

HYDROGEOLOGIC, GEOPHYSICAL, AND GROUND-WATER-QUALITY RECONNAISSANCE AT
AND NEAR THE CIBA-GEIGY SUPERFUND SITE, OCEAN COUNTY, NEW JERSEY

By Gary J. Barton and Tamara Ivahnenko

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U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Mountain View Office Park
810 Bear Tavern Road
Suite 206
West Trenton, NJ 08628

Copies of this report can be
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CONVERSION FACTORS AND VERTICAL DATUM

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4047	hectare
square mile (mi ²)	2.590	square kilometer
cubic yard (yd ³)	0.7646	cubic meter
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
pound (lb)	4.536	kilogram

Temperature Conversion

Temperature in degrees Celsius (°C) is converted to degrees Fahrenheit (°F) by using the equation: $^{\circ}\text{F} = (9/5) ^{\circ}\text{C} + 32$.

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

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ABSTRACT

Ground water is the principal source of drinking water in the vicinity of the Ciba-Geigy Superfund site near Toms River in Ocean County, New Jersey. Organic compounds and trace metals from several point sources have contaminated ground water at the Ciba-Geigy Toms River Chemical Company plant. The point sources of contamination include a production area, a backfilled-lagoons area, a former fire-prevention training area, several sludge-disposal areas, and a drum-disposal area. A gravel pit or borrow area also is considered a potential source of contamination. The number and locations of buried drums containing hazardous chemicals at the site are unknown.

In order to evaluate the hydrogeologic conditions and extent of ground-water contamination at the Superfund site and in adjacent areas, the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, conducted a hydrogeologic and ground-water-quality reconnaissance on the property of the plant (which includes the Superfund site) and in Winding River Park, which borders the Toms River immediately to the east of the Superfund site. This study determined the electrical conductivity of the upper part of the Kirkwood-Cohansey aquifer system in the vicinity of the Superfund site and further defined the extent and character of ground-water contamination at and near the site by using surface- and borehole-geophysical techniques and by sampling ground water from drive points. In addition, geophysical methods were used to locate possible buried trenches in part of the borrow area.

The field investigation consisted of an electromagnetic-induction survey covering 45 line miles, installing 5 temporary drive points; gamma-ray logging in 8 wells and at 5 drive-point sites; measuring specific conductance of ground water in 20 wells; measuring ground-water levels in 20 wells; and conducting a ground-penetrating-radar survey in part of the borrow area. The area of investigation totaled approximately 1,870 acres. Thirteen sets of water-quality samples and two duplicate sets of samples were collected from the drive points for analysis for purgeable organic compounds, inorganic constituents, and nutrients.

The Kirkwood-Cohansey aquifer system is approximately 150 to 200 feet thick in the vicinity of the Superfund site. From land surface to approximately 20 to 60 feet below sea level, aquifer materials are primarily sand with discontinuous silt and clay layers. The aquifer system is less well defined at greater depths because few observation or production wells at the site penetrate deeper than 60 feet below sea level. The aquifer system is underlain by a confining unit consisting of glauconitic sand, silt, and clay. Test holes were drilled into the confining unit, but no wells were completed in the unit.

The hydraulic connection between the Kirkwood-Cohansey aquifer system, the Toms River, and the associated wetlands is poorly understood. Ground water from the shallow part of the aquifer system discharges into the Toms River; however, ground water from the deep part of the aquifer system may flow beneath the river and the associated wetlands.

Results of the electromagnetic-terrain-conductivity survey show that the apparent terrain-conductivity is higher than background levels in an area extending eastward from the production area to the Toms River, and in part of Winding River Park. Areas with apparent terrain-conductivity higher than background levels are limited to, and approximately coincide with, areas where ground-water contamination was identified previously. Regression analysis of apparent terrain-conductivity of sediments and ground water and specific conductance of ground water shows that terrain conductivity is a rough indicator of ground-water contamination in the absence of other influences.

The depth of the ground-penetrating-radar exploration ranged from approximately 30 feet in the central and southeastern part of the borrow area to greater than 56 feet in the northwestern part of the borrow area. Ground-penetrating-radar anomalies detected form a continuous east-west-trending band across part of the borrow area. They are generally trough-shaped and may indicate the presence of a buried trench, but a natural feature such as a buried channel also could cause the anomalies. These ground-penetrating-radar anomalies generally extend to depths ranging approximately from 8 to 11 feet. The trend of the anomalies is similar to the trend of a trench previously identified from aerial photographs in the western part of the borrow area.

Electrically conductive ground water (maximum specific conductance 1,860 millisiemens per centimeter) extends about 2,000 feet eastward from the production area to the Toms River, and underlies part of Winding River Park. Areas of elevated specific conductance coincide roughly with areas containing purgeable organic compounds.

Drive-point water-quality data confirm the presence of organic compounds beneath the floodplain west of the Toms River where no wells have been installed, near the borrow area, and in the Equestrian Park in Winding River Park. The deepest interval sampled at all five drive-point sites contained purgeable organic compounds; however, the depth to the base of the contaminated ground water is unknown because sampling was limited to depths of less than 50 feet. A total of 36 purgeable organic compounds were identified in the water-quality samples; these compounds included two that had not been found previously in ground water at the Superfund site--1,2,3-trichloropropane and 1,2-dichloropropane. Two ground-water-quality samples contained concentrations of cadmium and selenium exceeding the U.S. Environmental Protection Agency's maximum drinking-water contaminant limits for these constituents. On the basis of the presence of trichloroethylene and chlorobenzene in 51 wells and drive point sites, the following conclusions can be drawn: (1) concentrations are highest at the source areas and decrease downgradient, toward the Toms River, except in the Equestrian Park; (2) the zone of ground-water contamination appears to have migrated east of the Toms River; and (3) wells deeper than those sampled during this study are required to determine the depth of contamination.

INTRODUCTION

Ground water is the principal source of drinking water in the vicinity of the Ciba-Geigy Toms River Chemical Company plant¹ (hereafter called the plant), Dover Township, Ocean County, New Jersey (fig. 1). The presence of many point sources of contamination at the plant has resulted in severe degradation of ground-water quality and has increased the potential for water-supply problems. The presence of contaminated ground water at the plant site was first identified in 1959 (Leggette, Brashears, & Graham, 1959), and in 1982 the U.S. Environmental Protection Agency (USEPA) placed part of the plant and vicinity on the National Priorities Superfund List. The part of the plant and vicinity on the National Priorities List is now known as the Ciba-Geigy Superfund site (hereafter called the Superfund site).

Previous studies have identified a number of actual or potential source areas of contamination at the site. These include the production area, a backfilled-lagoons area, a drum-disposal area, an active landfill, a compactor area, several sludge-disposal areas, a former fire-prevention training area, a borrow area, a "suspected" overflow area, and a "casual" dumping area. These source areas are described later in this report. The contamination already identified includes both inorganic (metals) and organic constituents--specifically, inorganic and organic compounds used in the manufacture of synthetic organic pigments, organic dye stuffs and intermediates, and epoxy resins. Drums containing hazardous chemicals are buried at the site, but the number of drums is not known, nor have all drum locations been verified.

In order to more fully assess the extent and nature of ground-water contamination at and near the Superfund site, the U.S. Geological Survey (USGS), in cooperation with the USEPA, evaluated the hydrogeologic conditions and conducted a geophysical and water-quality reconnaissance to determine the distribution of contamination at selected locations at and near the Superfund site. This information will help the USEPA to select the locations and depths of monitoring wells in selected areas, the placement of trenches for locating buried drums in part of the borrow area, and the locations of soil-sampling sites.

Purpose and Scope

This report presents the results of a hydrogeologic, geophysical, and ground-water-quality reconnaissance conducted during 1989 at selected sites at and near the Ciba-Geigy Superfund site.

The report includes lithologic and gamma-ray logs along lines through the study area, contour maps of apparent electromagnetic terrain-conductivity of the subsurface, a map of ground-penetrating-radar anomalies in part of the borrow area, maps of specific conductance of ground water and water levels, and hydrochemical lines showing concentrations of trichloroethylene and chlorobenzene in monitoring wells and drive points. The report also includes

¹ Use of company names in this report is for identification only and does not impute responsibility for any present or potential effects on the natural resources.

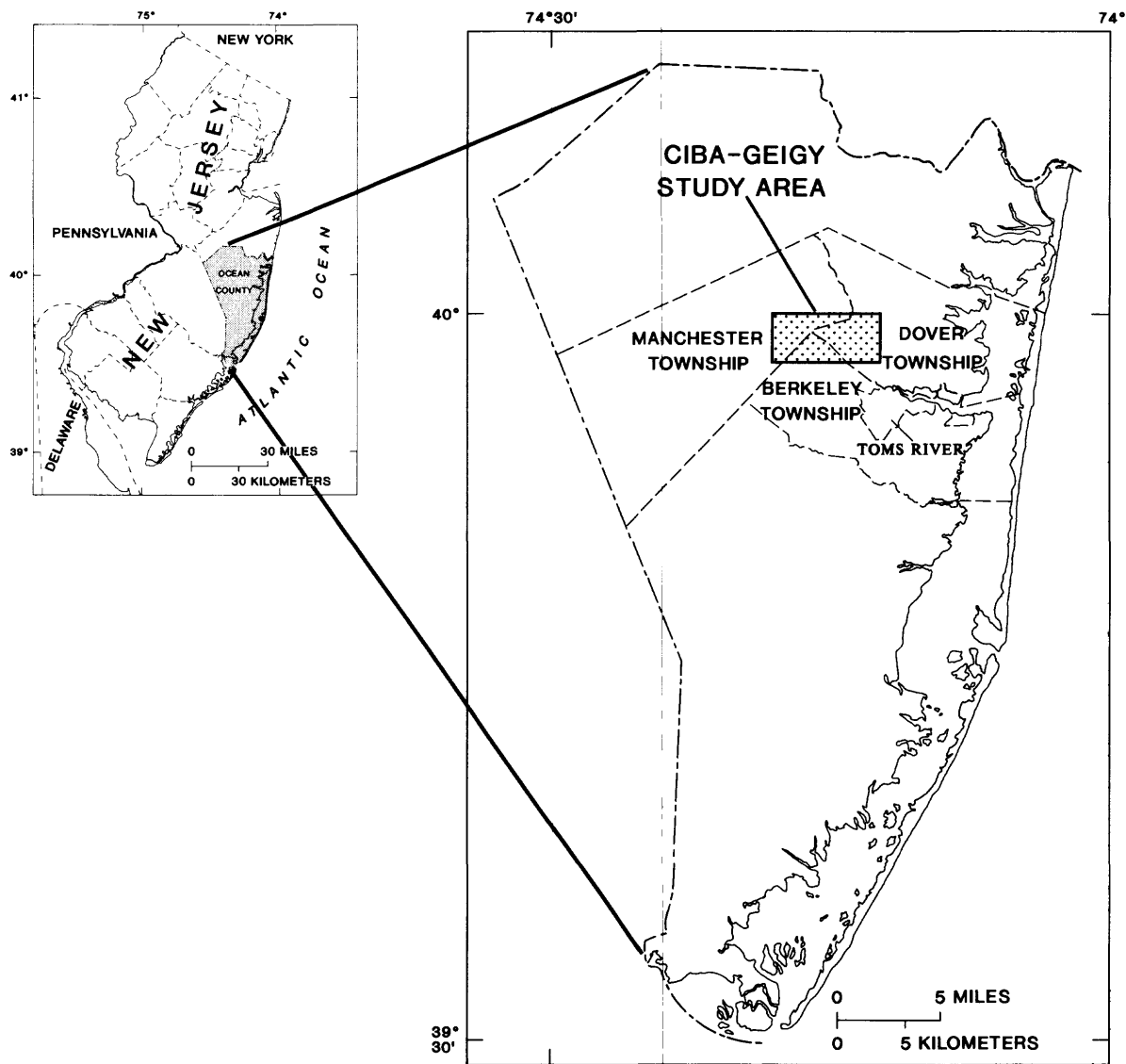


Figure 1.--Location of the study area.

tabulated results of well- and drive-point-construction data, quality-assurance and quality-control procedures, and results of water-quality sampling and analysis.

Delineation of the hydrogeologic framework in the study area was limited by the absence of deep wells. Water levels were measured only at selected wells in conjunction with specific-conductance measurements; therefore, water-level data are sparse. The ground-penetrating-radar (GPR) survey was conducted only in the part of the borrow area that was accessible to the equipment. The electromagnetic terrain-conductivity (EM) data, however, are comprehensive because the survey lines covered most of the area at the plant and extended into the floodplain on both banks of the Toms River. Ground-water samples were collected from depths of 50 ft or less below land surface because the drive points could not be installed to depths greater than 50 feet; therefore, water quality in the deep parts of the aquifer system was not investigated.

History of the Site

The chemical plant at Toms River was constructed in 1950-52; production began in 1952. The earliest known hydrogeologic study at the plant was conducted by Ranney Method Water Supplies, Inc. (1956). This investigation recommended that water supply for the plant consist of several production wells northeast of the production area near the Toms River floodplain. After contamination was discovered in two production wells, Leggette, Brashears & Graham (1959) studied the extent of the ground-water contamination and predicted which additional production wells were likely to become contaminated in the future. Geonics, Inc. (1978), conducted the initial hydrologic investigation at the then-proposed landfill at the plant. Geonics, Inc. (1980, 1982), also reported on the presence of contamination in soils at the known source areas.

In 1980, the plant owners (Ciba-Geigy Corporation and Sandoz Limited) contracted AWARE, Inc., as their primary hydrogeologic and environmental consultant. (AWARE, Inc., became Eckenfelder, Inc., in 1988.) This company conducted a performance test on the active landfill (AWARE, Inc., 1980), developed a computer model to simulate the water-table aquifer and effects of pumping a proposed recovery-well system (AWARE, Inc., 1984), and conducted an intensive hydrogeologic investigation which included characterizing the hydrogeologic framework, the hydraulic properties of the aquifers, ground-water-flow patterns, and soil and ground-water contamination (AWARE, Inc., July 18, 1986a). As part of an annual monitoring program, AWARE, Inc. (1986b, 1987c) and Eckenfelder, Inc. (1989), measured apparent electromagnetic-terrain-conductivity in the vicinity of the active landfill. AWARE, Inc., studied treatment alternatives for decontaminating ground water (1987a), conducted a supplemental investigation focusing on soil contamination in the backfilled-lagoons area and filtercake-disposal area (1987b), and investigated the source of organic compounds in ground water in the vicinity of the active landfill area (1988).

USEPA involvement at the plant began in early 1980; throughout that year, the agency performed a site inspection and hazardous-waste investigations. In 1982, part of the plant and the adjacent land was designated a Superfund site.

USEPA contracted NUS Corporation to conduct a remedial investigation/feasibility study for the USEPA. The NUS report (NUS Corporation, 1988)² included characterization of the hydrogeologic framework, the hydraulic properties of the aquifer, ground-water-flow patterns, and soil and ground-water contamination at and near the plant.

ENVIRON (1986a) developed a computer model to simulate ground-water flow at the Superfund site and vicinity and assessed environmental risks associated with ground-water contamination at the Superfund site (ENVIRON, 1986b).

During 1986, officials of Ciba-Geigy Corporation appointed a scientific advisory committee to review hydrogeologic investigations conducted at the Toms River plant. The resulting report (Pinder and others, 1988) includes information on the hydrogeologic character of the Kirkwood Formation; the effects of the Toms River on the regional flow system, the potential migration of dense, nonaqueous phase liquids, and the potential contamination of the unit referred to as the Kirkwood no. 1 sand.

Camp Dresser & McKee, Inc. (1988), developed a computer model for USEPA to simulate ground-water flow and solute transport at the Superfund site and the nearby Toms River Water Company fields. (The model simulated the effectiveness of ground-water decontamination.) Camp Dresser & McKee, Inc. (1989), and subcontractor Dynamac developed a workplan for characterizing contamination at the source areas for USEPA. This work began in late 1989.

Acknowledgments

The authors express gratitude to John Simas of the Ciba-Geigy Toms River Chemical Company plant for providing an on-site field office, air-quality data for monitoring wells, construction of roads for the USGS drilling rig, and acquisition of a digital map of the site. We also thank Dennis O'Neil and Gary Krammer of the Dover Township Parks and Recreation Department for information about, and access to, Winding River Park for drilling and geophysical surveys.

DESCRIPTION OF THE STUDY AREA

Location and Extent

The Ciba-Geigy Toms River Chemical Company plant is in Dover Township, Ocean County, New Jersey, approximately 3 mi (miles) northwest of Toms River, New Jersey (fig. 1). The plant is an active manufacturing facility consisting of 30 major buildings on 320 acres (fig. 2). The plant site comprises 1,402 acres, with 1,082 acres undeveloped and mainly forested. The plant site is bounded by the Toms River, Winding River Park, and the development adjacent to Cardinal Drive (hereafter the Cardinal Drive area) on the east; by Route 37, residential developments, and commercial and light-industrial complexes to the south and west; and by the Pine Lake residential development to the north.

² The views represented in this report (NUS Corporation, 1988) are not necessarily the views of the U.S. Environmental Protection Agency.

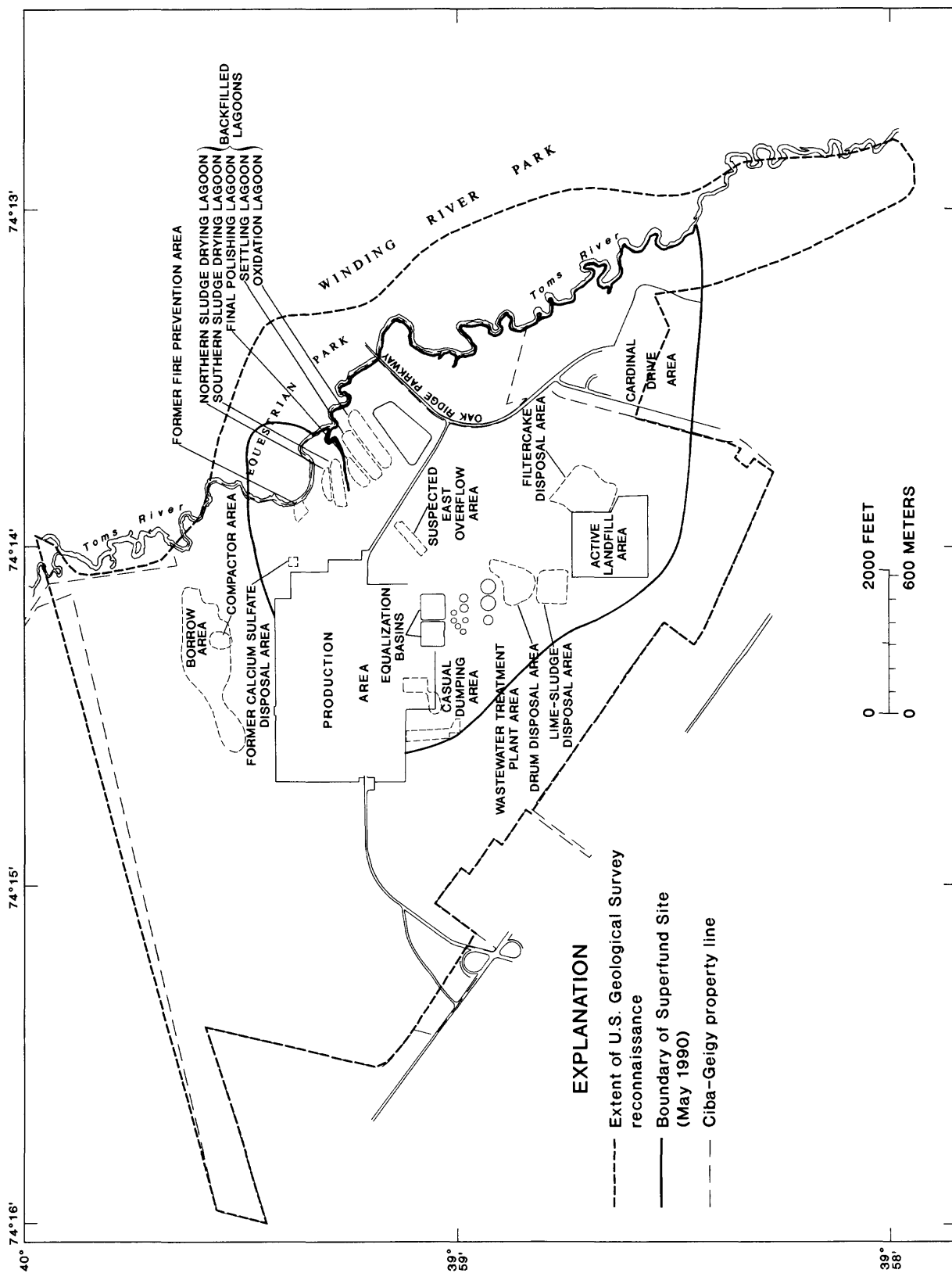


Figure 2.--Ciba-Geigy Toms River Chemical Company plant and vicinity.

The study area includes the plant site, parts of Winding River Park, and the Cardinal Drive area (fig. 2). The study area is flat except for a scarp adjacent to the Toms River. Altitudes range from approximately 70 ft (feet) above sea level in the extreme western part to approximately 10 ft above sea level along the Toms River.

A Superfund site is defined as the area that is presently contaminated and adjacent areas where contamination is likely to migrate (S. Cipot, U.S. Environmental Protection Agency, oral commun., 1990). Although the boundary of the Ciba-Geigy Superfund site is variable because the exact location and extent of the contamination are unknown, the approximate boundary, estimated on the basis of previous work (NUS Corporation, 1988, fig. 4-29), is shown in figure 2.

Hydrogeology

Structural Setting

The Superfund site is situated in the New Jersey Coastal Plain, a seaward-dipping wedge of unconsolidated sediments that range in age from Cretaceous to Holocene (table 1). These sediments, for the most part, are composed of clay, silt, sand, and gravel (Zapeczka, 1989, p. B-5) and are classified as continental, coastal, or marine deposits. The Cretaceous and Tertiary sediments generally strike northeast-southwest and dip gently to the southeast at 10 to 60 ft/mi (feet per mile). Overlying Quaternary deposits, where present, are essentially flat-lying. The Coastal Plain deposits thicken seaward (Zapeczka, 1989, p. B-5 and pl. 3) and are approximately 2,100 ft thick in the study area. The Coastal Plain sediments lie unconformably on pre-Cretaceous bedrock that consists mainly of metamorphic and igneous rocks.

In 1968 a deep test hole drilled in the study area in Cretaceous sediments to 2,254 ft below land surface was completed as a USGS observation well (Toms River Chemical 84 well) screened in the Potomac-Raritan-Magothy aquifer system (app. A). Cores from the test hole were used to determine the geologic age of the sediments at the site. Figure 3 shows the Cretaceous geologic units from 600 ft below the surface to the bottom of the hole (Perry and others, 1975, fig. 11). Enright (1969) used the core samples from the upper part of the same test hole to describe the Eocene deposits in the northern Coastal Plain of New Jersey. Enright (1969, p. 16 and 18) places the bottom of the Manasquan Formation of Eocene age at about 500 ft below land surface and the top of the Eocene Shark River Formation at about 220 ft below land surface at the test hole. The Shark River Formation is overlain by Miocene (Kirkwood Formation) sediments. In areas in the northeastern Coastal Plain of New Jersey, the Piney Point Formation may be equivalent to part of the Shark River Formation. Overlying the Kirkwood Formation in the study area is the Miocene Cohansey Sand (Carter, 1978) and, where present, younger Quaternary sediments.

Hydrogeologic Units

The hydrogeologic framework of the New Jersey Coastal Plain was described by Zapeczka (1989) primarily on the basis of subsurface correlations of distinctive signatures of electric and natural gamma-ray logs. The hydrologic framework was described in a series of structure-contour and isopach maps,

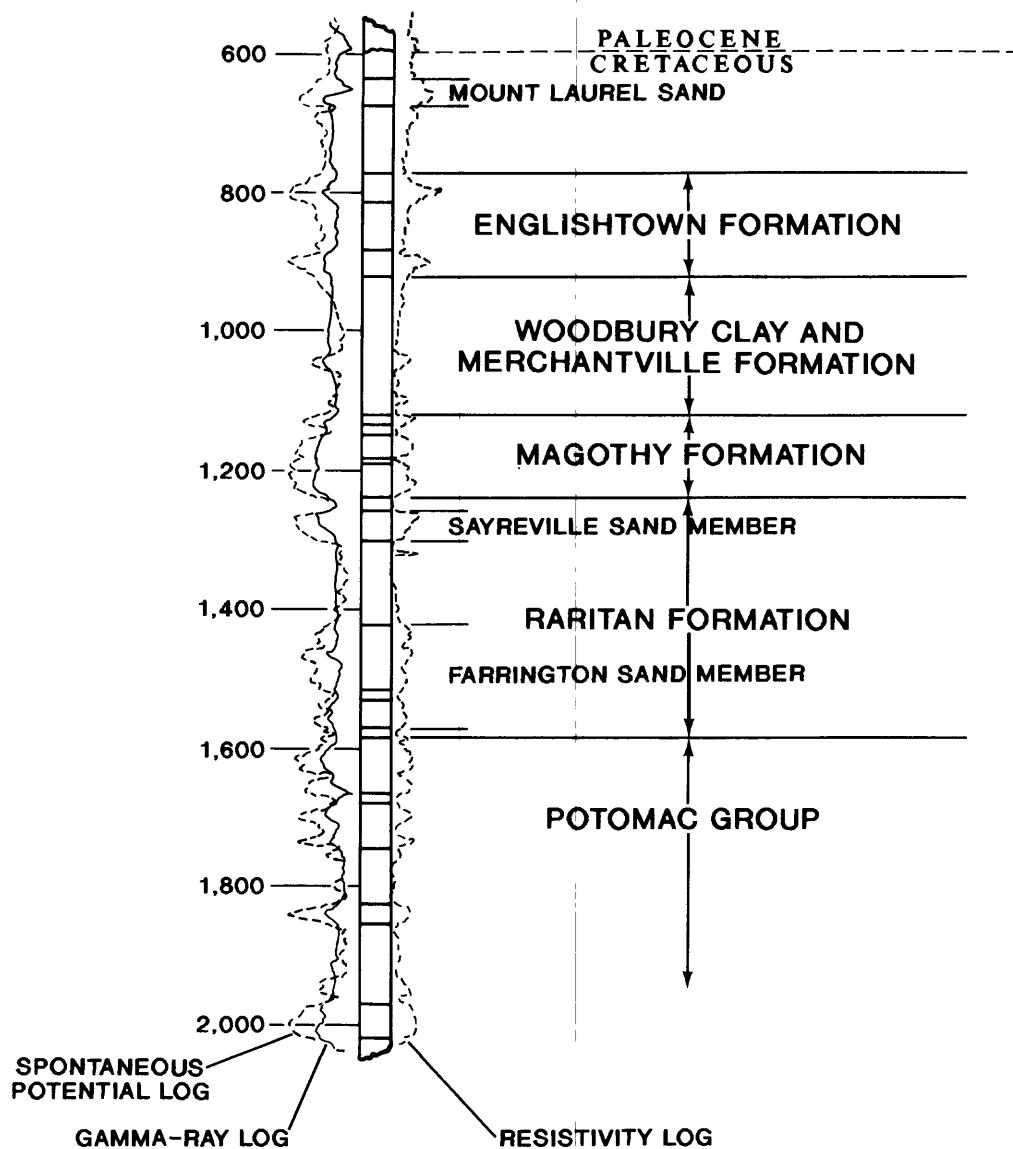
Table 1. Geologic and hydrogeologic units in the Coastal Plain of New Jersey

(Modified from Zapeczka, 1989, table 2)

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT	HYDROLOGIC CHARACTERISTICS	
Quaternary	Holocene	Alluvial deposits	Sand, silt, and black mud.	Undifferentiated	Surficial material, commonly hydraulically connected to underlying aquifers. Locally some units may act as confining units. Thicker sands are capable of yielding large quantities of water.	
		Beach sand and gravel	Sand, quartz, light-colored, medium- to coarse-grained, pebbly.			
	Pleistocene	Cape May Formation				
Tertiary	Miocene	Pensauken Formation	Sand, quartz, light-colored, heterogeneous, clayey, pebbly.	Kirkwood-Cohansey aquifer system	A major aquifer system. Ground water occurs generally under water-table conditions. In Cape May County, the Cohansey Sand is under artesian conditions.	
		Bridgeton Formation				
		Beacon Hill Gravel	Gravel, quartz, light-colored, sandy.			
		Cohansey Sand	Sand, quartz, light-colored, medium- to coarse-grained, pebbly; local clay beds.			
		Kirkwood Formation		Sand, quartz, gray and tan, very fine to medium-grained, micaceous, and dark-colored diatomaceous clay.	Confining unit	Thick diatomaceous clay bed occurs along coast and for a short distance inland. A thin water-bearing sand is present in the middle of this unit.
	Rio Grande water-bearing zone					
	Confining unit					
	Atlantic City 800-foot sand				A major aquifer along the coast.	
					Poorly permeable sediments.	
	Oligocene	Piney Point Formation ¹	Sand, quartz and glauconite, fine- to coarse-grained.	unit	Piney Point aquifer	Yields moderate quantities of water.
		Eocene	Manasquan Formation		Clay, silty and sandy, glauconitic, green, gray, and brown, contains fine-grained quartz sand.	Poorly permeable sediments.
						Paleocene
	Hornerstown Sand	Sand, clayey, glauconitic, dark-green, fine- to coarse-grained.		Poorly permeable sediments.		
	Cretaceous	Upper Cretaceous	Tinton Sand	Sand, quartz and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.	Composite	
Red Bank Sand			Red Bank Sand			Yields small quantities of water in and near its outcrop area.
Navesink Formation			Sand, clayey, silty, glauconitic, green and black, medium- to coarse-grained.	Poorly permeable sediments.		
Mount Laurel Sand			Sand, quartz, brown and gray, fine- to coarse-grained, slightly glauconitic.	Wenonah-Mount Laurel aquifer	A major aquifer.	
Wenonah Formation			Sand, very fine- to fine-grained, gray and brown, silty, slightly glauconitic.			
Marshalltown Formation			Clay, silty, dark-greenish-gray; contains glauconitic quartz sand.	Marshalltown-Wenonah confining unit	A leaky confining unit.	
Englishtown Formation			Sand, quartz, tan and gray, fine- to medium-grained; local clay beds.	Englishtown aquifer system	A major aquifer. Two sand units in Monmouth and Ocean Counties.	
Woodbury Clay			Clay, gray and black, and micaceous silt.	Merchantville-Woodbury confining unit	A major confining unit. Locally the Merchantville Formation may contain a thin water-bearing sand.	
Merchantville Formation			Clay, glauconitic, micaceous, gray and black; locally very fine grained quartz and glauconitic sand are present.			
Lower Cretaceous			Magothy Formation	Sand, quartz, light-gray, fine- to coarse-grained. Local beds of drak gray lignitic clay. Includes Old Bridge Sand Member.	Potomac-Raritan-Magothy aquifer system	Upper aquifer
		Raritan Formation	Sand, quartz, light-gray, fine- to coarse-grained, pebbly, arkosic; contains red, white, and variegated clay. Includes Farrington Sand Member.	Confining unit		
				Middle aquifer		
		Potomac Group	Alternating clay, silt, sand, and gravel.	Confining unit		
				Lower aquifer		
Pre-Cretaceous		Bedrock	Precambrian and lower Paleozoic crystalline rocks, metamorphic schist, and gneiss; locally Triassic sandstone and shale and Jurassic diabase are present.	Bedrock confining unit	No wells obtain water from these consolidated rocks, except along Fall Line.	

¹ of Olsson and others, 1980

TOMS RIVER CHEMICAL WELL 84



(Location of well shown on figure 19)

Figure 3.--Generalized hydrogeologic section through the Coastal Plain in Ocean County, New Jersey. (Modified from Perry and others, 1975, fig. 11.)

hydrogeologic sections, and a table of the tops and bases of hydrogeologic units of wells and test holes, including the Toms River Chemical 84 test hole, located in the study area. Hydrogeologic data obtained from below 600 ft in that test hole are shown in figure 3.

The uppermost hydrogeologic unit in the study area is the Kirkwood-Cohansey aquifer system, which is predominantly a water-table aquifer with locally perched water tables and semiconfined conditions (Zapeczka, 1989, p. 32). This aquifer system is composed of the Kirkwood Formation and the Cohansey Sand, and, depending on location, it can include overlying Tertiary and Quaternary deposits (Rhodehamel, 1973). This aquifer system is 225 ft thick at the Toms River Chemical 84 well site and is a major source of domestic, public, and industrial water supply in Ocean County (Vowinkel, 1984, p. 7 and 19).

The Kirkwood Formation has a variable lithology. In coastal areas, thick clay beds with interbedded zones of sand and gravel are dominant. Updip from the coast, fine to medium sand and silty sand are common, and regionally extensive clay beds are found in the basal part. The base of the Kirkwood-Cohansey aquifer system at the Toms River Chemical 84 well site is 140 ft below sea level.

The Cohansey Sand, also of Miocene age, tends to be coarser grained than the underlying Kirkwood Formation. It is predominantly a light-colored quartz sand containing minor amounts of pebbly sand, fine- to coarse-grained sand, silty and clayey sand, and interbedded clay (Rhodehamel, 1973, p. 24). Some local clay beds within the Cohansey Sand are relatively thick.

Underlying the Kirkwood-Cohansey aquifer system is a composite confining unit that consists of a complex series of geologic units ranging in age from Late Cretaceous to Miocene. The predominant lithology of most of these units is silty and clayey glauconitic quartz sand. The units have low to moderate permeabilities and generally are grouped together and described hydrologically as a composite confining unit (Rush, 1968; Anderson and Appel, 1969; and Nemickas, 1976). In some areas of the Coastal Plain, the composite confining units are sufficiently sandy to serve as aquifers. Depending on location within the Coastal Plain, the composite confining unit can include most, or only a few, of the following geologic units: Red Bank Sand, Tinton Sand, Hornerstown Sand, Vincentown Formation, Manasquan Formation, Shark River Formation, Piney Point Formation, and the basal clay of the Kirkwood Formation (Zapeczka, 1989, p. 24). At the Toms River Chemical 84 well, the bottom of the composite confining unit is 589 ft below sea level (Zapeczka, 1989, p. B45).

The hydrogeologic units below the composite confining unit are the Wenonah-Mount Laurel aquifer, the Marshalltown-Wenonah confining unit, the Englishtown aquifer system, the Merchantville-Woodbury confining unit, and the Potomac-Raritan-Magothy aquifer system. The lithology of the geologic formations comprising these hydrogeologic units and their hydrogeologic characteristics are given in table 1. The tops and bases of these hydrogeologic units are shown in figure 3.

Ground-Water Withdrawals

Potable water for the study area and vicinity is obtained from either domestic or public wells. Residential areas in Dover Township obtain water from domestic wells or from the Toms River Water Company. Although in the past residents in the Cardinal Drive area (fig. 2) relied solely on domestic wells for potable water, all now receive public water. Potable water in Dover Township, including the Cardinal Drive area, is furnished by the Toms River Water Company. Residents in the Coulter Street area still (1990) obtain water from domestic wells. In the past, residents of Pine Lake Park, Manchester Township, north and east of the study area, have relied solely on water from domestic wells; however, the area will soon receive public water. In 1989-90, two deep wells screened from 997 to 1,146 and 1,013 to 1,189 ft below land surface in the Potomac-Raritan-Magothy aquifer system were placed into operation by the Manchester Township Municipal Utility Authority. Part of Pine Lake Park is currently (1990) served by these wells.

A number of large-capacity wells in and near the study area are used for industrial, ground-water-decontamination (fig. 4), and public-supply purposes (app. A; fig. 5). The wells are located within a radius of 2 mi of the center of the Ciba-Geigy plant (fig. 4 and 5). In 1990 Ciba-Geigy operated eight production wells and seven ground-water-decontamination (purge) wells on the plant site. Some of the production wells provide potable water for the plant. Ciba-Geigy production wells withdrew 3.8 Mgal/d (million gallons per day), and the purge-well system along Cardinal Drive withdrew 0.36 Mgal/d for the time November 1985 through January 1986. (Camp, Dresser & McKee, March 1988, p. 3-8).

Toms River Water Company operated 13 wells within 2 mi of the Ciba-Geigy plant site in 1989. Eleven wells were screened in the Kirkwood-Cohansey aquifer system, one in the Piney Point aquifer, and one in the Potomac-Raritan-Magothy aquifer system. Total withdrawals in 1989 were 29 Mgal/d.

Site Operations

Construction at the Ciba-Geigy Toms River plant began in 1950. The manufacturing facility commenced operation in 1952. By 1962 the manufacturing facility at the Ciba-Geigy Superfund site comprised 30 major buildings, a wastewater-treatment plant with a rated capacity of 7.5 Mgal/d, and a lined reservoir for emergency storage of untreated and treated wastewater (NUS Corporation, 1988, p. 3-51). The active landfill, consisting of three cells in various stages of operation, began operation in 1977 (Roman Luzeky, N.J. Department of Environmental Protection, written commun., 1990). Many of the buildings have since been demolished or are scheduled for demolition. The property is fenced except for the wooded area in the northwestern part of the study area.

A variety of synthetic organic pigments, organic dye stuffs and intermediates, and epoxy resins were produced at the plant during 1952-88. The facility had a daily production capacity of 220,000 pounds of dye stuffs and intermediates and 105,000 pounds of epoxy resins (NUS Corporation, 1988). Dye manufacturing was phased out in 1988. Epoxy-resin manufacturing is scheduled to end in late 1991. Dye-standardization operations are expected to continue indefinitely (Camp Dresser & McKee, Inc., 1989, p. 2-2).

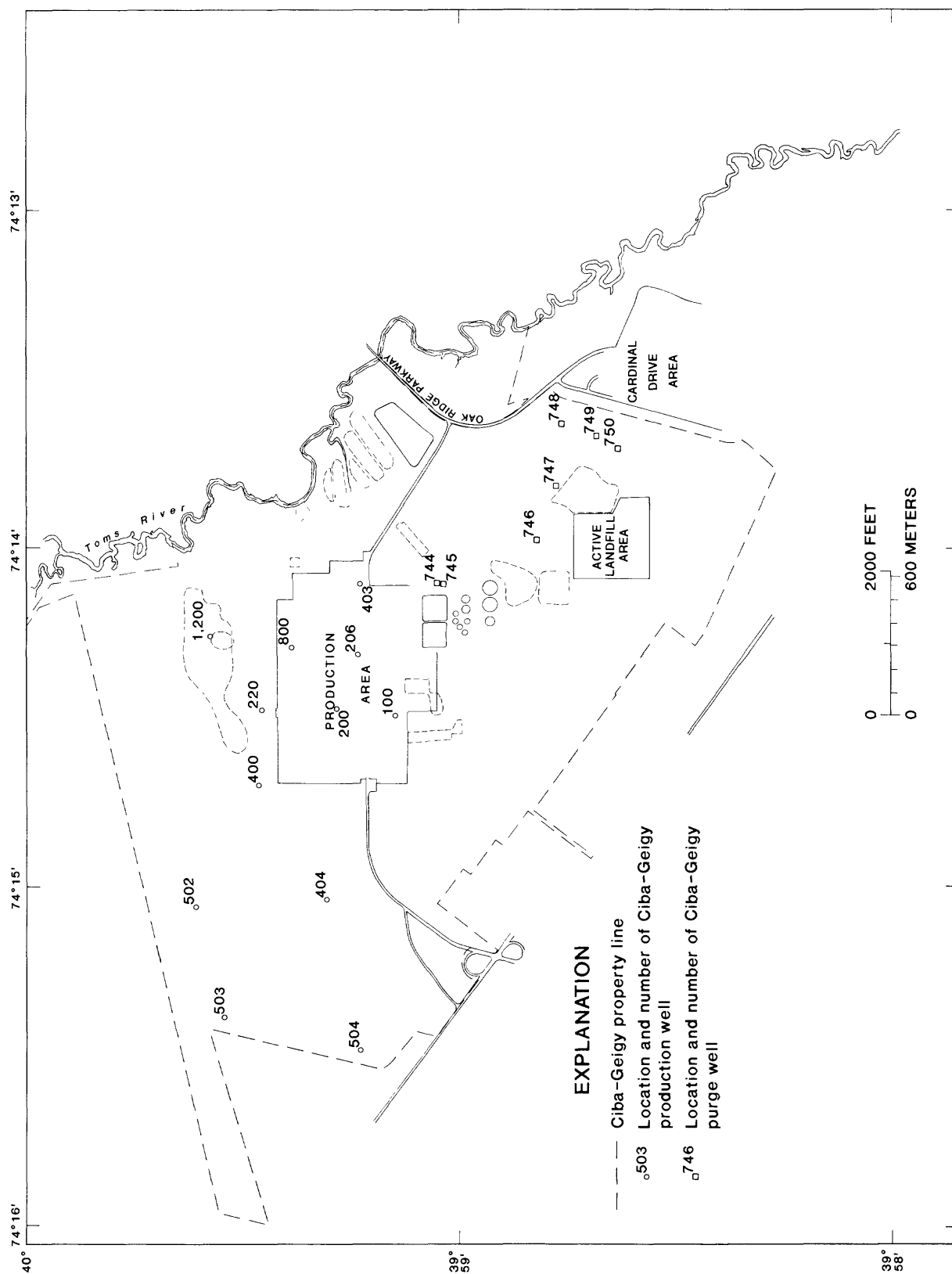


Figure 4.--Locations of production and purge wells at the Ciba-Geigy Toms River Chemical Company plant.

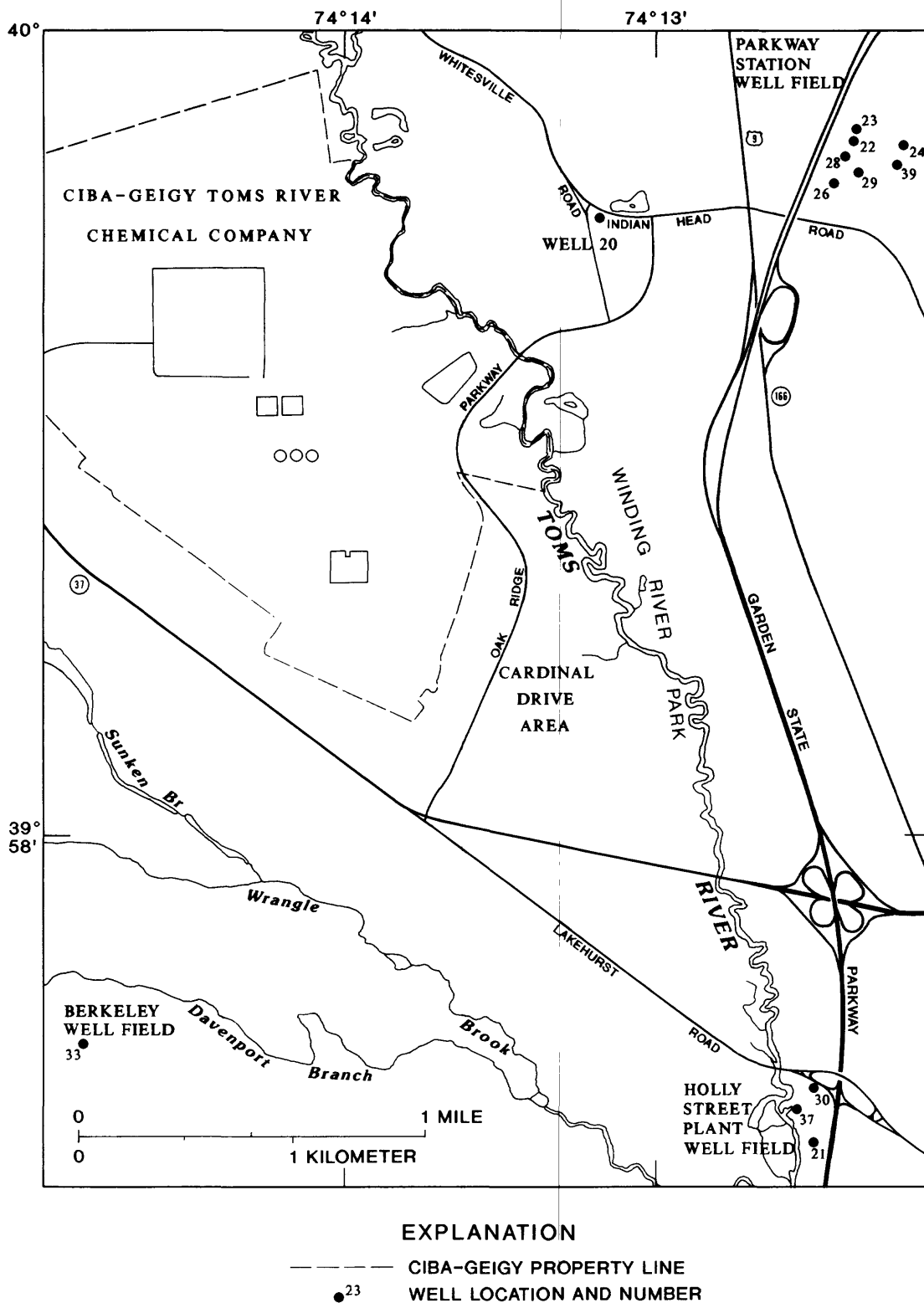


Figure 5.--Locations of public-supply wells in the vicinity of the Ciba-Geigy Toms River Chemical Company plant.

The manufacturing operations produce both liquid and solid wastes. As of 1990, liquid waste is treated on-site in a wastewater-treatment plant prior to discharge to the Atlantic Ocean. Solid wastes are disposed of off-site. Sludges from the wastewater-treatment plant are disposed of in the third cell of the permitted on-site solid-waste landfill. In the past, solid waste and sludges from the on-site wastewater-treatment plant, as well as bulk or drummed solvent-soaked residue, were disposed of in several unlined on-site lagoons and landfills (Camp Dresser & McKee, Inc., 1989, p. 2-5).

Twelve soil- and ground-water-contamination source areas and potential source areas have been reported at the plant (NUS Corporation, 1988, p. 3-1). The locations of the source areas are shown in figure 2. The 12 source areas cover approximately 194 acres. At least 107,000 drums were placed in one or more of the source areas. The total volume of waste at the site is estimated to exceed 5,885,000 gallons (NUS Corporation, 1988, p. 3.1 and 3.51). According to Pinder and others (1988, p. 21), dense, nonaqueous-phase liquids (DNAPLs) probably also are present at the Superfund site.

Organic and inorganic contaminants detected in soil and ground water during a number of previous investigations are listed in appendix B. Detailed descriptions of source areas are available in Camp Dresser & McKee, Inc. (1989, p. 3-1 to 3-35).

Location of Soil- and Ground-Water-Contamination Sites

Production Area.--This area is the industrial facility where manufacturing occurs (fig. 2). Several tank- and drum- storage areas are located here. Until 1980, inspection reports indicated a lack of spill-prevention controls in some drum-storage areas (Camp Dresser and McKee, Inc., 1989). This area is a possible source of DNAPL contamination (Pinder and others, 1988, p. 22).

Backfilled Lagoons Area.--This area contains five unlined lagoons (fig. 2) that received effluent from the former wastewater-treatment system, which operated from 1952 through 1977. The three southern lagoons were used for sediment settling and biological treatment, and the two northern lagoons were sludge-drying beds. Closure in 1978 involved the removal of waste, which was placed in the active landfill, and backfilling of lagoons (NUS Corporation, 1988, p. 3-6).

Drum-Disposal Area.--This area covers 5.3 acres (fig. 2) and originally was part of a large, unlined settling lagoon. Drums are evident in photographs taken in 1965 (Hickerson, 1984, p. 15). An estimated 92,000 drums in the drum-disposal area contain resin residues, clarification residues, and distillation residues from manufacturing epoxy resins, dyes, and pigments (Camp Dresser & McKee, Inc., 1989, p. 3-6). During closure, the site was overlain with a 30-mil PVC (polyvinyl chloride) membrane. The PVC casing of well 0111, located near the drum-disposal area (fig. 2), was dissolved above the water table at the top of a clay layer (NUS Corporation, 1988, p. 3-28). A granular, asphalt-like material appears to have flowed through the dissolved part of the PVC casing, down the well casing, and probably out through the screen. Some of the granular, asphalt-like material was found in the interior of the casing and on the screen. Consequently, DNAPLs may be present in the vicinity of well 0111 (Camp Dresser & McKee, Inc., 1989, p. 3-9). The deteriorated well casing subsequently was removed.

Lime-Sludge-Disposal Area.--This 3.9-acre area was used from 1952 to 1977 and contains approximately 49,600 cubic yards of waste (fig. 2). Waste consisted of calcium carbonate sludge enriched with metals from the wastewater-treatment operations. The area was closed with a 30-mil PVC liner (Camp Dresser & McKee, Inc., 1989, p. 3-24).

Filtercake-Disposal Area.--This area covers approximately 12 acres (fig. 2) and was used from 1952 to 1977 for disposal of dried sludge from wastewater-treatment operations. Aerial photographs taken in 1956 show evidence of disposal activity and drums appear on photographs taken in 1961 (Hickerson, 1984, p. 7 and 9). The site was covered with a soil layer on closure.

Former Calcium Sulfate-Disposal Area.--This area was used in the mid-1960's as a repository for calcium sulfate sludge (fig. 2). The site consisted of a 75-ft² (square feet) pit excavated to a depth of 10 ft that currently is covered with soil (Camp Dresser & McKee, Inc., 1989).

Wastewater-Treatment-Facility Area.--The wastewater-treatment facility began operation in 1952 and has been upgraded continually. The facility discharged wastewater to the Toms River from 1952 to 1966 and to the Atlantic Ocean through a pipeline from 1966 to the present (1990). The original facility was south of the production area. Modifications included the addition of five lagoons adjacent to the Toms River (see section on backfilled-lagoons area). The current facility (fig. 2) began operation in 1987 (Camp Dresser & McKee, Inc., 1989).

Active Landfill.--This facility, which became operational in 1977, consists of three cells and covers approximately 18 acres. Landfill cells 1 and 2 are double-lined with 30-mil PVC and include a leachate-collection system. Cell 3 is double-lined with 80-mil high-density polyethylene, and only wastewater-treatment-facility sludge is permitted for disposal (Roman Luzecky, N.J. Department of Environmental Protection, written commun., 1990). Wastes permitted for disposal in cells 1 and 2 are filtercake from the wastewater-treatment plant and resin residues, clarification residues, and distillation residues from the manufacture of epoxy resins, dyes, and pigments. The upper landfill liners of cells 1 and 2 have been reported to leak into the lower detection system above the second liner (Roman Luzecky, N.J. Department of Environmental Protection, written commun., 1990). During 1984, 34 drums of toluene-contaminated waste were removed from the landfill. More than 15,000 drums of waste were removed from cell 2 in 1985 and 1986 (NUS Corporation, 1988, p. 3-49).

Compactor Area.--Nonhazardous plant refuse, predominantly construction debris, reportedly was compacted here beginning in 1975 (fig. 2; NUS Corporation, 1988, p. 3-56). Packaging material containing residual wastes may have been disposed of in this area. (NUS Corporation, 1988, p. 3-56.)

Fire Prevention-Training Area.--This area is located east of the production area and adjacent to the Toms River (fig. 2). Oils and solvents reportedly were burned in kettles in this area for fire-prevention exercises (AWARE, Inc., 1986a). Water used to put out the fires apparently flushed contaminants into the soils and ground water (AWARE, Inc., 1986a). According

to Pinder and others (1988, p. 22), "the high concentrations of contaminants (2.5-quote of the solubility of the observed compounds) at RI-9 suggest the possibility of the fire prevention area as a DNAPL source." (RI-9 is an observation well near the fire-prevention area.)

Borrow Area.--The gravel pit or borrow area is a large site north of the production area that has been a source of fill and a place for piling construction debris resulting from plant activities. Aerial photographs taken in 1956 (Hickerson, 1984, p. 7) show the first evidence of activity in this area (fig. 2). Two separate areas of activity were identified--the first is north of the eastern half of the production area, and contains debris; the second is southwest of the production area, and consists of an access road leading from the western half of the production area to a pit. Aerial photographs taken during 1962 (Hickerson, 1984, p. 13) show that the original sites were expanded into one large area. Drums were stored in this area, which contained a large trench, and the old pit area was covered with fill. By 1965, the large trench also had been covered with fill. In 1976, many drums were stored in the borrow area.

Suspected East-Overflow Area.--This area parallels the pipeline that carries effluent from the wastewater-treatment plant to the backfilled lagoons (fig. 2). This area first appeared as a light-toned "possible" impoundment in aerial photographs taken in 1976 (Hickerson, 1984). This area existed in 1983 and has since been covered with fill.

Casual Dumping Area.--By 1956 several roads crossed this area (Hickerson, 1984, p. 7). During 1962, the road network included a clearing where ground-staining was evident (Hickerson, 1984, p. 11). By 1976, the production area had expanded to encompass the road network. Deteriorated drums currently are exposed on the ground surface in this area.

STUDY METHODS

In order to delineate areas of ground-water contamination at and near the Superfund site, geophysical techniques were used in combination with water-quality sampling. Geophysical methods also were used to identify possible burial sites for drums containing waste, and to enhance the interpretation of the hydrogeologic framework in the study area. A surface geophysical technique--electromagnetic- (EM) terrain-conductivity--was combined with measurements of ground-water specific conductance to identify areas of electrically conductive ground water, and to facilitate the optimum placement of drive points for collection of water-quality data from potentially contaminated parts of the study area. A borehole geophysical technique--gamma-ray logging--was used to assist in delineating the hydrogeologic framework. Another surface geophysical technique--ground-penetrating radar--was used in part of the borrow area to locate possible buried trenches that might be repositories for drums containing waste.

Geophysical Reconnaissance

Electromagnetic-Terrain-Conductivity Survey

Theory

The EM terrain-conductivity technique measures variations in the apparent conductivity of the surficial material. A Geonics EM34-3³ terrain-conductivity meter was used during this investigation. The EM34-3 consists of a transmitter and receiver, each consisting of a portable coil and an electronic module. Coils are held in a coplanar position (in the same plane), and are placed on edge for the horizontal-dipole configuration and flat for the vertical-dipole configuration. The electromagnetic dipole that is created passes through the transmitting coil's center perpendicular to the plane of the coil. This instrument has coil-spacing options of 32.8, 65.5, and 131.2 ft and is calibrated so that it directly measures apparent conductivity in mS/m (millisiemens per meter) on the basis of the low induction number (McNeil, 1980; Grantham and others, 1987).

In the horizontal-dipole configuration, the instrument is most responsive to material from land surface to depths of one-half the coil spacing; in the vertical-dipole configuration, it is most responsive to materials at depths of one-quarter to three-quarters the coil spacing (fig. 6). Increased coil separation proportionately increases depth of penetration of the magnetic field generated by the instrument in both coil positions (McNeil, 1980).

After placement of coils at the land surface at a specific coil separation and orientation, the transmitter is energized by an alternating current at an audio frequency of 0.4, 1.6, or 6.4 kHz (kiloHertz). The alternating current generates a time-varying primary magnetic field, which in turn induces eddy currents in the ground. Eddy currents generate a secondary magnetic field, which is measured by the voltage induced in the receiver coil (Keller and Frischknecht, 1966, p. 278). The magnitude and phase of the secondary magnetic field are functions of coil spacing, ground conductivity, and the operating frequency of the transmitter. Figure 6 shows the primary and secondary magnetic fields and the eddy currents generated by the instrument in the vertical-dipole mode.

The EM surveying method detects lateral and vertical changes in the apparent conductivity of the terrain. High apparent-conductivity values in most cases indicate a shallow water table, metal, the presence of clays, and (or) highly conductive ground water, such as saltwater or water contaminated with electrically conductive inorganic or organic material. Where ground-water contamination is entirely organic, and therefore nonconductive, ground-water contamination may not be detected by using this method. Low apparent-conductivity values indicate a deep water table, sands, and (or) dilute ground water. Geologic and borehole geophysical logs are then used to determine whether high apparent conductivity is caused by geologic materials.

³ Use of the trade names in this report is for identification only and does not constitute endorsement by the U.S. Geological Survey.

ELECTROMAGNETIC-INDUCTION SYSTEM

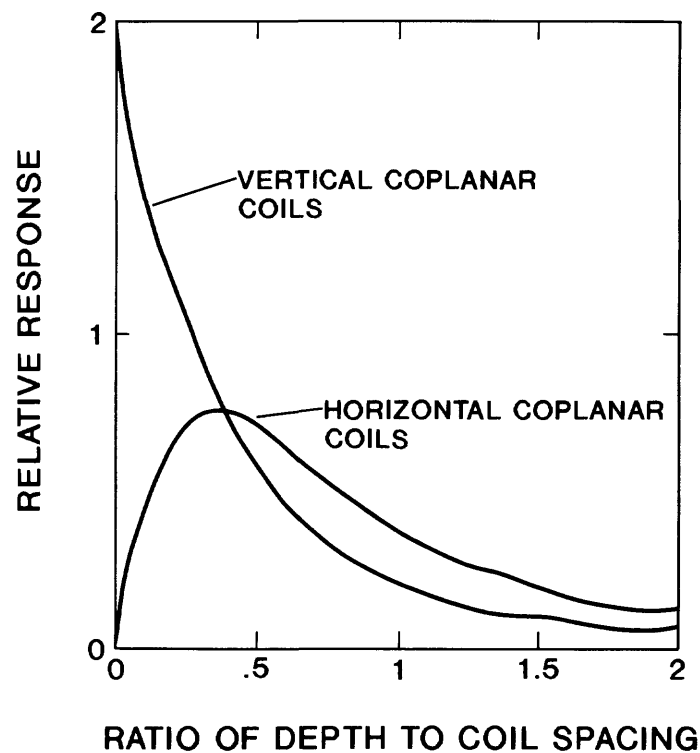
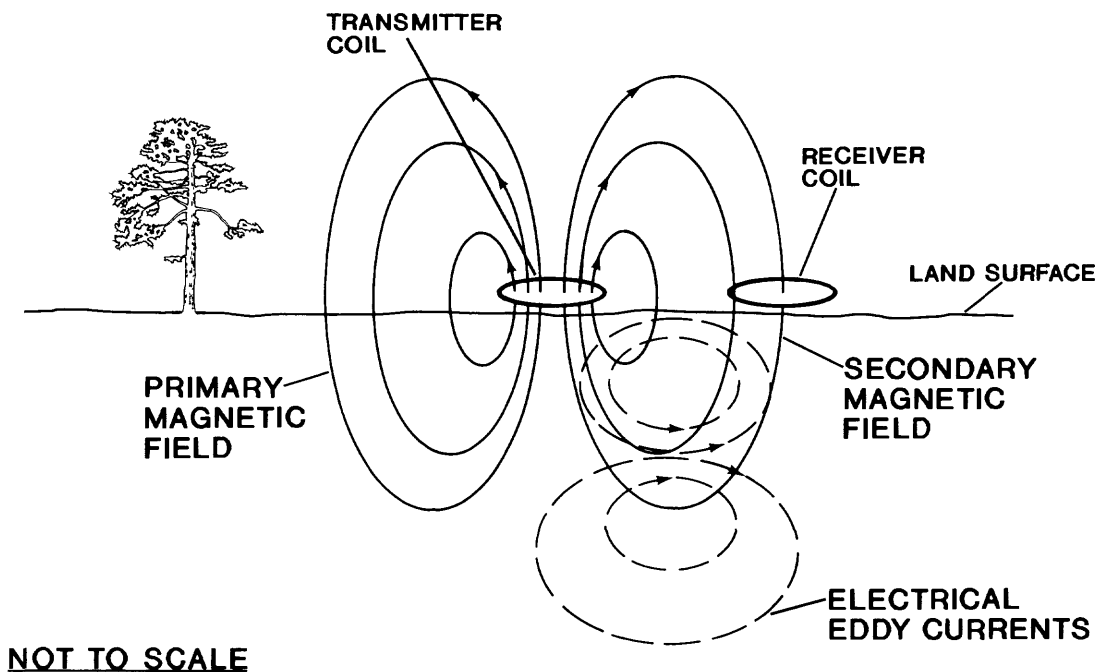


Figure 6.--Diagram showing configuration of electromagnetic-terrain-conductivity equipment and depth of exploration. (Modified from McNeil, 1980, fig. 1.)

Field Procedure

Apparent conductivity was measured at selected stations along roads, fire breaks, open fields, and wooded areas (fig. 7). Areas with above-ground and buried utilities were avoided to minimize interferences that affect electromagnetic fields. Distances between EM measuring stations along survey lines throughout the study area were either 100 or 200 ft. Equipment-calibration procedures are given in Barton (1989).

Quality Assurance and Quality Control

EM measurements were made at the start and end of each field day at the base station (fig. 7) to ensure instrument precision. The two daily base-station readings with each coil orientation and coil spread are shown in appendix C. Daily base-station readings for coil spacings of 65.6 and 131.2 ft are within 0.5 mS/m of each other, whereas daily base-station readings for instrument coil spacings of 32.8 ft (both dipole modes) are within 1.2 mS/m of each other. Transient changes of about 1.5 mS/m in apparent terrain-conductivity occurred during the survey, which was conducted during a period of 90 days. Lack of repeatability is a function of the dynamic range of the instrument (approximately 1-1,000 mS/m; McNeil, 1980, p. 10) and the shallow, dry, sandy soil at the base station, which has a conductivity of less than 1 mS/m. Transient changes probably result from alteration of the conductivity of the shallow soil by precipitation. Instrument precision at instrument coil spacings of 65.5 and 131.2 ft (both dipole modes) is more than acceptable, and at 32.8 ft (both dipole modes) is adequate.

In order to further ensure precision of the terrain-conductivity meter, apparent terrain-conductivity measurements were made at selected stations where EM-survey lines intersect or were repeated. These measurements, compared in table 2, typically are within 1 mS/m of each other. The percent difference between measurements, tabulated in table 2b, is less than 10 for the majority of stations, which is within the recommended control limit of 15 percent (Lockhead Engineering and Management Services Company, Inc., 1984).

Borehole Gamma-Ray Logging

Gamma-ray logs were run at eight wells and five drive points (fig. 8) in order to identify lithology by determining changes in conductivity and ambient radioactivity of subsurface material. These logs were used in conjunction with existing gamma-ray logs to define the hydrogeologic framework of the study area, and to help interpret the electromagnetic terrain-conductivity data and water-quality data from drive-point sampling.

A gamma-ray log is a record of the amount of natural gamma radiation that is emitted by the sediments that surround a borehole as a function of depth. This radiation results primarily from the radioisotopes of uranium, thorium, and potassium-40 and their decay products. In the New Jersey Coastal Plain the natural gamma radiation is proportional to the clay content of the formation. The chief uses of natural gamma-ray logs are the identification of lithology and stratigraphic correlation (Keys and McGary, 1971, p. 64). The logging tool measures natural gamma radiation in counts per second. Observation wells and drive-point holes were logged from the bottom to land surface.

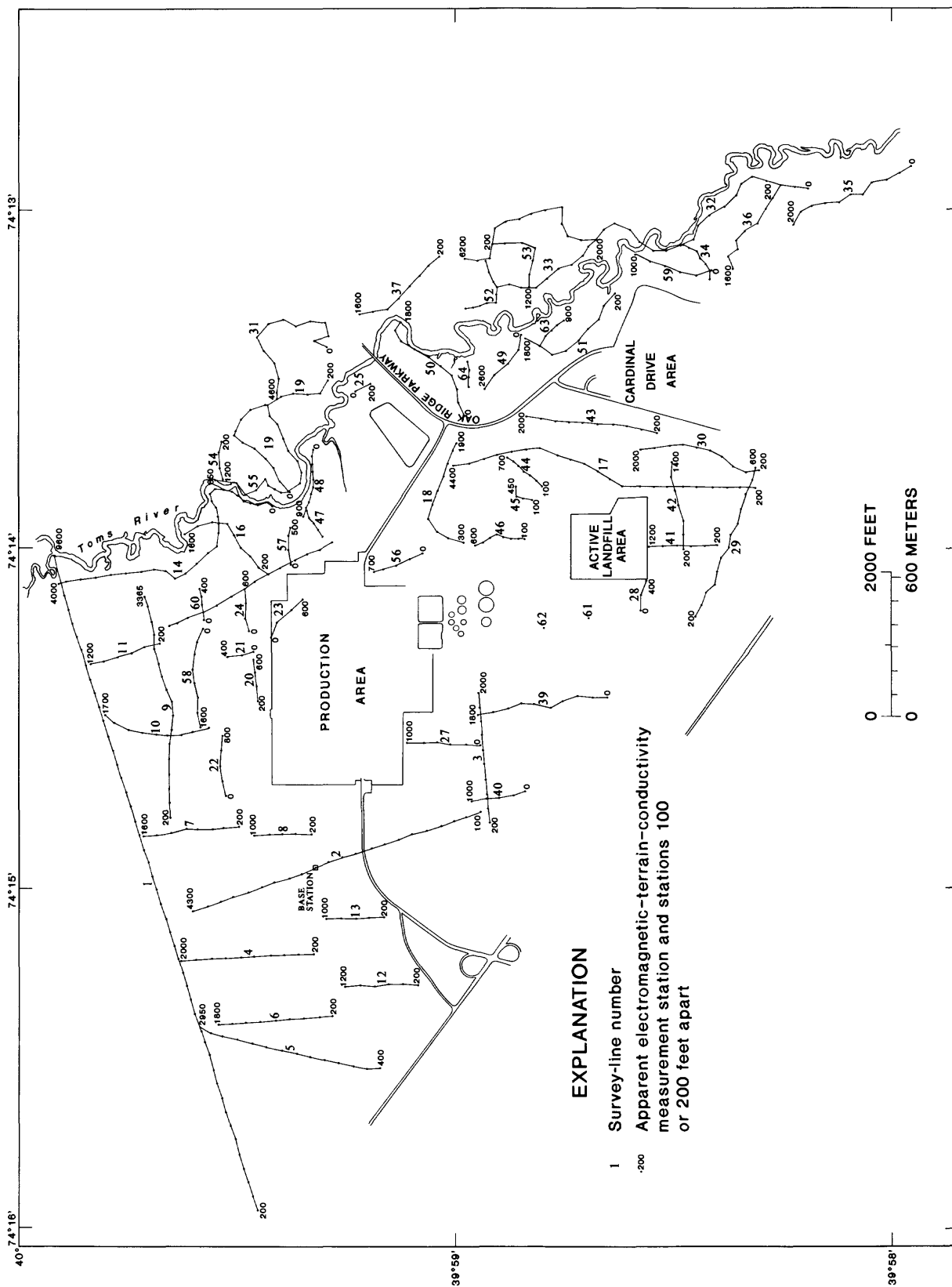


Table 2A.--Comparison of apparent-electromagnetic-terrain-conductivity measurements made twice at a station where survey lines intersect or at repeated stations in the study area

[EM, electromagnetic; VD, vertical dipole; HD, horizontal dipole; --, data not available]

EM survey line number	Station number	Distance between coils						EM survey line number	Station number	Distance between coils					
		32.8 feet VD	32.8 feet HD	65.6 feet VD	65.6 feet HD	131.2 feet VD	131.2 feet HD			32.8 feet VD	32.8 feet HD	65.6 feet VD	65.6 feet HD	131.2 feet VD	131.2 feet HD
1	2800	--	--	1.7	0.55	4.5	2.2	5	2950	--	--	1.7	1.8	4.7	2.3
1	3800	--	--	2.4	1.1	5.6	2.4	4	2000	--	--	2.0	1.6	5.3	2.7
1	5600	--	--	1.8	.6	4.6	1.5	7	1600	--	--	1.8	.7	5.1	1.2
1	7000	--	--	1.8	.9	4.7	1.2	10	1700	--	--	1.5	.4	5.0	2.0
1	8000	--	--	2.4	1.2	5.6	1.8	11	1200	--	--	2.5	.9	6.7	3.9
1	9200	--	--	3.5	1.8	8.1	5.6	14	4200	--	--	3.4	2.9	8.5	5.5
3	600	--	--	1.8	1.1	4.4	2.5	40	800	--	--	1.8	1.6	4.0	2.4
15	1600	2.3	1.2	2.6	2.0	8.0	5.2	24	600	2.3	1.7	2.6	1.8	6.2	3.2
19	2600	9.2	6.4	11.0	9.0	11.0	10.0	55	0	9.2	5.6	11.0	8.0	10.0	8.0
32	400	2.2	1.2	3.1	2.6	4.6	3.2	36	0	3.4	3.0	3.0	2.8	4.8	3.2
50	400	9.8	6.2	14.0	11.0	8.0	10.0	64	50	9.8	5.8	13.0	8.8	9.0	9.0
19	1200	2.6	2.4	3.0	2.4	6.5	3.2	19	4200	3.5	2.2	3.5	3.2	6.7	4.3
19	1200	2.6	2.4	3.0	2.4	6.5	3.2	31	2600	2.7	1.7	3.4	2.0	6.0	3.4
10	400	--	--	1.5	.5	5.0	2.3	58	1400	--	--	1.7	.6	4.9	1.8

Table 2B.--Percent difference between apparent-electromagnetic-terrain-conductivity measurements made twice at a station where survey lines intersect or at repeated stations in the study area

[VD, vertical dipole; HD, horizontal dipole; --, data not available]

Distance between coils					
32.8 feet VD	32.8 feet HD	65.6 feet VD	65.6 feet HD	131.2 feet VD	131.2 feet HD
--	--	0	56	2	4.3
--	--	9.1	18.5	2.8	5.9
--	--	0	7.7	5.2	11
--	--	9.1	38	3	2.8
--	--	2.0	25	8.9	37
--	--	1.4	23	2.3	.9
--	--	0	18.5	12	2.0
0	17	0	5.2	2.7	28.8
0	6.6	0	5.9	4.8	11.1
21.4	42	1.6	3.7	2.1	0
0	3.3	3.7	11	5.9	5.3
14.8	4.3	7.7	14.2	1.5	14.7
1.9	17	6.3	9.1	4	3.0
--	--	6.3	7.1	1.0	12.2

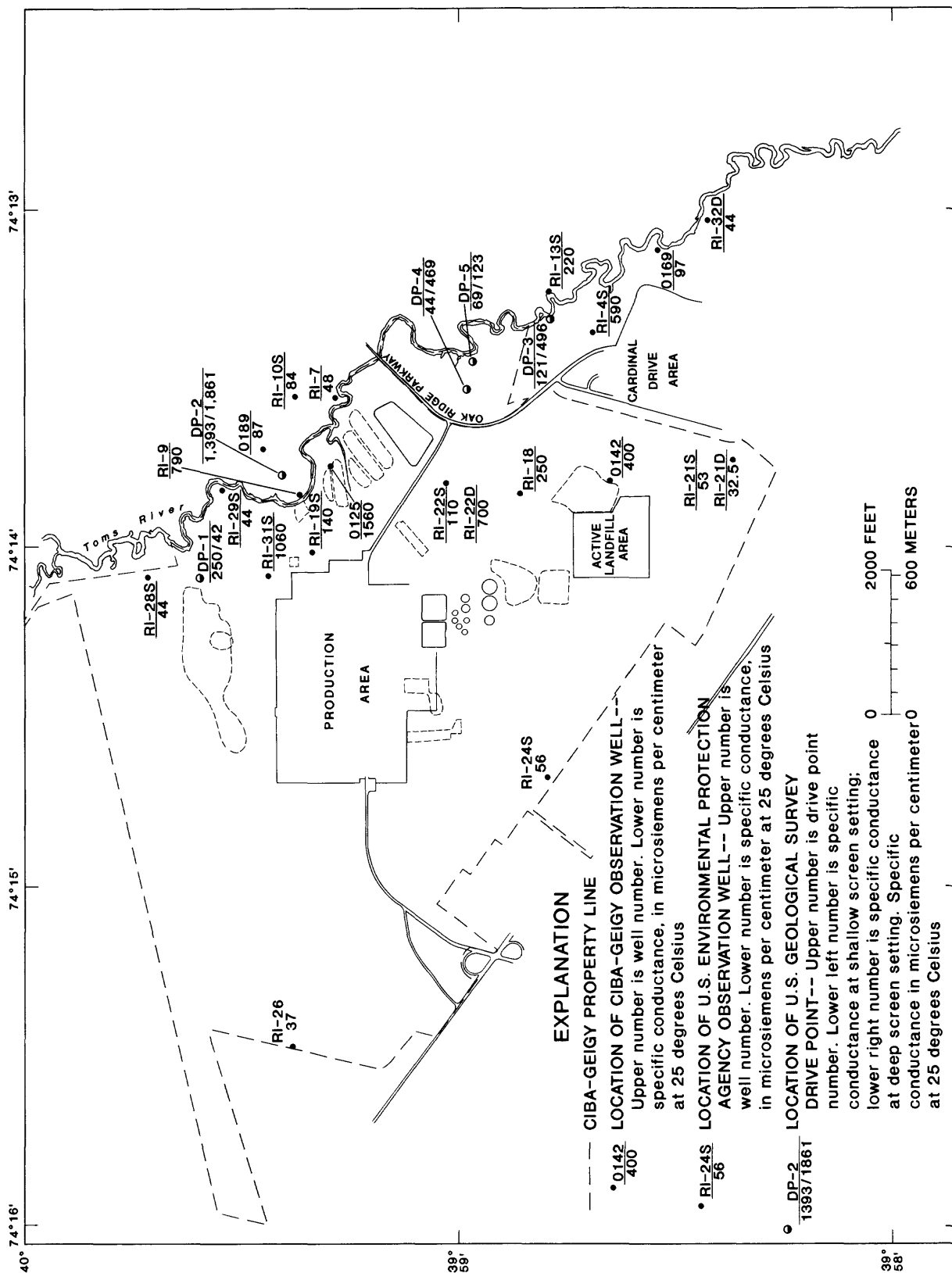


Figure 8.--Locations of wells at which gamma-ray logs were run, and specific conductance of ground water and water levels were measured; and location of ground-penetrating-radar survey grid.

Ground-Penetrating-Radar Survey

A ground-penetrating-radar (GPR) survey was conducted at the plant in part of the borrow area (fig. 8). Because records of waste disposal at the plant are incomplete, it is unknown whether drums of waste were buried in the borrow area; previously existing trenches were identified from aerial photographs. The GPR survey was undertaken to identify subsurface structures that might be trenches or buried drums.

Theory

GPR systems radiate short pulses of electromagnetic energy from a transmitting antenna. This energy enters the subsurface and, when electrical inhomogeneities are encountered, some energy is reflected back to the radar antenna and some is transmitted downward to deeper layers (fig. 6). Electrical inhomogeneities are caused by changes in degree of saturation, clay content, and composition of the subsurface materials, and by anthropogenic features such as buried drums.

The GPR record displays total travel time for a signal to pass through the subsurface, reflect from an inhomogeneity, and return to the surface (fig. 9). This two-way travel time, measured in nanoseconds (ns, equal to 10^{-9} seconds), can be converted to depth below land surface if the relative dielectric permittivity of the subsurface material is known or if a control point is available from which it can be calculated (Sheriff, 1984, p. 51).

If depth to a GPR reflector is known, relative dielectric permittivity at a given point can be calculated by using the following equation (Haeni and others, 1987, p. 6):

$$Er = (t/2)^2 \times (c/d)^2$$

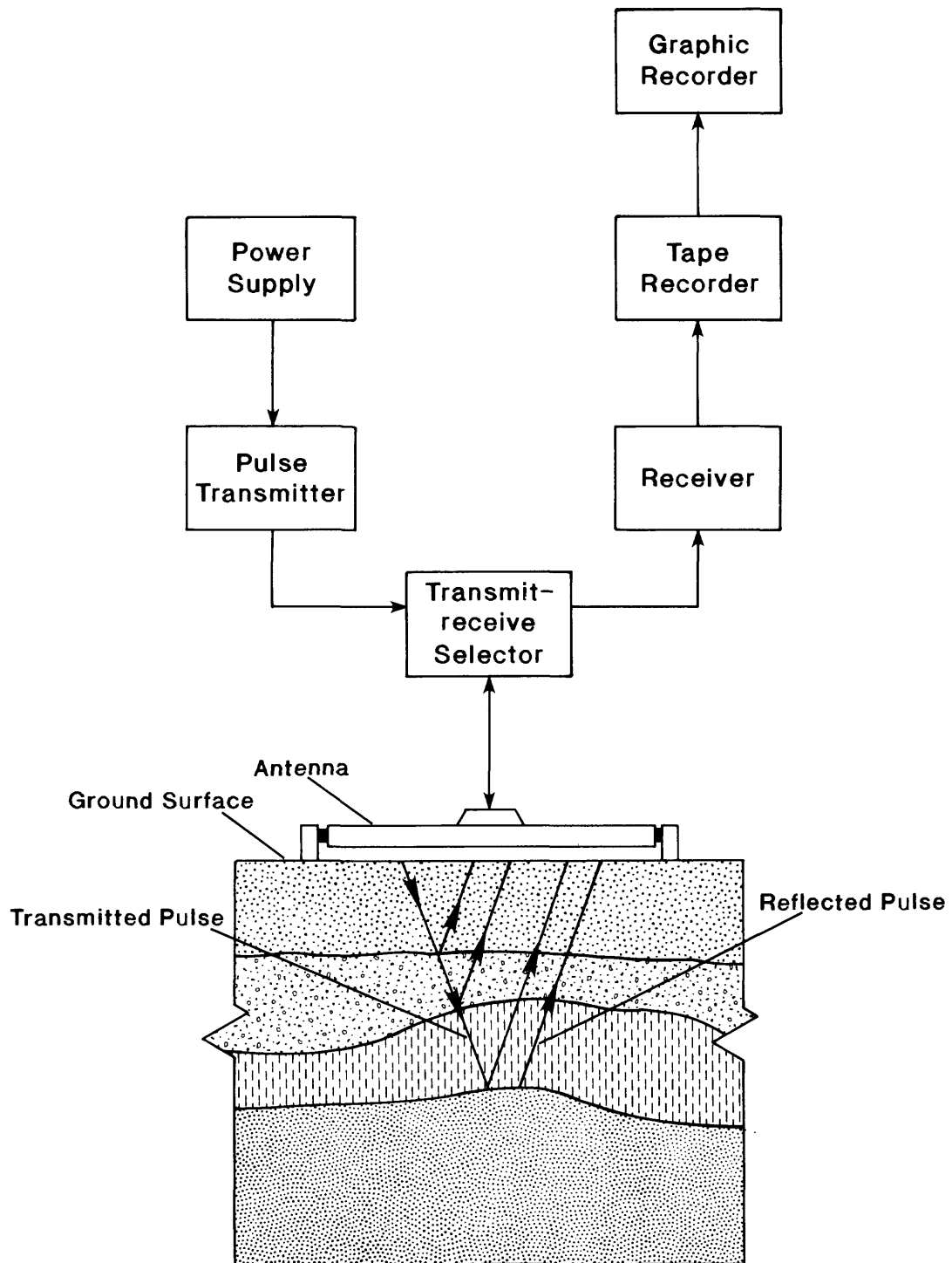
where Er = relative dielectric permittivity (a dimensionless ratio);
 t = two-way travel time, in seconds;
 c = speed of light in free space (9.835712×10^8 ft/s unit of measurement), and
 d = depth to the reflector, in feet.

If relative dielectric permittivity is calculated from the equation above or is estimated from published data, depth to a reflector can be calculated by use of the equation:

$$d = \frac{ct}{2} \sqrt{2} ,$$

where t = two-way travel time, in seconds;
 c = speed of light in free space (9.835712×10^8 ft/s unit of measurement), and
 d = depth to the reflector, in feet.

PROFILING RADAR



NOT TO SCALE

Figure 9.--Functional operation of a ground-penetrating-radar system.
(Modified from Haeni and others, 1987, fig. 3.)

Field procedure

A GPR system manufactured by Geophysical Survey Systems with an 80- and 300-MHz (megahertz) transceiver was used to profile the subsurface of the borrow area (fig. 8). The GPR grid was established by using standard surveying methods. Each cell of the grid measures 50 ft by 50 ft. The latitude and longitude of selected grid locations were measured, enabling reconstruction of the grid at a later date. GPR profiles were collected continuously along north-south traverses (total length of 2,400 ft) and west-east traverses (total length 2,100 ft). All GPR profiles were run with a scan of 300 ns (two-way travel time), which for this survey gives a penetration depth of approximately 56 ft.

Water-Quality Reconnaissance

Measurement of Specific Conductance

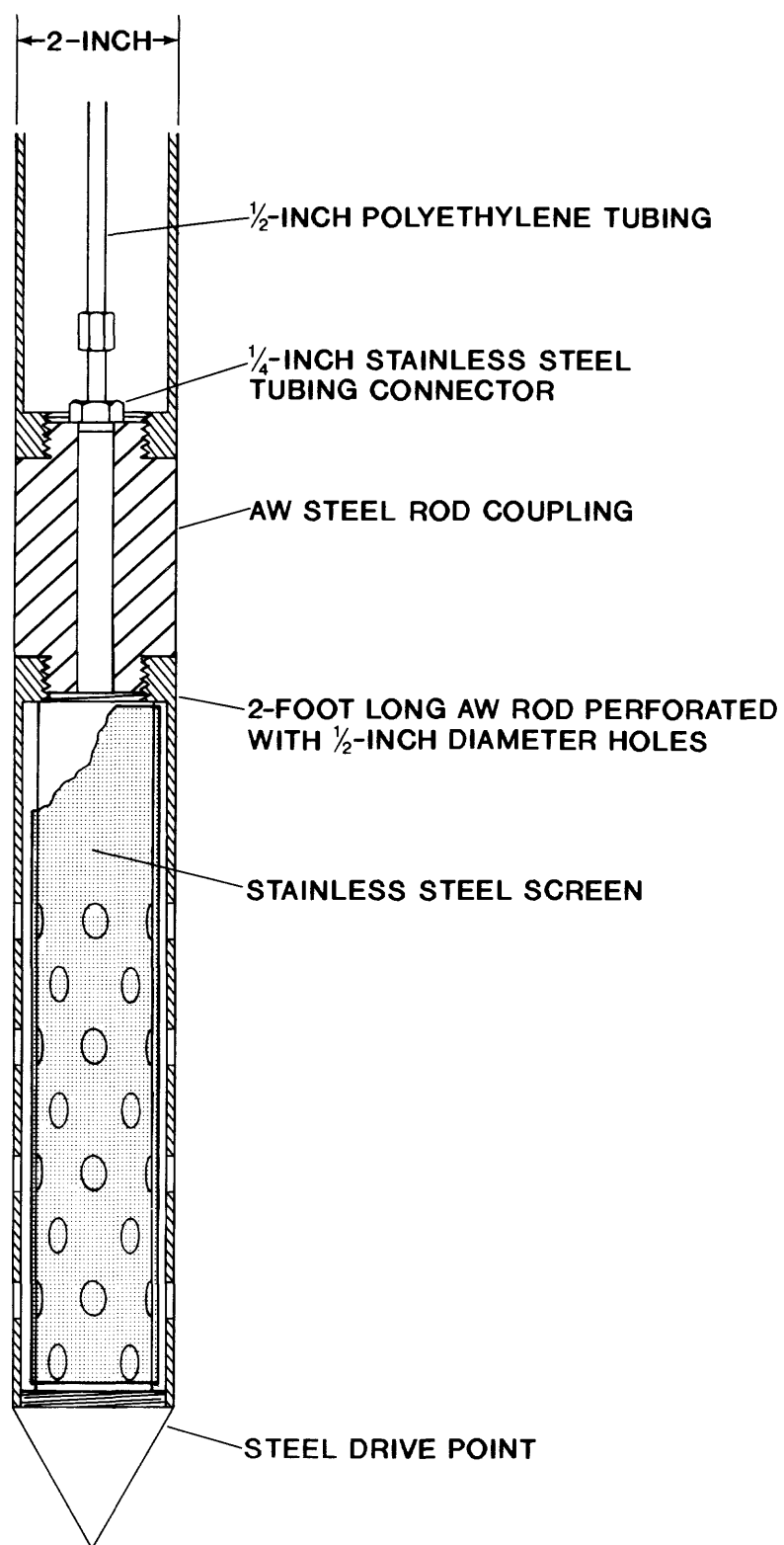
Nineteen of the existing observation wells were selected for measurement of specific conductance. A broad geographic distribution of wells was chosen to ensure that the specific-conductance measurements would be representative of conditions throughout the site. One well nest (one shallow well and one deep well) was included. Static ground-water levels (app. D) were measured with a steel tape to determine the required purging volume for the well. Wells were pumped with a submersible or centrifugal pump. Three casing volumes were pumped and purging continued until three successive measurements of specific conductance, made at 5-minute intervals, differed by less than five percent.

Drive-Point Sampling

Ground-water samples were collected by use of a drive-point sampler at five sites, one site adjacent to the borrow area, two Ciba-Geigy-owned sites adjacent to Winding River Park, and two sites in the park (fig. 8). Site selection for drive points was based on the results of the EM terrain-conductivity survey and the layout of the observation-well network. Ground water was sampled at two or three depths at each drive-point site. (Locations of drive points were surveyed by the U.S. Geological Survey's National Mapping Division.)

Drive-point installation and sample collection

The drive-point water-quality sampler is constructed from a 2-ft length of steel AW drill rod (fig. 10). Thirty-eight 1/2-in.-diameter holes were drilled in rows 2 in. apart into the drill rod. A stainless-steel 100-mesh wire cloth screen is inside the drill rod. A hardened-steel drive point is screwed onto the bottom of the sampler to facilitate driving the device into the subsurface. At the top of the sampler, a 3/8-in. outside-diameter stainless-steel tubing connector is threaded into the top of the coupling to allow attachment of polyethylene sample tubing. Five-ft-long sections of drill rod were added to the top of the drive-point sampler as it penetrated the subsurface. The drive point was driven into the subsurface using either a 140- or 300-pound safety hammer.



NOT TO SCALE

Figure 10.--Drive-point water-quality sampler.

Sampling intervals were determined from lithologic and gamma-ray lines and from field observations of water yields from particular intervals. When the drive point reached the sampling depth, sample tubing was attached to the peristaltic pump. Imbrigiotta and others (1988) reported a loss of purgeable organic compounds (POCs) by vacuum pumps to be approximately 20 percent. The peristaltic pump causes the POCs to degas into the vacuum created by the pump's suction-lift mechanism; however, samples can be obtained from the drive-point sampler only with a peristaltic pump. Before water samples were collected, five or more casing volumes were purged until three successive measurements of temperature, specific conductance, pH, and dissolved oxygen, taken at 5-minute intervals, differed by less than 0.2 °C (degrees Celsius), 5 percent (or 5 μ S/cm when less than 100 μ S/cm), 0.1 unit, and 0.1 mg/L (milligrams per liter), respectively. Data from the field forms are listed in appendix E.

After the sample was collected, another drill rod was attached and the sampler was driven to the next sampling interval. The drive-point sampler was removed from the ground after sampling at each site was completed. A temporary 2-in.-inside-diameter black steel (BW casing) drive point was installed in the same hole. Borehole gamma-ray logs were collected in the 2-in.-inside-diameter BW casing. The drive point was removed after gamma-ray logging, and the hole was filled to land surface with a cement (95 percent) and bentonite (5 percent) slurry by means of a tremie pipe to prevent vertical migration of contaminants.

The drive-point sampler was decontaminated according to USEPA guidelines (Kenneth Wilkowski, U.S. Environmental Protection Agency, Monitoring Management Branch, written commun., 1989). The steps are listed below--

1. Wash with a low-phosphate detergent.
2. Rinse with tap water.
3. Rinse with 10-percent nitric acid, ultrapure.
4. Rinse with tap water.
5. Rinse with acetone.
6. Rinse with deionized, analyte-free water.
7. Air dry.
8. If not used immediately, wrap the drive point in aluminum foil.

New polyethylene sample tubing was used at each drive-point sampling site, and wash- and rinse-water was contained and disposed of at Ciba-Geigy's wastewater-treatment facility. This procedure was followed to avoid possible contamination of water-quality samples with organic rinses and to ensure that the presence of other contaminants in these samples would not be masked. Also, the use of 10-percent nitric acid to rinse steel drill rods could contaminate samples with metals.

Sample Analysis

Samples collected from drive points were sent to the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado, for analysis. The NWQL is a USEPA-Region II-approved laboratory for determinations of the USEPA regulated POCs and the following trace elements and nutrients: arsenic, barium, cadmium, chromium, silver, lead, mercury, nitrate, fluoride, and selenium. Analytical methods for the determination of constituents in ground-water samples are described in Fishman and Friedman (1985) and in Wershaw and others (1987).

Drive-point water-quality samples were analyzed for dissolved ions, POCs, phenolic compounds, dissolved metals, and dissolved nutrients. Twenty-five percent of the samples collected were analyzed for total metals. Constituents determined and constituent reporting levels are listed in table 3. The sample-collection procedures are described in Hardy and others (1990). Sample treatment, preservation and containers, and container preparation are described in Feltz and others (1985). Sample holding times are those recommended by the USEPA (1986). The samples were chilled and shipped overnight to the NWQL on the day of collection on Mondays through Thursdays; samples collected on Friday were kept chilled and shipped overnight on the following Monday. Samples collected on Friday include those from drive point 1 at sampling intervals of 28 to 30 ft, 40 to 42 ft, and 45 to 57 ft; those from drive point 2, at sampling intervals of 40 to 42 ft and 47 to 49 ft; and those from drive point 5 at a sampling interval of 2 to 4 ft.

Quality Assurance and Quality Control

The quality assurance and quality control (QA/QC) program is described in Barton (1989, p. 36) and is summarized here. Included are checks on data precision (comparison of differences in concentration between sequential samples) and procedural precision (the repeatability of the measurement). The NWQL's QA/QC program is described in Jones (1987) and Friedman and Erdman (1982).

Accuracy.--The accuracy (the relation between the reported data and the "true" values) of the analytical methods for ground-water-quality analysis for this study was determined on the basis of USEPA's most recent (February 1989) performance-evaluation study. Because spiked samples are submitted by USEPA to the NWQL on a regular basis to determine analytical accuracy, no spiked drive-point samples were submitted to the NWQL.

Performance and system audits and data validation.--Field instruments (pH, specific-conductance, and dissolved-oxygen meters) were calibrated at each sampling site. Of the samples collected, five percent were replicated and submitted "blind" (as an unknown QA/QC sample) to the NWQL. The drive-point water-quality samplers were rinsed with deionized water after decontamination; the rinse water was submitted for analysis as a wash blank to determine the effectiveness of the decontamination procedure. Trip blanks of deionized, analyte-free water were shipped with the samples to NWQL and were analyzed.

HYDROGEOLOGY

Framework

Hydrogeologic sections were developed to help in selecting sites for drive-point water-quality sampling and to assist in interpreting surface EM-conductivity data. The locations of the hydrogeologic sections were chosen to provide information throughout the study area (fig. 11). Sections A-A' and B-B' (pls. 1 and 2) profile the study area north-south and east-west, respectively, and section C-C' (pl. 3) shows a north-south profile through Winding River Park. Drive-point sections D-D', E-E', and F-F' (pls. 4-6) are east-west profiles from the plant to Winding River Park through the Toms River floodplain. Collectively, the six sections show data from gamma-ray logs,

Table 3.--Minimum reporting levels of properties and constituents determined in water samples from drive points installed in the study area, August to September 1989

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

Physical and chemical properties			
Alkalinity (lab, as CaCO ₃)	1.0 mg/L	Specific conductance	1.0 µS/cm
pH	1.0		
Dissolved constituents			
Arsenic	1.0 µg/L	Molybdenum	10.0 µg/L
Barium	2.0 µg/L	Nickel	1.0 µg/L
Beryllium	.5 µg/L	Nitrogen (ammonia plus organic)	.2 mg/L
Cadmium	1.0 µg/L	Phosphorous ortho (as P)	.01 mg/L
Calcium	.02 mg/L	Silica	1.0 µg/L
Chloride	.1 mg/L	Silver	1.0 µg/L
Chromium	1.0 µg/L	Sodium	.2 mg/L
Cobalt	3.0 µg/L	Strontium	5.0 µg/L
Copper	10.0 µg/L	Sulfate	.2 mg/L
Iron	3.0 µg/L	Vanadium	6.0 µg/L
Lead	10.0 µg/L	Zinc	3.0 µg/L
Lithium	4.0 µg/L		
Manganese	1.0 µg/L		
Magnesium	.01 mg/L		
Mercury	.1 µg/L		
Total constituents			
Arsenic	1.0 µg/L	Mercury	.1 µg/L
Barium	100 µg/L	Nitrate	.1 mg/L
Cadmium	1.0 µg/L	Phenols	1.0 µg/L
Chromium	1.0 µg/L	Silver	1.0 µg/L
Lead	5.0 µg/L	Selenium	1.0 µg/L
Purgeable organic compounds			
Dichlorobromomethane	3.0 µg/L	1,1,2-Trichloroethane	3.0 µg/L
Carbon tetrachloride	3.0 µg/L	1,1,2,2-Tetrachloroethane	3.0 µg/L
1,2-Dichloroethane	3.0 µg/L	1,2-Dichlorobenzene	3.0 µg/L
Bromoform	3.0 µg/L	1,2-Dichloropropane	3.0 µg/L
Chloro-dibromomethane	3.0 µg/L	1,2-Trans-dichloroethene	3.0 µg/L
Chloroform	3.0 µg/L	1,3-Dichloropropene	3.0 µg/L
Phenols	3.0 µg/L	1,3-Dichlorobenzene	3.0 µg/L
Toluene	3.0 µg/L	1,4-Dichlorobenzene	3.0 µg/L
Benzene	3.0 µg/L	2-Chloroethyl vinyl ether	3.0 µg/L
Chlorobenzene	3.0 µg/L	Dichloro-difluoromethane	3.0 µg/L
Chloroethane	3.0 µg/L	Trans-1,3-dichloropropene	3.0 µg/L
Ethylbenzene	3.0 µg/L	Cis-1,3-dichloropropene	3.0 µg/L
Methylbromide	3.0 µg/L	Vinyl chloride	3.0 µg/L
Methylchloride	3.0 µg/L	Trichloroethylene	3.0 µg/L
Methylene chloride	3.0 µg/L	Styrene	3.0 µg/L
Tetrachloroethylene	3.0 µg/L	1,2-Dibromoethane water, whole	3.0 µg/L
Trichlorofluoromethane	3.0 µg/L	Xylene	3.0 µg/L
1,1-Dichloroethane	3.0 µg/L		
1,1-Dichloroethylene	3.0 µg/L		
1,1,1-Trichloroethane	3.0 µg/L		

lithologic interpretations, and water-quality data from 36 observation wells, 3 purge wells, 3 production wells, and 4 drive-point sites. Construction details for wells and drive points used to determine the framework are listed in appendix A. Lines were constructed from gamma-ray logs, drillers' logs, and geologists' logs.

Gamma-ray logs were collected at several wells in the study area by the USGS, AWARE, and ETE for NUS Corporation. ETE is a consulting company subcontracted by NUS Corporation to collect gamma-ray logs. Logs collected by USGS, AWARE, and ETE for NUS Corporation are compared in figures 12, 13, and 14. These logs show comparable responses to natural gamma-ray activity. Gamma-ray logs collected by the USGS for this study are shown on plates 1 through 6 and in figure 21.

The Kirkwood-Cohansey aquifer system in northern Ocean County has been mapped as a single geohydrologic unit (Zapeczka, 1989, pl. 3) consisting of sand and silt with interbedded clay layers. Because the sediments that comprise the aquifer system dip gently to the southeast at approximately 11 to 25 feet per mile (Isphording, 1970, p. 987), layering is nearly horizontal.

In the study area, the aquifer system consists of sand with discontinuous silt and clay layers and some lenses of gravel from land surface to approximately 60 ft below sea level. Southwest and southeast of the production area at the plant, the shallow part of the aquifer system is composed primarily of sand with discontinuous clayey silt layers (pl. 6, well RI-24XD; pl. 2, well RI-27XD) and some clay layers. Although the layers of fine material are discontinuous across the site, they are in some places continuous over 1,880 ft, as shown in line F-F', pl. 6, wells 0122 through 0139. At some sites, as determined from borehole gamma-ray logs, the upper part of the aquifer system consists mainly of sandy material. The upper 82 to 85 ft at wells RI-32XD (from 17 ft above sea level to 65 ft below sea level, pl. 3) and RI-24XD (from 65 ft above sea level to 20 ft below sea level, pl. 6) is mainly sand.

All production wells and most observation wells at the plant in the study area are screened above 60 ft below sea level. Observation wells generally are screened in fine sands and silts. Data from well logs for production wells 403, 404, and 206 are included in lines D-D' and B-B' (pls. 4 and 2, respectively); data from logs for purge wells 748, 747, and 750 are shown in lines A-A' and F-F' (pls. 1 and 6, respectively).

A clay layer, identified in logs of four deep wells in the study area, was mapped by AWARE, Inc., as the Kirkwood-Cohansey transitional unit (AWARE, Inc., 1986a, fig. 4-27). Because few wells at and near the plant penetrate deeper than 60 ft below sea level, the hydrogeologic framework of the deep part of the Kirkwood-Cohansey aquifer system is poorly defined, and the lateral continuity of layers cannot be determined. On the basis of limited data from several well logs, silt, clayey silt, and clay layers appear to be thicker in the deep (more than 60 ft below sea level) part of the aquifer system than silt and clay layers in the shallow part of the aquifer system. A silt layer identified in the gamma-ray log of deep well RI-32XD, located from 74 to 150 ft below sea level, is 76 ft thick (pl. 5).

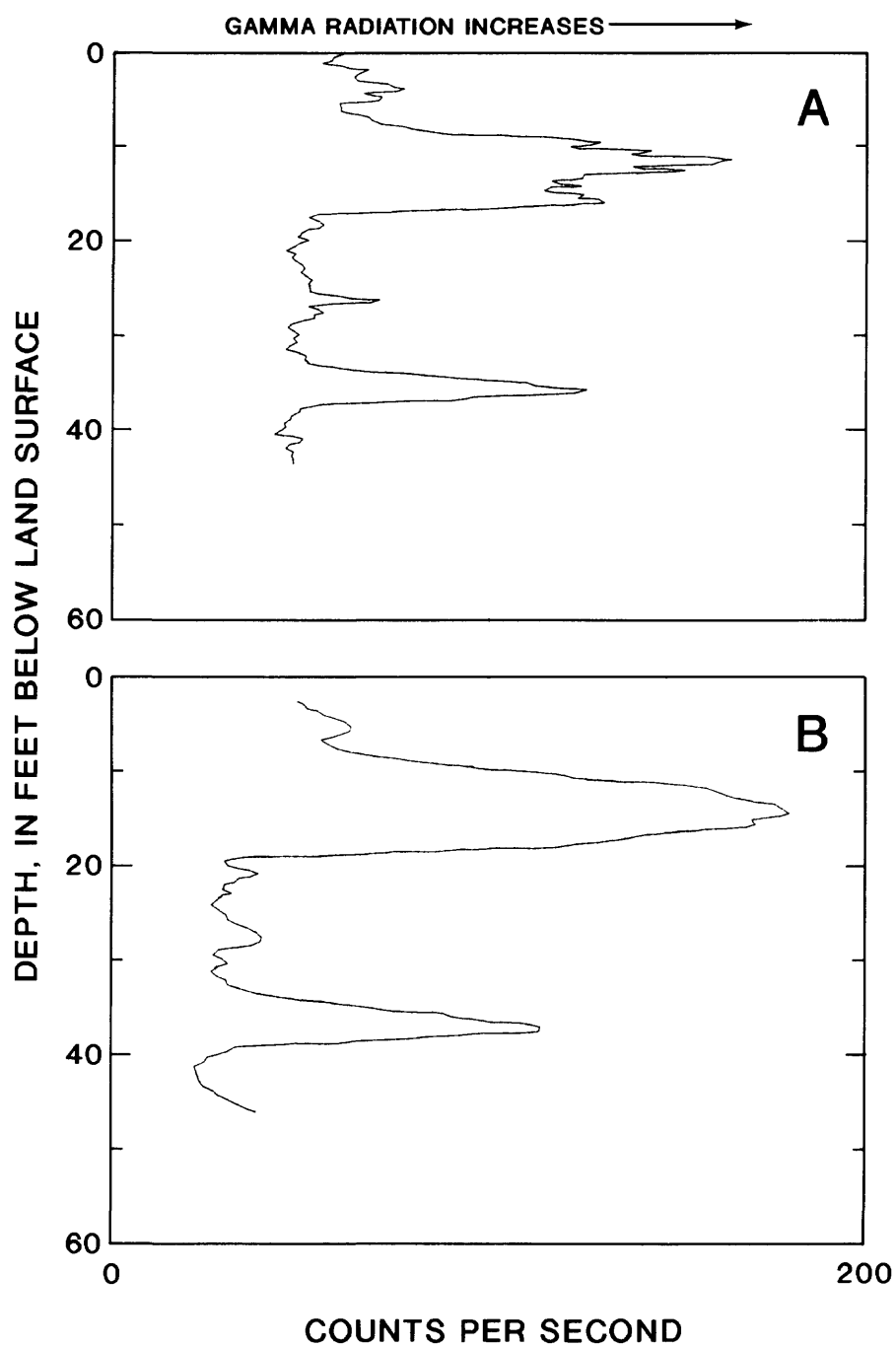


Figure 12.--Comparison of borehole gamma-ray log (A) run by the U.S. Geological Survey with log (B) run by AWARE, Inc., in well 0139 at the Ciba-Geigy Superfund site near Toms River, New Jersey.

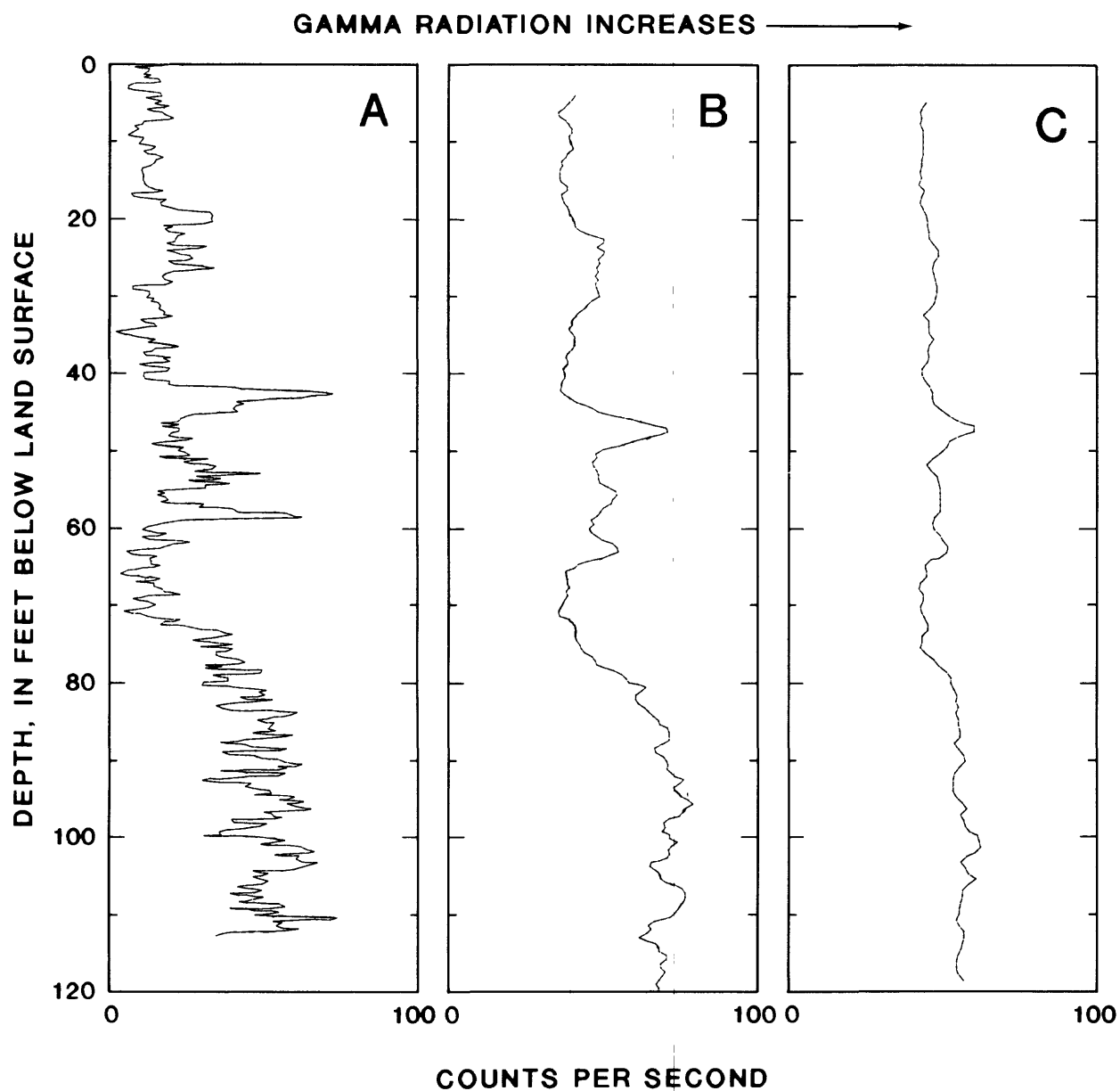


Figure 13.--Comparison of borehole gamma-ray log (A) run by the U.S. Geological Survey with log (B) run by AWARE, Inc., and log (C) run by NUS Corporation in well 0167 at the Ciba-Geigy Superfund site near Toms River, New Jersey.

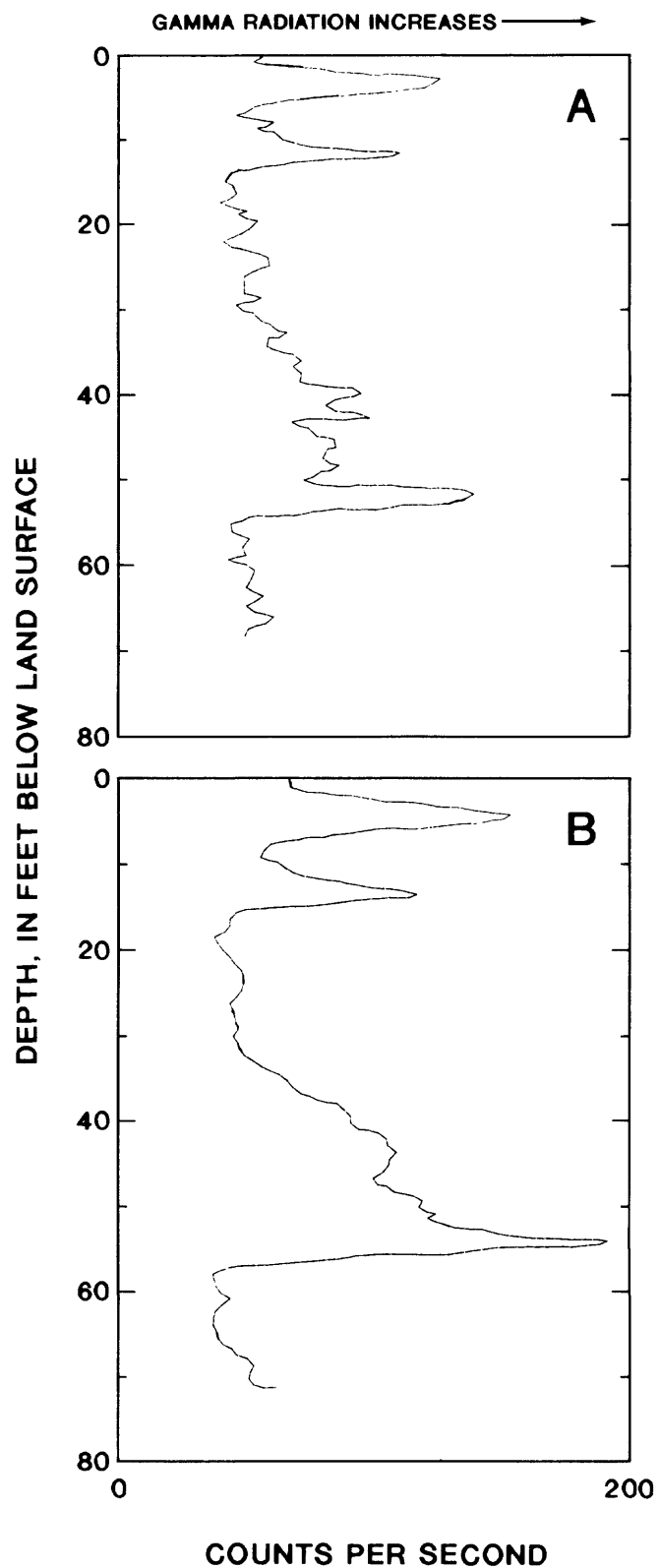


Figure 14.--Comparison of borehole gamma-ray log (A) run by the U.S. Geological Survey with log (B) run by AWARE, Inc., in well 0187 at the Ciba-Geigy Superfund site near Toms River, New Jersey.

In the deep part of the aquifer system, two sand layers were identified in the logs of deep wells; these layers appear to be relatively continuous within the study area. The upper sand layer is found at altitudes ranging from 64 ft below sea level (log of well RI-27XD, pl. 2) to 98 ft below sea level (log of well RI-21XD, pl. 1). The thickness of the upper sand layer ranges from 8 ft (logs of wells 0182 and RI-21XD) to 26 ft (log of well 0179); this layer is absent in the log of well RI-32XD. The upper sand layer in the deep part of the aquifer system was mapped by AWARE, Inc. (1986a, fig. 4-14), as the Kirkwood No. 1 sand.

The altitude of the upper surface of the lower sand layer ranges from 132 ft below sea level (log of well 0182, pl. 2) to 150 ft below sea level (logs of wells RI-21XD, pl. 1, and RI-32XD, pl. 3). The lower sand unit was not found in the log of the USGS Toms River Chemical well 84 (fig. 15; Zapezca, 1989, pl. 18), which is located near well RI-27XD. Further, the lower sand layer was not positively identified in the log of well RI-27XD. This lower sand layer was mapped by AWARE, Inc. (1986a, fig. 4-11), as the Kirkwood no. 2 sand.

The limited well-log data available indicate that the deep part of the aquifer system is predominantly sand with lenses of greenish silt and clay, which probably contain glauconite. The basal Kirkwood Formation (Isphording, 1970, p. 996) and the underlying Shark River and Manasquan Formations also contain glauconite (Enright, 1969, p. 18).

Several observation wells (0182, 0179, RI-21XD, RI-24XD, and RI-27XD) were drilled to depths below their screened intervals. Split-spoon samples were collected from the formation below the finished depth of the well, but no gamma-ray logs were run in these boreholes below the screened interval. According to geologists' logs, the top of the composite confining unit underlying the Kirkwood-Cohansey aquifer system ranges from 152 ft to 162 ft below sea level (pls. 1-3). The confining unit consists of fine to medium glauconitic sand with lenses of clay and silt (NUS Corporation, 1988, app. D-9). The altitude of the upper surface of the composite confining unit at the USGS Toms River Chemical observation well 84 is approximately 140 ft below sea level (fig. 15; Zapezca, 1989).

Hydrologic Characteristics of the Aquifer System

Movement of contaminated water within the ground-water system at and near the Superfund site depends on the hydrologic characteristics of the aquifer system. Aquifer tests have been conducted at a few locations. The Ranney Company conducted a test using wells in the vicinity of well RI-28D (Ranney Method Water Supplies, 1956, p. 1-2). Wells used in this test were screened from 17 to 57 ft below river level. An aquifer test at purge well 747 (screened from 12.0 ft above sea level to 26.0 ft below sea level, pl. 1), conducted by AWARE, Inc., in 1986, showed that hydraulic conductivities ranged from 2.66×10^{-2} ft/d (feet per day) to 3.4×10^{-2} ft/d (AWARE, Inc., 1986a, p. 4-32). (Purge and production wells and their specific capacities at the time of installation are listed in app. A.)

**Toms River Chemical
Well 84
29-85**

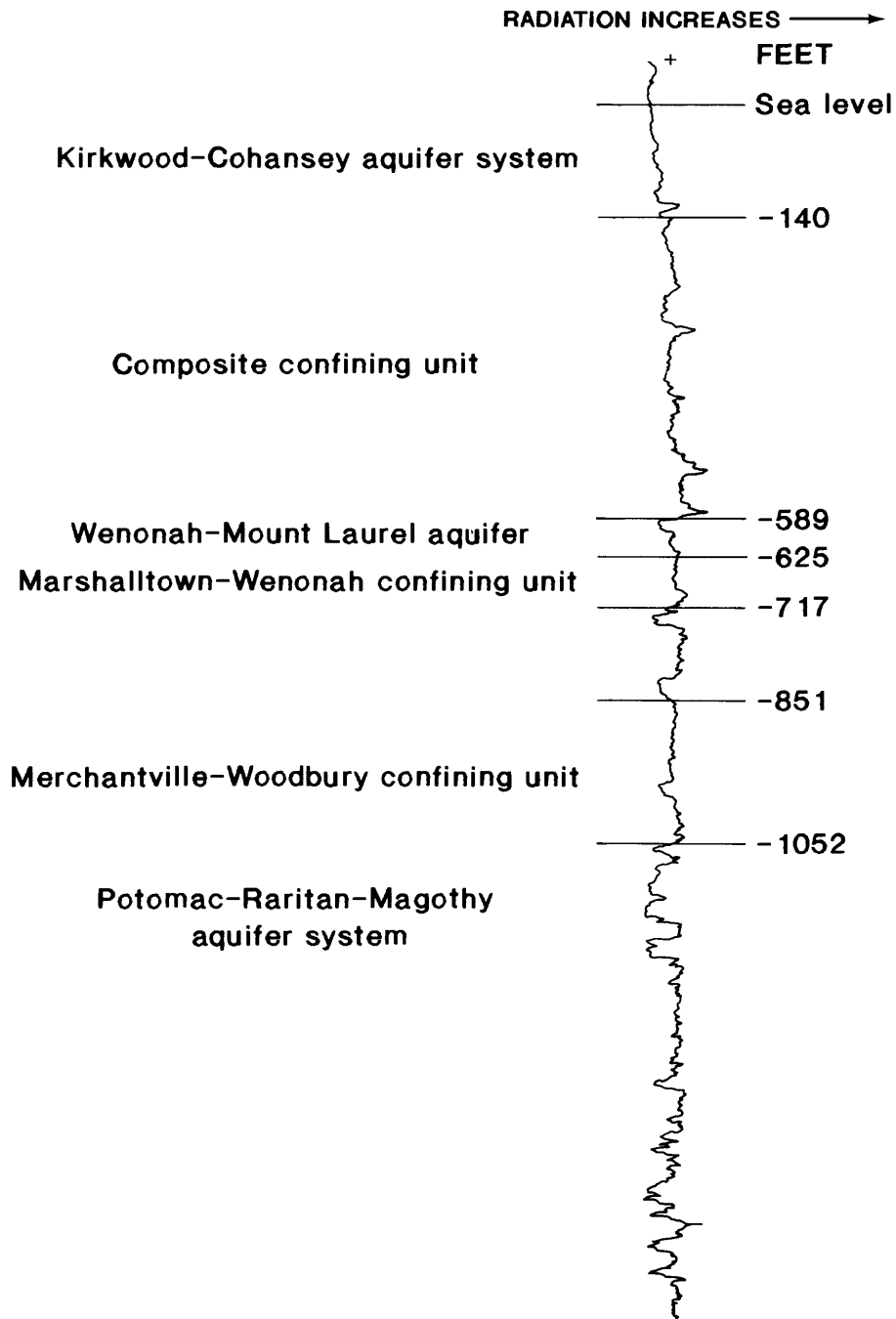


Figure 15.--Gamma-ray log of Toms River Chemical Well 84. (Modified from Zapecza, 1989, pl. 3 and table 4.)

Because no aquifer tests were conducted using wells screened in the deep (greater than 60 ft below sea level) part of the aquifer system, the hydraulic conductivity of that part of the aquifer system is unknown. Similarly, no hydraulic-conductivity data are available for the underlying confining unit. However, a regional ground-water-flow model of the New Jersey Coastal Plain simulated a hydraulic conductivity of 5.0×10^{-5} ft/d in the upper 100 ft of the confining unit (Martin, 1990, figs. 16 and 71).

Ground-water-flow patterns within the study area have been studied previously. Water-table maps generated as part of previous investigations indicate an east-southeast gradient towards the Toms River (AWARE, Inc., 1986a; NUS Corporation, 1988). The water-table maps probably do not represent the true water table, because semiconfined conditions, caused by clay lenses, are likely to exist in some parts of the study area. Further, pumping at the purge wells (see fig. 4 for locations) affects ground-water movement at and near the Superfund site. Water levels measured during the current study (app. C) show a pronounced decrease in the area east and southeast of the active landfill and west of Cardinal Drive (fig. 16). This water-table depression can be related to the pumping of the purge wells. Water levels in both shallow and deep wells (RI-21S and RI-21D) were measured in the southernmost part of the plant area immediately west of Cardinal Drive. The head gradient in this area shows a strong downward component with a difference in head of 5.82 ft between shallow and deep wells. Additional water-level data from other nests of wells are needed to accurately determine the magnitude of the vertical component of ground-water flow at the site.

The few water-level measurements shown in figure 16 indicate that, in general, shallow ground water moves toward, and apparently discharges to, the Toms River. Again, because of the lack of deep wells, the hydraulic connection between the deep part of the aquifer system and the Toms River and associated wetlands is poorly understood. The presence of dissolved contaminants on the east bank of the Toms River suggests that ground water from the deep part of the system (well RI-9, screened from 7.2 ft above to 28.3 ft below sea level) may pass beneath the river rather than discharging to it. Additional data are required to adequately assess ground-water movement beneath the river.

GEOPHYSICAL CHARACTERISTICS

Apparent Terrain-Conductivity and Specific Conductance

Apparent terrain-conductivity measured in the study area from April through July 1989 ranges from less than 1 to 56 mS/m. Anomalously high values of apparent terrain-conductivity (greater than 10 mS/m) extend eastward from the production area at the plant to the Toms River, and east of the Toms River into the Equestrian Park. The areal extent of anomalously high apparent-terrain-conductivity values, shown on plates 7 through 9, approximately coincides with those areas where organic contamination of ground water was identified previously (NUS Corporation, 1988, fig. 4-30). The mapped area of contaminated ground water extends into the Cardinal Drive area; no apparent-conductivity measurements could be taken in the Cardinal Drive area, however, because of anthropogenic interferences. On the basis of its coincidence with known areas of contamination, anomalously high apparent terrain-conductivity values probably indicate the presence of contaminated ground water. No other

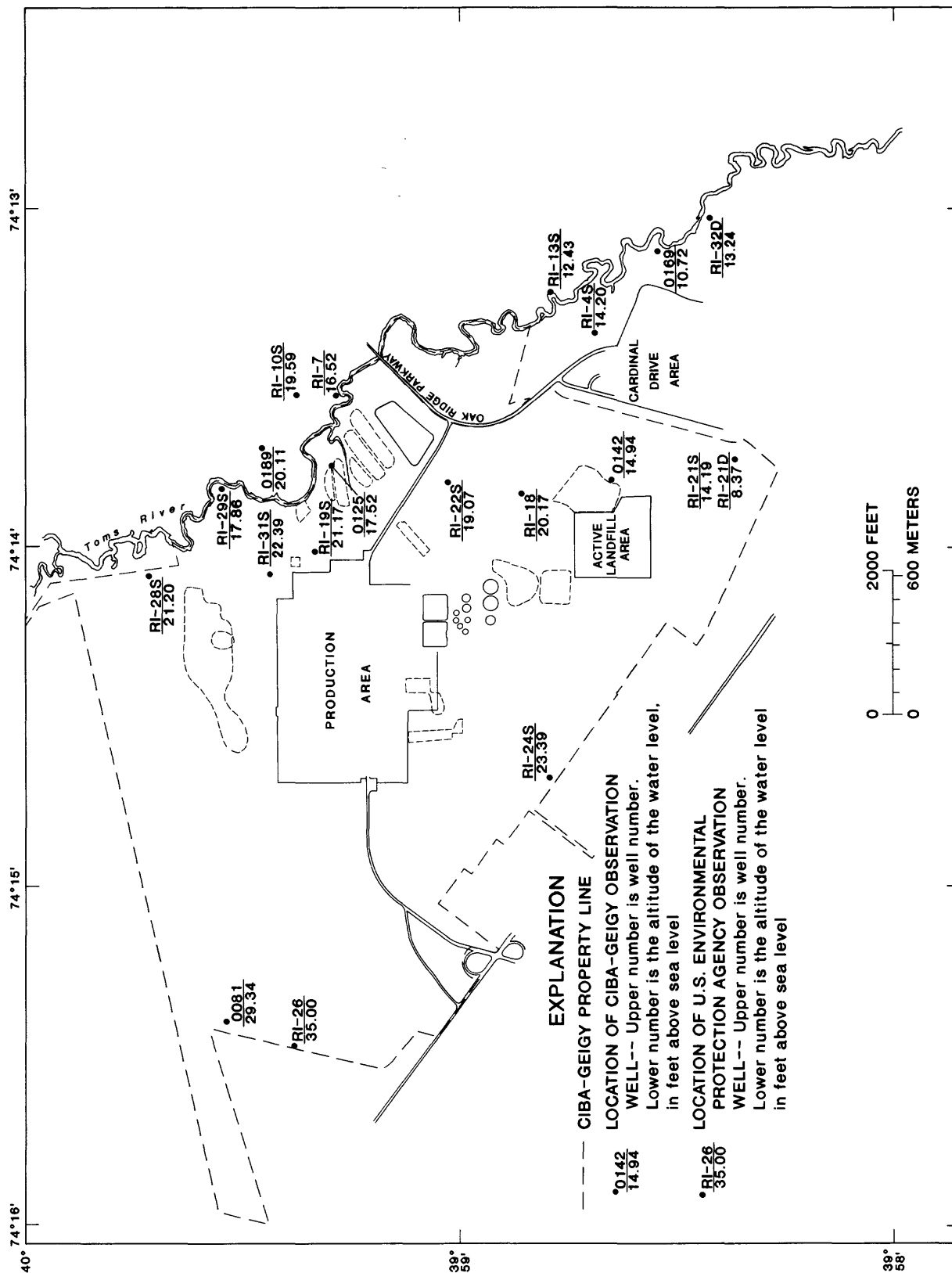


Figure 16.--Water levels measured in the study area, May 11-19, 1989.

areas of high (greater than 5 mS/m) apparent conductivity were detected during the EM survey. An area with apparent-conductivity values slightly higher than background was found northeast of the borrow area, however. These slightly elevated values could result from the presence of organic silt layers, but also could be caused by the presence of ground water that is less dilute than ambient ground water in the area.

Throughout the study area, apparent-conductivity values at EM stations generally increased with increasing depth of exploration. This trend is most likely related to an increase of silt and clay with depth (silt and clay are more conductive than sand and gravel) and the depth to the water table. In the area of ground-water contamination, the trend also could be related, in part, to the distribution of contaminants within the aquifer system.

Ground water in the area near Toms River, New Jersey, generally has low specific conductance. Wells screened in the Kirkwood-Cohansey aquifer system within a 5-mi radius of the study area yield water with a mean specific conductance of 70 $\mu\text{S}/\text{cm}$ (microsiemens per centimeter at 25 °C). The specific conductance of water from observation wells (fig. 17) that does not contain POCs or inorganic elements or compounds in concentrations greater than the USEPA maximum contaminant level (MCL) range from 37 $\mu\text{S}/\text{cm}$ (well RI-26) to 56 $\mu\text{S}/\text{cm}$ (well RI-24S). Ions in solution (metals, chloride, and sulfate) cause water to be electrically conductive. Specific conductance increases with increasing concentrations of dissolved inorganic and some (ionic) organic compounds. Electrically conductive ground water (maximum specific conductance 1,560 $\mu\text{S}/\text{cm}$ (well 0127)) extends eastward from the production area to the Toms River. Electrically conductive ground water also is present in the Equestrian Park (maximum specific conductance 1,860 $\mu\text{S}/\text{cm}$ (DP-2)) and in the vicinity of observation well RI-13S in lower Winding River Park (fig. 17). Elevated specific-conductance values coincide approximately with elevated chloride concentrations (AWARE, Inc., 1986, fig. 4-45) and total POCs (NUS Corporation 1988, fig. 4-30).

The relation between the apparent terrain-conductivity of the sediments and fluids and the specific conductance of water sampled from wells and drive points throughout the study area is shown in figure 18. Criteria for regression analysis included selecting water samples from wells and drive points to represent both ambient and contaminated ground water, and proximity (within 100 ft) of an EM station to the sampled well or drive point. Less than five percent (28 samples) of the terrain-conductivity data was used in a regression analysis because the number of sampled wells near EM stations was limited. The screened depth in the sampled wells determined the choice of EM34-3 coil spacing and dipole orientation used in the regression analysis. The depth from land surface to the bottom of the well screen ranged from 10.5 ft to 106 ft; altitudes of the screened intervals ranged from 3.3 ft above sea level to 33 ft below sea level. The locations of the wells and drive points sampled are shown in figure 8.

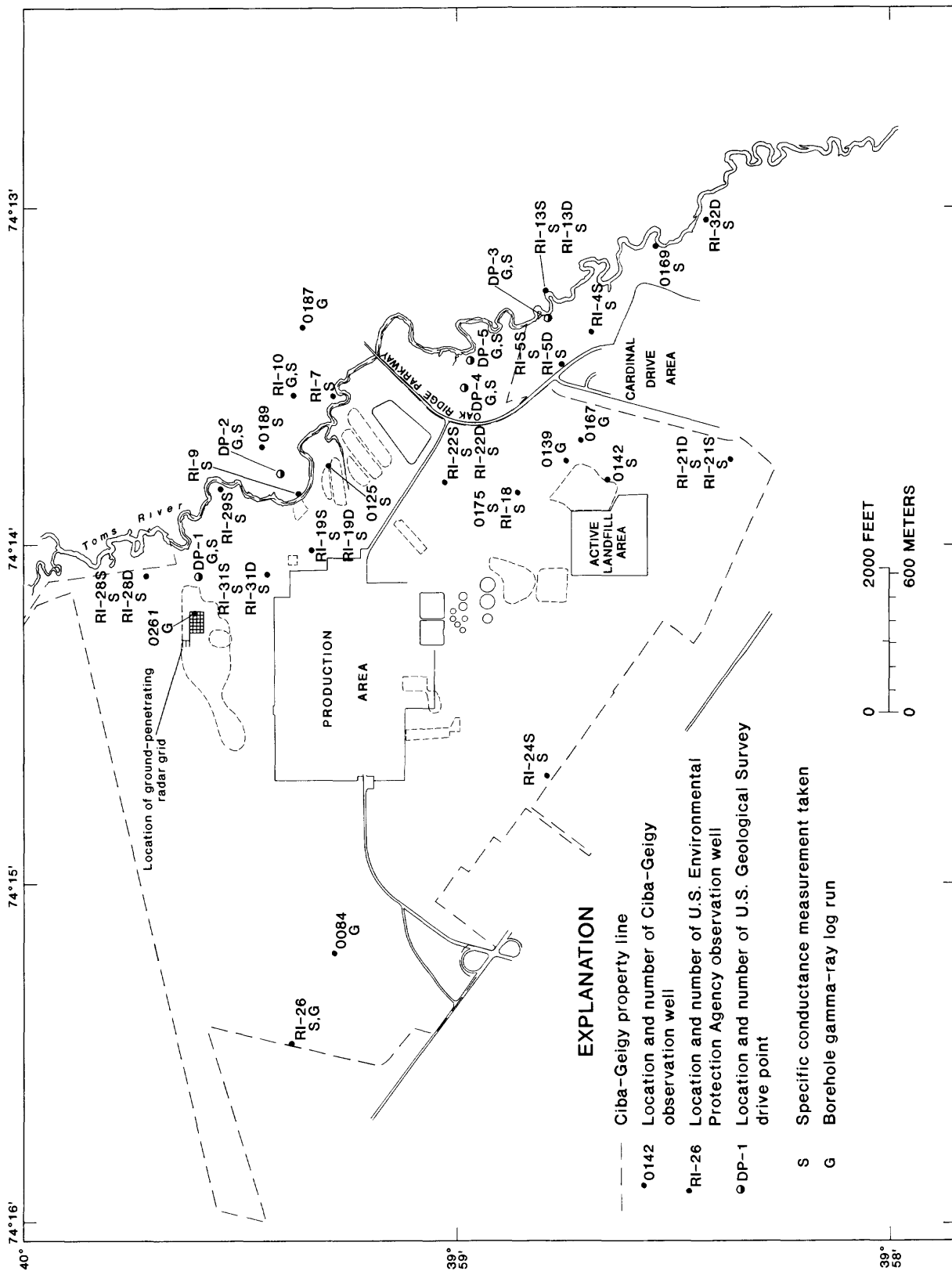


Figure 17.--Specific conductance of ground-water samples from selected wells and drive points in the study area.

The relation between apparent terrain-conductivity (ATC) in millisiemens per meter and specific conductance (SC) in microsiemens per centimeter in the study area (shown in fig. 18) can be described by the regression equation

$$ATC = -4.66 + 2.24 \ln SC.$$

The correlation coefficient is 0.427. Unexplained variance associated with the regression line was greater than 50 percent, indicating that other variables, such as heterogeneity of the sediments and the concentration of dissolved ions in the contamination plume, probably have a large influence on the concentrations of measured constituents.

Apparent-terrain-conductivity values are a rough indication of ground-water contamination. On the basis of the low correlation coefficient and large variance, accurate prediction of specific-conductance values from apparent-terrain-conductivity values is difficult without considering other influencing variables.

Geophysical Anomalies in the Eastern Part of the Borrow Area

GPR profiles were collected along 3,400 ft of survey lines in the eastern part of the borrow area. The entire borrow area comprises about 17 acres; however, the western part was inaccessible to the GPR instrument. Therefore, only about 16 percent of the borrow area was surveyed (fig. 19), and no assessment of the presence of manmade structures or buried debris was possible in the western part of the borrow area.

Figure 20 shows the GPR-survey grid and the locations of the geophysical anomalies detected in the eastern part of the borrow area. The GPR profiles and the interpreted subsurface conditions are shown on plate 10. During the survey, the water table was approximately 14 ft below land surface at well 0146, 60 ft southwest of the southern boundary of the GPR grid. Water levels within the grid could not be measured because well 0261, located within the grid, had been damaged.

Two-way travel-time velocities of GPR pulses within the surveyed area were calculated by use of the equation on page 24 and published relative dielectric permittivities (Geophysical Survey Systems, Inc., 1974, p. 20). An average GPR velocity of 0.38 ft/ns (feet per nanosecond) was calculated for the unsaturated layer from GPR profile 14, grid coordinates 1000 NS - 1000 EW, and profile 8, grid coordinates 0950 NS - 1400 EW, (pl. 10). GPR velocities below the water table ranged from 0.1 to 0.3 ft/ns.

The depth of exploration ranged from approximately 30 ft on GPR profile O-O', grid coordinates 1100 NS - 1250 EW (pl. 10), to greater than 56 ft in the northwestern part of the surveyed area (GPR profiles S-S', T-T', and U-U', fig. 21). The GPR signal was attenuated throughout the northeastern and southeastern parts of the surveyed area except near grid coordinates 1100 NS - 1200 EW on GPR profiles L-L' and P-P' (fig. 20). The signal attenuation generally was pronounced beneath identified GPR anomalies, which appeared as shallow, trough-shaped reflectors that cut across nearly horizontal reflectors (pl. 10). Signal attenuation can be caused by landfilled anthropogenic

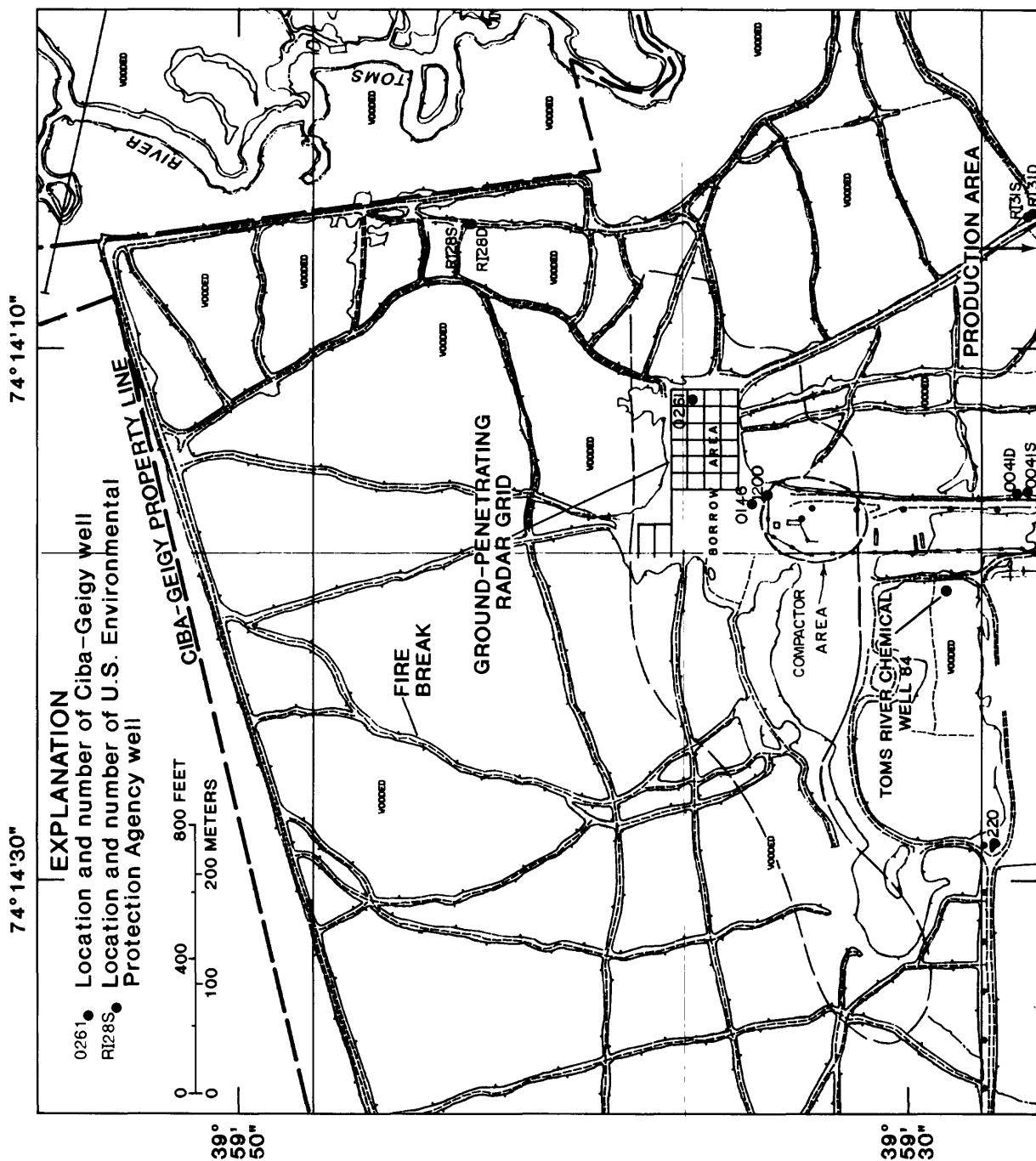
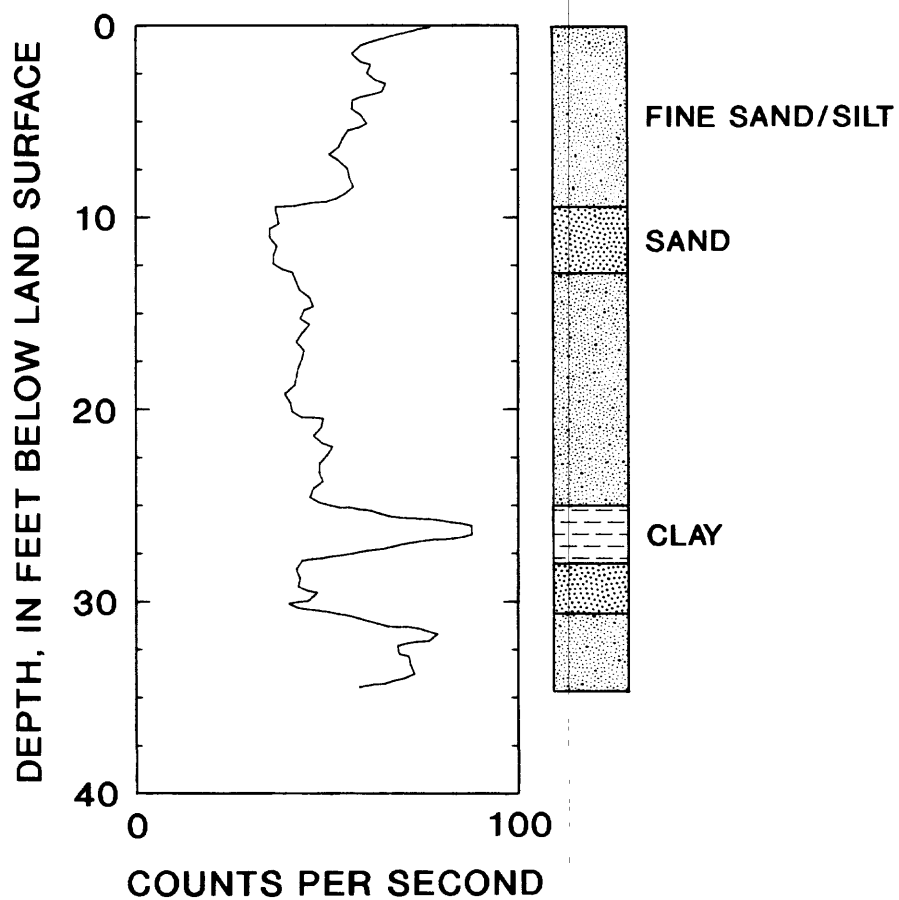


Figure 19.--Location of ground-penetrating-radar-survey grid in the borrow area at the Toms River Chemical Company plant near Toms River, New Jersey.



(well location shown in fig. 8)

Figure 21.-- Gamma-ray borehole log and corresponding lithology of well 0261.

materials or by changes in lithology. Typically, clay-rich sediments tend to attenuate the GPR signals. Landfilled anthropogenic materials can cause signal-scattering losses, and the presence of clay increases subsurface electrical conductivity, causing electrical losses (Geophysical Survey Systems, Inc., 1974, p. 43-44). A local "silty clay" layer that was found at approximately 25 to 27 ft below land surface in well 0261 (identified on a gamma-ray borehole log, fig. 21) may be responsible for attenuation of the GPR signal.

All profiles show strong GPR reflection associated with the water table. For example, on profile T-T' (pl. 14) this signal is seen at a two-way travel time of approximately 85 ns (nanoseconds). In general, GPR profiles show that shallow stratigraphic layers are virtually horizontal; however, some deeper layers dip to the southwest at a low angle. For example, on profile O-O' (pl. 10), at grid coordinates 1050 NS-1150 NS, a GPR reflection that dips roughly 5 ft over a distance of 100 ft may be related to a buried streambed. Intermittent attenuation of the GPR signal suggests that some of the stratigraphic layering could be discontinuous (for example, GPR profiles H-H' and J-J' on plate 13).

The locations of signal attenuation were plotted and cover approximately 65 percent of the surveyed area. Signal attenuation was not observed in the northwestern part of the surveyed area (fig. 20). The trough-shaped anomalies also were plotted, and appear to form a band trending approximately east-west across the surveyed area. The trend of the anomalies shown in figure 20 is similar to the trend of a trench identified by Hickerson (1984) in an aerial photograph taken on March 1, 1962. Because the trend of this trench and the GPR anomalies is similar to the trend of intermittent drainage identified in the same aerial photograph, it is unknown whether the anomalies result from a manmade feature, such as a trench, or a natural feature, such as a buried streambed. The trench identified by Hickerson (1984), as well as adjacent excavated and filled areas, are found in the western part of the borrow area, which was inaccessible to the GPR instrumentation.

GROUND-WATER QUALITY

The same water quality analyses were performed on all 15 samples collected using a drive point. These analyses and the analyses of quality-assurance samples are tabulated in app. G. The concentrations of inorganic compounds and nutrients are considered to be representative of the quality of ground water in the study area because the drive points were purged a minimum of five drill-rod volumes and samples were taken after the field measurements stabilized. Concentrations of POCs, however, are only estimates. Ground-water samples for POC analysis were collected with a peristaltic pump. Imbrigiotta and others (1988) reported the loss of POCs by vacuum pumps to be approximately 20 percent. The peristaltic pump causes degassing of POCs into the vacuum created by the pump's suction-lift mechanism; however, samples can be collected by the drive-point sampler only with a peristaltic pump. Samples with POC concentrations less than the minimum reporting level may have contained POCs when sampling commenced. Detected concentrations of POCs may be less than the actual in situ concentrations. Comparison of results of POC analyses of samples from DP-2 and well RI-9, separated by only 200 ft, suggests that representative samples were collected with the peristaltic pump, within the above-mentioned limitations of the sampling method. Samples from

DP-2, screened from 15 to 17 ft below land surface, contained the same seven POCs detected in well RI-9, screened from 15 to 21 ft below land surface, and in each case the concentrations were comparable (NUS Corporation, 1988, app. A-1).

Two of the 12 samples collected were replicated. The relative percent difference (RPD) was calculated for constituents found in concentrations greater than the analytical minimum reporting level (app. F). Therefore, an RPD was calculated for 18 of 35 inorganic constituents and only 4 of 35 POCs. The RPD for inorganic constituents is less than 4.0 percent, with the exceptions of zinc and magnesium, which had RPD's of 57.5 and 15.4, respectively. The nutrients had the poorest reproducibility of all the constituents analyzed. Nitrogen as $\text{NO}_2 + \text{NO}_3$ dissolved had a 115 percent RPD. The RPD was calculated for 4 POCs (1,2,3-Trichloropropane, 1,2-dichlorobenzene, TCE, and chlorobenzene) and ranges from 0 to 9.5 percent. Analytical results for duplicate samples agree for both inorganic and organic constituents at concentrations below the analytical minimum reporting level.

All water-quality data met the USEPA recommended holding-time criteria. Equipment-decontamination procedures followed USEPA protocol as outlined in Barton (1989). Equipment blanks showing detectable POC contamination were those for DP-2 (toluene), and DP-4 and DP-5 (chloroform). Water used for equipment blanks could contain small amounts of chloroform and other organic compounds which may not be removed by the purifying cartridges. Neither compound was detected in any samples collected from the drive point for which the blank was collected. The iron and nitrate concentrations reported for the equipment blanks for DP-2, DP-3, and DP-4 probably resulted from rinsing the steel drive point with 10-percent nitric acid.

The results of analyses of water samples from drive points for physical properties, common ions, nutrients, dissolved and total metals, total phenols, and POCs are listed in app. G. Minimum and maximum concentrations of inorganic elements and compounds, POCs, and total phenols in water from drive points are given in table 4. Constituents exceeding the USEPA MCLs and New Jersey Department of Environmental Protection and Energy drinking-water criteria also are given in table 4.

Physical Properties and Inorganic Constituents

Ground water at all five drive-point sites is moderately acidic (pH of 4.0 to 5.7), which is typical of ground water in the Kirkwood-Cohansey aquifer system in Ocean County. Specific conductance ranged from 42 to 1860 $\mu\text{S}/\text{cm}$, whereas the maximum specific conductance in water from sampled wells outside the area of contaminated ground water (for example, RI-24S, fig. 17) was 56 $\mu\text{S}/\text{cm}$. Specific conductance increased with depth at the drive-point sites on the Toms River floodplain and at the Equestrian Park. Concentrations of calcium, magnesium, chloride, and sulfate also increased with depth at these four drive-point sites. The concentrations of these four constituents typically were substantially higher in sampled intervals that also contained detectable concentrations of POCs. The waste-disposal sites at the plant (fig. 2) are possible sources of inorganic constituents associated with the organic-compound-contaminated ground water; biochemical and (or) chemical reactions in the contaminated ground water also could affect the observed concentrations of inorganic constituents.

Table 4.--Maximum and minimum concentrations of inorganic elements or compounds, and organic compounds, and values of physical properties, in water from drive points installed in the study area, August through September 1989

[Constituents are reported as totals and are in micrograms per liter unless otherwise indicated; mg/L, milligrams per liter; μ S/cm, microsiemens per centimeter at 25 degrees Celsius; <, less than; \geq , greater than or equal to; <1.0, less than the analytical reporting level; purgeable-organic-compound concentration of <3.0 is a rejected analysis and ≥ 3.0 is an estimated concentration because samples were collected with a peristaltic pump which may cause degassing and loss of purgeable organic compounds; SE, drinking-water standards have not been established; USEPA, U.S. Environmental Protection Agency; NJDEP, New Jersey Department of Environmental Protection]

Constituent	Maximum concentration	Minimum concentration	USEPA maximum contaminant level ¹	NJDEP drinking-water criteria ²
Nitrogen, ammonia + organic dissolved (mg/L)	4.7	0.2	SE	SE
Nitrogen, NO ₂ + NO ₃ dissolved (mg/L)	1.3	<.01	10 (mg/L)	10 (mg/L)
Phosphorous ortho, dissolved (mg/L)	.225	<.001	SE	SE
Calcium, dissolved (mg/L)	60	.14	SE	SE
Magnesium, dissolved (mg/L)	39	.12	SE	SE
Sodium, dissolved (mg/L)	1,860	42	SE	SE
Chloride, dissolved (mg/L)	230	3.2	SE	SE
Sulfate, dissolved (mg/L)	820	1.0	SE	SE
Silica, dissolved (mg/L)	11.0	1.6	SE	SE
Arsenic, dissolved	1	<1	50	50
Arsenic, total	<1	<1	SE	SE
Barium, dissolved	68	2.0	1,000	1,000
Barium, total	<100	<100	SE	SE
Beryllium, dissolved	<5	<5	SE	SE
Cadmium, dissolved	13	<1	10	10
Cadmium, total	<1	<1	SE	SE
Chromium, dissolved	5	<5	50	50
Chromium, total	<11	<1	SE	SE
Cobalt, dissolved	<20	<3.0	SE	SE
Copper, dissolved	<16	<10	1,000	SE
Iron, dissolved	240,000	960	SE	SE
Lead, dissolved	20	<10	50	50
Lead, total	20	<10	SE	SE
Lithium, dissolved	5	<4.0	SE	SE
Manganese, dissolved	4,000	10	SE	SE
Mercury, dissolved	.3	<.1	2	2
Mercury, total	.6	<.1	SE	SE
Molybdenum, dissolved	<10	<10	SE	SE
Nickel, dissolved	70	<10	SE	SE
Selenium, total	17	<1.0	10	10
Silver, dissolved	1	<1	50	50
Silver, total	5	<1.0	SE	SE
Strontium, dissolved	34	<6.0	SE	SE
Vanadium, dissolved	2,400	26	SE	SE
Zinc, dissolved	30	<1.0	5,000	SE
Dichlorobromomethane, total	<3.0	<3.0	100	100
Carbon tetrachloride, total	<3.0	<3.0	SE	2
1,2-Dichloroethane, total	<3.0	<3.0	SE	2
Bromoform, total	<3.0	<3.0	100	100
Chloro-dibromomethane, total	<3.0	<3.0	100	100
Chloroform, total	120	<3.0	100	100
Phenols, total	64	<1.0	SE	SE
Toluene, total	<3.0	<3.0	SE	SE
Benzene, total	110	<3.0	SE	1
Chlorobenzene, total	470	<3.0	SE	4
Chloroethane, total	<3.0	<3.0	SE	SE
Ethylbenzene, total	<3.0	<3.0	SE	SE
Methylbromide, total	<3.0	<3.0	SE	SE
Methylchloride, total	<3.0	<3.0	SE	SE
Methylene chloride, total	7.4	<3.0	SE	2
Tetrachloroethylene, total	3.1	<3.0	SE	1
Trichlorofluoromethane, total	<3.0	<3.0	SE	SE
1,1-Dichloroethane, total	<3.0	<3.0	SE	SE
1,1-Dichloroethylene, total	3.3	<3.0	SE	2
1,1,1-Trichloroethane, total	<3.0	<3.0	SE	26
1,1,2-Trichloroethane, total	11.0	<3.0	SE	SE
1,1,2,2-Tetrachloroethane, total	50.0	<3.0	SE	SE
1,2-Dichlorobenzene, total	11.0	<3.0	SE	600
1,2-Dichloropropane, total	19.0	<3.0	SE	SE
1,2-Trans-dichloroethene, total	90.0	<3.0	SE	SE
1,2,3-Trichloropropane, total	1,100	<3.0	SE	SE
1,3-Dichloropropene, total	<3.0	<3.0	SE	SE
1,3-Dichlorobenzene, total	<3.0	<3.0	SE	600

Table 4.--Maximum and minimum concentrations of inorganic elements or compounds, and organic compounds, and values of physical properties, in water from drive points installed in the study area, August through September 1989--Continued

Constituent	Maximum concentration	Minimum concentration	USEPA maximum contaminant level ¹	NJDEP drinking-water criteria ²
1,4-Dichlorobenzene, total	<3.0	<3.0	SE	75
2-Chloroethyl vinyl ether, total	<3.0	<3.0	SE	SE
Dichloro-difluoromethane, total	<3.0	<3.0	SE	SE
Trans-1,3-Dichloropropene, total	<3.0	<3.0	SE	SE
Cis 1,3-Dichloropropene, total	<3.0	<3.0	SE	SE
Vinyl chloride, total	<1.0	<1.0	SE	2
Styrene, total	<3.0	<3.0	SE	SE
Trichloroethylene, total	5,300	<3.0	SE	SE
1,2-Dibromoethane water whole, total	<3.0	<3.0	SE	SE
Xylene, total	<3.0	<3.0	SE	SE
Specific conductance (lab)	1,860	42	SE	SE
pH	6.1	4.0	SE	SE
Alkalinity (lab) (mg/L)	27.0	<1.0	SE	SE

¹ From U.S. Environmental Protection Agency (1986)

² From New Jersey Priority Drinking Water Criteria, New Jersey Department of Environmental Protection (1989)

Concentrations of nitrate-nitrite in drive-point samples were low (maximum concentration 1.3 mg/L, DP-5) and did not exceed the USEPA MCL for nitrate (10 mg/L). Cadmium (12 µg/L (micrograms per liter), DP-2) and selenium (17 µg/L, DP-2) were the only metals found at concentrations that exceed the USEPA MCLs for these metals.

Purgeable Organic Compounds

Results of analyses of water from the drive points for POCs can be used only to make qualitative interpretations because the samples were collected with a peristaltic pump. POCs were identified at all 5 drive-point sites in 7 of the 13 depth intervals sampled. The deepest interval sampled at each site contained POCs. Because the drive points could not be installed at depths greater than 50 ft, the water quality at depths greater than 50 ft were not ascertained.

Thirteen of the 36 POCs determined were present at concentrations greater than the analytical minimum reporting level: benzene, chlorobenzene, chloroform, methylene chloride, 1,2-dichlorobenzene, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, 1,2-dichloropropane, toluene, trichloroethylene, 1,1-dichloroethylene, 1,2,3-trichloropropane, and 1,2-trans-dichloroethylene. Two of these compounds--1,2-dichloropropane and 1,2,3-trichloropropane--were not identified in previous studies at the plant. All seven samples (and one replicate) in which POCs were present contained trichloroethylene (TCE) and 1,2,3-trichloropropane. The maximum observed TCE concentration was 5,300 µg/L. The maximum observed 1,2,3-trichloropropane concentration was 1,100 µg/L. Chlorobenzene was detected in six samples (and one duplicate); 1,2-transdichloroethene also was detected in six samples. The other compounds mentioned above were detected in at least three samples, with the exception of chloroform, methylene chloride, and toluene, each of which were detected in only one sample. The concentration of total POCs ranged from 26.8 µg/L in a sample from DP-1 to 7,157 µg/L in a sample from DP-2.

On the basis of drive-point water-quality data and data from previous studies (NUS Corporation, 1988; Aware, Inc., 1986a), TCE and chlorobenzene appear to be ubiquitous in the contaminated ground water. The presence of TCE and chlorobenzene in water from 23 sampling intervals along hydrochemical lines D-D', E-E', and F-F' is shown in plates 4, 5, and 6. The water-quality data presented on these lines were compiled from results of the current study and a number of additional sources (NUS Corporation, 1988; AWARE, Inc., 1986a; Barry Cohen, Ciba-Geigy Corporation, written commun., 1989.) The minimum reporting level for data from Ciba-Geigy Corporation is much higher (50 µg/L) than the minimum reporting levels for data from the other sources; therefore, only constituent concentrations greater than 50 µg/L were used in these lines. Data from well and drive-point samples collected from September 1985 through October 1989 are included. Because these data span roughly 5 years and POC concentrations change with time, the concentrations shown on the lines are only an estimate of conditions during that period. Further, results of analyses of samples collected during the current study could be less than the actual concentrations as a result of sampling with a peristaltic pump. Total POCs, generally used to describe the extent of a contaminant plume, are not discussed because (1) the number of compounds determined varied for different studies, (2) different sampling techniques were used for each investigation, and (3) data from previous studies may not reflect current concentrations.

Hydrochemical line D-D' (pl. 4) shows high TCE concentrations at the production area (well 1104) and in the Equestrian Park. Water in well 1104, screened from 100 to 110.6 ft below sea level in the production area, is highly contaminated with TCE (15,000 $\mu\text{g/L}$); Pinder and others (1988, p. 22) stated that the production area is one of the three probable sources of DNAPLs at the site. Nearby production well 403, screened from 88 to 108 ft below sea level, was removed from service in October 1955 (Leggette, Brashears & Graham, 1959) because it contained contaminated water. The depth of contamination in the vicinity of well 1104 is unknown because no deep wells exist in this area; however, hydrogeologic conditions and the density of TCE and chlorobenzene could facilitate downward migration of contamination. TCE and chlorobenzene concentrations decreased along hydrochemical line D-D' toward the Toms River; line D-D', however, does not approximate a flow line. Concentrations of TCE increased dramatically at RI-17 (950 $\mu\text{g/L}$), possibly as a result of proximity to the fire-prevention area. High concentrations of TCE and chlorobenzene are present east of the Toms River at RI-9 (11,000 $\mu\text{g/L}$, TCE; 2,200 $\mu\text{g/L}$, chlorobenzene) and at all sampling intervals at DP-2 (3,900-5,300 $\mu\text{g/L}$, TCE; 158-470 $\mu\text{g/L}$, chlorobenzene). At both the well and drive-point locations, the depth of contamination is unknown because only shallow zones were sampled. High concentrations (3,900 $\mu\text{g/L}$, TCE; 270 $\mu\text{g/L}$, 1,2,3-trichloropropane) of POCs in the deepest sampled interval (47-49 ft) at DP-2 suggest that contamination probably extends deeper than 49 ft within the aquifer system. The fire-prevention area could be the source of contamination found in ground water underlying the Equestrian Park; however, ground-water/surface-water relations in the study area are poorly defined.

Line E-E' (pl. 5) extends from the equalization basins at the wastewater-treatment facility to the Toms River floodplain. The line includes drive points DP-4 and DP-5. Well 0133 (fig. 11), located east of the equalization basins, contained high concentrations of chlorobenzene (8,300 $\mu\text{g/L}$). (Pinder and others (1988) note that, in this area, inorganic contamination is found in water from the deep sand layer that they refer to as the Kirkwood no. 1 sand.) Both TCE and chlorobenzene were detected in ground water east of the wastewater-treatment facility and were found in lower concentrations downgradient. At both drive-point sites, both compounds were detected only in the deepest sampling intervals. Along line E-E' (pl. 5) the contamination appeared to extend below a shallow clay and silt layer. Because of the lack of deep wells, the vertical extent of the contamination at well sites 0133, RI-22S, RI-22D, and RI-16, and at drive-point sites DP-4 and DP-5, is unknown. Additional wells east of DP-5 and on both sides of the Toms River would help to define the extent of contamination.

Hydrochemical line F-F' (pl. 6) shows that TCE and chlorobenzene in ground water appeared to originate at the filtercake-disposal area, and possibly at the drum-disposal area. Neither contaminant had been detected previously in ground water sampled near the western border of the active landfill (well 0122). TCE and chlorobenzene concentrations were highest at the presumed source areas (the drum-disposal area and filtercake-disposal area) and were lower in ground water closer to the purge well. The active landfill is not a likely source area for chlorobenzene and TCE. Analyses of the active-landfill leachate did not detect TCE (Roman Luzecky, New Jersey Department of Environmental Protection, written commun., 1990). In the floodplain, TCE and chlorobenzene were found only in samples from the deepest

wells in the RI-5 and RI-13 well clusters and in the deepest drive-point interval. At wells 0166 and RI-5D, POC contamination was found below a clay and silt layer at roughly 10 ft below sea level; however, chlorobenzene was detected (93 $\mu\text{g/L}$) at 60 ft below sea level (well 0167). Because both TCE and chlorobenzene were detected in water from wells and a drive point installed in the wetlands between the Superfund site and the Toms River, the presence of contamination suggests that the source could be the plant. Recent (1989) analysis of water from RI-13D suggests that contamination also has migrated east of the Toms River. No deep observation wells are screened in the base of the Kirkwood-Cohansey aquifer system along line F-F', with the exception of RI-24XD, which is located upgradient from known contamination. Because of the multiple source areas within the Superfund site and the complexity of the flow system, it is possible that contaminants do not form a single "plume" but rather a series of "fingers" that coalesce as they move away from the source areas.

SUMMARY AND CONCLUSIONS

Ground water is the principal source of drinking water in the vicinity of Ciba-Geigy Superfund site, near Toms River, Ocean County, New Jersey. Organic compounds and trace metals from several point sources have contaminated ground water at Ciba-Geigy's Toms River Chemical Company plant.

The field investigation consisted of an electromagnetic-induction survey covering 45 line-miles; gamma-ray logging in 8 wells; installation of 5 temporary drive points; gamma-ray logging at 5 drive-point sites; measurement of specific conductance of ground water in 20 wells; measurement of ground-water levels in 20 wells; and a GPR survey conducted in a small part of the borrow area. Thirteen sets of water-quality samples and two duplicate sets of samples were collected from the drive points for analysis for POCs, inorganic constituents, and nutrients.

The USGS, in cooperation with the USEPA, conducted a hydrogeologic, geophysical, and ground-water-quality reconnaissance at and near the Superfund site. This study determined the electrical conductivity of the shallow part of the Kirkwood-Cohansey aquifer system in the vicinity of the site, and provided additional information on the extent and character of ground-water contamination at and near the site by means of surface- and borehole-geophysical techniques and ground-water sampling at drive points. In addition, a GPR survey was used to locate possible buried trenches in the eastern part of the borrow area.

Geophysical logs run for the present study and available gamma-ray and geologists' logs were examined. Geologic and geophysical data from the logs indicate that the shallow aquifer system (altitudes above 20 to 60 ft below sea level) underlying the study area is composed primarily of sand with discontinuous silt and clay layers. Data for the deep part of the system are sparse because few test holes or deep wells have been drilled at the site. On the basis of limited data from several well logs, silt, clayey silt, and clay layers appear to be thicker in the deep part of the aquifer system than in the shallow part. Data are inadequate to establish the lateral continuity of the deep layers. Two sand layers in the deep part of the aquifer system were identified in logs of the deep wells; these layers appear to be continuous in the study area.

The Toms River is the only major surface-water feature in the study area. The hydraulic connection between the Kirkwood-Cohansey aquifer system and the Toms River and associated wetlands is not clearly understood. The shallow aquifer system discharges to the Toms River. The presence of dissolved contaminants in ground water in the eastern bank of the Toms River suggests that ground water from the deep part of the system (screened zone 7.2 ft above to 28.3 ft below sea level) may not discharge to the river but rather could pass beneath. More data are required to assess ground-water movement beneath the river accurately.

High values of apparent terrain-conductivity generally indicate the presence of one or more of the following: highly conductive ground water, clay, a shallow water table, and metal. Lithologic and borehole-geophysical logs were examined to determine the presence of clay, especially in areas of anomalously high apparent terrain-conductivity. Water-table effects on EM data were minimized by separating data collected over a shallow and a deep water table. Areas with anthropogenic features, such as buried and overhead utilities and fences, were avoided.

Electromagnetic-induction surveys used to detect ground-water contamination where dissolved inorganic contaminants increase the electrical conductivity of the water. Such surveys are not likely to detect contamination that is entirely organic and nonconductive. Results of the survey performed in the study area indicated that apparent-terrain-conductivity values higher than background levels extend eastward from the production area to the Toms River. Values greater than background also were found in the Equestrian Park and near observation well RI-13 in Lower Winding River Park. Areas with apparent-terrain-conductivity values higher than background levels are limited to, and approximately coincide with, areas where ground-water contamination has been identified.

A GPR survey was performed in the eastern part of the borrow area. Depth of the GPR exploration ranged from roughly 30 ft below land surface in the central and southeastern parts of the surveyed area to greater than 56 ft in the northwestern part of the surveyed area. The GPR signal was attenuated throughout the central and southeastern parts of the surveyed area. Signal attenuation probably is caused by landfilled anthropogenic materials and (or) by the influence of a local silt and clay layer at 25 to 27 ft below land surface. In general, GPR profiles for part of the borrow area show that sand layers and silt and clay layers are horizontally layered and discontinuous. GPR anomalies that form a continuous east-west trending band across the eastern part of the borrow area were identified. The anomalies are trough-shaped and could indicate the presence of either a buried trench or a natural feature, such as a buried streambed. The GPR anomalies generally extend to depths of approximately 8 to 11 ft below land surface. The trend of the anomalies is similar to the trend of a trench previously identified from aerial photographs.

Specific conductance of ground water in the shallow Kirkwood-Cohansey aquifer system generally is less than 70 $\mu\text{S}/\text{cm}$. The specific conductances of water from uncontaminated areas in the study area ranged from 37 to 56 $\mu\text{S}/\text{cm}$.

Electrically conductive ground water with a maximum known specific conductance of 1,860 $\mu\text{S}/\text{cm}$ extends eastward from the production area to the Toms River, and also is present in the Equestrian Park and in the vicinity of observation well RI-13 in Lower Winding River Park. The areal extent of the elevated specific-conductance measurements approximately coincides with the extent of ground water containing POCs and elevated chloride concentrations. A regression analysis performed on electromagnetic-terrain-conductivity and specific-conductance data show a logarithmic relation. The unexplained variance associated with the regression line exceeds 50 percent, indicating that other variables, such as the heterogeneity of the sediments and the concentration of dissolved ions in the contamination plume, could have a large effect on the electromagnetic-terrain-conductivity values.

Of the five temporary drive points installed, three were installed in the floodplain on the western bank of the Toms River, one was installed in the Equestrian Park, and one was installed 100 ft downgradient from the borrow area. Ground water was sampled at two or three depths at each drive-point site. Ground water at all five drive-point sites is moderately acidic--typical of ground water in the Kirkwood-Cohansey aquifer system in Ocean County. The specific conductance of ground water ranged from 42 to 1,860 mS/cm . Specific-conductance values increased with depth at all three drive-point sites on the Toms River floodplain, and in the Equestrian Park. Concentrations of calcium, magnesium, chloride, and sulfate also increased with depth at these four sites. The concentrations of these inorganic constituents were one to two orders of magnitude greater in water samples from within the organic-contaminant plume than in samples from zones that apparently do not contain organic compounds. Concentrations of nitrate did not exceed the USEPA MCL. Cadmium and selenium were the only metals found in concentrations exceeding the USEPA MCLs.

Thirty-six POCs were identified in the water samples from the drive points. Approximately half of the water samples contained POCs in concentrations that exceed New Jersey primary drinking-water criteria. (POC analyses of water from drive points were used only to make qualitative interpretations because samples were collected with a peristaltic pump.) Total POC concentrations ranged from 26.8 to 7,157 $\mu\text{g}/\text{L}$ and increased with depth at all five drive-point sites. All samples with POCs contained trichloroethylene (maximum concentration, 5,300 $\mu\text{g}/\text{L}$). Two compounds identified in the current study--1,2,3-trichloropropane and 1,2-dichloropropane--had not been identified in previous studies. Additional sampling is needed to verify the presence of these two compounds both at the drive-point sites and elsewhere within the mapped area of contaminated water. Because 1,2,3-trichloropropane was present in many of the drive-point water samples, it is likely that this compound is present throughout a significant part of the mapped area of contaminated ground water.

Results of the geophysical techniques used in the current study do not strongly indicate the presence of extensive new areas of contamination. Results of the EM survey indicate that apparent-conductivity values in the vicinity of the borrow area were slightly higher than background levels. Whether the slightly elevated values were caused by a change in lithology is unclear. POCs were detected in water samples from the drive-point site downgradient from the borrow area, but their concentrations were low compared to POC concentrations in samples from other drive-point sites.

The drive-point water-quality data confirm the presence of organic compounds in the floodplain on the west bank of the Toms River, where no wells had been installed previously; in the Equestrian Park on the east bank; and downgradient from the borrow area. At each site ground water from the deepest interval sampled contained POCs, although the POC concentrations near the borrow area were relatively low (26.8 $\mu\text{g/L}$). Because the drive points could not be installed to a depth greater than 50 ft below land surface, the depth to which the contaminated ground water extends is unknown. Ground-water sampling at greater depths at each site is needed in order to determine the vertical extent of ground-water contamination.

Drive-point water-quality data and results of previous studies indicate that trichloroethylene and chlorobenzene are ubiquitous POCs wherever contaminated ground water was sampled. Both compounds were found in 51 wells and drive points. Concentrations were highest at the source areas and decreased downgradient, toward the Toms River, except in the Equestrian Park, where they were high. Recent (1989) analysis of water from RI-13D suggest that the contamination has migrated east of the Toms River. Resampling of well RI-13D is needed to verify the presence of TCE. Deeper wells than those installed for this study and well clusters screened at different intervals are required to determine the depth of contamination.

The hydrogeologic framework at and near the Superfund site is poorly defined. Well logs (gamma-ray logs and geologists' logs) indicate that the silt and clay layers in the shallow (20-60 ft below sea level) part of the system are discontinuous, and therefore unlikely to present an effective barrier to the downward migration of contaminants. Sparse data for the deep part of the aquifer system do not permit an accurate assessment of the movement of contaminants at depth. Additional hydrogeologic information is needed to determine the nature of the hydrogeologic complexities at the site so that the ground-water-flow system and the movement of contaminants within it can be described.

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GLOSSARY

Angular frequency: Repetition rate measured in radians per second; equal to $2\pi f$ where f is the frequency in Hertz.

Apparent conductivity: Conductivity measured by using inductive electromagnetic techniques; differs from true conductivity as a result of inhomogeneities of the Earth.

Apparent resistivity: Resistivity measured by using inductive electromagnetic techniques; differs from true resistivity as a result of inhomogeneities of the Earth.

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Conductivity: Ability of a material to conduct electrical current; in an isotropic material, the reciprocal of resistivity.

Confined aquifer: An aquifer containing water under sufficient pressure so that, when penetrated by a well, the water level stands at some height above the top of the aquifer but not necessarily above the land surface. Synonymous with artesian aquifer.

Confining unit: a body of relatively impermeable material stratigraphically adjacent to one or more aquifers.

Depth of well:

Depth drilled or total depth of hole is the total depth in feet below land-surface datum to which the hole was drilled, regardless of the finished depth of the well.

Depth of well is the maximum depth in feet below land-surface datum at which the well was originally finished.

Dipole: Poles of opposite signs, ideally infinitesimally close together; in electromagnetic techniques, an electric- or magnetic-field transmitting or receiving antenna that is small enough to be represented mathematically as a dipole.

e: Base of natural logarithm; $e = 2.7183$.

Eddy current: Circulating electrical currents induced in a conductive body by a time-varying magnetic field; the direction of eddy current flow produces a secondary magnetic field which opposes the primary field; the secondary field has a quadrature component which depends on the ratio of the resistance to the reactance of the eddy-current path.

i: In complex-number plane, $i = \text{square root of } -1$.

Induction: Process by which electric currents are generated in a conductor by placing it in an electromagnetic field.

GLOSSARY--Continued

Land-surface datum: A datum plane that is approximately at the land surface at a site. Well and exploratory-borehole depths, screen settings, and water levels listed in table 4 were measured with reference to the land-surface datum.

Microgram per liter ($\mu\text{g/L}$): A unit used to express the concentration of chemical constituents in a solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligram per liter (mg/L): A unit used to express the concentration of chemical constituents in a solution as weight (milligrams) per unit volume (liter) of water.

Minimum reporting level: For a particular chemical constituent and analytical procedure, that concentration below which the presence of the constituent cannot be verified. In this report the minimum reporting levels are listed in table 2 and can be identified as those entries in the water-quality tables (tables 4-10) that are preceded by a "less-than" (<) symbol.

Purgeable organic compounds: A group of synthetic organic substances that include several chlorinated hydrocarbon solvents. These compounds are less than 2-percent soluble in water, and have boiling points less than 150 °C.

Reactance: The opposition to alternating current flow offered by inductance or capacitance.

Relative dielectric permittivity: A measure of the capacity of a material to store a charge when an electric field is applied relative to the same capacity in a vacuum.

Resistance: The opposition to the flow of direct current.

Resistivity: Property of a material that resists the flow of electrical current; units are ohm-meters.

Specific conductance: A measure of the ability of water to conduct an electrical current, expressed in microsiemens per centimeter at 25 °C (degrees Celsius). Because the specific conductance is related to the particular chemical types of ions in solution and their concentrations, it can be used to approximate the dissolved-solids concentration of the water. The dissolved-solids concentration in milligrams per liter is about 55 to 75 percent of the specific conductance in microsiemens per centimeter at 25 °C (Hem, 1985).

APPENDIXES

Appendix A--Records of selected wells and drive points at the Ciba Geigy Superfund site and vicinity

[--, data not available; all wells screened in the Kirkwood-Cohansey aquifer system, except where noted; (gal/min)/ft, gallons per minute per foot of drawdown; USGS, U.S. Geological Survey]

Local ident- ifier	Well ident- ifica- tion number	Permit number	Lati- tude	Longi- tude	Date con- structed	Type of driller	Depth of well (feet)	Diam- eter of well (in- ches)	Depth of screen below land surface Top Bottom (feet) (feet)		Altitude of land surface (feet above sea level)	Spe- cific ca- pac- ity ((gal/ min)/ ft)
Ciba-Geigy observation wells												
0081	290983	53-00075-7	395935	0741525	04-00-62	--	96.0	--	--	--	70	--
0084	290968	33-01179	395917	0741514	06-18-65	--	76.2	4	73.2	76.2	65.69	--
0104A	291012	--	395841	0741355	05-07-77	COMMERCIAL	63.5	4	53.5	63.5	49.45	--
0112	290943	33-03730	395830	0741341	06-18-76	COMMERCIAL	49.3	4	43.3	49.3	51.93	--
0113	290951	33-03728	395848	0741334	09-18-76	COMMERCIAL	57.07	4	47.7	57.07	32.07	--
0114	290955	33-03729	395859	0741341	09-18-76	--	60.4	4	54.4	60.4	51.04	--
0122	291011	33-05192	395837	0741406	01-04-78	COMMERCIAL	56.83	4	38.83	46.8	57.39	--
0125	290965	21-01476	395917	0741344	08-17-78	COMMERCIAL	66.96	4	62.0	66.96	26.84	--
0127	290964	21-01567	395917	0741341	08-09-78	COMMERCIAL	64.8	4	59.8	64.8	23.00	--
0130	291019	--	395910	0741354	08-08-78	COMMERCIAL	43	4	33	43	61.56	--
0131	290958	53-00086-2	395910	0741355	08-07-78	COMMERCIAL	69.8	4	64.8	69.8	61.65	--
0133	291018	33-10350	395906	0741410	12-18-81	COMMERCIAL	51.11	4	31.1	41.1	53.04	--
0139	291013	33-10809	395844	0741344	06-07-82	COMMERCIAL	48.48	4	28.5	38.5	46.31	--
0142	290925	33-10812	395841	0741348	06-08-82	COMMERCIAL	59.8	--	39.8	49.8	49.84	--
0146	290980	33-11335	395935	0741417	01-04-83	COMMERCIAL	48.79	4	18.8	38.8	37.47	--
0160	291016	33-11478	395858	0741344	05-18-83	COMMERCIAL	68.53	4	56.5	66.5	53.29	--
0166	291014	33-13295	395844	0741336	12-00-83	COMMERCIAL	71.17	4	59.2	69.2	42.19	--
0167	291015	33-13067	395844	0741340	12-14-83	COMMERCIAL	118.24	4	106.2	116.2	51.17	--
0169	290944	33-13922	395834	0741308	04-26-84	COMMERCIAL	22.5	4	10.5	20.5	13.84	--
0175	291017	33-15550	395851	0741351	01-17-85	COMMERCIAL	59.0	4	37	57	39.80	--
0179	290959	33-17285-4	395910	0741355	09-04-85	--	214.0	4	200.0	214.0	61.90	--
0182	290984	33-17288-4	395916	0741427	10-08-85	COMMERCIAL	204.6	4	195.0	199.0	59.90	--
0185	290993	33-17699	395913	0741322	12-12-85	COMMERCIAL	73.1	4	61.0	71.0	23.87	--
0187	290985	33-17701	395920	0741322	12-17-85	COMMERCIAL	77	4	65.0	75.0	31.18	--
0189	290990	33-17737	395927	0741344	12-19-85	COMMERCIAL	62.0	4	49.0	60.0	23.75	--
0190	290989	33-17740	395927	0741344	12-19-85	COMMERCIAL	25.0	4	12.6	22.6	23.56	--
0191	290987	33-17738	395927	0741333	01-08-86	COMMERCIAL	72.0	4	60.0	70.8	25.69	--
0192	290988	33-17739	395927	0741333	01-08-86	COMMERCIAL	25.0	4	13.0	23.0	25.72	--
0198	291020	33-18342	395920	0741351	01-30-86	--	88.0	4	76.5	86.5	44.56	--
0261	290992	--	395938	0741413	08-23-82	COMMERCIAL	37.99	2	33.89	36.89	37.44	--
0262	290966	53-00104-4	395917	0741504	08-31-82	COMMERCIAL	89.50	2	39.5	89.5	66.92	--
0263	290972	53-00105-2	395920	0741504	09-03-81	COMMERCIAL	88.9	2	38.9	88.9	67.27	--
1104	290991	33-18654	395938	0741413	02-26-86	COMMERCIAL	112.0	4	100.0	110.6	66.13	--
1118	290986	33-19721	395920	0741456	06-05-86	COMMERCIAL	90.0	4	83.0	88.6	47.67	--

Appendix A--Records of selected wells and drive points at the Ciba-Geigy Superfund site and vicinity--Continued

Local ident- ifier	Well ident- ification number	Permit number	Lati- tude	Longi- tude	Date con- structed	Type of driller	Depth of well (feet)	Diam- eter of well (in- ches)	Depth of screen below land surface Top Bottom (feet) (feet)		Alti- tude of land surface (feet above sea level)	Spe- cific ca- pac- ity ((gal/ min)/ ft)
U.S. Environmental Protection Agency observation wells												
RI-2XD	291024	33-16120-8	395840	0741308	05-22-85	COMMERCIAL	53.0	4	39.0	50.0	14.29	--
RI-4S	290948	33-16123-2	395841	0741323	05-10-85	COMMERCIAL	45.0	4	34.0	45.0	49.10	--
RI-5S	291026	33-16125-9	395844	0741326	05-08-85	COMMERCIAL	35.0	4	23.88	35.0	39.95	--
RI-5D	291027	33-16126-7	395844	0741326	05-02-85	COMMERCIAL	64.25	4	53.25	64.25	39.85	--
RI-7	290962	33-16128-3	395917	0741334	05-14-85	COMMERCIAL	32.0	4	23.0	29.0	18.76	--
RI-9	290975	33-16130-5	395924	0741352	05-24-85	COMMERCIAL	24.0	4	15.0	21.0	21.18	--
RI-10S	290973	33-16131-3	395924	0741334	05-29-85	COMMERCIAL	37.2	4	28.2	34.2	23.12	--
RI-10D	291037	33-16155-1	395924	0741334	08-09-85	COMMERCIAL	68.0	4	59.0	65.0	23.20	--
RI-13S	290950	33-16135-6	395848	0741316	06-05-85	COMMERCIAL	21.0	4	14.9	21.0	13.49	--
RI-13D	291029	33-16136-4	395848	0741316	06-04-85	COMMERCIAL	42.2	4	30.2	41.2	13.63	--
RI-16	290956	33-16141-1	395859	0741341	06-19-85	COMMERCIAL	75.2	4	61.2	72.2	51.40	--
RI-17	290976	33-16142-9	395924	0741355	06-24-85	COMMERCIAL	34.5	4	26.5	32.5	23.50	--
RI-18	290918	33-16143-7	395852	0741352	06-27-85	COMMERCIAL	42.0	4	35.6	42.0	39.80	--
RI-19S	290971	33-16144-5	395920	0741402	06-18-85	COMMERCIAL	37.0	4	30.9	37.0	49.90	--
RI-19D	290919	33-16145-3	395920	0741402	06-18-85	COMMERCIAL	52.5	4	38.5	49.5	49.90	--
RI-21S	290940	33-16162-3	395823	0741344	08-21-85	COMMERCIAL	40.0	4	34.0	40.0	48.19	--
RI-21D	291021	33-16160-7	395823	0741344	08-20-85	COMMERCIAL	99.0	4	85.0	96.0	48.20	--
RI-21XD	290920	33-16161-5	395823	0741344	08-27-85	COMMERCIAL	213.0	4	202.0	208.0	48.10	--
RI-22S	290957	33-16159-3	395902	0741348	08-22-85	COMMERCIAL	46.5	4	40.0	46.5	55.10	--
RI-22D	290921	33-16173-9	395902	0741348	10-02-85	COMMERCIAL	73.0	4	59.0	70.0	54.90	--
RI-24S	290952	33-16163-1	395848	0741442	09-05-85	COMMERCIAL	65.0	4	59.0	65.0	65.59	--
RI-24D	291032	33-16164-0	395848	0741442	09-04-85	COMMERCIAL	88.0	4	74	85	65.79	--
RI-24XD	291033	33-16165-8	395848	0741442	09-04-85	COMMERCIAL	214.0	4	203.0	209.0	65.79	--
RI-26	290977	33-16170-4	395924	0741530	10-01-85	COMMERCIAL	109.0	4	95.0	106.0	73.0	--
RI-27XD	291038	33-16167-4	395927	0741442	09-20-85	COMMERCIAL	216.0	4	205	211.0	59.90	--
RI-28S	290981	33-16171-2	395942	0741406	10-04-85	COMMERCIAL	44.5	4	30.5	41.5	28.50	--
RI-28D	290922	33-16172-1	395942	0741406	10-03-85	COMMERCIAL	66.5	4	52.5	63.5	28.80	--
RI-29S	290979	33-16148-8	395935	0741352	06-25-85	COMMERCIAL	33.0	4	27.0	33.0	18.80	--
RI-31S	290978	33-16157-7	395928	0741406	08-22-85	COMMERCIAL	47.25	4	40.85	47.25	46.30	--
RI-31D	290923	33-16158-5	395928	0741406	08-21-85	COMMERCIAL	92.0	4	78.0	89.0	46.70	--
RI-32D	290942	33-16168-2	395826	0741301	09-30-85	COMMERCIAL	67.0	4	53.0	64.0	17.18	--
RI-32XD	291022	33-16169-1	395826	0741301	09-26-85	COMMERCIAL	179.5	4	168.5	174.5	17.35	--
Drive-point boreholes												
DP-1	290929	33-26729	395936	0741409	08-11-89	USGS	48	3	0	48.0	50	--
DP-1	291042	33-26729	395936	0741409	08-11-89	USGS	30	3	28.0	30.0	50	--
DP-1	291043	33-26729	395936	0741409	08-11-89	USGS	42	3	40.0	42.0	50	--
DP-1	291044	33-26729	395936	0741409	08-11-89	USGS	47	3	45	47	50	--
DP-2	290930	33-26652	395925	0741347	08-21-89	USGS	50	3	0	50.0	21	--

Appendix A--Records of selected wells and drive points at the Ciba Geigy Superfund site and vicinity--Continued

Local ident- ifier	Well ident- ifica- tion number	Permit number	Lati- tude	Longi- tude	Date con- structed	Type of driller	Depth of well (feet)	Diam- eter of well (in- ches)	Depth of screen below land surface Top Bottom (feet) (feet)		Alti- tude of land surface (feet above sea level)	Spe- cific ca- pac- ity ((gal/ min)/ ft)
Drive-point boreholes--Continued												
DP-2	291045	33-26652	395925	0741347	08-21-89	USGS	17	3	15	17	21	--
DP-2	291046	33-26652	395925	0741347	08-21-89	USGS	42	3	40	42	21	--
DP-2	291047	33-26652	395925	0741347	08-21-89	USGS	49	3	47	49	21	--
DP-3	290931	33-26734	395848	0741323	08-31-89	USGS	28	3	0	28	14.5	--
DP-3	291048	33-26734	395848	0741323	08-31-89	USGS	14	3	12	14	14.5	--
DP-3	291049	33-26734	395848	0741323	08-31-89	USGS	27	3	25	27	14.5	--
DP-4	290932	33-26731	395857	0741331	09-07-89	USGS	33	3	0	33	16	--
DP-4	291050	33-26731	395857	0741331	09-07-89	USGS	19	3	17	19	16	--
DP-4	291051	33-26731	395857	0741331	09-07-89	USGS	32	3	30	32	16	--
DP-5	290933	33-26730	395856	0741327	09-12-89	USGS	53	3	0	53	15	--
DP-5	291052	33-26730	395856	0741327	09-12-89	USGS	4	3	2	4	15	--
DP-5	291053	33-26730	395856	0741327	09-12-89	USGS	14	3	12	14	15	--
DP-5	291054	33-26730	395856	0741327	09-12-89	USGS	34	3	32	34	15	--
USGS well												
TRC84†	290085	--	395929	0741420	06-68	COMMERCIAL	1,480	6	1,460	1,480	66.71	--
Ciba-Geigy production wells												
PD-100	290072	33-00047	395910	0741430	09-09-52	COMMERCIAL	103	16	83	103	60.0	5.06
PD-200	290073	33-00044	395917	0741428	09-11-52	COMMERCIAL	102	16	82	102	65.0	9.04
PD-206*	290074	33-00049	395917	0741428	08-13-52	COMMERCIAL	108	16	88	108	65.0	8.42
PD-220	290078	--	375919	0741421	08-09-55	COMMERCIAL	97	12	82	97	61.0	18.29
PD-400	290081	33-00958	395920	0741432	04-20-61	COMMERCIAL	98	12	83	98	68.0	18.33
PD-403*	291036	--	395913	0741406	04-16-51	--	108	16	88	108	65.3	--
PD-404	290075	33-01032	395918	0741503	06-26-62	COMMERCIAL	97	12	82	97	69.0	13.92
PD-502	290093	33-01033	395934	0741503	07-13-62	COMMERCIAL	88	12	73	88	56.0	13.38
PD-503	290087	53-01142	395931	0741520	07-15-66	COMMERCIAL	110	12	85	110	70.0	13.79
PD-504	290076	33-01257	395918	0741522	06-09-71	COMMERCIAL	93	12	78	93	60.0	7.51
PD-800*	290077	33-00048	395919	0741418	08-12-52	COMMERCIAL	100	16	80	100	62.0	14.00
PD-1200*	290082	--	395924	0741418	07-09-55	COMMERCIAL	75	12	60	75	36.0	13.51
Ciba-Geigy purge wells												
PG-746	291031	33-15053	395848	0741359	09-29-84	COMMERCIAL	69	8	24	64	43	23.99
PG-747	291030	33-15054	395848	0741348	10-08-84	COMMERCIAL	75	8	32	70	44	23.81
PG-748	291028	33-15055	395844	0741341	10-22-84	COMMERCIAL	70	8	19	65	41.5	27.77
PG-749	291025	33-15056	395841	0741341	10-15-84	COMMERCIAL	91	8	41	86	57	25.00
PG-750	291023	33-15057	395837	0741344	10-17-84	COMMERCIAL	95	8	44	90	59	40.00
PG-754	291035	33-18898	395904	0741406	05-07-86	COMMERCIAL	72	8	26	67	60	15.24
PG-755	291034	33-18899	395903	0741407	05-07-86	COMMERCIAL	72	8	26	67	55	16.55

Appendix A--Records of selected wells and drive points at the Ciba Geigy Superfund site and vicinity--Continued

Local ident- ifier	Well ident- ifica- tion number	Permit number	Lati- tude	Longi- tude	Date con- structed	Type of driller	Depth of well (feet)	Diam- eter of well (in- ches)	Depth of screen below land surface		Alti- tude of land surface (feet above sea level)	Spe- cific cap- acity ((gal/ min)/ ft)
									Top (feet)	Bottom (feet)		
Toms River Water Company public-supply wells												
DUGANS 22	290097	33-01229	395945	0741222	03-02-70	COMMERCIAL	126	12	106	126	80	17.44
DUGANS 23	290098	33-01230	395945	0741222	03-07-70	COMMERCIAL	274	12	254	275	80	1.75
DUGANS 24	290094	33-11227	395941	0741209	04-02-70	COMMERCIAL	125	12	105	125	75	14.35
DUGANS 26	290083	33-01231	395926	0741237	04-23-70	COMMERCIAL	134	12	113	133	80	13.36
TRWC-20	290088	33-01147	395933	0741312	08-15-66	COMMERCIAL	86	12	66	86	40	13.24
TRWC-21	290058	33-01185	395715	0741231	05-10-68	COMMERCIAL	56	12	46	56	10	25.16
TRWC-28	290627	33-02075	395936	0741229	-- -- 74	COMMERCIAL	125	12	105	125	80	22.00
TRWC-29	290628	33-02076	395936	0741217	-- -- 74	COMMERCIAL	137	12	115	135	80	21.35
TRWC-30†	290626	33-10224	395721	0741230	05-28-81	COMMERCIAL	1,875	12	1,700	1,875	9	17.72
TRWC-31	290591	29-09781	400226	0741431	06-28-79	COMMERCIAL	102	36	82	102	90	25.29
TRWC-33	290928	33-13599	395935	0741440	10-15-84	COMMERCIAL	102.5	16	72	102.5	30	28.95
TRWC-37	290937	33-23928	395719	0741233	12-15-87	--	238.5	16	190	210	6	--
TRWC-39**	291039	33-26307	395943	0741214	07-20-89	COMMERCIAL	288	14	248	288	75	--
Manchester Township Municipal Utilities Authority wells												
10††	291040	29-23401	400041	0741519	11-01-89	COMMERCIAL	1,189	18	1,013	1,184	60	15.55
12††	291041	29-23400	400046	0741533	03-23-90	COMMERCIAL	1,146	18	997	1,141	60	23.25

* Sealed well.

** Well is screened in Piney Point aquifer.

† Well is screened in the Potomac-Raritan-Magothy aquifer system.

†† Well is screened in the upper aquifer of the Potomac-Raritan-Magothy aquifer system.

Appendix B.--Inorganic and organic contaminants detected in soil and ground water at the Ciba-Geigy Superfund site during selected previous investigations, 1984-89

Organic contaminants

[from NUS Corporation, 1988, p. 4-63, and AWARE, Inc., 1986, p. 4-49]

1,1-Dichloroethene	Carbon tetrachloride
1,1,1-Trichloroethane	Chlorobenzene
1,1,2,2-Tetrachloroethane	Chloroform
1,2-Dichlorobenzene	Chloromethane
1,2-Dichloroethane	Chloropropene
1,2,4-Trichlorobenzene	Di-ethyl phthalate
1,3-Dichlorobenzene	Di-n-octyl phthalate
1,4-Dichlorobenzene	Di-N-butyl phthalate
2-Butanone	Ethylbenzene
2-Hexanone	Fluorene
2-Chloronaphthalene	Hexachlorobenzene
2-Chlorophenol	Hexachlorobutadiene
2-Nitroaniline	Isophorone
2,4-Dinitrotoluene	Monochlorobenzene
4-Chloroaniline	N-Nitrosodimethylamine
4-Methyl-2-pentanone	Naphthalene
4-Methylphenol	Nitrobenzene
4-Nitroaniline	Ortho-chloro-toluene
4-Nitrophenol	Pentachlorophenol
Acenaphthene	Pentanol
Aniline	Phenol
Azobenzene	Pyrene
Benzene	Tetrachloroethene
Benzo-a-anthracene	Tetrahydrofuran
Benzoic Acid	Toluene
Benzyl Alcohol	Total xylenes
Bis(2-Chloroethyl) ether	trans-1,2-Dichloroethene
Bis-(2-Chloroethoxy)-methane	Trichloroethene
Bis(2-Ethylhexyl) phthalate	Trichloropropane
Bromoform	Trimethylpentene
Carbon disulfide	Vinyl chloride

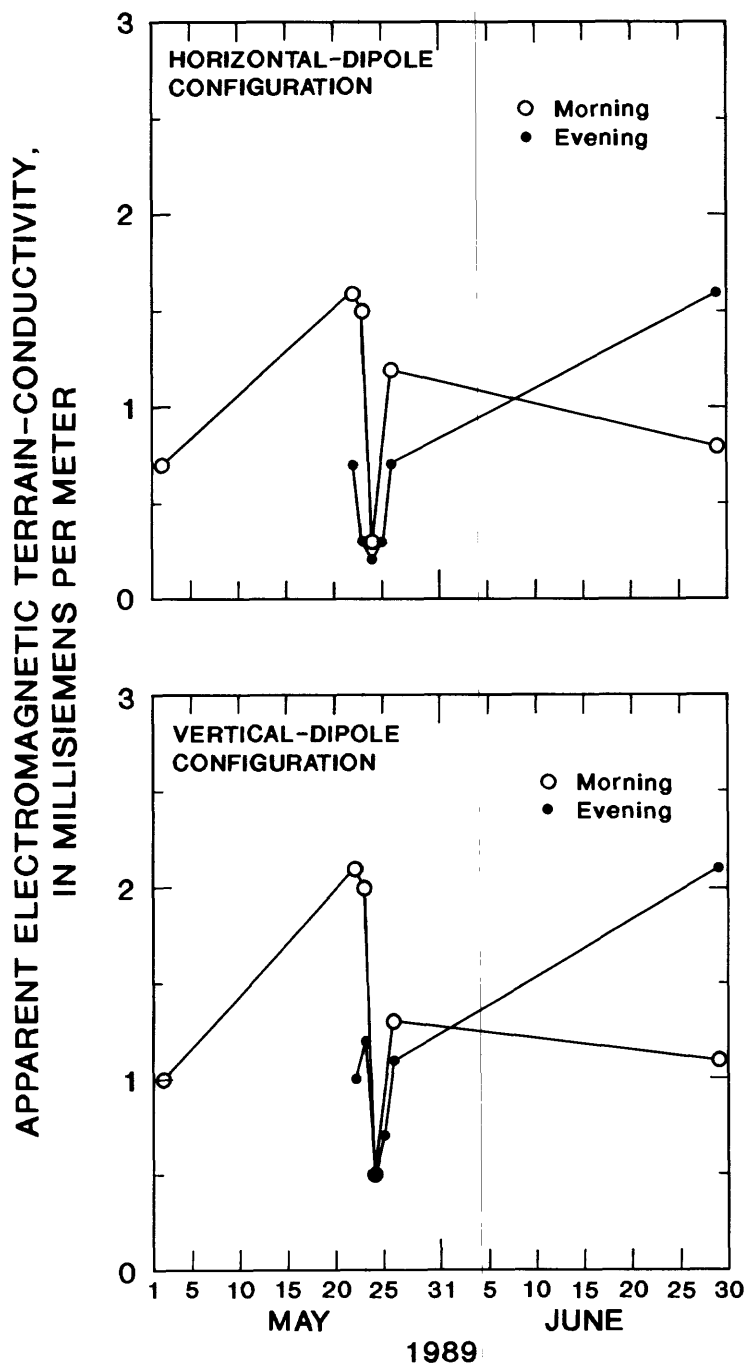
Inorganic contaminants

[from NUS Corporation, 1988, app. A-3, v. 3]

Arsenic	Lead
Barium	Mercury
Cadmium	Selenium
Chromium	Silver

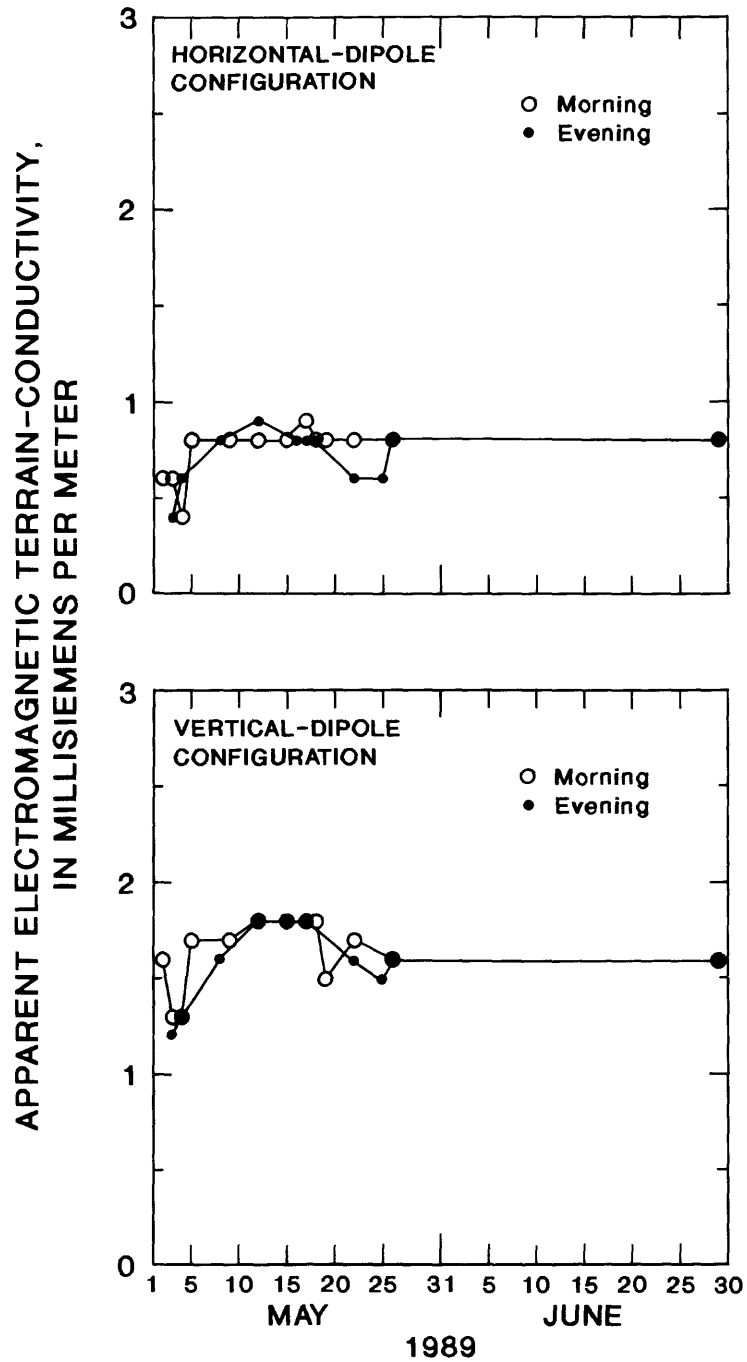
APPENDIX C

This appendix includes six graphs that show electromagnetic-terrain conductivity at the base station at the Ciba-Geigy Superfund site in 1989. The conductivity measurements were made as part of the quality-assurance/quality-control program.



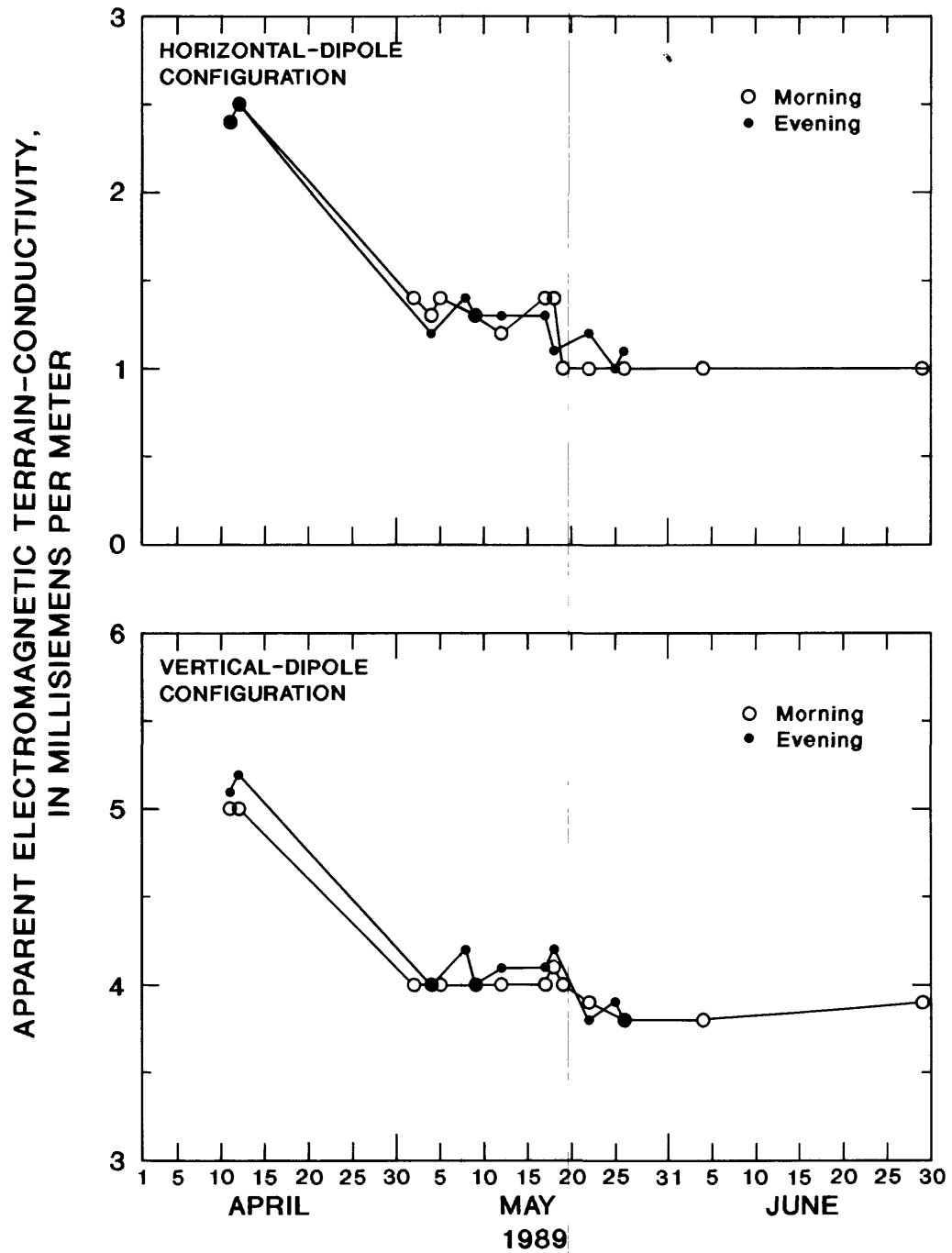
Vertical- and horizontal-dipole configurations with 32.8 feet between coils

APPENDIX C--Continued.



Vertical- and horizontal-dipole configurations with 65.6 feet between coils

APPENDIX C--Continued.



Vertical- and horizontal-dipole configurations with 131.2 feet between coils

Appendix D.--Ground-water levels at the Ciba-Geigy Superfund site, May 11-28, 1989

[--, data unavailable]

Well number	Land-surface elevation (feet)	Depth of screen below land surface		Depth to water below land surface (feet)	Altitude of water table (feet above sea level)	Date measured
		Top (feet)	Bottom (feet)			
RI-4S	49.10	34.0	45.0	34.9	14.20	5-19-89
RI-7	18.76	23.0	32.0	2.24	16.52	5-11-89
RI-10S	23.12	28.0	34.0	3.53	19.59	5-11-89
RI-13S	13.49	14.9	21.0	1.06	12.43	5-11-89
RI-18	39.80	35.6	42.0	19.63	20.17	5-18-89
RI-19S	49.90	30.9	37.0	28.19	21.17	5-17-89
RI-21S	48.19	34.0	40.0	34.00	14.19	5-17-89
RI-21D	42.20	85.0	96.0	33.83	8.37	5-19-89
RI-22S	55.10	40.0	46.0	36.03	19.07	5-22-89
RI-24S	65.59	59.0	65.0	42.40	23.39	5-19-89
RI-26	73.00	95.0	106.0	38.00	35.00	5-11-89
RI-28S	28.50	30.0	44.5	7.30	21.20	5-11-89
RI-29S	18.80	27.0	33.0	0.94	17.86	5-11-89
RI-31S	46.30	40.9	47.3	23.91	22.39	5-17-89
RI-32D	17.18	53.0	64.0	3.94	13.24	5-11-89
0081	70.00	--	--	40.66	29.34	5-11-89
0125	26.84	62.0	66.9	9.32	17.52	5-19-89
0142	49.84	39.8	49.8	34.90	14.94	5-17-89
0146	37.47	18.77	38.77	14.64	22.83	7-11-89
0169	13.84	10.5	20.5	3.12	10.72	5-11-89
0189	23.75	49.0	60.0	3.64	20.11	5-19-89

Appendix E.--Data from field forms used during drive-point sampling, Ciba-Geigy Superfund site, July through September 1989

[°C, degrees Celsius; μ S/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μ g/L, micrograms per liter]

Drive-point number and depth of screened interval in feet below land surface	Date sampled	Time sampled	Temperature (°C)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (μ g/L)
DPl 15-17	08-10-89	1609	14.3	4.1	5.8	258
		1614	14.0	1.6	6.0	252
		1620	13.7	.6	5.7	252
		1624	13.7	.5	5.7	250
		1627	13.7	.5	5.7	250
DPl 40-42	08-11-89	1012	16.7	5.3	5.1	86
		1017	15.9	3.3	5.1	45
		1022	17.7	1.8	5.0	42
		1027	17.7	1.3	5.0	42
		1032	17.7	1.0	4.9	42
		1037	17.7	.8	4.9	42
		1045	17.7	.5	5.0	42
DPl 45-47	08-11-89	1510	18.5	4.3	5.6	179
		1515	17.1	3.1	5.4	173
		1520	17.1	3.0	5.3	168
		1525	17.4	3.0	5.3	166
		1530	17.4	3.1	5.2	163
		1535	17.3	3.1	5.2	154
DP2 15-17	08-15-89	1420	19.8	2.3	4.1	1,381
		1425	19.1	.9	4.1	1,383
		1430	17.9	.5	4.1	1,420
		1435	18.7	.4	4.0	1,394
		1445	18.1	.4	4.0	1,401
		1450	18.0	.3	4.0	1,393
DP2 40-42	08-17-89	1320	20.6	1.8	4.4	1,425
		1327	15.9	.6	4.0	1,460
		1330	15.3	.8	4.5	1,455
		1335	15.2	.6	4.1	1,480
		1340	15.1	.5	4.1	1,481
		1345	15.1	.4	4.1	1,470

Appendix E.--Data from field forms used during drive-point sampling, Ciba
Geigy Superfund site, July through September 1989--Continued.

Drive-point number and depth of screened interval in feet below land surface	Date sampled	Time sampled	Temperature (°C)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µg/L)
DP2 47-49	08-17-89	1640	18.3	3.0	4.4	1,810
		1645	17.7	.6	4.9	1,835
		1650	17.2	1.6	4.7	1,825
		1655	17.0	.9	4.3	1,880
		1700	16.1	.8	4.1	1,869
		1705	16.2	.4	4.1	1,859
		1710	16.3	.6	4.1	1,857
		1715	16.1	.8	4.2	1,861
DP3 12-14	08-28-89	1527	16.5	7.9	5.1	121
		1532	15.9	5.8	4.9	122
		1537	15.6	5.3	4.9	121
		1542	15.6	5.7	4.9	121
DP3 25-27	08-28-89	1709	13.1	.4	4.5	496
		1714	12.9	.7	4.6	496
		1718	12.9	.7	4.6	496
		1725	13.1	.7	4.6	495
DP4 17-19	09-06-89	1120	16.2	8.2	5.4	94
		1125	16.1	7.7	5.4	92
		1130	16.0	7.6	5.4	93
		1135	16.2	7.5	5.4	93
		1140	15.9	7.6	5.4	93
DP4 30-32	09-06-89	1350	16.8	1.1	6.1	470
		1355	16.8	1.1	6.1	469
		1400	16.7	.9	6.1	469
		1410	16.6	.8	6.1	468
		1415	16.7	.8	6.1	468
		1421	16.7	.8	6.1	469
DP5 2-4	09-08-89	1240	20.0	1.8	4.3	60
		1245	19.8	1.2	4.2	61
		1250	19.7	1.1	4.3	61
		1255	19.8	.9	4.3	61
DP5 12-14	09-11-89	1110	13.8	.4	4.9	102
		1115	13.9	.3	4.9	102
		1120	13.9	.3	4.9	102
		1125	13.9	.3	4.9	102

Appendix E.--Data from field forms used during drive-point sampling, Ciba
Geigy Superfund site, July through September 1989--Continued.

Drive-point number and depth of screened interval in feet below land surface	Date sampled	Time sampled	Temperature (°C)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µg/L)
DP5 32-34	09-11-89	1350	13.3	0.7	5.1	123
		1355	12.7	.8	5.1	122
		1400	12.7	.8	5.1	122
		1405	12.5	.5	5.1	123

Appendix F.--Relative percent difference¹ in concentrations of inorganic and organic elements and compounds and values of physical properties in water sampled twice from drive points at Ciba-Geigy Superfund site, 1989

[--, comparison not possible because all values were less than the analytical detection limit]

Constituents	Relative percent difference between sample and duplicate concentrations or values ² duplicate set 1 ³	Relative percent difference between sample and duplicate concentrations or values ² duplicate set 2 ³
Nitrogen, ammonia + organic dissolved	28.5	9.5
Nitrogen, NO ₂ + NO ₃ dissolved	115.0	0
Phosphorous ortho, dissolved	5.9	--
Calcium, dissolved	0	0
Magnesium, dissolved	0	15.4
Sodium, dissolved	1.8	0
Chloride, dissolved	2.0	0
Sulfate, dissolved	0	0
Silica, dissolved	0	0
Arsenic, dissolved	--	--
Arsenic, total	--	--
Barium, dissolved	0	0
Barium, total	--	--
Beryllium, dissolved	--	--
Cadmium, dissolved	--	--
Cadmium, total	--	--
Chromium, dissolved	--	--
Chromium, total	--	--
Cobalt, dissolved	--	--
Copper, dissolved	--	--
Iron, dissolved	0	0
Lead, dissolved	--	0
Lead, total	--	0
Manganese, dissolved	0	0
Mercury, dissolved	--	--
Mercury, total	--	--
Molybdenum, dissolved	--	--
Nickel, dissolved	--	--
Silver, dissolved	--	--
Silver, total	--	--
Strontium, dissolved	0	--
Vanadium, dissolved	--	--
Zinc, dissolved	57.5	0
Lithium, dissolved	--	--
Selenium, total	--	--
Dichlorobromomethane, total	--	--
Carbon tetrachloride, total	--	--
1,2-Dichloroethane, total	--	--
Bromoform, total	--	--
Chloro-Dibromomethane, total	--	--
Chloroform, total	--	--
Phenols, total	--	93
Toluene, total	--	--
Benzene, total	--	--
Chlorobenzene, total	--	0
Chloroethane, total	--	--
Ethylbenzene, total	--	--
Methylbromide, total	--	--
Methylchloride, total	--	--
Methylene chloride, total	--	--
Tetrachloroethylene, total	--	--
Trichlorofluoromethane, total	--	--
1,1-Dichloroethane, total	--	--
1,1-Dichloroethylene, total	--	--
1,1,1-Trichloroethane, total	--	--
1,2,3-Trichloropropane, total	--	5.8
1,1,2-Trichloroethane, total	--	--
1,1,2,2-Tetrachloroethane, total	--	--
1,2-Dichlorobenzene, total	--	9.5
1,2-Dichloropropane, total	--	--
1,2-Trans-Dichloroethene, total	--	--
1,3-Dichloropropene, total	--	--
1,3-Dichlorobenzene, total	--	--
1,4-Dichlorobenzene, total	--	--
2-Chloroethyl vinyl ether, total	--	--
Dichloro-difluoromethane, total	--	--

Appendix F.--Relative percent difference¹ in concentrations of inorganic and organic elements and compounds and values of physical properties in water sampled twice from drive points at Ciba-Geigy Superfund site, 1989--Continued

Constituents	Relative percent difference between sample and duplicate concentrations or values ² duplicate set 1 ³	Relative percent difference between sample and duplicate concentrations or values ² duplicate set 2 ³
Trans-1,3-dichloropropene, total	--	--
Cis-1,3-Dichloropropene, total	--	--
Vinyl chloride, total	--	--
Trichloroethylene, total	--	0
Styrene, total	--	--
1,2-Dibromoethane water whole, total	--	--
Xylene, total	--	--
Specific conductance (lab)	0	0
Alkalinity (lab)	--	0

¹ Relative percent difference = $(1S-D1 \div [(S+D) \div 2]) \times 100$ where S=concentration of constituent or value of property in sample and D=concentration of constituent or value of property in duplicate sample.

² Values used to compare constituent concentrations and values of physical properties in samples and duplicates are provided in appendix G.

³ Duplicate samples are identified in appendix G.

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989

[°C, degrees Celsius; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; $\mu\text{g}/\text{L}$, micrograms per liter; mg/L , milligrams per liter; --, data not available; *, sample in duplicate set 1; **, sample in duplicate set 2; NA, not applicable; <, less than; DIS., dissolved; USGS, U.S. Geological Survey]

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE TOP BOTTOM (FEET)(FEET)	DATE SAMPLED	TEMPERATURE WATER (°C)	SPECIFIC CONDUCTANCE ($\mu\text{S}/\text{cm}$)	PH (STANDARD UNITS)	OXYGEN, DIS-SOLVED (mg/L)	ALKALINITY LAB (mg/L AS CaCO_3)	CALCIUM DIS-SOLVED (mg/L)	SULFATE DIS-SOLVED (mg/L)	SODIUM, DIS-SOLVED (mg/L)
DRIVE-POINT SAMPLES											
DP-1	291042	28-30	08-10-89	13.5	250	5.7	0.5	27	1.7	1.0	1.7
DP-1	291043	40-42	08-11-89	17.5	42	5.0	.5	6.0	1.2	7.0	11
DP-1	291044	45-47	08-11-89	17.5	159	5.2	3.1	4.0	4.4	11	17
DP-2	291045	15-17	08-15-89	18.0	1,390	4.0	.3	<1.0	55	670	56
DP-2	291046	40-42	08-17-89	15.0	1,470	4.1	.4	--	26	560	76
DP-2	291047	47-49	08-17-89	16.0	1,860	4.2	.8	<1.0	60	820	84
DP-3	291048	12-14	08-28-89	15.5	121	4.9	5.7	3.0	1.3	12	12
DP-3	291049	25-27	08-28-89	13.0	496	4.6	.7	<1.0	16	160	26
DP-4	291050	17-19	09-06-89	16.0	93	5.4	7.6	3.0	3.5	19	3.0
DP-4	291051	30-32	09-06-89	16.5	469	6.1	.8	30	21	150	23
DP-5	291052	2-4	09-08-89	20.0	61	4.3	.9	<1.0	.2	11	2.1
DP-5	291053	12-14	09-11-89	14.0	102	4.9	.3	<1.0	1.7	13	5.6
DP-5*	291053	12-14	09-11-89	14.0	102	4.9	.3	<1.0	1.7	13	5.7
DP-5	291054	32-34	09-11-89	12.5	123	5.1	.5	2.0	.14	20	13
DP-5**	291054	32-34	09-11-89	12.5	123	5.1	.5	2.0	.14	20	13
ANALYTE-FREE WATER AND EQUIPMENT BLANKS											
Analyte-free water		NA	07-05-89	--	--	7.5	--	--	<.02	<1.0	<.2
DP-1	290929	NA	08-09-89	--	--	7.4	--	1.0	.15	<1.0	<.2
DP-2	290930	NA	08-14-89	--	--	7.4	--	1.0	.03	<1.0	<.2
DP-3	290931	NA	08-28-89	--	--	--	--	1.0	.09	<1.0	<.2
DP-4	290932	NA	09-05-89	--	--	--	--	1.0	.09	<1.0	<.2
DP-5	290933	NA	09-08-89	--	--	6.7	--	3.0	.09	<1.0	<.2

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE TOP BOTTOM (FEET)(FEET)	DATE SAMPLED	MAGNESIUM, DIS-SOLVED (mg/L)	CHLORIDE, DIS-SOLVED (mg/L)	SILICA, DIS-SOLVED (mg/L)	IRON, DIS-SOLVED ($\mu\text{g}/\text{L}$)	MANGANESE, DIS-SOLVED ($\mu\text{g}/\text{L}$)	NITROGEN, AMMONIA + ORGANIC DIS-SOLVED (mg/L as N)	NITROGEN, NO ₂ +NO ₃ DIS-SOLVED (mg/L as N)	PHOSPHOROUS ORTHO, DIS-SOLVED (mg/L as P)
DRIVE-POINT SAMPLES											
DP-1	291042	28-30	08-10-89	0.94	3.2	3.5	64,000	280	3.0	0.028	0.001
DP-1	291043	40-42	08-11-89	.92	17	3.0	6,500	270	.7	.81	.225
DP-1	291044	45-47	08-11-89	1.5	25	4.6	6,100	250	.4	1.10	<.001
DP-2	291045	15-17	08-15-89	30	130	11	120,000	3,000	4.7	.016	.006
DP-2	291046	40-42	08-17-89	13	190	6.9	240,000	1,800	4.3	<.01	.006
DP-2	291047	47-49	08-17-89	39	230	9.7	26,000	4,000	--	<.01	.006
DP-3	291048	12-14	08-28-89	2.4	16	5.5	1,300	36	.2	.669	<.001
DP-3	291049	25-27	08-28-89	13	27	6.1	1,800	590	1.4	<.01	<.001
DP-4	291050	17-19	09-06-89	3.0	5.4	4.4	1,100	290	.2	.196	<.001
DP-4	291051	30-32	09-06-89	25	18	2.9	8,400	500	1.0	.356	.003
DP-5	291052	2-4	09-08-89	.29	4.7	3.7	7,600	89	.6	.050	.003
DP-5	291053	12-14	09-11-89	2.4	9.8	4.5	7,900	14	.4	.052	.035
DP-5*	291053	12-14	09-11-89	2.4	10	4.5	7,900	14	.3	.014	.033
DP-5	291054	32-34	09-11-89	.12	11	1.6	960	10	3.3	1.30	<.001
DP-5**	291054	32-34	09-11-89	.14	11	1.6	960	10	3.0	1.30	<.001
ANALYTE-FREE WATER AND EQUIPMENT BLANKS											
Analyte-free water		NA	07-05-89	.05	<.1	.02	4	<1	<.2	<.1	<.01
DP-1	290929	NA	08-09-89	.03	<.1	.02	16	3	<.2	1.90	<.001
DP-2	290930	NA	08-14-89	.02	.1	.01	89	9	.3	.053	.007
DP-3	290931	NA	08-28-89	.08	.2	.04	140	9	.2	.02	<.001
DP-4	290932	NA	09-05-89	.05	<.1	.08	280	14	.2	.13	.011
DP-5	290933	NA	09-08-89	.02	<.1	.09	37	5	<.2	.023	<.001

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989--Continued

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE TOP (FEET) BOTTOM (FEET)	DATE SAMPLED	ARSENIC, DIS-SOLVED (µg/L)	ARSENIC, TOTAL (µg/L)	BARIUM, DIS-SOLVED (µg/L)	BARIUM, TOTAL RECOVERABLE (µg/L)	BERYL-LIUM, DIS-SOLVED (µg/L)	CADMIUM, DIS-SOLVED (µg/L)	CADMIUM, TOTAL RECOVERABLE (µg/L)	CHROMIUM, DIS-SOLVED (µg/L)	CHROMIUM, TOTAL RECOVERABLE (µg/L)
DRIVE-POINT SAMPLES												
DP-1	291042	28-30	08-10-89	1	<1	2	<100	<0.5	4	<1	<5	3
DP-1	291043	40-42	08-11-89	<1	--	39	--	<.5	1	--	5	--
DP-1	291044	45-47	08-11-89	<1	--	68	--	<.5	<1	--	<5	--
DP-2	291045	15-17	08-15-89	1	--	19	--	<.5	6	--	<5	--
DP-2	291046	40-42	08-17-89	<1	<1	15	<100	<.5	13	<1	--	5
DP-2	291047	47-49	08-17-89	<1	--	18	--	<.5	12	--	<5	--
DP-3	291048	12-14	08-28-89	<1	--	27	--	<.5	<1	--	<5	--
DP-3	291049	25-27	08-28-89	1	<1	35	100	<.5	<1	<1	<5	4
DP-4	291050	17-19	09-06-89	<1	--	38	--	<.5	<1	--	<5	--
DP-4	291051	30-32	09-06-89	<1	<1	15	<100	<.5	<1	<1	<5	41
DP-5	291052	2-4	09-08-89	<1	--	10	--	<.5	<1	--	<5	--
DP-5	291053	12-14	09-11-89	<1	--	22	--	<.5	<1	--	<5	--
DP-5*	291053	12-14	09-11-89	<1	--	22	--	<.5	<1	--	<5	--
DP-5	291054	32-34	09-11-89	<1	<1	14	<100	<.5	<1	<1	<5	<1
DP-5**	291054	32-34	09-11-89	<1	<1	14	<100	<.5	<1	<1	<5	<1
ANALYTE-FREE WATER AND EQUIPMENT BLANKS												
Analyte-free water		NA	07-05-89	<1	--	<2	100	<.5	<1	<1	<5	<1
DP-1	290929	NA	08-09-89	<1	<1	<2	<100	<.5	<1	<1	<5	<1
DP-2	290930	NA	08-14-89	2	--	<2	--	<.5	<1	--	<5	--
DP-3	290931	NA	08-28-89	1	--	<2	--	<.5	<1	--	<5	--
DP-4	290932	NA	09-05-89	<1	<1	<2	<100	<.5	<1	<1	<5	<1
DP-5	290933	NA	09-08-89	<1	--	<2	--	<.5	<1	--	<5	--
LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE TOP (FEET) BOTTOM (FEET)	DATE SAMPLED	COBALT, DIS-SOLVED (µg/L)	COPPER, DIS-SOLVED (µg/L)	CYANIDE, DIS-SOLVED (mg/L)	LEAD, DIS-SOLVED (µg/L)	LEAD, TOTAL RECOVERABLE (µg/L)	MERCURY, DIS-SOLVED (µg/L)	MERCURY, TOTAL RECOVERABLE (µg/L)	MOLYBDENUM, DIS-SOLVED (µg/L)	
DRIVE-POINT SAMPLES												
DP-1	291042	28-30	08-10-89	<3	<10	<0.01	20	1	<0.1	<0.1	<10	
DP-1	291043	40-42	08-11-89	<3	<10	<0.01	<10	--	<0.1	--	<10	
DP-1	291044	45-47	08-11-89	<3	<10	<0.01	<10	--	<.1	--	<10	
DP-2	291045	15-17	08-15-89	20	<10	--	<10	--	<.1	--	<10	
DP-2	291046	40-42	08-17-89	<3	<10	--	<10	2	<.1	.3	<10	
DP-2	291047	47-49	08-17-89	<3	<10	--	<10	--	<.5	--	<10	
DP-3	291048	12-14	08-28-89	<3	<10	--	<10	--	<.1	--	<10	
DP-3	291049	25-27	08-28-89	4	<10	--	<10	3	<.1	.1	<10	
DP-4	291050	17-19	09-06-89	<3	<10	--	<10	--	<.1	--	<10	
DP-4	291051	30-32	09-06-89	<3	<10	--	<10	14	.3	.6	<10	
DP-5	291052	2-4	09-08-89	<3	<10	--	<10	--	.1	--	<10	
DP-5	291053	12-14	09-11-89	<3	<10	--	<20	--	<.1	--	<10	
DP-5*	291053	12-14	09-11-89	<3	<10	--	<20	--	<.1	--	<10	
DP-5	291054	32-34	09-11-89	<3	<10	--	10	1	<.1	<.1	<10	
DP-5**	291054	32-34	09-11-89	<3	<10	--	10	1	.1	<.1	<10	
ANALYTE-FREE WATER AND EQUIPMENT BLANKS												
Analyte-free water		NA	07-05-89	<3	<10	--	10	1	<.1	--	<10	
DP-1	290929	NA	08-09-89	<3	<10	<.01	<10	2	<.1	<.1	<10	
DP-2	290930	NA	08-14-89	<3	<10	--	<10	--	.1	--	<10	
DP-3	290931	NA	08-28-89	<3	<10	--	<10	--	<.1	--	<10	
DP-4	290932	NA	09-05-89	<3	<10	--	<10	2	<.1	<.1	<10	
DP-5	290933	NA	09-08-89	<3	<10	--	<10	--	<.1	--	<10	

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989--Continued

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	NICKEL, DIS-SOLVED (µg/L)	SILVER, DIS-SOLVED (µg/L)	SILVER, TOTAL RECOVERABLE (µg/L)	STRONTIUM, DIS-SOLVED (µg/L)	VANADIUM, DIS-SOLVED (µg/L)	ZINC, DIS-SOLVED (µg/L)	LITHIUM, DIS-SOLVED (µg/L)	SELENIUM, TOTAL (µg/L)
		TOP (FEET)	BOTTOM (FEET)									
DRIVE-POINT SAMPLES												
DP-1	291042	28-30	08-10-89	<10	<1.0	<1	9	9	210	<4	<1	
DP-1	291043	40-42	08-11-89	<10	<1.0	--	12	<6	490	<4	--	
DP-1	291044	45-47	08-11-89	20	<1.0	--	45	<6	210	<4	--	
DP-2	291045	15-17	08-15-89	20	<1.0	--	51	16	2,400	5	--	
DP-2	291046	40-42	08-17-89	20	<1.0	5	30	31	470	<4	17	
DP-2	291047	47-49	08-17-89	70	<1.0	--	55	34	220	5	--	
DP-3	291048	12-14	08-28-89	<10	<1.0	--	18	<6	270	<4	--	
DP-3	291049	25-27	08-28-89	<10	1.0	<1	17	<6	300	<4	<1	
DP-4	291050	17-19	09-06-89	<10	<1.0	--	15	<6	770	<4	--	
DP-4	291051	30-32	09-06-89	<10	<1.0	<1	18	<6	710	<4	<1	
DP-5	291052	2-4	09-08-89	<10	<1.0	--	3	<6	1,300	<4	--	
DP-5	291053	12-14	09-11-89	<10	<1.0	--	19	<6	47	<4	--	
DP-5*	291053	12-14	09-11-89	<10	<1.0	--	19	<6	26	<4	--	
DP-5	291054	32-34	09-11-89	<10	<1.0	<1	<1	<6	29	<4	<1	
DP-5**	291054	32-34	09-11-89	<10	<1.0	<1	1	<6	29	<4	<1	
ANALYTE-FREE WATER AND EQUIPMENT BLANKS												
Analyte-free water		NA	07-05-89	<10	2.0	1	<1	<6	5	<4	--	
DP-1	290929	NA	08-09-89	10	<1.0	<1	<1	<6	13	<4	<1	
DP-2	290930	NA	08-14-89	<10	<1.0	--	<1	<6	60	<4	--	
DP-3	290931	NA	08-28-89	<10	2.0	--	1	<6	48	<4	--	
DP-4	290932	NA	09-05-89	<10	1.0	<1	1	<6	140	<4	<1	
DP-5	290933	NA	09-08-89	<10	<1.0	--	<1	<6	70	<4	--	

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	BENZENE, TOTAL (µg/L)	BROMOFORM, TOTAL (µg/L)	1,2 DI-CHLOROETHANE, TOTAL (µg/L)	CARBON-TETRACHLORIDE, TOTAL (µg/L)	CHLORO-BENZENE, TOTAL (µg/L)	CHLORO-DI-BROMOMETHANE, TOTAL (µg/L)	CHLORO-ETHANE, TOTAL (µg/L)	CHLOROFORM, TOTAL (µg/L)	DI-CHLORO-BROMOMETHANE, TOTAL (µg/L)
		TOP (FEET)	BOTTOM (FEET)										
DRIVE-POINT SAMPLES													
DP-1	291042	28-30	08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291043	40-42	08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291044	45-47	08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291045	15-17	08-15-89	32	<3.0	<3.0	<3.0	160	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291046	40-42	08-17-89	110	<3.0	<3.0	<3.0	470	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291047	47-49	08-17-89	61	<3.0	<3.0	<3.0	210	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	291048	12-14	08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	291049	25-27	08-28-89	29	<3.0	<3.0	<3.0	70	<3.0	<3.0	<3.0	120	<3.0
DP-4	291050	17-19	09-06-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	291051	30-32	09-06-89	<3.0	<3.0	<3.0	<3.0	33	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291052	2-4	09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291053	12-14	09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5*	291053	12-14	09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291054	32-34	09-11-89	<3.0	<3.0	<3.0	<3.0	25	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5**	291054	32-34	09-11-89	<3.0	<3.0	<3.0	<3.0	25	<3.0	<3.0	<3.0	<3.0	<3.0
ANALYTE-FREE WATER AND EQUIPMENT BLANKS													
Analyte-free water		NA	07-20-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	290929	NA	08-09-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	290930	NA	08-14-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA	08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA	09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	8.5	<3.0
DP-5	290933	NA	09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	8.0	<3.0
TRIP BLANKS													
DP-1	290929	NA	08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA	08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA	09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA	09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA	09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989--Continued

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	DI-CHLORO-FLUORO-METHANE, TOTAL (µg/L)	ETHYL-BENZENE TOTAL (µg/L)	METHYL-BROMIDE TOTAL (µg/L)	METHYL-ENE CHLORIDE TOTAL (µg/L)	1,3-DI-CHLORO-PROPENE TOTAL (µg/L)	METHYL-CHLORIDE TOTAL (µg/L)	1,2-DI-CHLORO-BENZENE TOTAL (µg/L)	1,1,2-TRI-CHLORO-ETHANE TOTAL (µg/L)
		TOP (FEET)	BOTTOM (FEET)									
DRIVE-POINT SAMPLES												
DP-1	291042	28-30		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291043	40-42		08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291044	45-47		08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291045	15-17		08-15-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	4.1
DP-2	291046	40-42		08-17-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	3.8	11
DP-2	291047	47-49		08-17-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	3.4
DP-3	291048	12-14		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	291049	25-27		08-28-89	<3.0	<3.0	<3.0	7.4	<3.0	<3.0	<3.0	<3.0
DP-4	291050	17-19		09-06-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	291051	30-32		09-06-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	6.8	<3.0
DP-5	291052	2-4		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5*	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291054	32-34		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	10.0	<3.0
DP-5**	291054	32-34		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	11.0	<3.0
ANALYTE-FREE WATER AND EQUIPMENT BLANKS												
Analyte-free water		NA		07-20-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	290929	NA		08-09-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	290930	NA		08-14-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
TRIP BLANKS												
DP-1	290929	NA		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	1,1,2,2-TETRA-CHLORO-ETHANE TOTAL (µg/L)	1,2-DI-CHLORO-PROPANE TOTAL (µg/L)	TETRA-CHLORO-ETHYL-ENE TOTAL (µg/L)	TOLUENE TOTAL (µg/L)	TRI-CHLORO-ETHYL-ENE TOTAL (µg/L)	TRI-CHLORO-FLUORO-METHANE TOTAL (µg/L)	VINYL CHLORIDE TOTAL (µg/L)	1,1-DI-CHLORO-ETHYL-ENE TOTAL (µg/L)
		TOP (FEET)	BOTTOM (FEET)									
DRIVE-POINT SAMPLES												
DP-1	291042	28-30		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-1	291043	40-42		08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-1	291044	45-47		08-11-89	<3.0	<3.0	<3.0	<3.0	5.5	<3.0	<1.0	<3.0
DP-2	291045	15-17		08-15-89	9.7	<3.0	<3.0	<3.0	5,000	<3.0	<1.0	3.2
DP-2	291046	40-42		08-17-89	50	19	<3.0	<3.0	5,300	<3.0	<1.0	3.3
DP-2	291047	47-49		08-17-89	11	<3.0	<3.0	<3.0	3,900	<3.0	<1.0	3.1
DP-3	291048	12-14		08-28-89	<3.0	3.2	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-3	291049	25-27		08-28-89	36	<3.0	<3.0	<3.0	430	<3.0	<1.0	<3.0
DP-4	291050	17-19		09-06-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-4	291051	30-32		09-06-89	<3.0	<3.0	3.1	<3.0	11.0	<3.0	<1.0	<3.0
DP-5	291052	2-4		09-08-89	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0	<1.0	<3.0
DP-5	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-5*	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-5	291054	32-34		09-11-89	<3.0	<3.0	<3.0	<3.0	3.0	<3.0	<1.0	<3.0
DP-5**	291054	32-34		09-11-89	<3.0	<3.0	<3.0	<3.0	3.0	<3.0	<1.0	<3.0
ANALYTE-FREE WATER AND EQUIPMENT BLANKS												
Analyte-free water		NA		07-20-84	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-1	290929	NA		08-09-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-2	290930	NA		08-14-89	<3.0	<3.0	<3.0	3.9	<3.0	<3.0	<1.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
TRIP BLANKS												
DP-1	290929	NA		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0
DP-5	290933	NA		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<1.0	<3.0

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989--Continued

LOCAL IDENTIFIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	1,1-DI-CHLORO-ETHANE	1,1,1-TRI-CHLORO-ETHANE	1,2,3-TRI-CHLORO-PROPANE	1,2-TRANS-DI-CHLORO-ETHENE	2-CHLORO-ETHYL-VINYL-ETHER	1,4-DI-CHLORO-BENZENE	1,3-DI-CHLORO-BENZENE	TRANS-1,3-DI-CHLORO-PROPENE	CIS-1,3-DI-CHLORO-PROPENE
		TOP (FEET)	BOTTOM (FEET)		TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)	TOTAL (µg/L)
DRIVE-POINT SAMPLES													
DP-1	291042	28-30		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291043	40-42		08-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	291044	45-47		08-11-89	<3.0	<3.0	14.0	7.3	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291045	15-17		08-15-89	<3.0	<3.0	160.0	42	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291046	40-42		08-17-89	<3.0	<3.0	1,100.0	90	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	291047	47-49		08-17-89	<3.0	<3.0	270.0	42	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	291048	12-14		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	291049	25-27		08-28-89	<3.0	<3.0	230.0	23	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	291050	17-19		09-06-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	291051	30-32		09-06-89	<3.0	<3.0	4.2	7.3	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291052	2-4		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5*	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	291054	32-34		09-11-89	<3.0	<3.0	6.7	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5**	291054	32-34		09-11-89	<3.0	<3.0	7.1	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
ANALYTE-FREE WATER AND EQUIPMENT BLANKS													
Analyte-free water		NA		07-20-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-1	290929	NA		08-09-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-2	290930	NA		08-14-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
TRIP BLANKS													
DP-1	290929	NA		08-10-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
DP-5	290933	NA		09-11-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

Appendix G.--Physical properties of, and concentrations of common ions, nutrients, total phenols, trace metals, and purgeable organic compounds in, water sampled from drive points, including duplicates and equipment and trip blanks, Ciba-Geigy Superfund site, July through September 1989--Continued

LOCAL IDENTI- FIER	USGS WELL NUMBER	DEPTH OF SCREEN BELOW LAND SURFACE		DATE SAMPLED	STYRENE TOTAL (µg/L)	1,2- DIBROMO- ETHANE WATER WHOLE TOTAL (µg/L)	XYLENE TOTAL WATER WHOLE TOT REC (µg/L)	PHENOLS TOTAL (µg/L)
		TOP	BOTTOM					
		(FEET)	(FEET)					
DRIVE-POINT SAMPLES								
DP-1	291042	28-30		08-10-89	<3.0	<3.0	<3.0	<1
DP-1	291043	40-42		08-11-89	<3.0	<3.0	<3.0	<1
DP-1	291044	45-47		08-11-89	<3.0	<3.0	<3.0	3
DP-2	291045	15-17		08-15-89	<3.0	<3.0	<3.0	27
DP-2	291046	40-42		08-17-89	<3.0	<3.0	<3.0	64
DP-2	291047	47-49		08-17-89	<3.0	<3.0	<3.0	47
DP-3	291048	12-14		08-28-89	<3.0	<3.0	<3.0	5
DP-3	291049	25-27		08-28-89	<3.0	<3.0	<3.0	17
DP-4	291050	17-19		09-06-89	<3.0	<3.0	<3.0	<1
DP-4	291051	30-32		09-06-89	<3.0	<3.0	<3.0	5
DP-5	291052	2-4		09-08-89	<3.0	<3.0	<3.0	4
DP-5	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<1
DP-5*	291053	12-14		09-11-89	<3.0	<3.0	<3.0	<1
DP-5	291054	32-34		09-11-89	<3.0	<3.0	<3.0	11
DP-5**	291054	32-34		09-11-89	<3.0	<3.0	<3.0	4
ANALYTE-FREE WATER AND EQUIPMENT BLANKS								
Analyte-free water	NA			07-20-89	<3.0	<3.0	<3.0	<1
DP-1	290929	NA		08-09-89	<3.0	<3.0	<3.0	<1
DP-2	290930	NA		08-14-89	<3.0	<3.0	<3.0	<1
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	<1
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	<1
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	1
TRIP BLANKS								
DP-1	290929	NA		08-10-89	<3.0	<3.0	<3.0	--
DP-3	290931	NA		08-28-89	<3.0	<3.0	<3.0	--
DP-4	290932	NA		09-05-89	<3.0	<3.0	<3.0	--
DP-5	290933	NA		09-08-89	<3.0	<3.0	<3.0	--
DP-5	290933	NA		09-11-89	<3.0	<3.0	<3.0	--