 9.76]
Total organic carbon,(b) μg/L	5	4	7.5287	362.00	191.788	1,943.7	1,943.7
Total organic halides, μg/L	4	3	10.8689	3.15	1.912	26.4	26.4

(a) Based on semiannual sampling events from July 1997 to June 1999 for upgradient well 299-E26-11 except for specific conductance and pH, which were based on quarterly sampling events from September 1999 to June 2000.
(b) Critical means 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 12 comparisons.

Table A.37. Monitoring Wells and Constituents for Low-Level Waste Management Area 1 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E28-26^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E28-27^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E28-28^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-5^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-6^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-7^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-8^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-10^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-28^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-29^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-30^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-34^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-35^{90}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols[(a)]
Tritium
Turbidity
Uranium

(a) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.38. Critical Mean Values for Low-Level Waste Management Area 1(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	27(b)	26	4.1774	390.259	53.332	617.1	617.1
Field pH	28	27	4.4138	7.968	0.216	[7.00, 8.94]	[7.00, 8.94]
Total organic carbon,(c) µg/L	28	27	4.1542	465.625	263.589	1,580	1,580
Total organic halides, µg/L	27(b)	26	4.1774	3.132	1.891	11.2	11.2

(a) Based on semiannual sampling events from December 1997 to June 1999 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) Excluding outlier or data exceeding the holding time requirement.
(c) 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 68 comparisons.

Table A.39. Monitoring Wells and Constituents for Low-Level Waste Management Area 2 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E27-8^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-9^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-11^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-17^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-5^{87}(a)	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-11^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-12^{92}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols(b)
Polychlorinated biphenyls
Tritium
Turbidity

(a) Used for supplemental information; no statistical evaluation.
(b) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.40. Critical Mean Values for Low-Level Waste Management Area 2$^{(a)}$

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	7	6	7.0210	448.321	46.78	799.4	799.4
Field pH	12	11	5.4261	8.0246	0.126	[7.31, 8.74]	[7.31, 8.74]
Total organic carbon, µg/L	12	11	4.9785	554.375	253.489	1,867.9	1,867.9
Total organic halides,$^{(b)}$ µg/L	12	11	4.9785	3.013	1.148	9.0	9.0

(a) Data collected from January 1998 to April 1999 for upgradient wells 299-E27-10, 299-E34-3, and 299-E34-7, except for specific conductance that included data collected in the same period for upgradient wells 299-E27-10 and 299-E34-3.
(b) 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 48 comparisons.

Table A.41. Monitoring Wells, Constituents, and Enforcement Limits for the Treated Effluent Disposal Facility (adapted from WHC-SD-EN-WP-012, Rev. 1)

Well	Hydrogeologic Unit	Sampling Frequency	Water-Level Measurement	Well Standard
699-40-36^{92}	Ringold confined	Quarterly	Quarterly	RCRA
699-41-35^{92}	Ringold confined	Quarterly	Quarterly	RCRA
699-42-37^{92}	Ringold confined	Quarterly	Quarterly	RCRA

Constituent$^{(a)}$	Enforcement Limit (µg/L)
Cadmium	5
Cyanide	50
Lead	10
Total trihalomethanes	66
Trichloroethane	5
pH	6.5 - 8.5 pH units

(a) Also monitored for ICP metals, anions, trace metals, volatile and semivolatile organic compounds, total petroleum hydrocarbons, ammonia, alkalinity, specific conductance, total dissolved solids, turbidity, total organic carbon, oil and grease, gross alpha, gross beta, radium-226, and radium-226/228. No enforcement limits for those constituents.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.42. Monitoring Wells, Constituents, and Enforcement Limits for the 400 Area Process Ponds (specified in state waste discharge permit)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-2-6A^{97}	Unconfined aquifer	Quarterly	Quarterly	RCRA
699-2-7^{78}	Unconfined aquifer	Quarterly	Quarterly	PRE
699-8-17^{50}	Unconfined aquifer	Quarterly	Quarterly	PRE

Constituent	Enforcement Limit (µg/L)(a,b)
Cadmium (unfiltered)	10
Chromium (unfiltered)	50
Lead (unfiltered)	50
Manganese (unfiltered)	50
Mercury (unfiltered)	2
pH	Monitor only
Sulfate	Monitor only
Total organic carbon	Monitor only

(a) Defined as the average of four quarterly measurements from a well. Average to be calculated using the four most recent quarterly measurements from a well.
(b) Enforcement limit in groundwater shall be met in point-of-compliance well 699-2-7.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.43. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill (adapted from PNNL-12227)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-25-33A^{87}(a)	Top of LPU(b)	Semiannual	Semiannual	RCRA
699-25-34A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-25-34B^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-25-34D^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-33^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-34A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-34B^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-35A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-35C^{87}(a)	Top of LPU(a)	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Anions	Turbidity
Specific conductance	ICP metals (filtered)	Volatile chlorinated hydrocarbons
Total organic carbon	Phenols	
Total organic halides		

(a) Used for supplemental information; no statistical evaluation.
(b) Low-permeability unit in upper Ringold Formation.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.44. Critical Mean Values for the Nonradioactive Dangerous Waste Landfill(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	11	10	4.8092	452.89	29.427	600.7	600.7
Field pH	11	10	5.2814	7.450	0.164	[6.55, 8.35]	[6.55, 8.35]
Total organic carbon,(b) μg/L	11	10	4.8092	308.682	242.278	1,597.7	1,597.7
Total organic halides,(b) μg/L	11	10	4.8092	4.278	2.054	14.6	14.6

(a) Data collected based on semiannual sampling events from August 1997 to February 1999 for upgradient wells 699-26-34A and 699-26-35A.

(b) Critical means 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 A.45. Monitoring Wells and Constituents for the Solid Waste Landfill (adapted from WHC-SD-EN-AP-043)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-22-35^{93}	Top of unconfined	Quarterly	Quarterly	RCRA
699-23-34A^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-23-34B^{93}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-33$^{48(b)}$	Top of unconfined	Quarterly(a)	Quarterly	PRE
699-24-34A^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-34B^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-34C^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-35^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-25-34C^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-26-35A^{86}	Top of unconfined	Quarterly	Quarterly	RCRA

Parameters/Constituents Required by WAC 173-304-490		Site-Specific Parameters	
Ammonia as nitrogen	Nitrate	Anions	Tritium
Chemical oxygen demand	Nitrite	Gross alpha	Volatile organic compounds
Chloride	pH	Gross beta	(1,1,1-Trichloroethane,
Specific conductance	Sulfate	ICP metals (filtered)	Trichloroethylene)
Dissolved iron	Temperature		
Dissolved zinc	Total coliform		
Manganese	Total organic carbon		

(a) Well sampled for supporting data.

(b) Used for supplemental information; no statistical evaluations.

Bold italic = Upgradient wells.

Superscript = Year of installation.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.46. Sampling Results for Required Constituents[a] at the Solid Waste Landfill

Constituent, unit	Tolerance Interval[b]	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-34A	Well 699-24-34B
Temperature, °C	20.7	December 1999	17.6	18	17.4	18.3	18.5
		March 2000	17.6	18.2	17.6	18.5	18.4
		May 2000	18.1	17.9	17.9	18.5	18.7
Specific conductance, µS/cm	583	December 1999	837[c]	707[c]	781[c]	654[c]	669[c]
		March 2000	862[c]	714[c]	801[c]	683[c]	693[c]
		May 2000	851[c]	709[c]	793[c]	672[c]	689[c]
Field pH	[6.68, 7.84]	December 1999	6.91	6.5[c]	7.02	6.76	6.72
		March 2000	6.93	6.54[c]	6.72	6.58[c]	6.72
		May 2000	6.88	6.62[c]	6.72	6.71	6.67[c]
Total organic carbon, µg/L	1,168	December 1999	315	323	253	345	418
		March 2000	298	235	320	498	243
		May 2000	430	300	420	260	300
Chloride, µg/L	7,820	December 1999	5,700	5,300	5,600	5,400	5,400
		March 2000	5,600	5,300	5,500	5,500	5,500
		May 2000	5,700	5,400	5,700	5,300	5,400
Nitrate, µg/L	29,000	December 1999	15,051	11,510	15,051	11,510	12,395
		March 2000	15,051	11,952	14,608	12,395	12,395
		May 2000	14,608	11,067	14,608	11,067	11,510
Nitrite, µg/L	359	December 1999	<80[d]	<80	<80	<80	<80
		March 2000	<80	<80	<80	<80	<80
		May 2000	<80	<80	<80	<80	<80
Ammonium, µg/L	165	December 1999	<44.4	<44.4	<44.4	<44.4	<44.4
		March 2000	<44.4	<44.4	<44.4	<44.4	<44.4
		May 2000	<44.4	<44.4	<44.4	<44.4	<44.4
Sulfate, µg/L	47,200	December 1999	54,900[c]	44,800	54,000[c]	42,700	42,200
		March 2000	53,300[c]	44,900	52,200[c]	44,500	42,800
		May 2000	51,300[c]	43,800	50,900[c]	41,400	40,500
Iron, filtered, µg/L	160	December 1999	95.6	121	58.9	73.6	71.5
		March 2000	43.7	32.7	42.5	49.7	24.7
		May 2000	51.6	43.1	49.3	37.5	47.2
Zinc, filtered, µg/L	34.9	December 1999	<3	4.8	<3	11.4	<3
		March 2000	4.9	3.3	9	24.5	5.7
		May 2000	<3.1	<3.1	<3.1	<3.1	<3.1
Manganese, filtered, µg/L	10	December 1999	5	5	6.5	6.4	5.5
		March 2000	2.8	2.8	2.8	3.6	<1.1
		May 2000	3	3	3.3	3.6	2.9
Chemical oxygen demand, µg/L	10,000	December 1999	6,000	4,000	8,000	<3,100	<3,100
		March 2000	<3,100	19,000[c]	<3,100	13,000[c]	<3,100
		May 2000	<3,100	<3,100	<3,100	<3,100	<3,100
Coliform bacteria, most probable number	3.7	December 1999	0	0	0	0	0
		March 2000	0	0	0	0	0
		May 2000	0	0	0	0	0

Table A.46. (contd)

Constituent, unit	Tolerance Interval[b]	Date	Well 699-24-34C	Well 699-24-35	Well 699-25-34C	Well 699-26-35A	Well 699-24-33
Temperature, °C	20.7	December 1999	18.5	17.6	18.3	19.3	19.6
		March 2000	18.2	17	18.5	19.5	19.3
		May 2000	18.5	17.6	18.8	19.3	19.3
Specific conductance, µS/cm	583	December 1999	692[c]	561	626[c]	500	742[c]
		March 2000	730[c]	536	651[c]	518	749[c]
		May 2000	709[c]	578	643[c]	525	731[c]
Field pH	[6.68, 7.84]	December 1999	7.00	7.17	7.28	7.49	7.30
		March 2000	7.00	7.13	7.32	7.27	6.85
		May 2000	6.97	6.83	7.28	7.23	6.90
Total organic carbon, µg/L	1,168	December 1999	315	363	373	305	500
		March 2000	505	575	270	750	223
		May 2000	340	300	310	420	550
Chloride, µg/L	7,820	December 1999	6,100	5,300	7,200	7,700	6,000
		March 2000	6,100	5,200	7,100	7,300	5,900
		May 2000	5,900	5,200	7,000	7,400	5,900
Nitrate, µg/L	29,000	December 1999	15,051	11,067	18,593	20,363	15,051
		March 2000	15,051	11,067	18,593	20,806	15,051
		May 2000	14,166	10,624	17,265	19,921	14,166
Nitrite, µg/L	359	December 1999	<80	<80	<80	<80	<80
		March 2000	<80	<80	<80	<80	<80
		May 2000	<80	<80	<80	<80	<80
Ammonium, µg/L	165	December 1999	<44.4	<44.4	<44.4	<44.4	<44.4
		March 2000	<44.4	<44.4	<44.4	<44.4	<44.4
		May 2000	<44.4	<44.4	<44.4	<44.4	<44.4
Sulfate, µg/L	47,200	December 1999	39,900	43,700	41,000	40,300	41,100
		March 2000	40,300	44,000	41,200	44,400	40,400
		May 2000	38,900	42,400	39,600	39,400	39,400
Iron, filtered, µg/L	160	December 1999	61	50.5	45.7	35.6	50.8
		March 2000	42.9	48.5	32.6	26.2	38.8
		May 2000	88.6	64.8	46.7	40.5	38.3
Zinc, filtered, µg/L	34.9	December 1999	10	<3	7.1	9.8	15.9
		March 2000	8.2	6.3	4.9	11.3	16.2
		May 2000	3.5	<3.1	10.5	3.3	12.1
Manganese, filtered, µg/L	10	December 1999	5.6	3.3	4.6	3.4	6.4
		March 2000	3.2	5.3	2.9	3	4.4
		May 2000	3	2	4	2.7	3.9
Chemical oxygen demand, µg/L	10,000	December 1999	<3,100	<3,100	8,000	<3,100	<3,100
		March 2000	7,000	5,000	<3,100	11,000[c]	18,000[c]
		May 2000	<3,100	<3,100	<3,100	<3,100	<3,100
Coliform bacteria, most probable number	3.7	December 1999	0	0	0	0	0
		March 2000	0	0	0	0	0
		May 2000	0	0	0	0	0

(a) WAC 173-304.

(b) Number obtained from Table A.47, background threshold value column.

(c) Exceeding or below (for pH) background threshold values.

(d) < = Data values less than the method of detection limit; number given is the respective limit.

Table A.47. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill

Constituent, unit	Test Statistic, W' Log Value	Test Statistic, W' Raw Data	Upper Tolerance Limit	Background Threshold Value[a]
Temperature, °C	0.953 s	0.961 s	20.7[b]	20.7
Specific conductance, μS/cm	0.978 ns	NA	583[c]	583
Field pH	0.988 ns	NA	[6.68, 7.84][c]	[6.68, 7.84]
Total organic carbon, μg/L	NC	NC	842[b] 1,168[d]	1,168
Chloride, μg/L	0.954 s	0.962 s	7,820[b]	7,820
Nitrate, μg/L	0.833 s	0.844 s	29,000[b]	29,000
Nitrite, μg/L	NC	NC	359[e]	359
Ammonium, μg/L	NC	NC	90[b] 165[e]	165
Sulfate, μg/L	0.983 ns	NA	47,200[c]	47,200
Iron, filtered, μg/L	0.960 s	0.802 s	160[b] 137[e]	160
Zinc, filtered, μg/L	NC	NC	34.9[b] 19[e]	34.9
Manganese, filtered, μg/L	NC	NC	10[b] 2.3[e]	10
Coliform, most probable number	NC	NC	3.7[f]	3.7
Chemical oxygen demand, μg/L	NC	NC	10,000[f]	10,000

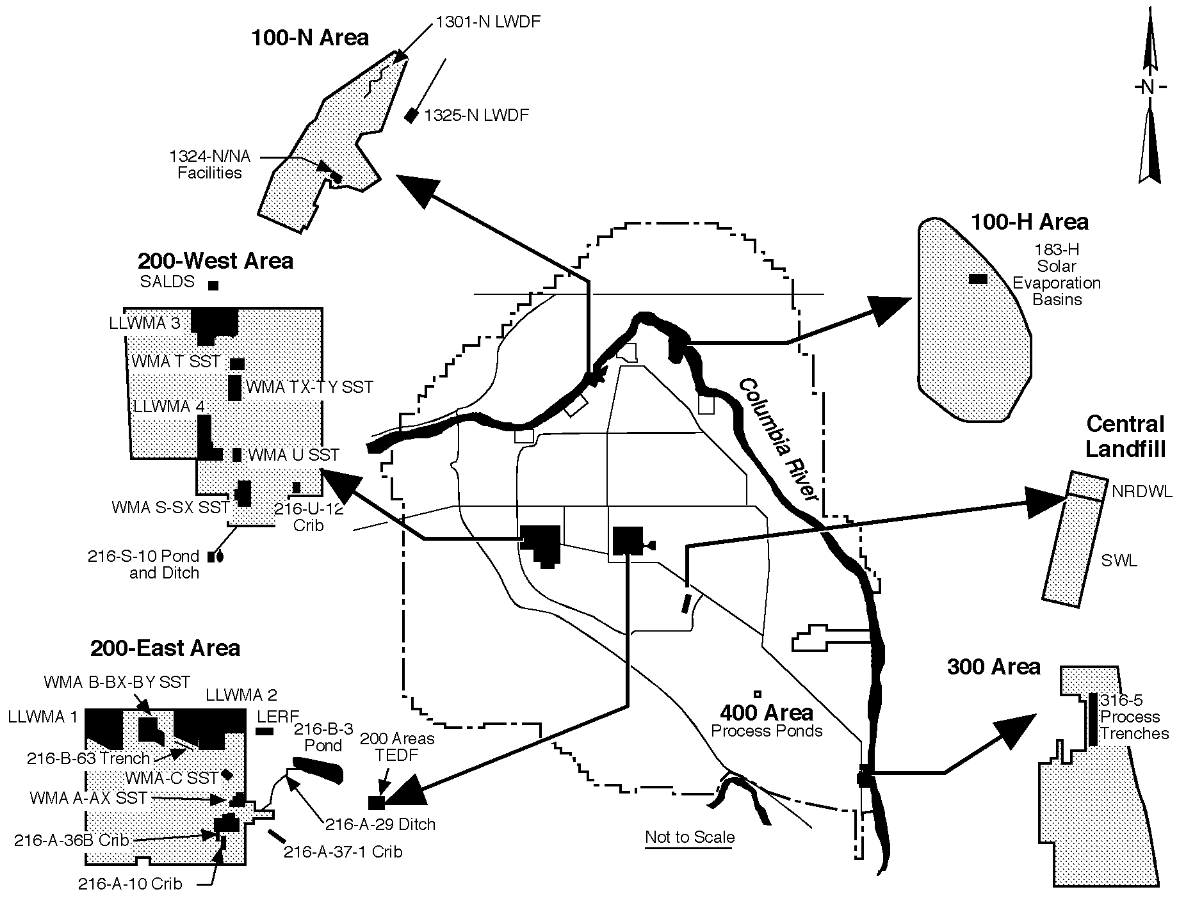
(a) Background threshold values for each constituent is the larger of the upper tolerance limit or the applicable limit of quantitation.
(b) Maximum value reported.
(c) Based on log-normal distribution.
(d) Based on limit of quantitation using field blank data for the fourth quarter of fiscal year 2000.
(e) Based on limit of quantitation using method detection limit (Hartman et al. 2001, Table B.20).
(f) Based on laboratory practical quantitation limit.
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 A.48. Monitoring Wells and Constituents for the 316-5 Process Trenches (adapted from WHC-SD-EN-AP-185)

Well	Hydrogeologic Unit Monitored	Sampling Frequency(a)	Water-Level Measurement	Well Standard
399-1-10A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-10B^{91}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-16A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-16B^{87}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-17A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-17B^{86}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-18A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-18B^{87}	Bottom of unconfined	Semiannual	Semiannual	RCRA

Field-Measured Parameters	Site-Specific Parameters	
pH	cis-1,2-dichloroethene	Trichloroethene
Specific conductance	Tetrachloroethene	Uranium
Turbidity	Thallium	

(a) Sampled and measured monthly for 4 months for each semiannual sampling period.
Bold italic = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.



LERF	Liquid Effluent-Retention Facility	SST	Single-Shell Tank
LLWMA	Low-Level Waste Management Area	SWL	Solid Waste Landfill
LWDF	Liquid Waste-Disposal Facility	TEDF	Treated Effluent-Disposal Facility
NRDWL	Nonradioactive Dangerous Waste Landfill	WMA	Waste Management Area
SALDS	State-Approved Land-Disposal Site		

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Figure A.1. Regulated Units on the Hanford Site Requiring Groundwater Monitoring

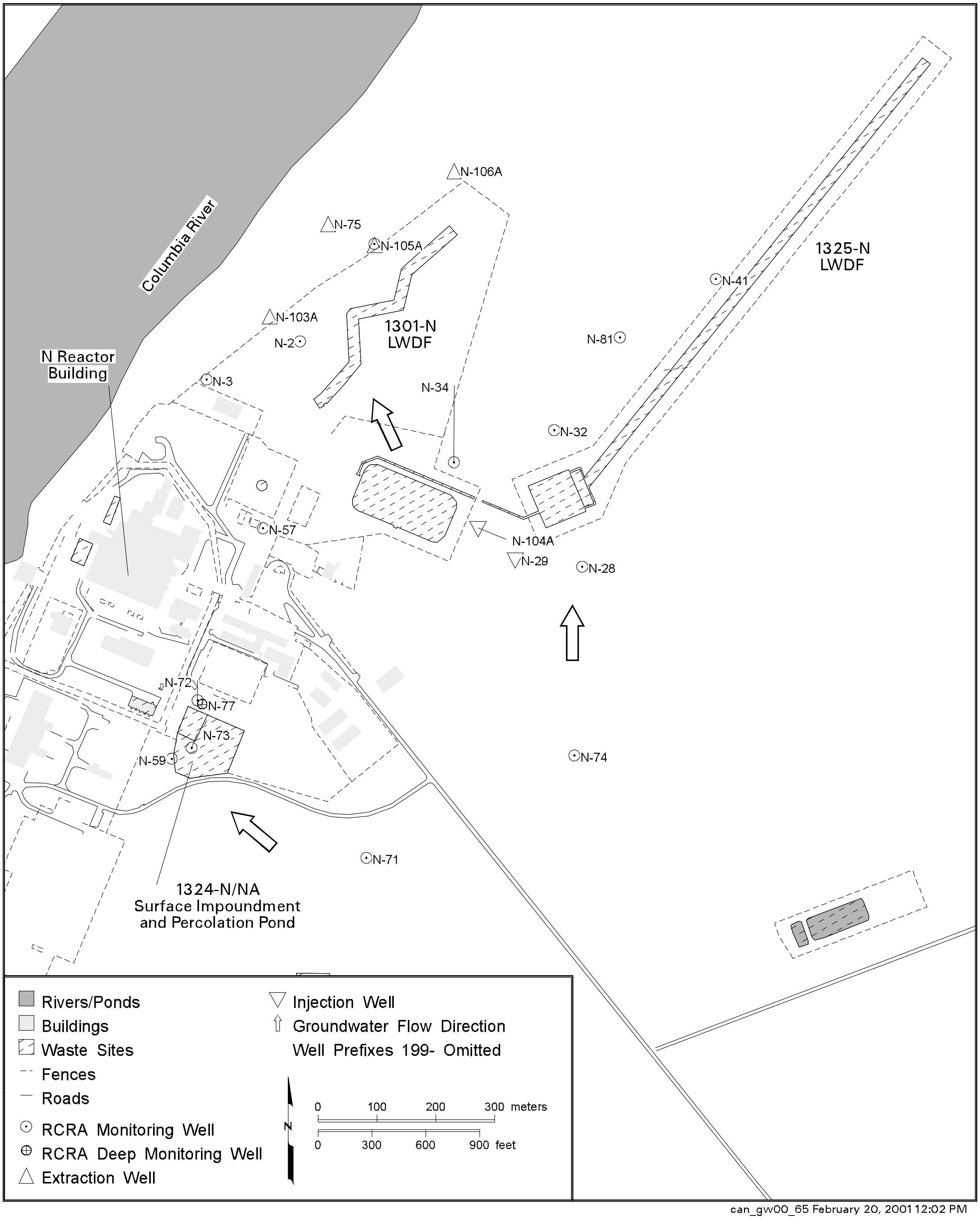

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Figure A.2. Groundwater Monitoring Wells in the 100 N Area

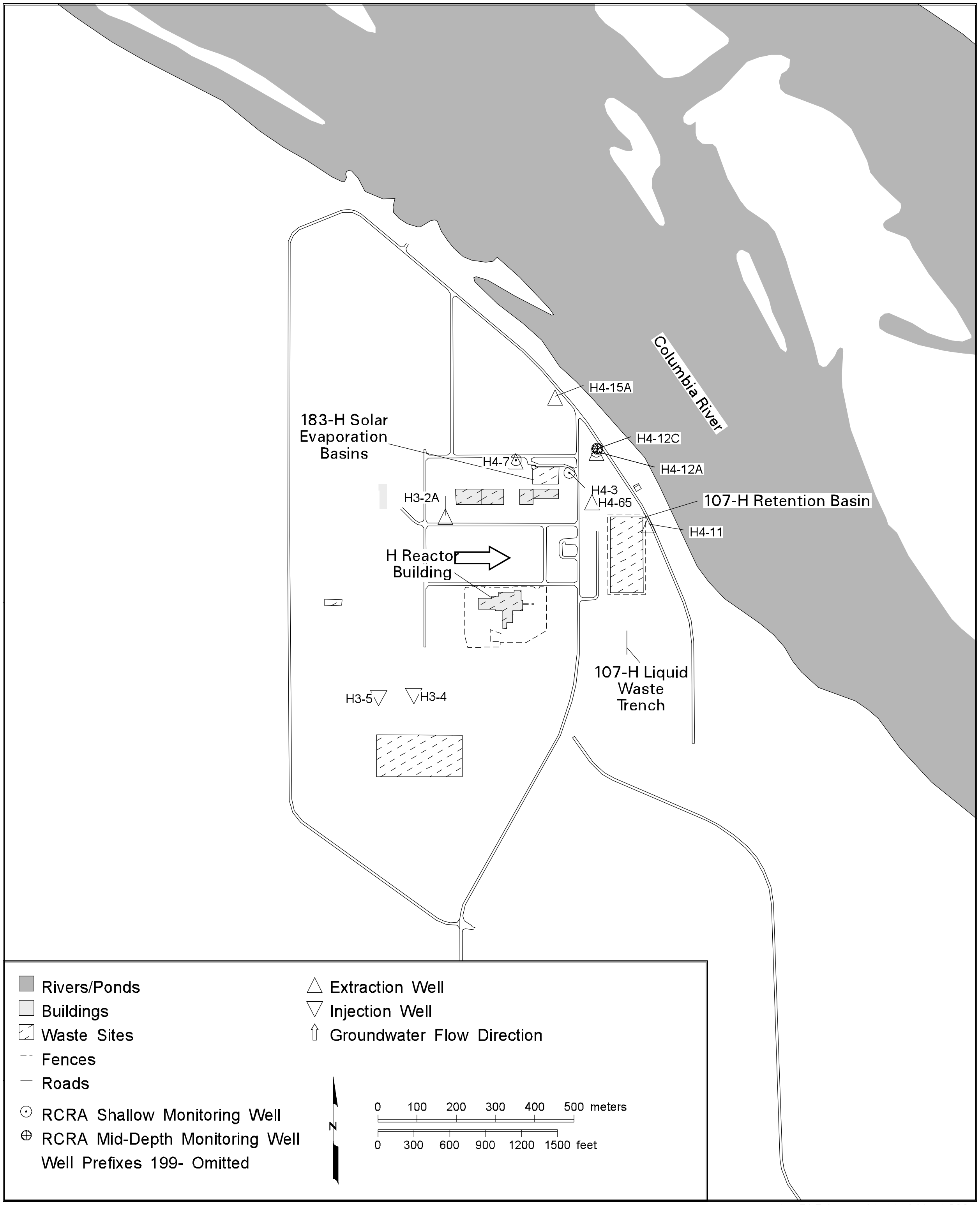

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Figure A.3. Groundwater Monitoring Wells at the Former 183-H Solar Evaporation Basins

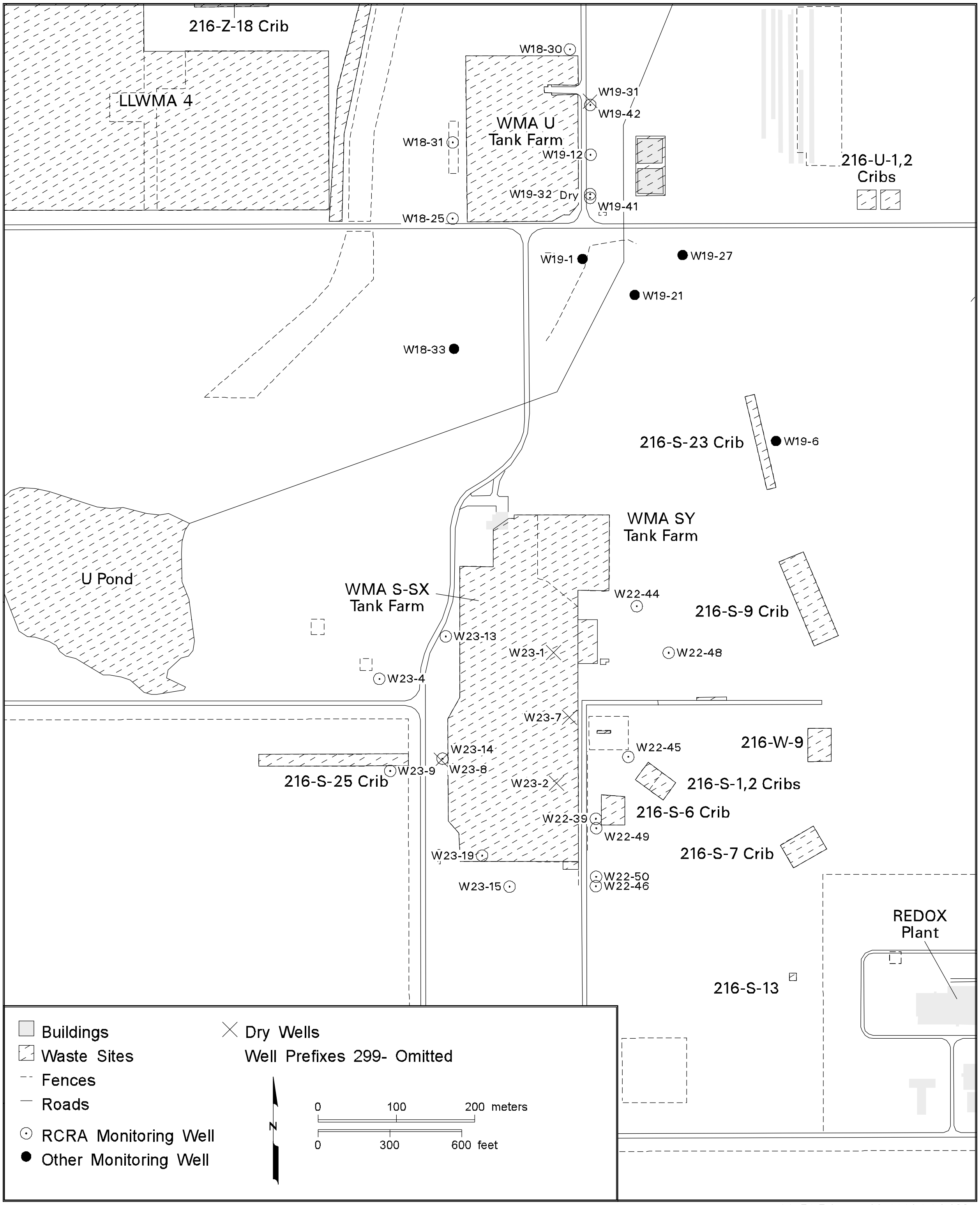

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Figure A.4. Groundwater Monitoring Wells at Waste Management Areas S-SX and U

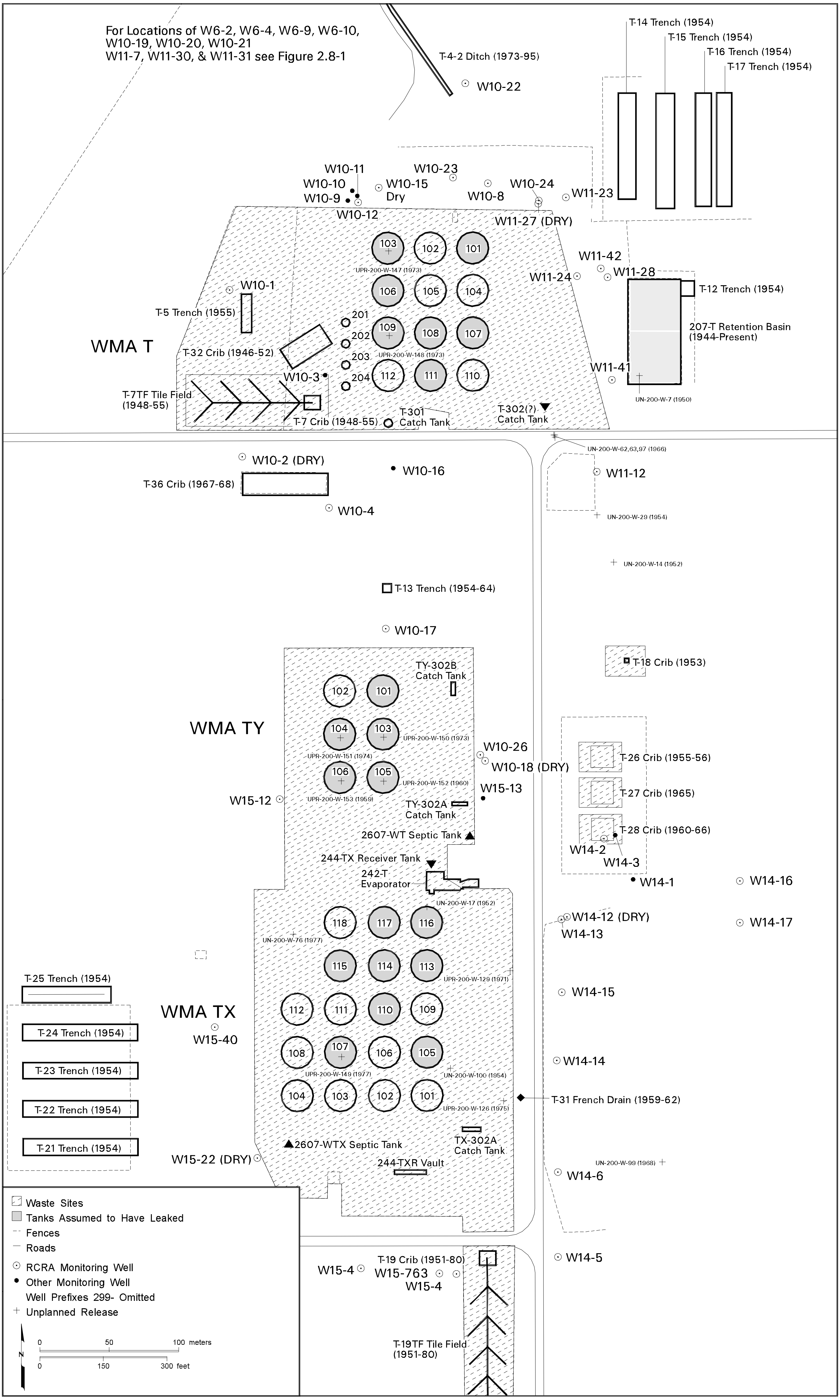

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Figure A.5. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY

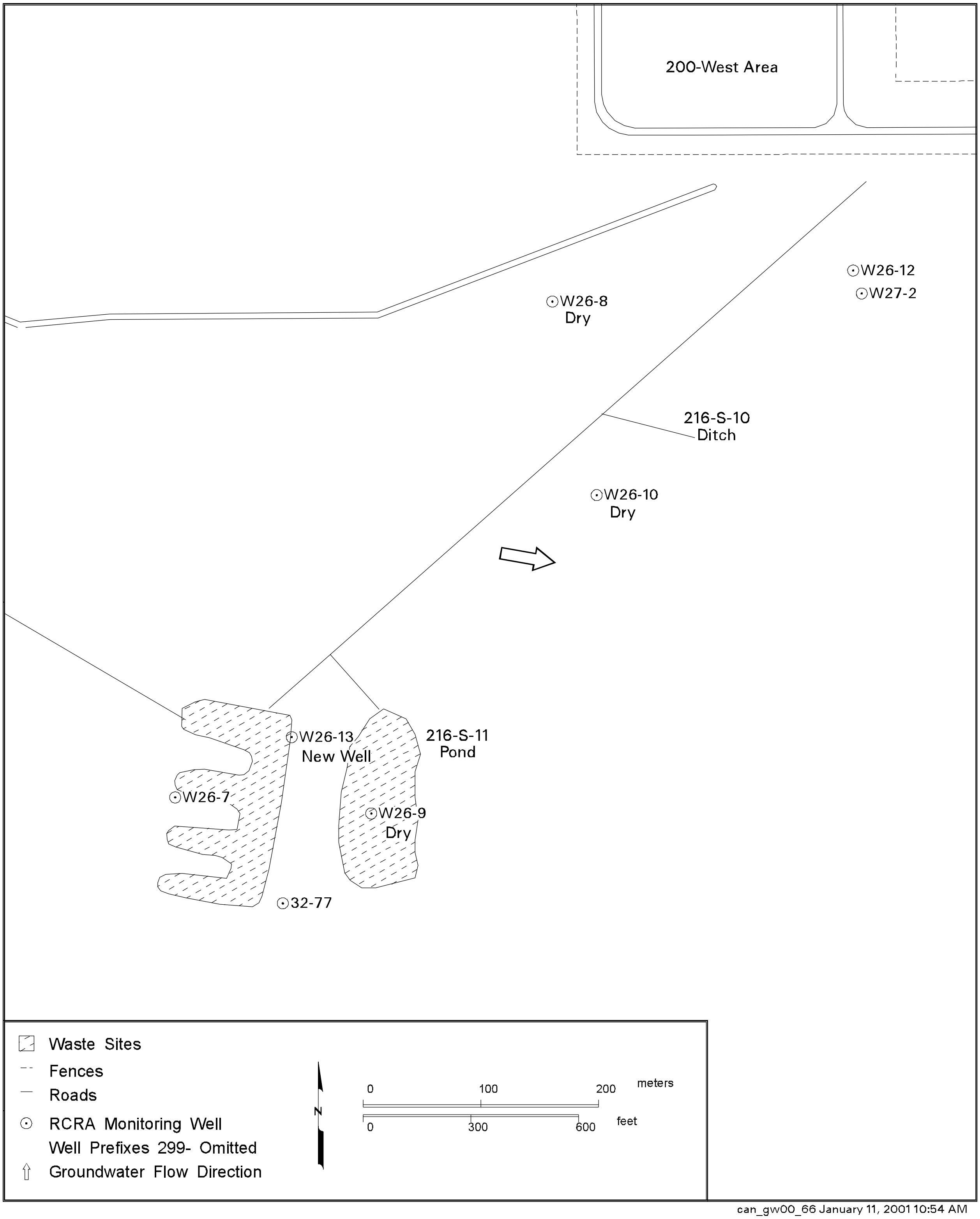

Figure A.6. Groundwater Monitoring Wells at the 216-S-10 Pond and Ditch

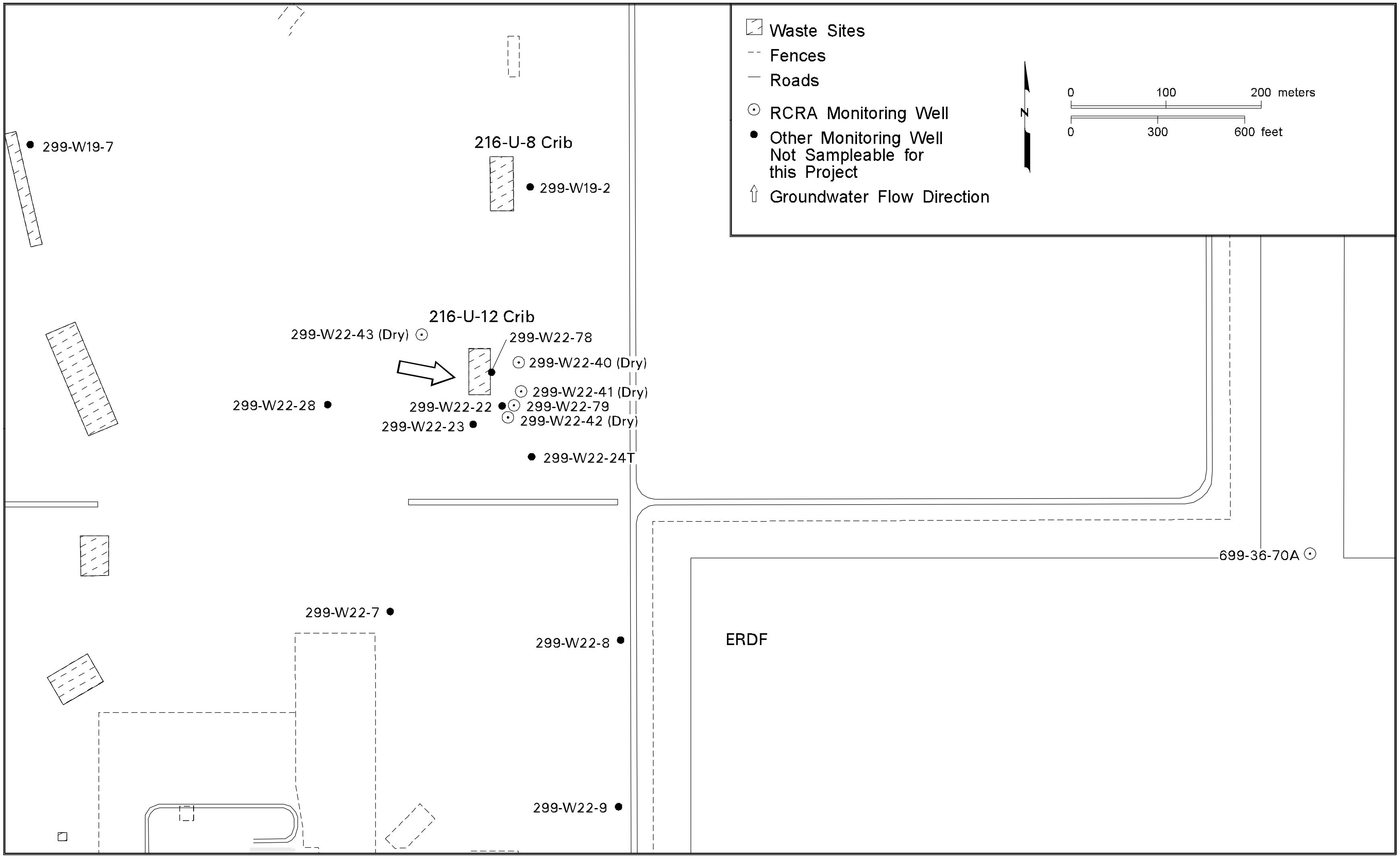

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Figure A.7. Groundwater Monitoring Wells at the 216-U-12 Crib

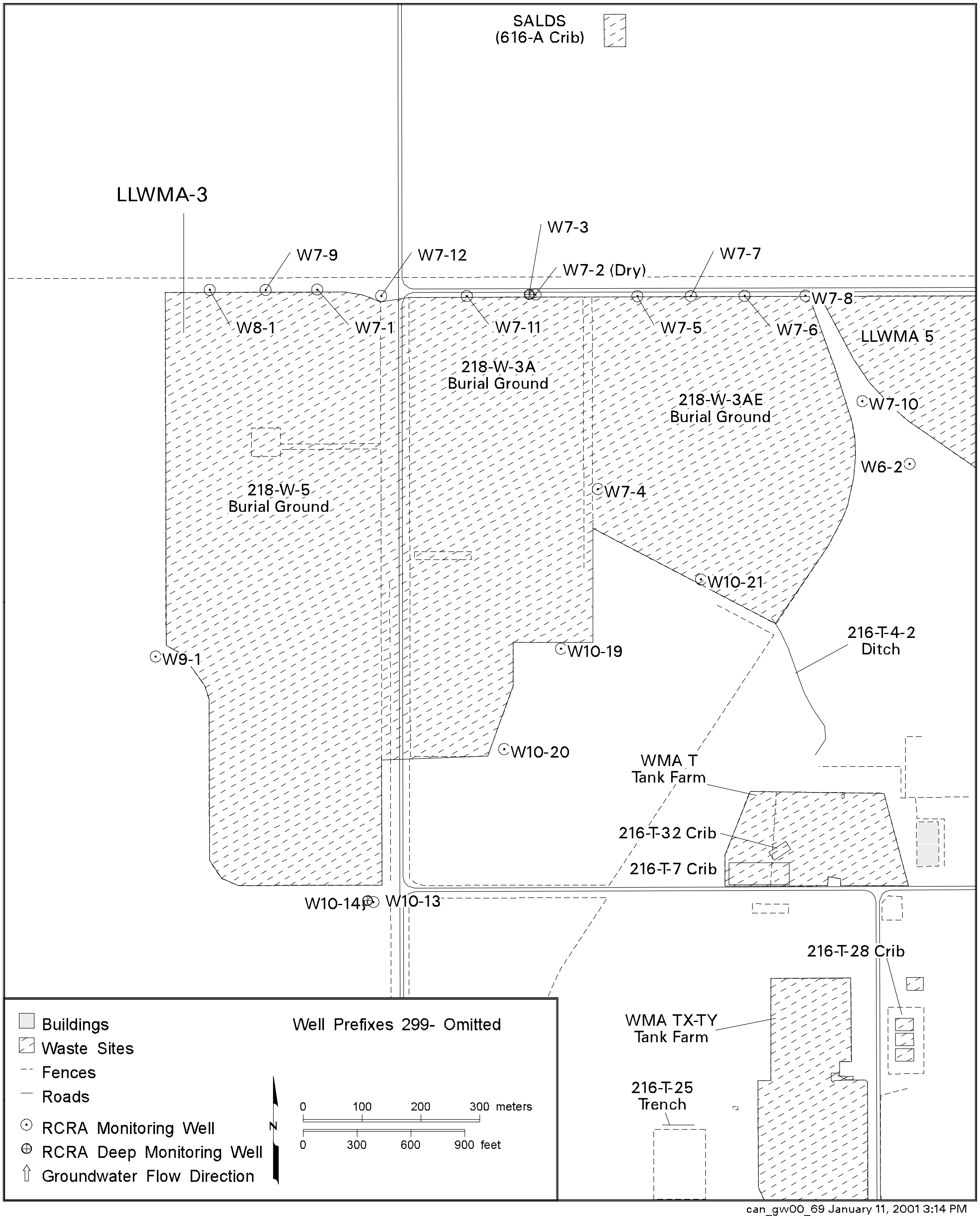

Figure A.8. Groundwater Monitoring Wells at Low-Level Waste Management Area 3

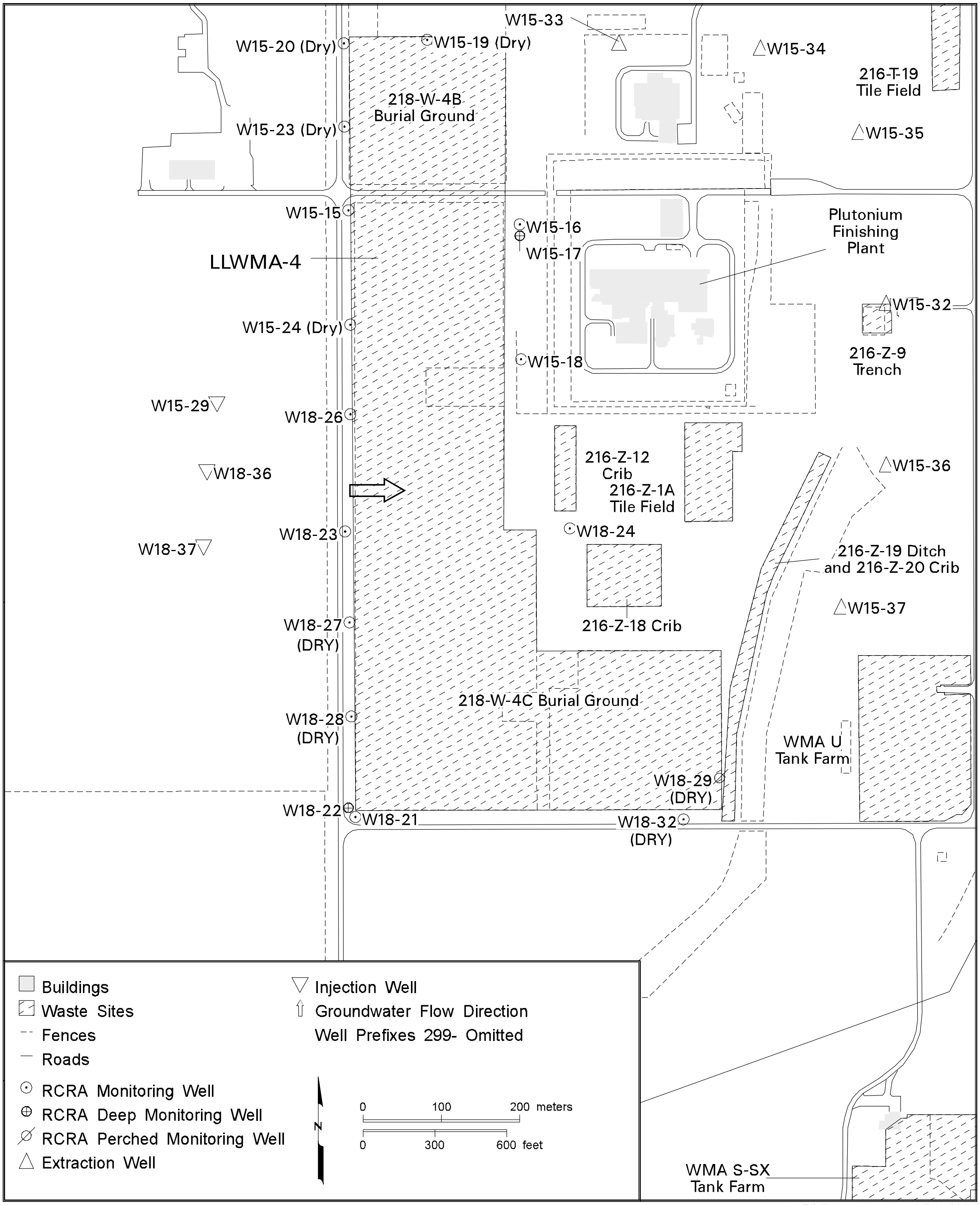

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Figure A.9. Groundater Monitoring Wells at Low-Level Waste Management Area 4

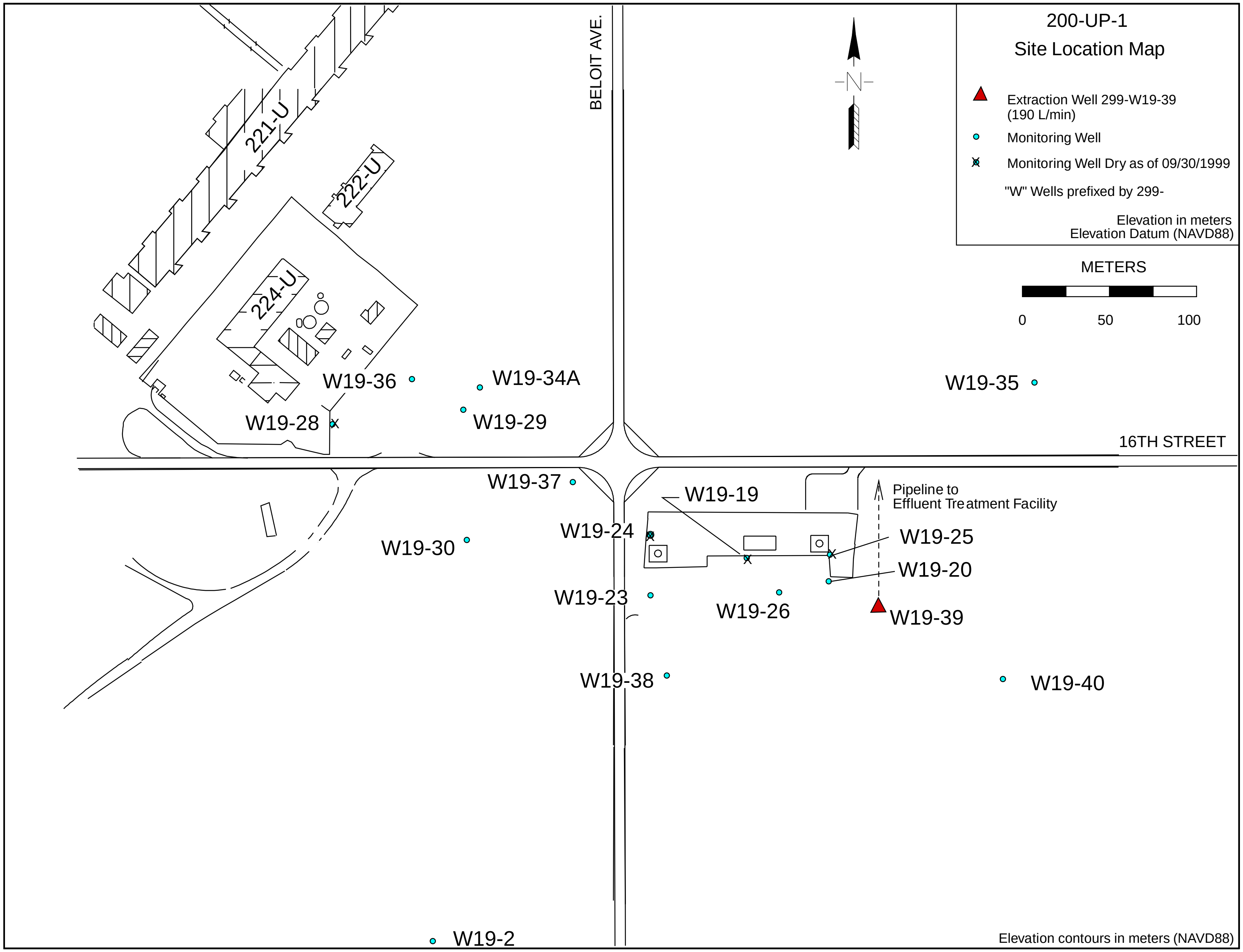

Figure A.10. Groundwater Monitoring Wells at the 200-UP-1 Operable Unit

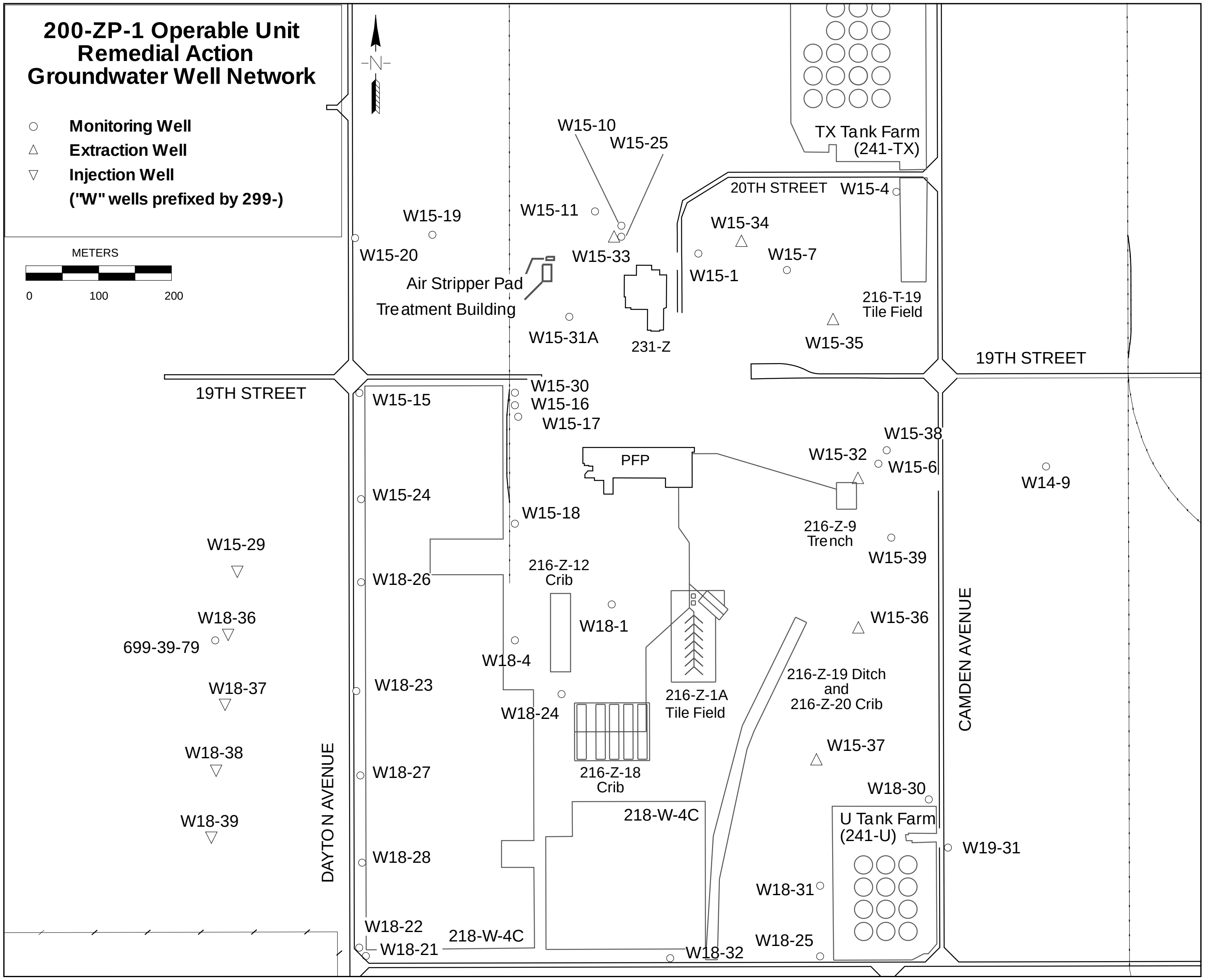

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Figure A.11. Groundwater Monitoring Wells at the 200-ZP-1 Operable Unit

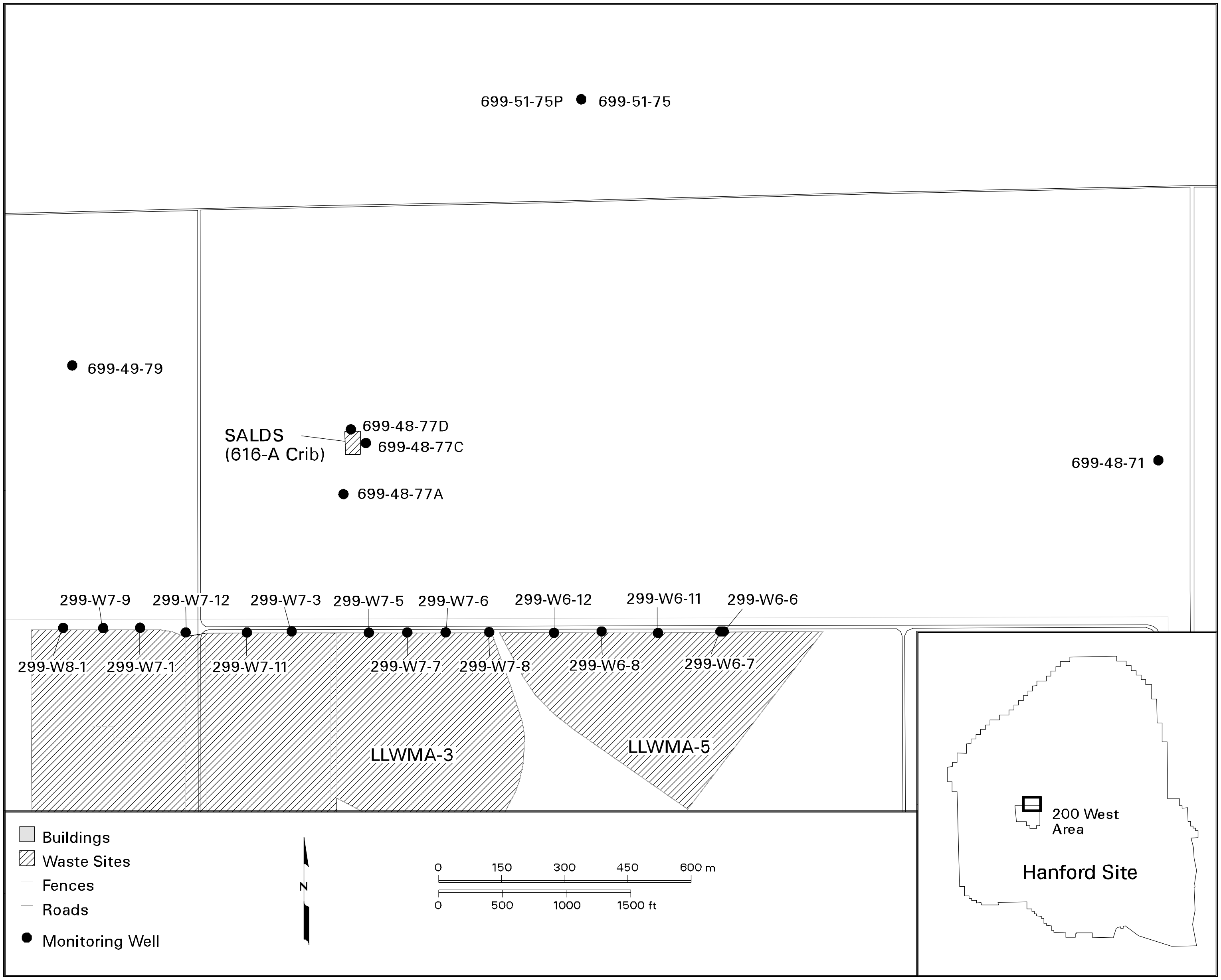

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Figure A.12. Groundwater Monitoring Wells at the State-Approved Land Disposal Site

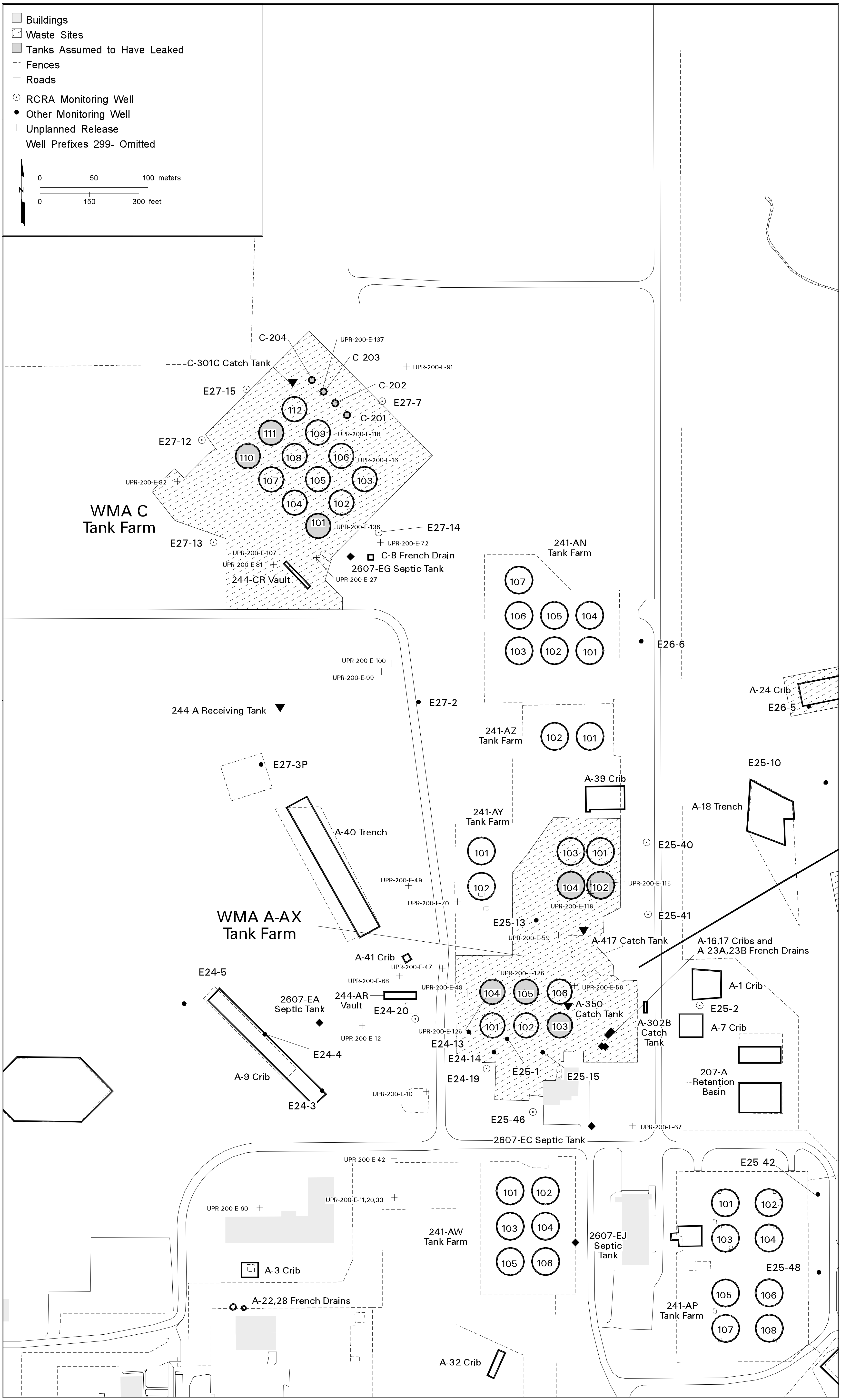

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Figure A.13. Groundwater Monitoring Wells at Waste Management Areas A-AX and C

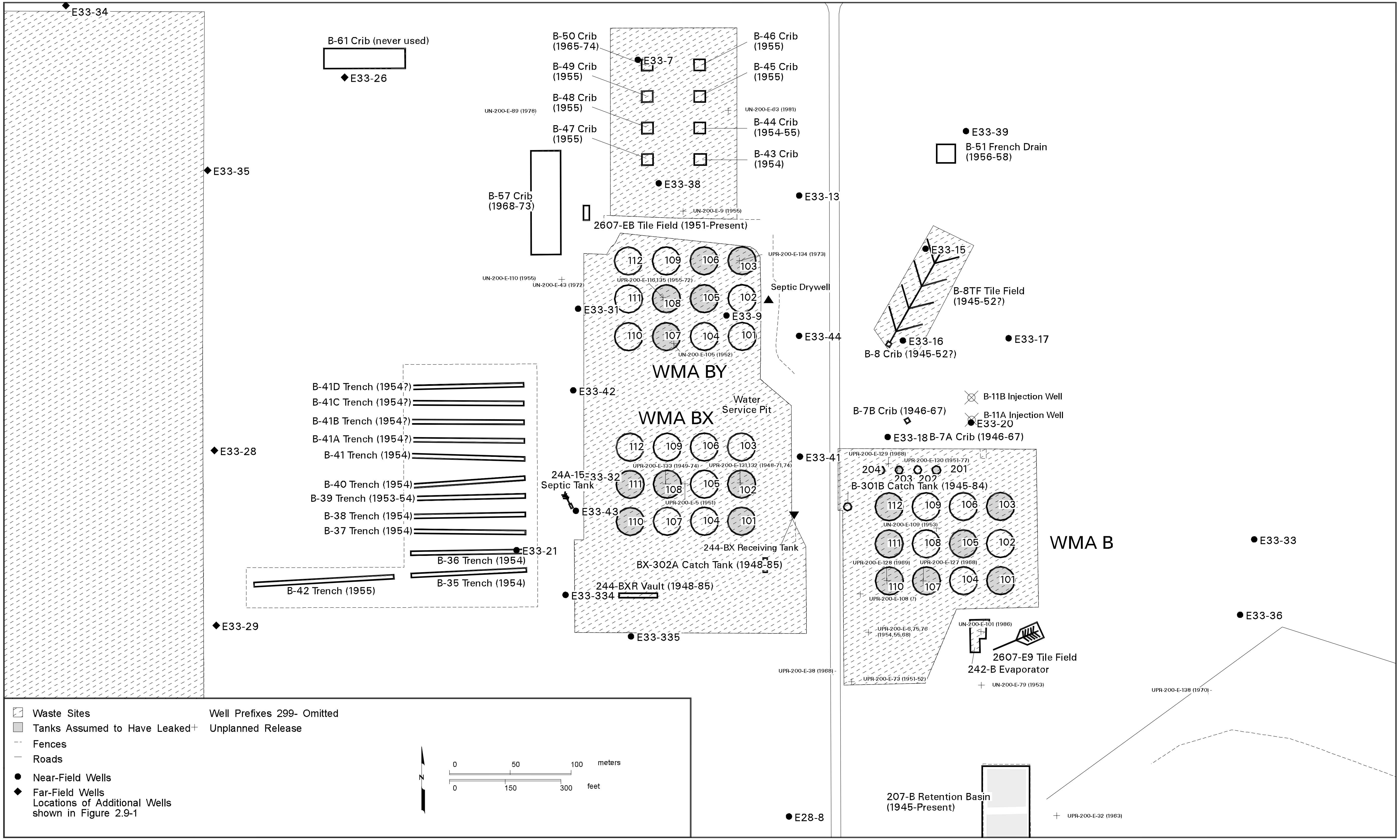

Figure A.14. Groundwater Monitoring Wells at Waste Management Area B-BX-BY

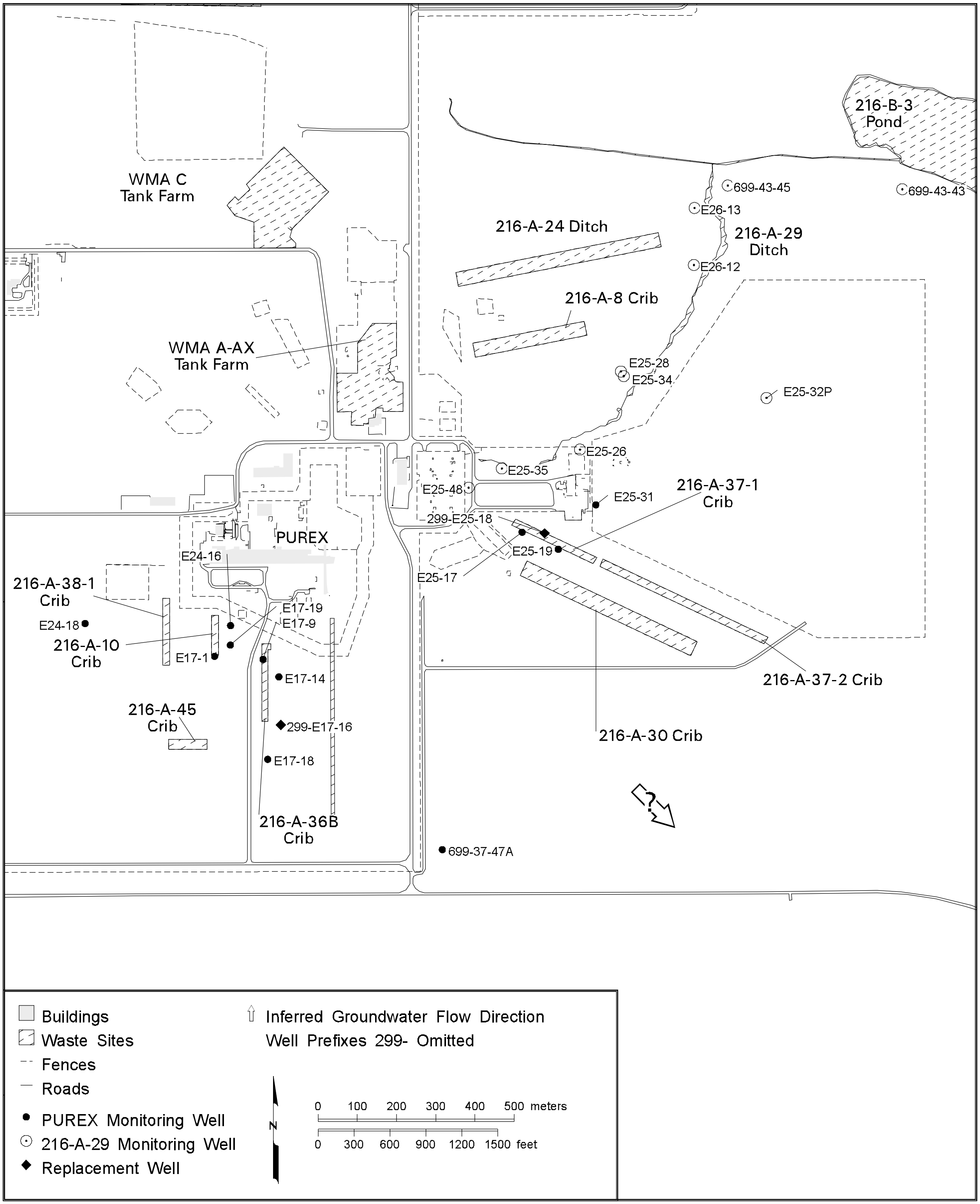

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Figure A.15. Groundwater Monitoring Wells at the PUREX Cribs and 216-A-29 Ditch

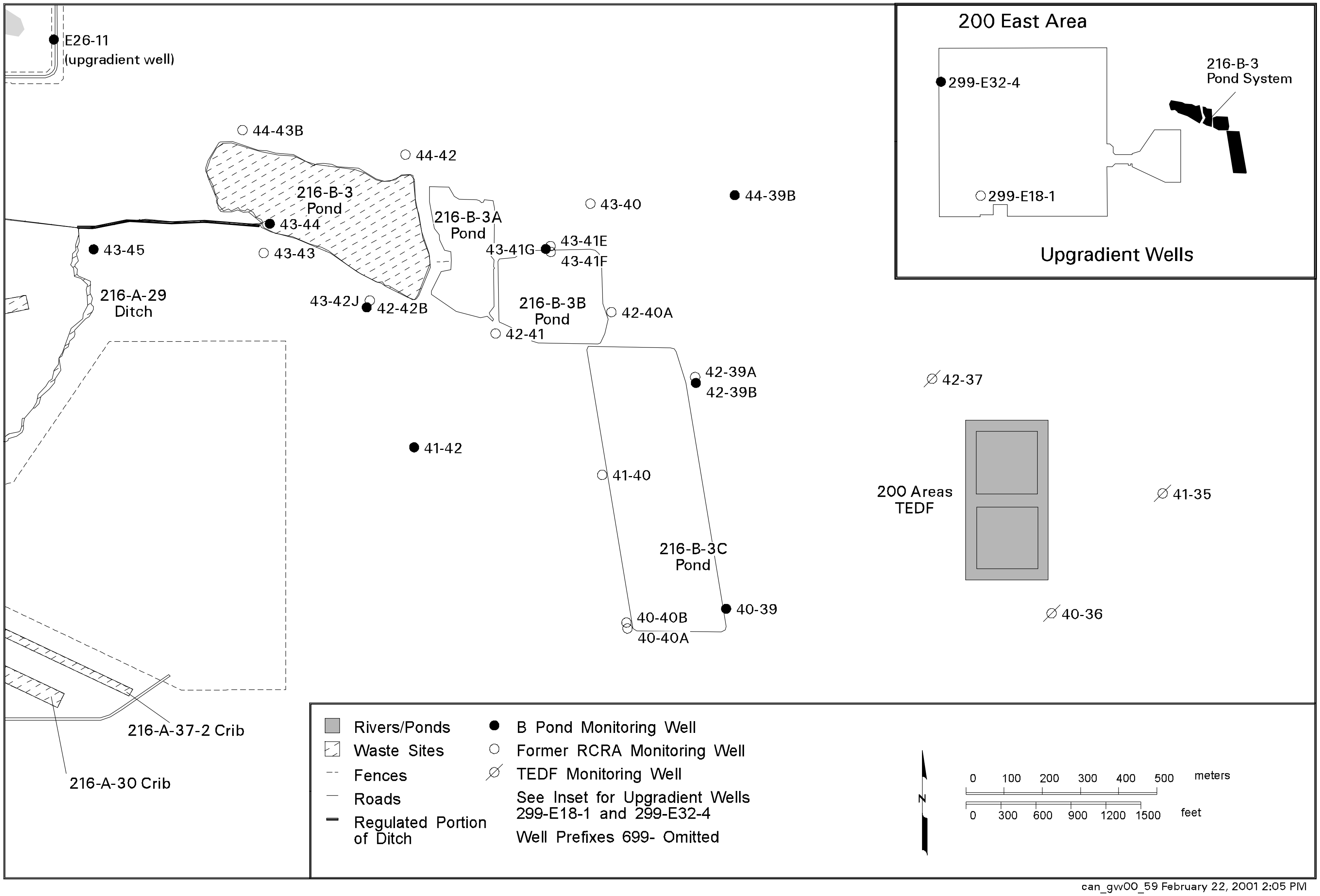

Figure A.16. Groundwater Monitoring Wells at the 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility

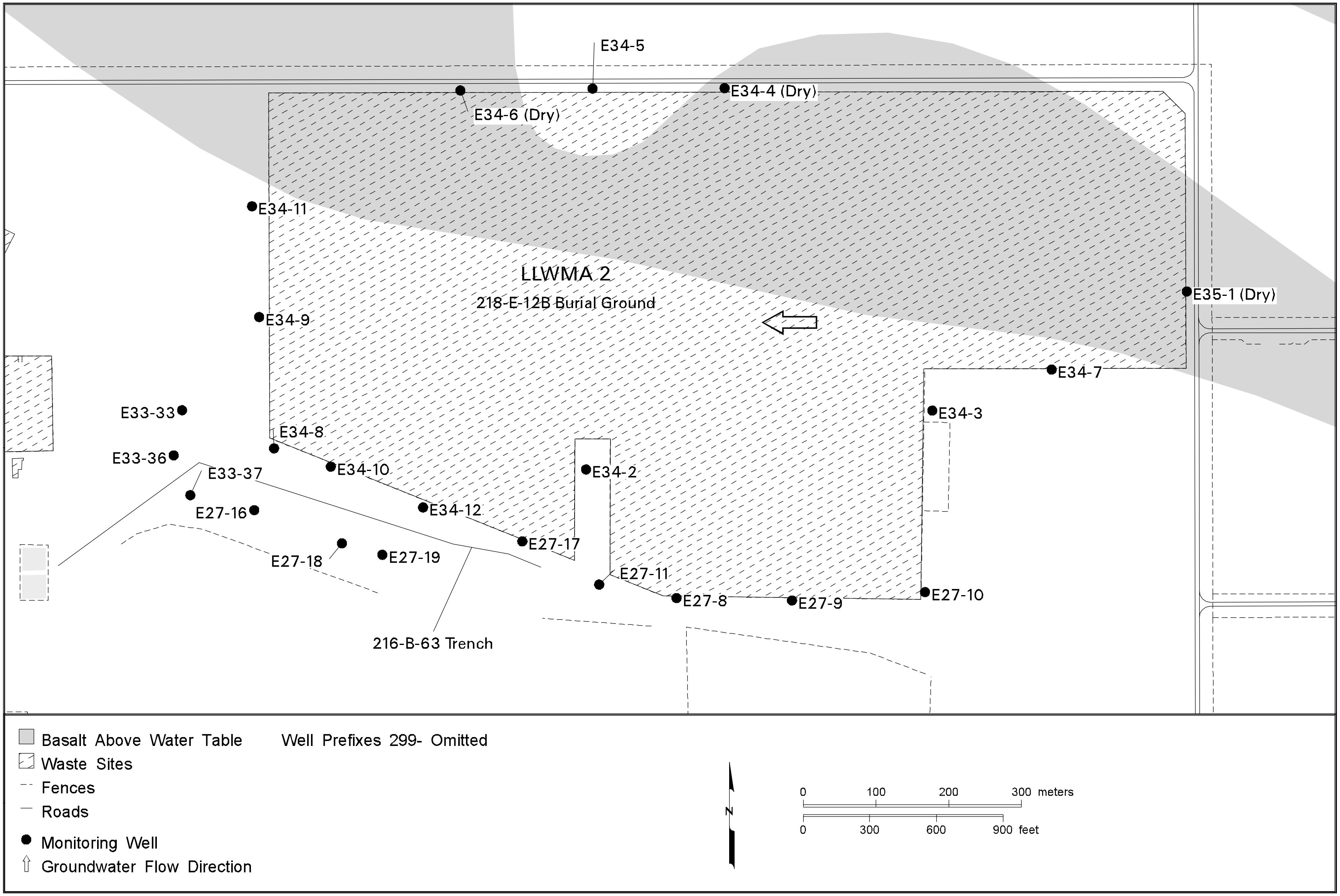

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Figure A.17. Groundwater Monitoring Wells at the 216-B-63 Trench and Low-Level Waste Management Area 2

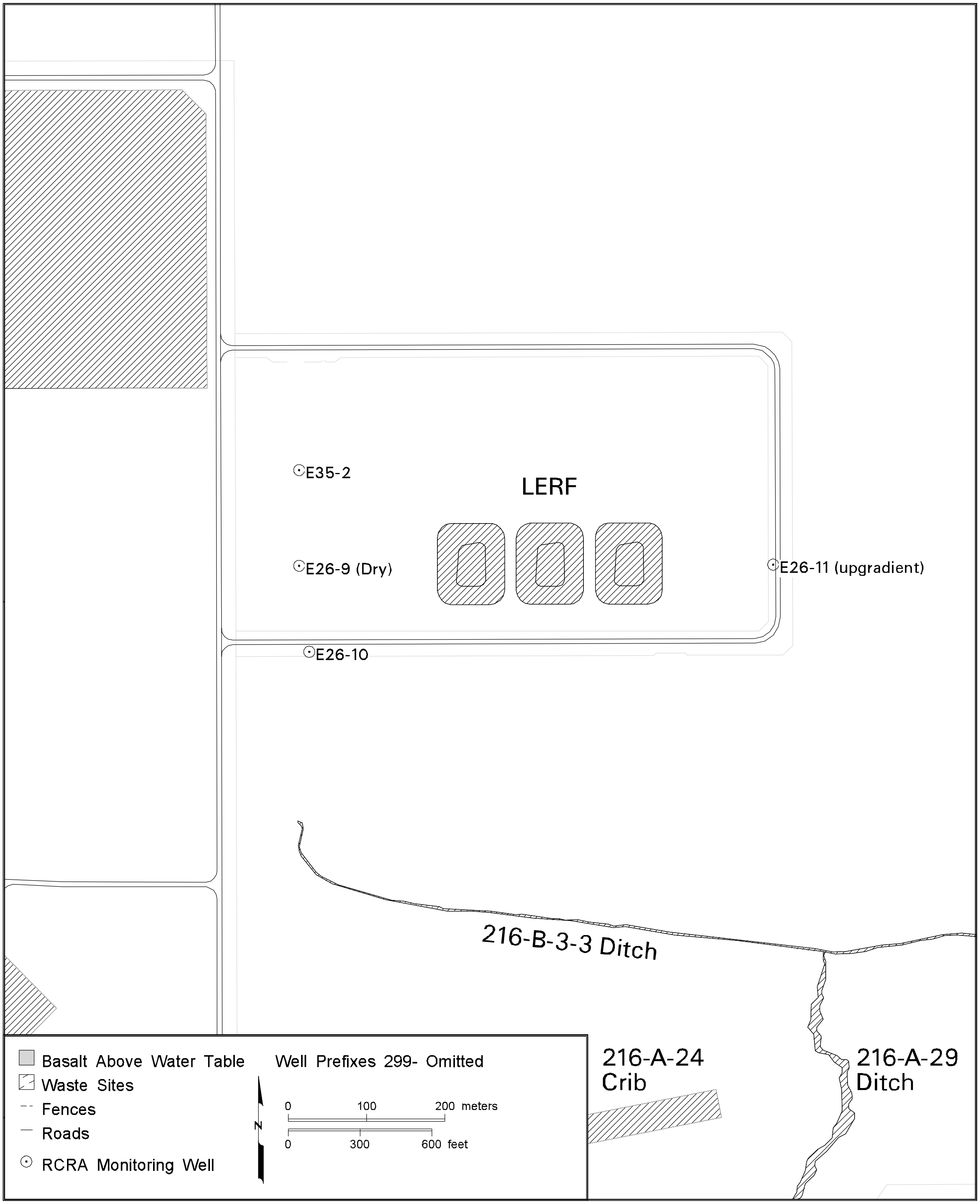

Figure A.18. Groundwater Monitoring Wells at the Liquid Effluent Retention Facility

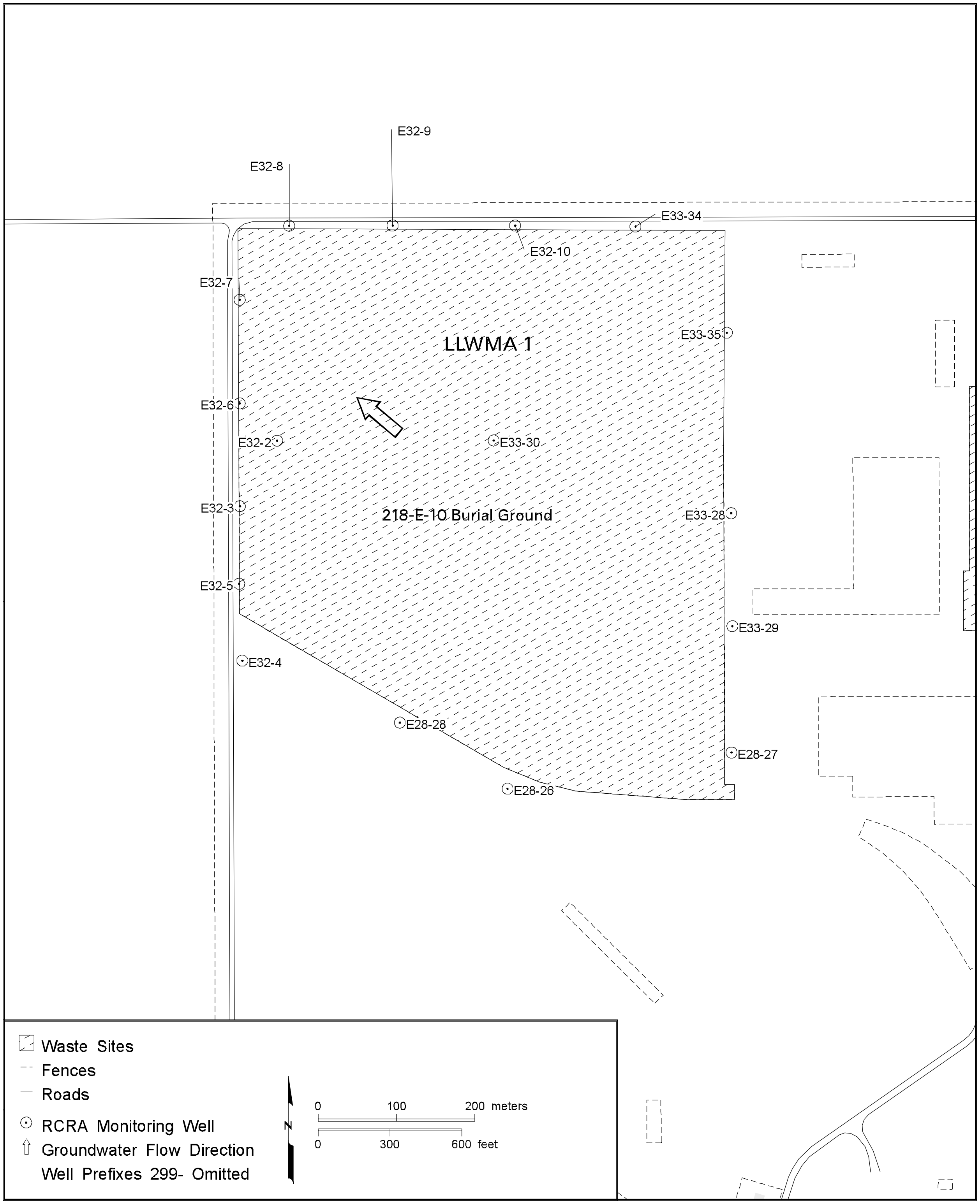

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Figure A.19. Groundwater Monitoring Wells at Low-Level Waste Management Area 1

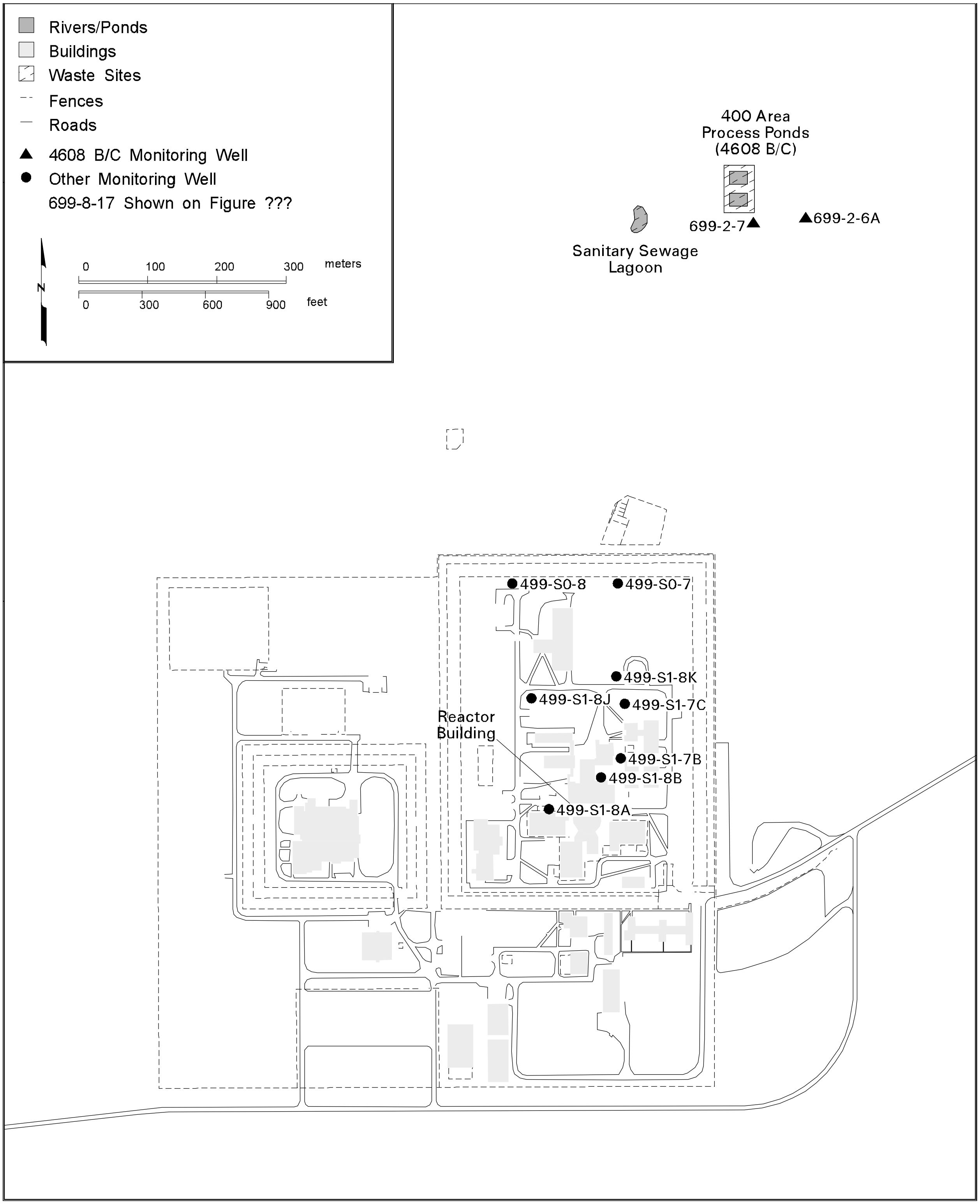

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Figure A.20. Groundwater Monitoring Wells at the 400 Area Process Ponds

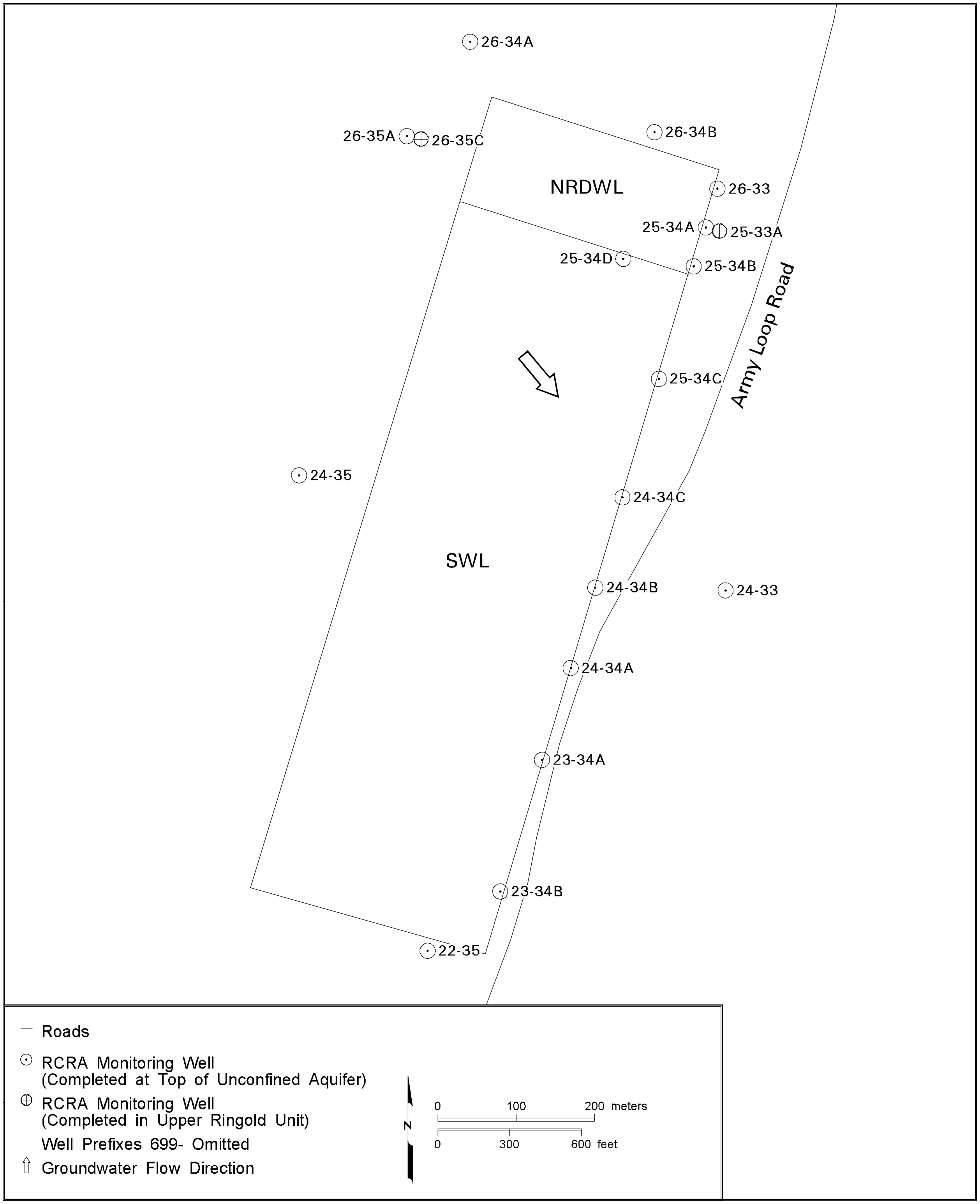

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Figure A.21. Groundwater Monitoring Wells at the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill

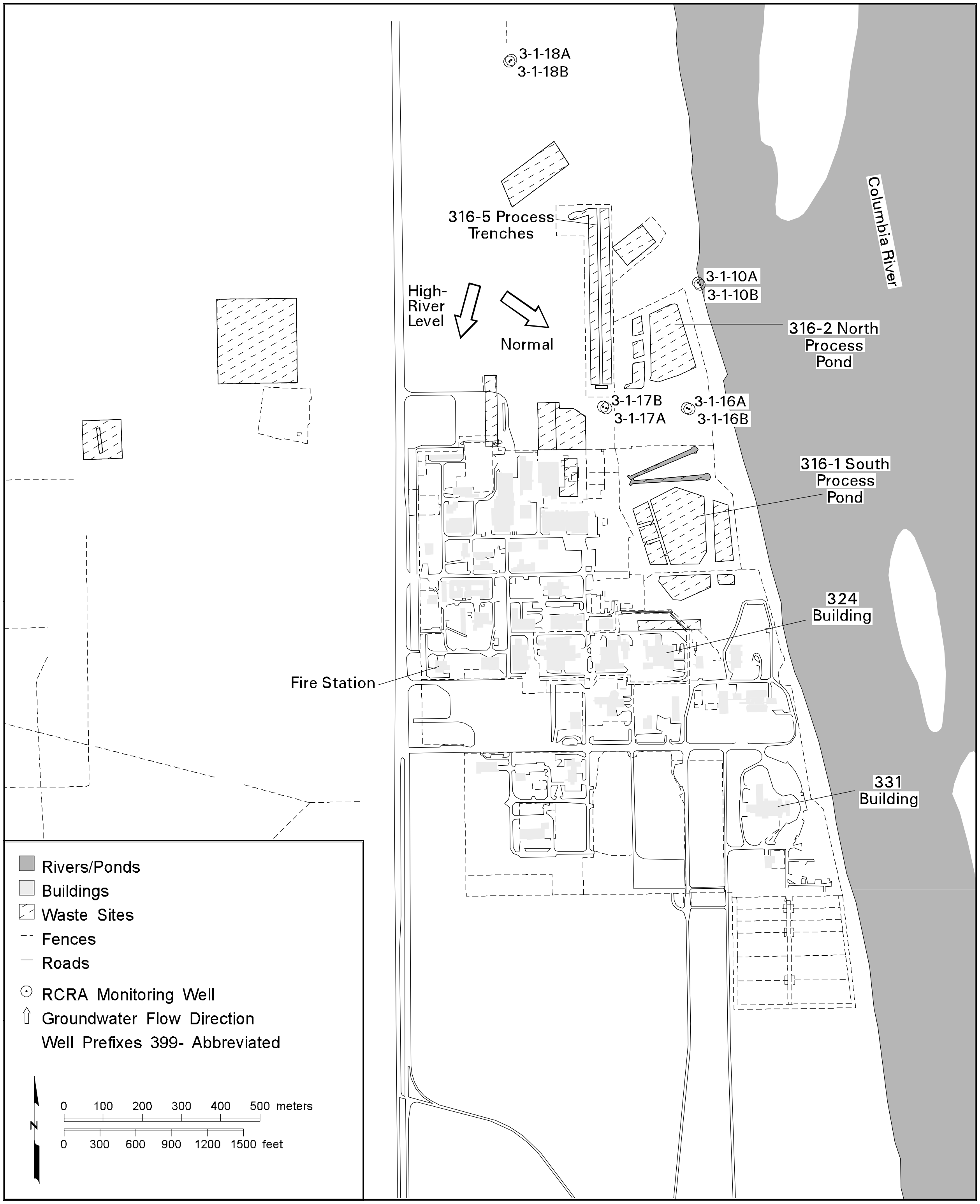

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Figure A.22. Groundwater Monitoring Wells at the 316-5 Process Trenches

Appendix B

Quality Assurance and Quality Control

Contents

Tables

Appendix B

Quality Assurance and Quality Control

This appendix presents fiscal year 2000 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 of 1976* (RCRA) and the *Atomic Energy Act of 1954*. Long-term monitoring also includes monitoring performed at *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) sites with no groundwater remediation. Pacific Northwest National Laboratory (PNNL) manages long-term monitoring via the Hanford Groundwater Monitoring Project (groundwater project). Interim action monitoring encompasses monitoring at sites with active groundwater remediation under CERCLA. Bechtel Hanford, Inc. manages interim action groundwater monitoring.

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) (OSWER-9950.1; SW-846). U.S. Department of Energy (DOE) orders and internal requirements provide the guidance for the collection and analysis of samples for long-term monitoring. The QA/QC practices for the groundwater project are described in the project-specific QA plan. Guidance for interim action monitoring QA/QC practices is provided in project-specific documents (e.g., BHI-00038; 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).

A glossary of QA/QC terms is provided in PNNL-13080.

B.1 Sample Collection and Analysis

C. J. Thompson

Duratek Federal Services, Incorporated conducted groundwater sampling for fiscal year 2000. 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.

Severn Trent Laboratories, Incorporated, St. Louis, Missouri (STL St. Louis) performed most routine analyses of hazardous and non-hazardous chemicals for the groundwater project. Previously known as Quanterra Incorporated, St. Louis, the laboratory was acquired by Severn Trent in January 2000. Recra Environmental, Inc., Lionville, Pennsylvania (Recra) served as the project's secondary laboratory for chemical analyses of split samples and blind standards. However, Recra performed the majority of chemical analyses for interim action groundwater monitoring. STL St. Louis also analyzed samples from sites with active groundwater remediation.

Severn Trent Laboratories, Incorporated, Richland, Washington (STL Richland) was the primary radiological laboratory for the groundwater project. ThermoRetec, Richmond, California, also performed radiological analyses on

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[a] SOW-243841-A-B2. 1998. Statement of Work between Pacific Northwest National Laboratory and Duratek Federal Services, Incorporated.

long-term monitoring samples. The roles of these laboratories were reversed for interim action groundwater monitoring (i.e., ThermoRetec served as the primary laboratory, while STL Richland was used as a backup laboratory).

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.

B.2 Field Quality Control Samples

C. J. Thompson and R. L. Weiss

Field QC samples include field duplicates 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, while field blanks provide an overall measure of contamination introduced during the sampling and analysis process.

B.2.1 Long-Term Monitoring (Hanford Groundwater Monitoring 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.
- 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. For radiological data, blank results are flagged if they are greater than two times the total propagated analytical uncertainty.

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 (96%) and duplicate (99%) results evaluated in fiscal year 2000 were high, indicating little problem with contamination and good precision overall. Tables B.1 through B.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. Most of the out-of-limit blank results were less than five times the method detection limit (i.e., below quantifiable limits). A few constituents such as calcium, chloride, magnesium, sodium, and total dissolved solids had several quantifiable field blank results, but the concentrations were much lower than the levels of these constituents in almost all groundwater samples. Two full-trip blanks had unusually high results that appeared to be the result of an isolated sample contamination problem, a swapped sample, or a laboratory error. The first had a total organic carbon result of 8,000 μg/L, and the second had high levels of chloride

(11,200 µg/L), fluoride (180 µg/L), nitrogen in nitrate (6,700 µg/L), and sulfate (47,500 µg/L). All other field blank results for these parameters were significantly lower. Furthermore, none of the samples associated with either trip blank appeared to be compromised for total organic carbon or anions based on trend data at the associated wells.

All of the field blank results for laboratory-measured specific conductivity were greater than 2 times the method detection limit, and 75% of the results were above levels seen in Hanford groundwater (~200 µS/cm). Measurement errors, possibly caused from reading extremely low-level samples in between actual groundwater samples, are the likely reason for the elevated results. Comparison of field- and laboratory-measured conductivity values for samples that were measured at both locations showed agreement within 10% in almost all cases. Moreover, all of the blind-standard results for laboratory-measured conductivity were within 10% of the expected values. Laboratory contamination seems unlikely because the highest method-blank result for specific conductivity was less than 1 µS/cm. PNNL staff discussed the elevated field-blank results with the groundwater project's primary laboratory, and the laboratory will be taking additional steps to avoid potential measurement errors in the future.

Twenty-seven percent of the field blank results for total organic carbon exceeded the QC limits. In general, the blank concentrations were low (only 1 result was greater than 1,000 µg/L), but the values are of concern for RCRA detection monitoring because total organic carbon is an indicator parameter. Most of the out-of-limit results were for samples collected during the second quarter. The source water used to prepare the blanks was changed during the second quarter; thus, the source water may have been contaminated. Periodic changes in the analyzer's performance could also be responsible for some of the elevated results.

Metals were the chemical class with the greatest number of out-of-limit field blank results. Most of the unacceptable results were within a factor of two of the QC limits. Many of the out-of-limit values were probably false detections, resulting from the practice of reporting metal results down to the instrument detection limit. Instrument detection limits do not take into account sample-matrix effects, which can have a negative impact on analyte detection.

Approximately one-fourth of the flagged blank results for volatile organic compounds were at concentrations greater than five times the method detection limits, resulting in quantifiable contamination of 2-butanone, chloroform, 1,4-dichlorobenzene, cis-1,2-dichloroethene, methylene chloride, and trichloroethene. In general, these compounds had low frequencies of detection (i.e., less than 10%) in field blanks, and the impact on the data is minor. Chloroform and methylene chloride had relatively high percentages of unacceptable field-transfer blank results (approximately 18% for both compounds). Chloroform may have been present in the water used to prepare the field blanks because of incomplete removal by the water-purification system. Methylene chloride is a common laboratory contaminant that was also detected at similar concentrations in laboratory method blanks. Accordingly, laboratory contamination is the suspected source of the methylene chloride.

Comparison of full-trip and equipment blank results suggests that the use of non-dedicated sampling equipment at some wells did not have a significant impact on data quality. Overall, fewer constituents were detected in equipment blanks, and the concentrations of most constituents were lower in equipment blanks. However, only a limited comparison can be made because only 10 equipment blanks were collected compared to 60 full trip blanks. It should also be noted that the percentages of out-of-limit results were slightly higher in equipment blanks for those constituents detected in both types of blanks.

Duplicate results were flagged for total dissolved solids, four anions, five metals, and two radiological parameters (Table B.4). Overall, the relative number of flagged duplicate results was very low (1%), but the percentages of unacceptable results were high for chromium (14%), iron (47%), manganese (17%), potassium (25%), and zinc (19%) based on the number of duplicates that met the evaluation criteria. A few of the metal samples were unfiltered; thus, suspended solids in heterogenous sample fractions may have caused some of the discrepancies in the metal results. Most 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 B.4.2 and B.4.3). 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 one or more pairs of results for the following: iron (2,250 and 912 µg/L; 45.9 and 168 µg/L), manganese (22.0 and 11.4 µg/L), nitrogen in nitrate (3,800 and 2,100 µg/L), and total dissolved solids (1,680 and 677 mg/L). Swapped samples or procedural deviations at the laboratory may have caused the unmatched results.

B.2.2 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 fiscal year 2000, 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 groundwater project, except the 20% relative percent difference criterion for field duplicate and split sample results was relaxed for sample analytical results near (i.e., typically within five times) the method detection limits.

For field blank samples, ~83% of all results were returned as non-detected. Greater than 75% of the blank results reported detected were common metals (e.g., calcium, iron, manganese, sodium) measured by the inductively coupled plasma method at levels close to analysis procedure detection limits. All detected organic constituents (i.e., ~10% of all reported detected results) were common laboratory contaminants or seen at very low levels (<1 µg/L). Minimal radioactive contamination was reported, and the results for all detected constituents except tritium were very near analysis detection limits. Two of six tritium results were above detection limits (values of ~200 and 400 pCi/L). Tritium is a known contaminant in some water sources used for the preparation of blanks. Evaluation of other field blank sample results shows no evidence of unexpected or excessive contamination of blanks in the field or by the laboratory. The constituents and levels of contamination found should have no impact on decision making for interim action monitoring. No changes were noted from evaluation of the previous year’s blank samples.

Field duplicate and split results showed ~7% exceeding the criteria used for evaluation. The percentage of out-of-limit splits was approximately 3 times higher than the relative number of out-of-limit duplicates. It should be noted that the criteria used 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).

As noted in previous years, metals analysis by inductively coupled plasma method accounts for the largest “group” of analyses (almost 45% of all) exceeding the criteria. Again as in previous years, the only higher concentration results (significantly above analytical quantitation limits) exceeding the criteria were on unfiltered samples. Unfiltered samples accounted for ~80% of all results which exceeded the criteria. Unfiltered samples would be expected to show greater variability because of suspended solids.

This year’s interlaboratory splits included volatile organic analyses performed in the field and at the commercial (fixed) laboratories. All field/fixed splits for carbon tetrachloride greater than 50 µg/L (as measured in the field) showed significantly lower levels (i.e., approximately one-third lower) reported by the fixed laboratory. The other field/fixed organic split results were all much closer to analytical detection limits and were within criteria, but elevation of the field results was noted here as well. This may be the result of volatile losses occurring during shipping/storage to and at the fixed laboratory, or the differences may result from the different analytical method used.

Last year’s evaluation noted an apparent non-random variability in interlaboratory splits for analysis of vanadium at low levels. This was noted again this year along with similar trends for other metals. At levels below approximately 50 µg/L, results reported by STL St. Louis were noted greater than by Recra for the following metals: beryllium, copper, iron, manganese, vanadium, and zinc. In many cases, Recra reported non-detection at significantly lower concentrations than reported as positive by STL St. Louis for the same split samples. The different analytical technology being used by the commercial laboratories (i.e., traditional inductively coupled plasma spectroscopy at STL St. Louis versus super trace [low detection limits] inductively coupled plasma at Recra) is the most likely source of these differences. If low concentrations of these metals become of interest, the differences between analytical technologies should be investigated.

Overall evaluation indicates no significant issues between procedures and analyses performed by the laboratories providing services to Bechtel Hanford, Inc. The overall performance for fiscal year 2000 appeared essentially unchanged from the previous year.

B.3 Holding Times

D. S. Sklarew

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 changes. 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 B.5. Radiological constituents do not have recommended maximum holding times because these constituents do not typically change chemically under ambient temperatures when appropriate preservatives are used. Results of radionuclide analysis are corrected for decay from sampling date to analysis date.

During fiscal year 2000, recommended holding times were exceeded for 214 out of 7,238 (3.0%) of the groundwater project's non-radiological sample analysis requests. A sample analysis request is defined as a sample that is submitted for analysis by a particular analytical method. The constituents with the most missed holding times were 84 anions, 32 alkalinity, 25 total dissolved solids, 14 cyanide, 14 total organic halides, and 11 coliform. Coliform analyses are normally performed by STL Richland; the others were conducted by STL St. Louis. This information was discussed with STL St. Louis and Richland to help the laboratories identify areas where improvements are needed. Recra did not exceed holding times for any of the samples that they analyzed for the groundwater project.

Specific evaluation of adherence to analytical holding times for interim action monitoring was not performed for this report. Analytical holding times are monitored as part of ongoing sample and data management activities throughout the year. No remediation decisions were affected by missed holding times in fiscal year 2000.

B.4 Laboratory Performance

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Laboratory performance is measured by several indicators, including nationally based 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 Recra and ThermoRetec are also presented throughout this section.

B.4.1 Nationally Based Performance Evaluation Studies

During fiscal year 2000, Environmental Resources Associates, New York State Department of Health, and DOE conducted nationally based studies to evaluate laboratory performance for chemical and radiological constituents. STL St. Louis and Recra participated in the EPA-sanctioned Water Pollution and Water Supply Performance Evaluation studies conducted by New York State Department of Health (Environmental Laboratory Approval Program) and Environmental Resources Associates, respectively. STL Richland and ThermoRetec took part in DOE's Quality Assessment Program. STL Richland participated in Environmental Resources Associates' InterLaB RadCheM Proficiency Testing Program, which has replaced the National Exposure Research Laboratory studies. 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.

B.4.1.1 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. Every month, standard water samples are distributed as blind standards 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 an accredited performance evaluation provider such as New York State Department of Health or Environmental Resources Associates, 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 performance evaluation provider found acceptable, independently verify the level of laboratory performance.

For the two water pollution studies in which STL St. Louis participated this year (NY ELAP 223 and 233), the percentage of acceptable results ranged from 91% to 96% (Table B.6). Of the 23 constituents with unacceptable results, none were out of limits more than once. Iron and zinc were high because of a laboratory contamination problem that has been corrected. Endrin was high because of a dilution error. The remaining out-of-limit results were insignificant because they were caused by reporting or calculation errors, were only slightly out of acceptance limits, or were not applicable to Hanford groundwater samples.

Recra participated in three water pollution and water supply studies this year, WP-56, WP-60, and WS-43. The percentage of Recra's acceptable results ranged from 93% to 96% (Table B.7). Of the 20 constituents with unacceptable results, two were out of limits twice. Total organic carbon and cyanide were each unacceptable in one of the two cases because of a sample preparation error.

B.4.1.2 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. EML provides blind standards that contain specific amounts of one or more radionuclides to participating laboratories. Constituents analyzed can include americium-241, cesium-137, cobalt-60, gross alpha, gross beta, iron-55, manganese-54, nickel-63, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, and total uranium. After sample analysis, each participating laboratory forwards the results to EML for comparison with known values and with results from other laboratories. 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% (less than 5th percentile or more than 95th percentile) of historical data (EML-605; EML-608).

For the two studies conducted this fiscal year, QAP51 and QAP52 (EML-605 and EML-608), the percentages of STL Richland's acceptable results were 100% both times (Table B.8). However, four constituents (31%) in the second study had results that were evaluated as acceptable with warning (Table B.8).

The percentages of ThermoRetec's results that were acceptable for the two studies were 93% and 100%, respectively (Table B.9). The constituent with unacceptable results in the first study was total uranium. Gross alpha had results that were evaluated as acceptable with warning in both studies.

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.

All fiscal year 2000 results (MAPEP-99-W7) for inorganics for STL St. Louis were acceptable (see Table B.8). All results for STL Richland except one, nickel-63, were acceptable (see Table B.8). All results for ThermoRetec and Recra were acceptable (see Table B.9).

B.4.1.3 InterLaB RadCheM Proficiency Testing Program Studies

The purpose of the InterLaB RadCheM Proficiency Testing Program, conducted by Environmental Resources Associates, was 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).

All Environmental Resources Associates' results from STL Richland were within the control limits (92%) except for one study that included barium-133, cesium-134, cesium-137, cobalt-60, and zinc-65. The unacceptable results were caused by a dilution error. Four constituents (24%) in the Environmental Resources Associates study had one or two results that were evaluated as acceptable with warning (see Table B.8).

ThermoRetec does not participate in the Environmental Resources Associates program.

B.4.2 Double-Blind Standard Evaluation

The groundwater project forwarded blind QC standards to STL Richland and St. Louis, Recra, ThermoRetec, and the University of Miami during fiscal year 2000. 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. Cyanide standards and one standard containing technetium-99 were prepared in organic free, 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).

Tables B.10 and B.11 list the number and types of blind standards used in fiscal year 2000 along with the control limits for each constituent. Not listed in the tables is a tritium standard that was submitted to the University of Miami. The control limits for the tritium standard were ±30%, and the laboratory's result was within the control limits. Overall, 80% of the blind spike determinations were acceptable. Ninety percent of the results from STL Richland and St. Louis were within the control limits, which is the same percentage of acceptable results Quanterra obtained in fiscal year 1999. Recra's and ThermoRetec's overall performance was poor; only 36% of the results from those two labs were acceptable.

Table B.12 lists the blind-standard spike concentrations and the average results for STL Richland and St. Louis. One or more individual results (not listed separately in Table B.12) were unacceptably high for gross beta, plutonium-239, total organic carbon, and total organic halides. Similarly, one or more results were biased low for carbon tetrachloride, cyanide, total organic halides, and technetium-99. Three constituents, carbon tetrachloride, plutonium-239, and technetium-99, were out of limits only once; the anomalous results appear to reflect isolated instances of poor analytical precision. STL Richland and St. Louis had problems with the constituents cyanide, gross beta, total organic carbon, and total organic halides. Results for these constituents and an investigation of a tritium interference problem with technetium-99 analyses are discussed below.

Although only one result for total organic carbon from STL St. Louis was out of limits, all of the results from the first three quarters of the fiscal year were biased high by 10% to 20%. A similar tendency was observed in last year's blind standard results. The errors are not unreasonable because all of the total organic carbon standards were prepared at concentrations near the laboratory's practical quantitation limit (1,000 µg/L). However, the unknown source of bias in these results may also be partially responsible for some of the elevated total organic carbon results for field blanks (discussed in Section B.2.1).

Four of fourteen results for total organic halides from STL St. Louis were out of limits for the standards that were spiked with volatile organic compounds. Individual out-of-limit recoveries for these standards ranged from 53% to 73%. The groundwater project performed in-house analyses on splits of the standards and confirmed that the standards were spiked at the proper concentrations. Because all but one of the results for the 2,4,6-trichlorophenol standards were acceptable, 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 B.5).

Most of STL St. Louis' cyanide results were biased low by 25% to 50%. Similar results were also obtained during fiscal year 1999. Because the laboratory has had excellent results for cyanide in water pollution and other performance-evaluation studies, a problem with the blind standards was suspected. Two sets of cyanide standards were prepared and submitted to the laboratory during the second quarter to check whether the source of cyanide used to prepare the standards was reliable. The two sets were prepared using cyanide from two independent vendors. With one exception, all of the results were biased low by approximately 20% to 30%, indicating that the low recoveries were not uniquely associated with one particular supplier. Another check on the standard preparation was performed during the fourth quarter by preparing a set of standards gravimetrically using a cyanide salt. Previous standards had been prepared by diluting a small quantity of a certified cyanide solution. The recoveries for the gravimetric standards (88% to 90%) were significantly higher than the recoveries obtained for standards prepared by dilution (see Table B.12). Additional investigation of the commercially-prepared cyanide solutions revealed that some of the certified solutions used in the past were not preserved at a high pH level. Consequently, project staff believe that the low bias was caused by instability of the commercially-prepared cyanide solutions. Verification of proper preservation will be performed in the future to help ensure the cyanide standards are reliable. Additional gravimetric standards will also be utilized if necessary.

Half of STL Richland's gross beta results were unacceptably high. The cause may be that the standards prepared during the first and second quarters were spiked at a higher level than expected, since ThermoRetec obtained similar, high-biased results on splits of these samples. The reason for the other out of-limit result is unknown. In all cases, STL Richland performed re-analyses on the standards with unacceptable results, but the re-analysis results were also higher than the expected values.

During the investigation of high tritium levels at the 618-11 burial ground, PNNL and STL Richland discovered that tritium levels over 40,000 pCi/L introduce a positive bias in the technetium-99 results from the laboratory's new TEVA disk analysis method. Soon after the problem was identified, STL Richland added a sample evaporation step to the procedure to remove tritium from the sample matrix. In order to verify that the evaporation step removed the interference without introducing additional analytical problems, the groundwater project submitted a special set of four blind standards to STL Richland. All of the standards in the set were spiked with approximately 50 pCi/L of technetium-99. The first standard also contained approximately 5 million pCi/L of tritium in a background well-water matrix. The remaining standards contained 100,000 pCi/L of tritium in either deionized water, background well water, or background well water and 200 mg/L nitrate. The purpose of the diverse sample matrices was to determine whether the technetium-99 recovery might be affected by incomplete dissolution of salts and inorganic complexes in the sample matrix when the sample is reconstituted after evaporation. All of the standards' results were within control limits except for the standard prepared in deionized water. This latter result may have been compromised by a sample-preparation or laboratory error. Consequently, this study demonstrated that the tritium interference problem was eliminated, and the sample matrices investigated do not appear to have a significant impact on the technetium-99 results.

Table B.13 provides a detailed summary of Recra and ThermoRetec's blind standard results. Several high-biased results were reported for gross beta, total organic carbon, and total organic halides. The only parameter with an unacceptably low result was gross alpha (ThermoRetec). Recra's high recoveries for total organic carbon during the first quarter were attributed to a failure to remove inorganic carbon from the samples prior to analysis. Recra revised their procedure to correct this problem, and better results were obtained during the third and fourth quarters, though the fourth quarter recoveries were slightly out of limits. Almost all of Recra's total organic halide results were unacceptable, and several results were systematically biased high by factors of approximately 2, 5, and 10. Recra performed data rechecks on all of the out-of-limit results but did not find any mistakes. Nevertheless, a calculation error is suspected as the cause of the high values. The impact of Recra's out-of-limit results for total organic halides is minimal because Recra did not analyze any routine groundwater samples for total organic halides during fiscal year 2000. Finally, five of ThermoRetec's gross beta results were unacceptably high. As noted earlier, the results are believed to be high because of incorrectly spiked standards.

A single blind standard containing 231 pCi/L of tritium was submitted to the University of Miami in support of low-level tritium monitoring in northern Richland. The University's result for this sample was 223 pCi/L, demonstrating excellent accuracy (97% recovery).

Bechtel Hanford, Inc. sent no blind standards as part of interim action monitoring to the commercial laboratories in fiscal year 2000. 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.

B.4.3 Laboratory Internal QA/QC Programs

STL Richland, STL St. Louis, ThermoRetec, and Recra 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. The groundwater project does not currently use laboratory QC data for in-house validation of individual sample results unless the laboratory is experiencing unusual performance problems with an analytical method. An assessment of the laboratory QC data for fiscal year 2000 is summarized in this section. STL data are discussed in detail first and are presented in Tables B.14 through B.17. Constituents not listed in these tables did not exceed STL Richland and St. Louis QC limits. A brief summary of Recra and ThermoRetec data is presented at the end of the section.

QC limits for general chemical parameters, ammonia and anions, metals, and radiochemical parameters are typically quite consistent. In contrast, QC limits for volatile and semivolatile organic compounds are highly variable, both for different compounds and for different time periods. For laboratory control samples, QC limits are typically 80% to 120% for general chemical parameters, ammonia and anions, and metals (except silver) and 70% to 130% for radiochemical parameters. For matrix spikes and matrix spike duplicates, QC limits are typically 75% to 125% for general chemical parameters, ammonia and anions, and metals, and 70% to 130% for radiochemical parameters. For matrix duplicates, QC limits are typically ≤20% (relative percent difference) for general chemical parameters, ammonia and anions, metals, and radiochemical parameters.

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, several parameters had unacceptable results, and some were "significantly" out of limits. For method blanks, "significantly out of limits" means some results were greater than twice the QC limit. For laboratory control samples, matrix spikes, and duplicates, "significantly out of limits" means the results were outside the range of the QC limits plus or minus 10 percentage points (e.g., if the QC limits are 80% to 120%, significantly out of limits would mean less than 70% or greater than 130%). Results that were significantly out of limits are noted in Tables B.14 through B.17.

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 or instrument detection limit for chemical constituents and two times the total propagated error for radiochemical 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 B.14 summarizes STL Richland and St. Louis method blank results. The general chemical parameters, metals, and ammonia and anions categories had the greatest percentages of method blank results exceeding the QC limits. For the general chemical parameters, only specific conductance had more than 10% of method blank results outside the QC limits. The out-of-limit method blank results for conductance are not a significant problem because the values are much lower than the levels measured in Hanford Site groundwater. A large number of method blanks exceeded the QC limits for metals. This probably resulted in part from the practice of reporting metal results down to the instrument detection limit. For ammonia and anions, only chloride had greater than 10% of the method blanks outside the QC limits. The highest method blank result for chloride was 0.15 mg/L, which is lower than the chloride levels measured in Hanford groundwater. None of the other categories (i.e., volatile organic compounds, semivolatile organic compounds, and radiological parameters) had a constituent with greater than 10% of method blanks outside the QC limits.

Table B.15 summarizes results from STL Richland and St. Louis for the laboratory control samples. None of the categories had more than 1% of their measurements outside the QC limits. For constituents with ten or more measurements, only uranium-235 had greater than 10% of laboratory control samples outside of QC limits. Insufficient historical data were available for the wells associated with these uranium-235 laboratory control samples to determine if there was a negative impact.

Table B.16 summarizes results from STL Richland and St. Louis for the matrix spikes and matrix spike duplicates. Fewer than 5% of the matrix spikes or matrix spike duplicates for general chemical parameters, metals, volatile or semivolatile organic compounds were out of limits. Among the constituents with ten or more measurements, only cadmium had greater than 10% of matrix spikes/spike duplicates outside of QC limits. The ammonia and anions and radiochemical parameters categories had the greatest percentage of matrix spikes/spike duplicates exceeding the QC limits. Table B.16 indicates which constituents with ten or more measurements had greater than 10% of matrix spikes/spike duplicates out of limits.

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 B.17 lists the constituents that exceeded the relative percent difference limits. All categories except semivolatile organic compounds had fewer than 3% of their measurements outside the QC limits. The five constituents with 10 or more measurements that had greater than 10% of duplicates outside of QC limits are 2,3,4,6-tetrachlorophenol, plutonium-239/240, uranium-234, uranium-235, and uranium-238.

Surrogate data included eight compounds each for volatile organics and for semivolatile organics. For volatile organic compounds, 0.5% of the surrogate results were outside of QC limits; the corresponding percentage for semivolatile organic surrogates was 0.6%.

Laboratory QC data for ThermoRetec and Recra were limited for fiscal year 2000 because these laboratories did not analyze many samples for the groundwater project. Recra analyzed method blanks, laboratory control samples, matrix spikes, and matrix duplicates for total organic carbon and total organic halides. Most of the results were within QC limits. However, two total organic halide matrix spikes were outside the limits. ThermoRetec QC data were limited to gross alpha, gross beta, and tritium. All the QC data were within limits for these parameters.

B.4.3.1 Issue Resolution

Issue resolution forms are documents to record and resolve problems encountered with sample receipt, sample analysis, and data reporting (e.g., broken bottles or QC problems). The forms are generated by the laboratory and forwarded to the groundwater project as soon as possible after a potential problem is identified. The forms indicate if direction on the part of the project is required. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse effect on data integrity. Table B.18 indicates the specific issues identified during fiscal year 2000 and the number of times these occurred. The number of issues identified by the laboratories was small compared to the total number of samples submitted for analyses (~4,700, consisting of ~13,600 bottles). For the most part, the frequency of the individual issues remained the same as last year.

B.4.3.2 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.

Assessments of STL Richland and St. Louis were conducted December 6 to 8, 1999 and April 18 to 21, 2000, respectively. The Hanford Site's Integrated Contractor Assessment Team, consisting of representatives from Bechtel Hanford, Inc., Flour Hanford, Inc., and PNNL conducted the audits. The purpose of the assessments was to evaluate the continued support of analytical services to Hanford Site contractors as specified in the statement of work between Flour Hanford, Inc. and Severn Trent Laboratories (RFSH-SOW-93-0003).[a]

The assessment scope for these audits 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 for the STL Richland laboratory were personnel training, procedure compliance, sample receipt and tracking, instrument operation and calibration, equipment maintenance, instrument records and logbooks, implementation of Severn Trent Laboratories' QA Management Plan, and the implementation of corrective actions for deficiencies identified in previous audits.

For the STL St. Louis laboratory audit, emphasis was placed on the implementation of Severn Trent Laboratories' QA program in accordance with the requirement of Hanford Analytical Services Quality Assurance Document (HASQARD), compliance to technical operating procedures, and verification of the corrective actions initiated in response to the previous audit (May 1999). The specific areas reviewed included sample preparation, instrument calibration, quality control sample data and acceptance criteria, logbook review, and preventative maintenance.

Three findings and four observations were noted in the assessment of STL Richland, and sixteen findings and six observations were identified during the assessment of STL St. Louis. The increase in the number of deficiencies at the STL St. Louis laboratory was primarily due to lack of compliance to HASQARD. The findings and observations related to deficiencies in five specific programmatic areas: document control, quality improvement, work processes, training, and calibration. Corrective-action responses to the assessment findings and observations have been evaluated. The STL Richland laboratory has addressed all finding and observations, and the audit findings have been closed. STL St. Louis has addressed all findings and observations; all of the findings except three have been closed.

Representatives from Bechtel Hanford, Inc. and Flour Hanford, Inc. conducted assessments of ThermoRetec and its subcontractor laboratory, Recra, on June 20 to 22, 2000 and May 23 to 25, 2000, respectively. The scope of these audits focused on the analytical and QA requirements for sample analyses as specified in the contract with the laboratories. Special emphasis was given to the laboratories' compliance with HASQARD.

Five findings and three observations were identified during the audit of ThermoRetec. The findings and observations were related to incomplete corrective actions from past audits, non-compliance to HASQARD, and non-compliance to standard operating procedures and the statement of work. All corrective-action responses have been accepted, and the findings have been closed.

Ten findings and six observations were noted for Recra. These findings and observations were related to procedural non-compliance, overdue review of procedures, incomplete training records, non-compliance to the QC requirements in HASQARD, an inadequate and ineffective corrective action system, and reporting and software deficiencies. Closure of four of the audit findings is still pending.

(a) 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.

Members of the DOE-sponsored Environmental Management Consolidated Assessment Program also conducted audits of STL St. Louis, STL Richland, and ThermoRetec. The dates for these assessments were May 24 to 25, 2000, September 25 to 27, 2000, and August 7 to 9, 2000, respectively. The goal of the Environmental Management Consolidated Assessment Program is to design and implement a program for consolidating site audits of commercial and DOE environmental laboratories providing services to DOE Environmental Management.

The focus of the Environmental Management Consolidated Assessment Program audits included the following areas: general laboratory practices and quality management, data quality for radiochemistry, laboratory information management and electronic data deliverables, and hazardous and radioactive material management. STL Richland and St. Louis had findings in the following areas: incomplete or lack of procedures, procedural non-compliance, implementation of the preventative maintenance program, instrument calibration, records storage and management, training, and incomplete documentation for the handling of hazardous and radioactive materials. ThermoRetec had findings related to procedural noncompliance, training, database change control, and insufficient implementation of their waste disposal/storage program.

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.

B.4.3.3 Sample Collection Contractor Surveillances

Groundwater project staff regularly reviewed sample collection activities performed by Flour Hanford's nuclear chemical operators under the supervision of Duratek Federal Services, Inc. The purpose of the reviews was to ensure that samples were collected and submitted to the laboratories in accordance with high-quality standards. Monthly surveillances were conducted in the following areas: sample delivery and shipping, bottle preparation, sample collection, calibration of instruments, standard certifications and usage, procedure implementation and control, staff training, equipment decontamination, and paperwork processing. No major problems were identified, and all minor deviations that were noted have been corrected.

B.4.4 Data Completeness and Comparability

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. For fiscal year 2000, 87% of the groundwater project data were considered complete. Potentially invalid data were flagged in the database. The percentages of data flagged were 1.9% for field QC problems, 0.6% for exceeded holding times, 0.1% for rejected results, 0.2% for suspect values, and 10% for laboratory blank contamination. These values are similar to the percentages observed in fiscal year 1999.

For comparability, samples are split in the field (i.e., collected in duplicate) and forwarded to two or more laboratories when problems arise that require confirmation of analytical results. During fiscal year 2000, 11 samples were split for one or more analyses of anions, carbon-14, strontium-90, tritium, and uranium. Recra and STL St. Louis analyzed the split samples for hazardous and non-hazardous chemicals. Low-level tritium analyses of split samples were performed by STL Richland and the University of Miami, while analyses for the other radiological parameters were performed by STL Richland and ThermoRetec. Five pairs of split sample results had relative percent differences greater than 20% for concentrations that were more than five times greater than the analyzing laboratories' detection limits. The constituents with the discrepancies were chloride (2 pairs of results), carbon-14, strontium-90, and tritium. None of the results were obvious outliers when compared with previous values at the associated wells. Thus, it is difficult to determine which result in each pair is closest to the "true" value. However, all eight of Recra's split sample results for chloride were higher than the corresponding values from STL St. Louis. A similar trend also was observed for high-level tritium measurements; all six of ThermoRetec's results were higher than the matching STL Richland values. Despite theses discrepancies, the laboratories showed good agreement overall for constituents at mutually quantifiable concentrations, and the results were useful for confirmation purposes.

Specific evaluation of completeness and comparability issues for interim action groundwater monitoring was not performed for this report. Completeness and comparability issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in fiscal year 2000.

B.5 Limit of Detection, Limit of Quantitation, and Method Detection Limit

C. J. Chou, D. S. Sklarew, and C. J. Thompson

Detection and quantitation limits are essential for evaluating 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 to be present but is, in fact, absent. A false-negative error is an instance when an analyte is declared to be 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 B.19 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 B.19 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 ten 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 B.19.

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:

$$\mathrm{MDL} = 3.14 \text{ x } s$$

$$\begin{aligned}\mathrm{LOD} &= 3 \text{ x } \left(\sqrt{2} \text{ x } s\right)\\ &= 4.24 \text{ x } s\end{aligned}$$

$$\begin{aligned}\mathrm{LOQ} &= 10 \text{ x } \left(\sqrt{2} \text{ x } 2\right)\\ &= 14.14 \text{ x } s\end{aligned}$$

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 B.20. The values in the table apply to STL St. Louis only.

Specific evaluation of detection-limit issues for the interim action groundwater monitoring program 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 fiscal year 2000.

B.6 Conclusions

Overall, assessments of fiscal year 2000 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.
- Several indicator parameters, metals, and volatile organic compounds were detected at low levels in field and/or laboratory method blanks. Some of these constituents were found at similar levels in groundwater samples.
- Small, yet systematic differences were observed in the results for some anions, metals, and tritium for split samples that analyzed by STL Richland and St. Louis and Recra/ThermoRetec.
- Maximum recommended holding times were exceeded for 3% of groundwater project samples. Anions and indicator parameters were primarily affected, though the data impacts are considered minor.
- Recra's performance on double-blind standards for total organic carbon and total organic halides was poor. Most of the results had a high bias and were outside acceptance limits. STL St. Louis' performance was much better, although the results for total organic carbon tended to be biased high while the results for total organic halides were biased low. STL St. Louis performed all routine total organic carbon and total organic halides analyses for the groundwater project.
- A tritium interference problem with STL Richland's new technetium-99 analysis method was identified and corrected. However, some second quarter technetium-99 results may be biased high for samples that contain low levels of technetium-99 and elevated levels of tritium. Potentially affected results were flagged in the database.

B.7 References

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Table B.1. 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					
Specific conductance	11	11	100.0	0.556 µS/cm	0.88 - 2,100 µS/cm
Total dissolved solids	8	11	72.7	8,456 µg/L	13,000 - 50,000 µg/L
Total organic carbon	20	71	28.2	444.4 µg/L	450 - 8,000 µg/L
Total organic halides	1	64	1.6	8.54 µg/L	10.9 µg/L
Ammonia and Anions					
Chloride	16	51	31.4	69.2 - 692 µg/L	72 - 11,200 µg/L
Cyanide	1	3	33.3	3.18 µg/L	9.8 µg/L
Fluoride	1	51	2.0	20.8 µg/L	180 µg/L
Nitrogen in nitrate	2	51	3.9	22 - 220 µg/L	130 - 6,700 µg/L
Sulfate	3	51	5.9	216 - 1,080 µg/L	320 - 47,500 µg/L
Metals					
Antimony	1	44	2.3	39.4 - 49.4 µg/L	43.1 µg/L
Barium	1	44	2.3	1.8 - 7.8 µg/L	18.8 µg/L
Beryllium	1	44	2.3	0.4 - 1 µg/L	0.55 µg/L
Calcium	19	44	43.2	130.6 - 245 µg/L	138 - 807 µg/L
Iron	2	44	4.6	31.2 - 60.6 µg/L	61 - 371 µg/L
Magnesium	8	44	18.2	184.4 - 201.4 µg/L	212 - 490 µg/L
Manganese	11	44	25.0	1 - 1.8 µg/L	1.1 - 4.4 µg/L
Sodium	29	44	65.9	88.4 - 166.2 µg/L	104 - 787 µg/L
Strontium	4	44	9.1	0.8 - 2.4 µg/L	0.82 - 6.3 µg/L
Vanadium	5	44	11.4	6.8 - 9.4 µg/L	10.6 - 23 µg/L
Zinc	13	44	29.6	6.2 - 8.4 µg/L	8.6 - 23.2 µg/L
Volatile Organic Compounds					
1,4-Dichlorobenzene	2	25	8.0	0.2 - 0.28 µg/L	0.31 µg/L
2-Butanone	1	24	4.2	1.4 µg/L	2.5 µg/L
Carbon tetrachloride	2	26	7.7	0.46 - 0.64 µg/L	0.81 - 0.95 µg/L
Chloroform	6	26	23.1	0.46 - 0.76 µg/L	0.51 - 0.91 µg/L
Methylene chloride	2	26	7.7	1.85 - 11.9 µg/L	1.9 µg/L
Tetrahydrofuran	1	23	4.4	2.98 µg/L	3.2 µg/L
o-Xylene	1	2	50.0	0.26 µg/L	0.29 µg/L
Radiological Parameters					
Gross beta	1	38	2.6	2.2 - 3.4 pCi/L(b)	4.83 pCi/L
Tritium	2	46	4.4	19 - 440 pCi/L(b)	87.7 - 138 pCi/L

(a) Because method detection limits may change throughout the year, the 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.

Table B.2. 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	4	122	3.3	0.28 - 2.06	0.3 - 0.88
2-Butanone	9	126	7.1	1.4 - 4.96	1.8 - 6.9
Carbon disulfide	1	126	0.8	0.6 - 3.1	0.83
Carbon tetrachloride	4	126	3.2	0.46 - 2.34	0.47 - 0.97
Chloroform	22	126	17.5	0.46 - 1.64	0.47 - 11
cis-1,2-Dichloroethlene	1	126	0.8	0.36 - 1.4	4.4
Methylene chloride	22	126	17.5	1.85 - 25	1.9 - 13
Tetrahydrofuran	1	122	0.8	2.98 - 13.44	3.5
Trichloroethene	1	126	0.8	0.32 - 2.48	3.3

(a) Because method detection limits may change throughout the year, the 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.

Table B.3. Equipment 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			
Specific conductance	1	1	100.0	0.556 µS/cm	0.81 µS/cm
		Ammonia and Anions			
Chloride	5	9	55.6	69.2 µg/L	105 - 540 µg/L
Nitrogen in nitrate	1	9	11.1	22 µg/L	49 µg/L
Sulfate	1	9	11.1	216 µg/L	2,600 µg/L
		Metals			
Barium	1	9	11.1	1.8 - 7.8 µg/L	10.9 µg/L
Calcium	6	9	66.7	130.6 - 245 µg/L	180 - 354 µg/L
Iron	2	9	22.2	31.2 - 60.6 µg/L	68.4 - 86.6 µg/L
Manganese	3	9	33.3	1 - 1.8 µg/L	1.1 - 5.1 µg/L
Sodium	9	9	100.0	88.4 - 166.2 µg/L	207 - 468 µg/L
Zinc	5	9	55.6	6.2 - 8.4 µg/L	10.3 - 34.2 µg/L
		Volatile Organic Compounds			
Bromodichloromethane	2	4	50.0	0.4 µg/L	0.43 - 0.51 µg/L
Chloroform	5	5	100.0	0.46 µg/L	2.4 - 23 µg/L
		Radiological Parameters			
Uranium	1	5	20.0	0.0016 - 0.038 µg/L[(b)]	0.0821 µg/L

(a) Because method detection limits may change throughout the year, the 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.

Table B.4. 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)]
General Chemical Parameters					
Total dissolved solids	23	23	2	18.7	20.6 - 85.1
Ammonia and Anions					
Chloride	44	44	1	2.3	38.7
Cyanide	5	2	1	50.0	28.9
Fluoride	44	44	1	2.3	20.7
Nitrogen in nitrate	44	44	1	2.3	57.6
Metals					
Chromium	63	21	3	14.3	21.9 - 30.1
Iron	51	15	7	46.7	23.5 - 114.2
Manganese	51	30	5	16.7	22.2 - 63.5
Potassium	51	40	11	27.5	25.7 - 47.4
Vanadium	51	30	1	3.3	27.9
Zinc	51	16	3	18.8	61.8 - 76.6
Radiological Parameters					
Gross beta	37	19	1	5.3	32.4
Uranium	13	12	1	8.3	61.0

(a) Duplicates with both results less than five 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 B.5. Maximum Recommended Holding Times for Chemical Constituents

Methods	Constituents	Holding Times
8010/8020/8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction; 40 days after extraction
8080 (SW-846)	Pesticides	7 days before extraction; 40 days after extraction
8080 (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
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
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	72 hours
300.0 (EPA-600/4-81-004)	Nitrite	72 hours
300.0 (EPA-600/4-81-004)	Phosphate	72 hours
300.0 (EPA-600/4-81-004)	Sulfate	28 days
310.1 (EPA-600/4-81-004)	Alkalinity	14 days
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days
9222 B (Franson 1995)	Coliform	24 hours

Table B.6. Summary of Water Pollution Performance Evaluation Studies, Severn Trent Laboratories, St. Louis

Accreditation Laboratory	NY ELAP 223 January 2000 Percent Acceptable	NY ELAP 233 July 2000 Percent Acceptable
New York Environmental Laboratory Approval Program	91.9[(a)]	96.3[(b)]

(a) Unacceptable results were for total organic carbon, iron, potassium, zinc, benzene, 1,2-dichloroethane, endrin, 2,4-D, 4,4-DDD, alpha-BHC, dieldrin, endrin aldehyde, endosulfan I, heptachlor epoxide, undane, and total chlordane.

(b) Unacceptable results were for total suspended solids, total phosphorus, alkalinity, PCB 1260, specific conductance, PCB 1232 (soils), and PCB 1260 (soils).

Table B.7. Summary of Recra Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies

Accreditation Laboratory	WP-56 December 1999 Percent Acceptable	WP-60 March 2000 Percent Acceptable	WS-43 April 2000 Percent Acceptable
Environmental Resource Associates	93.5(a)	93.8(b)	96.5(c)

(a) Unacceptable results were for alkalinity, magnesium, total hardness, orthophosphate as P, and tetrachloroethene.
(b) Unacceptable results were for conductivity, total suspended solids, total organic carbon, chemical oxygen demand, total kjeldahl nitrogen, cyanide, and total residual chlorine.
(c) Unacceptable results were for cyanide, total organic carbon, dichlorodifluoromethane, 2,4-D, dicamba, pentachlorophenol, 1,2-dichlorobenzene, and 1,2-dichloroethane.

Table B.8. Summary of Severn Trent Interlaboratory Performance, Fiscal Year 2000

Constituent	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP51, QAP52) **Environmental Measurements Laboratory**		
Americium-241, cobalt-60, cesium-137, gross alpha, gross beta, nickel-63, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, uranium	2	2(a,b)
Iron-55	1	1(a)
DOE Mixed Analyte Performance Evaluation Program (MAPEP-99-W7) **Radiological and Environmental Sciences Laboratory**		
Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, iron-55, manganese-54, plutonium-238, strontium-90, uranium-234/233, uranium-238, zinc-65	1	1(c)
Nickel-63	1	0(c)
Arsenic, barium, beryllium, cadmium, selenium, thallium, vanadium, zinc	1	1(d)
ERA InterLaB RadCheM Proficiency Testing Program **Environmental Resource Associates**		
Gross alpha, gross beta, radium-226, radium-228, uranium	6	6(e,f)
Cesium-134, cesium-137, cobalt-60	5	4(e,f)
Strontium-89, strontium-90	4	4(e)
Barium-133, zinc-65	3	2(e,f)
Iodine-131, tritium	2	2(e)

(a) Control limits from EML-605 and EML-608.
(b) One result each for americium-241, gross alpha, gross beta, and uranium-238 was acceptable but outside warning limits.
(c) Results from STL Richland.
(d) Results from STL St. Louis.
(e) Control limits from National Standards for Water Proficiency Testing Studies Criteria Document.
(f) One result each for cobalt-60 and zinc-65 and two results each for cesium-134 and gross beta were acceptable but outside warning limits.

Table B.9. Summary of ThermoRetec and Recra Interlaboratory Performance, Fiscal Year 2000

Constituent	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP51, QAP52) Environmental Measurements Laboratory		
Americium-241, cobalt-60, cesium-137, iron-55, gross alpha, gross beta, nickel-63, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238	2	2[a,b]
uranium	1	0[a]
DOE Mixed Analyte Performance Evaluation Program (MAPEP-99-W7) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-137, cobalt-57, cobalt-60, iron-55, manganese-54, nickel-63, plutonium-238, strontium-90, uranium-234/233, uranium-238, zinc-65	1	1[c]
Arsenic, barium, beryllium, cadmium, nickel, selenium, thallium, vanadium, zinc	1	1[d]

(a) Results from ThermoRetec. Control limits from EML-605 and EML-608.
(b) Two results for gross alpha were acceptable but outside warning limits.
(c) Results from ThermoRetec.
(d) Results from Recra.

Table B.10. Summary of Double-Blind Standard Determinations, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Control Limits[b] (%)
General Chemical Parameters				
Specific conductance	Quarterly	9	0	±25
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	16	1	±25
Total organic halides (2,4,6-trichlorophenol spike)	Quarterly	14	1	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	Quarterly	14	2	±25
Anions				
Cyanide	Quarterly	18	12	±25
Fluoride	Quarterly	12	0	±25
Metals				
Aluminum	Annually	3	0	±25
Barium	Annually	3	0	±25
Beryllium	Annually	3	0	±25
Chromium	Semiannually	6	0	±20
Cobalt	Annually	3	0	±25
Copper	Annually	3	0	±25
Iron	Annually	3	0	±25
Manganese	Annually	3	0	±25
Nickel	Annually	3	0	±25
Vanadium	Annually	3	0	±25
Zinc	Annually	3	0	±25
Volatile Organic Compounds				
Carbon tetrachloride	Quarterly	12	1	±25
Chloroform	Quarterly	12	0	±25
Trichloroethene	Quarterly	12	0	±25
Radiological Parameters				
Gross alpha (plutonium-239 spike)	Quarterly	12	0	±25
Gross beta (strontium-90 spike)	Quarterly	12	6	±25
Cesium-137	Annually	3	0	±30
Cobalt-60	Annually	3	0	±30
Iodine-129	Semiannually	6	0	±30
Plutonium-239	Quarterly	12	1	±30
Strontium-90	Semiannually	6	0	±30
Technetium-99	Quarterly	16	1	±30
Tritium	Quarterly	13	0	±30
Uranium-238	Quarterly	12	0	±30

(a) Blind standards were generally submitted in triplicate or quadruplicate. Additional blind standards for cyanide, technetium-99, and tritium were submitted for special investigations as described in the text.

(b) Each result must be within the specified percentage of the known value to be acceptable.

Table B.11. Summary of Recra Environmental, Inc. and ThermoRetec Double-Blind Standard Determinations

Constituent	Sampling Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Control Limits[b] (%)
General Chemical Parameters				
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	12	6	±25
Total organic halides (2,4,6-trichlorophenol spike)	Quarterly	14	13	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	Quarterly	14	12	±25
Radiological Parameters				
Gross alpha (plutonium-239 spike)	Semiannually	6	1	±25
Gross beta (strontium-90 spike)	Quarterly	12	5	±25

(a) Blind standards were submitted in triplicate or quadruplicate.
(b) Each result must be within the specified percentage of the known value to be acceptable.

Table B.12. Double-Blind Standard Results, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
General Chemical Parameters (µg/L)					
Specific conductance	First	445	420	94	1
	Second	445	428	96	1
	Third	445	424	95	0
Total organic carbon(a)	First	2,510	3,025	121	4
	Second	999	1,075	108	5
	Third	1,506	1,775	118	3
	Fourth	2,003	2,000	100	0
Total organic halides(b) (phenol)	First	101	87.4	87	9
	Second	892	742	83	9
	Third	13	16.2	124	6
	Fourth	44	36.5	83	6
Total organic halides(c) (volatile organic mixture)	First	101	85.8	85	7
	Second	898	615	69	25
	Third	13	14.9	115	5
	Fourth	44	34.5	78	14
Anions (µg/L)					
Cyanide	First	400	292	73	3
	Second	200	188	94	41
	Third	300	196	65	2
	Fourth	50	26.9	54	4
Cyanide(d) (alternate supplier)	Second	198.31	155	78	1
Cyanide(e) (gravimetric preparation)	Fourth	50.15	44.4	89	2
Fluoride	First	5,000	5,033	101	1
	Second	5,000	5,100	102	0
	Third	3,000	3,333	111	2
	Fourth	2,000	2,167	108	3
Metals (µg/L)					
Aluminum	Fourth	200.5	205	102	3
Barium	Fourth	200.5	193	96	1
Beryllium	Fourth	5	4.67	93	3
Chromium	Second	200	217	108	9
	Fourth	20.1	18.4	92	4
Cobalt	Fourth	50.1	50.8	101	1
Copper	Fourth	25.1	25.0	100	6
Iron	Fourth	100.3	104	104	4
Manganese	Fourth	50.1	48.8	97	2
Nickel	Fourth	50.1	43.4	87	5
Vanadium	Fourth	50.1	48.8	97	5
Zinc	Fourth	50.1	52.8	105	4
Volatile Organic Compounds (µg/L)					
Carbon tetrachloride	First	7	6	86	2
	Second	499	433	87	1
	Third	5.3	5.5	104	2
	Fourth	20	16	80	17

Table B.12. (contd)

Constituent	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
Chloroform	First	100	94	94	2
	Second	219	223	102	3
	Third	5.2	5.53	106	6
	Fourth	20	18	90	6
Trichloroethene	First	7.2	6.37	88	2
	Second	229	217	95	3
	Third	5.1	4.9	96	4
	Fourth	10	8.1	81	6
Radiochemical Parameters (pCi/L)					
Gross alpha	First	20.28	19.5	96	8
	Second	294.33	285	97	5
	Third	14.84	16.3	110	19
	Fourth	101.01	115	114	4
Gross beta(f)	First	30.44	39.3	129	7
	Second	20.92	33.1	158	2
	Third	59.34	72.7	123	4
	Fourth	103.23	119	115	2
Cesium-137	Third	199.7	194	97	2
Cobalt-60	Third	50.08	47.7	95	17
Iodine-129	First	30.651	35.2	115	7
	Third	9.7	10.6	109	5
Plutonium-239	First	20.287	22.7	112	7
	Second	1.492	1.71	114	15
	Third	7.096	8.05	113	9
	Fourth	2.016	1.93	96	10
Strontium-90	Second	20.89	23.8	114	2
	Fourth	102.002	115	113	4
Technetium-99	First	469.1	477	102	3
	Second	1,019.4	1,050	103	1
	Third	201.16	216	107	1
	Fourth	100.06	104	104	8
Technetium-99(g) (deionized water)	Fourth	52.1	30.8	59	--
Technetium-99(g) (background well water)	Fourth	52.1	44.9	86	--
Technetium-99(g) (background well water spiked with sodium nitrate)	Fourth	52.1	51.8	99	--
Technetium-99(g) (high tritium matrix)	Fourth	52.1	46.9	90	--
Tritium	First	20,832	18,870	91	2
	Second	210.87	204	97	5
	Third	259.8	235	91	1
	Third	230.6	201	87	--
	Fourth	262.8	256	98	2

Table B.12. (contd)

Constituent	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
Uranium-238	First	63.009	64.1	102	1
	Second	148.941	158	106	1
	Third	915.498	980	107	6
	Fourth	322.923	316	98	6

(a) Total organic carbon standards were submitted in quadruplicate each quarter.

(b) Total organic halide (phenol) standards were submitted in quadruplicate during the second and third quarters. The standards were submitted in triplicate in the first and fourth quarters.

(c) Total organic halide (volatile) standards were submitted in quadruplicate during the first and fourth quarters. The standards were submitted in triplicate in the second and third quarters.

(d) Special cyanide standards were prepared from a stock solution purchased from an alternate vendor (Fisher Scientific).

(e) Special cyanide standards were prepared gravimetrically from a potassium cyanide salt.

(f) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

(g) Four special technetium-99 standards were prepared in different water matrices: deionized water, background well water, background well water spiked with 200 mg/L nitrate, and background well water spiked with 5,130,000 pCi/L tritium.

Table B.13. Recra Environmental, Inc. and ThermoRetec Double-Blind Standard Results

Constituent	Fiscal Year Quarter	Spike Amount	Average Result[a]	Average Recovery (%)	Relative Standard Deviation (%)
	General Chemical Parameters (µg/L)				
Total organic carbon[a]	First	2,510	4,015	160	2
	Third	1,506	1,662.5	110	2
	Fourth	2,003	2550	127	2
Total organic halides[b] (phenol)	First	101	206	204	4
	Second	892	1,160	130	9
	Third	13	142.75	1098	9
	Fourth	44	218	495	7
Total organic halides[c] (volatile organic mixture)	First	101	202	200	4
	Second	898	781	87	21
	Third	13	146	1126	15
	Fourth	44	213	485	6
	Radiological Parameters (pCi/L)				
Gross alpha (plutonium-239)	First	20.28	15.9	78	10
	Third	14.84	14.1	95	7
Gross beta (strontium-90)[d]	First	30.47	40.0	131	5
	Second	20.92	31.8	152	7
	Third	62.55	75.8	121	2
	Fourth	103.23	121	117	6

(a) Total organic carbon standards were submitted in quadruplicate each quarter.

(b) Total organic halide (phenol) standards were submitted in quadruplicate during the second and third quarters. The standards were submitted in triplicate in the first and fourth quarters.

(c) Total organic halide (volatile) standards were submitted in quadruplicate during the first and fourth quarters. The standards were submitted in triplicate in the second and third quarters.

(d) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

Table B.14. Method Blank Results, Severn Trent Laboratories (Richland and St. Louis)[a]

Constituent	Percent Out of Limit[b]	Number of Analyses	Concentration Range of Detections
General Chemical Parameters			
Total General Chemical Parameters	8.0	487	--
Alkalinity	0.9	110	5 mg/L
Conductivity	87.5	40	0.56 - 0.98 µS/cm
Total dissolved solids	1.6[c]	63	24 mg/L
Total organic carbon	1.1	91	0.46 mg/L
Total organic halides	0.6	175	12.7 µg/L
Ammonia and Anions			
Total Ammonia and Anions	3.5	956	--
Chloride	17.2[c]	180	0.071 - 0.15 µg/L
Nitrogen in nitrate	0.6	181	0.03 µg/L
Sulfate	0.6	179	0.28 µg/L
Metals			
Total Metals	6.8	1,660	--
Aluminum	32.5[c]	83	41.2 - 192 µg/L
Barium	1.2	83	10.7 µg/L
Beryllium	2.4	83	1.1 - 1.2 µg/L
Calcium	1.2	82	305 µg/L
Chromium	1.1	88	0.95 µg/L
Copper	7.2[c]	83	5.8 - 76.5 µg/L
Iron	46.5[c]	86	20.2 - 92.9 µg/L
Magnesium	4.9[c]	82	203 - 509 µg/L
Manganese	3.6	84	2.3 - 3.6 µg/L
Nickel	1.2	84	22.3 µg/L
Sodium	4.9[c]	82	185 - 412 µg/L
Vanadium	6.0[c]	83	5.6 - 28.7 µg/L
Zinc	21.2[c]	85	3.3 - 34.9 µg/L
Volatile Organic Compounds			
Total Volatile Organic Compounds	0.4	2,506	--
1,4-Dichlorobenzene	4.6	109	0.29 - 0.4 µg/L
Carbon disulfide	1.0	97	0.83 µg/L
Ethylbenzene	9.1	11	0.29 µg/L
Methylene chloride	1.9[d]	105	0.76 - 5 µg/L
Tetrahydrofuran	1.0	97	4.5 µg/L
Semivolatile Organic Compounds			
Total Semivolatile Organic Compounds	0	861	--
Radiochemical Parameters			
Total Radiochemical Parameters	0.7	1,368	--
Technetium-99	2.0[c]	101	31.1 - 53.3 pCi/L
Tritium	4.3	161	8.65 - 847 pCi/L[e]

(a) Includes only constituents that exceeded STL Richland and St. Louis QC limits.
(b) Quality control limits are twice the method detection limit.
(c) One or more results for footnoted compounds are "significantly out of limits" as defined in the text.
(d) Quality control limits for footnoted compounds are five times the method detection limit.
(e) Range values are from two methods.

Table B.15. Laboratory Control Samples, Severn Trent Laboratories (Richland and St. Louis)(a)

Constituent	Percent Out of Limit(b)	Number of Analyses
General Chemical Parameters		
Total General Chemical Parameters	0.4	488
Alkalinity	1.8	111
Ammonia and Anions		
Total Ammonia and Anions	0	958
Metals		
Total Metals	0.1	1,655
Iron	1.2	84
Zinc	1.2(b)	86
Volatile Organic Compounds		
Total Volatile Organic Compounds	0	572
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	0.2	531
Oil and grease	50.0	2
Radiochemical Parameters		
Total Radiochemical Parameters	0.8	953
Iodine-129	1.6(b)	63
Neptunium-237	100.0	1
Uranium-235	35.3(b)	17

(a) Includes only constituents that exceeded STL Richland and St. Louis QC limits.

(b) One or more results for footnoted compounds are “significantly out of limits” as defined in the text.

Table B.16. Matrix Spikes and Matrix Spike Duplicates, Severn Trent Laboratories (Richland and St. Louis)[(a)]

Constituent	Percent Out of Limit[(b)]	Number of Analyses
General Chemical Parameters		
Total General Chemical Parameters	4.9	163
Total organic carbon	4.7[(b)]	86
Total organic halides	5.2[(b)]	77
Ammonia and Anions		
Total Ammonia and Anions	27.6	359
Chloride	19.0[(b)]	63
Cyanide	5.0[(b)]	20
Fluoride	20.6[(b)]	63
Nitrogen in nitrate	49.2[(b)]	63
Nitrogen in nitrite	41.3[(b)]	63
Phosphate	25.0	4
Sulfate	22.7[(b)]	66
Metals		
Total Metals	1.5	2,928
Aluminum	0.7[(b)]	148
Antimony	1.4	146
Beryllium	0.7	146
Cadmium	11.7[(b)]	154
Calcium	1.4	146
Chromium	3.2[(b)]	154
Iron	1.4	148
Lead	8.7	46
Magnesium	0.7	146
Potassium	0.7	146
Silver	1.9[(b)]	154
Sodium	0.7	146
Strontium (elemental)	1.4[(b)]	144
Thallium	33.3[(b)]	6
Volatile Organic Compounds		
Total Volatile Organic Compounds	0.4	486
Chlorobenzene	1.1	88
Toluene	1.0	96
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	2.5	731
2,3,4,6-Tetrachlorophenol	2.6[(b)]	38
2,4,5-Trichlorophenol	2.6[(b)]	38
2,4,6-Trichlorophenol	2.6[(b)]	38
2,4-Dichlorophenol	2.6[(b)]	38
2,4-Dimethylphenol	2.6[(b)]	38
2,4-Dinitrophenol	2.6[(b)]	38
2,6-Dichlorophenol	2.6[(b)]	38
2-Chlorophenol	2.3	44
2-Methylphenol	2.6	38
2-Nitrophenol	2.6[(b)]	38
2-secButyl-4,6-dinitrophenol	2.6[(b)]	38
3-+4-Methylphenol	2.6	38
4,6-Dinitro-2-methylphenol	2.6[(b)]	38
4-Chloro-3-methylphenol	2.3[(b)]	44
Oil and grease	100[(b)]	1
Pentachlorophenol	2.3[(b)]	44
TPH diesel	25.0[(b)]	8
Radiochemical Parameters		
Total Radiochemical Parameters	28.7	171
Neptunium-237	100	1
Technetium-99	22.0[(b)]	100
Uranium	37.1[(b)]	70

(a) Includes only constituents that exceeded STL Richland and St. Louis QC limits.

(b) One or more results for footnoted compounds are “significantly out of limits” as defined in the text.

Table B.17. Matrix Duplicates, Severn Trent Laboratories (Richland and St. Louis)(a)

Constituent	Percent Out of Limit(b)	Number of Analyses
General Chemical Parameters		
Total General Chemical Parameters	1.9	324
Alkalinity	2.7	75
Total dissolved solids	7.1	42
Total organic carbon	1.2	84
Ammonia and Anions		
Total Ammonia and Anions	0.6	358
Bromide	16.7(b)	6
Chloride	1.6(b)	63
Metals		
Total Metals	0.1	1,464
Antimony	1.4(b)	73
Strontium (elemental)	1.4(b)	72
Volatile Organic Compounds		
Total Volatile Organic Compounds	2.5	238
Benzene	2.1	47
Chlorobenzene	9.3(b)	43
Trichloroethene	2.2	46
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	5.7	348
2,3,4,6-Tetrachlorophenol	11.1(b)	18
2,4,5-Trichlorophenol	5.6(b)	18
2,4,6-Trichlorophenol	5.6(b)	18
2,4-Dichlorophenol	5.6(b)	18
2,4-Dimethylphenol	5.6(b)	18
2,4-Dinitrophenol	5.6(b)	18
2,6-Dichlorophenol	5.6(b)	18
2-Chlorophenol	9.5(b)	21
2-Methylphenol	5.6(b)	18
2-Nitrophenol	5.6(b)	18
2-secButyl-4,6-dinitrophenol	5.6(b)	18
3-+4-Methylphenol	5.6(b)	18
4,6-Dinitro-2-methylphenol	5.6(b)	18
4-Chloro-3-methylphenol	9.5(b)	21
4-Nitrophenol	4.8	21
Pentachlorophenol	9.5(b)	21
Radiochemical Parameters		
Total Radiochemical Parameters	1.4	1,283
Carbon-14	16.7(b)	6
Gross alpha	3.7	81
Gross beta	2.4(b)	82
Iodine-129	1.6(b)	62
Plutonium-239/240	14.3	14
Technetium-99	1.1	93
Uranium	1.5	67
Uranium-234	20.0(b)	15
Uranium-235	13.3(b)	15
Uranium-238	13.3	15

(a) Includes only constituents that exceeded STL Richland and St. Louis QC limits.

(b) One or more results for footnoted compounds are "significantly out of limits" as defined in the text.

Table B.18. Summary of Issue Resolution Forms Received from Severn Trent Laboratories (Richland and St. Louis) for Fiscal Year 2000

Issue Category	Number of Occurrences Prior to Receipt at the Laboratory	After Receipt at the Laboratory
Hold time missed	23	11
Broken bottles	8	
Missing samples	5	
Temperature deviation	6	
pH variance	4	
Bottle size/type (insufficient volume)	7	
Chain of custody forms incomplete	5	
Laboratory QC out of limits		30
Analytical preparation deviations		3
Method failures/discontinued analyses		2

Table B.19. Summary of Analytical Laboratory Detection/Quantitation Limits Determined from Field Blank Data, Severn Trent Laboratories (Richland and St. Louis)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Total Organic Carbon (µg/L)					
10/26/99 - 12/27/99	15(a)	101.13	105.87	317.6(b)	1,058.7(b)
01/03/00 - 03/28/00	13(a)	129.06	114.28	342.9	1,142.8
04/03/00 - 06/27/00	17(a)	161.19	177.05	531.2	1,770.5
08/18/00 - 09/20/00	6	103.71	116.83	350.5	1,168
Summary	51	128.57	137.10	411.3	1,371
Constituent: Total Organic Halides (µg/L)					
10/26/99 - 12/27/99	16	0.91	1.38	4.1(b)	13.8(b)
01/03/00 - 03/28/00	21(a)	1.69	1.87	5.6	18.7
04/19/99 - 06/28/99	22	1.07	1.30	3.9	13.0
09/20/00 - 09/20/00	4	-0.46	0.71	2.1	7.1
Summary	63	1.14	1.52	4.6	15.2
Constituent: Antimony-125 (pCi/L)					
12/09/99 - 02/25/00	9	1.42	4.82	14.47(b)	48.25(b)
04/03/00 - 06/27/00	7	0.13	6.01	18.02	60.05
08/16/00 - 08/18/00	2	0.83	1.91	5.74	19.12
Summary	18	0.85	5.20	15.61	52.04
Constituent: Cesium-134 (pCi/L)					
12/09/99 - 02/25/00	9	-0.23	0.9	2.69(b)	8.97(b)
04/03/00 - 06/27/00	7	-1.25	1.95	5.85	19.49
08/16/00 - 08/18/00	2	-1.51	0.44	1.32	4.38
Summary	18	-0.77	1.4	4.20	14.00
Constituent: Cesium-137 (pCi/L)					
12/09/99 - 02/25/00	9	0.21	2.14	6.41(b)	21.37(b)
04/03/00 - 06/27/00	7	-0.07	1.33	3.98	13.27
08/16/00 - 08/18/00	2	-0.47	0.15	0.46	1.53
Summary	18	0.03	1.77	5.32	17.73
Constituent: Cobalt-60 (pCi/L)					
12/09/99 - 02/25/00	9	0.67	1.34	4.03(b)	13.42(b)
04/03/00 - 06/27/00	7	-0.33	1.33	4.00	13.34
08/16/00 - 08/18/00	2	0.48	0.32	0.96	3.19
Summary	18	0.26	1.30	3.89	12.96
Constituent: Europium-152 (pCi/L)					
12/09/99 - 02/25/00	9	0.40	4.35	13.04(b)	43.48(b)
04/03/00 - 06/27/00	7	1.39	4.53	13.59	45.30
08/16/00 - 08/18/00	2	-0.36	4.22	12.66	42.21
Summary	18	0.70	4.41	13.24	44.14
Constituent: Europium-154 (pCi/L)					
12/09/99 - 02/25/00	9	-1.14	6.35	19.04(b)	63.47(b)
04/03/00 - 06/27/00	7	0.03	7.62	22.86	76.21
08/16/00 - 08/18/00	2	-1.68	1.35	4.04	13.47
Summary	18	-0.74	6.70	20.09	66.96
Constituent: Gross Alpha (pCi/L)					
10/26/99 - 12/27/99	9	0.13	0.22	0.67(b)	2.24(b)
01/03/00 - 02/25/00	15	0.11	0.16	0.49	1.65
04/03/00 - 06/27/00	10	0.04	0.21	0.64	2.13
08/10/00 - 09/05/00	4	0.18	0.21	0.63	2.09
Summary	38	0.10	0.20	0.59	1.97

Table B.19. (contd)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Gross Beta (pCi/L)					
10/26/99 - 12/27/99	9	0.75	1.00	3.00(b)	10.00(b)
01/03/00 - 02/25/00	15(a)	0.60	0.81	2.44	8.12
04/03/00 - 06/27/00	10	0.48	0.64	1.93	6.45
08/10/00 - 09/05/00	4	0.97	0.55	1.64	5.47
Summary	38	0.64	0.80	2.41	8.02
Constituent: Iodine-129 (pCi/L)					
01/03/00 - 03/23/00	13	0.013	0.083	0.25(b)	0.83(b)
04/03/00 - 05/15/00	4	0.014	0.018	0.06	0.18
08/18/00 - 09/05/00	2	0.069	0.034	0.10	0.34
Summary	19	0.019	0.073	0.22	0.73
Constituent: Potassium-40 (pCi/L)					
01/03/00 - 02/25/00	9	-36.90	88.25	264.75(b)	882.51(b)
04/03/00 - 06/27/00	7	-47.86	34.33	103.00	343.33
08/16/00 - 08/18/00	2	-6.42	14.26	42.79	142.62
Summary	18	-37.77	68.11	204.33	681.08
Constituent: Ruthenium-106 (pCi/L)					
12/09/99 - 02/25/00	9	8.49	18.15	54.45(b)	181.50(b)
04/03/00 - 06/27/00	7	-6.38	18.67	56.00	186.68
08/16/00 - 08/18/00	2	8.35	18.74	56.21	187.38
Summary	18	2.69	18.40	55.20	183.98
Constituent: Strontium-90 (pCi/L)					
12/03/99 - 12/03/99	2	0.197	0.087	0.26(b)	0.87(b)
01/21/00 - 06/27/00	4	0.218	0.173	0.52	1.73
Summary	6	0.211	0.156	0.47	1.56
Constituent: Technetium-99 (pCi/L)					
12/02/99 - 12/09/99	3	3.93	12.45	37.36(b)	124.54(b)
01/03/00 - 03/23/00	12	-0.17	4.22	12.66	42.19
04/03/00 - 06/27/00	7	1.55	2.71	8.13	27.11
08/16/00 - 09/05/00	3	2.20	4.42	13.25	44.17
Summary	25	1.09	5.30	15.89	52.97
Constituent: Tritium (pCi/L)					
10/26/99 - 12/17/99	11	181.1	105.0	315.0(b)	1,049.9(b)
01/03/00 - 03/23/00	17	164.9	98.3	295.0	983.3
04/03/00 - 06/27/00	12	117.3	61.5	184.6	615.2
08/03/00 - 09/05/00	6	176.5	91.7	275.1	917.1
Summary	46	157.9	91.1	273.3	911.1
Constituent: Uranium (µg/L)					
11/05/99 - 12/09/99	4	0.0081	0.0072	0.030(c)	0.080(c)
01/20/00 - 03/23/00	5	0.0051	0.0033	0.015	0.038
04/13/00 - 06/27/00	7	0.0066	0.0063	0.026	0.070
08/01/00 - 09/07/00	3	0.0022	0.0007	0.004	0.010
Summary	19	0.006	0.005	0.022	0.060

(a) Excluded outliers.

(b) Limit of detection (blank corrected) equals 3 times the blank standard deviation; limit of quantitation (blank corrected) equals 10 times the blank standard deviation.

(c) Limit of detection equals the mean blank concentration plus 3 standard deviations; limit of quantitation equals the mean blank concentration plus 10 standard deviations.

Table B.20. 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]	0.278	0.375	1.252				
EPA-600/4-81-004, 160.1	Total dissolved solids	4,228	5,709	19,039				
EPA-600/4-81-004, 310.1	Alkalinity	2,230	3,011	10,042				
EPA-600/4-81-004, 410.4	Chemical oxygen demand	3,067	4,141	13,811				
Ammonia and Anions								
EPA-600/4-81-004, 300.0	Bromide	17.4	23.5	78.4				
EPA-600/4-81-004, 300.0	Chloride	34.6	46.7	155.8				
EPA-600/4-81-004, 300.0	Fluoride	10.4	14.0	46.8				
EPA-600/4-81-004, 300.0	Nitrogen in nitrate	11	14.9	49.5				
EPA-600/4-81-004, 300.0	Nitrogen in nitrite	7.4	10.0	33.3				
EPA-600/4-81-004, 300.0	Phosphate	34.8	47.0	156.7				
EPA-600/4-81-004, 300.0	Sulfate	108	146	486				
EPA-600/4-81-004, 350.1	Nitrogen in ammonia	30.1	40.6	135.5				
SW-846, 9012	Cyanide	1.59	2.15	7.16				
Metals								
SW-846, 6010	Aluminum	26.5	35.8	119.3	04/01/2000	41.8	56.4	188.2
SW-846, 6010	Antimony	19.7	26.6	88.7	04/01/2000	24.7	33.4	111.2
SW-846, 6010	Barium	0.9	1.2	4.1	04/01/2000	3.9	5.3	17.6
SW-846, 6010	Beryllium	0.2	0.3	0.9	04/01/2000	0.5	0.7	2.3
SW-846, 6010	Cadmium	2	2.7	9.0	04/01/2000	2.8	3.8	12.6
SW-846, 6010	Calcium	65.3	88.2	294.1	04/01/2000	122.5	165.4	551.6
SW-846, 6010	Chromium	2.7	3.6	12.2	04/01/2000	4.6	6.2	20.7
SW-846, 6010	Cobalt	2.5	3.4	11.3	04/01/2000	4.3	5.8	19.4
SW-846, 6010	Copper	4	5.4	18.0	04/01/2000	2.8	3.8	12.6
SW-846, 6010	Iron	30.3	40.9	136.4	04/01/2000	15.6	21.1	70.2
SW-846, 6010	Lead	9	12.2	40.5	04/01/2000	71.5	96.5	322.0
SW-846, 6010	Magnesium	100.7	136.0	453.5	04/01/2000	92.2	124.5	415.2
SW-846, 6010	Manganese	0.5	0.7	2.3	04/01/2000	0.9	1.2	4.1
SW-846, 6010	Nickel	10	13.5	45.0	04/01/2000	15.4	20.8	69.3
SW-846, 6010	Potassium	576	778	2,594	04/01/2000	1,467	1,981	6,608
SW-846, 6010	Silver	8	10.8	36.0	04/01/2000	6.9	9.3	31.1
SW-846, 6010	Sodium	44.2	59.7	199.0	04/01/2000	83.1	112.2	374.2
SW-846, 6010	Strontium (elemental)	0.4	0.5	1.8	04/01/2000	1.2	1.6	5.4
SW-846, 6010	Tin	27	36.5	121.6	04/01/2000	35	47.3	157.6
SW-846, 6010	Vanadium	4.7	6.3	21.2	04/01/2000	3.4	4.6	15.3
SW-846, 6010	Zinc	4.2	5.7	18.9	04/01/2000	3.1	4.2	14.0

Table B.20. (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, 7060	Arsenic	2	2.7	9.0				
SW-846, 7131	Cadmium	0.2	0.3	0.9				
SW-846, 7191	Chromium	0.3	0.4	1.4				
SW-846, 7421	Lead	0.8	1.1	3.6				
SW-846, 7470	Mercury	0.011	0.015	0.050				
SW-846, 7740	Selenium	0.9	1.2	4.1				
SW-846, 7841	Thallium	0.6	0.8	2.7				
Volatile Organic Compounds								
SW-846, 8010	1,1,1-Trichloroethane	0.028	0.038	0.126	12/02/99	0.35	0.47	1.58
SW-846, 8010	1,1,2-Trichloroethane	0.036	0.049	0.162	12/02/99	0.19	0.26	0.86
SW-846, 8010	1,1-Dichloroethane	0.024	0.032	0.108	12/02/99	0.36	0.49	1.62
SW-846, 8010	1,2-Dichloroethane	0.018	0.024	0.081	12/02/99	0.34	0.46	1.53
SW-846, 8010	1,4-Dichlorobenzene	0.026	0.035	0.117	12/02/99	0.1	0.14	0.45
SW-846, 8010	Carbon tetrachloride	0.025	0.034	0.113	12/02/99	0.32	0.43	1.44
SW-846, 8010	Chloroform	0.028	0.038	0.126	12/02/99	0.38	0.51	1.71
SW-846, 8010	cis-1,2-Dichloroethene	0.025	0.034	0.113	12/02/99	0.33	0.45	1.49
SW-846, 8010	Methylene chloride	0.207	0.280	0.932	12/02/99	2.38	3.21	10.72
SW-846, 8010	Tetrachloroethene	0.031	0.042	0.140	12/02/99	0.15	0.20	0.68
SW-846, 8010	trans-1,2-Dichloroethene	0.031	0.042	0.140	12/02/99	0.43	0.58	1.94
SW-846, 8010	Trichloroethene	0.028	0.038	0.126	12/02/99	0.26	0.35	1.17
SW-846, 8010	Vinyl chloride	0.294	0.397	1.324	12/02/99	0.25	0.34	1.13
SW-846, 8020	1,4-Dichlorobenzene	0.52	0.70	2.34	12/02/99	0.33	0.45	1.49
SW-846, 8020	Benzene	0.26	0.35	1.17	12/02/99	0.25	0.34	1.13
SW-846, 8020	Ethylbenzene	0.31	0.42	1.40	12/02/99	0.12	0.16	0.54
SW-846, 8020	Toluene	0.81	1.09	3.65	12/02/99	0.21	0.28	0.95
SW-846, 8020	Xylenes (total)	0.59	0.80	2.66	12/02/99	0.33	0.45	1.49
SW-846, 8260	1,1,1,2-Tetrachloroethane	0.76	1.03	3.42	10/20/99	0.33	0.45	1.49
SW-846, 8260	1,1,1-Trichloroethane	0.83	1.12	3.74	10/20/99	0.23	0.31	1.04
SW-846, 8260	1,1,2,2-Tetrachloroethane	2.92	3.94	13.15	10/20/99	0.34	0.46	1.53
SW-846, 8260	1,1,2-Trichloroethane	1.65	2.23	7.43	10/20/99	0.31	0.42	1.40
SW-846, 8260	1,1-Dichloroethane	0.5	0.7	2.3	10/20/99	0.19	0.26	0.86
SW-846, 8260	1,1-Dichloroethene	1.2	1.6	5.4	10/20/99	0.23	0.31	1.04
SW-846, 8260	1,2,3-Trichloropropane	1.2	1.6	5.4	10/20/99	0.25	0.34	1.13
SW-846, 8260	1,2-Dibromo-3-chloropropane	1.9	2.6	8.6	10/19/99			
SW-846, 8260	1,2-Dibromomethane	0.91	1.23	4.10	10/20/99	0.28	0.38	1.26
SW-846, 8260	1,2-Dichloroethane	0.98	1.32	4.41	10/20/99	0.17	0.23	0.77
SW-846, 8260	1,2-Dichloroethene (total)	1.37	1.85	6.17	10/20/99	0.33	0.45	1.49
SW-846, 8260	1,2-Dichloropropane	1.07	1.44	4.82	10/20/99	0.21	0.28	0.95

Table B.20. (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	1,4-Dichlorobenzene	1.03	1.39	4.64	10/20/99	0.14	0.19	0.63
SW-846, 8260	1-Butanol	46.8	63.2	210.7	10/20/99	6.55	8.84	29.50
SW-846, 8260	2-Butanone	2.48	3.35	11.17	10/20/99	0.7	0.95	3.15
SW-846, 8260	2-Hexanone	2.99	4.04	13.46	10/20/99	0.99	1.34	4.46
SW-846, 8260	4-Methyl-2-pentanone	1.88	2.54	8.47	10/20/99	1.27	1.71	5.72
SW-846, 8260	Acetone	10.38	14.02	46.74	10/20/99	4.02	5.43	18.10
SW-846, 8260	Acetonitrile	10.39	14.03	46.79	10/20/99	2.64	3.56	11.89
SW-846, 8260	Acrolein	11.96	16.15	53.86	10/20/99	2.56	3.46	11.53
SW-846, 8260	Benzene	1.32	1.78	5.94	10/20/99	0.23	0.31	1.04
SW-846, 8260	Bromodichloromethane	1.19	1.61	5.36	10/20/99	0.2	0.27	0.90
SW-846, 8260	Bromoform	2.56	3.46	11.53	10/20/99	0.24	0.32	1.08
SW-846, 8260	Bromomethane	0.67	0.90	3.02	10/20/99	0.23	0.31	1.04
SW-846, 8260	Carbon disulfide	1.55	2.09	6.98	10/20/99	0.3	0.41	1.35
SW-846, 8260	Carbon tetrachloride	1.17	1.58	5.27	10/20/99	0.23	0.31	1.04
SW-846, 8260	Chlorobenzene	1.69	2.28	7.61	10/20/99	0.28	0.38	1.26
SW-846, 8260	Chloroethane	0.84	1.13	3.78	10/20/99	0.23	0.31	1.04
SW-846, 8260	Chloroform	0.82	1.11	3.69	10/20/99	0.23	0.31	1.04
SW-846, 8260	Chloromethane	2.81	3.79	12.65	10/20/99	0.26	0.35	1.17
SW-846, 8260	cis-1,2-Dichloroethene	0.7	0.95	3.15	10/20/99	0.18	0.24	0.81
SW-846, 8260	cis-1,3-Dichloropropene	1.14	1.54	5.13	10/20/99	0.16	0.22	0.72
SW-846, 8260	Dibromochloromethane	1.33	1.80	5.99	10/20/99			
SW-846, 8260	Dichlorodifluoromethane	1.16	1.57	5.22	10/20/99	0.13	0.18	0.59
SW-846, 8260	Ethyl cyanide	1.47	1.98	6.62	10/20/99	2.6	3.51	11.71
SW-846, 8260	Ethylbenzene	1.63	2.20	7.34	10/20/99	0.35	0.47	1.58
SW-846, 8260	Methylene chloride	5	6.8	22.5	10/20/99	0.37	0.50	1.67
SW-846, 8260	Styrene	1.23	1.66	5.54	10/20/99	0.33	0.45	1.49
SW-846, 8260	Tetrachloroethene	1.48	2.00	6.66	10/20/99	0.57	0.77	2.57
SW-846, 8260	Tetrahydrofuran	6.72	9.07	30.26	10/20/99	1.49	2.01	6.71
SW-846, 8260	Toluene	1.09	1.47	4.91	10/20/99	0.33	0.45	1.49
SW-846, 8260	trans-1,2-Dichloroethene	0.71	0.96	3.20	10/20/99	0.26	0.35	1.17
SW-846, 8260	trans-1,3-Dichloropropene	1.7	2.30	7.66	10/20/99	0.32	0.43	1.44
SW-846, 8260	Trichloroethene	1.24	1.67	5.58	10/20/99	0.16	0.22	0.72
SW-846, 8260	Trichloromonofluoromethane	0.98	1.32	4.41	10/20/99			
SW-846, 8260	Vinyl acetate	1.84	2.48	8.29	10/20/99	0.29	0.39	1.31
SW-846, 8260	Vinyl chloride	1.41	1.90	6.35	10/20/99	0.17	0.23	0.77
SW-846, 8260	Xylenes (total)	3.41	4.60	15.36	10/20/99	0.61	0.82	2.75
SW-846, 8260	1,4-Dichlorobenzene	0.93	1.26	4.19				

Table B.20. (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)
Semivolatile Organic Compounds								
SW-846,8015	TPH, diesel function	92.3	124.6	415.6				
EPA-600/4-81-004, 413.1	Oil and grease	699	944	3,148				
SW-846, 8040	2,3,4,6-Tetrachlorophenol	2.09	2.82	9.41				
SW-846, 8040	2,4,5-Trichlorophenol	4.7	6.35	21.16				
SW-846, 8040	2,4,6-Trichlorophenol	4.96	6.70	22.34				
SW-846, 8040	2,4-Dichlorophenol	1.23	1.66	5.54				
SW-846, 8040	2,4-Dimethylphenol	2.87	3.88	12.92				
SW-846, 8040	2,4-Dinitrophenol	1.82	2.46	8.20				
SW-846, 8040	2,6-Dichlorophenol	1.1	1.49	4.95				
SW-846, 8040	2-Chlorophenol	2.13	2.88	9.59				
SW-846, 8040	2-Methylphenol (cresol, o-)	2.43	3.28	10.94				
SW-846, 8040	2-Nitrophenol	1.92	2.59	8.65				
SW-846, 8040	2-secButyl-4,6-dinitrophenol (DNBP)	2	2.70	9.01				
SW-846, 8040	3- + 4-Methyl phenol	3.54	4.78	15.94				
SW-846, 8040	4,6-Dinitro-2-methylphenol	1.36	1.84	6.12				
SW-846, 8040	4-Chloro-3-methylphenol	1.01	1.36	4.55				
SW-846, 8040	4-Nitrophenol	0.92	1.24	4.14				
SW-846, 8040	Pentachlorophenol	1.5	2.03	6.75				
SW-846, 8040	Phenol	0.54	0.73	2.43				
SW-846, 8082	Aroclor-1016	0.105	0.142	0.473				
SW-846, 8082	Aroclor-1221	0.105	0.142	0.473				
SW-846, 8082	Aroclor-1232	0.105	0.142	0.473				
SW-846, 8082	Aroclor-1242	0.105	0.142	0.473				
SW-846, 8082	Aroclor-1248	0.105	0.142	0.473				
SW-846, 8082	Aroclor-1254	0.252	0.340	1.135				
SW-846, 8082	Aroclor-1260	0.252	0.340	1.135				
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	1.98	2.67	8.92				
SW-846, 8270	1,2,4-Trichlorobenzene	0.97	1.31	4.37				
SW-846, 8270	1,2-Dichlorobenzene	0.89	1.20	4.01				
SW-846, 8270	1,3-Dichlorobenzene	0.9	1.22	4.05				
SW-846, 8270	2,2'-Oxybis(1-chloropropane)	1.18	1.59	5.31				
SW-846, 8270	2,4,5-Trichlorophenol	0.78	1.05	3.51				
SW-846, 8270	2,4,6-Trichlorophenol	0.66	0.89	2.97				
SW-846, 8270	2,4-Dichlorophenol	1	1.35	4.50				
SW-846, 8270	2,4-Dimethylphenol	0.97	1.31	4.37				
SW-846, 8270	2,4-Dinitrophenol	0.97	1.31	4.37				
SW-846, 8270	2,4-Dinitrotoluene	0.68	0.92	3.06				
SW-846, 8270	2,6-Dinitrotoluene	0.71	0.96	3.20				

Table B.20. (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-Chloronaphthalene	0.98	1.32	4.41				
SW-846, 8270	2-Chlorophenol	1.12	1.51	5.04				
SW-846, 8270	2-Methylnaphthalene	1	1.35	4.50				
SW-846, 8270	2-Methylphenol (cresol, o-)	1	1.35	4.50				
SW-846, 8270	2-Nitroaniline	0.59	0.80	2.66				
SW-846, 8270	2-Nitrophenol	1.18	1.59	5.31				
SW-846, 8270	3,3'-Dichlorobenzidine	0.55	0.74	2.48				
SW-846, 8270	3-Nitroaniline	0.5	0.68	2.25				
SW-846, 8270	4,6-Dinitro-2-methylphenol	1.74	2.35	7.84				
SW-846, 8270	4-Bromophenylphenyl ether	0.78	1.05	3.51				
SW-846, 8270	4-Chloro-3-methylphenol	0.84	1.13	3.78				
SW-846, 8270	4-Chloroaniline	0.88	1.19	3.96				
SW-846, 8270	4-Chlorophenylphenyl ether	1.02	1.38	4.59				
SW-846, 8270	4-Methylphenol (cresol, p-)	0.77	1.04	3.47				
SW-846, 8270	4-Nitroaniline	0.87	1.17	3.92				
SW-846, 8270	4-Nitrophenol	0.48	0.65	2.16				
SW-846, 8270	Acenaphthene	0.87	1.17	3.92				
SW-846, 8270	Acenaphthylene	0.98	1.32	4.41				
SW-846, 8270	Aniline	1.76	2.38	7.93				
SW-846, 8270	Anthracene	0.48	0.65	2.16				
SW-846, 8270	Benzo(a)anthracene	0.58	0.78	2.61				
SW-846, 8270	Benzo(a)pyrene	0.6	0.81	2.70				
SW-846, 8270	Benzo(b)fluoranthene	0.88	1.19	3.96				
SW-846, 8270	Benzo(ghi)perylene	0.95	1.28	4.28				
SW-846, 8270	Benzo(k)fluoranthene	0.74	1.00	3.33				
SW-846, 8270	Benzyl alcohol	1.1	1.49	4.95				
SW-846, 8270	Bis(2-Chloroethoxy)methane	1.14	1.54	5.13				
SW-846, 8270	Bis(2-chloroethyl) ether	1.12	1.51	5.04				
SW-846, 8270	Bis(2-ethylhexyl) phthalate	1.29	1.74	5.81				
SW-846, 8270	Butylbenzylphthalate	0.72	0.97	3.24				
SW-846, 8270	Chrysene	0.42	0.57	1.89				
SW-846, 8270	Di-n-butylphthalate	1.34	1.81	6.03				
SW-846, 8270	Di-n-octylphthalate	1.35	1.82	6.08				
SW-846, 8270	Dibenz[a,h]anthracene	1.43	1.93	6.44				
SW-846, 8270	Dibenzofuran	0.77	1.04	3.47				
SW-846, 8270	Diethylphthalate	1.5	2.03	6.75				
SW-846, 8270	Dimethyl phthalate	3.04	4.10	13.69				

Table B.20. (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	Fluoranthene	0.6	0.81	2.70				
SW-846, 8270	Fluorene	0.72	0.97	3.24				
SW-846, 8270	Hexachlorobenzene	0.58	0.78	2.61				
SW-846, 8270	Hexachlorobutadiene	0.91	1.23	4.10				
SW-846, 8270	Hexachlorocyclopentadiene	0.91	1.23	4.10				
SW-846, 8270	Hexachloroethane	0.86	1.16	3.87				
SW-846, 8270	Indeno(1,2,3-cd)pyrene	0.61	0.82	2.75				
SW-846, 8270	Isophorone	0.86	1.16	3.87				
SW-846, 8270	N-Nitroso-di-n-dipropylamine	0.9	1.22	4.05				
SW-846, 8270	N-Nitrosodimethylamine	0.74	1.00	3.33				
SW-846, 8270	N-Nitrosodiphenylamine	0.45	0.61	2.03				
SW-846, 8270	Naphthalene	1.09	1.47	4.91				
SW-846, 8270	Pentachlorophenol	0.87	1.17	3.92				
SW-846, 8270	Phenanthrene	0.46	0.62	2.07				
SW-846, 8270	Phenol	0.55	0.74	2.48				
SW-846, 8270	Pyrene	0.71	0.96	3.20				

(a) MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

(b) µmhos/cm.

MDL = Method detection limit.

LOD = Limit of detection.

LOQ = Limit of quantitation.

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