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# Hanford Site Ground-Water Monitoring for 1992

P.E. Dresel
D.R. Newcomer
J.C. Evans
W.D. Webber
F.A. Spane, Jr.
R.G. Raymond
B.E. Opitz

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Pacific Northwest Laboratory
Richland, Washington 99352

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# Abstract

Monitoring activities were conducted to determine the distribution of radionuclides and hazardous chemicals present in ground water as a result of Hanford Site operations and, whenever possible, relate the distribution of these constituents to Site operations. A total of 720 wells were sampled during 1992 by all Hanford ground-water monitoring activities.

The Ground-Water Surveillance Project prepared water-table maps of DOE's Hanford Site for June 1992 from water-level elevations measured in 287 wells across the Hanford Site and outlying areas. These maps are used to infer ground-water flow directions and gradients for the interpretation of contaminant transport. Water levels beneath the 200 Areas decreased as much as 0.75 m (2.5 ft) between December 1991 and December 1992. Water levels in the Cold Creek Valley decreased approximately 0.5 m in that same period. The water table adjacent to the Columbia River along the Hanford Reach continues to respond significantly to fluctuations in river stage. These responses were observed in the 100 and 300 areas. The elevation of the ground-water mound beneath B Pond did not change significantly between December 1991 and December 1992. However, water levels from one well located at the center of the mound indicate a water-level rise of approximately 0.3 m (1 ft) during the last quarter of 1992. Water levels measured from unconfined aquifer wells north and east of the Columbia River in 1992 indicate that the primary source of recharge is from irrigation practices.

Radiological monitoring results indicated that tritium, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, and uranium concentrations in ground water were at levels above the U.S. Environmental Protection Agency or the Washington State drinking water standards (DWS). Nitrate, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene were also present in Hanford ground water at levels above their DWS in 1992 sampling. Concentrations of tritium in the 200 Areas were above the derived concentration guide (DCG) of 2,000,000 pCi/L specified by DOE Order 5400.5. Strontium-90 concentrations in the 100-N and 200-East areas were also above the DCG of 1000 pCi/L. Concentrations of uranium in the 200-West Area were above the DCG for one or more isotopes (500 pCi/L for uranium-234, 600 pCi/L for uranium-235, and 600 pCi/L for uranium-236). No constituents had concentrations greater than 10 times the DCG.

# Summary

The Pacific Northwest Laboratory monitors ground-water quality across the Hanford Site for the U.S. Department of Energy (DOE) to assess the impact of Site operations on the environment. Monitoring activities were conducted to determine the distribution of radionuclides and hazardous chemicals present in ground water as a result of Site operations and, whenever possible, relate the distribution of these constituents to Site operations. Additional monitoring was conducted at individual waste sites by the Site Operating Contractor, Westinghouse Hanford Company, to assess the impact that specific facilities have had on ground-water quality and to comply with the Resource Conservation and Recovery Act. Ground-water monitoring was also conducted for programs under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 to characterize the impacts of past operations. A total of 720 wells were sampled during 1992 by all Hanford ground-water monitoring activities.

The Ground-Water Surveillance Project prepared water-table maps of DOE's Hanford Site for June 1992 from water-level elevations measured in 287 wells across the Hanford Site and outlying areas. These maps are used to infer ground-water flow directions and gradients for the interpretation of contaminant transport. The greatest changes in the elevation of the water table at Hanford occurred beneath the 200 Areas, the 1100 and 3000 areas, the Cold Creek Valley in the western part of the Hanford Site, and adjacent to the Columbia River.

Water levels beneath the 200 Areas, including those beneath the decommissioned U Pond, decreased as much as 0.75 m (2.5 ft) between December 1991 and December 1992, primarily in response to decreasing wastewater discharged to various ponds, cribs, and trenches in the 200 Areas and continued dissipation of the ground-water mound beneath much of the 200-West Area. Water levels below the 200-East Area declined approximately 0.3 m (1 ft) between December 1991 and December 1992. In the 1100 and 3000 areas, the elevation of the water table is affected by pumping and recharge by the city of Richland's wellfield and ground-water recharge basin system and to recharge from irrigation practices west and southwest of the 1100 Area. Water levels in the Cold Creek Valley declined steadily during 1992, with a decrease of approximately 0.5 m (1.6 ft) at well 699-43-104 between December 1991 and December 1992. The observed change is associated with irrigation practices in the upper Cold Creek Valley, but water levels may also be responding to wastewater disposal practices in the 200 Areas.

The water table adjacent to the Columbia River along the Hanford Reach continues to respond significantly to fluctuations in river stage. These water-level changes were observed in the 100 and 300 areas.

Water-level data from B Pond, which continues to receive wastewater, indicate that the elevation of the ground-water mound beneath B Pond did not change significantly between December 1991 and December 1992. However, water levels from one well located at the center of the mound indicate a water-level rise of approximately 0.3 m (1 ft) during the last quarter of 1992.

Water levels measured from unconfined aquifer wells north and east of the Columbia River in 1992 indicate that the primary source of recharge is from irrigation practices. The configuration of the water table is controlled by the morphology of the basalt surface, hydrogeologic characteristics of the unconfined aquifer sediments, and topographic features.

Salient hydrogeologic features for the upper-confined aquifer system include a prominent, broad recharge mound extending northeastward from the Yakima Ridge - 200-West Area, a small recharge mound immediately east of the 200-East Area in the vicinity of B Pond, the presence of a low hydraulic head (potential discharge) region in the Umtanum Ridge - Gable Mountain structural area, and a high hydraulic head region to the north and east of the Columbia River resulting from recharge attributed to agricultural activities. The potentiometric map for the upper-confined aquifer is consistent with the areal head pattern indicated for the Mabton interbed, which is a deeper and more areally extensive confined aquifer underlying the Hanford Site.

Radiological monitoring results indicated that tritium, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, and uranium concentrations in ground water were at levels above the U.S. Environmental Protection Agency or the Washington State drinking water standards (DWS). Nitrate, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene (TCE), and tetrachloroethylene were also present in Hanford ground water at levels above their DWS in 1992 sampling.

Concentrations of tritium in the 200 Areas were above the derived concentration guide (DCG) of 2,000,000 pCi/L specified by DOE Order 5400.5. Strontium-90 concentrations in the 100-N and 200-East areas were also above the DCG of 1000 pCi/L. Concentrations of uranium in the 200-West Area were above the DCG for one or more isotopes (500 pCi/L for uranium-234, 600 pCi/L for uranium-235, and 600 pCi/L for uranium-236). No constituents had concentrations greater than 10 times the DCG.

Antimony-125 was only infrequently detected in ground water on site in 1992. This and other short-lived radionuclides have diminished below detectibility in ground water because of radioactive decay since cessation of plutonium production activities. Other infrequently detected radionuclides include cobalt-60, cesium-137, and plutonium.

Strontium-90 is the only constituent detected at levels above the DWS in the 100-B/C Area. The highest levels of strontium-90 are found downgradient of the retention basins and liquid overflow trenches. Strontium-90 at concentrations above the DWS is also found in wells to the southwest of the B Reactor Building. Tritium levels in the 100-B/C Area above the DWS are reported in only one well.

Tritium, strontium-90, nitrate, and chromium are found at levels greater than the DWS in the 100-D Area. The chromium plume from the 100-D Area extends east into the 600 Area and possibly as far as the 100-H Area. Tritium levels less than the DWS detected in 600 Area wells northeast of the 100-D Area may also be related to 100-D Area activities.

Interpretation of the ground-water chemistry in the 100-F Area is impeded by the sparse monitoring well coverage. This is a particular problem for TCE, which has a suspected source upgradient of the 100-F Area and has been detected at concentrations above the DWS in the 100-F Area and in surrounding parts of the 600 Area. Other major ground-water contaminants in the 100-F Area include strontium-90 and uranium.

Major ground water contaminants at the 100-H Area include strontium-90, technetium-99, uranium, nitrate, and chromium. Chromium may have a source in the 100-D Area, upgradient of the 100-H Area.

Tritium is the primary constituent of concern in the 100-K Area. Other constituents detected in the 100-K Area include strontium-90, antimony-125, nitrate, and chromium.

Tritium, strontium-90, antimony-125, and nitrate are the major contaminants of concern in the 100-N Area. Strontium-90 is probably 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.

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. Chromium detected in unfiltered samples from the 300 Area appears to be related to stainless-steel monitoring well construction. The main uranium plume is located in the northern part of the 300 Area downgradient from the 316-5 Process Trenches and the 316-2 North Process Pond. A second, smaller area of elevated uranium concentration is located in the southern part of the 300 Area. Few wells in the 300 Area contain concentrations of TCE greater than the DWS in spite of the known TCE usage and estimates of significant quantities disposed to ground. The presence of cis-1,2-dichloroethylene in some samples indicates that anaerobic biodegradation of TCE has occurred.

No sources contributing to 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 Plutonium Uranium Extraction (PUREX) Plant in the 200-East Area have been identified in 400 Area wells. The 400 Area water supply has remained below the DWS for all but one sampling event since supply well 499-S1-8J went on line in 1985.

Several wells at the Solid Waste Landfill contained TCE close to but slightly below the DWS. Solid Waste Landfill wells had shown TCE concentrations above the DWS in previous years. These wells also continued to show levels of tetrachloroethylene just above the 5 $\mu$g/L DWS.

The 1100 Area, 3000 Area, the 600 Area south of the 300 Area, and nearby offsite parts of Richland are considered together in this report as the North Richland Area. Ground-water constituents of concern in the North Richland Area include gross alpha or uranium and TCE. Particular concern in the North Richland Area is related to the potential for future impacts at the North Richland wellfield. Low-level tritium analyses on samples collected from the North Richland wells in 1992 do not indicate any impact of site activities on the wellfield. Flow to the east and northeast across the North

Richland Area is believed to limit the migration of the 200-East Area tritium plume into the North Richland Area. In addition, ground-water recharge at the North Richland wellfield recharge basins forms a ground-water mound limiting contaminant migration toward the water-supply wells.

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# Abbreviations

| | |
|---|---|
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CFR | Code of Federal Regulations |
| DCE | dichloroethylene |
| DCG | derived concentration guide |
| DOE | U.S. Department of Energy |
| DWS | drinking water standard |
| EPA | U.S. Environmental Protection Agency |
| FFTF | Fast Flux Test Facility |
| GC | gas chromatography |
| HEIS | Hanford Environmental Information System |
| ICP | inductively coupled plasma |
| ITC | International Technology Corporation |
| LWDF | liquid waste disposal facility |
| MCL | maximum contaminant level |
| MS | mass spectrometry |
| NRDW | nonradioactive dangerous waste |
| PFP | Plutonium Finishing Plant |
| PNL | Pacific Northwest Laboratory |
| PUREX | Plutonium Uranium Extraction (Plant) |
| RCRA | Resource Conservation and Recovery Act |
| REDOX | Reduction Oxidation (Plant) |
| SARA | Superfund Amendments and Reauthorization Act |

| | |
|---|---|
| SPC | Siemens Power Corporation |
| SWL | Solid Waste Landfill |
| TCE | trichloroethylene |
| USBR | U.S. Bureau of Reclamation |
| USGS | U.S. Geological Survey |
| UST | United States Testing Company |
| WAC | Washington Administrative Code |
| WHC | Westinghouse Hanford Company |

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# 1.0 Introduction

The Pacific Northwest Laboratory (PNL)[a] monitors 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 through the Ground-Water Surveillance Project and is designed to meet the requirements of DOE Order 5400.1 that apply to environmental surveillance and ground-water monitoring (DOE 1988). DOE Order 5400.1 was issued November 9, 1988, to establish direction for the required environmental protection programs at DOE facilities. Environmental surveillance activities are conducted to monitor the effects, if any, of DOE activities at Hanford to onsite and offsite environmental and natural resources. The Ground-Water Surveillance Project is designed to satisfy one or more of the following program objectives as identified in the DOE order:

- 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 qual..y problems.

In addition to the Ground-Water Surveillance Project, which monitors contaminant distribution across the Site, ground-water monitoring activities are being conducted at Hanford by Westinghouse Hanford Company (WHC). Ground-water samples are collected for operational monitoring in an around the 200 Areas for compliance with DOE orders. Facility-specific monitoring is conducted for compliance with the Resource Conservation and Recovery Act (RCRA) (40 CFR 264) and Washington Administrative Code (WAC 173-303 and -304). The results of some of these activities are discussed briefly in this report and are reported in more detail elsewhere (e.g., DOE 1993) The compliance monitoring results (primarily for chemicals) 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. Ground-water monitoring is also 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 of known or

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(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

suspected environmental contamination that may have resulted from past site activities. The CERCLA ground-water data, when available, were integrated into the Ground-Water Surveillance Project interpretations. The use of ground-water data obtained from other programs on site avoids 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 1992. The rest of this section briefly describes the site geology and hydrogeology. Section 2.0 reports the results of water-level monitoring in the unconfined and confined aquifers. Section 3.0 describes the radiological and chemical monitoring programs, with emphasis on summarizing the Surveillance Project activities. The results of the chemical and radiological sampling are discussed in Section 4.0. The monitoring results are generally related to probably source areas although potential receptor locations such as the 400 Area drinking-water supply and the North Richland wellfield are discussed separately. Results of monitoring in the confined aquifer system are also considered separately.

## 1.1 Geology

The Hanford Site and the adjacent area north and east of the Columbia River in parts of Grant, Adams, and Franklin counties lie within the Pasco Basin, one of many topographic and structural basins within the Columbia Plateau. Principal geologic units beneath the area covered in this report include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and a series of deposits informally referred to as the Hanford formation. These units are covered locally by no more than a few meters of recent alluvial or windblown deposits. Rocks of the Columbia River Basalt Group and older geologic units have been deformed into a series of roughly east-west trending folds. A more complete description of the geology of the Hanford Site is contained in reports by DOE (1988), Newcomb et al. (1972), and Myers et al. (1979). A more complete geologic description of the areas north and east of the Columbia River is covered in Grolier and Bingham (1978). Recent reports that provide additional information on the geology of specific ares of the Site include Connelly et al. (1992a, 1992b) for the 200-East and 200-West aggregate areas, Swanson (1992) for the 300 Area, and Peterson (1992) for the 100 Areas and surroundings.

## 1.2 Hydrology

Both confined and unconfined aquifers are present beneath the mapped areas shown in Plate 1. The confined aquifers lie primarily within the Columbia River basalts. The unconfined aquifer lies in river and lake deposits of the Ringold Formation and glaciofluvial sediments of the Hanford formation, as well as some more recent alluvial sediments in areas adjacent to the Columbia River (Gephart et al. 1979). Perched water-table conditions have been encountered in sediments above the

unconfined aquifer in the 200-West Area (Airhart 1990) and in irrigated areas east of the Columbia River (Brown 1979).

The unconfined aquifer is bounded below by either the basalt surface or locally by the relatively impervious clays and silts of the lower unit of the Ringold Formation. Laterally, the unconfined aquifer is bounded by the basalt ridges that surround the basin and hydrologically by the Yakima and Columbia rivers. The basalt ridges have a low permeability and act as a barrier to lateral flow of ground water (Gephart et al. 1979) where they rise above the water table. The Columbia River acts as a line of discharge for the unconfined aquifer on both sides of the Columbia River. The water table on the west side of the Columbia River is not interrelated with the water table on the east side of the Columbia River.

On the Hanford Site, the saturated thickness of the unconfined aquifer is greater than 61 m (200 ft) in some areas and pinches out along the flanks of the basalt ridges. 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) and 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 up to approximately 50 m (165 ft) in the Esquatzel Coulee.

The hydraulic conductivity of the unconfined aquifer has a major effect on contaminant transport direction and velocities. The conductivity distribution shown in Figure 1.2 is being developed through aquifer test analysis, geologic interpretation, and calibration of a sitewide two-dimensional finite element ground-water transport model (Jacobson and Freshley 1990).

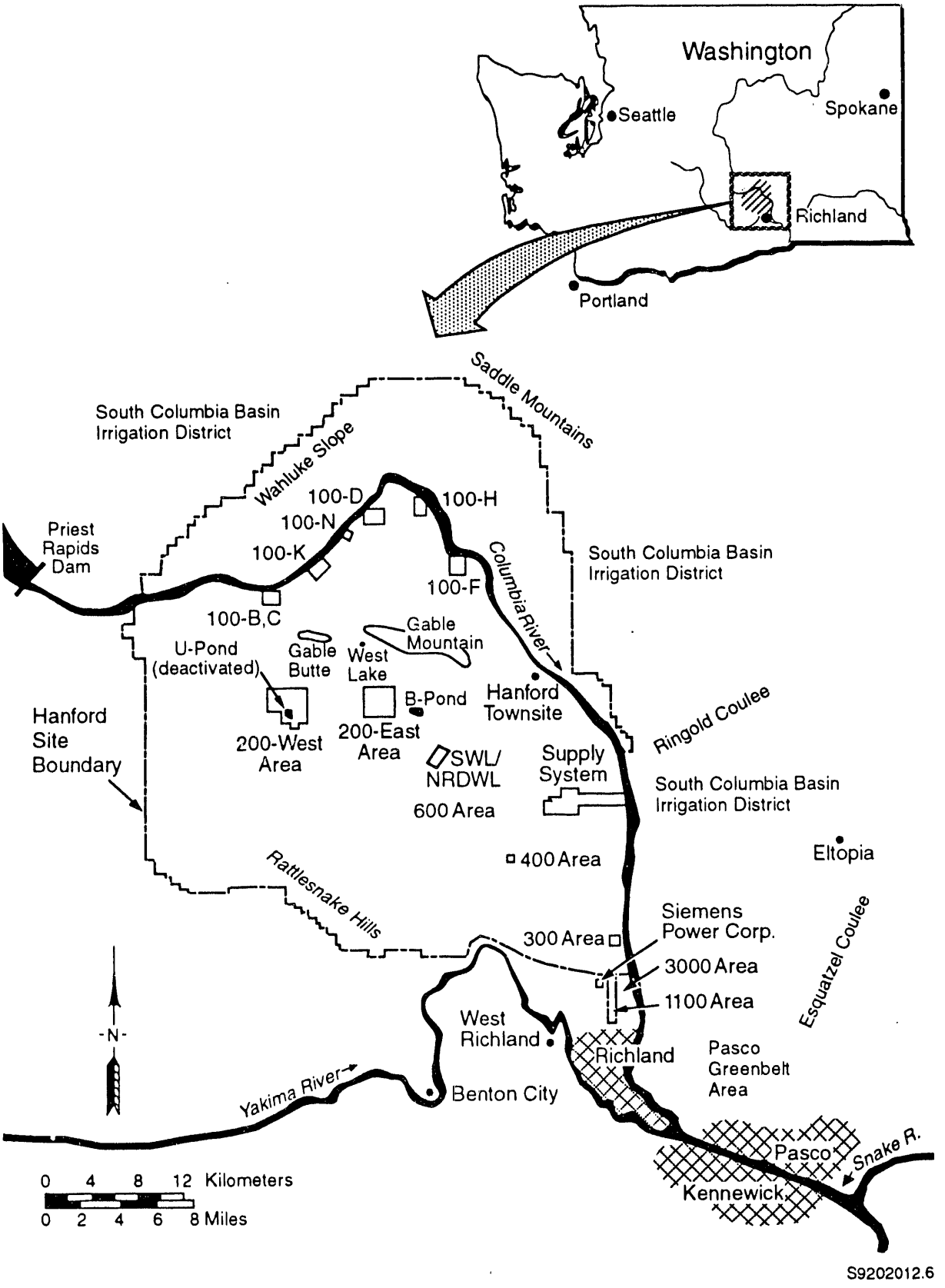



**Figure 1.1.** Hanford Site Location Map

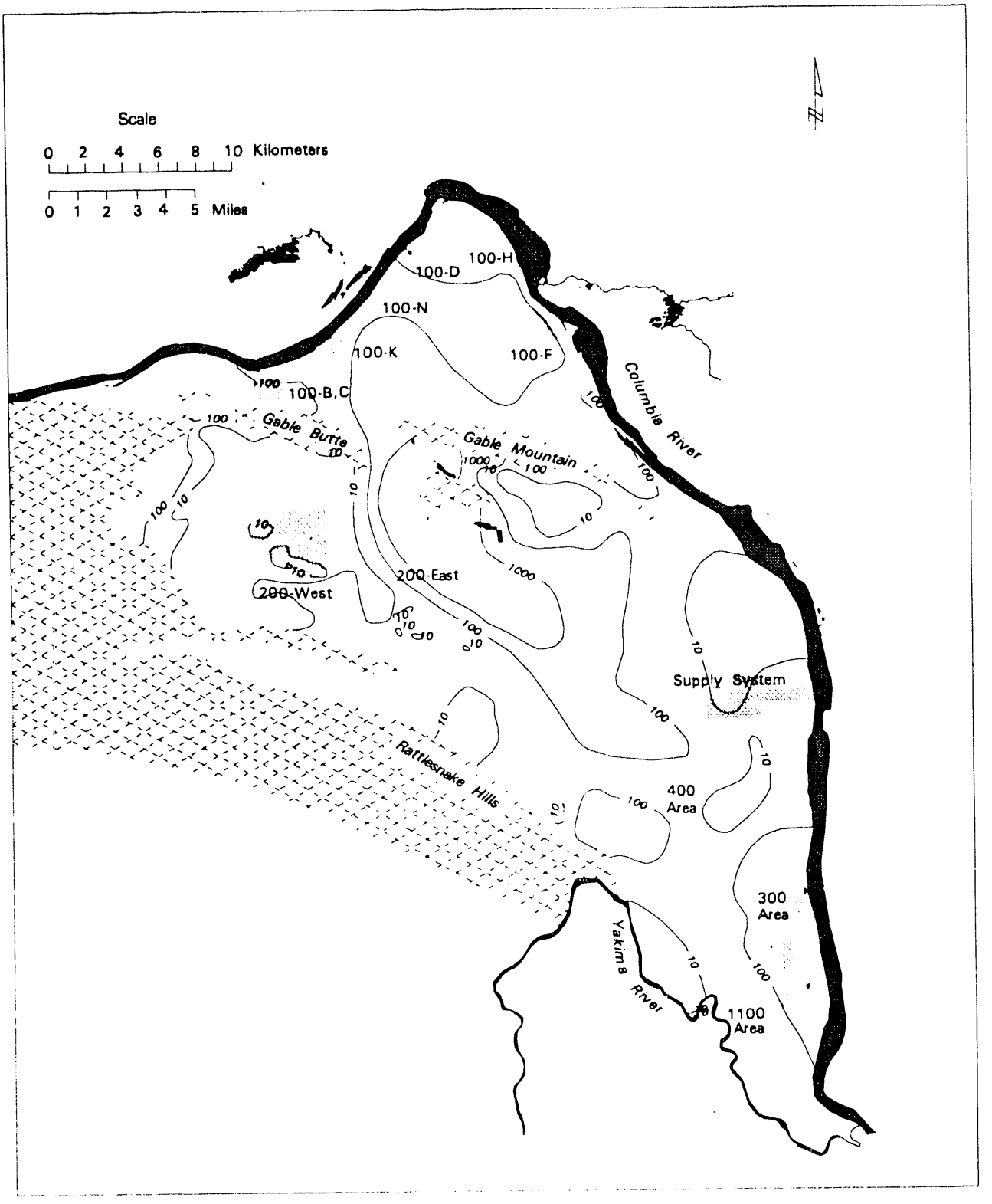



Figure 1.2. Hydraulic Conductivity Distribution for the Unconfined Aquifer (m/day)

# 2.0 Water-Level Measurements

D.R. Newcomer, F.A. Spane, Jr., W.D. Webber, and J.R. Raymond

The Site Characterization and Assessment Section, Environmental Sciences Department of PNL, prepared water-level maps of the unconfined and upper confined aquifers for the Hanford Site and outlying areas for 1992. An introduction to water-level maps of the Hanford Site and outlying areas, including how these maps can be used, is discussed below. Section 2.1 provides an overview of well constructions, water-level measurement procedures and uncertainties, and data processing associated with field data collection. Results of the 1992 water-level measurements are presented and water-table features of the Hanford Site are identified in Section 2.2. In Section 2.3, water-level changes during 1992 are discussed for several areas of the Hanford Site. Water-table features east and north of the Columbia River and the upper-confined aquifer system are described in Sections 2.4 and 2.5, respectively.

Water levels in selected wells completed in the unconfined aquifer on the Hanford Site west and south of the Columbia River are traditionally measured in June and December of each year. The purpose of these measurements is to determine the annual changes in the configuration of the water table. 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. These measurements are used to monitor water-level changes and drainage patterns associated with recharge from irrigation practices (Walters and Grolier 1960).

Water-level measurements for the unconfined aquifer were used to construct a water-table map that represents the elevation of the water-table surface. The wells used to measure water-levels were chosen based on geologic and hydrologic information available. The water-table map can be used to infer general directions of ground-water flow, particularly in the upper part of the aquifer. Similar inferences can be made from pieziometric surface maps constructed from water-level measurements in the upper confined aquifer. Ground water moves from regions of higher water potentials to regions of lower water potentials perpendicular to contours of equal potential, assuming conditions of isotropic hydraulic conductivities. Water-table maps can be used to

- identify recharge and discharge areas
- evaluate the physical influence of wastewater 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.

Production of water-table maps of the Hanford Site prior to 1991 encompassed an area bounded by the Columbia River to the north and east, the anticlinal basalt ridges (i.e., 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 the entire Hanford Site and irrigated agricultural areas north and east of the Columbia River (Newcomer et al. 1992). The region covered by the map in Plate 1 was extended so that the hydrology of the Hanford Site could be presented in the context of the regional flow system. The map area is bounded to the north by the Saddle Mountains basalt, Jackass Mountain to the east, and the Columbia and Yakima rivers to the south.

In addition to water levels measured in wells distributed across the Hanford Site, water levels were measured more intensely at four specific areas within Hanford. Included are areas around the decommissioned 216-U-10 Pond (U Pond) in the 200-West Area, 216-B-3 Pond (B Pond), 100-N Area, and the southern part of the Hanford Site, which includes the 300, 1100, and 3000 areas. The locations of these areas, including the adjacent area north and east of the Columbia River, are shown in Figure 1.1. Water-table maps of these areas are intended to enhance the definition of the water-table configuration beneath wastewater discharge facilities in the 100-N, 200, and 300 areas, and beneath irrigation lands and municipal facilities beneath the 1100 and 3000 areas. Aquifer recharge from these facilities may influence ground-water flow.

Water-level measurements and a water-table elevation map of the Hanford Site for June 1991 were presented in Newcomer et al. (1992). Semiannual water-level measurements and a water-table map of the Separations Areas, which includes 200-East and 200-West areas, and 100 Areas of the Hanford Site for December 1991 and June 1992 are presented in Kasza et al. (1992a; 1992b). Historical water-level data and an evaluation of past changes to the water-table surface are presented in Zimmerman et al. (1986) and Newcomer (1990). Water levels were measured by the U.S. Geological Survey (USGS) in Grant and Franklin counties, located north and east of the Columbia River, for 1986 to 1989 (Drost et al. 1989). A regional map of ground-water levels in materials overlying the Columbia River Basalt Group for Spring 1985, including unconfined aquifer water-level contours for the Pasco Basin, is shown in Bauer et al. (1985). Brown (1979) presented water-table maps of the Pasco Basin for 1979, one of the southern half and one of the northern half, and characterized the occurrence of unconfined ground water in the eastern part of the Pasco Basin.

## 2.1 Data Collection

During June 1992, water levels were measured in 223 wells completed in the unconfined aquifer at the Hanford Site, and 64 wells completed in the unconfined aquifer in Grant, Adams, and Franklin

counties north and east of the Columbia River. Additional measurements were taken in wells completed in the unconfined aquifer, near U Pond, B Pond, the 100-N Area, 1100 Area, 3000 Area, and the 300 Area. One hundred eighty-four water levels measured across the Hanford Site during December 1992 were used to determine water-level changes between December 1991 and December 1992.

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 (McGhan 1989). 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 generally open to the upper 3 to 6 m (10 to 20 ft) of the aquifer. This type of completion allows measurements representative of the water-table elevation. Most of the observation wells monitored by the USBR are 4, 8, 10, or 15 cm (1.5, 3, 4, or 6 in.) in diameter and are completed with perforated steel casing (Walters and Grolier 1960; personal communication, Tony Gladue, technician, USBR). Well locations for water-level monitoring are shown in Figure E.1, Appendix E.

A written procedure developed in accordance with the techniques described in American Society for Testing and Materials (ASTM 1988), U.S. Environmental Protection Agency (EPA 1986), Garber and Koopman (1968), and U.S. Geological Survey (USGS 1977) was followed to measure water levels in piezometers and wells across the Hanford Site, including the specific area around the decommissioned U Pond (PNL 1992a). Westinghouse Hanford Company used the procedure described in WHC (1989) to measure water levels at the Hanford Site, including areas around B Pond, in the 100-N Area, in the 1100 and 3000 areas, and in the 300 Area. Both PNL and WHC use calibrated steel tapes for measuring water levels and use only those standardized steel tapes that deviate in length from the calibrated steel tape by less than 0.10 ft ($\pm$ 0.10 ft). The USBR measures water levels with an electric sounding tape or a steel tape. Although no formal written procedure is documented, the USBR follows standard water-level measurement procedures.

In accordance with the water-level measurement procedure described in PNL (1992a), a chalked, standardized steel tape was used to measure the depth to the water surface in units of feet from a surveyed measuring point. These measurements were repeated to confirm the initial value. If the second measurement differed by more than 0.02 ft from the first, the water level was remeasured until two measurements within this tolerance were obtained. Measurements were compared to previous measurements of depth to water to provide a check for gross errors.

Elevation of the water table was determined by subtracting the depth-to-water measurement from the elevation of the surveyed measuring point marked on the well casing. The reference for all reported elevations is mean sea level. The elevation of the water-table surface, S, can be expressed as

$$S = E - D$$

where S = elevation of the water-table surface above mean sea level
E = elevation of surveyed measuring point above mean sea level
D = depth to the water-level surface in the piezometer or well, measured below the surveyed measuring point.

All water-level measurements from the Hanford Site and from the areas east and north of the Columbia River were collected within a one-month period (June 1992). The greatest short-term water-level changes that occur 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. Thus, there is greater uncertainty in the location of the contours adjacent to the river (Plate 1).

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.

## 2.2 Results of the 1992 Water-Level Measurements

Water levels measured on the Hanford Site and outlying areas in June 1992 are listed in Appendix A. Water levels measured on the Hanford Site during December 1992 are listed in Appendix B. Water levels measured during June 1992 for specific areas within the Hanford Site are listed in Appendix C. Water-level measurement for the upper confined aquifer are listed in Appendix D.

The Hanford Site unconfined water-table map, presented in Plate 1, was constructed by hand-contouring measured values of water-level elevations for the Hanford Site and outlying areas. The contours in Plate 1 are in units of meters and 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 are indexed in Figure E.1, Appendix E. 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. Top of basalt maps from Myers et al. (1979) were used to estimate the generalized outcrop of basalt above the water table.

In the area between the Saddle Mountains and the Columbia River extending southeast to Columbia Flat, the water-table contours are inferred from water-level data collected by the USGS in 1989 (Drost et al. 1989). Unpublished water-table maps by the USGS, using the 1989 data, indicate that the contours are controlled by the basalt surface and the topography. Comparison between 1989 and 1992 water-level data indicate that the water-table elevation in this area has not changed significantly between 1989 and 1992.

### 2.2.1 Hanford Site Water-Table Features

Elevated water levels in the western region of the Hanford Site may be attributable to ground-water recharge in Cold Creek and Dry Creek valleys and on the adjacent ridges (i.e., Yakima, Umtanum, and Rattlesnake ridges). The source of recharge is most likely infiltration of rain and snow at the higher elevations and offsite irrigation of agricultural land at the lower elevations.

The Hanford Reach is the free-flowing stretch of the Columbia River between Priest Rapids Dam and the city of Richland. Water-table elevation generally decreases toward the Columbia River at 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 abrupt change in the hydraulic gradient of the water table between the 200-West and 200-East areas is attributed to an increase in the hydraulic conductivity of the sediments from west to east (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 have been caused by process cooling water and other liquid wastes recharging the ground water at those locations. The ground-water mound beneath the 1100 Area, which is discussed later, has been caused by recharge from the city of Richland's recharge infiltration basins.

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 being recharged by the Yakima River. Water levels measured in this region also indicate that ground water recharged by the Yakima River flows to the east beneath the southern portion of the Hanford Site and discharges to the Columbia River.

## 2.3 Changes in the Hanford Site Water Table During 1992

The most prominent changes to the water table at Hanford between December 1991 and December 1992 occurred below the 200-Area plateau, which includes the decommissioned U Pond in the 200-West Area; in and adjacent to the 1100 and 3000 areas; in the upper Cold Creek Valley west of the 200 Areas; and along the Hanford Reach of the Columbia River, which includes the 100 and 300 areas. Contours of the water-level changes for these and other areas of the Hanford Site are presented in Figure 2.1. The latest summary of wastewater discharges to disposal facilities in the 200 and 600 Areas is presented by WHC (1992).

### 2.3.1 200 Areas

The elevation of the water table beneath the 200-Area plateau declined between December 1991 and December 1992. The largest changes occurred in the 200-West Area near decommissioned U Pond, where the water table declined approximately between 0.36 m (1.2 ft) and 0.75 m (2.5 ft). Hydrographs for wells in the 200-West Area are presented in the section below on the decommissioned U Pond. Hydrographs of wells 299-E23-2Q, 299-E32-02, and 299-E34-02 indicate that the water table in the 200-East Area declined approximately 0.3 m (1 ft) between December 1991 and December 1992 (Figure 2.2). These water-level changes are also reflected in areas downgradient from the 200-Area plateau. Hydrographs of well 699-60-60 (Figure 2.3), located in the gap between Gable Butte and Gable Mountain, and well 699-20-20 (Figure 2.4), located southeast of the 200-East Area, also show declining water levels.

The water-level declines in the 200 Areas are primarily attributed to 1) an overall decrease in wastewater 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 wastewater 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, as discussed below.

### 2.3.2 216-B-3 Pond

A map of the water table influenced by 216-B-3 Pond (B Pond), presented in Figure 2.5, indicates a ground-water mound, which implies radial flow beneath B Pond. Hydrographs of wells 699-39-39, 699-40-39, 699-41-40, 699-42-40B, and 699-43-43 shown in Figure 2.6, indicate that the water-table elevation remained fairly steady between December 1991 and December 1992. However, the hydrograph of well 699-42-40B indicates that the water level rose approximately 0.3 m (1 ft) at the center of the ground-water mound during the last quarter of the calendar year. The annual volume of waste water discharged to B Pond has decreased from 2.22E+10 L in 1988 to 7.48E+09 L in 1991 (Cooney and Thomas 1989; Brown et al. 1990; WHC 1992).

A water-table map of B Pond for June 1991 is presented in Newcomer et al. (1992). Water-table maps of the Separations Areas for December 1991 and June 1992, which include the B Pond area, are presented in Kasza et al. (1992a; 1992b).

### 2.3.3 Decommissioned U Pond

A map of the water table beneath the decommissioned U Pond is presented in Figure 2.7. This map indicates that ground water flows radially, mostly to the north and east from an area near the 216-U-14 Ditch, located east-northeast of the decommissioned U Pond. This ditch continues to receive wastewater (WHC 1992). The total discharge of wastewater to ground in the 200-West Area

is far below that during the operation of U Pond (WHC 1992; Newcomer 1990). The water-table map for the Hanford Site and outlying areas in Plate 1 indicates that the ground-water mound in this area has influenced regional ground-water flow.

The elevation of 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 elevation of the ground-water level beneath the decommissioned U Pond, as reflected in the water level in well 299-W18-15, decreased as much as 5.7 m (18.7 ft) between June 1984 (RHO 1984) and January 1992. Between December 1991 and December 1992, the elevation of the ground-water level decreased as much as 0.76 m (2.5 ft), as reflected in the water level in well 299-W23-11. The decline in the elevation of the ground-water level beneath the deactivated U Pond has been observed in wells throughout the 200-West Area.

Hydrographs of wells 299-W10-13, 299-W18-21, 299-W19-12, and 299-W19-32 are presented in Figure 2.8 and hydrographs of wells 299-W11-10, 299-W23-11, and 699-37-78A are presented in Figure 2.9. These plots indicate that water levels in the 200-West Area declined between December 1991 and December 1992. The locations of these wells are shown in Figure 2.7.

A water-table map of the deactivated U Pond area for June 1991 is presented in Newcomer et al. (1992). Water-table maps of the Separations Areas for December 1991 and June 1992, which include the deactivated U Pond area, are presented in Kasza et al. (1992a; 1992b).

### 2.3.4 1100 and 3000 Areas

Ground water beneath the 1100 and 3000 areas generally flows from west to east toward the Columbia River (see Plate 1). The primary sources of recharge are the ground-water recharge basins associated with the North Richland wellfield and recharge from irrigation in the 3000 Area and west and southwest of the 1100 Area. The sources of pumping are the North Richland wellfield and wells used for irrigation.

A water-table map of the 1100 and 3000 areas, illustrated in Figure 2.10, indicates that operation of the North Richland wellfield and associated recharge basins influences the water table. However, water levels in neighboring monitoring wells varied less in 1992 than in previous years. Figure 2.11 shows a hydrograph of well 699-S40-E14 for calendar year 1992. The hydrograph indicates that the water level did not vary more than about 1 m (3 ft). Well 699-S40-E14 is located on the western edge of the recharge basins (see Figure 2.10).

In the vicinity of the wellfield and recharge basins, the water table was approximately 1 to 2 m lower in June 1992 than in June 1991. A map of the June 1991 water levels indicates a ground-water mound in this area, which forms a radial flow pattern superimposed on the regional flow direction toward the Columbia River (Newcomer et al. 1992). However, the water-table map for June 1992 indicates a diminished ground-water mound in this area (see Figure 2.10).

At the North Richland wellfield, water is pumped from the intake structure at the Columbia River and piped to a system of basins (ICF 1987), which recharges the unconfined aquifer. Water is then pumped from the aquifer via the wellfield for the city's water-supply system. This system is primarily used between January and March each year when the filtration plant is shut down for maintenance and during the summer months to supplement the city's water supply. Throughout the year, recharge exceeds pumping by approximately two times (personal communication, Stan Arlt, Water and Waste Utilities Director, City of Richland). The wellfield consists of 11 wells for pumping (ICF 1987).

Ground-water levels in the 1100 and 3000 areas are influenced by irrigation practices. The sources of irrigation water are the Columbia River and a shallow pumping well near two wells informally called EC-1 and W-1 (see Figure 2.10). Hydrographs of water levels in wells 699-S31-1, 699-S34-E10, 699-S41-E11, and EC-1 for January 1990 to January 1993 are shown in Figures 2.12, 2.13, 2.14, and 2.15. These wells are located around the perimeter of the irrigated fields west and southwest of the 1100 Area, between Horn Rapids Landfill and Lamb-Weston's potato-processing plant. Hydrographs of wells 699-S34-E10, 699-S41-E11, and EC-1 indicate annual water-level fluctuations primarily in response to recharge from irrigation practices west and southwest of the 1100 Area. The water level in well 699-S31-1, located approximately 3.2 km (2 miles) west of the Horn Rapids Landfill along the northern perimeter of the irrigation fields (see Figure E.1, Appendix E), rose 0.2 m (0.6 ft) between December 1991 and December 1992.

### 2.3.5 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. A hydrograph of well 699-43-104 is shown in Figure 2.16. This well is located downvalley from the irrigation fields in upper Cold Creek Valley (see Figure E.1, Appendix E). The hydrograph indicates that the water table declined steadily during 1992. The water level declined approximately 0.5 m (1.6 ft) between December 1991 and December 1992. Water levels in this well have declined since about 1988. It is hypothesized that the declining water level in this well is responding to less irrigation water recharging the unconfined aquifer because of changes in irrigation practices by St. Michelle Vineyards. Between 1982 and 1983, St. Michelle Vineyards converted their irrigation system from a sprinkler system to drip irrigation, which reduced consumptive use by 40 to 50% (Newcomer 1990). The observed water-level decline may also be responding to dissipation of the ground-water mound beneath the 200-West Area.

### 2.3.6 Hanford Reach

Water-level changes also occurred in wells near the Columbia River. Water levels have been observed to fluctuate several feet in response to the rise and fall of the river stage. These changes are the result of pressure waves transmitted from the river to the unconfined aquifer, but also include bank storage effects. Hydrographs showing the influence of the river stage on the unconfined aquifer at various locations along the Columbia River are presented in Newcomb and Brown (1961), Jensen (1987), Liikala et al. (1988), Schalla et al. (1988), Fruland and Lundgren (1989), and McMahon and

Peterson (1992). The Columbia River stage changes in response to releases at the Priest Rapids Dam upstream from the Hanford Reach and to seasonal influences. The river stage downstream from the 300 Area is also influenced by the pool of Lake Wallula. Ground water in the 100 and 300 areas is heavily influenced by river stage fluctuations; therefore water-level changes in these areas will be discussed below.

### 2.3.7 100 Areas

The Hanford Site water-table map indicates that ground water flows north through the gaps between Umtanum Ridge and Gable Butte and between Gable Butte and Gable Mountain and passes beneath the 100 Areas. Ground-water elevations in the 100 Areas are primarily influenced by changes in Columbia River stage.

Water-level elevations of the 100 Areas for June 1992 are shown in Plate 1. Hydrographs of wells 199-N-27, 199-D2-5, 199-H3-1, whose water levels are influenced by river stage, are presented in Figures 2.17, 2.18, and 2.19 for January 1990 to December 1993.

The total volume of waste-water effluent currently discharged to the ground in the 100 Areas was approximately 2.62E+9 L for 1991 (WHC 1992). In the 100-N Area, the volume of recent waste-water effluents is less than that when N Reactor was operating. Ground-water mounding caused by recharge from liquid waste disposal facilities in the 100-N Area has diminished since the N Reactor went on standby (Newcomer et al. 1992). A water-table map of the 100-N Area for June 1992 is shown in Figure 2.20.

Water-table maps of the 100 Areas for December 1991 and June 1992, are presented in Kasza et al. (1992a; 1992b). A water-table map of the 100-N Area for June 1991 is presented in Newcomer et al. (1992).

### 2.3.8 300 Area

A water-table map of the 300 Area for June 1992 is shown in Figure 2.10. The water-table contours 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 to the ground-water elevation in the 300 Area is changes in Columbia River stage.

The water table beneath the 300 Area is also influenced by recharge from process effluents. The process trenches receive the largest volume of process water in the 300 Area. In 1991, the process trenches received 1.3E+9 L (WHC 1992). The configuration of the water table is dependent on these influences.

The water table declined approximately 0.15 m (0.5 ft) in most of the 300 Area between December 1991 and December 1992. This decline is primarily the result of the change in Columbia River stage. A hydrograph for well 399-8-1, shown in Figure 2.21, illustrates that the primary water-

level response to the river stage occurred during spring of 1992. A water-table map of the 300 Area for June 1991 is presented in Newcomer et al. (1992).

## 2.4 Water-Table Features East and North of the Columbia River

The dominant pattern of unconfined ground-water flow in the outlying areas 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. Bauer et al. (1985) reported that lateral water-table gradients appear to be approximately equal to or slightly less than the structural gradients on the flanks of the anticlines or where the basalt is steeply dipping. Plate 1 depicts steep water-table gradients on the flanks of the Saddle Mountains anticline. Bauer et al. (1985) indicated that water-table conditions are sometimes found to exist in the uppermost basalt flows, but did not identify specific locations where these conditions exist. The water-table aquifer lies within sediments overlying the basalt in these areas.

The water-table configuration is heavily influenced by recharge from irrigation practices in the region between the Columbia River and the basalt anticlinal ridges. The effects of human-induced recharge on the water-table configuration are shown by the downgradient contour flexures and ground-water mounding in Plate 1.

The outlying 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 consists of 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 east to near Eltopia. The other principal area of irrigation is the northern part of the basin on Wahluke Slope between the Columbia River and the Saddle Mountain anticline. In these district areas water available for recharging the unconfined aquifer includes leakage from canals and wasteways, the runoff from irrigated land, discharge or spillover of excess water from irrigation canals, and the from the irrigated land itself (Brown 1979). Pumping from wells tapping 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.

An area of increased ground-water flux in the South Columbia Basin Irrigation District is in Ringold Coulee, where Pasco gravels reside on the coulee floor (Brown 1979). Brown (1979) reported that runoff from spring discharge at the mouth of Ringold Coulee is probably over 0.6 $m^3s^{-1}$. Water-level data indicate that the hydraulic gradient is steep along the edge of the coulee, where the topography changes abruptly. Ground water in the coulee flows southwest from the area north of Ringold Coulee, between Othello and Eagle Lakes and Scooteney Reservoir (see Plate 1).

Othello is located approximately 12.8 km (8 miles) north of Eagle Lakes. Elsewhere in the irrigation district, the unconfined aquifer lies in the less permeable Ringold Formation.

The water-table map in Plate 1 shows a steep hydraulic gradient along the edge of the Columbia River where the White Bluffs rise above the river. Because of the abrupt topographic elevation change between the Columbia River and the top of the bluffs, the water-level rise in the irrigated areas has resulted in the formation of a series of springs issuing from White Bluffs. The steep hydraulic gradient is illustrated in Figure 2.22, which shows a cross section of the water table and land surface between well 699-43-104 in Cold Creek Valley and well 12/30 30R01 east of Owens flat. Figure 2.22 shows that the gradient of the water table is steep between the Columbia River and Owens flat, but gentle between the Columbia River and Cold Creek Valley.

Water-table contours along the Wahluke Slope north of the Columbia River are inferred because of limited data (i.e., lack of wells to measure water level). However, other available sources of information were used to infer the contours. Across the Columbia River from the 100-N and 100-K areas, the elevation of ponds and seeps in the Saddle Mountain Natural Wildlife Refuge, used in conjunction with topographic elevations, indicates 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. The shape of the flexures and the ground-water mound near Columbia flat are consistent with those on a water-table map previously published in Newcomer et al. (1992).

Irrigation on the Wahluke Slope and the area east of the Columbia River has caused development of extensive perched ground water (Brown 1979). Perched water is also a source for spring discharge along the White Bluffs. The extent of perched conditions is not well defined because few wells tap the perched aquifers.

Esquatzel Coulee, like Ringold Coulee, is an area of increased ground-water flux, as indicated by the water-table contours in Plate 1. South of the irrigation district between the Esquatzel Diversion channel and the Columbia River near Pasco lies the Pasco Greenbelt Area. In spite of extensive ground-water withdrawal from wells for irrigation, the water table in the Pasco Greenbelt Area has risen in the past in response to drainage from the South Columbia Irrigation District (Brown 1979). The water-table contours in Plate 1 indicate that ground water flows south from the district to the Pasco Greenbelt Area.

Figure 2.23 shows that the hydraulic gradient becomes less steep as ground water enters the Pasco Greenbelt Area before discharging to the Columbia and Snake rivers. The highly permeable Pasco gravels are the most prominent sediments of the unconfined aquifer in the Pasco Greenbelt Area and are the principal reason for the lower water-table gradient (Brown 1979).

## 2.5 Upper-Confined Aquifer System

Figure 2.24 shows a preliminary potentiometric map and inferred ground-water flow patterns for the upper-confined aquifer system for September 1992. The map was developed from water-level measurements obtained from 28 onsite wells that comprise the upper-confined aquifer monitoring network. Wells within the network are monitored for water-level elevations on a quarter-annual frequency. Additional information from six wells previously completed within the upper-confined aquifer system were also utilized qualitatively to construct the potentiometric map.

Salient hydrogeologic features shown in Figure 2.24 for the upper-confined aquifer system include:

- a prominent, broad recharge mound extending northeastward from the Yakima Ridge - 200-West Area
- a small recharge mound immediately east of the 200-East Area, in the vicinity of B Pond
- the presence of a low hydraulic head (potential discharge) region in the Umtanum Ridge - Gable Mountain structural area
- a high hydraulic head region to the north and east of the Columbia River, which is associated with recharge attributed to agricultural activities in these areas.

The potentiometric map for the upper-confined aquifer is consistent with the areal head pattern indicated for the Mabton interbed, which is a deeper and more areally extensive confined aquifer underlying the Hanford Site (Spane 1987; DOE 1988). Similar conclusions are reported by WHC (1993) using a more limited data set. Efforts during fiscal year 1993 will include acquisition of offsite water-level information in the region south and east of the Hanford Site, to improve the definition of areal ground-water flow conditions in these areas.

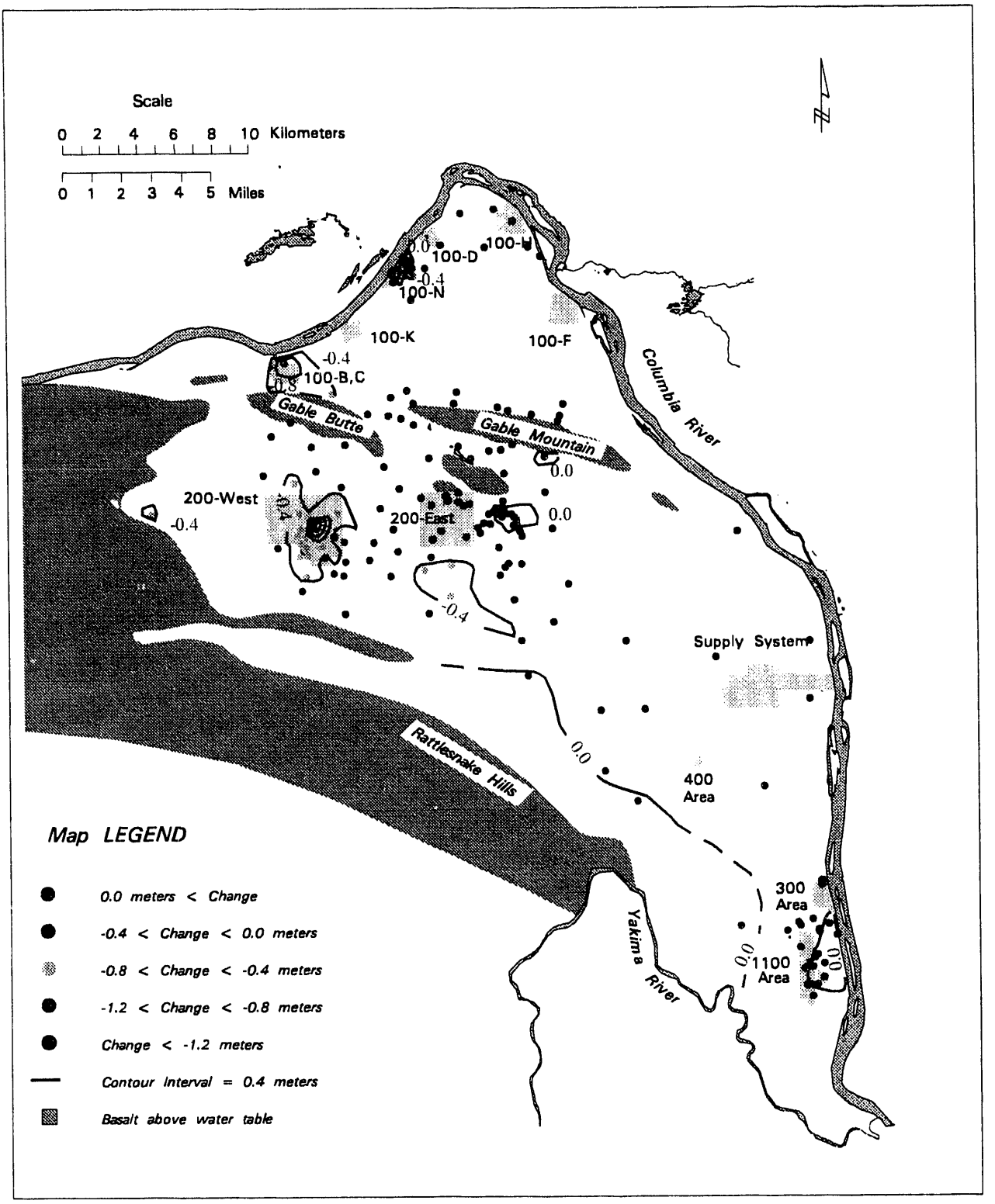



**Figure 2.1.** Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1991 and December 1992

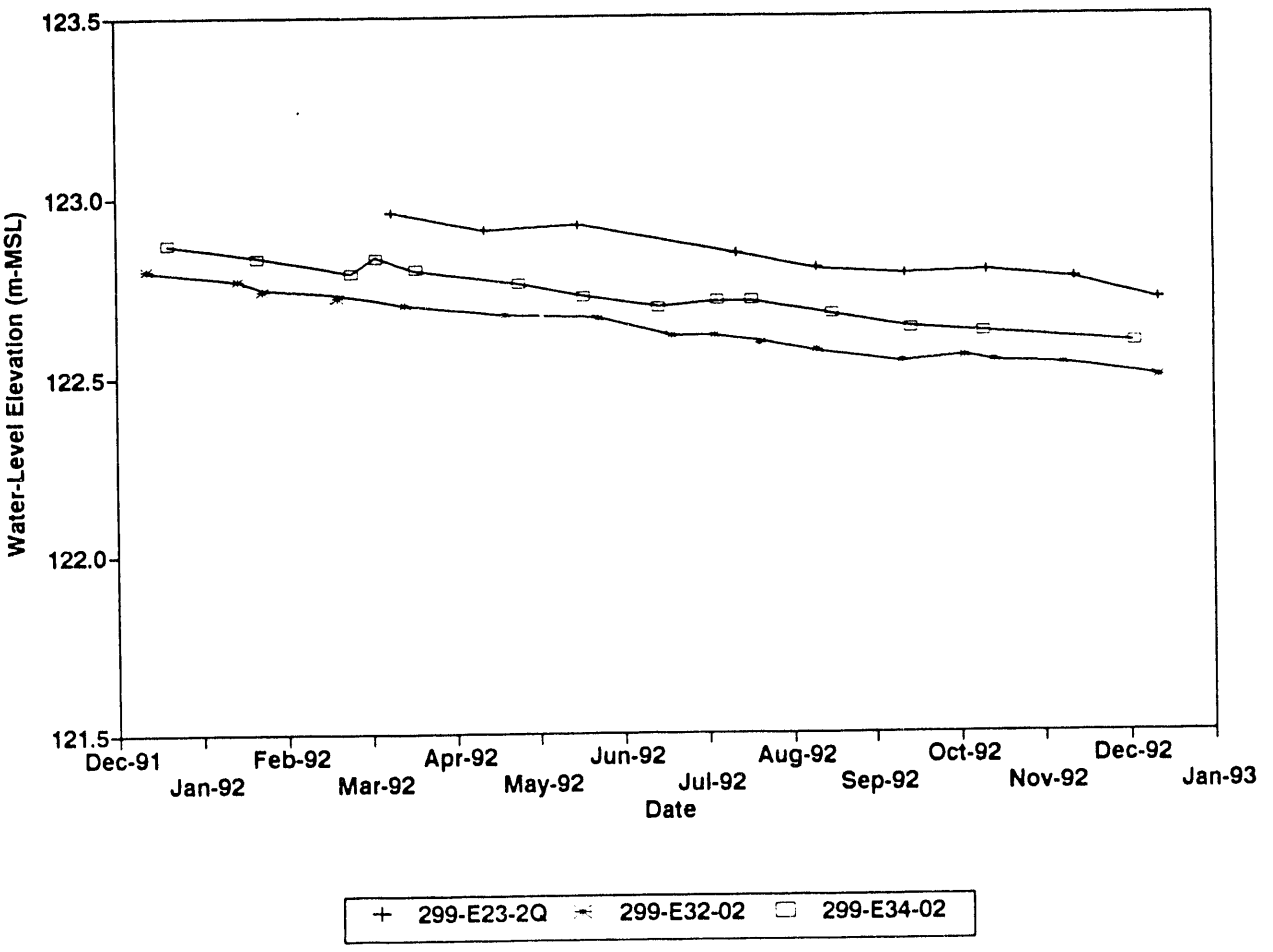



**Figure 2.2.** Hydrograph of Wells 299-E23-2Q, 299-E32-02, and 299-E34-02

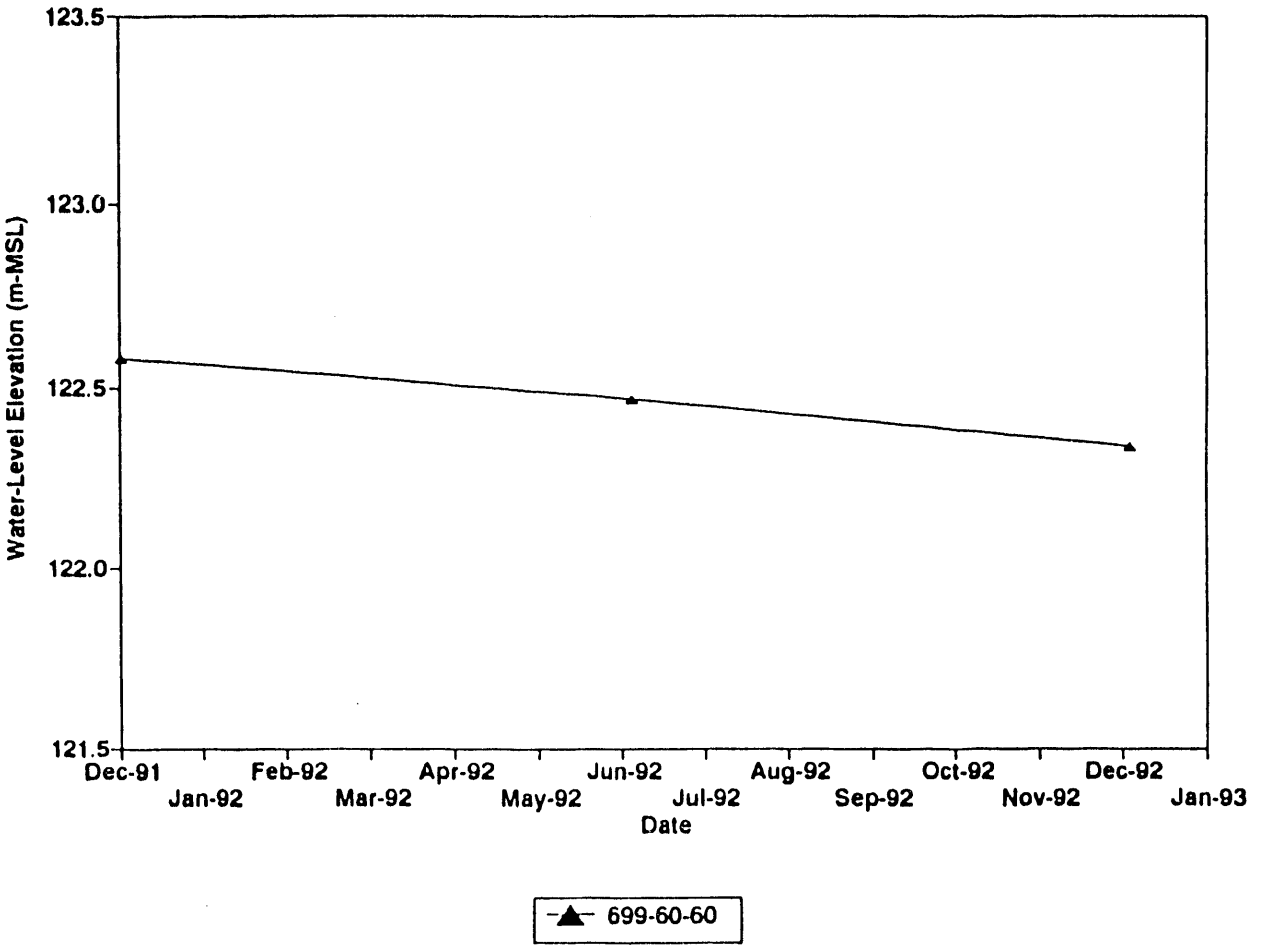



**Figure 2.3.** Hydrograph of Well 699-60-60

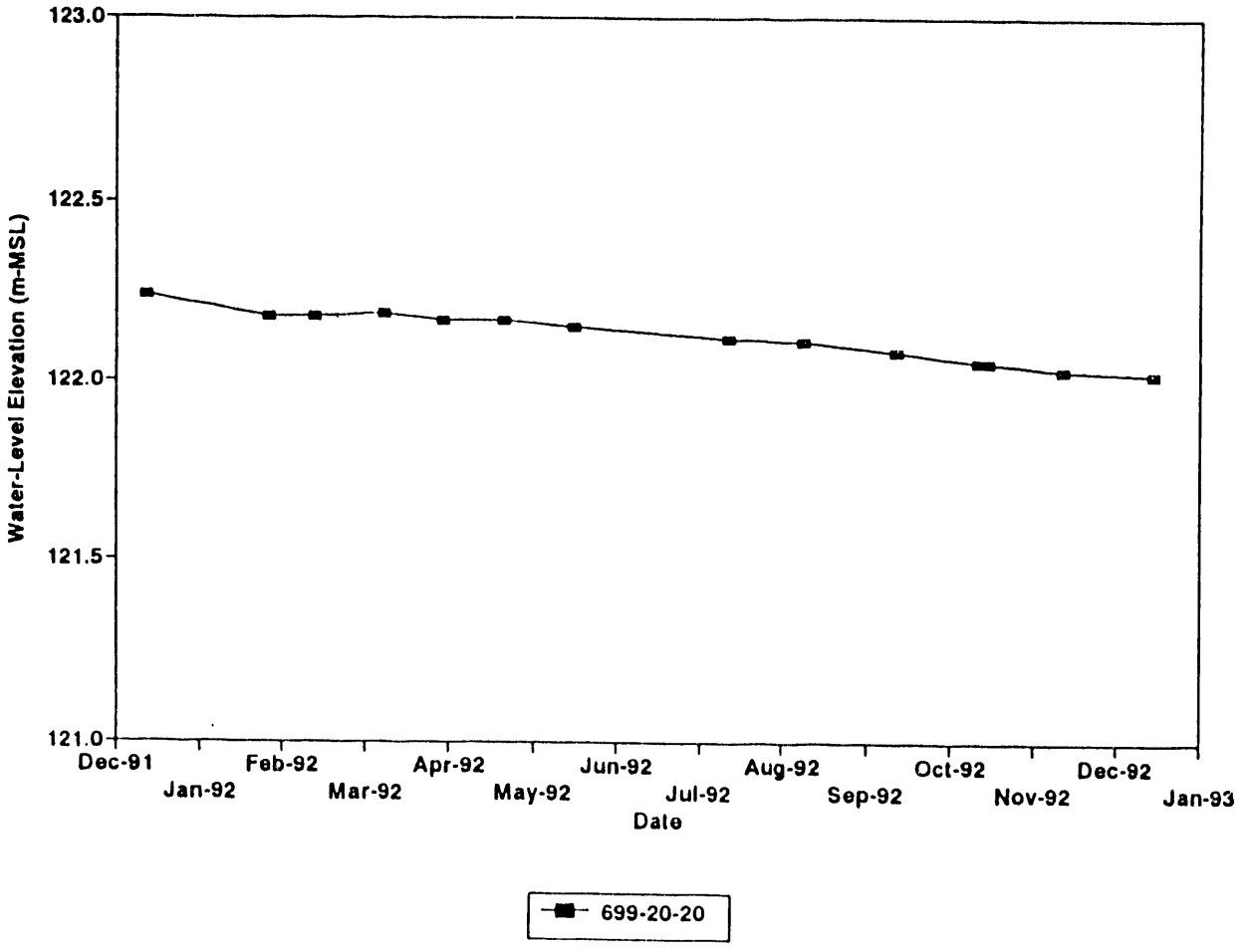



**Figure 2.4.** Hydrograph of Well 699-20-20

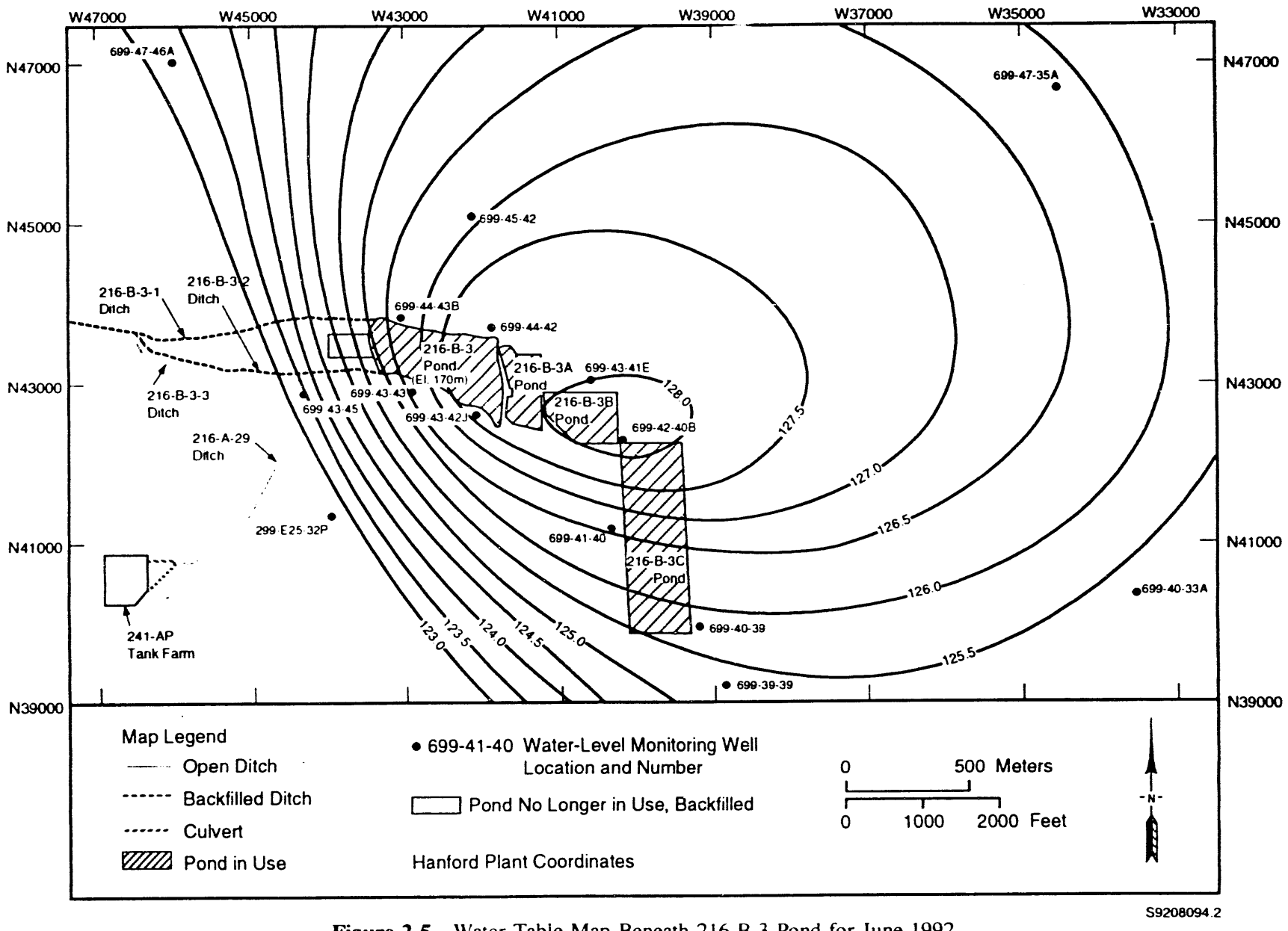



**Figure 2.5.** Water-Table Map Beneath 216-B-3 Pond for June 1992

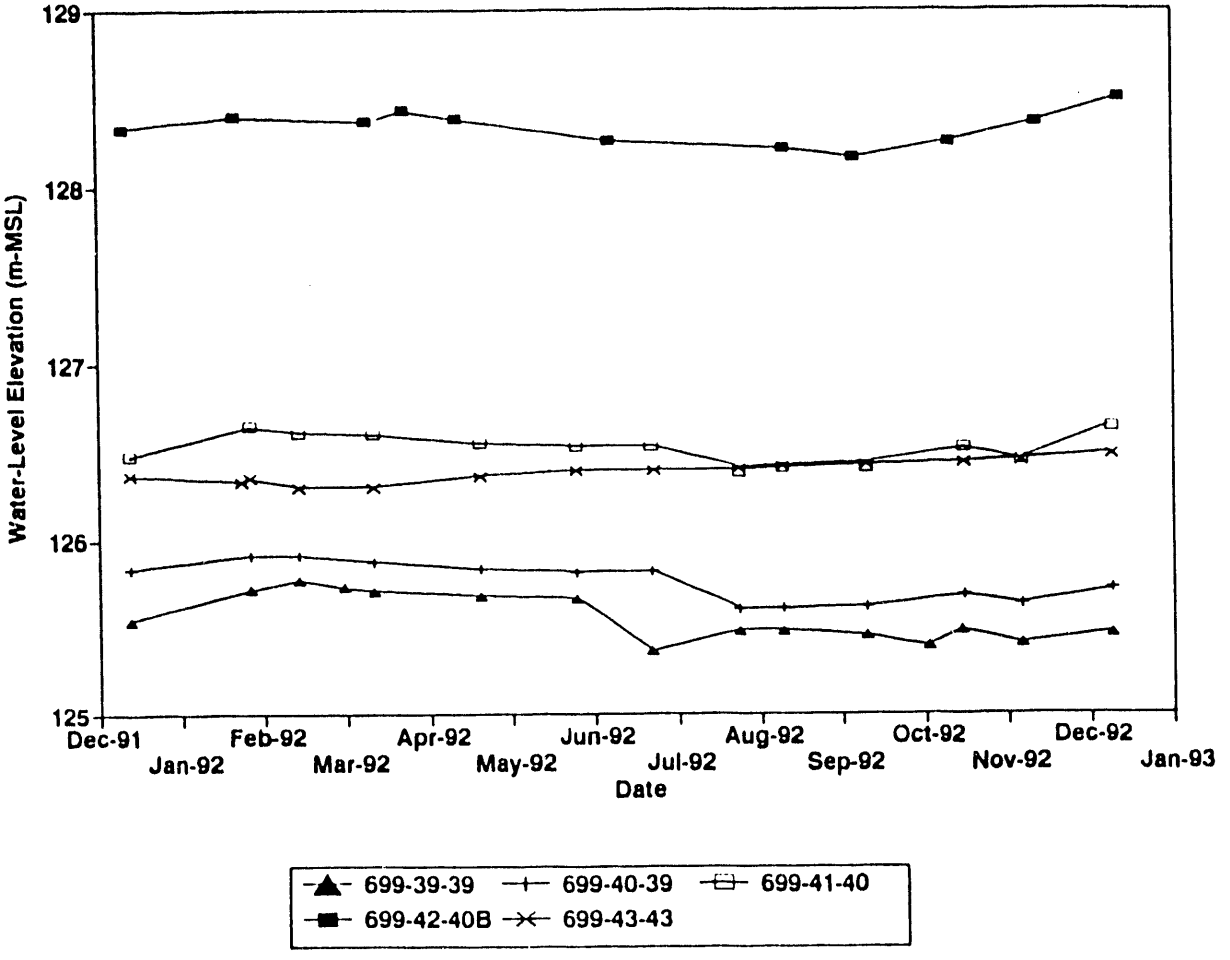



**Figure 2.6.** Hydrograph of Wells 699-39-39, 699-40-39, 699-41-40, 699-42-40B, and 699-43-43

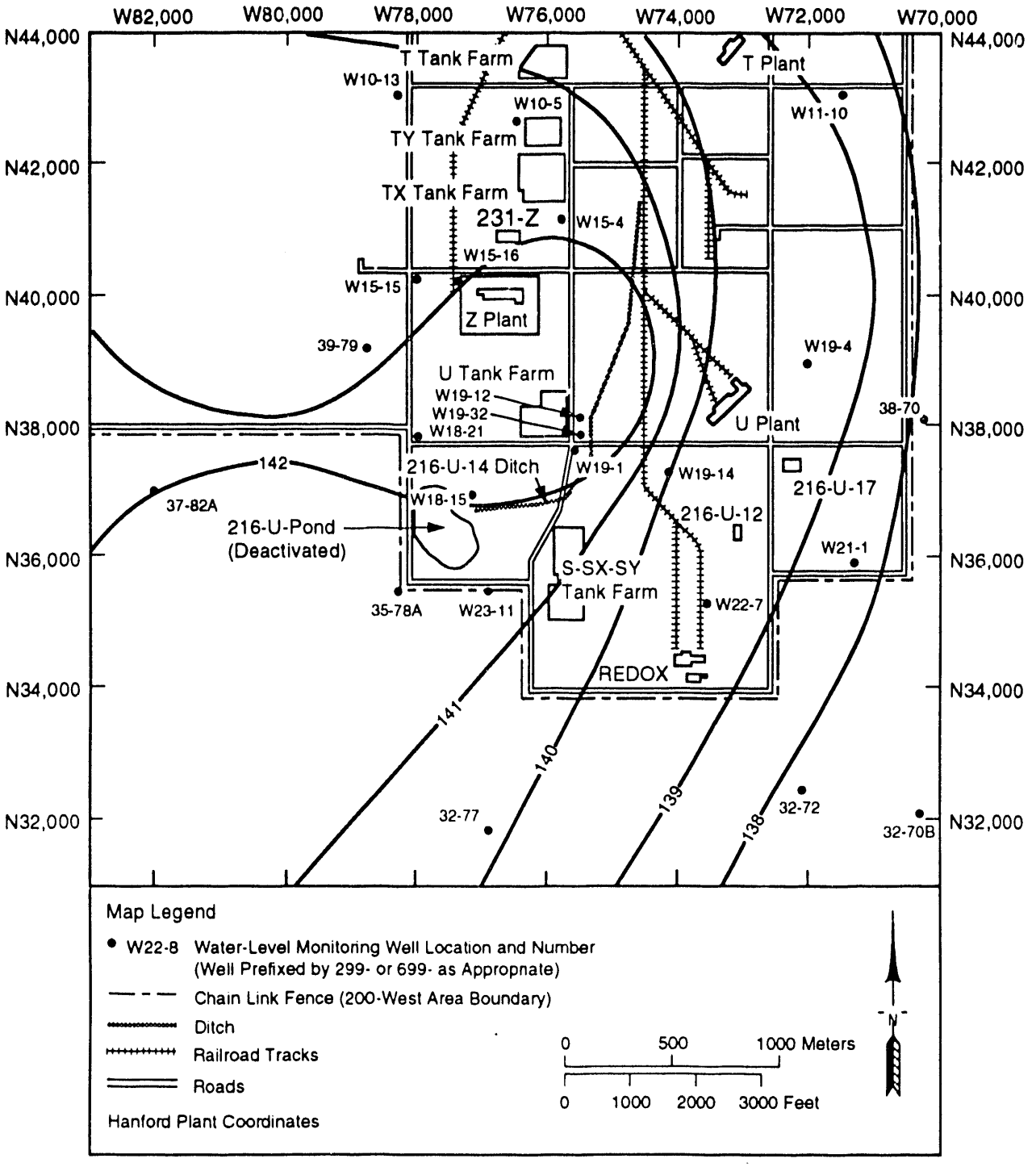



**Figure 2.7.** Water-Table Map of the Area Beneath the Decommissioned U Pond in the 200-West Area for June 1992

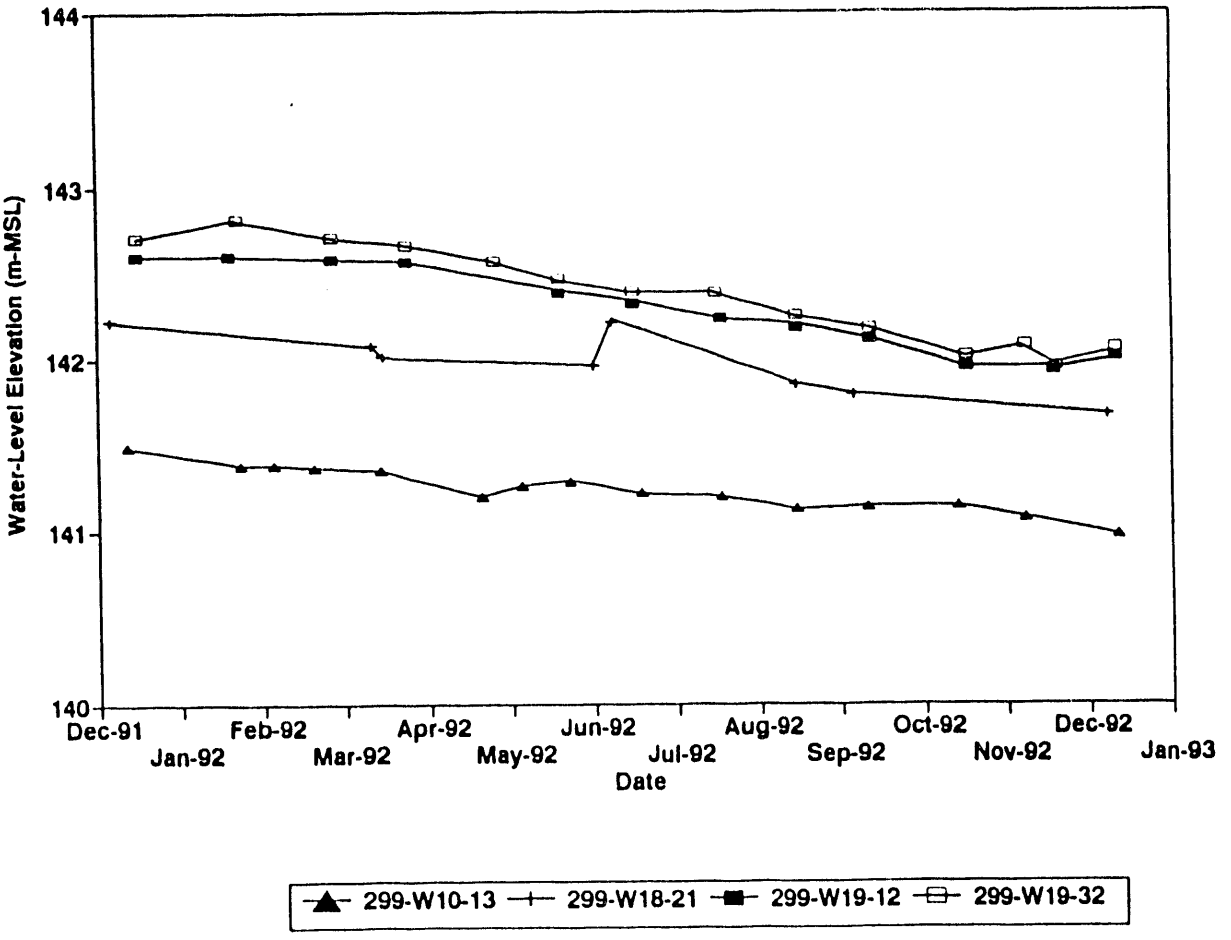



Figure 2.8. Hydrograph of Wells 299-W10-13, 299-W18-21, 299-W19-12, and 299-W19-32

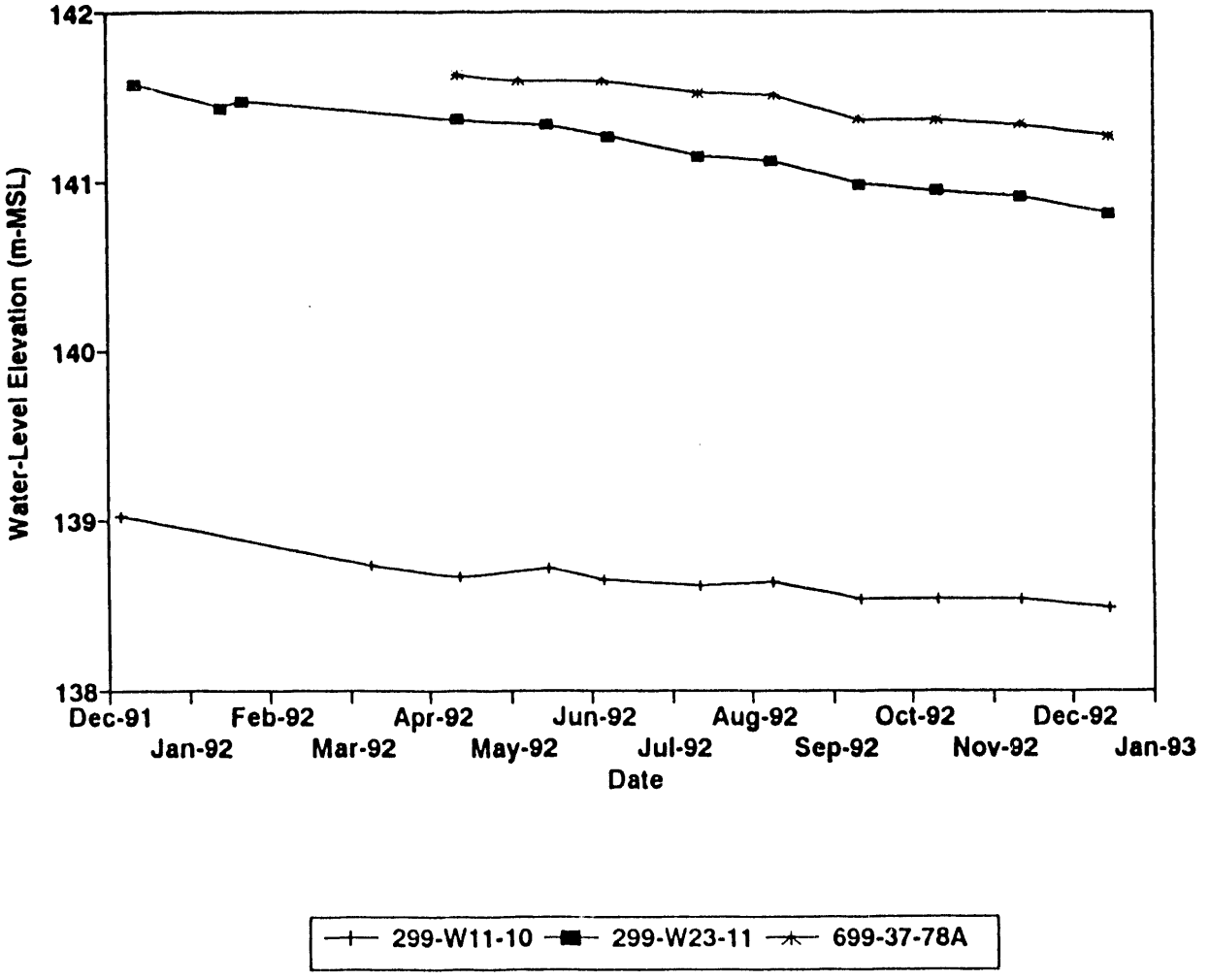
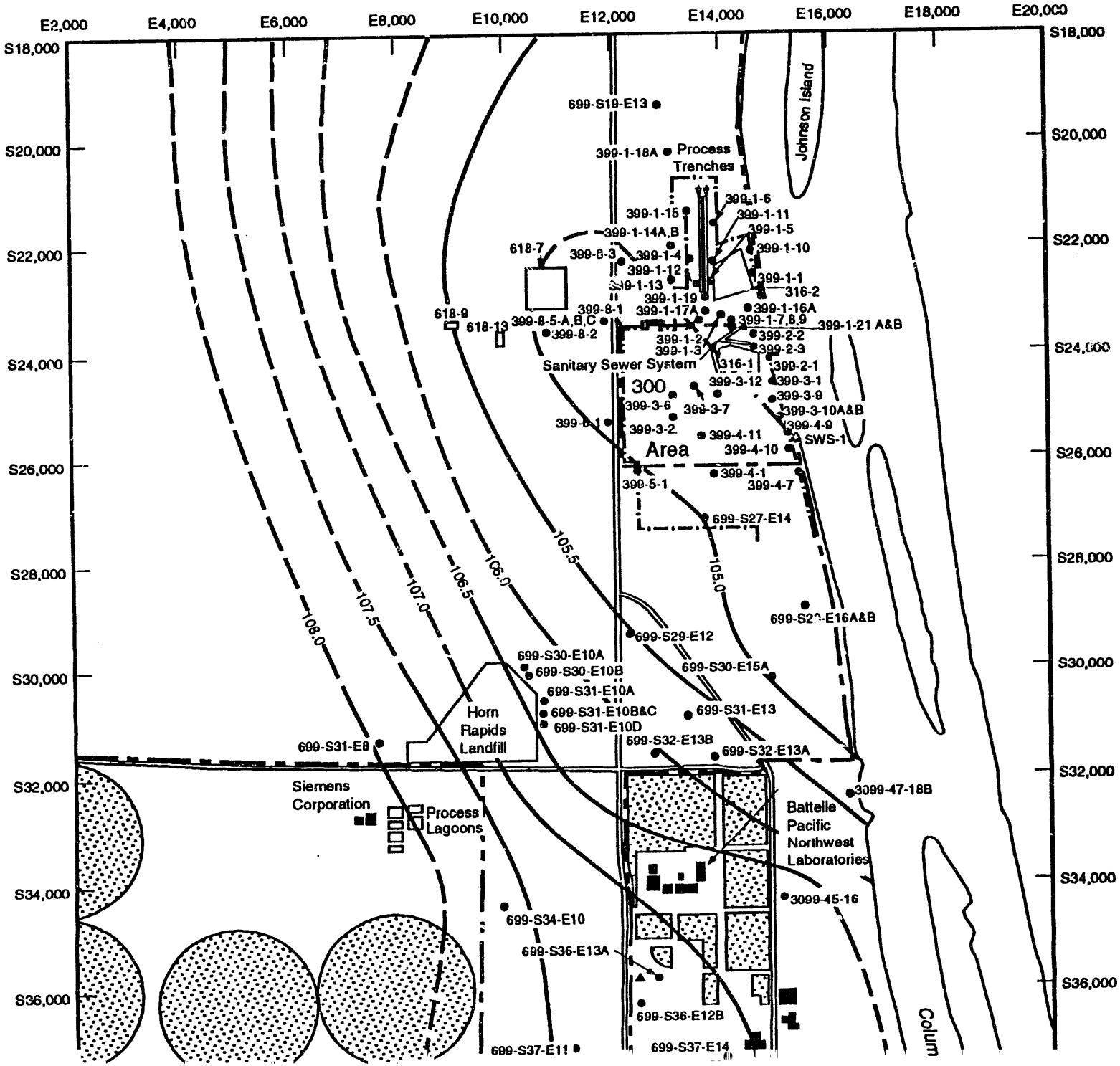



**Figure 2.9.** Hydrograph of Wells 299-W11-10, 299-W23-11, and 699-37-78A


E2,000
E4,000
E6,000
E8,000
E10,000
E12,000
E14,000
E16,000
E18,000
E20,000
S18,000
S20,000
S22,000
S24,000
S26,000
S28,000
S30,000
S32,000
S34,000
S36,000
Johnson Island
699-S19-E13
399-1-18A
Process Trenches
399-1-6
399-1-15
399-1-11
399-1-14A,B
399-1-5
618-7
399-8-3
399-1-4
399-1-10
399-1-12
399-1-13
399-1-1
316-2
399-1-19
399-1-16A
618-9
618-13
399-8-5-A,B,C
399-8-1
399-1-17A
399-1-7,8,9
399-1-21 A&B
399-8-2
399-2-2
399-1-2
399-1-3
399-2-3
Sanitary Sewer System
316-1
399-2-1
300
399-3-12
399-3-1
399-3-9
399-3-6
399-3-7
399-3-10A&B
399-3-2
399-4-11
399-4-9
SWS-1
Area
399-4-10
399-4-1
399-5-1
399-4-7
699-S27-E14
105.5
105.0
108.0
107.5
107.0
106.5
106.0
699-S29-E12
699-S30-E10A
699-S30-E10B
699-S30-E15A
699-S31-E10A
699-S31-E10B&C
699-S31-E13
699-S31-E10D
Horn Rapids Landfill
699-S31-E8
699-S32-E13B
699-S32-E13A
Siemens Corporation
Process Lagoons
3099-47-18B
Battelle Pacific Northwest Laboratories
3099-45-16
699-S34-E10
699-S36-E13A
699-S36-E12B
699-S37-E11
699-S37-E14

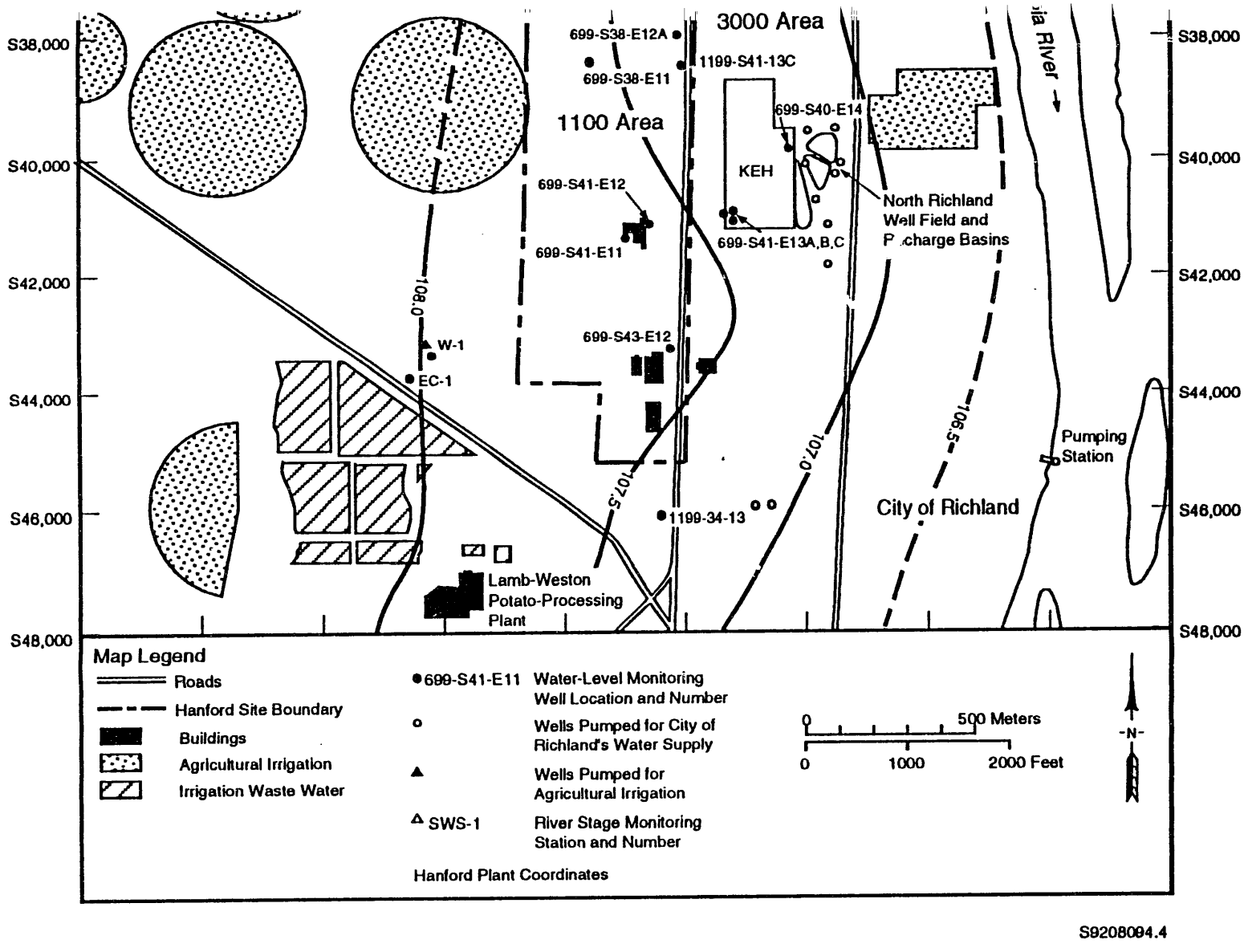



**Figure 2.10.** Water-Table Map Beneath the 300, 1100, and 3000 Areas for June 1992

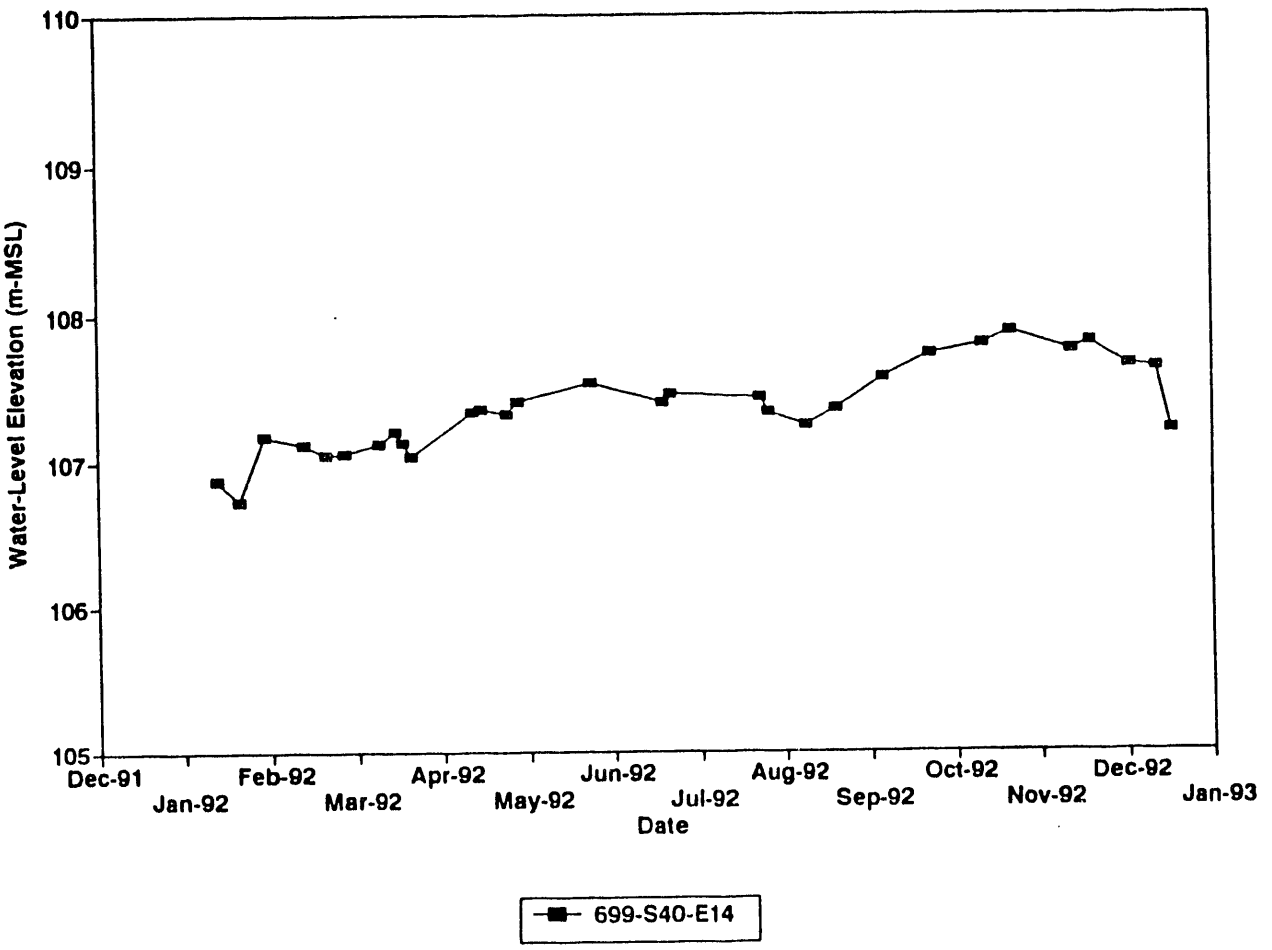



**Figure 2.11.** Hydrograph of Well 699-S40-E14

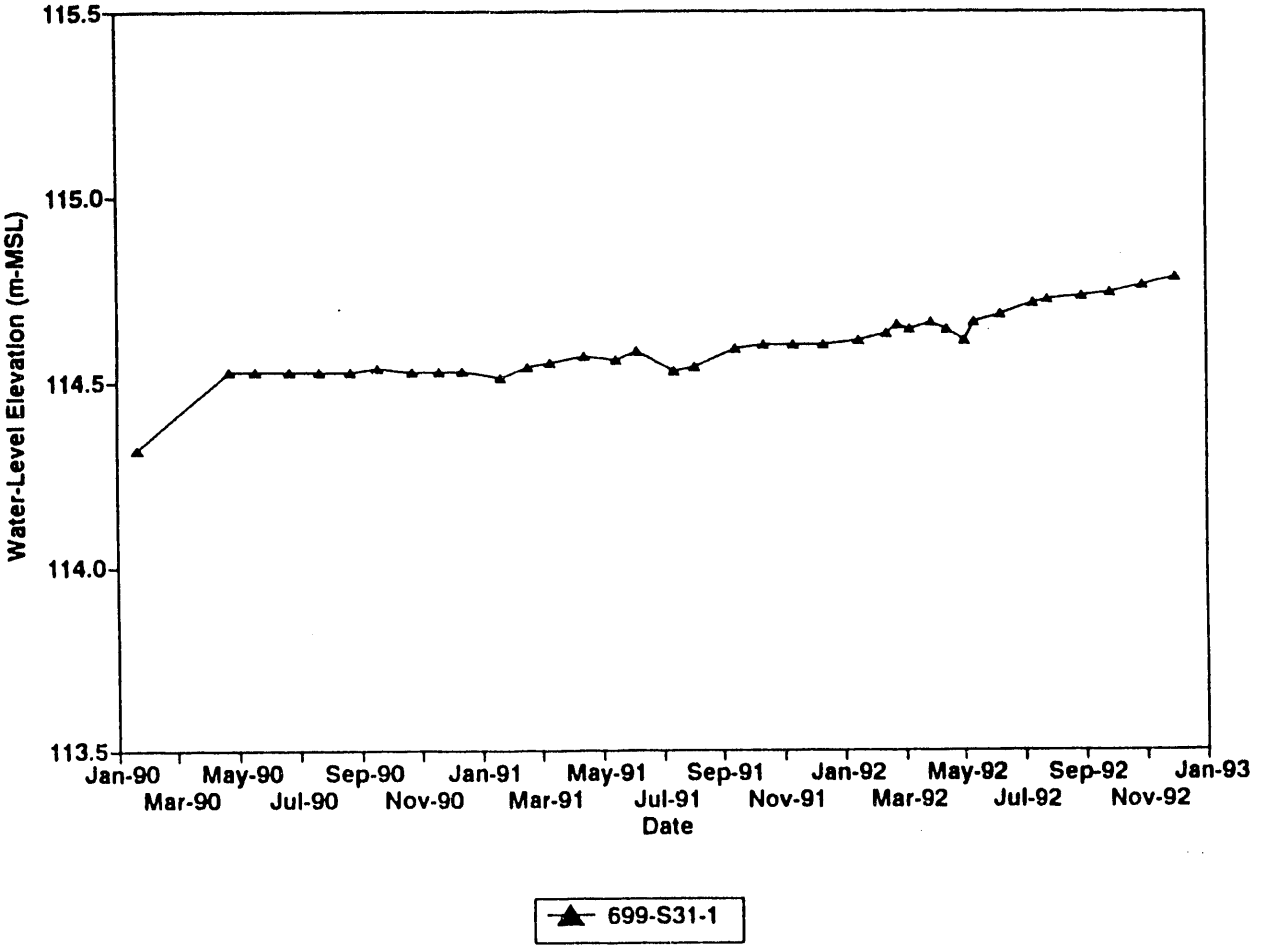



**Figure 2.12.** Hydrograph of Well 699-S31-1

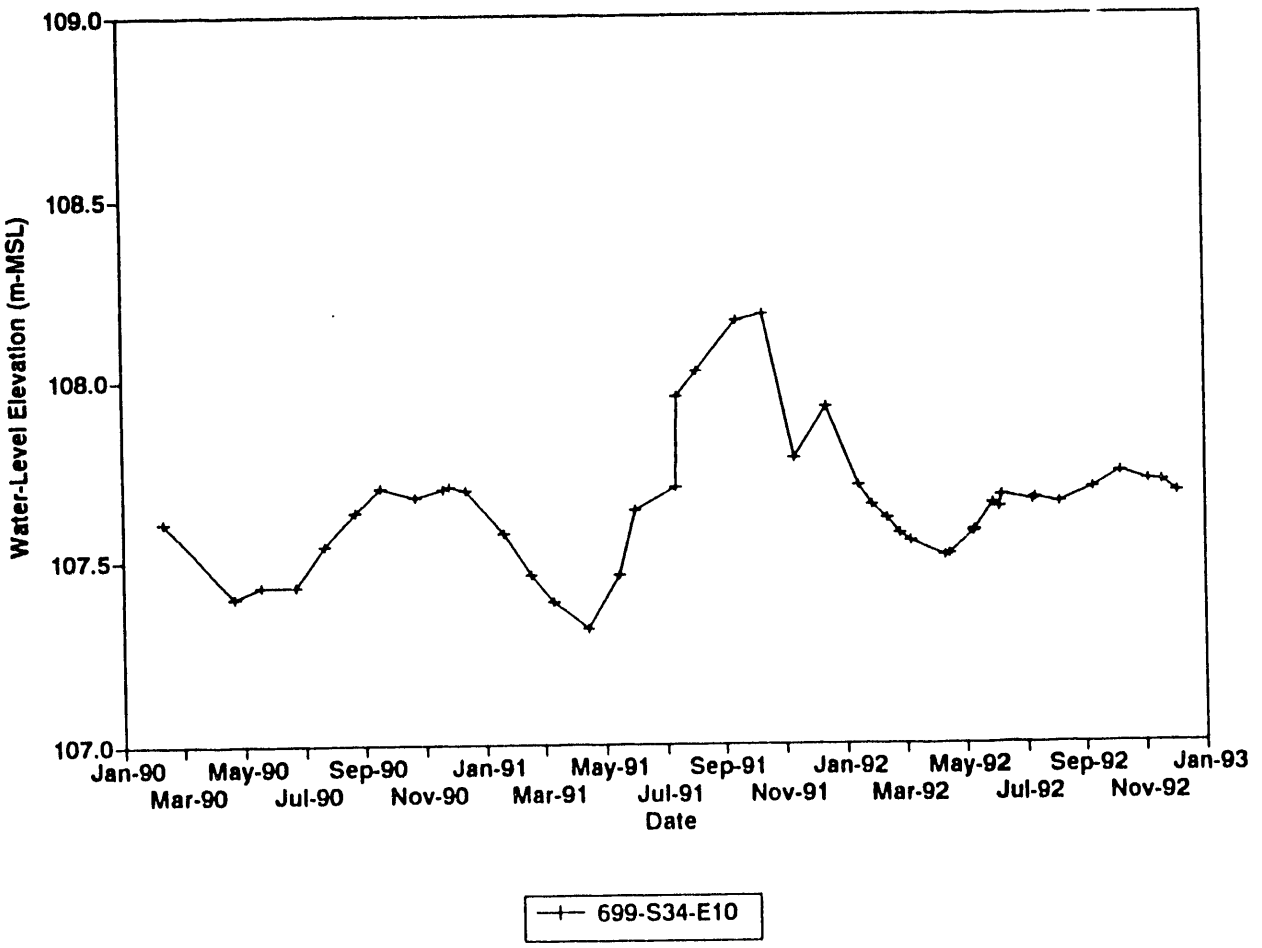



**Figure 2.13.** Hydrograph of Well 699-S34-E10

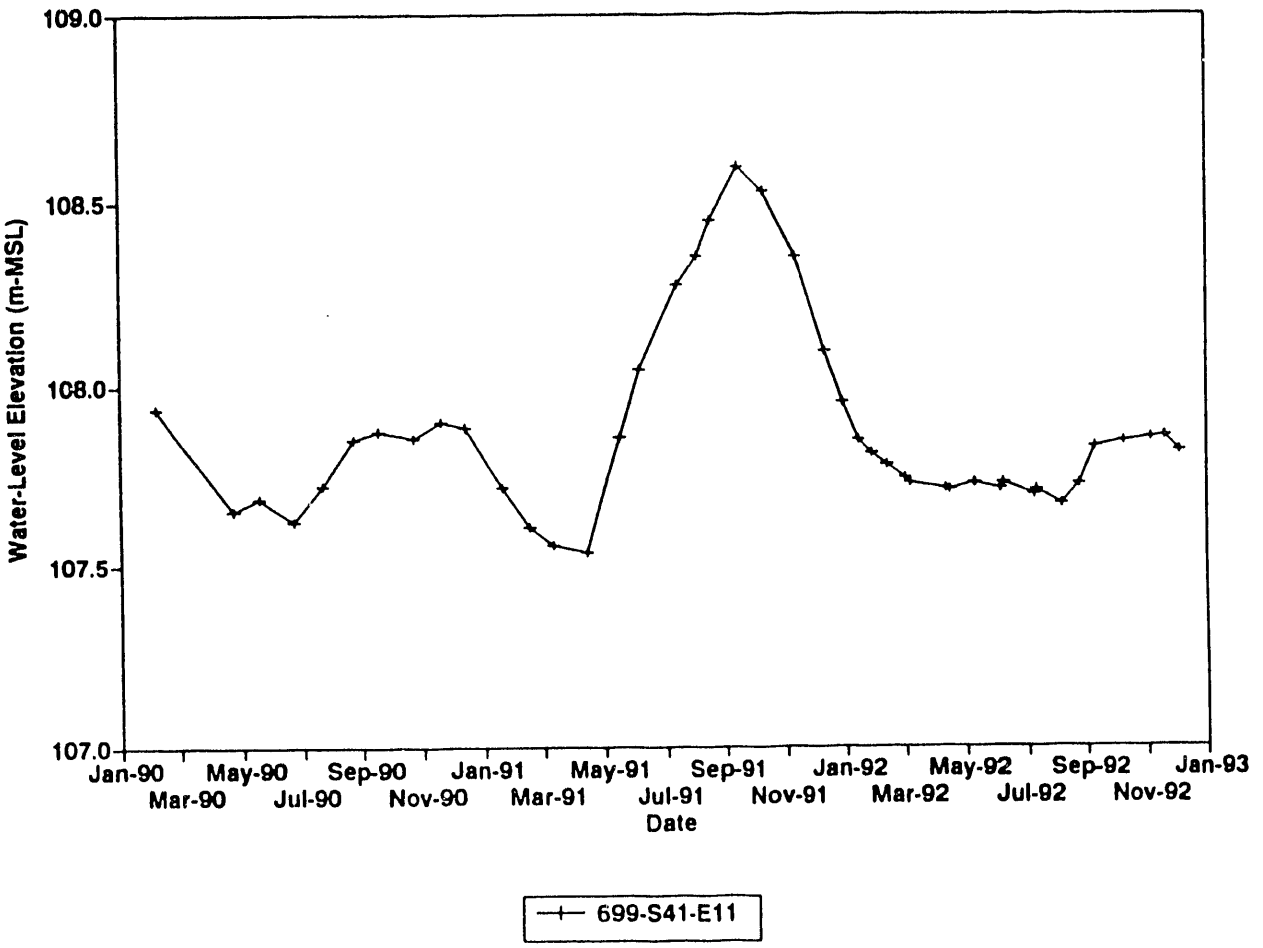



**Figure 2.14.** Hydrograph of Well 699-S41-E11

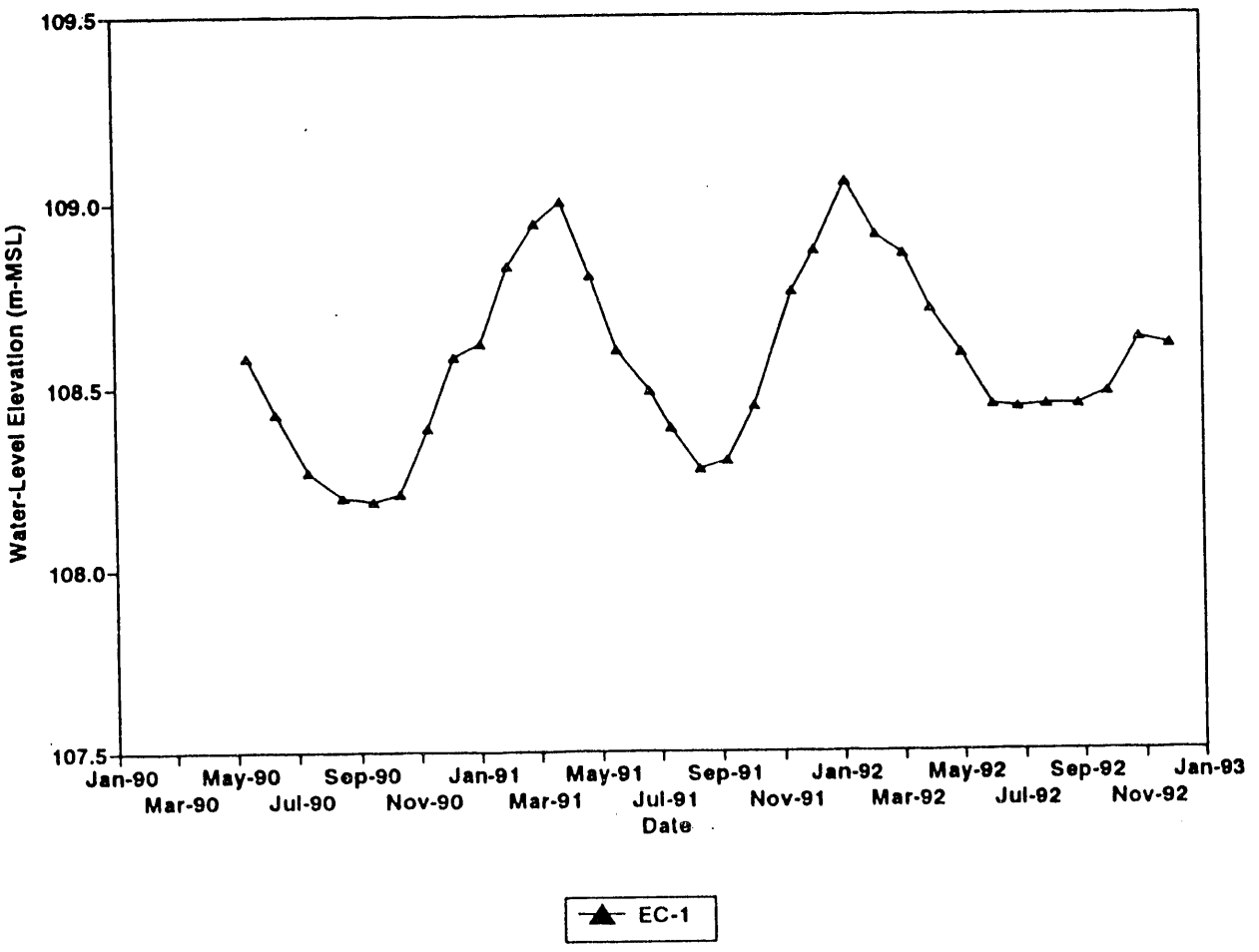



**Figure 2.15.** Hydrograph of Well EC-1

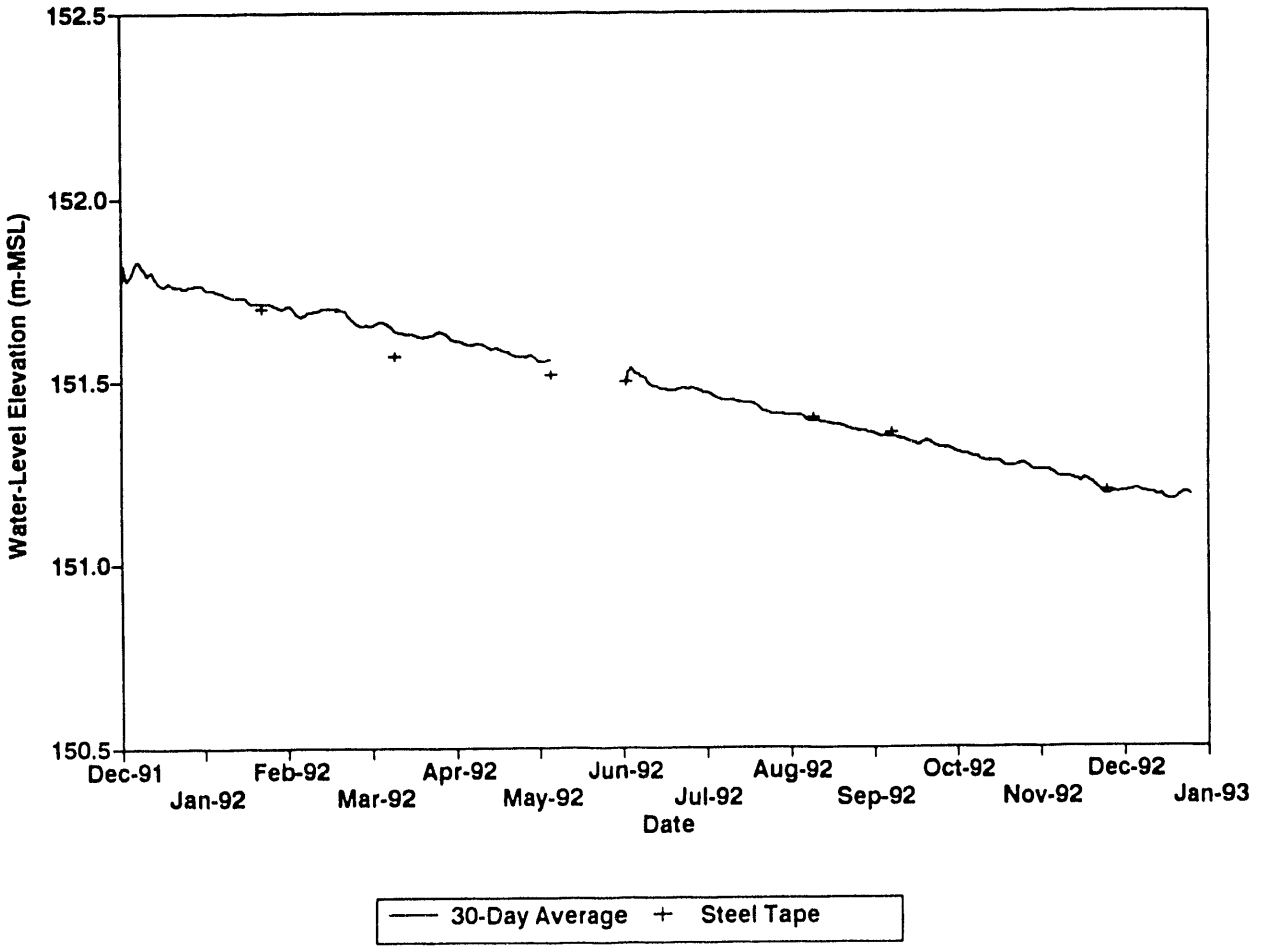



**Figure 2.16.** Hydrograph of Well 699-43-104

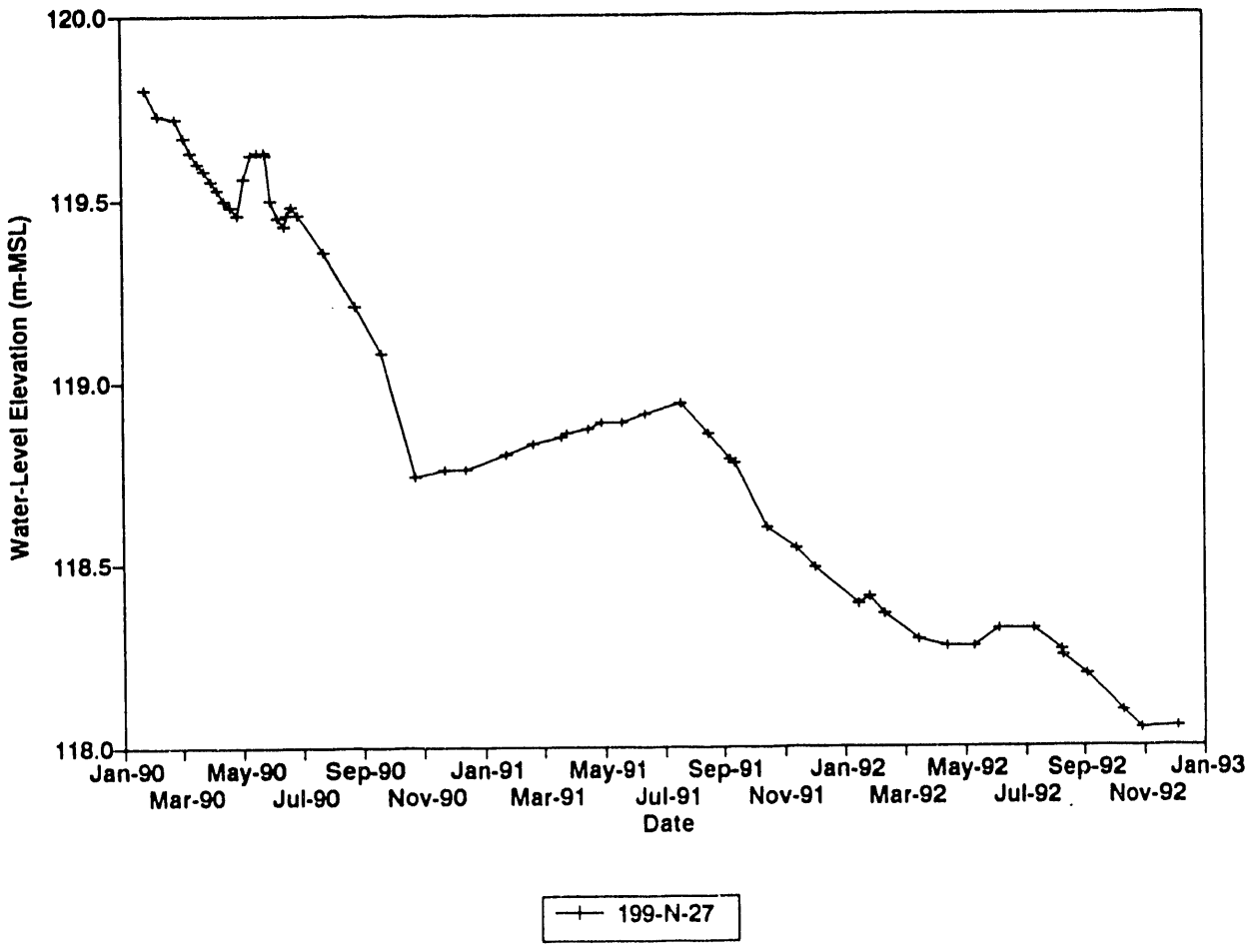



**Figure 2.17.** Hydrograph of Well 199-N-27

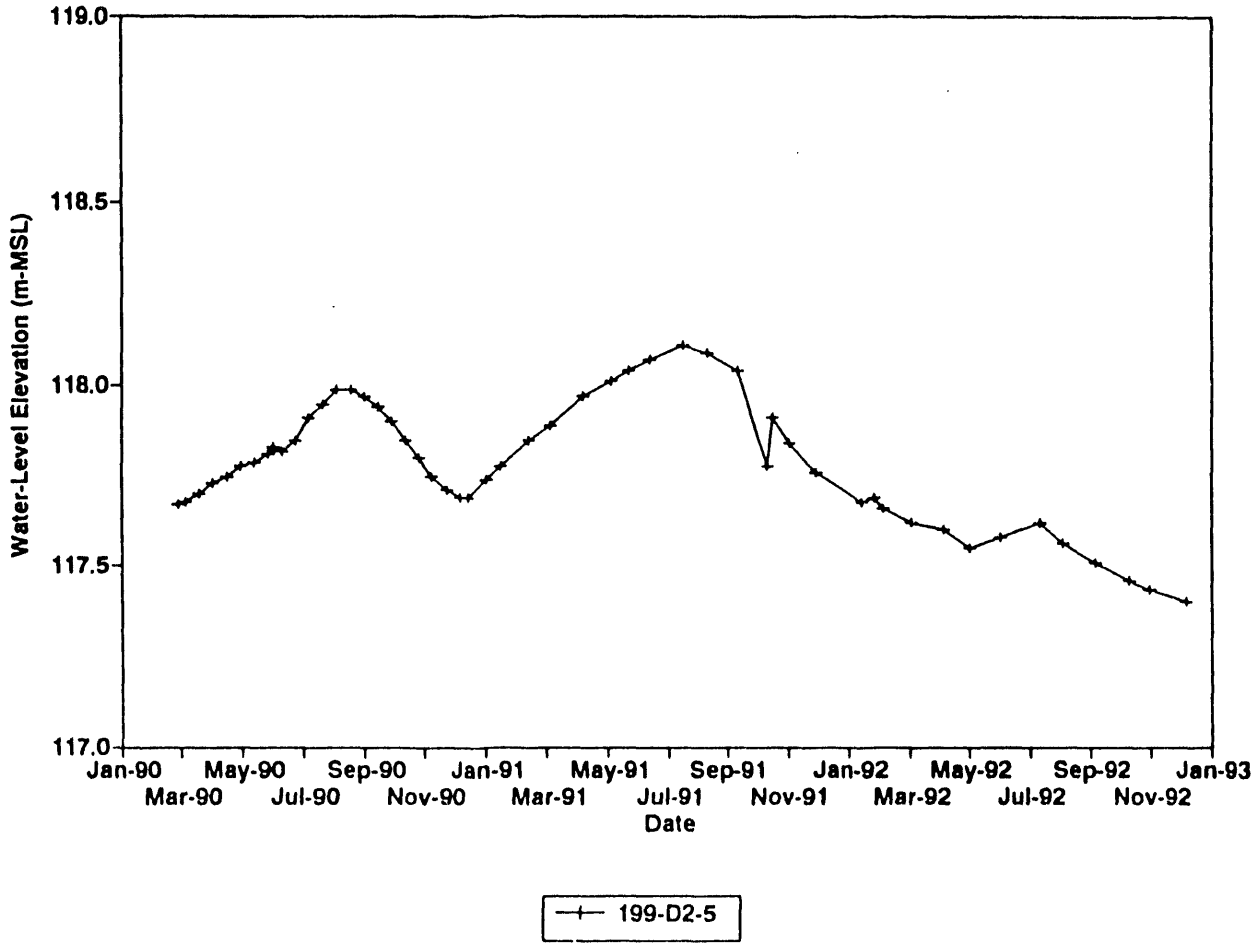



**Figure 2.18.** Hydrograph of Well 199-D2-5

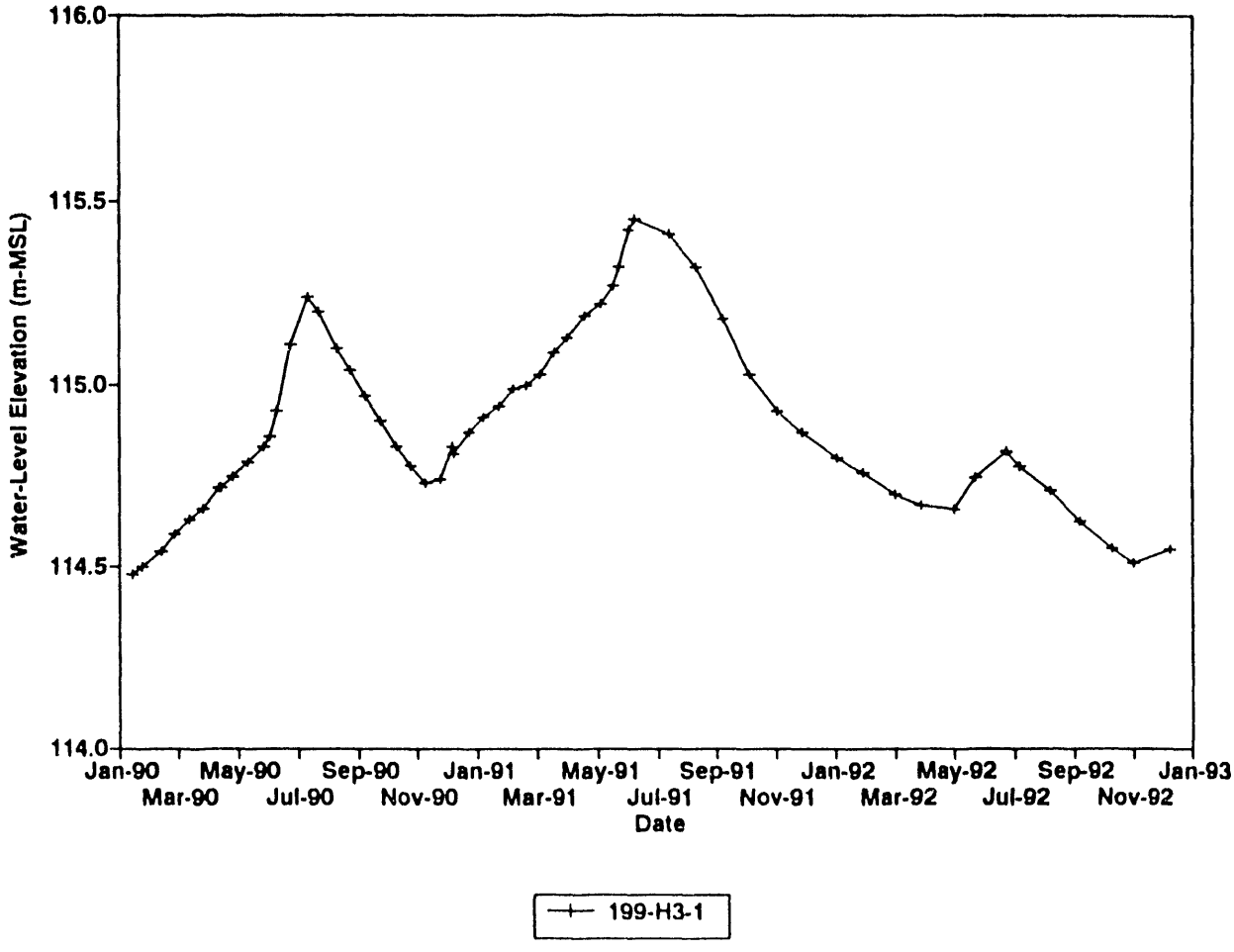



**Figure 2.19.** Hydrograph of Well 199-H3-1

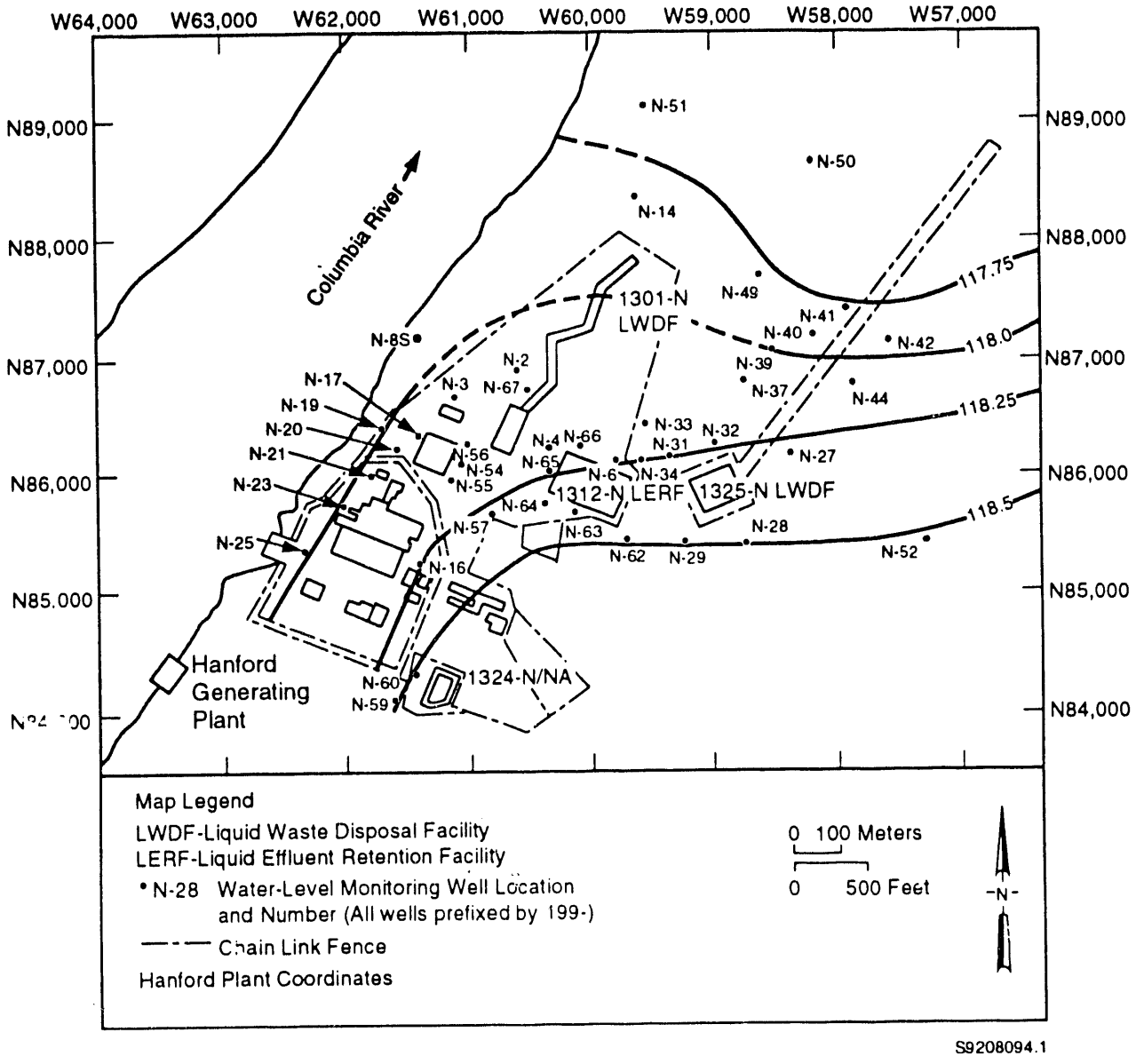



**Figure 2.20.** Water-Table Map Beneath the 100-N Area for June 1992

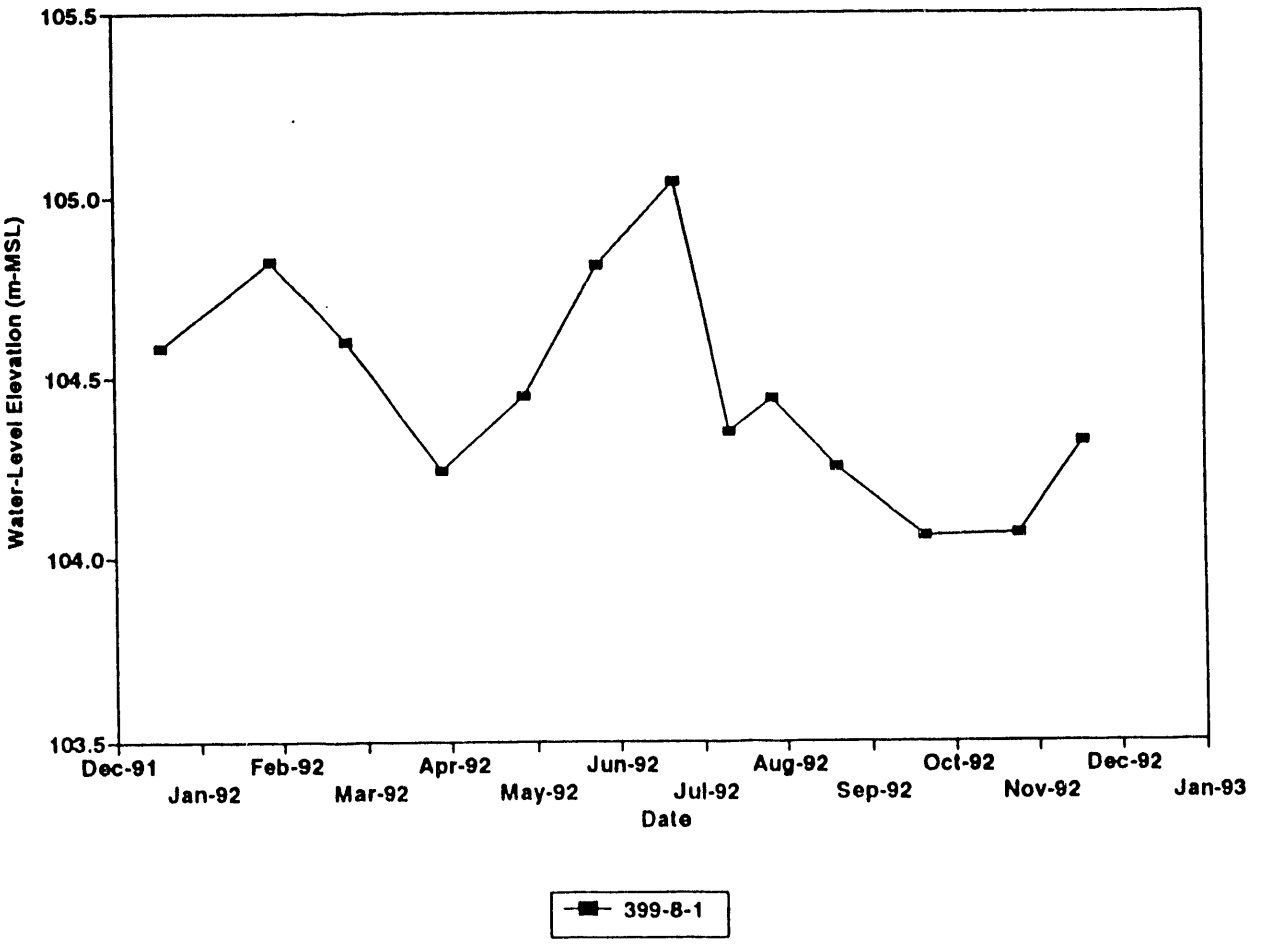



**Figure 2.21.** Hydrograph of Well 399-8-1

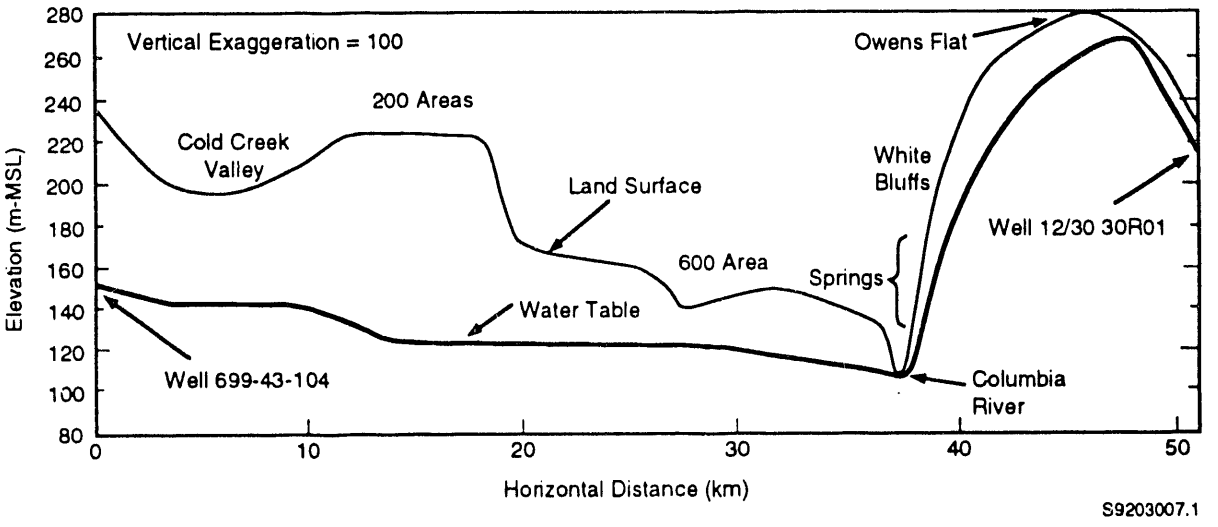



**Figure 2.22.** Cross Section of the Land Surface and Water Table Between Well 699-43-104 and Well 12/30 30R01

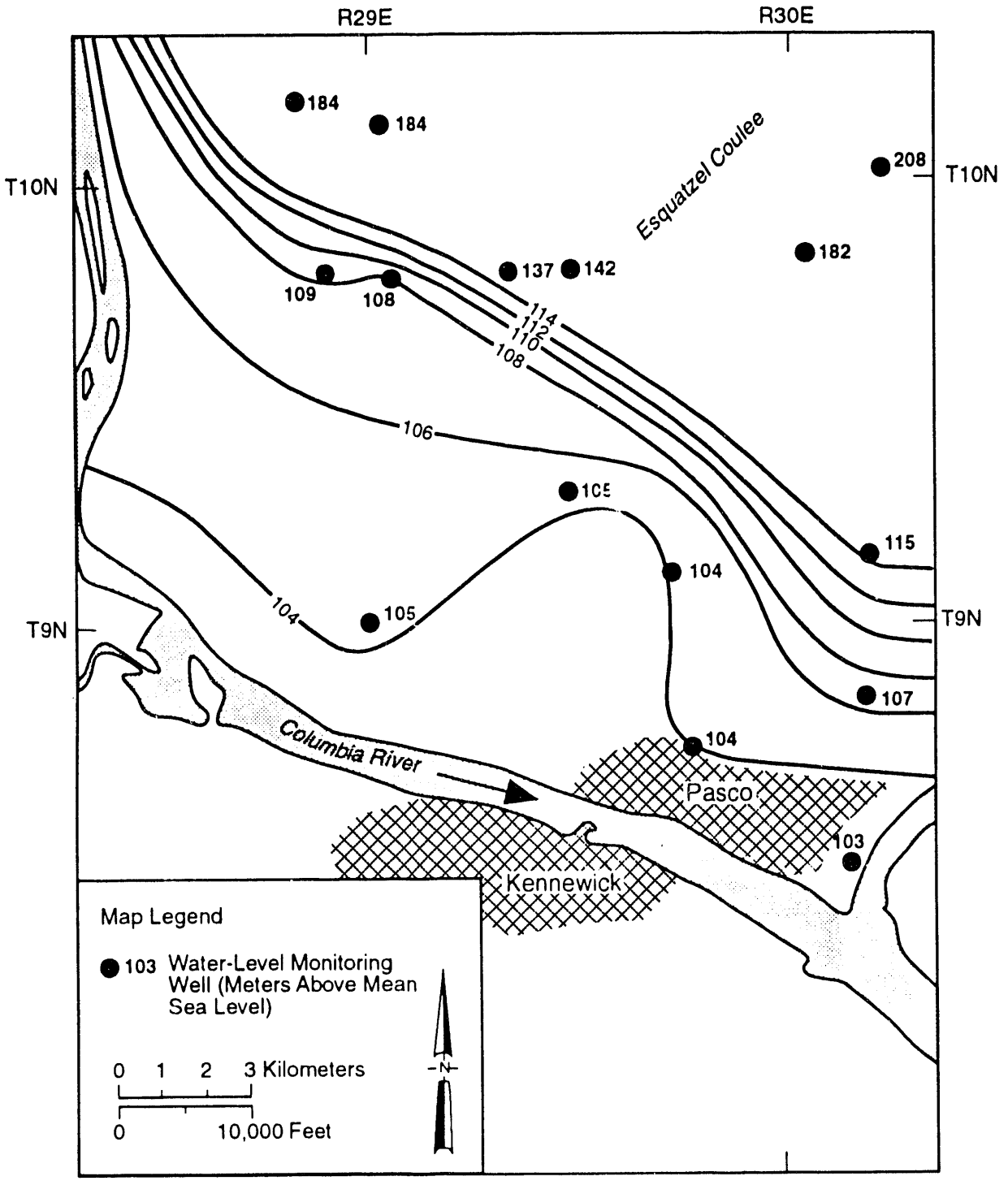



**Figure 2.23.** Water-Table Map of the Pasco Greenbelt Area

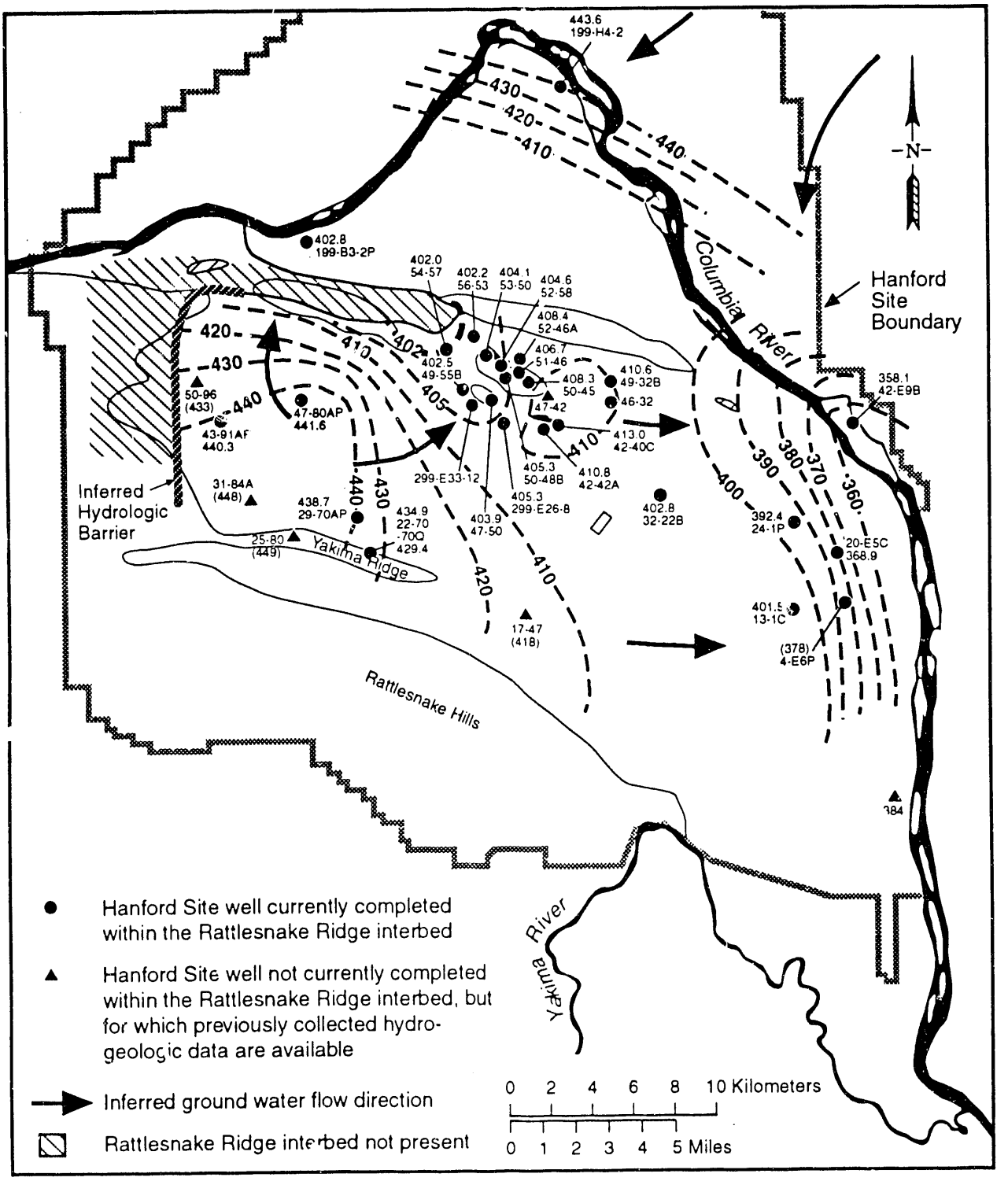



**Figure 2.24.** September 1992 Potentiometric Map - Rattlesnake Ridge Interbed

# 3.0 Radiological and Chemical Ground-Water Monitoring

P.E. Dresel, J.C. Evans, and B.E. Opitz

## 3.1 Data Collection

The well network used for the Ground-Water Surveillance Project is a combination of several networks that have been designed for RCRA facility-specific, Operational, CERCLA, and 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. The sampling schedules for the Operational, RCRA, and CERCLA networks are reviewed in the context of Ground-Water Surveillance Project needs. A supplemental monitoring network is developed to meet the objectives specific to the Ground-Water Surveillance Project (Bisping 1992). During 1992 approximately 720 wells were sampled for radiological and chemical constituents for the Hanford ground-water investigations. The distribution of wells sampled by the various programs in 1992 is shown in Figure 3.1.

Analytical results for samples collected for RCRA, Operational, and the Ground-Water Surveillance Projects were produced by International Technology Corporation (ITC) in Richland, Washington, and DataChem Corporation in Salt Lake City, Utah. Most volatile organic compound analyses for the Ground-Water Surveillance Project were performed by PNL laboratories. The CERCLA projects used a variety of analytical laboratories. Sample collection for RCRA and operational and ground-water monitoring is performed by PNL following a consistent set of procedures (PNL 1992a). Sample collection for RCRA and Operational monitoring is performed for WHC.

All ground-water analytical results are entered into the Hanford Environmental Information System (HEIS) database. The HEIS system forms a repository for analytical data and allows information to be disseminated to interested parties. Analytical methods, data validation procedures, and constituent lists vary between HEIS users, but the data structure allows for intercomparison of data for many purposes.

### 3.1.1 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 frequencies are specified in RCRA regulations (40 CFR 264) and by Washington Administration Code (WAC 173-303 and -304). Ground-water monitoring systems at each site must 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 contaminants known to have been disposed of at the facility being monitored. The frequency of sampling for each parameter is also specified in the RCRA regulations, based on the permitting status of the facility (e.g., interim status, permitted status). Annual reports (e.g., DOE 1993) document monitoring networks and analytical plans for these RCRA sites.

### 3.1.2 Operational Monitoring

Operational monitoring near waste facilities in the 200 Areas is conducted by WHC to allow the performance of waste disposal and storage sites to be evaluated and to assess the impact of specific sites on ground water. The operational monitoring program was significantly redesigned in 1989 to reflect the diminishing importance of Site production operations. A focused study entitled "Liquids Effluent Study" (WHC 1990a, 1990b) was performed in 1989 and 1990, which aimed at characterization of ground water associated with key operational areas of remaining concern. The study involved 90 wells in the 200 Areas. Some of the wells were specially remediated for the purposes of the study, thus providing new sampling locations not previously (or at least not recently) sampled. All wells were sampled for EPA RCRA Appendix 9 chemical constituents as well as gross alpha, gross beta, and tritium. In addition, some selected radiological constituents such as technetium-99, uranium, and plutonium were included if operational information suggested contamination potential by those species. Results from the Operational Monitoring Program are entered into the HEIS database and results from 1990 to 1992 are reported in WHC (1993). Fifty-seven wells in the operational network were sampled in 1992.

### 3.1.3 Ground-Water Surveillance Project Monitoring

The objective of ground-water surveillance is to identify 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 selection 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. This sampling strategy is discussed in more detail in Bryce et al. (1991). During 1992, approximately 400 wells were sampled by the Ground-Water Surveillance Project. Radionuclides and chemicals related to Site operations that are potential ground-water contaminants are listed in Table 3.1.

#### Radiological Monitoring

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 seldom samples for gross alpha or gross beta, preferring to perform more specific tests. Gross alpha and gross beta analyses are performed by other programs on site, in cosampling events with regulatory agencies, and by offsite investigators. Specific analytes are discussed below.

Elevated gross alpha readings in ground water on the Hanford Site may generally be related the presence of uranium and in rare instances to plutonium. Past monitoring for plutonium, as well as numerous geochemical studies, suggest that it is very immobile in ground water and hence it has in past years been 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.

Elevated gross beta concentrations are more difficult to associate with individual radionuclides because of the relatively large number of beta-emitting radionuclides that have been discharged in Hanford liquid wastes. Of the beta-emitting radionuclides discharged on Site, strontium-90 has been a common contributor to elevated gross beta concentrations in ground water. Strontium-90 is monitored in ground-water samples collected throughout the Hanford Site, with emphasis on the operating areas. Other relatively mobile beta emitters of potential dose 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.

Tritium is the most commonly analyzed radionuclide on site. 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. Tritium exists as part of the water molecule and as such moves with the ground water virtually unretarded by chemical and physical interaction with dissolved constituents or aquifer materials. Tritium was also concentrated in certain large-volume wastes, such as reactor coolant in the 100 Areas and process condensates in the 200 Areas.

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 short-lived fission and activation products, as well as some naturally occurring isotopes such as potassium-40 are reported when detected.

Uranium analyses are generally performed by a chemical method (laser-induced fluorescence) but may also be performed by alpha-counting after chemical separation. 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 are similar to that in naturally occurring rocks. In this case, the activity in pCi/L may be converted to concentration in $\mu$g/L by multiplying by a factor of 1.49. This factor is used in the interpretations below to produce a consistent set of units.

Iodine-129 analyses present a particular challenge because of the high sensitivity required. The iodine-129 drinking water standard (DWS) is 1 pCi/L—lowest of any radionuclide. The contractual detection limit (minimally detectable concentration) is currently at the 1 pCi/L level for the most sensitive method used by the primary radiological laboratory.

### Chemical Monitoring

Most well samples collected in 1992 were analyzed for potentially hazardous chemical (non-radioactive) constituents. Wells selected for chemical analysis are 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 knowledge of contaminant distributions from prior sampling events. The constituents analyzed by the RCRA and CERCLA programs are based on regulatory requirements in addition to 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 also exist for nitrate. Ground-water samples collected from wells located in or near areas of known or suspected ground-water contamination are analyzed for appropriate hazardous constituents. In addition, geochemical indicator parameters such as pH, major cations, and major anions may also be 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.

Analysis of anionic inorganic species in ground-water samples are made using an ion-chromatography method. Metal species are generally analyzed by inductively coupled plasma (ICP). Volatile organic constituent analyses for the Ground-Water Surveillance Project are typically analyzed by gas chromatographic (GC) methods 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 although the positive identification of specific constituents is more certain with GC/MS. Experience with site plumes has not indicated any problems with misidentifying the GC peaks associated with contaminants of concern.

## 3.1.4 Sample Collection and Reporting for 1992

Approximately 400 wells across the Hanford Site were visited during 1992 in support of the Hanford Site Ground-Water Surveillance Project.

Based on the historical monitoring efforts of the project, as well as new items of interest, a well sampling network is developed for each calendar year. The sampling schedule is integrated with other well sampling programs to develop a yearly sampling schedule in addition to a constituent list for collection.

Sample collection kits are prepared that include copies of the chain-of-custody forms for sample tracking, field record forms for recording of data gathered in the field, and the sample analysis requests for the laboratory. Included with the documentation are the sample containers (and appropriate preservatives if necessary) for the samples to be collected from the respective wells. Unique sample numbers are generated by the HEIS database, insuring that "blind" samples with no location information are received by the laboratories, and that analytical results may be entered properly into the HEIS database.

Once the sample kits are ready the samples are collected from one of three types of ground-water wells on the Hanford Site: wells that require the use of bailers, wells equipped with pneumatic Hydrostar pumps or wells with electrical submersible pumps in them. Wells fitted with pumps are sampled after pumping for a sufficient time (at least 20 min) to allow ground-water temperature, pH, and specific conductivity to stabilize. The purging process removes stagnant water in the well, allowing collection of a sample that is representative of the ground water in the aquifer near the well.

Upon completion of the well sampling activities, the samples are submitted to the appropriate laboratory. Results from the analytical laboratories are typically returned to PNL within 25 to 30 working days.

Several procedures have been instituted to ensure sample integrity and to protect worker and public safety during collection of ground-water samples from the Hanford Site. The first is training consistent with accepted ground-water collection and handling standards. Sample collection staff receive extensive training. Samples are collected using documented sampling procedures (PNL 1992a) that follow formal, established guidelines (EPA 1986). The basis for most procedures is derived from the EPA SW-846 sample handling, documentation, and analysis protocol. The Ground-Water Surveillance Project Quality Assurance Project Plan (PNL 1992b) and the RCRA and Operational Ground-Water Monitoring Support Project Quality Assurance Project Plan (PNL 1992c) address project quality assurance. In addition, there are many operational considerations with respect to site-specific area access on the Hanford Site that are included in training requirements. Because the same staff is supporting RCRA compliance sampling activities, the Ground-Water Surveillance Project procedures are consistent with RCRA sampling protocol.

Second, with the large number of wells sampled by all programs on the Hanford Site, a purge-water management system is in place for the site contractors including PNL, WHC, and Kaiser Engineers Hanford. The DOE, EPA, and Washington State Department of Ecology jointly developed a purge-water management strategy that has specified criteria for containment of purge water containing constituents above an agreed upon level (DOE 1990). In conjunction with WHC, PNL actively monitors the constituent concentrations from the various wells across the site and when required, the purge water generated while sampling a well is contained in a purge-water tank truck. As the truck is filled it periodically is off-loaded at the Liquid Effluent Retention Facility for ultimate disposal by WHC.

The purge-water management includes a semi-annual review of data for updates to the list of wells requiring containment or identification of wells that can be deleted from the containment list. This review utilizes the HEIS, which is the primary storage system for the data.

One recent innovation used in sample collection is the Belhaven OWM Power System Monitor jointly developed by Belhaven Inc. and PNL. This device is an electrical system monitor designed to protect staff from electrical hazards including potential electrocution while operating submersible electric pumps. The device is attached to the well sampling vehicles in line with the portable electrical generators and performs a safety pretest of the electrical connections for proper ground, potential high voltage leaks and or electrical short circuits. Once the pretest is complete and no problems are encountered the staff member may initiate the run cycle to start the electrical component. If at any time during the run cycle an abnormal electrical condition is encountered, the device automatically stops the electrical current to the equipment. The staff can then perform the test again to find out where the problem is. The device is not only a monitor but is also a diagnostic tool to facilitate minor field repairs.

### 3.1.5 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. 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 samples to be collected near the top of the aquifer where maximum concentrations for radionuclides are generally found on the Hanford Site (Eddy et al. 1978). Confined aquifer monitoring wells have screens, perforated casing, or an open hole within the monitored horizon.

Well and pump maintenance is essential to the collection of acceptable ground-water samples. A maintenance schedule is followed so that the wells in the Ground-Water Surveillance Project network are cleaned and the pumps replaced or cleaned at least once every 5 years. The rehabilitation of wells includes scouring the casing wall and removing sediment from the bottom of the well.

### 3.1.6 Monitoring Network

Wells used to sample the unconfined aquifer ground-water in 1992 is shown in Figure E.2, Appendix E. Wells from which samples were collected from the uppermost confined aquifer are shown in Figure E.3, Appendix E. Detailed maps of monitoring well locations for the 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, 200-West, 300, 400, and 1100/3000/North Richland areas are included in Appendix A.

## 3.2 Radiological and Chemical Monitoring Results for the Unconfined Aquifer

Results of the ground-water monitoring are discussed in detail in Section 4.0. Analytical results are published or otherwise made available in several sources. The HEIS database is the central repository for all ground-water monitoring results obtained on site. The interpretations below are based on the data available in HEIS at the time of the interpretation. There is some lag time in entering data to HEIS and in data validation. The lag time depends on the projects involved and the form of the data received. Additional data sources include RCRA quarterly and annual reports (e.g., DOE 1993).

### 3.2.1 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 3.2. These concentration levels are discussed below.

The MCLs are federal or state mandated drinking water standards. The MCL is defined as the maximum level of a constituent that is allowable in drinking water before corrective action must be taken. The MCLs are generally set by considering available data on the risk caused by lifetime ingestion of 2.0 L/day of water, the available treatment technology, and economic factors. The resulting 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.

Complications occur in applying standards developed for production wells to monitoring wells, which may be constructed to different standards. Monitoring wells are generally purged for only a relatively short time prior to sampling so the particulate matter content may be greater than in production wells. This is mainly a problem for metal analyses since the metals may be sorbed to particulate matter in the well-bore. Drinking water standards are defined for samples of water as consumed, so non-filtered samples from wells are generally used to compare to MCLs. Monitoring wells may produce a greater proportion of particulate matter than production wells, so the samples may not be representative of what is expected from water supplies. Filtered samples are more representative of the dissolved load and are better suited to interpretation of transport geochemistry. Most Ground-Water Surveillance Project samples for metals analysis were performed on filtered samples. Samples for radiological analysis were generally unfiltered because this provides the most sensitive method for detecting radionuclides that 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 to the affected organ of 4 mrem/yr. The levels of individual radionuclides that are calculated to result in this dose are shown in Table 3.2. The levels may be additive, however, when more than one radionuclide is present.

The 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. Derived concentration guides are presented in DOE Order 5400.5 (DOE 1990) and are summarized in Table 3.3.

### 3.2.2 Background Concentrations

Background concentrations for radiological and chemical constituents found on site were evaluated using 1988 data by Evans et al. (1989). Data from site wells considered to be unaffected by Hanford operations were used. High-sensitivity ICP/MS was used to address background concentrations of several elements. The background levels estimated by Evans et al. (1989) are summarized in Table 3.4.

Recent work presented in DOE (1993) developed a conceptual model for defining background concentrations for specific areas in the Site and specific hydrogeochemical regimes. This document presents "provisional threshold values" based on a 95% tolerance interval for background concentrations and discusses the relationship to the values of Evans et al. (1989).

## 3.3 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 the sources of uncertainty are discussed below. Several techniques are used in this discussion to interpret the sample results given these uncertainties and are also discussed in this section.

The chemical composition of ground water may fluctuate with time because of differences in the contaminant source, recharge, or the flow-field. The range of this concentration fluctuation can be estimated by taking many samples, but there is a limit to the number that can be practically taken. Comparison of results through time help interpret this 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 in our ability to collect representative samples or even to define precisely what volume of aquifer is represented in the sample. Proper well construction, well purging, sample preservation and in some instances filtering are techniques used to help ensure consistent and representative samples. Careful sample labeling protocols, chain-of-custody documentation, and bottle preparation avoid many gross errors (e.g., sampling the incorrect well, mislabeling samples) in sample results. Duplicate samples and field blanks help assess the sampling procedure.

Uncertainties are inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory or at other stages in the sampling. Gross errors include transcription errors, calculation errors, mislabeling results, or other errors that result from not following established procedures.

Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review procedures are used to investigate and correct gross errors.

Random errors are unavoidably introduced in the analytical procedures. Usually there are insufficient replicate analyses to assess the overall random error. Instruments for analysis of radioactive constituents count a known traction of the number of radioactive decays 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 less than the counting error indicate the constituent was not detected. The counting methods may result in the reporting of results that are less than zero. Although this is physically impossible, the negative values may be of use for some statistical analyses. In this report negative values will be treated simply as less than detection.

Systematic errors may result from instrument calibration, standard or sample preparation, chemical interferences in analytical techniques, as well as sampling methodology and sample handling. Sample and laboratory protocols have been designed to minimize systematic errors. The laboratories used by the Ground-Water Surveillance and other programs participate in inter-laboratory comparisons in which many laboratories analyze blind samples prepared by the EPA. The laboratories used have compared favorably with other laboratories.

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 overall long-term trends can be distinguished from short-term variability. The interpretation of concentrations 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.

Plume maps presented in this report are diagrammatic representations of the interpretation of site ground water chemistry. Although analytical data are only available at 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 somewhat simplified representations of plume geometry because of the map scale, the lack of detailed information, and because the plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are a powerful tool because knowledge of concentrations in surrounding wells, knowledge of ground-water flow, site geology, and other available information may be factored into the preparation. This minimizes the impact of uncertainty or error in any particular sample.

Plume maps in this report were prepared using the averages of 1992 sample analyses from each well. Nondetect values were considered to be zero in calculating averages. In a few instances suspect data believed to represent gross errors in sample collection and analysis were removed from the data set prior to averaging. Sample data from prior years were used in some instances to provide further information in areas not sampled in 1992. The data were contoured using a combination of computerized algorithms and hand contouring.

## 3.4 Summary of Radiological and Chemical Constituents in Ground Water

Section 4.0 of this report discusses specifics regarding individual ground-water contamination plumes in relation to the probable source area or areas for the plumes. The most important constituents of concern are summarized below, and the source areas for each discussed briefly. The distribution of radionuclides in Site ground water is summarized in Figure 3.2. The distribution of hazardous chemicals in ground water is summarized in Figure 3.3.

### 3.4.1 Tritium

Tritium concentrations greater than the 20,000-pCi/L DWS were detected in portions of the 100-B, 100-D, 100-K, 100-N, 200-East, 200-West, 400, and 600 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 3.2). This plume discharges to the Columbia River along a stretch from the Hanford Townsite to the 300 Area. A somewhat smaller but high 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 Section 4.0.

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.

### 3.4.2 Cobalt-60

Cobalt-60 is strongly adsorbed on sediments on Site so it is rarely observed in ground water. Exceptions include 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. As discussed in Section 4.0, the cobalt-60 contamination north of the 200-East Area apparently has been mobilized by the presence of cyanide and ferrocyanide.

### 3.4.3 Strontium-90

Concentrations of strontium-90 were above the 8-pCi/L DWS in wells in the 100-B, 100-D, 100-F, 100-H, 100-N, 200-East, and 600 areas. Concentrations of strontium-90 were greater than the 1000-pCi/L DCG in the 100-N and 200-East areas. Areas with strontium-90 above the DWS are shown in Figure 3.2. Strontium-90 is of concern because of its moderately long half-life of 28.8 yr and its potential to concentrate in bone tissue.

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 Section 4.0 indicate that the 100-N Area strontium-90 plume is not increasing perceptibly in extent at the 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 near the Gable Mountain Pond in the 600 Area is related to disposal of 200-East Area waste.

### 3.4.4 Technetium-99

Concentrations of technetium-99 greater than the 900-pCi/L DWS were detected in wells in the 200-East and 200-West areas. Concentrations greater than the DWS also extended to portions of the 600 Area east of the 200-West and north of the 200-East areas. These locations are identified in Figure 3.2. Technetium is transported in ground water as a negatively charged (anionic) species, which is highly mobile. Technetium shares some similar chemical characteristics with uranium and tends to "follow" uranium through the fuel processing system. Uranium, however, is less mobile in ground water under Site conditions.

### 3.4.5 Antimony-125

Antimony-125 was observed in samples collected from a few wells in the 100-N and 100-K areas during 1992. Concentrations measured in samples from these two areas have been as high as 305 pCi/L near the 1325-N LWDF in 1987. The DWS for antimony-125 is 300 pCi/L, and the DCG is 60,000 pCi/L. Antimony-125 was not detected at levels above the DWS in 1992.

### 3.4.6 Iodine-129

The presence of iodine-129 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 relatively long half-life (16 million years). 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 of limited adsorption onto organic material or mineral surfaces. Iodine-129 is essentially as mobile as tritium in Site ground water.

### 3.4.7 Cesium-137

Concentrations of cesium-137 were below the detection limit (20 pCi/L) except in one well, 299-E28-23, located near the 216-B-5 Injection Well (Figure 3.2). Cesium-137 is restricted to the immediate vicinity of the injection well by its extremely low mobility in ground water.

### 3.4.8 Uranium

The EPA has proposed a DWS of 20 $\mu$g/L for uranium. This is in contrast to other radionuclides where the standards are given in pCi/L. The reasons for the difference are that uranium is often analyzed by a fluorescence method that is calibrated in $\mu$g/L and that there is evidence that uranium ingestion may cause kidney damage, which is better assessed as a chemical hazard rather than a radiological hazard. However, uranium may be analyzed by an alpha-counting method and has an associated risk through its radioactivity so it is important to be able to convert between ground-water concentrations expressed in $\mu$g/L and those expressed in pCi/L. The conversion factor depends on the proportions of uranium-234, uranium-235, and uranium-238 in the ground water. The EPA-proposed DWS of 20 $\mu$g/L to be equivalent to a standard of 30 pCi/L—based on a series of ground-water analyses throughout the United States (Federal Register 1991). 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. The relationship between uranium activity and concentration developed for the Hanford Site is pCi x 1.49 = $\mu$g/L. This conversion gives a proposed DWS equivalent of 13.4 pCi/L. The site-specific conversion factor provides a more stringent standard for activity data and will be used in the discussion below.

Uranium has been detected at concentrations above the proposed DWS in the 100-F, 100-H, 200-East, 200-West, and 300 areas. The highest concentrations detected on site in 1992 were in the 200-West Area near the 216-U-1 and 216-U-2 cribs. An Expedited Response Action performed on the 300 Area Process Trenches in mid-1991 was aimed at reducing 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 discharge to the trenches is much lower than in the past. As discussed in Section 4.0 the Expedited Response Action and/or the reduction in flow appears to have reduced the uranium concentrations in at least one well monitoring the 300 Area Process Trenches.

### 3.4.9 Plutonium

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

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. Alternately, 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.

### 3.4.10 Nitrate

Most ground-water samples collected in 1992 were analyzed for nitrate. Nitrate was measured at concentrations greater than the DWS (45 mg/L as $NO_3^-$) 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 offsite sources of nitrate are located to the west and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 3.3. The nitrate distribution shown in Figure 3.3 is similar to previous evaluations.

### 3.4.11 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 rules, 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 the DWSs are only an indication of the degree of contamination since the area of elevated fluoride 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-East and 200-West areas (Figure 3.3).

### 3.4.12 Cyanide

The source of a cyanide plume in and directly north of the 200-East Area is believed to be wastes containing ferrocyanide disposed of in the BY cribs. Cyanide forms two distinct plumes in the 200-West Area (Figure 3.3). 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 $\mu$g/L has been proposed by the EPA. Ferrocyanide is not specifically regulated but is commonly considered with the total cyanide

since it is indistinguishable from cyanide in the standard analytical methods. However, ferrocyanide is thought to be considerably less toxic than free cyanide.

### 3.4.13 Chromium

A major source for chromium contaminants to ground water was the use of sodium dichromate as a corrosion inhibitor in cooling water for the 100 Area reactors. Chromium is detected in ground water from each of the 100 Areas but the major plumes are related to the 100-D, 100-H, 100-K, and 100-N areas. Surrounding parts of the 600 Area are also affected. The federal DWS for chromium is 100 $\mu$g/L while the Washington State standard is 50 $\mu$g/L.

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

### 3.4.14 Carbon Tetrachloride

Carbon tetrachloride contamination was found in the unconfined aquifer beneath much of the 200-West Area. The contamination is believed to be primarily from waste disposal operations associated with Z Plant before 1973 (Figure 3.3). The DWS for carbon tetrachloride is 5 $\mu$g/L.

### 3.4.15 Chloroform

The 200-West Area chloroform plume appears to be associated, but not exactly coincident, with the carbon tetrachloride plume. The DWS for chloroform is 100 $\mu$g/L (total trihalomethanes)—20 times higher than that for carbon tetrachloride. The location of the chloroform plume is shown on Figure 3.3.

### 3.4.16 Trichloroethylene

Trichloroethylene (TCE) has a DWS of 5 $\mu$g/L. It was commonly used as a degreasing compound in the late 1950s through the 1970s and 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 (SWL) in the 600 Area.

Trichloroethylene has been detected in 1992 at levels less than the DWS in 100-B/C Area wells and at levels above the DWS in one 100-F and several 100-K Area wells. In addition, TCE was found at levels up to 29 $\mu$g/L in well 699-77-36, west of the 100-F Area.

Trichloroethylene was detected in 1992 at levels above the DWS in the 200-West Area in two locations. The first location is to the west of the T Plant. The second location is near the U Plant. In the past TCE has been detected near the REDOX Plant in the 200-West Area.

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

Several wells at the SWL located in the 600 Area contained TCE at levels close to but slightly below the DWS. The SWL wells have shown TCE concentrations above the DWS in previous years.

### 3.4.17 Tetrachloroethylene

Tetrachloroethylene, also referred to as perchloroethylene is found at levels below the DWS in a number of areas of the site including the 200-West Area, 300 Area, and southern portion of the 600 Area. A number of samples from wells in the 1100 and 3000 areas contained low concentrations of tetrachloroethylene. The only area where tetrachloroethylene was detected at concentrations above the DWS is the SWL where the concentrations reached a maximum of 6.6 $\mu$g/L in well 699-24-34B.

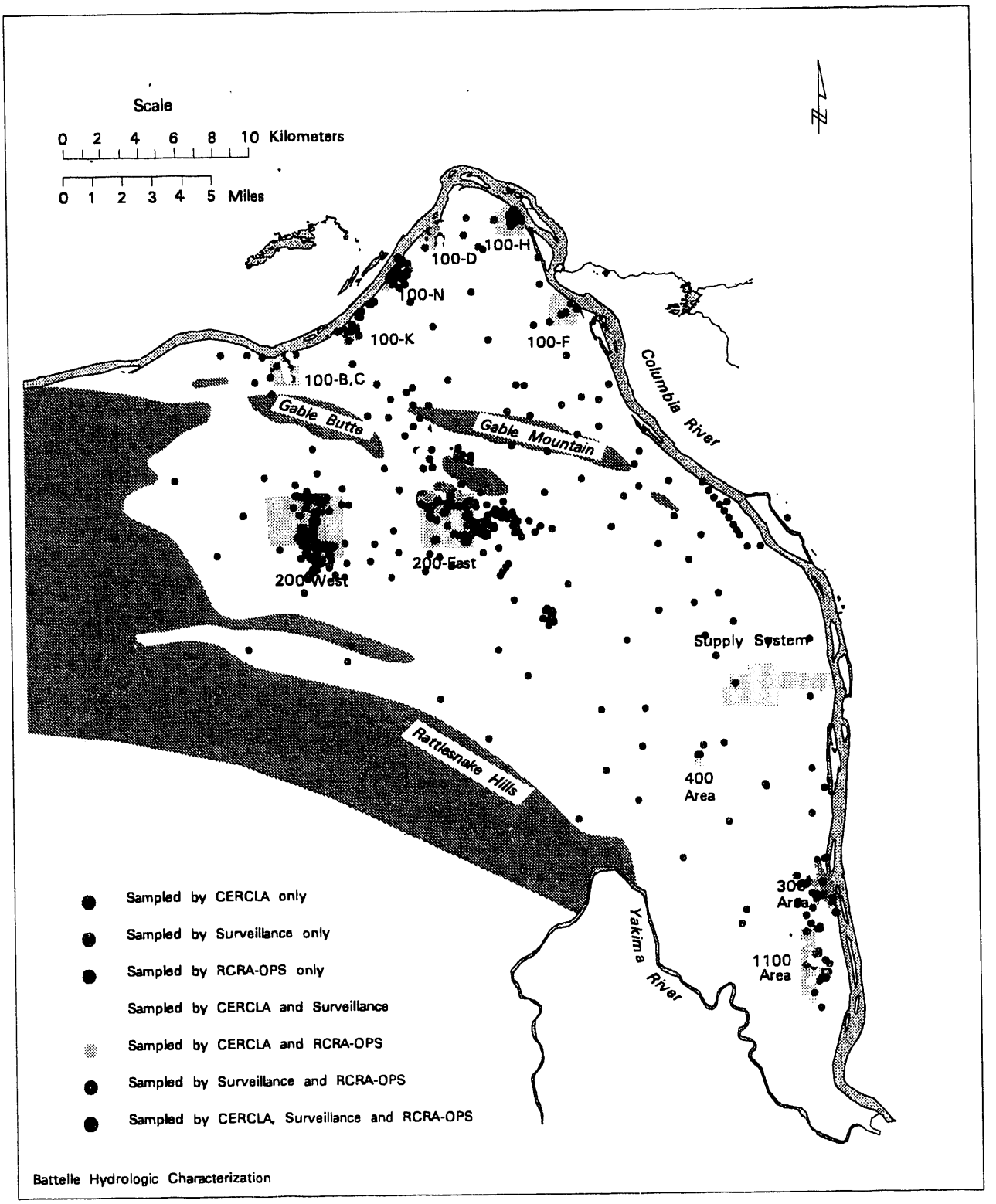



**Figure 3.1.** Wells Sampled by RCRA, CERCLA, and Ground-Water Surveillance Projects in 1992

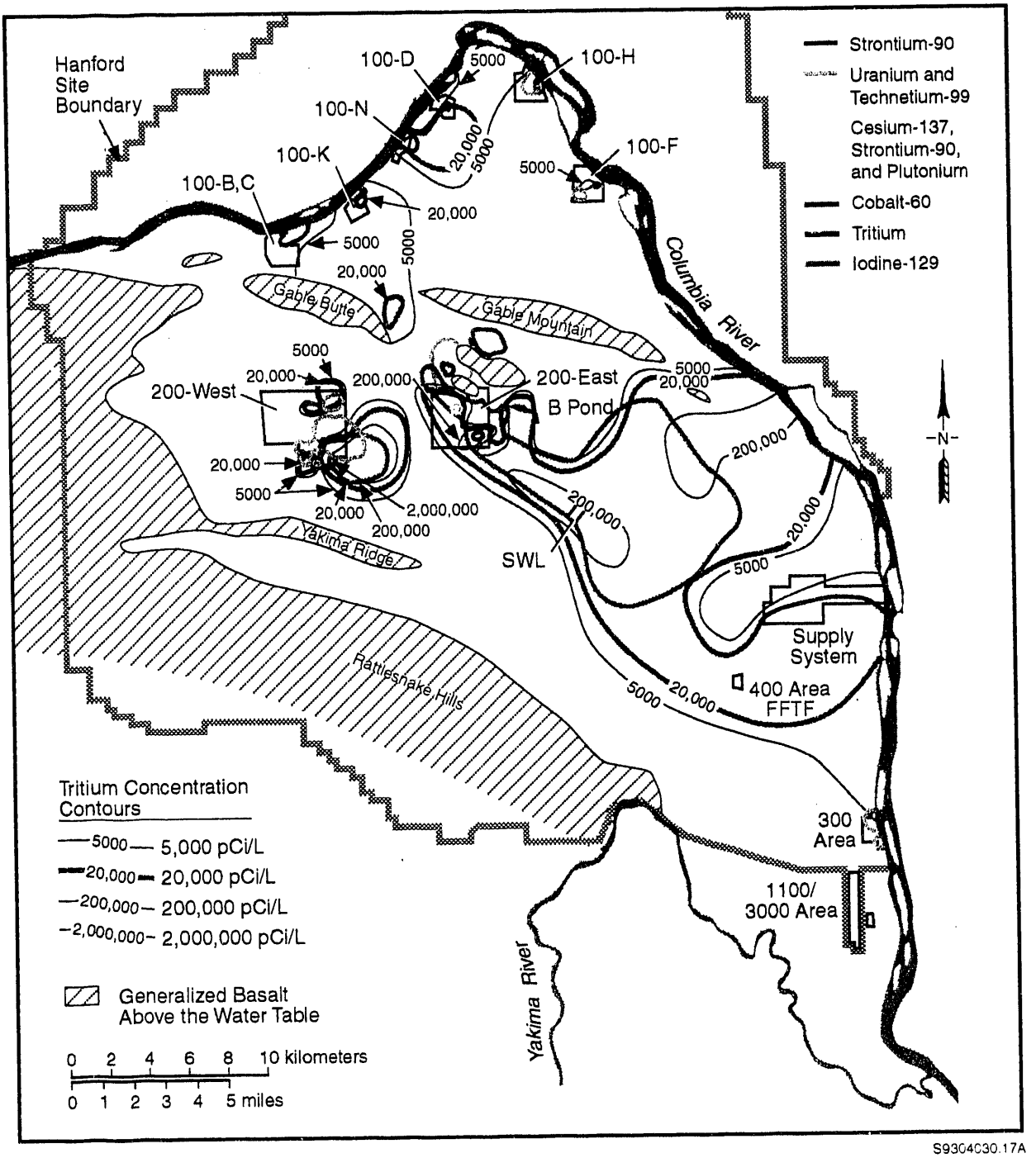



**Figure 3.2.** Areas of Radiological Constituents in Ground Water at Concentrations Above the Drinking Water Standard

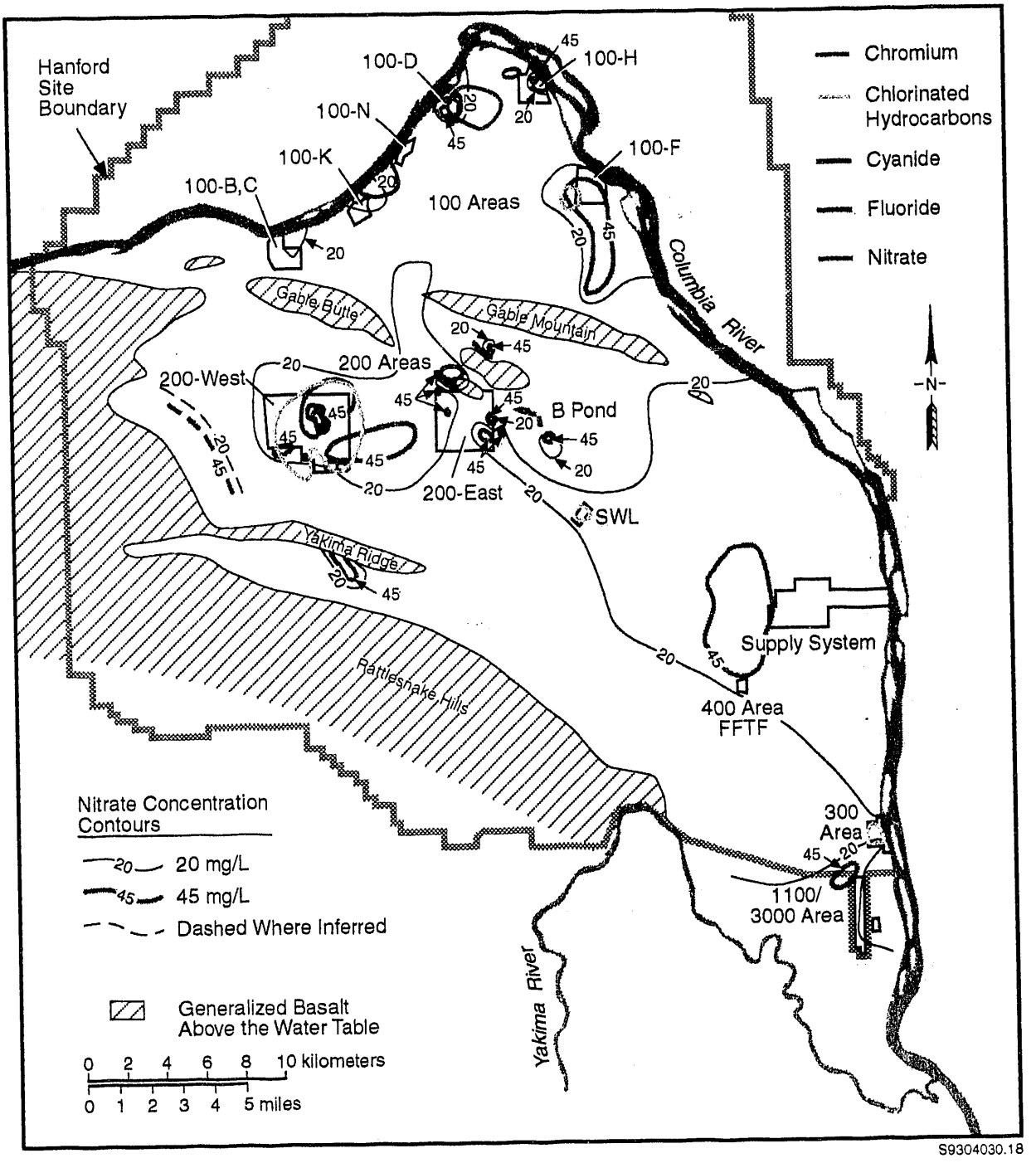



**Figure 3.3.** Areas of Hazardous Chemical Constituents in Ground Water at Concentrations Above the Drinking Water Standard

**Table 3.1.** 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 3.2.** 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 | |
| Trichloroethylene | 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 | 8 pCi/L[d] | EPA | |
| Technetium | 900 pCi/L[d] | EPA | |
| Ruthenium | 30 pCi/L[d] | EPA | |
| Antimony | 300 pCi/L[d] | EPA | |
| Iodine | 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 3.3.** Derived Concentration Guides[a,b,c]

| Radionuclide | Water, pCi/L ($10^{-9}\mu$Ci/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 | NS[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) NS = No standard.

**Table 3.4.** Estimated Background Levels for Selected Constituents in Hanford Ground Water (from Evans et al. 1988)

| Constituent | Detection Limit[a] | Background Concentration[a] |
|---|---|---|
| Aluminum | 2[b] | <2[b] |
| Ammonia | 50 | <50 |
| Arsenic | 0.2[b] | 3.9 ± 2.4[b] |
| Barium | 6 | 42 ± 20 |
| Beryllium | 0.3[b] | 0.3[b] |
| Bismuth | 0.02[b] | 0.02[b] |
| Boron | 50[b] | <50[b] |
| Cadmium | 0.2[b] | 0.02[b] |
| Calcium | 50 | 40,400 ± 10,300 |
| Chloride | 500 | 10,300 ± 6,500 |
| Chromium | 2[b] | 4.0 ± 2.0[b] |
| Copper | 1[b] | <1[b] |
| Cyanide | 10 | <10 |
| Fluoride | 500 | 370 ± 100 |
| Lead | 0.5[b] | <0.5[b] |
| Magnesium | 10 | 11,800 ± 3,400 |
| Manganese | 5 | 7 ± 5 |
| Mercury | 0.1 | <0.1 |
| Nickel | 4[b] | <4[b] |
| Phosphate | 1,000 | <1,000 |
| Potassium | 100 | 4,950 ± 1,240 |
| Selenium | 2[b] | <2[b] |
| Silver | 10 | <10 |
| Sodium | 10 | 18,260 ± 10,150 |
| Strontium | 20 | 236 ± 102 |
| Sulfate | 500 | 34,300 ± 16,900 |
| Uranium | 0.5[c] | 1.7 ± 0.8[c] |
| Vanadium | 5 | 17 ± 9 |
| Zinc | 5 | 6 ± 2 |
| Alkalinity | -- | 123,000 ± 21,000 |
| pH | -- | 7.64 ± 0.16 |
| Total Organic Carbon | 200 | 586 ± 347 |
| Conductivity | 1[d] | 380 ± 82[d] |
| Gross Alpha | 0.5[c] | 2.5 ± 1.4[c] |
| Gross Beta | 4[c] | 19 ± 12[c] |
| Radium | 0.2[c] | 0.2[c] |

(a) Units in ppb unless otherwise noted. Uncertainties are ± one standard deviation.
(b) Based on ICP/MS data.
(c) Units in pCi/L.
(d) Units in $\mu$mho/cm.

# 4.0 Extent of Ground-Water Contamination at the Hanford Site

P.E. Dresel and J.C. Evans

## 4.1 Source Areas

Ground-water contamination at the Hanford Site has been related to a number of sources within the operational areas. In some cases a number of potential sources such as cribs, trenches, or other disposal facilities may contribute to a particular ground-water plume and can not 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 North Richland and the 400 Area.

### 4.1.1 100-B/C Area

The 100-B/C Area is located farthest upstream along the Columbia River of all the reactor areas. The B Reactor was the first production nuclear reactor in the world. The B Reactor 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 on site 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. Considerable disposal of liquid to ground in the past is indicated by water-table maps showing ground-water mounding in the 1950s.

Tritium levels in the 100-B/C Area were below the DWS except in well 199-B3-47, which had a maximum concentration of 24,000 pCi/L. Tritium levels from well 699-65-72 located to the southeast of the 100-B/C Area reached a maximum of 19,900 pCi/L in the August 1992 sample. It is possible that past disposal practices at the 100-B/C Area resulted in some flow to the southeast. Hydraulic gradients are fairly flat in this part of the site and there is some suggestion that the Columbia River is recharging the upper unconfined aquifer upstream from the 100-B/C Area. An alternate possibility is that in the past sufficient gradient existed in the gap between Gable Mountain and Gable Butte to transport tritium from the 200 Areas westward from the gap. 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 was detected at levels above the DWS in the 100-B/C Area. It was detected in the majority of 100-B/C Area wells monitored in 1992. The maximum concentrations ranged up to 57 pCi/L in well 199-B3-46. The distribution of strontium-90 is shown in Figure 4.1. The highest levels of strontium-90 are found downgradient of the retention basins and liquid overflow trenches. Strontium-90 at concentrations above the DWS is also found in wells to the southwest of the B

Reactor Building. The extent of strontium-90 in ground water to the east of the 100-B/C Area is not defined by the current monitoring network.

### 4.1.2 100-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 DH Reactor was also located in the 100-D Area and 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.

Tritium is found in the 100-D Area at concentrations greater than the DWS in several wells with a maximum concentration of 78,000 pCi/L detected in well 199-D5-17. Tritium detected at levels 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. Changes in river stage affect ground-water flow near the river.

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 33 pCi/L in the February Ground-Water Surveillance Project sample. This well is located adjacent to the D Reactor Building.

Nitrate is found at concentrations greater than the DWS from a large part of the 100-D Area (Figure 3.3). The nitrate plume appears to be most concentrated in the western half of the area, but the well coverage is not sufficient to determine the precise extent or to identify a source. The liquid waste disposal facilities are probably not the sole nitrate source since they are close to the river and downgradient from much of the plume.

The highest chromium concentrations in the 100-D Area are found in the vicinity of the reactor building with values over 2000 $\mu$g/L in well 199-D5-15 (Figure 4.2). Chromium levels are similar in filtered and unfiltered samples from the 100-D Area indicating that the bulk of the chromium is in solution and is expected to be mobile. The chromium plume extends to the east into the 600 Area (Figure 4.2). The probable source of the chromium is 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). Sodium dichromate was used for corrosion control in the single-pass cooling reactors.

### 4.1.3 100-F Area

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

Strontium-90 was detected above the DWS at 32 pCi/L in well 199-F5-1. The extent of strontium-90 in ground water at the 100-F Area has not been well defined.

Uranium continues to be detected at levels above the proposed DWS in well 199-F8-1. The 1992 sample contained uranium at 40 μg/L. This is down from a maximum concentration of 618 μg/L in 1988. Well 199-F8-2 has historically contained uranium at concentrations greater than the proposed DWS but has not been sampled since 1990.

Relatively few chromium analyses are available from the 100-F Area in 1992. Of these, only one filtered sample had detectable chromium and this was less than the DWS.

Trichloroethylene has been detected at concentrations above the DWS in the 100-F Area and in surrounding parts of the 600 Area (Figure 4.3). The maximum TCE detected in 1992 from the 100-F Area was 25 μg/L in well 199-F7-1, in the southwestern corner of the area. The TCE in well 199-F7-1 has ranged from 19 μg/L to 35 μg/L since 1990. The TCE concentrations reached a maximum of 29 μg/L in well 699-77-36, to the west and upgradient of the 100-F Area. The TCE levels in this well have been fairly constant with time. Thus it is probable that the TCE source is from a location in the 600 Area, which has not yet been identified. The CERCLA 100-IU-2 Operable Unit study will address potential sources west of the 100-F Area.

### 4.1.4 100-H Area

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

Chromium was detected at levels greater than the DWS from a large part of the 100-H Area. Chromium was usually found at similar levels in both filtered and non-filtered 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 4.2.

Potential chromium sources in the 100-H Area include disposal of sodium dichromate near the reactor building and to the 107-H Liquid Waste Trench, and 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 concentration of chromium in the 100-H Area in 1992 was in well 199-H4-14, located between the H Reactor Building and the 183-H Solar Evaporation Basins, where a maximum concentration of 410 μg/L was reported in the July 1992 sample. 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 chromium concentration of 170 μg/L in 1992. This supports the existence of an upgradient source.

Chromium levels have been decreasing in upper unconfined aquifer wells 199-H4-12A and 199-H4-12B. In the middle-unconfined well at the same location, 199-H4-12C, the chromium levels rose sharply in approximately 1987 and then leveled off (Figure 4.4). This suggests the upper part of the aquifer is being flushed with cleaner water at present. Chromium in the middle unconfined aquifer

well is most likely related to upgradient sources. This interpretation is supported by the technetium-99 trends in the 199-H4-12 well nest, discussed below.

Elevated technetium-99 activities are found in several wells in the 100-H Area, although none were above the DWS in 1992. The maximum technetium-99 recorded in 1992 in the 100-H Area was 793 pCi/L in the January 1992 sample from well 199-H4-4. Technetium is transported in ground water as an anionic species that is not expected to be retarded significantly by adsorption onto sediments. The technetium-99 trend from the 199-H4-12 well nest is shown in Figure 4.5. The decreasing trend of technetium-99 in the upper confined aquifer wells 199-H4-12A and 199-H4-12B is similar to the decreasing chromium trend in these wells. By contrast, technetium-99 was never detected in the middle unconfined well 199-H4-12C. This provides additional evidence that the chromium detected in well 199-H4-12C is not related to the 100-H Area. If the chromium had a local source, then the other mobile local constituents such as technetium-99 should also be detected.

Uranium continues to be detected at levels greater than the DWS in wells 199-H4-3, 199-H4-4, and 199-H4-12A, which have historically shown elevated uranium concentrations. The maximum uranium concentration detected in 1992 was 70 $\mu$g/L in the January sample from well 199-H4-4. Fluctuations in uranium concentrations in these wells indicate that the levels are affected by the Columbia River stage. The three wells are downgradient of the 183-H Solar Evaporation Basins. Elevated gross-alpha measurements in these wells are related to the uranium concentrations.

Strontium-90 was detected at levels greater than the DWS in 1992 samples from three wells in the 100-H Area. The maximum concentration detected in 1992 was 33 pCi/L in the October sample from 199-H4-13. Two of these 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 typically not monitored in most 100-H Area wells since the 1980s. In many wells, including the three discussed above, the 1992 samples are the first reported strontium-90 values. Thus little is known regarding the history of strontium-90 in 100-H Area ground water.

Nitrate concentrations lower than the DWS are found through most of the 100-H Area (Figure 4.6). Concentrations above the DWS were detected in wells 199-H4-3, 199-H4-4, and 199-H4-12A, which are located between the 183-H Solar Evaporation Basins and the Columbia River. The maximum concentration detected in the 100-H Area in 1992 was 220 mg/L in the February 1992 sample from well 199-H4-4. The highest concentrations are found downgradient of the 183-H Solar Evaporation Basins.

### 4.1.5 100-K Area

Two reactors, the KE and KW, were operated from 1945 to 1965 in the 100-K Area. Cooling water from the 100-K Area reactors was discharged to the liquid waste disposal trench rather than through cooling basins and directly 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. Other constituents detected in the 100-K Area include strontium-90, antimony-125, nitrate, and chromium.

The DOE declared an unusual occurrence at the KE Basin in early 1993 because of indications that the basin was leaking. The KE basins contain unencapsulated irradiated fuel elements from the N Reactor. The water in the basin contains tritium at a concentration of 2,000,000 pCi/L, strontium-90 at 1,000,000 pCi/L, cesium-137 at 2,000,000 pCi/L, and plutonium-239/240 at 80,000 pCi/L. According to DOE (1991), this basin has leaked in the past.

The 100-K Area is situated within a portion of the 600 Area that is impacted by tritium contamination at levels between 5000 pCi/L and the 20,000 pCi/L DWS (Figure 3.2). 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 within the 100-K Area increase dramatically above the surrounding levels. The maximum tritium detected in 1992 in the 100-K Area was 1,690,000 pCi/L in the October 1992 sample from well 199-K-30. This concentration is the highest in the 100 Areas, but remained below the DCG of 2,000,000 pCi/L. The tritium levels in well 199-K-30 are now approximately as high or slightly higher than the previous maximum reached in 1988 (Figure 4.7) and approach the levels detected in the KE Basin.

Strontium-90 has been detected in the past in wells 199-K-19 and 199-K-20 at levels above the DWS. The maximum detected in well 199-K-19 in 1988 was 21 pCi/L and in well 199-K-20 was 16 pCi/L. These wells are part of the operational monitoring network and were not sampled for strontium-90 in 1992.

Antimony-125 has been detected in the past in a few wells in the 100-K Area. In 1992, antimony-125 was only detected in well 199-K-27, with a maximum concentration of 58 pCi/L in October. 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 is the result of the radioactive decay.

Nitrate detected in the 100-K Area is indicative of impact by Site activities (Figure 3.3). In 1992 it was only found at levels greater than the DWS in well 199-K-30, near the K-East Reactor Building where the maximum detected was 110 mg/L in March.

Chromium was detected in 1992 at levels greater than the DWS in a number of 100-K Area wells. Where data for both filtered and unfiltered samples are available, the chromium levels were similar. The maximum chromium detected in the 100-K Area in 1992 was 1400 $\mu$g/L in well 199-K-36.

### 4.1.6 100-N Area

The N Reactor was 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 at the N Reactor but radionuclide concentrations appear

to be higher. The N Reactor is the most recently built and the most recently decommissioned of the site reactors. Primary disposal locations in the 100-N Area were the 1301-N Liquid Waste Disposal Facility (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 the present. Currently a low volume of non-dangerous effluent is disposed to this facility (DOE 1993). In addition to the above facilities, the 1324-NA Percolation Pond was used from 1977 to 1986 for disposal of treated wastes containing sulfuric acid and sodium hydroxide at variable pH. This pond was unlined. From 1986 to 1988 the wastes were treated in a lined pond, the 1324-N Surface Impoundment. Tritium, strontium-90, antimony-125, and nitrate are the major contaminants of concern in the 100-N Area.

Tritium in the 100-N Area is found at concentrations greater than the DWS in the northern half of the area and extends into the 600 Area to the north and east (Figure 3.2). Tritium was apparently discharged to both the 1301-N LWDF and the 1325-N LWDF. Ground-water flow in the 100-N Area is strongly affected by the stage of the Columbia River. However, the area that may be recharged from the river at times is not well defined. Further study of current and past flow fields is needed to understand the transport of tritium discharges in the 100-N Area.

Strontium-90 is probably 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. The strontium plume in the 100-N Area is shown in Figure 4.8.

The two LWDFs are apparently the source of the ground-water strontium-90 plume, although the effects of operations in the N Reactor Building have not been ruled out. The maximum strontium-90 concentration detected in the 100-N Area in 1992 was 6550 pCi/L in well 199-N-46, between the 1301-N LWDF and the Columbia River. An area south of the 1325-N LWDF with strontium-90 concentrations greater than 100 pCi/L may represent residual from an earlier period of strontium-90 disposal. Wells downgradient to the northwest of this facility contain lower concentrations of strontium-90, possibly resulting from dilution by cleaner, and later, disposal. The strontium-90 plume's spread northward in the 1980s is illustrated by the trend data from well 199-N-14 (Figure 4.9). The strontium-90 concentrations in this well have remained approximately level since 1989. Wells further north do not show detectable strontium-90. The steady levels indicate that the plume is not spreading at any discernable rate at this time. Strontium-90 discharges to the Columbia River through springs.

Antimony-125 continues to be detected at levels below the DWS in several wells in the 100-N Area. Antimony-125 concentrations reached 305 pCi/L in 1987 near the 1325-N LWDF. Antimony-125 is a fission product with a half-life of 2.76 years. Thus the concentrations in ground water will decrease rapidly now that the N Reactor is no longer operating.

Nitrate attributable to 100-N Area operations is detected in ground water throughout the area but levels are less than the DWS. The maximum nitrate detected in the 100-N Area in 1992 was 28 mg/L

in well 199-N-32. The 100-N Area nitrate plume shown in Figure 3.3 is less extensive than the tritium plume shown in Figure 3.2.

### 4.1.7 200 Areas

The 200 Areas at Hanford have been used for chemical separation and purification of plutonium along with associated waste management. These operations were performed in both the 200-West and 200-East areas. For reasons of safety and security these two areas were established with a significant spatial separation 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. For the purposes of discussion, four key source term areas in the environs of the 200-West Area will be discussed. These are respectively, the T Plant, REDOX Plant, U Plant, and the Plutonium Finishing Plant (PFP), which was formerly referred to as Z Plant. In the 200-East Area, specific waste disposal sources include the PUREX complex, the BY Cribs, and the 216-B-5 Injection Well. Operation of the facilities discussed have contributed to ground-water contamination. Various waste disposal facilities associated with these activities include cribs, trenches, tile fields, surface impoundments, injection wells, tank farms, and landfills. Because of the complex nature of the past waste disposal operations in the 200 Areas as well as the close spacing of the facilities it is often not possible to determine the exact source of contamination. For example, while it is well known that numerous tank leaks have occurred in both the 200-West and 200-East areas, to date there is no compelling evidence for ground-water impacts from tank leaks. In most cases the tanks are located very close to cribs or other waste disposal facilities that have received similar wastes during the same periods.

### 4.1.8 200-West Area

#### 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 both 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. The carbon tetrachloride plume originating near the PFP extends throughout the T Plant area. There is a small tritium plume near T Plant, but otherwise radiological contamination of the ground-water is minor in the T Plant area.

<u>Nitrate</u>

Several wells in the northern part of the 200-West Area still contain nitrate at concentrations in excess of the DWS. These wells are located near several inactive LWDFs that received waste from

early T Plant operations. Maximum concentrations in these wells in 1992 ranged up to 650,000 $\mu$g/L in well 299-W15-4, similar to that observed in previous years.

Cyanide

Cyanide forms two distinct plumes in the 200-West Area. The northern lobe is located near the 216-T-26 Crib, which received a total estimated inventory of 6000 kg of ferrocyanide in 1955 and 1956 (Stenner et al. 1988). The source of the other lobe is uncertain. At least six wells in the 200-West Area have shown detectable cyanide. The highest cyanide levels observed in 1992 were in wells 299-W14-2 and 299-W18-5, each containing 70 $\mu$g/L.

Chromium

A large and apparently complex chromium plume exists in the T Plant area. The distribution of chromium in the 200-West Area is detailed in Figure 4.10. Three separate maxima are indicated for that area; however, at least part of that structure may be an artifact of the low well density in the area and geologic factors. In any case, 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 for decontamination of systems containing uranium, that crib is a likely candidate as at least one source.

## REDOX

The REDOX Plant began operation in 1951 and continued through 1967. Its primary mission was separation of plutonium from uranium and fission products through use of a solvent extraction. The solvent extraction process used tributyl phosphate as a complexing agent in an organic solvent (hexone). Chemical contaminants found in the ground water near REDOX include nitrate, chromium, and minor amounts of trichloroethylene. The carbon tetrachloride plume prevalent in most of the rest of the 200-West Area is largely absent near REDOX apparently as a consequence of the low permeability of aquifer materials in that area. The main radiological contaminants are tritium and iodine-129.

Nitrate

A major nitrate plume emanates from the REDOX area originating primarily at the 216-S-25 Crib, which routinely received process condensate from REDOX operations.

Chromium

Figure 4.10 shows a chromium plume located near the REDOX Plant. That plume almost certainly originates from the 216-S-13 Crib, which was retired in July 1972 after receiving an estimated 10,000 kg of sodium dichromate over a 20-year period (Stenner et al. 1988).

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. Only one well in the 200-West Area (299-W22-9) continued to show tritium levels in excess of the DCG during 1992; however, that well contained up to 4,450,000 pCi/L, the highest tritium levels of any ground-water monitoring wells on the Site. The tritium detected in 299-W22-9 has decreased steadily since 1977 (Figure 4.11).

Movement of the REDOX Plant tritium plume is expected to be slow because of the low permeability of the sediments in this area and the declining flow from 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 1992 in Hanford ground water was 52.9 pCi/L found in well 299-W14-12. The iodine-129 plume from the 200-West Area extends into the 600 Area to the east, and is essentially coincident with the tritium and nitrate plumes, which originate at REDOX process condensate LWDFs (Figures 3.3 and 4.12).

## U Plant

U Plant was originally designed as a plutonium separation facility but was never used for that purpose. The plant was converted to a uranium recovery operation in 1952 to recover uranium waste generated by the bismuth phosphate process and stored in tanks up to that time. Wastes generated by that process 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 seen in the U Plant area include nitrate, uranium, and technetium-99.

Nitrate

The highest nitrate concentrations on the Site in 1992 continued to be found in wells east of U Plant near the 216-U-17 Crib. The presence of nitrate in wells near this crib was observed 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 kg 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 U Plant continued to decrease, with concentrations in several wells dropping below the DWS. For example the nitrate concentrations in well 299-W19-18 located near U Plant have decreased to less than the DWS as shown in Figure 4.13.

Uranium

The highest uranium levels in Hanford ground water occurred near U Plant in the 200-West Area in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs (Figure 3.2). Uranium concentrations in these wells have been decreasing over the past 5 years following remediation activities associated with these cribs. A trend plot of uranium concentrations in samples from well 299-W19-18, immediately downgradient from the cribs, is shown in Figure 4.14. The uranium levels in this well continue to decrease slowly but remain greater than the DWS. The maximum concentration detected in this area in 1992 was 4090 $\mu$g/L; however, results from that well have been erratic since 1991 and further data are needed to interpret the trends.

Technetium-99

Technetium-99 has been typically found to follow uranium throughout much of the fuel cycle. There is thus a sizable technetium-99 plume also associated with the 216-U-1 and 216-U-2 cribs in essentially the same location as the uranium plume. The extent of the technetium plume is, however, somewhat greater because of the higher mobility of technetium in the aquifer (see Figure 3.2).

## Plutonium Finishing Plant (Z Plant)

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 Plutonium Finishing Plant (PFP). The mission of the PFP remained essentially unchanged; however, liquid discharges were significantly reduced. Primary wastes associated with the plant include transuranics (plutonium and americium primarily), nitrate, carbon tetrachloride, tributyl phosphate, dibutyl phosphate, dibutylbutyl phosphorate, aluminum fluoride nitrate, and lard oil. Transuranic contaminants typically remain bound in the soil column at relatively shallow depths although there may be some minor exceptions. Tributyl phosphate has not been observed in the ground water and its fate is still relatively obscure. Lard oil is expected to remain at shallow depths in the soil. 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 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 Crib. The 216-Z-9 Crib received a large burden of transuranics from Z Plant liquid effluent streams. That well was not monitored in 1992 because water levels have declined below the well screen. The origin of the transuranic contaminants in that well is unclear. It may be associated with poor quality well completion and thus be very localized. The plutonium was found to be associated only with unfiltered samples and was thus in a relatively immobile form.

Nitrate

The 216-Z-9 Trench received an estimated 1.3 million kg of nitrate-containing chemicals over the course of its operation from 1955 to 1962. Other LWDFs associated with the Z Plant received lesser but significant amounts of nitrate. A major nitrate plume originates in this area. The maximum nitrate level measured in 1992 in that area was 260 mg/L in well 299-W15-8.

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 Z Plant (now referred to as the PFP) before 1973. Three LWDFs near Z Plant (216-Z-18 Crib, 216-Z-1A Tile Field, and 216-Z-9 Trench) received on the order of 1000 tons of carbon tetrachloride during their operational history. A concentration of 8100 $\mu$g/L carbon tetrachloride was found in a well near the PFP first monitored in October 1988. Carbon tetrachloride concentrations in that well were somewhat lower in 1992 reaching a maximum of 6700 $\mu$g/L. Numerous other wells in the area had carbon tetrachloride levels ranging from 1000 to 5000 $\mu$g/L. The distribution of carbon tetrachloride in 200-West Area is shown in Figure 4.15.

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. The only discernible exception is the western or southwestern edge, which has shown considerable movement over the past 4 or 5 years. Figure 4.16 shows the trends in carbon tetrachloride concentrations with time for five 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. The other three locations show less dramatic change although there is a distinct increase in concentration in wells located to the southeast of the plume center.

Ground-water flow in that part of the site has been heavily influenced by the mounding created by the operation of the U Pond located at the southwest corner of the 200-West Area, which received large amounts of cooling water from REDOX 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 decommissioning U Pond through use of 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 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 Volatile Organic Compound-Arid Integrated Technology Demonstration have to date failed to reveal the presence of free-phase liquid; however, because of the difficulties and high

costs associated with subsurface access at that location, the investigation has been relatively limited in scope. It thus appears likely that the carbon tetrachloride plume will expand slowly.

The DWS for carbon tetrachloride is 5 $\mu$g/L. The 200-West Area/PFP site 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 1540 $\mu$g/L was measured in well 299-W15-8 in May 1990. It was not possible to sample this well in 1992 because of water-level decline. The maximum chloroform concentration detected in 1992 was 598 $\mu$g/L in the March 11 sample from well 299-W11-30. This sample was collected during drilling so it may not be fully representative of ground water at this location. The chloroform plume shown in Figure 4.16 is based on prior years' data from wells not sampled in 1992 and on 1992 sample data. The chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume. The chloroform appears to be associated primarily with the 216-Z-9 Trench area. The origin of the chloroform is unknown, but it is strongly suspected to be a degradation product of carbon tetrachloride. Since there were septic drainage fields in the area in the past close to the chloroform maximum, 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 $\mu$g/L (total trihalomethanes)—20 times higher than for carbon tetrachloride.

Fluoride

A few wells in the 200-West Area near T Plant showed elevated levels of fluoride during 1992. The maximum concentration in 1992 was 7.2 mg/L in well 299-W10-15, exceeding both the secondary DWS (2.0 mg/L) and the primary DWS (4.0 mg/L). The source of the small fluoride plume is believed to be several LWDFs associated with Z Plant. For example, the 216-Z-9 Trench received 210 kg of aluminum fluoride nitrate (Stenner et al. 1988) during the course of its operation from 1955 to 1962. A similar amount of aluminum fluoride nitrate was disposed to the 216-Z-18 Crib during its operation from 1969 to 1973. However, the fact that the plume is some distance from those facilities makes the identification of the source questionable.

### 4.1.9 200-East Area

#### 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 operation began again in 1983 and ceased in December 1988 when the Hanford weapons production mission effectively ended. PUREX operations 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 both campaigns

can be distinguished in some of the contaminant plumes. Contaminant plumes associated with the PUREX operation are primarily those species associated with process condensates, which include nitrate, tritium, and iodine-129.

Nitrate

The high nitrate concentrations in the 200-East Area continued to be found near LWDFs that received effluent from PUREX operations. 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 remained above the DWS even though these facilities were removed from service in 1987. The highest nitrate detected in this vicinity in 1992 was 170 mg/L in wells 299-E17-15 and 299-E17-20. 180 mg/L nitrate was detected in well 299-E28-12 near the B Plant.

The configuration of the nitrate plume emanating from 200-East Area (Figure 3.3) shows the influence of two periods of PUREX operation and recent changes in the operation of B Pond. The location of B Pond is shown in Figure 1.1.

Tritium

Concentrations greater than the 2,000,000-pCi/L DCG were detected in four wells in the 200-East Area. The highest tritium concentrations in the 200-East Area continued to be in wells near cribs that have received effluent from the PUREX Plant. Tritium concentrations greater than the DCG were present in wells near the 216-A-10 and 216-A-36B cribs. Two wells monitoring downgradient of the 216-A-10 Crib were above the DCG in 1992. The tritium concentration in well 299-E17-1 continued a generally decreasing trend but remained above the DCG in 1992. Well 299-E17-20 also continued a generally decreasing trend in tritium concentration and dropped slightly below the DCG in December of 1992.

Well 299-E17-9, monitoring the 216-A-36B crib, continued to have the highest detected tritium concentrations in the 200-East Area. Tritium levels detected in this well in 1992 ranged from 3,660,000 to 4,080,000 pCi/L. Well 299-E17-14, which also monitors the 216-A-36B Crib, was slightly above the DCG in May 1992 but dropped to 1,890,000 pCi/L in December 1992.

The ground-water tritium concentration measured in well 299-E25-19, near the 216-A37-1 Crib, dropped below the DCG in late 1991 and in 1992. Tritium concentrations exceeding the DWS continued to occur in many wells affected by cribs near the PUREX Plant.

The movement of the widespread tritium plume (see Figure 3.2) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Woodruff and Hanf 1992; Evans et al. 1992). Separate tritium pulses associated with the two episodes of PUREX operations can be distinguished in the plume. The 200,000- to 2,000,000-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. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. Elevated tritium concentrations

measured in several wells (for example, wells 699-32-43 and 699-24-33) downgradient from the 200-East Area represent the formation of 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 4.17, which clearly shows arrival of the plume in early 1987 following the passage of the plume from the earlier campaign. The first plume had reached much higher levels in the mid 1960s. By contrast, a trend plot of the tritium concentrations in well 699-40-1 located near the shore of the Columbia River (Figure 4.18) shows the arrival in the early 1970s of the plume from the first campaign with no discernible effect from the second plume.

Iodine-129

The highest iodine-129 concentrations in the 200-East Area are in the southeast portion near the PUREX Plant. The maximum detected iodine-129 in 1992 in the 200-East Area was 16 pCi/L in well 299-E17-20, south of the PUREX Plant. The iodine-129 plume from the PUREX area extends southeast into the 600 Area and appears coincident with the tritium and nitrate plumes. The more limited extent of the iodine-129 plume shown in Figure 4.12 results from the lower initial concentrations of iodine-129 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. Iodine-129 has nearly the same high mobility in ground water as tritium and nitrate.

Strontium-90

Strontium-90 was detected at concentrations above the DWS in wells near the 216-A-10 and 216-A-36-B cribs. The maximum concentration was 17.5 pCi/L in well 299-E17-14. The strontium-90 is restricted to the immediate vicinity of the cribs. This may be because of either adsorption or chemical reaction with aquifer materials.

### 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 were 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 in the ground water as well as some cesium-137. 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 have included nitrate, sulfate, and cyanide (as ferrocyanide). Calcium and strontium, which were present in the supernatant as hold-back carrier, are also clearly present in excess over natural backgrounds. 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 that area are associated primarily with the technetium plume. There is some evidence in the past few years that a small amount of uranium may also be present in the plume.

Nitrate

The plume originating from the BY Cribs contains some of the highest ground-water nitrate levels on the Site. Well 699-50-53A contained nitrate concentrations of 580 mg/L in February of 1992, similar to previous measurements for that well.

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. The maximum cyanide concentration in samples taken from the 200-East Area in 1992 was 130 $\mu$g/L in one sample from well 299-E33-41, which is in the 241-B tank farm area, southeast of the BY Cribs. Other samples from this well do not confirm the presence of cyanide. Well 699-50-53A, north of the BY Cribs, still contains detectable cyanide (110 $\mu$g/L in 1992) 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; however, the origin of that species is not known. It may be a stable fission product because the heavier selenium isotopes have significant fission yields; however, an isotopic analysis will be required to confirm that hypothesis. A maximum selenium level of 61 $\mu$g/L was reported in well 699-50-53A in November of 1991. The highest selenium level reported for that well in 1992 was 38 $\mu$g/L. The DWS for selenium is 50 $\mu$g/L.

Cobalt-60

Well 699-50-53A, which is located in a region north of the 200 Areas affected by waste disposed of in the BY Cribs (Figure 3.2), has consistently shown the presence of detectable cobalt-60 in recent years. The range of cobalt-60 in this well in 1992 was up to 332 pCi/L, which is lower than the 1991 maximum of 449 pCi/L. 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

The presence of elevated technetium-99 apparently associated with the BY Cribs plume continued to be observable in 1992. A technetium-99 level of 5280 pCi/L, well above the 900 pCi/L DWS, was measured in well 699-50-53A in August of 1992.

Uranium

A uranium level of 8 $\mu$g/L was measured in a ground-water sample from well 699-50-53A collected in February of 1992. Continued monitoring of this well will be needed to determine if a uranium plume is present; however, because the waste stream was associated with uranium recovery such a result is not unexpected.

## 216-B-5 Injection Well

The 216-B-5 Injection Well was operated briefly from April 1945 to September 1946. It received a number of 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. Radiological contaminants associated with that facility include strontium-90, cesium-137, and plutonium.

Strontium-90

Concentrations of strontium-90 ranged up to 7660 pCi/L in the 200-East Area near the 216-B-5 Injection Well. It was not possible in 1992 to sample several of the wells in this vicinity which have been historically high in strontium-90. The 216-B-5 Injection Well received an estimated 24.0 Ci of strontium-90 (decayed through December 31, 1992) during its use for waste disposal from 1945 to 1946 (Stenner et al. 1988).

Cesium-137

Concentrations of cesium-137 were below the detection limit (20 pCi/L) except in one well, 299-E28-23, located near the 216-B-5 Injection Well (Figure 3.2). The 1992 sample from well 299-E28-23 contained cesium-137 at 1860 pCi/L. The 216-B-5 Injection Well received an estimated 27.6 Ci of cesium-137 (decayed through December 31, 1992) during its use for waste disposal from 1945 to 1946 (Stenner et al. 1988). The DWS for cesium-137 is 200 pCi/L, and the DCG is 3000 pCi/L. The area with cesium-137 above the DWS, based on 1992 and past results, is depicted in Figure 3.2. Most of the wells located near the 216-B-5 Injection Well were not sampled in 1992 because of restrictions on entry to radiation protection zones. Cesium-137 is restricted to the immediate vicinity of the injection well by its extremely low mobility in ground water.

Plutonium

Concentrations of plutonium-239/240 in ground water sampled at the 200-East Area well 299-E28-23, which is located near the 216-B-5 Injection Well, ranged from 24.2 to 33.0 pCi/L in 1992. This is comparable to levels observed in 1990. Plutonium-238 was also detected in well 299-E28-23 but at considerably lower levels ranging from 0.09 to 0.15 pCi/L. 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 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. Alternately, 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.

### 4.1.10 300 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. 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 is complicated by fluctuations in the Columbia River stage and associated changes in gradient and bank storage.

Uranium

The major role of the 300 Area in Hanford Site operations was the processing of uranium into fuel elements for the reactors. During this processing, uranium was reportedly disposed to the process ponds and trenches in dissolved and particulate form. 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. The 316-5 Process Trenches are the last of these facilities currently active.

The uranium distribution in the 300 Area is shown in Figure 4.19. The main uranium plume is 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 this area is 140 $\mu$g/L in well 399-1-10A. The Process Trenches and the North Process Pond both received waste uranium in the past. The 316-5 Process Trenches are currently active but are receiving much less discharge than in the past—approximately 0.9 Mgal/day down from a maximum of approximately 3 Mgal/day. Currently the trenches receive process cooling water with a small quantity of nonhazardous maintenance and process waste (DOE 1993). 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 appear to be remaining low (Figure 4.20) with the 1992 average of 18 $\mu$g/L, just below the proposed DWS. The reduced uranium in this well may be a function of the Expedited Response Action and/or the reduced flow to the trench.

A second, smaller area of elevated uranium concentration in the southern part of the 300 Area is indicated by well 399-4-7, which had a concentration of 43.3 $\mu$g/L in the 1992 annual sample. The source for the uranium in this area is not well defined. Well 399-4-12, which is used to supply water for the trout research ponds south of the 331 Building, contained 22.6 $\mu$g/L in the single sample reported in 1992.

Trichloroethylene

Few wells in the 300 Area contain concentrations of TCE greater than the DWS in spite of the known TCE usage and estimates of significant quantities disposed to ground (Stenner et al. 1988). The distribution of TCE in the 300 Area is shown in Figure 4.21. The presence of cis-1,2-DCE in some samples indicates that anaerobic biodegradation of TCE has occurred. However, the lack of vinyl chloride detected in the 300 Area indicates that the degree of biodegradation is relatively low. Cis-1,2-DCE is less readily degraded to vinyl chloride than TCE is to cis-1,2-DCE. The maximum detected concentration of cis-1,2-DCE in monitoring well 399-1-16B was 120 $\mu$g/L, approximately 10 times the TCE concentration.

The highest TCE concentrations detected in the 300 Area are in the 399-1-16A,B,C well nest located in the 316-2 North Process Pond area. This pond was active from 1949 to 1974. The 316-5 Process Trenches, upgradient from this well nest, are still active. The TCE concentrations in the 399-1-16 well nest are generally highest in the lower unconfined aquifer well, 399-1-16B (maximum of 16 $\mu$g/L in 1992 samples). Although TCE has been detected in the upper confined aquifer well, 399-1-16C, these values are thought to be probably related 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. Well 399-1-16D, which was still deeper, was abandoned because of suspected well-construction problems.

The reason for higher TCE concentrations in the lower unconfined aquifer than in the upper unconfined aquifer in the 399-1-16 well nest may be related to flushing of the upper unconfined aquifer by disposal of TCE-free water to the 316-5 Process Trenches. The water disposed to the Process Trenches will have the greatest flushing effect at the water table. The presence of dense non-aqueous phase liquid TCE at depth within the aquifer has not been established. 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.

Trichloroethylene was also detected at levels up to 5 $\mu$g/L in well 399-2-2 near the 300 Area Sanitary Waste Trenches, between the north and south process ponds. It is difficult to determine if the source of the TCE is related to the 300 Area sewer system.

Trichloroethylene is present at low levels in many samples from the southern portion of the 300 Area. The TCE concentrations in samples collected in 1992 were below 10 $\mu$g/L in all samples from the 316-1 South Process Pond and further south; in most cases TCE concentrations were below the 5 $\mu$g/L DWS. 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 has been detected at concentrations above the DWS in a few non-filtered samples from the 300 Area. The concentrations in filtered samples remain below the DWS and the detected values in the non-filtered samples are erratic. This suggests that the high chromium concentrations found in these monitoring wells represent particulate matter, which may be related to well construction and are affected by the well purging procedures, the time between samples, or other effects that do not reflect the general ground-water quality.

### 4.1.11 400 Area (FFTF)

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. 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 used to a lesser extent for the 400 Area water supply.

The 400 Area drinking water supply is monitored for tritium by the Hanford Environmental Health Foundation. The water supply has remained below the DWS for all but one sample since supply well 499-S1-8J went on line. The concentration of tritium in the water supply closely reflects that in the main supply well, 499-S1-8J, in spite of occasional use of the backup wells. Tritium in well 499-S0-8 stayed below the DWS in 1992 but those in 499-S0-7 remained above the DWS (Figures 4.22 to 4.24). Nitrate remained below the DWS through 1992 in samples from all three supply wells in the 400 Area.

### 4.1.12 600 Area

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

The Central Landfill Complex includes the nonradioactive dangerous waste (NRDW) Landfill, a RCRA facility, and the SWL, a non-RCRA facility in the 600 Area southeast of the 200-East Area (Figure E.2, Appendix E). The NRDW Landfill received dangerous non-radioactive waste from 1977 to 1985 and continued to receive asbestos waste until 1988. The SWL 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 Hanford Site bus garage washwater was disposed to the SWL between 1985 and 1987 (DOE 1993). Chlorinated hydrocarbon compounds, including trichloroethylene and tetrachloro-ethylene detected at the SWL are attributed to the bus garage washwater. A soil gas su' ey of the SWL performed in 1989 (Evans et al. 1989) confirmed the presence and document he distribution of chlorinated hydrocarbons in the landfill. Chlorinated

Particular concern in the North Richland Area is related to the potential for future impacts at the North Richland wellfield.

The North Richland wellfield consists of a cluster of eight active unconfined aquifer wells 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 wellfield area. The city's operational goal is to recharge twice as much water as is withdrawn from the wells. The North Richland wells are most heavily used when the Richland water-treatment plant is down for servicing and for summer peak-demand supply.

Ground-water constituents of concern in the North Richland Area include gross alpha or uranium and TCE. Tritium from Site operational areas is being investigated to assess the potential for transport into the North Richland Area.

Tritium from the 200-East Area discharge has been transported to the Columbia River as far south as the 300 Area (Figure 3.2). Tritium levels in monitoring wells north of the 300 Area continue to increase and have raised concern regarding offsite transport and the future safety of the North Richland water supply wells. The increasing trend in well 699-S19-E13, north of the 300 Area is shown in Figure 4.28. Low-level tritium analyses on samples collected from the North Richland wells in 1992 do not indicate any impact of Site activities on the wellfield (see Figure 4.29).

Several factors are believed to limit the migration of the 200-East Area tritium plume toward the North Richland Area. The first of these is the eastward flow across the area produced by the Yakima River stage. The Yakima River stage is approximately 15 m higher to the west of the North Richland Area than is the Columbia River to the east. The net result is ground-water recharge from the Yakima River, eastward flow across the area and discharge to the Columbia River. This limits the southward component of the tritium plume transport (Plate 1). Additional recharge from irrigation in the western North Richland Area is also believed to contribute to the eastward flow. The ground-water mound at the recharge basins also serves to limit 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 2.11).

Nitrate distributions in the North Richland 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 SPC facility (Figure 3.3). In addition, somewhat elevated nitrate concentrations are located upgradient of SPC in the western portion of the North Richland Area. These upgradient sources may be related to agricultural fertilizer application and irrigation. Potential nitrate sources from the SPC operations are discussed in DOE (1993). 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 wellfield recharge basins. This is interpreted as representing the effect of infiltrating low-nitrate Columbia River water.

Trichloroethylene has been detected in ground-water samples in wells from the SPC and Horn Rapids Landfill areas. The maximum TCE detected in sampling by the Ground-Water Surveillance Project was 55 $\mu$g/L in wells 699-S31-10A and 699-S31-10D.

The only potential TCE source identified in the North Richland Area was the use of TCE in installing and maintaining pond liners at the SPC facility (DOE 1993). Trichloroethylene has been detected in ground water at the SPC facility and downgradient. No TCE was detected in soil surveys from the Horn Rapids Landfill. Trichloroethylene in soil gas at the landfill probably results from volatilization of the ground-water plume.

Gross alpha levels up to 100 pCi/L have been detected in 1992 at the SPC facility (Geraghty and Miller, Inc. 1992). Although the gross alpha DWS of 15 pCi/L excludes uranium, uranium measurements were not reported and no correction can be made. It is probable that uranium has 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 proposed DWS have not been detected in Hanford wells monitoring the Horn Rapids Landfill. Gross alpha measurements from past years also indicate that the area of elevated gross alpha contamination does not extend downgradient from 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 plume geometry indicates that the source is located offsite.

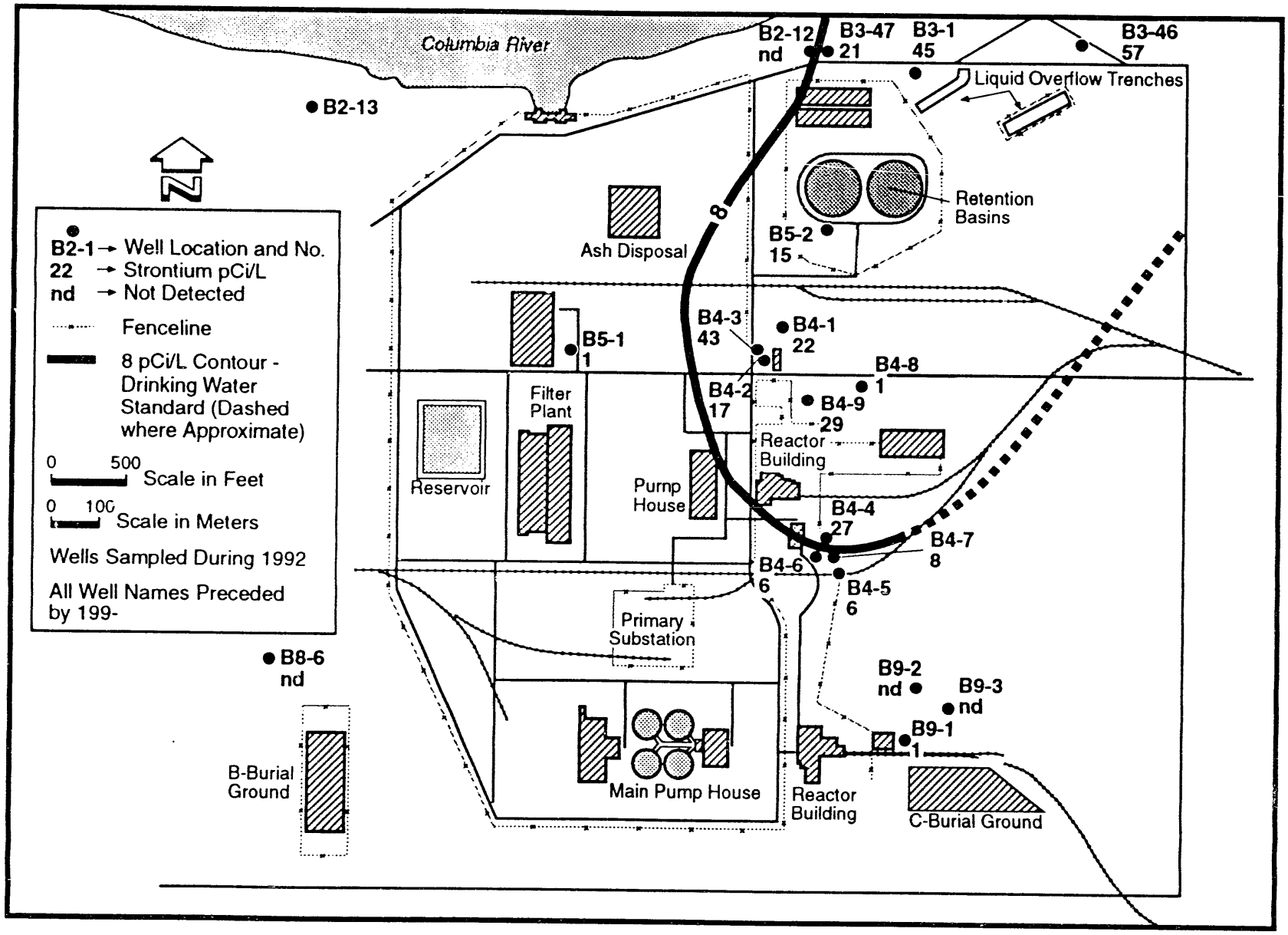



**Figure 4.1.** Distribution of Strontium-90 in Ground-Water Samples from the 100-B/C Area

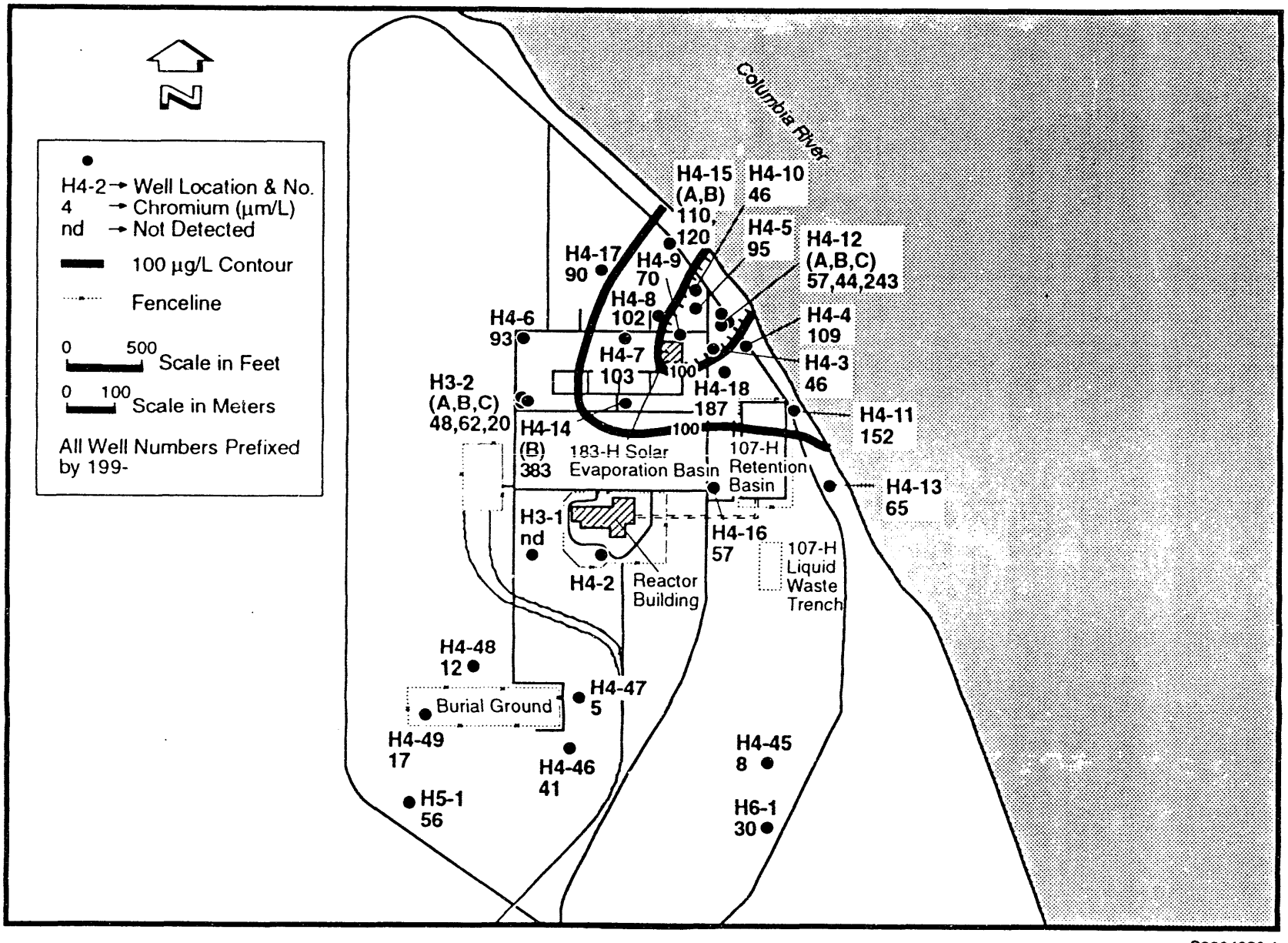



**Figure 4.2.** Distribution of Chromium in 1992 Filtered Ground-Water Samples from the 100-H Area

S9304030.1

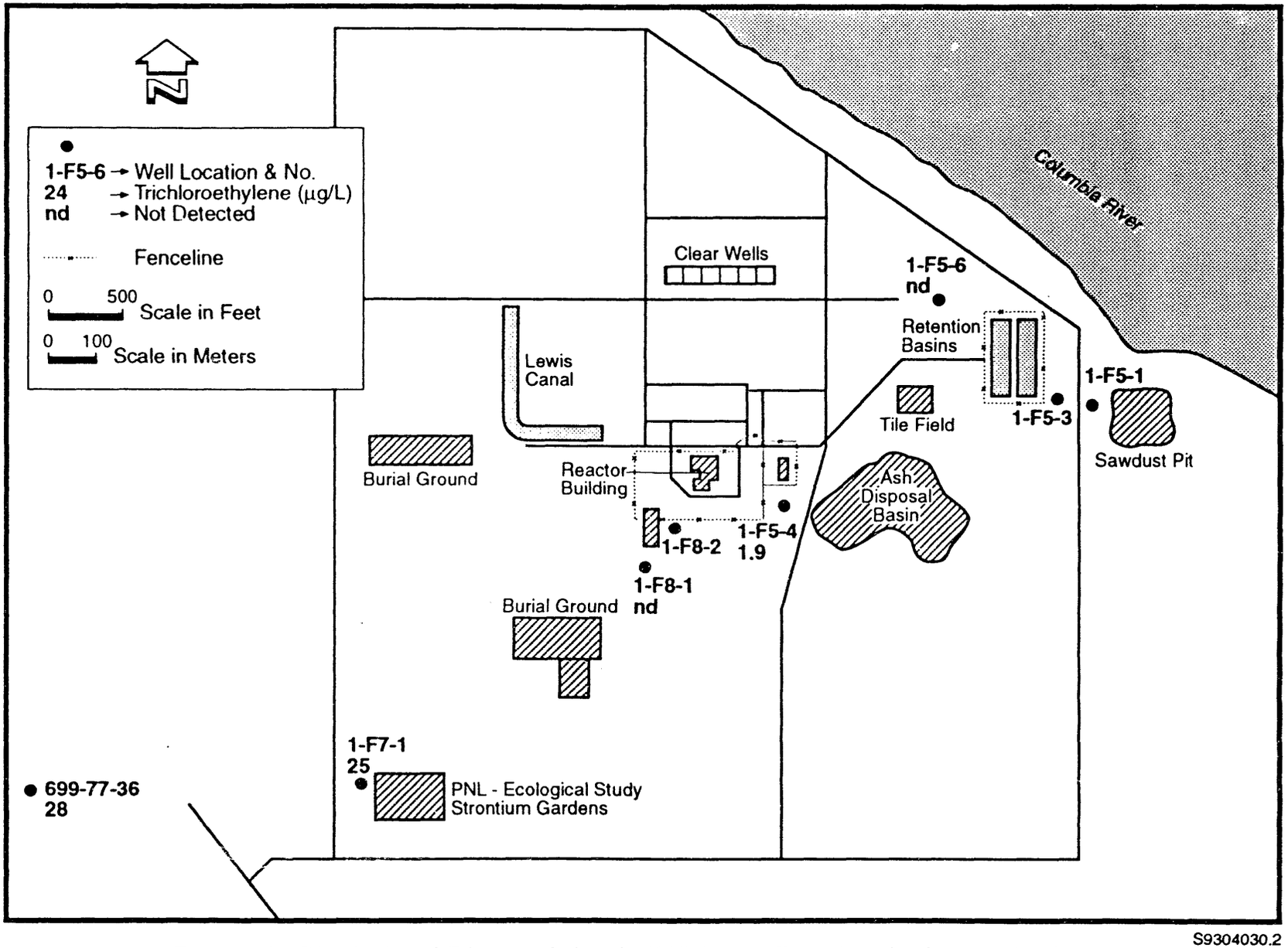



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**Figure 4.3.** Distribution of Trichloroethylene in 1992 Ground-Water Samples from the 100-F Area

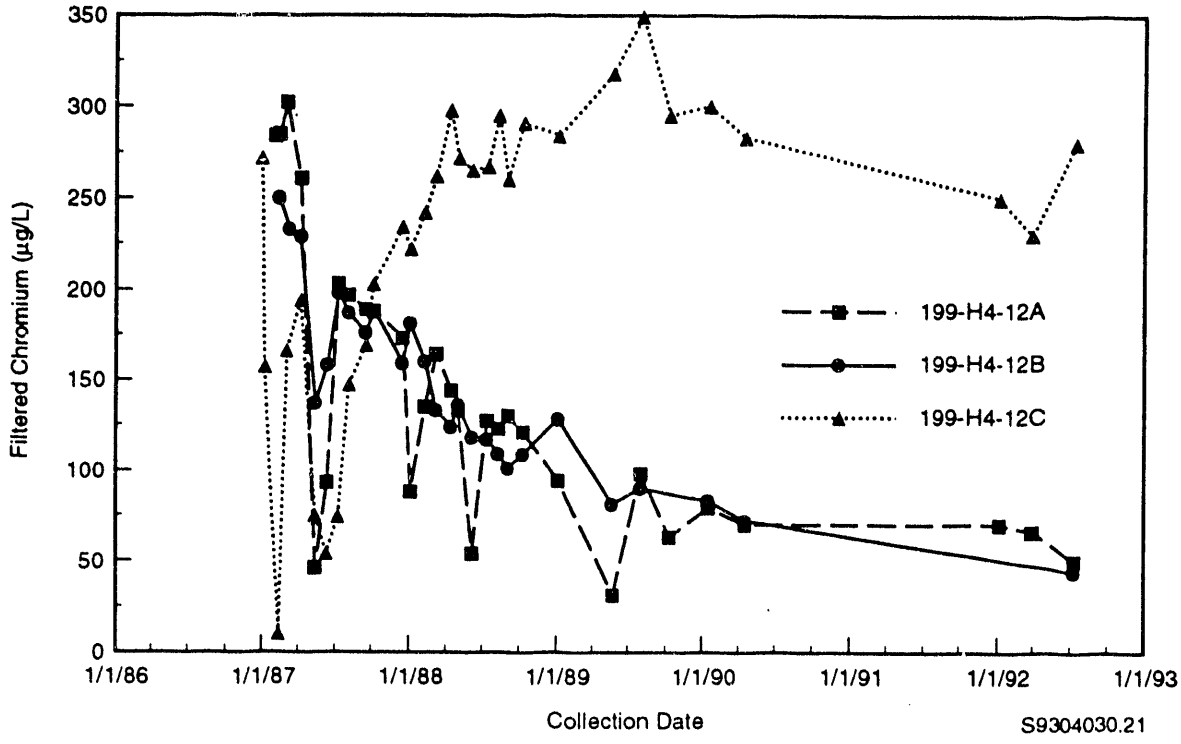


Figure 4.4. Filtered Chromium Concentration Trends in the 199-H4-12 Well Nest

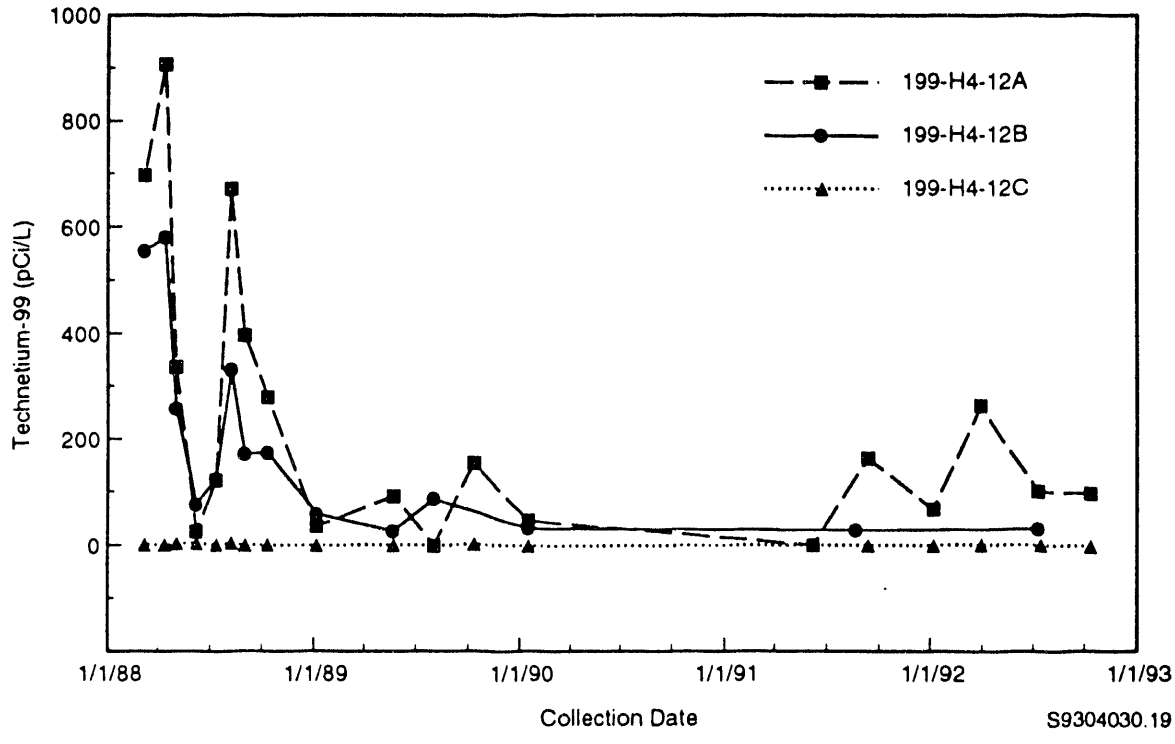


Figure 4.5. Technetium-99 Activity Trends in the 199-H4-12 Well Nest

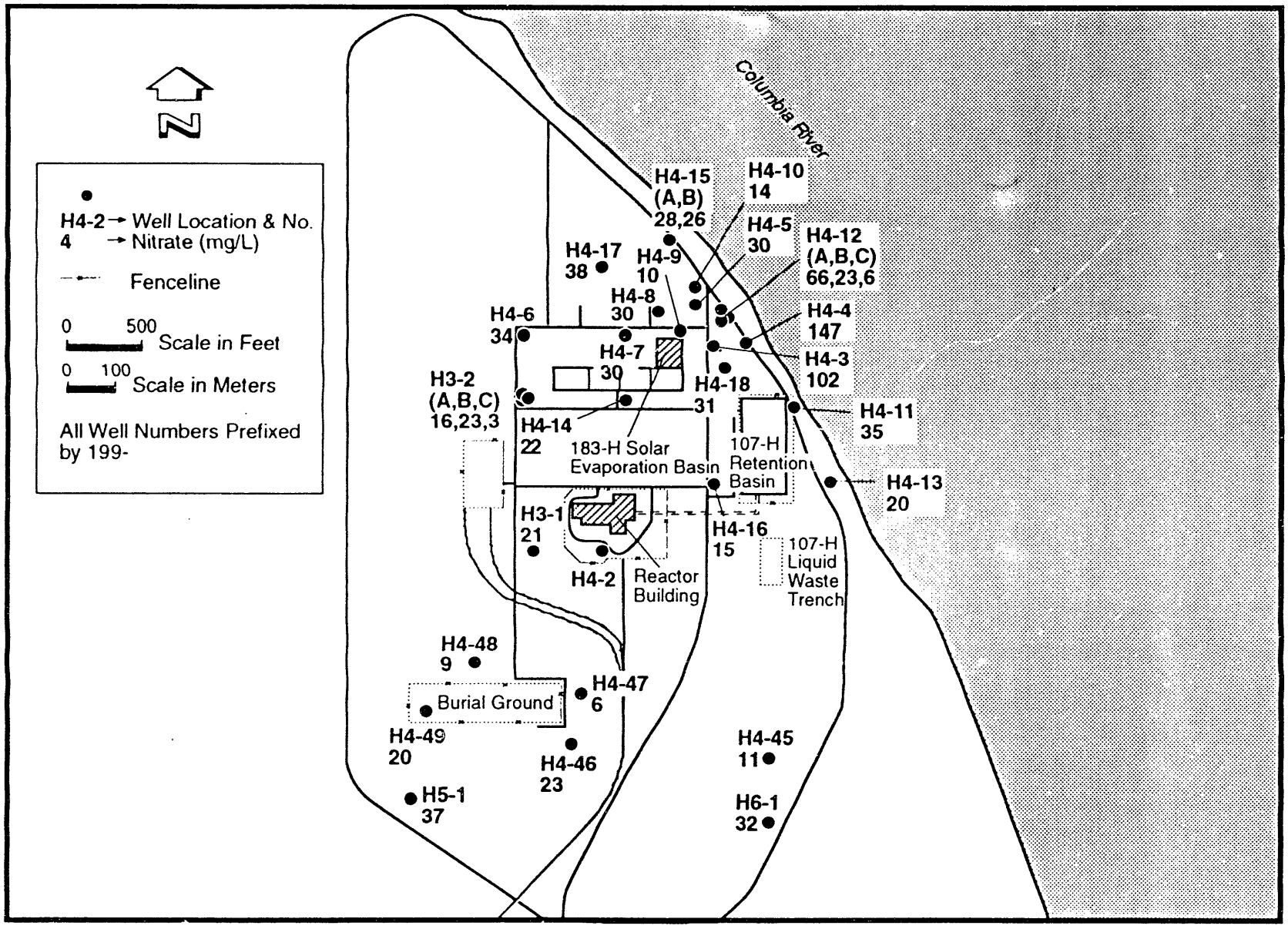


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**Figure 4.6.** Distribution of Nitrate in 1992 Ground-Water Samples from the 100-H Area

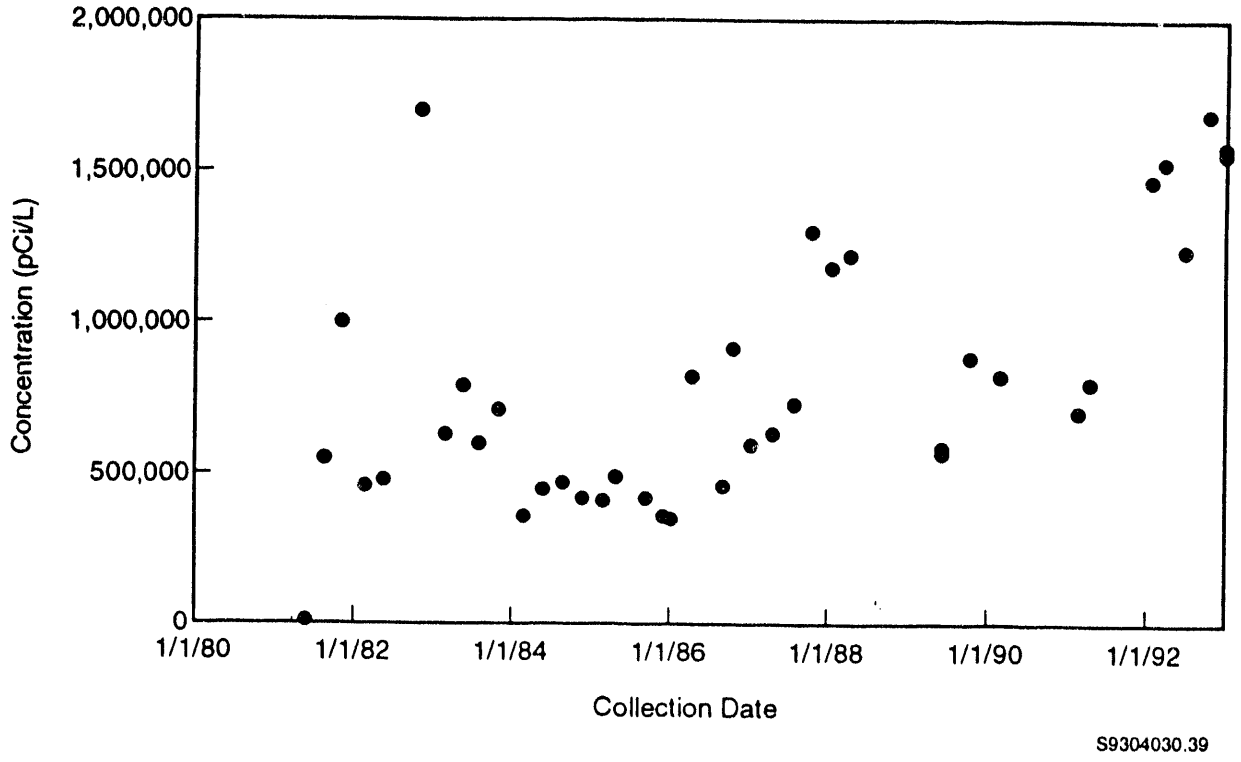


**Figure 4.7.** Tritium Concentration Trend in Well 199-K-30

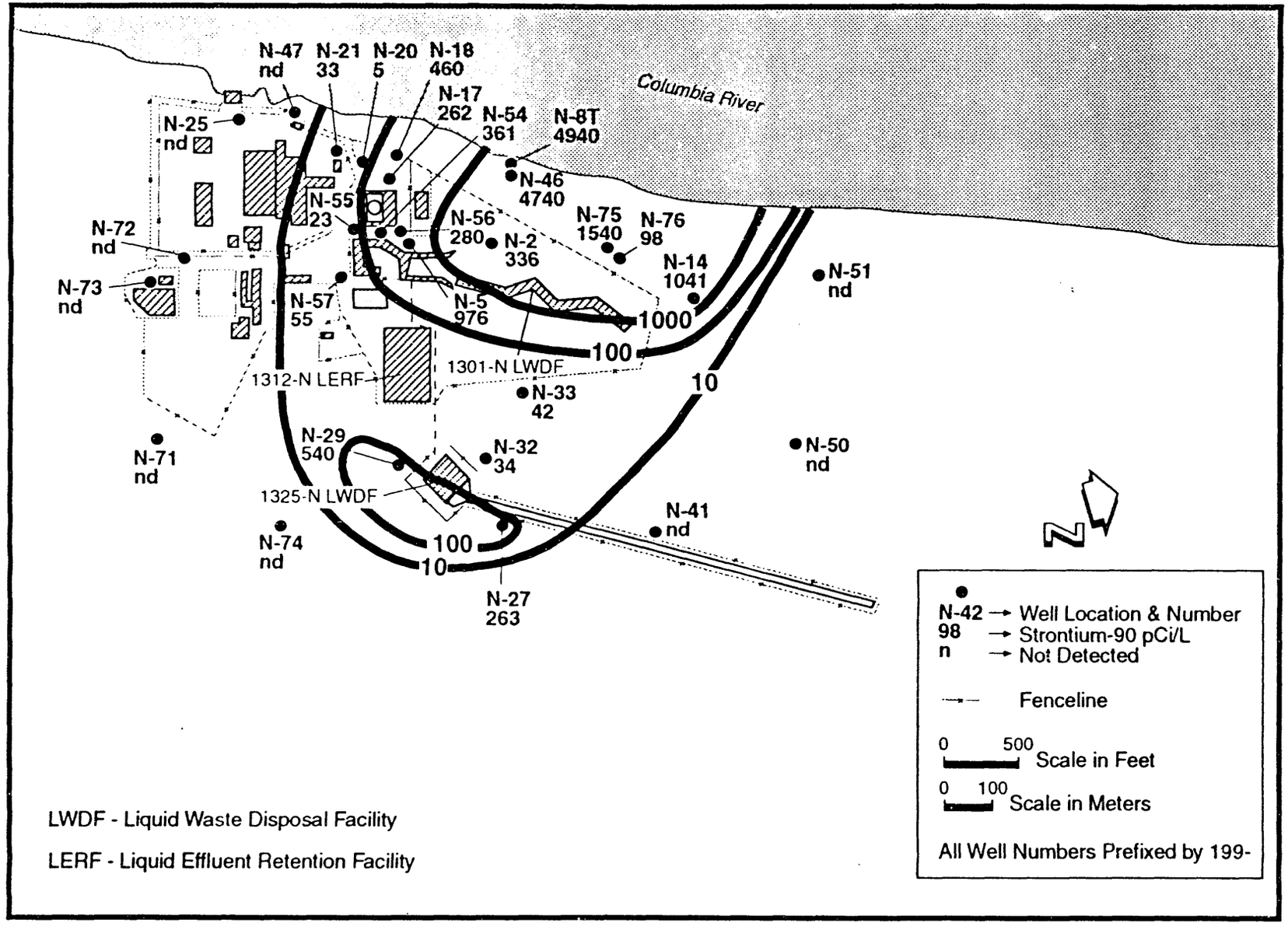


**Figure 4.8.** Distribution of Strontium-90 in 1992 Ground-Water Samples from the 100-N Area

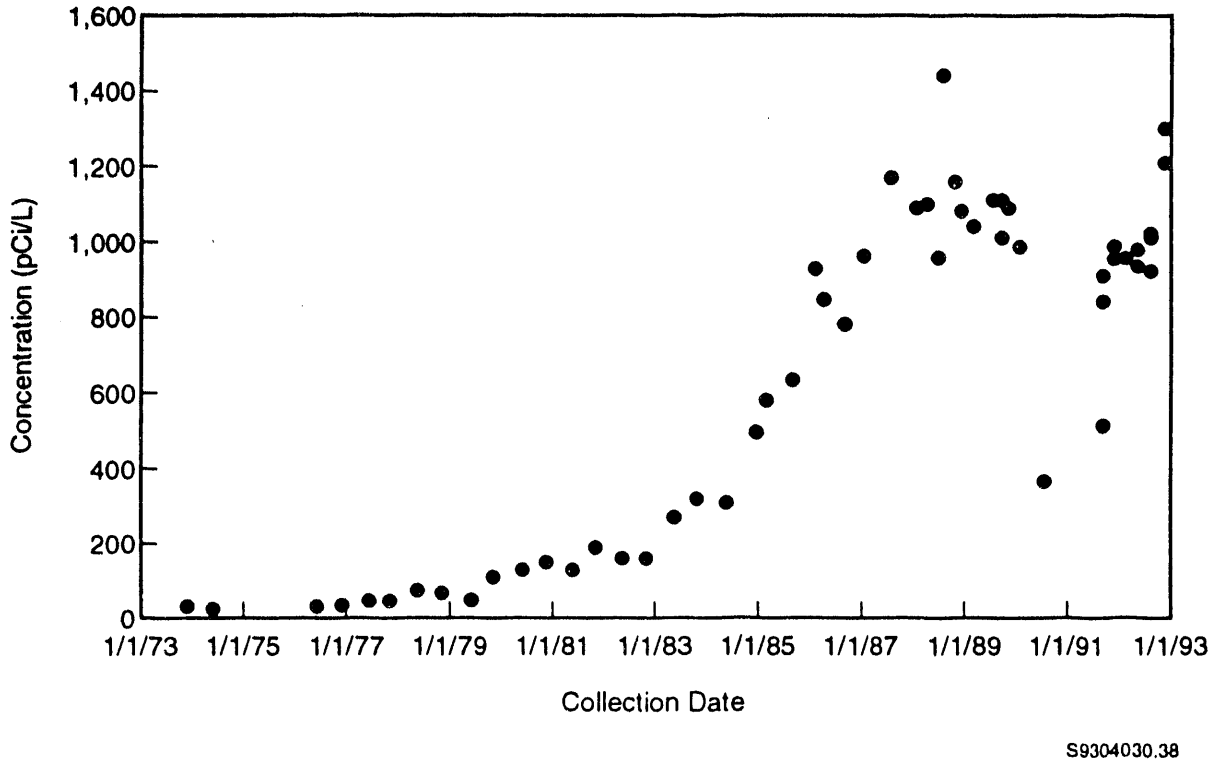


**Figure 4.9.** Strontium-90 Activity Trend in Well 199-N4-14

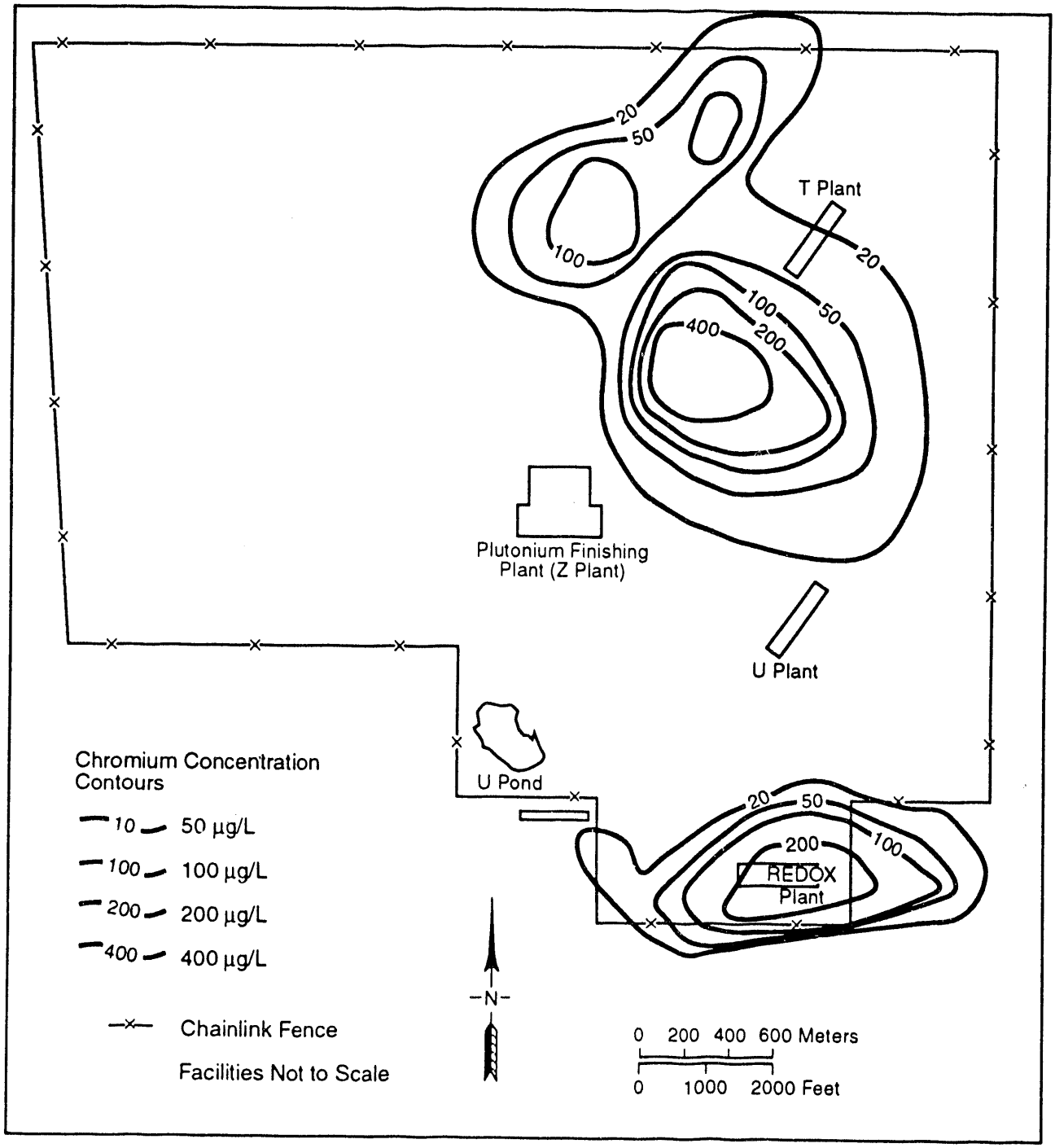


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Figure 4.10. Distribution of Chromium in 1992 Ground-Water Samples from the 200-West Area

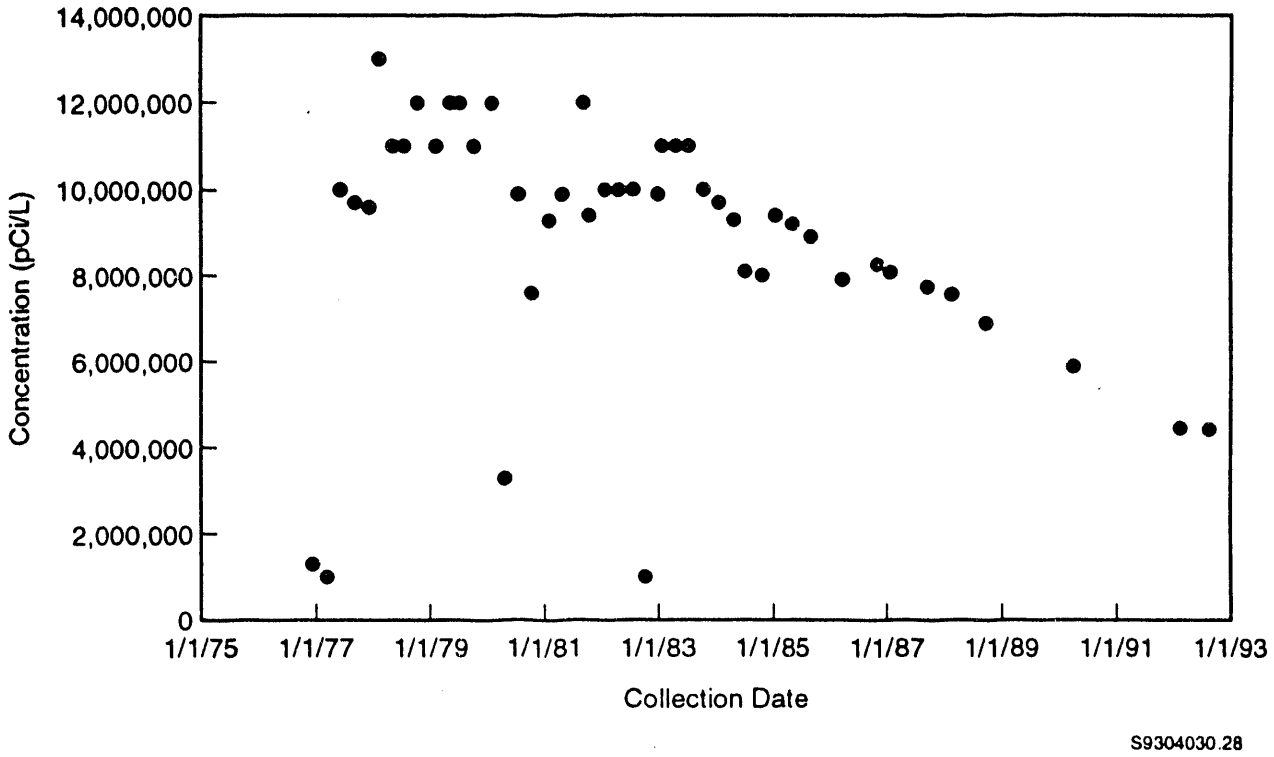


**Figure 4.11.** Tritium Concentration Trend in Well 299-W22-9

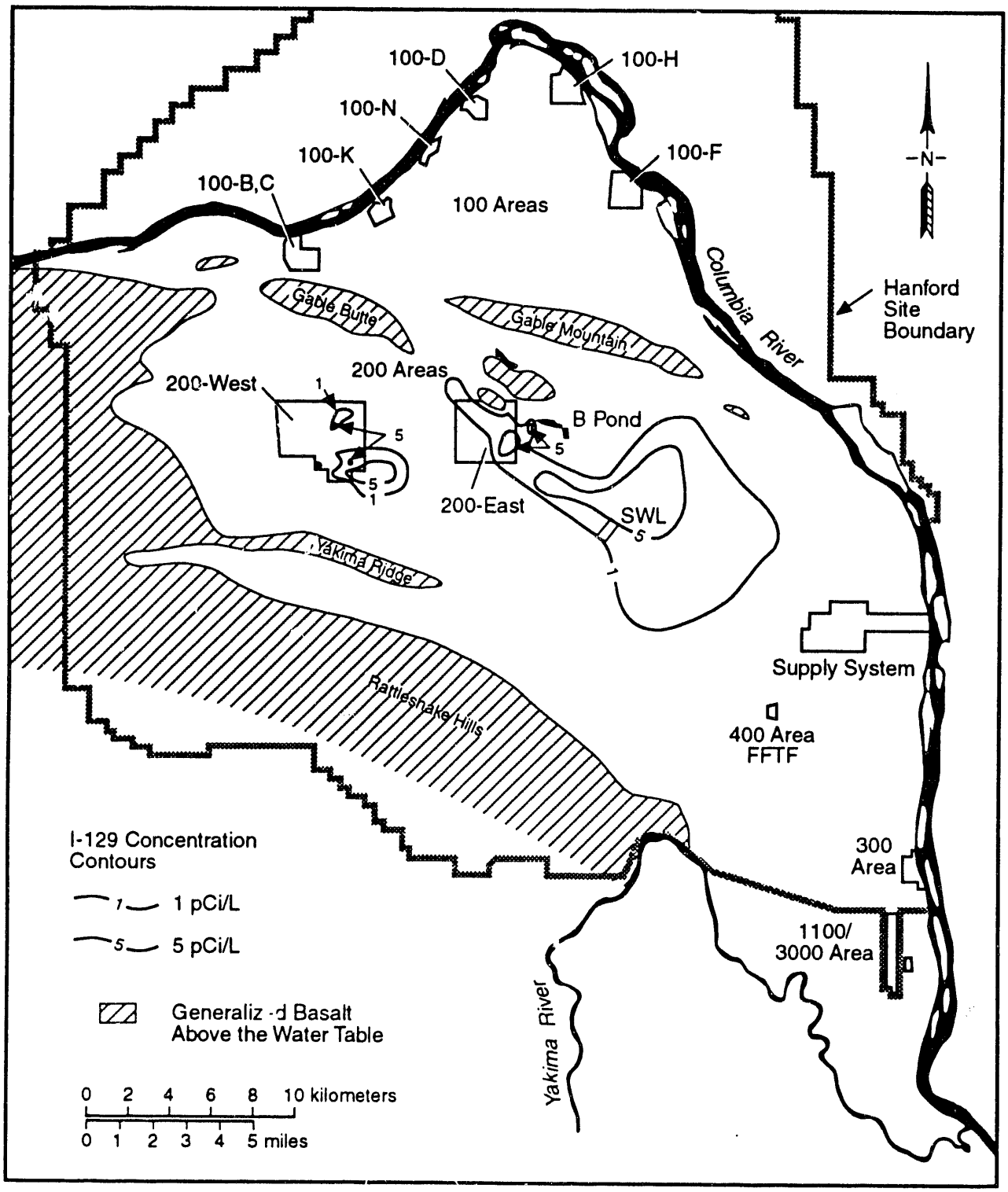


**Figure 4.12.** Distribution of Iodine-129 in Ground Water at the Hanford Site

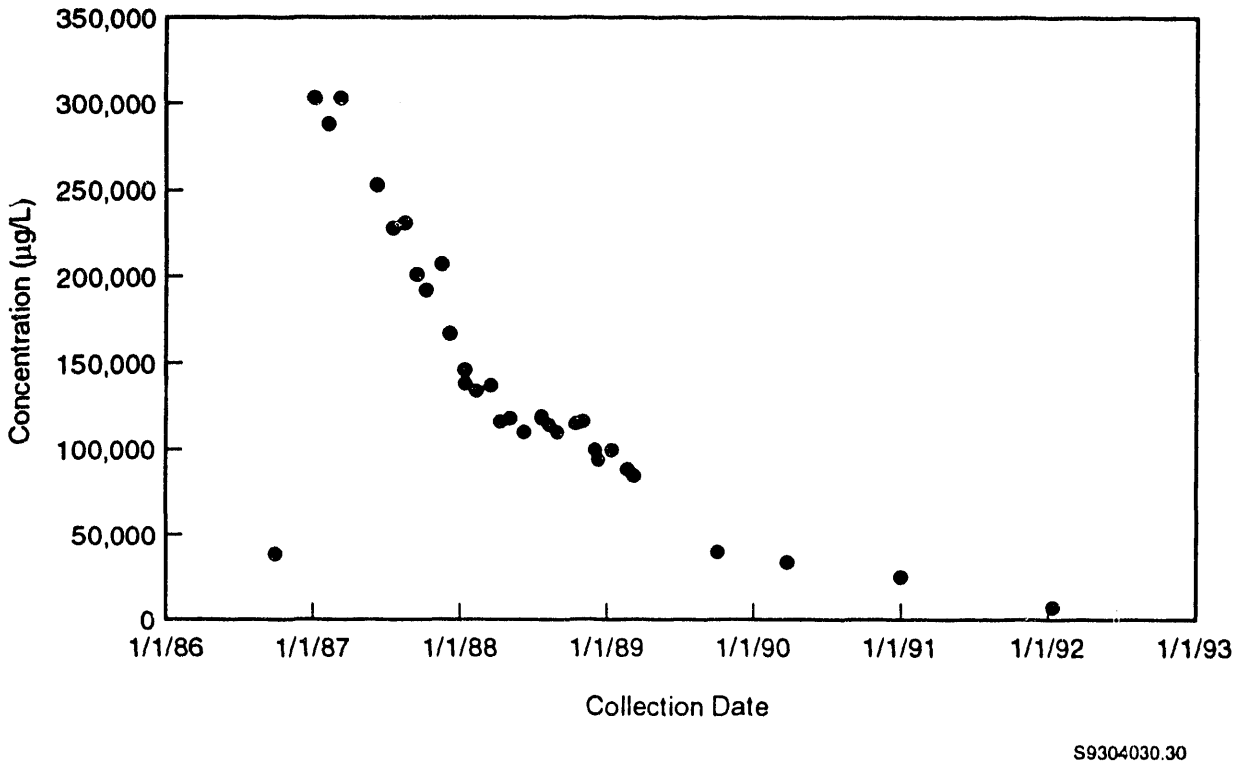


**Figure 4.13.** Nitrate Concentration Trend in Well 299-W19-18

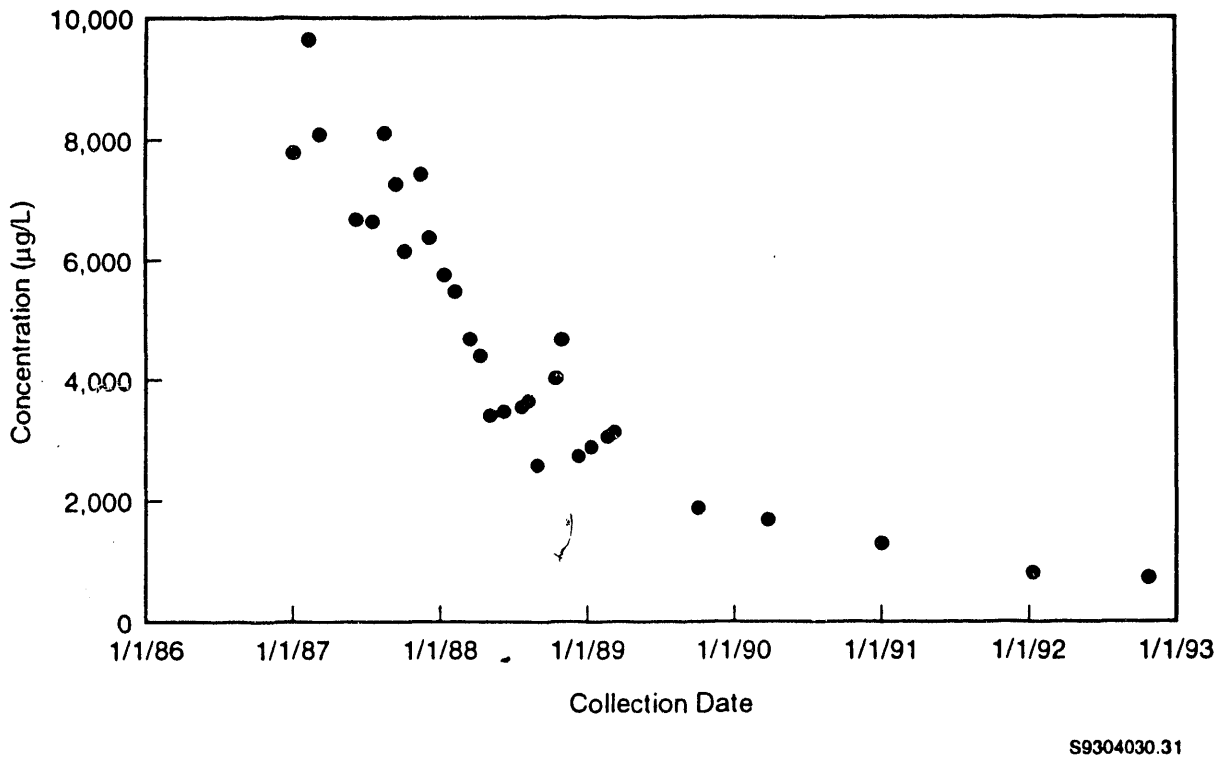


**Figure 4.14.** Uranium Concentration Trend in Well 299-W19-18

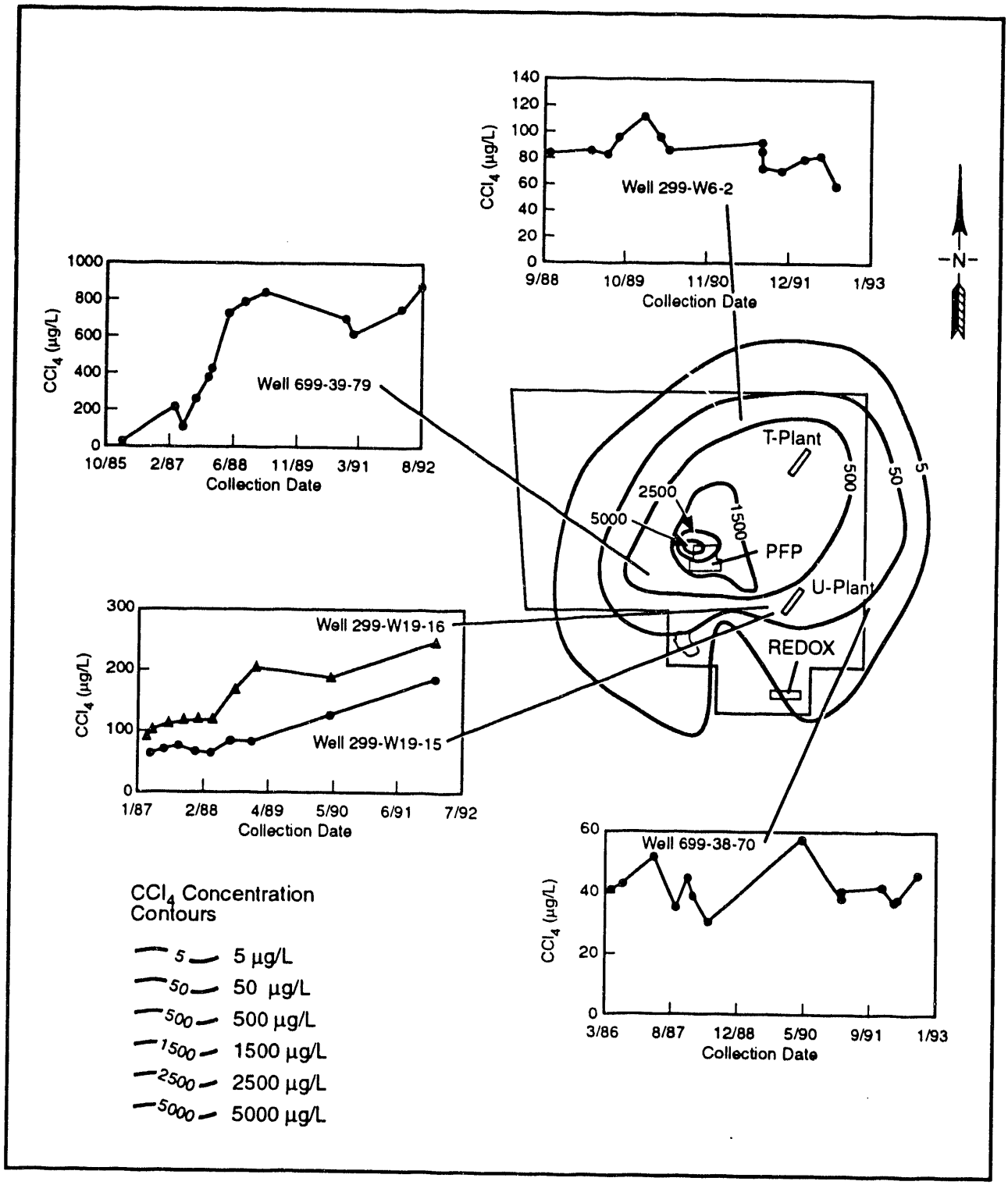


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**Figure 4.15.** Distribution of Carbon Tetrachloride ($CCl_4$) in the 200-West Area and Concentration Trends in Selected Wells

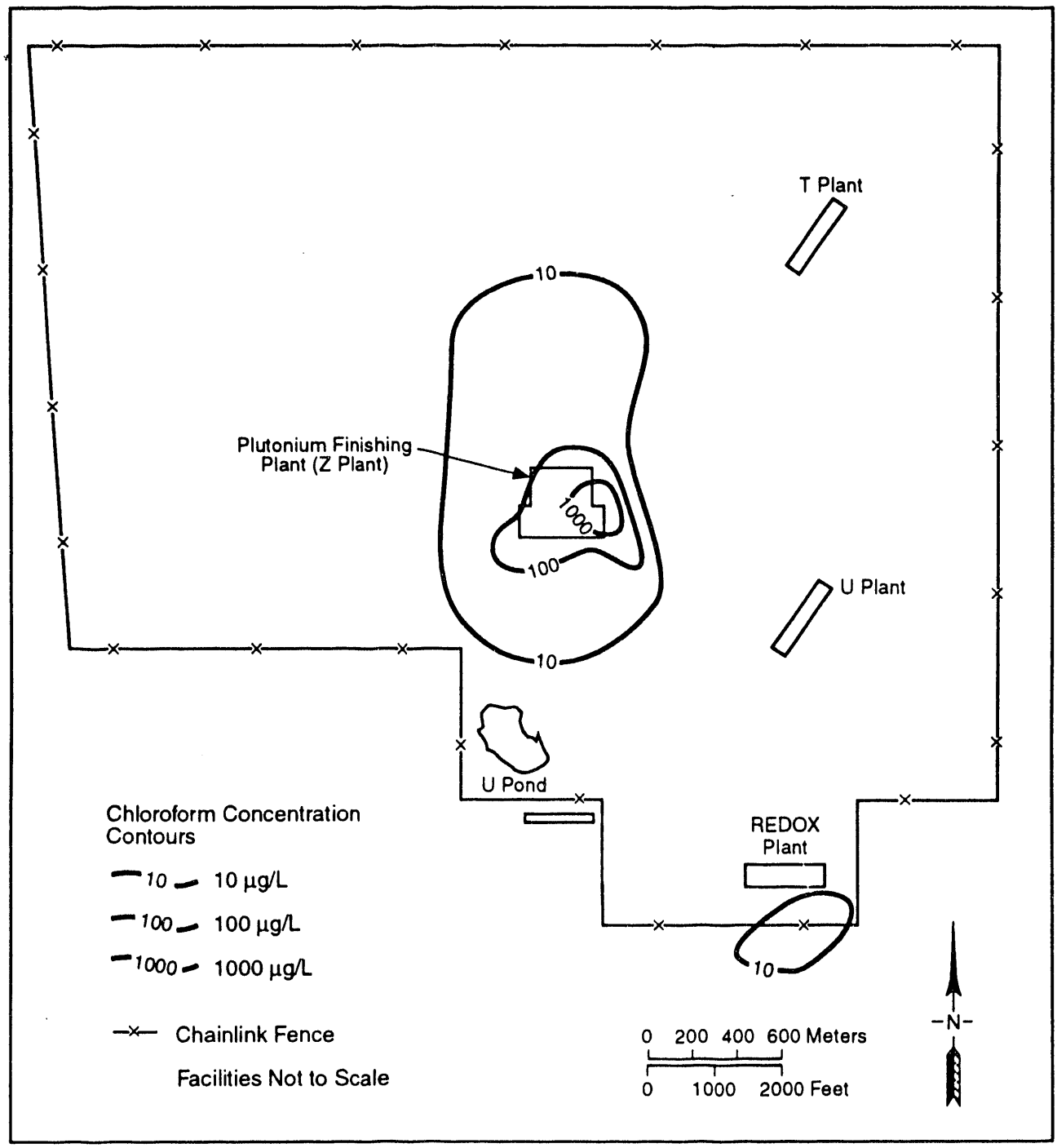


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**Figure 4.16.** Distribution of Chloroform in the 200-West Area

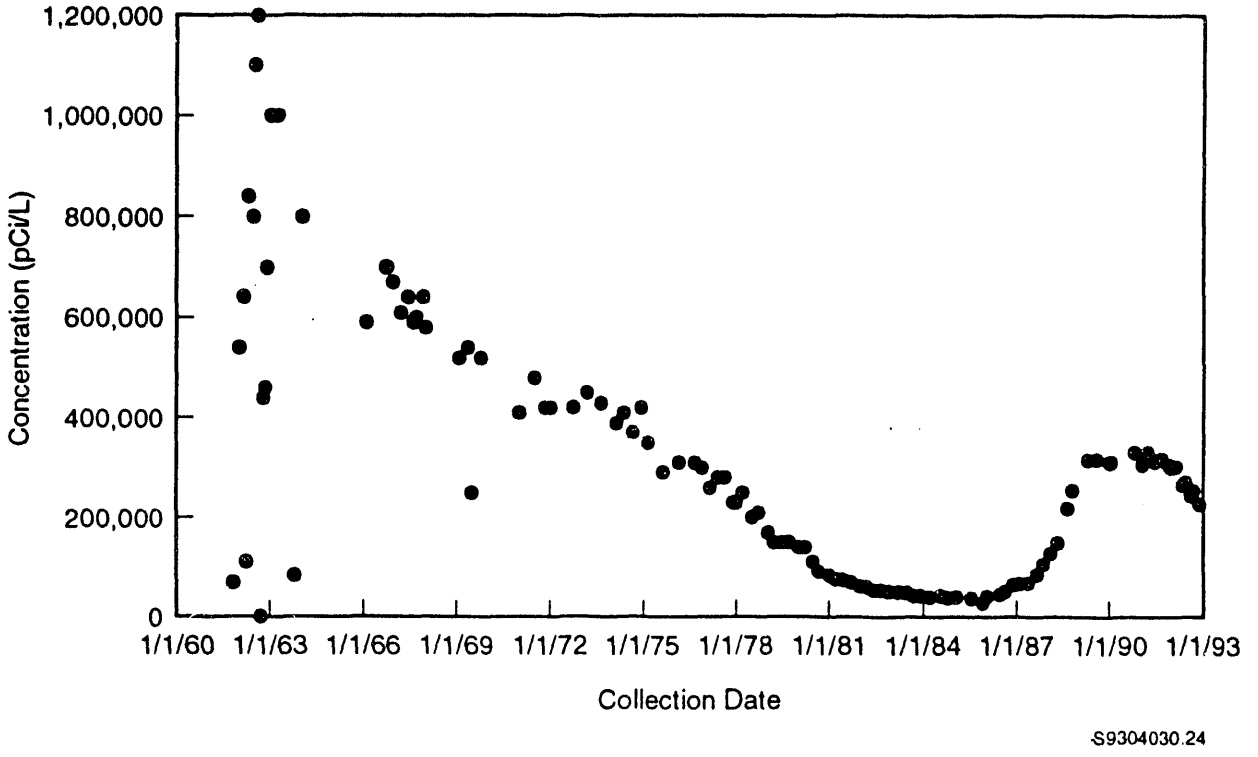



**Figure 4.17.** Tritium Concentration Trend in Well 699-24-33

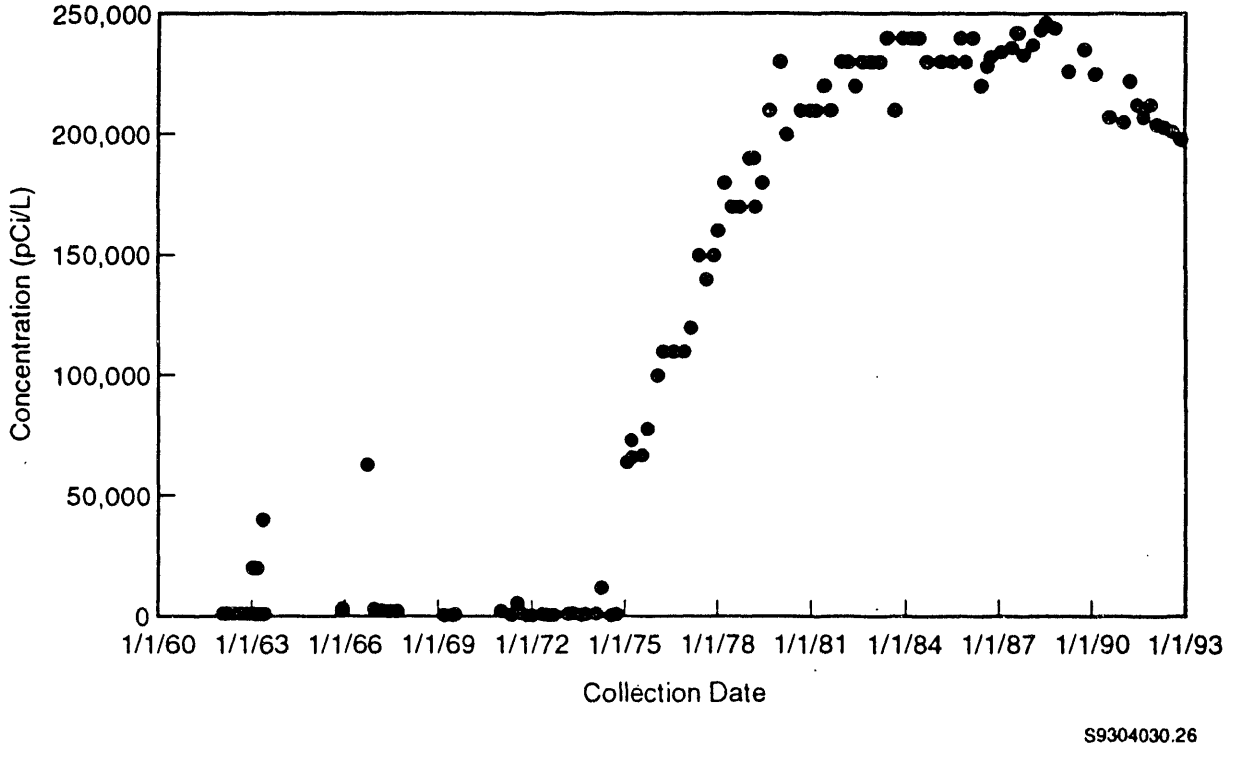



**Figure 4.18.** Tritium Concentration Trend in Well 699-40-1

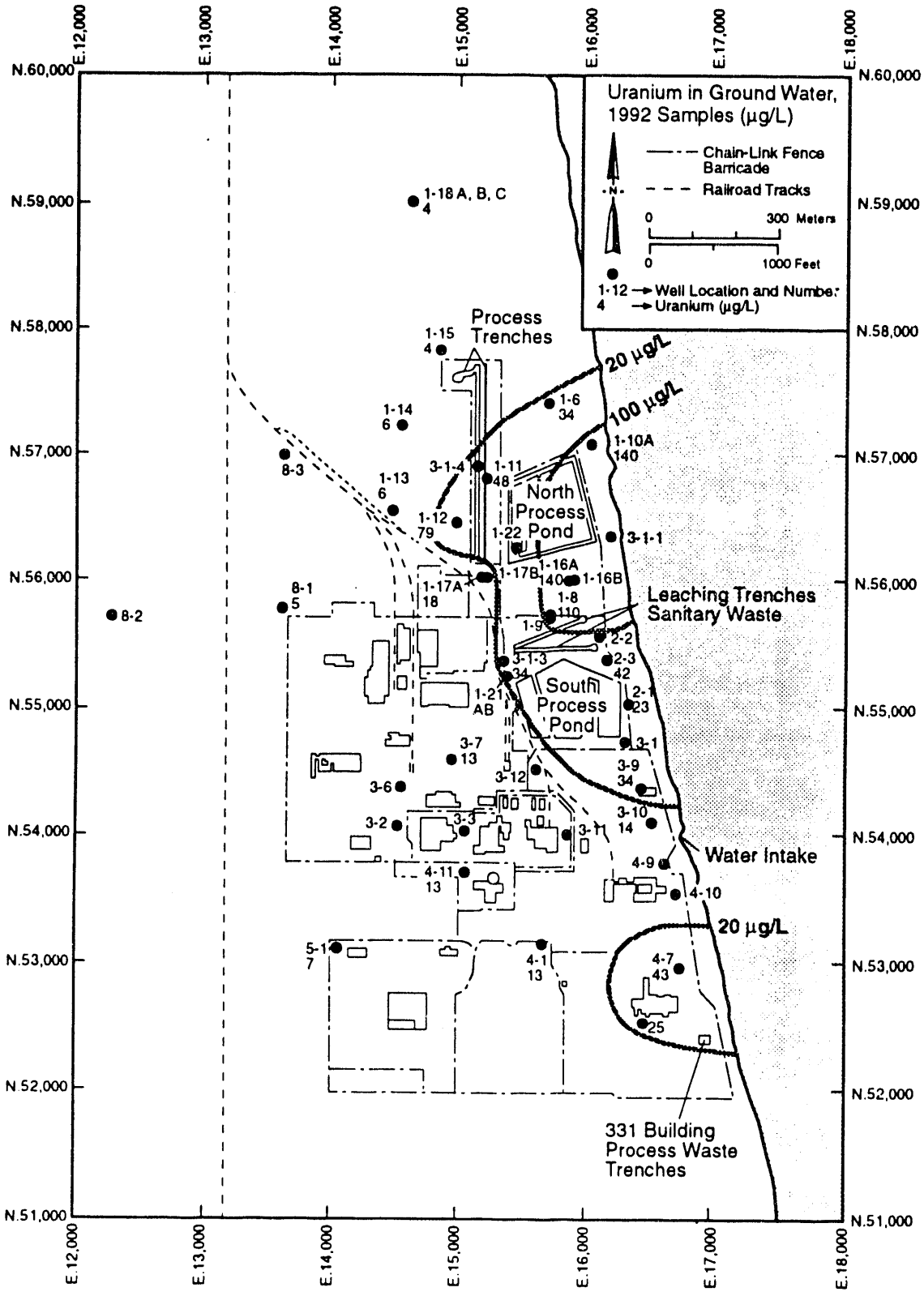



**Figure 4.19.** Distribution of Uranium in 1992 Ground-Water Samples from the 300 Area

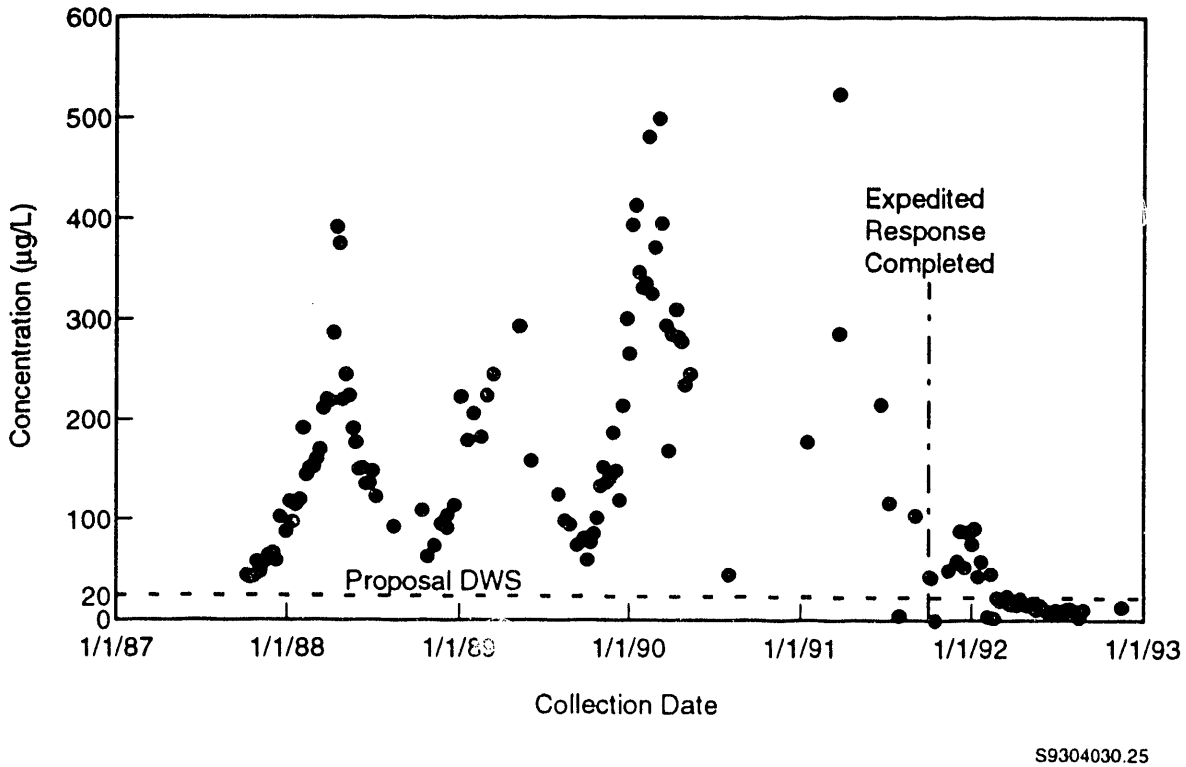



**Figure 4.20.** Uranium Concentration Trend in Well 399-1-17A, Near the 300 Area Process Trenches

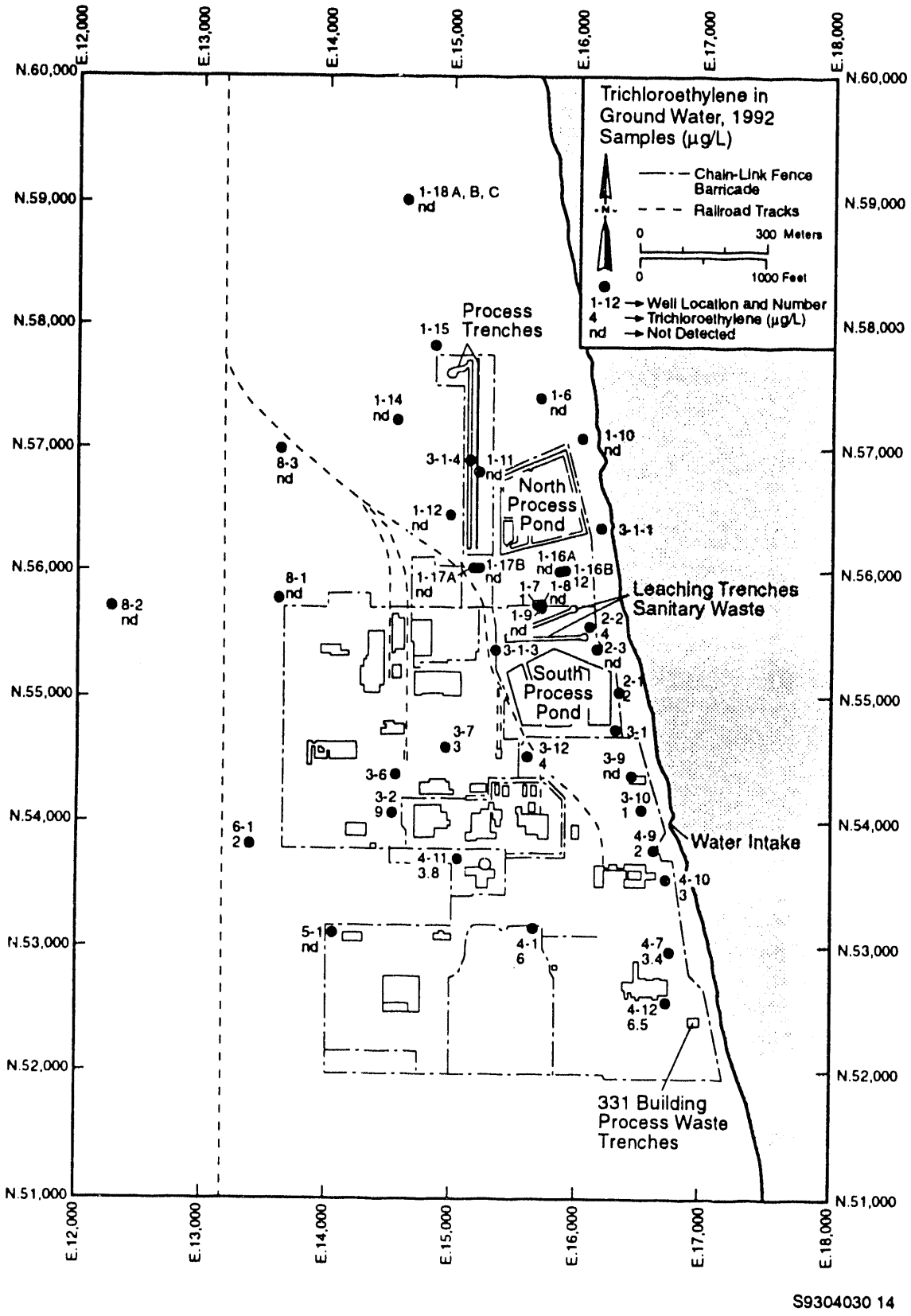



**Figure 4.21.** Distribution of Trichloroethylene in 1992 Ground-Water Samples from the 300 Area

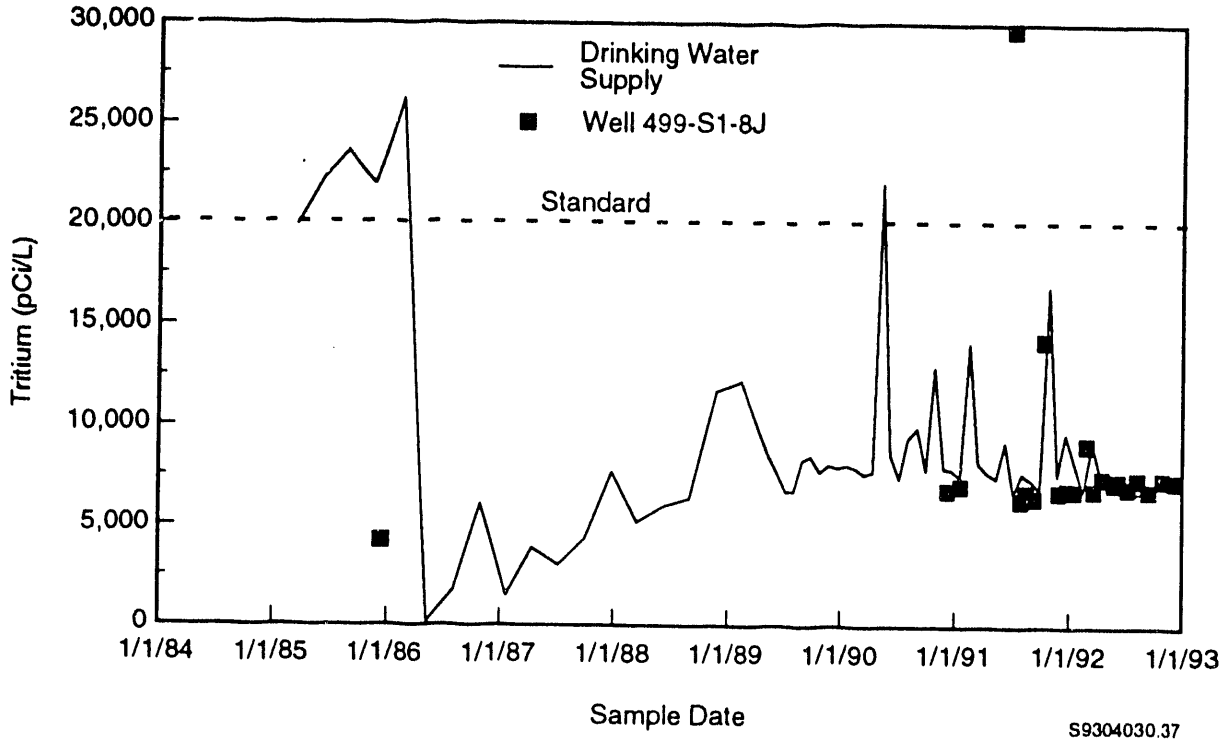



**Figure 4.22.** Comparison of Tritium Trend in Primary Water Supply Well 499-S1-8J and 400 Area Drinking Water

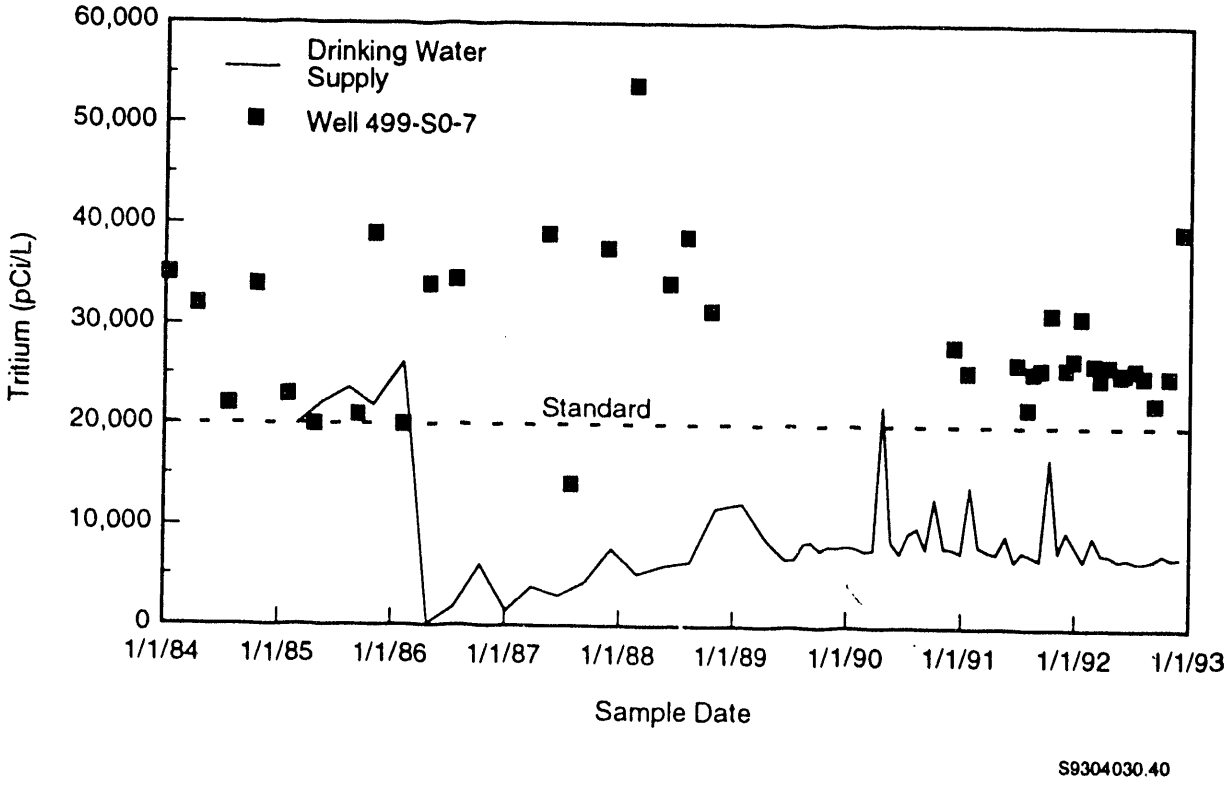



**Figure 4.23.** Comparison of Tritium Trend in Backup Water Supply Well 499-S0-7 and 400 Area Drinking Water

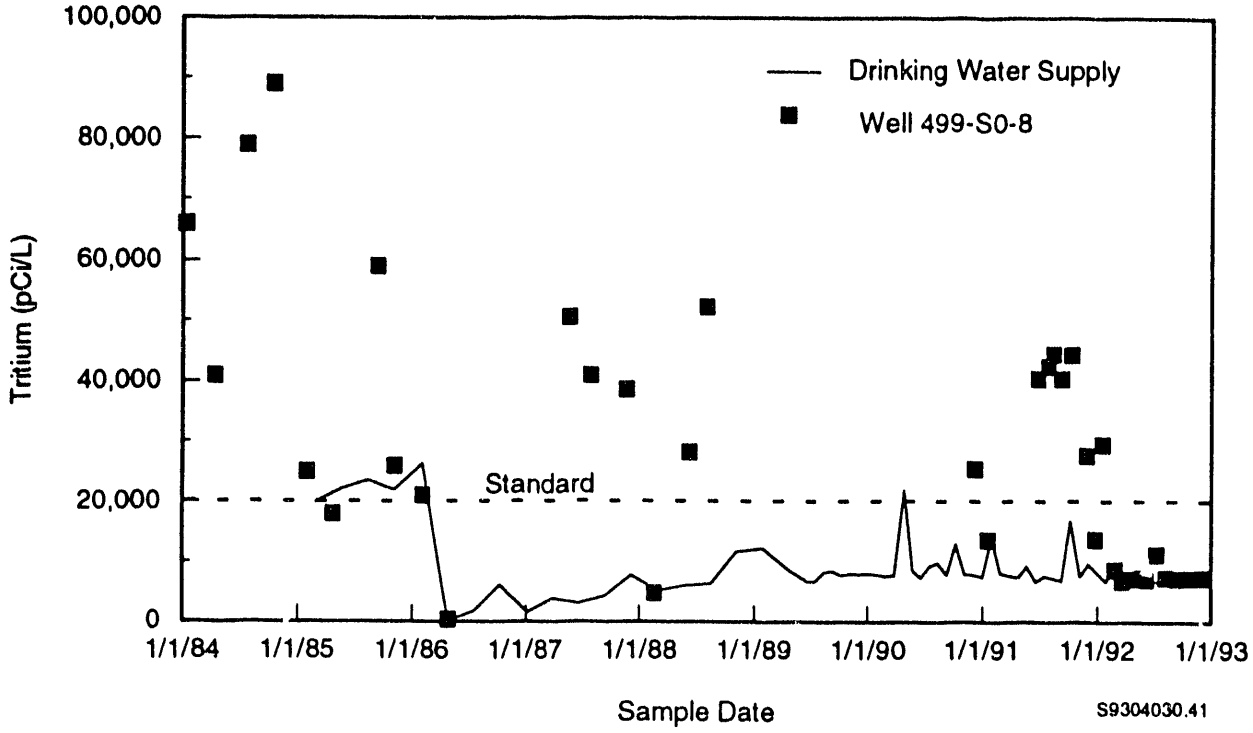



**Figure 4.24.** Comparison of Tritium Trend in Backup Water Supply Well 499-S0-8 and 400 Area Drinking Water

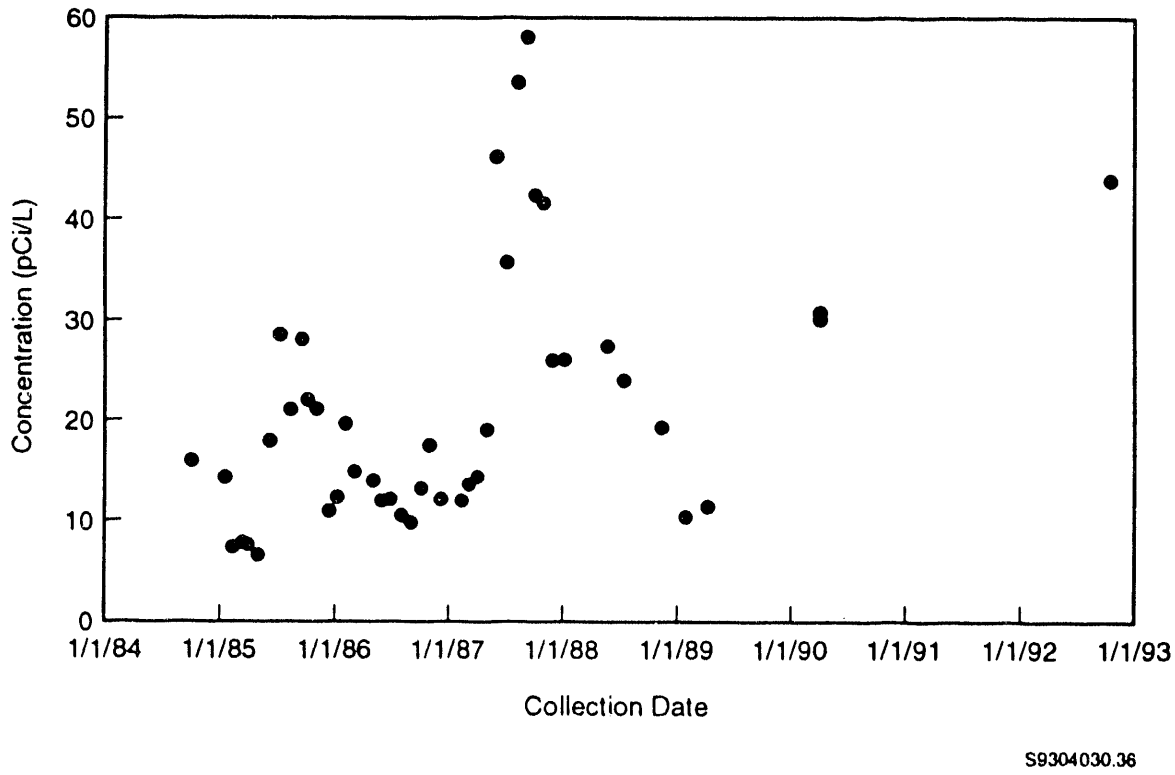
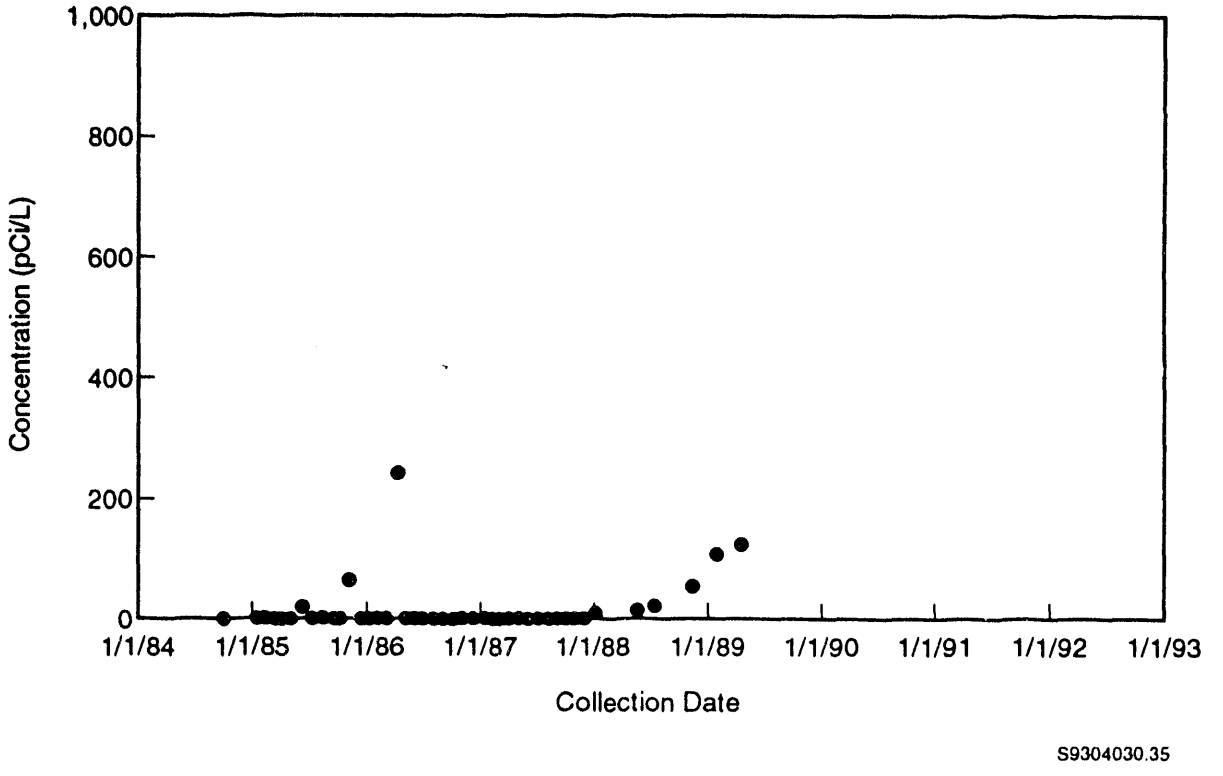



**Figure 4.25.** Strontium-90 Concentration Trend in Gable Mountain Pond Area Well 699-54-49




gure 4.26. Strontium-90 Concentration Trend in Gable Mountain Pond Area Well 699-53-48A

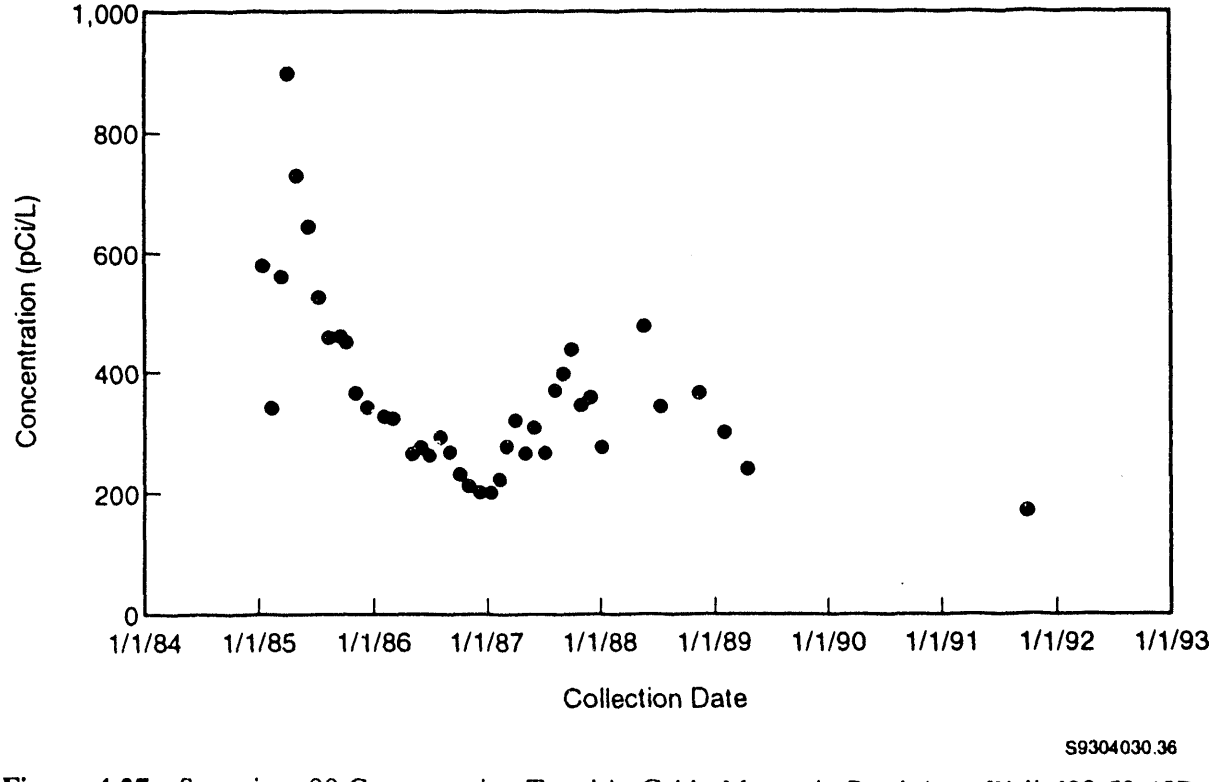



Figure 4.27. Strontium-90 Concentration Trend in Gable Mountain Pond Area Well 699-53-48B

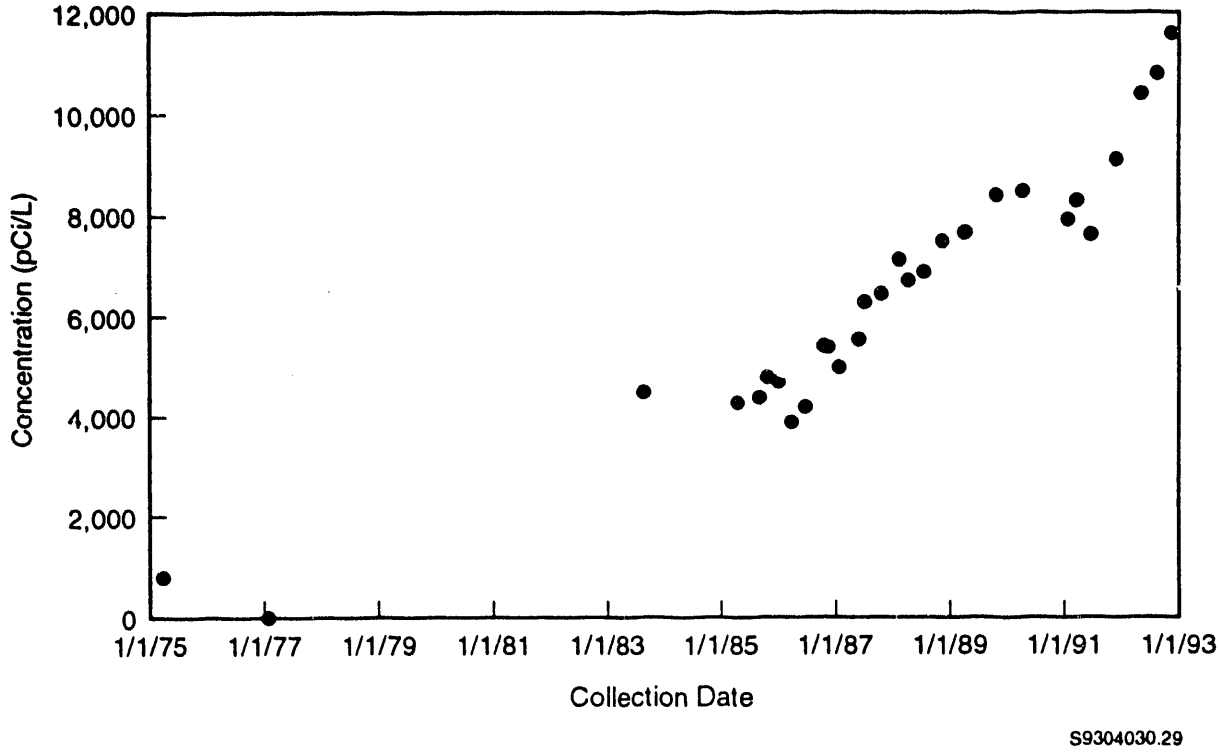



**Figure 4.28.** Tritium Concentration Trend in Well 699-S19-E13, North of the 300 Area

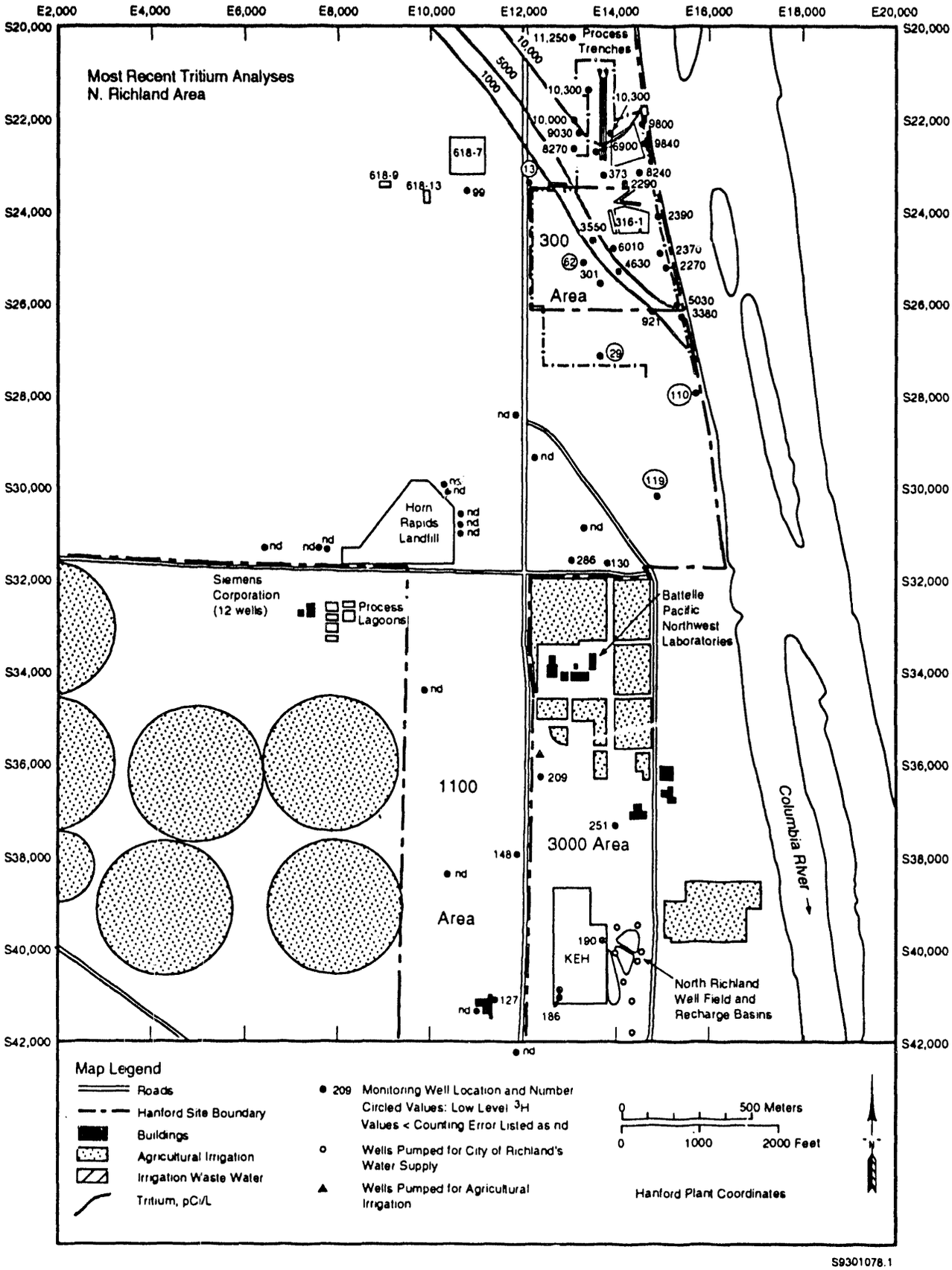



**Figure 4.29.** Tritium Concentrations in the 300 Area and North Richland Areas

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# Appendix A

## Water-Level Measurements for the Unconfined Aquifer, Hanford Site and Outlying Areas, June 1992

TABLE A.1. Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site Proper, June 1991 (measured by PNL except as noted)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 199-B04-01 | 06/04/92 | 461.80 | 63.26 | 398.54 | 121.48 |
| 199-D02-05 | 06/18/92 | 460.87 | 74.54 | 386.33 | 117.75 |
| 199-F05-01 | 06/04/92 | 406.56 | 34.78 | 371.78 | 113.32 |
| 199-H03-01 | 06/09/92 | 421.48 | 45.01 | 376.47 | 114.75 |
| 199-K-11 | 06/05/92 | 467.66 | 73.62 | 394.04 | 120.10 |
| 199-N-27 | 06/22/92 | 449.08 | 60.90 | 388.18 | 118.32 |
| 299-E13-10 | 06/11/92 | 738.84 | 335.72 | 403.12 | 122.87 |
| 299-E17-10 | 06/11/92 | 714.74 | 312.16 | 402.58 | 122.71 |
| 299-E18-01 | 06/30/92 | 720.24 | 317.53 | 402.71 | 122.75 |
| 299-E23-02 | 06/08/92 | 720.64 | 317.92 | 402.72 | 122.75 |
| 299-E25-11 | 06/11/92 | 681.28 | 278.56 | 402.72 | 122.75 |
| 299-E25-32P | 06/30/92 | 669.19 | 267.51 | 401.68 | 122.43 |
| 299-E25-34 | 06/30/92 | 662.87 | 259.88 | 402.99 | 122.83 |
| 299-E25-35 | 06/30/92 | 674.39 | 271.65 | 402.74 | 122.76 |
| 299-E26-01 | 06/08/92 | 617.25 | 213.88 | 403.37 | 122.95 |
| 299-E27-09 | 06/11/92 | 629.21 | 226.56 | 402.65 | 122.73 |
| 299-E28-27 | 06/22/92 | 680.37 | 277.97 | 402.40 | 122.65 |
| 299-E32-02 | 06/22/92 | 670.06 | 267.79 | 402.27 | 122.61 |
| 299-E33-14 | 06/17/92 | 622.05 | 219.23 | 402.82 | 122.78 |
| 299-E33-33 | 06/22/92 | 640.17 | 237.60 | 402.57 | 122.70 |
| 299-E34-02 | 06/17/92 | 630.80 | 228.28 | 402.52 | 122.69 |
| 299-E34-05 | 06/17/92 | 590.79 | 186.96 | 403.83 | 123.09 |
| 299-W10-05 | 06/09/92 | 672.31 | 208.58 | 463.73 | 141.35 |
| 299-W10-13 | 06/22/92 | 699.04 | 235.71 | 463.33 | 141.22 |
| 299-W11-10 | 06/09/92 | 728.89 | 274.00 | 454.89 | 138.65 |
| 299-W15-16 | 06/11/92 | 684.89 | 218.96 | 465.93 | 142.02 |
| 299-W18-21 | 06/11/92 | 668.62 | 202.06 | 466.56 | 142.21 |
| 299-W18-24 | 06/11/92 | 684.35 | 217.96 | 466.39 | 142.16 |
| 299-W19-01 | 06/11/92 | 673.77 | 206.23 | 467.54 | 142.51 |
| 299-W19-04 | 06/11/92 | 715.26 | 257.24 | 458.02 | 139.60 |
| 299-W21-01 | 06/11/92 | 699.26 | 245.41 | 453.85 | 138.33 |
| 299-W23-11 | 06/11/92 | 664.14 | 200.68 | 463.46 | 141.26 |
| 699-02-03 | 06/04/92 | 477.14 | 86.64 | 390.50 | 119.02(b) |
| 699-02-33A | 06/03/92 | 536.37 | 132.36 | 404.01 | 123.14 |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-03-45 | 06/02/92 | 504.54 | 92.52 | 412.02 | 125.58 |
| 699-08-17 | 06/04/92 | 522.44 | 124.31 | 398.13 | 121.35 |
| 699-08-25 | 06/03/92 | 509.30 | 109.89 | 399.41 | 121.74 |
| 699-08-32 | 06/05/92 | 554.39 | 154.35 | 400.04 | 121.93(b) |
| 699-09-E02 | 06/04/92 | 418.09 | 45.91 | 372.18 | 113.44 |
| 699-10-54A | 06/08/92 | 516.40 | 103.08 | 413.32 | 125.98 |
| 699-10-E12 | 06/05/92 | 430.86 | 73.42 | 357.44 | 108.95 |
| 699-11-45A | 06/05/92 | 578.58 | 166.62 | 411.96 | 125.57(b) |
| 699-14-38 | 06/05/92 | 514.89 | 110.04 | 404.85 | 123.40(b) |
| 699-14-47 | 06/03/92 | 587.23 | 175.29 | 411.94 | 125.56 |
| 699-15-15A | 06/04/92 | 547.14 | 148.76 | 398.38 | 121.43 |
| 699-15-26 | 06/03/92 | 523.83 | 123.19 | 400.64 | 122.12 |
| 699-17-05 | 06/05/92 | 433.19 | 45.09 | 388.10 | 118.29 |
| 699-17-70 | 06/09/92 | 563.18 | 88.74 | 474.44 | 144.61(b) |
| 699-19-43 | 06/03/92 | 551.58 | 147.95 | 403.63 | 123.03 |
| 699-19-58 | 06/05/92 | 573.05 | 153.96 | 419.09 | 127.74(b) |
| 699-19-88 | 06/03/92 | 644.45 | 130.76 | 513.69 | 156.57 |
| 699-20-20 | 06/10/92 | 505.58 | 104.92 | 400.66 | 122.12 |
| 699-20-39 | 06/05/92 | 539.98 | 137.36 | 402.62 | 122.72(b) |
| 699-20-E12 | 06/05/92 | 437.25 | 79.48 | 357.77 | 109.05 |
| 699-21-17 | 06/18/92 | 527.31 | 130.45 | 396.86 | 120.96 |
| 699-24-01T | 06/05/92 | 475.54 | 99.59 | 375.95 | 114.59 |
| 699-24-33 | 06/10/92 | 524.21 | 122.19 | 402.02 | 122.54 |
| 699-25-55 | 06/ /92 | 676.55 | 263.74 | 412.81 | 125.82 |
| 699-25-70 | 06/ /92 | 629.78 | 182.30 | 447.48 | 136.39 |
| 699-26-15A | 06/03/92 | 442.64 | 44.68 | 397.96 | 121.30 |
| 699-26-89 | 06/09/92 | 653.08 | 181.11 | 471.97 | 143.86(b) |
| 699-27-08 | 06/05/92 | 465.67 | 71.93 | 393.74 | 120.01 |
| 699-28-40 | 06/05/92 | 559.44 | 156.84 | 402.60 | 122.71(b) |
| 699-28-52A | 06/ /92 | 684.67 | 280.32 | 404.35 | 123.25 |
| 699-29-78 | 06/ /92 | 647.05 | 184.35 | 462.70 | 141.03 |
| 699-31-31 | 06/10/92 | 529.32 | 127.30 | 402.02 | 122.54 |
| 699-32-22 | 06/09/92 | 517.55 | 117.35 | 400.20 | 121.98 |
| 699-32-43 | 06/05/92 | 516.62 | 113.91 | 402.71 | 122.75(b) |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-32-62 | 06/ /92 | 707.09 | 278.74 | 428.35 | 130.56 |
| 699-32-70B | 06/ /92 | 666.68 | 216.40 | 450.28 | 137.25 |
| 699-32-72 | 06/ /92 | 668.16 | 215.90 | 452.26 | 137.85 |
| 699-32-77 | 06/ /92 | 653.74 | 193.97 | 459.77 | 140.14 |
| 699-33-56 | 06/ /92 | 717.03 | 313.15 | 403.88 | 123.10 |
| 699-34-39A | 06/10/92 | 537.07 | 134.54 | 402.53 | 122.69 |
| 699-34-41B | 06/ /92 | 570.89 | 168.29 | 402.60 | 122.71 |
| 699-34-42 | 06/ /92 | 540.20 | 137.52 | 402.68 | 122.74 |
| 699-34-51 | 06/11/92 | 736.76 | 333.57 | 403.19 | 122.89 |
| 699-34-88 | 06/09/92 | 632.82 | 164.06 | 468.76 | 142.88(b) |
| 699-35-09 | 06/04/92 | 499.83 | 114.29 | 385.54 | 117.51 |
| 699-35-66 | 06/08/92 | 725.65 | 287.20 | 438.45 | 133.64 |
| 699-35-70 | 06/08/92 | 693.72 | 243.61 | 450.11 | 137.19 |
| 699-35-78A | 06/09/92 | 660.65 | 196.07 | 464.58 | 141.60 |
| 699-36-61A | 06/05/92 | 748.11 | 340.20 | 407.91 | 124.33(b) |
| 699-36-93 | 06/02/92 | 644.77 | 173.69 | 471.08 | 143.59 |
| 699-37-43 | 06/10/92 | 690.17 | 286.92 | 403.25 | 122.91 |
| 699-37-82A | 06/09/92 | 636.75 | 170.74 | 466.01 | 142.04 |
| 699-38-65 | 06/08/92 | 753.33 | 323.98 | 429.35 | 130.87 |
| 699-38-70 | 06/08/92 | 710.67 | 259.02 | 451.65 | 137.66(b) |
| 699-39-39 | 06/25/92 | 536.65 | 125.37 | 411.28 | 125.36 |
| 699-39-79 | 06/10/92 | 673.52 | 208.25 | 465.27 | 141.81 |
| 699-40-01 | 06/04/92 | 438.71 | 75.75 | 362.96 | 110.63 |
| 699-40-33A | 06/10/92 | 518.05 | 107.24 | 410.81 | 125.22 |
| 699-40-62 | 06/08/92 | 747.78 | 342.26 | 405.52 | 123.60(b) |
| 699-41-23 | 06/09/92 | 466.50 | 68.99 | 397.51 | 121.16 |
| 699-42-12A | 06/04/92 | 514.27 | 138.71 | 375.56 | 114.47 |
| 699-42-40B | 06/11/92 | 546.46 | 125.56 | 420.90 | 128.29(b) |
| 699-43-42 | 06/10/92 | 566.36 | 146.12 | 420.24 | 128.09 |
| 699-43-89 | 06/09/92 | 644.15 | 178.21 | 465.94 | 142.02(b) |
| 699-43-104 | 06/02/92 | 776.07 | 269.20 | 496.87 | 151.45 |
| 699-44-64 | 06/10/92 | 725.60 | 319.08 | 406.52 | 123.91 |
| 699-45-42 | 06/10/92 | 577.33 | 160.98 | 416.35 | 126.90 |
| 699-45-69A | 06/10/92 | 725.46 | 278.25 | 447.21 | 136.31 |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-46-21B | 06/11/92 | 522.02 | 130.95 | 391.07 | 119.20(b) |
| 699-47-35A | 06/10/92 | 476.36 | 62.69 | 413.67 | 126.09 |
| 699-47-46A | 06/10/92 | 580.14 | 175.81 | 404.33 | 123.24 |
| 699-47-60 | 06/17/92 | 651.52 | 249.08 | 402.44 | 122.66 |
| 699-48-07 | 06/04/92 | 384.72 | 27.09 | 357.63 | 109.01 |
| 699-48-71 | 06/08/92 | 688.15 | 242.70 | 445.45 | 135.77(b) |
| 699-49-13E | 06/04/92 | 412.72 | 51.45 | 361.27 | 110.12 |
| 699-49-28 | 06/08/92 | 535.40 | 141.45 | 393.95 | 120.08 |
| 699-49-79 | 06/10/92 | 689.20 | 233.13 | 456.07 | 139.01 |
| 699-50-30 | 06/08/92 | 528.84 | 134.58 | 394.26 | 120.17 |
| 699-50-42 | 06/11/92 | 466.84 | 55.85 | 410.99 | 125.27(b) |
| 699-50-53A | 06/17/92 | 557.46 | 154.91 | 402.55 | 122.70 |
| 699-50-85 | 06/08/92 | 739.35 | 284.07 | 455.28 | 138.77 |
| 699-51-63 | 06/08/92 | 571.84 | 166.86 | 404.98 | 123.44(b) |
| 699-51-75 | 06/08/92 | 641.51 | 192.32 | 449.19 | 136.91 |
| 699-52-19 | 06/11/92 | 411.08 | 49.37 | 361.71 | 110.25(b) |
| 699-53-35 | 06/05/92 | 530.99 | 131.24 | 399.75 | 121.84 |
| 699-53-48B | 06/05/92 | 442.71 | 38.65 | 404.06 | 123.16 |
| 699-53-55C | 06/17/92 | 576.13 | 174.15 | 401.98 | 122.52 |
| 699-54-19 | 06/09/92 | 383.60 | 21.77 | 361.83 | 110.29 |
| 699-54-34 | 06/11/92 | 550.24 | 140.27 | 409.97 | 124.96(b) |
| 699-54-42 | 06/05/92 | 511.49 | 115.31 | 396.18 | 120.76 |
| 699-54-45A | 06/05/92 | 494.29 | 96.37 | 397.92 | 121.29 |
| 699-54-48 | 06/05/92 | 457.02 | 55.02 | 402.00 | 122.53 |
| 699-55-21 | 06/11/92 | 395.96 | 35.41 | 360.55 | 109.90(b) |
| 699-55-40 | 06/05/92 | 543.13 | 133.66 | 409.47 | 124.81 |
| 699-55-44 | 06/08/92 | 519.67 | 124.04 | 395.63 | 120.59 |
| 699-55-50C | 06/05/92 | 444.43 | 42.43 | 402.00 | 122.53 |
| 699-55-70 | 06/05/92 | 569.03 | 136.84 | 432.19 | 131.73 |
| 699-55-76 | 06/08/92 | 583.24 | 138.95 | 444.29 | 135.42(b) |
| 699-55-89 | 06/03/92 | 617.43 | 163.11 | 454.32 | 138.48 |
| 699-55-95 | 06/08/92 | 777.05 | 311.78 | 465.27 | 141.81 |
| 699-56-43 | 06/10/92 | 540.42 | 131.74 | 408.68 | 124.57 |
| 699-57-25A | 06/05/92 | 414.57 | 50.53 | 364.04 | 110.96 |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-57-29B | 06/11/92 | 416.18 | 54.28 | 361.90 | 110.31(b) |
| 699-57-83A | 06/08/92 | 577.96 | 145.12 | 432.84 | 131.93 |
| 699-58-24 | 06/05/92 | 418.80 | 57.09 | 361.71 | 110.25 |
| 699-59-32 | 06/05/92 | 424.29 | 62.18 | 362.11 | 110.37 |
| 699-59-58 | 06/08/92 | 497.77 | 96.02 | 401.75 | 122.45 |
| 699-59-80B | 06/10/92 | 583.25 | 153.65 | 429.60 | 130.94(b) |
| 699-60-32 | 06/05/92 | 425.30 | 63.39 | 361.91 | 110.31 |
| 699-60-60 | 06/08/92 | 512.03 | 110.23 | 401.80 | 122.47 |
| 699-61-37 | 06/08/92 | 442.94 | 61.18 | 381.76 | 116.36 |
| 699-61-41 | 06/08/92 | 428.92 | 33.00 | 395.92 | 120.68 |
| 699-61-62 | 06/10/92 | 497.51 | 95.64 | 401.87 | 122.49(b) |
| 699-61-66 | 06/08/92 | 522.18 | 121.18 | 401.00 | 122.23 |
| 699-62-31 | 06/11/92 | 434.12 | 72.18 | 361.94 | 110.32(b) |
| 699-62-43A | 06/08/92 | 432.30 | 36.07 | 396.23 | 120.77 |
| 699-63-25A | 06/05/92 | 395.15 | 33.49 | 361.66 | 110.23 |
| 699-63-51 | 06/10/92 | 424.54 | 24.79 | 399.75 | 121.84(b) |
| 699-63-58 | 06/08/92 | 491.90 | 91.18 | 400.72 | 122.14 |
| 699-63-90 | 06/05/92 | 509.73 | 110.64 | 399.09 | 121.64 |
| 699-64-27 | 06/05/92 | 414.29 | 52.40 | 361.89 | 110.30 |
| 699-64-62 | 06/08/92 | 500.25 | 99.75 | 400.50 | 122.07 |
| 699-65-50 | 06/10/92 | 467.06 | 67.27 | 399.79 | 121.86(b) |
| 699-65-59A | 06/08/92 | 506.96 | 106.56 | 400.40 | 122.04 |
| 699-65-72 | 06/08/92 | 540.28 | 141.34 | 398.94 | 121.60 |
| 699-65-83 | 06/08/92 | 485.63 | 87.23 | 398.40 | 121.43 |
| 699-65-95 | 06/04/92 | 452.26 | 52.17 | 400.09 | 121.95 |
| 699-66-23 | 06/11/92 | 389.01 | 26.37 | 362.64 | 110.53(b) |
| 699-66-38 | 06/05/92 | 436.24 | 33.76 | 402.48 | 122.68 |
| 699-66-39 | 06/05/92 | 453.78 | 47.15 | 406.63 | 123.94 |
| 699-66-58 | 06/05/92 | 503.33 | 103.00 | 400.33 | 122.02 |
| 699-66-64 | 06/05/92 | 505.92 | 105.98 | 399.94 | 121.90 |
| 699-66-91 | 06/10/92 | 467.75 | 67.73 | 400.02 | 121.93(b) |
| 699-66-103 | 06/05/92 | 463.01 | 64.23 | 398.78 | 121.55 |
| 699-67-51 | 06/03/92 | 524.59 | 124.82 | 399.77 | 121.85 |
| 699-67-86 | 06/04/92 | 472.39 | 74.03 | 398.36 | 121.42 |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-67-98 | 06/04/92 | 455.47 | 55.68 | 399.79 | 121.86 |
| 699-68-105 | 06/09/92 | 451.85 | 55.39 | 396.46 | 120.84(b) |
| 699-69-38 | 06/03/92 | 424.10 | 22.15 | 401.95 | 122.51 |
| 699-69-45(0) | 06/03/92 | 487.18 | 88.09 | 399.09 | 121.64 |
| 699-70-23 | 06/02/92 | 391.71 | 27.60 | 364.11 | 110.98 |
| 699-70-68 | 06/02/92 | 526.21 | 127.14 | 399.07 | 121.64 |
| 699-71-30 | 06/11/92 | 400.68 | 30.37 | 370.31 | 112.87(b) |
| 699-71-52 | 06/02/92 | 523.04 | 123.82 | 399.22 | 121.68 |
| 699-71-77 | 06/02/92 | 472.28 | 75.29 | 396.99 | 121.00 |
| 699-72-73 | 06/02/92 | 482.57 | 85.23 | 397.34 | 121.11 |
| 699-72-88 | 06/02/92 | 437.37 | 36.19 | 401.18 | 122.28 |
| 699-72-92 | 06/10/92 | 452.22 | 51.60 | 400.62 | 122.11(b) |
| 699-73-61 | 06/02/92 | 531.53 | 132.39 | 399.14 | 121.66 |
| 699-74-44 | 06/02/92 | 445.18 | 48.65 | 396.53 | 120.86 |
| 699-74-48 | 06/02/92 | 487.18 | 89.17 | 398.01 | 121.31 |
| 699-77-36 | 06/02/92 | 412.28 | 36.42 | 375.86 | 114.56 |
| 699-77-54 | 06/10/92 | 480.59 | 83.29 | 397.30 | 121.10(b) |
| 699-78-62 | 06/02/92 | 469.88 | 74.49 | 395.39 | 120.52 |
| 699-81-38 | 06/03/92 | 406.47 | 27.22 | 379.25 | 115.60 |
| 699-81-58 | 06/22/92 | 439.55 | 45.86 | 393.69 | 120.00 |
| 699-82-45A | 06/03/92 | 413.73 | 24.79 | 388.94 | 118.55 |
| 699-83-47 | 06/10/92 | 435.27 | 46.35 | 388.92 | 118.54(b) |
| 699-86-42 | 06/03/92 | 409.92 | 25.24 | 384.68 | 117.25 |
| 699-87-55 | 06/18/92 | 458.63 | 71.64 | 386.99 | 117.95 |
| 699-89-35 | 06/09/92 | 397.46 | 25.72 | 371.74 | 113.31 |
| 699-90-45 | 06/09/92 | 422.15 | 37.28 | 384.87 | 117.31 |
| 699-91-37 | 06/10/92 | 422.93 | 48.88 | 374.05 | 114.01(b) |
| 699-92-49 | 06/18/92 | 432.00 | 48.24 | 383.76 | 116.97 |
| 699-96-49 | 06/18/92 | 419.29 | 36.86 | 382.43 | 116.56 |
| 699-97-43 | 06/09/92 | 421.81 | 42.54 | 379.27 | 115.60 |
| 699-S03-25 | 06/03/92 | 523.50 | 124.40 | 399.10 | 121.65 |
| 699-S03-E12 | 06/04/92 | 397.90 | 43.45 | 354.45 | 108.04(b) |
| 699-S06-E04D | 06/09/92 | 430.47 | 57.93 | 372.54 | 113.55 |
| 699-S06-E14A | 06/09/92 | 378.29 | 27.60 | 350.69 | 106.89 |

TABLE A.1. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-S07-34 | 06/09/92 | 527.12 | 118.84 | 408.28 | 124.44(b) |
| 699-S08-19 | 06/05/92 | 503.81 | 106.89 | 396.92 | 120.98(b) |
| 699-S12-03 | 06/04/92 | 435.52 | 54.84 | 380.68 | 116.03 |
| 699-S12-29 | 06/02/92 | 487.68 | 83.39 | 404.29 | 123.23 |
| 699-S14-20A | 06/02/92 | 492.74 | 91.93 | 400.81 | 122.17 |
| 699-S18-E02A | 06/04/92 | 434.85 | 75.41 | 359.44 | 109.56 |
| 699-S19-11 | 06/04/92 | 483.74 | 93.70 | 390.04 | 118.88 |
| 699-S19-E13 | 06/04/92 | 394.51 | 49.66 | 344.85 | 105.11(b) |
| 699-S29-E12 | 06/04/92 | 387.96 | 41.98 | 345.98 | 105.45(b) |
| 699-S30-E15A | 06/22/92 | 400.14 | 56.54 | 343.60 | 104.73 |
| 699-S31-01 | 06/25/92 | 460.00 | 83.74 | 376.26 | 114.68 |
| 699-S31-E08 | 06/22/92 | 374.75 | 20.82 | 353.93 | 107.88 |
| 699-S34-E10 | 06/16/92 | 382.37 | 29.18 | 353.19 | 107.65(b) |
| 699-S37-E14 | 06/22/92 | 408.28 | 57.20 | 351.08 | 107.01 |
| 699-S38-E11 | 06/22/92 | 398.60 | 45.64 | 352.96 | 107.58 |
| 699-S40-E14 | 06/22/92 | 402.85 | 50.44 | 352.41 | 107.41 |
| 699-S43-E12 | 06/16/92 | 405.60 | 52.52 | 353.08 | 107.62(b) |
| 1199-34-13 | 06/19/92 | 394.78 | 42.89 | 351.89 | 107.26 |
| 3099-45-16 | 06/22/92 | 408.04 | 56.03 | 352.01 | 107.29 |

(a) MSL = mean sea level.
(b) Measured by Westinghouse Hanford Company.

TABLE A.2. Water-Level Measurements from Unconfined Aquifer Wells North and East of the Columbia River, July 1992 (measured by U.S. Bureau of Reclamation)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 08/30 03A01 | 07/08/92 | 390 | 51.9 | 338 | 103 |
| 09/29 12A01 | 06/24/92 | 416 | 71.1 | 345 | 105 |
| 09/29 15N01 | 06/24/92 | 402 | 58.1 | 344 | 105 |
| 09/30 14D01 | 06/24/92 | 497 | 119.4 | 378 | 115 |
| 09/30 17C01 | 07/08/92 | 425 | 83.1 | 342 | 104 |
| 09/30 23N01 | 06/24/92 | 440 | 90.2 | 350 | 107 |
| 09/30 29K01 | 06/24/92 | 378 | 37.3 | 341 | 104 |
| 10/29 01A01 | 06/22/92 | 663 | 27.8 | 635 | 194 |
| 10/29 08R01 | 06/17/92 | 621 | 16.3 | 605 | 184 |
| 10/29 15D01 | 06/17/92 | 615 | 12.1 | 603 | 184 |
| 10/29 25A01 | 06/22/92 | 498 | 31.6 | 466 | 142 |
| 10/29 26A01 | 06/17/92 | 496 | 45.8 | 450 | 137 |
| 10/29 27C01 | 06/17/92 | 484 | 130.4 | 354 | 108 |
| 10/29 28B01 | 06/17/92 | 504 | 147.3 | 357 | 109 |
| 10/30 04E01 | 06/22/92 | 556 | 16.7 | 539 | 164 |
| 10/30 05B01 | 06/22/92 | 590 | 12.2 | 578 | 176 |
| 10/30 05N01 | 06/22/92 | 553 | 29.4 | 524 | 160 |
| 10/30 08F01 | 06/22/92 | 538 | 20.8 | 517 | 158 |
| 10/30 14N01 | 06/19/92 | 714 | 29.9 | 684 | 208 |
| 10/30 21R01 | 06/19/92 | 605 | 8.5 | 597 | 182 |
| 11/28 25R02 | 06/22/92 | 860 | 11.3 | 849 | 259 |
| 11/29 05D01 | 06/23/92 | 917 | 14.3 | 903 | 275 |
| 11/29 14R01 | 06/22/92 | 781 | 23.4 | 758 | 231 |
| 11/29 16N01 | 06/22/92 | 912 | 31.4 | 881 | 269 |
| 11/29 19R01 | 06/22/92 | 875 | 9.4 | 866 | 264 |
| 11/29 24R01 | 06/22/92 | 686 | 30.2 | 656 | 200 |
| 11/29 26D01 | 06/22/92 | 831 | 36.8 | 794 | 242 |
| 11/30 06N01 | 06/23/92 | 852 | 17.0 | 835 | 255 |
| 11/30 08N01 | 06/23/92 | 747 | 41.5 | 706 | 215 |
| 12/28 11J01 | 06/25/92 | 668 | 34.0 | 634 | 193 |
| 12/29 15D01 | 06/17/92 | 718 | 29 | 689 | 210 |
| 12/29 25D01 | 06/23/92 | 927 | 28.0 | 899 | 274 |
| 12/30 18D01 | 06/23/92 | 963 | 20.8 | 942 | 287 |
| 12/30 30R01 | 06/23/92 | 726 | 8.0 | 718 | 219 |

TABLE A.2. (contd)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 13/28 03A01 | 06/25/92 | 993 | 10.3 | 983 | 300 |
| 13/28 03N01 | 06/25/92 | 967 | 12.1 | 955 | 291 |
| 13/28 14B01 | 06/25/92 | 974 | 6.4 | 968 | 295 |
| 13/28 16J01 | 06/25/92 | 939 | 7.0 | 932 | 284 |
| 13/28 22B01 | 06/25/92 | 963 | 12.0 | 951 | 290 |
| 13/28 24D01 | 06/25/92 | 951 | 7.4 | 944 | 288 |
| 13/28 26R01 | 06/25/92 | 941 | 10.7 | 930 | 283 |
| 13/28 27Q01 | 06/25/92 | 928 | 13.5 | 915 | 279 |
| 13/29 10N01 | 06/04/92 | 950 | DRY | | |
| 13/29 20D01 | 06/25/92 | 992 | 7.2 | 985 | 300 |
| 13/29 32D01 | 06/25/92 | 951 | 14.9 | 936 | 285 |
| 13/29 36D01 | 06/23/92 | 771 | 34.2 | 737 | 225 |
| 13/30 28D01 | 06/23/92 | 892 | 24.2 | 868 | 265 |
| 13/30 30H01 | 06/23/92 | 857 | 11.9 | 845 | 258 |
| 14/25 03E01 | 06/23/92 | 675 | 12.0 | 663 | 202 |
| 14/25 05N01 | 06/23/92 | 731 | 32.9 | 698 | 213 |
| 14/25 10J01 | 06/23/92 | 640 | 56.8 | 583 | 178 |
| 14/25 17A01 | 06/23/92 | 687 | 39.2 | 648 | 198 |
| 14/27 26E01 | 07/07/92 | 680 | 15.9 | 664 | 202 |
| 14/27 27A01 | 07/07/92 | 683 | 15.0 | 668 | 204 |
| 14/28 30M01 | 07/07/92 | 733 | 11.4 | 722 | 220 |
| 14/28 30N01 | 07/07/92 | 736 | 10.1 | 726 | 221 |
| 14/29 21A01 | 06/25/92 | 1013 | 31.2 | 982 | 299 |
| 14/29 28A01 | 06/25/92 | 926 | 11.0 | 915 | 279 |
| 15/24 26R01 | 06/18/92 | 897 | 41.0 | 856 | 261 |
| 15/25 30H01 | 06/23/92 | 866 | 41.6 | 824 | 251 |
| 15/25 30R01 | 07/07/92 | 811 | 15.7 | 795 | 242 |
| 15/25 32N01 | 06/23/92 | 761 | 33.7 | 727 | 222 |
| 15/25 34D01 | 06/23/92 | 789 | 38.7 | 750 | 229 |
| 15/26 30H01 | 06/18/92 | 854 | 20.7 | 833 | 254 |

(a) MSL = mean sea level.

# Appendix B

## Water-Level Measurments for the Unconfined Aquifer, Hanford Site Proper, December 1992

TABLE B.1. Water-Level Measurements from Unconfined Aquifer Wells on the Hanford Site Paper, December 1992 (measured by Westinghouse Hanford Company except as noted)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 199-D2-5 | 92-12-28 | 460.30 | 75.12 | 385.18 | 117.40 |
| 199-H3-1 | 92-12-29 | 421.48 | 45.66 | 375.82 | 114.55 |
| 199-N-27 | 92-12-23 | 449.08 | 61.78 | 387.30 | 118.05 |
| 299-E23-2Q | 92-12-18 | 721.26 | 318.68 | 402.58 | 122.71 (b) |
| 299-E32-2 | 92-12-18 | 670.06 | 268.19 | 401.87 | 122.49 |
| 299-E34-2 | 92-12-09 | 630.80 | 228.62 | 402.18 | 122.59 |
| 299-W10-13 | 92-12-18 | 699.04 | 236.54 | 462.50 | 140.97 |
| 299-W11-10 | 92-12-21 | 728.89 | 274.53 | 454.36 | 138.49 (b) |
| 299-W18-15 | 92-12-07 | 660.76 | 195.45 | 465.31 | 141.83 |
| 299-W18-21 | 92-12-14 | 688.62 | 203.81 | 464.81 | 141.68 |
| 299-W19-12 | 92-12-17 | 673.25 | 207.36 | 465.89 | 142.01 |
| 299-W19-32 | 92-12-17 | 674.90 | 208.83 | 466.07 | 142.06 |
| 299-W23-11 | 92-12-21 | 664.14 | 202.15 | 461.99 | 140.81 (b) |
| 699-20-20 | 92-12-21 | 505.58 | 105.26 | 400.32 | 122.02 (b) |
| 699-37-78A | | | | | |
| 699-39-39 | 92-12-15 | 536.65 | 125.04 | 411.61 | 125.46 |
| 699-40-39 | 92-12-15 | 541.84 | 129.38 | 412.46 | 125.71 |
| 699-41-40 | 92-12-15 | 545.94 | 130.49 | 415.45 | 126.63 |
| 699-42-40B | 92-12-18 | 546.46 | 124.87 | 421.59 | 128.50 (b) |
| 699-43-43 | 92-12-15 | 579.37 | 164.42 | 414.95 | 126.47 |
| 699-43-104 | 92-12-18 | 766.07 | (c) | 495.73 | 151.10 (b) |
| 699-60-60 | 92-12-10 | 512.03 | 110.67 | 401.36 | 122.34 |
| 699-S31-1 | 92-12-21 | 460.00 | 83.42 | 376.58 | 114.78 (b) |
| 699-S34-E10 | 92-12-23 | 382.37 | 29.08 | 353.29 | 107.68 |
| 699-S40-E14 | 92-12-18 | 402.85 | 49.71 | 353.14 | 107.64 (b) |
| 699-S41-E11 | 92-12-23 | 401.36 | 47.62 | 353.74 | 107.82 |
| EC-1 | 92-12-18 | 362.57 | 6.23 | 356.34 | 108.61 (b) |

(a) MSL = mean sea level.
(b) Measured by PNL.
(c) Transducer measurement.

# Appendix C

## Water-Level Measurments for the Unconfined Aquifer at Specific Hanford Site Areas, June 1992

TABLE C.1. 216-B-3 Pond Water-Level Measurements in Unconfined Aquifer Wells, June 1992 (measured by Westinghouse Hanford Company)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 299-E25-32P | 06/30/92 | 669.19 | 267.51 | 401.68 | 122.43 |
| 699-39-39 | 06/25/92 | 536.65 | 125.37 | 411.28 | 125.36 |
| 699-40-33A | 06/10/92 | 518.05 | 107.24 | 410.81 | 125.22 |
| 699-40-39 | 06/25/92 | 541.84 | 129.04 | 412.80 | 125.82 |
| 699-41-40 | 06/25/92 | 545.94 | 130.80 | 415.14 | 126.53 |
| 699-42-40B | 06/11/92 | 546.46 | 125.56 | 420.90 | 128.29 |
| 699-43-41E | 06/26/92 | 550.86 | 130.83 | 420.03 | 128.03 |
| 699-43-42J | 06/26/92 | 581.68 | 163.52 | 418.16 | 127.46 |
| 699-43-43 | 06/26/92 | 579.37 | 164.52 | 414.85 | 126.45 |
| 699-43-45 | 06/26/92 | 597.68 | 193.91 | 403.77 | 123.07 |
| 699-44-42 | 06/26/92 | 579.22 | 158.96 | 420.26 | 128.10 |
| 699-44-43B | 06/26/92 | 580.12 | 164.77 | 415.35 | 126.60 |
| 699-45-42 | 06/10/92 | 577.33 | 160.98 | 416.35 | 126.90 |
| 699-47-35A | 06/10/92 | 476.36 | 62.69 | 413.67 | 126.09 |
| 699-47-46A | 06/10/92 | 580.14 | 175.81 | 404.33 | 123.24 |

(a) MSL = mean sea level.

TABLE C.2. Decommissioned 216-U-Pond Water-Level Measurements in Unconfined Aquifer Wells, June 1992 (measured by Westinghouse Hanford Company)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 299-W10-05 | 06/09/92 | 672.31 | 208.58 | 463.73 | 141.35 |
| 299-W10-13 | 06/22/92 | 699.04 | 235.71 | 463.33 | 141.22 |
| 299-W11-10 | 06/09/92 | 728.89 | 274.00 | 454.89 | 138.65 |
| 299-W15-04 | 06/09/92 | 662.00 | 196.36 | 465.64 | 141.93 |
| 299-W15-15 | 06/11/92 | 697.96 | 232.64 | 465.32 | 141.83 |
| 299-W15-16 | 06/11/92 | 684.89 | 218.96 | 465.93 | 142.02 |
| 299-W18-15 | 06/ /92 | 660.76 | 194.58 | 466.18 | 142.09 |
| 299-W18-21 | 06/11/92 | 668.62 | 202.06 | 466.56 | 142.21 |
| 299-W19-01 | 06/11/92 | 673.77 | 206.23 | 467.54 | 142.51 |
| 299-W19-04 | 06/11/92 | 715.26 | 257.24 | 458.02 | 139.60 |
| 299-W19-12 | 06/19/92 | 673.25 | 206.32 | 466.93 | 142.32 |
| 299-W19-14 | 06/11/92 | 693.21 | 231.18 | 462.03 | 140.83 |
| 299-W19-32 | 06/19/92 | 674.90 | 207.73 | 467.17 | 142.39 |
| 299-W21-01 | 06/11/92 | 699.26 | 245.41 | 453.85 | 138.33 |
| 299-W22-07 | 06/11/92 | 687.41 | 229.38 | 458.03 | 139.61 |
| 299-W23-11 | 06/11/92 | 664.14 | 200.68 | 463.46 | 141.26 |
| 699-32-70B | 06/ /92 | 666.68 | 216.40 | 450.28 | 137.25 |
| 699-32-72 | 06/ /92 | 668.16 | 215.90 | 452.26 | 137.85 |
| 699-32-77 | 06/ /92 | 653.74 | 193.97 | 459.77 | 140.14 |
| 699-35-78A | 06/09/92 | 660.65 | 196.07 | 464.58 | 141.60 |
| 699-37-82A | 06/09/92 | 636.75 | 170.74 | 466.01 | 142.04 |
| 699-38-70 | 06/08/92 | 710.67 | 259.02 | 451.65 | 137.66(b) |
| 699-39-79 | 06/10/92 | 673.52 | 208.25 | 465.27 | 141.81 |

(a) MSL = mean sea level.

TABLE C.3. 1100 and 3000 Areas Water-Level Measurements in Unconfined Aquifer Wells, June 1992 (measured by Westinghouse Hanford Company except as noted)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 699-S29-E12 | 06/04/92 | 387.96 | 41.98 | 345.98 | 105.45(b) |
| 699-S30-E10A | 06/22/92 | 392.29 | 43.47 | 348.82 | 106.32 |
| 699-S30-E10B | 06/22/92 | 392.07 | 42.72 | 349.35 | 106.48 |
| 699-S30-E15A | 06/22/92 | 400.14 | 56.54 | 343.60 | 104.73 |
| 699-S31-01 | 06/25/92 | 460.00 | 83.74 | 376.26 | 114.68 |
| 699-S31-E08 | 06/22/92 | 374.75 | 20.82 | 353.93 | 107.88 |
| 699-S31-E10A | 06/22/92 | 384.57 | 36.18 | 348.39 | 106.19 |
| 699-S31-E10B | 06/22/92 | 383.71 | 34.60 | 349.11 | 106.41 |
| 699-S31-E10D | 06/22/92 | 380.58 | 31.66 | 348.92 | 106.35 |
| 699-S31-E13 | 06/22/92 | 394.06 | 47.22 | 346.84 | 105.72 |
| 699-S32-E13A | 06/22/92 | 390.46 | 43.32 | 347.14 | 105.81 |
| 699-S32-E13B | 06/22/92 | 394.72 | 47.35 | 347.37 | 105.88 |
| 699-S34-E10 | 06/22/92 | 382.37 | 29.22 | 353.15 | 107.64 |
| 699-S36-E12B | 06/22/92 | 399.04 | 47.70 | 351.34 | 107.09 |
| 699-S36-E13A | 06/22/92 | 399.30 | 47.94 | 351.36 | 107.09 |
| 699-S37-E11 | 06/22/92 | 399.30 | 47.39 | 351.91 | 107.26 |
| 699-S37-E14 | 06/22/92 | 408.28 | 57.20 | 351.08 | 107.01 |
| 699-S38-E11 | 06/22/92 | 398.60 | 45.64 | 352.96 | 107.58 |
| 699-S38-E12A | 06/22/92 | 404.95 | 53.17 | 351.78 | 107.22 |
| 699-S40-E14 | 06/22/92 | 402.85 | 50.44 | 352.41 | 107.41 |
| 699-S41-E11 | 06/22/92 | 401.36 | 47.96 | 353.40 | 107.72 |
| 699-S41-E12 | 06/22/92 | 401.93 | 48.96 | 352.97 | 107.59 |
| 699-S41-E13A | 06/22/92 | 410.56 | 58.18 | 352.38 | 107.41 |
| 699-S41-E13B | 06/22/92 | 410.10 | 57.72 | 352.38 | 107.41 |
| 699-S43-E12 | 06/16/92 | 405.60 | 52.52 | 353.08 | 107.62 |
| 1199-34-13 | 06/19/92 | 394.78 | 42.89 | 351.89 | 107.26 |
| 1199-41-13C | 06/22/92 | 405.98 | 54.10 | 351.88 | 107.25 |
| 3099-45-16 | 06/22/92 | 408.04 | 57.32 | 350.72 | 106.90 |
| 3099-47-18B | 06/19/92 | 374.95 | 29.88 | 345.07 | 105.18(b) |
| EC-1 | 06/16/92 | 362.57 | 6.76 | 355.81 | 108.45(b) |
| W-1 | 07/15/92 | 359.78 | 6.03 | 353.75 | 107.82(b) |

(a) MSL = mean sea level.
(b) Measured by PNL with a float recorder.
(c) Measured by PNL.

TABLE C.4. 100-N Area Water-Level Measurements in Unconfined Aquifer Wells, June 1992 (measured by Westinghouse Hanford Company)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 199-N-02 | 06/25/92 | 459.83 | 72.11 | 387.72 | 118.18 |
| 199-N-03 | 06/26/92 | 459.45 | 71.55 | 387.90 | 118.23 |
| 199-N-14 | 06/22/92 | 453.15 | 66.64 | 386.51 | 117.81 |
| 199-N-16 | 06/22/92 | 456.70 | 68.72 | 387.98 | 118.26 |
| 199-N-17 | 06/22/92 | 461.20 | 73.86 | 387.34 | 118.06 |
| 199-N-19 | 06/22/92 | 453.90 | 66.68 | 387.22 | 118.02 |
| 199-N-20 | 06/22/92 | 455.90 | 68.40 | 387.50 | 118.11 |
| 199-N-21 | 06/22/92 | 457.00 | 69.57 | 387.43 | 118.09 |
| 199-N-23 | 06/22/92 | 456.30 | 68.80 | 387.50 | 118.11 |
| 199-N-27 | 06/22/92 | 449.08 | 60.90 | 388.18 | 118.32 |
| 199-N-29 | 06/22/92 | 465.25 | 76.65 | 388.60 | 118.45 |
| 199-N-32 | 06/22/92 | 462.08 | 74.26 | 387.82 | 118.21 |
| 199-N-33 | 06/22/92 | 459.87 | 72.28 | 387.59 | 118.14 |
| 199-N-34 | 06/22/92 | 459.63 | 71.66 | 387.97 | 118.25 |
| 199-N-40 | 06/22/92 | 456.35 | 69.61 | 386.74 | 117.88 |
| 199-N-41 | 06/22/92 | 457.59 | 71.08 | 386.51 | 117.81 |
| 199-N-42 | 06/22/92 | 455.14 | 68.36 | 386.78 | 117.89 |
| 199-N-49 | 06/22/92 | 450.72 | 64.32 | 386.40 | 117.77 |
| 199-N-50 | 06/22/92 | 453.36 | 77.08 | 376.28 | 114.69 |
| 199-N-51 | 06/22/92 | 462.18 | 76.05 | 386.13 | 117.69 |
| 199-N-52 | 06/22/92 | 463.70 | 74.75 | 388.95 | 118.55 |
| 199-N-54 | 06/22/92 | 457.51 | 69.94 | 387.57 | 118.13 |
| 199-N-55 | 06/22/92 | 457.85 | 70.26 | 387.59 | 118.14 |
| 199-N-56 | 06/22/92 | 458.09 | 70.85 | 387.24 | 118.03 |
| 199-N-57 | 06/22/92 | 457.76 | 69.57 | 388.19 | 118.32 |
| 199-N-59 | 06/22/92 | 459.53 | 70.55 | 388.98 | 118.56 |
| 199-N-60 | 06/25/92 | 461.94 | 72.75 | 389.19 | 118.63 |
| 199-N-62 | 06/22/92 | 463.59 | 74.91 | 388.68 | 118.47 |
| 199-N-63 | 06/22/92 | 466.70 | 78.20 | 388.50 | 118.42 |
| 199-N-64 | 06/26/92 | 454.63 | 66.40 | 388.23 | 118.33 |
| 199-N-65 | 06/25/92 | 456.44 | 68.57 | 387.87 | 118.22 |
| 199-N-66 | 06/26/92 | 465.25 | 77.71 | 387.54 | 118.12 |
| 199-N-67 | 06/25/92 | 458.46 | 71.27 | 387.19 | 118.02 |
| 199-N-69 | 06/25/92 | 458.84 | 71.67 | 387.17 | 118.01 |
| HGP[b] | 06/24/91 | | | 386.90 | 117.93 |

(a) MSL = mean sea level.
(b) Hanford Generating Plant (River Stage Elevation).

TABLE C.5. 300-Area Water-Level Measurements in Unconfined Aquifer Wells, June 1992 (measured by Westinghouse Hanford Company)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above MSL |
|---|---|---|---|---|---|
| 399-1-01 | 06/25/92 | 375.90 | 31.54 | 344.36 | 104.96 |
| 399-1-02 | 06/25/92 | 384.52 | 42.32 | 342.20 | 104.30 |
| 399-1-03 | 06/25/92 | 384.73 | 40.00 | 344.73 | 105.07 |
| 399-1-04 | 06/25/92 | 381.11 | 35.55 | 345.56 | 105.33 |
| 399-1-05 | 06/25/92 | 379.82 | 34.99 | 344.83 | 105.10 |
| 399-1-06 | 06/25/92 | 373.81 | 28.56 | 345.25 | 105.23 |
| 399-1-07 | 06/25/92 | 385.63 | 40.94 | 344.69 | 105.06 |
| 399-1-08 | 06/25/92 | 384.91 | 40.21 | 344.70 | 105.06 |
| 399-1-09 | 06/25/92 | 384.80 | 23.52 | 361.28 | 110.12 |
| 399-1-10 | 06/25/92 | 373.65 | 28.41 | 345.24 | 105.23 |
| 399-1-11 | 06/25/92 | 377.79 | 32.71 | 345.08 | 105.18 |
| 399-1-12 | 06/25/92 | 384.45 | 39.65 | 344.80 | 105.10 |
| 399-1-13 | 06/25/92 | 388.62 | 43.84 | 344.78 | 105.09 |
| 399-1-14 | 06/25/92 | 383.23 | 38.20 | 345.03 | 105.17 |
| 399-1-15 | 06/25/92 | 379.59 | 34.40 | 345.19 | 105.21 |
| 399-1-16A | 06/25/92 | 381.51 | 36.82 | 344.69 | 105.06 |
| 399-1-17A | 06/25/92 | 377.47 | 32.75 | 344.72 | 105.07 |
| 399-1-18A | 06/25/92 | 390.83 | 45.36 | 345.47 | 105.30 |
| 399-1-19 | 06/25/92 | 374.64 | 29.80 | 344.84 | 105.11 |
| 399-2-01 | 06/25/92 | 375.26 | 30.57 | 344.69 | 105.06 |
| 399-2-02 | 06/25/92 | 375.53 | 30.80 | 344.73 | 105.07 |
| 399-2-03 | 06/25/92 | 375.44 | 30.77 | 344.67 | 105.06 |
| 399-3-01 | 06/25/92 | 384.43 | 39.84 | 344.59 | 105.03 |
| 399-3-06 | 06/25/92 | 392.85 | 48.38 | 344.47 | 104.99 |
| 399-3-07 | 06/25/92 | 394.22 | 49.75 | 344.47 | 104.99 |
| 399-3-09 | 06/25/92 | 387.31 | 43.58 | 343.73 | 104.77 |
| 399-3-10 | 06/25/92 | 385.40 | 40.97 | 344.43 | 104.98 |
| 399-3-12 | 06/25/92 | 386.38 | 43.89 | 342.49 | 104.39 |
| 399-4-01 | 06/25/92 | 395.00 | 51.28 | 343.72 | 104.77 |
| 399-4-07 | 06/25/92 | 376.99 | 34.26 | 342.73 | 104.46 |
| 399-4-09 | 06/25/92 | 381.40 | 37.72 | 343.68 | 104.75 |
| 399-4-10 | 06/25/92 | 377.59 | 33.17 | 344.42 | 104.98 |
| 399-4-11 | 06/25/92 | 404.53 | 60.07 | 344.46 | 104.99 |
| 399-5-01 | 06/25/92 | 395.60 | 51.17 | 344.43 | 104.98 |
| 399-6-01 | 06/25/92 | 386.93 | 44.32 | 342.61 | 104.43 |
| 399-8-01 | 06/25/92 | 394.88 | 51.58 | 343.30 | 104.64 |
| 399-8-02 | 06/25/92 | 396.06 | 53.44 | 342.62 | 104.43 |
| 399-8-03 | 06/25/92 | 393.11 | 50.01 | 343.10 | 104.58 |
| 699-S19-E13 | 06/04/92 | 394.51 | 49.66 | 344.85 | 105.11(b) |
| 699-S27-E14 | 06/25/92 | 399.76 | 55.41 | 344.35 | 104.96 |
| 699-S29-E12 | 06/04/92 | 387.96 | 41.98 | 345.98 | 105.45(b) |
| 699-S30-E15A | 06/22/92 | 400.14 | 56.54 | 343.60 | 104.73 |
| SWS-1 | 06/25/92 | (River Stage Elevation) | | 345.38 | 105.27 |

(a) MSL = mean sea level.

# Appendix D

## Water-Level Measurements for the Confined Aquifer at the Hanford Site

TABLE D.1. Water-Level Measurements from Upper-Confined Aquifer Wells on the Hanford Site Proper, September 1992 (measured by PNL)

| Well | Date | Casing Elevation, ft above MSL[a] | Depth to Water, ft | Water-Table Elevation, ft above MSL | Water-Table Elevation, m above |
|---|---|---|---|---|---|
| 199-B3-2P | 09/09/92 | 443.38 | 40.59 | 402.79 | 122.77 |
| 199-H4-2[b] | 09/09/92 | 421.12 | 22.15 | 443.27 | 135.11 |
| 699-13-1C | 09/10/92 | 440.33 | 38.82 | 401.51 | 122.38 |
| 699-20-E5Q | 09/08/92 | 466.89 | 98.02 | 368.87 | 112.43 |
| 699-22-70 | 09/09/92 | 614.96 | 180.04 | 434.92 | 132.56 |
| 699-20-70Q | 09/09/92 | 614.96 | 185.54 | 429.42 | 130.89 |
| 699-24-1P | 09/08/92 | 474.55 | 82.12 | 392.43 | 119.61 |
| 699-29-70AP | 09/09/92 | 629.75 | 191.08 | 438.67 | 133.71 |
| 699-32-22B | 09/08/92 | 516.93 | 114.15 | 402.78 | 122.77 |
| 699-42-40C | 09/08/92 | 546.16 | 133.16 | 413.00 | 125.88 |
| 699-42-42A | 09/09/92 | 602.20 | 191.45 | 410.75 | 125.20 |
| 699-42-E9B | 09/10/92 | 386.42 | 28.34 | 358.08 | 109.14 |
| 699-43-91AP | 09/09/92 | 671.51 | 231.25 | 440.26 | 134.19 |
| 699-47-80AP | 09/09/92 | 713.03 | 271.48 | 441.55 | 134.58 |
| 699-49-32B | 09/09/92 | 515.55 | 104.99 | 410.56 | 125.14 |
| 699-49-55B | 09/21/92 | 530.33 | 127.83 | 402.50 | 122.68 |
| 699-50-45 | 09/08/92 | 451.41 | 43.09 | 408.32 | 124.46 |
| 699-50-48B | 09/08/92 | 550.39 | 144.64 | 405.75 | 123.67 |
| 699-51-46 | 09/08/92 | 444.63 | 37.91 | 406.72 | 123.97 |
| 699-52-46A | 09/08/92 | 455.61 | 47.22 | 408.39 | 124.48 |
| 699-52-48 | 09/08/92 | 466.06 | 61.48 | 404.58 | 123.32 |
| 699-53-50 | 09/08/92 | 444.21 | 40.12 | 404.09 | 123.17 |
| 699-54-57 | 09/09/92 | 575.58 | 173.61 | 401.97 | 122.52 |
| 699-56-53 | 09/09/92 | 434.34 | 32.13 | 402.21 | 122.59 |

(a) MSL = mean sea level.
(b) Flowing artesian. Depth to water is feet above casing.

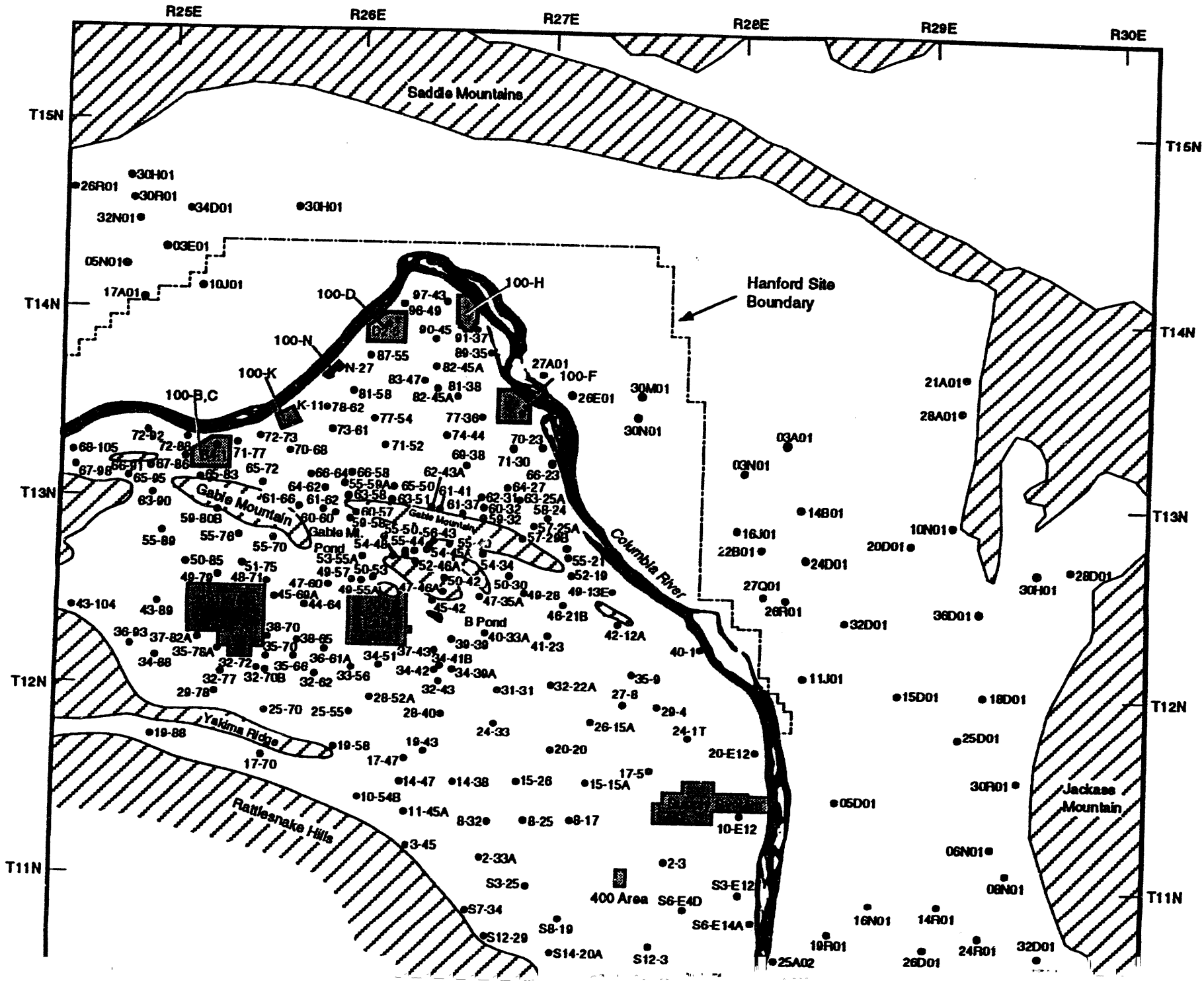
TABLE D.2. Water-Level Measurements from Inactive Upper-Confined Aquifer Wells on the Hanford Site Proper, 1978 to 1987

| Well | Date | Water-Table Elevation, ft above MSL[a] | Water-Table Elevation, m above MSL |
|---|---|---|---|
| 699-S16-E14 | 1980 | 384 | 117.0 |
| 699-17-47 | 1978 | 418 | 127.4 |
| 699-25-80 | 1978 | 449 | 136.9 |
| 699-31-84A | 1981 | 448 | 136.6 |
| 699-47-42 | 1979 | 409 | 124.7 |
| 699-50-96 | 1987 | 433 | 132.0 |

(a) MSL = mean sea level.

# Appendix E

# Locations of Monitoring Wells Sampled in 1992


R25E
R26E
R27E
R28E
R29E
R30E
T15N
T14N
T13N
T12N
T11N
Saddle Mountains
Hanford Site Boundary
100-D
100-H
100-N
100-K
100-B,C
100-F
Gable Mountain
Gable Mt. Pond
B Pond
Columbia River
Yakima Ridge
Rattlesnake Hills
Jackass Mountain
400 Area

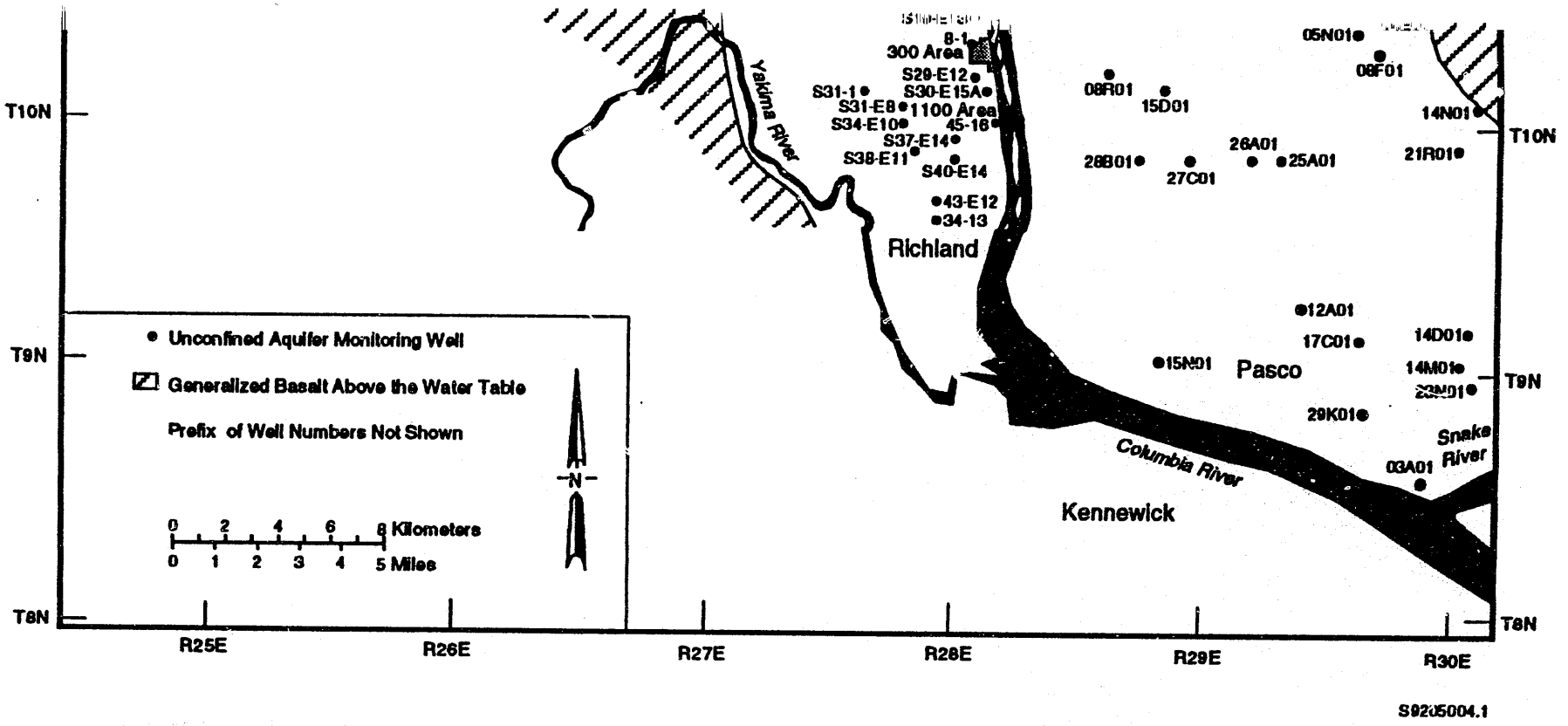
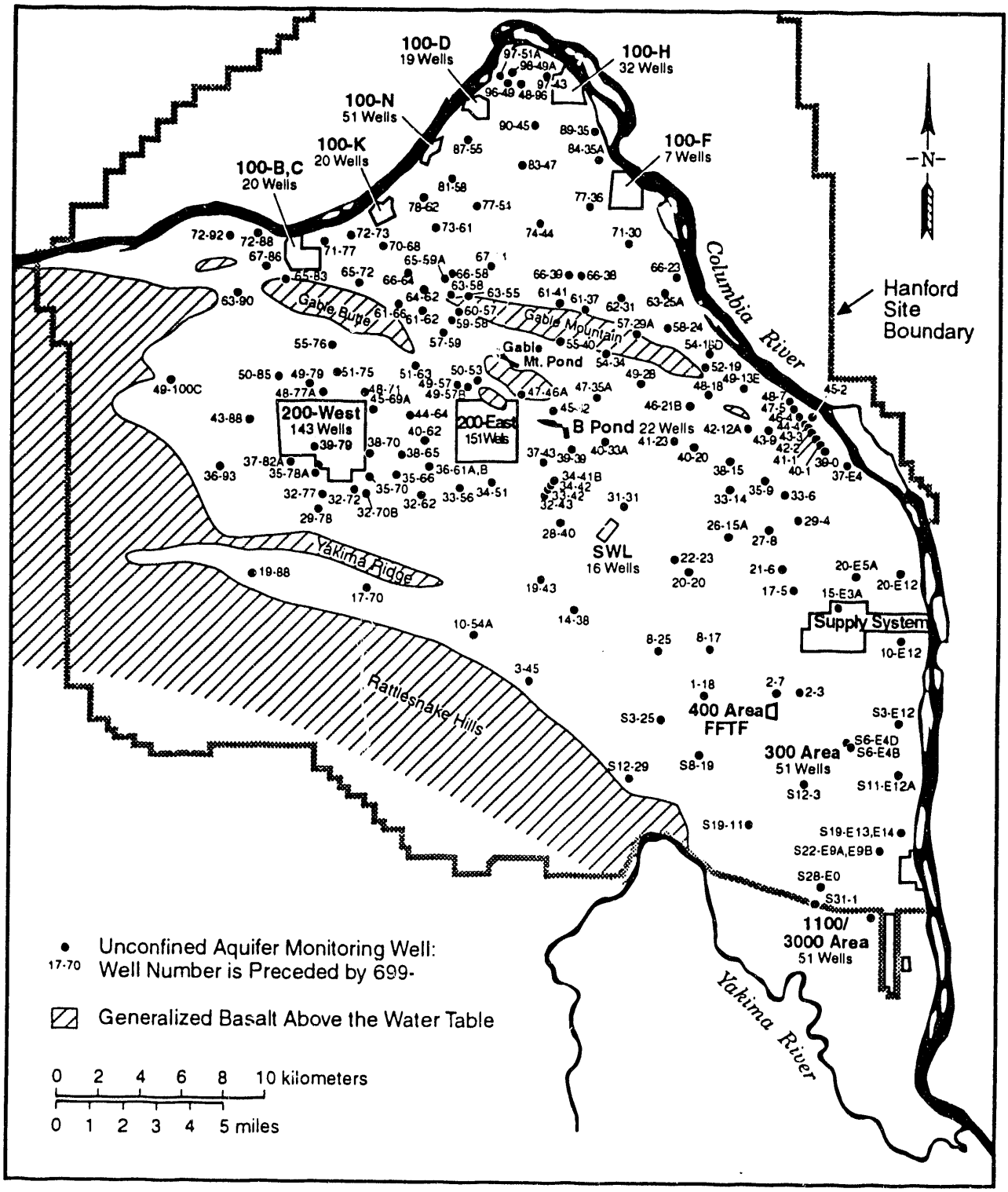



**Figure E.1.** Index Map for Location of Wells Used for Water-Level Measurements




S9304030.15

**Figure E.2.** Unconfined Aquifer Monitoring Well Locations

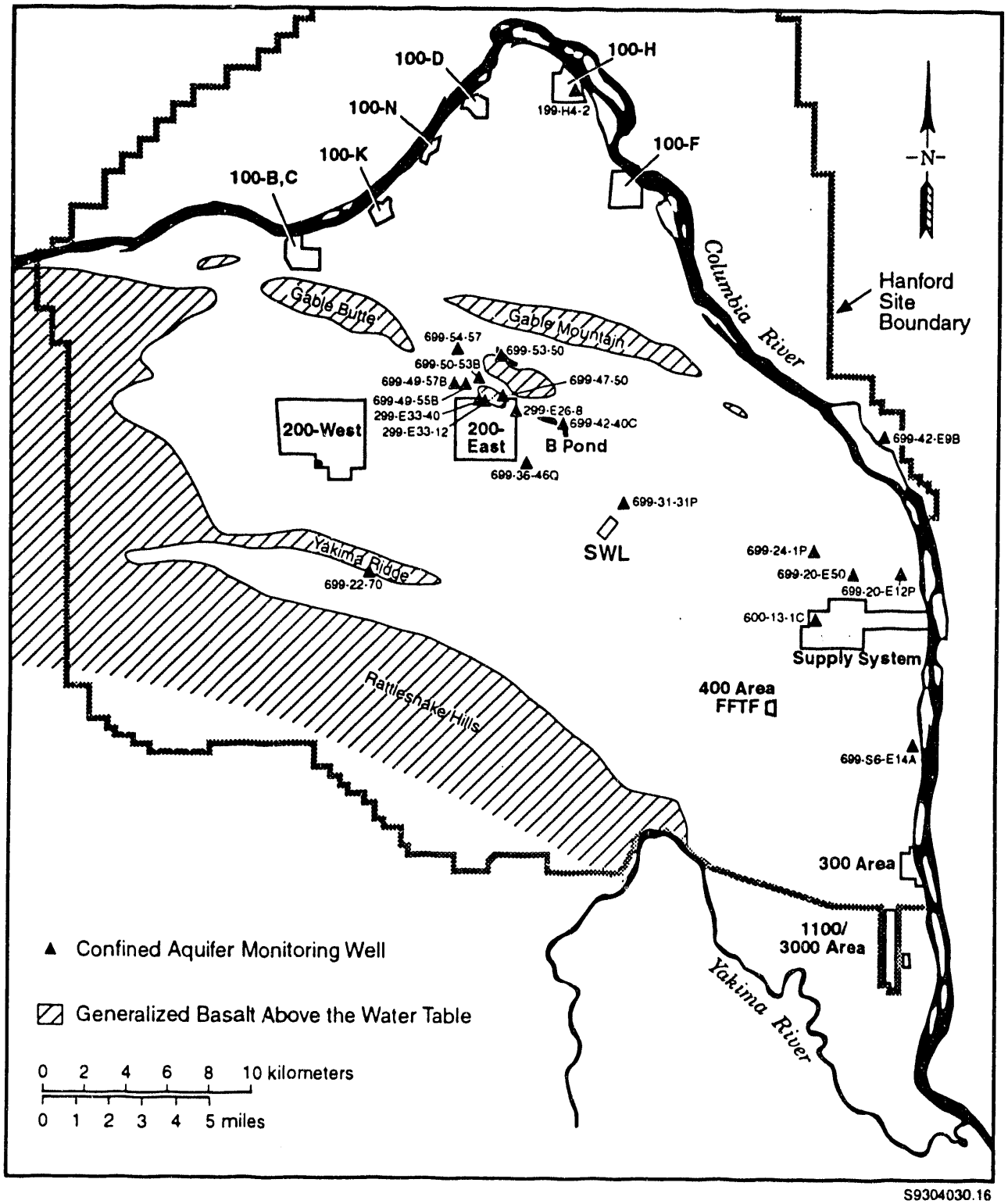



**Figure E.3.** Confined Aquifer Monitoring Well Locations

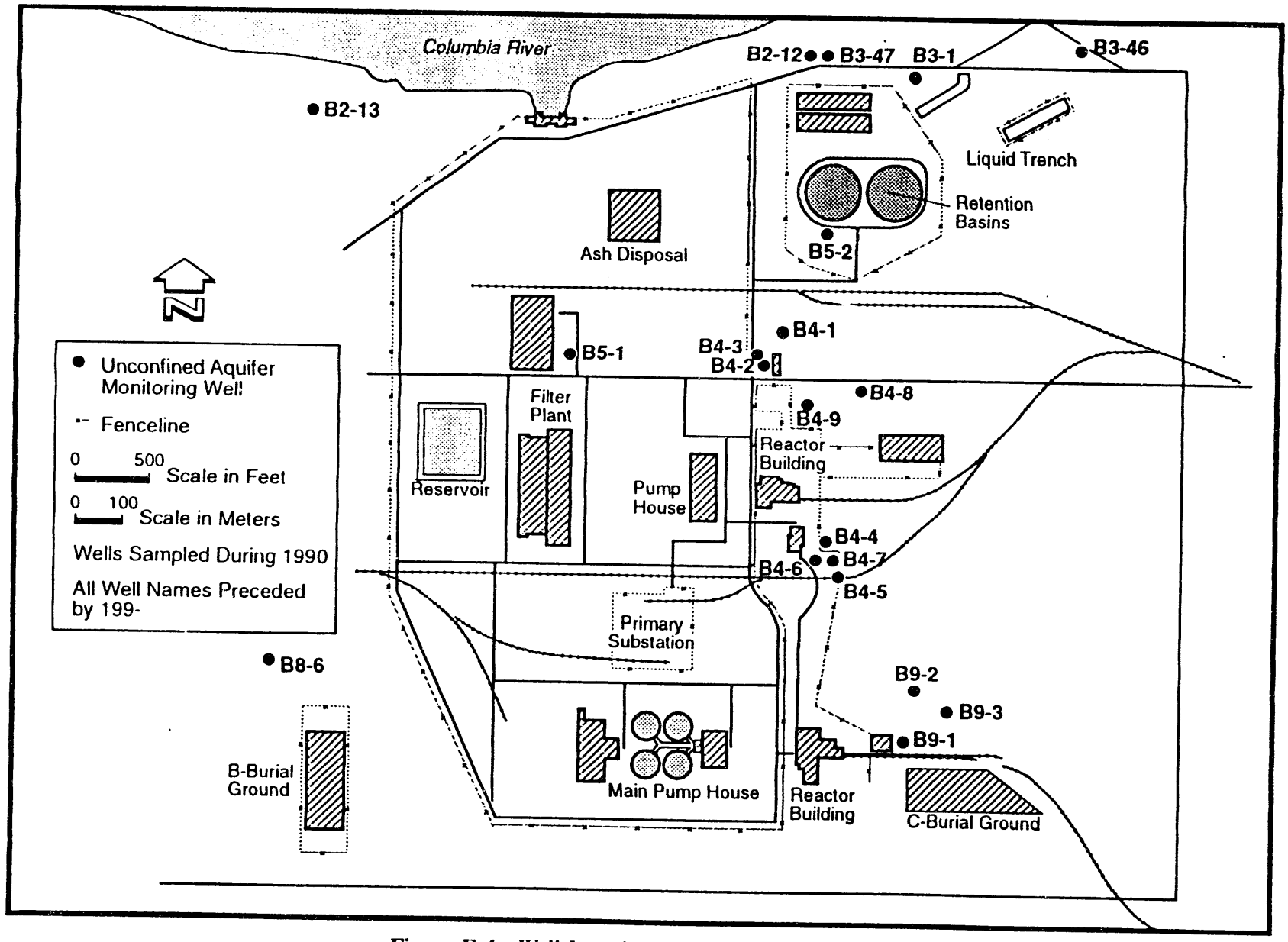



**Figure E.4.** Well Location Map for the 100-B/C Area

S9304030.7

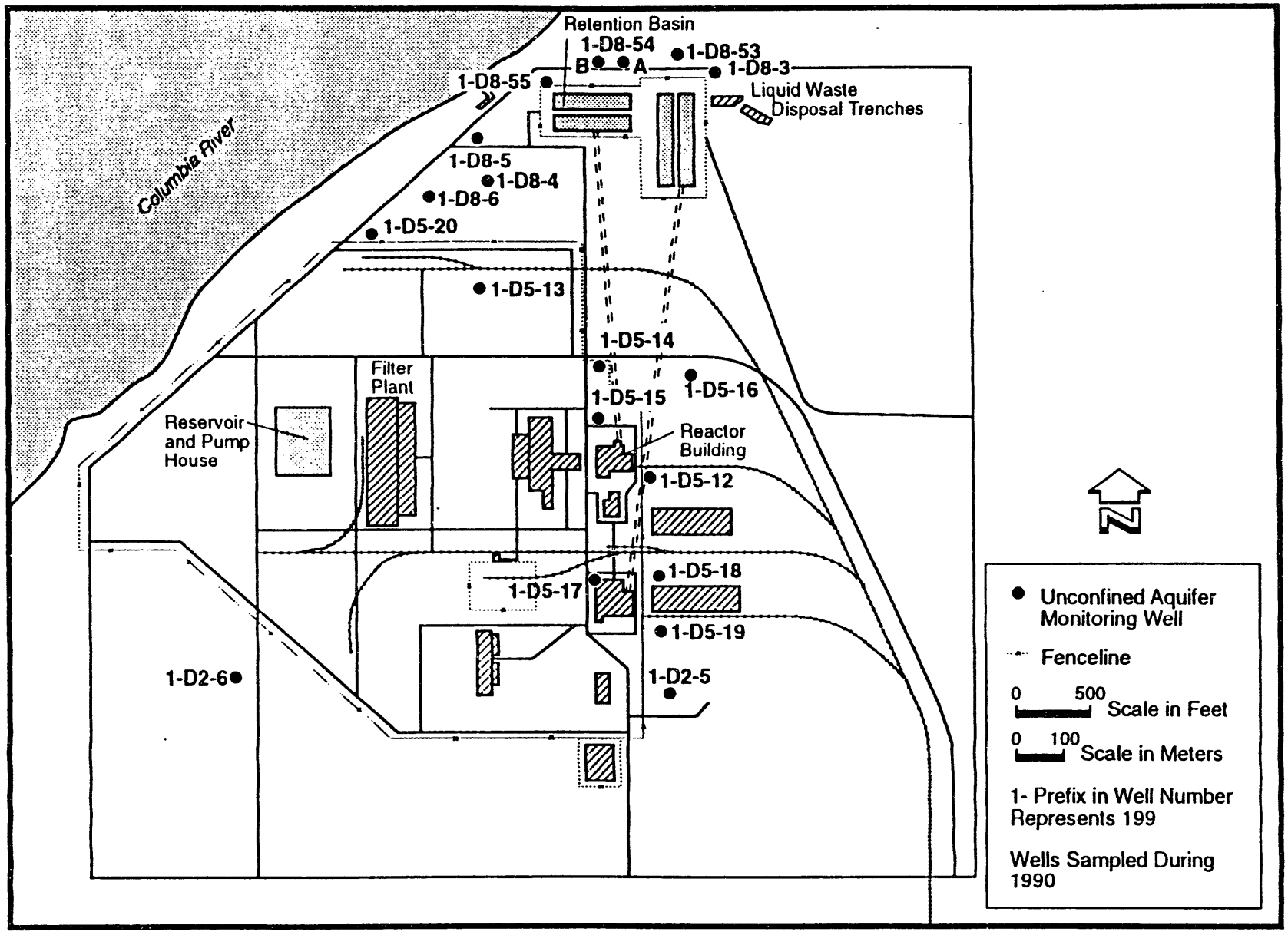



**Figure E.5.** Well Location Map for the 100-D Area

S9304030.11

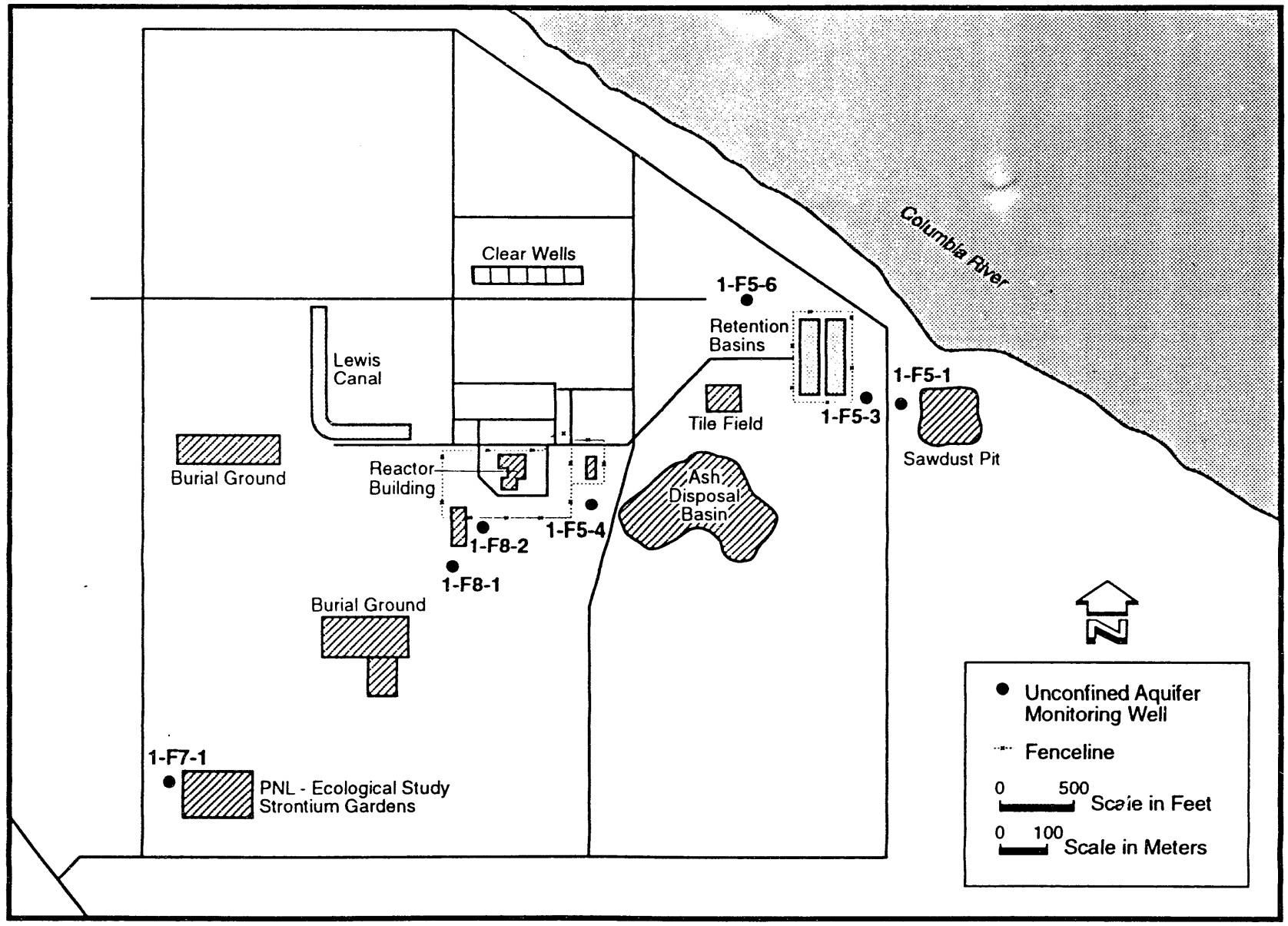



**Figure E.6.** Well Location Map for the 100-F Area

S9304030.2

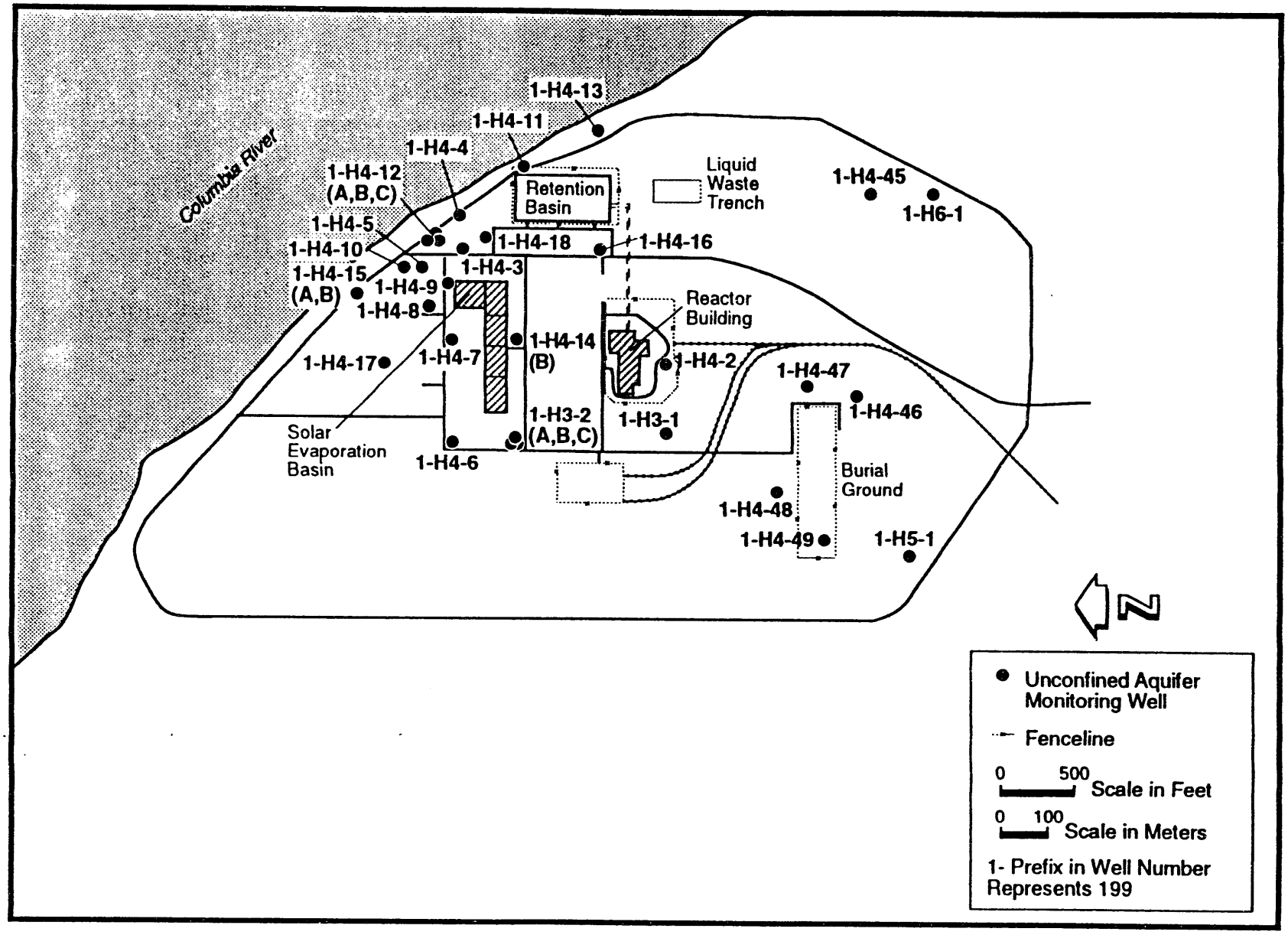
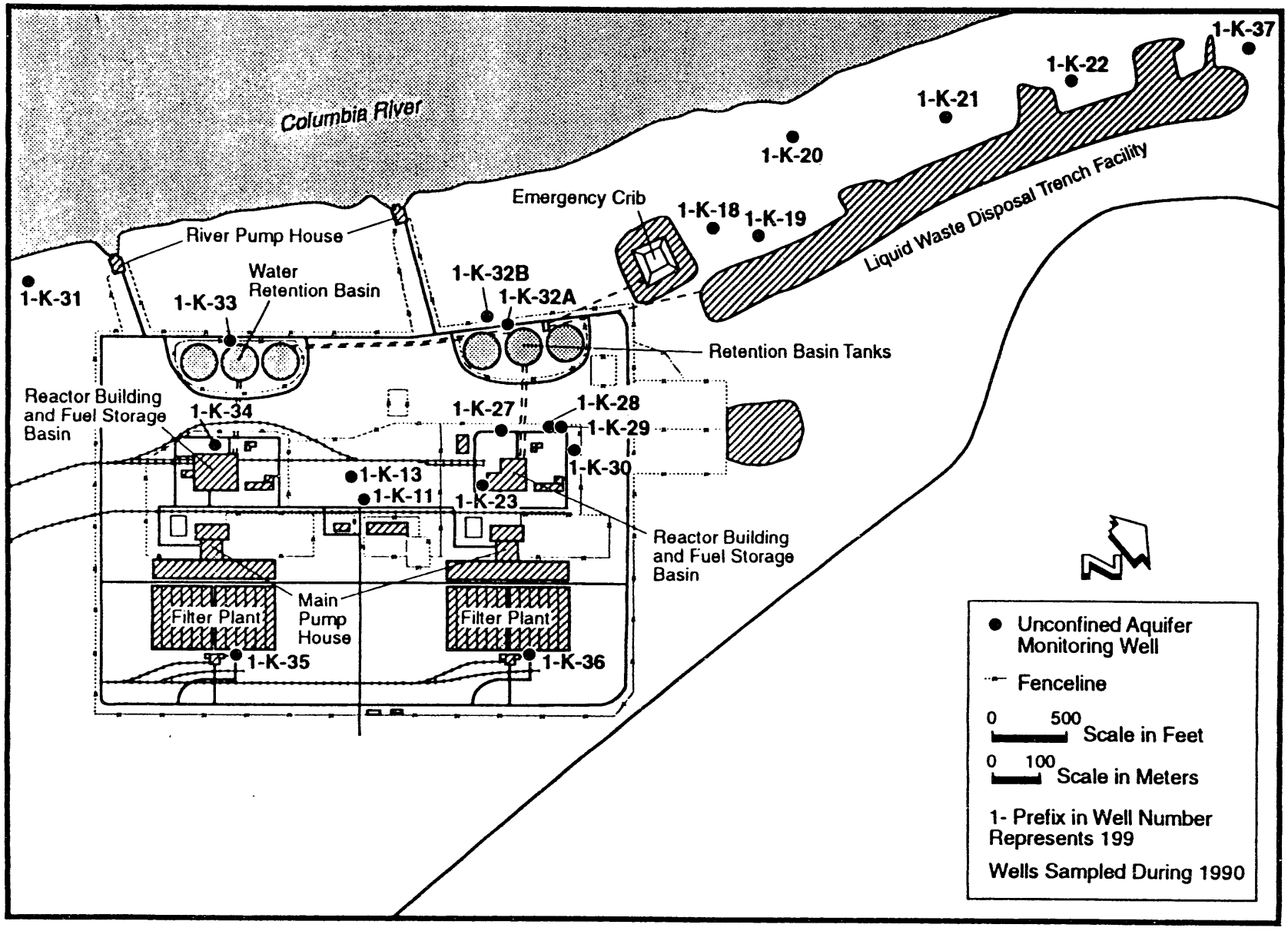



**Figure E.7.** Well Location Map for the 100-H Area

S9304030.1




S9304030.8

**Figure E.8.** Well Location Map for the 100-K Area

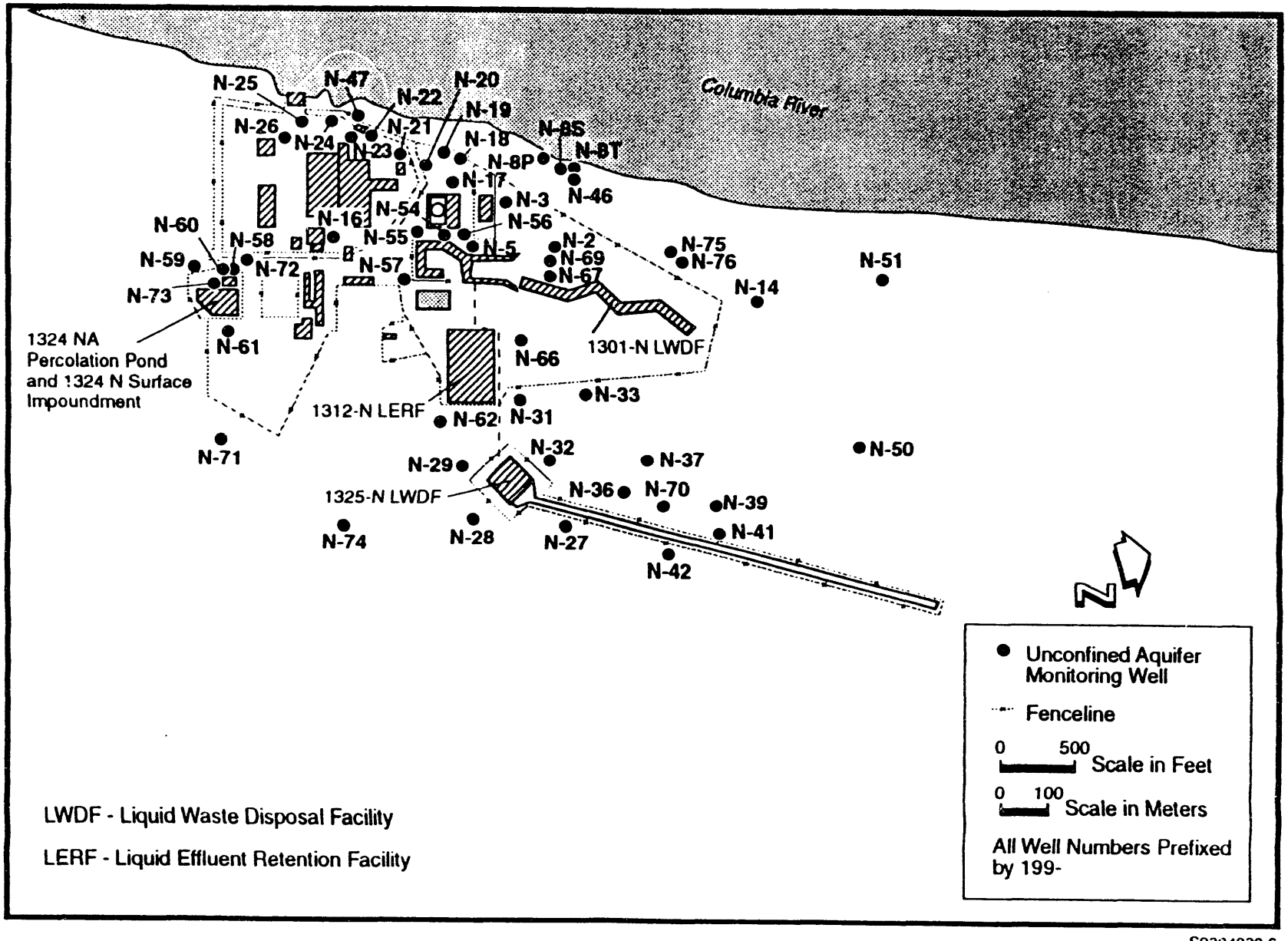
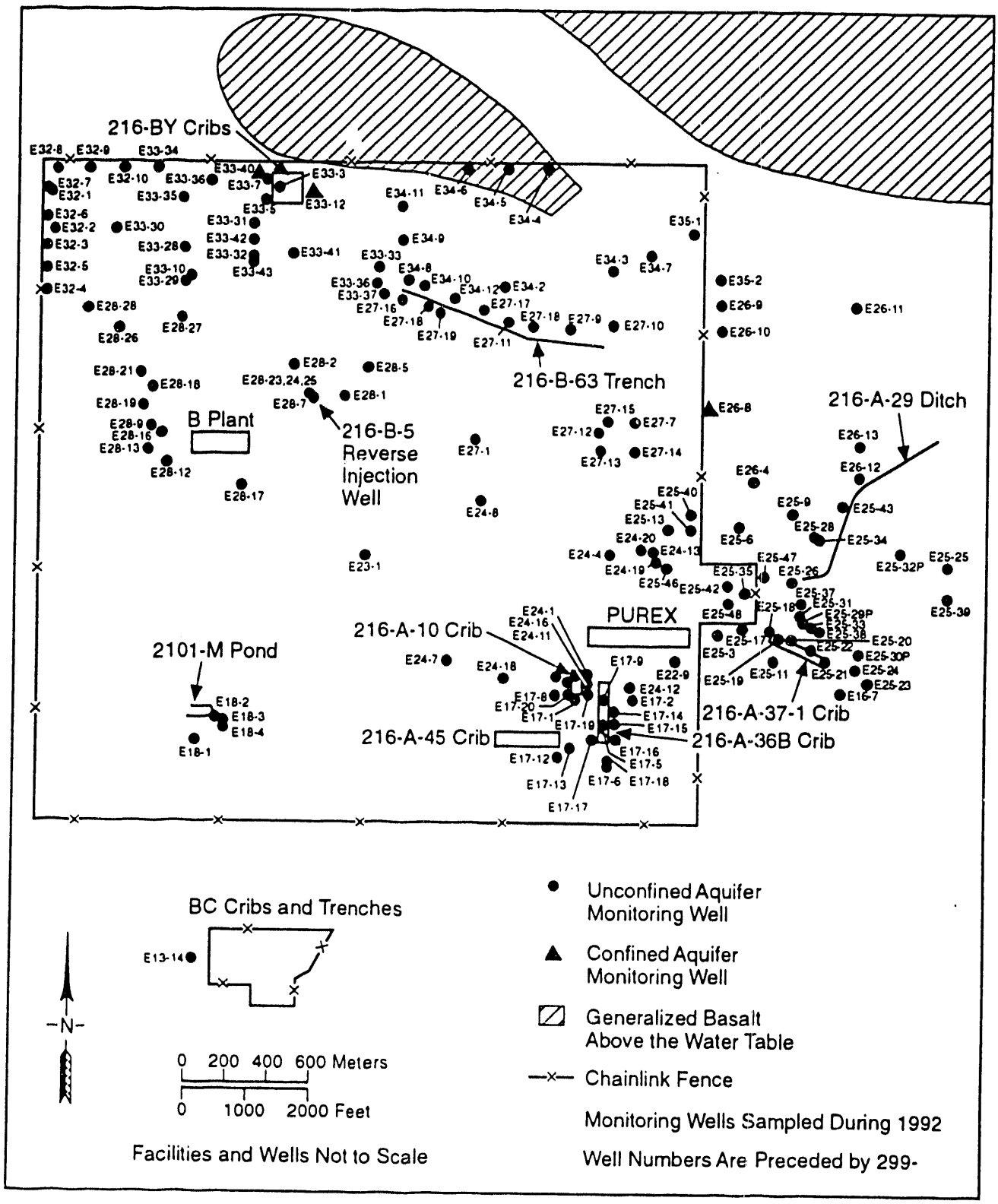


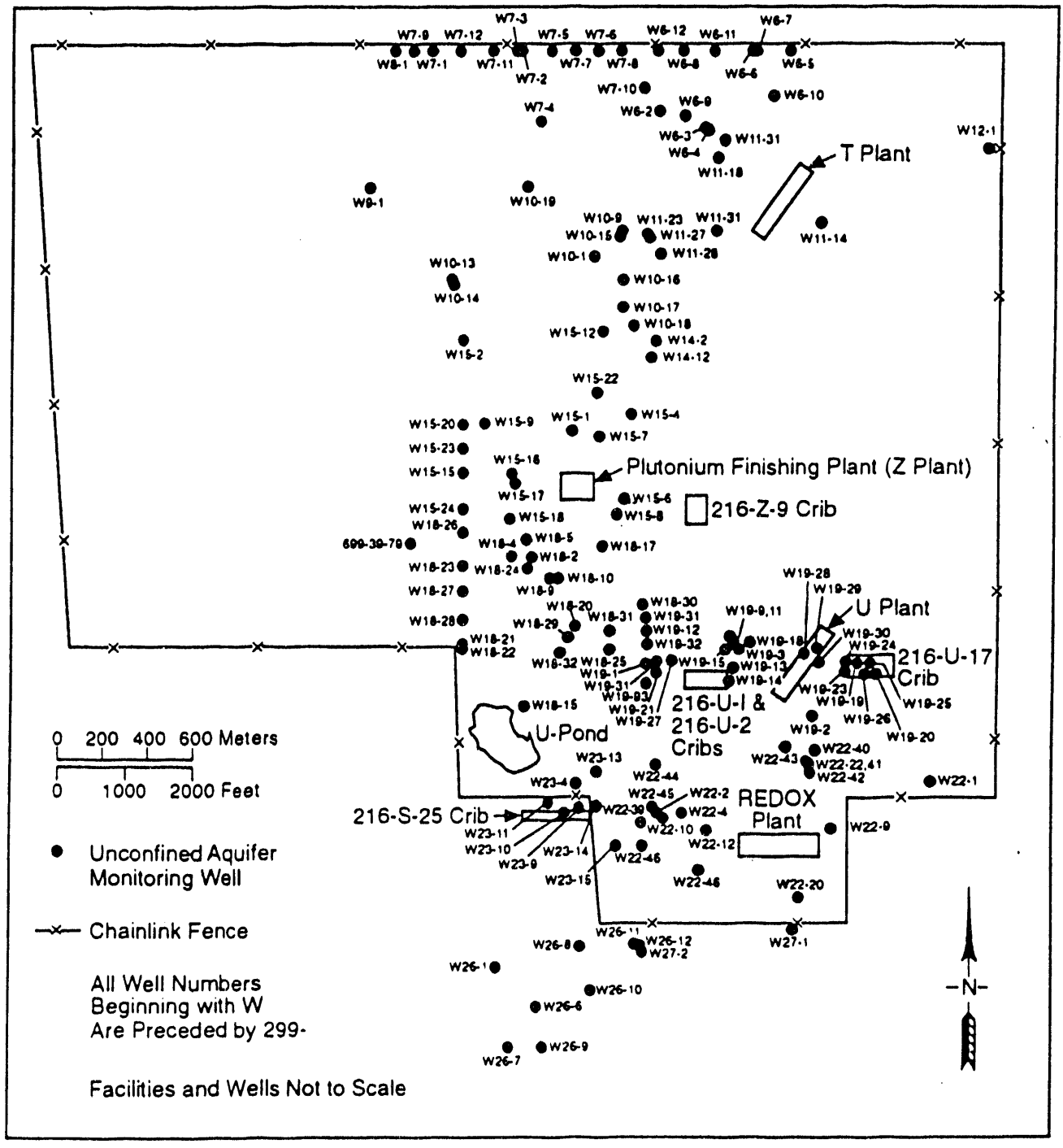

**Figure E.9.** Well Location Map for the 100-N Area

S9304030.6




S9304030.3

**Figure E.10.** Well Location Map for the 200-East Area




S9304030.4

**Figure E.11.** Well Location Map for the 200-West Area

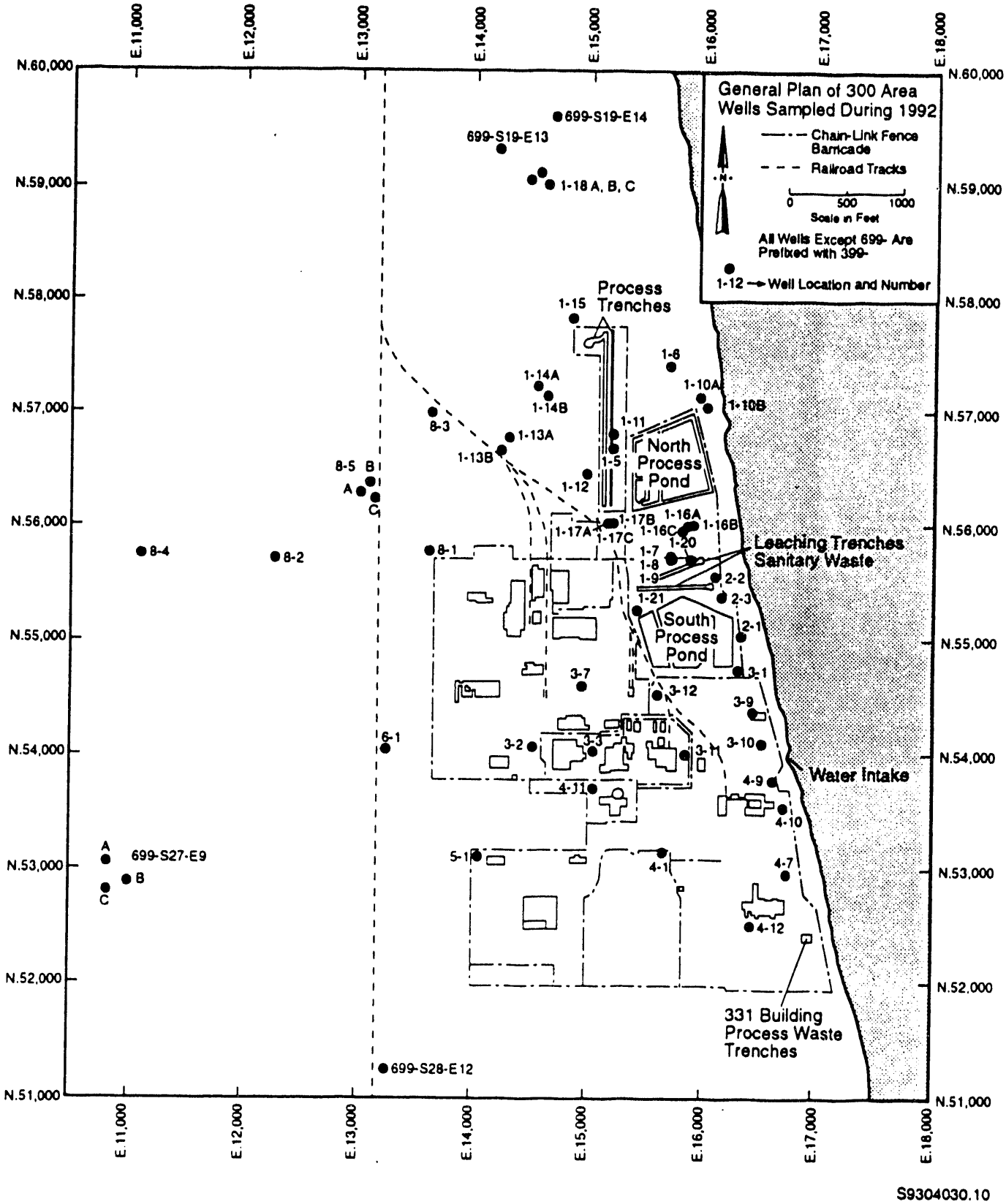
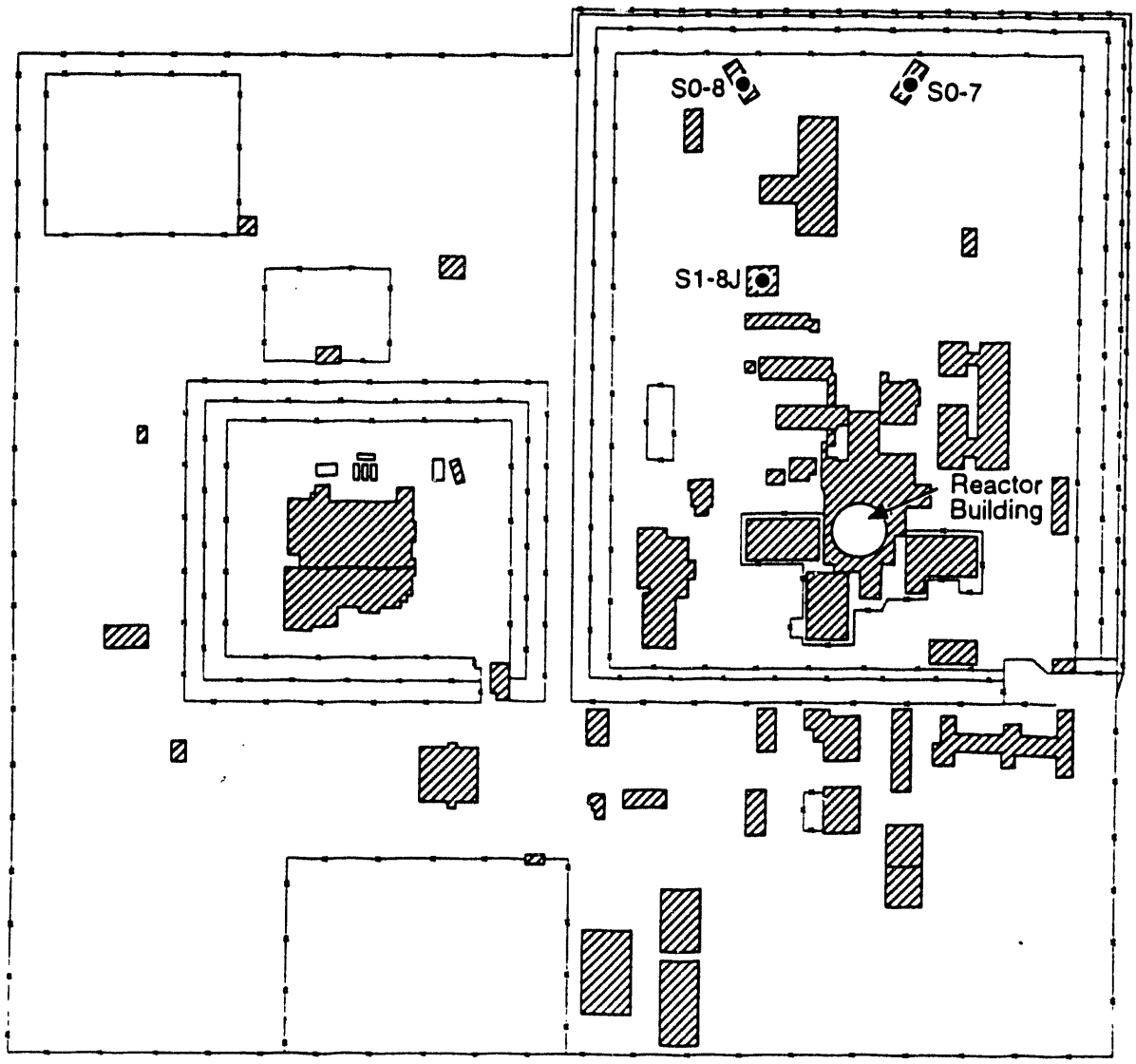



**Figure E.12.** Well Location Map for the 300 Area




All Well Numbers Prefixed by 499

● Unconfined Aquifer Monitoring Well

Fenceline

0 200 m

Wells Sampled During 1990

S9304030.9

**Figure E.13.** Well Location Map for the 400 Area

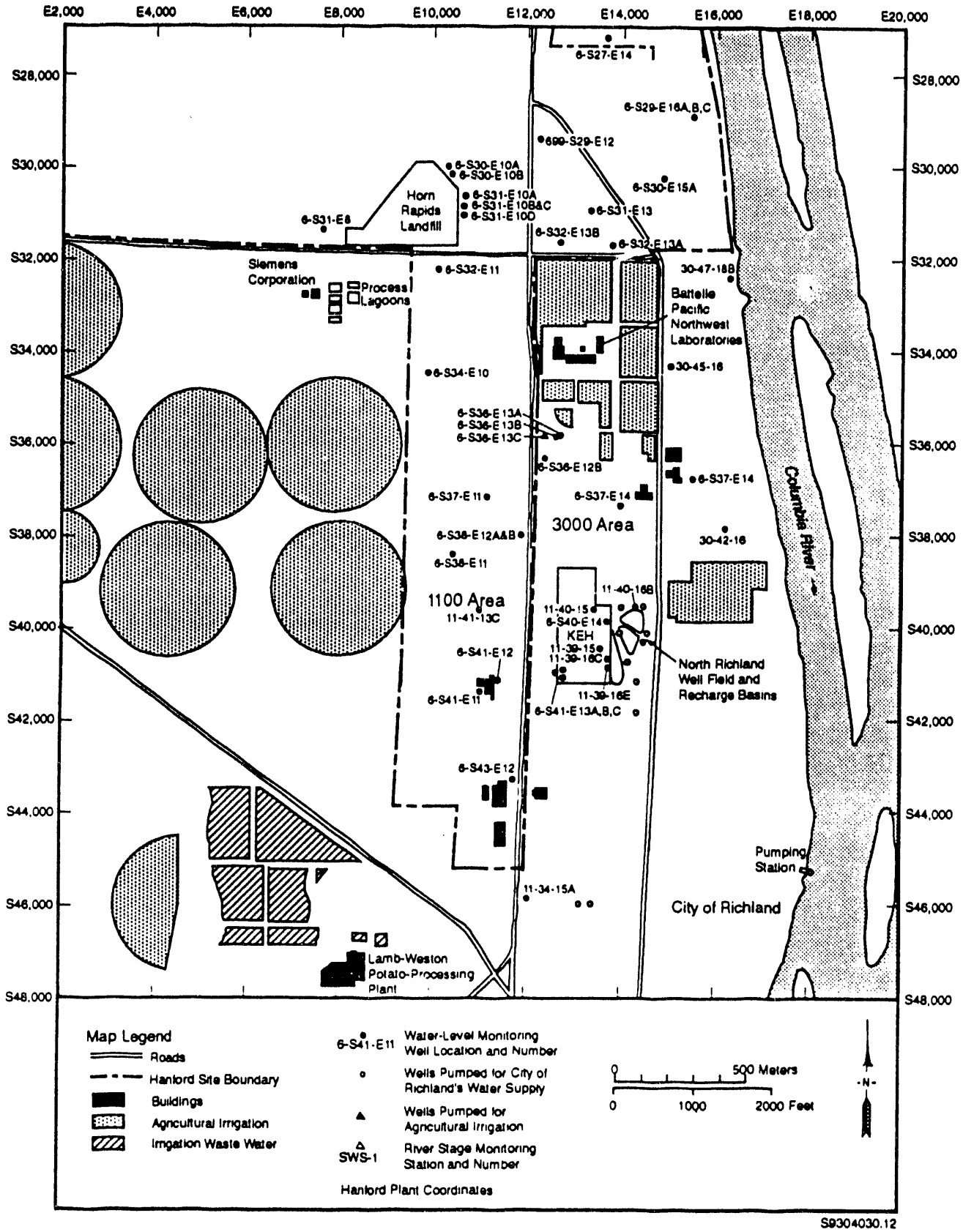



**Figure E.14.** Well Location Map for the North Richland Area

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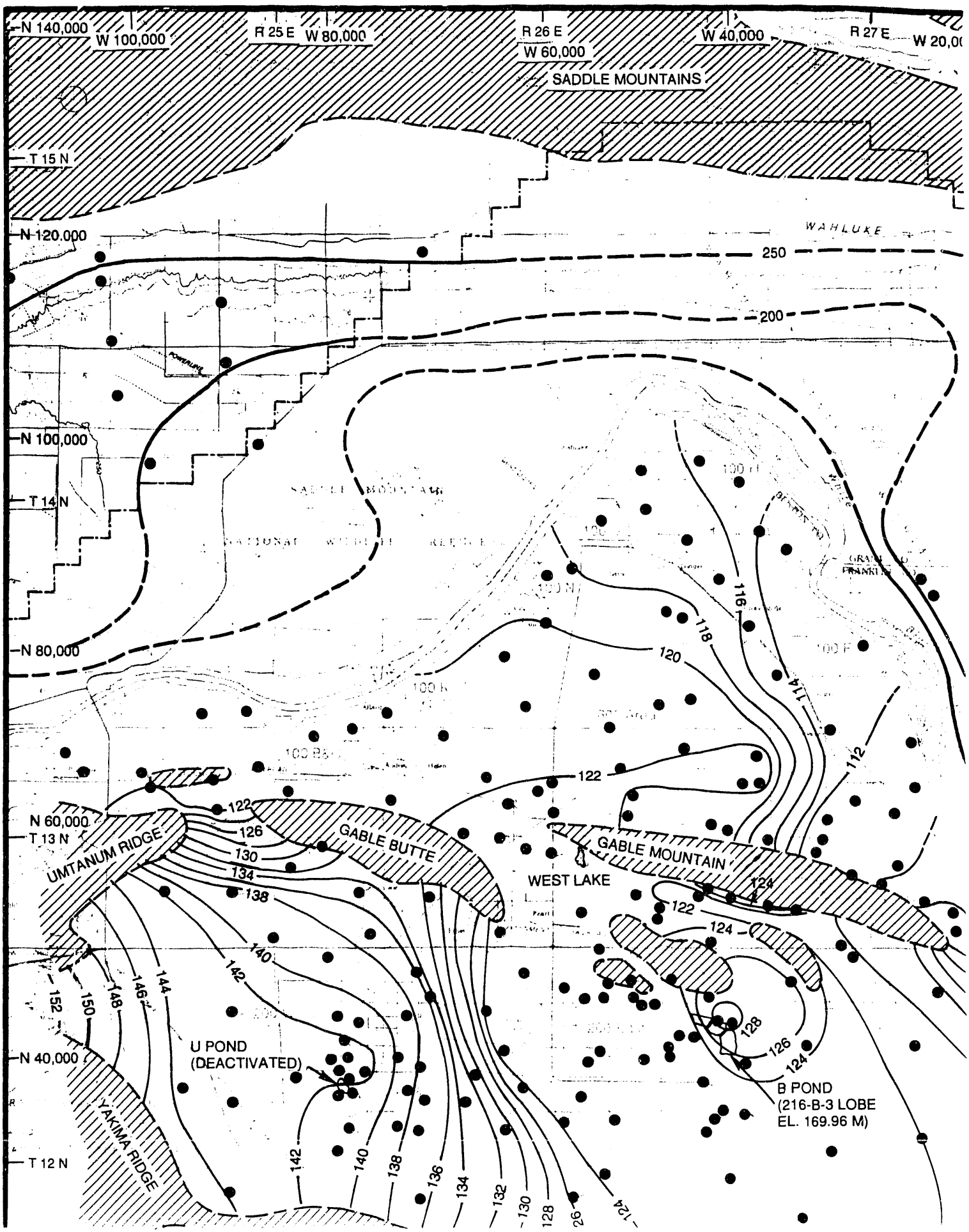
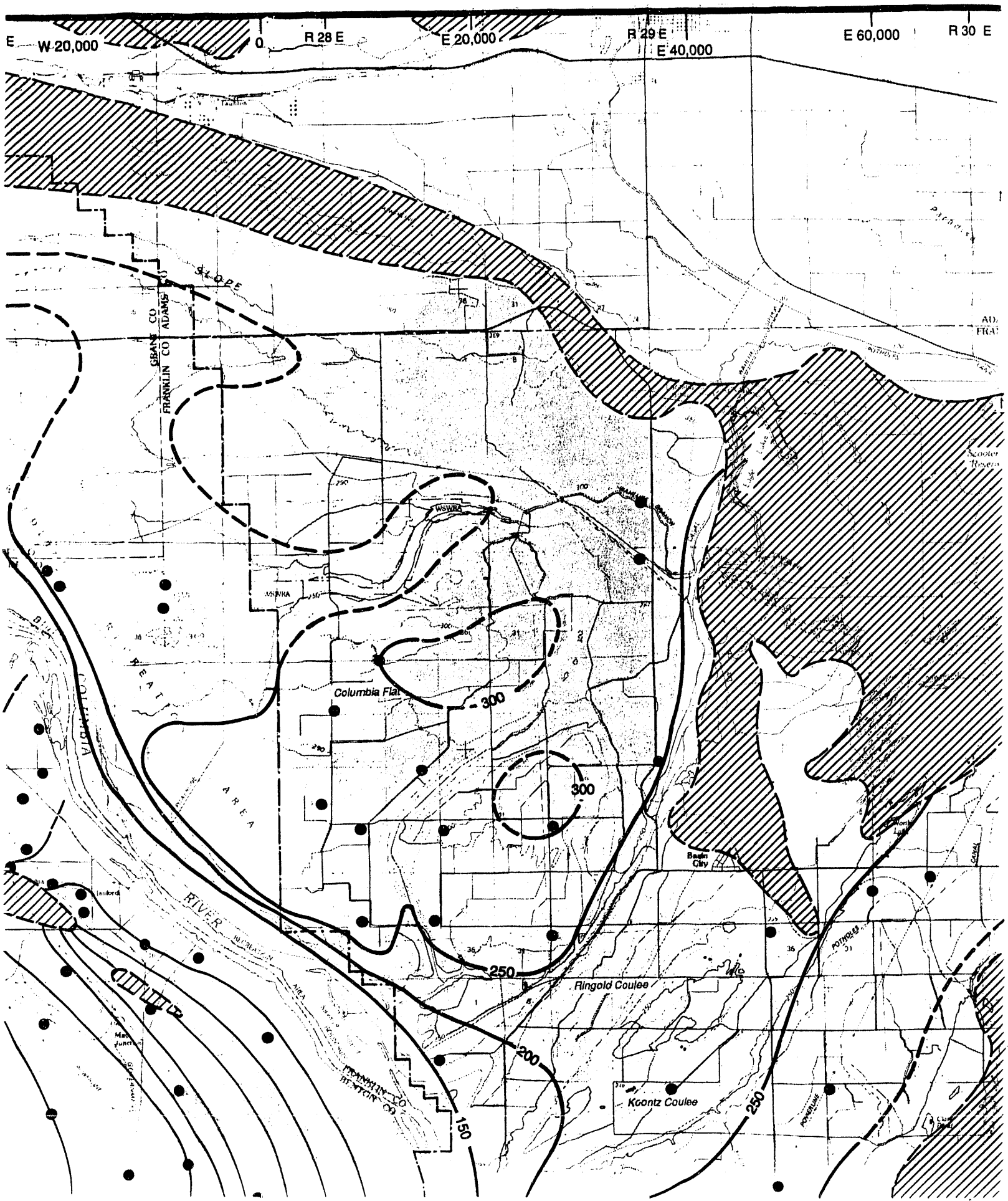


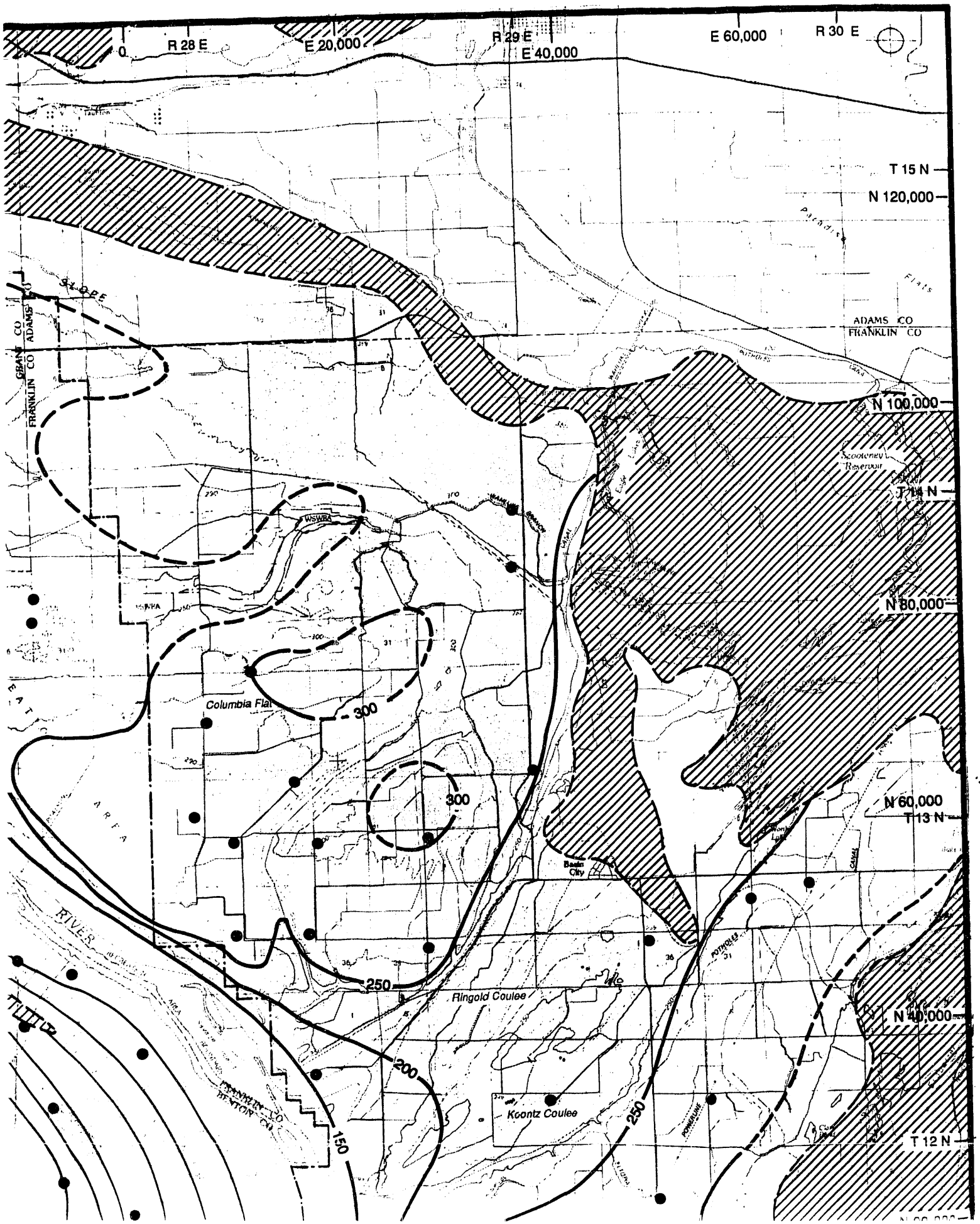
# ıg Areas Water-Table Map

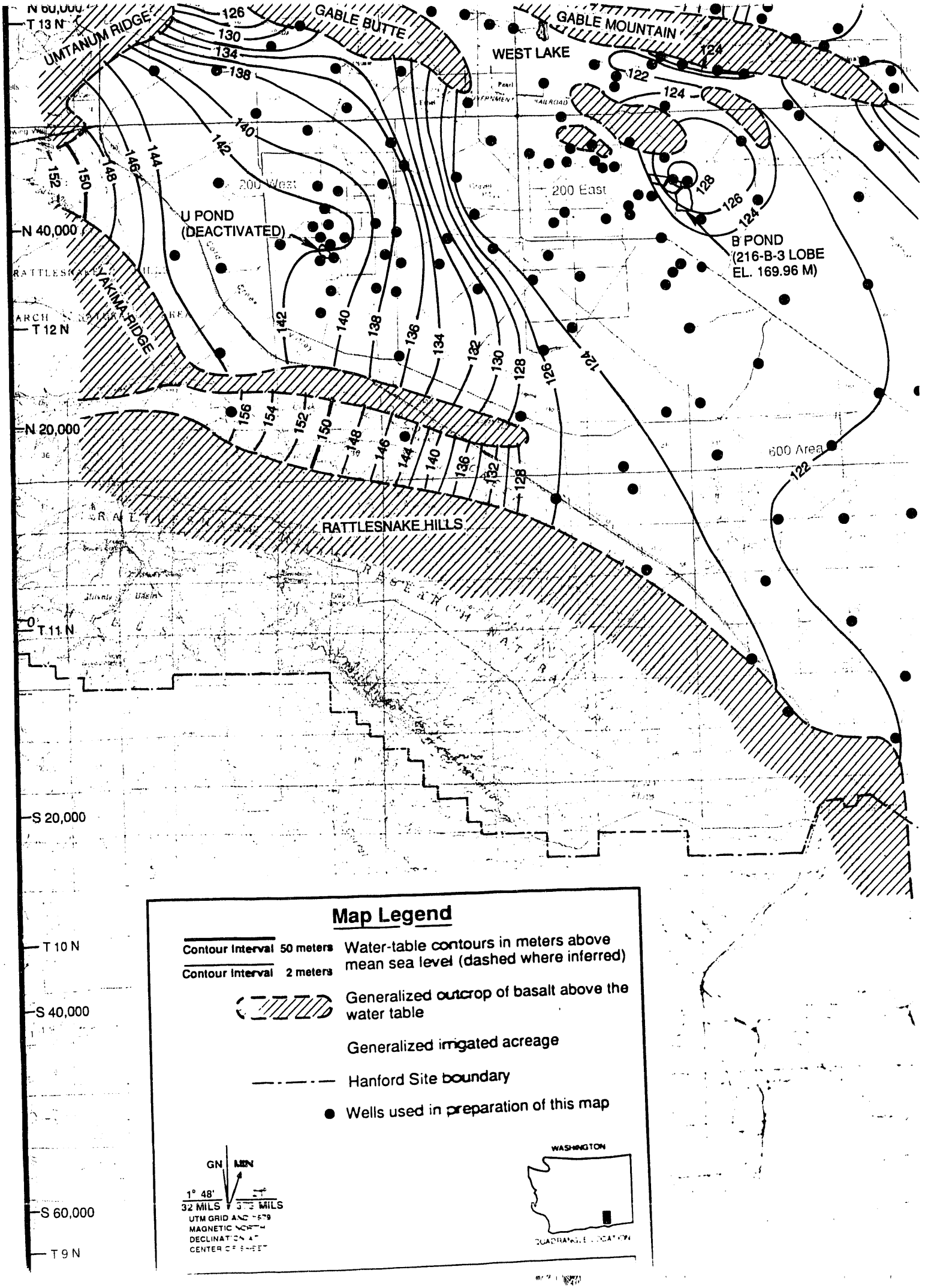
June



# eas Water-Table Map

June 1992

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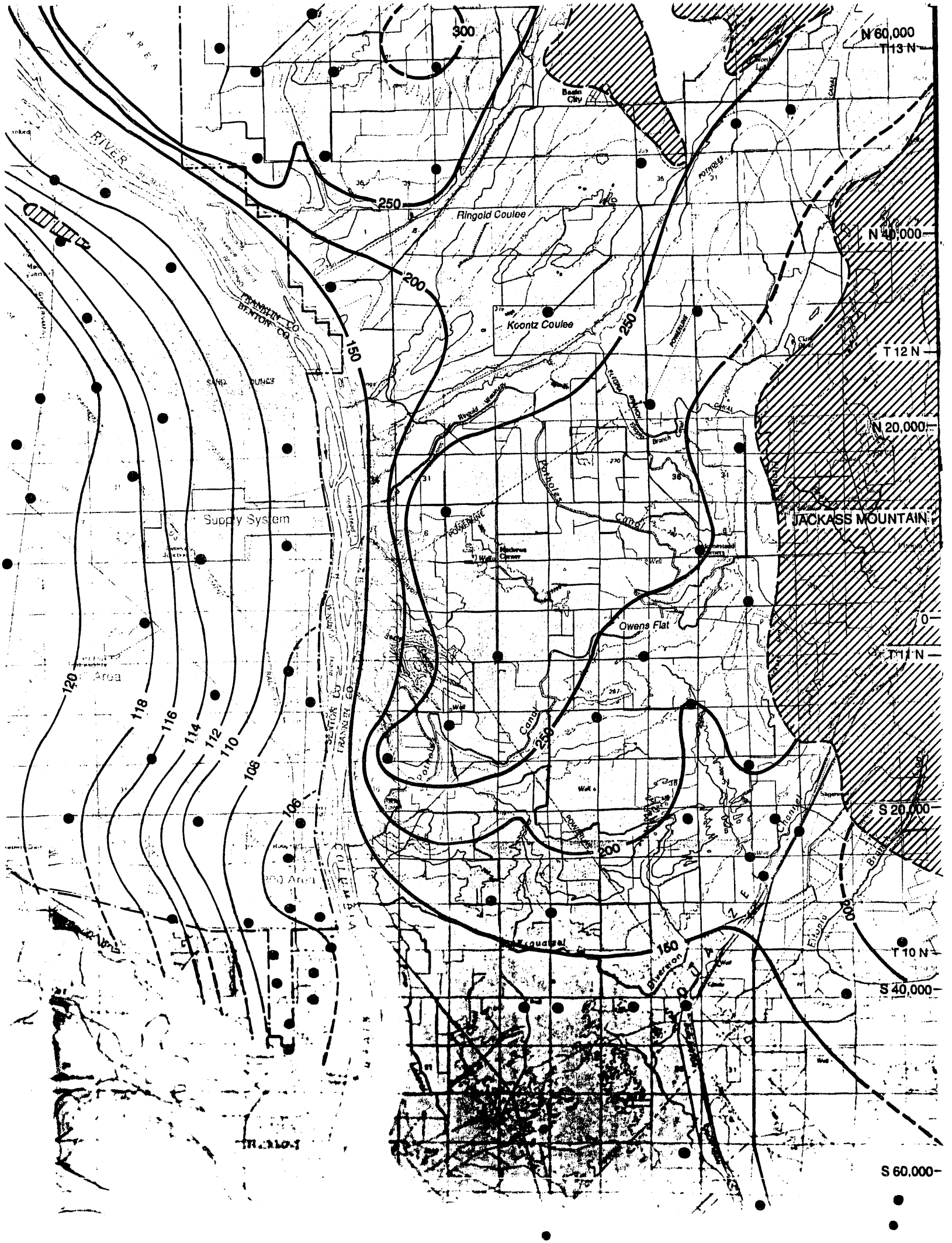
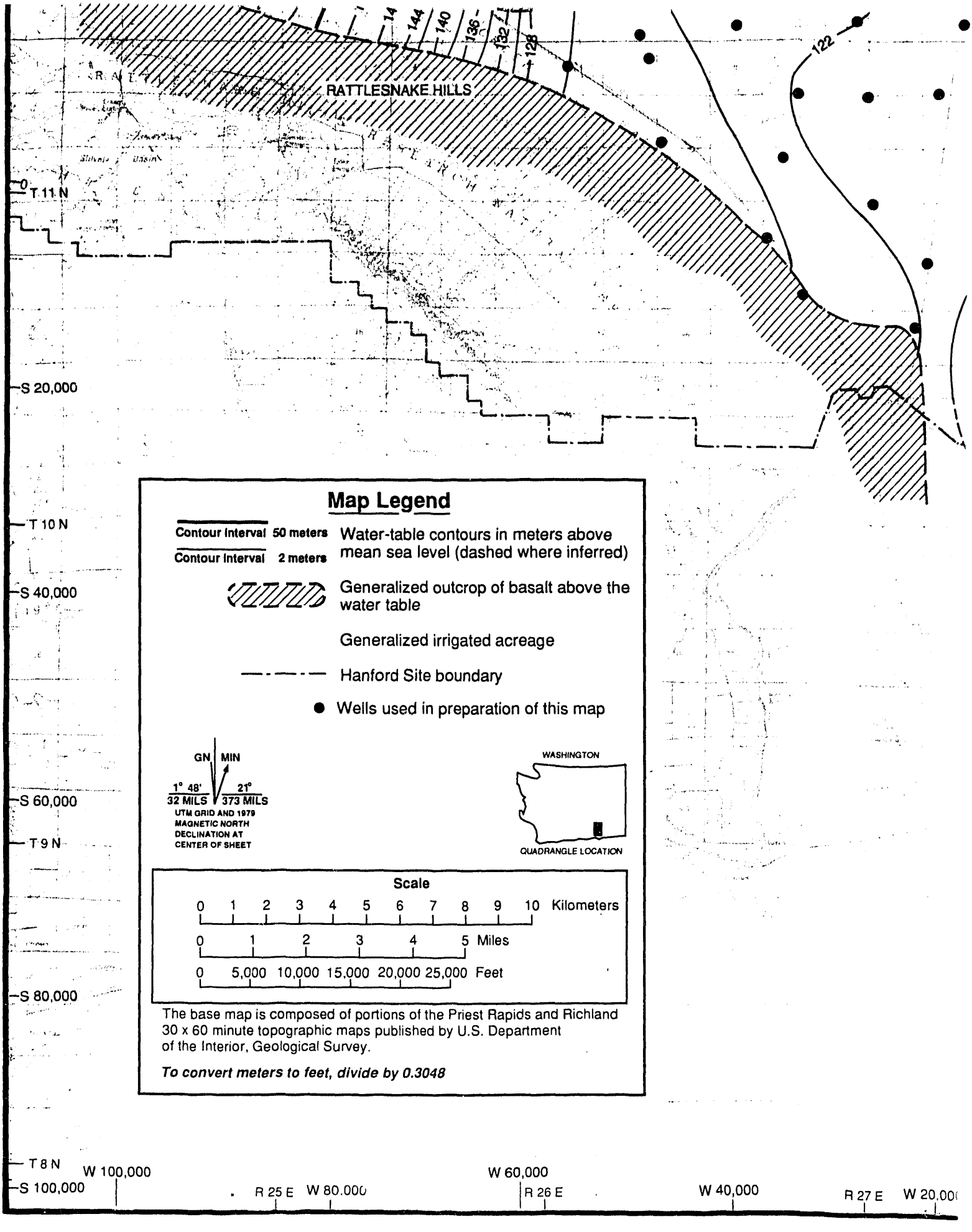
T 13 N
UMTANUM RIDGE
GABLE BUTTE
GABLE MOUNTAIN
WEST LAKE
200 West
200 East
U POND
(DEACTIVATED)
B POND
(216-B-3 LOBE
EL. 169.96 M)
N 40,000
YAKIMA RIDGE
T 12 N
N 20,000
600 Area
RATTLESNAKE HILLS
0
T 11 N
S 20,000
T 10 N
S 40,000
S 60,000
T 9 N
Map Legend
Contour Interval 50 meters
Contour Interval 2 meters
Water-table contours in meters above mean sea level (dashed where inferred)
Generalized outcrop of basalt above the water table
Generalized irrigated acreage
Hanford Site boundary
Wells used in preparation of this map
GN
MN
1° 48'
32 MILS
WASHINGTON


N 60,000
T 13 N
N 40,000
T 12 N
N 20,000
0
T 11 N
S 20,000
T 10 N
S 40,000
S 60,000
JACKASS MOUNTAIN
Ringold Coulee
Koontz Coulee
Owens Flat
Basin City
Supply System
Area
RIVER
FRANKLIN CO
BENTON CO
Canal
Potholes
Diversion
300
250
200
150
160
120
118
116
114
112
110
106


RATTLESNAKE HILLS
14
144
140
136
132
128
122
T 11 N
S 20,000
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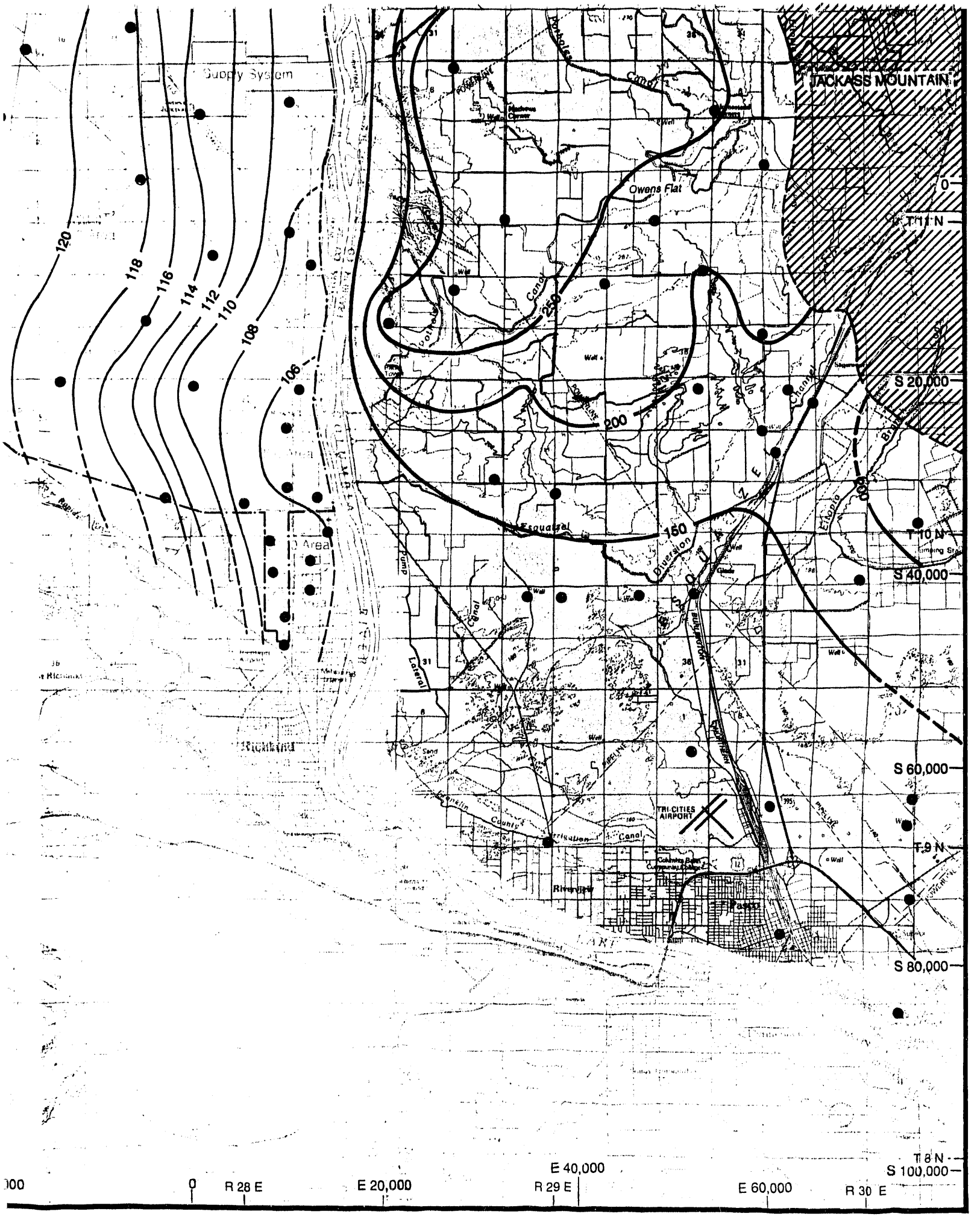
T 9 N
S 80,000
T 8 N
S 100,000
W 100,000
R 25 E
W 80,000
W 60,000
R 26 E
W 40,000
R 27 E
W 20,000
Map Legend
Contour Interval 50 meters
Contour Interval 2 meters
Water-table contours in meters above mean sea level (dashed where inferred)
Generalized outcrop of basalt above the water table
Generalized irrigated acreage
Hanford Site boundary
Wells used in preparation of this map
GN
MIN
1° 48'
32 MILS
21°
373 MILS
UTM GRID AND 1979 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
WASHINGTON
QUADRANGLE LOCATION
Scale
0 1 2 3 4 5 6 7 8 9 10 Kilometers
0 1 2 3 4 5 Miles
0 5,000 10,000 15,000 20,000 25,000 Feet
The base map is composed of portions of the Priest Rapids and Richland 30 x 60 minute topographic maps published by U.S. Department of the Interior, Geological Survey.
To convert meters to feet, divide by 0.3048


JACKASS MOUNTAIN
Supply System
Owens Flat
Canal
Potholes
Esquatzel
Diversion
Canal
Lateral
Pump
Ethola
Channel
Bridge
Richland
Area
Riverview
Pasco
TRI-CITIES AIRPORT
Columbia Basin Community College
Franklin County
Irrigation
Canal
120
118
116
114
112
110
108
106
250
200
150
100
0
T 11 N
T 10 N
T 9 N
T 8 N
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S 80,000
S 100,000
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# END

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9/20/93