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Hanford Site Ground-Water Monitoring for 1993

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Summary

This report presents the results of the Ground-Water Surveillance Project monitoring for calendar year 1993 on the Hanford Site, Washington. Hanford Site operations from 1943 onward produced large quantities of radiologic and chemical waste that have impacted ground-water quality on the Site. Monitoring of water levels and ground-water chemistry is performed to track the extent of contamination and trends in contaminant concentrations. The 1993 monitoring was also designed to identify emerging ground-water quality problems. The information obtained is used to verify compliance with applicable environmental regulations and to evaluate remedial actions. Data from other monitoring and characterization programs were incorporated to provide an integrated assessment of Site ground-water quality. Additional characterization of the Site's geologic setting and hydrology was performed to support the interpretation of contaminant distributions. Numerical modeling of sitewide ground-water flow also supported the overall project goals.

Water-level monitoring was performed to evaluate ground-water flow directions, to track changes in water levels, and to relate such changes to changes in site disposal practices. Water levels over most of the Hanford Site continued to decline between June 1992 and June 1993. The greatest declines occurred in the 200-West Area. These declines are part of the continued response to the cessation of discharge to U Pond and other disposal facilities. The low permeability in this area which enhanced mounding of waste-water discharge has also slowed the response to the reduction of disposal. Water levels remained nearly constant in the vicinity of B Pond, as a result of continued disposal to the pond. Water levels measured from wells in the unconfined aquifer north and east of the Columbia River indicate that the primary source of recharge is irrigation practices.

Radiological monitoring results indicated that tritium, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, and plutonium were present at levels above the U.S. Environmental Protection Agency or the Washington State drinking water standards (DWS) at the Hanford Site. Concentrations of tritium in the 200 Areas and the 100-K Area were above the derived concentration guide (DCG) specified by DOE Order 5400.5. Strontium-90 concentrations in the 100-N Area and the 200-East Area were above the DCG. No constituents had concentrations greater than 10 times the DCG.

Nitrate, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene were present in 1993 Hanford ground water samples at levels above their DWS.

Acknowledgments

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Abbreviations

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DCG	derived concentration guides
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FFTF	Fast Flux Test Facility
GC/MS	gas chromatography/mass spectrometry
GC	gas chromatography
HEHF	Hanford Environmental Health Foundation
HEIS	Hanford Environmental Information System
ICP	inductively coupled plasma (spectroscopy)
ITAS	International Technology Analytical Service
LWDF	Liquid Waste Disposal Facility
MCL	maximum contaminant level
MDC	minimum detectable concentration
MDL	method detection level
NRDWL	Non-Radioactive Dangerous Waste Landfill
PFP	Plutonium Finishing Plant

PNL	Pacific Northwest Laboratory
PUREX	Plutonium-Uranium Extraction (Plant)
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction Oxidation (Plant)
TCE	trichloroethylene
TRU	transuranic
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
VOC	volatile organic compounds
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company

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1.0 Introduction

S.P. Luttrell

The Pacific Northwest Laboratory (PNL)[a] monitors and documents the distribution of radionuclides and other hazardous materials in ground water at the Hanford Site (Figure 1.1) for the U.S. Department of Energy (DOE). This work is performed by the Ground-Water Surveillance Project and is designed to meet those requirements of DOE Order 5400.1 that apply to environmental surveillance and ground-water monitoring (DOE 1988b). DOE Order 5400.1 was issued November 9, 1988, to establish direction for environmental protection programs at DOE facilities. The environmental surveillance activities are conducted to monitor the effects, if any, of DOE activities at Hanford to onsite and offsite environmental and natural resources or to the public. The Ground-Water Surveillance Project is part of the Hanford Site Environmental Surveillance Program, which is designed to satisfy the following program objectives, as identified in DOE Order 5400.1:

- verify compliance with applicable environmental laws and regulations
- verify compliance with environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents
- characterize and define trends in the physical, chemical, and biological condition of the environment
- establish baselines of environmental quality
- provide a continuing assessment of pollution abatement programs
- identify and quantify new or existing environmental quality problems.

In addition to activities of the Ground-Water Surveillance Project, which monitors contaminant distribution in ground water across the entire Site, other ground-water monitoring activities are being conducted at Hanford by Westinghouse Hanford Company (WHC). Ground-water samples are collected by WHC for operational monitoring in and around the 200 Areas, in compliance with DOE orders. Facility-specific monitoring is conducted by WHC for compliance with the Resource Conservation and Recovery Act (RCRA) (40 CFR 264 and 40 CFR 265) and Washington Administrative Code (WAC 173-303 and -304). The results of some of these other activities are discussed briefly in

(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute, under Contract DE-AC06-76RLO 1830.

this report but are reported in more detail elsewhere (e.g., DOE-RL 1994a and WHC in press). The results of compliance monitoring (primarily for chemical constituents) are valuable in determining the total impact of Site operations on ground water, and therefore are used by the Ground-Water Surveillance Project to meet its objectives.

Additional ground-water characterization and monitoring activities were conducted by WHC to support investigations under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) program. The CERCLA investigations are under way at a number of areas where known or suspected environmental contamination may have resulted from past site activities. The CERCLA ground-water data, when available, have been integrated into the Ground-Water Surveillance Project interpretations. The use of ground-water data obtained from other programs onsite precludes the need for costly, redundant sampling and enables the Ground-Water Surveillance Project to review activities of other programs in support of DOE's overall environmental objectives.

This annual report discusses the Ground-Water Surveillance Project's ground-water monitoring activities at the Hanford Site during 1993. Section 2.0 briefly describes the site geology and hydrogeology and provides an overview of conceptual and numerical modeling activities conducted on the Project. Section 3.0 reports the results of water-level monitoring in the unconfined and confined aquifers. Section 4.0 describes the monitoring programs, with emphasis on the Ground-Water Surveillance Project's activities, including network design, sample collection, sample analysis, quality assurance and quality control, and data management. The results and interpretations of chemical and radiological monitoring are discussed in Section 5.0. The monitoring results are generally presented relative to known and probable source areas, although potential receptor locations, such as the 400 Area drinking-water supply and the North Richland well field, are discussed separately. Conclusions are presented in Section 6.0. Sources referred to in the text are listed in Section 7.0. A more extensive bibliography, which includes a large number of references to historical and current reports related to ground water on or pertaining to the Hanford Site, is included as Section 8.0. Figures and tables appear at the ends of the section in which they are discussed. Pockets at the end of the document include plates of the Hanford Site water-table map as well as a disk containing chemical and radiological ground-water data. The ground-water data included in the disk is described in Appendix D.

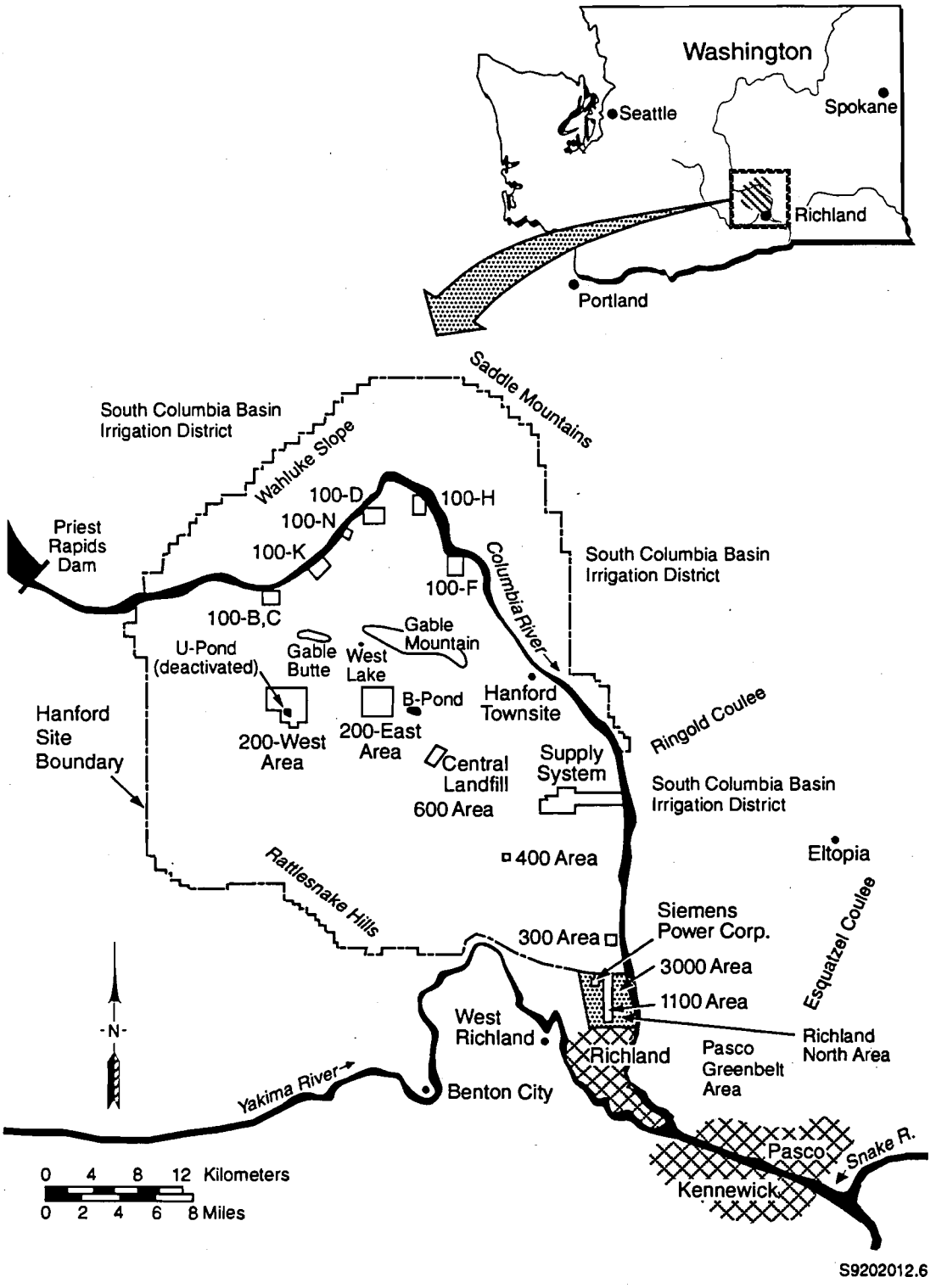

Figure 1.1. Hanford Site Location Map

2.0 Geologic and Hydrologic Characterization

P.D. Thorne and M.A. Chamness

2.1 Geologic Setting

The Hanford Site and adjacent areas north and east of the Columbia River in Grant, Adams, and Franklin counties lie within the Pasco Basin, a structural depression that has accumulated a relatively thick sequence of fluvial, lacustrine, and glaciofluvial sediments (Figures 2.1 and 2.2). Figure 2.3 shows an east-west cross section illustrating the relationship of geology at the Hanford Site. The Pasco Basin and nearby anticlines and synclines are formed in the underlying Columbia River Basalt Group, a sequence of continental flood basalts covering more than 160,000 km^2. These basalt flows were formed from molten lava during the late Tertiary Period. The most recent laterally extensive basalt flow underlying the Hanford Site is the Elephant Mountain Member of the Saddle Mountains Basalt Formation. Sandwiched between various basalt flows are sedimentary interbeds collectively called the Ellensburg Formation. The Ellensburg Formation includes fluvial and lacustrine sediments consisting of mud, sand, and gravel. The Rattlesnake Ridge Interbed is the uppermost laterally extensive interbed of the Ellensburg Formation.

Overlying the basalt within the Pasco Basin are fluvial and lacustrine sediments of the Ringold Formation. The ancestral Columbia and Salmon-Clearwater river systems flowed into the Pasco Basin, depositing coarse-grained sediments in the migrating river channels and fine-grained sediments in the overbank flood deposits. The Plio-Pleistocene unit, consisting of a paleosol/calcrete and/or basaltic sidestream sediments, and the early "Palouse" soil, an eolian sand and silt deposit, are present only in the western portion of the Pasco Basin. The uppermost sedimentary unit covering much of the Hanford Site is the Hanford formation, a complex series of coarse- and fine-grained sediments deposited by cataclysmic floods (called the Missoula floods) during the last ice age. For the most part, the fine-grained sediments are found near the margins of the basin and in areas protected from the main flood currents, which deposited the coarse-grained sediments. Capping the Hanford formation in many areas is a thin veneer of eolian sands and/or recent fluvial deposits.

As the post-basalt sediments were being deposited, the basalt underwent structural deformation. The basin continued to subside, and the ridges continued to rise. This process led to the formation of sedimentary units that are thickest in the center of the basin and become thin or, in places, pinch out along the anticlines. Hanford formation sediments directly overlie the basalt in a few places where the Ringold Formation either was never deposited or was eroded away by ancestrial Columbia and/or Salmon-Clearwater rivers prior to the Missoula floods or by the Missoula floods.

More complete descriptions of the geology of the Hanford Site are contained in reports by DOE (1988a), Newcomb et al. (1972), Myers et al. (1979), and Reidel et al. (1992). A more complete geologic description of the areas north and east of the Columbia River is reported by Grolier and Bingham (1978). Recent reports that provide additional information on the geology of specific areas of the Site include those by Connelly et al. (1992a,b) for the 200-East and 200-West aggregate areas, Swanson (1992) for the 300 Area, and Peterson (1992) for the 100 Areas and surroundings.

2.2 Hydrogeologic Setting

An uppermost unconfined aquifer and a sequence of confined aquifers lie beneath most of the Hanford Site. Perched water-table conditions have been encountered in sediments above the unconfined aquifer in the 200-West Area (Airhart 1990; Last and Rohay 1993) and in irrigated areas east of the Columbia River (Brown 1979). The unconfined aquifer is generally located in unconsolidated to semiconsolidated sediments that overlie the basalt bedrock. In some areas, permeable units within the suprabasalt sediments are locally confined by overlying mud units. However, because the entire suprabasalt aquifer system is interconnected on a sitewide scale, it has commonly been referred to as the "Hanford unconfined aquifer." The confined aquifers are composed of the brecciated tops of basalt flows and sedimentary interbeds located within the Columbia River Basalt Group. The uppermost aquifers located within the Columbia River Basalt are referred to as the "upper-basalt confined aquifer system" (Spane and Raymond 1993).

The unconfined aquifer at Hanford occurs mainly within the Ringold and Hanford formations. Because the sand and gravel facies of the Ringold Formation are generally more consolidated, contain more silt, and are less well sorted, they are about 10 to 100 times less permeable than the sediments of the overlying Hanford formation (DOE 1988a). Prior to waste-water disposal operations at the Hanford Site, the uppermost aquifer was almost entirely within the Ringold Formation, and the water table extended into the Hanford formation at only a few locations near the Columbia River (Newcomb et al. 1972). However, waste-water discharges have caused the water-table elevation to rise into the Hanford formation in the vicinity of the 200-East Area and in a wider area near the Columbia River.

The unconfined aquifer is bounded below by either the basalt surface or, in places, by relatively impervious clays and silts of the lower mud unit of the Ringold Formation. Laterally, the unconfined aquifer is bounded by the basalt ridges that surround the basin and by the Yakima and Columbia rivers. Where they rise above the water table, the basalt ridges have low permeabilities and act as barriers to lateral flow of ground water (Gephart et al. 1979). On the Hanford Site, the saturated thickness of the unconfined aquifer is greater than 61 m (200 ft) in some areas but pinches out along the flanks of the basalt ridges. At the Hanford Site, depth from the ground surface to the water table ranges from less than 0.3 m (1 ft) near the Columbia River to more than 106 m (348 ft) near the 200 Areas. In some areas east of the Columbia River, the saturated thickness of the unconfined aquifer is greater than 107 m (350 ft) but again pinches out along the flanks of the basalt ridges. Depth from the ground surface to the water table ranges from 0.3 m (1 ft) near the Columbia River to approximately 50 m (165 ft) in the Esquatzel Coulee.

Ground water in the confined aquifers underlying the Hanford Site comes mainly from infiltration of precipitation and streamflow within recharge areas along the periphery of the Pasco Basin (DOE 1988a). The potential exists for ground water from the unconfined aquifer to recharge the uppermost confined aquifer locally, where discharge of waste water from Hanford operations has resulted in ground-water mounds beneath the decommissioned U Pond in the 200-West Area and B Pond east of the 200-East Area (Spane and Raymond 1993). Hydraulic-head information indicates that ground water in the confined aquifers flows generally toward the Columbia River and, in some places where vertical flow is enhanced, upward to the unconfined system (Bauer et al. 1985; Spane 1987; DOE 1988a; Spane and Raymond 1993).

Ground water in the unconfined aquifer at Hanford generally flows from recharge areas in the elevated region near the western boundary of the Hanford Site toward the Columbia River. The Columbia River is a discharge zone for the unconfined aquifer on both sides of the Columbia River. The water table to the north and east of the Columbia River is not interrelated with the water table to the south and west of the Columbia River. The Yakima River borders the Hanford Site on the southwest and is generally regarded as a source of recharge to the unconfined aquifer.

Natural areal recharge from precipitation at the Hanford Site is variable, ranging from 0 to more than 100 mm/yr (Gee et al. 1992). Recharge is generally higher near the basalt ridges because of greater precipitation and runoff. Areas with shrubs and fine-textured soils like silt loams tend to have low recharge rates, while areas with little vegetation and coarse-textured soils tend to have high recharge rates. A map of estimated recharge rates across the Hanford Site is being prepared. Figure 2.4 shows a preliminary version of the map. The recharge rates that were used to build the map were derived from a combination of measurements (precipitation, water content, tracers, lysimeters) and computer modeling. The rates were distributed across the Hanford Site based on a soil map (Hajek 1966) and a vegetation/land use map (Downs et al. 1994).

Since 1944, the artificial recharge from Hanford waste-water disposal operations has been greater than the natural recharge. As of 1989, an estimated 1,681,000,000 m^3 (444 billion gallons) of liquid had been discharged to the ground through disposal ponds, trenches, and cribs (Freshley and Thorne 1992). Additional discharges of 14,000,000 m^3 (3,696 million gallons) for 1990, 11,000,000 m^3 (2,904 million gallons) for 1991, 8,200,000 m^3 (2,165 million gallons) for 1992, and 6,200,000 m^3 (1,637 million gallons) for 1993 have been reported by WHC (1992a,b, 1993a, and in press). Waste-water discharges to these facilities have resulted in ground-water mounds in some areas that have altered the patterns of flow within the unconfined aquifer system. The volume of artificial recharge resulting from waste-water disposal has decreased during the past few years, causing decreases in water-table elevation in some areas.

2.3 Ground-Water Model Development

A three-dimensional, multilayer ground-water model of the unconfined aquifer system is being developed to assist in the interpretation of contaminant information for Hanford (Wurstner and Devary 1993). The objective of the model is to predict the movement of ground water and contaminants under present and predicted future site conditions. The model will help determine the best location for monitoring wells to intercept contaminant plumes. The model may also be used to predict the effects of various cleanup and land-use alternatives on contaminant movement.

Models have been used in the past at Hanford to assess the effects of proposed changes in waste-water disposal practices and to assess the potential for human exposure to contaminants transported along the ground-water pathway. However, most of these models have been two-dimensional and assumed that the concentration of contaminants did not vary vertically in the aquifer. Because the Hanford unconfined aquifer is heterogeneous and anisotropic, and because contaminants were generally introduced at the water table, the distribution of contaminants within the aquifer is expected to vary vertically. Therefore, these two-dimensional models cannot accurately predict the movement of contaminants through the heterogeneous unconfined aquifer system that exists on the Hanford Site.

Numerical ground-water flow modeling is being supported by development of a conceptual model of the unconfined aquifer flow system. The conceptual model includes the description of the flow system geometry, definition of hydraulic properties throughout the model region, boundary conditions, and initial conditions for such variables as hydraulic head and contaminant concentrations. For the three-dimensional conceptual model, describing flow system geometry involves defining the orientation and extent of hydrogeologic layers that make up the unconfined aquifer system. This is being done by defining relatively continuous lithofacies that are expected to have similar hydraulic flow properties.

As an intermediate step in the process of converting to a three-dimensional numerical flow model, the two-dimensional conceptual model was extended to the south and the coordinate system was converted as described by Wurstner and Devary (1993). This model was then used to determine the potential for tritium from the Hanford Site to travel to the vicinity of the North Richland well field. A pathline analysis was used to predict the likely travel path of contaminants. Results are described by Wurstner and Devary (1993).

Site-specific sub-models depicting ground-water flow and contaminant transport have been developed by WHC to support CERCLA and RCRA investigations (e.g., Connelly et al. 1992a,b; Connelly 1994).

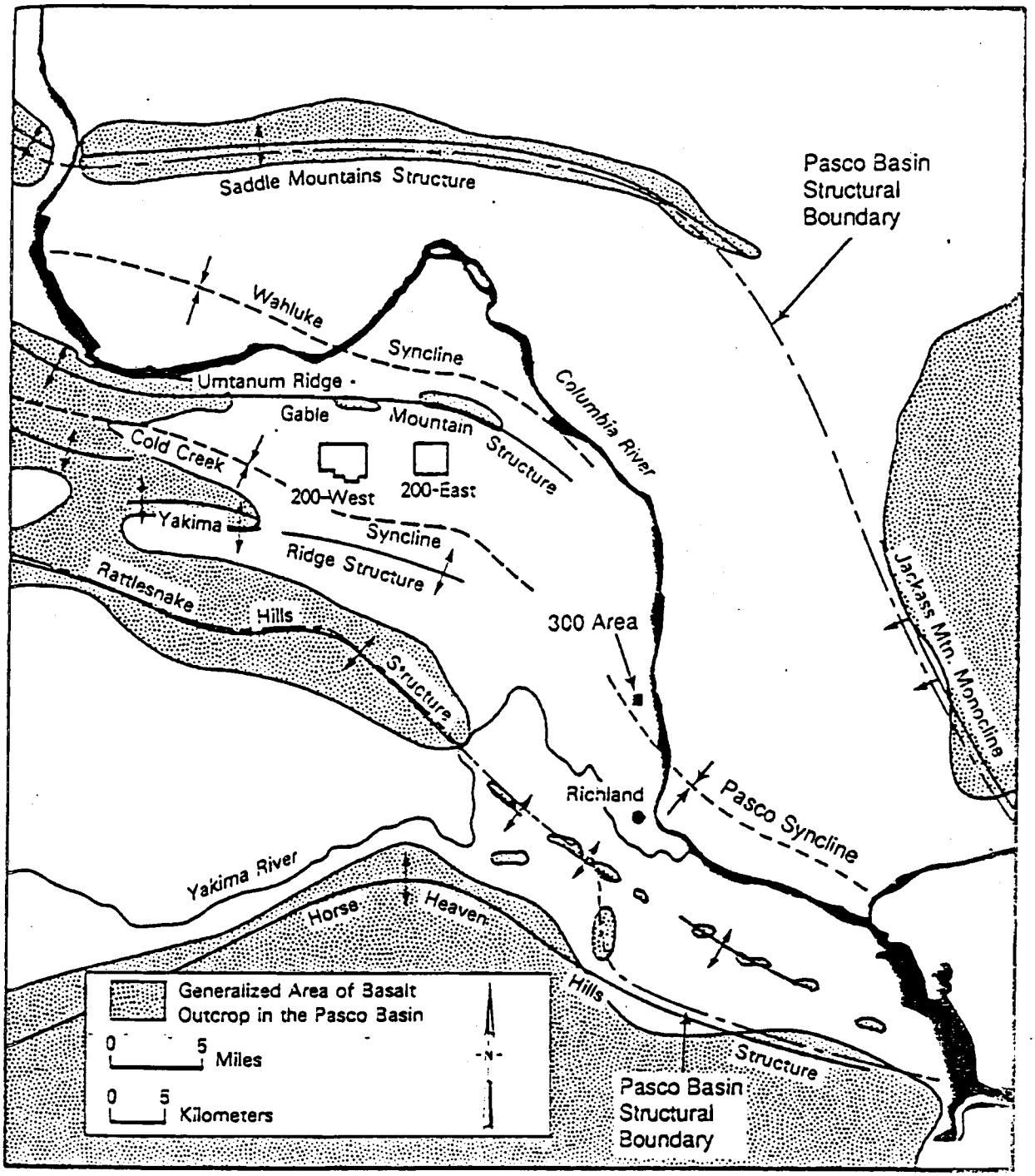

Figure 2.1. Structural Features of the Pasco Basin

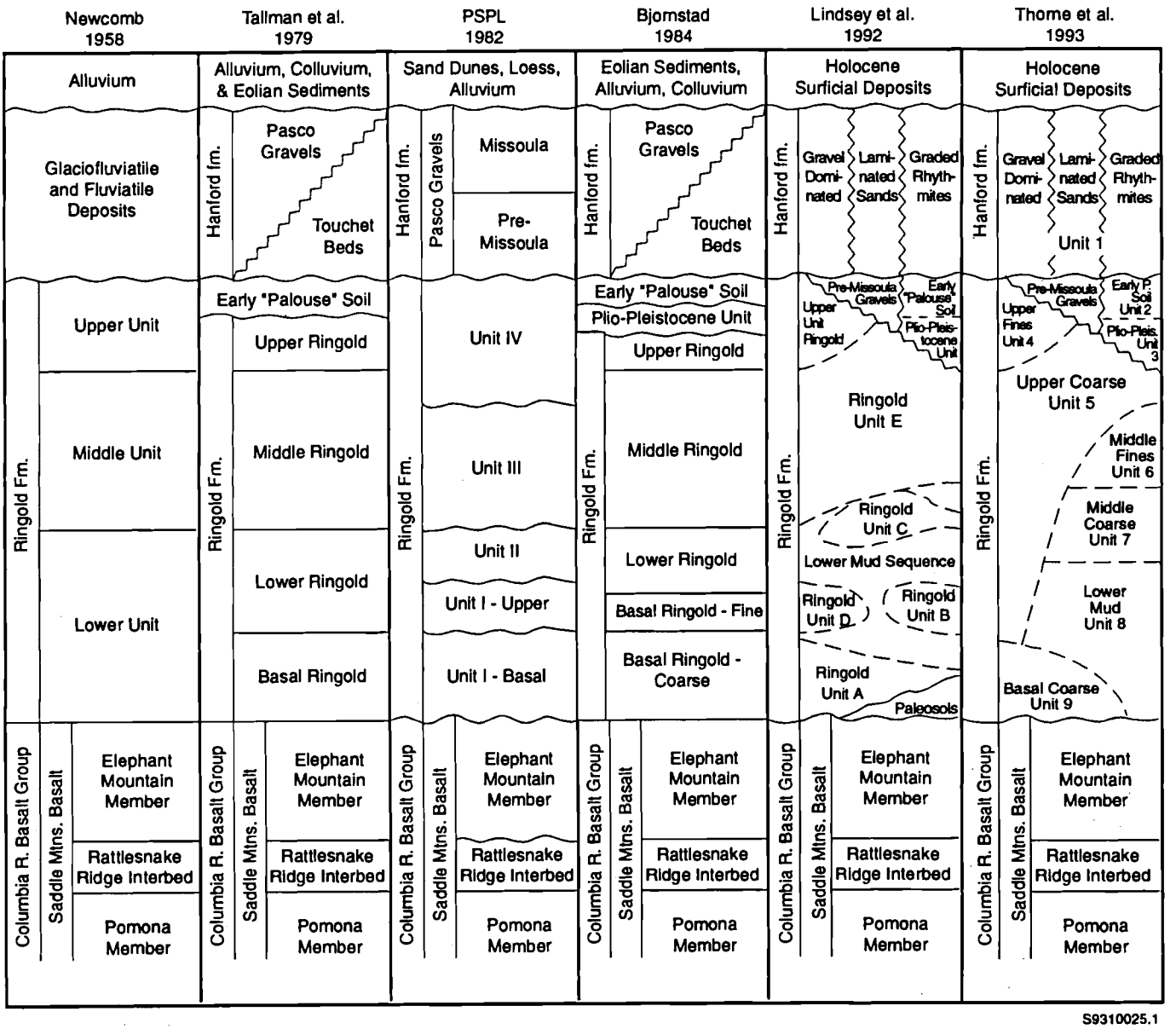

Figure 2.2. Stratigraphic Column for the Hanford Site Showing Nomenclature of Various Authors

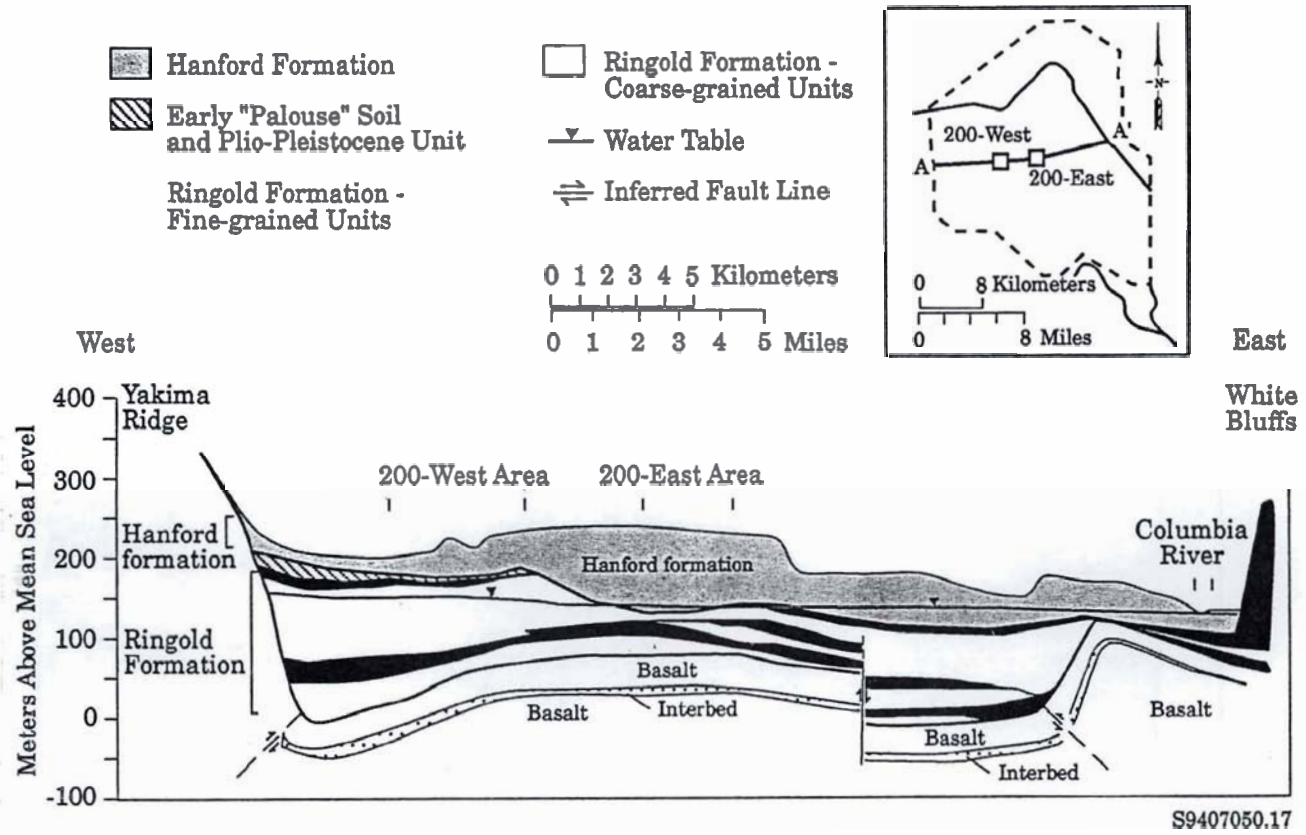

Figure 2.3. Geologic Cross Section of the Hanford Site

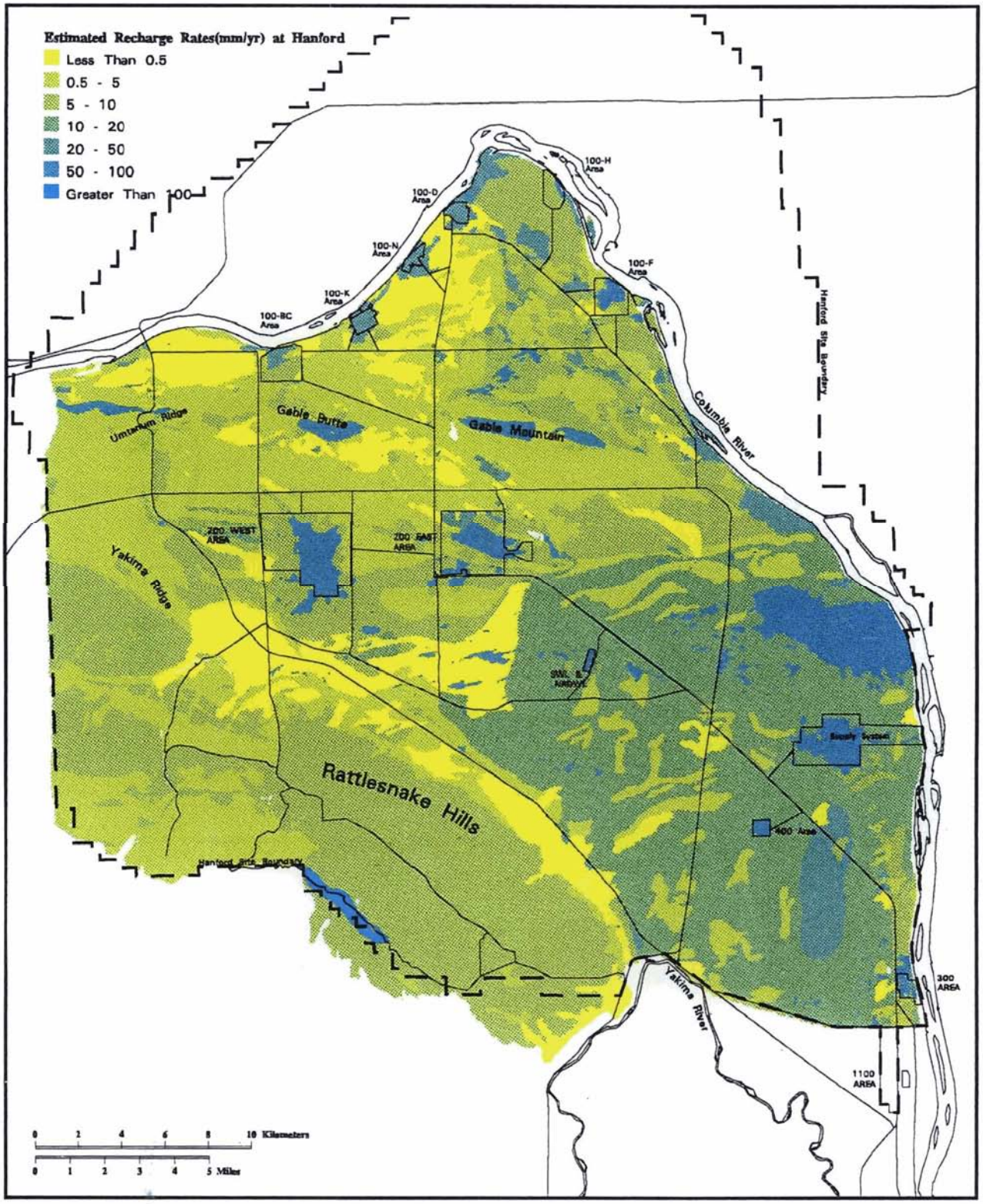

Figure 2.4. Estimated Recharge at the Hanford Site from Infiltration of Precipitation and Irrigation

3.0 Water-Level Measurements

W.D. Webber

Water levels in selected wells completed in the unconfined aquifer beneath the Hanford Site west and south of the Columbia River are measured in June and December of each year. The purpose of these measurements is to determine changes in the configuration of the water table. The Ground-Water Surveillance Project also measures water levels in selected offsite wells north and east of the Columbia River in Grant, Adams, and Franklin counties in June, and the U.S. Bureau of Reclamation (USBR) measures water levels quarterly in selected observation wells completed in the unconfined aquifer north and east of the Columbia River in Grant, Adams, and Franklin counties. The USBR measurements are used to monitor water-level changes and drainage patterns associated with recharge from irrigation practices (Walters and Grolier 1960; USGS 1977; Drost et al. 1993).

Water-level measurements for the unconfined aquifer were used to construct a water-table map that represents the elevation of the water-table surface for June 1993. The wells used to measure water levels were chosen based on geologic and hydrologic information. The water-table map can be used in inferring general directions of ground-water flow, particularly in the upper part of the aquifer. Ground-water flow can also be inferred from potentiometric surface maps constructed from water-level measurements in the upper-basalt confined aquifer. The inference is based on the fact that ground water moves from regions of high water potential to regions of low water potential, perpendicular to contours of equal potential, assuming conditions of isotropic hydraulic conductivities. In addition, water-table maps can be used to

- identify recharge and discharge areas
- evaluate the physical influence of waste-water discharges on ground-water flow directions
- identify the potential for water movement between adjacent ground-water and surface-water bodies
- represent the horizontal hydraulic gradient, which is required to estimate the average linear velocity of ground-water flow
- improve the design of the water-level monitoring-well network
- provide information required to calibrate ground-water flow models
- evaluate ground-water flow for interpreting contaminant fate and transport.

Prior to 1991, water-table maps of the Hanford Site encompassed an area bounded by the Columbia River to the north and east; the anticlinal basalt ridges, Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills to the west and southwest; and the Hanford Site boundary between Horn Rapids and the 300 Area to the south. Beginning in 1991, the annual water-table map was extended to include both the entire Hanford Site and irrigated agricultural areas north and east of the Columbia River (Newcomer et al. 1992). This map area is bounded by the Saddle Mountains basalt to the north, Jackass Mountain to the east, and the Columbia and Yakima rivers to the south (see Plate 1). Subsequent maps were also extended so that the hydrology of the Hanford Site could be presented in the context of the regional ground-water flow system.

In addition to water levels measured in wells scattered across the Hanford Site, water levels were measured at four specific areas within the Hanford Site. These areas are around the decommissioned 216-U-10 Pond (U Pond) in the 200-West Area, the 216-B-3 Pond (B Pond), the 100-N Area, and the Richland North Area, which includes the 300 Area, 1100 Area, 3000 Area, and their vicinity. Artificial recharge to the Hanford unconfined aquifer from these facilities has resulted in ground-water mounding that appears to influence ground-water flow. The locations of these areas, as well as the adjacent area north and east of the Columbia River, are shown in Figure 1.1. The water-table maps of specific areas are intended to enhance definition of water-table features beneath waste-water discharge facilities in the 200-West Area and 300 Area, and beneath irrigation lands and municipal facilities around the Richland North Area.

Historical water-level data and evaluations of past changes to the water-table surface are presented by Zimmerman et al. (1986) and Newcomer (1990). Brown (1979) presented water-table maps of the Pasco Basin for 1979, one for the southern half and one for the northern half, and characterized the occurrence of unconfined ground water in the eastern part of the Pasco Basin. A regional map of ground-water levels in materials overlying the Columbia River basalt group for spring 1985, including water-level contours of the unconfined aquifer in the Pasco Basin, is presented by Bauer et al. (1985). Water-level measurements and a map of water-table elevations on the Hanford Site and in outlying areas located north and east of the Columbia River in Grant and Franklin counties for June 1991 and June 1992 were published by Newcomer et al. (1992) and Dresel et al. (1993), respectively. Semi-annual water-level measurements and water-table maps of the Hanford Site south of Gable Butte and Gable Mountain, including the 200 Areas, 300 Area, the Richland North Area, and maps of the 100 Areas for December 1991, June 1992, December 1992, June 1993, and December 1993 were published by Kasza et al. (1992a, 1992b, 1993, 1994a, and 1994b, respectively). Water levels north and east of the Columbia River in Grant and Franklin counties were measured by the U.S. Geological Survey (USGS) for 1986-1989 (Drost et al. 1989), and a water-table map for the area north and east of the Columbia River in Franklin County for March 1986 was prepared by Drost et al. (1993).

3.1 Data Collection

During June 1993, WHC and the Ground-Water Surveillance Project measured water levels in more than 500 wells completed in the unconfined aquifer beneath the Hanford Site. The Ground-Water Surveillance Project also measured water levels in about 100 wells completed in the unconfined aquifer north and east of the Columbia River in Grant, Adams, and Franklin counties during June 1993.

Most monitoring wells at the Hanford Site used for water-level measurement are 15 or 20 cm (6 or 8 in.) in diameter and are constructed of steel casing (Chamness and Merz 1993). Several small-diameter [5-cm (2-in.)] piezometers and some larger-diameter wells are also used. Wells constructed for RCRA ground-water monitoring are 10 or 15 cm (4 or 6 in.) in diameter and are constructed of stainless steel. Monitoring wells used to measure water levels for the unconfined aquifer are completed with well screens or perforated casing that is generally open to the upper 3 to 6 m (10 to 20 ft) of the aquifer. This type of completion allows measurements generally representative of the water-table elevation. Most offsite wells monitored by the Ground-Water Surveillance Project are 4, 8, 10, or 15 cm (1.5, 3, 4, or 6 in.) in diameter and completed with perforated steel casing (Walters and Grolier 1960; personal communication, Tony Gladue, Technician, USBR).

A written procedure developed in accordance with the techniques described by the American Society for Testing and Materials (ASTM 1988), U.S. Environmental Protection Agency (EPA 1986b), Garber and Koopman (1968), and USGS (1977) was followed to measure water levels in piezometers and wells across the Hanford Site. WHC also used a standard procedure (WHC 1989) to measure water levels at the Hanford Site. Both PNL and WHC used calibrated steel tapes for measuring water levels; crews use only those standardized steel tapes that deviate in length from the calibrated steel tape by less than ± 0.03 m (± 0.10 ft). PNL also used laminated steel electric sounding tapes that meet standardization requirements similar to those for steel tapes. Water levels are reported as elevation above the National Geodetic Verticle Datum (NGVD29).

All water-level measurements from the Hanford Site and outlying areas east and north of the Columbia River were collected within a one-month period (June 1993). The greatest short-term water-level changes that occurred within this period were in wells influenced by fluctuations in Columbia River stage. Water-level fluctuations in wells influenced by river-stage fluctuations may introduce errors in representing the water-table surface adjacent to the river. Therefore, the water-level contours adjacent to the river shown in Plate 1 have a greater uncertainty.

Other minor uncertainties in the water-level measurements are caused by effects from diurnal changes (e.g., barometric effects, earth tides), deviations from the vertical in wells, errors in the elevation of the surveyed measuring points, and errors within the measuring tolerances of the field equipment. However, most uncertainties are insignificant relative to site-wide water-table gradients.

3.2 Results of the 1993 Water-Level Measurements

Water levels specific to the unconfined aquifer measured on the Hanford Site and in outlying areas during June 1993 are listed in Appendix A. Those measured on the Hanford Site during December 1993 are listed in Appendix B.

The map of the Hanford unconfined water table, presented in Plate 1, was constructed by hand-contouring water-level elevations for the Hanford Site and outlying areas. The contours in Plate 1 are in units of meters; the contour interval is 2 m west and south of the Columbia River (the Hanford Site proper) and 50 m north and east of the Columbia River.

The locations of the wells used to prepare the water-table map are indexed in Figure C.1, Appendix C. Wells north and east of the Columbia River are numbered by the USGS well-numbering system, prefixed by township and range. Wells on the Hanford Site, west of the Columbia River, are named with their Hanford coordinates. Maps of the top of basalt by Myers et al. (1979) were used to estimate the location of basalt above the water table. However, given that water levels across most of the Hanford Site have declined in recent years, it is possible that portions of the basalt previously mapped as below the water table are currently above the water table (Plate 1).

Water-table maps by the USGS (Drost et al. 1989) indicate that the contours in the area between the Saddle Mountains and the Columbia River extending southeast to Columbia Flat are controlled by the surface and topography of the land surface and the underlying basalt. Comparison of water-level data indicates that the water-table elevation in this area did not change significantly between 1989 and 1993.

3.2.1 Hanford Site Water-Table Features

Steep gradients in the western region of the Hanford Site likely result from ground-water recharge in the Cold Creek and Dry Creek valleys and along the adjacent ridges (i.e., Yakima Ridge, Umtanum Ridge, and Rattlesnake Hills). Possible sources of recharge include infiltration of runoff from rain and snow at higher elevations and offsite irrigation of agricultural land at lower elevations.

Water-table elevation generally decreases toward the Columbia River along the eastern edge of the Hanford Site and north of the Gable Mountain-Gable Butte anticline, implying discharge of unconfined ground water to the Columbia River along the Hanford Reach. The Hanford Reach is the free-flowing stretch of the Columbia River between Priest Rapids Dam and the city of Richland.

The hydraulic gradient of the water table decreases abruptly between the 200-West and 200-East Areas. This change in gradient corresponds to an area of high hydraulic conductivity that has been attributed to the presence of reworked Ringold Formation and Hanford formation sediments (Graham et al. 1981). The increased cross-sectional area of the unconfined aquifer as ground water flows to the

east beyond the confines of Gable Butte and Yakima Ridge may also contribute to this abrupt change in hydraulic gradient.

Ground-water mounds beneath B Pond and the decommissioned U Pond resulted from recharge by process cooling water and other liquid wastes discharged to the ground at those locations. A ground-water mound beneath the Richland North Area, which includes the 1100 and 3000 Areas, is discussed later, has resulted from recharge at the city of Richland's recharge infiltration basins.

A local ground-water high exists north of Gable Mountain. This high was reported by Jenkins (1922) even before the Hanford Site was established and it has persisted to the present. Possible explanations for this local ground-water high include the occurrence of local perched water-table conditions, past leakage from the Hanford Irrigation Ditch, greater surface runoff from the adjacent catchment area on Gable Mountain, or mounding of natural recharge from direct infiltration of precipitation as it reaches the water table that occurs within the Ringold fines in the area north of Gable Mountain.

The elevation of the water table in the region between the Yakima River near Horn Rapids Dam and the Columbia River is lower than the Yakima River stage, which is approximately 122 m (400 ft) above mean sea level. This implies that unconfined ground water is recharged by the Yakima River, Columbia Canal, and Horn Rapids Ditch, which originate at Horn Rapids Dam. Water levels measured in this region also indicate that ground water recharged by the Yakima River, Columbia Canal, and Horn Rapids Ditch flows to the east beneath the southern portion of the Hanford Site and discharges to the Columbia River.

3.3 Changes in the Hanford Site Water Table - 1992 to 1993

Water levels over most of the Hanford Site declined from June 1992 to June 1993. The greatest changes in the water table on the Hanford Site occurred beneath the 200 Areas plateau near the decommissioned U Pond in the 200-West Area. Substantial water level decline also occurred in the 300 Area. However, water levels along the southern boundary of the Hanford Site east of the 1100 Area rose near irrigated agricultural areas. Contours of the water-level changes for these and other areas of the Hanford Site are presented in Figure 3.1.

3.3.1 100 Areas

The Hanford Site water-table map indicates that ground water flows north through the gaps between Umtanum Ridge and Gable Butte and Gable Mountain and passes beneath the 100 Areas, discharging to the Columbia River. Ground-water elevations in the 100 Areas are primarily influenced by changes in Columbia River stage, discussed further in Section 3.3.6. Water-level elevations of the 100 Areas in June 1993 are shown in Plate 1. Hydrographs of wells 199-N-49, 199-D2-5, and

In the 100-N Area, the volume of recent waste-water effluent is much less than when N Reactor was operating [1.1E+9 L during 1987 (Rokkan 1988; WHC in press)]. Therefore, ground-water mounding caused by recharge from liquid waste disposal facilities (LWDFs) in the 100-N Area has dissipated (Newcomer et al. 1992). The total volume of waste water discharged to the ground in the 100 Areas during 1992 was approximately 1.8E+7 L (WHC 1993b). Hydrographs of wells 199-N-33, 199-N-34, and 199-N-67 indicate that water levels in the 100-N Area are approaching a new state of equilibrium with the reduced level of discharge (Figure 3.3).

Water-table maps of the 100 Areas for June 1993 and December 1993 have been published by Kasza et al. (1994a,b, respectively).

3.3.2 200 Areas

The elevation of the water table beneath most of the 200 Areas plateau declined from June 1992 through June 1993. The largest changes occurred in the 200-West Area near the decommissioned U Pond, where the water table declined 0.79 m (2.59 ft) at well 299-W23-14 from June 1992 to June 1993. Hydrographs of wells 299-E23-2Q, 299-E32-2, and 299-E34-2 indicate that the water table in the 200-East Area declined approximately 0.17 m (0.56 ft) between June 1992 and June 1993 consistent with the past 5-year trend (Figure 3.4). Similar water-level changes are also reflected in areas downgradient from the 200 Areas plateau. Hydrographs of well 699-60-60, located in the gap between Gable Butte and Gable Mountain, and well 699-20-20, located southeast of the 200-East Area, also show declining water levels between 1992 and 1993 and consistent with the past 5-year trend (Figure 3.5).

The water-level declines in the 200 Areas are primarily attributed to 1) an overall decrease in the amount of waste water discharged to various cribs, trenches, and ponds in the 200 Areas and 2) continued dissipation of the ground-water mound beneath U Pond since it was decommissioned in 1984. The decrease in waste-water discharge corresponds to the shutdown of production facilities in the 200 Areas. Ground water in the 200 Areas is also influenced by a ground-water mound beneath B Pond. However, water levels near B Pond did not change significantly from June 1992 to June 1993.

Water-table maps of the 200 Areas for June 1993 and December 1993 have been published by Kasza et al. (1994a,b).

216-B-3 Pond

The occurrence of the ground-water mound shown beneath B Pond in Plate 1 indicates radial flow beneath the pond. Hydrographs of wells 699-39-39, 699-40-39, 699-41-40, 699-42-40B, and 699-43-43 (Figure 3.6) indicate that the water-table elevation remained nearly constant between June 1992 and June 1993. The 5-year trend for these wells indicates a slight lowering of the water table even though water levels were higher in June 1993 than June 1992. Declining water levels in this area

likely reflect annual volumes of waste water discharged to B Pond, which have decreased significantly since 1988 (Cooney and Thomas 1989; Brown et al. 1990; WHC in press).

Decommissioned U Pond

A detailed map of the water table beneath the decommissioned U Pond for June 1993 is presented in Figure 3.7. Water levels beneath the decommissioned U Pond indicate that ground water flows mostly to the north and east. The 216-U-14 Ditch, which is located north and east of the decommissioned U Pond, continued to receive waste water in 1993 [270,000 m^3 (71 million gallons)] (WHC in press). The annual discharge of waste water to the ground in the 200-West Area is far below the discharges that occurred during the operation of U Pond (Newcomer 1990; WHC in press). The water-table map for the Hanford Site and outlying areas (Plate 1) indicates that the ground-water mound in this area has influenced regional ground-water flow.

The ground-water mound beneath the 200-West Area has continued to decline since U Pond was decommissioned in 1984. The maximum elevation of the ground-water mound, which occurred in 1984, was approximately 148 m (485 ft) above mean sea level. The ground-water level, as reflected by the water level in well 299-W18-15, decreased by 6.3 m (20.6 ft) between June 1984 (RHO 1984) and June 1993; approximately 0.54 m (1.76 ft) of this decline occurred between June 1992 and June 1993. The decline in the ground-water level beneath the decommissioned U Pond has been observed in wells throughout the 200-West Area.

Hydrographs of wells 299-W10-13, 299-W11-10, 299-W18-21, 299-W19-32, and 299-W23-11 presented in Figure 3.8 indicate that water levels in the 200-West Area declined about 0.53 m (1.73 ft) between June 1992 and June 1993.

3.3.3 300 Area

The water levels beneath the 300 Area and Richland North Area for June 1993 (Plate 1) indicate that ground water flows from the northwest, west, and southwest and discharges to the Columbia River in the vicinity of the 300 Area. The primary influence on changes of ground-water elevation in the 300 Area is the fluctuation in Columbia River stage.

The water table beneath the 300 Area is also influenced by recharge from process effluent. The process trenches receive the largest volume of waste water in the 300 Area, 4.2E+8 L in 1993 (WHC in press). The configuration of the water table at any given time is dependent on these influences. The water table in most of the 300 Area declined approximately 0.5 m (1.6 ft) between June 1992 and June 1993.

A detailed water-table map of the 300 Area for June 1992 is presented by Dresel et al. (1993). Water-table maps of the 300 Area for June 1993 and December 1993 have been published by Kasza et al. (1994a,b, respectively).

3.3.4 Richland North Area

Ground water beneath the Richland North Area generally flows from west to east between the Yakima and Columbia rivers (see Plate 1). The sources of ground-water recharge include infiltration along the Yakima River, infiltration at the North Richland well field infiltration basins, irrigation in the Richland North Area, and irrigation of agricultural land to the west and southwest. Ground-water extraction by pumping occurs at the North Richland well field and wells used for irrigation.

At the North Richland well field located east of the 1100 Area, water is pumped from the intake structure at the Columbia River and piped to a system of basins (ICF 1987) that recharge the unconfined aquifer. Water is then pumped from the aquifer via the well field for the city's water supply system. During 1993, the volume of water delivered to the infiltration basins was about 2.5 times greater than the volume pumped from the well field (Scott Meyer, City of Richland, personal communication). This system is primarily used when the filtration plant is shut down for annual maintenance between January and March and during the summer months to supplement the city's water supply. Figure 3.9 shows a hydrograph of well 699-S40-E14A, which is located on the western edge of the recharge basins. The hydrograph indicates that the water level rose about 3 m (9.8 ft) between June 1992 and June 1993.

Ground-water levels in the Richland North Area are influenced by irrigation practices west of the 1100 Area. The sources of irrigation water are the Columbia River and a shallow pumping well. A hydrograph of water levels in well 699-S31-1 that includes the period from January 1989 to January 1993 is shown in Figure 3.10. The water level in well 699-S31-1, located approximately 3 km (2 miles) west of the Horn Rapids Landfill along the northern perimeter of the irrigated fields, has risen about 0.7 m (2.4 ft) since 1990; approximately 0.2 m (0.7 ft) of the rise occurred between June 1992 and June 1993.

3.3.5 Upper Cold Creek Valley

Zimmerman et al. (1986) postulated that the water table in the western part of the Hanford Site responded to irrigation practices in the upper Cold Creek Valley. Figure 3.11 shows a hydrograph of well 699-43-104, which is located down the valley from the irrigated fields in upper Cold Creek Valley (see Figure C.1, Appendix C). The hydrograph indicates that the water table has declined steadily since at least 1990. In fact, water levels in this well have declined since about 1988. The water level declined approximately 0.6 m (1.9 ft) between June 1992 and June 1993. It is hypothesized that the declining water level in this well is responding to decreased recharge of the unconfined aquifer by irrigation water, resulting from changes in irrigation practices by Ste. Michelle Vineyards. Between 1982 and 1983, Ste. Michelle Vineyards converted their irrigation system from a sprinkler system to drip irrigation, which reduced consumption by 40% to 50% (Newcomer 1990).

3.3.6 Hanford Reach

Water levels in wells near the Columbia River have been observed to fluctuate several feet daily in response to the rise and fall of the river stage. These changes are primarily the result of pressure waves transmitted from the river to the unconfined aquifer, but they also reflect bank storage effects. The Columbia River stage changes in response to releases at the Priest Rapids Dam upstream from the Hanford Reach and in response to seasonal influences. Ground-water levels in the 100 and 300 Areas are heavily influenced by river-stage fluctuations. Hydrographs showing the influence of the river stage on the unconfined aquifer at various locations along the Columbia River are presented by Newcomb and Brown (1961), Jensen (1987), Liikala et al. (1988), Schalla et al. (1988), Fruland and Lundgren (1989), and McMahon and Peterson (1992).

3.4 Water-Table Features East and North of the Columbia River

The dominant pattern of ground-water flow in the unconfined aquifer east and north of the Columbia River is from the anticlinal axes of the basalt ridges toward the Columbia River, which flows within a structural syncline. The water-table aquifer lies within sediments overlying the basalt in these areas.

The water-table configuration is heavily influenced by recharge from irrigation in the region between the Columbia River and the basalt anticlinal ridges. The areas east and north of the Columbia River are irrigated by the South Columbia Basin Irrigation District, which is part of the Columbia Basin Irrigation Project (Brown 1979). The South Columbia Basin Irrigation District comprises two principal areas. One area is located east of the Columbia River and the Hanford Site boundary, extending from the north to south between the lower flanks of the Saddle Mountains and the Esquatzel Diversion channel (see Plate 1). This area extends to near Eltopia. The other principal area of irrigation is the northern part of the basin on the Wahluke Slope between the Columbia River and the Saddle Mountain anticline. In these areas, surface water recharges the unconfined aquifer as a result of leakage from canals and wasteways, surface runoff from irrigated land, discharge or spillover of excess water from irrigation canals, and seepage from the irrigated land (Brown 1979). Pumping from wells that tap the unconfined aquifer is mostly for domestic, stock, and irrigation purposes, but yield is commonly very low (Bauer et al. 1985). For this reason, pumping from the unconfined aquifer in the South Columbia Basin Irrigation District has little influence on water levels.

The water-table map in Plate 1 shows a steep hydraulic gradient east of Gable Mountain along the eastern bank of the Columbia River near White Bluffs. Because of the abrupt topographic elevation change between the Columbia River and the top of the bluffs, the water-table rise in the irrigated areas has caused the formation of a series of springs issuing from White Bluffs.

Water-table contours along the Wahluke Slope north of the Columbia River are inferred because data are limited (i.e., there are few wells for measuring water levels). The sources of information used

to infer the contours include the elevation of ponds and seeps in the Saddle Mountain Natural Wildlife Refuge across the Columbia River from the 100-N and 100-K Areas. These data, used in conjunction with topographic elevations, indicate that the 150-m contour swings south and east of the ponds (see Plate 1). Along the northeast border of the Hanford Site, contour flexures are inferred from topographic elevations.

Irrigation on the Wahluke Slope and the area east of the Columbia River has caused the development of extensive perched water bodies (Brown 1979). Perched water is another source of the spring discharge along the White Bluffs. The extent of perched conditions is poorly defined because few wells tap the perched aquifers.

A water-table map of the Franklin County north and east of the Columbia River for March 1986 was published by Drost et al. (1993).

3.5 Confined Aquifer System

The term "upper-basalt confined aquifer system" refers to the flow system which occurs in basalt fractures and joints, interflow contacts, and intercalated sedimentary interbeds within the upper Saddle Mountains basalt formation (see Figure 2.2). Water is confined to this aquifer system by dense, low-permeability interior sections of the basalt flows and silt and clay units within the overlying suprabasalt sediments (i.e., Ringold Formation).

The Ground-Water Surveillance Project prepared a preliminary potentiometric map for the upper-basalt confined aquifer system for March 1993 (Figure 3.12) and evaluated the flow dynamics of the upper-basalt confined aquifer system (Spane and Raymond 1993). The following five measurement sources, consisting of more than forty monitoring wells and boreholes, were used to collect hydraulic head information:

- onsite monitoring wells completed primarily within the Rattlesnake Ridge interbed
- onsite monitoring wells completed within other hydrogeologic units of the upper Saddle Mountains Basalt (e.g., Elephant Mountain interflow contact, Levey interbed) overlying the Rattlesnake Ridge interbed
- onsite boreholes completed in the top of the upper Saddle Mountains Basalt
- inactive onsite monitoring wells completed within hydrogeologic units of the upper Saddle Mountains Basalt
- offsite private or domestic wells completed within the upper Saddle Mountains Basalt.

The inferred lateral flow pattern shown in Figure 3.12 is believed to be representative of steady-state ground-water flow conditions within the upper-basalt confined aquifer system and is nearly identical with patterns delineated by Spane (1987) and DOE (1988a) for the Mabton interbed, which marks the lower stratigraphic boundary of the Saddle Mountains Basalt.

Salient hydrogeologic features shown in Figure 3.12 for the upper-confined aquifer system include

- a prominent, broad recharge mound extending northeastward from the Yakima Ridge in the 200-West Area
- a small recharge mound immediately east of the 200-East Area in the vicinity of B Pond
- a hydrogeologic barrier (i.e., an impediment to ground-water flow) at the mouth of Cold Creek Valley. The Rattlesnake Ridge interbed and the Elephant Mountain basalt interflow contact are not present west of this feature.
- the presence of a region of low hydraulic head (potential discharge) in the Umtanum Ridge and Gable Mountain structural area
- a region of high hydraulic head to the north and east of the Columbia River that is associated with recharge attributed to agricultural activities.

Recharge to the upper-basalt confined aquifer is believed to result from natural and artificial recharge associated with offsite irrigation and discharge of waste water from facilities on the Hanford Site. The hydrologic barrier at the mouth of Cold Creek Valley is believed to be related to faulting. The region of low hydraulic head in the Umtanum Ridge and Gable Mountain structural area is believed to result from hydraulic intercommunication between overlying and underlying aquifer systems. Spane and Raymond (1993) discuss these features in more detail.

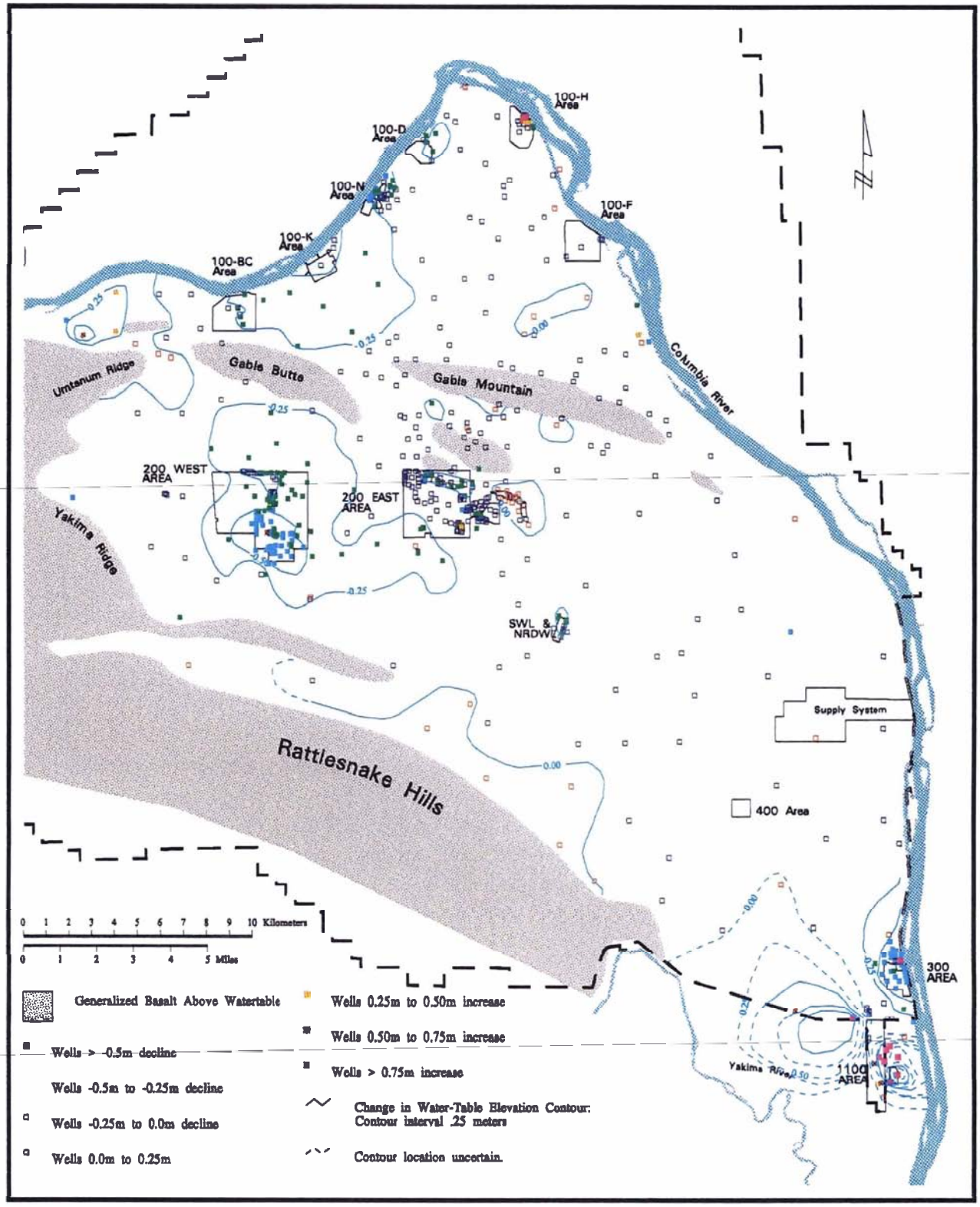

Figure 3.1. Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between June 1992 and June 1993

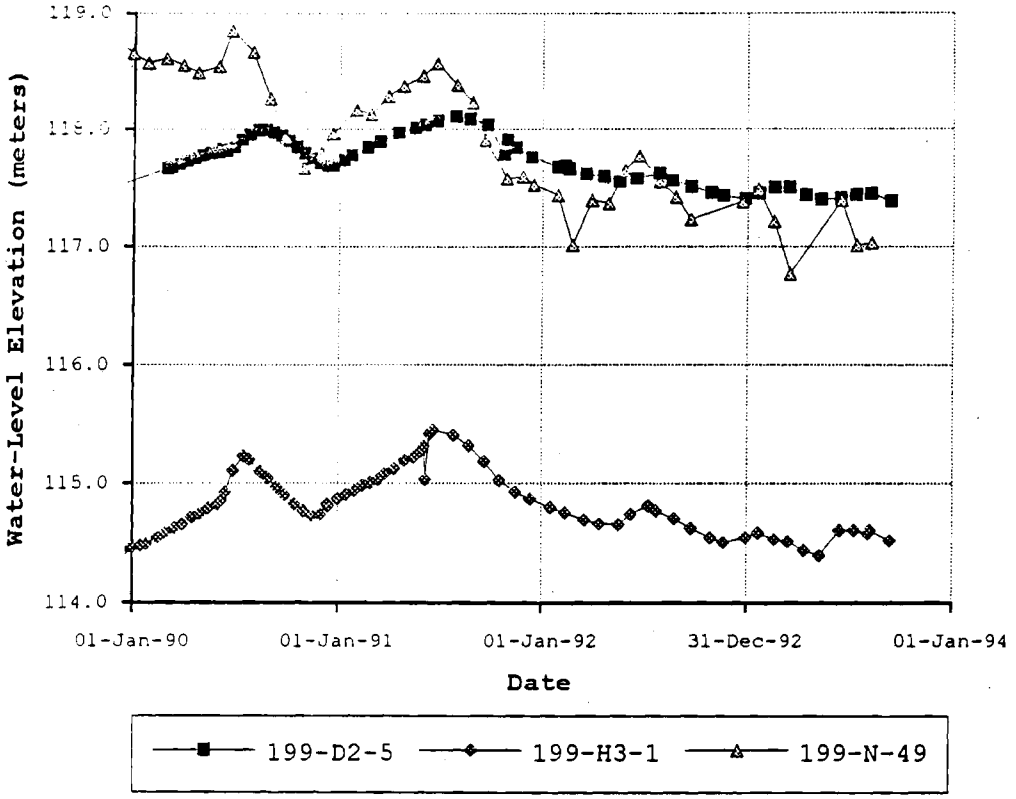

Figure 3.2. Hydrograph of Wells 199-D2-5, 199-H3-1, and 199-N-49

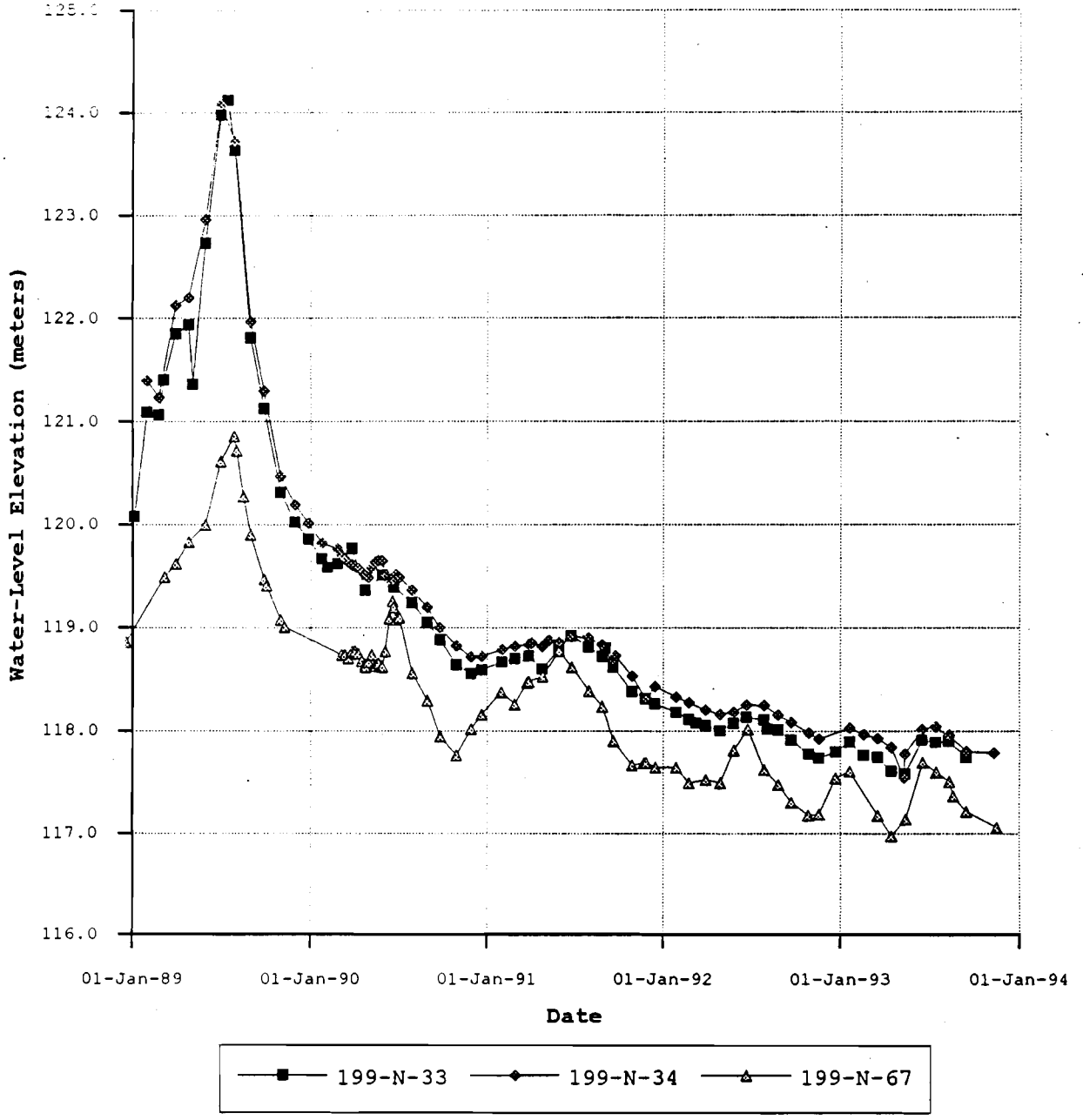

Figure 3.3. Hydrograph of Wells 199-N-33, 199-N-34, and 199-N-67

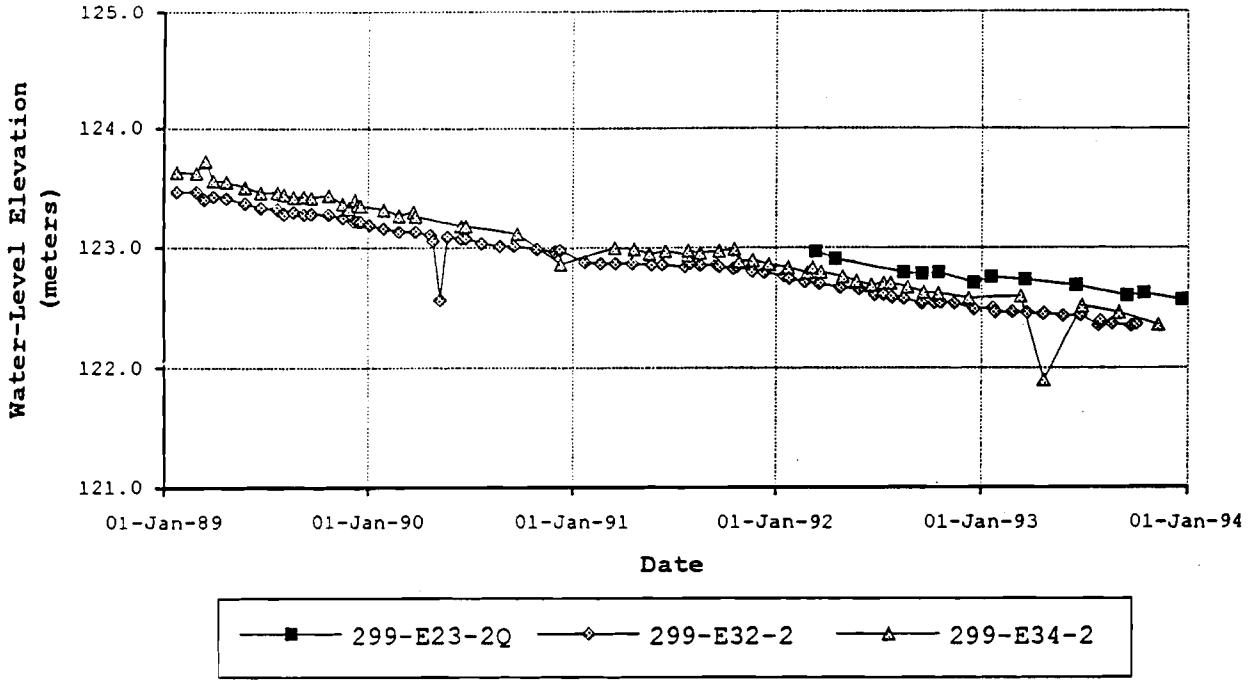

Figure 3.4. Hydrograph of Wells 299-E23-2Q, 299-E32-2, and 299-E34-2

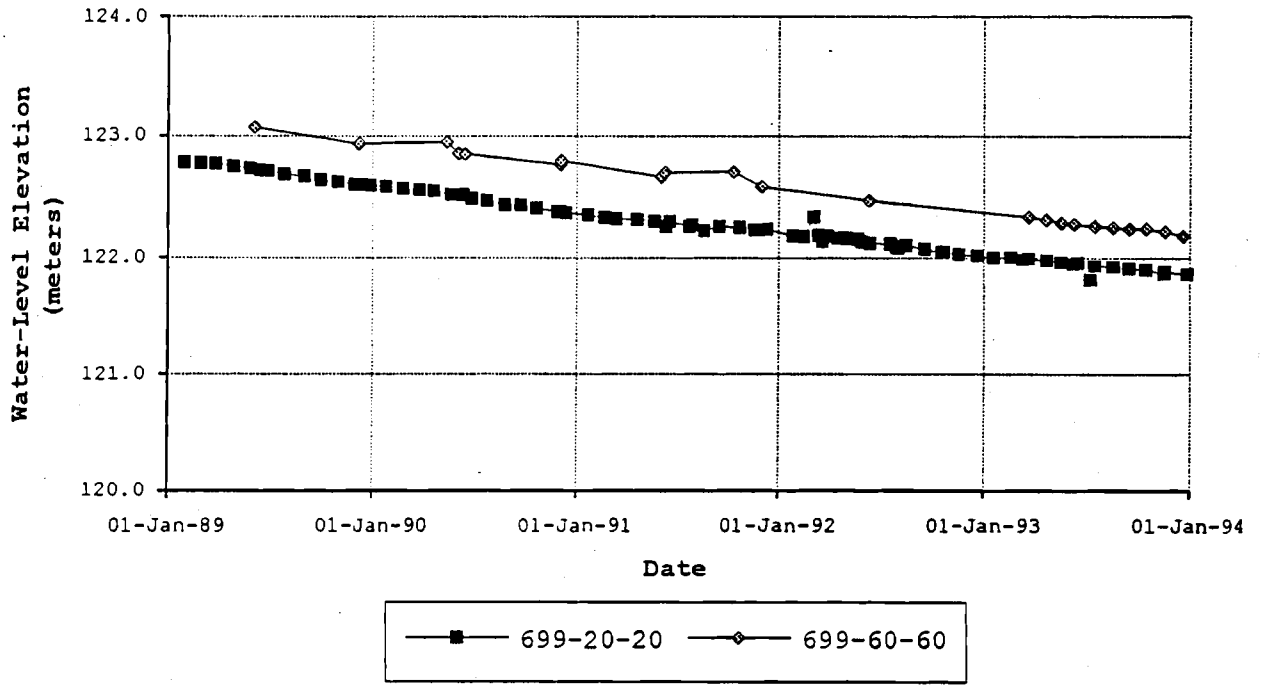

Figure 3.5. Hydrograph of Wells 699-60-60 and 699-20-20

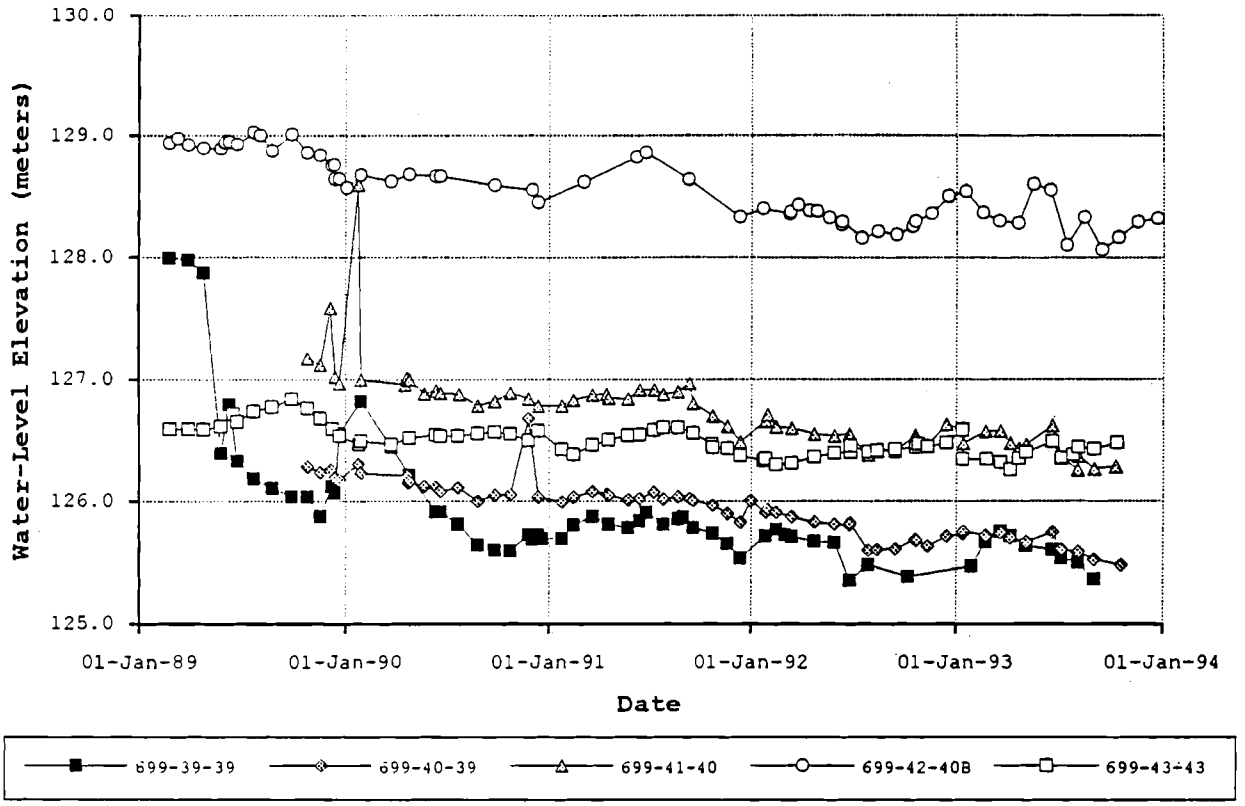

Figure 3.6. Hydrograph of Wells 699-39-39, 699-40-39, 699-41-40, 699-42-40B, and 699-43-43

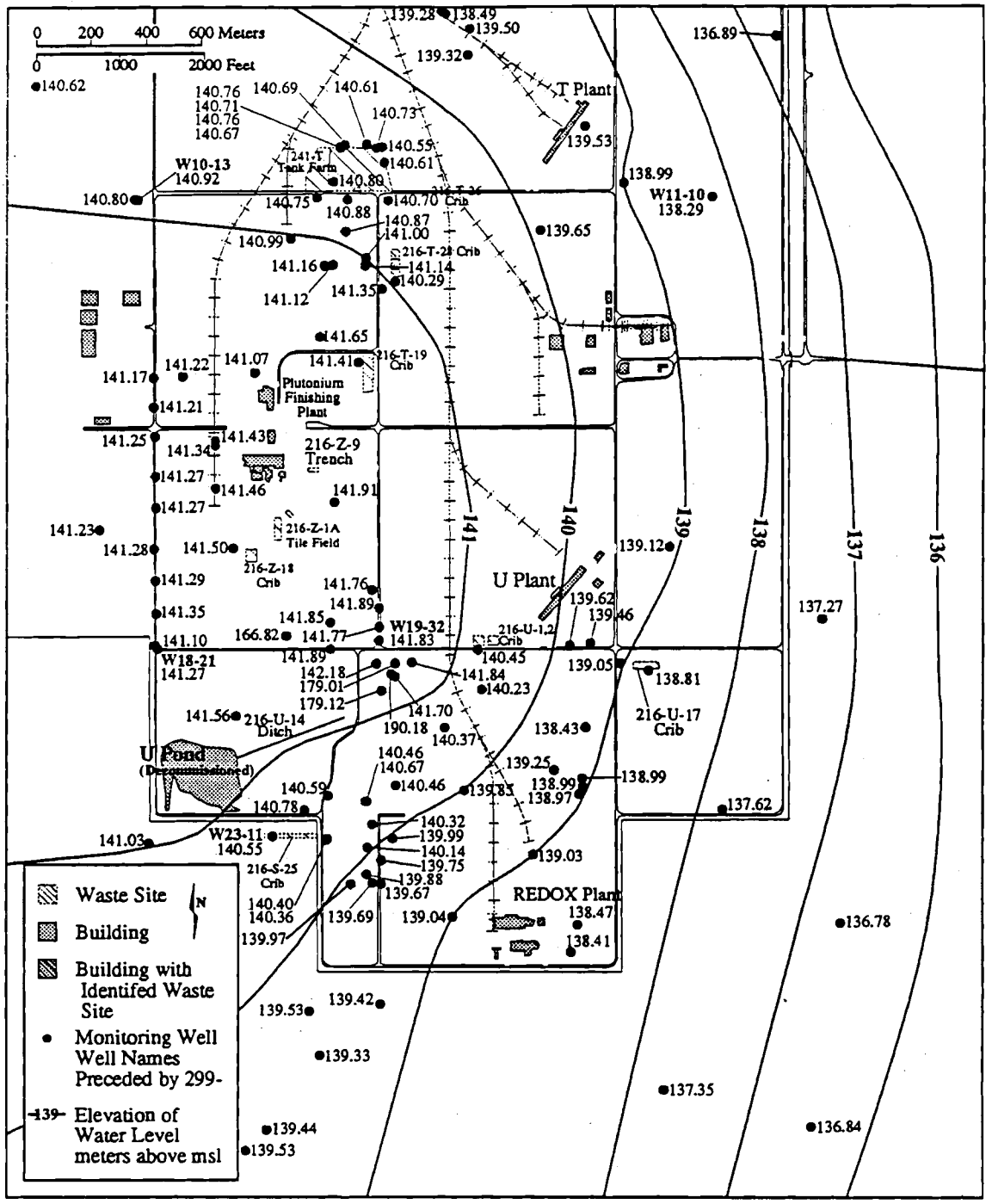

Figure 3.7. Water-Table Map of the Area beneath the Decommissioned U Pond at the 200-West Area for June 1993

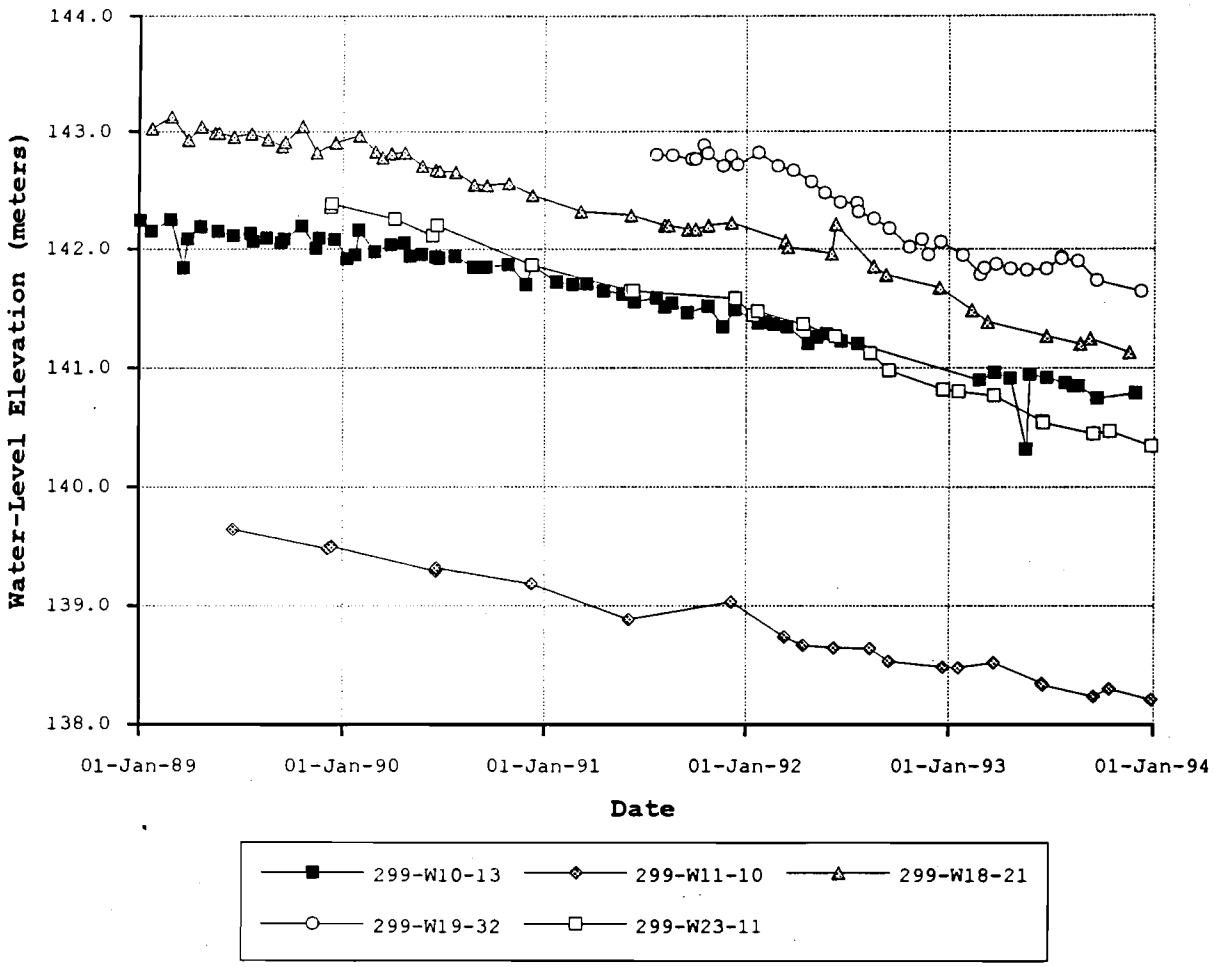

Figure 3.8. Hydrograph of Wells 299-W10-13, 299-W11-10, 299-W18-21, 299-W19-32, and 299-W23-11

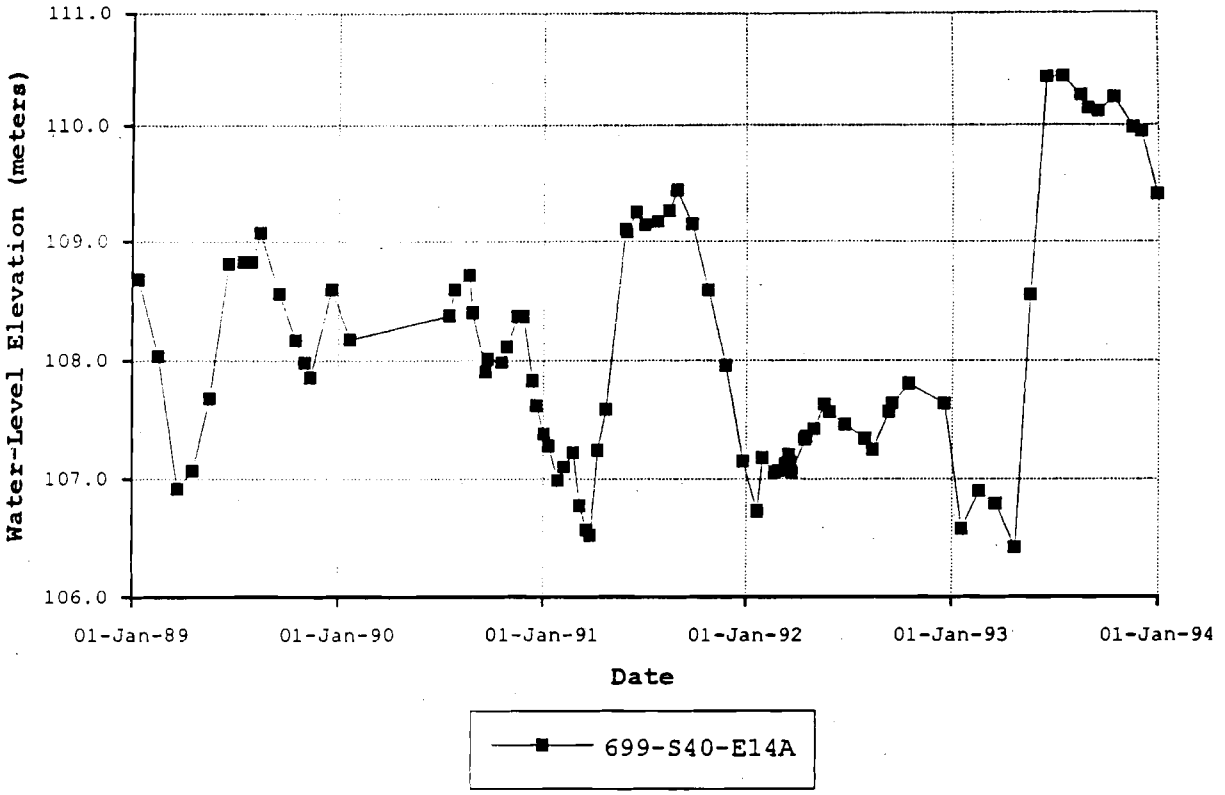

Figure 3.9. Hydrograph of Wells 699-S40-E14A

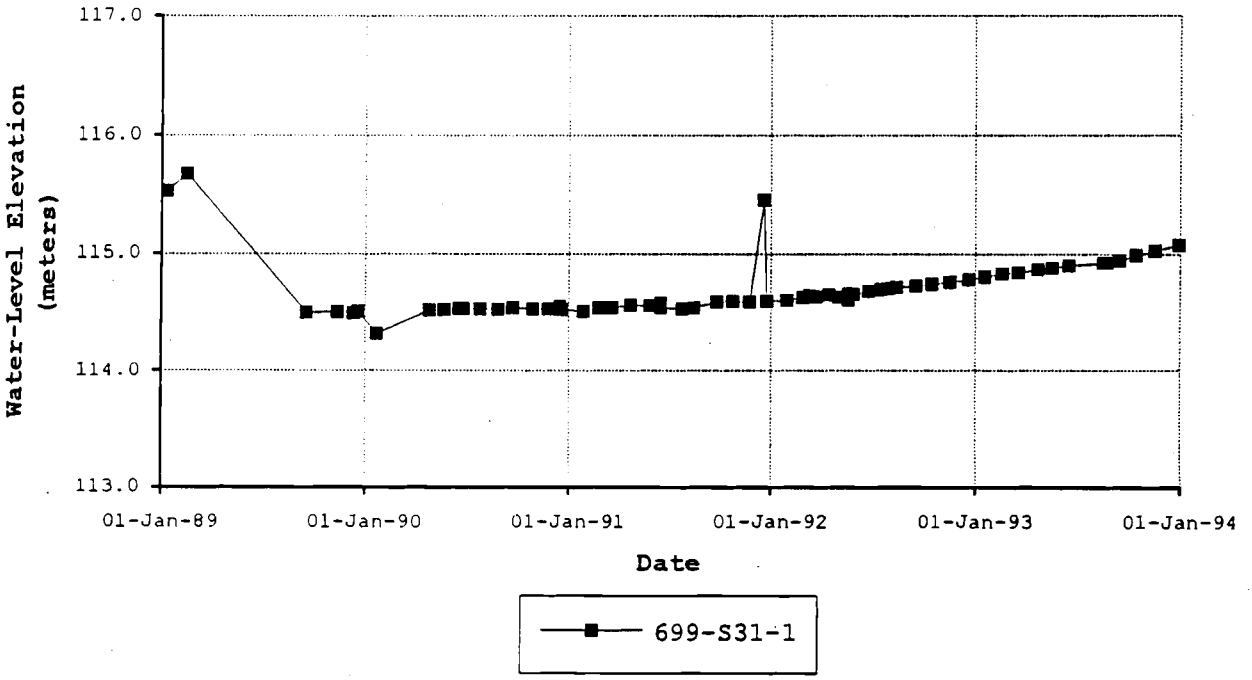

Figure 3.10. Hydrograph of Wells 699-S31-1

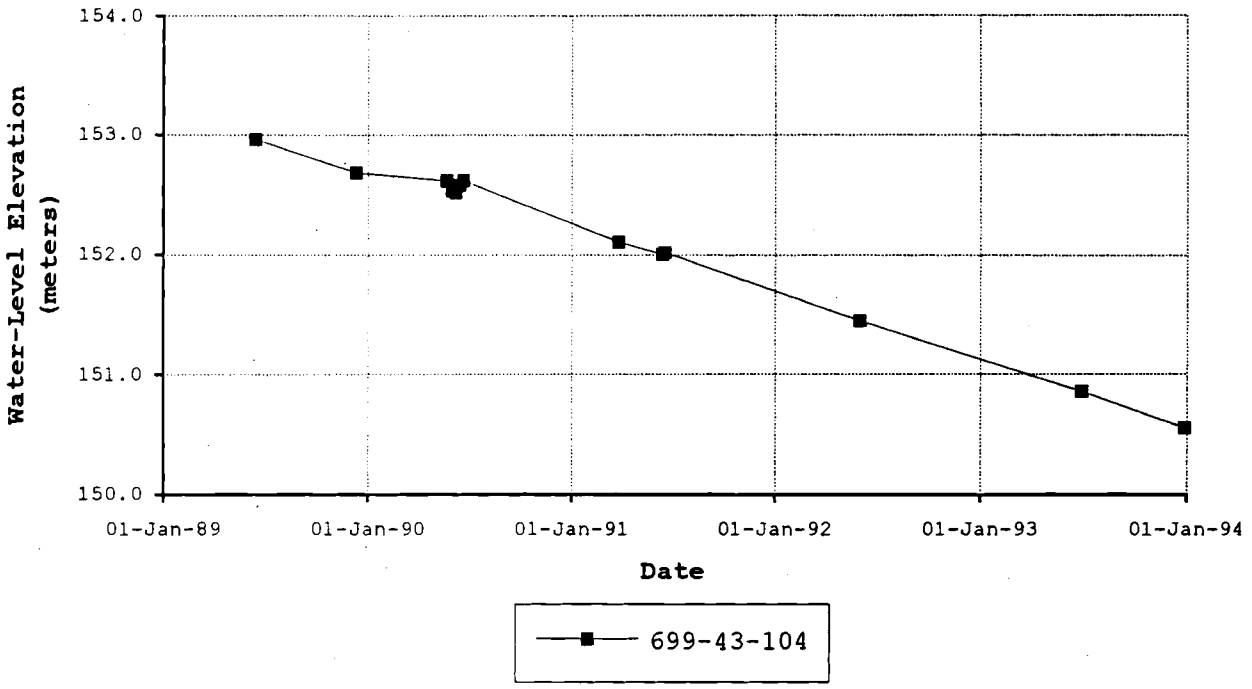

Figure 3.11. Hydrograph of Wells 699-43-104

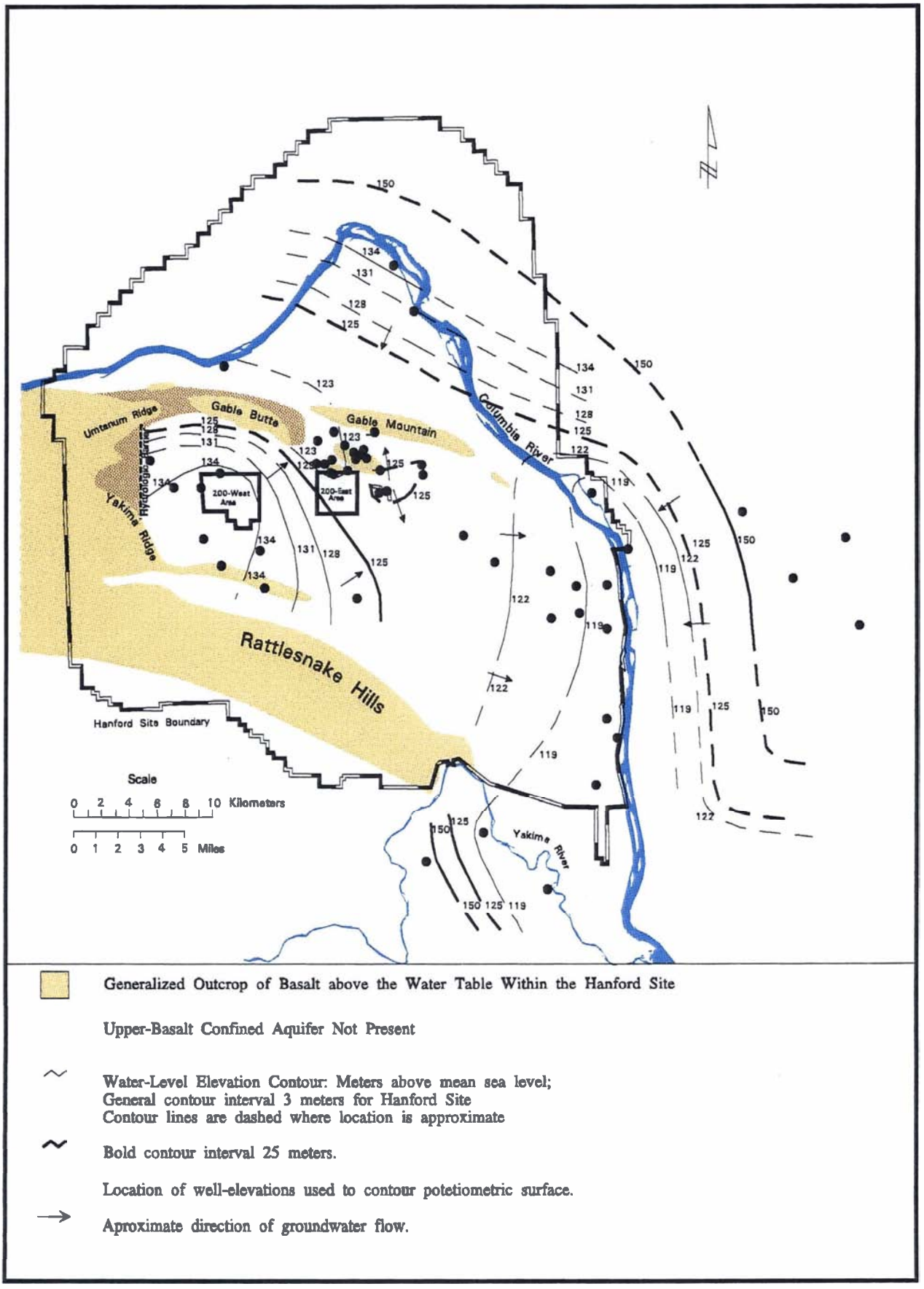

Figure 3.12. Potentiometric Map for the Upper-Basalt Confined Aquifer System - March 1993

4.0 Radiological and Chemical Ground-Water Monitoring

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4.1 Data Collection

The well network used for the Ground-Water Surveillance Project is a combination of several networks that have been designed for ground-water monitoring for RCRA-related, Operational, CERCLA-related, and specific Ground-Water Surveillance Project activities. The basis for selecting wells, the sampling frequencies, and the constituents analyzed are different for each of these projects and are determined by individual project objectives. Each year, the sampling schedules for the Operational, RCRA, and CERCLA networks are reviewed in the context of Ground-Water Surveillance Project needs, and a supplemental monitoring network is developed to meet the objectives of the Ground-Water Surveillance Project (Bisping 1993).

Analytical results for samples collected for RCRA-related, Operational, and Ground-Water Surveillance projects were obtained from International Technology Analytical Services (ITAS) in Richland, Washington, and DataChem Corporation in Salt Lake City, Utah. However, most volatile organic compound (VOC) analyses for the Ground-Water Surveillance Project were performed by PNL's internal laboratories. CERCLA-related projects used a variety of analytical laboratories. Samples for RCRA-related and Operational monitoring are collected by PNL, under contract to WHC, and the procedures are consistent with the Ground-Water Surveillance Project's sample collection. The discussion of sample collection and reporting thus applies equally to the RCRA and Operational sampling.

4.1.1 RCRA Facility-Specific Monitoring

Well networks have been established around specific waste-disposal facilities to comply with RCRA requirements. The requirements for monitoring-well design and location, constituents to be sampled, and sampling frequency are specified in RCRA regulations (40 CFR 265) and by WAC 173-303 and -304. Ground-water monitoring systems at each site consist of at least one monitoring well hydraulically upgradient and at least three monitoring wells downgradient of the facility. The location, depth, and number of wells included in the network must ensure that results obtained to evaluate the migration of contaminants to the uppermost aquifer are statistically significant. The RCRA regulations require that ground water be sampled and analyzed for 1) drinking-water parameters, 2) parameters that establish ground-water quality, and 3) parameters used as indicators of ground-water contamination. Samples are also analyzed for specific contaminants that are known to have been disposed of at the facility being monitored. The frequency of sampling for each parameter is

specified in the RCRA regulations, based on the permitting status of the facility (e.g., interim status, permitted status). Annual reports [e.g., U.S. Department of Energy, Richland Operations Office (DOE-RL) 1994a] document the results presented in quarterly reports (DOE-RL 1993d,e, 1994d,e).

4.1.2 Operational Monitoring

Operational monitoring near waste facilities in the 200 Areas is conducted by WHC to obtain information for evaluating the performance of radioactive waste-disposal sites. The highly focused "Liquids Effluents Study" was performed in 1989 and 1990 and aimed at very intensive characterization of ground water associated with key operational areas of remaining concern. The study involved 90 wells in both 200 Areas. Some of the wells were specially remediated for the purposes of the study, providing new sampling locations not previously (or at least not recently) sampled. All wells were sampled for a base set of 9 chemical constituents as well as gross alpha, gross beta, and tritium. In addition, selected radiological constituents, such as technetium-99, uranium, and plutonium, were included if operational information suggested that contamination by those species might have occurred. Results of that study have been published in two reports by WHC (1990a,b). The Operational Monitoring Program sampled approximately 117 wells in 1993. Results from the Operational Monitoring Program are entered into the Hanford Environmental Information System (HEIS) Database. Operational monitoring results and an interpretation of data collected by other programs were presented by Johnson (1993).

4.1.3 Ground-Water Surveillance Project Monitoring

The objective of ground-water surveillance monitoring is to delineate the distribution and movement of radionuclides and other potentially hazardous materials in ground water at the Hanford Site. The work is performed to satisfy the environmental surveillance requirements identified in DOE Order 5400.1 as it applies to ground water. The selections of wells, constituents for which samples are collected and analyzed, and sampling frequency are based on knowledge of waste-disposal practices and inventories, regulatory requirements, contaminant mobility, and the site hydrogeology. During 1993, approximately 770 wells were sampled for radiological and chemical constituents as part of the various Hanford ground-water investigations. The Ground-Water Surveillance Project analyzed samples from approximately 454 wells. The Ground-Water Surveillance Project has attempted to coordinate with other programs to cosample wells, avoiding redundant analyses and minimizing investigation-derived waste.

Radiological Monitoring

The radiological monitoring network was developed to monitor the extent of contamination, identify new instances of contaminant release to the ground water, and sample for selected radionuclides that may contribute to radiation dose. The Ground-Water Surveillance Project reviews and uses sample data available from other onsite monitoring programs as part of its evaluation.

Radionuclide analyses are performed by a variety of alpha-, beta-, and gamma-counting methods and by chemical analyses. Gross alpha and gross beta analyses provide indications of radionuclide distributions but may be difficult to relate to specific constituents. The Ground-Water Surveillance Project therefore seldom samples for gross alpha or gross beta, preferring to perform more specific tests. However, gross alpha and gross beta analyses are performed by other programs onsite, in cosampling with regulatory agencies, and by offsite investigators. Specific analytes are discussed below.

Elevated gross alpha readings in ground water on the Hanford Site generally relate to the presence of uranium and in rare instances to that of plutonium. Past monitoring for plutonium suggests that it is very immobile in ground water and hence in past years it was monitored in only a few wells near facilities suspected of receiving plutonium. These wells are all located within the 200 Areas. A major expansion of the plutonium monitoring effort in 1990 and 1991 confirmed this assessment (Evans et al. 1992a,b).

Elevated gross beta concentrations are more difficult to associate with individual radionuclides because a relatively large number of beta-emitting radionuclides have been discharged in Hanford liquid wastes. Of the beta-emitting radionuclides discharged onsite, strontium-90 has been a common contributor to elevated gross beta concentrations in ground water. Strontium-90 is therefore monitored in ground-water samples collected throughout the Hanford Site, with emphasis on the 100 and 200 Areas. Other relatively mobile beta-emitters of potential concern in the ground water are technetium-99 and iodine-129. Radioactive decay products of uranium also contribute to gross beta concentrations in areas with elevated uranium levels.

Tritium is the most commonly analyzed radionuclide onsite. Tritium was concentrated in certain large-volume wastes, such as reactor coolant in the 100 Areas and process condensates in the 200 Areas. The maximum extent of radionuclide contamination in ground water beneath the Hanford Site is generally delineated by the tritium plumes, because nearly all radioactive waste disposed of at Hanford contains tritium. Because tritium exists as part of the water molecule, it moves with the ground water virtually unretarded by chemical and physical interaction with dissolved constituents or aquifer materials.

The relationship between uranium activity and chemical concentration depends on the isotopic abundance in ground water. Uranium-234, uranium-235, and uranium-238 isotopic measurements on ground-water samples from the Hanford Site indicate that the relative abundances of the isotopes are similar to those in naturally occurring indigenous rocks. In this case, the total activity in picocuries per liter may be converted to concentration in micrograms per liter by multiplying by a factor of 1.49. This factor was used to produce a consistent set of units for the interpretations that follow.

Chemical Monitoring

Many well samples collected in 1993 were analyzed for potentially hazardous chemical (non-radioactive) constituents. Wells selected for chemical analysis were chosen primarily for their proximity to known active and inactive chemical disposal areas in the 100, 200, and 600 Areas, on the basis of the compiled waste inventories (Stenner et al. 1988), and on the basis of knowledge of contaminant distributions from prior sampling events. The constituents analyzed by the RCRA and CERCLA programs were selected based on regulatory requirements as well as known contaminants.

Nitrate is monitored in most of the wells sampled. Nitrate, which is mobile in ground water, was present in many of the waste streams disposed of to the ground and, like tritium, can be used to help define the extent of contamination in Hanford aquifers. Extensive historical records for nitrate also exist. Other chemicals and radionuclides related to Site operations that are potential ground-water contaminants are listed in Table 4.1. Ground-water samples collected from wells located in or near areas of known or suspected ground-water contamination are analyzed for appropriate hazardous constituents (Table 4.2). In addition, geochemical indicator parameters, such as pH, major cations, and major anions, are often also analyzed in the same samples as an aid to interpretation and for use in constructing ion balances needed for quality control checks on analytical data.

4.1.4 Monitoring Network

The ground-water monitoring network for 1993 is shown in Figure 4.1. Detailed maps of monitoring-well locations for the 100-B/C, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, 200-West, 300, 400, 600, and Richland North areas are included in Appendix C.

Each fall, the ground-water monitoring network is developed for the next calendar year's monitoring. Details of the 1993 planned network were published with the sampling plans for other aspects of the Environmental Surveillance Program in a report by Bisping (1993). The network is based on the historical monitoring efforts of this project, as well as any relevant new items. The wells in the monitoring network are chosen to track the concentrations and extent of known ground-water plumes, to monitor concentrations upgradient of source areas and at the perimeter of the Site, to identify emerging or inadequately characterized ground-water quality problems, and to address specific questions regarding ground-water fate and transport. The Ground-Water Surveillance Project's monitoring is coordinated as much as practical with the other ground-water sampling activities onsite. Sampling for RCRA compliance is scheduled on a fiscal-year basis and results are made available to the Ground-Water Surveillance Project. Therefore, the Ground-Water Surveillance Project avoids duplication of sample analysis at wells used by the RCRA program. Sampling for the additional constituents needed for the Ground-Water Surveillance Project is coordinated with the RCRA sampling. Coordination with sampling for CERCLA compliance is somewhat more complex because the CERCLA-related sampling plans are frequently changed on short notice. Coordination with CERCLA-related sampling is accomplished through informal discussions with CERCLA operable unit managers.

Modifications to the monitoring network are made throughout the year as needed. Wells sampled and constituent lists may change in response to changes in other sampling programs. Additional sampling needs identified during the year are incorporated in the schedule. These changes are documented in the project files. Scheduled wells may be found to be unsampleable and are dropped from the schedule.

4.1.5 Sample Collection and Reporting

Approximately 454 wells across the Hanford Site were visited during 1993 in support of the Ground-Water Surveillance Project. Each year, the list of wells in the sampling network to be sampled over the upcoming year is submitted to the Sample Scheduling task leader, who integrates the requests with those of other well-sampling programs and develops a yearly sampling schedule and a list of constituents for collection. The schedule and associated environmental tracking documentation, as well as laboratory contractual documentation, are forwarded to the Sample Set Preparation staff, who prepare the field sampling kits.

Field sampling kits include chain-of-custody forms for sample tracking, field record forms for well information, and sample analysis requests for the laboratory. Included with the documentation are the sample containers (with appropriate preservatives if necessary) for the samples to be collected from each well. Several types of chemical preservatives are used in the field sampling kits. Acids, bases, or other chemical additives are added to specific bottles to preserve chemical components contained in the collected samples.

Once the kits are ready, the environmental field staff go into the field to collect the samples requested. The field staff collect well samples from three types of ground-water wells on the Hanford Site: wells that require the use of bailers, wells equipped with pneumatic Hydrostar pumps, and wells with electric submersible pumps. Collected samples are packaged for transport to the analytical laboratory in ice chests. The ice chests contain either wet ice or "blue ice" to cool the samples as soon after collection as possible, according to recommended preservation protocol contained in EPA guidance manuals (e.g., EPA 1986a). Samples stored at PNL facilities before delivery to the labs are kept at $4 \pm 2°C$.

When transport packaging activities are complete, the environmental field staff submit the samples to the appropriate laboratory; some samples go to technical staff within PNL but the majority are delivered to two contractually arranged analytical laboratories for analysis of chemical constituents and radionuclides. Results from the analytical laboratories are typically returned to PNL within 25 to 30 working days. The data are then reviewed by project staff.

All field sampling and analysis staff receive extensive procedural training consistent with accepted ground-water collection and handling standards and cross training with respect to their area of expertise. The basis for most procedures is EPA SW-846 (EPA 1986b) sample handling, documentation, and analysis protocol. Operational considerations with respect to site-specific area access on the

Hanford Site are included in training requirements. Since the same staff is supporting RCRA compliance sampling activities, sitewide surveillance procedures are consistent with RCRA sampling protocol. These procedures are documented in PNL's procedures for ground-water investigations.

Because of the large number of wells sampled by all programs on the Hanford Site, a proactive purge-water management system is in place for the site contractors, including PNL, WHC, and ICF Kaiser. The DOE, EPA, and the Washington State Department of Ecology (Ecology) jointly developed a purge-water management strategy, which specifies criteria for containment of purge water that contains constituents above an agreed-upon level. In conjunction with WHC, PNL actively monitors constituent concentrations from the various wells across the site and, when required, the purge water generated in sampling a well is contained in a special purge-water tank truck. When the truck is filled, it is emptied at the Liquid Effluent Retention Facility, from which the water is ultimately disposed by WHC.

The purge-water management strategy entails a review of data to update the list of wells requiring containment and to identify wells that can be removed from the containment list. This review utilizes the HEIS database, which is the primary storage system for the data received from the analytical laboratories.

Samples submitted to the analytical laboratory for analysis are tracked for anticipated receipt of data. When the data are received, several contractual compliance evaluations are performed immediately. These include checks for analytical completeness, whether requirements for turnaround and holding times were met, whether the data were provided in the proper format, and whether any incident reports were submitted for the samples. Once these checks are complete, the information is forwarded to the project staff for technical review and use. Electronic copies of the information are forwarded to the project staff for eventual incorporation into the HEIS database.

4.1.6 Monitoring-Well Design and Maintenance

Most monitoring wells on the Hanford Site are 10, 15, or 20 cm (4, 6, or 8 in.) in diameter and are constructed of steel casing. Several small-diameter [5-cm (2-in.)] piezometers are sampled for radionuclides only. Most monitoring wells for the unconfined aquifer are completed with well screens or perforated casing in the upper 3 to 6 m (10 to 20 ft) of the aquifer. Completion at the water table allows collection of samples near the top of the aquifer, which is where maximum concentrations for radionuclides are generally found on the Hanford Site (Eddy et al. 1978). Monitoring wells for the confined aquifer have screens, perforated casing, or an open hole within the monitored horizon.

Maintenance of wells and pumps is essential to the collection of acceptable ground-water samples. Maintenance is scheduled so that the wells in the Ground-Water Surveillance Project network are cleaned and the pumps replaced or cleaned at least once every five years. This maintenance includes

scouring the casing wall and removing sediment from the bottom of the well, and it is performed by a drilling subcontractor. Over time, the cost of this maintenance is much less than the cost of repairing or rebuilding a well that has not been maintained.

4.1.7 Sample Analysis

Holding Times

Chemical constituent concentrations in ground-water samples are required to be determined within a specified time frame or "holding time" from the time of collection to the time of analysis or preparation. Samples must be analyzed within this time frame, or the concentration of the constituents of concern will be compromised by decomposition or chemical change. Samples are also refrigerated to slow the chemical changes within the sample matrix. For EPA SW-846 methods (EPA 1986b), the holding time is 14 days for volatile organic analysis, 7 days before extraction and 40 days after extraction for semivolatile analysis, 14 days for cyanide analysis, and 6 months for inductively coupled plasma (ICP) analysis of metals. As required by ASTM (1986) and O'Dell et al. (1984) methodology, holding times are 48 hours for the determination of nitrate, nitrite, and phosphate and 28 days for the determination of chloride, bromide, fluoride, sulfate, and ammonium. There is no designated holding time for radiochemical constituents because they do not change chemically or decompose under ambient temperatures.

Of the 897 chemical constituent analyses conducted specifically for the Ground-Water Surveillance Project in 1993, only one of the 225 volatile organic carbon analyses was not performed within the specified holding time. No other holding times were determined to have been violated.

Analytical Methods

The methodology for analysis of chemical constituents conforms to EPA SW-846 *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1986b), the *Annual Book of ASTM Standards* (ASTM 1986), EPA *Methods for Chemical Analysis of Water and Wastes* (EPA 1982), or other EPA methods. The methodology used for analysis of radiochemical constituents is developed by the analyzing laboratory and recognized as acceptable procedures within the technical radiochemical industry. The methodologies used to obtain routine data results for the Ground-Water Surveillance Project samples are briefly described below.

Chemical Analyses

Common anionic inorganic species in ground-water samples are analyzed using ion chromatography. Metal species are generally analyzed by ICP. Volatile organic constituents for the Ground-Water Surveillance Project are typically analyzed by gas chromatography (GC) with a combination of chemical detectors, although gas chromatography/mass spectrometry (GC/MS) is also used in some instances. The GC methods provide a lower detection limit than GC/MS, but the positive identification

of specific constituents is more certain with GC/MS. Experience with site plumes has not indicated any problems of misidentifying the GC peaks associated with contaminants of concern.

Volatile Organic Compounds

VOCs were analyzed by SW-846 Method 8010/8020, SW-846 Method 8240, or EPA Method 502.2. VOCs are extracted from the water sample through a purge-and-trap system [e.g., SW-846 Method 5030 (EPA 1986b)]. Purged sample components are trapped in a tube containing suitable sorbent materials. When purging is complete, the sorbent tube is heated and backflushed with helium to desorb trapped sample components onto a GC column. The column separates the analytes, which are then detected with a photoionization detector and a halogen-specific detector placed in series for Methods 8010/8020 and 502.2. For Method 8240, the compounds are identified and quantified using a mass-spectrometer.

Semivolatile Organic Compounds

Semivolatile organic compounds analyzed by SW-846 Method 8270 are extracted into methylene chloride, eluted from a GC fused-silica capillary column, and analyzed via GC/MS. Polynuclear aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, and phenols (including nitrophenols) can be analyzed using this methodology.

Cyanide

Cyanide is analyzed by SW-846 Method 9010 or 9012 (EPA 1986b). The sample is acidified, converting any cyanide to hydrocyanic acid. The sample is then distilled and the hydrocyanic acid is trapped in an absorber-scrubber of sodium hydroxide solution. The cyanide ion is converted to cyanogen chloride with Chloramine-T, and color formation is achieved through the addition of pyridine-barbituric acid. The cyanide concentration is then determined by either colorimetry or automated UV colorimetry.

ICP Metals Analysis

Samples are acid-digested before analysis by SW-846 Method 6010 (EPA 1986b).

Alkalinity

The alkalinity of a sample is determined using the method described in ASTM D1067A, the *Annual Book of ASTM Standards* (ASTM 1986), or EPA's Method 310.2 (EPA 1982). These are calorimetric methods using methyl orange indicator.

Anions

The anions nitrate, nitrite, bromide, chloride, fluoride, phosphate, and sulfate are determined using the methodology described in ASTM D4327-88, the *Annual Book of ASTM Standards* (ASTM 1986), or EPA Method 300.0 (O'Dell et al. 1984). The sample is introduced into an ion chromatograph, and the anions of interest are separated and measured.

Radiological Analyses

Gross Alpha and Gross Beta

Gross alpha and gross beta are determined by SW-846 Method 9310 (EPA 1986b). An aliquot of water is evaporated onto a stainless steel counting planchet. The residue is dried to constant weight and counted for alpha and beta radioactivity. Activity is determined using a standardized counting efficiency vs. sample solids curve for the detector system. Efficiencies are determined by using americium-241 and strontium/yttrium-90 certified standards.

Gamma Spectrometry

Gamma scans provide a quantitative assay for a large number of gamma-emitting isotopes with a range of half-lives. Because these assays are performed by high-resolution counting techniques, it is possible to identify isotopes of interest with a high degree of confidence. In addition, a software library search can be used to identify unknowns. Isotopes routinely reported include cesium-137, cobalt-60, ruthenium-106, and antimony-125; numerous other isotopes are reported when detected.

Samples are counted directly using an intrinsic (hyperpure) germanium or lithium-drifted germanium detector. Isotopes with gamma-ray energies from 60 to 2000 KeV are detected. Activity concentrations are determined using a Nuclear Data computer system supplied with a library of isotopes.

Total Uranium

Total uranium analyses are generally performed by fluorophotometry but may also be performed by alpha-counting determinations of individual isotopes for activity. The activity is then converted to mass determinations using a conversion factor of 1.49.

In the fluorophometry method, the sample is evaporated and fused with sodium and lithium fluoride flux. The yellow-green uranium fluorescence is then measured using a fluorophotometer. A uranium-232 tracer is used to determine recovery from the purification process, and a natural uranium standard addition is used to adjust for interferences and quantify sample reading.

Uranium Isotopes

Uranium is separated from thorium, radium, and lead on a hydrochloric acid anion-exchange resin column; iron is removed by passing the sample through an nitric acid anion-exchange resin column. The uranium fraction is eluted and electrodeposited on a disc for alpha spectrometry counting.

Tritium

Sodium hydroxide is added to the sample. The alkaline sample is then distilled and a fraction (5 ml) is mixed with scintillation cocktail, allowed to sit while the chemiluminescence decays, and then counted by liquid-scintillation instrumentation.

Low-Level Tritium

The sample is distilled in the presence of potassium permanganate to eliminate solids and organic material that may cause quenching. The sample is then enriched in a basic medium by electrolysis to a small volume. The enriched volume is transferred to a liquid-scintillation vial with scintillation cocktail and allowed to set for 24 hours while the chemiluminescence decays and temperature equilibrium is reached. It is then counted by liquid-scintillation instrumentation.

Technetium-99

The samples are wet ashed with nitric acid and hydrogen peroxide to destroy organic material in the sample. Actinides, lanthinides, alkaline earths, transition metals, and lead are removed through precipitation as hydroxides and carbonates. Technetium as the pertechnetate ion is adsorbed from a weak nitric acid solution on a strongly basic anion-exchange resin column. The technetium is then eluted with a stronger nitric acid solution and counted by liquid-scintillation beta counting.

Strontium-90

Samples are precipitated first as a nitrate and then as a carbonate. Calcium, barium, radium, and lead are removed by co-precipitation on barium chromate. Iron and other fission products are removed through hydroxide scavenging. The gravimetric yield of carrier (or strontium-85 tracer yield) is determined along with the strontium-89 and strontium-90 activities by beta-counting following final carbonate precipitation. Yttrium-90 is then separated from the strontium by hydroxide and oxalate precipitations. The yttrium oxalate is converted to yttrium oxide, weighed for chemical recovery, and counted by beta-proportional counting for activity.

Americium-241

Americium and curium are concentrated in the sample by coprecipitation on ferric hydroxide. Plutonium and thorium are separated from the americium and curium as the sample is passed through

an anion-exchange resin column conditioned with dilute nitric acid. The iron is then separated from the americium and curium by coprecipitation of the americium and curium on calcium oxalate. The americium and curium are then extracted into a bidentate organophosphorus solvent (DDCP) from a nitric acid solution and then back-extracted with weak nitric acid. Traces of iron, thorium, and any organic residue are removed by passing the solution through a cation-exchange resin column. The americium and curium are eluted from the cation-exchange resin column with dilute hydrochloric acid, electrodeposited or precipitated on a counting disk, and counted by alpha spectrometry.

Plutonium Isotopes

The sample is acidified with nitric acid, the plutonium oxidation state is adjusted to +4 with sodium nitrite, and the solution is loaded onto an anion-exchange resin column. The plutonium is eluted with hydrochloric acid and ammonium iodide. The sample is electrodeposited or coprecipitated on a counting disc and the activity counted by alpha spectrometry.

Iodine-129

Iodine-129 analyses present a particular challenge because of the need for especially sensitive measurement. The iodine-129 drinking-water standard (DWS) is 1 pCi/L -- the lowest for any radionuclide. The contractual detection limit [referred to as the "minimum detectable concentration" (MDC)] is currently 1 pCi/L for the most sensitive method used by the primary radiological laboratory.

Iodine isotopes are first separated from interfering radioactive isotopes by oxidation to iodine (I_2) with sodium nitrite and then extracted into carbon tetrachloride from dilute acid media. The iodine is next reduced to iodide with sodium bisulfite. It is then back-extracted into water, precipitated as silver iodide, and counted on a low-energy photon detector. Chemical yield is determined gravimetrically.

4.1.8 Data Management

The data management task of the Ground-Water Surveillance Project is responsible for making sure that data for the project are made accessible in the HEIS database. This database resides on a Sequent® S27 UNIX-based multiprocessor computer; ORACLE® is the database software, and Uniface® is the user interface software.

Several types of environmental data are stored in the HEIS database. Those stored and maintained by the Ground-Water Surveillance Project include analytical results of ground-water samples collected from wells on the Hanford Site, hydraulic head measurements at the wells, and well information, such as surveyed elevations. By far the largest group of data is the ground-water analytical results.

The majority of the analytical results are received from two laboratories that are under subcontract to PNL; these are DataChem Corporation in Salt Lake City, Utah, and ITAS in Richland, Washington.

Data are delivered from these two laboratories on electronic media in a format specified by the contracts. The electronic media can be loaded into HEIS using software written and maintained by HEIS personnel. Some analyses are also performed at secondary laboratories, some within PNL and some outside. The data from these laboratories, along with field measurements such as pH and specific conductance, are received in hard-copy form and entered manually into the database using Uniface® entry screens. The manually entered data are verified after entry by comparison to the hard copies.

The HEIS programmers and HEIS data owners ensure database integrity and data consistency through membership in the HEIS Configuration Control Board and other ad hoc groups. The HEIS personnel are responsible for maintaining certain data tables central to the operation of HEIS.

4.2 Analytical Findings

Results of the Ground-Water Surveillance Project's monitoring are discussed in detail in Chapter 5. The HEIS database is the central repository for all ground-water monitoring results obtained onsite. The interpretations presented here are based on the data available in the HEIS database at the time of the interpretation. However, there is some lag time in entering data into the HEIS database and for data verification or validation, so all 1993 data may not be represented. The amount of lag time depends on the projects involved and the form in which the data were received. Additional sources of data include the RCRA quarterly reports (DOE-RL 1993d,e; 1994d,e).

4.2.1 Maximum Contaminant Levels and Derived Concentration Guides

Maximum contaminant levels (MCLs) and derived concentration guides (DCGs) provide useful reference concentrations for comparison with the results of ground-water analyses. The MCLs for constituents of concern at the Hanford Site are presented in Table 4.3. These concentration levels are discussed below.

MCLs are federal or state-mandated DWSs. An MCL is defined as the maximum level of a constituent that can be allowed in drinking water before corrective action must be taken. The MCLs are generally set by considering available data on the risk associated with lifetime ingestion of 2.0 L/day of water, the available treatment technology, and economic factors. As a result, the MCL may not be directly related to the estimated health risk. Secondary DWSs are based on aesthetic rather than health considerations and are generally not legally enforceable. Monitoring wells are constructed to different standards from those for drinking-water production wells and monitoring wells are generally purged for only a relatively short time before sampling which complicates the application of standards. This is mainly a problem for metal analyses, because the metals may be sorbed to particulate matter in the well-bore. DWSs are defined for samples of water as it would be consumed, so unfiltered samples from wells are generally compared to MCLs. Monitoring wells are likely to produce a greater proportion of particulate matter than production wells, so the samples may not be representative of what would be found for water supplies. Filtered samples are more representative of the dissolved load

and are better suited to interpretation of transport geochemistry. Therefore, most Ground-Water Surveillance Project analyses for metals were performed on filtered samples. Samples for radiological analysis were generally unfiltered, because this provides more sensitivity for detecting radionuclides, which may be partially sorbed onto particulate matter.

Specific MCLs have not been set for most anthropogenic radionuclides. The MCLs for beta- and photon-emitters are based on an annual dose of 4 mrem/yr to the affected organ. The levels of individual radionuclides that are calculated to result in this dose are shown in Table 4.3. The levels may be additive, however, when more than one radionuclide is present.

DCGs are calculated only for radionuclides and are based on a whole body dose of 100 mrem/yr. Thus DCGs are less stringent than MCLs. DCGs are presented in DOE Order 5400.5 (DOE 1990) and summarized in Table 4.4.

4.2.2 Assessment of the Monitoring Network

Most major ground-water contaminant plumes on the Site are now believed to be identified and reasonably well characterized; however, some uncertainties remain. The most serious limitation to knowledge comes from the nature of the well network itself, because the wells are irregularly distributed and generally do not provide sufficient spatial density for optimal contouring. Areas where the well density is insufficient for accurate plume definition include 1) the area north of the BY Cribs in the 200-East Area; 2) the area south of the BC Cribs near the 200-East Area; 3) the area between the 200-East and 200-West Areas; 4) the eastern portion of the plumes originating in the U1/U2 Cribs in the 200-West Area; 5) the area of chromium contamination between the 100-D Area and 100-H Area; and 6) the 100-F Area and vicinity. With the recent onset of drilling activities associated with CERCLA, this situation is improving, and eventually a sufficient number of wells will have been sampled often enough to characterize at least some of these areas.

The monitoring network is being adversely impacted by declining water levels in the operational areas. The termination of operational activities has resulted in decreasing discharges to disposal facilities in the operational areas, and the water table is declining towards pre-operational levels. This has resulted in several monitoring wells becoming impossible to sample because water levels have declined below the pump intake or because yield is insufficient. An investigation is being conducted in 1994 to assess the impact of the declining water levels on the monitoring network and to predict the loss of monitoring locations.

Monitoring data indicate that the zones of contamination generally are found near the water table in the unconfined aquifer. There are certain areas of the site where this does not hold and where monitoring data are insufficient for determining the vertical extent of contaminant plumes. Carbon tetrachloride disposal in the 200-West Area may have caused transport of dense non-aqueous phase liquid carbon tetrachloride into the aquifer. The presence or depth of penetration of any non-aqueous phase liquid source is not known and the depth of ground-water contamination is poorly defined by the

present monitoring network. Disposal of high total-dissolved-solid waste in the BY Cribs in the 200-East Area may have produced density-driven flow to significant depths in the aquifer (Smith 1980). Monitoring of the bottom of the unconfined aquifer in the 200-East Area is sparse. The sparseness of 3-dimensional monitoring data also complicates interpretation of contamination in the other operational areas.

4.2.3 Interpretation of Analytical Results

Each analysis of a ground-water sample provides information on the composition of ground water at one time at one location in the aquifer. Uncertainty in the analysis results from a number of sources, some of which are discussed below. Given these uncertainties, several techniques are used in interpreting the sample results, and these are also discussed in this section.

The chemical composition of ground water fluctuates with time because of differences in the contaminant source, recharge, or flow field. The range of this fluctuation can be estimated by taking many samples, but there is a practical limit to the number that can be taken. Comparison of results through time helps in interpreting the natural variability.

Sampling techniques are designed to provide a sample that is reasonably representative of the aquifer concentration when the sample is taken. However, there are limitations to our ability to collect representative samples or even to define precisely the volume of aquifer that is represented in the sample. Proper well construction, well purging, sample preservation, and in some instances filtering are used to help ensure that samples are consistent and representative. Careful sample-labeling protocols, chain-of-custody documentation, and bottle preparation prevent many gross errors in sample results. Duplicate samples and field blanks help in assessing the sampling procedure.

Uncertainties are also inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory as well as during sampling. Such errors include transcription errors, calculation errors, mislabeling of results, and other errors that result from failing to follow established procedures. Often these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review procedures are used to identify and correct gross errors.

Random errors are unavoidably introduced in the analytical procedures. Usually there are too few replicate analyses to assess the overall random error. Instruments for analyzing radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted out. The nature of radioactive decay and the instrument design result in a random counting error, which is reported with the analytical result. Generally, sample results that are less than the counting error are an indication that the constituent was not detected. The counting methods may also result in the reporting of results that are less than zero. Although they are physically impossible, the negative values may be of use for some statistical analyses. In this report, negative values are treated simply as representing levels less than the detection limit.

Systematic errors may result from inaccurate instrument calibration, improper standard or sample preparation, chemical interferences in analytical techniques, or faulty sampling methodology and sample handling. Sample and laboratory protocols have therefore been designed to minimize systematic errors. The laboratories used by the Ground-Water Surveillance Project and other monitoring programs participate in interlaboratory comparisons, in which many laboratories analyze blind samples prepared by the EPA. The laboratories used have compared favorably with other laboratories, indicating that the level of systematic error from many sources is small enough to be acceptable.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis, in turn, aids in refining the conceptual model of the chemical transport.

The plume maps presented in this report are diagrammatic representations of the interpretation of the ground-water chemistry at the Hanford Site. Although analytical data are available only for specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity. The contour maps are necessarily simplified representations of plume geometry given the map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Nevertheless, plume mapping is a powerful tool, reflecting concentrations in surrounding wells, ground-water flow, site geology, and other available information. This combination of information minimizes the impact of uncertainty or error in any particular sample.

Plume maps in this report were prepared using the averages for 1993 sample analyses from each well. Values below detection limits were considered to be zero in calculating averages. In a few instances, data believed to represent gross errors in sample collection and analysis were removed from the data set before averaging. Sample data from prior years were used in some cases to provide further information for areas that were not sampled in 1993. The data were contoured using a combination of computerized algorithms and hand contouring.

4.3 Quality Control

Quality control practices encompass all aspects of the Ground-Water Surveillance Project. Samples are analyzed according to documented standard analytical procedures. The quality of analytical data is verified by a continuing program of internal laboratory quality control, participation in interlaboratory cross-checks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

Quality control for the Ground-Water Surveillance Project also includes procedures and protocols for 1) documenting instrument calibrations, 2) conducting activities in the field and laboratory, 3) maintaining wells to ensure that representative samples are collected, and 4) using dedicated sampling pumps to avoid cross-contamination.

Comprehensive quality assurance programs, including various quality control practices, are maintained to ensure the quality of data collected through the Ground-Water Surveillance Project. Quality assurance plans are maintained for all surveillance activities and define the appropriate controls and documentation required to meet the guidance of DOE orders and the American Society of Mechanical Engineers (ASME) as represented by their NQA-1 quality assurance program document (ASME 1989), which is the U.S. nuclear industry's standard.

4.3.1 Project Management

Site surveillance implements the requirements of DOE-RL Order RL 5700.6C, "Quality Assurance," and is based on ASME NQA-1 (ASME 1989). The program is defined in PNL's quality assurance manual. The manual provides guidance for implementation by addressing 18 quality assurance elements:

1. Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures, and Drawings
6. Document Control
7. Control of Purchased Items and Services
8. Identification and Control of Items
9. Control of Processes
10. Inspection
11. Test Control
12. Control of Measuring and Test Equipment
13. Handling, Storage, and Shipping
14. Inspection, Test, and Operation Status
15. Control of Nonconforming Items
16. Corrective Action
17. Quality Assurance Records
18. Audits

The Ground-Water Surveillance Project's current quality assurance plan describes specific quality assurance elements and how they apply to the project. All plans are approved by PNL's independent quality assurance organization, which conducts surveillances and audits to verify compliance with the plans. Work performed under contracts with external groups, such as sample analysis, must meet the

same quality assurance requirements. Potential suppliers of equipment and services may be audited before contracts for services are awarded or before the approval of purchase of materials that could have a significant impact on a project's quality.

4.3.2 Sample Collection

Samples for ground-water monitoring are collected by trained staff according to approved and documented procedures. Chain-of-custody procedures (EPA 1986b) include the use of evidence tape in sealing sample bottles to maintain the integrity of the samples during shipping. A field quality control program, designed specifically for the Ground-Water Surveillance Project, was initiated in 1993. Full trip blanks and field duplicates were obtained during field operations.

The following radiochemical constituents were not within the control limits (i.e., were not below total propagated error) for individual full trip blanks; associated contract MDCs are also listed:

Constituent	Result (pCi/L)	Total Propagated Error (pCi/L)	Contract MDC (pCi/L)
Technetium-99	243	206	15
Tritium	286	212	500
Tritium	230	205	500
Uranium	0.653	0.283	0.1
Uranium	0.323	0.177	0.1
Uranium	0.269	0.174	0.1
Uranium	6.07	1.81	0.1
Uranium	5.10	1.53	0.1

The recurring uranium concentration problem will be investigated to determine why control limits are not being met.

Those duplicate field results not meeting the ±20% relative percent difference or ± method detection level (MDL) criteria are listed below:

Metal	Result	Duplicate Result	Contract MDC
Barium	47 μg/L	94 μg/L	0.11 μg/L
Calcium	23,000 μg/L	46,000 μg/L	14.5 μg/L
Iron	49 μg/L	93 μg/L	10.5 μg/L
Magnesium	6,100 μg/L	12,000 μg/L	31 μg/L
Manganese	78 μg/L	160 μg/L	1.74 μg/L
Manganese	3.2 μg/L	2 μg/L	1.74 μg/L
Nitrate	300 μg/L	400 μg/L	44 μg/L
Potassium	4,800 μg/L	9,700 μg/L	223 μg/L
Sodium	22,000 μg/L	43,000 μg/L	45.4 μg/L
Uranium	0.767 pCi/L	0.601 pCi/L	0.32 pCi/L
Zinc	20 μg/L	10 μg/L	3.44 μg/L

No corrective action for duplicate results is being taken at this time. A larger database is needed to establish trends for a constituent problem to be apparent.

4.3.3 Analytical Results

Routine analyses of hazardous and nonhazardous chemicals in Ground-Water Surveillance Project water samples were performed by DataChem Corporation of Salt Lake City, Utah, and by PNL internal laboratories. DataChem participates in the EPA Water Pollution and Water Supply Performance Evaluation Studies and maintains an internal quality control program that meets the requirements of EPA SW-846 (EPA 1986b) and that PNL audits and reviews. In addition, PNL submitted quality control blind spiked samples for analysis.

Routine radiochemical analyses of Ground-Water Surveillance Project samples were performed by ITAS in Richland, Washington. ITAS's Richland laboratory participates in DOE's quality assessment program and EPA's Laboratory Intercomparison Studies. In addition, a quality control blind spike sample program was conducted. ITAS's Richland laboratory also maintains an internal quality control program, which is audited and reviewed both internally and by PNL. Additional information on these quality control efforts is provided in the following subsections.

U.S. Department of Energy and U.S. Environmental Protection Agency Comparison Studies

DataChem participated in the EPA Water Pollution and Water Supply Performance Evaluation Studies. Standard water samples were distributed as blind samples to participating laboratories. These

samples contained specific organic and inorganic analytes at concentrations that were unknown to the analyzing laboratories. After analysis, the results were submitted to EPA for comparison with known values and with those obtained by other participating laboratories. Results during the year are summarized in Table 4.5. Approximately 98% of the results during the year were within the "36 control limits" (±3 standard errors of the mean) that are typically used. This reflects excellent performance on the samples analyzed in the study.

ITAS's Richland laboratory participated in DOE's Quality Assessment Program and EPA's Laboratory Intercomparison Studies Program. These programs provide standard samples containing specific amounts of one or more radionuclides that are unknown to the participating laboratory. After sample analysis, the results were forwarded to DOE or EPA for comparison with known values and with results from other laboratories. Both EPA and DOE have established criteria for evaluating the accuracy of results (Jarvis and Siu 1981; Sanderson 1985). Summaries of the 1993 results for water samples for the programs are provided in Tables 4.4 and 4.5. All of the results during the year were within 35 control limits. This reflects excellent performance on the samples analyzed in the study.

Pacific Northwest Laboratory Evaluation

In addition to DOE and EPA interlaboratory quality control programs, a quality control program is maintained by PNL to evaluate its analytical contractors' precision and accuracy and to conduct special intercomparisons. This program includes the use of blind spiked samples and replicate samples. Blind spiked quality control samples and blanks were prepared in triplicate and submitted to check the accuracy and precision of analyses at DataChem and ITAS's Richland laboratory. Overall, 67% of DataChem's blind spiked determinations were within control limits and 82% of ITAS's blind spike determinations were within control limits (Tables 4.6 and 4.7). Blind spiked samples of VOCs were submitted but results reflected problems associated with preparation of the spiked samples and laboratory analysis. Corrective action is being taken. Other results not within ±30% of the spiked value are as follows:

- One set of blind spiked samples was spiked with about 0.5 pCi/L of iodine-129. The MDC required by the contract is 1 pCi/L. The laboratory determined about 0.7 pCi/L, which is better than required by the contract.

- The plutonium isotopic blind spiked sample for the second calendar quarter was spiked at 3.25 pCi/L, well above the contract MDC of 0.1 pCi/L. The laboratory analyzed the sample at 2 pCi/L with good precision. A referee laboratory received a similar spike of 3.25 pCi/L and analyzed the sample at 1.8 pCi/L. For the next two quarters, plutonium isotopic determinations were biased low compared to the spiked concentration. The concentration of the standard is being re-evaluated.

- The metals sample for the third quarter was spiked with 0.25 μg/L chromium. This is well below the contract required quantitation limit of 20 μg/L and the MDL of 11 μg/L. There had been an error in preparing the spiked standard; the error was remedied for the succeeding quarters.

- The fluoride blind spiked sample results have all been flagged by the analyzing laboratory as having a possible positive interference. This possibility will be evaluated with the laboratory.

- The uranium spiked sample results for the fourth quarter are considerably outside control limits. The data results are being reviewed by the laboratory.

In addition to the program, PNL participates in a quality assurance task force that is conducted by the Washington State Department of Health. Public and private organizations from Idaho, Oregon, and Washington participate in analyzing the intercomparison samples. No samples were designated for analysis in 1993 but plans for a 1994 intercomparison study are under way.

Laboratory Internal Quality Assurance Programs

Under their contracts with PNL, DataChem and ITAS are required to maintain internal quality control programs. These programs are periodically reviewed and audited for compliance both internally and by PNL. The quality control program at DataChem meets the quality control criteria of EPA SW-846 (EPA 1986b). This program requires the laboratory to maintain a system for reviewing and analyzing the results of the quality control samples to detect problems arising from contamination, inadequate calibrations, calculations, or procedure performance. MDLs are determined twice a year.

ITAS's internal quality control program involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check source and background counts, replicate and spiked sample analyses, use of matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations.

In 1993, one inspection of DataChem and one inspection of ITAS were conducted under the contracts that supported the Ground-Water Surveillance Project. These inspections documented each analytical facility's conformance with contractual requirements and provided the framework for identifying and resolving potential performance problems. Responses to audit and inspection findings were documented in writing, and corrective actions were verified by follow-up audits and inspections.

The results of the internal laboratory quality control programs are summarized by the laboratories in quarterly reports. The results of the quality control sample summary reports and the observations noted by each laboratory indicated an acceptable functioning quality control program.

Laboratory Comparisons

Additional comparisons are conducted on individual samples. The Washington State Department of Health cosampled 22 ground-water wells during 1993. The data will be made available in the Washington State Department of Health report, *Environmental Radiation 1993 Annual Report, 32nd Edition.*

4.4 Summary of Radiological and Chemical Constituents in Ground Water

In this section, the most important constituents of concern are summarized, and the source areas for each are discussed briefly. Chapter 5 of this report discusses individual ground-water contamination plumes in relation to their probable source area or areas. The distribution of radionuclides in ground water is summarized in Figure 4.2. The distribution of hazardous chemicals in ground water is summarized in Figure 4.3.

Tritium

Tritium is the most widely distributed radiological contaminant onsite. Tritium was present in many waste streams discharged to the soil column and is the most mobile radionuclide on the Site. As a result, tritium reflects the maximum extent of contamination from Site operations in the ground water and is the radionuclide most frequently monitored at the Hanford Site.

Tritium concentrations greater than the 20,000 pCi/L DWS were detected in portions of the 100-D, 100-F, 100-K, 100-N, 200-East, 200-West, 400, and 600 Areas. Tritium at concentrations greater than the DCG were detected in the 100-K Area and 200 Areas. Tritium in the 400 and 600 Areas can be related to migration from sources in the other operational areas. In particular, tritium migration from sources near the Plutonium-Uranium Extraction (PUREX) Plant in the 200-East Area has impacted a large part of the 600 Area to the east and southeast, the 400 Area, and the northern 300 Area (Figure 4.2). This plume discharges to the Columbia River along a stretch extending from the old Hanford townsite to the 300 Area. A somewhat smaller but higher-concentration plume in the region between the 200-East and 200-West Areas has its source in the vicinity of the 200-West Area Reduction Oxidation (REDOX) Plant. This plume is relatively slow moving, as discussed in Chapter 5.

Large portions of the site north of Gable Mountain and Gable Butte have been affected by tritium from site activities. The major sources appear to be the 200-East Area, the 100-K Area, and the 100-N Area.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes generated by processing of irradiated fuel or with reactor effluent water. Cobalt-60 is normally present as a divalent cation that is strongly adsorbed on sediments onsite and so is rarely observed in ground water. Cobalt-60 is

observed onsite in an area north of the 200-East Area 216-BY Cribs and in a small area in the immediate vicinity of the 200-East Area 216-B-5 Injection Well. The cobalt-60 contamination north of the 200-East Area apparently has been mobilized by the presence of cyanide and ferrocyanide. Cobalt-60 observed in the 100-N Area appears to be related to suspended solids in the samples and is unlikely to be mobile in ground water. The moderately short half-life of cobalt-60 (5.3 years) means that its concentration onsite has been decreasing rapidly since production operations ended. Thus cobalt-60 from most source areas is unlikely to migrate offsite.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is therefore present in waste streams associated with fuel processing. It may also be released by fuel element failures during reactor operations. Concentrations of strontium-90 were above the 8 pCi/L DWS in wells in the 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, and 600 Areas. Concentrations of strontium-90 were greater than the 1,000 pCi/L DCG in the 100-N and 200-East Areas. Areas with strontium-90 above the DWS are shown in Figure 4.2. Strontium-90 is of concern due to its moderately long half-life of 28.8 years, its potential for concentrating in bone tissue, and the relatively high energy of the beta decay from the yttrium-90 daughter product.

Strontium-90 distributions have not been completely defined in each of the 100 Areas. The highest concentrations have been found in the 100-N Area. Strontium-90 is discharged from the 100-N Area to the Columbia River through seeps, which represent a potential point of public exposure. Data discussed in Chapter 5 indicate that the extent of the 100-N Area's strontium-90 plume is not increasing perceptibly at present.

Strontium-90 is detected at concentrations above the DWS in the immediate vicinity of the 216-B-5 Injection Well in the 200-East Area. Strontium-90 is also found at levels above the DWS in the immediate vicinity of cribs south of the PUREX Plant. Strontium-90 near the decommissioned Gable Mountain Pond in the 600 Area is related to disposal of waste from the 200-East Area.

Technetium-99

Technetium-99 is produced as a moderately high-yield fission product and is present in waste streams associated with fuel processing. Some technetium-99 may also be released in reactor areas by fuel element breaches. However, elevated technetium-99 concentrations are rarely observed in the reactor areas. Concentrations of technetium-99 greater than the 900-pCi/L DWS were detected in wells in the 200 Areas. Concentrations greater than the DWS also extended to portions of the 600 Area east of the 200-West Area and northwest of the 200-East Area. These locations are identified on Figure 4.2. Technetium is transported in ground water as a negatively charged (anionic) species that is highly mobile. Technetium shares some chemical characteristics with uranium and tends to "follow" uranium through the fuel-processing system. The uranium, however, is less mobile in ground water under site conditions.

Antimony-125

Antimony-125 is a moderately high-yield fission product and, in the past, was measured in a few wells in the 100-N and 100-K Areas. Concentrations measured in samples from these two areas have been as high as 305 pCi/L near the 1325-N Land Waste Disposal Facility in 1987. The DWS for antimony-125 is 300 pCi/L, and the DCG is 60,000 pCi/L. Antimony-125 was detected at levels above the DWS in only one 100-N Area well in 1993. The antimony-125 in the sample is believed to be related to high concentrations of suspended solids and not to be representative of mobile ground-water concentrations.

Iodine-129

The presence of iodine-129, a moderately low-yield fission product, in ground water is significant, because of its relatively low DWS (1 pCi/L), its potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and its long half-life (16 million years). However, its relatively low fission yield and long half-life have limited its activity in Hanford ground water. At Hanford, the main contributor of iodine-129 to ground water has been liquid discharges to cribs in the 200 Areas. Assay of that isotope by high-sensitivity, direct-counting methods requires long counting times with correspondingly low analytical throughput. The highest concentrations observed onsite are downgradient from the PUREX and REDOX Plants, in the 200-East and 200-West Areas, respectively. No iodine-129 samples were above the DCG of 500 pCi/L.

Iodine-129 is transported in ground water as the anionic I^- species. Anionic species tend to be highly mobile in ground water because their adsorption onto organic material or mineral surfaces is limited. Iodine-129 is essentially as mobile as tritium in Hanford Site ground water.

Cesium-137

Cesium-137 is produced as a high-yield fission product and is present in waste streams associated with fuel processing; it may have also been released in reactor areas by fuel element breaches. Concentrations of cesium-137 were below the detection limit (20 pCi/L) except near the 216-B-5 Injection Well. Cesium-137 is restricted to the immediate vicinity of the injection well by its extremely low mobility in ground water.

Uranium

There are numerous potential sources of uranium release at Hanford, including fuel fabrication, fuel processing, and uranium recovery from separation activities. Uranium may exist in several states, including elemental uranium, uranium oxide, and tetravalent or trivalent ions in aqueous solution. Only the hexavalent form has significant mobility in ground water -- largely as the result of carbonate complexation. Uranium mobility is thus dependent on both Eh and pH. Uranium migration at Hanford is retarded relative to that of tritium and technetium-99.

The EPA has proposed a DWS of 20 μg/L for uranium. This is in contrast to other radionuclides, for which the standards are given in picocuries per liter. The reasons for the difference are that there is evidence that uranium ingestion may cause kidney damage, which is better assessed as a chemical hazard than as a radiological hazard, and that uranium is often analyzed by a fluorescence method that is calibrated in micrograms per liter. However, uranium may also be analyzed by an alpha-counting method and some risk is associated with its radioactivity, so it is important to be able to convert between ground-water concentrations expressed in micrograms per liter and those expressed in picocuries per liter. The conversion factor depends on the proportions of uranium-234, uranium-235, and uranium-238 in the ground water. Based on a series of ground-water analyses throughout the United States, EPA considers the proposed DWS of 20 μg/L to be equivalent to a standard of 30 pCi/L. However, site-specific data for Hanford indicate that the proportion of the different uranium isotopes in ground water is nearly identical to the average proportion in natural rock. In this case, the total uranium activity in picocuries per liter should be multiplied by 1.49 to convert to the concentration in micrograms per liter, and the proposed DWS equivalent would be 13.4 pCi/L. This site-specific conversion factor provides a more stringent standard for activity data and will be used in the discussion below. It should be noted that this factor includes only alpha decays from uranium itself. Decay products contribute additional activity.

Uranium has been detected at concentrations above the DWS in the 100-F, 100-H, 200-East, 200-West, and 300 Areas. The highest concentrations detected onsite in 1993 were in the 200-West Area near the 216-U-1 and 216-U-2 cribs. An expedited response action was performed on the 300 Area Process Trenches in mid-1991 to reduce the uranium source in that area. Use of the trenches for disposal of cooling water was resumed following completion of the remedial action, although current discharges to the trenches are much lower than those in the past. As discussed in Chapter 5, the expedited response action and the reduction in discharge appear to have reduced the uranium concentrations in at least one well monitoring the 300 Area Process Trenches.

Plutonium

Concentrations of plutonium were below the detection limit in all wells sampled in 1993 except for one well near the 216-B-5 Injection Well in the 200-East Area and one well in the 200-West Area upgradient from the S-SX single shell tanks. The source of the plutonium in the 200-West Area has not been determined. Although plutonium-239/240 was detected in 1990 and 1991 in a 200-West Area well, 299-W15-8, which monitors the 216-Z-9 Crib, the well could not be sampled in 1992 or 1993 because water levels had declined below the well screen. The 216-Z-9 Crib is of concern because it received a large burden of plutonium and americium from Z Plant liquid effluent streams.

The DCG for plutonium-239 is 30 pCi/L. There is no explicit DWS for plutonium-239; however, the gross alpha DWS of 15 pCi/L would be applicable. Alternatively, if the DCG (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the DWS, 1.2 pCi/L would be the relevant guideline. Plutonium is generally considered to bind strongly to sediments and thus its mobility in the aquifer is limited.

Nitrate

Most ground-water samples collected in 1993 were analyzed for nitrate. Nitrate was measured at concentrations greater than the DWS (45 mg/L as NO_3 ion) in wells in all operational areas except the 100-B and 400 Areas.

Although nitrate is associated primarily with process condensate liquid wastes, other liquids discharged to ground also contained nitrate. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate, like tritium, can be used to define the extent of contamination because nitrate is present in many waste streams and is mobile in ground water. However, additional sources of nitrate are located offsite to the west and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 4.3. The nitrate distribution shown in Figure 4.3 is similar to that from previous evaluations.

Fluoride

Fluoride currently has a primary DWS of 4.0 mg/L and a secondary standard of 2.0 mg/L. Secondary standards are based primarily on aesthetic considerations and are not federally enforceable, although the State of Washington claims the right to require corrective action from drinking-water suppliers if secondary standards are exceeded. Both standards will be used in the discussion below; however, it should be remembered that only the primary standard is based on health considerations and that in any case the DWS is only an indication of the degree of contamination, since the area of elevated fluoride concentrations is far from any drinking-water supply. Fluoride was detected at levels above the primary DWS in the 200-West Area and above the secondary standard in the 200 Areas. Aluminum fluoride nitrate used in the 200-West Area process is a probable source of fluoride contamination.

Cyanide

The source of a cyanide plume in and directly north of the 200-East Area is believed to be wastes containing ferrocyanide that were disposed of in the BY Cribs. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed and mobilized by cyanide or ferrocyanide.

No formal DWS has been established for cyanide. A standard of 200 μg/L has been proposed by the EPA. Ferrocyanide is not specifically regulated but is commonly considered with the total cyanide because it is indistinguishable from cyanide in the standard analytical methods. However, ferrocyanide is considered far less toxic than free cyanide.

Chromium

A major source for chromium onsite was the use of sodium dichromate as a corrosion inhibitor in cooling water for the 100 Area reactors. Chromium is detectable in ground water from each of the 100 Areas but the major plumes are related to the 100-D, 100-H, and 100-K Areas. Surrounding parts of the 600 Area are also affected.

Both filtered and unfiltered samples were collected for chromium and other metals from many of the wells onsite. Unfiltered samples may contain metals present as particulate matter; filtered samples are more representative of the more mobile dissolved metals. Comparison of filtered to unfiltered samples provides a better understanding of the transport of chromium onsite. DWSs are based on unfiltered concentrations; however, differences in well construction and pumping between monitoring wells and water-supply wells make it difficult to predict potential drinking-water concentrations based on monitoring-well data. The use of stainless steel in recently constructed monitoring wells appears to have added a source of chromium in some well samples.

Carbon Tetrachloride

Carbon tetrachloride contamination was found in the unconfined aquifer beneath much of the 200-West Area. The plume extends beyond the area boundary. The contamination is principally from waste-disposal operations associated with the Z Plant, where it was used as a solvent in plutonium processing. The DWS for carbon tetrachloride is 5 μg/L.

Chloroform

The 200-West Area chloroform plume appears to be associated but not exactly coincident with the carbon tetrachloride plume. The chloroform may be a degradation product of carbon tetrachloride. The DWS for chloroform is 100 μg/L (total trihalomethanes) -- 20 times higher than that for carbon tetrachloride.

Trichloroethylene

Trichloroethylene (TCE) has a DWS of 5 μg/L. TCE was commonly used as a degreasing compound from the late 1950s through the 1970s. TCE has been detected in wells in the 100-B/C Area, 100-F Area, 100-K Area, 200-West Area, 300 Area, and the Solid Waste Landfill part of the 600 Area.

In 1993, TCE was detected at levels less than the DWS in 100-B/C Area wells and at levels above the DWS in the 100-F Area. In addition, TCE was found at levels up to 29 μg/L in well 699-77-36, west of the 100-F Area.

TCE was detected in 1993 at levels above the DWS at two locations in the 200-West Area. The first location is to the west of the T Plant. The second location is near the U Plant. TCE has been detected in the past near the REDOX Plant in the 200-West Area.

TCE and cis-1,2-dichloroethylene were found in wells monitoring the lower portion of the unconfined aquifer in the 300 Area near the North Process Pond. Cis-1,2-dichloroethylene is a product of TCE biodegradation.

Several wells at the Solid Waste Landfill located in the 600 Area contained TCE at levels close to but slightly below the DWS. Wells monitoring the Solid Waste Landfill have shown TCE concentrations above the DWS in previous years. TCE is found at levels above the DWS near Siemens Power Corporation and the Horn Rapids Landfill, which are located in the Richland North Area and the southern 600 Area.

Tetrachloroethylene

Tetrachloroethylene, also referred to as perchloroethylene, is found at levels below the DWS in a number of areas on the site, including the 200-West Area, the 300 Area, and the southern portion of the 600 Area. A number of samples from wells in the Richland North Area contained low concentrations of tetrachloroethylene. The only area where tetrachloroethylene was detected at concentrations above the DWS is the Solid Waste Landfill, where concentrations reached a maximum of 5.9 μg/L.

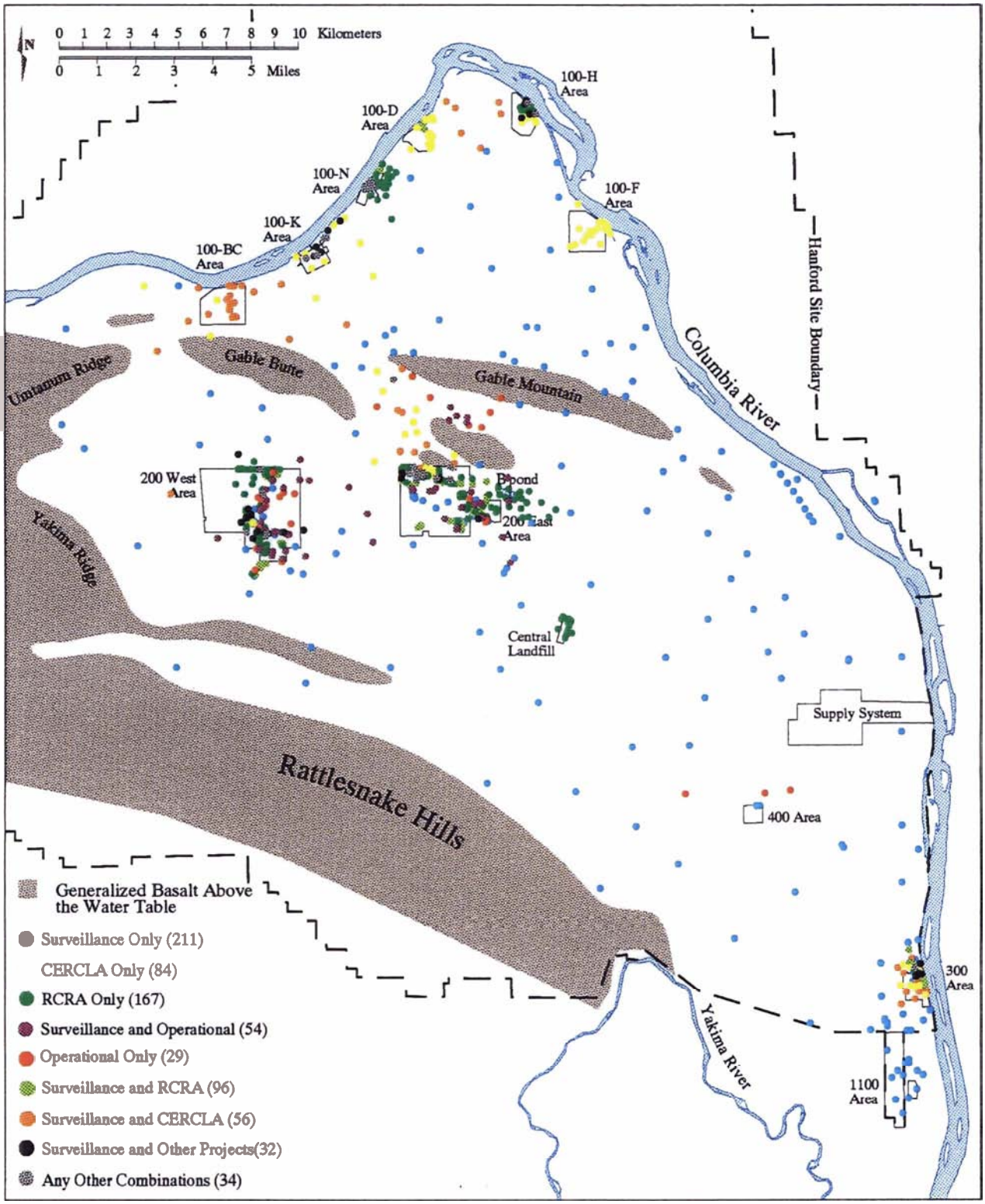


Figure 4.1. Ground-Water Monitoring-Well Network for 1993

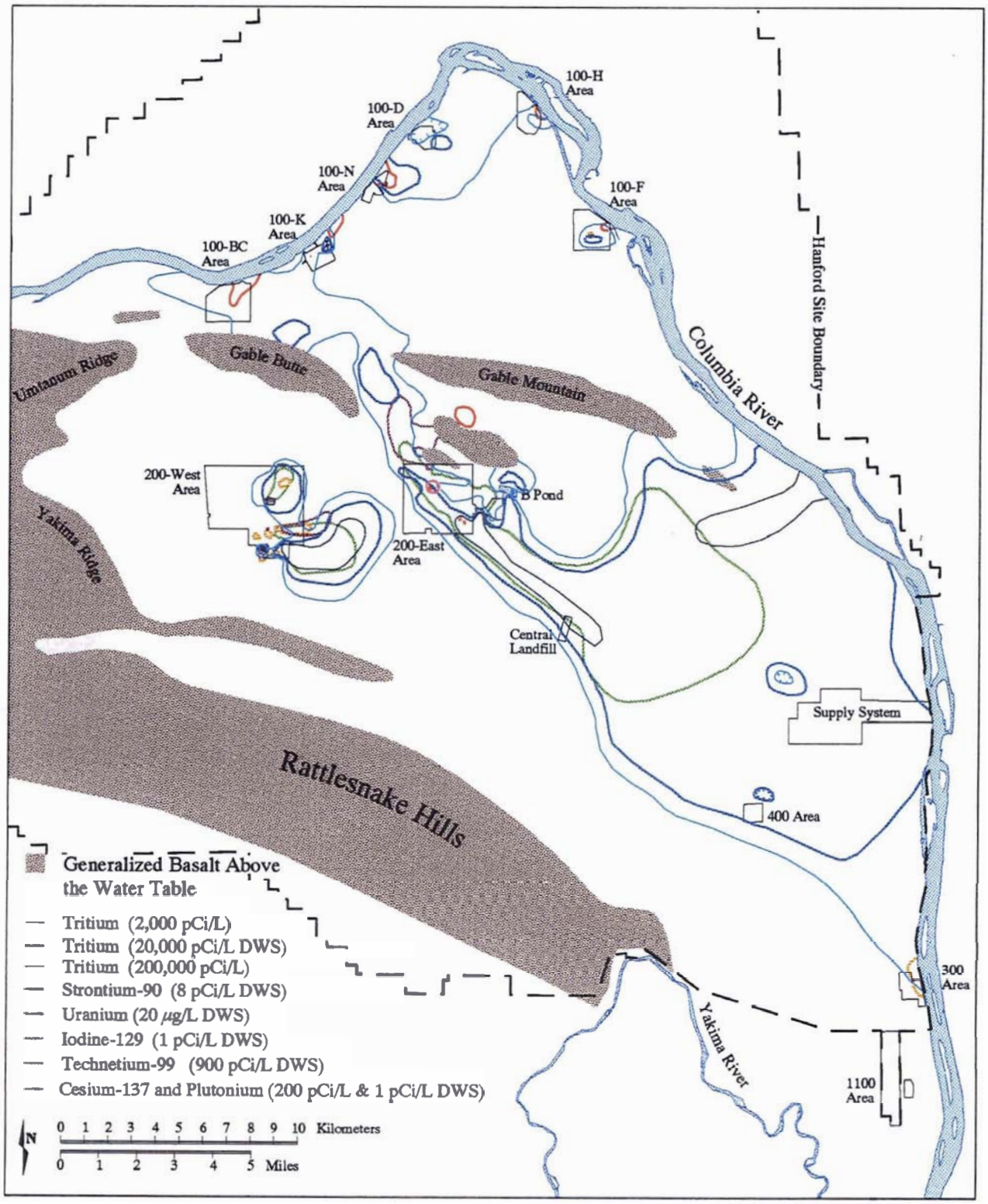


Figure 4.2. Distribution of Radionuclides in Ground Water at Concentrations Above the Drinking Water Standard

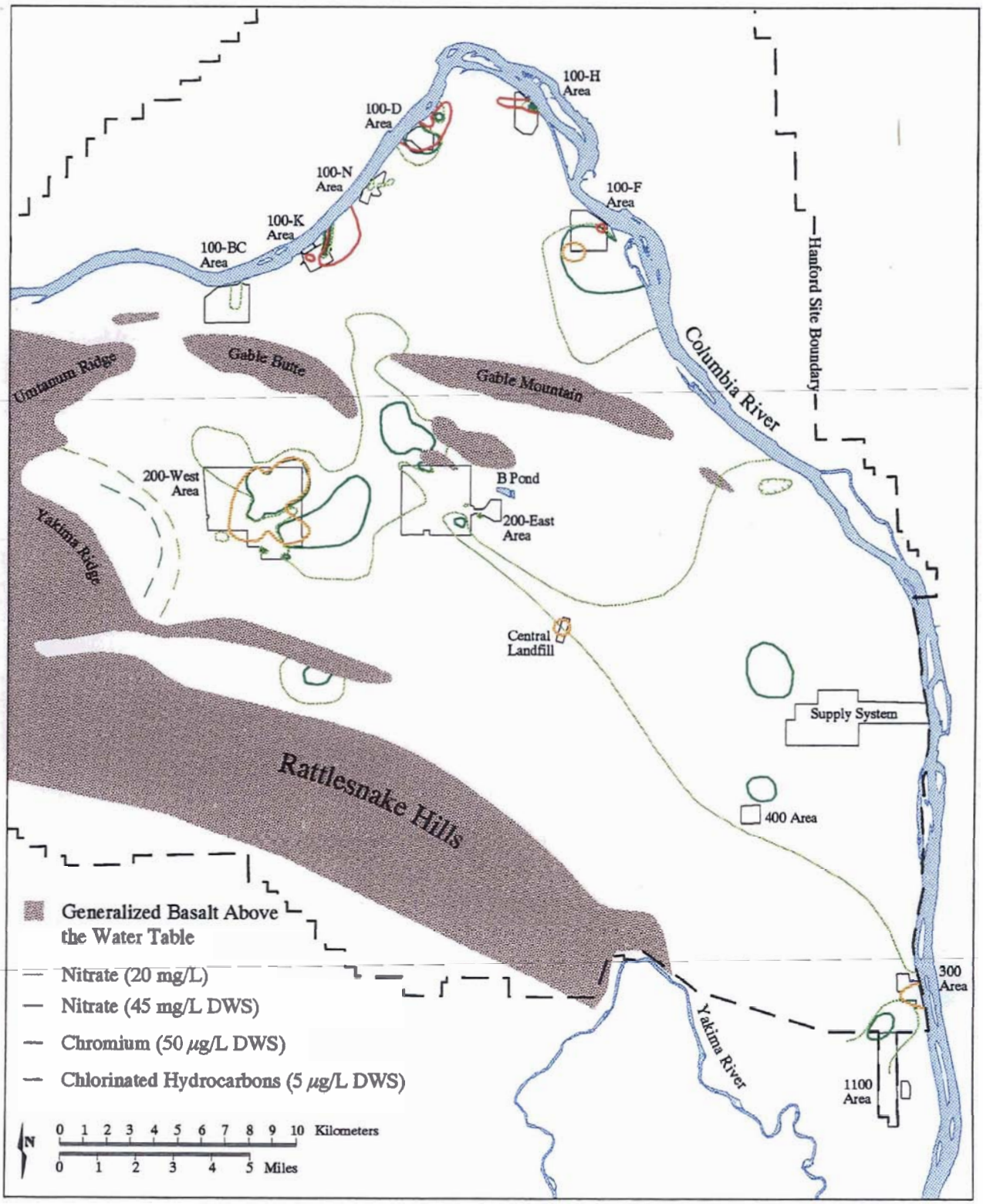


Figure 4.3. Distribution of Hazardous Chemicals in Ground Water at Concentrations Above the Drinking Water Standard

Table 4.1. Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations

Facilities Type	Area	Constituents
Reactor Operations	100	^{3}H, ^{60}Co, ^{90}Sr, Cr^{6+}, SO_4^{2-}
Irradiated Fuel Processing	200	^{3}H, ^{137}Cs, ^{90}Sr, ^{129}I, ^{99}Tc, NO_3, Cr^{6+}, CN^-, F^-, uranium, plutonium
Plutonium Purification	200	CCl_4, $CHCl_3$, plutonium
Uranium Recovery	200	uranium, ^{99}Tc, NO_3
Fuel Fabrication	300	uranium, ^{99}Tc, Cr^{6+}, NO_3, trichloroethylene

Table 4.2. Summary of Ground-Water Surveillance Field Duplicate Samples, 1993[a]

Constituent	Number of Results Reported	Number Above Detection Level	Number Within Control Limits[b]
Radionuclides			
Gamma isotopes (^{60}Co, ^{137}Cs, ^{106}Ru and ^{125}Sb)	1	0	NA[c]
^{129}I	1	0	NA
Tritium	6	2	2
Total uranium	3	2	2
ICP Metals (18 elements per report)	90	38	29
Ions - sulfate, bromide, chloride, fluoride, nitrate, nitrite, phosphate	42	31	30
Cyanide	2	1	1
Alkalinity	1	1	1
VOA Constituents	72	1	1

(a) The field QC program was initiated in July 1993.

(b) Control limits are as follows: If the result is less than 5 times the detection level, then duplicate results must be ± detection level. If the result is greater than 5 times the detection level, then results must be ± 20% relative percent difference. If either value was less than detection level then relative percent difference was not calculated.

(c) NA = Not applicable because sample results were below detection level.

Table 4.3. Maximum Contaminant Levels

Constituent	Primary MCL	Agency	EPA Status
Fluoride	4 mg/L	EPA, DOH[a]	Final/under review
Nitrate	45 mg/L	EPA, DOH	Final
Chromium	100 μg/L	EPA	Final
	50 μg/L	DOH	
Trichlorethylene	5 μg/L	EPA, DOH	Final
Tetrachloroethylene	5 μg/L	EPA	Final
Carbon Tetrachloride	5 μg/L	EPA. DOH	Final
Chloroform (THM)[b]	100 μg/L	EPA	
Uranium	20 μg/L	EPA	Proposed
Total alpha (excluding uranium)	15 pCi/L	EPA, DOH	Final
Beta particle and photon activity	4 mrem/yr[c]	EPA, DOH	Final
Tritium	20,000 pCi/L[d]	EPA	
Cobalt	100 pCi/L[d]	EPA	
Strontium-90	8 pCi/L[d]	EPA	
Technetium	900 pCi/L[d]	EPA	
Ruthenium	30 pCi/L[d]	EPA	
Antimony	300 pCi/L[d]	EPA	
Iodine-129	1 pCi/L[d]	EPA	
Cesium	200 pCi/L[d]	EPA	

(a) DOH = Washington State Department of Health.
(b) Standard is for total trihalo methanes.
(c) Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose greater than 4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, ^{3}H, and ^{90}Sr are less than 50, 20,000, and 8 pCi/L, respectively.
(d) Concentration assumed to yield an annual dose of 4 mrem/yr.

Table 4.4. Derived Concentration Guides[a,b,c]

Radionuclide	Water, pCi/L (10p-9μCi/mL)	Air, pCi/m^3 ($10^{-12}\mu$Ci/mL)
^{3}H	2,000,000	100,000
^{14}C	70,000	500,000
^{51}Cr	1,000,000	60,000
^{54}Mn	50,000	2,000
^{60}Co	5,000	80
^{65}Zn	9,000	600
^{85}Kr	NA[d]	3,000,000
^{90}Sr	1,000	50
^{99}Tc	100,000	2,000
^{103}Ru	50,000	2,000
^{106}Ru	6,000	30
^{125}Sb	60,000	1,000
^{129}I	500	70
^{131}I	3,000	400
^{137}Cs	3,000	400
^{144}Ce	7,000	30
^{234}U	500	0.09
^{235}U	600	0.1
^{238}U	600	0.1
^{238}Pu	40	0.03
^{239}Pu	30	0.02
^{240}Pu	30	0.02

(a) Concentration of a specific radionuclide in water or air that could be continuously consumed or inhaled at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr. An exception is the limit for ^{85}Kr, which is based on the skin dose limit of 5 rem from immersion in a plume.
(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford operations, and may be adjusted upward (larger) if accurate solubility information is available.
(c) From DOE Order 5400.5.
(d) NA = No standard.

Table 4.5. Summary of International Technology Performance on EPA Intercomparison Program Samples, 1993

Medium	Radionuclides	Number of Results Reported for Each	Number Within Control Limits[a]
Water	^{133}Ba, Pu-isotopic, ^{106}Ru, ^{65}Zn	1	1
Water	^{60}Co, ^{134}Cs, ^{137}Cs, Tritium, ^{89}Sr	2	2
Water	^{226}Ra, ^{228}Ra, ^{90}Sr, Uranium	3	3
Water	Gross Alpha, Gross Beta	4	4

(a) Control limits are from Jarvis and Siu (1981).

Table 4.6. Summary of Ground-Water Surveillance Project Quarterly Blind Spike Determinations[a]

Radionuclide	Number of Results Reported[b]	Number Within ±30% RPD
^{60}Co	9	8
^{137}Cs	9	9
^{129}I	9	5
^{90}Sr	9	9
^{99}Tc	9	8
^{239}Pu	9	5
Total uranium	9	6
Tritium	9	9
Cyanide	6	5
Chromium +6	6	3
Nitrate	6	5
Fluoride	6	3
Carbon tetrachloride	6	[c]
Chloroform	6	[c]
TCE	6	[c]

(a) Submission of quarterly blind samples began in the second quarter of 1993. Only radiochemical blind spiked samples were submitted that quarter.

(b) Blind samples were submitted in triplicate each quarter and compared to actual spike values.

(c) None of the results fell within ±30% of the spiked constituent concentrations. Problems with preparation of the standards and laboratory analysis hindered accurate evaluation of spike concentrations.

Table 4.7. Ground-Water Surveillance Project Quarterly Blind Spike Determinations[a]

(Calendar) Quarter	Const.	Spike Conc. (pCi/L)	Spike Uncert. (1 sigma)	Spike Conc. (μg/L)	Spike Uncert. (1 sigma)	Lab Conc. (pCi/L or μg/L)	Uncert. (2 sigma)	RPD
2nd 1993	^{60}Co	382.5	4.97			476.00	65.5	24.44
						349.00	51.48	-8.76
						400.00	54.98	4.58
							15.65% Std Dev	
2nd 1993	^{137}Cs	87.09	1.13			91.50	19.15	5.06
						88.40	18.56	1.50
						83.70	19.02	-3.89
							4.47% Std Dev	
2nd 1993	^{129}I	0.482	0.01			-0.08	0.337	**-116.56**
						0.76	0.3944	**58.09**
						0.77	0.3528	**58.92**
							0.37% Std Dev	
2nd 1993	^{90}Sr	85.8	1.12			81.10	15.29	-5.48
						82.90	15.44	-3.38
						88.60	16.04	3.26
							4.65% Std Dev	
2nd 1993	^{99}Tc	1020	13.26			934.00	103.1	-8.43
						855.00	94.53	-16.18
						937.00	103.4	-8.14
							5.12% Std Dev	
2nd 1993	^{239}Pu	3.25	0.04			2.00	0.285	**-38.46**
						2.25	0.2931	**-30.77**
						2.05	0.2836	**-36.92**
							6.30% Std Dev	
2nd 1993	U-nat*	1070	13.91	3182.53	41.37	3220.00	896.8	1.18
						2690.00	743.7	-15.48
						2800.00	789.9	-12.02
							9.63% Std Dev	
2nd 1993	^{3}H	17830	231.79			17000.00	1388	-4.66
						17000.00	1389	-4.66
						17300.00	1413	-2.97
							1.01% Std Dev	
3rd 1993	CN			2.99	0.04	3.00		0.33
						6.00		100.67
						3.00		0.33
							43.30% Std Dev	
3rd 1993	Cr^{+6}			0.249	0.00 <	5.42		**2076.71**
						8.30		**3233.33**
						6.40		**2470.28**
							21.83% Std Dev	

Table 4.7. (contd)

(Calendar) Quarter	Const.	Spike Conc. (pCi/L)	Spike Uncert. (1 sigma)	Spike Conc. (µg/L)	Spike Uncert. (1 sigma)	Lab Conc. (pCi/L or µg/L)	Uncert. (2 sigma)	RPD
3rd 1993	NO_3^-			4978	64.71	6000.00		20.53
						6100.00		22.54
						6500.00		30.57
							4.27% Std Dev	
3rd 1993	F^-			20	0.26 ^	400.00		**1900.00**
					^	400.00		**1900.00**
					^	400.00		**1900.00**
							0.00% Std Dev	
3rd 1993	CCl_4			2.5	0.03	680.00		**27100.00**
						720.00		**28700.00**
						65.00		**2500.00**
3rd 1993	CHCL3			50	0.65	1000.00		**1900.00**
						1100.00		**2100.00**
						100.00		**100.00**
3rd 1993	TCE			2.5	0.03 <	7.00		**180.00**
					<	7.00		**180.00**
					<	7.00		**180.00**
3rd 1993	^{60}Co	45.57	0.59			38.00	13.96	-16.61
						29.90	17.59	**-34.39**
						36.40	16.1	-20.12
							12.34% Std Dev	
3rd 1993	^{137}Cs	172.6	2.24			173.00	28.16	0.23
						157.00	25.86	-9.04
						160.00	27.12	-7.30
							5.21% Std Dev	
3rd 1993	^{129}I	0.961	0.01			1.37	0.4287	**42.56**
						1.23	0.4302	27.99
						0.82	0.2957	-14.67
							25.07% Std Dev	
3rd 1993	^{90}Sr	851.7	11.07			826.00	156.2	-3.02
						843.00	156.4	-1.02
						868.00	152.6	1.91
							2.50% Std Dev	
3rd 1993	^{99}Tc	2038	26.49			1410.00	154.7	**-30.81**
						1730.00	189.8	-15.11
						1820.00	200.2	-10.70
							13.03% Std Dev	

Table 4.7. (contd)

(Calendar) Quarter	Const.	Spike Conc. (pCi/L)	Spike Uncert. (1 sigma)	Spike Conc. (μg/L)	Spike Uncert. (1 sigma)	Lab Conc. (pCi/L or μg/LL)	Uncert. (2 sigma)	RPD
3rd 1993	^{239}Pu	6.477	0.08			5.34		-17.55
						4.89		-24.50
						4.51		-30.37
							8.46% Std Dev	
3rd 1993	U-nat*	321.6	4.18	956.55	12.44	787.00	231	-17.72
						795.00	232.6	-16.89
						697.00	206.4	-27.13
							7.16% Std Dev	
3rd 1993	^{3}H	88220	1146.86			87200.00	6493	-1.16
						87000.00	6478	-1.38
						86800.00	6468	-1.61
							0.23% Std Dev	
4th 1993	CN			400.00	2.00	360.00		-10.00
						300.00		-25.00
						310.00		-22.50
							9.94% Std Dev	
4th 1993	Cr^{+6}			50.00	0.25	56.00		12.00
						55.00		10.00
						57.00		14.00
							1.79% Std Dev	
4th 1993	NO_3^-			22000.00	110.00	22000.00		0.00
						22000.00		0.00
						22000.00		0.00
							0.00% Std Dev	
4th 1993	F^-			5000.00	25.00 ^	5500.00		10.00
					^	5600.00		12.00
					^	5600.00		12.00
							1.04% Std Dev	
4th 1993	CCl_4			5.00	<	0.87		**-82.60**
					<	0.87		**-82.60**
					<	0.87		**-82.60**
4th 1993	$CHCl_3$			100.00	<	20.00		**-80.00**
						80.00		**-20.00**
					<	20.00		**-80.00**
4th 1993	TCE			5.00	<	55.00		**1000.00**
					<	55.00		**1000.00**
					<	55.00		**1000.00**

Table 4.7. (contd)

(Calendar) Quarter	Const.	Spike Conc. (pCi/L)	Spike Uncert. (1 sigma)	Spike Conc. (μg/L)	Spike Uncert. (1 sigma)	Lab Conc. (pCi/L or μg/L)	Uncert. (2 sigma)	RPD
4th 1993	^{60}Co	89.98	0.72			52.70	24	**-41.43**
						86.90	23.54	-3.42
						87.40	20.24	-2.87
							26.29% Std Dev	
4th 1993	^{137}Cs	428.8	7.72			410.00	51.3	-4.38
						431.00	52.94	0.51
						400.00	50.24	-6.72
							3.82% Std Dev	
4th 1993	^{129}I	9.64	0.06			9.00	1.159	-6.64
						8.08	1.065	-16.18
						8.66	0.052	-10.17
							5.42% Std Dev	
4th 1993	^{90}Sr	4.24	0.03			4.26	1.078	0.47
						4.65	1.082	9.67
						4.51	1.058	6.37
							4.42% Std Dev	
4th 1993	^{99}Tc	4066	20.33			3570.00	389.9	-12.20
						3650.00	399	-10.23
						3570.00	390.4	-12.20
							1.28% Std Dev	
4th 1993	^{239}Pu	0.643	0.01			0.51	0.1278	-20.06
						0.43	0.1143	**-33.28**
						0.51	0.1623	-20.68
							9.90% Std Dev	
4th 1993	U-nat*	641.1	10.90	1906.84	24.79	16400.00	4551	**760.06**
						15700.00	4367	**723.35**
						15200.00	4200	**697.13**
							3.82% Std Dev	
4th 1993	^{3}H	43640	610.96			40600.00	3109	-6.97
						40500.00	3099	-7.20
						41900.00	3204	-3.99
							1.90% Std Dev	

(a) Submission of quarterly blind samples began in the second quarter of 1993. Only radiochemical blind spiked samples were submitted that quarter.

(b) Blind samples were submitted in triplicate each quarter and compared to actual spike values.

(c) None of the data results fell within ±30% of the spiked constituent concentrations. Problems with preparation of the standards and laboratory analysis hindered accurate evaluation of spike concentrations.

* indicates conversion to μg/L using 3.362E-07 Ci/g.

Bold numbers indicate accuracy and precision out of ± 30% limits.

^ indicates noncharacteristic fluoride peaks, which may indicate a positive interference. F⁻ may be lower.

< indicates nondetects (MDL corrected for dilution factors).

5.0 Extent of Ground-Water Contamination at the Hanford Site

P.E. Dresel and J.C. Evans

Ground-water contamination at the Hanford Site has been related to a number of sources within the operational areas. In some cases, several potential sources, such as cribs, trenches, or other disposal facilities, may contribute to a particular ground-water plume and their contributions cannot be readily distinguished. In these cases, the sources are discussed together. The sources discussed are grouped by operational area. Additional discussions are included for the potential receptor areas in the Richland North Area and 400 Area and for the uppermost basalt confined aquifer system.

5.1 100-B/C Area

The 100-B/C Area is farthest upstream of the reactor areas along the Columbia River. The B Reactor was the world's first production nuclear reactor. It was placed in service in 1944 and operated until 1968. The C Reactor operated from 1952 to 1969. The B and C reactors, like all other production reactors onsite except the N Reactor, used a single-pass system for cooling water. After passing through the reactor, the cooling water was discharged to the Columbia River. A considerable amount of past disposal of liquid to the ground is indicated by historical water-table maps showing ground-water mounding in the 1950s. Currently, strontium-90 is the only constituent detected at levels above the DWS in the 100-B/C Area. However, past data show tritium levels greater than the DWS. In addition, technetium-99, which is found at levels well below the DWS, appears to be related to disposal activities in the 100-B/C Area.

The 100-B/C Area ground water is addressed as part of the 100-B/C-5 Operable Unit and was the subject of a CERCLA-related Limited Field Investigation (DOE-RL 1993a). The report of this activity summarized the known disposal facilities that may have affected the ground water; the results of sampling were screened based on regulatory and risk-based criteria. The report recommended that no expedited response action or interim remedial measures be undertaken.

Tritium

Tritium levels in the 100-B/C Area are currently below the DWS (Figure 5.1). The maximum tritium concentration detected in 1993 was 17,000 pCi/L in well 199-B3-47. Tritium in well 199-B3-47 had been above the DWS in the second half of 1992, when the initial samples from this new well were collected. Tritium levels from well 699-65-72, which is located to the southeast of the 100-B/C Area, are higher, reaching a maximum of 28,000 pCi/L in the April 1993 sample. It is possible that past disposal practices at the 100-B/C Area resulted in some flow to the southwest. Hydraulic gradients are fairly small in this part of the site, and there is some suggestion that the Columbia River recharges the upper unconfined aquifer upstream from the 100-B/C Area. Another possibility is that in the past the gradient in the gap between Gable Mountain and Gable Butte was sufficient to transport tritium from the 200 Areas westward. The network of wells available to monitor the ground water in this vicinity is inadequate to determine the source of tritium in well 699-65-72.

Strontium-90

Strontium-90 was detected in the majority of 100-B/C Area wells monitored in 1993. The distribution of strontium-90 is shown in Figure 5.2. The highest levels of strontium-90 are found downgradient of the 116-B-1 and 116-C-1 liquid overflow trenches. These trenches received cooling water contaminated with relatively high concentrations of radionuclides after fuel cladding failures. The 116-B-11 and 116-C-5 Retention Basins may have also contributed strontium to ground water in this area. The maximum concentrations ranged up to 150 pCi/L in well 199-B3-46. Strontium-90 at concentrations above the DWS is also found in wells to the west and southwest of the B Reactor Building. Liquid waste disposal sites in this area received contaminated water from the B Reactor Fuel Storage Basin, contaminated cooling water, and water from decontamination activities. Figure 5.2 indicates that ground water containing strontium-90 at levels above the DWS is discharging to the Columbia River in the 100-B/C Area. The extent of strontium-90 in ground water to the east of the 100-B/C Area cannot be defined by the current monitoring network.

Technetium-99

Technetium-99 is detectable at levels well below the 900 pCi/L DWS in the 100-B/C Area. It appears that there may be a technetium-99 source from liquid waste disposal sites near the B Reactor. However, the technetium-99 extends a considerable distance to the east toward the 100-K Area and Gable Mountain. This suggests a possible additional source from the 200 Areas. It is unclear what disposal activities would have resulted in a technetium-99 source in this area.

5.2 100-D Area

Tritium, strontium-90, nitrate, and chromium are found at levels greater than the DWS in the 100-D Area. The D Reactor operated from 1944 to 1967. The DR Reactor, also located in the 100-D Area, operated from 1950 to 1965. The chromium plume from the 100-D Area extends east into the 600 Area and possibly as far as the 100-H Area.

A small part of the 100-D Area in the vicinity of the 100-D Ponds is the subject of RCRA monitoring (Hartman 1994b). The 100-D Ponds were used for the discharge of effluent from the 183-D Filter Plant and 189-D Building engineering testing laboratories. Currently, an average of approximately 9 L/min (2.4 gal/min) is discharged to the ponds. Potential impacts on ground water from the 100-D Ponds was assessed by Alexander (1993). Sampling for this project began in 1992.

The ground-water impacts of 100-D Area past practices are being investigated under the 100-HR-3 CERCLA project. A limited field investigation was undertaken for this CERCLA operable unit (DOE-RL 1993a). This investigation summarized the known disposal facilities that may have impacted ground water and screened the results of sampling based on regulatory and risk-based criteria. Comments and recommendations by regulators and the public on the limited field investigation were not yet incorporated as the present report was being prepared.

Tritium

Tritium in the 100-D Area is found at concentrations greater than the DWS in several wells in the vicinity of the 100-DR Reactor (Figure 5.3). The maximum value for tritium reported in 1993 was 73,000 pCi/L in well 199-D5-18. Many of the wells with tritium above the DWS were installed in 1992, so long-term trend data are unavailable. Tritium levels (which are less than the DWS) in 600 Area wells northeast of the 100-D Area may also be related to 100-D Area activities. The water-level contours shown in Plate 1 indicate that ground-water flow in the 100-D Area is approximately to the northeast, nearly parallel to the Columbia River. Thus little discharge to the river is expected to occur in the 100-D Area. As the ground water approaches the river, the changes in river stage affect its flow. The low tritium concentrations found adjacent to the Columbia River in the 100-D Area suggest that disposal of non-radioactive waste to the 100-D Ponds has reduced ground-water concentrations in the immediate area of the ponds (Hartman 1994a).

Strontium-90

Strontium-90 was found in the 100-D Area at levels greater than the DWS only in well 199-D5-12, where the concentration was 41 pCi/L in the February sample. This well is located adjacent to the D Reactor Building. Strontium-90 was also detected near the 116-D-7 and 116-DR-9 Retention Basins. The maximum levels reported near the retention basins were just under the DWS.

Nitrate

Nitrate was found at concentrations greater than the DWS over a large part of the 100-D Area (Figure 5.4). Many of the nitrate data in this area were collected for CERCLA characterization activities, and the method used combined nitrate plus nitrite as nitrogen concentration. Past data from this area indicate that nitrate will dominate this analysis method because of the highly oxidizing nature of the ground water. For the purposes of this report, all nitrate plus nitrite nitrogen was assumed to be present as nitrate and the results were converted to milligrams per liter as NO_3 by multiplying by 4.5. The nitrate plume appears to be most concentrated in the western half of the area, but the well coverage is not sufficient to determine its precise extent or to identify a source or sources. A small plume appears to originate in the vicinity of the 116-D-7 and 116-DR-9 Retention Basins and 116-DR-1 and 116-DR-2 Disposal Trenches near the river.

Chromium

The highest chromium concentrations in the 100-D Area were found in the vicinity of the D-Reactor Building, with values up to a maximum of 19,100 μg/L in well 199-D5-15. Chromium levels were similar in filtered and unfiltered samples from the 100-D Area, indicating that the bulk of the chromium is in solution and probably mobile. The chromium plume extends east into the 600 Area (Figure 5.5). A possible source of the chromium is the disposal of large inventories of chromium waste to the 116-D-1A and 116-D-1B trenches in the 1950s and 1960s (Stenner et al. 1988). Alternatively, the source may have been leakage from the sodium dichromate distribution system (DOE-RL 1993a). Sodium dichromate was used for corrosion control in the single-pass-cooling reactors. The extent of chromium from the 100-D Area reaching into the 600 Area is not well defined because of the sparseness of well spacing in the 600 Area to the east.

5.3 100-F Area

The F Reactor operated from 1945 to 1965. Interpretation of the ground-water chemistry in the 100-F Area is limited by the sparse monitoring-well coverage. This is a particular problem for TCE, which apparently comes from a source upgradient of the 100-F Area. Other major ground-water contaminants in the 100-F Area include tritium, strontium-90, and uranium.

The amount of information on ground-water quality in the 100-F Area is improving due to site characterization of the 100-FR-3 CERCLA operable unit. Thirteen new wells were installed in the 100-F Area for CERCLA-related characterization activities. No RCRA projects are located in the 100-F Area.

Tritium

Tritium is found in the 100-F Area at concentrations greater than the DWS in well 199-F8-3 in the vicinity of the 118-F-1 Burial Ground (Figure 5.6). The maximum value for tritium reported for this well in 1993 was 180,000 pCi/L. This plume extends east toward the Columbia River.

Strontium-90

Strontium-90 was detected at levels above the DWS in wells in the eastern part of the 100-F Area (Figure 5.7). The maximum concentration detected in 1993 was 250 pCi/L in well 199-F5-3. The source appears to be waste disposal at or near the 116-F-14 Retention Basins, and the plume extends to the Columbia River.

Uranium

Uranium analyses for the 100-F Area in 1993 were performed by alpha spectroscopy to meet CERCLA requirements. These analyses were converted to micrograms of total uranium per liter by summing the activities of the individual isotopes and multiplying by 1.45 μg/pCi. This conversion assumes that the uranium isotopes are in secular equilibrium and neglects minor effects from a small excess of uranium-234 commonly present in natural waters and any uranium isotopic enrichment or depletion during site operations.

Uranium continues to be detected at levels above the proposed DWS in well 199-F8-2 (Figure 5.8). The 1993 samples from this well contained a maximum of 30 μg/L total uranium. This is down from a maximum concentration of 618 μg/L in 1988. Well 199-F8-1 has historically contained uranium at concentrations greater than the proposed DWS but was not sampled in 1993.

Chromium

Only one of the 100-F Area wells sampled in 1993, well 199-F5-46, contained chromium at levels greater than the DWS. The maximum levels of 206 μg/L in a unfiltered sample and 197 μg/L in a filtered sample were greater than the state and federal standards. This well is located downgradient of

the ash disposal basin, but the chromium source has not been established. The presence of similar chromium levels in both the filtered and unfiltered samples indicates that the chromium is in solution and is mobile.

Trichloroethylene

TCE has been detected at concentrations above the DWS in the 100-F Area and in surrounding parts of the 600 Area (Figure 5.9). The maximum TCE level detected in 1993 in the 100-F Area was 28 μg/L in well 199-F7-1, in the southwestern corner of the area. TCE is also detected at levels generally less than the DWS in other wells in the 100-F Area. The TCE concentration in well 699-77-36, to the west and upgradient of the 100-F Area was 27 μg/L in the 1993 sample. TCE levels in well 699-77-36 have been fairly constant with time. Thus it is probable that the TCE source is in the 600 Area, but it has not yet been identified. Efforts related to the CERCLA 100-IU-2 Operable Unit will address potential sources west of the 100-F Area.

5.4 100-H Area

The H Reactor operated from 1945 to 1965. Major ground-water contaminants in the 100-H Area include strontium-90, technetium-99, uranium, nitrate, and chromium. As discussed below, chromium may come from a source upgradient of the 100-H Area as well as a local source.

The 183-H Solar Evaporation Basins are monitored by the RCRA program (Peterson 1994). These Basins were in active use from 1974 through 1985. Ground-water characterization of the 100-H Area is being conducted by the 100-HR-3 CERCLA project, which published a limited field investigation report in 1993 (DOE-RL 1993b). The investigation screened ground-water analyses to determine whether interim remedial measures should be initiated. Comments on the limited field investigation by the regulators and the public were not yet incorporated as the present report was being prepared.

The increase in constituent concentrations noted in the 100-H Area in 1993 indicates a greater uncertainty in ground-water characterization in this area than was previous recognized. The fluctuations in concentrations should be recognized in evaluating the needs for remedial measures and for assessing the impacts of any remediation. Long-term monitoring will be required to interpret trends in contaminant distributions.

Chromium

Chromium was detected at levels greater than the DWS over a large part of the 100-H Area. Chromium was usually found at similar levels in both filtered and unfiltered samples, indicating that the chromium is mobile. The distribution of filtered chromium in ground-water samples from the 100-H Area is shown in Figure 5.10.

Potential chromium sources in the 100-H Area include disposal of sodium dichromate to the ground near the reactor building and to the 107-H liquid waste trench, as well as chromium in acid wastes stored in the 183-H Solar Evaporation Basins (Peterson and Connelly 1992). Peterson and Connelly also suggest the possibility of an upgradient source affecting 100-H Area chromium concentrations.

The highest concentrations of chromium in the 100-H Area in 1993 were 490 μg/L in wells 199-H4-12C and 199-H4-17. These values are considerably higher than the 1992 values for 199-H4-17. Increases in concentrations of several constituents, including chromium, in other wells were also noted, as discussed by Peterson (1994). In contrast, concentrations in 199-H4-14 dropped from a high in 1992.

Chromium levels have been decreasing in wells in nest 199-H4-12, which monitor the upper part of the unconfined aquifer (199-H4-12A and 199-H4-12B). In the well monitoring the middle unconfined aquifer, 199-H4-12C, chromium levels rose sharply in about 1987 and then leveled off (Figure 5.11). This suggests that the upper part of the aquifer is being flushed with cleaner water at present. Chromium in the 199-H4-12C well is most likely related to upgradient sources. This interpretation is supported by the technetium-99 trends identified in the 199-H4-12 wells, discussed below. There may be a significant flux of chromium to the Columbia River from the deeper part of the aquifer as indicated by concentration in well 199-H4-12C. The study by Hall (1989) also supports the existence of sources at the 183-H Solar Evaporation Basins and upgradient.

Chromium was also detected in parts of the 600 Area adjacent to the 100-H Area. The 600 Area well closest to the 100-H Area, 699-97-43, contained a maximum of 167 μg/L in 1993. This value is nearly identical to that in 1992 and supports the existence of an upgradient source. The most probable upgradient source is the 100-D Area. Elevated chromium levels in the 100-D Area are discussed above. Flow from the 100-D Area to the 100-H Area would result from the gradient across the "horn" of the Columbia River and possibly from past ground-water mounding caused by disposal practices in the 100-D Area.

Technetium-99

Elevated technetium-99 activities were found in several wells in the 100-H Area, although only one well, 199-H4-3, had levels above the DWS. The maximum technetium-99 activity in this well was 2,750 pCi/L in the July 1993 sample. The concentrations in well 199-H4-3 have fluctuated greatly with time (Figure 5.12). Technetium is transported in ground water as an anionic species, which would not be retarded significantly by adsorption onto sediments. The technetium-99 trend from the 199-H4-12 wells is shown in Figure 5.13. This figure illustrates the trend of decreasing technetium-99 in the upper unconfined aquifer wells (199-H4-12A and 199-H4-12B). By contrast, technetium-99 was never detected in the middle unconfined aquifer well, 199-H4-12C. This provides additional evidence that the chromium detected in well 199-H4-12C is not related to the 100-H Solar Evaporation Basins. If the chromium had a local source, then the other mobile local constituents, such as technetium-99, should also be detected. It is possible that a different local chromium source containing no technetium-99 was present, possibly resulting from disposal near the H Reactor Building. However, this location is relatively far from well 199-H4-12C and any plume from the H Reactor Building would probably have been farther south, flowing toward the river.

Uranium

Uranium continues to be detected at levels greater than the proposed DWS in wells 199-H4-3 and 199-H4-4, which are downgradient of the 183-H Solar Evaporation Basins and have historically shown elevated uranium concentrations (Figure 5.14). The maximum uranium concentration detected in 1993 was 534 μg/L in the April sample from well 199-H4-4. This value was more than ten times the value

in other samples. The elevated gross-alpha measurements in these wells reflect the uranium concentrations. Fluctuations in concentrations of uranium and other constituents in these wells suggest that they are affected by the Columbia River stage.

Strontium-90

Strontium-90 was detected at levels greater than the DWS in 1993 in samples from three wells in the 100-H Area (Figure 5.15). The maximum concentration detected in 1993 was 26 pCi/L in well 199-H4-13. Wells 199-H4-11 and 199-H4-13 are downgradient and close to the 107-H Retention Basin. The third well, 199-H4-45, is to the south of the 107-H Retention Basin and 107-H Liquid Waste Trench. Strontium-90 was not monitored in most 100-H Area wells between 1988 and 1992. Thus little is known regarding the history of strontium-90 in 100-H Area ground water.

Nitrate

Nitrate concentrations lower than the DWS are found through most of the 100-H Area. Concentrations above the DWS were detected in wells between the 183-H Solar Evaporation Basin and the Columbia River (Figure 5.16). The maximum concentration detected in the 100-H Area in 1993 was 870 mg/L in well 199-H4-3. Nitrate concentrations increased greatly in a number of wells in the 100-H Area in 1993. The cause of this increase is unclear, but it is correlated with increases in turbidity, chromium, sulfate, and sodium (Peterson 1994).

5.5 100-K Area

The KE and KW reactors in the 100-K Area were operated from 1945 to 1965. During operations, cooling water from the 100-K Area reactors was discharged to the Liquid Waste Disposal Trench rather than through cooling basins into the Columbia River, as was the practice at the other single-pass reactors. Tritium is the primary constituent of concern in the 100-K Area and reached levels greater than the DCG in 1993. Other constituents detected in the 100-K Area include strontium-90, antimony-125, nitrate, and chromium.

In addition to the Ground-Water Surveillance Project's sampling, ground-water sampling for selected constituents is conducted in the 100-K Area by the Operational Monitoring Program. Characterization is also carried out by the 100-KR-4 Operable Unit CERCLA project. A CERCLA-related limited field investigation recommended that interim remedial measures be pursued in this area (DOE-RL 1993c).

The 100-K Area is situated within a portion of the 600 Area that is impacted by tritium contamination at levels between 5,000 pCi/L and the 20,000 pCi/L DWS (Figure 5.1). The monitoring network in this part of the 600 Area is relatively sparse, and the exact extent of the tritium plume or plumes is subject to some debate.

Tritium levels near the KE Reactor are dramatically higher than the surrounding levels (Figure 5.17). An unusual occurrence report filed in February 1993 (Occurrence Report Number RL-WHC-KBASINS-1993-0007) reported a potential leak in the KE Fuel Storage Basin. The

KE basins contain unencapsulated irradiated fuel elements from the N Reactor. In 1993, the tritium concentration in the basin ranged from 2,090,000 to 3,360,000 pCi/L. Past tritium values in the basin were higher, with values between 4,000,000 and 6,000,000 pCi/L common from 1984 to 1989. Plutonium in the basin ranged from 6,150 to 246,000 pCi/L in 1993. Strontium-90 ranged from 348,000 to 4,810,000 pCi/L. Cesium-137 concentrations ranged from 882,000 to 24,900,000 pCi/L. Preliminary work to encapsulate the fuel elements has begun. Encapsulation is scheduled to begin in June 1994 and to take approximately five years.

Tritium

The maximum tritium concentration detected in 1993 in the 100-K Area was 3,320,000 pCi/L in the May sample from well 199-K-30. The tritium concentration in this well was above the DCG in both April and May 1993. The tritium concentration in well 199-K-27 was also high, ranging up to 359,000 pCi/L. Wells 199-K-28 and 199-K-29, located between wells 199-K-27 and 199-K-30, show lower tritium concentrations, with 1993 maxima of 1,970 and 116,000 pCi/L, respectively. The distribution of concentrations in wells near the KE Reactor Building suggest a very narrow plume or plumes. The narrowness of the plume may also be indicated by the variability of the sample values -- minor changes in gradient then would have a major effect on measured concentrations. However, the extent of tritium to the east of the reactor and downgradient is not well defined.

The tritium trends in wells near the KE Reactor also show different patterns, suggesting the possibility of separate sources. The trend for well 199-K-30 shown in Figure 5.18 indicates that the levels have been high since at least 1981. However, the trend for 199-K-27 (Figure 5.19) shows an increase in concentration in 1989 and a sharp second rise in 1993. This suggests that the tritium in 199-K-30 may result from an older source. Additional chemical differences between the two wells include carbon-14, antimony-125, and nitrate concentrations, as discussed below.

The 100-KR-4 limited field investigation report indicates that approximately 200 Ci of tritium and of carbon-14 were discharged to the 119-KW-1 and 119-KE-1 french drains during reactor operations (DOE-RL 1993c). Well 199-K-30, located approximately downgradient of the 119-KE-1 french drain, contained a maximum of 23,000 pCi/L of carbon-14 in 1993. The drain is thus a potential alternative or addition to the fuel storage basin as a source of tritium in this well. There is no well located immediately downgradient of the 199-KW-1 french drain, although the limited field investigation reported 13,000 pCi/L for carbon-14 in well 199-K-34 and 15,000 pCi/L in well 199-K-33, which are generally downgradient of the KW Reactor. Further characterization is needed to distinguish between potential contaminant sources in the 100-K Area.

Strontium-90

Strontium-90 has been detected at levels above the DWS in wells near the Liquid Waste Disposal Trench and near the KW Reactor (Figure 5.20). The maximum concentration detected in 1993 was 100 pCi/L in well 199-K-21, between the Liquid Waste Disposal Trench and the Columbia River, although most samples from that well were less than one-third of this value. Monitoring-well 199-K-34 is the only monitoring well close to the KW Reactor Building and contained up to 37 pCi/L of strontium-90.

Antimony-125

Antimony-125 has been detected in the past in a few wells in the 100-K Area. In 1993, antimony-125 was detected only in well 199-K-27, with a maximum concentration of 53 pCi/L. Antimony-125 is a gamma-emitter with a half-life of 2.76 years. The decreasing extent and concentrations of reported antimony-125 in ground water are results of radioactive decay. The antimony-125 trend for well 199-K-27 shown in Figure 5.21 shows that antimony-125 was present even before the increase in tritium concentrations in 1989.

Nitrate

Nitrate was detected during 1993 in the 100-K Area at levels that indicate impact by site activities (Figure 5.22). For a number of wells in the 100-K Area, the nitrate values shown are calculated from total nitrate plus nitrite analyses by assuming that nitrite was not present. This assumption is based on past data and nitrite analyses from other wells in the area. The maximum nitrate concentration detected in the 100-K Area in 1993 was 120 mg/L in well 199-K-30. The nitrate source probably is not the KE basin, since deionized water is used in the basin. The fact that this nitrate appears in the same well as the highest tritium values suggests that either multiple plumes are represented at this well or the KE basin is not the tritium source. Nitrate found in wells near the Emergency Crib and Liquid Waste Disposal Trench may represent the downgradient portion of the nitrate plume impacting well 199-K-30. Nitrate is also found in wells near the KW Reactor and Water Retention Basins.

Chromium

Chromium was detected at levels greater than the DWS in a number of 100-K Area wells in 1993 (Figure 5.23). Where data for both filtered and unfiltered samples are available, the chromium levels were similar. However, analyses of filtered samples are unavailable for a number of wells in the 100-K Area. This hampers the interpretation of the data, particularly the data from new wells, which are constructed with stainless steel casing and screens. The maximum chromium concentration detected in the 100-K Area in 1993 was 2,040 μg/L in well 199-K-21. This value is higher than those from other analyses for this well by more than a factor of ten and is associated with a high nickel concentration, suggesting that the chromium results from corrosion of stainless steel.

5.6 100-N Area

The N Reactor was the last of the production reactors to be built onsite and operated from 1963 to 1987. The N Reactor was unique among the Hanford reactors, in that it was designed for both plutonium production and steam generation. In addition, the N Reactor recycled cooling water, whereas the other reactors used single-pass cooling. The result was that smaller quantities of water were disposed of from the N Reactor, but radionuclide concentrations appear to have been higher because of increased residence time in the reactor and reduced dilution.

Primary disposal locations in the 100-N Area were the 1301-N LWDF and the 1325-N LWDF. The 1301-N LWDF was the primary disposal facility for the N Reactor from 1963 to 1985. Radioactive fission and activation products were received by this facility. The 1325-N LWDF was

constructed in 1983 and used until late 1991. No wastes are currently disposed of at these facilities (Hartman 1994b). In addition to these facilities, the unlined 1324-NA Percolation Pond was used from 1977 to 1986 for disposal of treated wastes containing sulfuric acid and sodium hydroxide at variable pH. From 1986 to 1988, the wastes were treated in a lined pond, the 1324-N Surface Impoundment, at essentially the same location. Tritium, strontium-90, antimony-125, and nitrate are the major contaminants of concern in the 100-N Area.

The 1301-N LWDF, 1325-N LWDF, and 1324-N/NA site are monitored by the RCRA ground-water program (Hartman 1994b). Alexander and Johnson (1993) have published a ground-water impact assessment for the 1325-N LWDF. The 100-N Area ground water is included in the 100-NR-2 CERCLA operable unit.

Tritium

Tritium was found at concentrations greater than the DWS in the northern half of the 100-N Area and extending into the 600 Area to the north and east (Figure 5.24). Tritium was apparently discharged to both the 1301-N LWDF and the 1325-N LWDF. The maximum tritium level detected in the 100-N Area in 1993 was 104,000 pCi/L in well 199-N-14. This result is high compared to the trend data (Figure 5.25) and to another sample collected at the same location and time, in which the concentration was 73,600 pCi/L. Tritium levels in this well are currently decreasing. Water levels in the 100-N Area are declining because disposal activities have been reduced, and as a result it has become impossible to sample a number of wells that had high tritium levels in past sampling.

Ground-water flow in the 100-N Area is generally toward the Columbia River, with a strong component in the downstream direction of the river. The flow is strongly affected by the Columbia River stage. The area of the unconfined aquifer that is subject to recharge from river-stage fluctuations is not completely defined. The hydrogeology of the 100-N Area was recently addressed by Hartman and Lindsey (1993). It appears that much of the present tritium distribution in the 100-N Area and surrounding areas can be attributed to past water-table mounding that resulted from 100-N Area disposal activities.

Strontium-90

Strontium-90 is the constituent of greatest concern at the 100-N Area. This is the only one of the 100 Areas where strontium-90 exceeds the DCG of 1,000 pCi/L. The strontium plume in the 100-N Area is shown in Figure 5.26.

The two LWDFs are apparently the source of the strontium-90 plume, although additional effects from operations in and near the N Reactor Building have not been ruled out. The maximum strontium-90 concentration detected in the 100-N Area in 1993 was 6,160 pCi/L in well 199-N-67, between the 1301-N LWDF and the Columbia River. The trend for strontium-90 in well 199-N-67 is shown in Figure 5.27. An area where strontium-90 concentrations exceed 100 pCi/L south of the 1325-N LWDF may represent residual from an earlier period of strontium-90 disposal. Wells downgradient and to the northwest of this facility contain lower concentrations of strontium-90, possibly diluted by later, cleaner disposal to the 1325-N LWDF. The strontium-90 plume's spread northward in the 1980s is illustrated by the trend data from well 199-N-14 (Figure 5.28). The strontium-90 concentrations in this well have remained approximately level since 1989. Wells farther northeast do not show

detectable strontium-90. The steady levels indicate that the plume is not spreading at a discernible rate at this time. Ground water containing strontium-90 at levels above the DWS is discharging to the Columbia River in the 100-N Area. Strontium-90 discharge through springs along the Columbia River presents a potential route of exposure of the public.

Cobalt-60 and Antimony-125

Cobalt-60 and antimony-125 have been found in the past in a few wells in the 100-N Area. In 1993, only two wells, 199-N-49 and 199-N-33, had concentrations above the DWSs of 100 pCi/L for cobalt-60 or 300 pCi/L for antimony-125. The cobalt-60 concentration detected in well 199-N-49 in August 1993 was 1310 pCi/L. The cobalt-60 concentration detected in well 199-N-33 in August 1993 was 423 pCi/L and the antimony-125 concentration then was 385 pCi/L. The high concentrations of radionuclides in these wells appear to be related to high concentrations of suspended solids in the samples, which had a high turbidity (6,460 NTU for the 199-N-33 sample and 3,300 NTU for the 199-N-49 sample). Concentrations of other strongly sorbed constituents and constituents of sediment solids, including strontium-90, cesium-137, and aluminum, were all elevated. The water levels in these wells have declined to near the bottom of the screens, which is apparently the reason for the high levels of suspended solids. Cobalt-60 and antimony-125 are normally strongly sorbed to aquifer materials. Samples collected for radionuclide analysis were not filtered prior to analysis. The analysis from these wells is therefore not considered representative of the concentrations that are mobile in ground water, although they do indicate that cobalt-60 and antimony-125 remain present. Cobalt-60 and antimony-125 have half-lives of 5.3 and 2.76 years, respectively. The concentrations sorbed onto sediment and in ground water will decrease now that discharge has ceased.

Nitrate

Nitrate attributable to 100-N Area operations was detected in ground water throughout the area but occurred at levels greater than the DWS in only two wells (Figure 5.29). The first of these, 199-N-26, is located generally downgradient of the 1324-N/NA percolation pond and surface impoundment. The wells immediately adjacent to the 1324-N/NA facilities exhibit lower nitrate concentrations, suggesting that the nitrate source has been removed and the aquifer is being cleaned. The second well containing nitrate at levels above the DWS is well 199-N-64, located generally upgradient of the 1301-N LWDF. The maximum concentration detected in well 199-N-64 in 1993 was 47 mg/L.

5.7 200-West Area

The 200-West Area at Hanford was used historically for chemical separation and purification of plutonium with associated waste management. For reasons of safety and security, the area was established with a significant spatial separation from the 200-East Area and with some redundancy of function. Differences in hydrogeology between the two sites have resulted in significant differences in the degree of the spread of contaminants. Four key source areas in the environs of the 200-West Area will be discussed. These are the T Plant, REDOX Plant, U Plant, and Plutonium Finishing Plant (PFP), which was formerly referred to as Z Plant. Operation of the facilities has contributed or is expected to contribute to ground-water contamination. Waste-disposal facilities associated with these activities include cribs, trenches, tile fields, surface impoundments, injection wells, tank farms, and

landfills. Because of the complexity of past waste-disposal operations in the 200 Areas, as well as the close spacing of the facilities, it is generally impossible to determine the exact source of contamination. For example, although it is well known that numerous tank leaks have occurred in the 200-West Area, there is as yet no compelling evidence for ground-water impacts from tank leaks. In most cases the tanks are located close to cribs or other waste-disposal facilities that also received similar wastes in the same periods.

5.7.1 T Plant

T Plant was constructed during the Manhattan Project and used for plutonium separation with the bismuth phosphate precipitation process. T Plant operated as a separations facility from April 1945 to October 1952. More recently, T Plant has been used as an equipment decontamination facility. Major waste-disposal facilities in the area include cribs and tank farms. Of particular interest is the 216-T-26 Crib, which received diverse chemical and radiological waste, and the adjacent 216-T-28 Crib, which received large amounts of water as well as some decontamination wastes. Ground-water plumes originating from this area include nitrate, cyanide, and chromium. A fluoride plume is present in the area, but there is evidence that the plume originated farther south, near the PFP. A carbon tetrachloride plume originating near the PFP extends throughout the T Plant area. Aqueous discharges to the 216-T-19 Crib may be responsible for part of the carbon tetrachloride plume in that area (Rohay et al. 1994). Plumes of tritium, iodine-129, and technetium-99, occur southwest of T Plant, for which the exact sources have not been determined.

Nitrate

Several wells in the northern part of the 200-West Area continued to contain nitrate at concentrations in excess of the DWS (Figure 5.30). These wells are located near several inactive LWDFs that received waste from early T Plant operations. Maximum concentrations in these wells in 1993 ranged up to 590,000 μg/L in well 299-W15-4, similar to those observed in previous years. A trend plot of nitrate concentrations in well 299-W15-4 is shown in Figure 5.31. The figure clearly shows the dramatic impact of the T Plant operations on the ground water during the late 1950s, followed by a decrease associated with the shutdown of T Plant and a long period of relatively constant nitrate contamination levels over the next twenty years.

Cyanide

In past years, low-level cyanide contamination was found in two very limited locations in the 200-West Area. The northern location was located near the 216-T-26 Crib, which received a total estimated inventory of 6,000 kg of ferrocyanide in 1955-1956 (Stenner et al. 1988). The source and extent of contamination at other locations farther south were uncertain. At least six wells in the 200-West Area have shown detectable cyanide in past years; however, measurements in 1993 showed that the cyanide plumes have essentially disappeared.

Chromium

Chromium contamination has been found in the T Plant area, but the rather erratic distribution of the chromium has made it difficult to define a plume, particularly since concentrations have declined in

some of the wells that had shown significant chromium contamination in the past, and the presence of a plume is less obvious. The origin of the contamination is unclear. The 216-T-28 Crib is reported to have received miscellaneous decontamination waste from T Plant. Since hexavalent chromium was frequently used in decontaminating systems containing uranium, that crib is a likely source. The highest filtered chromium concentration observed in the area in 1993 was 510 μg/L in well 299-W14-12.

Carbon Tetrachloride

Although the bulk of the carbon tetrachloride plume in the 200-West Area is known to have originated from LWDFs in the vicinity of the PFP, a secondary maximum in the ground-water concentrations (>2,000 μg/L) found near the southern end of the 241-T tank farm may have a local origin (Figure 5.32). According to Rohay et al. (1994), 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, which is located approximately 550 meters south of where the secondary maximum in the plume was measured.

5.7.2 REDOX Plant

Operation of the REDOX Plant began in 1951 and continued through 1967. Its primary mission was separation of plutonium from uranium and fission products through use of counter-current solvent extraction. The solvent extraction process used an organic solvent (hexone) to separate plutonium from uranium fuel that had been dissolved in nitric acid. Chemical contaminants found in the ground water near the REDOX Plant include nitrate and minor amounts of TCE. The carbon tetrachloride plume prevalent in most of the rest of the 200-West Area is largely absent near the REDOX Plant, apparently as a consequence of the low soil permeability in that area and the lack of any local discharges of carbon tetrachloride (Figure 5.32). The main radiological contaminants are tritium and iodine-129.

Nitrate

A major nitrate plume emanates from the REDOX Plant area, originating primarily at the 216-S-25 Crib, which routinely received process condensate from REDOX operations (Figure 5.30). A trend plot of nitrate concentrations in well 299-W22-20 is shown in Figure 5.33. Nitrate impacts appeared almost immediately after the startup of the REDOX Plant, with very large impacts occurring in the mid-1970s, some time after the termination of REDOX production operations. Although levels have been slowly decreasing since that time, they remain well above the DWS.

Tritium

The movement of tritium plumes in the 200-West Area was consistent with previous observations. The plume extending from near the REDOX Plant in the southern part of the 200-West Area continued to move slowly to the east and north. One well in the 200-West Area (299-W22-9) continued to show tritium levels in excess of the DCG during 1993; however, that well contained up to 3,590,000 pCi/L. This is the highest tritium level of any ground-water monitoring well on the Site (Figure 5.34). The concentrations of tritium detected in 299-W22-9 have decreased steadily since 1977 (Figure 5.35).

Movement of the REDOX Plant tritium plume is expected to be slow due to the low permeability of the sediments in this area and the dissipation of the ground-water mound beneath the nearby U Pond since the pond's deactivation. Tritium concentrations in individual wells are affected by the original source concentration, radioactive decay during the travel time to the well, and dispersion or dilution of the plume.

Iodine-129

The highest iodine-129 concentration observed in Hanford ground water in 1993 was 64.2 pCi/L, found in well 299-W14-12 and essentially identical with the 1992 measurement in that well. The iodine-129 plume from the 200-West Area extends into the 600 Area to the east and coincides with the tritium and nitrate plumes that originate at LWDFs that received REDOX process condensate (Figure 5.36).

5.7.3 U Plant

U Plant was originally designed as a plutonium separation facility but was never used for that purpose. The plant was converted for uranium recovery operations in 1952 to recover uranium waste generated by the bismuth phosphate process and stored in tanks up to that time. Wastes generated by processing resulted in subsurface contamination near the plant and in other areas as the wastes were moved to tanks in the 200-East Area. Ground-water contaminants in the U Plant area include nitrate, uranium, and technetium-99.

Nitrate

The highest nitrate concentrations on the Site in 1993 continued to be found in wells east of U Plant near the 216-U-17 Crib (Figure 5.30). Nitrate was already observed in wells near this crib before February 1988 when the crib went into operation. The source of nitrate is believed to be wastes disposed of in the 216-U-1 and 216-U-2 cribs. These cribs received over 1 million kilograms of nitrate during their operation from 1951 to 1967 (Stenner et al. 1988). Nitrate concentrations in wells located near the 216-U-1 and 216-U-2 cribs west of the U Plant have continued to decrease, with concentrations in several wells dropping below the DWS. For example, the nitrate concentration in well 299-W19-3 near the U Plant has decreased to less than the DWS, as shown in Figure 5.37.

Uranium

The highest uranium levels in Hanford ground water in 1993 occurred near the U Plant in the 200-West Area in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs (Figure 5.38). Uranium concentrations in these wells have been decreasing over the past five years, since remediation activities associated with these cribs were undertaken. A trend plot of uranium concentrations in samples from well 299-W19-3, immediately downgradient from the cribs, is shown in Figure 5.39. The uranium levels in this well continue to decrease slowly but remain greater than the proposed DWS. The maximum concentration detected in this area in 1993 was 3,320 μg/L in one sample from well 299-W19-29. Results from the well have been erratic since 1991, and further data are needed to interpret the trends. However, the 1993 uranium concentration detected in well 299-W19-29 was greater than the DCG.

Technetium-99

Technetium-99 has typically followed uranium throughout much of the fuel cycle. Thus a sizable technetium-99 plume is associated with the 216-U-1 and 216-U-2 cribs in essentially the same location as the uranium plume (Figure 5.40). The extent of the technetium plume is greater because of the higher mobility of technetium in the aquifer. The maximum technetium-99 concentration associated with this plume in 1993 was 20,500 pCi/L, found in well 299-W19-24.

5.7.4 Plutonium Finishing Plant (Z Plant)

The Z Plant was constructed in 1949 to purify plutonium and reduce it to a metallic state. In the early 1980s the plant was modernized and renamed the PFP. The mission of the plant remained essentially unchanged, but liquid discharges were significantly reduced. Primary wastes associated with the Plant include transuranics (TRUs) (primarily plutonium and americium), nitrate, carbon tetrachloride, tributyl phosphate, dibutyl phosphate, dibutyl phosphonate, aluminum fluoride nitrate, and lard oil. TRU contaminants typically remain bound in the soil column at relatively shallow depths, although there may be minor exceptions. Alkyl phosphates have not been observed in the ground water and their fate is still relatively obscure. Lard oil is expected to remain at shallow depth in the soil due to its high viscosity. Nitrate and carbon tetrachloride associated with the PFP Cribs have produced very extensive plumes. Some minor fluoride contamination north of the PFP near the T Plant area may have originated from the PFP Cribs.

Plutonium and Americium

Plutonium-239,240 and americium-241 were detected at low levels in 1990 and 1991 in well 299-W15-8, which monitors the 216-Z-9 Trench. The 216-Z-9 Trench received a large burden of TRUs from Z Plant liquid effluent streams. That well has not been monitored for TRUs since 1991 because the water level has dropped below the well screen. The origin of the TRU contaminants in the well is unclear. They may be associated with poor quality well completion and thus very localized. The plutonium was associated only with unfiltered samples and was thus found to be in a relatively immobile form.

Nitrate

The 216-Z-9 Trench received an estimated 1.3 million kilograms of nitrate containing chemicals over the course of its operation from 1955 to 1962. Other LWDFs associated with the Z Plant received smaller but significant amounts of nitrate. There is thus a major nitrate plume originating in this area, with nitrate levels ranging up to several hundred milligrams per liter in several wells (Figure 5.30).

Chlorinated Hydrocarbons

Carbon tetrachloride contamination was found in the unconfined aquifer beneath much of the 200-West Area. The presence of this plume was first noted in early 1987, although trend data from two wells extend back to early 1986. The contamination is believed to be from waste operations associated with the PFP before 1973. Three LWDFs near the Z Plant (216-Z-18 Crib, 216-Z-1A Tile Field, and 216-Z-9 Trench) received an estimated 577 to 922 metric tons of carbon tetrachloride during

their operational history (Rohay et al. 1994). A concentration of 8,100 μg/L was found in a well near the PFP that was first monitored in October 1988 (well 299-W15-16). Carbon tetrachloride concentrations in the well were somewhat lower in 1993, reaching a maximum of 7,000 μg/L. Other wells in the area had carbon tetrachloride levels ranging from 1,000 to 5,000 μg/L (Figure 5.32).

The carbon tetrachloride distribution in the 200-West Area ground water has remained relatively stable since the presence of the contaminant plume was first noted. Figure 5.32 shows the trends in carbon tetrachloride concentrations with time for wells located at the east, west, north, and south boundaries of the plume. Well 699-39-79 shows a major increase during 1987 and 1988, indicating arrival of the bulk of the plume at that time. Since 1988, concentrations in well 699-39-79 have remained relatively constant. Wells 299-W7-4 and 299-W6-2 to the north show an increase in concentration in the last two years that was not evident previously. Concentrations in wells 299-W19-16 and 299-W19-15 located southeast of the PFP have shown a slow but persistent rise over the past few years, while concentrations in well 699-38-70, located on the eastern edge of the plume, remained essentially unchanged in 1993.

Ground-water flow beneath the 200-West Area has been heavily influenced by mounding caused by operation of the U Pond located at the southwest corner of the 200-West Area. The U Pond received large amounts of cooling water from the REDOX Plant and other facilities. Although U Pond has been decommissioned, a large residual head remains. The spreading of the 200-West Area carbon tetrachloride plume to the west, and now apparently to the south as well, is thus somewhat unexpected, since it is counter to the accepted ground-water flow direction. Changes in ground-water flow since the decommissioning of U Pond and shift to newer facilities may influence the exact plume location and the configuration in particular locations. Another potential influence is the continued spreading of the carbon tetrachloride above the water table -- in either the liquid or the vapor phase. Free-phase liquid carbon tetrachloride above and possibly below the water table could provide a continuing source of contamination. Subsurface investigations performed in association with the ongoing expedited response action and the VOCs-Arid Integrated Demonstration have so far failed to conclusively demonstrate the presence of free-phase liquid, though the extremely high soil gas concentrations found at several locations suggest the presence of free-phase liquid. Because of the difficulties and high costs associated with subsurface access, the investigation has been relatively limited in scope, and any conclusions concerning the presence of free-phase liquid will of necessity be based on indirect evidence. Present evidence suggests that non-aqueous phase liquid is probably present above and below the water table. It appears likely based on observations to date that the carbon tetrachloride plume will expand slowly until more aggressive remedial measures are implemented.

The DWS for carbon tetrachloride is 5 μg/L. The 200-West Area is the only location at Hanford where significant carbon tetrachloride contamination has been detected.

In addition to carbon tetrachloride, lesser amounts of other chlorinated hydrocarbons, particularly chloroform, have been found in the same area. A chloroform concentration of 1,540 μg/L was measured in well 299-W15-8 in May 1990. The highest recorded chloroform level in 1993 was 300 μg/L, in well 299-W18-2. The chloroform plume appears to be associated, but not exactly coincident, with the carbon tetrachloride plume. The chloroform appears to be associated primarily with the 216-Z-9 Trench area (Figure 5.41). The origin of the chloroform is unknown, but it is strongly suspected to be a degradation product of carbon tetrachloride. In the past, septic drainage fields were in the area close to where the chloroform maximum was measured, so anaerobic bacterial

degradation processes are strongly implicated. Minor amounts of dichloromethane have also been observed in both ground-water and sediment samples, further supporting that hypothesis. The DWS for chloroform is 100 μg/L (total trihalomethanes) -- 20 times higher than that for carbon tetrachloride.

Fluoride

A few wells in the 200-West Area near the T Plant showed elevated levels of fluoride during 1993 (Figure 5.42). The maximum concentration in 1993 was 4.9 mg/L in well 299-W10-9; this exceeded both the secondary DWS (2.0 mg/L) and the primary DWS (4.0 mg/L). Well 299-W15-4 had the maximum fluoride onsite in 1992 (7.2 mg/L) but was not sampled in 1993. The source of the small fluoride plume is believed to be several LWDFs associated with the PFP. For example, the 216-Z-9 Trench received 210 kg of aluminum fluoride nitrate during the course of its operation from 1955 to 1962 (Stenner et al. 1988). A similar amount of aluminum fluoride nitrate was disposed of to the 216-Z-18 Crib during its operation from 1969 to 1973. However, the fact that the plume is some distance from both of those facilities makes the identification of the source questionable.

5.8 200-East Area

The 200-East Area at Hanford was used historically for chemical separation and purification of plutonium with associated waste management. For reasons of safety and security, the area was established with a significant spatial separation from the 200-West Area and with some redundancy of function. Differences in hydrogeology between the two sites have resulted in significant differences in the spread of contaminants. In the 200-East Area, specific waste-disposal sources include the PUREX complex, the BY Cribs, and the 216-B-5 Reverse Injection Well. Operation of the facilities has contributed or is expected to contribute to ground-water contamination. Waste-disposal facilities associated with operations include cribs, trenches, tile fields, surface impoundments, injection wells, tank farms, and landfills. Because of the complexity of past waste-disposal operations in the 200 Areas, as well as the close spacing of the facilities, it is generally impossible to determine the exact source of contamination. For example, although it is well known that numerous tank leaks have occurred in the 200-East Area, there is as yet no compelling evidence for ground-water impacts from tank leaks. In most cases, the tanks are located close to cribs or other waste-disposal facilities that also received similar wastes in the same periods.

5.8.1 PUREX Plant

The PUREX Plant started operation in 1956. It eventually replaced the REDOX Plant as the Hanford plutonium separations facility. The first PUREX campaign extended from 1956 to 1972. Following an 11-year shutdown, the plant began operations again in 1983 and ceased in December 1988 when the Hanford weapons production mission ended. Operations at the PUREX Plant are currently focused on diverse waste management needs. Because of the high permeabilities found downgradient of PUREX and the relatively long period of shutdown, the effects of the two operations campaigns can be distinguished in some of the contaminant plumes. Contaminant plumes associated with PUREX operations are primarily those species associated with process condensates, including nitrate, tritium, and iodine-129.

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 (Figure 5.43). Concentrations greater than the 2,000,000 pCi/L DCG were detected in only one well in the 200-East Area, well 299-E17-9 located downgradient of the 216-A36-B Crib. The maximum concentration detected in this well in 1993 was 3,540,000 pCi/L. Concentrations in two other wells monitoring the PUREX cribs, wells 299-E17-1 and 299-E24-11, dropped below the DCG in 1993 samples. Tritium concentrations exceeding the DWS continued to be found in many wells affected by cribs near the PUREX Plant.

The movement of the widespread tritium plume (see Figure 5.1) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Woodruff and Hanf 1993; Dresel et al. 1993). Separate tritium pulses associated with the two episodes of PUREX operations can be distinguished in the plume. The greater-than-200,000-pCi/L lobe east of the 200-East Area near the Columbia River is a result of discharges to ground water during the operation of the PUREX Plant from 1956 to 1972. Elevated tritium concentrations measured in several wells (for example, wells 699-32-43 and 699-24-33) downgradient from the 200-East Area represent a second pulse of tritium moving away from PUREX waste-disposal facilities. Large-scale movement of the leading edge of this plume is best observed in well 699-24-33 (Figure 5.44), which clearly shows arrival of the plume in early 1987, well after the passage of the plume from the earlier campaign. The first plume had reached much higher levels in the mid-1960s. A trend plot of the tritium concentrations in well 699-40-1, located near the shore of the Columbia River (Figure 5.45), shows the arrival in the early 1970s of the first plume and no discernible effect from the second plume as yet.

Iodine-129

The highest iodine-129 concentrations in the 200-East Area are in the southeast near the PUREX Plant (Figure 5.36). The maximum detected iodine-129 concentration in 1993 in the 200-East Area was 12 pCi/L in well 299-E17-9, which monitors the 216-A36B Crib south of the PUREX Plant. The iodine-129 plume extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes. The more limited extent of the iodine-129 plume results from the initial concentrations of iodine-129 being lower than the initial concentrations of tritium and nitrate. It is likely that the iodine-129 plume had the same sources as the tritium and nitrate, and iodine-129 has nearly the same high mobility in ground water as tritium and nitrate, so the smaller apparent extent of the iodine-129 is likely to be a function of the detection limit.

Strontium-90

Strontium-90 is found at levels above the DWS in a few wells near cribs that received discharge from the PUREX Plant (Figure 5.46). The maximum strontium-90 concentration detected in 1993 was 15.6 pCi/L in well 299-E17-14, located next to the 216-A-36 Crib. Well 299-E17-20, adjacent to the 216-A-10 Crib, exhibited concentrations greater than the DWS in 1991 and 1992 but was not sampled in 1993. The effect is very localized due to the lower mobility of strontium-90 as compared to tritium, iodine-129, and nitrate.

Nitrate

The highest nitrate concentrations in the 200-East Area continued to be found near LWDFs that received effluent from PUREX operations. The maximum nitrate concentration detected near PUREX in 1993 was 130 mg/L in well 299-E17-20, which is adjacent to the 216-A-10 Crib. Nitrate concentrations in wells near the 216-A-10 and 216-A-36B Cribs have generally tended to decrease in the past few years but remain above the DWS, even though the facilities were removed from service in 1987. The extent of the nitrate plume emanating from the 200-East Area (Figure 5.30) is nearly identical to that of the tritium plume.

5.8.2 BY Cribs

In 1954 and 1955, scavenged uranium recovery waste supernatant containing large amounts of nickel ferrocyanide and other chemical and radiological components from U Plant operations was discharged to the BY Cribs and to one of the BX Trenches located in the northern part of the 200-East Area (Waite 1991). This practice was soon discontinued because of the appearance of unacceptably high levels of cobalt-60, as well as some cesium-137, in the ground water. With the decommissioning of Gable Mountain Pond in recent years, ground water in that area has begun flowing northward, and a number of ground-water contaminant plumes have reappeared north of the 200-East Area boundary. Chemical contaminants include nitrate, sulfate, and cyanide (as ferrocyanide). Calcium and strontium, which were present in the supernatant as hold-back carrier added to prevent solubilization of strontium-90, also clearly exceed natural background levels. Selenium has also been present in this plume at enhanced levels for several years. Radiological contaminants include a small tritium plume, minor amounts of cobalt-60, and substantial levels of technetium-99. Elevated gross beta levels in the area are associated primarily with the technetium plume. There is some evidence in the past few years for a small amount of uranium also being present in the plume.

Remediation of the BY Cribs is being managed under the 200-BP-1 CERCLA project. The record of decision for this project calls for capping of the crib area to prevent infiltration of precipitation. A field-scale pump-and-treat treatability test to address contamination by cyanide, technetium-99, and cobalt-60 in the area northwest of the BY Cribs is slated for 1994. RCRA monitoring in the northwestern 200-East Area is performed by the 200 Area Low-Level Burial Ground Program and the Single-Shell Tank Program.

Nitrate

The plume originating from the BY Cribs contains some of the highest ground-water nitrate levels on the Site (Figure 5.30). A sample from well 699-50-53A contained 94 mg/L of nitrate in 1993. This is much higher than the 1992 maximum of 58 mg/L. The maximum concentration detected in 1993 in the 600 Area to the northwest of the BY Cribs was 110 mg/L in well 699-55-57.

Cyanide

In past monitoring activities, cyanide was detected in samples collected from wells in and directly north of the 200-East Area. The cyanide source is believed to be wastes containing ferrocyanide disposed of in the BY Cribs. Samples taken from the 200-East Area in 1993 had a maximum cyanide

concentration of 41.5 μg/L in one sample from well 299-E33-12, just east of the BY Cribs. This sample also contained 37 pCi/L of cobalt-60. Well 299-E33-12 is completed in the basalt, indicating that these contaminants have migrated to considerable depth in the flow system. Migration through the unconsolidated sediments may have been increased by the higher hydraulic head caused by past disposal activities and by the high density of some of the waste streams (Smith 1980; Graham et al. 1984). Characterization of the deeper parts of the unconfined aquifer and the confined aquifer in the vicinity of the BY Cribs is considerably less complete than the characterization of the top of the unconfined aquifer. Well 699-50-53A, north of the BY Cribs, contains higher cyanide concentrations than found within the 200-East Area (199 μg/L in 1993) but at concentrations considerably lower than in previous years. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed and mobilized by cyanide or ferrocyanide.

Selenium

The presence of significant levels of selenium in ground-water samples from well 699-50-53A has been noted since 1987, but the origin of the selenium is not known. It may be a stable fission product, since the heavier selenium isotopes have significant fission yields; an isotopic analysis will be required to confirm that hypothesis. A maximum selenium level of 61 μg/L in well 699-50-53A was found in November 1991. The highest selenium level reported for that well in 1993 was 38 μg/L. The DWS for selenium is 50 μg/L.

Cobalt-60

Well 699-50-53A, which is located north of the 200 Areas in an area that has been affected by waste disposed of in the BY Cribs, has consistently shown the presence of detectable cobalt-60 in recent years. Cobalt-60 in this well in 1993 ranged up to 56 pCi/L, continuing the decline from a maximum in 1989-1990, as shown in Figure 5.47. A prior maximum cobalt-60 concentration occurred about 1960 and was considerably higher. Much of that cobalt-60 has now decayed away because of its 5.3-year half-life. Cobalt-60 in this area appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating in the BY Cribs.

Technetium-99

Elevated technetium-99 levels apparently associated with the BY Cribs plume continued to be observable in 1993. Technetium-99 levels in well 699-50-53A are dropping with time, but the maximum detected in 1993 (3,700 pCi/L) is well above the 900 pCi/L DWS (Figure 5.48). The decline in technetium-99 is similar but less steep than that for cobalt-60. The half-life of technetium-99 (2.21×10^5 years) is much longer than that of cobalt-60, and thus the decreasing technetium-99 concentrations reflect changes in flow direction or source concentrations rather than radioactive decay. The extent of technetium-99 to the northwest of the BY Cribs is shown in Figure 5.49.

Uranium

A uranium level of 8 μg/L was measured in a ground-water sample from well 699-50-53A collected in 1992. The highest concentration detected in this well in 1993 was 7.0 μg/L. Continued

monitoring of this well will be needed to determine whether a uranium plume is present; however, since the waste stream was associated with uranium recovery, the presence of such a plume is not unexpected. It is possible that these uranium levels represent a somewhat elevated natural background concentration.

5.8.3 216-B-5 Injection Well

The 216-B-5 Injection Well was operated from April 1945 to September 1946. It received radioactive wastes from B Plant activities, including some hot cell drainage and supernatant overflow from settling tanks. The waste was pressure-injected below the water table, resulting in radiological contamination that is still apparent nearly 50 years later. Radiological contaminants associated with the facility include strontium-90, cesium-137, and plutonium. These three contaminants are restricted to the immediate vicinity of the injection well by their low mobility in ground water and the extremely low hydraulic gradient in this area. Characterization activities in the vicinity of the 216-B-5 Injection Well were reported by Smith (1980).

Remediation of ground water in the area of the 216-B-5 Injection Well is being planned under the 200-BP-5 CERCLA project. A field-scale treatability test for a pump-and-treat remediation system is to be conducted in 1994. The low mobility of the contaminants of concern is likely to limit the system's ability to remove them unless a more aggressive treatment strategy is adopted.

Strontium-90

Concentrations of strontium-90 in 1993 ranged up to 7,890 pCi/L in well 299-E28-23 near the 216-B-5 Injection Well (Figure 5.46). The 216-B-5 Injection Well received an estimated 27.9 Ci of strontium-90 (decayed through April 1, 1986) during the time that it was used for waste disposal (1945 to 1946; Stenner et al. 1988).

Cesium-137

Concentrations of cesium-137 in 1993 reached 2,080 pCi/L in well 299-E28-23, located near the 216-B-5 Injection Well. The 1992 sample from well 299-E28-23 had contained 1,860 pCi/L of cesium-137. The 216-B-5 Injection Well received an estimated 31.8 Ci of cesium-137 (decayed through April 1, 1986) while it was used for waste disposal from 1945 to 1946 (Stenner et al. 1988). The DWS for cesium-137 is 200 pCi/L, and the DCG is 3,000 pCi/L.

Plutonium

The maximum concentration of plutonium-239/240 detected near the 216-B-5 Injection Well in 1993 was 125 pCi/L in well 299-E28-25. The 216-B-5 Injection Well received an estimated 244 Ci of plutonium-239/240 during its operation from 1945 to 1946 (Stenner et al. 1988). The DCG for plutonium-239 is 30 pCi/L. There is no explicit DWS for plutonium-239; however, the gross alpha DWS of 15 pCi/L would be applicable at a minimum. Alternatively, if the DCG (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the DWS, 1.2 pCi/L would be the relevant guideline. Plutonium is generally considered to bind strongly to sediments and thus has limited mobility in the aquifer.

5.9 300 Area

Constituents of concern detected in ground water at the 300 Area include uranium and TCE. Although tritium levels greater than the DWS have not been detected in the 300 Area, the tritium plume from the 200-East Area impacts the northern part of the 300 Area (Figure 5.50). The regional tritium plume and its effects on the 300 Area have been discussed in relation to its source area in the 200-East Area. Chromium detected in unfiltered samples from the 300 Area appears to be related to stainless steel monitoring-well construction. Ground-water flow and contaminant transport in the 300 Area are complicated by fluctuations in the Columbia River stage and associated changes in gradient and bank storage.

The major role of the 300 Area in Hanford Site operations was the processing of uranium into fuel elements for the reactors. Fuel fabrication activities ended in 1987. During fuel fabrication, uranium was reportedly disposed of to the process ponds and trenches in dissolved and particulate forms. Facilities known to have received uranium include the 316-1 South Process Pond, the 316-2 North Process Pond, and the 316-5 Process Trenches. Of these, only the 316-5 Process Trenches are currently active.

The 316-5 Process Trenches are monitored by the RCRA program (Borghese 1994). Use of the trenches began in 1975. Impacts on ground water from past activities in the 300 Area are being addressed by the 300-FF-5 CERCLA project. The Phase I Remedial Investigation Report and Phase I and II Feasibility Study Report for the 300-FF-5 Area have been published (DOE-RL 1994b,c).

Uranium

The uranium distribution in the 300 Area is shown in Figure 5.51. The highest uranium concentrations are located in the northern part of the 300 Area, downgradient from the 316-5 Process Trenches and the 316-2 North Process Pond. The maximum uranium concentration detected in the 300 Area in 1993 was 145 μg/L in well 399-1-16A. The 316-5 Process Trenches and the 316-2 North Process Pond both received waste uranium in the past. The 316-5 Process Trenches are currently active but receive much less discharge than in the past -- approximately 850 L/min, down from a maximum of approximately 7,600 L/min (Borghese 1994). Currently the trenches receive process cooling water with a small quantity of nonhazardous maintenance and process waste. All of the current discharge goes to the east trench. Contaminated material was removed from the inflow area of the trenches as part of an expedited response action in 1991. Well 399-1-17A monitors the upper unconfined aquifer near the inflow of the trenches. This well has shown cyclical variations in uranium concentration in the past. Currently concentrations remain low (Figure 5.52) but were above the DWS in some samples. The lower uranium concentration in well 399-1-17A may be a function of the expedited response action and/or the reduced flow.

The area of elevated uranium concentration in the southern part of the 300 Area reaches a local maximum at well 399-4-7, which had a maximum concentration of 51 μg/L in 1993. The source of the uranium in this area is not well defined. The zone of lower uranium concentrations between the two highs corresponds approximately to a zone of lower-permeability sediments. The plume geometry

probably reflects the effect of this lower-permeability zone on ground-water flow. Well 399-4-12, which supplies water for ponds used in trout research south of the 331 Building, contained 25 μg/L in 1993 sampling.

Trichloroethylene

Few wells in the 300 Area contain concentrations of TCE greater than the DWS (Figure 5.53), although TCE was used during fuel fabrication and significant quantities were disposed to the ground (Stenner et al. 1988). The presence of cis-1,2-dichloroethylene (DCE) in some samples indicates that anaerobic biodegradation of TCE has occurred. However, the fact that vinyl chloride has not been detected in the 300 Area indicates that the degree of biodegradation is relatively low (cis-1,2-DCE is degraded to vinyl chloride less readily than TCE is degraded to cis-1,2-DCE). The analytical method used by the RCRA monitoring in 1993 did not distinguish cis-1,2-DCE from trans-1,2-DCE, so the results were reported as total 1,2-DCE. It should also be noted that data collected until 1990 by the RCRA programs and the Ground-Water Surveillance Project apparently also did not distinguish cis-1,2-DCE from trans-1,2-DCE; however, the data were reported as trans-1,2-DCE. The more detailed characterization in 1992 demonstrates that nearly all of the DCE is cis-1,2-DCE. The maximum detected concentration of total DCE in monitoring-well 399-1-16B in 1993 was 180 μg/L, more than an order of magnitude greater than the TCE concentration.

The highest TCE concentrations detected in the 300 Area are in the 399-1-16A,B,C well nest, which is located near the 316-2 North Process Pond area. The 316-5 Process Trenches, upgradient from this well nest, are still active. TCE concentrations in the 399-1-16 wells are highest in the lower unconfined aquifer well, 399-1-16B, where the maximum concentration detected in 1993 was 11 μg/L. Although TCE has been detected in past samples from the upper confined aquifer well, 399-1-16C, these values probably relate to leakage from the unconfined aquifer around the well-bores. Shortly after installation of the wells, the water level in 399-1-16C declined to near that of 399-1-16B, suggesting aquifer intercommunication resulting from well installation. Well 399-1-16C was remediated in 1993 and TCE was not detected in 1993 samples from well 399-1-16C. Well 399-1-16D, which was still deeper, was abandoned because of suspected well-construction problems.

The reason for TCE concentrations being higher in the lower unconfined aquifer than in the upper unconfined aquifer in the 399-1-16 wells is probably related to greater flushing of the upper unconfined aquifer by relatively cleaner water being disposed of to the 316-5 Process Trenches. Hydraulic gradients in the 300 Area are toward the river and upward, so it is unlikely that TCE is being transported to greater depths by the current flow system. Past disposal practices, however, may have produced sufficient mounding beneath the 316-2 North Process Pond to transport disposal water to significant depths. The presence of dense non-aqueous phase liquid TCE at depth within the aquifer is unlikely. If dense non-aqueous phase liquid were present, it would probably remain at residual saturation through the upper sediments in the source area and provide a continuing source of contamination to the shallow flow system. TCE was detected at low concentrations (maximum of 2.7 μg/L in 1993) in the upper unconfined aquifer monitored by well 399-1-16A. The present distribution of contamination is best explained by flushing of aqueous phase TCE from a source that has now been removed.

TCE is present at low levels in many samples from the southern portion of the 300 Area. Concentrations in samples collected in 1993 were below 10 μg/L in all samples from the 316-1 South Process Pond and farther south; in most cases TCE concentrations were below the 5-μg/L DWS. The

only exception comes from one sample from well 399-4-12, which contained 6 μg/L of TCE. The large area of low-level TCE in ground water in the southern part of the 300 Area suggests a widely distributed source, such as the sewer system, or a source upgradient from the area.

Chromium

Chromium continues to be detected sporadically in unfiltered samples from the 300 Area. The concentrations in filtered samples remain below the DWS for all samples, but those in three unfiltered samples were above the Washington State DWS of 50 μg/L. Chromium was not detected in any filtered samples from the 300 Area in 1993. The maximum concentration of chromium found in unfiltered samples in 1993 was 81 μg/L, in well 399-1-18A. Their erratic presence in unfiltered samples only suggests that the high chromium concentrations in these monitoring wells represent particulate matter, probably related to the stainless steel well construction. The erratic concentrations are caused by minor changes in well-purging procedures, the length of time between samples, or other effects that do not reflect the general ground-water quality.

5.10 400 Area

The 400 Area is the location of the Fast Flux Test Facility (FFTF), which is a liquid-sodium-cooled reactor facility. This reactor is slated for decommissioning within the next few years.

No sources of ground-water contamination have been identified in the 400 Area. However, elevated levels of tritium and nitrate associated with the ground-water plume from the vicinity of the PUREX Plant in the 200-East Area have been identified in 400 Area wells (Figures 5.1 and 5.30). A new water supply well, 499-S1-8J, was drilled to the lower unconfined aquifer in 1985 to reduce tritium concentrations to below the DWS. Two water supply wells, 499-S0-7 and 499-S0-8, in the upper unconfined aquifer are also connected to the 400 Area water supply. Well 499-S0-7 is used for backup water supply, and well 499-S0-8 is maintained for emergency use. The tritium activities in wells 499-S1-8J, 499-S0-7, and 499-S0-8 are compared to those in the 400 Area drinking-water supply in Figure 5.54.

Tritium in the 400 Area drinking-water supply is monitored by the Hanford Environmental Health Foundation (HEHF). It has remained below the DWS for all but one sampling event since the new supply well (499-S1-8J) went on line in 1985. The concentration of tritium in the drinking-water supply closely reflects that in the main supply well, 499-S1-8J, in spite of occasional use of the backup wells. Tritium in backup well 499-S0-7 remained above the DWS. Tritium concentrations in well 499-S0-8 suddenly dropped below the DWS in 1992 and have remained low ever since. The reason for this drop is unclear. Well construction allows water from the 400 Area water supply to flow slowly down the well to lubricate the pump bearings. Since the well is seldom used, this practice may affect the sample quality. However, a change in sampling procedure to pump the 400 Area water supply wells for 20 minutes at approximately 760 L/min (200 gal/min), purging approximately 3 well volumes before sampling, did not affect the sample results. A zone of lower tritium concentration appears to be present in the general vicinity of the 400 Area. Nitrate remained below the DWS through 1992 in samples from all three supply wells in the 400 Area.

Assessment efforts associated with the 300-FF-2 CERCLA Operable Unit will extend to include ground-water contamination in the 400 Area.

5.11 600 Area

Most of the ground-water contamination found in the 600 Area is related to sources in the operational areas discussed above. However, several other sources or potential sources of contamination exist.

The Central Landfill Complex includes the Non-Radioactive Dangerous Waste Landfill (NRDWL), which is a RCRA facility, and the Solid Waste Landfill, a non-RCRA facility southeast of the 200-East Area (Figure 1.1). The Central Landfill Complex is included in the 200-IU-3 Operable Unit for the purposes of the Tri-Party Agreement. The 1993 RCRA monitoring of the NRDWL and monitoring of the Solid Waste Landfill has been summarized by Hodges (1994a,b).

The NRDWL received dangerous non-radioactive waste from 1977 to 1985 and continued to receive asbestos waste until 1988. The Solid Waste Landfill has been in operation since 1972 and has received principally paper waste, construction debris, asbestos waste, and lunchroom waste. In addition, some sewage waste and washwater from the Hanford Site bus garage were disposed of at the Solid Waste Landfill between 1985 and 1987 (DOE-RL 1992).

The chlorinated hydrocarbon compounds, including TCE and tetrachloroethylene, detected at the Solid Waste Landfill are attributed to the bus garage washwater. A soil gas survey of the Solid Waste Landfill performed in 1989 (Evans et al. 1989) confirmed the presence and documented the distribution of chlorinated hydrocarbons in the landfill. Chlorinated hydrocarbons detected in the soil gas survey include TCE, tetrachloroethylene, and 1,1,1-trichloroethylene

More recently, Jacques (1993) performed a soil-gas survey in the NRDWL with similar results. The NRDWL survey included detection of minor carbon tetrachloride contamination not seen in other parts of the landfill but occasionally seen at minor levels in the ground water.

Several wells at the Solid Waste Landfill contained TCE at levels close to but slightly below the DWS, with the maximum concentration detected in 1993 being 3.4 μg/L in well 699-23-34A. Wells monitoring the Solid Waste Landfill had had TCE concentrations above the DWS in previous years. These wells continued to have levels of tetrachloroethylene just above the 5-μg/L DWS. Tetrachloroethylene concentrations in 1993 reached a maximum of 5.9 μg/L in well 699-23-34A. Other VOCs detected in this vicinity in 1993 are carbon tetrachloride, chloroform, and 1,1,1-trichloroethane.

Gable Mountain Pond is a liquid waste disposal area located south of Gable Mountain. Gable Mountain Pond received liquid wastes from the 200-East Area until it was deactivated in 1987. The pond is currently dry. Concentrations of strontium-90 above the DWS are detected in several wells near Gable Mountain Pond (Figure 5.46). Strontium-90 in that area apparently resulted from the discharge of waste to that pond during its early use. The maximum concentration of strontium-90 detected in the Gable Mountain Pond area in 1993 in 1993 was 154 pCi/L in one sample from

well 699-54-49. Strontium-90 is also detected in the top of basalt in well 699-43-48A where the concentration was 91.4 pCi/L. The depth to basalt in this well is 44 ft.

5.12 Richland North Area

The Richland North Area, including the 1100 and 3000 Areas, that part of the 600 Area that is south of the 300 Area, and nearby offsite parts of Richland are considered together in this section. Thus, this area includes the CERCLA 1100-EM-1 Operable Unit, the Siemens Power Corporation facilities, the North Richland well field and recharge basins, and a number of other commercial, agricultural, and residential areas. Particular concern in the Richland North Area is related to the potential for future impacts at the North Richland well field.

The Horn Rapids Landfill is part of the 1100-EM-1 Operable Unit. Results of the CERCLA 1100-EM-1 investigations are presented in the Final Remedial Investigation/Feasibility Study (DOE-RL 1992), and the Tri-Party Agreement record of decision for the 1100-EM-1 Operable Unit was signed in September 1993. The remedy for ground water that was selected was natural attenuation and ground-water monitoring, with institutional controls on drilling of new ground-water wells.

The North Richland well field consists of a cluster of eight active wells into the unconfined aquifer and the associated recharge basins. Water from the Columbia River is pumped to the recharge basins and allowed to infiltrate, producing a ground-water mound in the well field area. The city's operational goal is to recharge twice as much water as is pumped from the wells. The North Richland wells are used when the Richland water treatment plant is down for servicing and when needed to meet summer peak demand.

Ground-water constituents of concern in the Richland North Area include gross alpha or uranium, nitrate, technetium-99, and TCE. The potential for transport of tritium from Site operational areas into the Richland North Area is also being assessed.

Tritium

Tritium from the 200-East Area discharge has been transported to the Columbia River as far south as the 300 Area (Figure 5.50). The levels in monitoring wells north of the 300 Area increased steadily until 1993 and have raised concern regarding possible future impact on the North Richland water supply wells. The trend in tritium activity in well 699-S19-E13, north of the 300 Area, is shown in Figure 5.55. Tritium analyses of samples collected from the North Richland wells do not indicate any impact of Site activities on the well field.

Several factors are believed to limit the migration of the 200-East Area tritium plume toward the Richland North Area. The first of these is the eastward flow across the area produced by the Yakima River stage. The Yakima River to the west of the Richland North Area is approximately 15 m higher than the Columbia River to the east. The net result is ground-water recharge from the Yakima, eastward flow across the area, and discharge to the Columbia. Additional recharge from irrigation in the western Richland North Area is also believed to contribute to the eastward flow. The ground-water

mound at the recharge basins also limits southward flow of ground water from the site. These factors produce converging flow lines and discharge to the Columbia River in the 300 Area (see Figure 5.50).

Nitrate

Nitrate distributions in the Richland North Area provide additional support for the interpretation of ground-water flow presented above. Nitrate concentrations greater than the DWS in ground water are found in the vicinity and downgradient of the Siemens Power Corporation plant (Figure 5.30). The maximum nitrate concentration detected in sampling near the Siemens Power Corporation plant in 1993 was 225 mg/L as NO_3 (Geraghty and Miller 1993). Somewhat elevated nitrate concentrations have also been found upgradient of Siemens Power Corporation in the western portion of the Richland North Area. The upgradient sources may be application of agricultural fertilizer and irrigation. Potential nitrate sources from the Siemens Power Corporation operations have been discussed by DOE-RL (1992). Nitrate was not identified as a soil contaminant in the Horn Rapids Landfill.

An area of low nitrate concentration is located around the North Richland well field recharge basins. This pattern is interpreted as representing the effect of infiltrating low-nitrate water from the Columbia River.

Trichloroethylene

TCE has been detected in ground-water samples from wells in the areas of Siemens Power Corporation and the Horn Rapids Landfill. The maximum TCE detected in the vicinity of the Horn Rapids Landfill in 1993 was 61 μg/L in well 699-S31-10A.

The only potential TCE source identified in the Richland North Area is the use of TCE in installing and maintaining pond liners at the Siemens Power Corporation facility (DOE-RL 1992). TCE has been detected in ground water at the Siemens Power Corporation facility and downgradient from it. No TCE was detected in soil samplings from the Horn Rapids Landfill. TCE detected in soil gas sampling at the landfill probably results from volatilization of the ground-water plume.

Gross Alpha

Gross alpha levels up to 120 pCi/L were detected in 1993 at the Siemens Nuclear Power Corporation plant (Geraghty and Miller 1993). Although the gross alpha DWS of 15 pCi/L excludes uranium, separate uranium measurements were not reported and no correction can be made. It is probable that uranium makes a large contribution to the gross alpha measurements at this location, since the facility is used to fabricate fuel rods for commercial nuclear power plants. Uranium concentrations greater than the DWS have not been detected in any of the Hanford wells monitoring the Horn Rapids Landfill. Gross alpha measurements indicate that the area of elevated gross alpha contamination extends downgradient at least to the eastern side of the Horn Rapids Landfill. The maximum extent of the plume has not been defined any more precisely because of the lack of wells within the landfill itself. The geometry of the plume indicates that its source is located offsite.

5.13 Confined Aquifer Chemistry

The Ground-Water Surveillance Project monitors the ground-water chemistry in the confined aquifer beneath the Hanford Site. Monitoring results reveal little potential for migration of contaminants to move offsite through the confined aquifer pathway. In the area south of Gable Mountain near B Pond, the Rattlesnake Ridge Interbed of the upper basalt confined aquifer is exposed to suprabasalt sediments, increasing the potential for intercommunication between the upper basalt confined aquifer and the overlying Hanford unconfined aquifer (Figure 3.13). Discharge of waste water from Hanford facilities to the ground has resulted in an elevated water table across much of the Hanford Site and the mounding of ground water near B Pond in the 200-East Area and around the decommissioned U Pond in the 200-West Area (Plate 1; Figure 3.5). A downward gradient exists beneath much of the 200 Areas plateau, particularly where ground-water mounding occurs, resulting in the potential for ground water from the Hanford unconfined aquifer to mix with ground waters of the upper basalt confined aquifer.

Tritium, nitrate, and iodine-129 are readily transported by ground water and can be used to assess the general extent of contaminants associated with Hanford Site activities in the upper confined aquifer. Tritium levels above the DWS have been reported for four wells completed within the upper basalt confined aquifer. However, reported concentrations above the DWS are outliers relative to the trend data and probably do not represent aquifer conditions. Tritium concentrations in well 699-42-40C have been increasing from 1984 to 1993. The maximum value for tritium observed in this well occurred in April 1993 (8,320 pCi/L). Well 699-42-40C is located adjacent to B Pond and monitors the Rattlesnake Ridge Interbed. Nitrate concentrations near and above the DWS have been reported for well 299-E33-12 and have remained fairly constant from 1991 through 1993. The 1993 value for nitrate measured in this well was 46 mg/L. Well 299-E33-12 is located along the northern boundary of the 200-East Area and completed within the Rattlesnake Ridge Interbed. Iodine-129 concentrations above the DWS have been reported only for well 699-50-53B, which is completed in the upper basalt confined aquifer. The value reported was not confirmed by subsequent analysis.

Tritium and nitrate concentrations in wells 699-42-40C and 299-E33-12, which are completed within the Rattlesnake Ridge Interbed, apparently result from mixing of waste water discharged from Hanford facilities in the 200-East Area. Downward gradients associated with ground-water mounding near B Pond result in areas of enhanced intercommunication (Graham et al. 1984) where the Rattlesnake Ridge Interbed is exposed to the Hanford formation and these likely induce flow from the Hanford unconfined aquifer to the upper basalt confined aquifer. Contaminants associated with Hanford Site operations have not been observed at levels greater than the DWS in wells completed within the upper basalt confined aquifer. The gradients in the confined aquifer indicate that the confined aquifer beneath the Hanford Site ultimately discharges to the Columbia River, although at this time there is no evidence for discharge of contaminated ground water from the confined aquifer to the river.

Figure 5.1. Contour Map of Tritium Concentrations Above the Drinking Water Standard

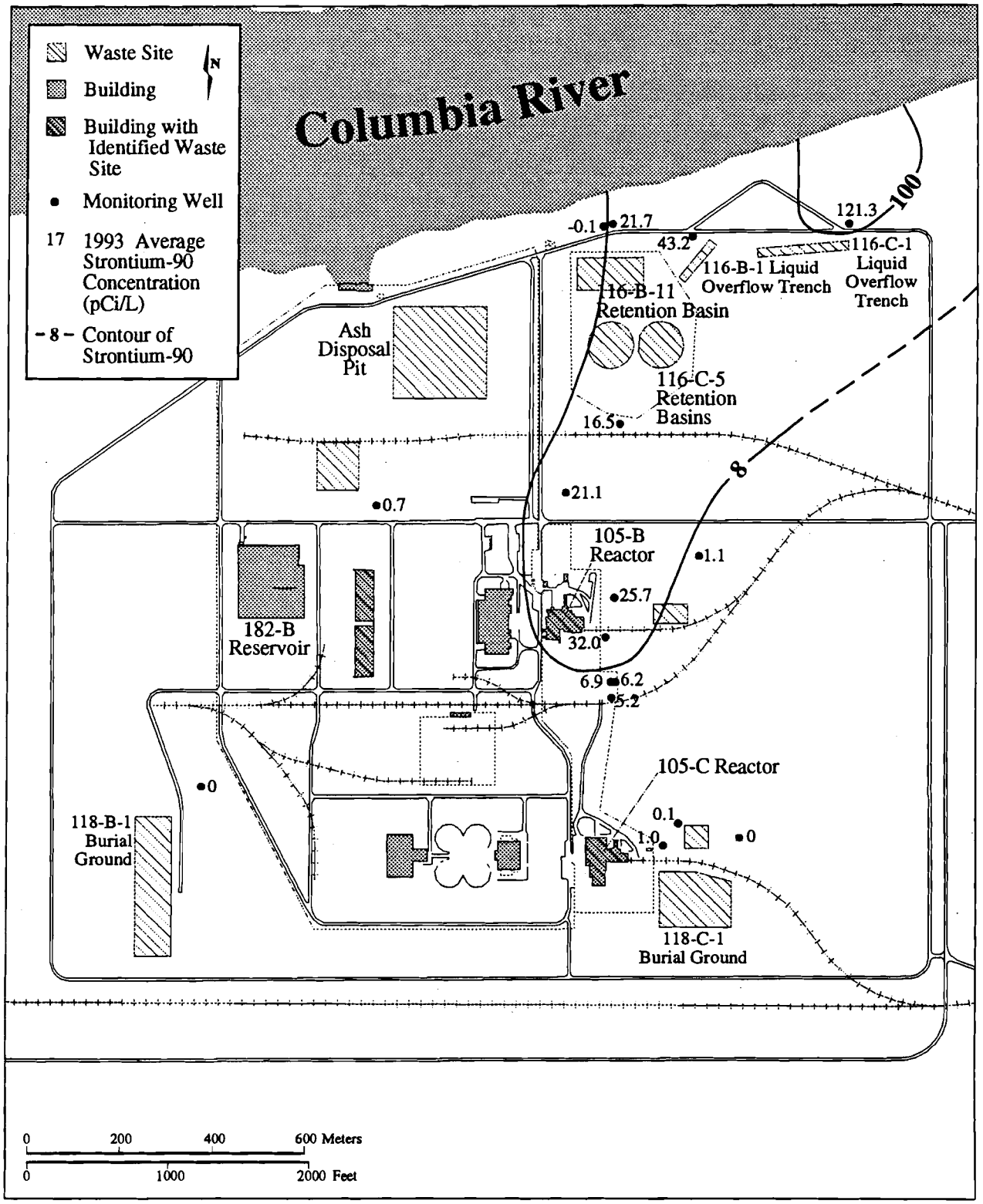


Figure 5.2. 1993 Average Strontium-90 in the 100-B/C Area

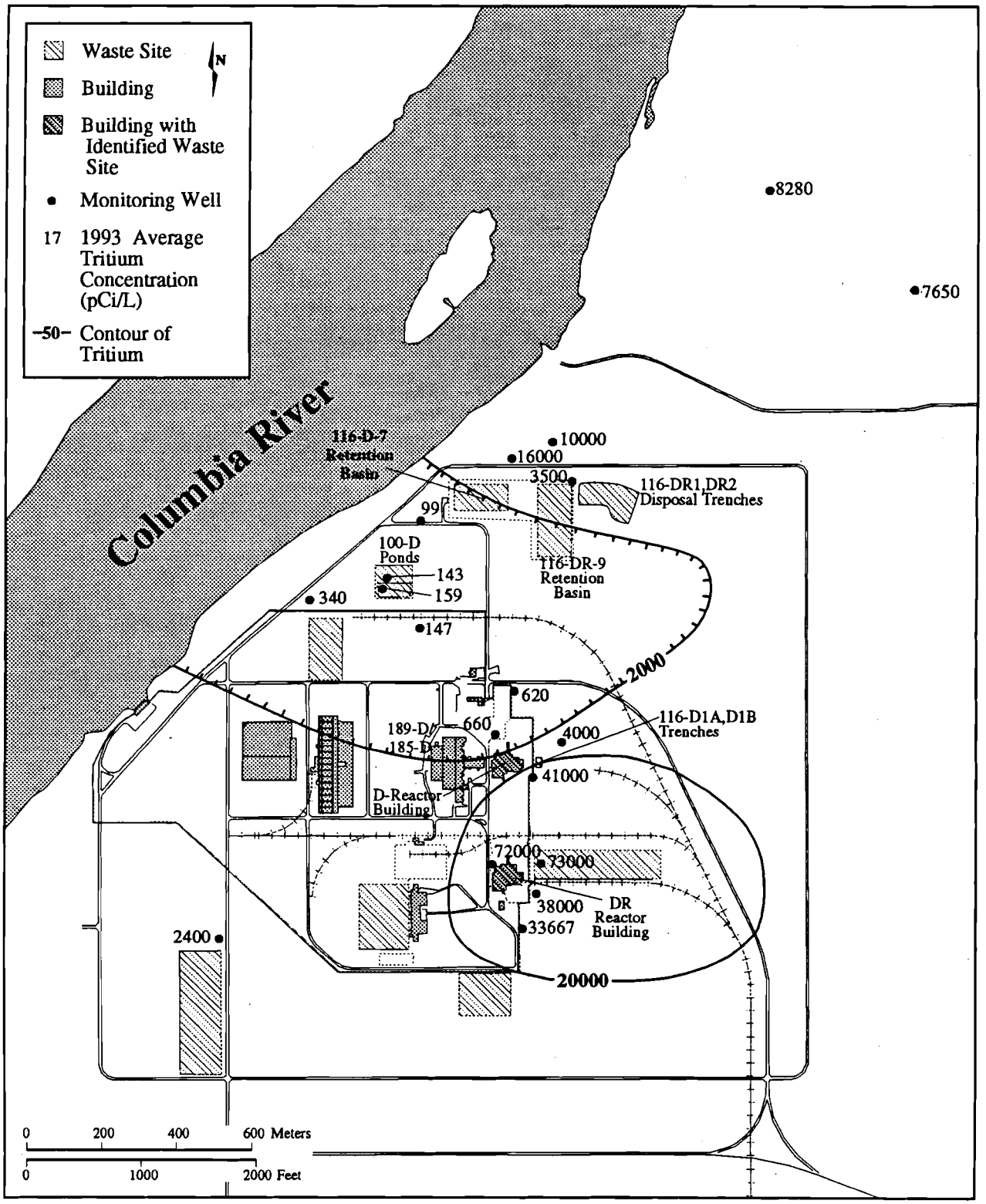


Figure 5.3. 1993 Average Tritium in the 100-D Area

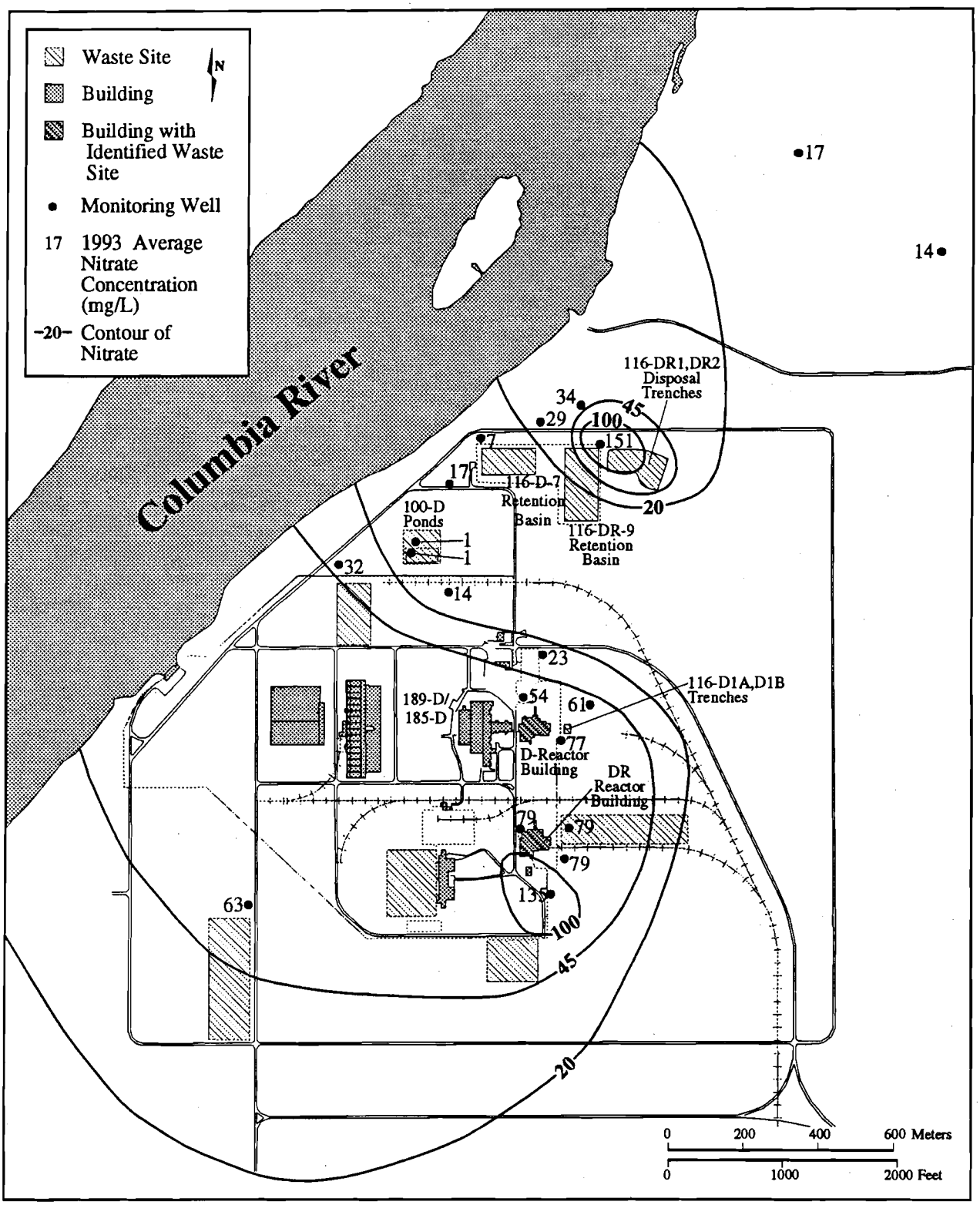


Figure 5.4. 1993 Average Nitrate in the 100-D Area

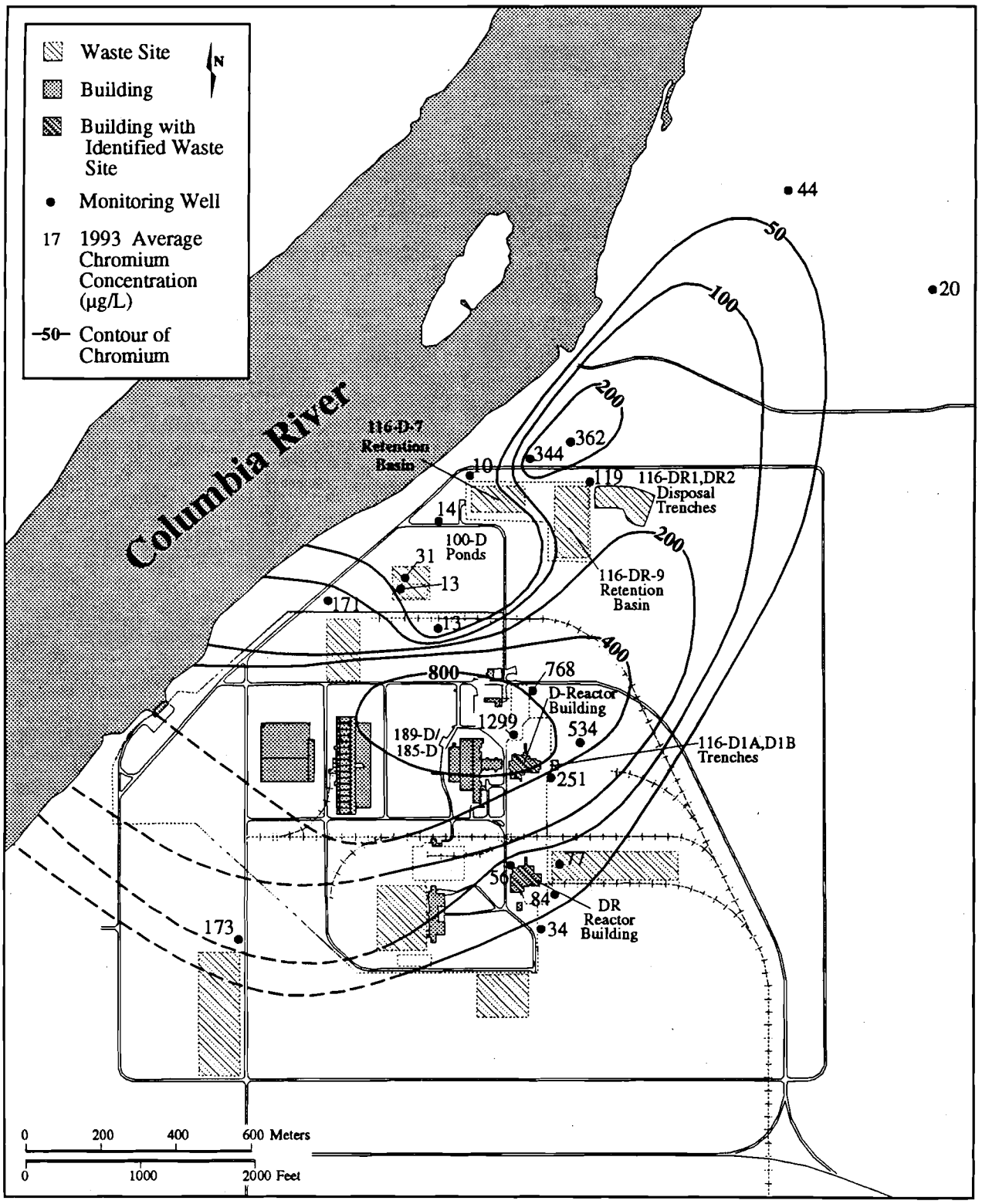


Figure 5.5. 1993 Average Chromium in the 100-D Area

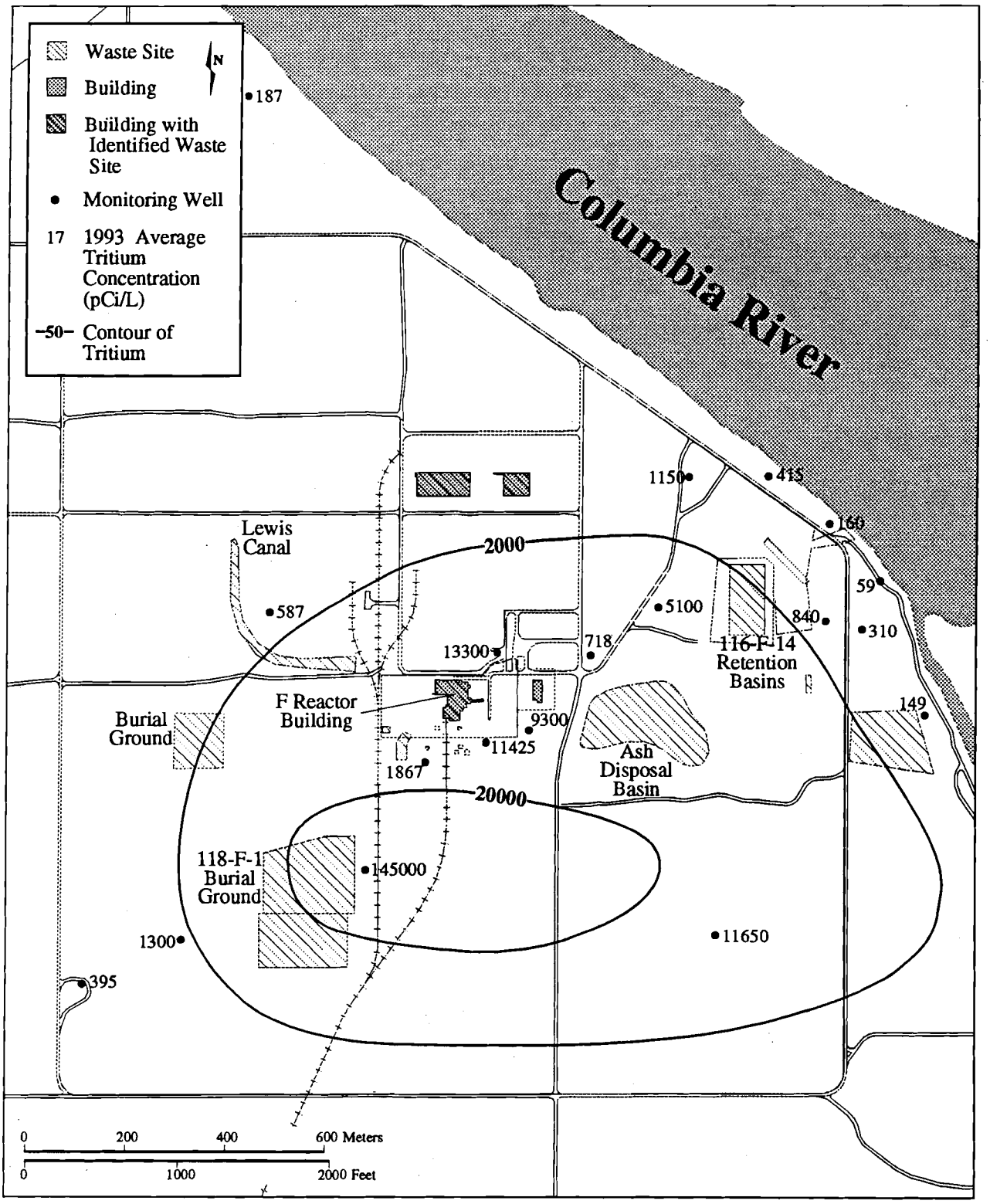


Figure 5.6. 1993 Average Tritium in the 100-F Area

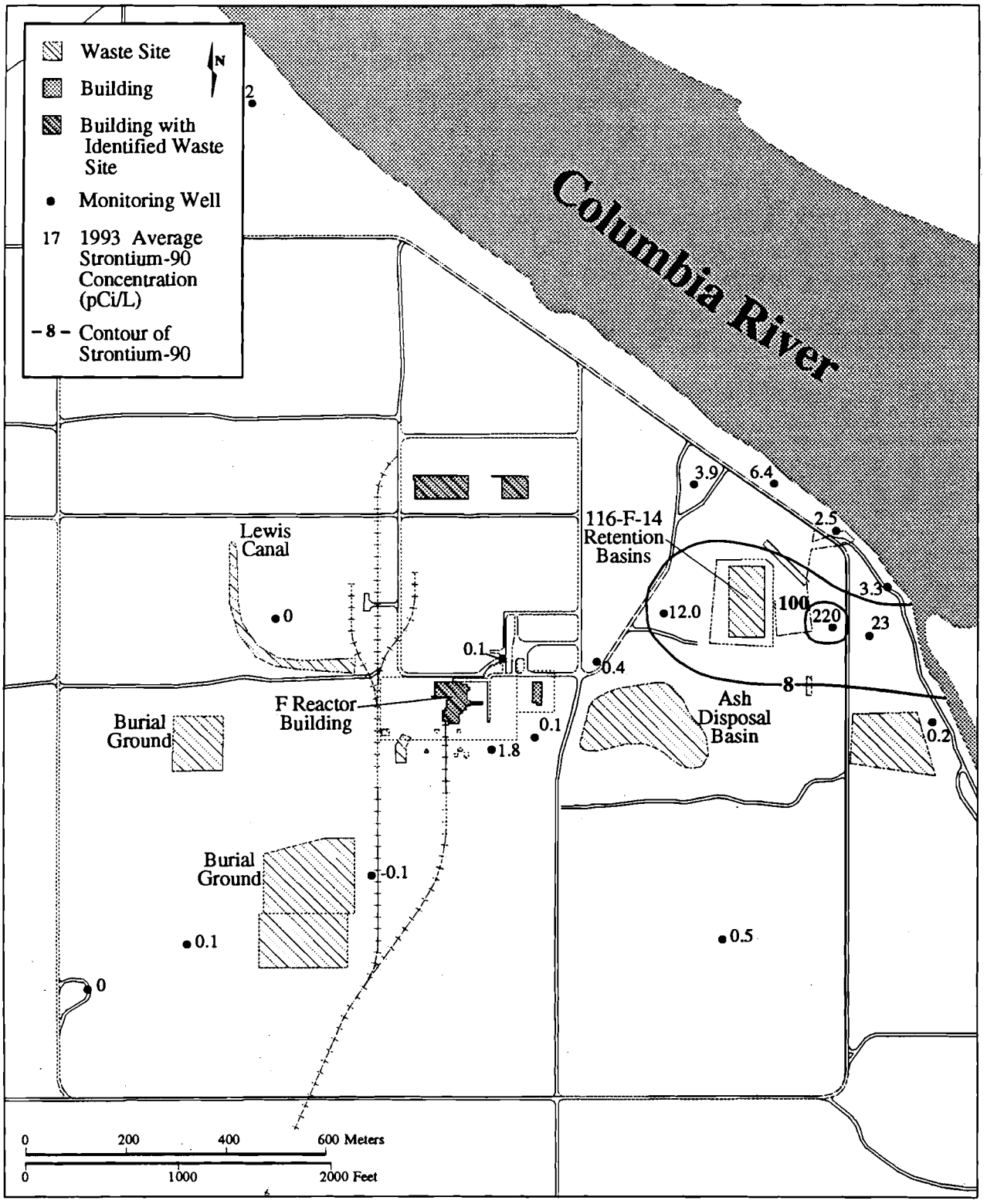


Figure 5.7. 1993 Average Strontium-90 in the 100-F Area

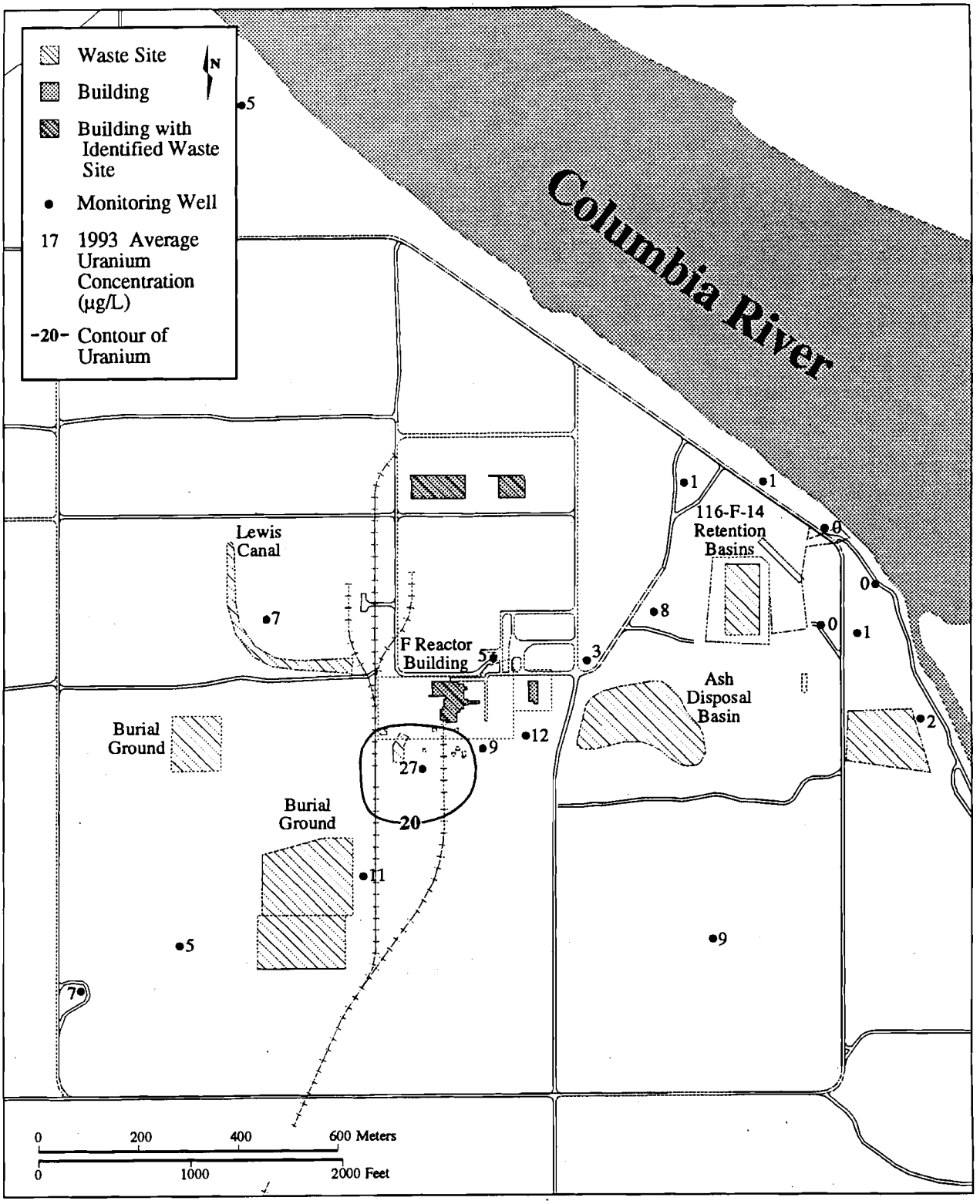


Figure 5.8. 1993 Average Uranium in the 100-F Area

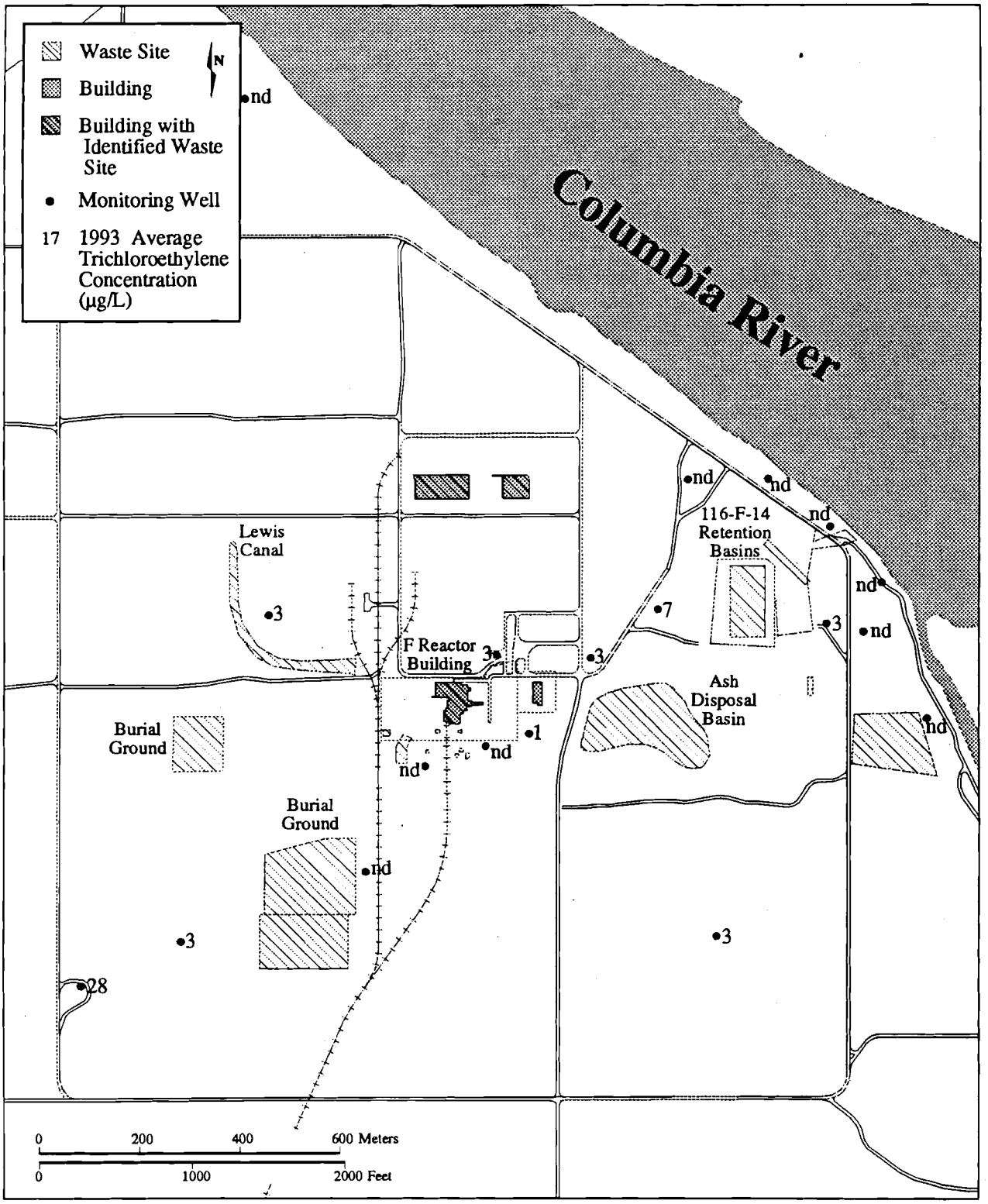


Figure 5.9. 1993 Average Trichloroethylene in the 100-F Area

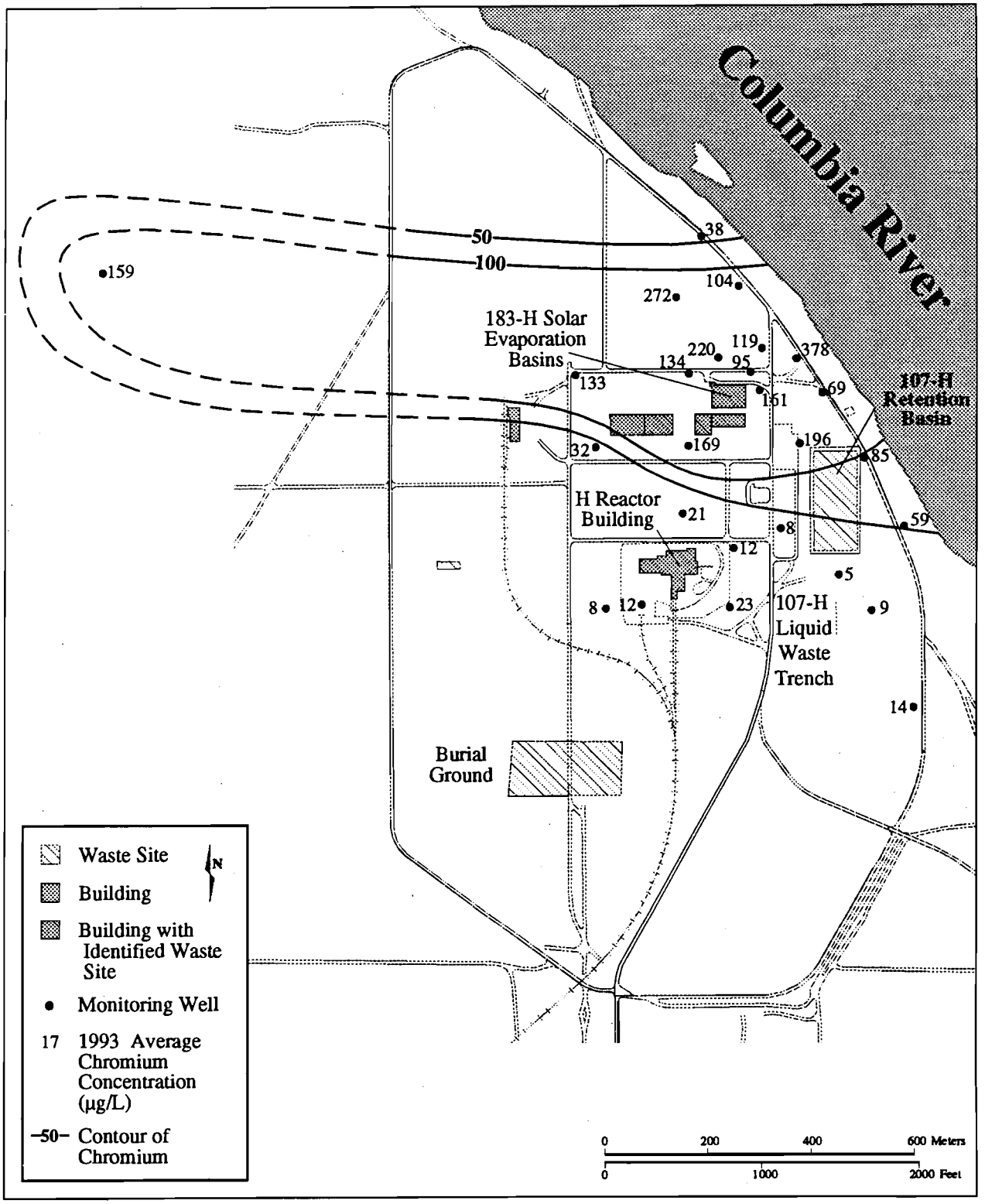


Figure 5.10. 1993 Average Chromium in the 100-H Area

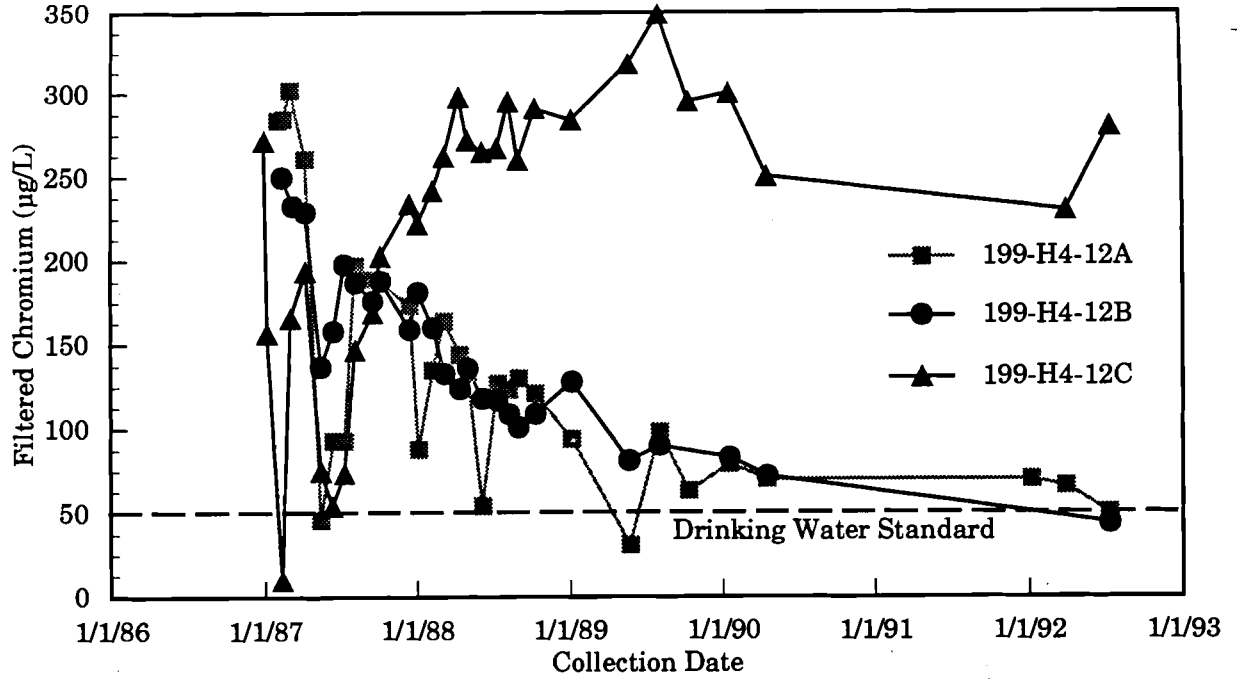


Figure 5.11. Filtered Chromium Concentration Trend in the 199-H4-12 Well Nest

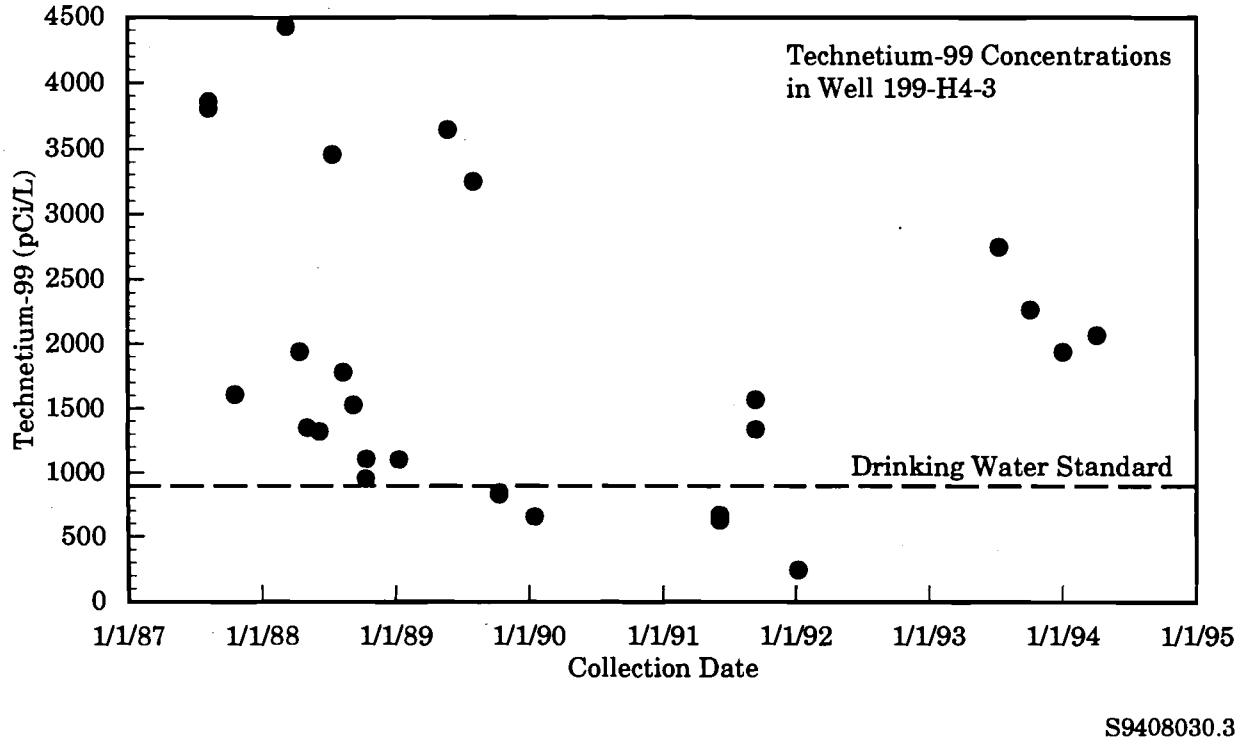


Figure 5.12. Technetium-99 Concentration Trend in Well 199-H4-3

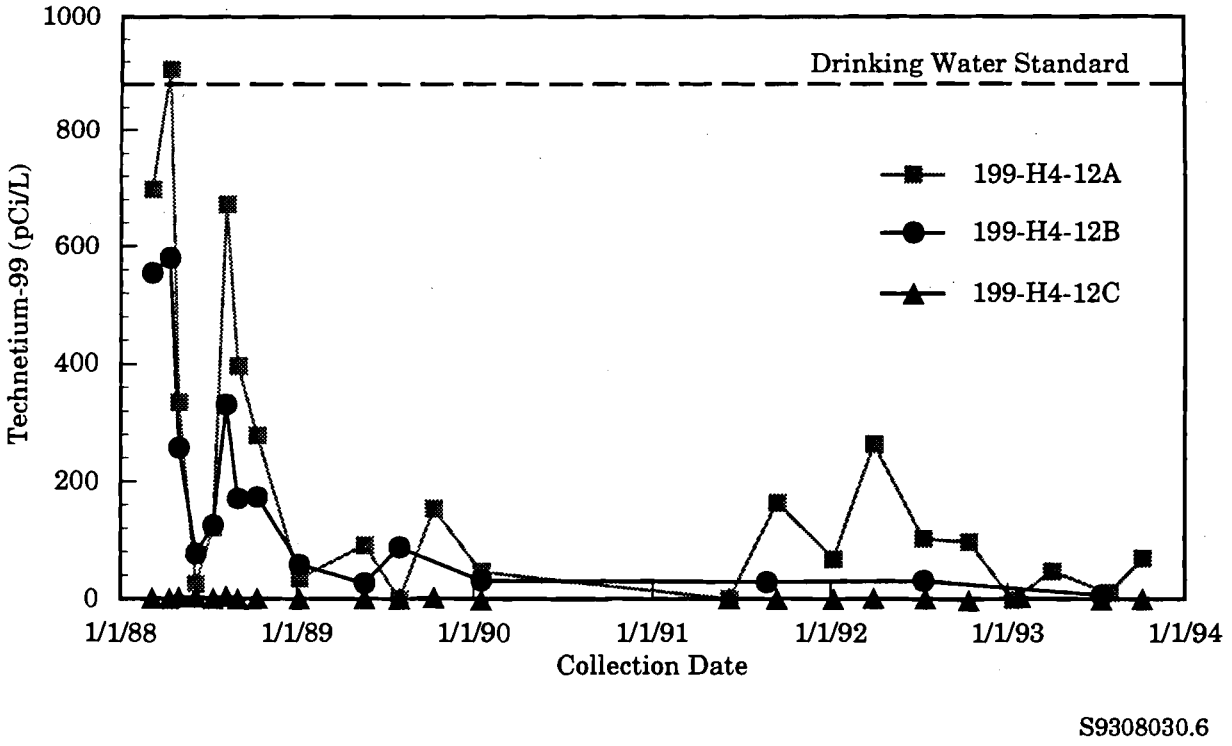


Figure 5.13. Technetium-99 Concentration Trend in the 199-H4-12 Well Nest

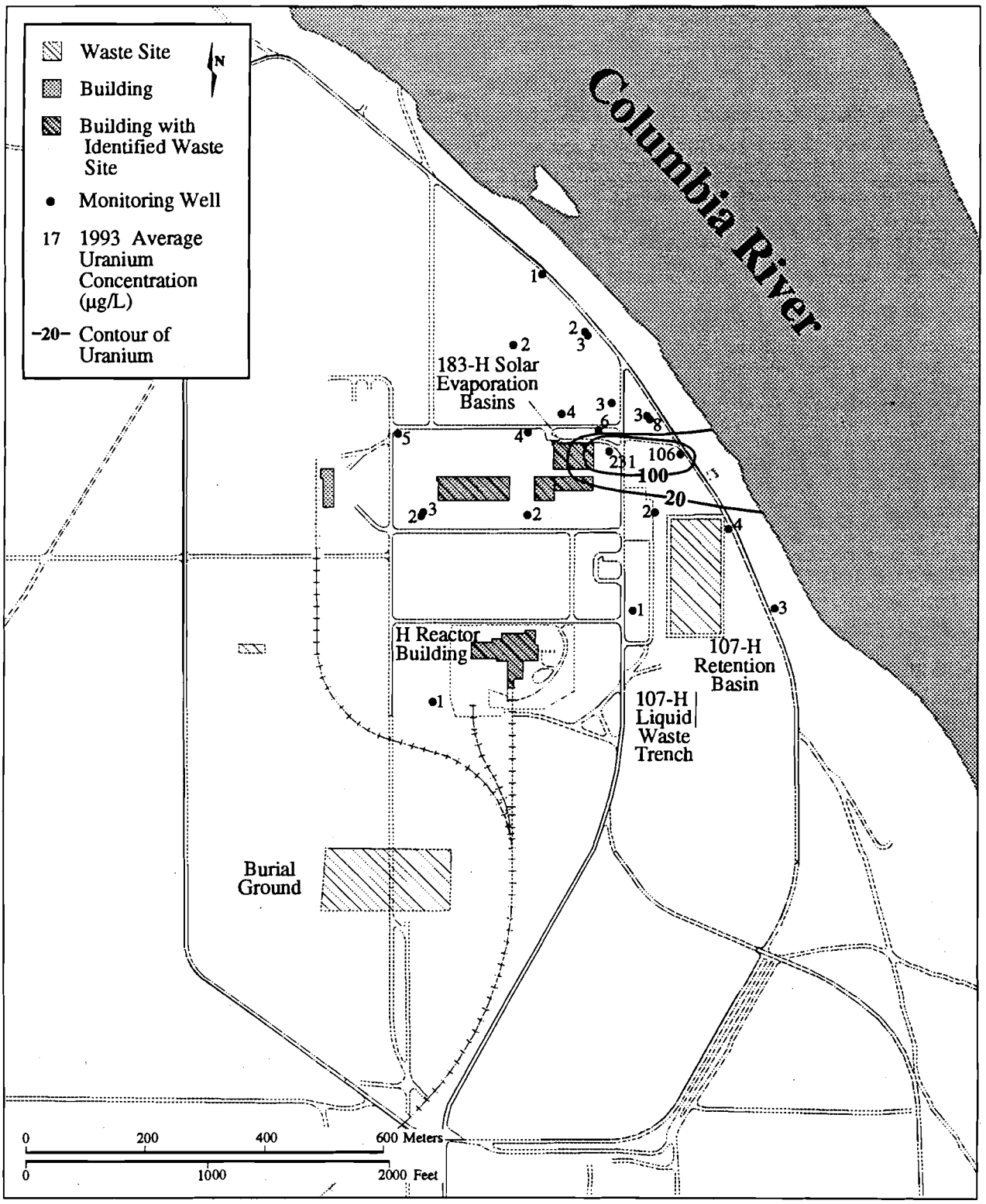


Figure 5.14. 1993 Average Uranium Concentration in the 100-H Area

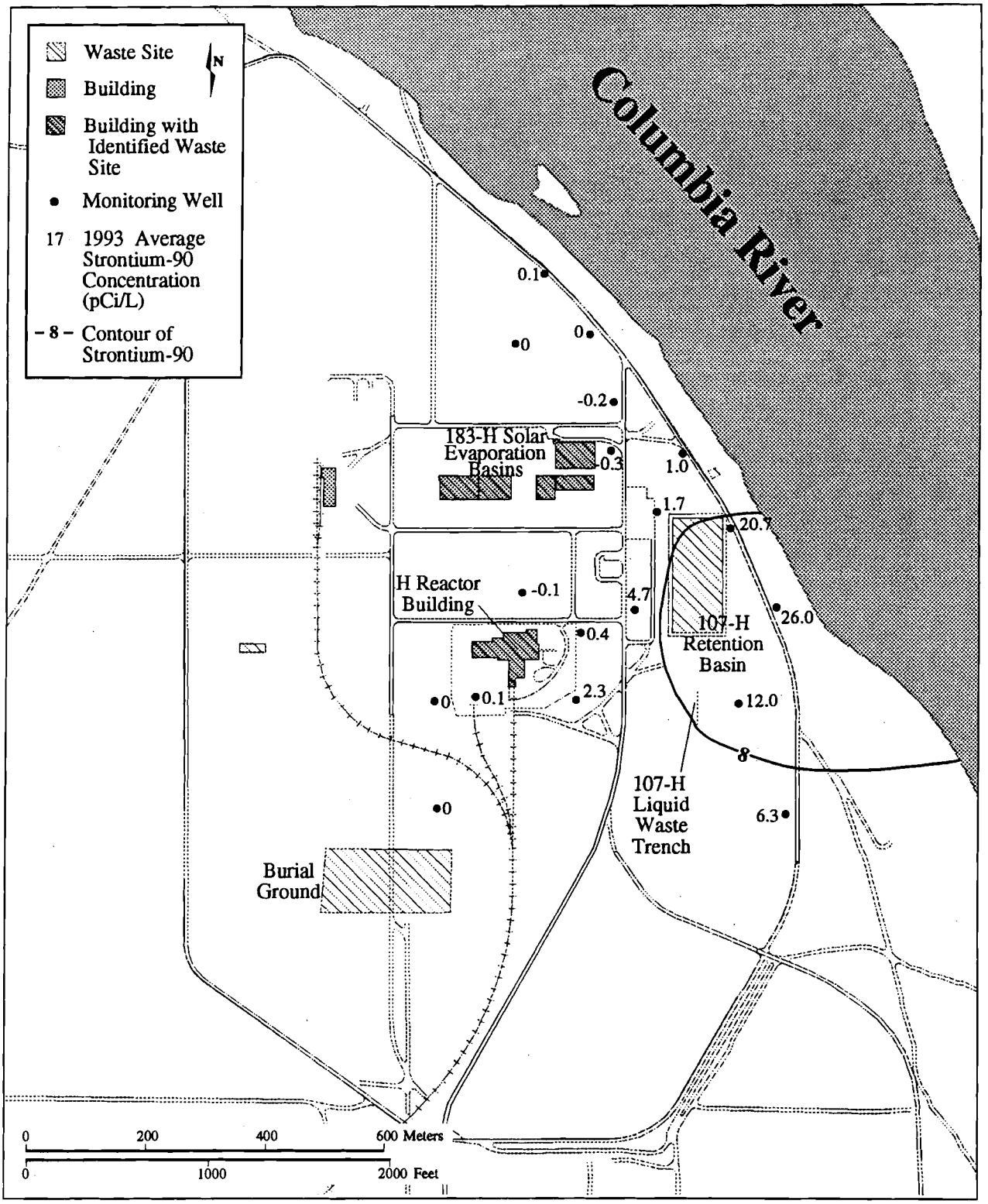


Figure 5.15. 1993 Average Strontium-90 Concentration in the 100-H Area

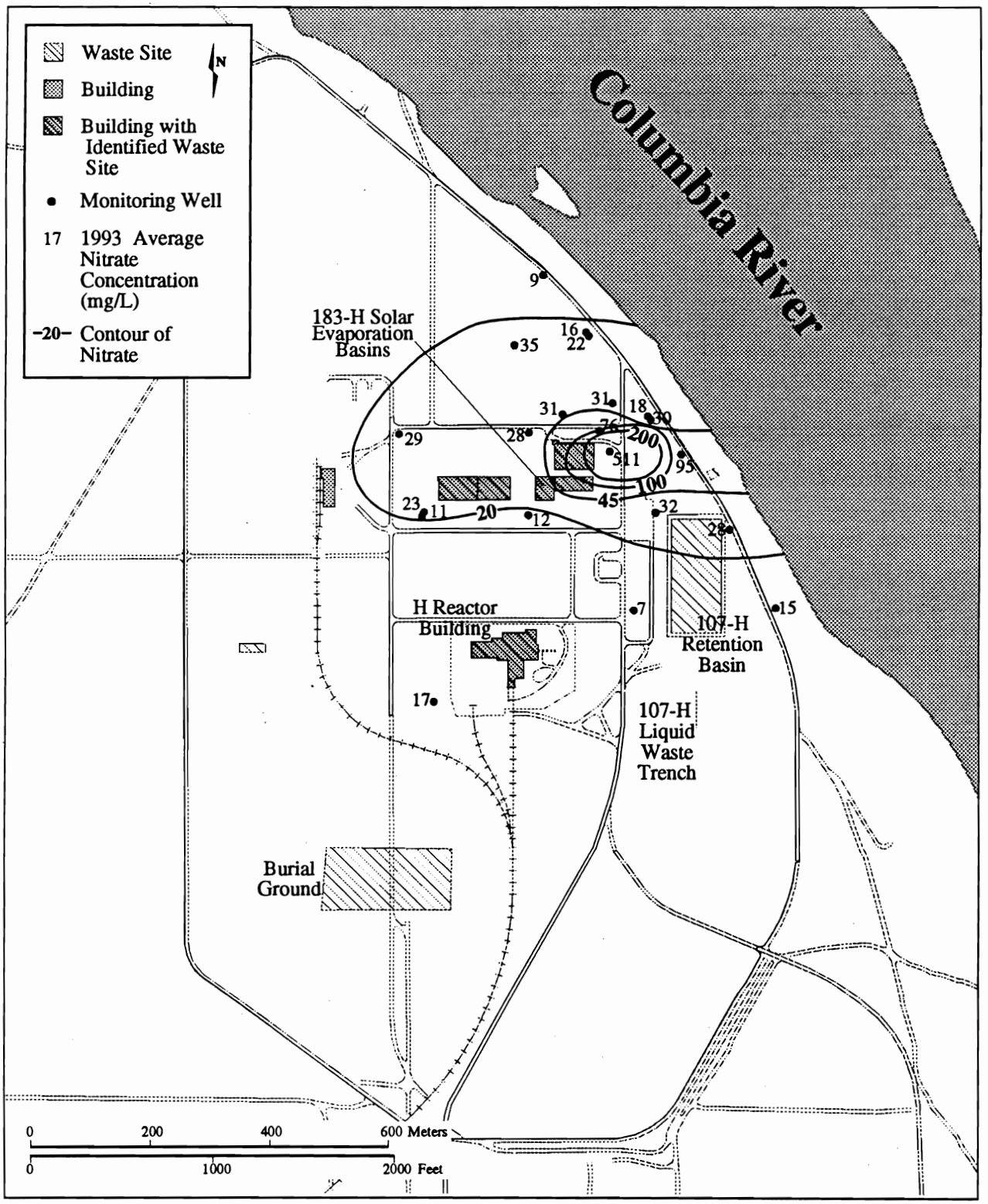


Figure 5.16. 1993 Average Nitrate Concentration in the 100-H Area

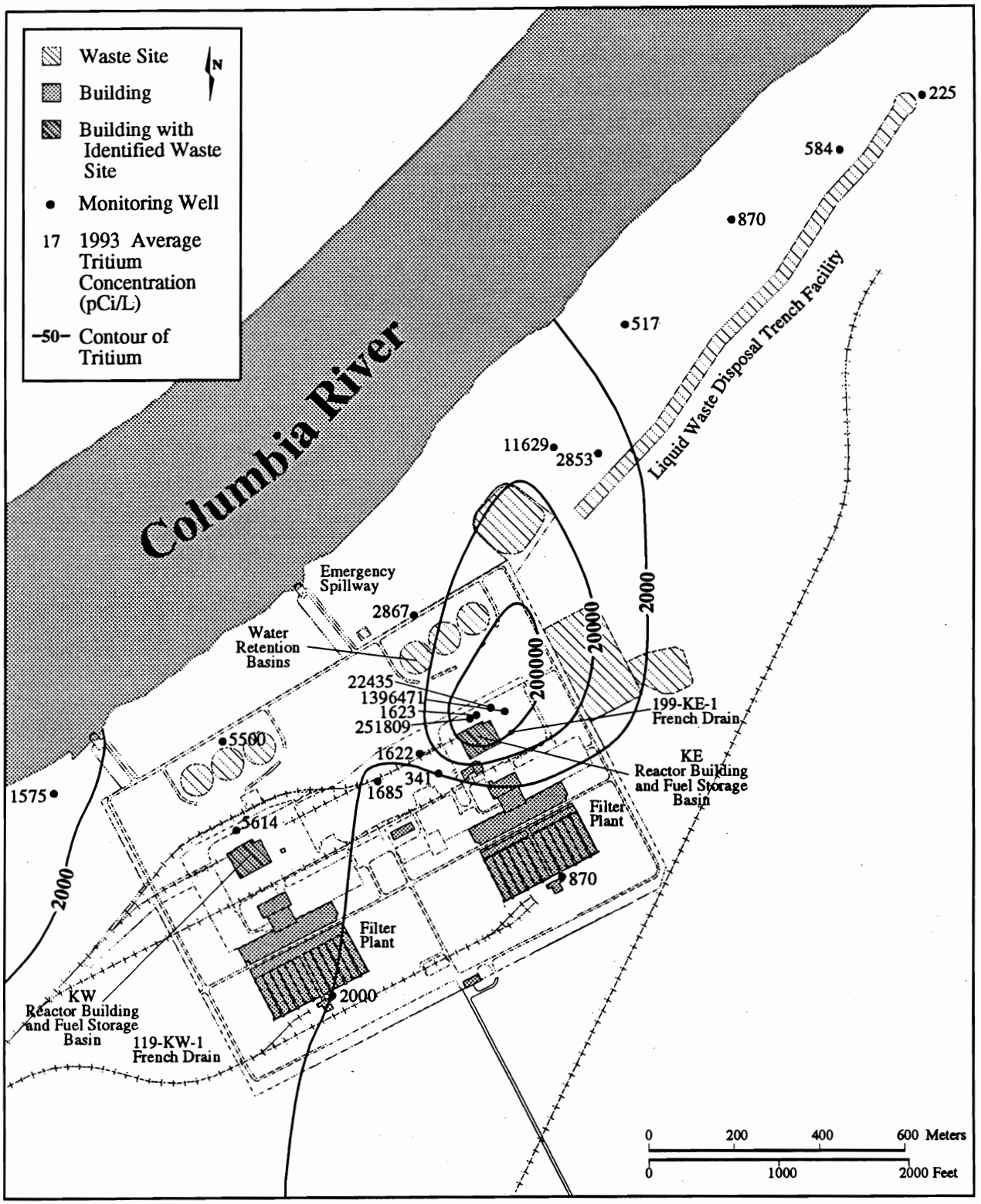


Figure 5.17. 1993 Average Tritium Concentration in the 100-K Area

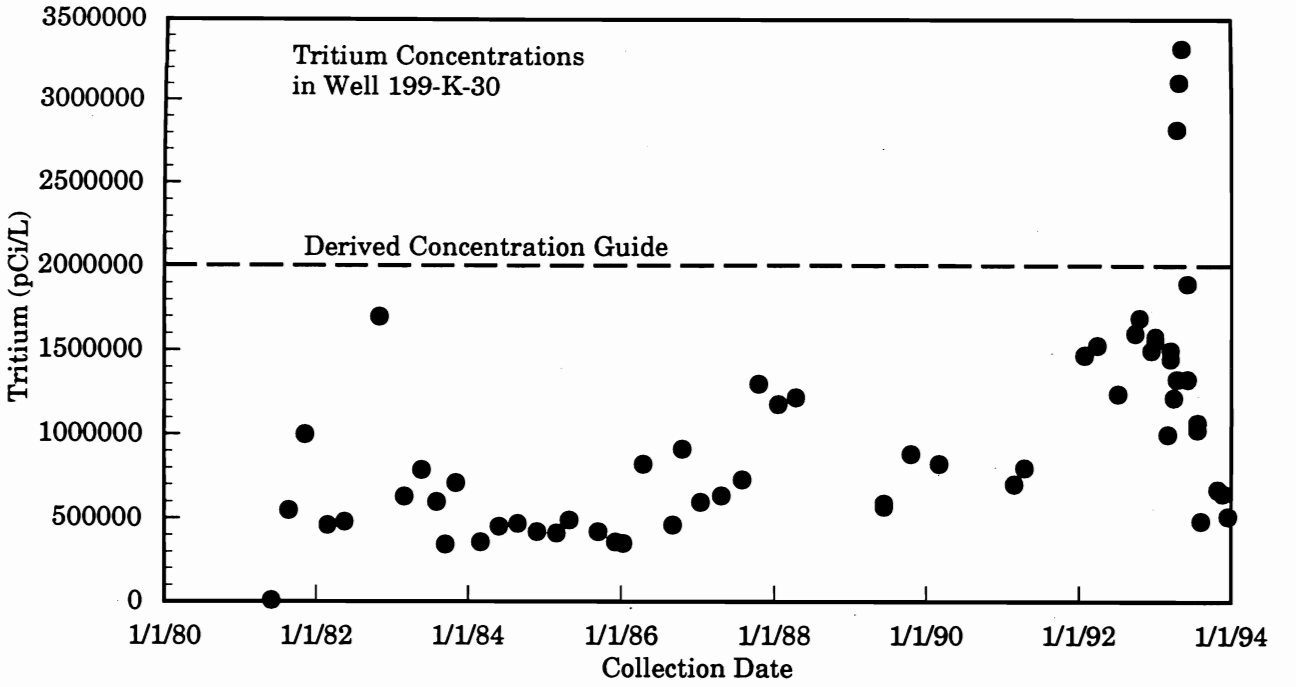


Figure 5.18. Tritium Concentration Trend for Well 199-K-30

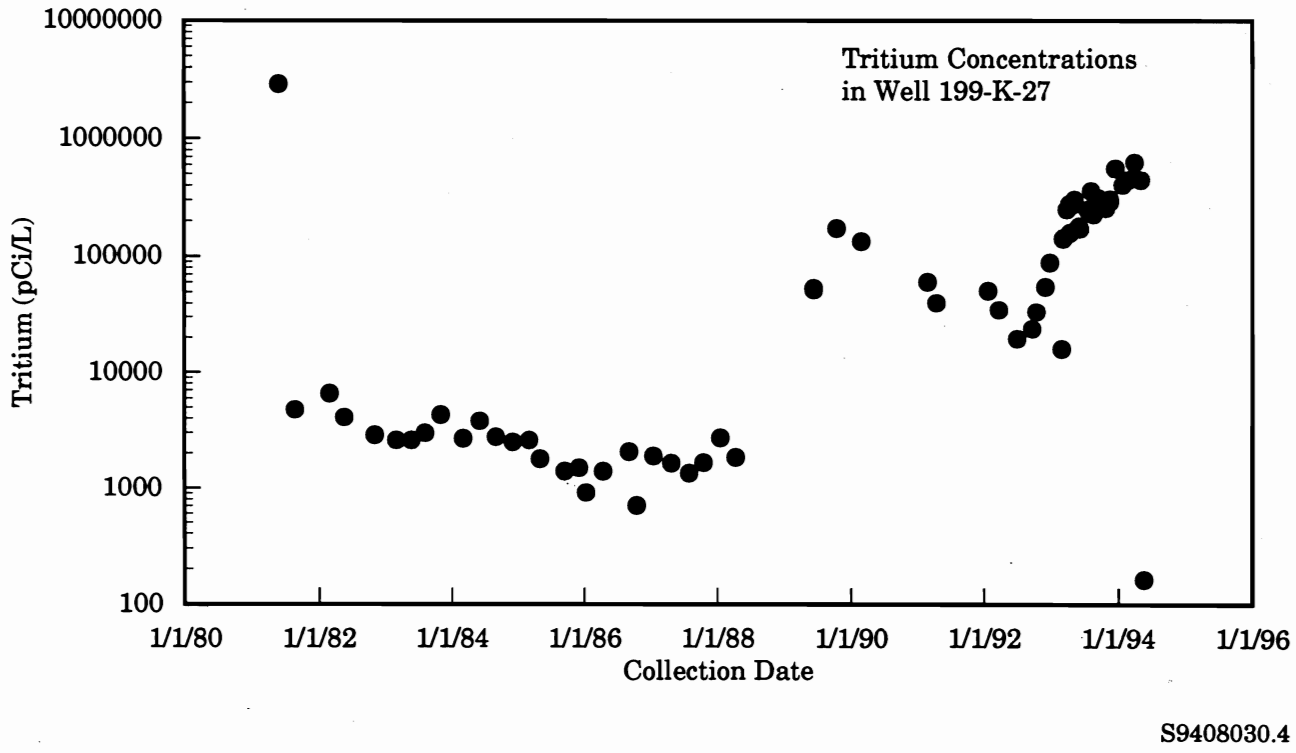


Figure 5.19. Tritium Concentration Trend for Well 199-K-27

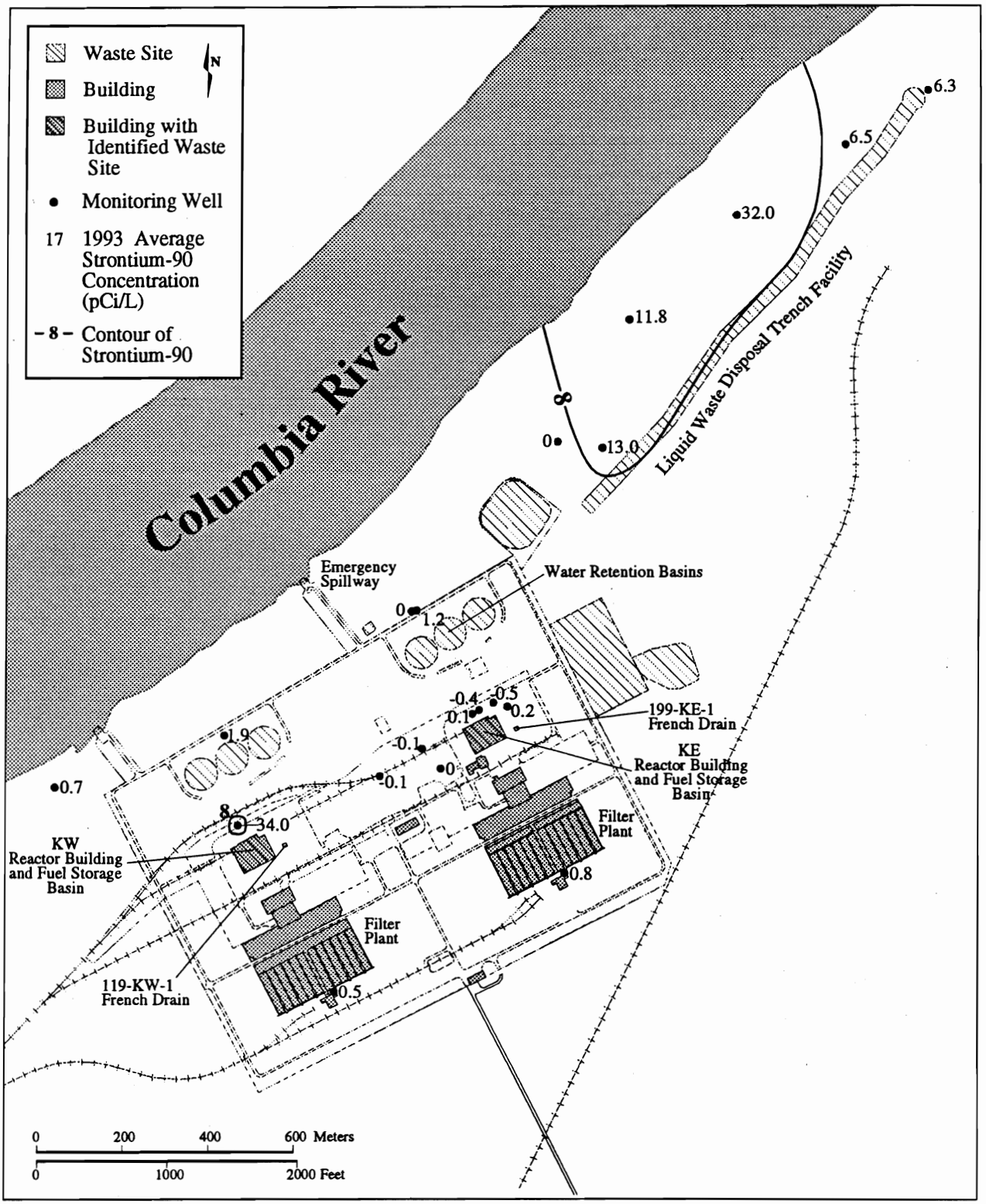


Figure 5.20. 1993 Average Strontium-90 Concentration in the 100-K Area

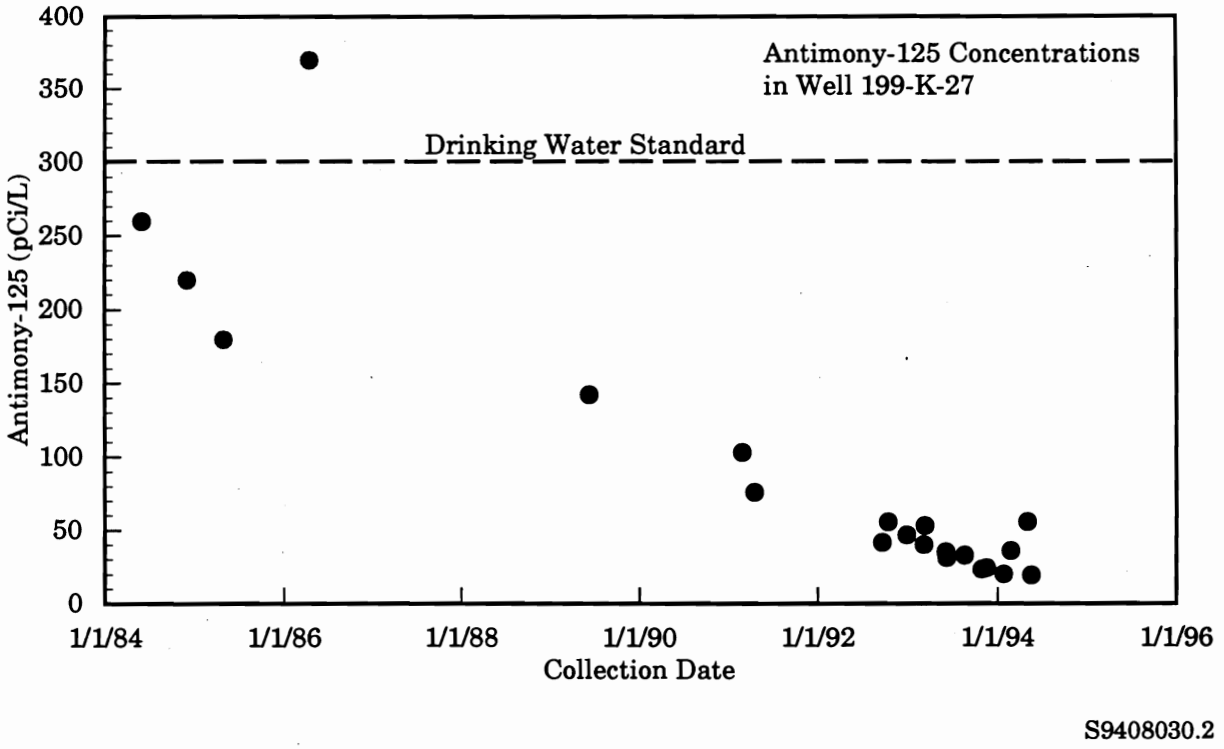


Figure 5.21. Antimony-125 Concentration Trend for Well 199-K-27

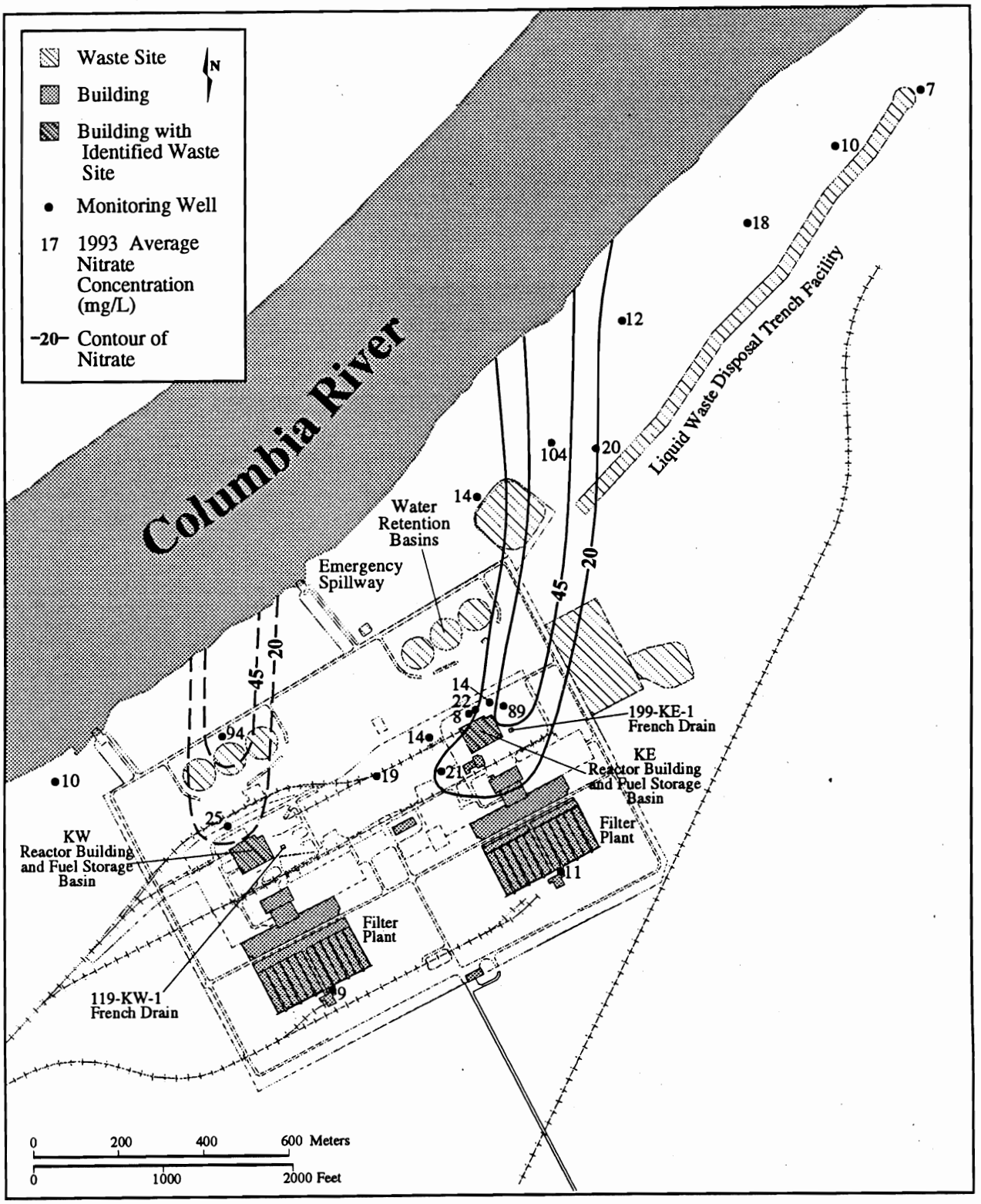


Figure 5.22. 1993 Average Nitrate Concentration in the 100-K Area

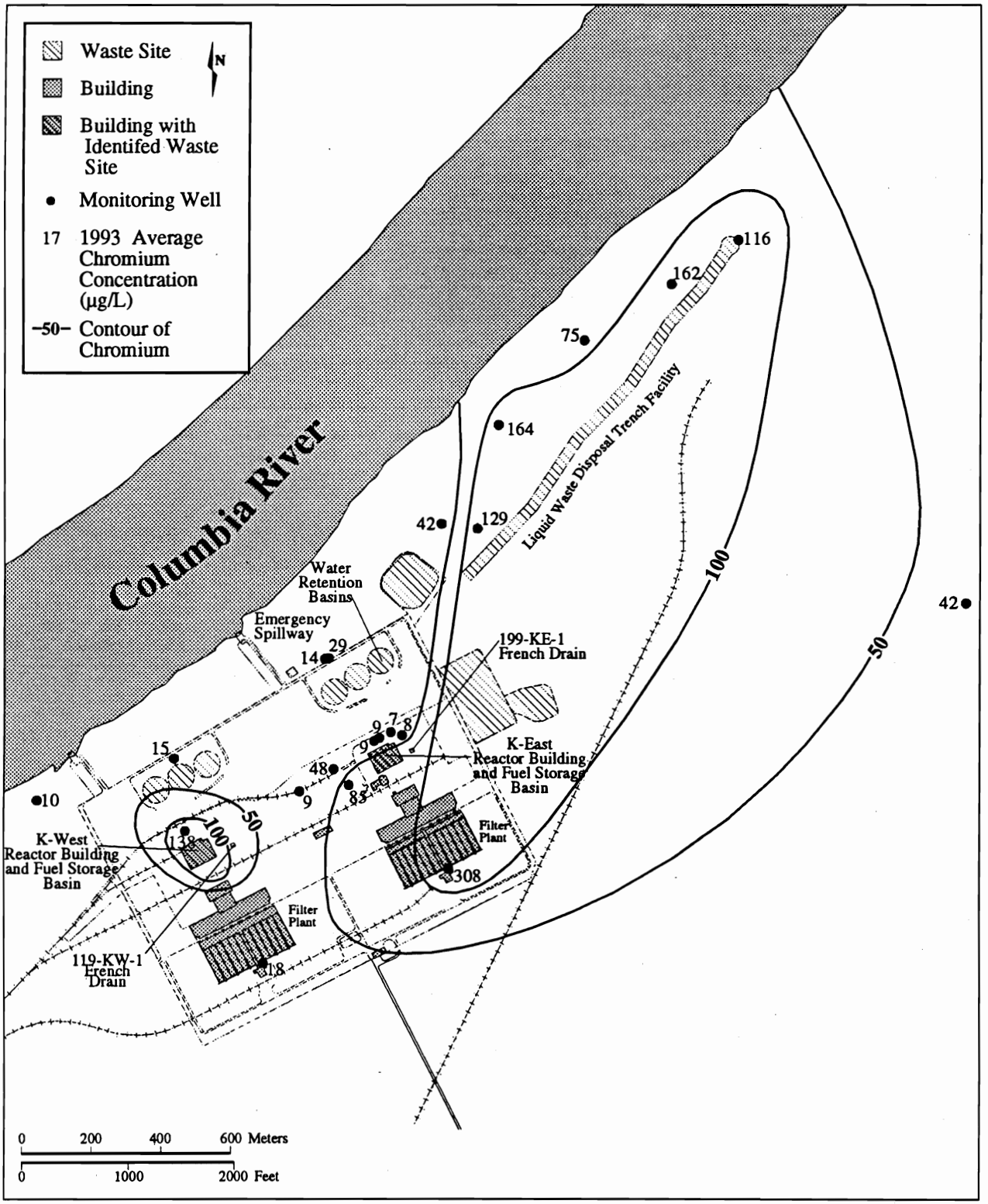


Figure 5.23. 1993 Average Chromium Concentration in the 100-K Area

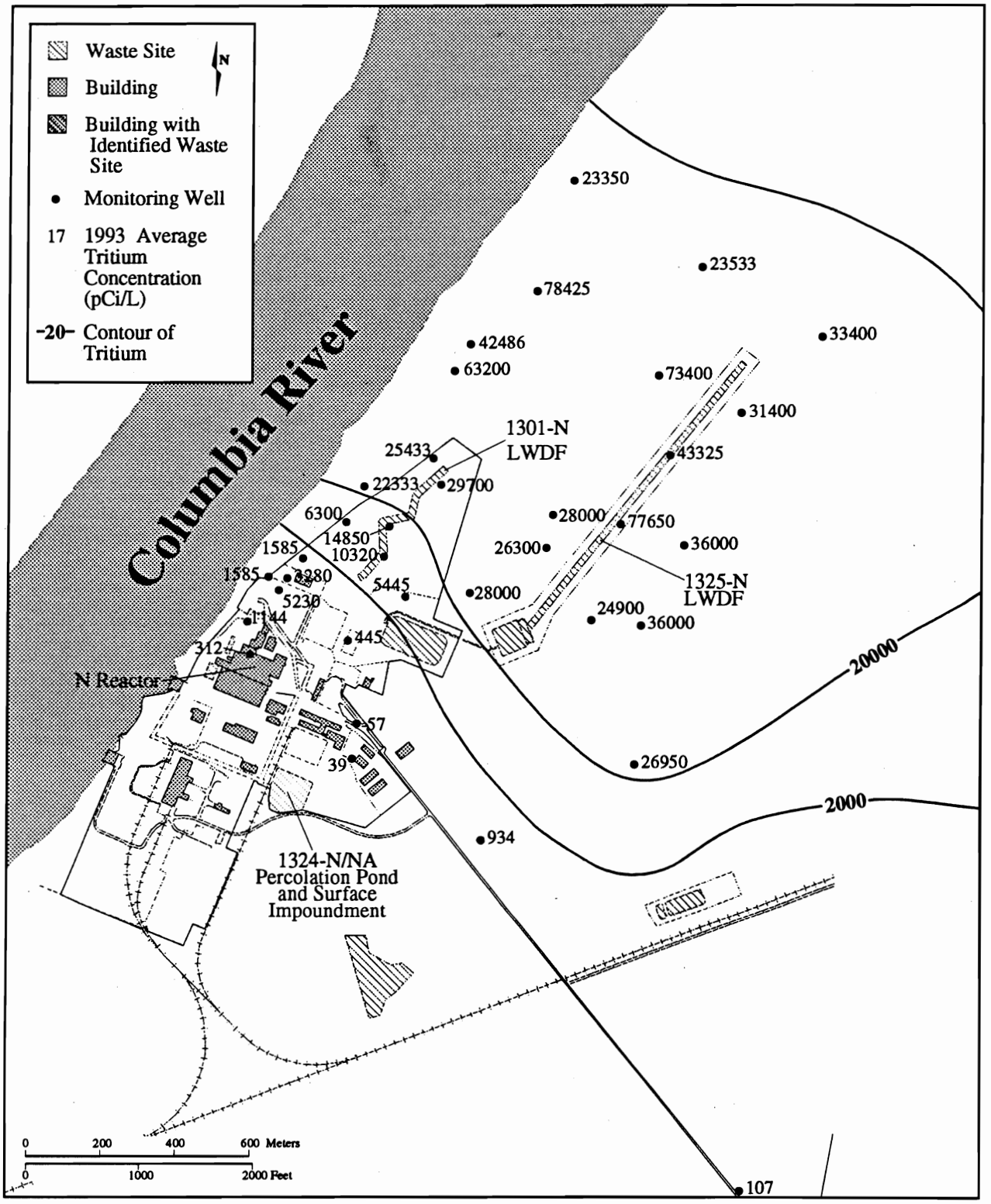


Figure 5.24. 1993 Average Tritium Concentration in the 100-N Area

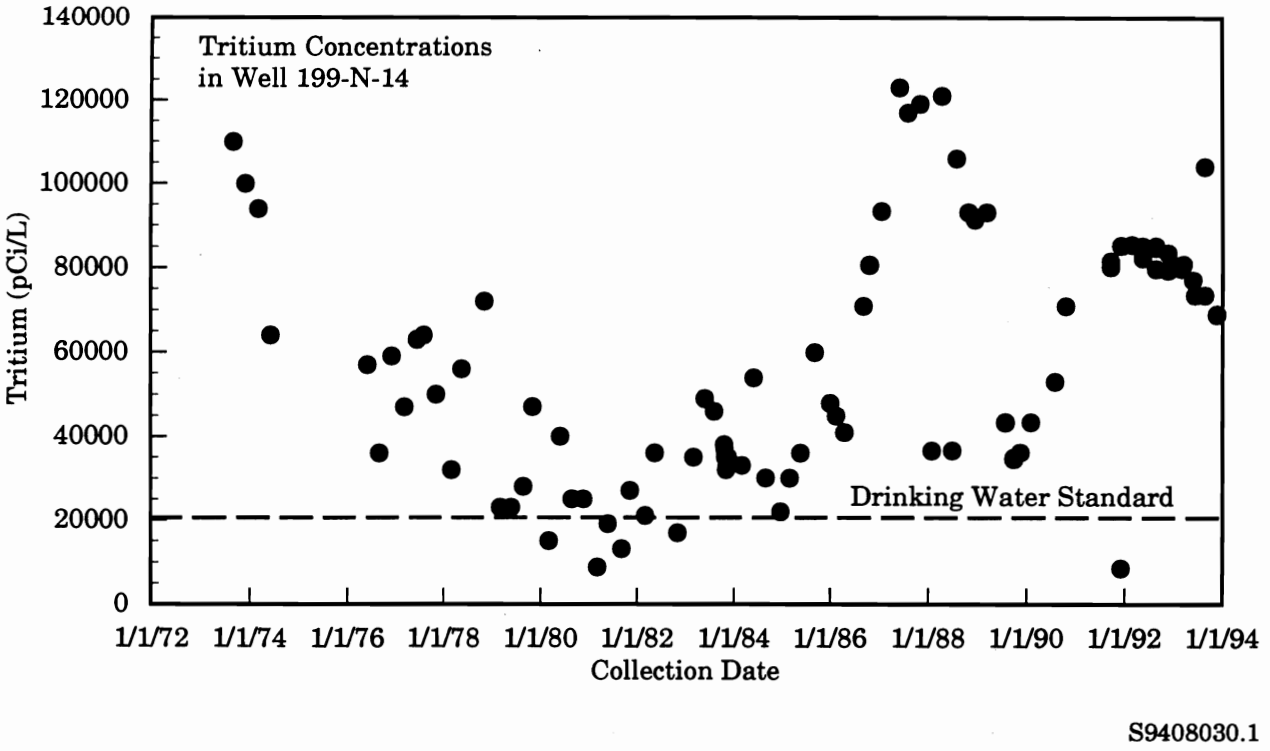


Figure 5.25. Tritium Concentration Trend for Well 199-N-14

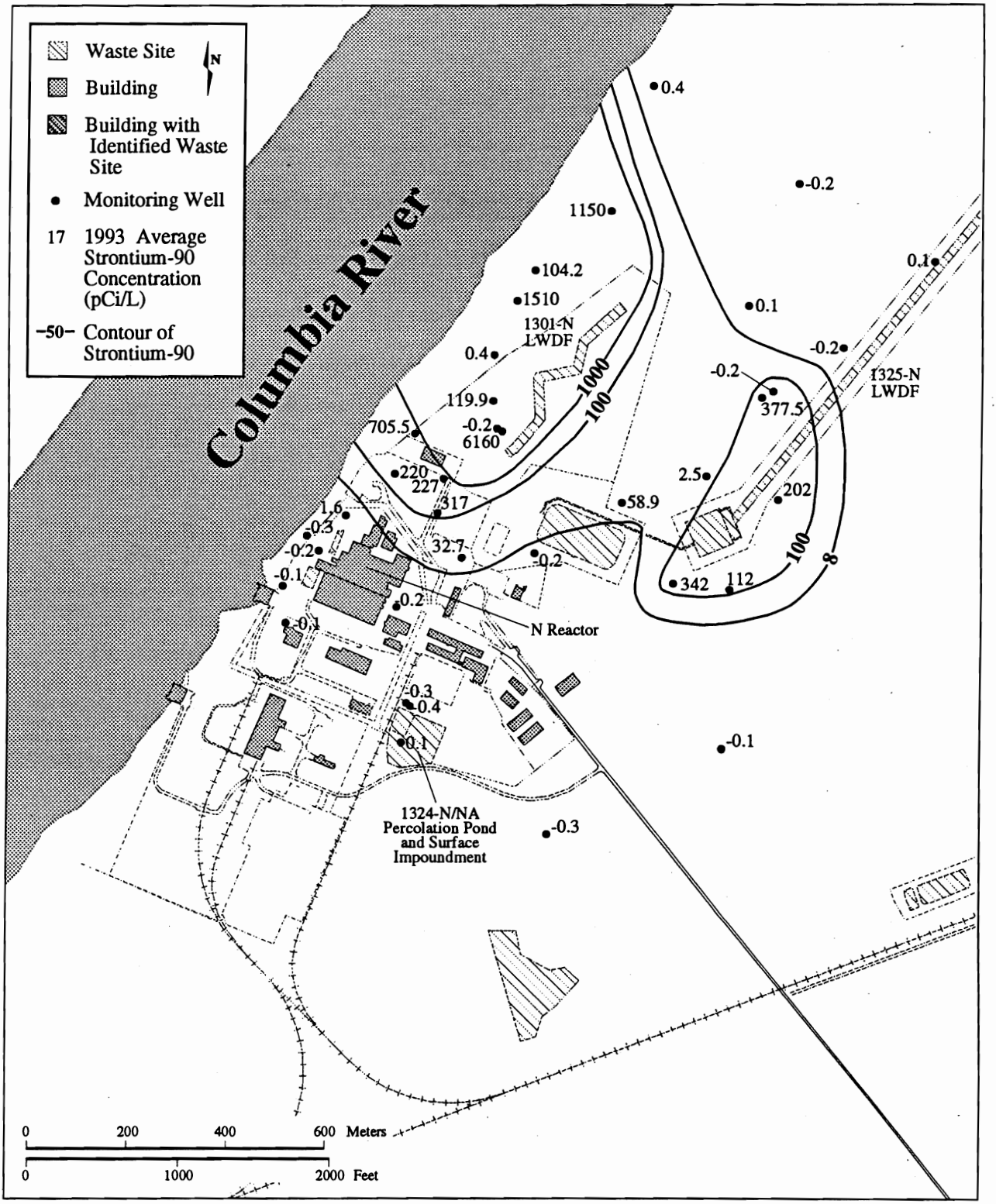


Figure 5.26. 1993 Average Strontium-90 Concentration for the 100-N Area

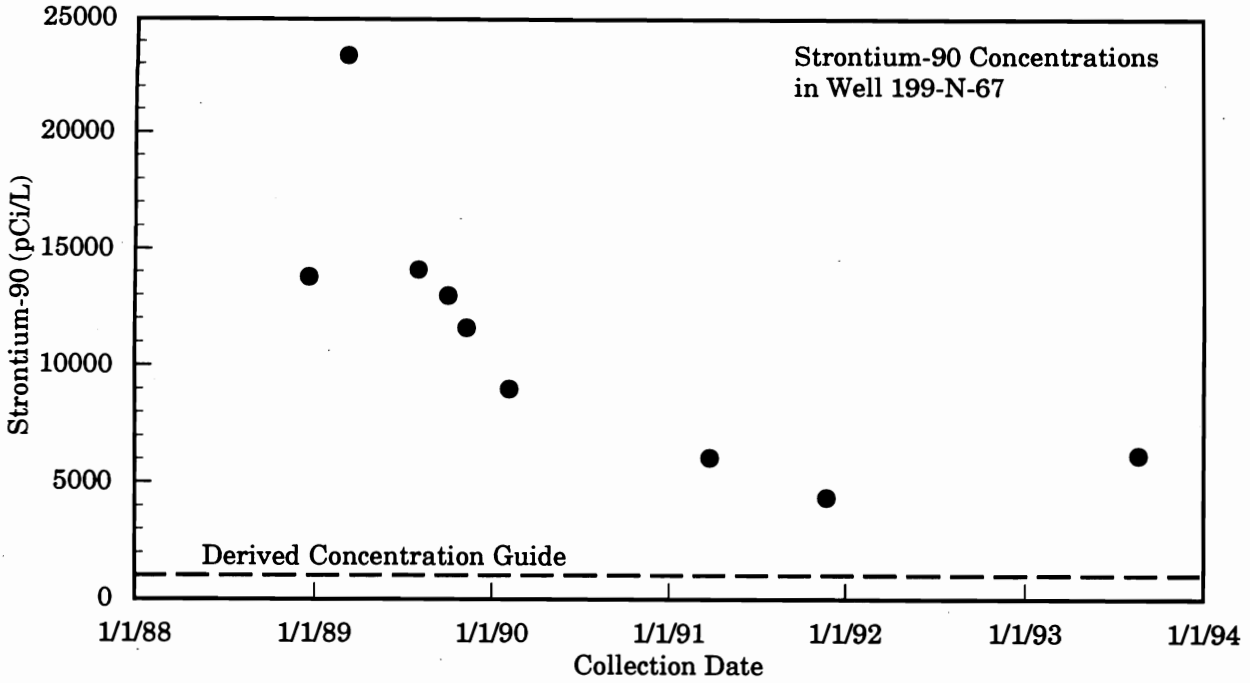


Figure 5.27. 1993 Average Strontium-90 Trend for Well 199-N-67

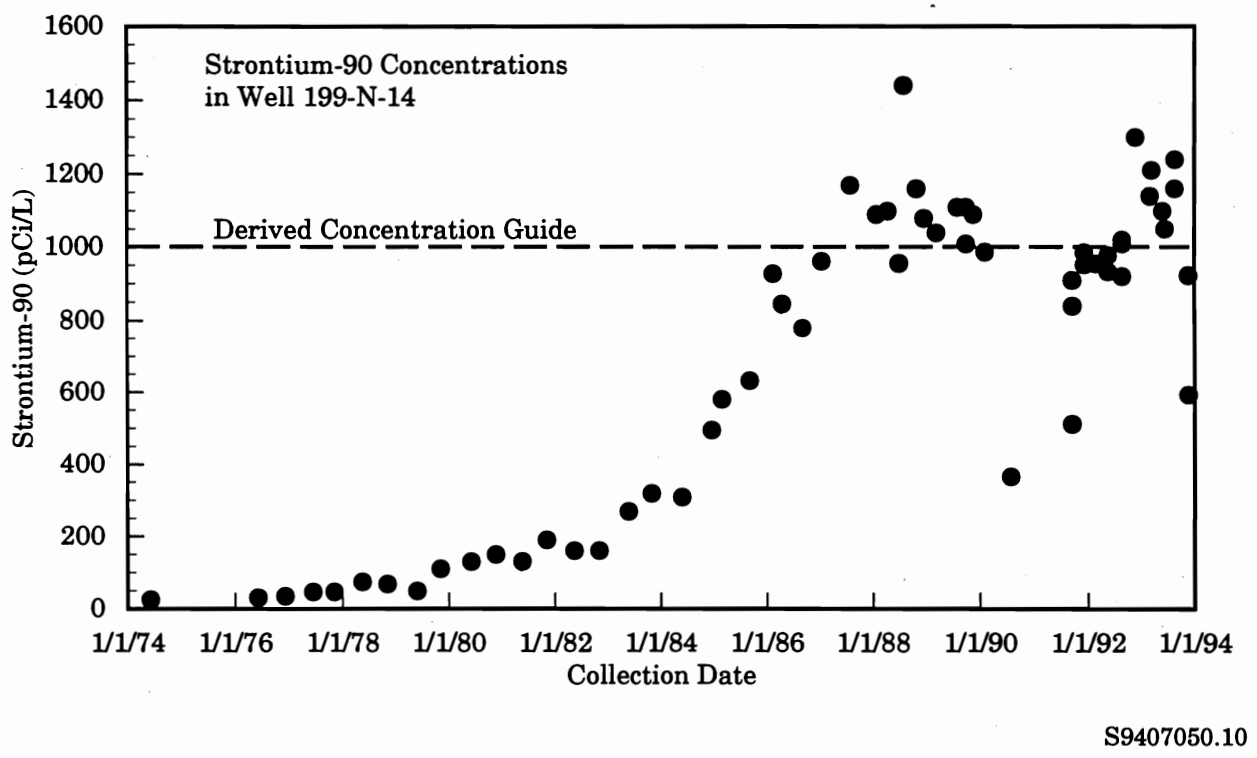


Figure 5.28. Strontium-90 Trend for Well 199-N-14

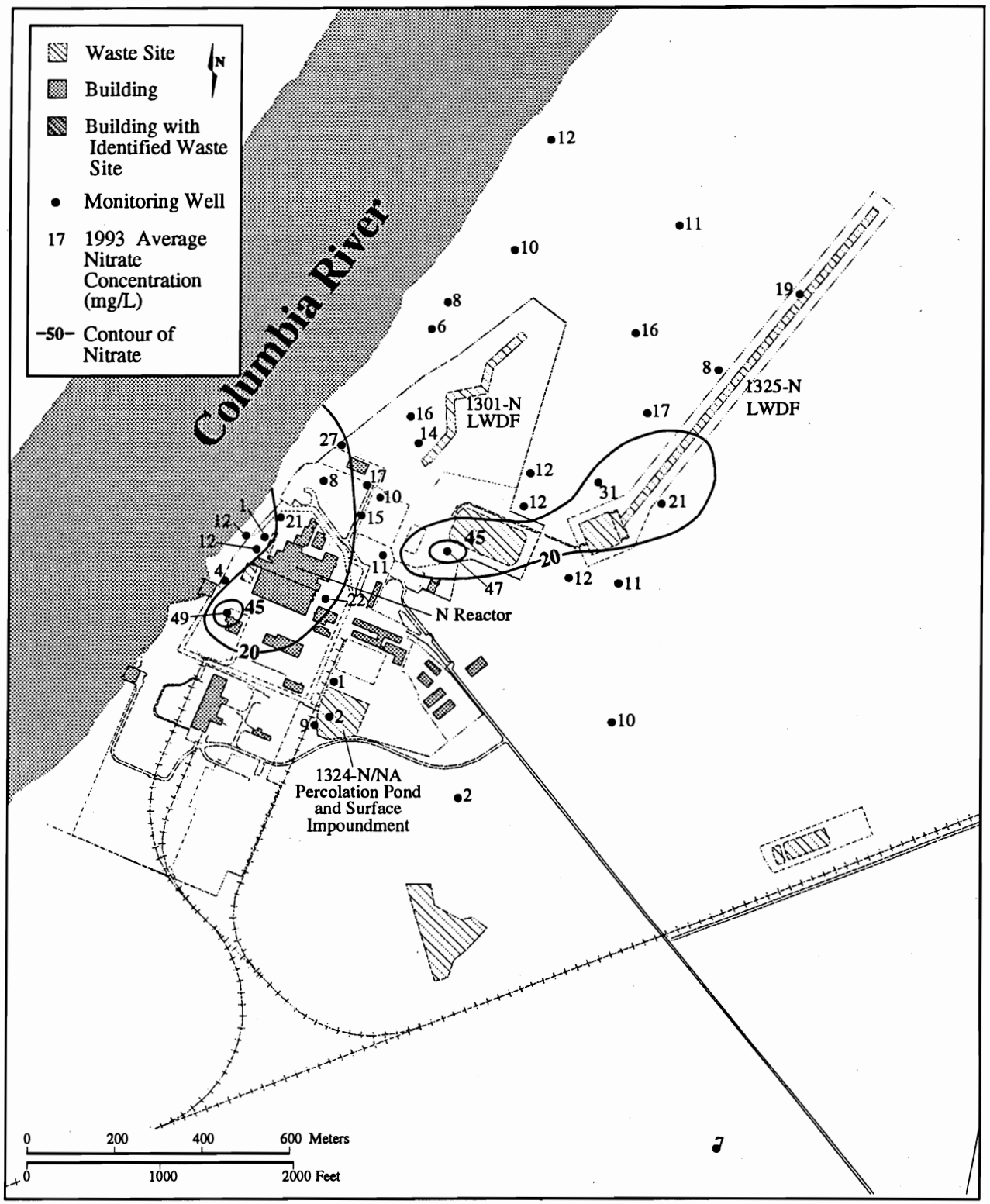


Figure 5.29. 1993 Average Nitrate Concentration for the 100-N Area

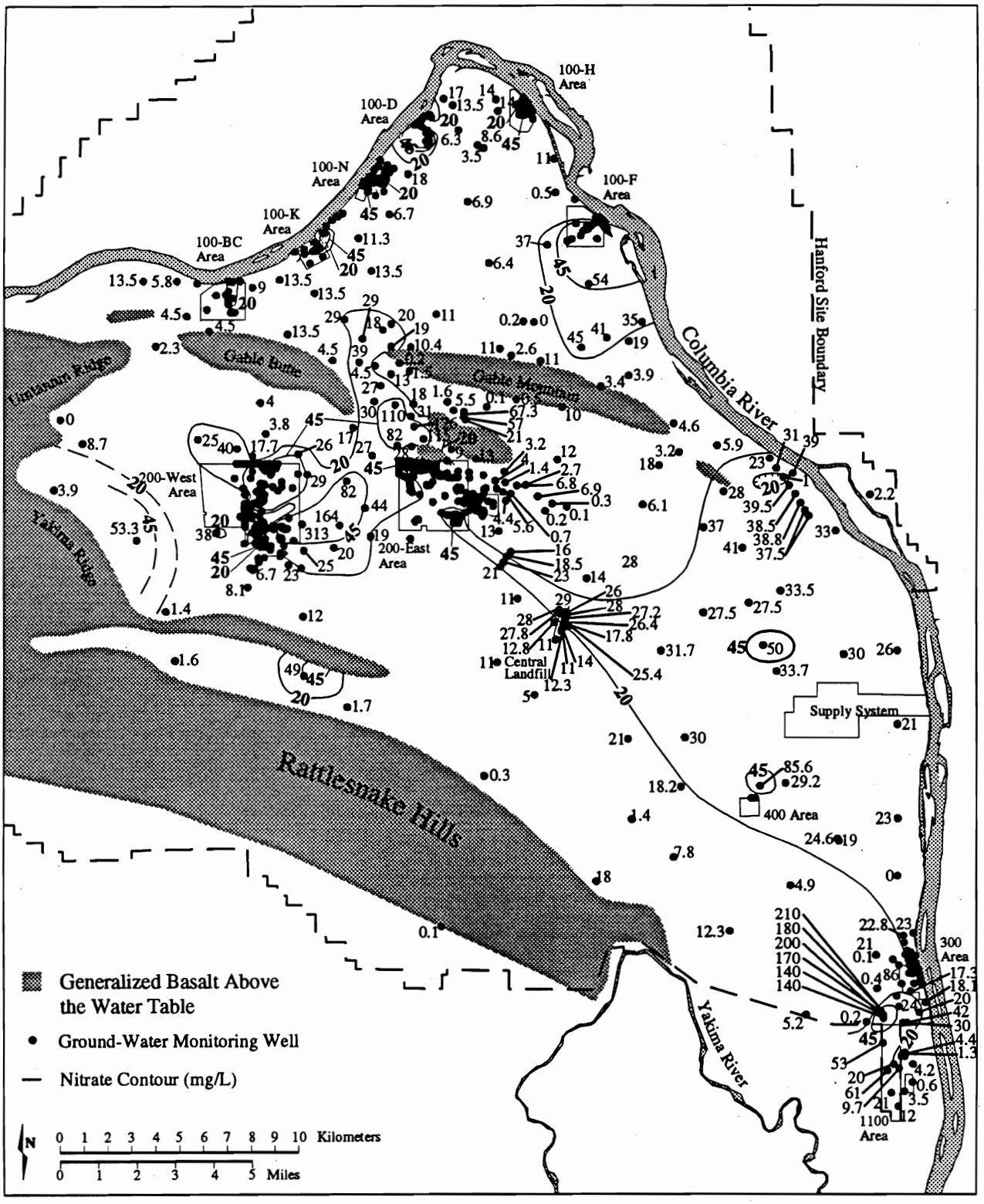


Figure 5.30. 1993 Average Nitrate Concentration for the Hanford Site

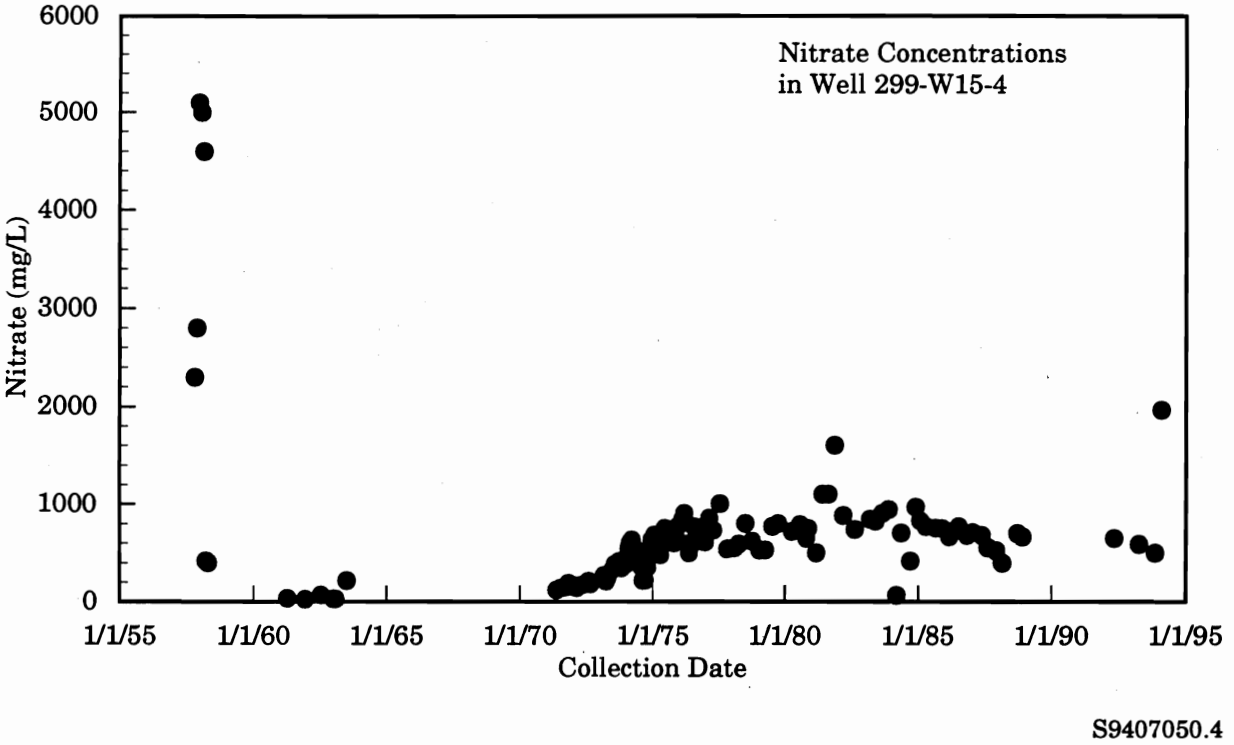


Figure 5.31. Nitrate Concentration Trend for Well 299-W15-4

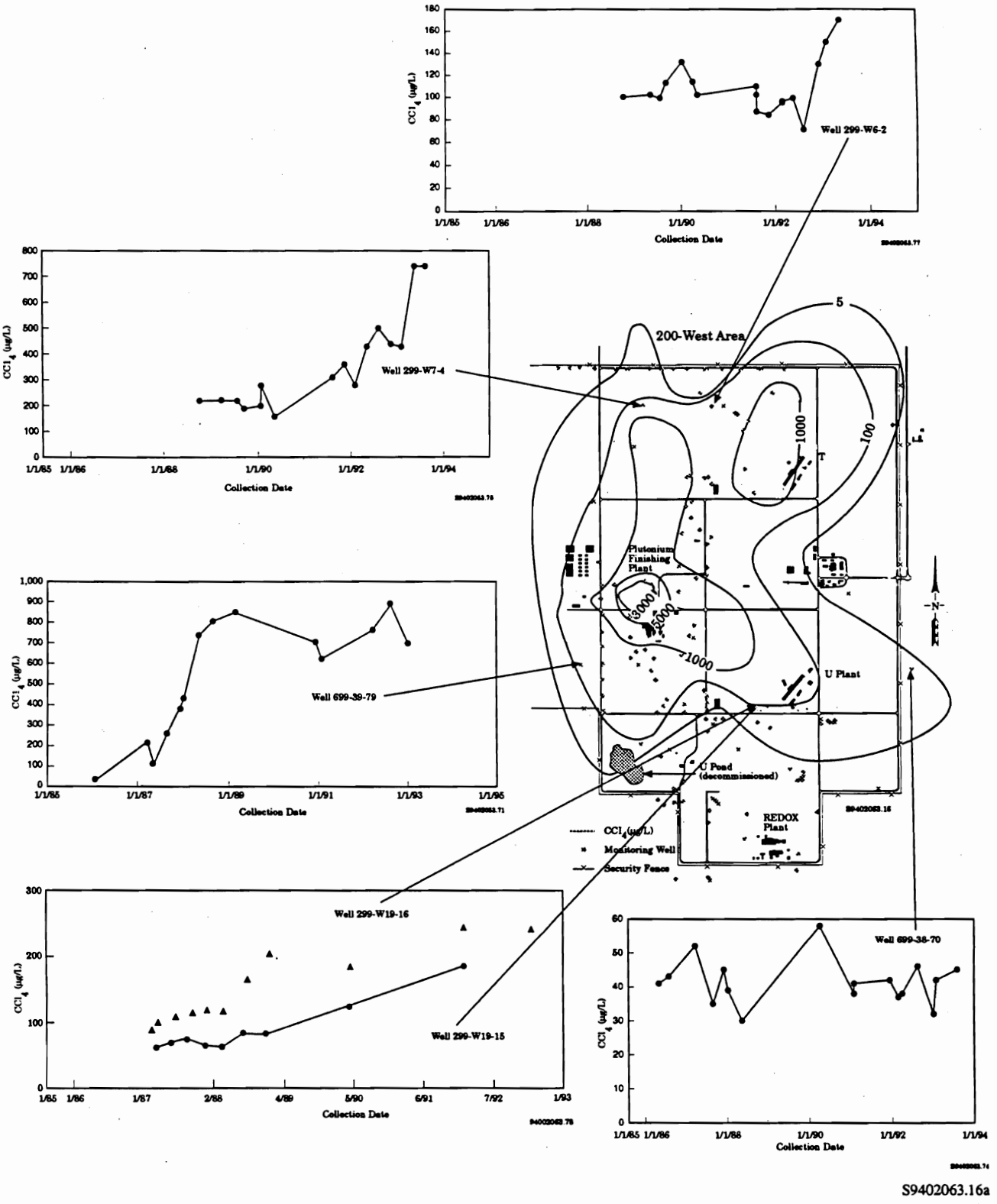


Figure 5.32. 1993 Distribution of Carbon Tetrachloride for the 200-West Area and Concentration Trends in Selected Wells

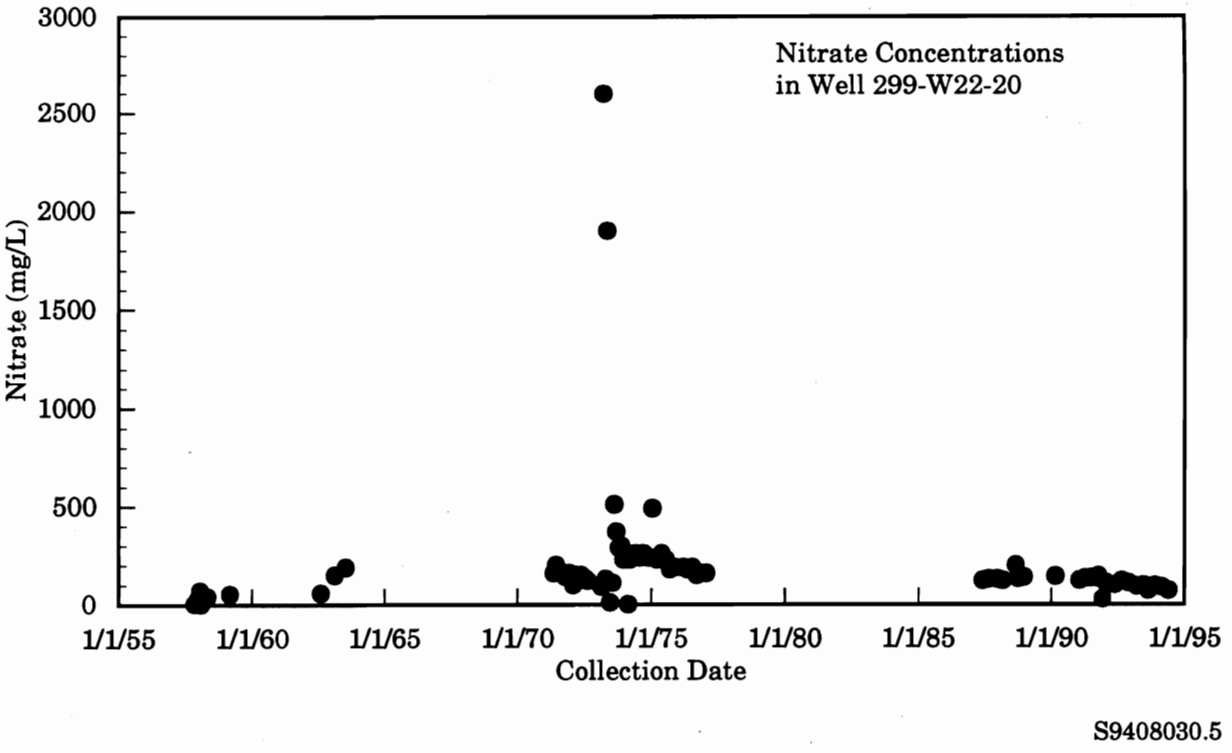


Figure 5.33. Nitrate Concentration Trend for Well 299-W22-20

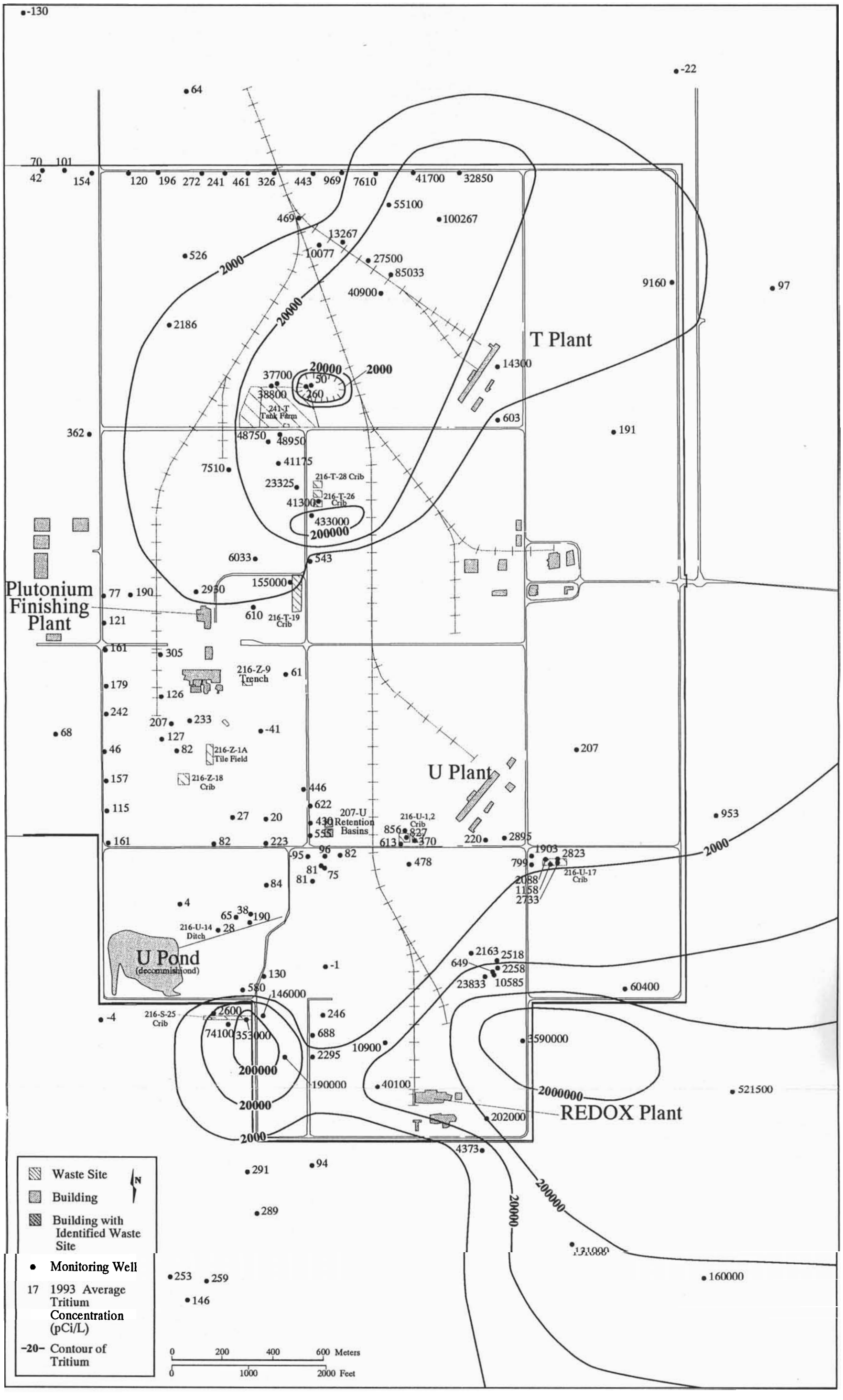


Figure 5.34. 1993 Average Tritium for the 200-West Area

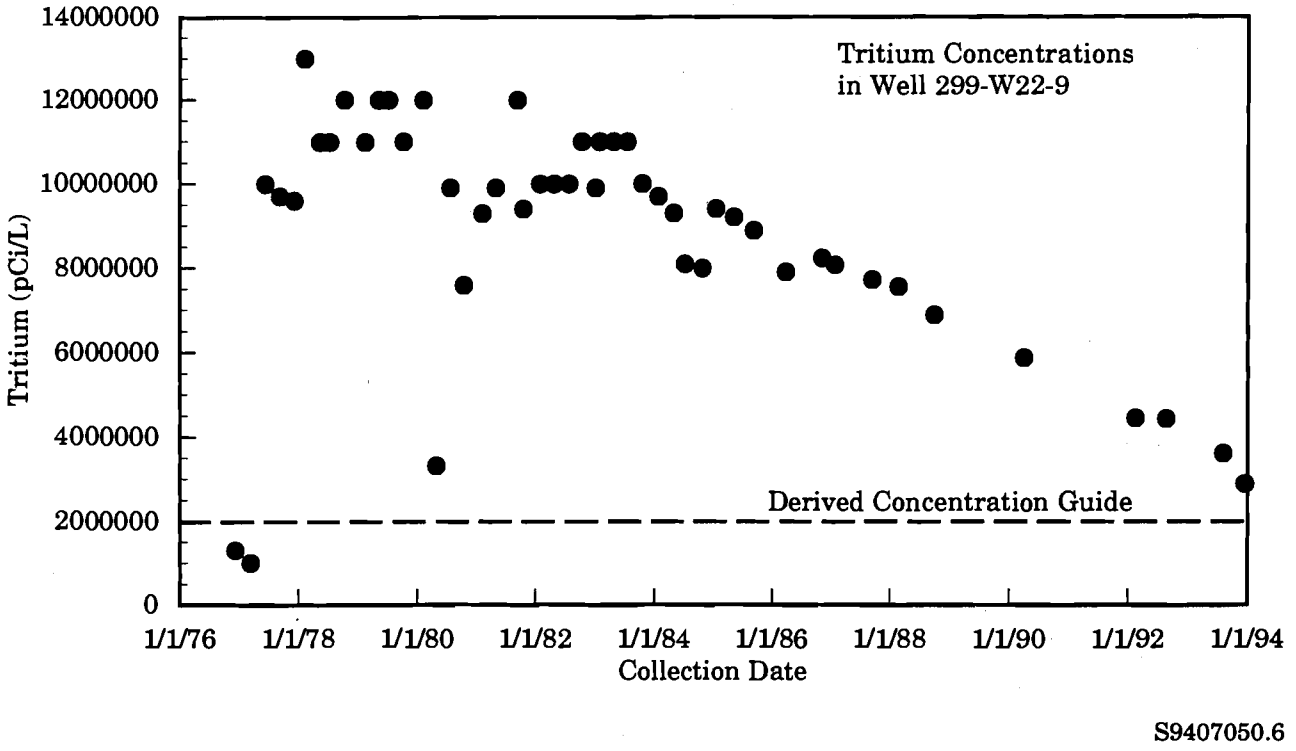


Figure 5.35. Tritium Concentration Trend for Well 299-W22-9

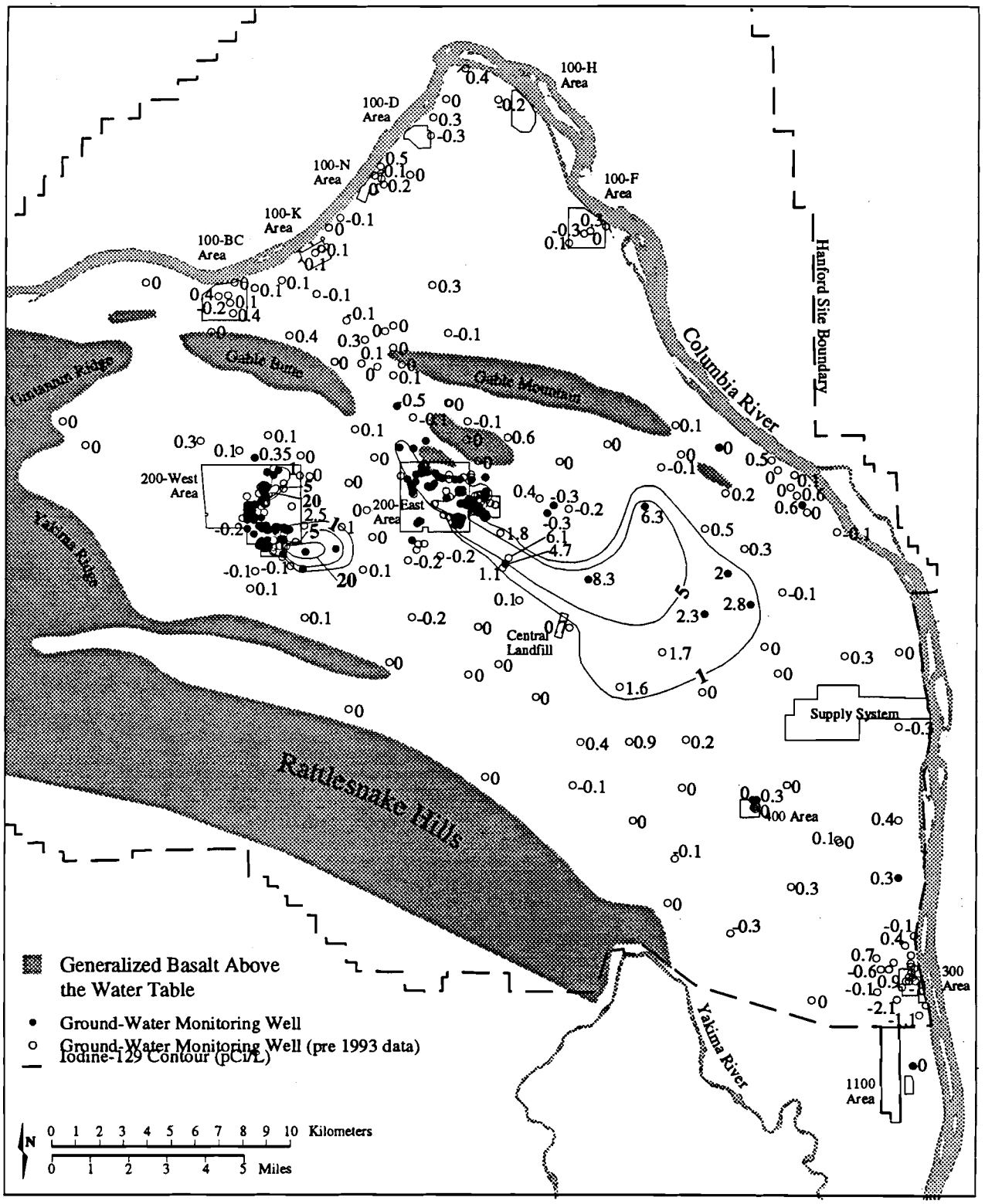


Figure 5.36. Distribution of Iodine-129 for the Hanford Site

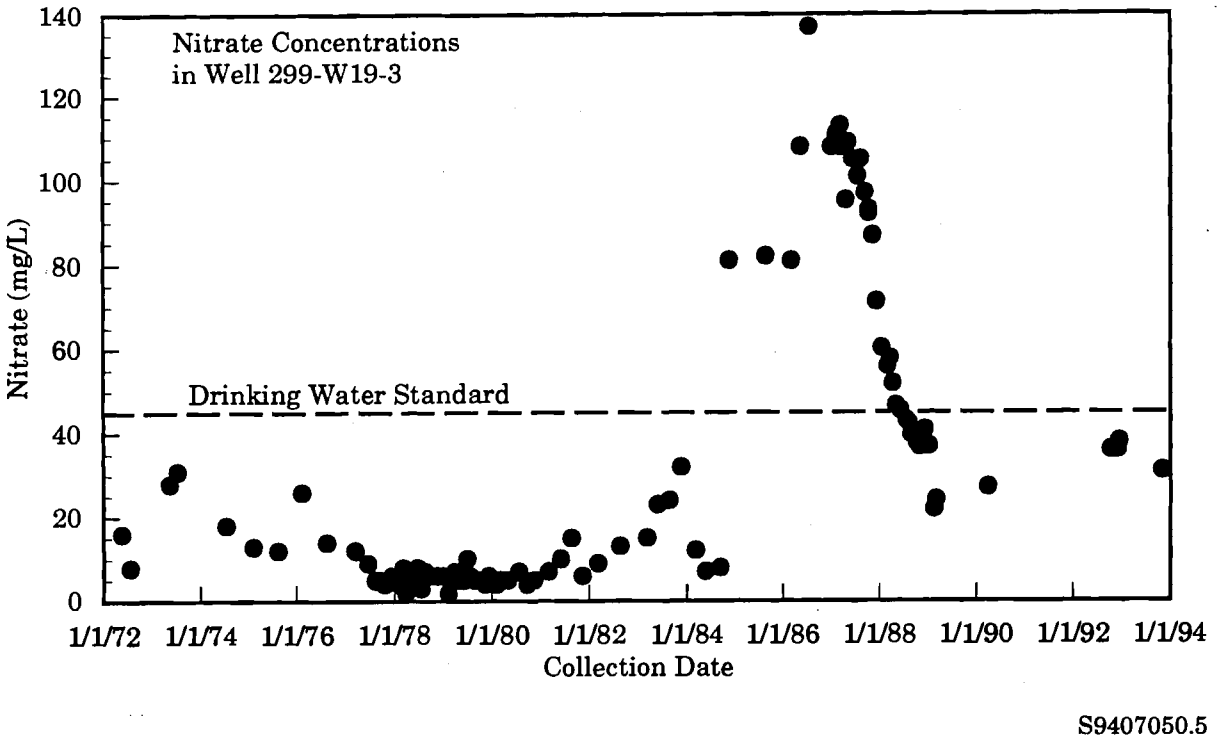


Figure 5.37. Nitrate Concentration Trend for Well 299-W19-3

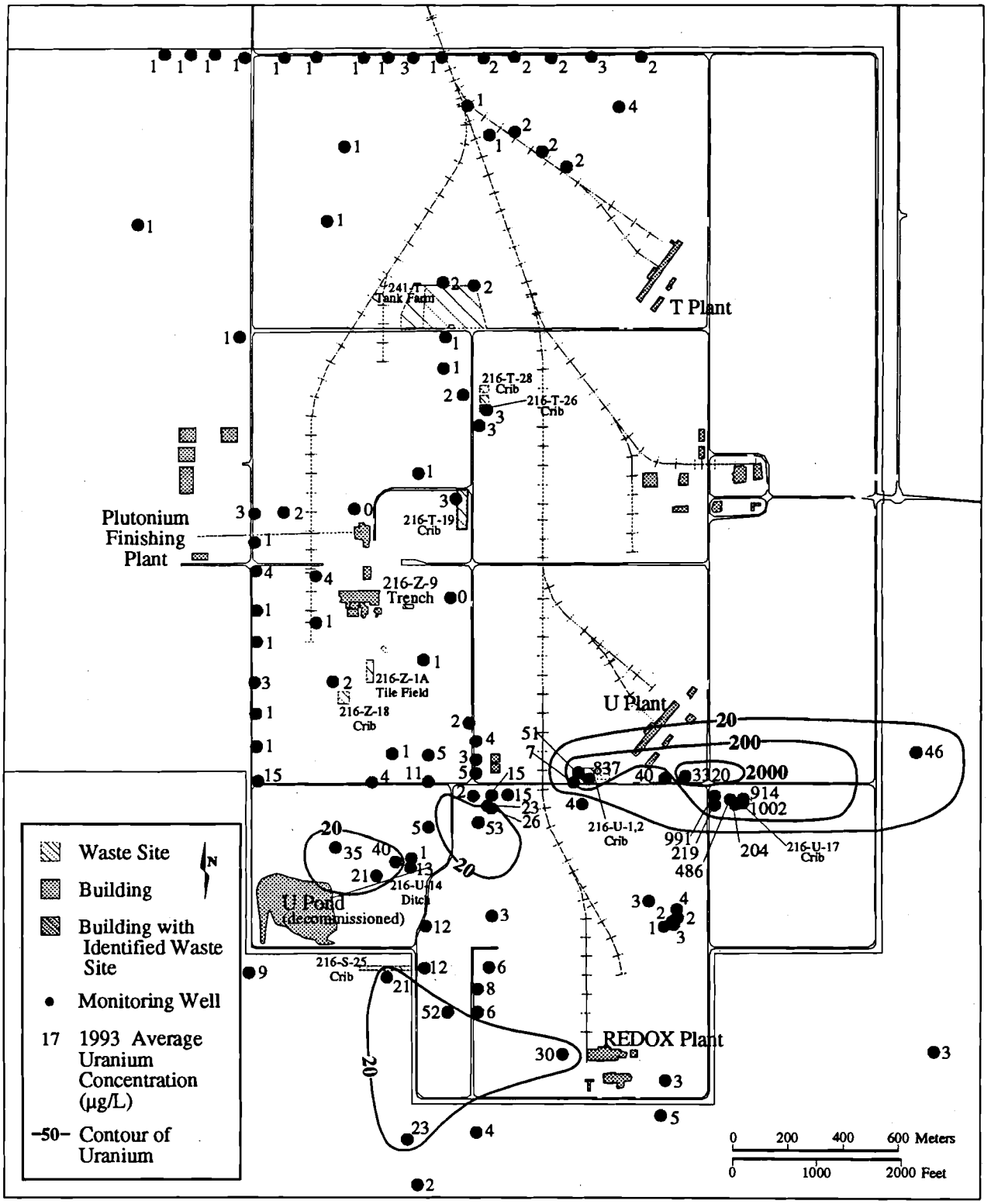
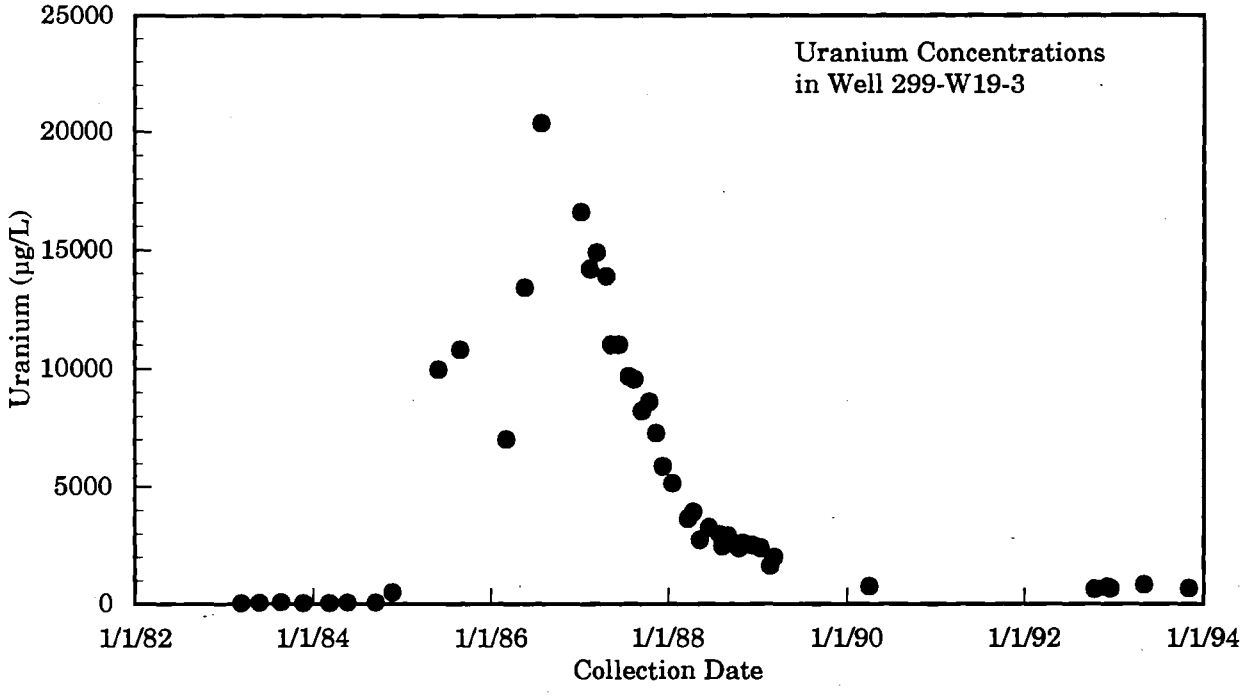


Figure 5.38. 1993 Average Uranium Concentration for the 200-West Area



S9407050.18

Figure 5.39. Uranium Concentration Trend for Well 299-W19-3

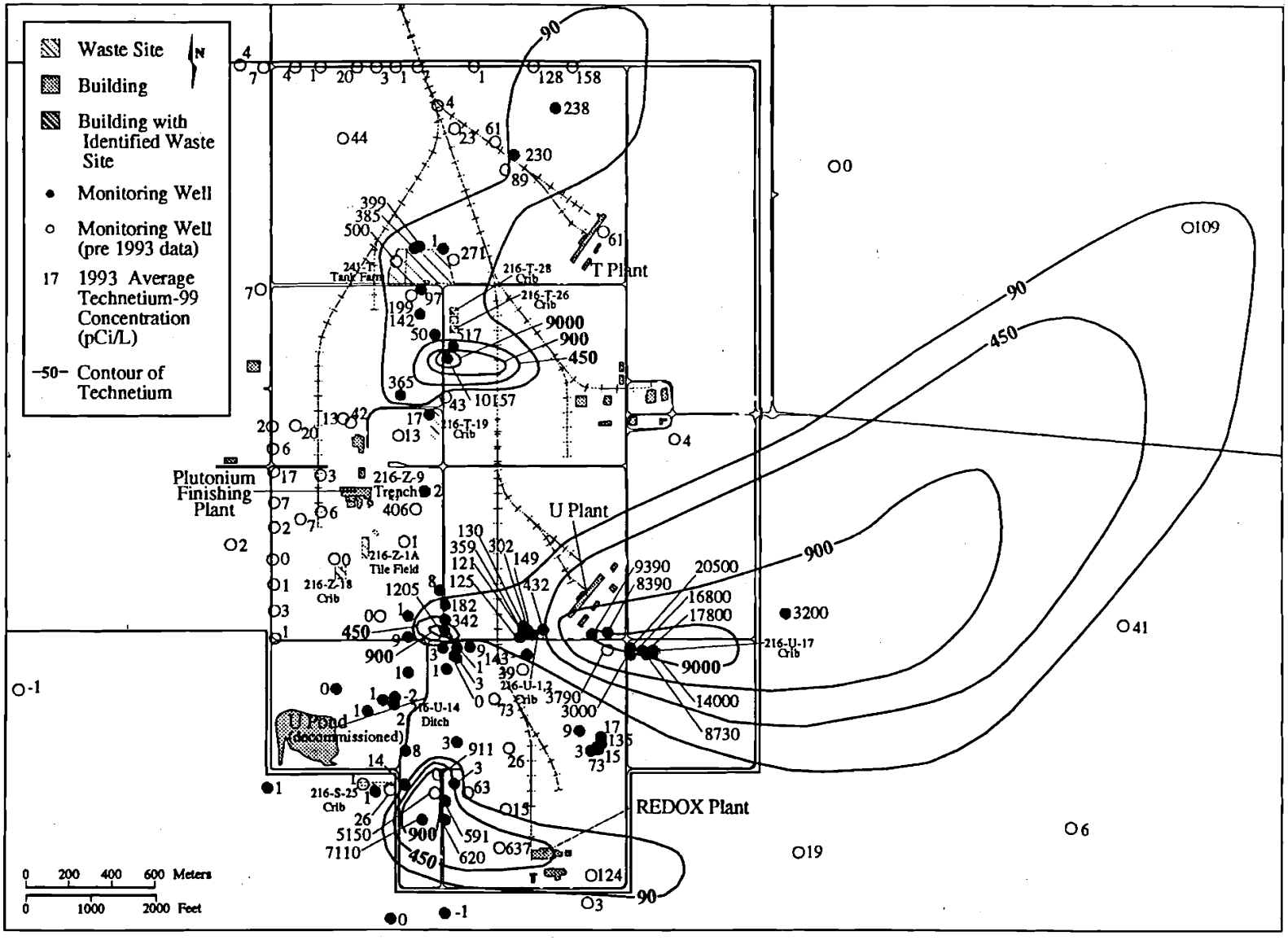


Figure 5.40. 1993 Average Technetium-99 for the 200-West Area

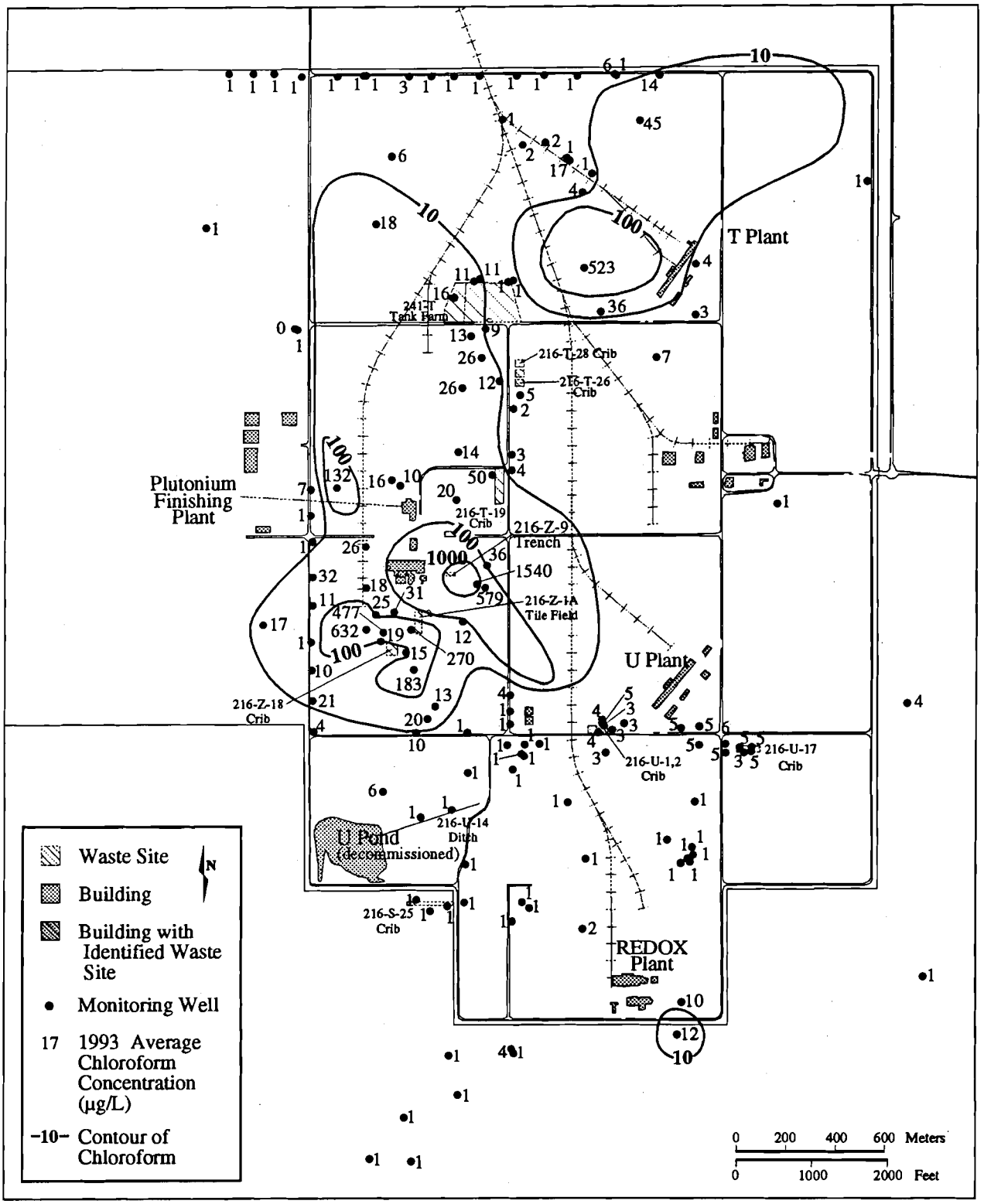


Figure 5.41. 1993 Average Chloroform Concentration for the 200-West Area

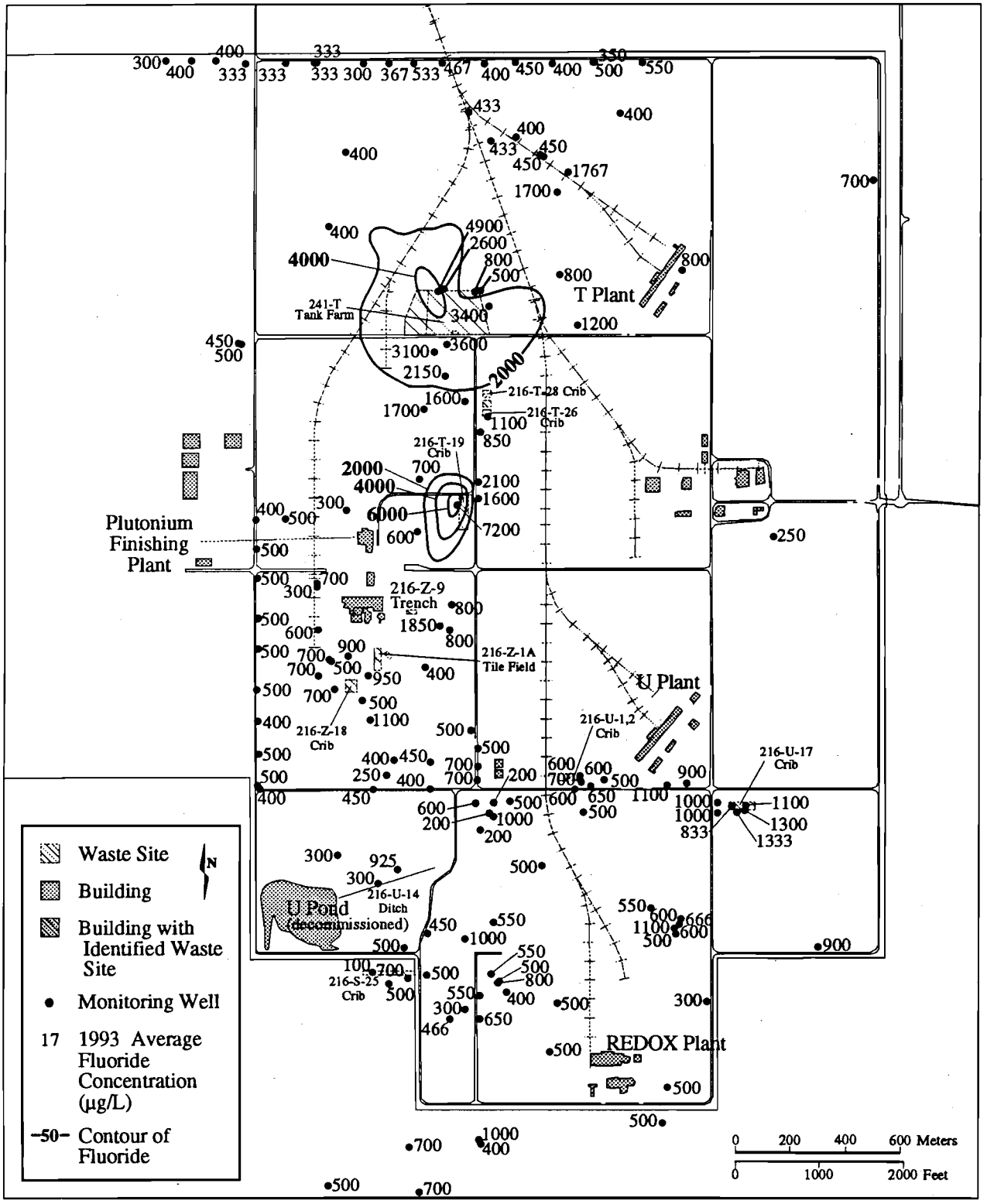


Figure 5.42. 1993 Average Fluoride Concentration for the 200-West Area

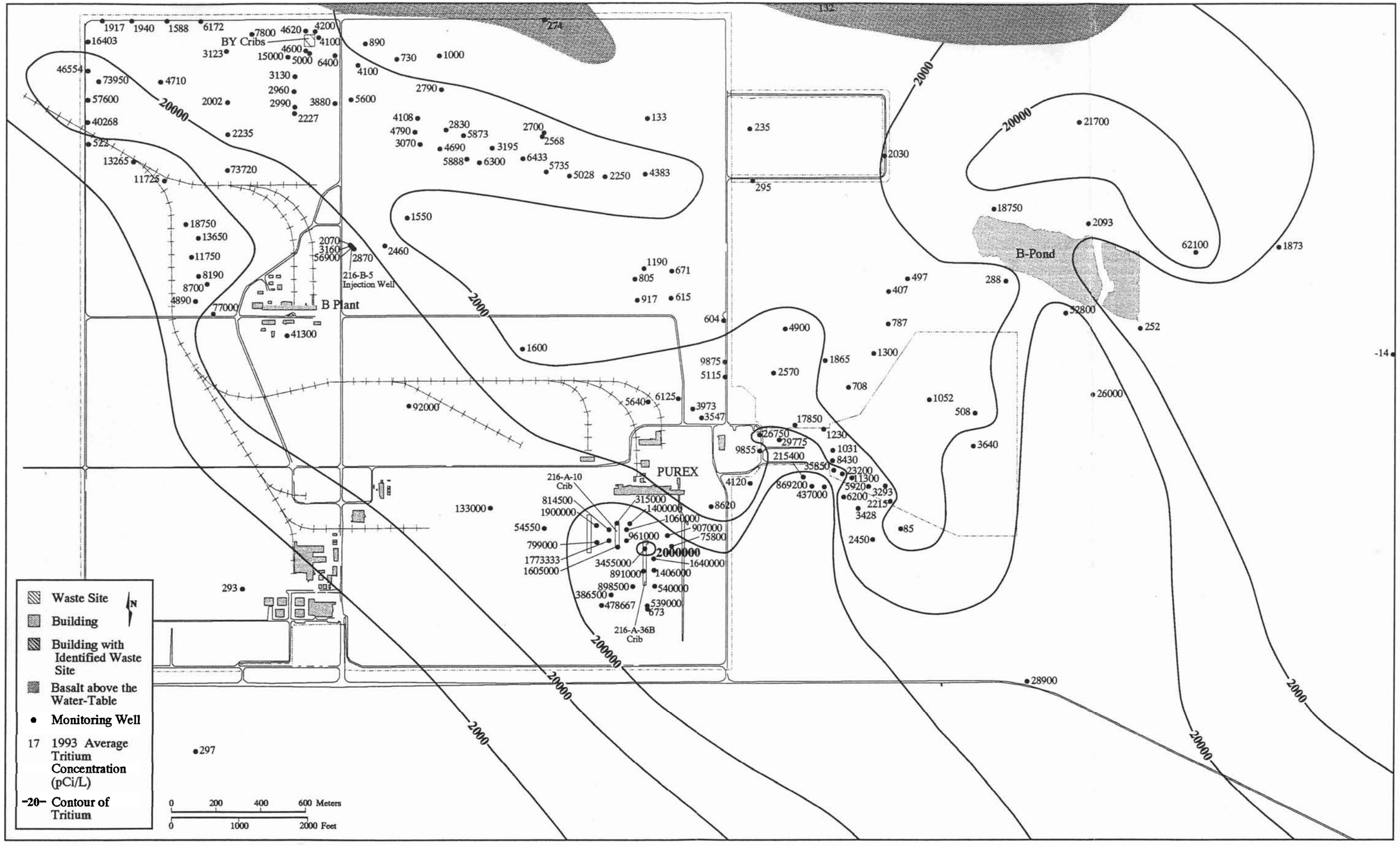


Figure 5.43. 1993 Average Tritium Concentration in the 200-East Area and Surrounding 600 Area

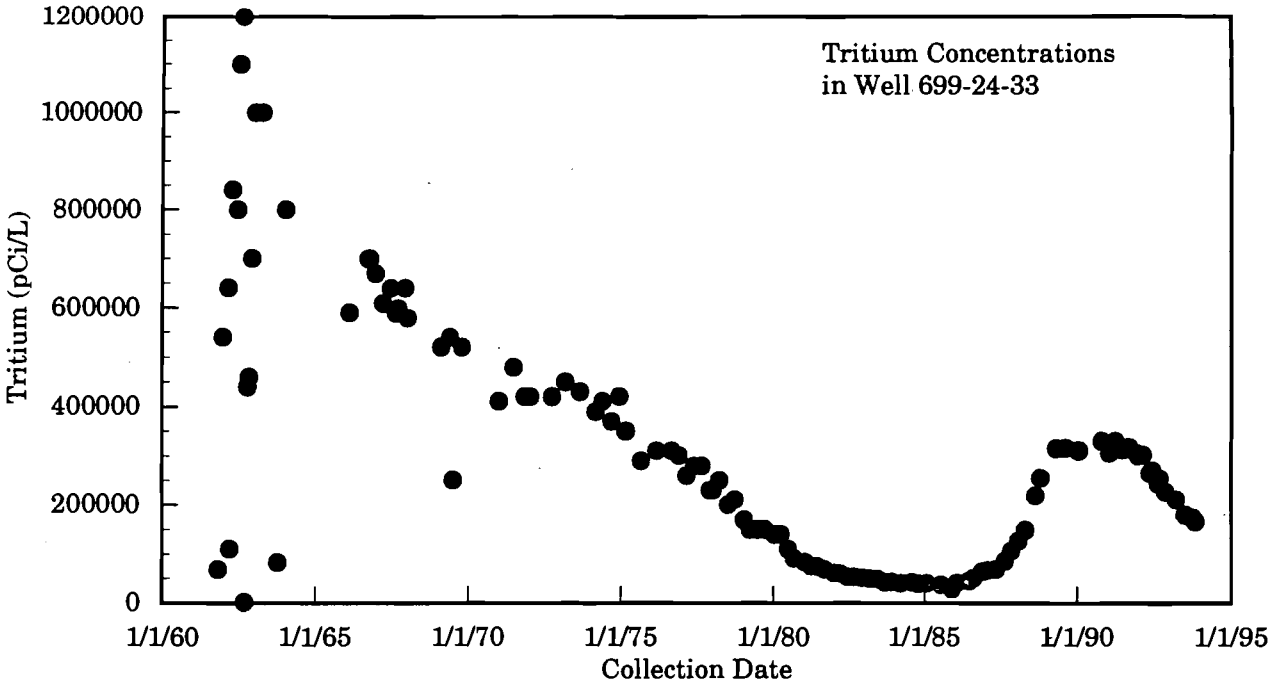


Figure 5.44. Tritium Concentration Trend for Well 699-24-33

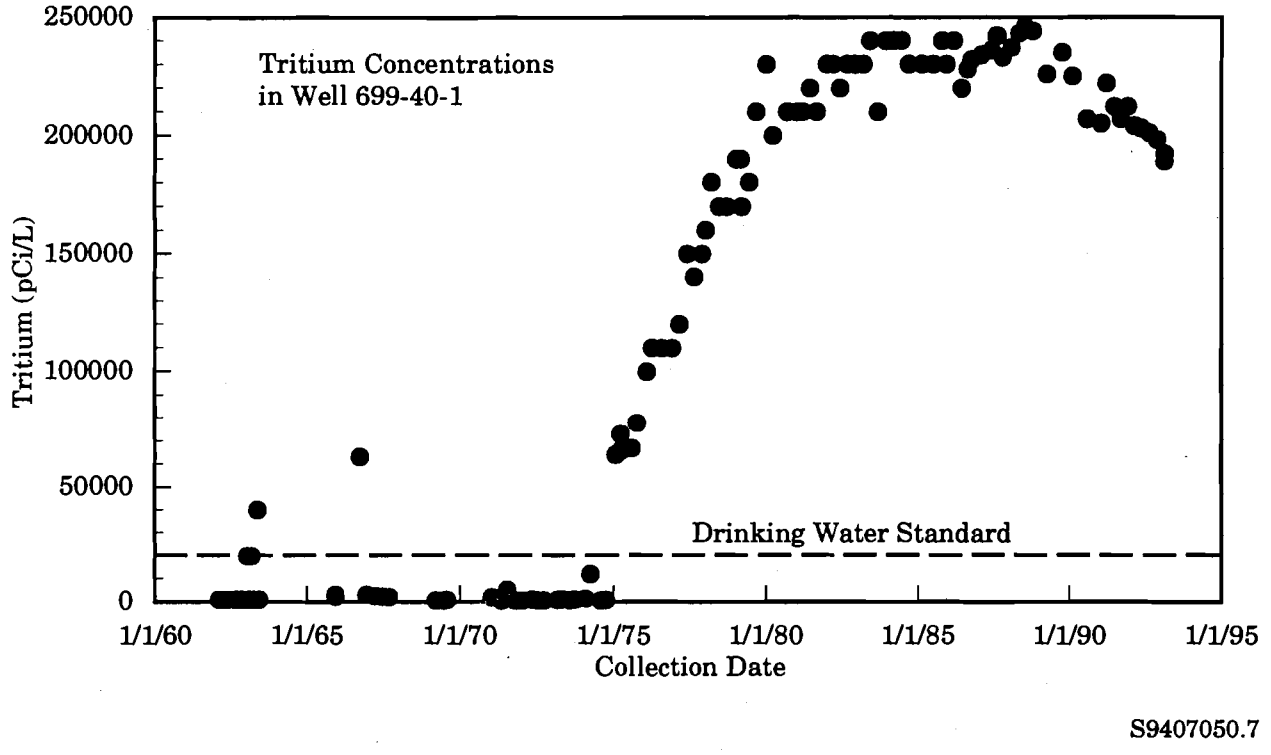


Figure 5.45. Tritium Concentration Trend for Well 699-40-1

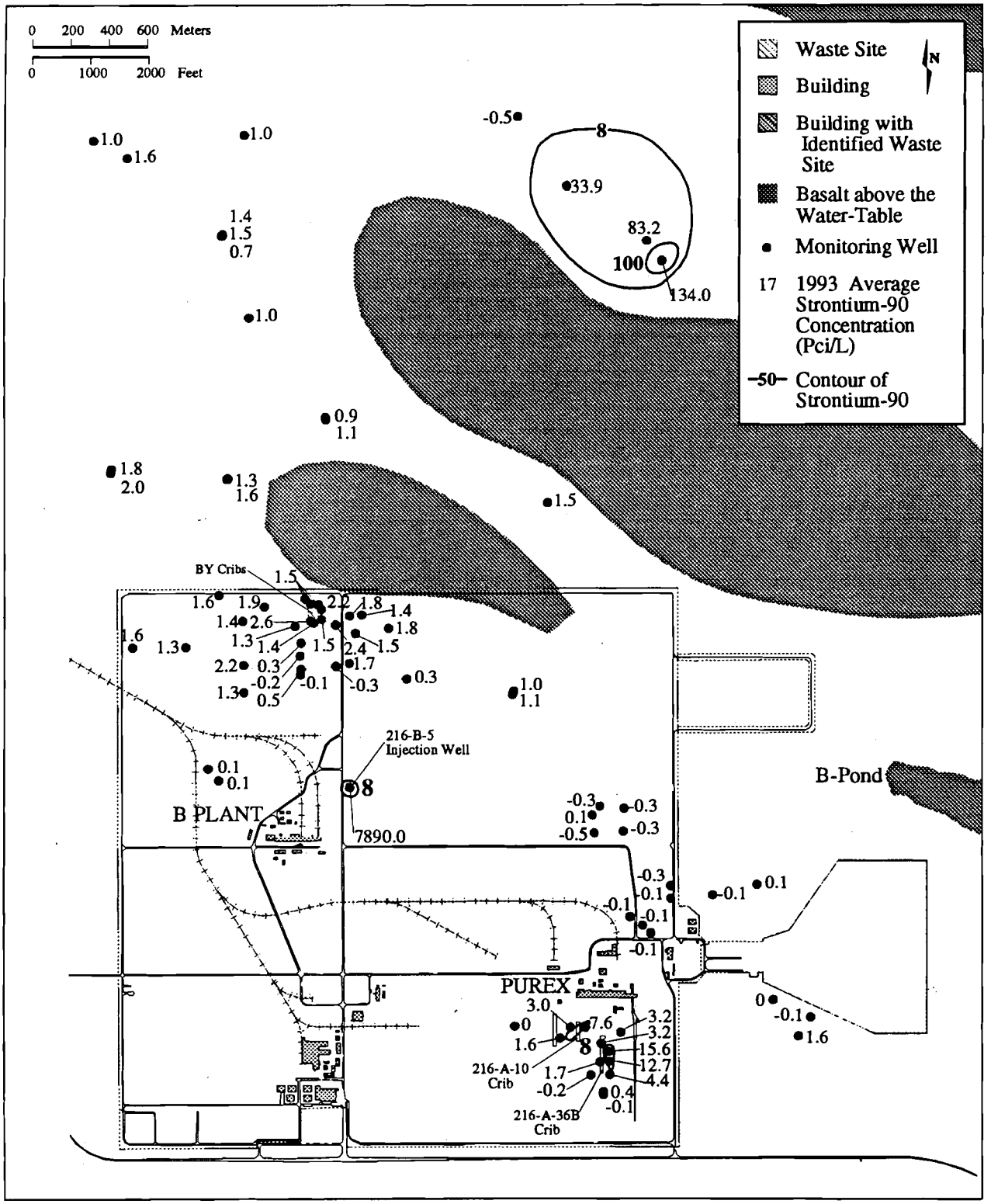


Figure 5.46. 1993 Average Strontium-90 Concentration in the 200-East Area and Surrounding 600 Area

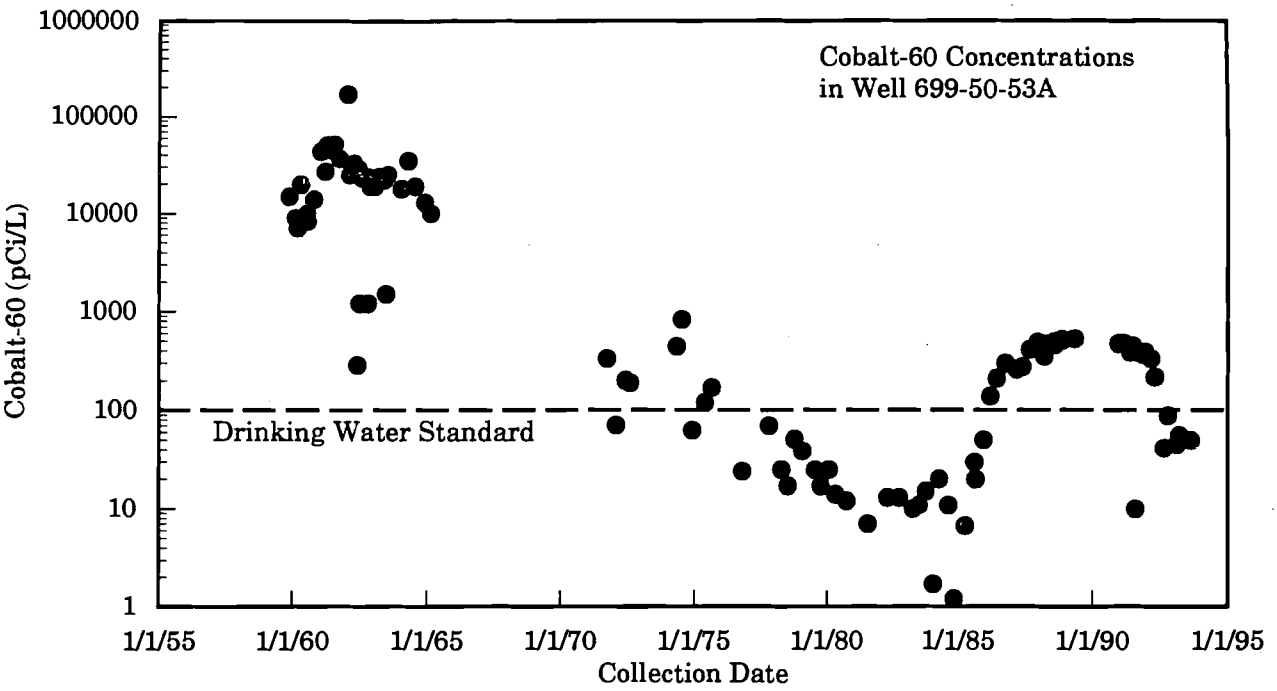


Figure 5.47. Cobalt-60 Concentration Trend for Well 699-50-63A

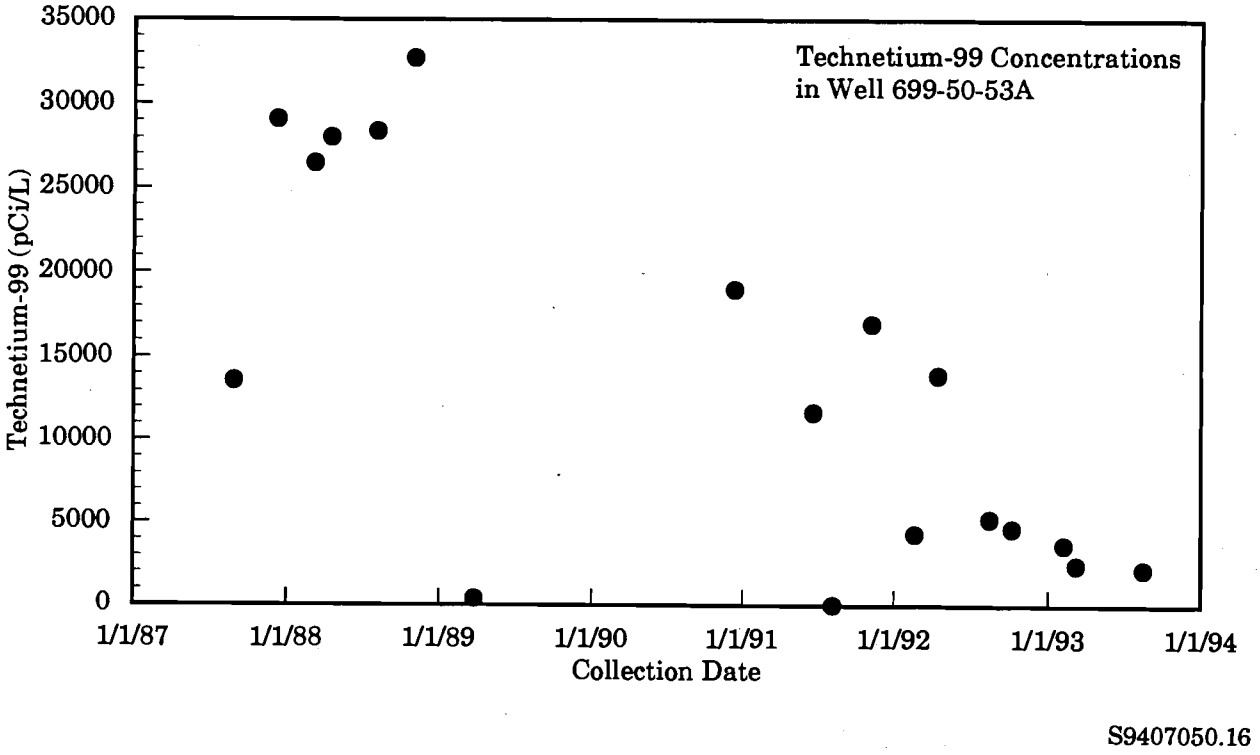


Figure 5.48. Technetium-99 Concentration Trend for Well 699-50-53A

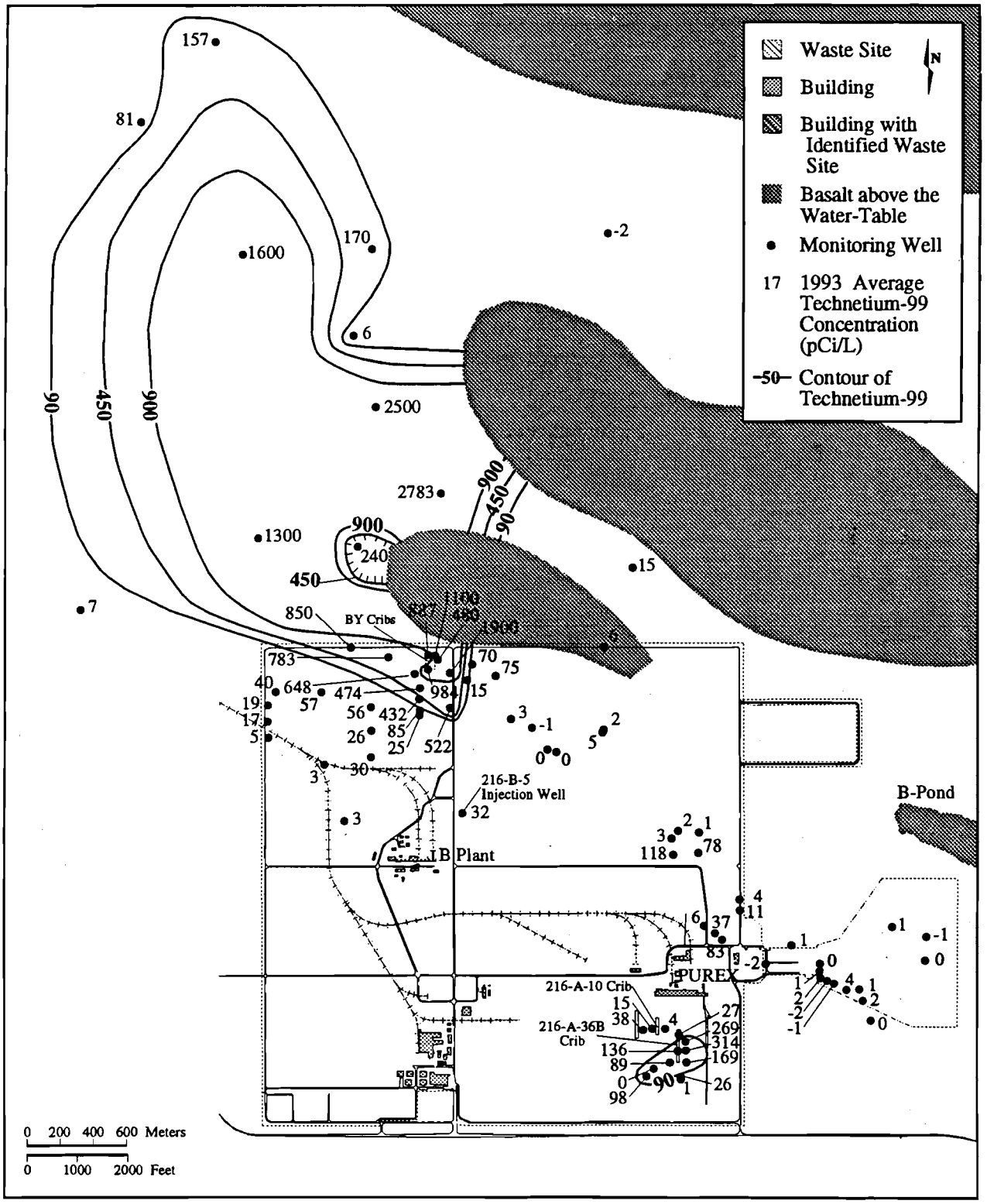


Figure 5.49. 1993 Average Technetium-99 Concentration in the 200-East Area and Surrounding 600 Area

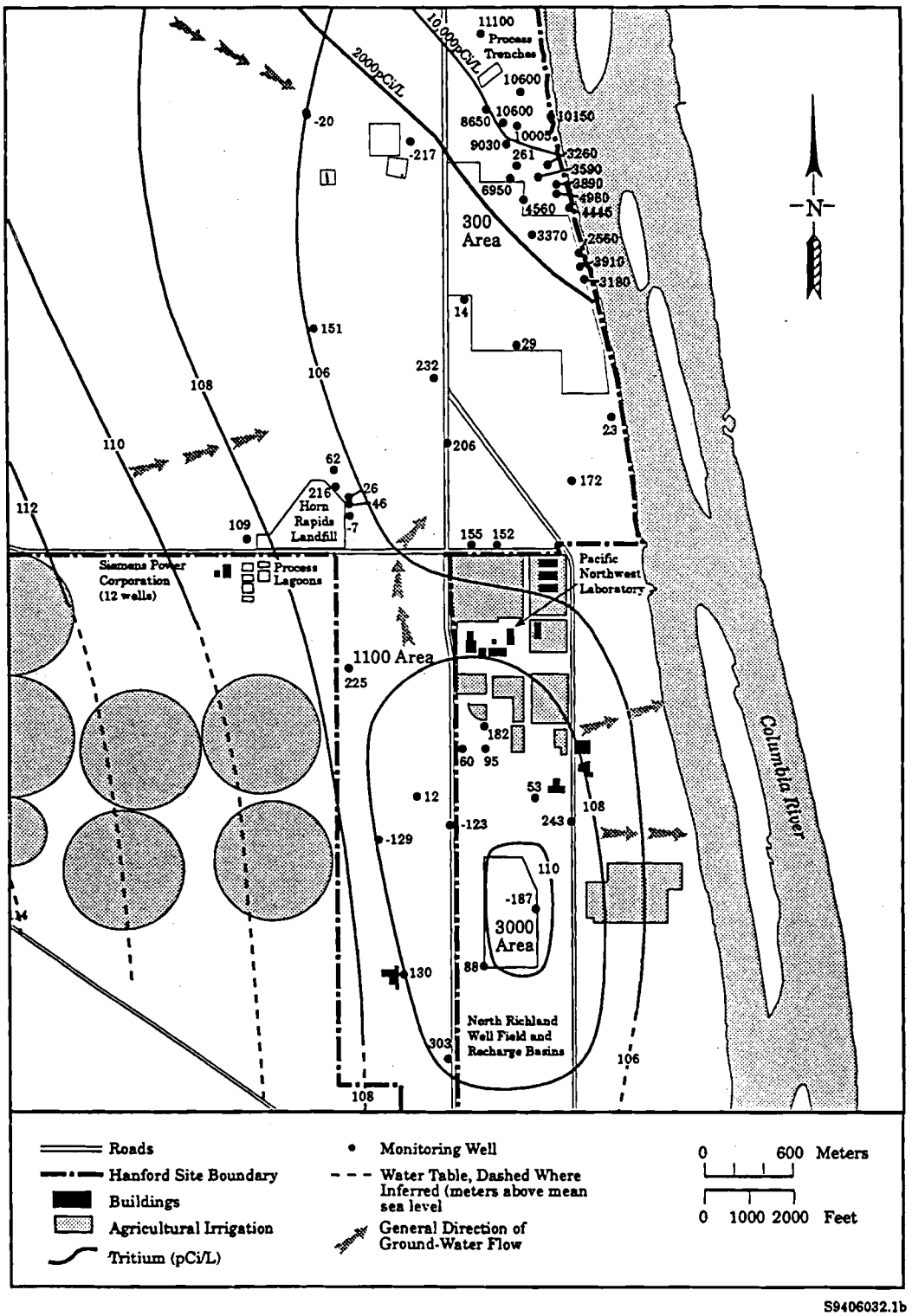


Figure 5.50. 1993 Average Tritium Concentrations in the 300 Area and Richland North Area

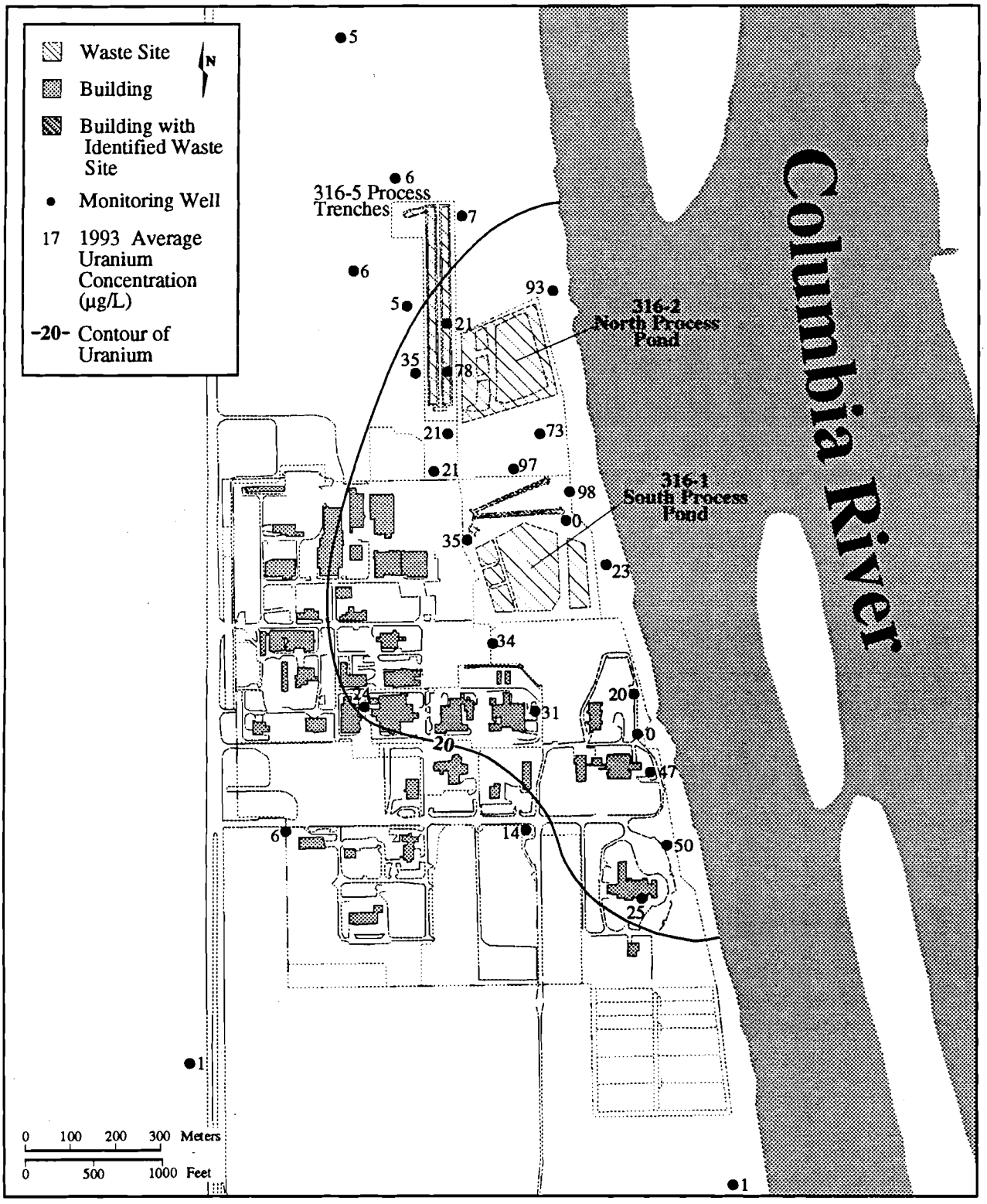


Figure 5.51. 1993 Average Uranium Concentration in the 300 Area

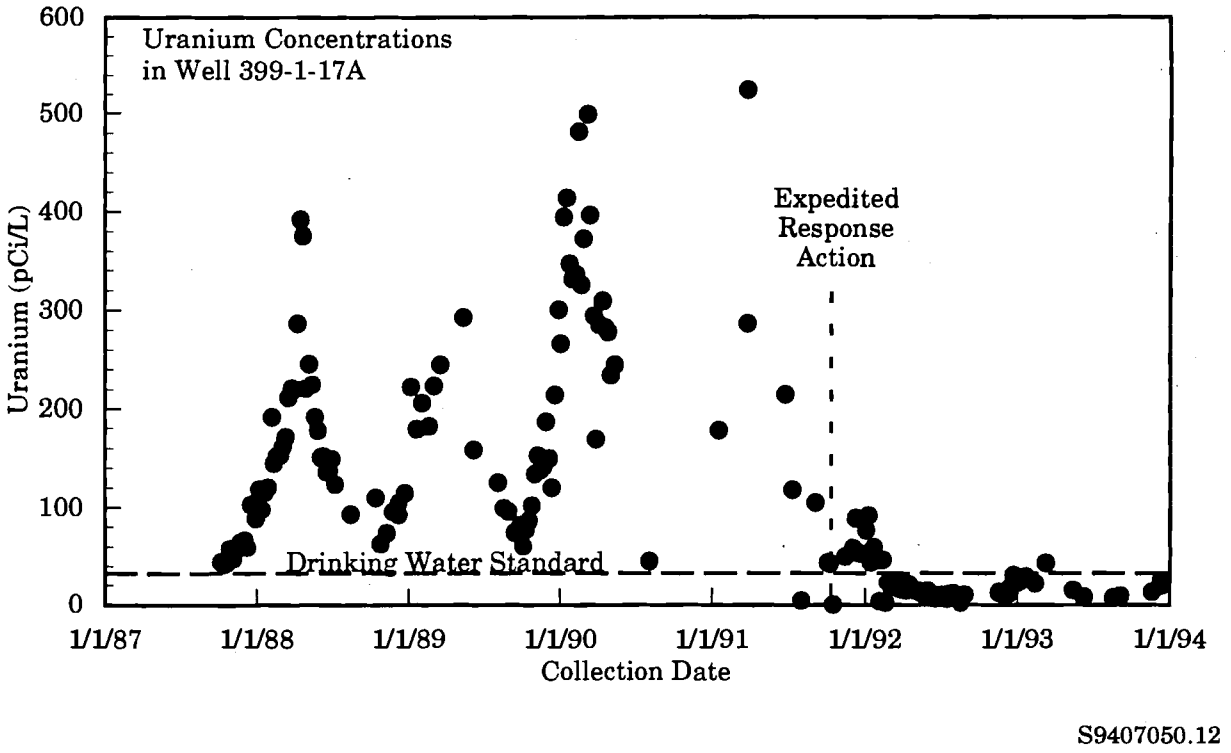


Figure 5.52. Uranium Concentration Trend for Well 399-1-17A

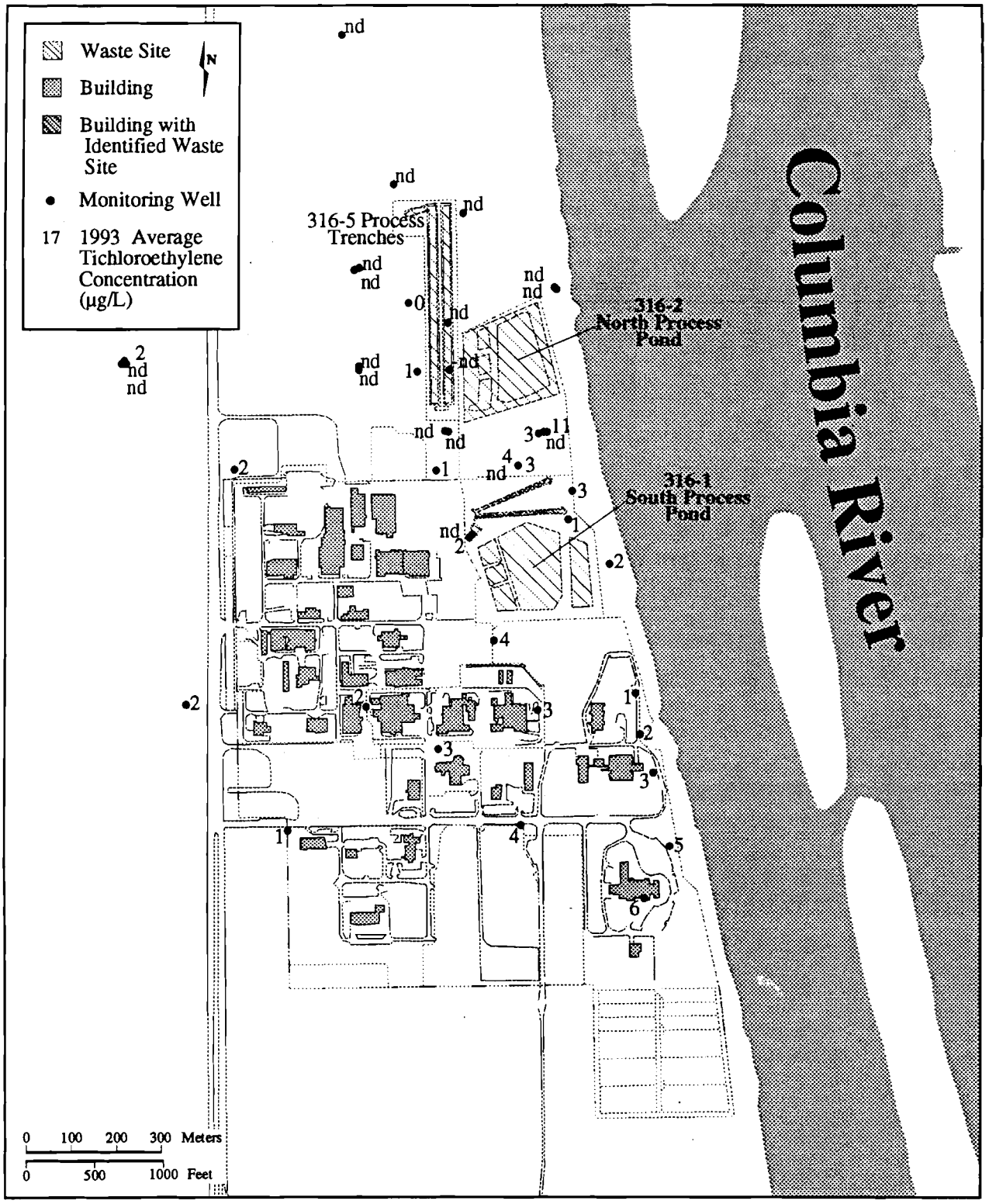


Figure 5.53. 1993 Average Trichloroethylene Concentrations in the 300 Area

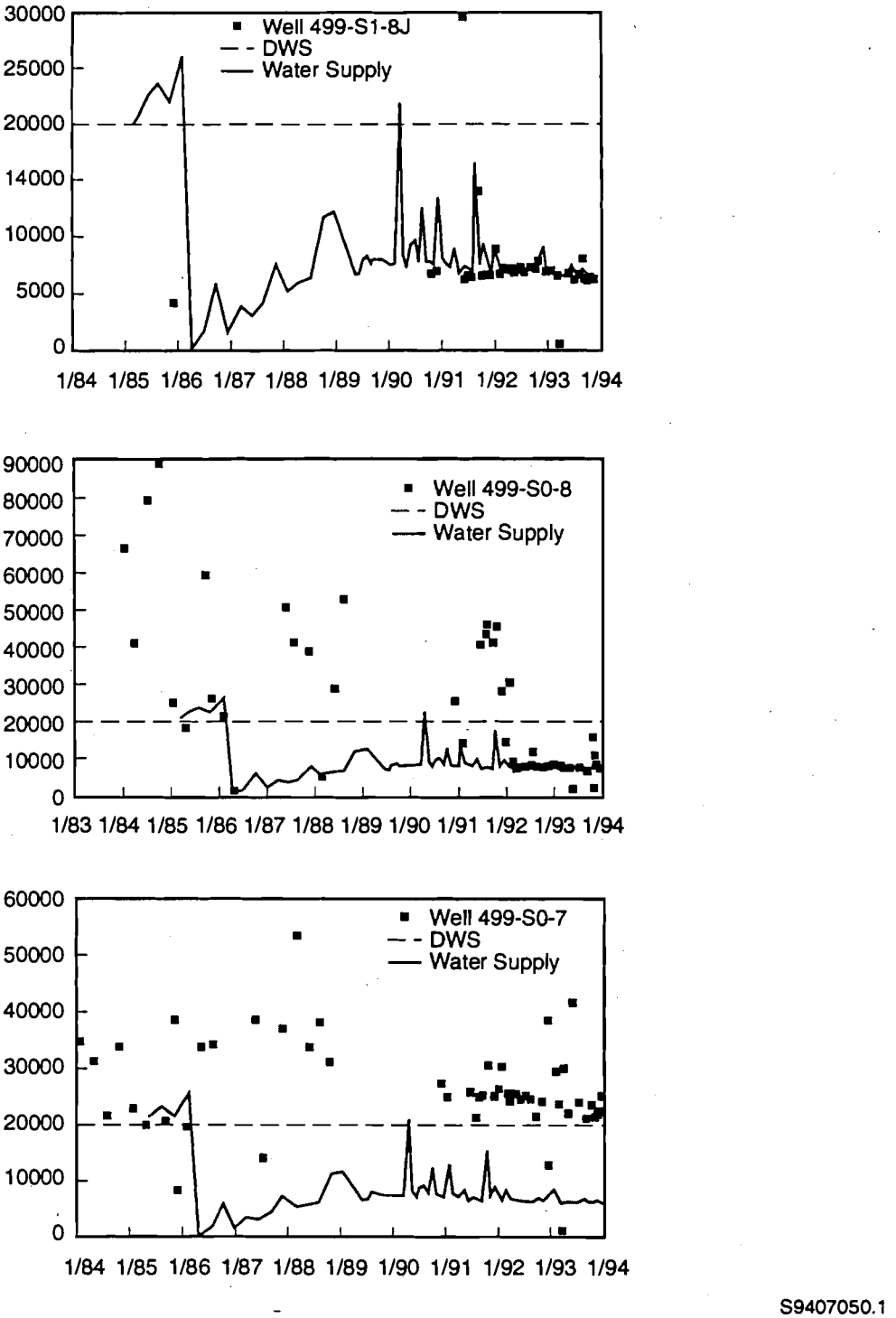


Figure 5.54. Comparison of Tritium Trends in the 400 Area Drinking Water

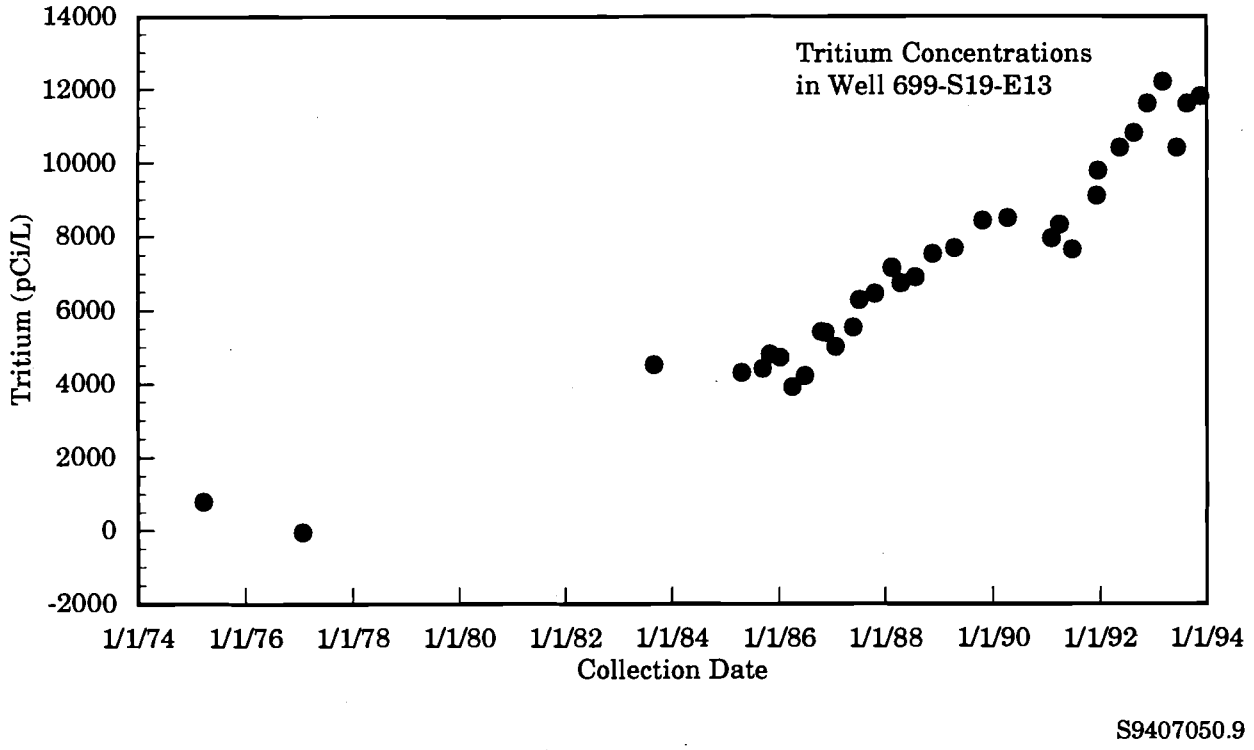


Figure 5.55. Tritium Concentration Trend for Well 699-S19-E13

6.0 Conclusions

P.E. Dresel

This report summarizes the results of 1993 ground-water monitoring performed by the Ground-Water Surveillance Project at the Hanford Site. The Ground-Water Surveillance Project collected water-level measurements and ground-water samples for chemical and radiological analysis. Data collected by the project were integrated with results from other programs to produce a sitewide assessment of ground-water hydrology and contaminant chemistry. Geologic and hydrologic characterization activities performed to support the monitoring are also summarized in this report.

New geologic and hydrologic characterization activities include further refinement of the three-dimensional geologic and hydrologic conceptual model and ongoing development of a multilayer finite-element ground-water model of the unconfined aquifer system. The model of natural areal recharge to the unconfined aquifer was refined, and a detailed map representing recharge across the site was developed.

Water levels in wells completed in the unconfined and confined aquifer system were measured to provide a basis for interpreting ground-water flow and contaminant transport. The measurements confirm the ongoing response of the unconfined aquifer to the decrease in liquid waste disposal. Slow dissipation of ground-water mounding in the 100-N, 200-West, and 200-East Areas, and to a lesser degree over most of the Site, is evident. However, water levels continue to rise in the immediate vicinity of B Pond. Offsite to the west and across the Columbia River to the north and east, water levels are strongly influenced by irrigation practices. Water levels near the Columbia River vary greatly in response to fluctuations in the river stage.

The Ground-Water Surveillance Project sampled 454 wells in 1993, and a total of about 770 wells were sampled by the various ground-water projects onsite. Most samples were analyzed for tritium and common anions, including nitrate, because tritium and nitrate are the most widespread contaminants on the Hanford Site. Additional radiological analyses were for cobalt-60, strontium-90, technetium-99, antimony-125, iodine-129, cesium-137, uranium, and plutonium. Other chemical contaminants evaluated were fluoride, cyanide, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene.

The only contaminant detected in the 100-B/C Area at levels above the DWS was strontium-90. Tritium and technetium-99 were also detected in the 100-B/C Area.

Tritium, strontium-90, nitrate, and chromium were found at levels above the DWS in the 100-D Area. Contaminants from 100-D Area sources may be transported northeastward toward the 100-H Area. Past disposal activities may have influenced the flow field.

Strontium-90, uranium, chromium, and trichloroethylene were detected at levels above the DWS in the 100-F Area. The uranium plume appears to be decreasing in size and concentration. Trichloroethylene apparently comes from a source upgradient of the 100-F Area.

Contaminants detected at concentrations above the DWS in the 100-H Area were strontium-90, technetium-99, uranium, chromium, and nitrate. The chromium appears to come from two sources. The first source is the 183-H Solar Evaporation Basins; the second may be upgradient of the 100-H Area. Elevated levels of technetium-99 are correlated with high chromium concentrations downgradient of the 183-H Solar Evaporation Basins. Uranium and nitrate are also found at levels above the DWS downgradient of the basins. Strontium-90 appears to come from a source at or near the 107-H Retention Basin or the 107-H Liquid Waste Trench. Constituent concentrations increased in a number of wells in the 100-H Area in 1993. This increase indicates a greater uncertainty in groundwater characterization in this area than was previously recognized.

Tritium, strontium-90, nitrate, and chromium were detected at levels above the DWS in the 100-K Area. Tritium was found at levels above the DCG in one well in April and May but then concentrations dropped back below the DCG. A tritium plume originating at or near the KE Reactor contains some of the highest tritium concentrations in ground water onsite. The KE fuel storage basin is a probable source for this tritium, although other local sources are also possible. Strontium-90 was found near the liquid waste disposal trench and the KW Reactor. The source of nitrate in the 100-K Area is not well defined.

Tritium and strontium-90 were found at levels above the DWS in the 100-N Area. Strontium-90 continues to exceed the DCG in 100-N Area ground water. Nitrate was found at levels greater than the DWS in two wells. The highest strontium-90 levels were found between the 1301-N LWDF and the Columbia River. The 1325-N LWDF was one source of the strontium-90. The plume is not spreading at a discernible rate at present.

A number of contaminants detected in the vicinity of the T Plant in the 200-West Area are probably related to past T Plant activities. Nitrate, chromium, and carbon tetrachloride contamination at levels greater than the DWS appears to be related to T Plant discharges. A cyanide plume noted in past monitoring appears to have disappeared.

Past operation of the REDOX Plant in the 200-West Area resulted in plumes of nitrate, tritium, and iodine-129 at levels above the DWS. One well continued to show tritium at levels greater than the DCG in 1993. Plume movement in this area is slowed by the low permeability of the sediments and is expected to decrease even more as gradients decline due to decreases in site discharge.

Contamination in the vicinity of the U Plant in the 200-West Area includes the highest nitrate and uranium concentrations found on the Hanford Site, as well as technetium-99. Uranium concentrations

in one well in this vicinity were greater than the DCG. Concentrations of uranium and nitrate show a general decline with time. The technetium-99 plume extends further downgradient than the uranium plume because of the greater mobility of technetium.

The PUREX Plant and associated disposal facilities are the source of extensive contamination on the Hanford Site. Plumes of tritium, iodine-129, and nitrate at levels above the DWS extend downgradient from the PUREX Plant. Ground water containing tritium at concentrations above the DWS discharges to the Columbia River along a large stretch of the Hanford Reach. This plume has impacted the 400 Area and reached as far south as the 300 Area. The tritium plume exhibits two pulses, which are correlated with the 1956-1972 and 1983-1988 periods of operation of the PUREX Plant. Iodine-129 and nitrate were not detected at levels above the DWS in those portions of the plume near the river.

Contamination from the vicinity of the BY Cribs in the northwestern 200-East Area extends northwest into the 600 Area. Constituents detected at levels greater than the DWS include nitrate, technetium-99, and iodine-129. Other constituents, such as cyanide and cobalt-60, were also detected but have declined in concentration in recent years.

Radiological wastes were injected below the water table via the 216-B-5 Injection Well in the 1940s. Strontium-90, cesium-137, and plutonium continue to be found at levels above the DWS in the immediate vicinity of the injection well. Strontium-90 and plutonium-239/240 were found at levels above the DCG in unfiltered samples. These constituents are extremely immobile in subsurface environments.

Uranium and trichloroethylene were detected at levels above the DWS in the 300 Area. Tritium (at levels less than the DWS) is found in the 300 Area as a result of the plume from the disposal areas associated with the PUREX Plant in the 200-East Area. The uranium contamination in the 300 Area is associated with the 316-5 Process Trenches and the decommissioned North and South Process Ponds. Uranium concentrations greater than the DWS were found in the southern part of the 300 Area. An expedited response action was performed in 1991 to remediate the 316-5 Process Trenches. At about the same time, flow to the trenches decreased substantially. In response to either the expedited response action or the decreased flow, uranium levels in well 399-1-17A near the trenches have decreased since that time, but uranium concentrations were above the DWS for some samples. Trichloroethylene is widespread in the 300 Area, at concentrations near or just above the DWS.

Ground water in the 400 Area has been impacted by nitrate and tritium plumes from the vicinity of the PUREX Plant in the 200-East Area, although only tritium has been detected at levels above the DWS. Tritium in the 400 Area drinking-water supply remained below the DWS for all samples in 1993. The backup water supply well, 499-S0-7, continued to contain tritium at concentrations above the DWS. The reason for the recent decline in tritium to levels below the DWS in the secondary backup well, 499-S0-8, is unclear. The primary supply well, 499-S1-8J, is completed deeper in the unconfined aquifer and no concentrations above the DWS were found in 1993.

The chlorinated solvents trichloroethylene and tetrachloroethylene have been detected in the vicinity of the Central Landfill Complex (including the Solid Waste Landfill and the Non-Radioactive Dangerous Waste Landfill). Tetrachloroethylene is the only of these compounds detected at levels above the DWS.

Trichloroethylene and nitrate were found at levels above the DWS in the Richland North Area. In addition, uranium and technetium-99 have been found in this area, although levels in samples collected on the Hanford Site were not above the DWS. The source of these constituents appears to be the Siemens Power Corporation facility adjacent to the Horn Rapids Landfill, although additional nitrate may come from an agricultural or urban horticultural source upgradient. The spread of tritium from the 200-East Area is not expected to impact the North Richland well field. The migration of the plume to the south is restricted by flow across Richland from the Yakima River to the Columbia River and by excess recharge to the North Richland recharge basins. These features produce flow that converges toward the 300 Area, creating a hydraulic barrier to the southward spread of the tritium plume.

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Appendix A

Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site and Outlying Areas, June 1993

Appendix A

Table A.1. Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site and Outlying Areas, June 1993. (Offsite well names are prefixed by GS.)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
199-B3-1	18-Jun-93	439.19	46.27	392.92	119.76	WHC
199-B3-2P	10-Jun-93	443.38	39.37	404.01	123.14	PNL
199-B4-1	18-Jun-93	461.19	64.06	397.13	121.04	WHC
199-B4-3	9-Jun-93	461.71	64.55	397.16	121.05	WHC
199-B4-4	18-Jun-93	472.14	76.05	396.09	120.72	WHC
199-B4-6	18-Jun-93	481.92	84.44	397.48	121.15	WHC
199-B5-1	18-Jun-93	455.58	58.53	397.05	121.01	WHC
199-D2-5	16-Jun-93	460.30	75.10	385.20	117.40	WHC
199-D5-12	16-Jun-93	469.69	85.12	384.57	117.21	WHC
199-D5-13	1-Jun-93	471.49	87.03	384.46	117.18	WHC
199-D5-13	16-Jun-93	471.49	86.62	384.87	117.30	WHC
199-D8-3	16-Jun-93	449.06	66.56	382.50	116.58	WHC
199-D8-4	1-Jun-93	468.73	83.91	384.82	117.29	WHC
199-D8-4	16-Jun-93	468.73	84.04	384.69	117.25	WHC
199-D8-5	16-Jun-93	452.49	69.14	383.35	116.84	WHC
199-D8-6	1-Jun-93	476.50	91.64	384.86	117.30	WHC
199-D8-6	16-Jun-93	476.50	91.90	384.60	117.22	WHC
199-F5-1	15-Jun-93	406.56	35.19	371.37	113.19	WHC
199-F5-3	15-Jun-93	408.62	38.24	370.38	112.89	WHC
199-F5-4	15-Jun-93	412.12	41.99	370.13	112.81	WHC
199-F5-6	15-Jun-93	412.95	43.06	369.89	112.74	WHC
199-F7-1	15-Jun-93	389.74	15.04	374.70	114.20	WHC
199-F8-1	15-Jun-93	405.86	35.16	370.70	112.98	WHC
199-F8-2	15-Jun-93	410.74	40.15	370.59	112.95	WHC
199-H3-1	16-Jun-93	421.48	45.46	376.02	114.61	WHC
199-H4-10	16-Jun-93	404.44	30.55	373.89	113.96	WHC
199-H4-11	16-Jun-93	416.84	44.16	372.68	113.59	WHC
199-H4-13	16-Jun-93	418.20	45.89	372.31	113.47	WHC
199-H4-16	16-Jun-93	424.23	48.80	375.43	114.43	WHC
199-H4-6	16-Jun-93	419.58	43.56	376.02	114.61	WHC
199-H4-8	16-Jun-93	420.00	44.47	375.53	114.46	WHC
199-K-19	18-Jun-93	422.17	33.53	388.64	118.45	WHC
199-K-20	18-Jun-93	422.57	34.55	388.02	118.26	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
199-K-32A	18-Jun-93	444.02	54.32	389.70	118.77	WHC
199-K-34	18-Jun-93	468.09	76.53	391.56	119.34	WHC
199-K-35	18-Jun-93	494.55	98.69	395.86	120.65	WHC
199-K-36	18-Jun-93	494.07	97.83	396.24	120.77	WHC
199-K-37	18-Jun-93	441.80	54.24	387.56	118.12	WHC
199-N-14	8-Jun-93	453.15	67.35	385.80	117.59	PNL
199-N-14	18-Jun-93	453.15	68.49	384.66	117.24	WHC
199-N-16	17-Jun-93	456.70	69.54	387.16	118.00	WHC
199-N-26	17-Jun-93	455.80	71.40	384.40	117.16	WHC
199-N-28	17-Jun-93	464.24	76.38	387.86	118.21	WHC
199-N-32	17-Jun-93	462.08	75.03	387.05	117.97	WHC
199-N-42	17-Jun-93	455.14	69.14	386.00	117.65	WHC
199-N-49	17-Jun-93	450.72	65.56	385.16	117.39	WHC
199-N-51	17-Jun-93	462.18	78.17	384.01	117.04	WHC
199-N-52	17-Jun-93	463.70	75.52	388.18	118.31	WHC
199-N-55	17-Jun-93	457.85	71.07	386.78	117.88	WHC
199-N-63	17-Jun-93	466.70	78.94	387.76	118.18	WHC
199-N-65	18-Jun-93	456.44	69.25	387.19	118.01	WHC
199-N-67	18-Jun-93	458.46	72.32	386.14	117.69	WHC
199-N-71	17-Jun-93	463.04	73.40	389.64	118.76	WHC
199-N-72	17-Jun-93	458.99	69.23	389.76	118.79	WHC
299-E13-12	11-Jun-93	731.34	330.96	400.38	122.03	WHC
299-E13-14	11-Jun-93	745.15	342.74	402.41	122.65	WHC
299-E17-12	10-Jun-93	721.70	319.90	401.80	122.46	WHC
299-E18-1	11-Jun-93	720.24	318.08	402.16	122.57	WHC
299-E18-1	22-Jun-93	720.24	318.30	401.94	122.51	WHC
299-E23-1	14-Jun-93	713.10	310.79	402.31	122.62	WHC
299-E23-2	11-Jun-93	720.64	318.66	401.98	122.52	WHC
299-E24-4	25-Jun-93	696.69	294.53	402.16	122.57	PNL
299-E24-7	10-Jun-93	716.01	314.02	401.99	122.52	WHC
299-E24-7	25-Jun-93	716.01	314.19	401.82	122.47	PNL
299-E24-8	22-Jun-93	688.81	286.50	402.31	122.62	WHC
299-E25-24	10-Jun-93	679.55	277.30	402.25	122.60	WHC
299-E25-28	22-Jun-93	662.44	259.91	402.53	122.69	WHC
299-E25-32P	22-Jun-93	669.19	267.60	401.59	122.40	WHC
299-E25-36	7-Jun-93	707.39	305.48	401.91	122.50	WHC
299-E25-36	22-Jun-93	707.39	305.46	401.93	122.50	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
299-E25-37	10-Jun-93	673.29	271.32	401.97	122.51	WHC
299-E25-39	14-Jun-93	671.23	268.30	402.93	122.81	WHC
299-E26-10	14-Jun-93	601.47	198.94	402.53	122.69	WHC
299-E26-11	14-Jun-93	599.68	194.32	405.36	123.55	WHC
299-E26-12	22-Jun-93	630.74	227.85	402.89	122.79	WHC
299-E26-4	9-Jun-93	647.76	245.46	402.30	122.62	WHC
299-E27-1	10-Jun-93	682.55	280.38	402.17	122.58	WHC
299-E27-14	15-Jun-93	658.34	256.39	401.95	122.51	WHC
299-E27-14	23-Jun-93	658.34	256.33	402.01	122.53	WHC
299-E27-19	9-Jun-93	650.88	249.89	400.99	122.22	WHC
299-E27-7	15-Jun-93	634.67	232.79	401.88	122.49	WHC
299-E27-7	23-Jun-93	634.67	232.42	402.25	122.60	WHC
299-E27-8	23-Jun-93	637.83	235.94	401.89	122.49	WHC
299-E28-17	14-Jun-93	708.56	305.34	403.22	122.90	WHC
299-E28-18	10-Jun-93	692.58	290.40	402.18	122.58	WHC
299-E28-7	9-Jun-93	685.91	284.48	401.43	122.35	WHC
299-E32-4	25-Jun-93	685.88	284.17	401.71	122.44	WHC
299-E32-7	25-Jun-93	658.42	256.44	401.98	122.52	WHC
299-E33-14	28-Jun-93	622.05	219.93	402.12	122.56	WHC
299-E33-30	25-Jun-93	663.70	261.82	401.88	122.49	WHC
299-E33-33	16-Jun-93	640.17	238.27	401.90	122.49	WHC
299-E33-33	23-Jun-93	640.17	238.37	401.80	122.46	WHC
299-E33-34	25-Jun-93	633.33	231.55	401.78	122.46	WHC
299-E33-7	28-Jun-93	626.58	225.73	400.85	122.17	WHC
299-E34-3	23-Jun-93	611.52	209.48	402.04	122.54	WHC
299-E34-5	28-Jun-93	590.79	187.73	403.06	122.85	WHC
299-E35-2	14-Jun-93	602.10	199.58	402.52	122.68	WHC
299-W10-13	25-Jun-93	699.04	236.71	462.33	140.91	WHC
299-W10-15	21-Jun-93	675.64	213.82	461.82	140.76	WHC
299-W10-15	24-Jun-93	675.64	214.11	461.53	140.67	WHC
299-W10-5	16-Jun-93	672.31	209.76	462.55	140.98	WHC
299-W11-10	16-Jun-93	728.89	275.20	453.69	138.28	WHC
299-W11-10	17-Jun-93	728.89	274.98	453.91	138.35	PNL
299-W11-14	16-Jun-93	715.16	257.39	457.77	139.52	WHC
299-W11-19	16-Jun-93	707.00	249.89	457.11	139.32	WHC
299-W11-6	16-Jun-93	716.23	258.06	458.17	139.64	WHC
299-W11-9	16-Jun-93	722.94	266.94	456.00	138.98	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
299-W12-1	16-Jun-93	726.46	277.35	449.11	136.88	WHC
299-W14-1	16-Jun-93	665.83	205.58	460.25	140.28	WHC
299-W15-16	24-Jun-93	684.89	220.88	464.01	141.42	WHC
299-W15-20	24-Jun-93	698.36	235.20	463.16	141.16	WHC
299-W15-4	16-Jun-93	662.00	198.08	463.92	141.40	WHC
299-W15-5	17-Jun-93	670.68	205.07	465.61	141.91	WHC
299-W18-15	17-Jun-93	660.76	196.34	464.42	141.55	WHC
299-W18-28	24-Jun-93	679.99	216.23	463.76	141.35	WHC
299-W18-30	22-Jun-93	672.84	207.75	465.09	141.75	WHC
299-W18-30	24-Jun-93	672.84	208.79	464.05	141.44	WHC
299-W19-14	18-Jun-93	693.21	233.14	460.07	140.22	WHC
299-W19-15	17-Jun-93	693.28	232.48	460.80	140.44	WHC
299-W19-20	18-Jun-93	691.04	235.62	455.42	138.81	WHC
299-W19-21	17-Jun-93	678.53	213.64	464.89	141.69	WHC
299-W19-28	17-Jun-93	703.35	245.27	458.08	139.62	WHC
299-W19-29	17-Jun-93	702.13	244.59	457.54	139.45	WHC
299-W19-4	17-Jun-93	715.26	258.83	456.43	139.11	WHC
299-W19-6	24-Jun-93	686.60	226.09	460.51	140.36	WHC
299-W21-1	17-Jun-93	699.26	247.75	451.51	137.61	WHC
299-W22-20	8-Jun-93	676.13	222.04	454.09	138.40	PNL
299-W22-26	18-Jun-93	680.30	221.49	458.81	139.84	WHC
299-W22-42	21-Jun-93	691.16	235.23	455.93	138.96	WHC
299-W22-42	25-Jun-93	691.16	235.51	455.65	138.88	WHC
299-W22-43	21-Jun-93	691.35	234.49	456.86	139.24	WHC
299-W22-43	25-Jun-93	691.35	234.75	456.60	139.16	WHC
299-W22-45	24-Jun-93	666.21	206.91	459.30	139.99	WHC
299-W22-46	24-Jun-93	671.18	212.75	458.43	139.72	WHC
299-W22-46	24-Jun-93	671.18	212.95	458.23	139.66	WHC
299-W22-7	17-Jun-93	687.41	231.26	456.15	139.03	WHC
299-W23-11	17-Jun-93	664.14	203.02	461.12	140.54	PNL
299-W23-11	18-Jun-93	664.14	202.98	461.16	140.55	WHC
299-W23-13	24-Jun-93	666.33	205.09	461.24	140.58	WHC
299-W23-13	24-Jun-93	666.33	207.89	458.44	139.73	WHC
299-W23-15	24-Jun-93	655.44	196.22	459.22	139.96	WHC
299-W23-15	25-Jun-93	655.44	195.96	459.48	140.04	WHC
299-W23-7	24-Jun-93	663.67	203.32	460.35	140.31	WHC
299-W26-12	21-Jun-93	675.69	218.26	457.43	139.42	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
299-W26-7	28-Jun-93	651.99	191.88	460.11	140.23	WHC
299-W26-8	21-Jun-93	666.31	208.52	457.79	139.53	WHC
299-W26-8	28-Jun-93	666.31	209.01	457.30	139.38	WHC
299-W6-10	14-Jun-93	712.48	257.78	454.70	138.59	WHC
299-W6-11	10-Jun-93	702.86	249.96	452.90	138.04	WHC
299-W7-10	25-Jun-93	689.66	232.45	457.21	139.35	WHC
299-W7-11	25-Jun-93	681.45	223.29	458.16	139.64	WHC
299-W7-6	25-Jun-93	678.64	222.05	456.59	139.16	WHC
299-W8-1	25-Jun-93	701.33	242.40	458.93	139.88	WHC
299-W9-1	25-Jun-93	737.73	276.39	461.34	140.61	WHC
399-47-18B	14-Jun-93	374.95	32.88	342.07	104.26	WHC
399-1-14A	29-Jun-93	383.23	40.24	342.99	104.54	WHC
399-1-18C	29-Jun-93	388.05	43.60	344.45	104.98	WHC
399-2-1	29-Jun-93	375.30	33.23	342.07	104.26	WHC
399-3-10	29-Jun-93	385.40	43.54	341.86	104.19	WHC
399-6-1	29-Jun-93	386.93	46.16	340.77	103.86	WHC
399-8-2	29-Jun-93	398.09	54.53	343.56	104.71	WHC
699-S11-E12A	22-Jun-93	365.83	16.20	349.63	106.56	PNL
699-S12-29	4-Jun-93	487.68	83.38	404.30	123.22	WHC
699-S12-3	3-Jun-93	435.52	54.75	380.77	116.05	WHC
699-S12-3	30-Jun-93	435.52	54.63	380.89	116.09	PNL
699-S14-20A	1-Jun-93	492.74	92.01	400.73	122.14	WHC
699-S18-E2A	9-Jun-93	434.85	75.47	359.38	109.53	WHC
699-S19-E14	29-Jun-93	373.86	30.06	343.80	104.79	WHC
699-S19-11	2-Jun-93	483.74	93.78	389.96	118.85	WHC
699-S19-11	10-Jun-93	483.74	93.61	390.13	118.91	PNL
699-S19-11	29-Jun-93	483.74	93.54	390.20	118.93	PNL
699-S22-E9A	29-Jun-93	374.19	29.05	345.14	105.19	WHC
699-S27-E14	29-Jun-93	399.76	57.89	341.87	104.20	WHC
699-S27-E9B	29-Jun-93	390.42	41.14	349.28	106.46	WHC
699-S28-E12	29-Jun-93	389.76	45.21	344.55	105.01	WHC
699-S29-E16A	29-Jun-93	379.73	38.34	341.39	104.05	WHC
699-S29-E16B	29-Jun-93	379.88	38.40	341.48	104.08	WHC
699-S30-E10A	14-Jun-93	392.29	43.78	348.51	106.22	WHC
699-S30-E15A	9-Jun-93	400.14	57.56	342.58	104.41	PNL
699-S30-E15A	11-Jun-93	400.14	57.77	342.37	104.35	WHC
699-S31-E10D	11-Jun-93	380.58	32.03	348.55	106.23	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-S31-1	11-Jun-93	460.00	81.49	378.51	115.36	WHC
699-S31-1	17-Jun-93	460.00	83.03	376.97	114.89	PNL
699-S32-E13B	11-Jun-93	394.72	47.75	346.97	105.75	WHC
699-S32-E8	14-Jun-93	375.79	15.82	359.97	109.71	WHC
699-S34-E10	11-Jun-93	382.37	29.48	352.89	107.56	WHC
699-S34-E10	30-Jun-93	382.37	28.42	353.95	107.88	PNL
699-S34-E15	14-Jun-93	408.04	55.80	352.24	107.36	WHC
699-S36-E12B	11-Jun-93	399.04	42.95	356.09	108.53	WHC
699-S36-E13A	11-Jun-93	399.30	43.66	355.64	108.39	WHC
699-S37-E11A	11-Jun-93	399.30	43.77	355.53	108.36	WHC
699-S37-E14	8-Jun-93	408.28	51.97	356.31	108.60	PNL
699-S37-E14	11-Jun-93	408.28	51.46	356.82	108.75	WHC
699-S38-E11	11-Jun-93	398.60	43.86	354.74	108.12	WHC
699-S38-E12A	11-Jun-93	404.95	47.84	357.11	108.84	WHC
699-S3-E12	1-Jun-93	397.90	43.65	354.25	107.97	WHC
699-S3-E12	16-Jun-93	397.90	43.69	354.21	107.96	PNL
699-S3-25	1-Jun-93	523.50	124.75	398.75	121.53	WHC
699-S40-E14	11-Jun-93	402.85	41.05	361.80	110.27	WHC
699-S40-E14	18-Jun-93	402.85	40.58	362.27	110.41	PNL
699-S41-E11A	11-Jun-93	401.36	46.95	354.41	108.02	WHC
699-S41-E12	14-Jun-93	401.93	46.78	355.15	108.24	WHC
699-S41-E13A	11-Jun-93	410.56	51.27	359.29	109.51	WHC
699-S41-E13B	11-Jun-93	410.10	50.72	359.38	109.53	WHC
699-S41-E13C	11-Jun-93	410.67	51.65	359.02	109.42	WHC
699-S43-E12	11-Jun-93	405.60	51.92	353.68	107.80	WHC
699-S43-E12	18-Jun-93	405.60	51.12	354.48	108.04	PNL
699-S6-E14A	1-Jun-93	378.29	27.92	350.37	106.79	WHC
699-S6-E4D	1-Jun-93	430.47	58.04	372.43	113.51	WHC
699-S6-E4D	10-Jun-93	430.47	58.00	372.47	113.52	PNL
699-S7-34	1-Jun-93	527.12	118.83	408.29	124.44	WHC
699-S7-34	30-Jun-93	527.12	118.77	408.35	124.46	PNL
699-S8-19	1-Jun-93	503.81	107.23	396.58	120.87	WHC
699-S8-19	17-Jun-93	503.81	107.12	396.69	120.91	PNL
699-101-48B	7-Jun-93	390.15	10.87	379.28	115.60	WHC
699-10-E12	1-Jun-93	430.86	73.71	357.15	108.85	WHC
699-10-54A	1-Jun-93	516.40	102.99	413.41	126.00	WHC
699-11-45A	1-Jun-93	578.58	166.65	411.93	125.55	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-11-45A	18-Jun-93	578.58	166.45	412.13	125.61	PNL
699-14-38	1-Jun-93	514.89	110.14	404.75	123.36	WHC
699-14-38	18-Jun-93	514.89	110.03	404.86	123.40	PNL
699-14-47	1-Jun-93	587.23	175.22	412.01	125.57	WHC
699-15-15A	1-Jun-93	547.14	149.27	397.87	121.26	WHC
699-15-26	1-Jun-93	523.83	123.78	400.05	121.93	WHC
699-17-5	2-Jun-93	433.19	45.47	387.72	118.17	WHC
699-17-5	29-Jun-93	433.19	45.46	387.73	118.17	PNL
699-17-70	3-Jun-93	563.18	88.77	474.41	144.59	WHC
699-17-70	30-Jun-93	563.18	88.69	474.49	144.62	PNL
699-19-43	2-Jun-93	551.58	148.45	403.13	122.87	WHC
699-19-58	2-Jun-93	573.05	154.48	418.57	127.57	WHC
699-19-58	18-Jun-93	573.05	154.18	418.87	127.67	PNL
699-19-88	3-Jun-93	644.45	130.76	513.69	156.57	WHC
699-20-E12	2-Jun-93	437.25	79.83	357.42	108.94	WHC
699-20-20	9-Jun-93	505.58	105.51	400.07	121.94	PNL
699-20-20	17-Jun-93	505.58	105.47	400.11	121.95	PNL
699-20-20	28-Jun-93	505.58	105.53	400.05	121.93	WHC
699-20-39	18-Jun-93	539.98	137.94	402.04	122.54	PNL
699-20-39	28-Jun-93	539.98	138.12	401.86	122.48	WHC
699-21-17	2-Jun-93	527.31	131.06	396.25	120.77	WHC
699-22-70	22-Jun-93	614.96	180.60	434.36	132.39	PNL
699-22-70Q	16-Jun-93	614.96	185.31	429.65	130.95	PNL
699-23-34A	28-Jun-93	532.86	131.34	401.52	122.38	WHC
699-24-33	28-Jun-93	524.21	122.78	401.43	122.35	WHC
699-24-35	28-Jun-93	538.81	137.27	401.54	122.38	WHC
699-25-34B	28-Jun-93	529.40	127.88	401.52	122.38	WHC
699-25-55	11-Jun-93	676.55	264.09	412.46	125.71	WHC
699-25-70	7-Jun-93	629.78	183.56	446.22	136.00	WHC
699-26-15A	2-Jun-93	442.64	45.19	397.45	121.14	WHC
699-26-35A	28-Jun-93	532.66	131.09	401.57	122.39	WHC
699-26-89	4-Jun-93	653.08	182.93	470.15	143.29	WHC
699-26-89	30-Jun-93	653.08	181.92	471.16	143.60	PNL
699-27-8	2-Jun-93	465.67	72.54	393.13	119.82	WHC
699-28-40	18-Jun-93	559.44	157.48	401.96	122.51	PNL
699-28-40	28-Jun-93	559.44	157.60	401.84	122.47	WHC
699-28-52A	11-Jun-93	684.67	281.08	403.59	123.01	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-29-78	8-Jun-93	647.05	187.14	459.91	140.17	WHC
699-2-3	1-Jun-93	477.14	86.99	390.15	118.91	WHC
699-2-3	17-Jun-93	477.14	86.96	390.18	118.92	PNL
699-2-33A	1-Jun-93	536.37	131.99	404.38	123.25	WHC
699-31-31	18-Jun-93	529.32	127.85	401.47	122.36	PNL
699-31-31	28-Jun-93	529.32	127.93	401.39	122.34	WHC
699-32-22B	18-Jun-93	516.93	113.23	403.70	123.04	PNL
699-32-43	9-Jun-93	516.62	114.66	401.96	122.51	PNL
699-32-43	9-Jun-93	516.62	114.67	401.95	122.51	WHC
699-32-43	18-Jun-93	516.62	114.54	402.08	122.55	PNL
699-32-62	8-Jun-93	707.09	279.44	427.65	130.34	WHC
699-32-70B	7-Jun-93	666.68	217.70	448.98	136.84	WHC
699-32-72A	8-Jun-93	668.16	217.55	450.61	137.34	WHC
699-32-77	8-Jun-93	653.74	195.96	457.78	139.52	WHC
699-33-56	11-Jun-93	717.03	313.99	403.04	122.84	WHC
699-34-39A	28-Jun-93	537.07	135.17	401.90	122.49	WHC
699-34-42	9-Jun-93	540.20	138.18	402.02	122.53	WHC
699-34-51	11-Jun-93	736.76	334.43	402.33	122.62	WHC
699-34-88	4-Jun-93	632.82	164.57	468.25	142.72	WHC
699-34-88	16-Jun-93	632.82	164.96	467.86	142.60	PNL
699-35-66A	8-Jun-93	725.65	288.22	437.43	133.32	WHC
699-35-70	8-Jun-93	693.72	244.99	448.73	136.77	WHC
699-35-78A	8-Jun-93	660.65	198.33	462.32	140.91	WHC
699-35-78A	17-Jun-93	660.65	197.97	462.68	141.02	PNL
699-35-9	7-Jun-93	499.83	115.06	384.77	117.27	WHC
699-35-9	16-Jun-93	499.83	114.96	384.87	117.30	PNL
699-36-61A	14-Jun-93	748.11	341.66	406.45	123.88	WHC
699-36-61A	17-Jun-93	748.11	340.75	407.36	124.16	PNL
699-36-93	3-Jun-93	644.77	174.31	470.46	143.39	WHC
699-37-43	17-Jun-93	690.17	287.13	403.04	122.84	WHC
699-37-82A	8-Jun-93	636.75	172.33	464.42	141.55	WHC
699-38-65	10-Jun-93	753.33	324.40	428.93	130.73	PNL
699-38-65	14-Jun-93	753.33	324.14	429.19	130.81	WHC
699-38-70	8-Jun-93	710.67	260.65	450.02	137.16	WHC
699-38-70	17-Jun-93	710.67	260.31	450.36	137.26	PNL
699-39-39	21-Jun-93	536.65	124.55	412.10	125.60	WHC
699-39-79	23-Jun-93	673.52	210.18	463.34	141.22	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-3-45	3-Jun-93	504.54	92.48	412.06	125.59	WHC
699-40-1	7-Jun-93	438.71	75.55	363.16	110.69	WHC
699-40-33A	10-Jun-93	518.05	107.69	410.36	125.07	PNL
699-40-33A	17-Jun-93	518.05	107.82	410.23	125.03	WHC
699-40-36	21-Jun-93	528.92	117.86	411.06	125.29	WHC
699-40-39	21-Jun-93	541.84	129.27	412.57	125.75	WHC
699-40-40A	21-Jun-93	541.21	129.80	411.41	125.39	WHC
699-40-40B	21-Jun-93	542.18	130.48	411.70	125.48	WHC
699-40-62	14-Jun-93	747.78	342.84	404.94	123.42	WHC
699-40-62	17-Jun-93	747.78	342.98	404.80	123.38	PNL
699-41-23	7-Jun-93	466.50	69.54	396.96	120.99	WHC
699-41-35	21-Jun-93	520.38	108.27	412.11	125.61	WHC
699-41-40	21-Jun-93	545.94	130.52	415.42	126.61	WHC
699-42-E9B	29-Jun-93	386.42	27.65	358.77	109.35	PNL
699-42-E9B	30-Jun-93	386.42	27.13	359.29	109.51	PNL
699-42-12A	7-Jun-93	514.27	139.19	375.08	114.32	WHC
699-42-37	21-Jun-93	519.42	104.42	415.00	126.49	WHC
699-42-39A	21-Jun-93	558.14	139.15	418.99	127.70	WHC
699-42-39B	21-Jun-93	558.32	139.57	418.75	127.63	WHC
699-42-40A	21-Jun-93	545.53	124.33	421.20	128.38	WHC
699-42-40B	17-Jun-93	546.46	124.74	421.72	128.53	WHC
699-42-40B	18-Jun-93	546.46	124.72	421.74	128.54	PNL
699-42-41	21-Jun-93	567.30	146.92	420.38	128.13	WHC
699-42-42A	18-Jun-93	602.20	191.60	410.60	125.14	PNL
699-43-104	2-Jun-93	766.07	271.15	494.92	150.84	WHC
699-43-104	30-Jun-93	766.07	271.14	494.93	150.85	PNL
699-43-40	21-Jun-93	542.20	122.46	419.74	127.93	WHC
699-43-41E	21-Jun-93	550.86	130.20	420.66	128.21	WHC
699-43-42	10-Jun-93	566.36	145.59	420.77	128.24	WHC
699-43-42J	21-Jun-93	581.68	163.02	418.66	127.60	WHC
699-43-43	21-Jun-93	579.37	164.39	414.98	126.48	WHC
699-43-45	21-Jun-93	597.68	194.44	403.24	122.90	WHC
699-43-89	4-Jun-93	644.15	178.70	465.45	141.86	WHC
699-43-89	14-Jun-93	644.15	178.90	465.25	141.80	PNL
699-44-42	21-Jun-93	579.22	158.56	420.66	128.21	WHC
699-44-43B	21-Jun-93	580.12	164.64	415.48	126.63	WHC
699-44-64	23-Jun-93	725.60	319.93	405.67	123.64	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-45-42	17-Jun-93	577.33	161.40	415.93	126.77	WHC
699-46-21B	7-Jun-93	522.02	131.73	390.29	118.95	WHC
699-46-21B	16-Jun-93	522.02	131.46	390.56	119.04	PNL
699-46-32	9-Jun-93	470.20	69.45	400.75	122.14	PNL
699-47-35A	17-Jun-93	476.36	63.40	412.96	125.86	WHC
699-47-35B	17-Jun-93	476.65	63.71	412.94	125.86	WHC
699-47-46A	17-Jun-93	580.14	176.99	403.15	122.87	WHC
699-47-50	9-Jun-93	584.22	180.84	403.38	122.94	PNL
699-47-50	21-Jun-93	584.22	180.86	403.36	122.94	PNL
699-47-50	28-Jun-93	584.22	180.94	403.28	122.91	WHC
699-47-60	28-Jun-93	651.52	249.70	401.82	122.47	WHC
699-48-71	17-Jun-93	688.15	243.69	444.46	135.46	PNL
699-48-71	22-Jun-93	688.15	243.82	444.33	135.43	WHC
699-49-13E	4-Jun-93	412.72	51.55	361.17	110.08	WHC
699-49-13E	11-Jun-93	412.72	51.42	361.30	110.12	PNL
699-49-28	4-Jun-93	535.40	141.79	393.61	119.97	WHC
699-49-32B	9-Jun-93	515.55	105.05	410.50	125.11	PNL
699-49-55B	9-Jun-93	531.12	129.08	402.04	122.54	PNL
699-49-55B	21-Jun-93	531.12	129.37	401.75	122.45	PNL
699-49-55B	28-Jun-93	531.12	129.12	402.00	122.52	WHC
699-49-57B	9-Jun-93	555.99	154.06	401.93	122.50	PNL
699-49-57B	30-Jun-93	555.99	152.17	403.82	123.08	PNL
699-49-79	22-Jun-93	689.20	234.08	455.12	138.71	WHC
699-50-28B	4-Jun-93	537.30	143.70	393.60	119.96	WHC
699-50-30	4-Jun-93	528.84	134.82	394.02	120.09	WHC
699-50-42	7-Jun-93	466.84	56.47	410.37	125.07	WHC
699-50-42	9-Jun-93	466.84	56.35	410.49	125.11	PNL
699-50-45	4-Jun-93	451.41	43.35	408.06	124.37	WHC
699-50-45	9-Jun-93	451.41	43.45	407.96	124.34	PNL
699-50-48B	4-Jun-93	550.39	145.00	405.39	123.56	WHC
699-50-48B	9-Jun-93	550.39	145.01	405.38	123.55	PNL
699-50-53B	9-Jun-93	557.62	155.38	402.24	122.60	PNL
699-50-53B	30-Jun-93	557.62	155.41	402.21	122.59	PNL
699-50-85	8-Jun-93	739.35	284.93	454.42	138.50	WHC
699-51-46	7-Jun-93	444.63	38.27	406.36	123.85	WHC
699-51-46	9-Jun-93	444.63	38.24	406.39	123.86	PNL
699-51-63	8-Jun-93	571.84	167.63	404.21	123.20	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-51-63	9-Jun-93	571.84	167.53	404.31	123.23	PNL
699-51-75	8-Jun-93	641.51	193.20	448.31	136.64	WHC
699-52-19	4-Jun-93	411.08	49.70	361.38	110.14	WHC
699-52-19	9-Jun-93	411.08	49.65	361.43	110.16	PNL
699-52-46A	4-Jun-93	455.61	47.43	408.18	124.41	WHC
699-52-46A	9-Jun-93	455.61	47.50	408.11	124.39	PNL
699-52-48	7-Jun-93	466.06	61.95	404.11	123.17	WHC
699-52-48	9-Jun-93	466.06	61.92	404.14	123.18	PNL
699-52-54	28-Jun-93	568.45	166.91	401.54	122.38	WHC
699-52-57	28-Jun-93	561.80	160.48	401.32	122.32	WHC
699-53-35	7-Jun-93	530.99	130.92	400.07	121.94	WHC
699-53-47A	7-Jun-93	438.28	32.69	405.59	123.62	WHC
699-53-47B	7-Jun-93	438.58	32.98	405.60	123.62	WHC
699-53-48A	7-Jun-93	442.45	39.41	403.04	122.84	WHC
699-53-48B	7-Jun-93	442.71	38.07	404.64	123.33	WHC
699-53-50	7-Jun-93	444.21	40.63	403.58	123.01	WHC
699-53-50	9-Jun-93	444.21	40.60	403.61	123.01	PNL
699-53-50	28-Jun-93	444.21	40.79	403.42	122.96	PNL
699-53-55A	28-Jun-93	576.56	175.27	401.29	122.31	WHC
699-53-55B	28-Jun-93	576.84	175.86	400.98	122.21	WHC
699-53-55C	28-Jun-93	576.13	174.84	401.29	122.31	WHC
699-54-19	4-Jun-93	383.60	22.18	361.42	110.16	WHC
699-54-34	4-Jun-93	550.24	140.47	409.77	124.89	WHC
699-54-34	9-Jun-93	550.24	140.57	409.67	124.86	PNL
699-54-37A	4-Jun-93	534.17	124.25	409.92	124.94	WHC
699-54-42	8-Jun-93	511.49	115.33	396.16	120.74	WHC
699-54-45A	8-Jun-93	494.29	96.56	397.73	121.22	WHC
699-54-48	7-Jun-93	457.02	55.77	401.25	122.30	WHC
699-54-57	9-Jun-93	576.24	174.70	401.54	122.38	PNL
699-54-57	22-Jun-93	576.24	175.00	401.24	122.29	PNL
699-54-57	28-Jun-93	576.24	174.81	401.43	122.35	WHC
699-55-21	4-Jun-93	395.96	35.77	360.19	109.78	WHC
699-55-40	7-Jun-93	543.13	134.12	409.01	124.66	WHC
699-55-44	4-Jun-93	519.67	123.94	395.73	120.61	WHC
699-55-50C	7-Jun-93	444.43	43.19	401.24	122.29	WHC
699-55-55	28-Jun-93	563.58	162.64	400.94	122.20	WHC
699-55-57	28-Jun-93	568.22	166.94	401.28	122.30	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-55-70	8-Jun-93	569.03	137.64	431.39	131.48	WHC
699-55-76	8-Jun-93	583.24	139.92	443.32	135.12	WHC
699-55-76	11-Jun-93	583.24	139.69	443.55	135.19	PNL
699-55-89	4-Jun-93	617.43	163.16	454.27	138.45	WHC
699-55-89	11-Jun-93	617.43	163.44	453.99	138.37	PNL
699-55-95	4-Jun-93	777.05	312.05	465.00	141.73	WHC
699-56-43	7-Jun-93	540.42	132.27	408.15	124.40	WHC
699-56-53	7-Jun-93	434.34	32.74	401.60	122.40	WHC
699-56-53	9-Jun-93	434.34	32.67	401.67	122.42	PNL
699-57-25A	3-Jun-93	414.57	50.87	363.70	110.85	WHC
699-57-29B	4-Jun-93	416.18	54.76	361.42	110.16	WHC
699-57-83A	8-Jun-93	577.96	145.82	432.14	131.71	WHC
699-58-24	3-Jun-93	418.80	57.45	361.35	110.13	WHC
699-59-32	4-Jun-93	424.29	62.67	361.62	110.22	WHC
699-59-58	28-Jun-93	497.77	96.76	401.01	122.22	WHC
699-59-80B	8-Jun-93	583.25	153.78	429.47	130.90	WHC
699-59-80B	11-Jun-93	583.25	153.69	429.56	130.92	PNL
699-60-32	4-Jun-93	425.30	63.85	361.45	110.16	WHC
699-60-57	28-Jun-93	469.64	68.26	401.38	122.33	WHC
699-60-60	10-Jun-93	512.03	110.85	401.18	122.27	PNL
699-60-60	28-Jun-93	512.03	110.97	401.06	122.24	WHC
699-61-37	4-Jun-93	442.94	61.56	381.38	116.24	WHC
699-61-41	3-Jun-93	428.92	33.30	395.62	120.58	WHC
699-61-62	3-Jun-93	497.51	96.45	401.06	122.24	WHC
699-61-62	10-Jun-93	497.51	96.37	401.14	122.26	PNL
699-61-66	3-Jun-93	522.18	121.96	400.22	121.98	WHC
699-62-31	4-Jun-93	434.12	72.71	361.41	110.15	WHC
699-62-31	8-Jun-93	434.12	72.64	361.48	110.17	PNL
699-62-43A	3-Jun-93	432.30	36.40	395.90	120.66	WHC
699-63-25A	3-Jun-93	395.15	33.86	361.29	110.12	WHC
699-63-51	4-Jun-93	424.54	25.53	399.01	121.61	WHC
699-63-51	10-Jun-93	424.54	25.51	399.03	121.62	PNL
699-63-55	4-Jun-93	426.54	26.92	399.62	121.80	WHC
699-63-58	3-Jun-93	491.90	91.94	399.96	121.90	WHC
699-63-90	18-Jun-93	509.73	110.43	399.30	121.70	WHC
699-63-92	8-Jun-93	497.50	96.86	400.64	122.11	WHC
699-64-27	3-Jun-93	414.29	52.95	361.34	110.13	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-64-62	22-Jun-93	500.25	100.53	399.72	121.83	WHC
699-65-22	23-Jun-93	391.10	29.47	361.63	110.22	WHC
699-65-23	23-Jun-93	387.93	25.86	362.07	110.35	WHC
699-65-50	3-Jun-93	467.06	68.09	398.97	121.60	WHC
699-65-50	10-Jun-93	467.06	68.02	399.04	121.62	PNL
699-65-59A	3-Jun-93	506.96	107.36	399.60	121.79	WHC
699-65-72	18-Jun-93	540.28	142.24	398.04	121.32	WHC
699-65-83	18-Jun-93	485.63	87.99	397.64	121.19	WHC
699-65-95	9-Jun-93	452.26	51.72	400.54	122.08	WHC
699-66-103	3-Jun-93	463.01	62.18	400.83	122.17	WHC
699-66-23	8-Jun-93	389.01	25.39	363.62	110.83	PNL
699-66-23	23-Jun-93	389.01	26.42	362.59	110.51	WHC
699-66-38	3-Jun-93	436.24	34.01	402.23	122.59	WHC
699-66-39	3-Jun-93	453.78	47.15	406.63	123.93	WHC
699-66-58	3-Jun-93	503.33	103.79	399.54	121.77	WHC
699-66-64	18-Jun-93	505.92	106.83	399.09	121.64	WHC
699-66-91	8-Jun-93	467.75	68.43	399.32	121.71	WHC
699-66-91	14-Jun-93	467.75	68.02	399.73	121.83	PNL
699-67-51	3-Jun-93	524.59	125.52	399.07	121.63	WHC
699-67-86	8-Jun-93	472.39	74.84	397.55	121.17	WHC
699-67-98	3-Jun-93	455.47	54.77	400.70	122.13	WHC
699-68-105	3-Jun-93	451.85	62.47	389.38	118.68	WHC
699-68-105	29-Jun-93	451.85	56.72	395.13	120.43	PNL
699-69-38	7-Jun-93	424.10	21.62	402.48	122.67	WHC
699-69-45O	3-Jun-93	487.18	88.58	398.60	121.49	WHC
699-70-23	23-Jun-93	391.71	28.71	363.00	110.64	WHC
699-70-68	10-Jun-93	526.21	127.99	398.22	121.37	PNL
699-70-68	18-Jun-93	526.21	128.06	398.15	121.35	WHC
699-71-30	8-Jun-93	400.68	30.40	370.28	112.86	PNL
699-71-30	15-Jun-93	400.68	30.39	370.29	112.86	WHC
699-71-52	3-Jun-93	523.04	124.59	398.45	121.44	WHC
699-71-77	18-Jun-93	472.28	76.21	396.07	120.72	WHC
699-72-73	18-Jun-93	482.57	86.20	396.37	120.81	WHC
699-73-61	18-Jun-93	531.53	133.30	398.23	121.37	WHC
699-74-44	3-Jun-93	445.18	48.80	396.38	120.81	WHC
699-74-48	3-Jun-93	487.18	89.82	397.36	121.11	WHC
699-77-36	15-Jun-93	412.28	36.53	375.75	114.52	WHC

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-77-54	3-Jun-93	480.59	84.03	396.56	120.87	WHC
699-77-54	8-Jun-93	480.59	83.99	396.60	120.88	PNL
699-78-62	18-Jun-93	469.88	75.41	394.47	120.23	WHC
699-80-43S	3-Jun-93	412.52	24.93	387.59	118.13	WHC
699-81-38	15-Jun-93	406.47	27.41	379.06	115.53	WHC
699-81-58	17-Jun-93	439.55	46.66	392.89	119.75	WHC
699-82-45A	3-Jun-93	413.73	25.06	388.67	118.46	WHC
699-83-36	7-Jun-93	418.63	41.03	377.60	115.09	WHC
699-83-47	3-Jun-93	435.27	46.79	388.48	118.40	WHC
699-83-47	8-Jun-93	435.27	46.74	388.53	118.42	PNL
699-84-35A	7-Jun-93	400.05	7.07	392.98	119.77	WHC
699-86-42	7-Jun-93	409.92	25.41	384.51	117.19	WHC
699-87-42A	7-Jun-93	416.53	32.71	383.82	116.98	WHC
699-87-55	16-Jun-93	458.63	72.20	386.43	117.78	WHC
699-88-41	16-Jun-93	416.04	33.90	382.14	116.47	WHC
699-89-35	16-Jun-93	397.46	26.34	371.12	113.11	WHC
699-8-17	1-Jun-93	522.44	124.76	397.68	121.21	WHC
699-8-25	1-Jun-93	509.30	110.39	398.91	121.58	WHC
699-8-32	1-Jun-93	554.39	154.87	399.52	121.77	WHC
699-8-32	18-Jun-93	554.39	154.74	399.65	121.81	PNL
699-90-34	16-Jun-93	392.39	20.90	371.49	113.22	WHC
699-90-45	16-Jun-93	421.60	37.62	383.98	117.03	WHC
699-91-46A	16-Jun-93	417.06	33.21	383.85	116.99	WHC
699-92-49	16-Jun-93	431.94	48.69	383.25	116.81	WHC
699-93-48A	16-Jun-93	437.79	54.97	382.82	116.68	WHC
699-96-43	16-Jun-93	421.84	42.80	379.04	115.53	WHC
699-96-49	16-Jun-93	419.26	37.21	382.05	116.44	WHC
699-97-43	16-Jun-93	421.84	43.06	378.78	115.45	WHC
699-97-51A	16-Jun-93	402.33	20.19	382.14	116.47	WHC
699-98-49A	16-Jun-93	401.80	19.94	381.86	116.39	WHC
699-9-E2	1-Jun-93	418.09	45.83	372.26	113.46	WHC
GS08/30_03A01	22-Jun-93	390	4.77	385.23	117.41	PNL
GS09/29_02C01	22-Jun-93	464	10.54	453.46	138.21	PNL
GS09/29_15N01	22-Jun-93	402	5.40	396.60	120.88	PNL
GS09/30_02B01	22-Jun-93	509	10.14	498.86	152.04	PNL
GS09/30_06D01	22-Jun-93	441	7.28	433.72	132.19	PNL
GS09/30_16F01	22-Jun-93	406	5.14	400.86	122.18	PNL

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
GS09/30_17C01	22-Jun-93	425	7.64	417.36	127.20	PNL
GS09/30_23N01	22-Jun-93	440	8.37	431.63	131.56	PNL
GS10/29_01A01	22-Jun-93	663	2.57	660.43	201.29	PNL
GS10/29_08R01	22-Jun-93	621	1.65	619.35	188.77	PNL
GS10/29_11N01	22-Jun-93	654	0.71	653.29	199.11	PNL
GS10/29_15D01	22-Jun-93	615	1.10	613.90	187.11	PNL
GS10/29_25A01	22-Jun-93	498	2.97	495.03	150.88	PNL
GS10/29_26A01	22-Jun-93	496	4.22	491.78	149.89	PNL
GS10/29_27C01	22-Jun-93	484	12.10	471.90	143.83	PNL
GS10/29_28B01	22-Jun-93	504	13.69	490.31	149.44	PNL
GS10/29_34C01	22-Jun-93	454	0.93	453.07	138.09	PNL
GS10/30_03Q02	22-Jun-93	641	2.13	638.87	194.72	PNL
GS10/30_04E01	22-Jun-93	556	1.59	554.41	168.97	PNL
GS10/30_05B01	22-Jun-93	590	1.14	588.86	179.47	PNL
GS10/30_05N01	22-Jun-93	553	2.76	550.24	167.71	PNL
GS10/30_08F01	22-Jun-93	538	1.99	536.01	163.37	PNL
GS10/30_14N01	22-Jun-93	714	2.58	711.42	216.83	PNL
GS10/30_18Q02	22-Jun-93	500	0.85	499.15	152.13	PNL
GS10/30_21R01	22-Jun-93	605	0.79	604.21	184.15	PNL
GS11/28_25R02	22-Jun-93	860	0.87	859.13	261.85	PNL
GS11/29_05D01	22-Jun-93	917	1.31	915.69	279.09	PNL
GS11/29_14R01	22-Jun-93	781	2.19	778.81	237.37	PNL
GS11/29_16N01	22-Jun-93	912	2.97	909.03	277.06	PNL
GS11/29_19R01	22-Jun-93	875	0.87	874.13	266.42	PNL
GS11/29_24R01	22-Jun-93	686	2.86	683.14	208.21	PNL
GS11/29_26D01	22-Jun-93	831	3.35	827.65	252.25	PNL
GS11/30_06N01	22-Jun-93	852	1.51	850.49	259.22	PNL
GS11/30_08N01	22-Jun-93	747	3.54	743.46	226.59	PNL
GS11/30_32D01	22-Jun-93	668	0.60	667.40	203.41	PNL
GS12/28_11J01	23-Jun-93	668	3.21	664.79	202.62	PNL
GS12/29_01M01	22-Jun-93	733	0.54	732.46	223.24	PNL
GS12/29_03R01	22-Jun-93	740	2.42	737.58	224.80	PNL
GS12/29_25D01	22-Jun-93	927	2.61	924.39	281.74	PNL
GS12/29_33D01	22-Jun-93	913	0.74	912.26	278.04	PNL
GS12/30_18D01	22-Jun-93	963	2.11	960.89	292.86	PNL
GS12/30_30R01	22-Jun-93	726	0.80	725.20	221.03	PNL
GS13/28_03A01	23-Jun-93	993	0.95	992.05	302.36	PNL

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
GS13/28_03N01	23-Jun-93	967	1.10	965.90	294.39	PNL
GS13/28_14B01	23-Jun-93	974	0.69	973.31	296.65	PNL
GS13/28_16J01	23-Jun-93	939	0.62	938.38	286.00	PNL
GS13/28_22B01	23-Jun-93	963	0.97	962.03	293.21	PNL
GS13/28_24D01	23-Jun-93	951	0.64	950.36	289.65	PNL
GS13/28_26R01	23-Jun-93	941	0.87	940.13	286.54	PNL
GS13/28_27Q01	23-Jun-93	928	1.28	926.72	282.45	PNL
GS13/29_04A01	23-Jun-93	945	2.59	942.41	287.23	PNL
GS13/29_32D01	23-Jun-93	951	1.65	949.35	289.35	PNL
GS13/29_36D01	22-Jun-93	771	3.11	767.89	234.04	PNL
GS13/30_28D01	22-Jun-93	892	2.19	889.81	271.20	PNL
GS13/30_30H01	22-Jun-93	857	1.14	855.86	260.85	PNL
GS13/30_32A01	22-Jun-93	899	3.08	895.92	273.06	PNL
GS14/25_01D02	23-Jun-93	674	1.81	672.19	204.87	PNL
GS14/25_03E01	23-Jun-93	675	1.04	673.96	205.41	PNL
GS14/25_05N01	23-Jun-93	731	3.01	727.99	221.88	PNL
GS14/25_10J01	23-Jun-93	640	5.23	634.77	193.47	PNL
GS14/25_17A01	23-Jun-93	687	3.70	683.30	208.26	PNL
GS14/27_03PA	29-Jun-93	674	11.20	662.80	202.01	PNL
GS14/27_03PB	23-Jun-93	674	5.17	668.83	203.85	PNL
GS14/27_03PC	23-Jun-93	674	2.63	671.37	204.62	PNL
GS14/27_16C01	23-Jun-93	665	4.38	660.62	201.35	PNL
GS14/27_16C02B	23-Jun-93	664	11.23	652.77	198.95	PNL
GS14/27_16C02C	23-Jun-93	664	4.47	659.53	201.01	PNL
GS14/27_26E01	23-Jun-93	680	1.57	678.43	206.77	PNL
GS14/27_26J01	23-Jun-93	722	2.76	719.24	219.21	PNL
GS14/27_26M01	23-Jun-93	675	1.12	673.88	205.39	PNL
GS14/27_27A01	23-Jun-93	683	1.42	681.58	207.73	PNL
GS14/28_30D01	23-Jun-93	737	0.87	736.13	224.36	PNL
GS14/28_30M01	23-Jun-93	733	1.00	732.00	223.10	PNL
GS14/28_30N01	23-Jun-93	736	0.89	735.11	224.05	PNL
GS14/29_21A01	23-Jun-93	1013	2.91	1010.09	307.86	PNL
GS14/29_28A01	23-Jun-93	926	0.97	925.03	281.94	PNL
GS15/24_34Q01	23-Jun-93	795	2.90	792.10	241.42	PNL
GS15/24_35J01	23-Jun-93	849	1.02	847.98	258.45	PNL
GS15/25_25E01	23-Jun-93	864	1.99	862.01	262.73	PNL
GS15/25_30H01	23-Jun-93	866	3.87	862.13	262.77	PNL

Table A.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
GS15/25_30R01	23-Jun-93	811	1.76	809.24	246.64	PNL
GS15/25_32N01	23-Jun-93	761	3.29	757.71	230.94	PNL
GS15/25_34D01	23-Jun-93	789	3.71	785.29	239.35	PNL
GS15/26_30H01	23-Jun-93	854	2.53	851.47	259.52	PNL

MSL = mean sea level.

Appendix B

Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site, December 1993

Appendix B

Table B.1. Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site, December 1993

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
199-D8-4	8-Dec-93	468.73	85.68	383.05	116.76	WHC
199-D8-5	7-Dec-93	452.49	70.68	381.81	116.38	WHC
199-D8-6	7-Dec-93	476.50	93.54	382.96	116.73	WHC
199-H4-3	8-Dec-93	420.29	46.78	373.51	113.85	WHC
199-H4-4	8-Dec-93	413.70	40.86	372.84	113.64	WHC
199-H4-9	6-Dec-93	418.08	44.48	373.60	113.87	WHC
299-E17-17	8-Dec-93	719.92	318.17	401.75	122.45	WHC
299-E17-18	13-Dec-93	720.65	319.11	401.54	122.39	WHC
299-E17-5	13-Dec-93	718.69	317.19	401.50	122.38	WHC
299-E17-9	8-Dec-93	717.64	316.42	401.22	122.29	WHC
299-E18-1	15-Dec-93	720.24	318.52	401.72	122.45	WHC
299-E18-2	20-Dec-93	721.21	319.68	401.53	122.39	WHC
299-E18-3	20-Dec-93	722.04	320.52	401.52	122.38	WHC
299-E18-4	15-Dec-93	721.57	319.47	402.10	122.56	WHC
299-E18-4	29-Dec-93	721.57	320.21	401.36	122.34	WHC
299-W10-14	1-Dec-93	699.43	237.89	461.54	140.68	WHC
299-W10-15	10-Dec-93	675.64	214.38	461.26	140.59	WHC
299-W10-16	16-Dec-93	672.76	211.34	461.42	140.64	WHC
299-W10-17	16-Dec-93	670.84	209.60	461.24	140.59	WHC
299-W10-17	28-Dec-93	670.84	208.83	462.01	140.82	WHC
299-W10-18	16-Dec-93	670.93	209.54	461.39	140.63	WHC
299-W10-18	28-Dec-93	670.93	208.39	462.54	140.98	WHC
299-W10-19	2-Dec-93	682.99	222.89	460.10	140.24	WHC
299-W11-27	13-Dec-93	685.27	224.23	461.04	140.53	WHC
299-W14-12	16-Dec-93	670.52	207.11	463.41	141.25	WHC
299-W14-12	28-Dec-93	670.52	207.00	463.52	141.28	WHC
299-W15-16	6-Dec-93	684.89	220.98	463.91	141.40	WHC
299-W15-19	3-Dec-93	691.60	228.30	463.30	141.22	WHC
299-W15-19	20-Dec-93	691.60	228.59	463.01	141.13	WHC
299-W15-22	10-Dec-93	670.77	205.80	464.97	141.72	WHC
299-W18-25	9-Dec-93	666.04	201.69	464.35	141.54	WHC
299-W18-29	28-Dec-93	674.14	126.75	547.39	166.85	WHC

Table B.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
299-W18-29	29-Dec-93	674.14	126.83	547.31	166.82	WHC
299-W18-30	9-Dec-93	672.84	208.26	464.58	141.61	WHC
299-W18-32	28-Dec-93	676.65	212.67	463.98	141.42	WHC
299-W19-31	9-Dec-93	674.19	209.20	464.99	141.73	WHC
299-W19-32	9-Dec-93	674.90	210.20	464.70	141.64	WHC
299-W22-23	17-Dec-93	690.70	235.59	455.11	138.72	WHC
299-W22-40	21-Dec-93	692.23	237.32	454.91	138.66	WHC
299-W22-41	20-Dec-93	691.74	236.68	455.06	138.70	WHC
299-W22-42	21-Dec-93	691.16	236.28	454.88	138.65	WHC
299-W22-43	20-Dec-93	691.35	236.12	455.23	138.76	WHC
299-W26-10	17-Dec-93	670.87	215.10	455.77	138.92	WHC
299-W26-12	17-Dec-93	675.69	219.25	456.44	139.12	WHC
299-W26-7	15-Dec-93	651.99	192.88	459.11	139.94	WHC
299-W26-8	15-Dec-93	666.31	209.38	456.93	139.27	WHC
299-W26-9	17-Dec-93	654.16	197.87	456.29	139.08	WHC
299-W27-2	16-Dec-93	677.11	220.98	456.13	139.03	WHC
299-W6-2	7-Dec-93	692.45	234.85	457.60	139.48	WHC
299-W7-1	6-Dec-93	690.71	232.62	458.09	139.63	WHC
299-W7-10	2-Dec-93	689.66	233.25	456.41	139.12	WHC
299-W7-10	20-Dec-93	689.66	233.12	456.54	139.16	WHC
299-W7-11	6-Dec-93	681.45	223.49	457.96	139.59	WHC
299-W7-12	3-Dec-93	687.93	229.76	458.17	139.65	WHC
299-W7-2	6-Dec-93	675.59	218.60	456.99	139.29	WHC
299-W7-3	7-Dec-93	676.14	219.95	456.19	139.05	WHC
299-W7-4	3-Dec-93	671.69	212.12	459.57	140.08	WHC
299-W7-5	6-Dec-93	673.05	217.15	455.90	138.96	WHC
299-W7-6	3-Dec-93	678.64	222.87	455.77	138.92	WHC
299-W7-7	2-Dec-93	674.94	218.45	456.49	139.14	WHC
299-W7-7	20-Dec-93	674.94	218.49	456.45	139.13	WHC
299-W7-8	3-Dec-93	687.35	232.17	455.18	138.74	WHC
299-W7-9	3-Dec-93	692.09	233.58	458.51	139.76	WHC
299-W8-1	3-Dec-93	701.33	242.73	458.60	139.78	WHC
299-W9-1	2-Dec-93	737.73	277.20	460.53	140.37	WHC
399-1-17A	9-Dec-93	377.47	35.42	342.05	104.26	WHC
699-S31-E10B	20-Dec-93	383.71	32.10	351.61	107.17	PNL
699-S31-E10E	21-Dec-93	383.41	32.10	351.31	107.08	PNL

Table B.1. (contd)

Well Name	Date	Reference Elevation, ft above MSL	Depth to Water, ft	Water-Table Elevation, ft above MSL	Water-Table Elevation, m above MSL	Depth Measured by
699-S32-E13A	20-Dec-93	390.46	42.61	347.85	106.03	PNL
699-S32-E13B	20-Dec-93	394.72	46.51	348.21	106.14	PNL
699-S32-E8	21-Dec-93	375.79	14.60	361.19	110.09	PNL
699-S36-E12B	14-Dec-93	399.04	41.66	357.38	108.93	PNL
699-S36-E13A	20-Dec-93	399.30	49.92	349.38	106.49	PNL
699-S36-E13B	14-Dec-93	399.61	42.66	356.95	108.80	PNL
699-S37-E11A	20-Dec-93	399.30	41.89	357.41	108.94	PNL
699-S38-E11	21-Dec-93	398.60	40.48	358.12	109.16	PNL
699-S38-E12B	21-Dec-93	405.00	47.72	357.28	108.90	PNL
699-S3-E12	14-Dec-93	397.90	43.96	353.94	107.88	PNL
699-S40-E14	2-Dec-93	402.85	42.15	360.70	109.94	PNL
699-S41-E11A	29-Dec-93	401.36	43.62	357.74	109.04	PNL
699-S41-E13A	21-Dec-93	410.56	51.90	358.66	109.32	PNL
699-S41-E13B	21-Dec-93	410.10	52.60	357.50	108.97	PNL
699-S41-E13C	21-Dec-93	410.67	52.32	358.35	109.23	PNL
699-S6-E14A	14-Dec-93	378.29	28.24	350.05	106.70	PNL
699-S6-E4B	13-Dec-93	421.36	50.55	370.81	113.02	PNL
699-23-34A	6-Dec-93	532.86	131.62	401.24	122.30	WHC
699-72-88	13-Dec-93	437.37	39.05	398.32	121.41	PNL
699-77-36	13-Dec-93	412.28	36.57	375.71	114.52	PNL
699-90-45	13-Dec-93	421.60	37.66	383.94	117.03	PNL
699-96-49	13-Dec-93	419.26	38.09	381.17	116.18	PNL
699-97-43	13-Dec-93	421.84	43.42	378.42	115.34	PNL

MSL = mean sea level.

Appendix C

Locations of Monitoring Wells Sampled in 1993

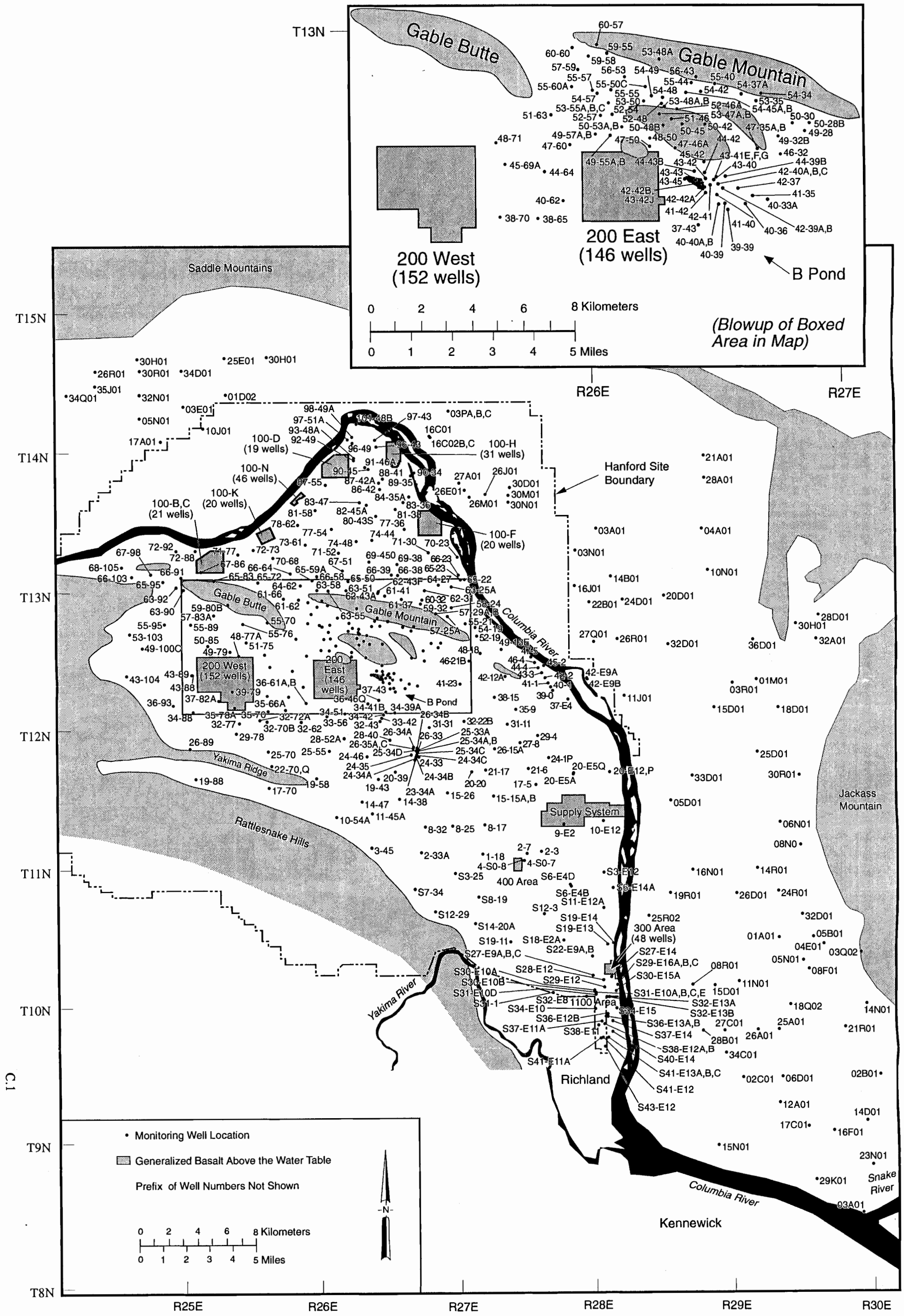

Figure C.1. Index Map for Location of Wells in the 600 Area and Wells off the Hanford Site

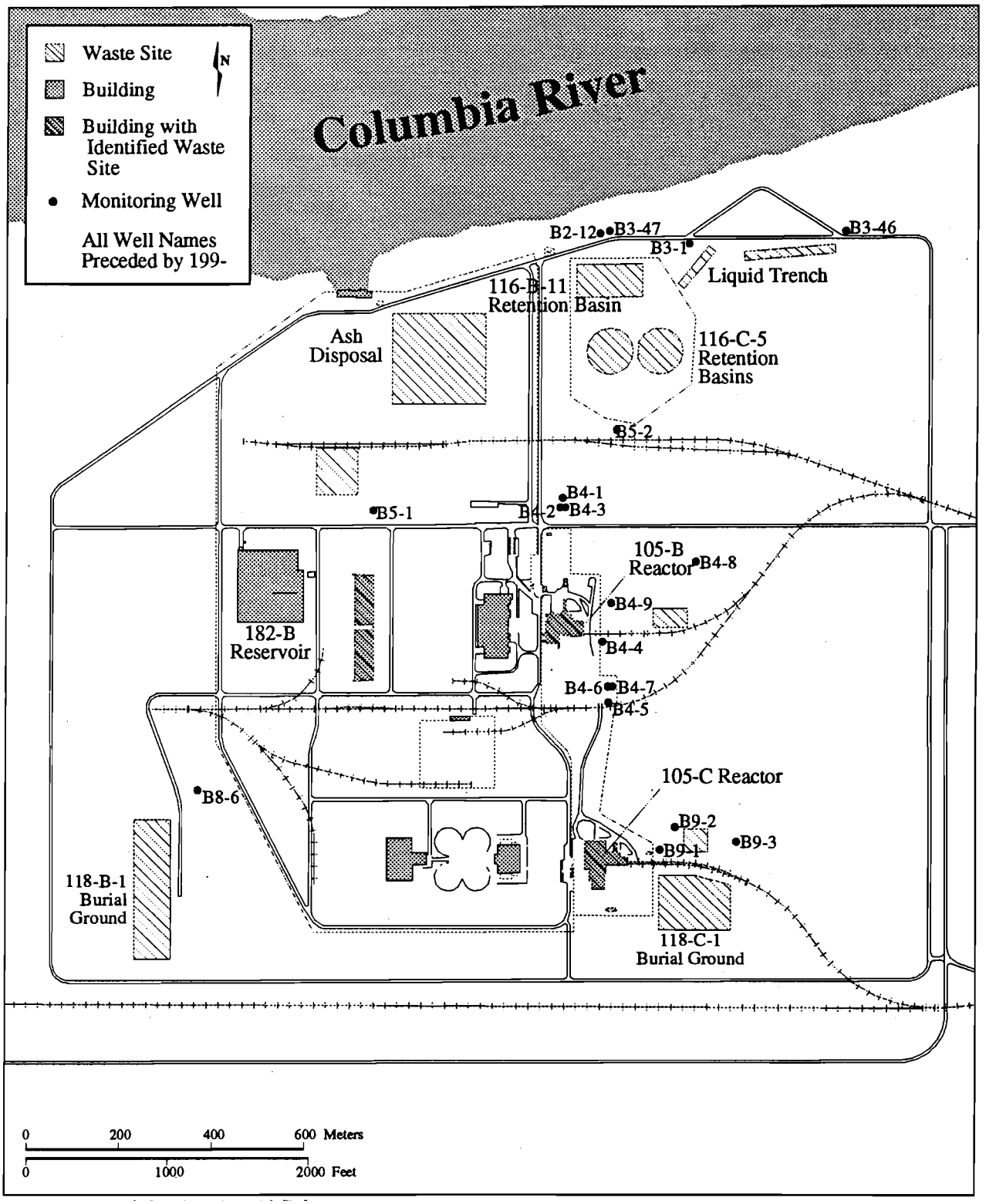

Figure C.2. Index Map for Location of Wells in the 100-B/C Area

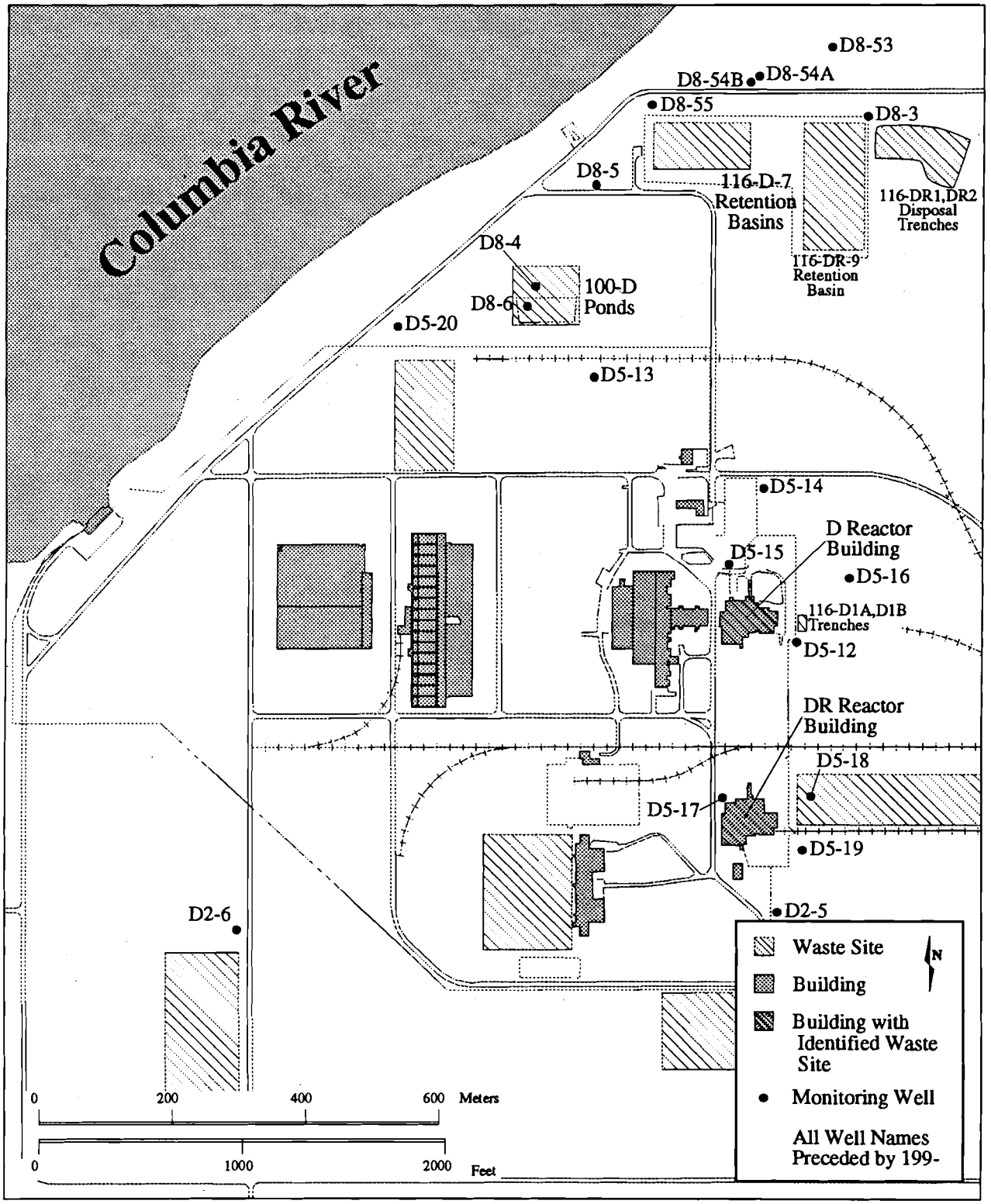

Figure C.3. Index Map for Location of Wells in the 100-D Area

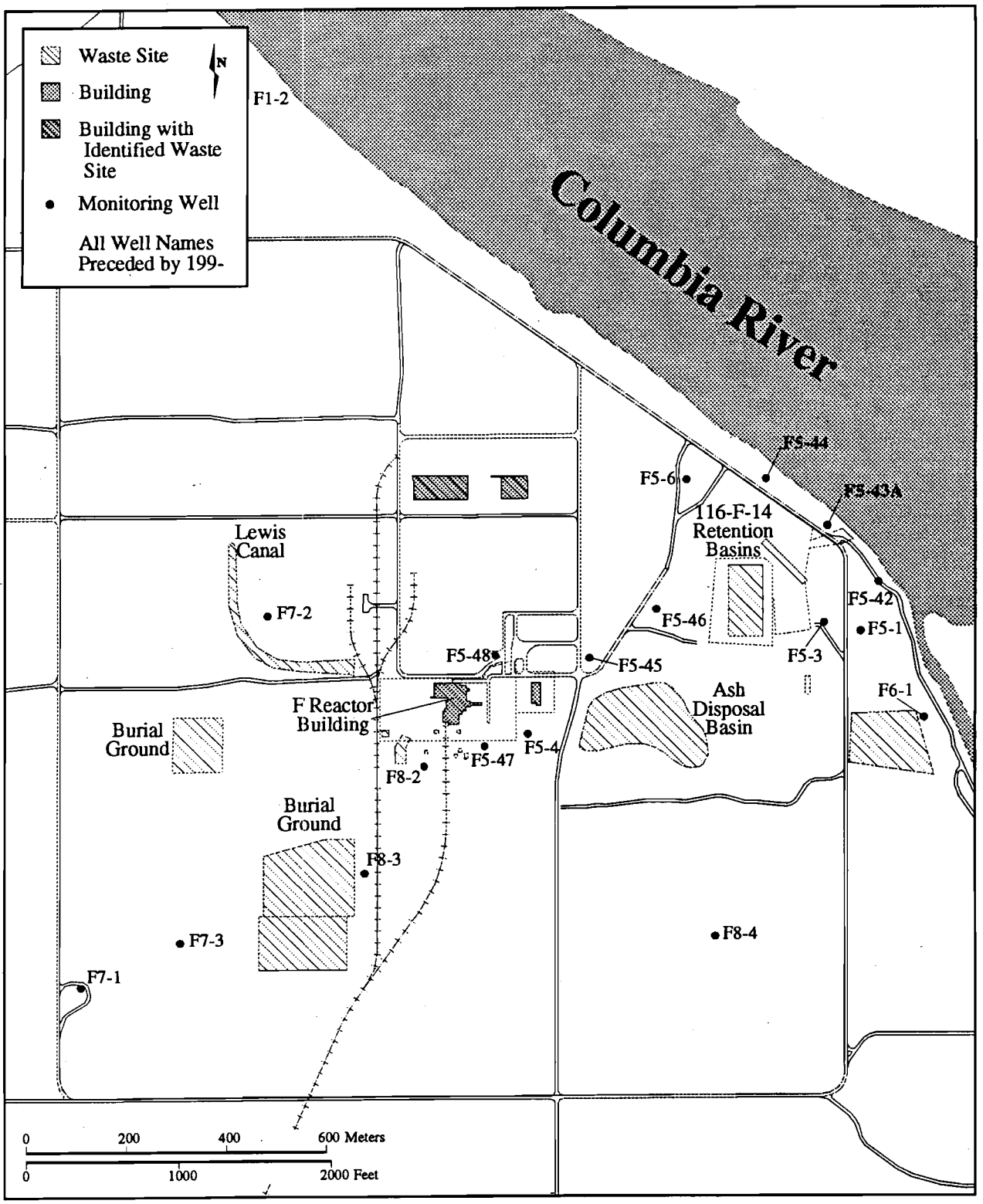

Figure C.4. Index Map for Location of Wells in the 100-F Area

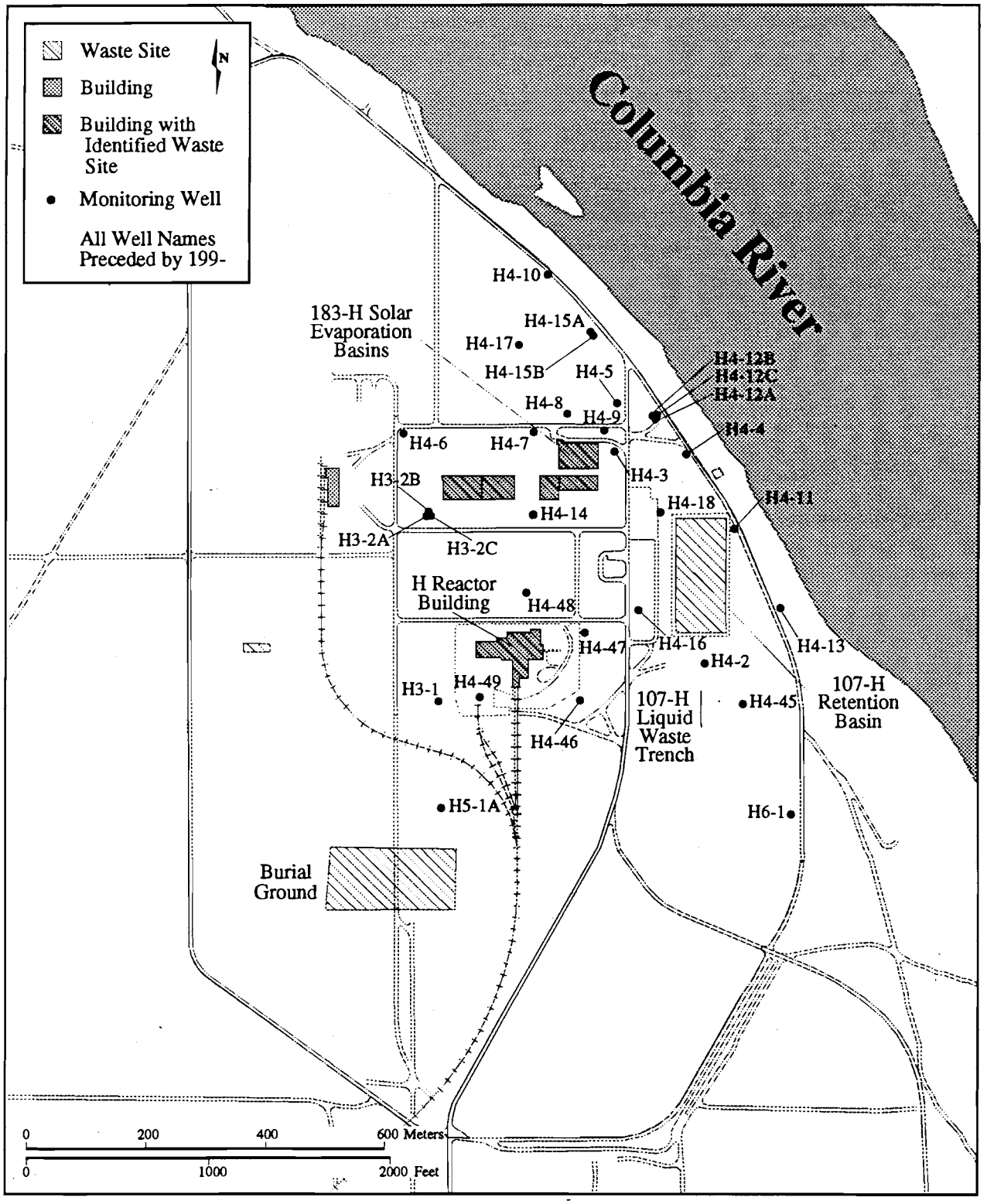

Figure C.5. Index Map for Location of Wells in the 100-H Area

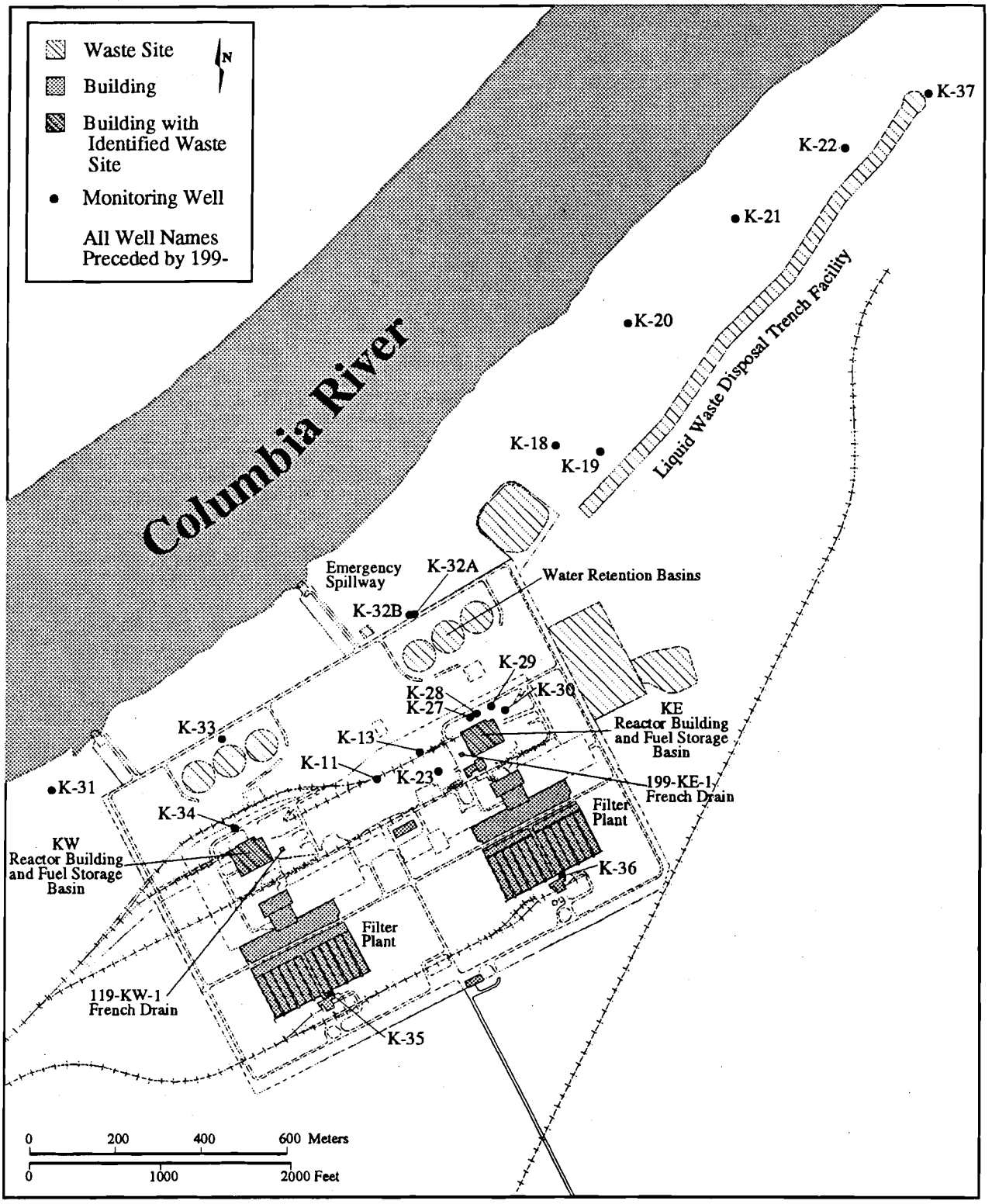

Figure C.6. Index Map for Location of Wells in the 100-K Area

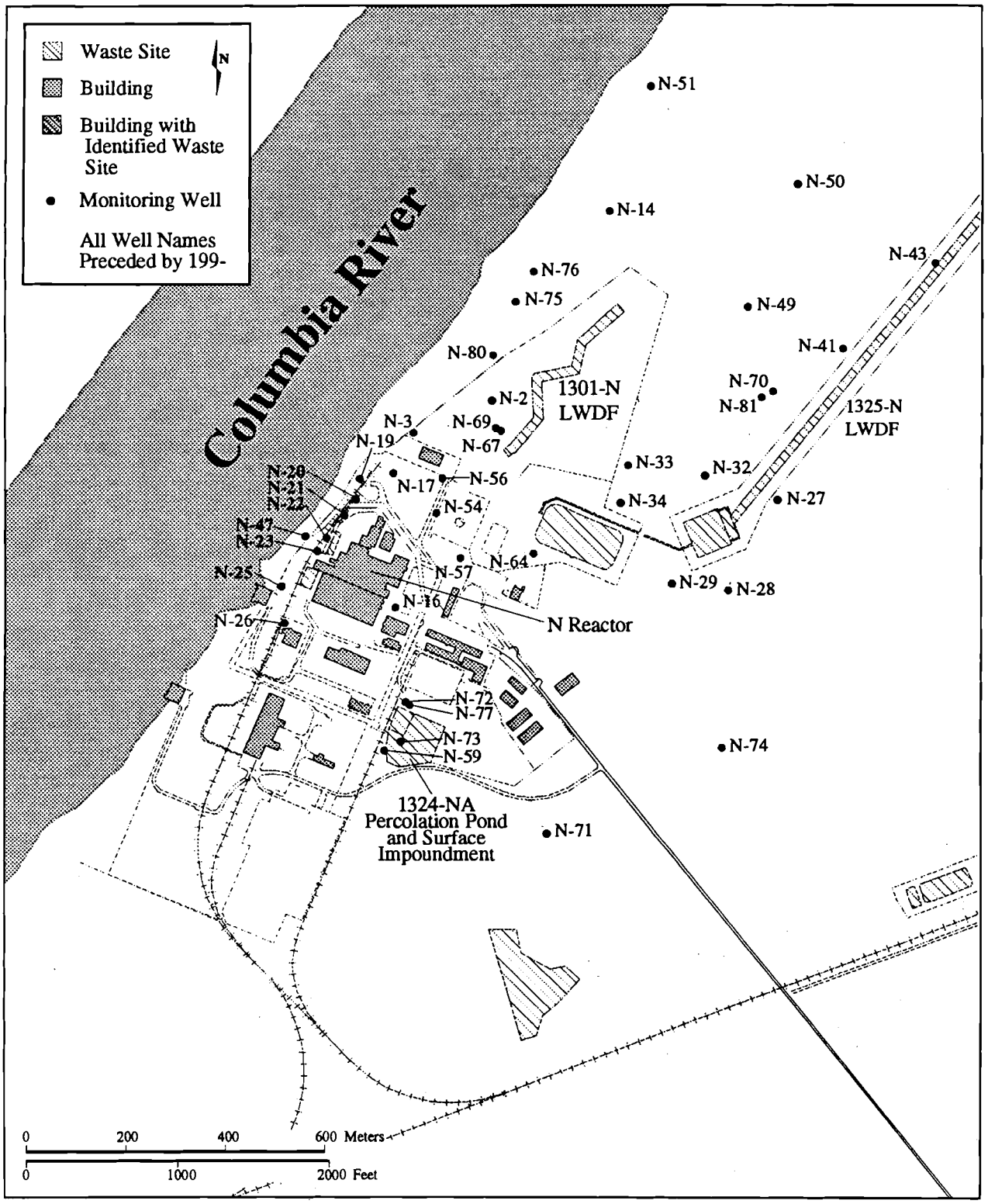

Figure C.7. Index Map for Location of Wells in the 100-N Area

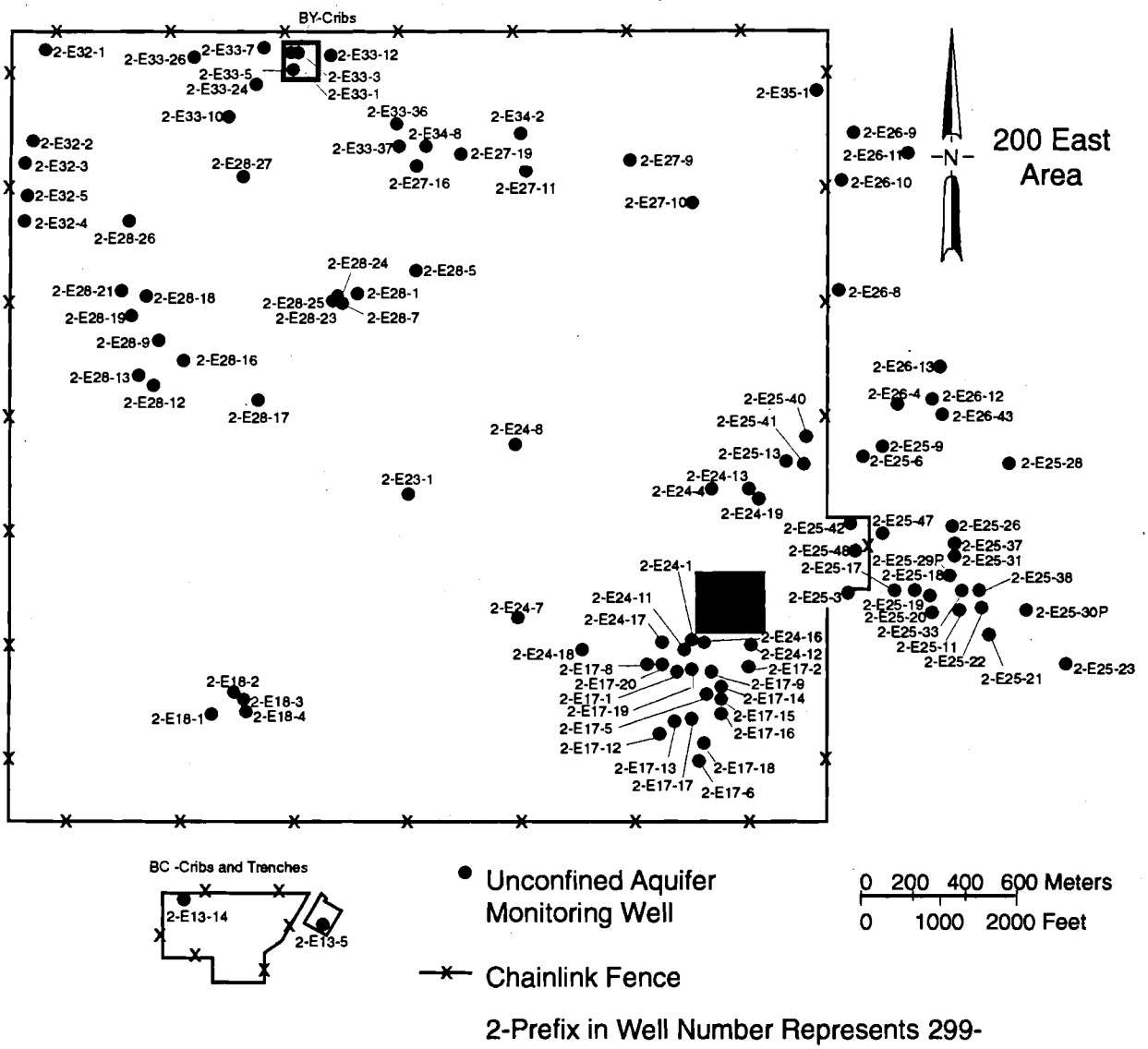

Figure C.8. Index Map for Location of Wells in the 200-East Area

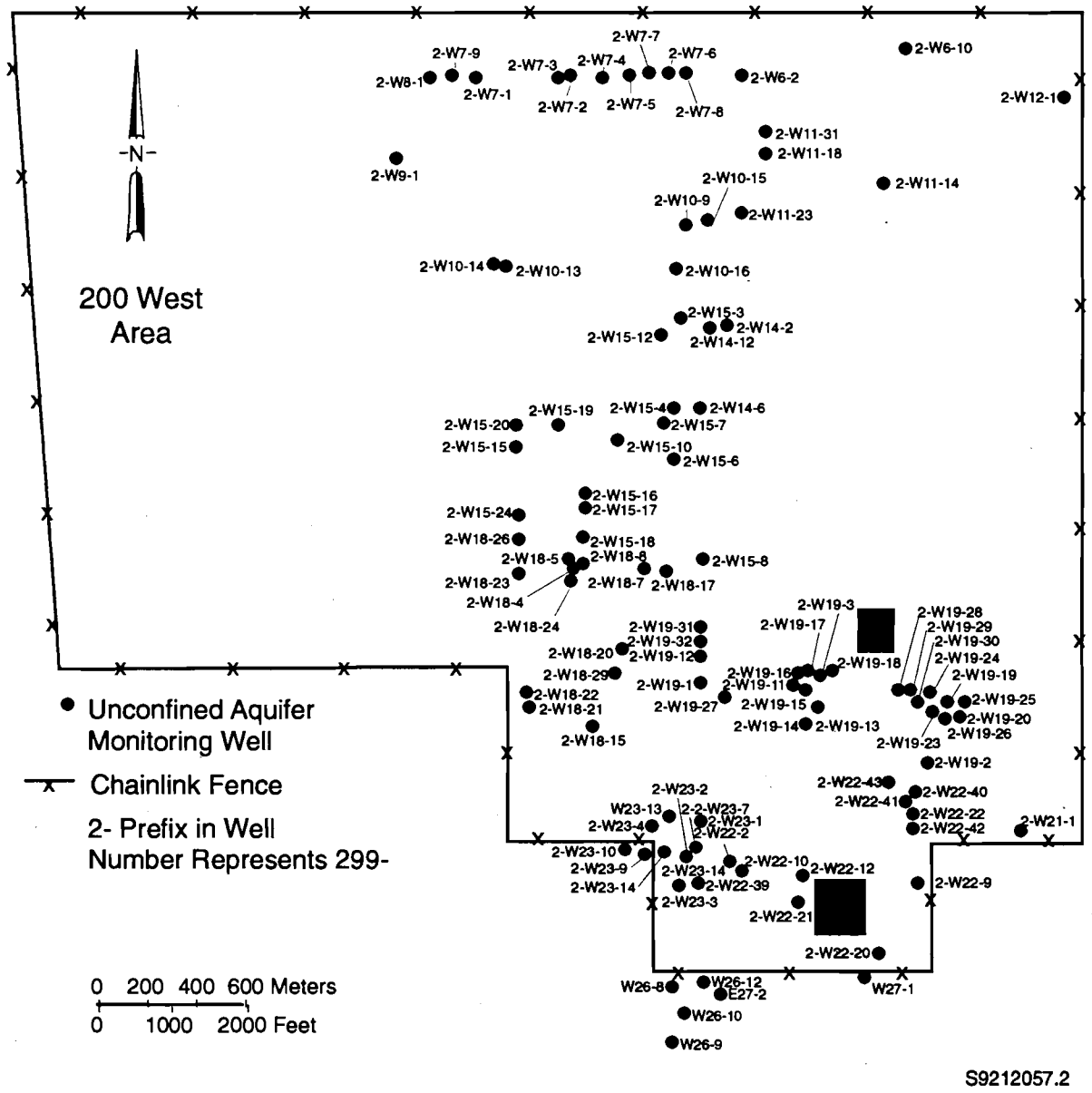

Figure C.9. Index Map for Location of Wells in the 200-West Area

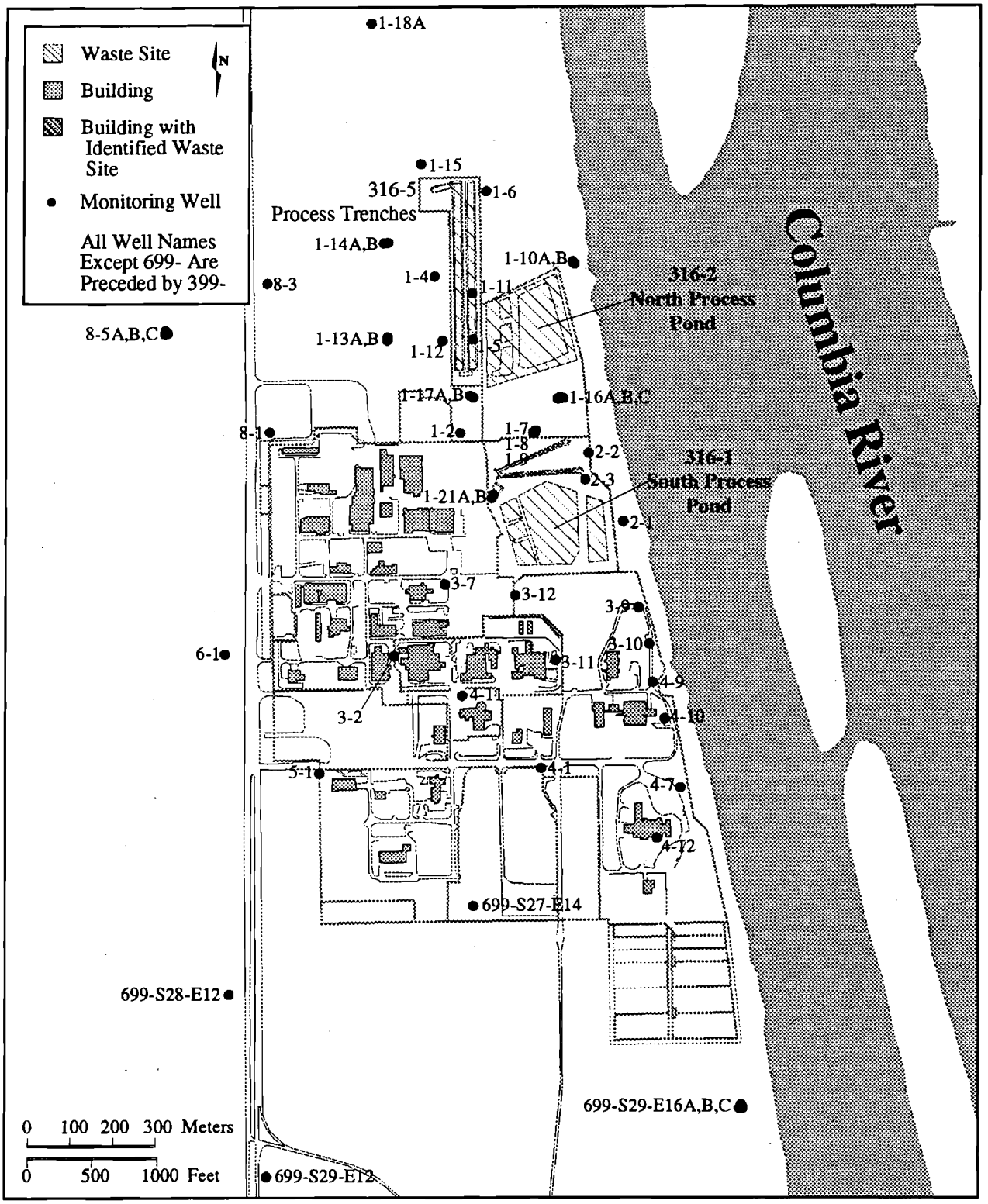

Figure C.10. Index Map for Location of Wells in the 300 Area

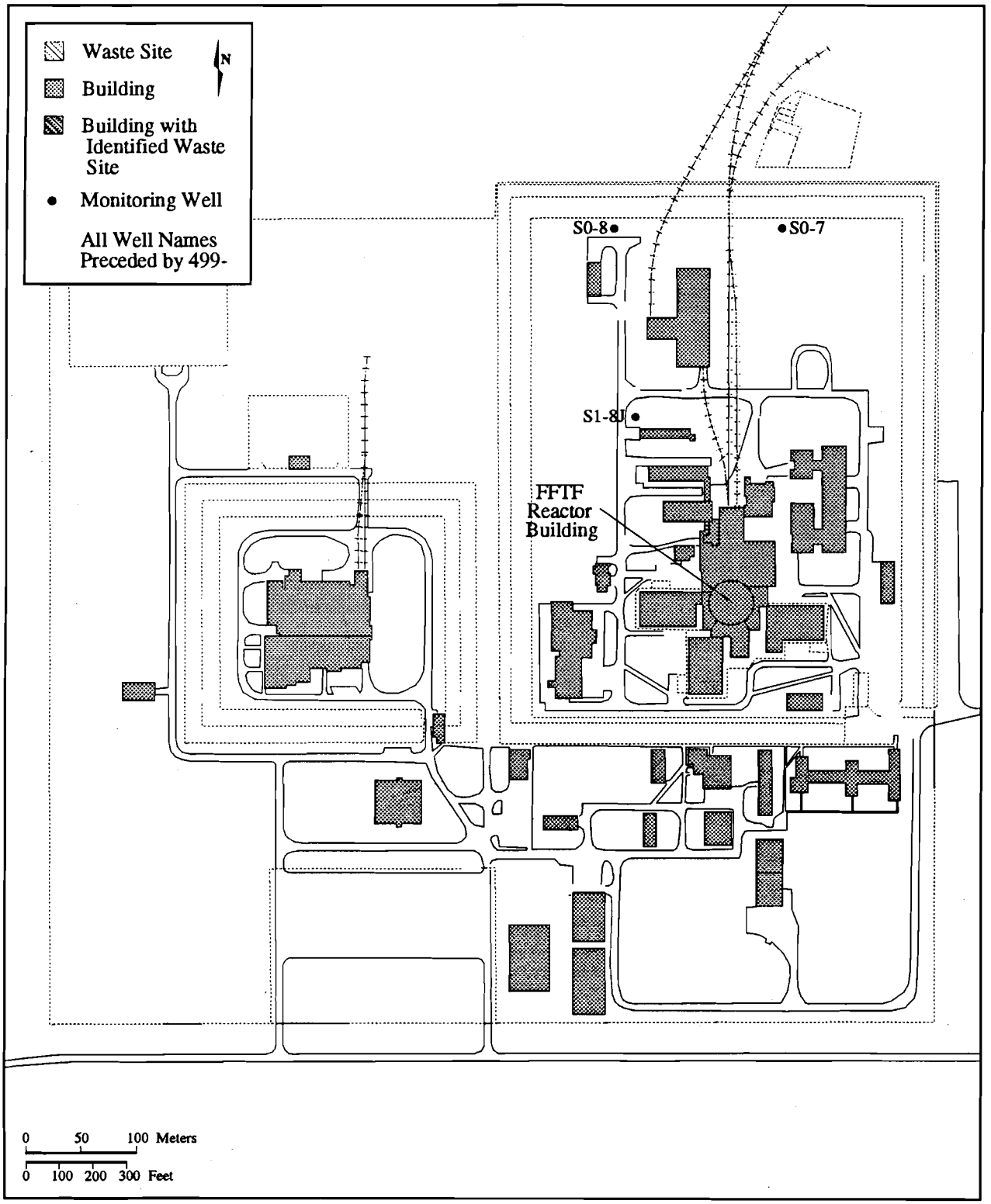

Figure C.11. Index Map for Location of Wells in the 400 Area

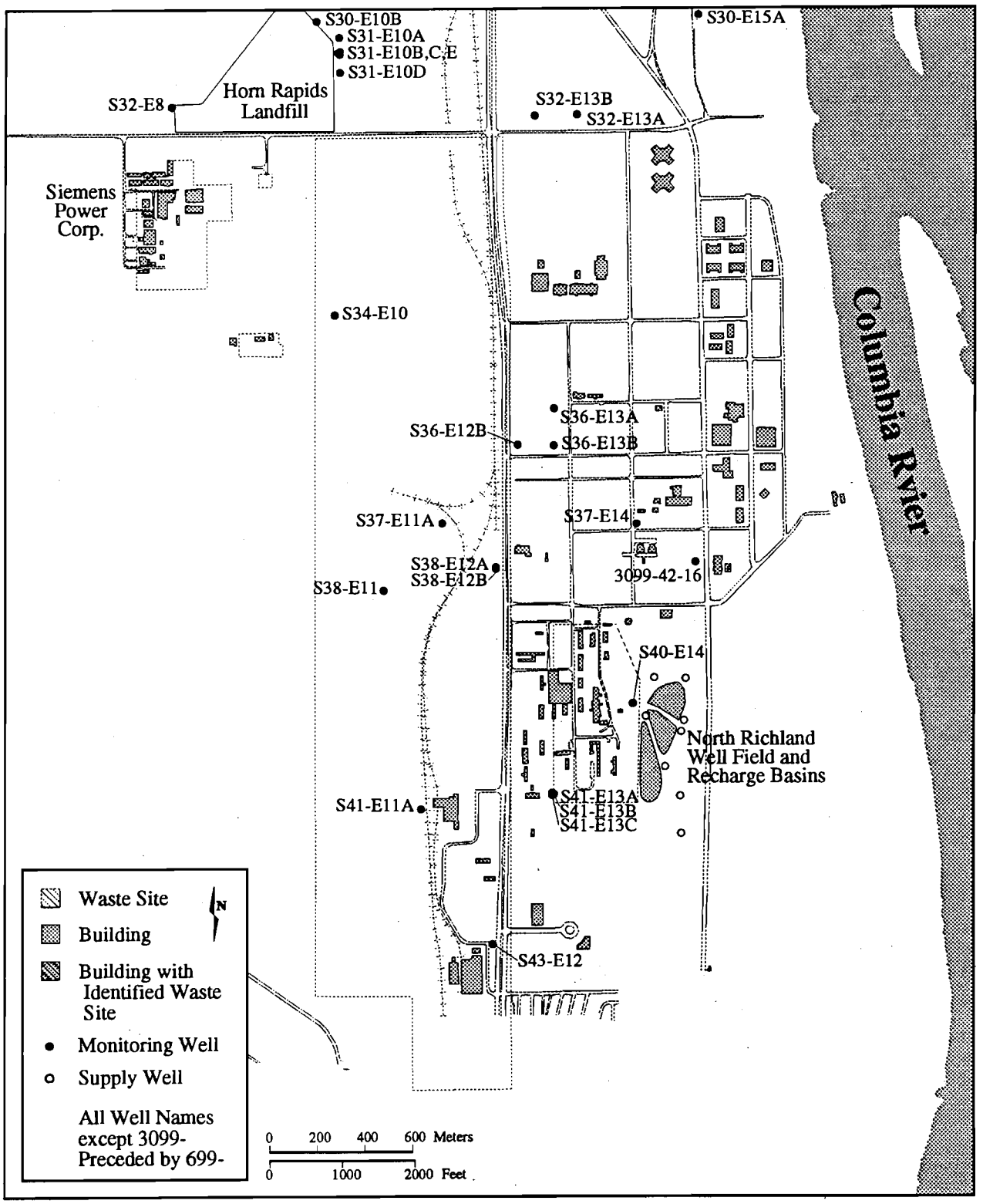

Figure C.12. Index Map for Location of Wells in the Richland North Area

Appendix D

Listing of Chemical and Radiological Data for Calendar Year 1993

Appendix D

Listing of Chemical and Radiological Data for Calendar Year 1993

This appendix describes the electronic listing of ground-water radiological and chemical monitoring data obtained on the Hanford Site during the period January through December 1993. Data is provided on an IBM PC compatible 3 1/2 inch diskette. Ground-water sampling was performed for DOE by PNL's Ground-Water Surveillance and other projects, by WHC's RCRA and CERCLA projects, and the U.S. Army Corps of Engineers CERCLA projects.

The data listings were generated from the HEIS database, which is designated as the central repository for Hanford ground-water data. Most of the sample analyses for calendar year 1993 are included; however, some data may not yet have been loaded into the HEIS database and so may not be included. All 1993 PNL and RCRA data loaded in the HEIS database have been included; only those 1993 CERCLA data that have been released for regulator review are included in the data listings. Effort has been made to provide the best analytical data possible. However, it cannot be guaranteed that the data are error-free.

The data were divided into seven groups: anions, radionuclides, metals, pesticides, semivolatile organics, volatile organics, and miscellaneous. Data within each group are listed in semicolon-delimited ASCII text files, arranged alphabetically by the short constituent name. Most groups were divided into multiple files, so that the number of records in each file would not exceed 16,000 records.

Table D.1 lists the disk file names and general contents. Data files for each group have been compressed, using the PKWARE zip utility. A copy of UNZIP.EXE is included on the diskette; UNZIP.EXE is a freely available utility that will inflate the seven zipped group files into their 20 text file components.

To unzip the files, copy the contents of the diskette onto your hard disk and run UNZIP.EXE. For example, to inflate the zipped pesticide file into the two pesticide text files, at the c:> prompt, enter **UNZIP PEST**. This will inflate PEST.ZIP into PEST1.TXT and PEST2.TXT files. Repeat for each group. It is NOT recommended that the text files be printed out, as they are quite large and will consume reams of paper. To read the text files into EXCEL, select the TEXT option for a semicolon-delimited file.

Table D.2 explains the fields included in the data listing. Additional information regarding a particular sample or well may be available in the HEIS database.

Table D.3 lists the full constituent name and the constituent ID for each of the short constituent names in the data listings. The constituent ID is the Chemical Abstract Services (CAS) number when one is available. The constituent name information is also available on the diskette in a semicolon-delimited text file, CONSTIT.TXT.

Tables D.4, D.5, and D.6 translate/define the data qualifiers for each form type.

Table D.7 defines the review codes.

Table D.1. Diskette Contents

File Name	Inflated Text File Name	Number of Records	Contents
ANION.ZIP	ANION.TXT	14683	All anion data
RAD.ZIP	RAD.TXT	14730	All radiological data
METALS.ZIP	METALS1.TXT	9213	Aluminum, Antimony, Arsenic, Barium
	METALS2.TXT	7907	Beryllium, Bismuth, Cadmium, Calcium
	METALS3.TXT	7899	Chromium, Cobalt, Copper
	METALS4.TXT	9944	Iron, Lead, Magnesium, Manganese
	METALS5.TXT	9262	Mercury, Nickel, Potassium, Selenium
	METALS6.TXT	8251	Silver, Sodium, Thallium, Tin
	METALS7.TXT	5266	Vanadium, Zinc
PEST.ZIP	PEST1.TXT	8825	Pesticides; 2,4,5-T to DDT
	PEST2.TXT	7869	Pesticides; Dieldrin to Toxaphene
SVOA.ZIP	SVOA1.TXT	10904	Semivolatiles; 1-Naphthylamine to Aramite
	SVOA2.TXT	10297	Semivolatiles; Benzo(a)anthracene to 2,4-Dinitrophenol
	SVOA3.TXT	9725	Semivolatiles; Di-n-octylphthalate to Pronamide
	SVOA4.TXT	2956	Semivolatiles; Pyrene to Tris-Z-Chloroethyl phosphate
VOA.ZIP	VOA1.TXT	10139	Volatiles; 1,1,1-Trichloroethane to Carbon disulfide
	VOA2.TXT	8660	Volatiles; Carbon Tetrachloride to Xylenes (total)
	VOA3.TXT	9216	Volatiles; Methyl methacrylate to Vinyl acetate
MISC.ZIP	MISC1.TXT	15497	COD, Coliform, Conductivity, Temperature, Organic BR, Organic CL, Organic I, Perchlorate, pH
	MISC2.TXT	7536	TDS, TOC, Total carbon, TOX, Turbidity
UNZIP.EXE			Freely available utility to expand the compressed files.
CONSTIT.TXT			Semicolon-delimited text file with constituent short names, con-id, and constituent long name. Same text as Table D.3.

Table D.2. Explanation of Fields Included in Data Listing

Field	Explanation
Well Name	The well identification. The first part of the number identifies the area, as follows: 199 - 100 Area wells 299-E - 200 East Area wells 299-W - 200 West Area wells 399 - 300 Area wells 499 - 400 Area wells 699 - 600 Area wells 1199 - 1100 Area wells 3099 - 3000 Area wells
Constituent	Short name for the specific chemical or radiological compound or physical property. See Table D.3 for full constituent names.
Filtered	A "Y" is placed in this field for filtered samples. Used primarily for metals analyses.
Date	Date that the sample was collected.
Qualifier	Data qualifiers associated with the sample results. See Tables D.4, D.5, and D.6 for an explanation of data qualifiers.
Concentration or Activity	Result of the analyses. For uniformity in the data files, all results have been listed to three decimal places.
Units	Reporting units for the analysis. Units reported for a given constituent may not be consistent.
Counting Error	Measurement error in radionuclide analyses. Analytical results may be negative values as the result of counting error.
Review	Indicator code that the quality of the results is or has been questioned. See Table D.7 for list of Review codes.
Form	Form type for the result. Determines which Qualifier translation to use from Tables D.4, D.5, and D.6. The four form types are: CLPI CLP analysis, Inorganic CLPO CLP analysis, Organic NCLP Non-CLP analysis LAS Laboratory Analytic Services analysis

Table D.3. Constituent Names

Short Name	ID	Long Name
1,1,1-T	71-55-6	1,1,1-Trichloroethane
1,1,2-T	79-00-5	1,1,2-Trichloroethane
1,1-DCL	75-34-3	1,1-Dichloroethane
1,2-DCL	107-06-2	1,2-Dichloroethane
1-napha	134-32-7	1-Naphthylamine
1112-tc	630-20-6	1,1,1,2-Tetrachloroethane
1122-tc	79-34-5	1,1,2,2-Tetrachloroethane
12-dben	95-50-1	1,2-Dichlorobenzene
123-trp	96-18-4	1,2,3-Trichloropropane
12DICHL	540-59-0	1,2-Dichloroethylene
13-dben	541-73-1	1,3-Dichlorobenzene
14-dben	106-46-7	1,4-Dichlorobenzene
14DI2BU	764-41-0	1,4-Dichloro-2-butene
1BUTANO	71-36-3	1-Butanol
1M2PYRL	872-50-4	1-Methyl-2-pyrrolidinone
2,4,5-T	93-76-5	2,4,5-T
2,4,5TP	93-72-1	2,4,5-TP
2,4-D	94-75-7	2,4-Dichlorophenoxyacetic acid
2-napha	91-59-8	2-Naphthylamine
2378TCD	1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin
24-dchp	120-83-2	2,4-Dichlorophenol
24-dint	121-14-2	2,4-Dinitrotoluene
245-trp	95-95-4	2,4,5-Trichlorophenol
246-trp	88-06-2	2,4,6-Trichlorophenol
24DIMET	105-67-9	2,4-Dimethylphenol
26-dchp	87-65-0	2,6-Dichlorophenol
26-dint	606-20-2	2,6-Dinitrotoluene
2HEXANO	591-78-6	2-Hexanone
2MENAPH	91-57-6	2-Methylnaphthalene
2METHPH	95-48-7	2-Methylphenol
2NITRAN	88-74-4	2-Nitroaniline
2NITRPH	88-75-5	2-Nitrophenol

Table D.3. (contd)

Short Name	ID	Long Name
33DIMBE	119-93-7	3,3'-Dimethylbenzidine
3NITRAN	99-09-2	3-Nitroaniline
46DINIT	534-52-1	4,6-Dinitro-o-cresol
4CHLOET	7005-72-3	4-Chlorophenylphenyl ether
4METHPH	106-44-5	4-Methylphenol
4NITQUI	56-57-5	4-Nitroquinoline-1-oxide
9H-CARB	86-74-8	9H-Carbazole
A-BHC	319-84-6	Alpha-BHC
ACEFENE	53-96-3	2-Acetylaminofluorene
ACENAPH	83-32-9	Acenaphthene
ACENATL	208-96-8	Acenaphthylene
ACETILE	75-05-8	Acetonitrile
ACETONE	67-64-1	Acetone
ACETOPH	98-86-2	Acetophenone
ACROLIN	107-02-8	Acrolein
ACRYILE	107-13-1	Acrylonitrile
ALDRIN	309-00-2	Aldrin
ALK	ALKALINITY	Alkalinity
ALLYLCL	107-05-1	Allyl chloride
ALPHA	ALPHA	Gross alpha
ALPHCHL	5103-71-9	alpha-Chlordane
ALUMINUM	7429-90-5	Aluminum
AM-241	14596-10-2	Americium-241
AMINOYL	92-67-1	4-Aminobiphenyl
AMM-ABS	7664-41-7	Ammonia
AMMONIA	14798-03-9	Ammonia
ANILINE	62-53-3	Aniline
ANTHRA	120-12-7	Anthracene
ANTIMONY	7440-36-0	Antimony
AR1016	12674-11-2	Aroclor-1016
AR1221	11104-28-2	Aroclor-1221

Table D.3. (contd)

Short Name	ID	Long Name
AR1232	11141-16-5	Aroclor-1232
AR1242	53469-21-9	Aroclor-1242
AR1248	12672-29-6	Aroclor-1248
AR1254	11097-69-1	Aroclor-1254
AR1260	11096-82-5	Aroclor-1260
ARAMITE	140-57-8	Aramite
ARSENIC	7440-38-2	Arsenic
B-BHC	319-85-7	Beta-BHC
BA-140	14798-08-4	Barium-140
BARIUM	7440-39-3	Barium
BDCM	75-27-4	Bromodichloromethane
BE-7	13966-02-4	Beryllium-7
BENZAAN	56-55-3	Benzo(a)anthracene
BENZALC	100-51-6	Benzyl alcohol
BENZBFL	205-99-2	Benzo(b)fluoranthene
BENZENE	71-43-2	Benzene
BENZOAC	65-85-0	Benzoic acid
BENZOPE	191-24-2	Benzo(ghi)perylene
BENZOPY	50-32-8	Benzo(a)pyrene
BERYLLIUM	7440-41-7	Beryllium
BETA	BETA	Gross beta
BIS2CHE	111-44-4	Bis(2-chloroethyl) ether
BIS2CHM	111-91-1	Bis(2-chloroethoxy)methane
BIS2EPH	117-81-7	Bis(2-ethylhexyl) phthalate
BIS2ETH	108-60-1	Bis(2-chloroisopropyl) ether
BISMUTH	7440-69-9	Bismuth
BNZKFLU	207-08-9	Benzo(k)fluoranthene
BNZOTHZ	95-16-9	Benzothiazole
BROMIDE	24959-67-9	Bromide
BROMORM	75-25-2	Bromoform
BROPHEN	101-55-3	4-Bromophenylphenyl ether

Table D.3. (contd)

Short Name	ID	Long Name
BUTBENP	85-68-7	Butylbenzylphthalate
BUTDINP	88-85-7	2-secButyl-4,6-dinitrophenol (DNBP)
C-14	14762-75-5	Carbon-14
CADMIUM	7440-43-9	Cadmium
CALCIUM	7440-70-2	Calcium
CARBIDE	75-15-0	Carbon disulfide
CARBTET	56-23-5	Carbon tetrachloride
CDBM	124-48-1	Dibromochloromethane
CE-141	13967-74-3	Cerium-141
CE-144	14762-78-8	Cerium-144
CHLANIL	106-47-8	4-Chloroaniline
CHLCRES	59-50-7	4-Chloro-3-methylphenol
CHLFORM	67-66-3	Chloroform
CHLLATE	510-15-6	Chlorobenzilate
CHLNAPH	91-58-7	2-Chloronaphthalene
CHLOANE	57-74-9	Chlordane
CHLORIDE	12595-89-0	Chloride
CHLORIDE	16887-00-6	Chloride
CHLPHEN	95-57-8	2-Chlorophenol
CHLROB	108-90-7	Chlorobenzene
CHLTHER	110-75-8	2-Chloroethyl vinyl ether
CHROMIUM	7440-47-3	Chromium
CHRYSEN	218-01-9	Chrysene
CIS13DI	10061-01-5	cis-1,3-Dichloropropene
CISDCE	156-59-2	cis-1,2-Dichloroethylene
CLETHAN	75-00-3	Chloroethane
CLOPREN	126-99-8	Chloroprene
CO-58	13981-38-9	Cobalt-58
CO-60	10198-40-0	Cobalt-60
COBALT	7440-48-4	Cobalt
COD	COD	Chemical oxygen demand

Table D.3. (contd)

Short Name	ID	Long Name
COLI	COLIFORM	Coliform bacteria
CONDUCT	CONDUCT	Conductivity
COPPER	7440-50-8	Copper
CR-51	14392-02-0	Chromium-51
CRESOLS	1319-77-3	Total cresols
CS-134	13967-70-9	Cesium-134
CS-137	10045-97-3	Cesium-137
CYANIDE	57-12-5	Cyanide
CYANIDE	CN	Cyanide
D-BHC	319-86-8	Delta-BHC
DDD	72-54-8	4,4'-DDD
DDE	72-55-9	4,4'-DDE
DDT	50-29-3	4,4'-DDT
DECANE	124-18-5	Decane
DIALLAT	2303-16-4	Diallate
DIBAHAN	53-70-3	Dibenz[a,h]anthracene
DIBENFR	132-64-9	Dibenzofuran
DIBPHTH	84-74-2	Di-n-butylphthalate
DIBRCHL	96-12-8	1,2-Dibromo-3-chloropropane
DIBRETH	106-93-4	1,2-Dibromoethane
DIBRMET	74-95-3	Dibromomethane
DICDIFM	75-71-8	Dichlorodifluoromethane
DICETHY	75-35-4	1,1-Dichloroethene
DICHBEN	91-94-1	3,3'-Dichlorobenzidine
DICPANE	78-87-5	1,2-Dichloropropane
DIELRIN	60-57-1	Dieldrin
DIEPHTH	84-66-2	Diethylphthalate
DIMBENZ	57-97-6	7,12-Dimethylbenz[a]anthracene
DIMEAMB	60-11-7	p-Dimethylaminoazobenzene
DIMETHO	60-51-5	Dimethoate
DIMPHAM	122-09-8	alpha,alpha-Dimethylphenethylamine

Table D.3. (contd)

Short Name	ID	Long Name
DIMPHTH	131-11-3	Dimethyl phthalate
DINPHEN	51-28-5	2,4-Dinitrophenol
DIOPHTH	117-84-0	Di-n-octylphthalate
DIOXANE	123-91-1	1,4-Dioxane
DIPHAMI	122-39-4	Diphenylamine
DIPRNIT	621-64-7	N-Nitroso-di-n-dipropylamine
DIPYRPH	297-97-2	0,0-Diethyl 0-2-pyrazinyl phosphorothioa
DISULFO	298-04-4	Disulfoton
DODECAN	112-40-3	Dodecane
ENDHYDE	7421-93-4	Endrin aldehyde
ENDO1	959-98-8	Endosulfan I
ENDOS2	33213-65-9	Endosulfan II
ENDRIN	72-20-8	Endrin
ENDRKET	53494-70-5	Endrin ketone
ENDSFAN	1031-07-8	Endosulfan sulfate
ETHBENZ	100-41-4	Ethylbenzene
ETHCYAN	107-12-0	Ethyl cyanide
ETHMETH	97-63-2	Ethyl methacrylate
ETHMETS	62-50-0	Ethyl methanesulfonate
EU-152	14683-23-9	Europium-152
EU-154	15585-10-1	Europium-154
EU-155	14391-16-3	Europium-155
FAMPHUR	52-85-7	Famphur
FE-59	14596-12-4	Iron-59
FLDCOND	90	(field) conductivity
FLDTEMP	89	(field) temperature
FLDTEMP	TEMPERATURE	Temperature (field measurement)
FLRENE	86-73-7	Fluorene
FLUORAN	206-44-0	Fluoranthene
FLUORIDE	16984-48-8	Fluoride
GAM-BHC	58-89-9	Gamma-BHC (Lindane)

Table D.3. (contd)

Short Name	ID	Long Name
GAMMCHL	5103-74-2	gamma-Chlordane
HEPTIDE	1024-57-3	Heptachlor epoxide
HEPTLOR	76-44-8	Heptachlor
HEXACHL	70-30-4	Hexachlorophene
HEXAENE	1888-71-7	Hexachloropropene
HEXCBEN	118-74-1	Hexachlorobenzene
HEXCBUT	87-68-3	Hexachlorobutadiene
HEXCCYC	77-47-4	Hexachlorocyclopentadiene
HEXCETH	67-72-1	Hexachloroethane
HEXONE	108-10-1	Hexone
HYDRAZINE	302-01-2	Hydrazine
I-129	I-129	Iodine-129
I-129LO	I-129L	Iodine-129, low level
I-131	10043-66-0	Iodine-131
INDENOP	193-39-5	Indeno(1,2,3-cd)pyrene
IODOMET	74-88-4	Iodomethane
IRON	7439-89-6	Iron
ISOBUTY	78-83-1	Isobutyl alcohol
ISODRIN	465-73-6	Isodrin
ISOPHER	78-59-1	Isophorone
ISOSOLE	120-58-1	Isosafrole
K-40	13966-00-2	Potassium-40
KEPONE	143-50-0	Kepone
KEROSEN	8008-20-6	Kerosene
LEAD	7439-92-1	Lead
LPHENOL	108-95-2	Phenol
M-XYLE	1330-20-7	Xylenes (total)
MAGNESIUM	7439-95-4	Magnesium
MANGANESE	7439-96-5	Manganese
MCRESOL	108-39-4	m-Cresol
MDINBEN	99-65-0	m-Dinitrobenzene

Table D.3. (contd)

Short Name	ID	Long Name
MERCURY	7439-97-6	Mercury
METACRY	80-62-6	Methyl methacrylate
METCHAN	56-49-5	3-Methylcholanthrene
METHACR	126-98-7	Methacrylonitrile
METHBRO	74-83-9	Bromomethane
METHCHL	74-87-3	Chloromethane
METHLOR	72-43-5	Methoxychlor
METHONE	78-93-3	2-Butanone
METHPAR	298-00-0	Methyl parathion
METHYCH	75-09-2	Methylenechloride
METMSUL	66-27-3	Methyl methanesulfonate
METPYRL	91-80-5	Methapyrilene
MN-54	13966-31-9	Manganese-54
MXYLENE	108-38-3	1,3-Dimethylbenzene
NAPHQUI	130-15-4	1,4-Naphthoquinone
NAPHTHA	91-20-3	Naphthalene
NICKEL	7440-02-0	Nickel
NITBENZ	98-95-3	Nitrobenzene
NITPHEN	100-02-7	4-Nitrophenol
NITRANI	100-01-6	4-Nitroaniline
NITRATE	14797-55-8	Nitrate
NITRITE	14797-65-0	Nitrite
NITRPYR	930-55-2	Nitrosopyrrolidine
NITRTOL	99-55-8	5-Nitro-o-toluidine
NNDIPHA	86-30-6	N-Nitrosodiphenylamine
NNIBUTY	924-16-3	N-Nitrosodi-n-butylamine
NNIDIEY	55-18-5	N-Nitrosodiethylamine
NNIDIME	62-75-9	N-Nitrosodimethylamine
NNIMETH	10595-95-6	N-Nitrosomethylethylamine
NNIMORP	59-89-2	N-Nitrosomorpholine
NNIPIPE	100-75-4	N-Nitrosopiperidine

Table D.3. (contd)

Short Name	ID	Long Name
NO2+NO3	NO2+NO3-N	Nitrite and nitrate
NO2-N	NO2-N	Nitrogen in nitrite
NO3-N	NO3-N	Nitrogen in nitrate
ORG BR	ORGANIC BR	Organic bromide
ORG CL	ORGANIC CL	Organic chloride
ORG I	ORGANIC I	Organic iodide
OTOLDIN	95-53-4	o-Toluidine
OXYLENE	95-47-6	1,2-Dimethylbenzene
PARATHI	56-38-2	Parathion
PCDDS	PCDDS	Polychlorodibenzodioxin
PCDFS	PCDFS	Polychlorodibenzofuran
PCYMENE	99-87-6	p-Cymene
PENTACH	76-01-7	Pentachloroethane
PENTCHB	608-93-5	Pentachlorobenzene
PENTCHN	82-68-8	Pentachloronitrobenzene (PCNB)
PENTCHP	87-86-5	Pentachlorophenol
PERCENE	127-18-4	Tetrachloroethene
PERCHLO	7601-89-0	Perchlorate
PH	PH	pH measurement
PHENANT	85-01-8	Phenanthrene
PHENDIA	106-50-3	p-Phenylenediamine
PHENTIN	62-44-2	Phenacetin
PHFIELD	199	pH-field measurement
PHORATE	298-02-2	Phorate
PHOSPHATE	14265-44-2	Phosphate
PICOLIN	109-06-8	2-Picoline
POTASSIUM	7440-09-7	Potassium
PRONIDE	23950-58-5	Pronamide
PU-238	13981-16-3	Plutonium-238
PU-239	15117-48-3	Plutonium-239
PU39-40	PU-239/240	Plutonium-239/40

Table D.3. (contd)

Short Name	ID	Long Name
PXYLENE	106-42-3	1,4-Dimethylbenzene
PYRENE	129-00-0	Pyrene
PYRIDIN	110-86-1	Pyridine
RA-223	15623-45-7	Radium-223
RA-224	13233-32-4	Radium-224
RA-226	13982-63-3	Radium-226
RA-228	15262-20-1	Radium-228
RADIUM	7440-14-4	Radium
RU-103	13968-53-1	Ruthenium-103
RU-106	13967-48-1	Ruthenium-106
SAFROL	94-59-7	Safrol
SB-125	14234-35-6	Antimony-125
SELENIUM	7782-49-2	Selenium
SILVER	7440-22-4	Silver
SN-113	13966-06-8	Tin-113
SN-113	SN-113	Tin-113
SN-125	14683-08-0	Tin-125
SODIUM	7440-23-5	Sodium
SR-90	10098-97-2	Strontium-90
STYRENE	100-42-5	Styrene
SULFATE	14808-79-8	Sulfate
SULFIDE	18496-25-8	Sulfides
SYMTRIN	99-35-4	sym-Trinitrobenzene
T14DC2B	110-57-6	trans-1,4-dichloro-2-butene
TC-99	14133-76-7	Technetium-99
TDS	TDS	Total dissolved solids
TETCHPH	25167-83-3	Tetrachlorophenol
TETDITH	3689-24-5	Tetraethyl dithiopyrophosphate
TETHYDF	109-99-9	Tetrahydrofuran
TETRADE	629-59-4	Tetradecane
TETRCHB	95-94-3	1,2,4,5-Tetrachlorobenzene

Table D.3. (contd)

Short Name	ID	Long Name
TETRCHP	58-90-2	2,3,4,6-Tetrachlorophenol
TH-228	14274-82-9	Thorium-228
TH-232	7440-29-1	Thorium-232
TH-234	15065-10-8	Thorium-234
THALLIUM	7440-28-0	Thallium
TIN	7440-31-5	Tin
TOC	TOC	Total organic carbon
TOLUENE	108-88-3	Toluene
TOTCARB	TC	Total carbon
TOX	TOX	Total organic halides
TOXAENE	8001-35-2	Toxaphene
TRANDCE	156-60-5	trans-1,2-Dichloroethylene
TRANS13	10061-02-6	trans-1,3-Dichloropropene
TRCMFLM	75-69-4	Trichloromonofluoromethane
TRIBUPH	126-73-8	Tributyl phosphate
TRICELN	79-01-6	Trichloroethene
TRICHLB	120-82-1	1,2,4-Trichlorobenzene
TRICHPH	25167-82-2	Trichlorophenol
TRIPHOS	126-68-1	0,0,0-Triethyl phosphorothioate
TRIS2CH	115-96-8	Tris-2-chloroethyl phosphate
TRITIUM	10028-17-8	Tritium
TURBIDITY	TURBIDITY	Turbidity
U-233/4	U-233/234	Uranium-233/234
U-234	13966-29-5	Uranium-234
U-235	15117-96-1	Uranium-235
U-238	U-238	Uranium-238
URANIUM	7440-61-1	Uranium
VANADIUM	7440-62-2	Vanadium
VINYIDE	75-01-4	Vinyl chloride
VINYLAC	108-05-4	Vinyl acetate

Table D.3. (contd)

Short Name	ID	Long Name
ZINC	7440-66-6	Zinc
ZN-65	13982-39-3	Zinc-65
ZR-95	13967-71-0	Zirconium-95

Table D.4. CLP Data Qualifiers - Organics (Form = CLPO)

Qualifier	Definition
B	The analyte is found in the associated blank as well as in the sample. Indicates possible contamination of the blank and warns the data user to take appropriate action. Should be replaced by "J" during validation.
D	Analysis was performed at a secondary dilution factor.
E	Identifies compounds whose concentrations exceed the calibration range of the GC/MS for that specific analysis.
J	The associated numerical value is an estimated quantity. The mass spectral data indicate the presence of a compound that meets the identification criteria, but the result is less than the contract-required quantitation limit and greater than zero.
NJ	Presumptive evidence of the presence of the material at an estimated quantity.
R	The data are unusable.
U	Undetected - analysis did not detect the material. The associated numerical value is the contract-required quantitation limit corrected for dilution and percent moisture.
UJ	The material was analyzed for but was not detected. The contract-required quantitation limit is estimated.

GC/MS = gas chromatograph/mass spectrometer.

Table D.5. CLP Data Qualifiers - Inorganics (Form = CLPI)

Qualifier	Definition
*	Duplicate analysis not within control limits.
+	Correlation coefficient for MSA is <0.995.
B	Reported value is less than the contract-required quantitation limit but is greater than the instrument detection limit. Should be replaced by "J" during data validation.
BJ	Reported value is less than the instrument standardization but is greater than the instrument detection limit. Should be replaced by "J" during data validation.
E	Serial dilution %D out of control limits.
J	The analyte was analyzed for and detected. The associated numerical value is an estimated quantity usable for decision-making processes.
M	Duplicate injection precision not met.
N	Spike sample recovery is outside control limits. Presumptive evidence of the presence of the analyte.
R	The data are unusable.
S	Reported value determined by the MSA.
U	Undetected - analyte is below the detection limits of the methods and instruments used. The associated numerical value is the calculated contract-required quantitation limit based on wet weight of the soil sample. The contract-required quantitation limit based on dry weight (stated in the work plan) is higher.
UJ	The material was analyzed for but was not detected. The contract-required quantitation limit is estimated.
W	Post-digestion spike recovery for GFAA out of control limit. Sample absorbance $<50\%$ of spike.

GFAA = graphite furnace atomic adsorption
MSA = method of standard addition

Table D.6. LAS Data Qualifiers (Form = LAS or NCLP)

Qualifier	Definition
A	Identifies a TIC as a suspected aldol-condensation product.
B	Used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action. This flag must be used for a TIC as well as for a TCL compound.
C	Applies to pesticide results where the identification has been confirmed by GC/MS. Single component pesticides that are ≥ 10 ng/μl in the final extract shall be confirmed by GC/MS.
D	Identifies all compounds identified in an analysis at a secondary dilution factor.
E	Identifies compounds whose concentration exceed the calibration range of the GC/MS for that specific analysis. This flag does not apply to pesticides/PCBs analyzed by GC/EC methods. If one or more compounds has a response greater than full scale, the sample or extract must be diluted and reanalyzed. If the dilution of the extract causes any compounds identified in the first analysis to be below the calibration range in the second analysis, then the results of both analyses are reported.
J	Indicates an estimated value. This flag is used either when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed, or when the mass spectral data indicate the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit and greater than zero. The sample quantitation limit is corrected for dilution and for percent moisture as in the "U" flag.
L	Used when an analytical result below a CRQL and at or above an MDL is reported.
U	Indicates compound was analyzed for but was not detected. The sample quantitation limit is corrected for dilution and for percent moisture.
X	Other specific flags and footnotes may be required to properly define the results. If used, they must be fully described and such description attached to the Sample Data Summary Package and Case Narrative. "X" is used first, if more than one flag is required, "Y" and "Z" are used as needed.

CRQL = contract required quantitation limit
GC/EC = gas chromatography/eddy current
GC/MS = gas chromatography/mass spectrometer
MDL = method detection limit
PCBs = polychlorinated byphenyls
TCL = target compound list
TIC = tentatively identified compound

Table D.7. Data Review Codes

Review Code	Translation
D	Result is associated with a documented laboratory nonconformance.
F	Result is undergoing further review.
G	Result is valid according to further review.
H	Laboratory holding time exceeded before the sample was analyzed.
P	Potential problem. Collection/analysis circumstances makes value questionable.
Q	Associated quality control sample is out of limits.
R	Result is not valid according to further review.
Y	Result is suspect. Review had insufficient evidence to show result valid or invalid.
Z	Miscellaneous circumstance exists. See project file.

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