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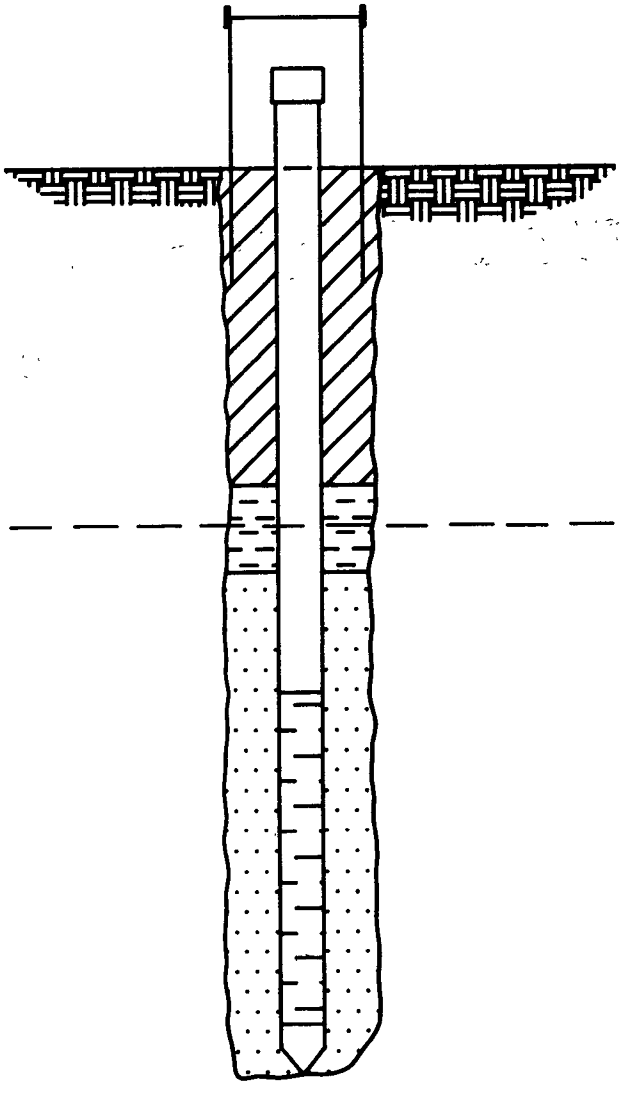
Water-Resources Investigations Report 88-4219

AN INVESTIGATION OF SHALLOW GROUND-WATER QUALITY NEAR EAST FORK POPLAR CREEK, OAK RIDGE, TENNESSEE



Prepared by the
U.S. GEOLOGICAL SURVEY

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

in cooperation with the
U.S. DEPARTMENT OF ENERGY

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By John K. Carmichael

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Nashville, Tennessee
1989

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who may prefer to use metric (International System) units rather than the inch-pound units herein, the conversion factors are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeters (mm)
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

Use of trade or firm names in this report is for identification only and does not constitute endorsement by the U.S. Geological Survey.

Well-Numbering System: Wells are identified according to the numbering system used by the U.S. Geological Survey throughout Tennessee. The well number consists of three parts: (1) an abbreviation of the name of the county in which the well is located; (2) a letter designating the $7^1/_2$-minute topographic quadrangle on which the well is plotted; and (3) a number generally indicating the numerical order in which the well was inventoried. The symbol An:D-1, for example, indicates that the well is located in Anderson County on the "D" quadrangle and is identified as well 1 in the numerical sequence. Quadrangles are lettered from left to right, beginning in the southwest corner of the county.

AN INVESTIGATION OF SHALLOW GROUND-WATER QUALITY NEAR EAST FORK POPLAR CREEK, OAK RIDGE, TENNESSEE

By John K. Carmichael

ABSTRACT

Alluvial soils and fill materials in and near the flood plain of East Fork Poplar Creek in Oak Ridge, Tennessee, are contaminated with various trace metals (primarily mercury), organic compounds, and radionuclides that were lost to the stream as a result of past operations at the Y-12 Plant, a nuclear-processing facility located within the U.S. Department of Energy's Oak Ridge Reservation. Observation wells were installed in the shallow (above bedrock) aquifer in and near the flood plain of East Fork Poplar Creek and water-quality samples were collected to determine if contaminants found in the soils and fill are also present in the shallow ground water.

The shallow aquifer in the East Fork Poplar Creek flood plain consists primarily of alluvial silt and clay with lesser amounts of sand and gravel. Thickness of the shallow aquifer ranges from essentially zero to as much as 20 feet. A silty-clay glei horizon is present between the base of the alluvium and the top of bedrock at most flood-plain locations and, where present, likely impedes downward ground-water movement.

Water in the shallow aquifer near East Fork Poplar Creek occurs under water-table conditions. Recharge to the shallow aquifer is principally from precipitation, and discharge is through springs and seeps to East Fork Poplar Creek and its tributaries. During spring, summer, and fall, evapotranspiration also accounts for the removal of water in storage in the shallow aquifer.

Water levels in the shallow aquifer fluctuate seasonally in response to variations in recharge and evapotranspiration. Generally, the depth to water in the observation wells ranged from about 1 to 4 feet below land surface in late winter, and from about 2 to 7 feet below land surface in late fall. During extremely dry periods, the water table recedes below the top of bedrock in some flood-plain areas, possibly causing East Fork Poplar Creek to lose water to the shallow aquifer along some reaches.

Contaminants found in water samples collected from several of the observation wells in concentrations (total and (or) total-recoverable) which equaled or exceeded drinking-water standards established by the U.S. Environmental Protection Agency are antimony, chromium, lead, mercury, selenium, total phenols, and strontium-90. Total and dissolved uranium concentrations exceeded 1.0 microgram per liter in samples from nearly 70 percent of the wells in the East Fork Poplar Creek flood

plain. Organic compounds that were identified in low concentrations in samples from a few wells in the flood plain are: Arochlor 1260, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, 3,3-dichlorobenzidine, di-n-butylphthalate, N-nitrosodiphenylamine, and pyrene. Water from one well in the East Fork Poplar Creek flood plain at a contaminated fill site contained 37 and 8 micrograms per liter of trichloroethene and trans-1,2-dichloroethene, respectively.

Comparison of the results of total and (or) total-recoverable trace-metal determinations with those from dissolved determinations demonstrates that elevated concentrations of these substances in water collected from several of the wells in the East Fork Poplar Creek flood plain resulted from sorption of trace metals (and possibly organic compounds and radionuclides) by fine sediment suspended in the samples. The occurrence of contaminated sediment in these samples is suspected to be the result of borehole contamination during well installation.

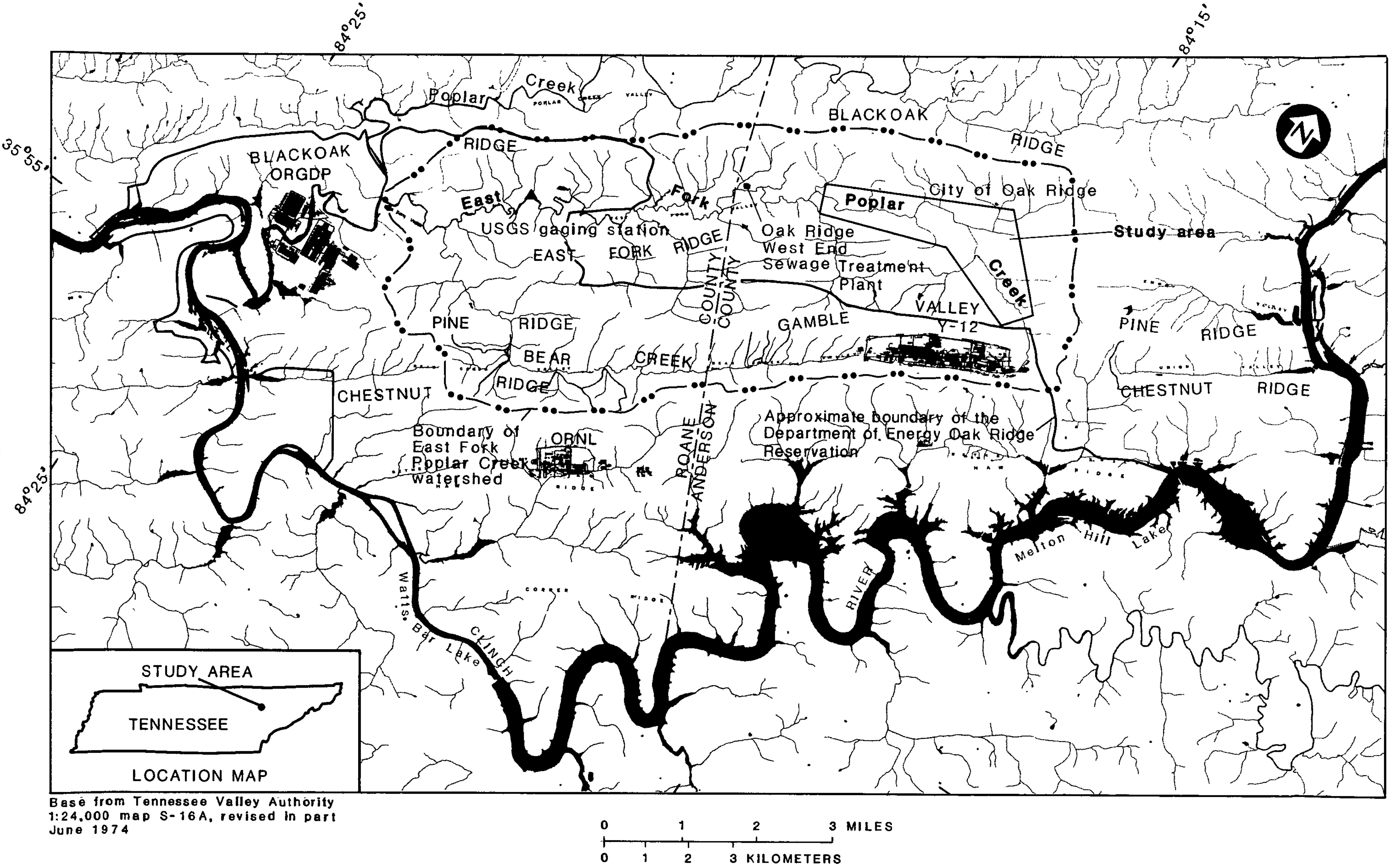
INTRODUCTION

During the past 40 years, operations at the Y-12 Plant, a nuclear-processing facility located within the U.S. Department of Energy's (DOE) Oak Ridge Reservation at Oak Ridge, Tennessee (fig. 1), have resulted in disposal and loss to the environment of a variety of chemical constituents and compounds (Union Carbide Corporation-Nuclear Division, 1983; Geraghty and Miller, 1985). For example, it has been estimated that since 1950, more than 733,000 pounds of elemental mercury have been lost from the Y-12 Plant, including an estimated 239,000 pounds of which were discharged directly into the headwaters of East Fork Poplar Creek, a small stream that begins as an industrial ditch inside the Y-12 facility and then flows through business and residential areas of Oak Ridge (Union Carbide Corporation-Nuclear Division, 1983, p. 14). Analyses of soil samples collected from borings in the flood plain of East Fork Poplar Creek as part of the Tennessee Valley Authority's (TVA) Instream Contaminant Study indicate that a substantial quantity of the mercury is now in the upper 18 inches of the alluvial material in the flood plain and stream channel (Tennessee Valley Authority, 1985b,c). In general, flood-plain soil-mercury concentrations decrease downstream, but occasionally occur in concentrations of 1,000 micrograms per gram ($\mu g/g$) or greater as far as 4 miles downstream from the Y-12 Plant.

The distribution and concentration of mercury and other trace metals, organic compounds, and radionuclides residing in the East Fork Poplar Creek flood-plain sediments have been documented as a result of part of the TVA's Instream Contaminant Study (Tennessee Valley Authority, 1985b,c), and by additional off-site (off the Oak Ridge Reservation) sampling by the Oak Ridge Associated Universities (ORAU), the results of which are maintained in the Environmental Monitoring and Compliance Section data base at the Oak Ridge National Laboratory (K. Daniels, Oak Ridge National Laboratory, oral commun., 1988). However, the Oak Ridge Task Force (ORTF), a panel established to evaluate off-site contamination and health effects and to make recommendations for remedial action, has expressed concern over the lack of information on concentrations of mercury and other contaminants in the shallow ground water occurring within the flood-plain alluvium. In response to this lack of information, the U.S. Geological Survey, in cooperation with the DOE, initiated an investigation to determine whether shallow ground water near East Fork Poplar Creek contains mercury and other contaminants originating from the Y-12 Plant.

PURPOSE AND SCOPE

The purpose of this report is to present the results of the investigation of shallow ground-water contamination near East Fork Poplar



Base from Tennessee Valley Authority
1:24,000 map S-16A, revised in part
June 1974

Figure 1.--Location of the East Fork Poplar Creek watershed and study area.

Creek. The study, which was designed to furnish water-quality and water-level data from the shallow (above bedrock) aquifer in areas where soil contamination is present, primarily included installation of a series of observation wells at off-site locations in and near the flood plain of East Fork Poplar Creek and at uncontaminated background sites along two similar streams in the greater Knoxville, Tennessee area, and collection of two rounds of water-quality samples from the wells. The following section presents a more-detailed, chronological description of all tasks performed during the investigation.

APPROACH

The investigation, which began in August 1986 and ended in September 1987, consisted of the following elements:

(1) review of TVA and ORAU soil-sampling data by members of the ORTF (a) to identify sites for observation wells, and (b) to develop a list of constituents whose presence and concentrations in water samples from the wells would be determined;

(2) review of TVA and ORAU soil-sampling data by the Geological Survey for the selection of appropriate observation-well design, construction materials, and installation techniques;

(3) installation of 16 observation wells in and near the flood plain of East Fork Poplar Creek and two additional observation wells, each at separate background sites in the greater Knoxville area, and compilation of lithologic data for the boreholes as they were drilled;

(4) development and collection of water-quality samples from 17 of the 18 observation wells (excluding 1 background-site well) for preliminary mercury-concentration determinations and scans for detectable levels of organic compounds;

(5) re-development and sampling of seven of the observation wells near East Fork Poplar Creek to obtain additional water-quality data for comparison with results of first-round samples from these wells;

(6) collection of water-quality samples from 16 of the 18 observation wells (excluding 1 well in the East Fork Poplar Creek flood plain and 1 background-site well) and analysis of the samples for concentrations of a broad range of organic and inorganic substances (including radionuclides) at a private laboratory and the DOE's K-25 Gaseous Diffusion Plant laboratory, respectively, and;

(7) measurement of water levels in each of the observation wells after drilling was completed, during development and sampling, and at various times throughout the study.

PREVIOUS STUDIES

Subsurface mercury contamination in both ground water and the geologic materials beneath the Y-12 Plant and property has been characterized by Rothchild and others (1984). The occurrence of contaminants in surface water, stream and flood-plain sediments, and the flora and fauna in and near East Fork Poplar Creek has been described in several reports by the Tennessee Valley Authority (1985 a-e, 1986). Other reports that were useful during this investigation include a map and description of the geology of the Oak Ridge Reservation and surrounding area by McMaster (1963), a summary of hydrologic data for the Oak Ridge area by McMaster (1967), soil surveys of Anderson county (1981) and Knox County (1955) by the U.S. Department of Agriculture, Soil Conservation Service, geologic maps of the Knoxville 7.5-minute quadrangle by Catermole (1958) and the Bearden 7.5-minute quadrangle by Catermole (1960), the annual water-resources data report for Tennessee by Lowery and others (1988), a summary of the 1983 Union Carbide Corporation-Nuclear Division Task Force study by Union Carbide Corporation-Nuclear Division (1983), and publications describing evaluations of remedial and sediment-control alternatives for East Fork Poplar Creek by Advanced Sciences, Incorporated (1986, 1987).

Acknowledgments

The author expresses appreciation to Dr. Clayton Gist, formerly of the Environmental Surveillance and Monitoring Section of the Manpower Education, Research, and Training (MERT) Division of ORAU, and now with the Environmental Protection Division of the U.S. Department of Energy, Oak Ridge Operations; and Mr. Henry Beiro of the MERT Division of ORAU, for their guidance in the selection of sites for observation wells, for the collection and analysis of soil samples obtained at the sites prior to well constructions, and for permission to include the analytical results of soil sampling in this report; to Mr. Tom Fortner, Services Superintendent for the Public Works Department of the city of Oak Ridge, for allowing the use of storage space and equipment at the Public Works facility while field work for the project was being conducted; and to the land owners who granted permission to construct observation wells on their property.

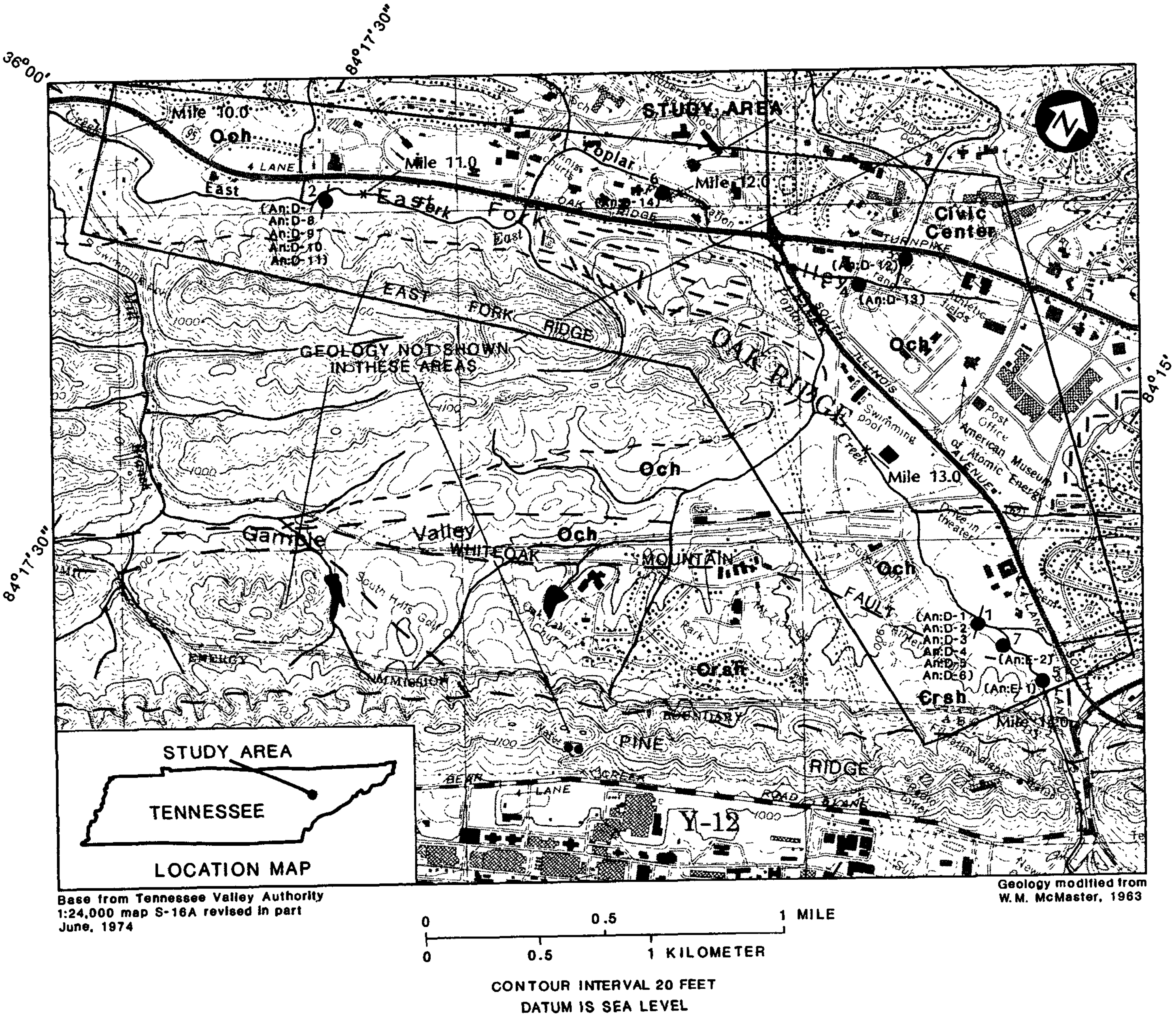
DESCRIPTIONS OF THE AREAS UNDER INVESTIGATION

For this investigation, a primary study area and two background sites were selected for observation-well installations and water-quality and water-level data collection. The study area is limited to off-site parts of the city of Oak Ridge which lie within the East Fork Poplar Creek watershed (fig. 1) and have been identified as being or having been contaminated with mercury and other substances originating from the Y-12 Plant. This area includes the flood plain of the stream between approximately river miles 10.0 and 14.0 (fig. 2), where mercury concentrations present in flood-plain sediments locally exceed 1,000 μg/g, and "low-level" sites at the Oak Ridge Civic Center (fig. 2) where fill from the flood plain was placed and later removed by the DOE after it was discovered to contain mercury and other contaminants. The two background sites, each at separate locations in the greater Knoxville area (figs. 3 and 4), were selected for the collection of background water-quality data. Observation well site-selection criteria, descriptions of each well-site location, and the basis for their selection are discussed in the Observation Wells section.

EAST FORK POPLAR CREEK STUDY AREA

The study area is located in Anderson County in the eastern half of the East Fork Poplar Creek watershed (fig. 1). The watershed has a drainage area of 29.8 mi^2 above the confluence of East Fork Poplar Creek and Poplar Creek. It is bounded by Blackoak Ridge on the northwest and Chestnut Ridge on the southeast. Altitudes range from about 740 feet at the mouth of East Fork Poplar Creek to about 1,280 feet at the crest of Pine Ridge. Land use within the watershed is primarily residential and woodland, with commercial and industrial development being limited to areas of the city of Oak Ridge no longer within the Oak Ridge Reservations, and to the Y-12 Plant.

East Fork Poplar Creek originates within the Y-12 Plant (fig. 1) as a drainage ditch which primarily receives process water from the Plant.



EXPLANATION

3● (An:D-12)	SINGLE OBSERVATION WELL SITE, SITE NUMBER, AND OBSERVATION WELL NUMBER (IN PARENTHESES)
2● (An:D-7 An:D-8 An:D-9 An:D-10 An:D-11)	OBSERVATION WELL TRANSECT SITE, SITE NUMBER, AND OBSERVATION WELL NUMBERS (IN PARENTHESES)--Lithologic cross sections along transect site traces shown on figure 20
— —	FAULT--Approximately located
- - - -	CONTACT--Approximately located
Och	CHICKAMAUGA LIMESTONE
Ꞓrsh	ROME FORMATION

Figure 2.--Geology of the East Fork Poplar Creek study area and locations of observation well sites.

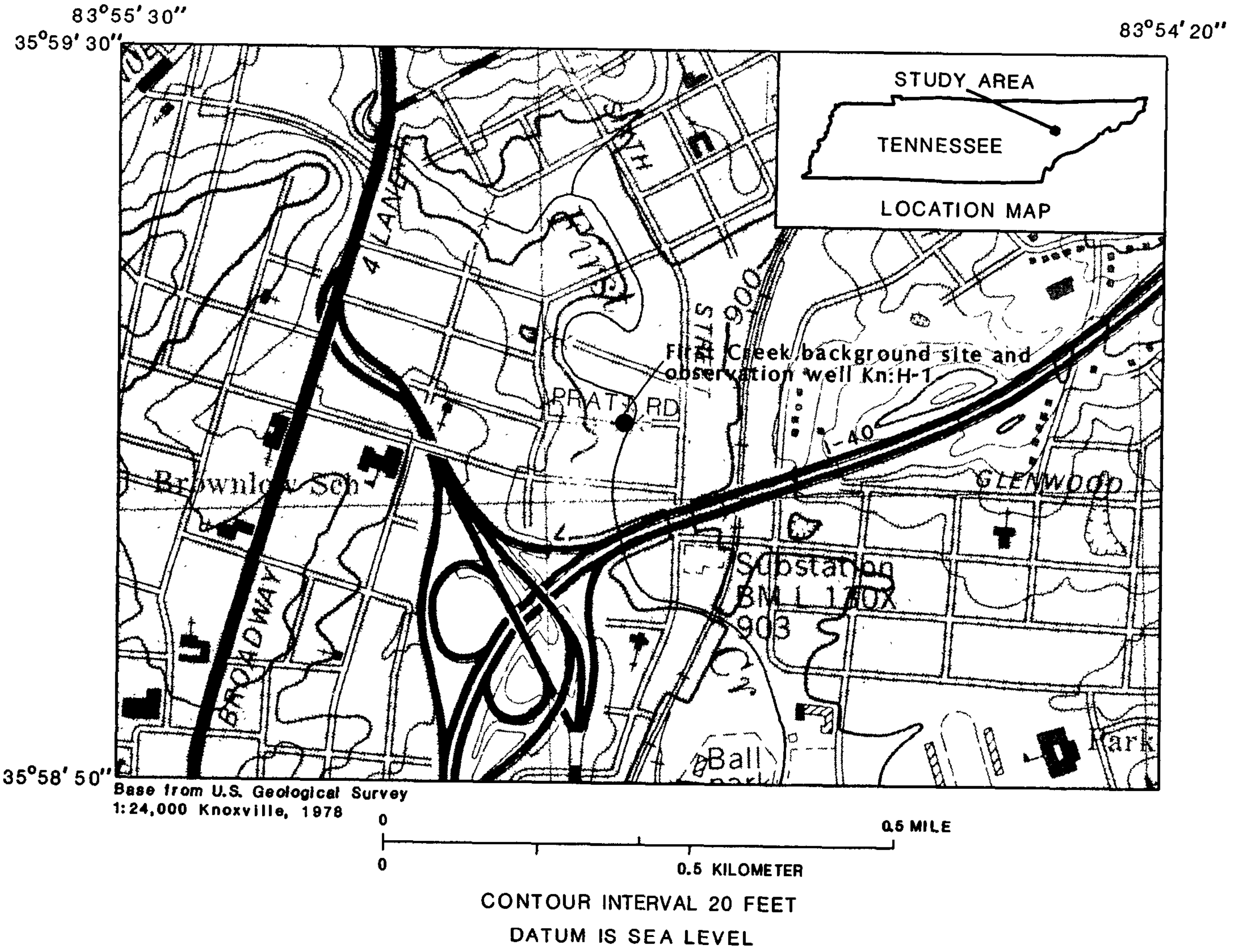
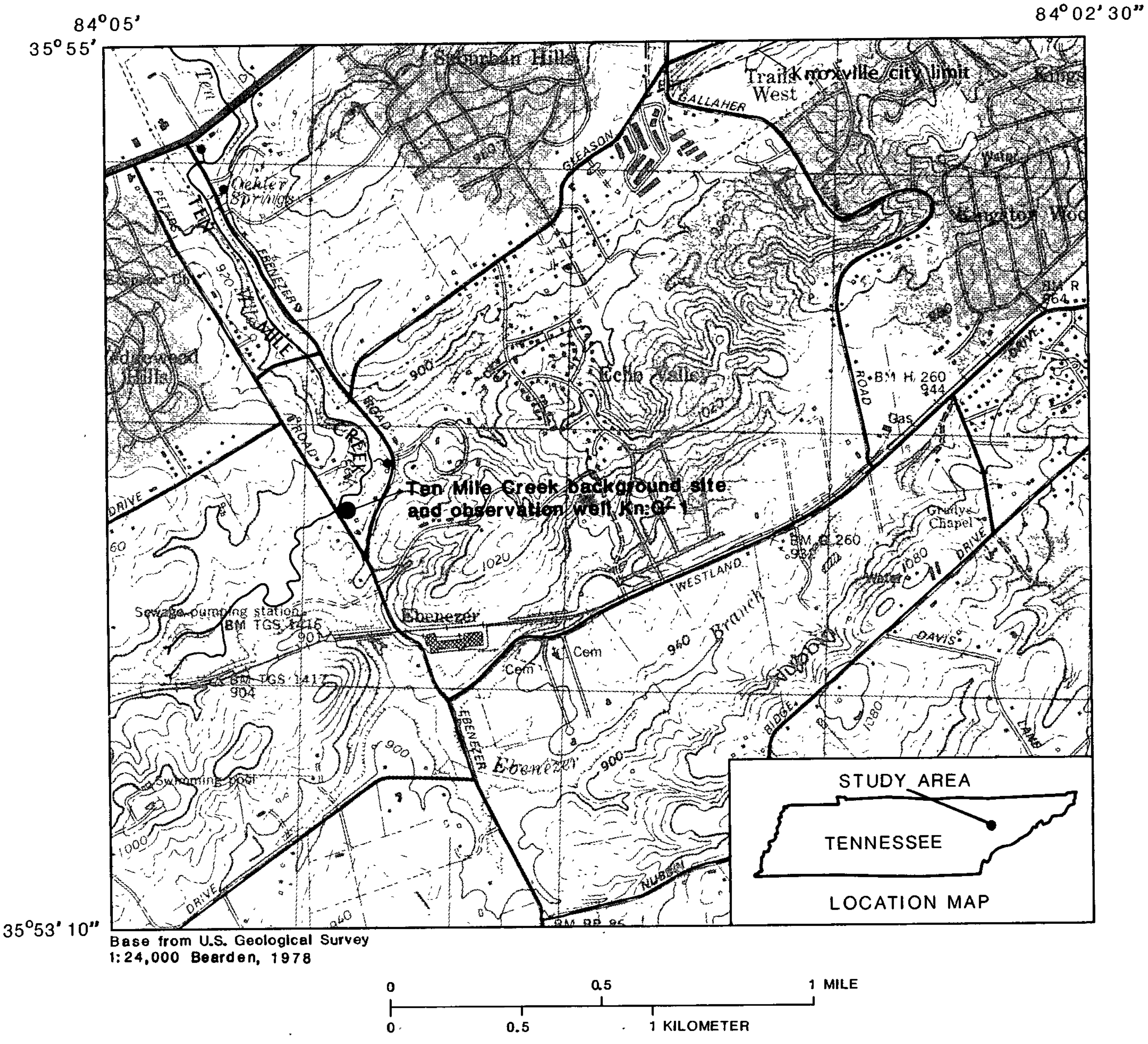


Figure 3.--Location of the First Creek background site and observation well Kn:H-1.



Base from U.S. Geological Survey
1:24,000 Bearden, 1978

Figure 4.--Location of the Ten Mile Creek background site and observation well Kn:G-1

From the Y-12 Plant, the stream flows northwest, leaving the Oak Ridge Reservation at river mile 14.10. At about river mile 12.50, the stream turns to the southwest, reentering and remaining within the Reservation from river mile 4.80 until its confluence with Poplar Creek. Bear Creek, whose drainage area lies within the East Fork Poplar Creek basin, is the only major tributary to East Fork Poplar Creek (fig. 1). Also beginning at the Y-12 Plant, Bear Creek flows southwestward, south of and parallel to East Fork Poplar Creek, entering East Fork Poplar Creek at river mile 1.47. East Fork Ridge, Pine Ridge, and Gamble Valley separate Bear Creek from East Fork Poplar Creek (fig. 1).

From its origin at the Y-12 Plant to its confluence with Poplar Creek, East Fork Poplar Creek falls approximately 200 feet, having an average fall of about 13 feet per mile. Bed gradient is steepest in the upper reaches, where the stream cuts through Pine Ridge, producing a narrow flood plain less than 100 feet wide. Downstream from Pine Ridge and within the study area, creek banks along parts of the northwesterly flowing section of the stream have been built up with fill and lined with rip-rap where development has occurred, essentially destroying the natural flood plain. After the stream turns southwest (about river mile 12.50), bed gradient decreases and the stream begins to meander across a broad, flat flood plain in places reaching a width of greater than 500 feet. Natural features common along the entire stream and flood plain are seeps and springs, point-bar and channel-fill deposits, cutbanks, and scour and overflow channels.

Records of streamflow have been collected by the Geological Survey at its gaging station (gage 03538250) at East Fork Poplar Creek mile 3.30 (fig. 1) since August 1960. Flow measured at this gage includes inputs of as much as 20 ft^3/s from the Y-12 Plant and 10 ft^3/s from the Oak Ridge West End Sewage Treatment Plant (Lowery and others, 1988), located at river mile 8.30 (fig. 1). Average flow (including inputs) for the period August 1960 through September 1987 is 50.3 ft^3/s, with a minimum of 12 ft^3/s and a maximum of 4,100 ft^3/s recorded (Lowery and others, 1988).

Geologic Setting

The study area is located in the Valley and Ridge physiographic province, an area characterized by an alternating succession of northeast-southwest trending ridges and valleys. Most of the valleys have developed in areas underlain by limestone and shale, whereas the ridges have formed on the more resistant units of shale, sandstone, and cherty dolomite. Beds commonly dip to the southeast as a result of thrust faulting.

Within the East Fork Poplar Creek watershed, bedrock consists of sedimentary rock of Cambrian to Mississippian age. Structural features within the watershed include several regional and local thrust faults oriented parallel to strike which produce repeating stratigraphic sequences, and East Fork Ridge, a syncline formed by folding of bedrock along the Whiteoak Mountain Fault.

Two major geologic units underlie the study area. The southeast corner of the area is underlain by the Rome Formation of Early Cambrian age, specifically by a maroon- to tan-colored shale bed that was mapped and described by McMaster (1963, p. 11) as the lower shale member of the Rome Formation. The remaining section of the study area is underlain by the Chickamauga Limestone of Middle and Late Ordovician age. Locally, the Chickamauga is characterized as a gray to blue-gray, shalely to silty limestone occasionally containing sinkholes and solution cavities that decrease in number and size with depth.

The Whiteoak Mountain fault cuts through the southeast corner of the study area, marking the contact where the older Rome Formation has been thrust-faulted over the younger Chickamauga Limestone. Locations of the outcrop belts of the two major geologic units within the study area are shown in figure 2.

Shallow Aquifer Materials

The shallow aquifer in the study area, as well as at the background sites, was defined for this investigation as being any alluvium, regolith, and (or) fill materials that occur above bedrock and are water bearing. This is not to imply that a separate aquifer exists at greater depth; it is intended only to define the source of shallow ground water for this investigation. As determined by visual inspection, soil sampling, and observation-well drilling at selected sites in the study area, thickness of the naturally occurring shallow-aquifer materials generally ranges from essentially zero where bedrock is exposed at land surface (commonly occurring along the flood-plain periphery) to about 10 feet near the center of the flood plain. Locally, thickness may be as much as 20 feet where fill materials have been placed above the flood-plain deposits. Alluvial soils consisting primarily of silt and clay with lesser amounts of sand and gravel comprise the upper 1 to 5 feet of the undisturbed flood-plain sediments. These soils are classified as either Hamblen or Newark varieties--silt-clay-loams which have vertical permeability rates ranging from 1 to 4 ft/d and are moderately resistant to erosion (U.S. Department of Agriculture, 1981).

In parts of the study area, coal particles which washed into East Fork Poplar Creek from the Y-12 Plant have been deposited, along with mercury and other contaminants, in a dark-colored layer several inches thick in the upper 18 inches of the flood-plain alluvium. Exposures of this layer in the upper parts of the stream's banks at certain locations are coincident with flood-plain areas having the highest identified soil concentrations of mercury and other contaminants.

At most observation-well locations in the flood-plain section of the study area, a blue-gray to brown, moderately to highly erosion-resistant, silty-clay glei horizon underlies the alluvium, the top of the glei marking the base of the more recent alluvial deposits. As determined from observation-well drilling, where present, this material directly overlies bedrock and ranges from only inches to as much as 5 feet in thickness. Because of its higher clay content relative to the overlying alluvium, the glei horizon likely impedes the rate of ground-water movement downward through the alluvium, probably causing perched water-table conditions during drier periods. At river mile 10.93 (adjacent to site 2) (fig. 2), East Fork Poplar Creek flows directly on the glei, exemplifying its relatively high degree of resistance to erosion. No samples of the glei collected in undisturbed flood-plain areas and analyzed as part of the ongoing off-site sediment sampling program have shown mercury contamination (C. Gist, Oak Ridge Associated Universities, oral commun., 1986).

BACKGROUND SITES

The two background sites chosen for this investigation are located in Knox County, in the greater Knoxville area, which also lies within the Valley and Ridge physiographic province. Both sites are located in the flood plains of small streams draining mainly commercial and residential areas; First Creek, which flows southward through north-central Knoxville and empties into the Tennessee River (fig. 3); and Ten Mile Creek, which flows southwestward in southwestern Knox County, just outside the western city limits of Knoxville, and then flows into a swallet about $^1/_2$ mile west of Ebenezer, continuing underground from this point to discharge into Fort Loudon Lake (fig. 4).

The shallow aquifers at each site consist mainly of alluvial silt and clay with lesser amounts of sand and gravel. Alluvial soils at the First Creek and Ten Mile Creek sites are classified as Melvin and Lindside silt-loam types, respectively (U.S. Department of Agriculture, 1955). Because only one well was installed at each site, relative ranges of thickness for the shallow aquifers at each site were not determined. However, bedrock outcrops locally in the flood plains and along the banks of both streams suggest that thickness of the alluvium is quite variable, ranging from essentially zero to as much as 15 feet in the vicinity of each site.

Alluvium at the First Creek background site is underlain by crystalline limestone of the Holston Formation of Middle Ordovician age (Catermole, 1958). At the Ten Mile Creek background site, underlying bedrock is dolomite of the upper Newala Formation, as used in Tennessee, and equivalent to the Mascot Dolomite of Early Ordovician age, which is the uppermost formation of the Knox Group (Catermole, 1960).

OBSERVATION WELLS

Eighteen shallow observation wells were installed at 9 sites for this investigation; 16 wells were installed at 7 sites (numbered 1 through 7) in the study area (fig. 2), and one well was installed at each of the two background sites (figs. 3 and 4). The background sites are not numbered--instead, they are referred to as the First Creek and Ten Mile Creek background sites.

GENERAL SITE-SELECTION CRITERIA

Observation-well sites in the study area were selected for this investigation on the basis of the results of soil sampling and trace-metal analysis (primarily for mercury) conducted by both the TVA and ORAU. From part of the TVA's Instream Contaminant Study (Tennessee Valley Authority, 1985b,c), two areas of the East Fork Poplar Creek flood plain were identified as having the highest soil-mercury concentrations: between river miles 10.0 and 11.5, and 13.5 and 14.0 (fig. 2). These two areas were prioritized for well sites so that water-quality samples could be collected from locations where the probability of shallow ground-water contamination was the greatest. Furthermore, the results of the TVA study also indicate a correlation between high concentrations of mercury in the flood-plain soils and elevated concentrations of other contaminants, particularly other trace metals and radionuclides (Tennessee Valley Authority, 1986). Therefore, it was thought likely that some of these other substances might also be identified in the shallow ground water from areas where high soil-mercury concentrations have been identified. Additional sites for wells were also selected in the study area to allow investigation of the shallow ground-water contamination in disturbed areas (both in and away from the East Fork Poplar Creek flood plain) where mercury-contaminated soil has been used as fill material.

The background sites were selected for the collection of water-quality data from the shallow alluvial aquifers along streams which drain areas similar to Oak Ridge and which, as far as is known, have not been subjected to the types of contaminants released to East Fork Poplar Creek.

DESCRIPTION OF SITE LOCATIONS AND REASON FOR SELECTION

Site 1 is located in an undeveloped wooded area south of South Illinois Avenue and in the flood plain of East Fork Poplar Creek at river mile 13.61 (fig. 2). This site was selected for shallow observation-well installations because of the high mercury concentrations (up to 1,800 $\mu g/g$) occurring in the undisturbed flood-plain soils between river miles 13.5 and 14.0. Six wells were installed at this site (three wells on each side of the stream) along a north-south transect spanning the entire flood plain perpendicular to the stream. The wells are numbered An:D-1 through 6, beginning with the northernmost well.

Site 2 is located south of State Highway 95 in an undeveloped, partially-wooded area in the flood plain of East Fork Poplar Creek at river mile 10.93 (fig. 2). This site was selected because it lies within the area where the highest mercury concentrations (as high as 3,900 μg/g) in the East Fork Poplar Creek flood-plain soils have been identified. Five wells (two north of and three south of the stream) were installed at this site along a north-south transect spanning the entire flood plain perpendicular to the stream. The wells are numbered An:D-7 through 11 beginning with the northernmost well.

Sites 3 and 4 are located south of State Highway 95 at the Oak Ridge Civic Center (fig. 2), near small tributaries to East Fork Poplar Creek. These two locations were chosen as "low-level" sites because soil-mercury concentrations are now less than 10 μg/g following removal of the mercury-contaminated soil used as backfill for the nearby sewer beltway. Individual wells at sites 3 and 4 are numbered An:D-12 and An:D-13, respectively.

Site 5 is located southwest of Scarboro Road and adjacent to and northeast of East Fork Poplar Creek at river mile 13.97 (fig. 2). This site was selected for installation of a single well (An:E-1) because fill material containing mercury-contaminated soil and various construction debris has been placed over contaminated flood-plain deposits at this location.

Site 6 is located in the East Fork Poplar Creek flood plain northwest of State Highway 95 and southeast of and adjacent to East Fork Poplar Creek at river mile 11.98 (fig. 2). This site was selected for installation of a single well (An:D-14) because mercury-contaminated fill has been placed over relatively uncontaminated flood-plain deposits at this location.

Site 7 is located in an undisturbed, sparsely wooded area in the flood plain and south of East Fork Poplar Creek at river mile 13.80 (fig. 2). This site was selected for installation of a single well (An:E-2) because soil-mercury concentrations as high as 2,600 μg/g have been identified at this location.

The First Creek background site is located in a relatively undisturbed flood-plain area east of the dead end of Pratt Road and west of First Creek, on property owned by the city of Knoxville (fig. 3). The Ten Mile Creek background site is also located in an undisturbed flood-plain area, east of Peters Road and south of Ten Mile Creek (fig. 4). First Creek and Ten Mile Creek background-site wells are numbered Kn:H-1 and Kn:G-1, respectively.

WELL CONSTRUCTION AND INSTALLATION

All 18 observation wells installed for this investigation were constructed with 2-inch diameter, stainless-steel well casing and 0.010-inch slot, wire-wrapped, stainless-steel drive-point screens in 2-, 3-, 4-, or 5-foot lengths. For wells requiring its use, 8-inch diameter black-steel pipe was installed for surface casing, as explained later in this section. High purity (98.4 percent silica minimum), 8-35 grit blasting sand was used to pack screens in all wells. Bentonite pellets ($^1/_2$-inch diameter) were used to develop a seal above the sand packs, and Portland cement was poured into the remaining annular space above the bentonite. After installation, all wells were outfitted with stainless-steel well caps (except well An:D-12 which was fitted with a slip-type PVC cap because the threads at the top of the casing were cut off after the well was installed), and 6-inch diameter steel well protectors with locking caps to prevent unauthorized entry.

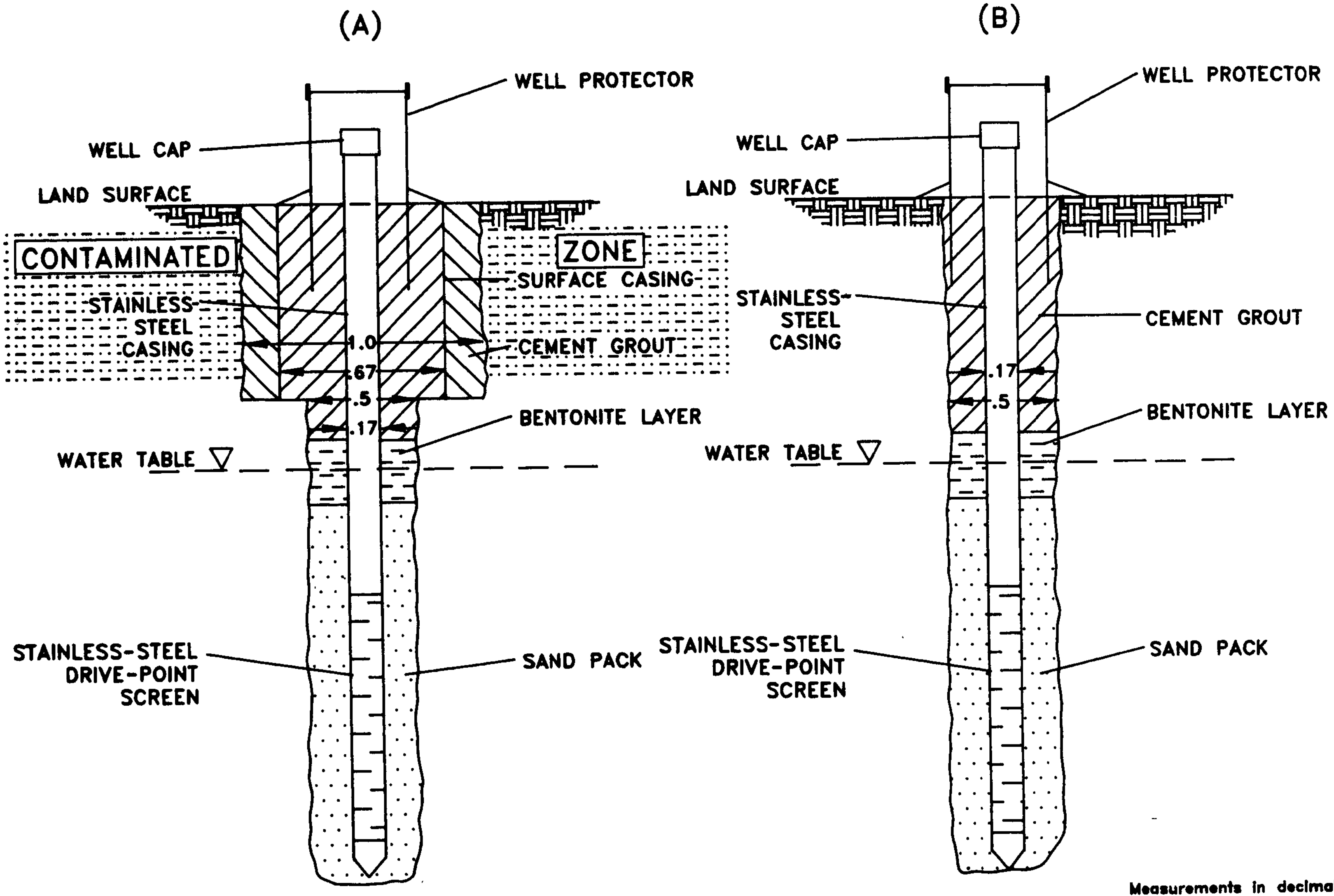
Prior to the installation of each well, both the interior and exterior of the auger flights, casing, and screens were (1) steam cleaned with a detergent solution, (2) rinsed with steam-cleaner water without detergent, (3) rinsed with a commercial grade of acetone, and (4) rinsed again with steam-cleaner water without detergent. The steam cleaner was furnished by the city of Oak Ridge and was supplied by city tap water.

Two versions of the same basic design were used for well construction, with the design used for each well being dependent on the soil-mercury concentrations identified at each well location. For wells at locations where mercury concentrations in the soil or fill materials are higher than about 1 μg/g, the well design consisted of the installation of surface casing prior to the well casing and screen to prevent contaminated material in the upper soil zones from being transported down the borehole during drilling and to seal the contaminated zone from the screened interval. For wells of this design, a 12-inch diameter borehole was augered through the upper contaminated zone and an appropriate length of 8-inch diameter steel casing was cemented into the hole (except in the case of site 2 well An:D-8 and D-9 and site 5 well An:E-1, where the surface casing was inadvertently installed in too short a length to completely seal off the contaminated zone). Lengths of surface casing used for each well were determined by the depth of mercury contamination (as identified by soil sampling and analysis) at each well location. After the cement had hardened, each borehole was completed to bedrock (as required for all wells by the USEPA) by drilling through the surface casing with 6-inch diameter augers. For wells at "low-level" and background sites, the installation of surface casing was omitted. At these sites, a 6-inch diameter borehole was augered from land surface to refusal. Schematic diagrams of the two shallow observation-well construction designs used for this investigation are shown in figure 5.

Upon completing the 6-inch diameter boreholes for each well, the auger flights were removed and an appropriate length of screen and casing were connected together and lowered into the hole. Due to the cohesiveness of the materials penetrated while drilling, all boreholes remained open after the auger flights were removed. For most wells, screen lengths were selected based upon the distance between the water table and top of bedrock at the time of drilling. However, because of drought conditions which were occurring throughout the southeastern United States during August 1986, bedrock was encountered before reaching the water table in a few of the boreholes in the study area and at the First Creek background site. At these locations, screen lengths were selected based upon both depth to bedrock and estimates of the water-table altitude above bedrock during wetter periods of the year.

After emplacing the casing and screen, the annular space adjacent to the entire screened interval was backfilled with sand. Bentonite pellets were then emplaced above the sand, creating a seal layer at least 6-inches thick in each well to prevent the downward migration of fluids in the annular space around the casing. The remainder of the annular space was then filled to land surface with cement and a well protector was installed over that part of the casing rising above land surface.

Two drilling methods were used for observation-well installations. Where site access was not a problem, a trailer-mounted auger rig and 5-foot long hollow-stem auger flights were used. Where access with the trailer-mounted rig was unobtainable, a portable, gasoline-powered auger with 3-foot long solid-stem auger flights was used. This drilling method performed satisfactorily except at the



Measurements in decimal increments of a foot.

Figure 5.--Generalized construction of observation wells installed at (A) contaminated sites and (B) "low-level" and background sites.

site 2 well locations south of East Fork Poplar Creek (wells An:D-9 through 11). At these locations, the glei horizon underlying the flood-plain alluvium was relatively thick and the portable auger would not penetrate its entire thickness. Therefore, wells An:D-9, 10, and 11 were not completed to bedrock. The drilling method used to install each well is listed in table 1. Construction data for each well are shown in figures 6 through 19.

SITE LITHOLOGY AND SOIL-MERCURY CONCENTRATIONS

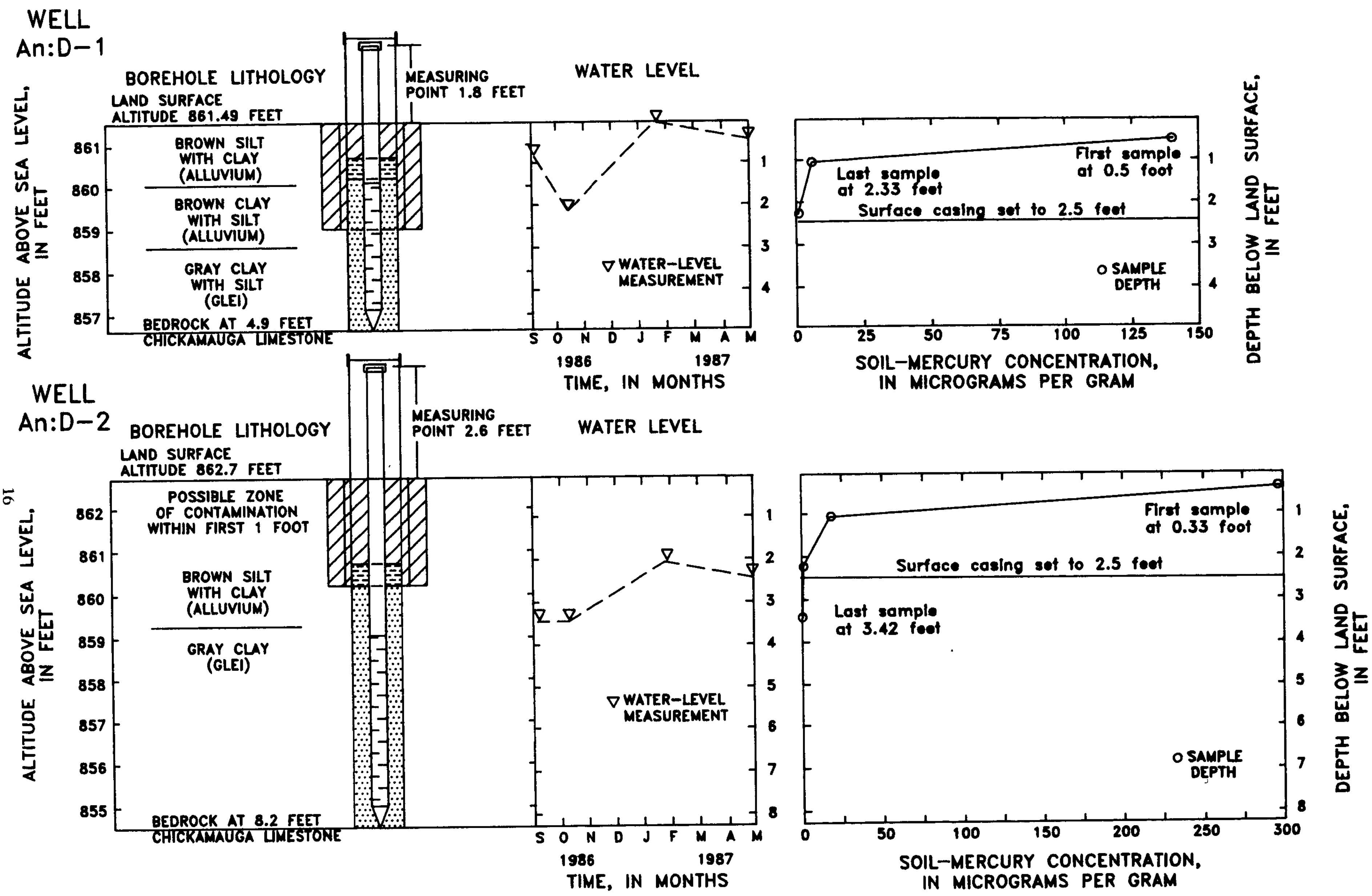
Lithologic descriptions of the soil horizons penetrated while drilling the observation wells and graphic representation of ORAU soil-analysis data showing mercury concentrations with depth at all well locations (except the First Creek background site, where soil-mercury samples were not collected) are shown in figures 6 through 19.

DEVELOPMENT AND YIELDS

After all of the observation wells were completed, they were developed to remove fine formation sediment from the borehole walls adjacent to the screened intervals in order to maximize yields during sample collection. However, the low water table in the study area and at the background sites delayed completion of this task until January 1987, at which time water levels in

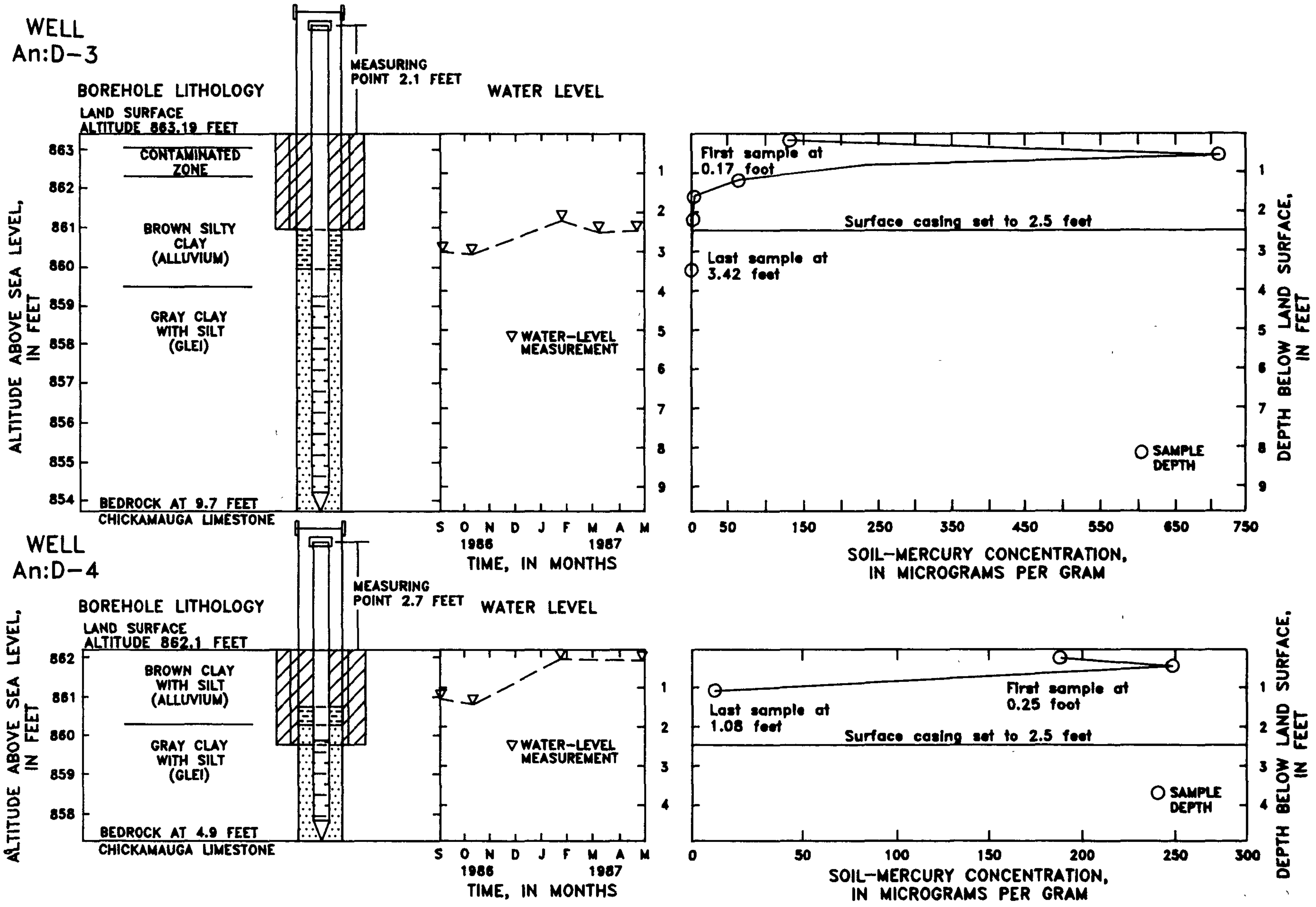
Table 1.--*Drilling method, time in development, and estimated maximum yield of observation wells in the study area and at background sites*

Well No./Site No.	Drilling method	Time in development, in hours	Estimated maximum yield, in gallons per minute
An:D-1/1	Portable Auger	2	1/4
An:D-2/1	do	2	1/4
An:D-3/1	do	2	<1/4
An:D-4/1	do	2	<1/4
An:D-5/1	do	2	<1/4
An:D-6/1	do	2	<1/4
An:D-7/2	Trailer-mounted auger rig.	1	<1/4
An:D-8/2	do	3	<1/4
An:D-9/2	Portable auger	3	3/4
An:D-10/2	do	4	1/4
An:D-11/2	do	4	1/4
An:D-12/3	Trailer-mounted auger rig.	8	1/4
An:D-13/4	do	8	1/4
An:E-1/5	do	4	1/4
An:D-14/6	do	4	1/4
An:E-2/7	Portable auger	3	1/4
Kn:G-1/Ten Mile Creek background site	Trailer-mounted auger rig.	3	3/4
Kn:H-1/First Creek background site	do	--	--



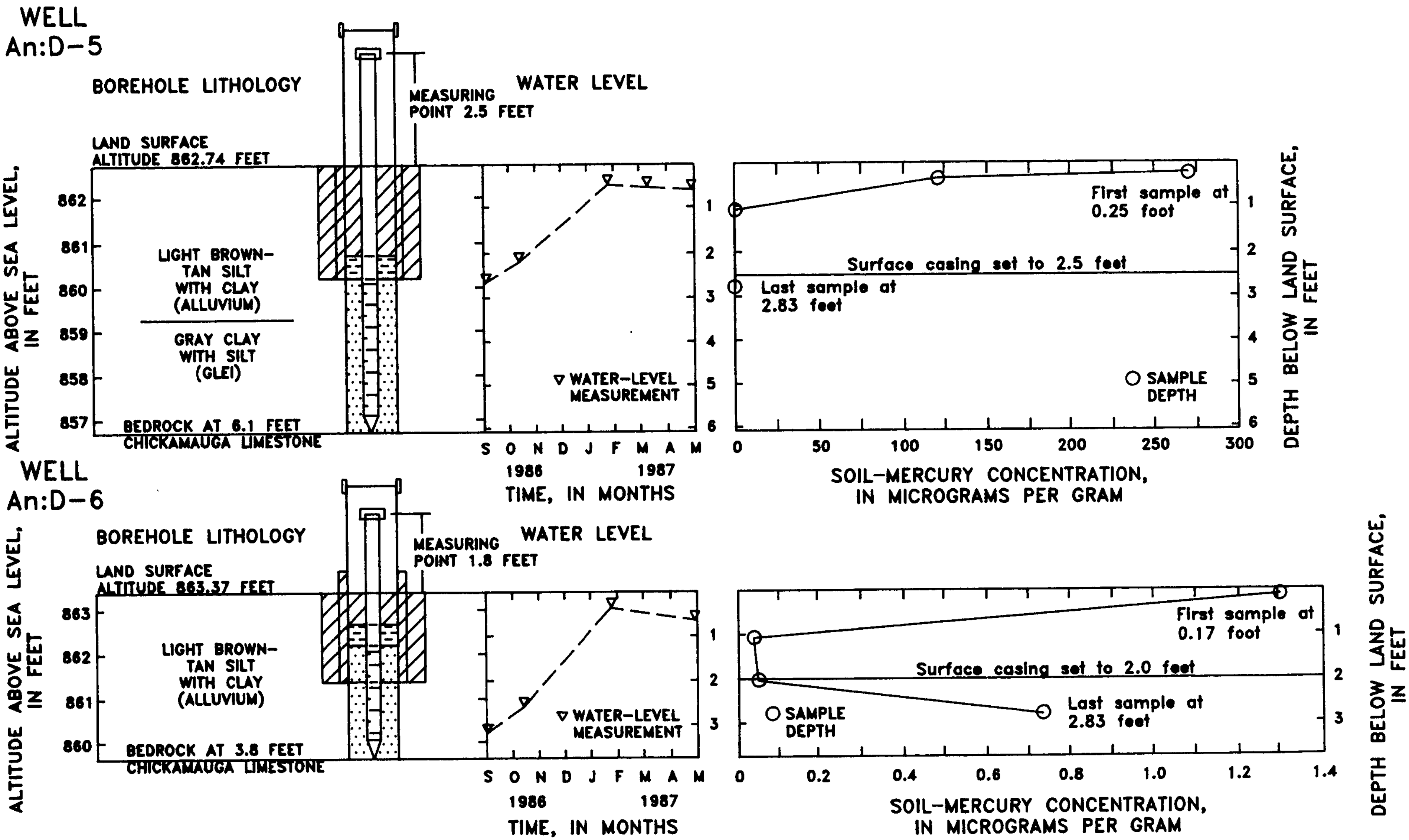
See figure 5 for generalized well-construction diagram.

Figure 6.--Construction, lithology, soil-mercury concentrations, and water levels at site 1 wells An:D-1 and An:D-2.



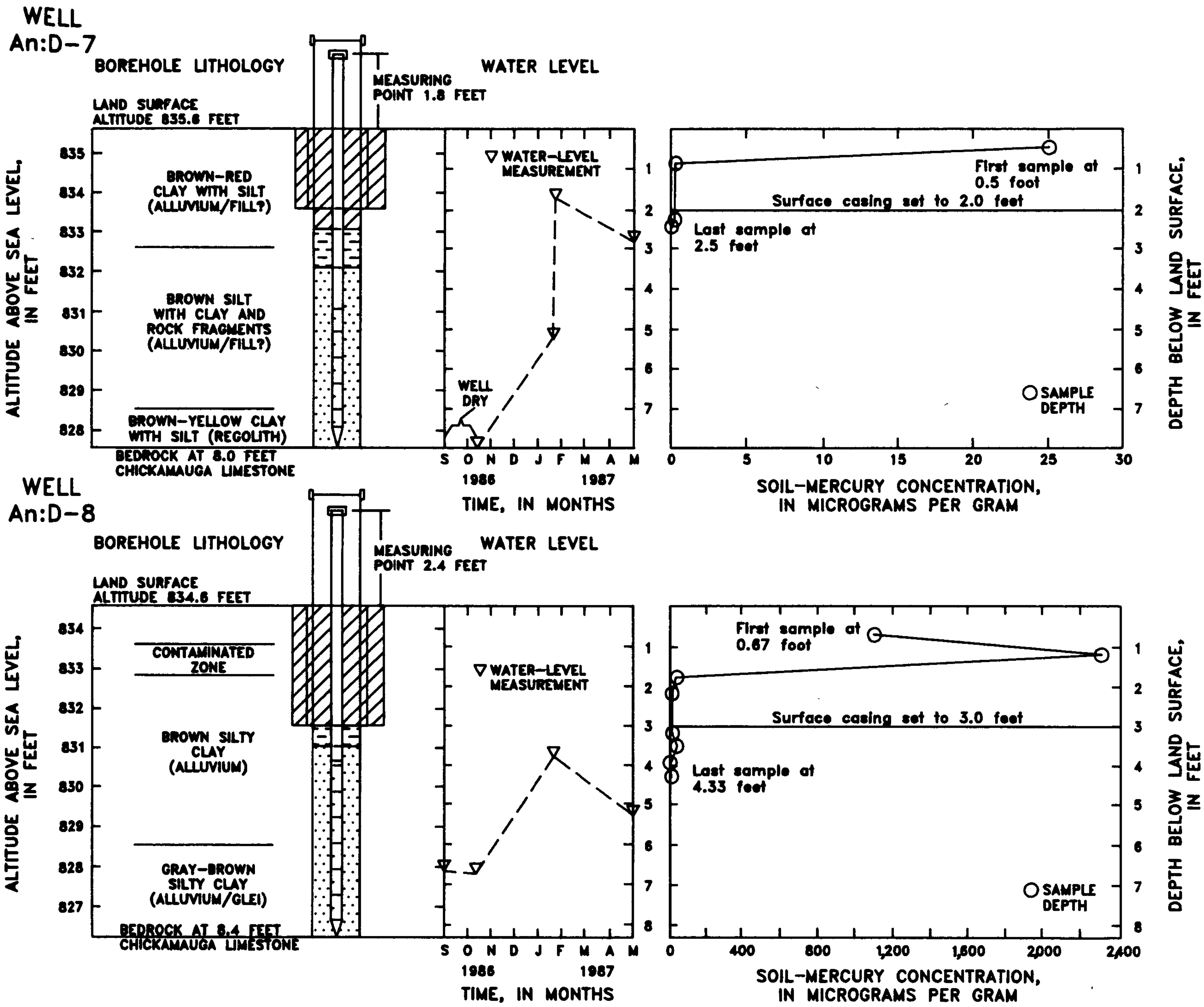
See figure 5 for generalized well-construction diagram.

Figure 7.--Construction, lithology, soil-mercury concentrations, and water levels at site 1 wells An:D-3 and An:D-4.



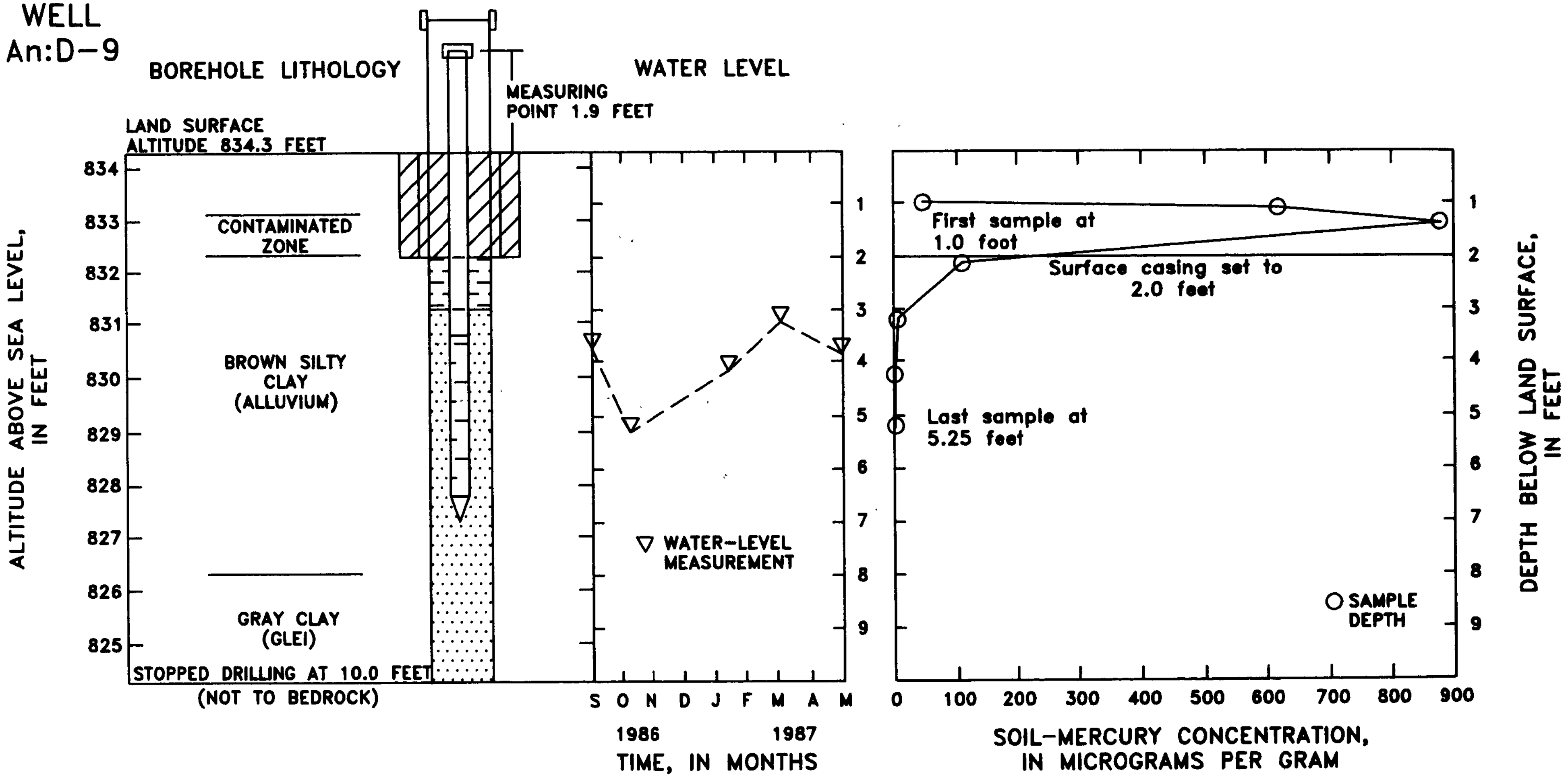
See figure 5 for generalized well-construction diagram.

Figure 8.--Construction, lithology, soil-mercury concentrations, and water levels at site 1 wells An:D-5 and An:D-6.



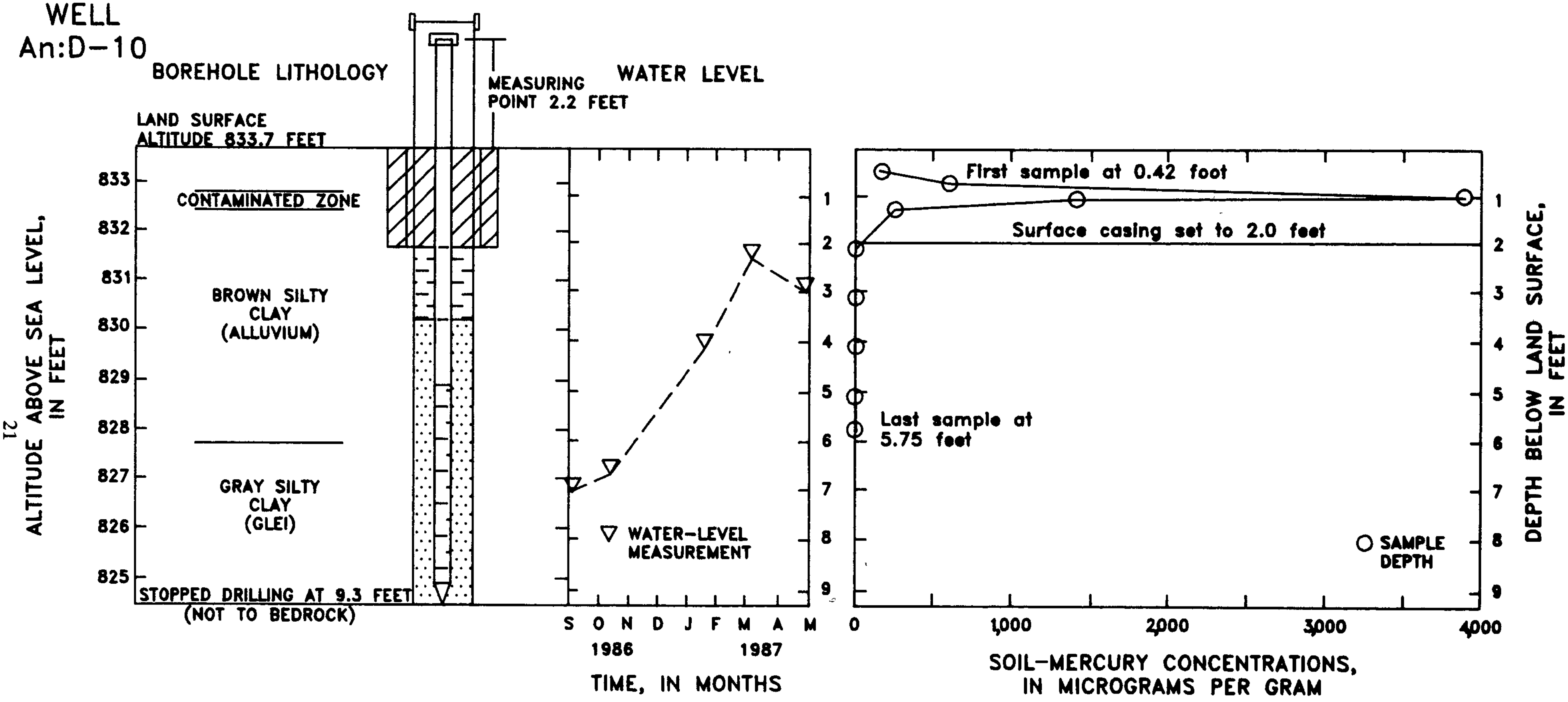
See figure 5 for generalized well-construction diagram.

Figure 9.--Construction, lithology, soil-mercury concentrations, and water levels at site 2 wells An:D-7 and An:D-8.



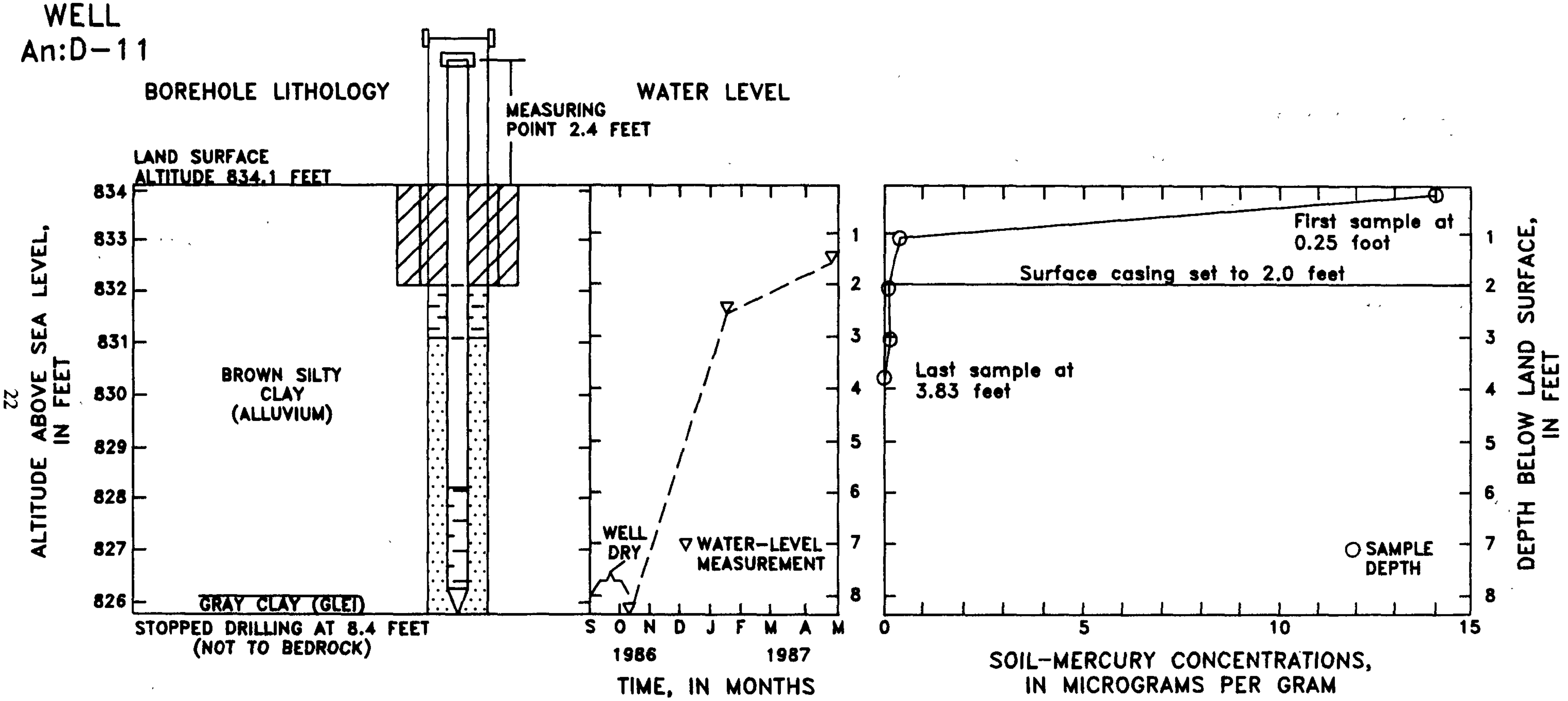
See figure 5 for generalized well-construction diagram.

Figure 10.--Construction, lithology, soil-mercury concentrations, and water levels at site 2 well An:D-9.



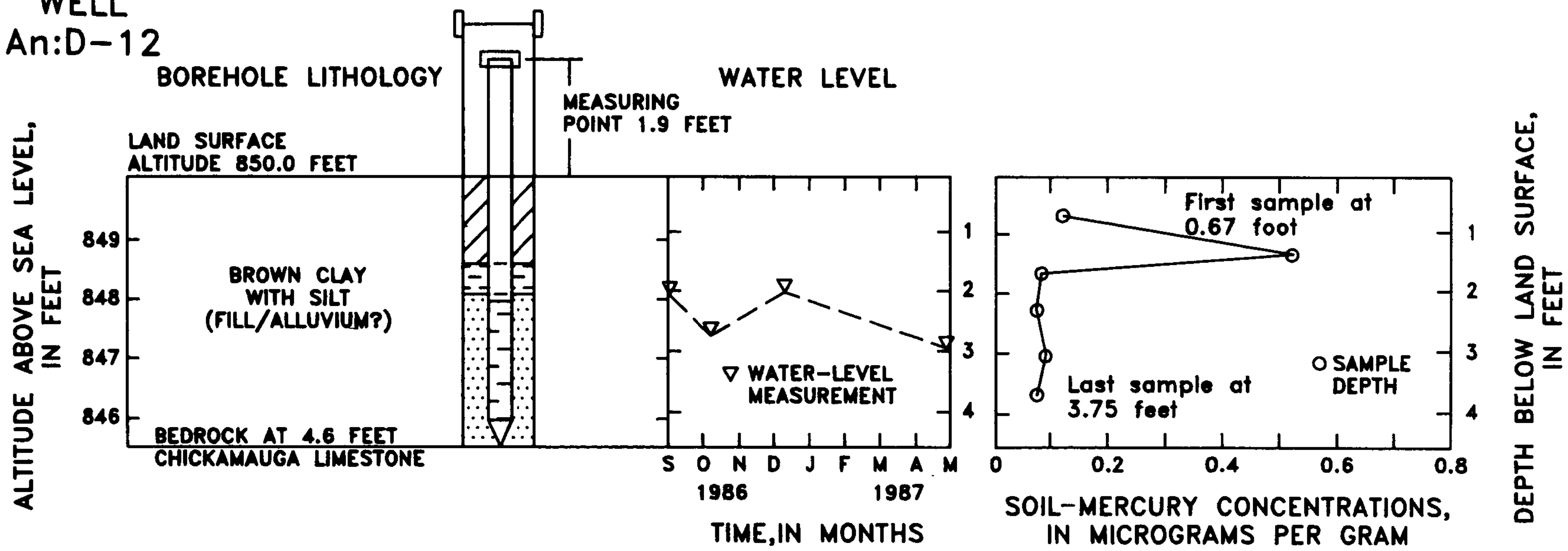
See figure 5 for generalized well-construction diagram.

Figure 11.--Construction, lithology, soil-mercury concentrations, and water levels at site 2 well An:D-10.



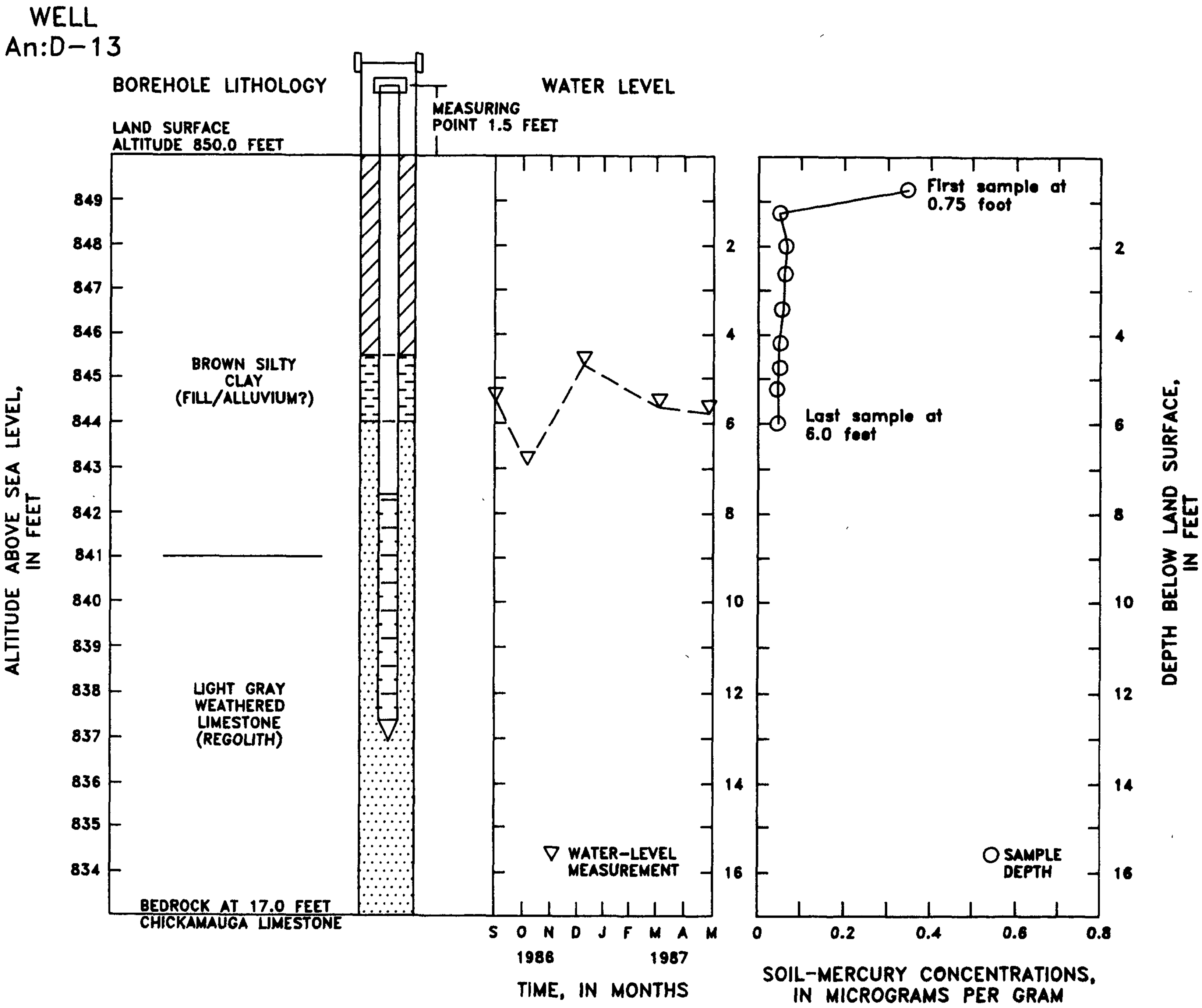
See figure 5 for generalized well-construction diagram.

Figure 12.--Construction, lithology, soil-mercury concentrations, and water levels at site 2 well An:D-11.



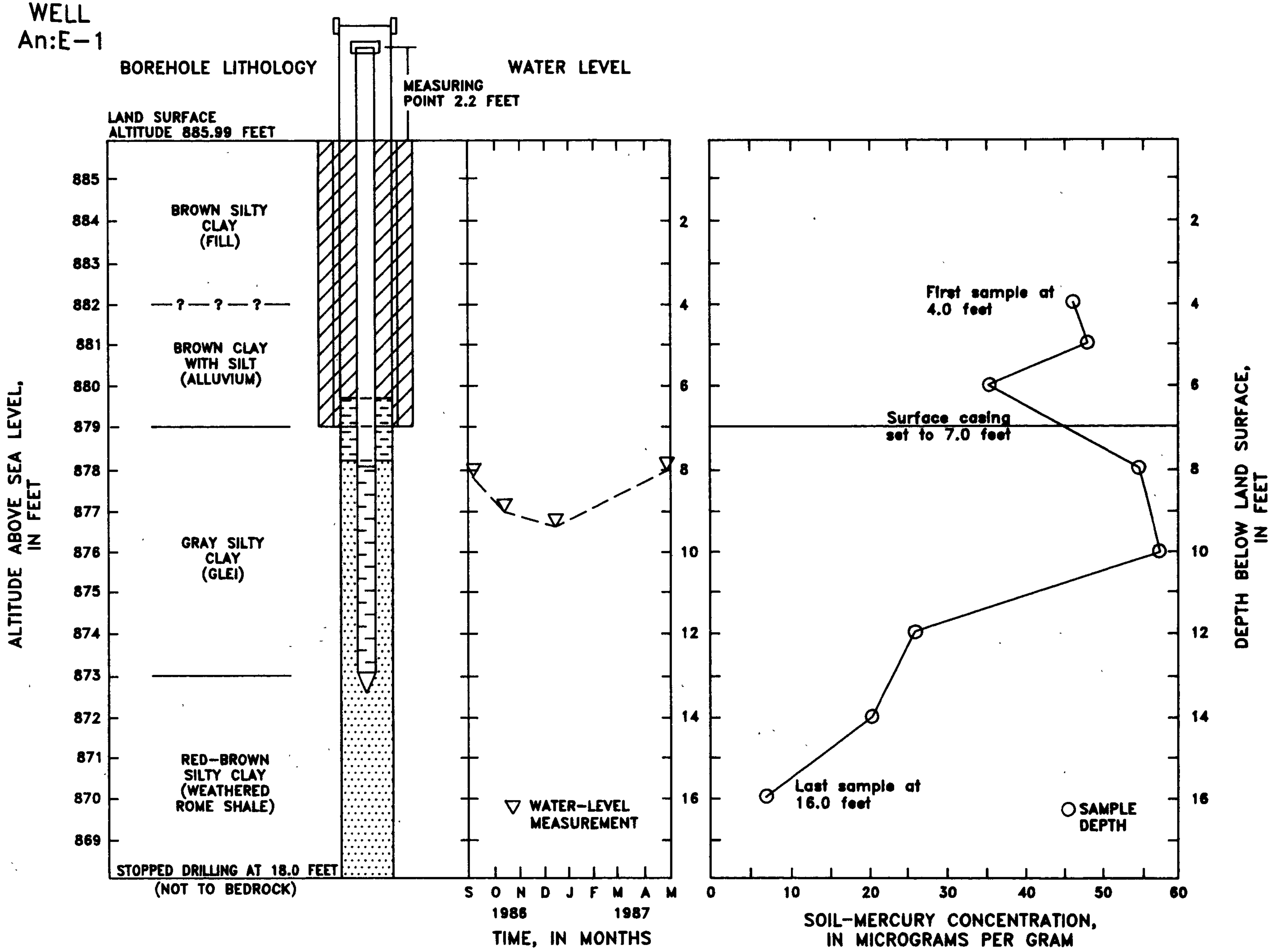
See figure 5 for generalized well-construction diagram.

Figure 13.--Construction, lithology, soil-mercury concentrations, and water levels at site 3 well An:D-12.



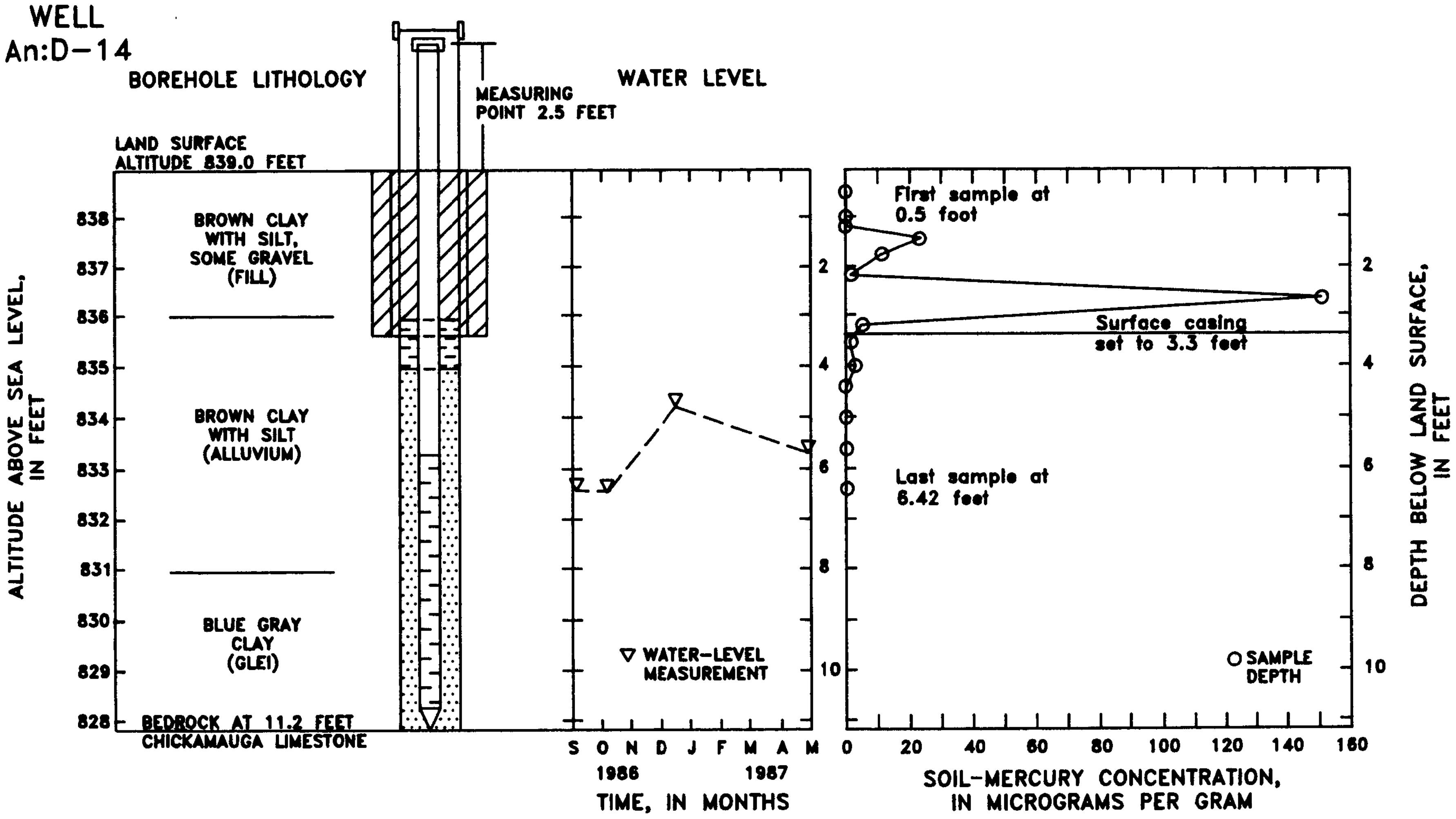
See figure 5 for generalized well-construction diagram.

Figure 14.--Construction, lithology, soil-mercury concentrations, and water levels at site 4 well An:D-13.



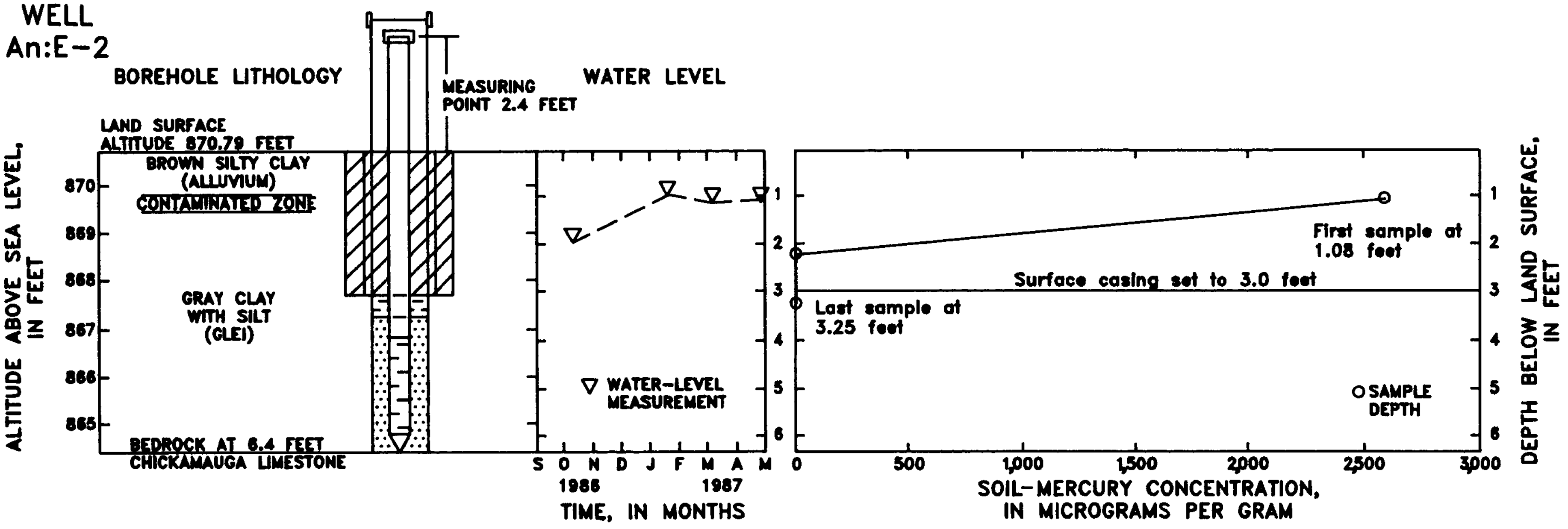
See figure 5 for generalized well-construction diagram.

Figure 15.--Construction, lithology, soil-mercury concentrations, and water levels at site 5 well An:E-1.



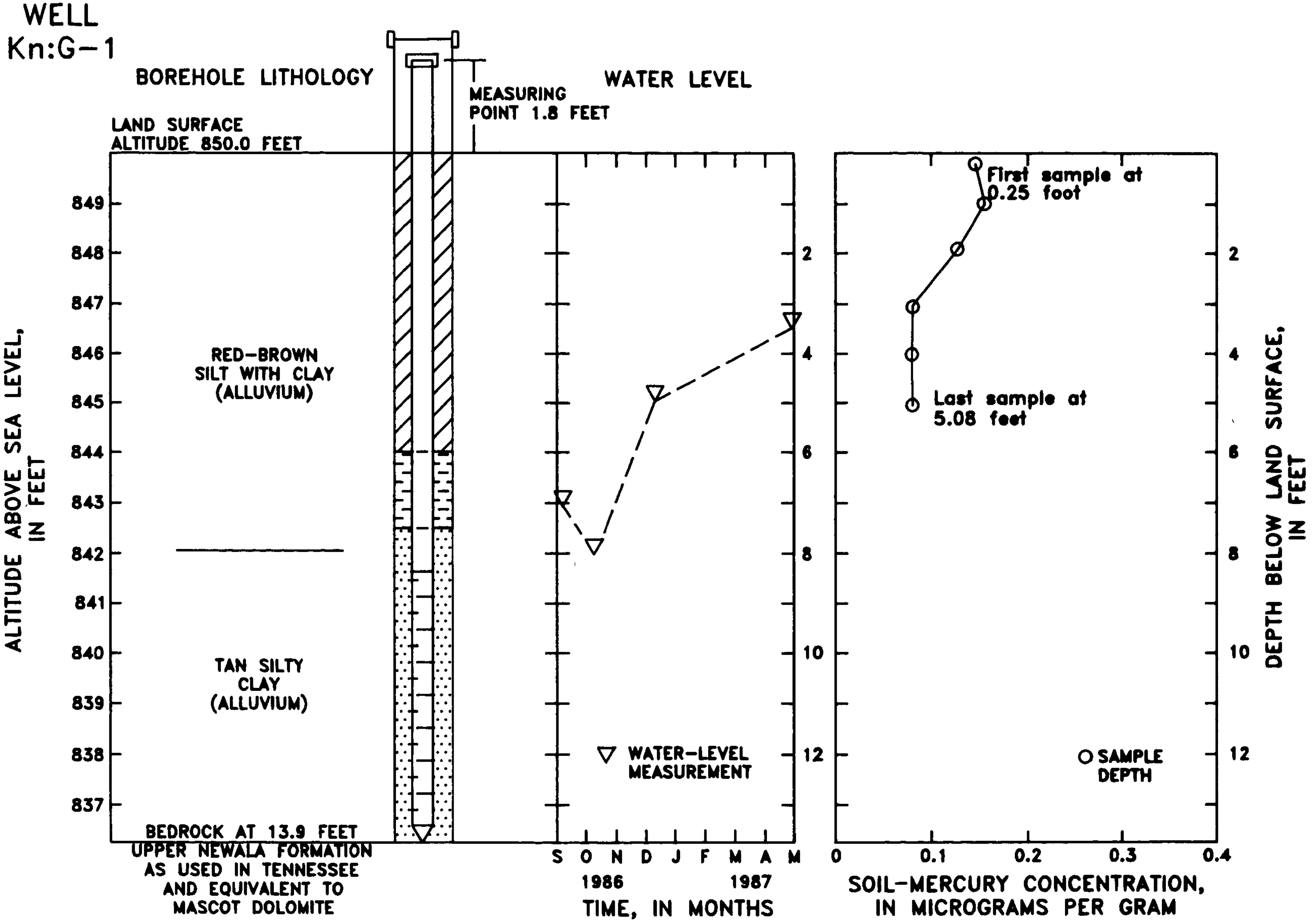
See figure 5 for generalized well-construction diagram.

Figure 16.--Construction, lithology, soil-mercury concentrations, and water levels at site 6 well An:D-14.



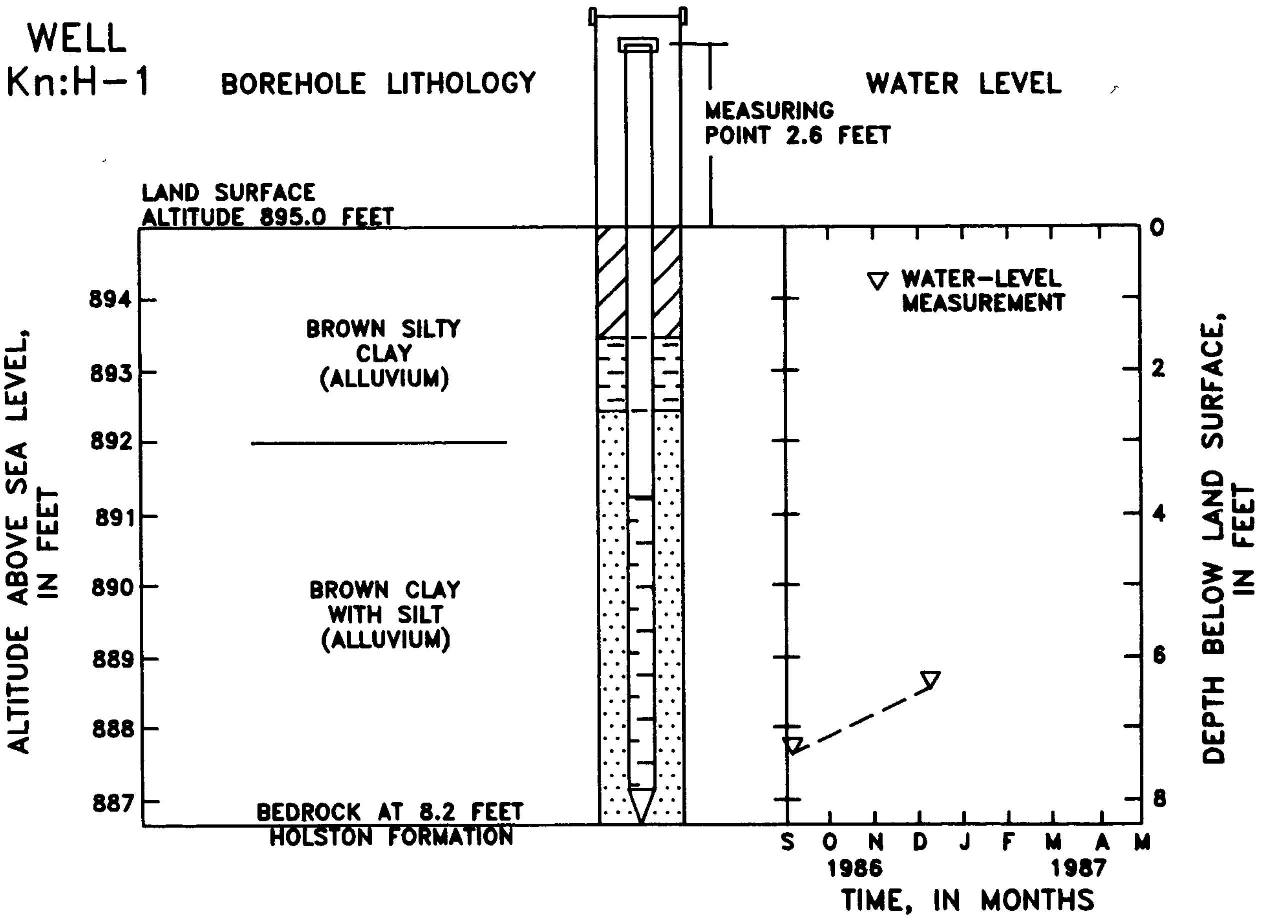
See figure 5 for generalized well-construction diagram.

Figure 17.--Construction, lithology, soil-mercury concentrations, and water levels at site 7 well An:E-2.



See figure 5 for generalized well-construction diagram.

Figure 18.--Construction, lithology, soil-mercury concentrations, and water levels at Ten Mile Creek background-site well Kn:G-1.



See figure 5 for generalized well-construction diagram.

No soil samples collected for mercury analysis at this site.

Figure 19.--Construction, lithology, and water levels at First Creek background-site well Kn:H-1.

of all the wells except well Kn:H-1 at the First Creek background site had recovered sufficiently for proper development. Because water levels were never observed to be high enough in well Kn:H-1 for proper development, this well was neither developed nor sampled during the study.

Well development consisted of initially purging all standing water and sediment from inside the well casings with a small centrifugal pump outfitted with a cleansed (by use of the same cleaning procedure as for augers, casing, and screen) $^3/_4$-inch PVC suction pipe, the intake of which was placed at the bottom of the screen. Once the standing water in each well was evacuated, the suction pipe was removed from the well and the water level was allowed to recover at least to the top of the screen. A cleansed (as above), 1-liter capacity, stainless-steel bailer equipped with a Teflon-ball check valve at the lower end was then lowered into the well below the water surface and was quickly raised and lowered within the water column to surge the sand pack and borehole wall. The bailer was then withdrawn and the well was repumped to remove the agitated water and sediment. This procedure was repeated in sequence until water pumped from each well became clear. The time in development for each well is included in table 1.

The maximum yield of each monitoring well was estimated during development by measuring the time taken to fill a 5-gallon bucket with the centifugal pump. Due to the high capacity of the pump [about 20 gallons per minute (gal/min)] relative to the wells, each well was quickly pumped to dryness and afterwards, only yielded water in slugs. Therefore, the discharge measured from each well is believed to represent an estimate of its maximum yield, or rate of recovery. Estimates for all wells were low, ranging from less than 0.25 to about 0.75 gal/min, and are included in table 1.

OCCURRENCE OF SHALLOW GROUND WATER

EAST FORK POPLAR CREEK STUDY AREA

As observed in the observation wells, ground water occurs in the shallow aquifer in the study area under water-table (unconfined) conditions.

Precipitation is the principal source of recharge to the shallow aquifer. Thus, precipitation falling on the flood-plain surface moves directly through the zone of soil contamination as it percolates to the water table. Locally, flood-plain sections of the shallow aquifer may also receive minor amounts of recharge in the form of bank storage when the water table is lower than stream level. This may occur during the summer and fall as (1) stream stage rises during and immediately after storms, or (2) when the discharge of sufficient process water from the Y-12 Plant causes stream stage to be maintained at an artificially higher altitude than the water table adjacent to the stream. However, during years having normal precipitation, these sources of recharge probably account for only a small percentage of ground water stored in the shallow aquifer because their influence is limited to areas adjacent to the stream channel and because water in bank storage drains back into the stream relatively rapidly as the stage recedes.

Most discharge from the shallow aquifer during normally wet years is presumed to be through springs and seeps to East Fork Poplar Creek and its tributaries, comprising the base-flow component of these streams. During the spring, summer, and fall, evapotranspiration also accounts for the removal of water in storage in the shallow aquifer.

Water levels in the observation wells are thought to represent the water table. Generally, the depth to water in the wells in late winter ranged from about 1 to 4 feet below land surface and in the fall, from about 2 to 7 feet below land surface. Two wells, open to depths of 7.5 and 7.9 feet below land surface, were dry in September and October. Water levels measured in wells in the study area at various times during the investigation are shown in figures 6 through 17.

During the winter and early spring months, the water table rises in the shallow aquifer due in combination to a large decrease in evapotranspiration and a small increase in precipitation relative to summer and fall months. Seasonal rise of the water table was evidenced during the winter and spring both by higher water levels in nearly all observation wells (figs. 6 through 17) and by visual observation of water standing on land surface in many low-lying flood-plain areas. Because wells were installed in several of these areas, visual correlation of water occurring at the same altitude in the wells as on land surface indicates that, at these times, the shallow aquifer in these areas was fully saturated.

During the summer and fall months, depth to the water table increases in the shallow aquifer, as seen by lower water levels in the observation wells (figs. 6 through 17). Water-level declines during these months result from a significant increase in ground-water losses to evapotranspiration, a small decrease in precipitation relative to winter and spring months, and continued ground-water discharge to the streams.

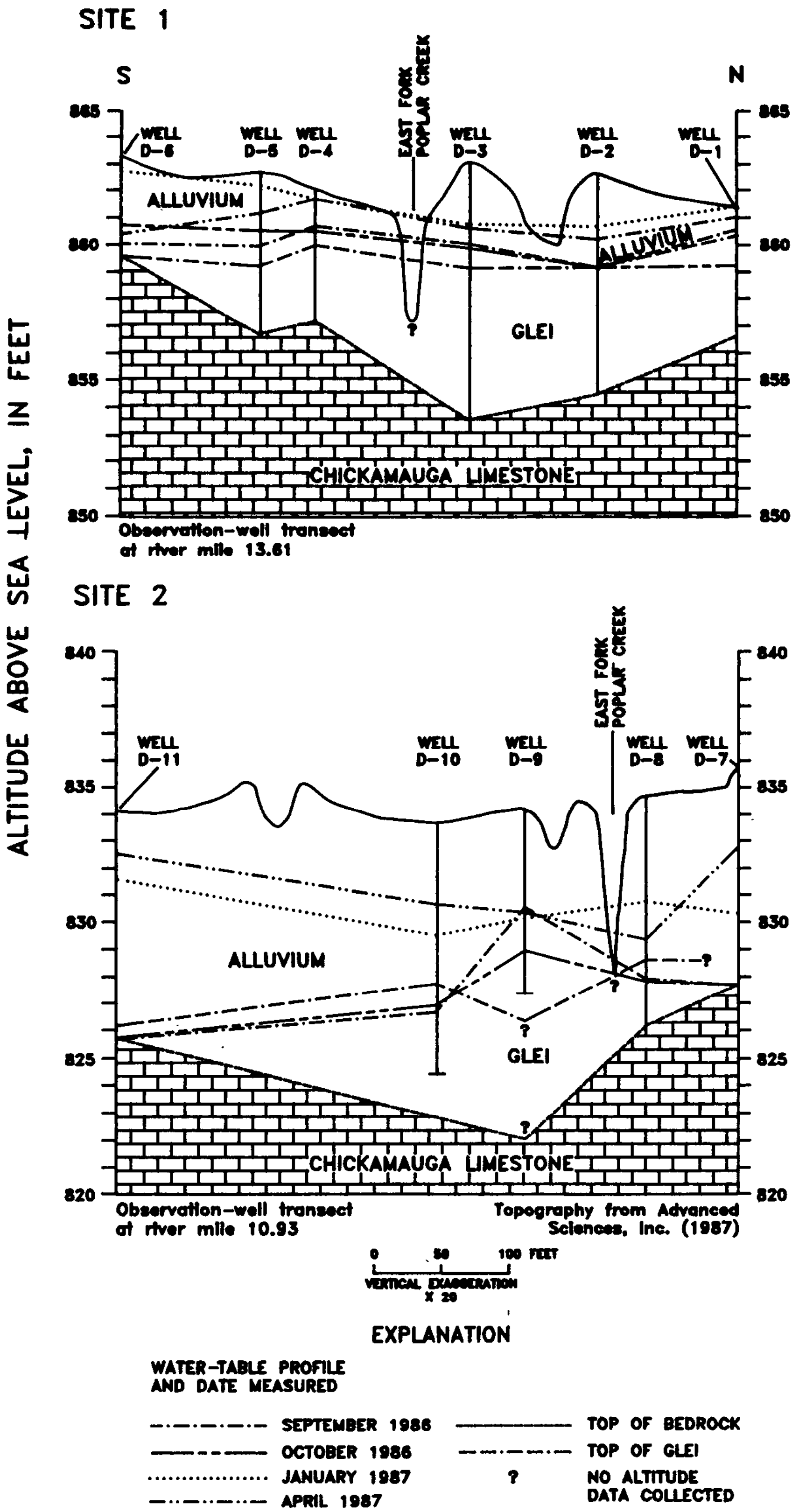
Water levels measured in the observation wells at sites 1 and 2 (transect sites) were plotted in cross section to illustrate ground-water gradients across the East Fork Poplar Creek flood plain at various times during the study (fig. 20). Stream-stage altitudes were not measured along with water levels in the wells. During the winter and spring, the water table generally sloped towards East Fork Poplar Creek and (or) other flood-plain drainage channels, indicating local discharge to the streams. However, during the late summer and fall, abnormally dry weather in the study area caused the water table to recede below the top of bedrock in some flood-plain areas. Due to the low water table, shallow ground-water gradients sloped away from East Fork Poplar Creek, suggesting that during these periods, the stream may have been losing water to the shallow aquifer along some reaches. Minor aberrations in the slope of the water table, as seen in figure 20, may be due to errors in land-surface or measuring-point altitudes, or to slow recovery of the wells after drilling and development.

GROUND-WATER QUALITY

PRELIMINARY SAMPLES

Two rounds of sampling were conducted for preliminary water-quality analyses. The first round of preliminary samples was collected during December 1986 and January 1987. For this round, all wells were sampled except well Kn:H-1 at the First Creek background site. First-round samples were collected in order that (1) screenings for mercury and organic-compound concentrations could be performed, and (2) mercury concentrations in the water samples could be compared with those in the soil at each location in order to evaluate the construction integrity of each well. All first-round samples were collected by the Geological Survey and were sent to its laboratory in Ocala, Florida, for analysis of total-recoverable mercury concentrations and gas chromatograph/flame-ionization detector (GC/FID) scans for detectable organic compounds.

On the basis of analyses of the first-round samples, seven of the wells in the study area (wells An:D-3, 5, 8, 9, 10, 13, and E-2) were redeveloped and resampled by Geological Survey, ORAU, and DOE personnel in March 1987 to compare results with those from the first-round. During the second round, three of the



NOTE: Surface-water, water-table, and lithologic-contact altitudes between wells are approximated.
Location of transects and river miles shown on figure 2.

Figure 20.--Lithologic cross sections and water-table configurations across East Fork Poplar Creek flood plain at site 1 and site 2.

seven wells (An:D-3, 10, and E-2) were resampled for both total-recoverable and dissolved mercury determinations, three of the seven wells (An:D-5, 8, and 13) were resampled for GC/FID scans, and one well (An:D-9) was resampled for both mercury determinations and a GC/FID scan. Second-round samples were again sent to the Geological Survey laboratory in Ocala for analysis. During the second round, duplicate samples were also collected from wells An:D-3, 9, 10, and E-2 for independent total-recoverable and dissolved mercury determinations at the ORAU laboratory.

First and second-round samples were collected from each well immediately after development and water-level recovery. Prior to development and sampling, the water level was measured in each well. All samples were collected using a stainless-steel bailer, cleansed by the same procedure as for augers, casing, and screen. Temperature and specific conductance of water from each well were also measured during sample collection.

Samples collected for analysis at the Geological Survey laboratory were stored in clean glass bottles, as appropriate for mercury determinations and organic-compound scans by GC/FID methods. All sample bottles were labeled and treated as required by standard Survey procedures, and were chilled in ice chests immediately after collection. At the end of each sampling trip, the chests were sealed and shipped to the Survey laboratory in Ocala.

In the fall of 1986, observation well An:D-8 at site 2 was vandalized and foreign material was placed in the casing. After discovery of this, all foreign material was removed from the casing and the well was resecured prior to development and first-round sampling. Because the GC/FID scans of water obtained from this well during both preliminary sampling rounds showed high concentrations of some unknown organic compound(s), the decision was made to discontinue sampling of the well because the origin of the contaminants found in the samples could never be determined and, therefore, the validity of any additional samples would be questionable.

COMPREHENSIVE SAMPLES

Water samples for comprehensive contaminant analyses were collected from all observation wells except wells An:D-8 and Kn:H-1 in April 1987 by personnel from the K-25 Gaseous Diffusion Plant (one of three nuclear-energy facilities on the Oak Ridge Reservation) and the Geological Survey. The samples were analyzed for selected organic compounds by the Analytical Services Section of the International Technology Corporation (ITC) in Knoxville, and for selected trace metals, miscellaneous organic substances, and radionuclides by the Analytical Chemistry Department at the K-25 Plant.

Observation wells An:D-10, 14, and Kn:G-1 were resampled in May 1987 by personnel from the K-25 Plant. The second set of samples collected from these three wells were analyzed for semi-volatile organic compounds at the ITC laboratory to determine the cause of low recoveries of acid-extractable surrogate compounds during analysis of samples collected from several of the wells in April. Low recoveries of the same surrogate compounds again occurred during analysis of the second set of samples from these three wells. Because laboratory blank samples containing the same surrogate compounds and analyzed along with both the April and May samples had acceptable surrogate recoveries, it was concluded that the recovery problems were the result of sample matrix effects (interference in analytical detection methods by other constituents in the samples) and not laboratory problems (Mitzie Miller, K-25 Plant Analytical Chemistry Department, written commun., 1987).

Selected Constituents

Comprehensive contaminant analyses included concentration determinations for those organic compounds on the USEPA's list of Superfund Contract Laboratory hazardous substances, and those trace metals and miscellaneous organic compounds on the USEPA's list of priority pollutants. Included in these lists were all constituents and compounds shown in table 2 (except lithium and zirconium) which were identified during TVA's Instream Contaminant Study as exceeding background concentrations, standards, criteria, and (or) analytical detection limits in East Fork Poplar Creek water, fish, and stream and flood-plain sediment (Tennessee Valley Authority, 1986).

Radioactive constituents were selected by members of the ORTF on the basis of those elements known to have been released from the Y-12 Plant as a result of operations at the facility. On the basis of results of the Instream Contaminant Study (Tennessee Valley Authority, 1986), cesium-137 was the only radionuclide whose activity exceeded background levels near East Fork Poplar Creek and this occurred exclusively in fish (table 2).

Selected constituents and their detection limits for which concentration determinations were made during comprehensive contaminant analyses are shown in table 3.

Procedures

Prior to collecting the water samples for comprehensive contaminant analyses, the water level was measured in each observation well. An initial (pre-purged) sample of water standing in the casing was then withdrawn from each well using a cleansed, 1-liter capacity stainless-steel or Teflon bailer furnished by the K-25 Plant laboratory [K-25 Plant laboratory equipment cleaning procedure consisted of (1) detergent scrub, (2) deionized water rinse, (3) pesticide-grade isopropanol rinse, and (4) deionized water rinse]. Initial samples were analyzed in the field for temperature, specific conductance, pH, oxidation-reduction potential, and dissolved oxygen. The wells were then purged using the small centrifugal pump and clean PVC suction pipe supplied by the Geological Survey. After the water level had recovered in each well, another sample for field measurements (as above) was collected using the same bailer as for the initial sample. Samples were then collected for all laboratory determinations. Properties of water measured in the field during collection of samples for comprehensive contaminant analyses are listed in table 4.

Several of the wells recovered very slowly during the collection of samples for comprehensive contaminant analyses. Because of the slow recovery and the quantity of water needed for the analyses, wells An:D-6 and 7 were purged and partially sampled 1 day, with sampling being completed the following day, and wells An:D-4 and 5 were purged the day before they were sampled.

Triplicate samples were collected from well An:D-9 for field duplicates and laboratory matrix spikes and matrix-spike duplicates.

All samples were stored in the bottles appropriate for their respective determinations and preserved according to the procedures outlined in the U.S. Code of Federal Regulations Title 40, October 1984 (M. Miller, K-25 Plant Analytical Chemistry Department, written commun., 1987). All samples, except those for trace metals, were chilled immediately after collection and returned to the K-25 laboratory at the end of each work day. Trace-metal samples were returned to the K-25 laboratory promptly after collection for filtration through a 0.45-micron filter (samples for dissolved determinations only) and preservation (all samples). Samples for volatile-organic determinations were not

Table 2.--*Constituents and compounds exceeding background concentrations, standards, criteria, and (or) analytical detection limits in East Fork Poplar Creek water, fish, and stream and flood-plain sediments*

[Dash indicates that analyses were performed, but concentrations or activities were within background levels; blank indicates that analyses were not performed. Source: Tennessee Valley Authority, 1986, Instream Contaminant Study, Task 5, January]

	Water	**Fish**	**Stream and flood-plain sediment**
Trace Metals			
Mercury	X	X	X
Cadmium	-	X	X
Copper	-	X	
Chromium	-	X	-
Lead	-	-	X
Nickel	-	-	X
Arsenic	-	X	X
Selenium	-	X	
Beryllium	-	-	
Thallium	-	X	
Silver	-	X	X
Zirconium			X
Lithium	X		
Priority Pollutant Organic Compounds			
Total PCB's	-	X	X
Anthracene	-	-	X
Benzo-a-anthracene	-	-	X
Chrysene	-	-	X
Fluoranthene	-	-	X
Bis(2-ethylhexyl) phthalate	-	X	X
Phenanthrene	-		X
Pyrene	-	-	X
Benzo-a-pyrene	-	-	X
Total phenols	-	-	X
Radionuclides			
Cesium-137	-	X	-

Table 3.--*Selected constituents and their detection limits, comprehensive contaminant analyses, April 1987*

[µg/L, micrograms per liter]

VOLATILE HAZARDOUS SUBSTANCE LIST COMPOUNDS[1]

Compound	Detection limit (µg/L)	Compound	Detection limit (µg/L)
chloromethane	10	1,2-dichloropropane	5
bromomethane	10	trans-1,3-dichloropropene	5
vinyl chloride	10	trichloroethene	5
chloroethane	10	dibromochloromethane	5
methylene chloride	5	1,1,2-trichloroethane	5
acetone	10	benzene	5
carbon disulfide	5	cis-1,3-dichloropropene	5
1,1-dichloroethene	5	2-chloroethylvinylether	10
1,1-dichloroethane	5	bromoform	5
trans-1,2-dichloroethene	5	4-methyl-2-pentanone	10
chloroform	5	2-hexanone	10
1,2-dichloroethane	5	tetrachloroethene	5
2-butanone	10	1,1,2,2-tetrachloroethane	5
1,1,1-trichloroethane	5	toluene	5
carbon tetrachloride	5	chlorobenzene	5
vinyl acetate	10	ethylbenzene	5
bromodichloromethane	5	styrene	5
		total xylenes	5

BASE/NEUTRAL EXTRACTABLE HAZARDOUS SUBSTANCE LIST COMPOUNDS[1]

Compound	Detection limit (µg/L)	Compound	Detection limit (µg/L)
bis(2-chloroethyl)ether	10	2,6-dinitrotoluene	10
1,3-dichlorobenzene	10	diethylphthalate	10
1,4-dichlorobenzene	10	4-chlorophenyl phenyl ether	10
benzyl alcohol	10	fluorene	10
1,2-dichlorobenzene	10	4-nitroaniline	50
bis(2-chloroisopropyl)ether	10	N-nitrosodiphenylamine[2]	10
N-nitroso-di-n-propylamine	10	4-bromophenyl phenyl ether	10
hexachloroethane	10	hexachlorobenzene	10
nitrobenzene	10	phenanthrene	10
isophorone	10	anthracene	10
bis(2-chloroethoxy)methane	10	di-n-butylphthalate	10
1,2,4-trichlorobenzene	10	fluoranthene	10
naphthalene	10	pyrene	10
4-chloroaniline	10	butylbenzylphthalate	10
hexachlorobutadiene	10	3,3′-dichlorobenzidine	20
2-methylnaphthalene	10	benzo(a)anthracene	10
hexachlorocyclopentadiene	10	bis(2-ethylhexyl)phthalate	10
2-chloronaphthalene	10	chrysene	10
2-nitroaniline	50	di-n-octyl phthalate	10
dimethyl phthalate	10	benzo(b)fluoranthene	10
acenaphthylene	10	benzo(k)fluoranthene	10
3-nitroaniline	50	benzo(a)pyrene	10
acenaphthene	10	indeno(1,2,3-cd)pyrene	10
dibenzofuran	10	dibenzo(a,h)anthracene	10
2,4-dinitrotoluene	10	benzo(g,h,i)perylene	10

Table 3.--*Selected constituents and their detection limits, comprehensive contaminant analyses, April 1987*—Continued

ACID EXTRACTABLE HAZARDOUS SUBSTANCE LIST COMPOUNDS[1]

Compound	Detection limit (μg/L)	Compound	Detection limit (μg/L)
phenol	10	4-chloro-3-methylphenol	10
2-chlorophenol	10	2,4,6-trichlorophenol	10
2-methylphenol	10	2,4,5-trichlorophenol	50
4-methylphenol	10	2,4-dinitrophenol	50
2-nitrophenol	10	4-nitrophenol	50
2,4-dimethylphenol	10	4,6-dinitro-2-methylphenol	50
benzoic acid	50	pentachlorophenol	50
2,4-dichlorophenol	10		

HAZARDOUS SUBSTANCE LIST—PESTICIDE AND PCB ANALYSIS[1]

Compound	Detection limit (μg/L)	Compound	Detection limit (μg/L)
α-BHC	0.05	endosulfan sulfate	0.10
β-BHC	.05	4,4′-DDT	.10
δ-BHC	.05	methoxychlor	.5
γ-BHC (lindane)	.05	endrin ketone	.10
heptachlor	.05	chlordane	.5
aldrin	.05	toxaphene	1.0
heptachlor epoxide	.05	Aroclor 1016	.5
endosulfan I	.05	Aroclor 1221	.5
dieldrin	.10	Aroclor 1232	.5
4,4′-DDE	.10	Aroclor 1242	.5
endrin	.10	Aroclor 1248	.5
endosulfan II	.10	Aroclor 1254	1.0
4,4′-DDD	.10	Aroclor 1260	1.0

Table 3.--*Selected constituents and their detection limits, comprehensive contaminant analyses, April 1987*—Continued

TRACE METAL PRIORITY POLLUTANTS[3]

Constituent	Detection limit (μg/L)	Constituent	Detection limit (μg/L)
Antimony (total recoverable)	50	Mercury (total recoverable)	0.2
Antimony (dissolved)	50	Mercury (dissolved)	.2
Arsenic (total)	5	Nickel (total recoverable)	50
Arsenic (dissolved)	5	Nickel (dissolved)	50
Beryllium (total recoverable)	1.0	Selenium (total)	5.0
Beryllium (dissolved)	1.0	Selenium (dissolved)	5.0
Cadmium (total recoverable)	3.0	Silver (total recoverable)	10
Cadmium (dissolved)	3.0	Silver (dissolved)	10
Chromium (total recoverable)	10	Thallium (total recoverable)	10
Chromium (dissolved)	10	Thallium (dissolved)	10
Copper (total recoverable)	4.0	Zinc (total recoverable)	20
Copper (dissolved)	4.0	Zinc (dissolved)	20
Lead (total recoverable)	50	Uranium[4] (total)	1.0
Lead (dissolved)	50	Uranium[4] (dissolved)	1.0

MISCELLANEOUS ORGANIC PRIORITY POLLUTANTS[3]

Compound	Detection limit (μg/L)	Compound	Detection limit (μg/L)
Total cyanide	1.0	Total phenols	1.0

RADIONUCLIDES[5]

Element-Isotope	Detection limit (pCi/L)	Element-Isotope	Detection limit (pCi/L)
Americium-214	1.0	Radium-226,228	3.0
Cesium-137	3.0	Ruthenium-106	9.0
Cobalt-60	3.0	Strontium-90	5.0
Curium-243,244	2.0	Technecium-99	366
Neptunium-237	.9	Thorium-228	1.9
Plutonium-238	2.2	Thorium-230	.6
Plutonium-239,240	1.3	Thorium-232	.4

[1] All determinations were for total concentrations.

[2] Detected as diphenylamine.

[3] Reported from K-25 laboratory in milligrams per liter.

[4] Not a priority pollutant metal.

[5] All determinations were for total activity.

Table 4.--*Properties of water measured in the field during collection of samples for comprehensive contaminant analyses, April 1987*

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter]

Well No./Site No.	Temperature (°C)		Specific conductance (µS/cm)		pH (standard units)		Oxidation-reduction potential (millivolts)		Oxygen, dissolved (mg/L)	
	Initial sample	Purged sample	Initial sample	Purged sample	Initial sample	Purged sample	Initial sample	Purged sample	Initial sample	Purged sample
An:D-1/1	17.2	17.5	60	440	7.4	7.3	-120	-27.5	5.2	4.3
An:D-2/1	14.0	14.0	830	750	7.7	7.2	-152	-97.5	4.8	6.2
An:D-3/1	16.1	14.3	550	590	7.9	8.5	145	115	2.3	2.8
An:D-4/1	16.0	16.5	380	360	10.2	8.2	-37.5	195	5.5	4.5
An:D-5/1	15.2	13.7	310	360	8.9	5.6	-110	175	3.2	3.8
An:D-6/1	16.9	15.0	160	140	7.6	7.8	-50.1	91.4	3.5	8.2
An:D-7/2	17.4	21.3	530	540	7.4	7.0	-47.8	-41.8	4.5	3.7
An:D-9/2	14.9	14.2	1,090	1,060	7.3	7.2	-10.0	-44.7	6.2	6.2
An:D-10/2	17.3	15.9	1,060	1,090	7.1	7.1	-22.1	225	2.3	6.3
An:D-11/2	16.5	17.1	380	210	7.5	6.6	-68.8	283	3.7	4.7
An:D-12/3	13.7	15.1	820	550	7.2	7.7	-107	64	3.8	3.8
An:D-13/4	13.8	13.4	680	650	8.1	7.6	154	186	3.2	4.5
An:E-1/5	14.8	14.7	1,700	930	7.4	7.6	-85.4	-72.5	4.6	1.9
An:D-14/6	13.5	13.7	1,010	1,080	5.8	7.4	29.5	80.8	3.5	3.0
An:E-2/7	16.0	14.7	310	320	8.8	8.9	83.5	8.8	5.2	4.8
Kn:G-1/Ten Mile Creek background site	14.4	14.6	420	390	7.5	7.5	-54.1	-11.8	1.8	5.2

preserved, but the 7-day holding times were met (M. Miller, K-25 Analytical Chemistry Department, written commun., 1987). Chain-of-custody protocol was observed for all samples from collection to analysis.

WATER-QUALITY DATA

Data from the two preliminary rounds of sampling are listed in table 5. Those constituents whose concentrations exceeded detection limits during comprehensive contaminant analyses are listed in table 6.

In the following discussions, water-quality data are compared to Tennessee Department of Health and Environment (TDHE) and (or) USEPA primary maximum contaminant levels for drinking water, where specified. Because the comprehensive contaminant analyses did not include routine determinations for chemical constituents common to ground water (major cations and anions) and because of limitations in the amount of background water-quality data collected, comparison of data from the study area to established drinking-water standards rather than to the background data was considered a more valid method of presenting the results of the analyses performed during this investigation.

Trace Metals

Total-recoverable mercury concentrations significantly exceeding 2.0 micrograms per liter (µg/L), the maximum contaminant level for drinking water specified by both the Tennessee Department of Health and Environment (1985) and the U.S. Environmental Protection Agency (1986), were found in samples collected from site 1 well An:D-3 and site 2 wells An:D-9 and 10

Table 5.--*Water-quality data from preliminary samples, December 1986 and January and March 1987*

[°C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; GC/FID, gas chromatograph/flame-ionization detector; *, analysis not performed – sample bottle broken in shipment; **, 11 peaks – 1 at <1 µg/L; 3 at 1-5 µg/L; 1 at 5-10 µg/L; 2 at 10-20 µg/L; 4 at 20-30 µg/L; All data is from U.S. Geological Survey field or laboratory measurements except second-round sample mercury data shown in parentheses, which are from independent analysis at Oak Ridge Associated Universities laboratory]

Well No./ Site No.	Sample		Temperature, field (°C)	Specific conductance, field (µS/cm)	pH, lab (standard units)	Mercury, total recoverable (µg/L)	Mercury, dissolved (µg/L)	Number of peaks and estimated concentration range of organic compounds detected by GC/FID scans
	Date	Time						
				First-round sample data				
An:D-1/1	1-22-87	1700	7.5	470	6.6	1.0	--	none
An:D-2/1	1-22-87	1530	10.0	690	6.5	.5	--	none
An:D-3/1	1-22-87	1500	11.0	650	6.8	100 ^{1,2}	--	1 at 30-50 µg/L
An:D-4/1	1-21-87	1800	9.0	450	7.6	1.0	--	none
An:D-5/1	1-21-87	1500	9.0	230	9.8	.7	--	1 at 1-5 µg/L
An:D-6/1	1-21-87	1200	7.0	160	8.1	.1	--	1 at 1-5 µg/L
An:D-7/2	1-19-87	1600	11.0	540	6.2	.2	--	none
An:D-8/2	1-20-87	1200	10.5	620	11.1	1.5	--	1 at 1-5 µg/L; 2 at 1-10 µg/L 1 at 300-400 µg/L
An:D-9/2	1-20-87	1000	10.0	1,080	7.3	25 ^{1,2}	--	1 at 1-5 µg/L
An:D-10/2	1-16-87	1630	13.0	1,050	6.7	36 ^{1,2}	--	none
An:D-11/2	1-16-87	1200	11.0	250	6.8	.2	--	none
An:D-12/3	12-11-86	1500	15.0	440	6.6	<.1	--	none
An:D-13/4	12-11-86	1500	17.0	800	6.4	<.1	--	2 at 1-5 µg/L
An:E-1/5	12-12-86	1500	17.0	420	6.6	.3	--	none
An:D-14/6	12-15-86	1700	16.5	925	6.5	<.1	--	none
An:E-2/7	1-20-87	1700	10.5	450	6.9	*	--	none
Kn:G-1/ Ten Mile Creek background site	12- 8-86	1600	16.5	470	6.5	<.1	--	none
				Second-round sample data				
An:D-3/1	3- 6-87	1200	11.0	700	--	1.3 (2.82)^{1,2}	0.4 (0.13)	--
An:D-5/1	3- 6-87	1700	10.0	340	6.4	--	--	none
An:D-8/2	3- 8-87	1245	10.5	520	6.3	--	--	**
An:D-9/2	3- 4-87	1500	10.0	1,100	6.2	.5 (0.96)	.4 (0.10)	none
An:D-10/2	3- 4-87	1330	10.0	1,100	--	.7^{3} (2.04)^{1,2}	1.3^{3} (0.195)	--
An:D-13/4	3- 7-87	1600	13.0	750	6.5	--	--	1 at 80-120 µg/L
An:E-2/7	3- 6-87	1615	11.0	375	--	1.1 (1.28)	.3 (0.74)	--

[1] Meets or exceeds U.S. Environmental Protection Agency (1986) National Primary Drinking Water Regulations for maximum contaminant levels.

[2] Meets or exceeds Tennessee Department of Health and Environment (1985) maximum contaminant levels for public-water supplies.

[3] Dissolved mercury is greater than total-recoverable – sample bottles probably were mislabeled in field at time of collection.

Table 6.--*Constituents and concentrations exceeding detection limits, comprehensive contaminant analyses, April 1987*

[µg/L. micrograms per liter: pCi/L. picocuries per liter: T. total or total-recoverable: D. dissolved: J. indicates an estimated value less than the detection limit: B. constituent was found in the trip blank as well as the sample (see 2 below): *. meets or exceeds Tennessee Department of Health and Environment (1985) maximum contaminant levels for public-water supplies: #. meets or exceeds U.S. Environmental Protection Agency (1986) National Primary Drinking Water Regulations for maximum contaminant levels: ◇.triplicate samples collected from this well—where more than one concentration is shown. constituent was found in either two or all three of the samples. with concentrations shown from lowest to highest: ●. exceeds U.S. Environmental Protection Agency (1987) National Primary Drinking Water Regulations for maximum contaminant levels: --. analysis performed but no constituents were found above detection limits]

Well No./ Site No. (Date sampled)	Volatile compounds	Concentrations (µg/L)	Base/Neutral extractable compounds	Concentrations (µg/L)	Acid extractable compounds	Concentrations (µg/L)	Pesticides/ PCB's	Concentrations (µg/L)	Trace metals	Concentrations (µg/L)^1	Miscellaneous organic compounds	Concentrations (µg/L)^1	Radionuclides	Total activity (pCi/L)
An:D-1/1 (4-23-87)	acetone[2]	7JB	--		--	--	--	--	Antimony(T) Arsenic(T) Mercury Uranium(T) Uranium(D)	54.0# 5.0 2.0*# 38.0 41.0	Total cyanide Total phenols	2.0 8.0#	Strontium-90	81.13#
An:D-2/1 (4-23-87)	--	--	di-n-butyl-phthalate	5J	--	--	--	--	Arsenic(T) Beryllium(T) Chromium(T) Copper(T) Mercury(T) Nickel(T) Uranium(T) Uranium(D)	10.0 .5 11.0 20.0 .7 31.0 6.0 4.0	Total cyanide Total phenols	3.0 3.0*	Strontium-90	75.15#
An:D-3/1 (4-24-87)	--	--	--	--	--	--	Aroclor 1260	1.3	Beryllium(T) Chromium(T) Copper(T) Mercury(T) Nickel(T) Uranium(T) Uranium(D) Zinc(T)	2.4 59.0*# 110 195*# 160 53.0 30.0 120	Total cyanide Total phenols	2.0 4.0#	Strontium-90 Thorium-230	10.77# 3.1
An:D-4/1 (4-24-87)	--	--	--	--	--	--	--	--	Antimony(T) Cadmium(T) Mercury(T) Nickel(T) Uranium(T) Uranium(D)	64.0# 3.1 2.3*# 66.0 8.0 6.0	Total cyanide Total phenols	2.0 7.0#	Strontium-90	7.53
An:D-5/1 (4/24/87)	acetone[2]	10	N-nitrosodi-phenylamine[3]	3J	--	--	--	--	Antimony(T) Beryllium(T) Chromium(T) Copper(T) Mercury(T) Nickel(T) Nickel(D) Uranium(T) Uranium(D) Zinc(T)	81.0# 2.2 23.0 17.0 7.0*# 100 80.0 3.0 2.0 98.0	Total cyanide Total phenols	40.0 2.0#	Strontium-90	8.84

Table 6.--*Constituents and concentrations exceeding detection limits, comprehensive contaminant analyses, April 1987*--Continued

Well No./ Site No. (Date sampled)	Volatile compounds	Concentrations (µg/L)	Base/Neutral extractable compounds	Concentrations (µg/L)	Acid extractable compounds	Concentrations (µg/L)	Pesticides/ PCB's	Concentrations (µg/L)	Trace metals	Concentrations (µg/L)[1]	Miscellaneous organic compounds	Concentrations (µg/L)[1]	Radionuclides	Total activity (pCi/L)
An:D-6/1 (4-23,24-87)	acetone[2]	3J	3,3'-dichlorobenzidine	3J	--	--	--	--	Chromium(T)	26.0	Total phenols	4.0#	Strontium-90	17.09#
			benzo(a)-anthracene	3J					Copper(T)	32.0				
			chrysene	3J					Mercury	3.0*#				
									Nickel(T)	68.0				
									Uranium(T)	3.0				
									Zinc(T)	35.0				
An:D-7/2 (4-22,23-87)	--	--	chrysene	2J	--	--	--	--	Chromium(T)	12.0	Total cyanide	4.0	Strontium-90	67.81#
			benzo(b)-fluoranthene	2J					Mercury(T)	.4	Total phenols	2.0#		
									Nickel(T)	57.0				
									Nickel(D)	74.0				
An:D-9/2◇ (4-23-87)	acetone[2]	1JB	pyrene	2J	--	--	--	--	Arsenic(T)	7.0,8.0,9.0	Total cyanide	3.0,4.0,4.0	Radium-226. 228	3.0,3.0
									Arsenic(D)	5.0,6.0	Total phenols	3.0#,4.0# 5.0#	Strontium-90	55.60#, 77.51#, 90.64#
									Beryllium(T)	1.0,1.3,2.0				
									Chromium(T)	25.0,32.0, 55.0*#				
									Copper(T)	170,200, 270				
									Lead(T)	68.0*#				
									Mercury(T)	93.0*# 114*# 138*#				
									Nickel(T)	82.0				
									Uranium(T)	379.406, 408				
									Uranium(D)	348,348, 350				
An:D-10/2 (4-22-87)	acetone[2]	36	N-nitrosodiphenylamine[3]	6J	--	--	--	--	Arsenic(T)	12.0	Total cyanide	4.0	Strontium-90	88.83#
	methylene Chloride	4J	di-n-butyl-phthalate	3J					Arsenic(D)	10.0	Total phenols	3.0#		
									Chromium(T)	19.0				
									Copper(T)	40.0				
									Mercury(T)	48.0*#				
									Nickel(T)	51.0				
									Selenium(T)	12.0*#				
									Uranium(T)	89.0				
									Uranium(D)	79.0				
									Zinc(T)	48.0				

Table 6.--*Constituents and concentrations exceeding detection limits, comprehensive contaminant analyses, April 1987*--Continued

Well No./ Site No. (Date sampled)	Volatile compounds	Concen- trations (µg/L)	Base/Neutral extractable compounds	Concen- trations (µg/L)	Acid extractable compounds	Concen- trations (µg/L)	Pesticides/ PCB's	Concen- trations (µg/L)	Trace metals	Concen- trations (µg/L)[1]	Miscellaneous organic compounds	Concen- trations (µg/L)[1]	Radio- nuclides	Total activity (pCi/L)
An:D-11/2 (4-22-87)	--	--	N-nitrosodi- phenylamine[3]	2J	--	--	--	--	Mercury(T) Uranium(T) Zinc(T)	0.7 1.0 28.0	Total cyanide Total phenols	4.0 3.0#	Radium-226, 228 Strontium-90	3.0 57.34#
An:D-12/3 (4-25-87)	--	--	--	--	--	--	--	--	Mercury(T) Zinc(T)	2.0*# 28.0	Total cyanide	4.0	--	--
An:D-13/4 (4-25-87)	--	--	--	--	--	--	--	--	Copper(T)	13.0	Total cyanide Total phenols	5.0 7.0#	--	--
An:E-1/5 (4-24-87)	trans-1,2- dichloro- ethene trichloroethene	8 37 ●	--	--	--	--	--	--	Arsenic(T) Copper(T) Mercury(T) Uranium(T) Uranium(D) Zinc(T)	5.0 17.0 4.0*# 12.0 10.0 59.0	Total phenols	3.0#	Strontium-90	14.44#
An:D-14/6 (4-25-87)	--	--	--	--	--	--	--	--	Arsenic(T) Beryllium(T) Chromium(T) Copper(T) Mercury(T) Zinc(T)	6.0 2.1 33.0 19.0 2.0*# 60.0	Total phenols	15.0#	Radium-226, 228 Strontium-90	3.0 7.74
An:E-2/7 (4-24-87)	acetone[2]	13	--	--	--	--	--	--	Mercury(T) Uranium(T) Uranium(D)	3.0*# 14.0 4.0	Total cyanide Total phenols	3.0 49.0#	Strontium-90	9.37
Kn:G-1/ Ten Mile Creek background site (4-25-87)	--	--	--	--	--	--	--	--	Arsenic(T) Beryllium(T) Chromium(T) Copper(T) Mercury(T) Zinc(T)	8.0 1.7 27.0 5.6 2.0*# 36.0	Total cyanide	3.0	--	--

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[1] Reported from K-25 laboratory in milligrams per liter.

[2] See Organic Compounds discussion in Water-Quality Data section.

[3] Detected as diphenylamine.

during first-round preliminary and comprehensive contaminant analyses (tables 5 and 6). Second-round preliminary samples collected from these three wells did not contain concentrations of total-recoverable mercury exceeding 2.0 μg/L except in the samples from wells An:D-3 and 10 that were analyzed by the ORAU laboratory (table 5). Concentrations of total-recoverable mercury equal to or slightly exceeding 2.0 μg/L were found during comprehensive contaminant analyses of samples from site 1 wells An:D-1, 4, 5, and 6; site 3 well An:D-12; site 5 well An:E-1; site 6 well An:D-14; and site 7 well An:E-2 (table 6). All water samples collected during this investigation and analyzed for dissolved mercury contained concentrations below the 2.0 μg/L maximum contaminant level.

During comprehensive contaminant analyses, samples from several of the study area wells were found to contain a few other trace metals in total and (or) total-recoverable concentrations that exceeded their respective drinking-water standards. Concentrations of total antimony in water samples from site 1 wells An:D-1, 4, and 5 (table 6) exceeded the 10 μg/L maximum contaminant level for drinking water specified by the USEPA (1986). Concentrations of total-recoverable chromium in water from site 1 well An:D-3 and in one of the triplicate samples collected from site 2 well An:D-9 (table 6), exceeded both the TDHE (1985) and the USEPA (1986) 50 μg/L maximum contaminant level for this element. Total-recoverable lead concentration in the sample from site 2 well An:D-9 (table 6) also exceeded both the TDHE (1985) and the USEPA (1986) maximum contaminant level of 50 μg/L for lead. The concentration of total selenium in water from site 2 well An:D-10 (table 6) exceeded both the TDHE (1985) and USEPA (1986) maximum contaminant level of 10 μg/L. All dissolved concentrations of the above metals were below their respective analytical detection limits. Furthermore, total or total-recoverable and dissolved concentrations of all other trace metals for which determinations were performed during the comprehensive contaminant analyses and having TDHE and (or) USEPA-specified drinking-water standards were found below their respective criteria.

Although no maximum contaminant level for drinking water has been established for uranium, during comprehensive contaminant analyses both total and dissolved concentrations of this element were found to exceed the K-25 laboratory's 1.0 μg/L analytical detection limit in samples from nearly 70 percent of the wells in the flood-plain section of the study area (table 6). Only dissolved uranium concentrations in water from site 1 well An:D-6 and site 2 well An:D-11, and total and dissolved uranium concentrations in water from site 2 well An:D-7 and site 6 well An:D-14 were below the 1.0 μg/L detection limit. The highest concentrations of both total and dissolved uranium (408 and 350 μg/L, respectively) were found in water samples from site 2 well An:D-9 (table 6). In general, dissolved uranium concentrations in the samples were lower than total concentrations. However, nearly all samples containing total uranium concentrations greater than or equal to 3.0 μg/L were also found to contain dissolved concentrations exceeding the 1.0 μg/L analytical detection limit.

Organic Compounds

Organic compounds detected by GC/FID methods during preliminary water-quality determinations were not specifically identified. Only estimated concentration ranges of the detected compounds were reported by the Geological Survey laboratory in Ocala (table 5). Nearly 90 percent of the first-round preliminary samples showed either no detectable organic compounds or estimated concentrations less than or equal to the 1 to 5 μg/L analytical detection limit for most compounds. However, the first-round preliminary sample from site 1 well An:D-3 contained an estimated 30 to 50 μg/L concentration of some unknown organic compound, and both first and second-round preliminary samples collected from site 2 well An:D-8 (vandalized well) contained relatively high estimated concentrations of some unknown compound(s) (table 5).

During comprehensive contaminant analyses, concentrations of a few volatile and semivolatile organic compounds were estimated by the ITC laboratory to occur below their respective analytical detection limits in samples collected from a few of the study area wells (table 6). No drinking-water standards exist for those compounds whose sample concentrations were estimated. However, the sample from site 5 well An:E-1 contained 8 μg/L of trans-1,2-dichloroethene, a concentration slightly exceeding the ITC laboratory's 5.0 μg/L analytical detection limit, and a 37 μg/L concentration of trichloroethene, significantly exceeding the 5.0 μg/L maximum contaminant level for drinking water specified by the USEPA (U.S. Environmental Protection Agency, 1987).

Other organic compounds found to exceed their respective analytical detection limits during comprehensive contaminant analyses were Arochlor 1260 in the sample from site 1 well An:D-3, and concentrations of total cyanide (ranging from 2.0 to 40 μg/L) in samples from all of the study area wells except site 1 well An:D-6, site 5 well An:E-1, and site 6 well An:D-14, and in well Kn:G-1 at the Ten Mile Creek background site (table 6). In addition, concentrations of total phenols (ranging from 2.0 to 47 μg/L) exceeding the 1.0 μg/L maximum contaminant level for drinking water specified by the USEPA (1986) were found in samples from all wells except site 3 well An:D-12 and well Kn:G-1 at the Ten Mile Creek background site.

Although acetone was reported to occur in samples from several wells in the study area in concentrations as high as 36 μg/L during comprehensive contaminant analyses (table 6), it was also found in concentrations as high as 35 μg/L in the sampling-trip blanks (laboratory water) stored and carried with the samples throughout sampling and analysis. Because acetone is a common laboratory solvent, the ITC laboratory considers this compound to be present in water samples only when its concentration is greater than 10 times that found in the laboratory or trip blanks (M. Miller, K-25 Analytical Chemistry Department, written commun., 1987). However, whether the trip blanks were contaminated before or after they were taken to the field is unknown. Therefore, it is impossible to determine if acetone was present in the samples when collected.

Radionuclides

During comprehensive contaminant analyses, strontium-90 was found in samples collected from all wells in the flood-plain section of the study area (table 6). Concentrations of strontium-90 in the samples from these wells ranged from 7.53 to 90.64 picocuries per liter (pCi/L), exceeding the USEPA (1986) 10 pCi/L maximum contaminant level for drinking water in samples from all wells in the flood plain except site 1 wells An:D-4 and 5, and site 6 and site 7 wells An:D-14 and E-2, respectively. Radium-226, 228 was also identified in water from site 2 wells An:D-9 and 11, and site 6 well An:D-14, but was below the USEPA 5.0 pCi/L maximum contaminant level. Thorium-230 concentration in the sample from site 1 well An:D-3 was 3.1 pCi/L; however, no drinking-water standard for this radionuclide has been established. Only samples from site 3 well An:D-12 and site 4 well An:D-13 located at the "low-level" sites near the Oak Ridge Civic Center, and well Kn:G-1 at the Ten Mile Creek background site contained no detectable radionuclides.

DISCUSSION OF RESULTS

The results of water-quality determinations performed during this investigation suggest that mercury and other trace metals are present in the shallow ground water near East Fork Poplar Creek. However, comparison of the results of total and (or) total-recoverable trace-metal determinations with those from the dissolved determinations indicates that the identified trace metals were associated principally with sediment in suspension in the water samples and not with the water itself. The suspended sediment consisted of clay and silt aquifer materials and was present in all samples as a result of low permeability of the shallow aquifer and the surging action of the bailer during sample collection. Because clay and silt have a high sorptive capacity for metals, and because removal of these materials from the samples by filtration significantly reduced nearly all trace-metal concentrations, it appears that most of the mercury and other trace-metal contaminants are sorbed to sediment composing the shallow-aquifer matrix rather than dissolved in the water moving through the aquifer. The exception to this statement is evident when the results of total and dissolved uranium determinations are compared (table 6). These data indicate that dissolved uranium composed an average of greater than 75 percent of the total concentration in more than 80 percent of the samples where both total and dissolved concentrations were detected. The reason for this is not known but may be due to the occurrence of uranium in a highly soluble oxidation state in the flood-plain soils. Thus, on the basis of the results of this investigation, except for uranium, water in the shallow aquifer near East Fork Poplar Creek does not appear to contain trace metals in concentrations that exceed TDHE and (or) USEPA drinking-water standards. Furthermore, although samples collected for organic-compound and radionuclide determinations were not filtered, where detected, at least some of these substances also may have been attached to suspended sediment in the samples. Additional sample collection and analysis is needed to confirm this hypothesis.

The preceeding discussion indicates that the wells that yielded samples containing elevated concentrations of total and (or) total-recoverable trace-metals (and presumably organic compounds and radionuclides) (tables 5 and 6) were most likely contaminated during installation primarily by fine, contaminated sediment, capable of being transported in suspension through the sand packs and into the wells during sampling. At site 2 wells An:D-8 and D-9 and site 5 well An:E-1, this most likely resulted from incomplete sealing of the contaminated zone by the surface casing and subsequent transport of contaminants down the 6-inch boreholes as the wells were drilled (figs. 9b, 10, and 15). The presence of contaminated sediment in the other wells also may have been the result of sediment in the upper soil zone at each location being transported down the borehole as the well was drilled. However, the depth to which surface casing was installed in most of these wells should have provided an effective seal between the zone of highest contamination and the screened interval in each well (figs. 6, 7, 8, 9a, 11, 12, 16, and 17).

A few additional factors may have affected the results of water-quality analyses performed during this investigation. For organic-compound determinations, (1) matrix effects between sample constituents could have resulted in lower concentrations being detected in the samples than actually occur in the water, (2) relatively high pH values measured in samples from a few of the wells (tables 4 and 5), which may have resulted from incomplete bentonite-seal development between cement and sand packs, could have influenced the speciation, sorption, and solubility of pH-sensitive constituents, and (3) the relatively high detection limits (compared to those of the Geological Survey's laboratory) for many of the organic compounds analyzed for during comprehensive contaminant analyses (table 3) could have resulted in extremely low organic-compound concentrations in the samples being undetected. For trace-metal determinations, any delay in filtration and preservation of dissolved samples could have caused precipitation of metals from solution, followed by their removal during filtration. This could have resulted in lower concentrations of dissolved trace metals being detected in the samples than actually occur in the water, therefore biasing the results of total and (or) total-recoverable versus dissolved determinations.

SUMMARY

Sixteen shallow observation wells were installed at seven sites in and near the flood plain of East Fork Poplar Creek at Oak Ridge, Tennessee. Water-quality samples were collected from each well to determine if water in the shallow (above bedrock) aquifer contains mercury and other contaminants that presently occur in the flood-plain soils and fill materials as a result of loss of these substances from the Y-12 Plant. Two shallow wells were also installed at separate sites in the flood plains of small streams in the greater Knoxville, Tennessee area, and samples were collected from one of the wells for background water-quality information.

The shallow aquifer in the East Fork Poplar Creek flood plain consists primarily of alluvial silt and clay with lesser amounts of sand and gravel. Thickness of the shallow aquifer ranges from essentially zero where bedrock is exposed at land surface to as much as 20 feet where fill materials have been placed above the flood-plain deposits. A silty-clay glei horizon is present between the base of the alluvium and top of bedrock at most flood-plain locations and, where present, likely impedes downward ground-water movement.

Water in the shallow aquifer near East Fork Poplar Creek occurs under water-table conditions. Recharge to the shallow aquifer is principally from precipitation, and discharge is through springs and seeps to East Fork Poplar Creek and its tributaries. During spring, summer, and fall, water in storage in the shallow aquifer is also lost to evapotranspiration.

Water levels in the shallow aquifer fluctuate seasonally in response to variations in recharge and evapotranspiration. During the investigation, the depth to water in the observation wells generally ranged from about 1 to 4 feet below land surface in late winter, and from about 2 to 7 feet below land surface in late fall. During extremely dry periods, the water table recedes below the top of bedrock in some flood-plain areas, possibly causing East Fork Poplar Creek to lose water to the shallow aquifer along some reaches.

Water samples collected from the observation wells were analyzed for a wide range of substances included on the USEPA's Priority Pollutant and Superfund Contract Laboratory Hazardous Substance Lists. Unfiltered samples collected from several of the wells in the East Fork Poplar Creek flood plain contained total and (or) total-recoverable concentrations of antimony, chromium, lead, mercury, selenium, total phenols, and (or) strontium-90 that exceeded drinking-water standards specified by the TDHE and (or) the USEPA. Water from one well in the East Fork Poplar Creek flood plain at a contaminated fill site contained a 37 μg/L concentration of trichloroethene, significantly exceeding the 5.0 μg/L maximum contaminant level for drinking water specified by the USEPA, and 8 μg/L of trans-1,2-dichloroethene, for which no drinking-water standard has been established. Other organic compounds that were identified in low concentrations in water samples from a few of the wells in the East Fork Poplar Creek flood plain include benzo(a)anthracene, benzo(b)fluoranthene, chrysene, 3,3'-dichlorobenzidine, di-n-butylphthalate, N-nitrosodiphenylamine, and pyrene.

Although no maximum contaminant level for drinking water has been established for uranium, both total and dissolved concentrations of this element exceeded 1.0 μg/L in samples from nearly 70 percent of the wells in the East Fork Poplar Creek flood plain. Comparison of the results of total and dissolved uranium determinations indicates that dissolved uranium composed an average of greater than 75 percent of the total concentration in more than 80 percent of the samples where both total and dissolved concentrations were detected.

Comparison of the results of total and (or) total-recoverable trace-metal determinations with those from the dissolved determinations indicates that, except for uranium, all trace metals identified in the samples were associated principally with silt and clay aquifer materials suspended in the water samples and not with the water itself. Therefore, on the basis of the results of this investigation, except of uranium, water in the shallow aquifer near East Fork Poplar Creek does not appear to contain trace metals in concentrations that exceed TDHE and (or) USEPA drinking-water standards. Additional sample collection and analysis is needed to define the relation between suspended sediment and concentrations of organic compounds and radionuclides in the samples.

Elevated concentrations of total and (or) total-recoverable trace-metals (and presumably organic compounds and radionuclides) in water samples from several wells are suspected to be the result of borehole contamination during well installation. Additional factors that may have affected the results of water-quality analyses performed during this investigation include: matrix effects between sample constituents, relatively high pH values measured in water samples from a few of the wells, relatively high laboratory detection limits for many of the organic compounds specifically analyzed for, and any delay in filtration and preservation of dissolved trace-metal samples.

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