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HYDROLOGY OF THE UNCONFINED AQUIFER SYSTEM, RANCOCAS CREEK AREA: RANCOCAS, CROSSWICKS, ASSUNPINK, ASSISCUNK, BLACKS, AND CRAFTS CREEK BASINS, NEW JERSEY, 1996

By Martha K. Watt, Allen C. Kane, Emmanuel G. Charles, and Donald A. Storck

ABSTRACT

The Rancocas Creek study area consists of six surface-water drainage basins--the Rancocas, Crosswicks, Assunpink, Assiscunk, Blacks, and Crafts Creek Basins--and the unconfined aquifers and confining units that lie beneath them. The unconfined aquifers in the study area include the Kirkwood-Cohansey aquifer system and the unconfined parts of the Vincentown aquifer, the Wenonah-Mount Laurel aquifer, the Englishtown aquifer system, and the Upper and Middle Potomac-Raritan-Magothy aquifers. A map of water levels in the unconfined ground-water system, constructed from measurements made during May, June, and July 1996 in 234 wells and at 357 surface-water sites, shows that water levels ranged from 15 feet below sea level to 216 feet above sea level. Seasonal fluctuations of water levels in two observation wells ranged from 2 to 6 feet. The horizontal hydraulic conductivities determined from aquifer tests range from 11.76 to 270 feet per day, the transmissivities range from 430 to 22,110 square feet per day, and the storage coefficients range from 0.0000926 to 0.060. Values of vertical hydraulic conductivity of the confining units range from 0.00000806 to 2.01 feet per day.

Base-flow-separation techniques were used to divide total surface-water discharge into base-flow and direct-runoff components for North Branch Rancocas Creek, Assunpink Creek, McDonalds Branch, and Crosswicks Creek. Mean annual base flow for North Branch Rancocas Creek at Pemberton during 1921-96 was 140.9 cubic feet per second, or 82.5 percent of total flow; for Assunpink Creek at Trenton during 1923-96 was 90.8 cubic feet per second, or 68.3 percent of total flow; for McDonalds Branch in Lebanon State Forest during 1954-96 was 2.0 cubic feet per second, or 93.9 percent of total flow; and for Crosswicks Creek at Extonville during 1940-96 was 88.9 cubic feet per second, or 66.1 percent of total flow. In addition, low-flow-correlation analyses were made and mean annual discharges and base flows were estimated for 25 low-flow partial-record gaging stations. Mean annual precipitation in the study area was 45.1 inches during 1932-95. Mean annual actual evapotranspiration estimated from monthly potential evapotranspiration and precipitation was about 25.9 inches for the period 1986-95. A water budget calculated for the study area for water years 1986-95 shows that ground-water recharge is about 14.1 inches per year, or about 30 percent of mean annual precipitation.

Approximately 38 percent of the land in the study area is forested, 31 percent is agricultural, 17 percent is urban, 12 percent is wetland, 1 percent is water, and 1 percent is barren. The State has identified 422 contaminated sites in the study area. Results of chemical analyses of samples from 25 ground-water and 29 surface-water sites distributed throughout the study area were compiled and analyzed to document the quality of surface water and unconfined ground water. Sites that may be affected by known sources of contamination were avoided to show ambient water-quality conditions. The U.S. Environmental Protection Agency primary drinking-water regulation for cadmium was exceeded in only 1 of 23 ground-water samples. The predominant cations in ground water were calcium and sodium plus potassium; the predominant anions were sulfate and bicarbonate. In surface water, the predominant cations were calcium and sodium plus potassium; the predominant anions were sulfate and chloride. The pattern of ground- and surface-water chemistry in the study area reflects differences in land use.

Total consumptive water use in the study area from surface water and unconfined ground water was about 3,367 Mgal (million gallons) in 1995--2,516 Mgal for non-cranberry irrigation, 522 Mgal for public-supplied and self-supplied domestic water, 133 Mgal for commercial use, 122 Mgal for mining, and 14 Mgal for industry. Withdrawals from confined aquifers account for a large percentage of total ground-water withdrawals and provide artificial recharge to the unconfined aquifer or surface-water system if the discharge is within the study area.

INTRODUCTION

Unconfined (water-table) aquifer systems are present throughout most of the Coastal Plain of New Jersey. These systems are a major source of water in the Coastal Plain, and withdrawals from them are expected to increase as the population grows. A detailed study of these systems and of their interaction with surface-water systems that are hydraulically connected to them, is needed to obtain the hydrologic information on which to base decisions that will ensure that the increasing demand for water from these aquifers will be met. Therefore, in 1986 the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP), began to compile data for selected ground- and surface-water systems in New Jersey. These ground- and surface-water systems coincide with Regional Water Resource Planning Areas, which are single drainage basins or groups of drainage basins delineated in the New Jersey Statewide Water Supply Master Plan (CH2M Hill; Metcalf and Eddy, Inc.; and New Jersey First, Inc.; 10 volumes with various publication dates).[1] Information from this study can be used to plan for the optimal management of unconfined ground water and surface water in the Rancocas Creek study area.

Purpose and Scope

This report presents the results of a 2-year study conducted during 1996-97 to investigate the hydrology of the unconfined aquifer system and the surface-water system of the Rancocas, Crosswicks, Assunpink, Assiscunk, Blacks, and Crafts Creek Basins, New Jersey (fig. 1-1). The combined areas of these basins and those of the minor tributaries to the Delaware River (fig. 1-2), referred to as the "Rancocas Creek study area" in this report, correspond to Regional Water Resource Planning Area number 14, the Rancocas Creek planning area, in the New Jersey Statewide Water Supply Master Plan (CH2M Hill; Metcalf and Eddy, Inc.; and New Jersey First, Inc.; 10 volumes with various publication dates). New data in this report include the results of water-level measurements in 234 wells and at 357 surface-water sites. Results of chemical analyses of samples from 25 wells and 29 surface-water sites for selected constituents are described. The extent of hydrogeologic units in the study area, interpreted from borehole geophysical logs and approximated from published maps and reports, is discussed. Results of base-flow-separation analyses of discharge measurements at streamflow-gaging stations in the study area and results of low-flow correlations of streamflow records from 25 low-flow partial-record stations in the study area are presented. A hydrologic budget is used to estimate recharge in the study area; included in this budget are precipitation, stream discharge, water use, and evapotranspiration.

Previous Investigations

Reports on county-wide studies of geology and ground-water resources were authored by Rush (1968) for Burlington County and by Anderson and Appel (1969) for Ocean County. Results of county-wide studies of ground-water resources in Monmouth County and Mercer County were authored by Jablonski (1968) and Vecchioli and Palmer (1962), respectively. General water-resource studies that cover the Rancocas Creek study area include Barksdale and others (1958) and Parker and others (1964). Zapecza (1989) describes the hydrogeologic framework of the Coastal Plain, and Martin (1998) provides an analysis of ground-water flow in the Coastal Plain.

Well-Numbering System

The well-numbering system used in this report is based on the system used by the USGS in New Jersey since 1978. It consists of a county-code number and a sequence number of the well within the county. County codes used in this report are Burlington (5), Camden (7), Mercer (21), Monmouth (25), and Ocean (29). For example, well number 5-719 represents the 719th well inventoried in Burlington County. Construction details for wells with this type of identifier are stored in the USGS Ground Water Site Inventory (GWSI) database.

Acknowledgments

The authors thank the many individuals and organizations who allowed access to their observation, public-supply, farm, commercial, industrial, or domestic wells for water-level measurements. We also thank Peter Sugarman of the New Jersey Geological Survey for discussions concerning details of the geology of the study area, and for assistance in the preparation of the hydrogeologic sections shown in this report.

Description of the Study Area

The Rancocas Creek study area consists of six principal drainage basins and several minor tributary basins that together make up an area of approximately 686 mi² in parts of Burlington, Camden, Mercer, Monmouth, and Ocean Counties (figs. 1-1, 1-2, and 1-3) and that include all or parts of 53 municipalities. (Definitions of abbreviations and conversions for units used in the text are shown in table 1-1.) The study area and basin boundaries can be defined by either topographic divides or ground-water drainage divides, which are nearly coincident and, for the purposes of this report, are considered to be the same. The northern one-third of the study area is a region of relatively high relief and high elevation in contrast to the southern part of the study area. Land-surface elevations range from 200 ft in the northwestern part of the study area to as much as 300 ft in the northeastern part and to sea level along the Delaware River. Land use in the study area has not changed appreciably since the early 1970s. Approximately 38 percent of the land in the study area is forested, 31 percent is used for agricultural purposes, 17 percent is urban, 12 percent is wetland, 1 percent is water, and 1 percent is barren land (fig. 1-4). These land-use percentages are from USGS National land-cover data for 1991-93 (U.S. Geological Survey, 1994). Most of the forested land is in the southeastern half of the study area; urban land is concentrated in the western parts, near the Delaware River; and agricultural land is distributed across the study area in a wide band from the southwest to the northeast. Most wetlands are in the Pine Barrens, in the southeastern part of the study area.

Contaminated Sites

The NJDEP's comprehensive contaminated site list (New Jersey Department of Environmental Protection, 1994a) includes 422 known contaminated sites that, on the basis of the street address, are within the study area. These contaminated sites tend to be most common in urban areas. There are too many sites to present here, but the list can be obtained from the NJDEP office in Trenton, N.J.

Geologic and Hydrogeologic Units

New Jersey is composed of four distinct geologic regions, or physiographic provinces--the Valley and Ridge, New England, and Piedmont Physiographic Provinces in the north and the Coastal Plain Physiographic Province in the south (fig. 1-5). The northern and southern physiographic provinces meet at the Fall Line, which separates older, consolidated rocks from younger, unconsolidated sediments. The Rancocas Creek study area is predominantly within the Coastal Plain Physiographic Province, but the extreme northwestern part of the study area (33.2 mi²) is in the Piedmont (fig. 1-5). The different rock types that crop out in the two provinces determine the hydrogeologic characteristics of the unconfined ground-water system.

Piedmont Province

The rocks of the Piedmont Physiographic Province range from Precambrian to Triassic in age (table 1-2) and dip to the northwest, away from the Fall Line (fig. 1-5). The unconfined ground-water system in the part of the Rancocas Creek study area that is in this province is composed of the parts of two geologic units--the Stockton and Lockatong Formations--that are sufficiently permeable to transmit water. These aquifers are underlain by the Precambrian and Paleozoic crystalline rocks that crop out immediately northwest of the Fall Line near Trenton. These rocks--predominantly metamorphic and igneous gneiss, schist, and gabbro--are the oldest rocks in the study area (fig. 1-6). Although their origins and physical and chemical characteristics differ, the Precambrian and Paleozoic crystalline rocks have similar hydrologic properties (table 1-2) and can be treated as a single unit. Nearly all water in these rocks is unconfined, as the primary water-bearing zones generally are found within the first several hundred feet of land surface and typically decrease in size and number with depth. Ground water is present mainly in zones of secondary porosity, such as fractures and joints in rocks. Little water is obtained from the crystalline rocks in the study area because of their limited capacity for storing and transmitting water and their small outcrop area. (See Vecchioli and Palmer, 1962.)

The remainder of the Piedmont Province in the study area consists of sedimentary rocks of the Newark Basin, which include the Triassic Stockton and Lockatong Formations (fig. 1-6). The Stockton Formation crops out northwest of the crystalline rocks and is composed primarily of reddish-brown arkosic sandstones and shales. It is the most reliable source of ground water in the Piedmont Province and ranges in thickness from 2,300 to 3,100 ft in the study area. In the study area, ground water is found under unconfined conditions in fractures, joints, and intergranular openings of sandstones where cementing material has been removed by weathering. The Stockton Formation is especially productive where it is covered by permeable surficial deposits or is located near surface-water bodies. (See Vecchioli and Palmer, 1962.)

The Lockatong Formation crops out in the northwesternmost part of the study area. It overlies the Stockton Formation and is composed of dark gray to black, highly fissile shale and hard, massive gray to black argillaceous mudstones and dark red shale. The Lockatong Formation generally is a poor source of water because its weathering product, a dense clay soil, tends to fill existing openings, thereby decreasing the capacity of the formation to store and transmit water. Its thickness ranges from 1,800 to 3,600 ft in the study area. (See Vecchioli and Palmer, 1962.)

Coastal Plain Province

The New Jersey Coastal Plain is a seaward-dipping wedge of unconsolidated sediments of Cretaceous to Quaternary age. Sediments thicken from a featheredge at the Fall Line to more than 2,000 ft in the southeastern extent of the Rancocas Creek study area, and overlie the Precambrian and Paleozoic consolidated bedrock (Zapecza, 1989, pl. 1). The Coastal Plain sediment wedge forms a complex ground-water system in which layers of silt or clay that impede the flow of water make up the confining units, and layers of unconsolidated sand and gravel, thick enough to provide useful quantities of water and not overlain by a confining unit, make up the unconfined aquifers. These sediments crop out in a series of irregular parallel bands that trend northeast-southwest across the study area (fig. 1-6). The unconfined ground-water system consists of the outcrop areas of these typically confined sediments (fig. 1-6).

Geologic units and associated hydrogeologic units in the Coastal Plain in the Rancocas Creek study area are shown in table 1-3. A hydrogeologic unit may consist of one or more stratigraphically adjacent geologic units or parts of geologic units that have similar water-bearing and water-transmitting characteristics.

Three hydrogeologic sections were constructed from interpretations of electric and gamma-ray geophysical logs to show the contacts between the aquifers and confining units in the Coastal Plain (figs. 1-7, 1-8, and 1-9). The sections trace the lateral continuity of the principal aquifers and confining units downdip from their outcrops. The outcrop areas of geologic units in the study area (fig. 1-6) are used to approximate the outcrop areas of the hydrogeologic units shown in figures 1-7, 1-8, and 1-9.

The unconfined ground-water system in the Coastal Plain part of the Rancocas Creek study area consists of six aquifers (table 1-3). The unconfined aquifers are (1) the Kirkwood-Cohansey aquifer system, (2) the outcrop of the Vincentown aquifer, (3) the outcrop of the Wenonah-Mount Laurel aquifer, (4) the outcrop of the Englishtown aquifer system, and the outcrops of the (5) Upper and (6) Middle Potomac-Raritan-Magothy aquifers. Confining units in the study area are (1) the silty and clayey parts of the composite confining unit, (2) the silty and clayey parts of the Wenonah and Marshalltown Formations, (3) the Merchantville-Woodbury confining unit, and (4) confining units within the Potomac-Raritan-Magothy aquifer system. The hydrogeologic units in the study area, from youngest to oldest, are described below.

The youngest units in the study area are the late Tertiary and Quaternary surficial deposits. These deposits, of the Pensauken and Cape May Formations, form a discontinuous veneer over the Coastal Plain and are found in isolated patches in the Piedmont Province (Vecchioli and Palmer, 1962). The Pensauken and Cape May Formations are composed of sand and gravel with some silt and clay layers. These deposits are not major aquifers but can provide moderate supply locally. In some places they act as confining units, and in others they increase the saturated thickness of the underlying aquifer.

The Kirkwood-Cohansey aquifer system is the youngest and most laterally extensive unconfined aquifer in the Rancocas Creek study area (fig. 1-6). The aquifer system consists predominantly of the Kirkwood Formation and Cohansey Sand and, depending on location, can include overlying deposits of the Beacon Hill Gravel, Bridgeton Formation, and Cape May Formation (Zapecza, 1989). The aquifer is 50 ft thick at the outcrop and thickens downdip to more than 200 ft in the southeastern part of the study area (fig. 1-8). The Cohansey Sand is a medium- to coarse-grained, light-colored quartz sand. The Kirkwood Formation is a fine to medium sand and silty sand. Regionally extensive clay units in the basal part of the Kirkwood Formation form the uppermost part of the composite confining unit that functions as the base of this unconfined aquifer system (Zapecza, 1989).

The composite confining unit is a complex series of geologic units that, depending on location, can include as many as nine distinct units. The part of the composite confining unit of interest in this study ranges in age from Late Cretaceous to early Miocene and is made up of the Hornerstown Sand, Red Bank Sand, Navesink Formation, Vincentown Formation, Manasquan Formation, Shark River Formation, Piney Point Formation, and the basal clay of the Kirkwood Formation. This group of low-permeability units consists mostly of silty and clayey glauconitic quartz sand (Zapecza, 1989). Three minor aquifers can be found in the composite confining unit--the Piney Point aquifer, Vincentown aquifer, and Red Bank Sand. The Piney Point aquifer is a minor aquifer that is present only under confined conditions in the southeastern part of the study area and is not discussed in this report. The unconfined part of the Vincentown aquifer coincides with the outcrop area of the Vincentown Formation (fig. 1-6). Section B-B' shows that the Vincentown aquifer is relatively thin, with an average thickness of only about 50 ft (fig. 1-8). Locally, the Vincentown aquifer is hydraulically connected to the Kirkwood-Cohansey aquifer system in updip parts of the Kirkwood Formation outcrop, where the Manasquan Formation and basal Kirkwood Formation are thin or absent (O.S. Zapecza, U.S. Geological Survey, written commun., 1998).

The Hornerstown Sand, Red Bank Sand, and Navesink Formation, which are found locally in the northeastern part of the study area, function as the part of the composite confining unit underlying the Vincentown aquifer. At land surface these units crop out northwest of the outcrop of the Vincentown Formation (fig. 1-6). The Red Bank Sand is a minor aquifer that supplies small amounts of water locally in the study area. More water is withdrawn from this aquifer north and east of the study area, where the aquifer is thicker (Rush, 1968).

The unconfined part of the Wenonah-Mount Laurel aquifer is northwest of the outcrop of the composite confining unit (fig. 1-6). This aquifer consists of the outcrops of the Mount Laurel Sand and the upper, sandy part of the Wenonah Formation, which are lithologically similar (Rush, 1968). Hydrogeologic sections A-A' and B-B' (figs. 1-7 and 1-8, respectively) show that the maximum thickness of the unconfined Wenonah-Mount Laurel aquifer is approximately 100 ft. A relatively thin confining unit, the Marshalltown-Wenonah confining unit, is found at land surface northwest of the unconfined Wenonah-Mount Laurel aquifer outcrop. This confining unit consists principally of the poorly sorted, glauconitic, silty fine sand in the lower part of the Wenonah Formation and glauconitic silt and sand of the Marshalltown Formation, and it ranges in thickness from 20 to 60 ft (Zapecza, 1989).

The unconfined part of the Englishtown aquifer system, composed of the sediments of the Englishtown Formation, is located directly updip from the outcrop area of the Marshalltown Formation (fig. 1-6). In outcrop this aquifer is composed of light gray to white micaceous, lignitic, fine-grained quartz sand (Rush, 1968). Aquifer thicknesses of less than 100 ft are common in the Rancocas Creek study area. Withdrawals from this aquifer are mostly by small domestic users in and near the outcrop. The underlying Merchantville-Woodbury confining unit is the most regionally extensive confining unit in the Coastal Plain. This unit is composed of the Merchantville Formation and the Woodbury Clay, both of which consist of dark gray to black micaceous clay to clayey silt (Rush, 1968). Where it crops out, this unit attains thicknesses of about 150 ft (figs. 1-7 and 1-9).

The Potomac-Raritan-Magothy aquifer system crops out along the Delaware River in the northwestern part of the study area (fig. 1-6). This aquifer system typically is composed of the Magothy Formation, Raritan Formation, and Potomac Group. The upper aquifer is the most extensive of the three units and coincides most closely with a single geologic unit, the Magothy Formation (Zapecza, 1989). The upper aquifer attains thicknesses of as much as 100 ft where it crops out (fig. 1-8) and is composed predominantly of coarse-grained sediments. Delineation of the unconfined part of the middle aquifer is difficult because this aquifer has not been related to a specific outcrop belt within the Raritan Formation and the Potomac Group (O.S. Zapecza, U.S. Geological Survey, written commun., 1998). Also, current geologic mapping indicates the Raritan Formation does not crop out within the study area. The middle aquifer is composed of sediments of the Potomac Group that probably crop out only locally near the extreme updip part of the Coastal Plain Province, near the Fall Line. The lower aquifer of the Potomac-Raritan-Magothy aquifer system does not crop out in the study area, and is present in the subsurface only in the extreme southeastern part of the study area.

Hydraulic Properties of Aquifers and Confining Units

Values of hydraulic properties of several aquifers and confining units in the Rancocas Creek study area were compiled from published reports and unpublished results of aquifer and laboratory tests. Many of the test results are for semi-confined or confined parts of the aquifers in the study area; these are used here because few test results are available for the unconfined parts of the aquifers. An aquifer test is the withdrawal of measured quantities of water from, or addition of water to, a well and the measurement of the resulting change in water level in the aquifer both during and after the period of discharge or recharge (Bates and Jackson, 1987). The properties typically determined by means of this analysis are transmissivity, hydraulic conductivity, and storage coefficient. Test locations are shown in figure 1-3; test results are reported in tables 1-4 and 1-5.

Reported values of the horizontal hydraulic conductivity (the rate at which water can move horizontally) of aquifers in and near the Rancocas Creek study area range from 11.76 to 270 ft/d (table 1-4). Reported transmissivities (aquifer thickness multiplied by hydraulic conductivity) of aquifers in and near the study area range from 430 to 22,110 ft²/d. The storage coefficient (virtually equal to specific yield in an unconfined aquifer) is a dimensionless value that represents the volume of water an aquifer will release per unit surface area per unit decrease in water level. Reported storage coefficients for aquifers in and near the study area range from 0.0000926 to 0.060. Storage coefficients for unconfined aquifers typically range from 0.01 to 0.30 (Freeze and Cherry, 1979)--considerably higher than most of those reported for aquifers in and near the study area. This discrepancy can be explained by the fact that most of the aquifer tests were conducted in confined or semiconfined parts of the aquifers. Values of vertical hydraulic conductivity of the confining units are derived mostly from the results of laboratory tests and range from 0.00000806 to 2.01 ft/d, a typical range for the lithologies in the study area.

[1] Available from the New Jersey Department of Environmental Protection, Trenton, N.J.

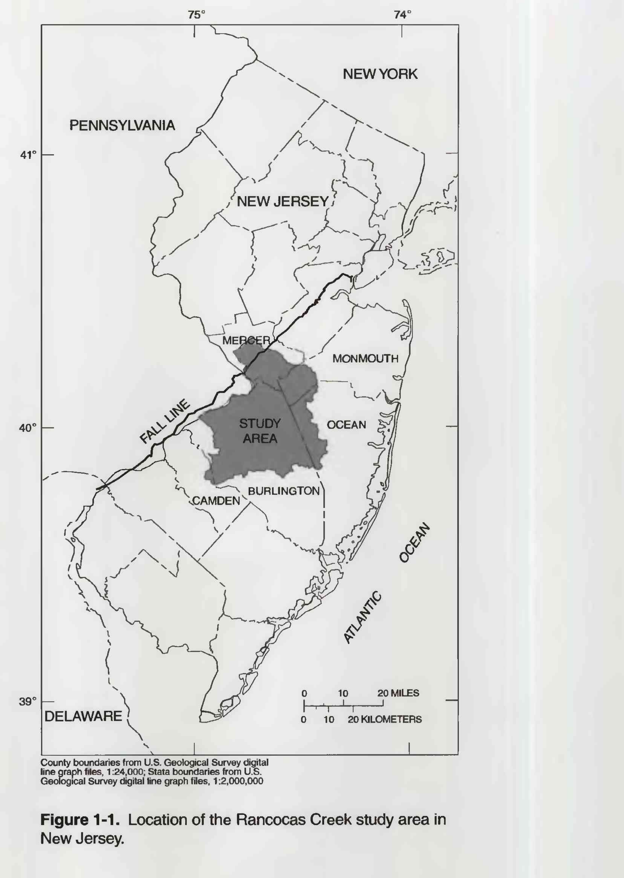


Figure 1-1. Location of the Rancocas Creek study area in New Jersey.

Table 1-1. Conversion factors and vertical datum

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
	Area	
acre	4,047	square meter
square mile (mi²)	2.590	square kilometer
	Volume	
million gallons (Mgal)	3,785	cubic meter
	Flow	
inch per year (in/yr)	2.54	centimeter per year
cubic foot per second (ft³/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06308	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	Transmissivity	
square foot per day (ft²/d)[1]	0.09290	square meter per day
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day

Temperature conversion formula: °F = 1.8 x °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 the United States and Canada, formerly called Sea Level Datum of 1929.

[1]This unit is used to express transmissivity, the capacity of an aquifer to transmit water. Conceptually, transmissivity is cubic feet (of water) per day per square foot (of aquifer area) times feet (of aquifer thickness), or (ft³/d)/ft² x ft. In this report, this expression is reduced to its simplest form, ft²/d.

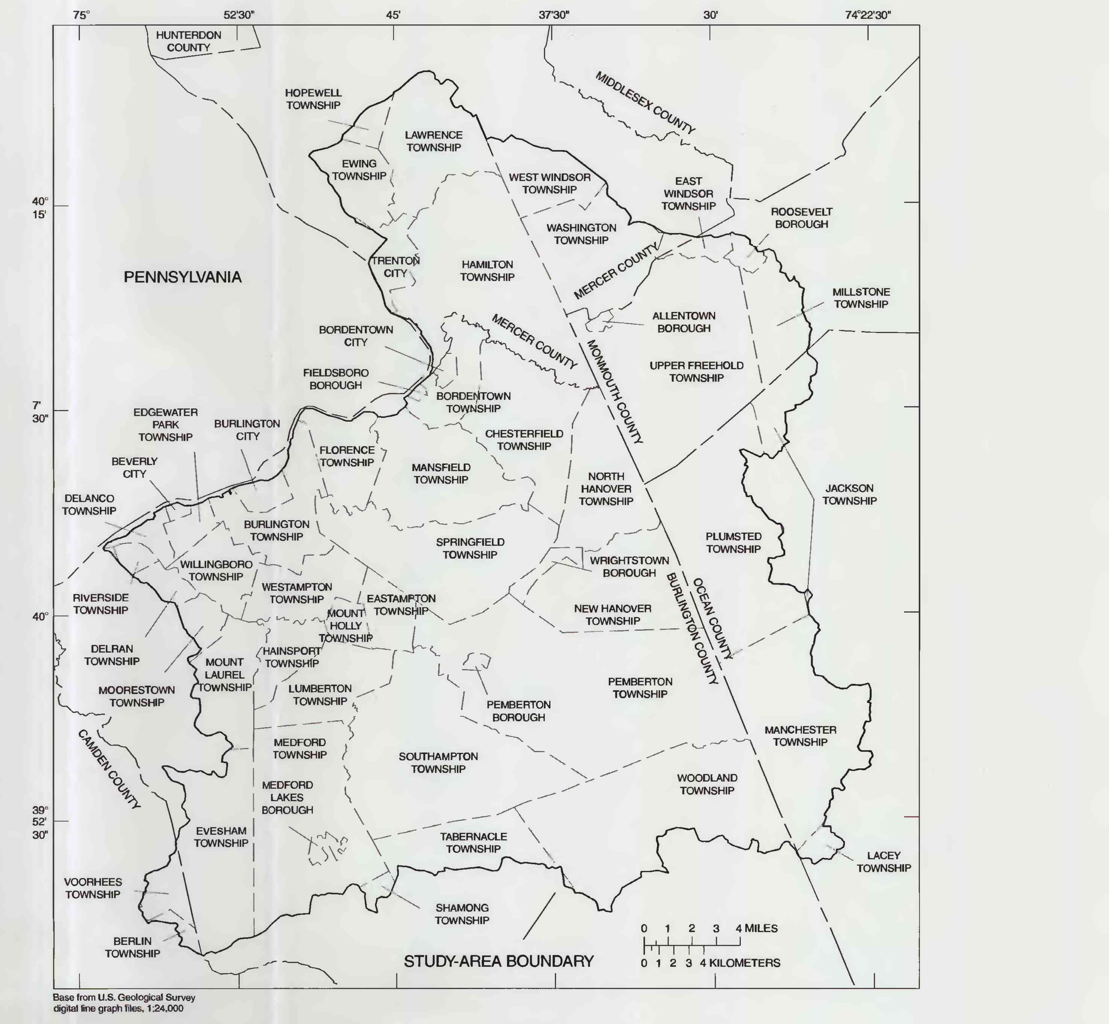


Figure 1-2. Municipalities in the Rancocas Creek study area, New Jersey.

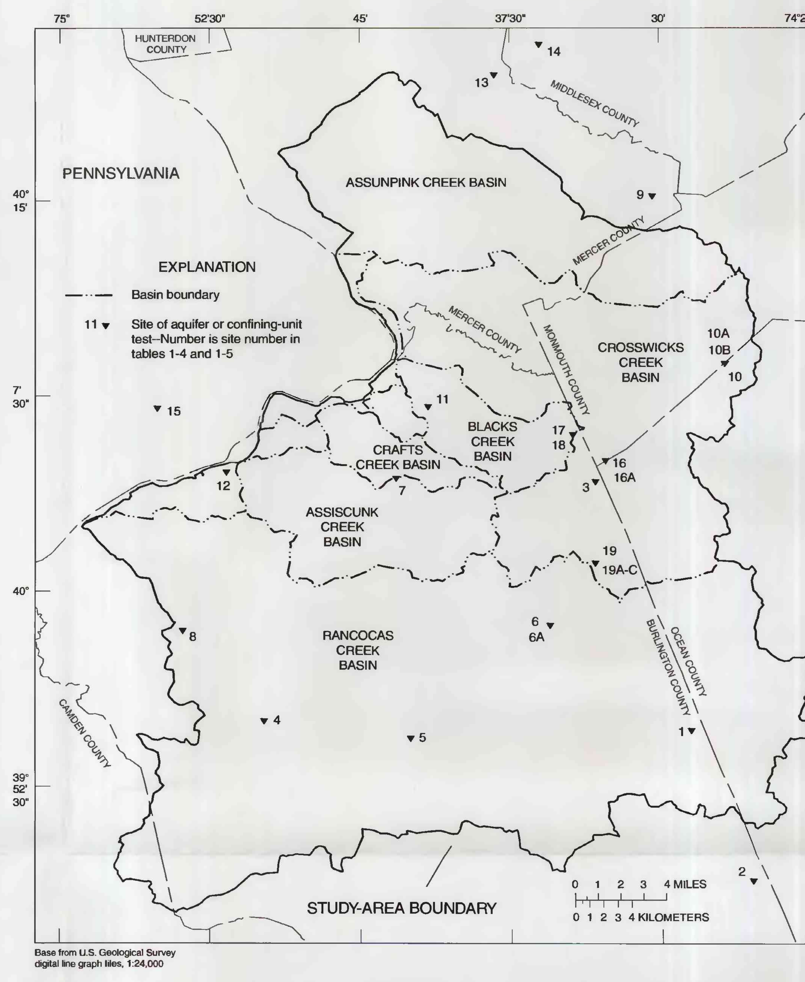


Figure 1-3. Major surface-water drainage basins and aquifer test sites in the Rancocas Creek study area, New Jersey.

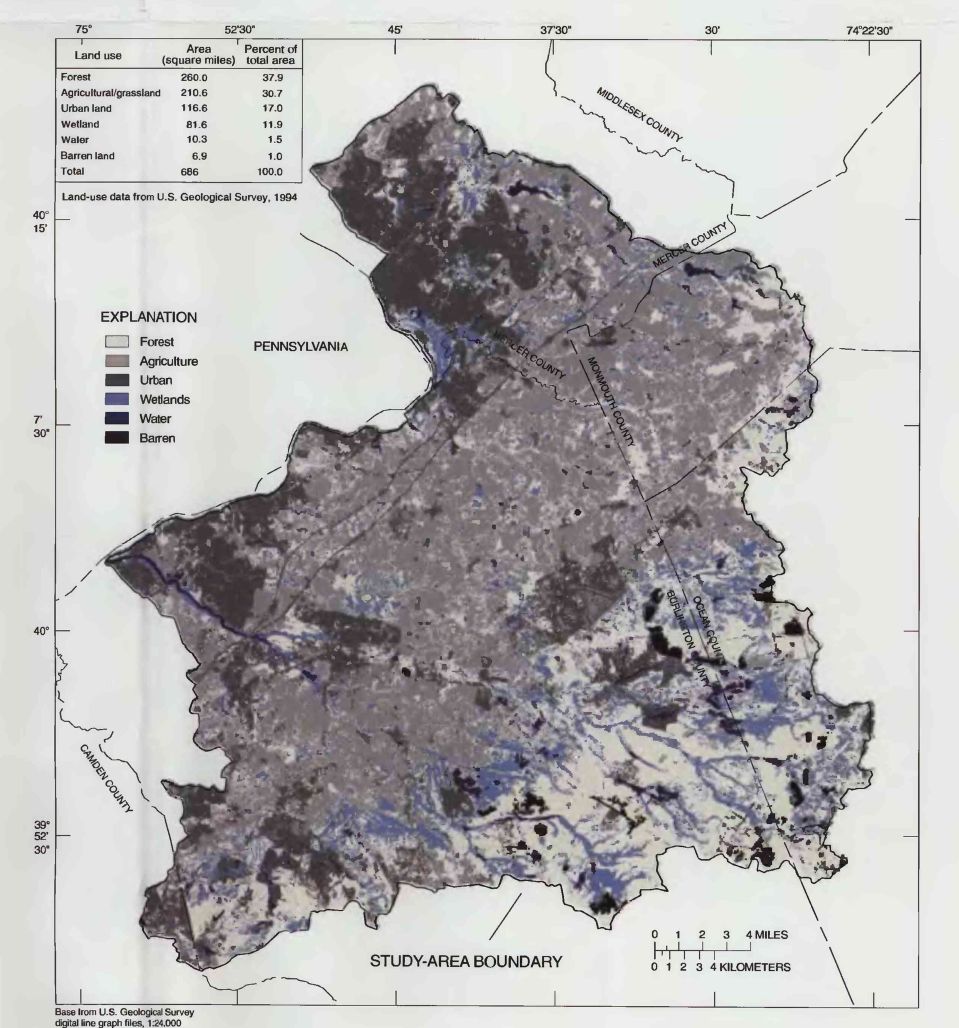


Figure 1-4. Land use in the Rancocas Creek study area, New Jersey.

Table 1-2. Hydrogeologic characteristics of geologic units in the Piedmont Physiographic Province in the Rancocas Creek study area, New Jersey

[Modified from Vecchioli and Palmer, 1962]

SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC CHARACTERISTICS
Triassic	Lockatong Formation	Dark-gray and black highly fissile shale and massive argillaceous mudstones. Dark-red shale and argillite found locally in upper part of formation	Yields small quantities of water locally primarily for domestic supply. Formation has low capacity to store and transmit water.
	Stockton Formation	Red, brown, gray, or white fine-grained arkosic sandstone and soft red shale	A reliable source of moderate to large supplies of water for domestic and public supply. Water occurs in fractures, joints, and intergranular openings.
Early Paleozoic	Igneous intrusives and Wissahickon Formation	Gabbro, banded micaceous schist and gneiss	Yields small quantities of water locally to wells mainly from the weathered rock near land surface. Not an important source of water in the Rancocas Creek study area.
Cambrian	Chickies Quartzite	Pale-green schistose quartzite	
Precambrian	Baltimore Gneiss	Medium-grained granite gneiss	

Table 1-3. Hydrogeologic characteristics of geologic units in the Coastal Plain Physiographic Province in the Rancocas Creek study area, New Jersey

[Modified from Zapecza, 1989, table 2]

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT	HYDROGEOLOGIC CHARACTERISTICS
Quaternary	Holocene	Alluvial deposits	Sand, silt, and black mud	Undifferentiated	These fine- and coarse-grained sediments are commonly hydraulically connected to the underlying aquifer system. Locally some units may act as confining layers and others may yield large amounts of water where they are thick and permeable.
		Beach sand and gravel	Sand, quartz, light-colored, medium- to coarse-grained, pebbly		
	Pleistocene	Cape May Formation	Sand, quartz, light-colored, heterogeneous, clayey, pebbly		
Tertiary	Miocene	Pensauken Formation			
		Bridgeton Formation		Kirkwood-Cohansey aquifer system	The major unconfined aquifer system. Ground water generally occurs under water-table conditions. In some areas, clay and silt layers locally semi-confine the aquifer.
		Beacon Hill Gravel	Gravel, quartz, light-colored, sandy		
		Cohansey Sand	Sand, quartz, light-colored, medium- to coarse-grained, pebbly; local clay layers		
		Kirkwood Formation	Sand, quartz, gray, tan, fine- to medium-grained, micaceous; tan to dark-colored clayey silt	Composite confining unit	
	Eocene	Piney Point Formation / Shark River Formation	Sand, quartz, and glauconite; fine- to coarse-grained	Piney Point aquifer	A confined aquifer that yields moderate amounts of water locally.
		Manasquan Formation	Clay, silty and sandy; glauconitic, green, gray, and brown, fine-grained quartz sand		Low-permeability sediments
	Paleocene	Vincentown Formation	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic; and brown, clayey, very fossiliferous glauconite and quartz calcarenite	Vincentown aquifer	Yields small to moderate quantities of water in and near its outcrop area.
		Hornerstown Sand	Sand, clayey, glauconitic, dark green, fine- to coarse-grained		Low-permeability sediments
Cretaceous	Upper Cretaceous	Red Bank Sand	Sand, quartz, and glauconite, brown and gray, fine- and coarse-grained, clayey, micaceous	Red Bank aquifer	Minor aquifer that yields small quantities of water in and near its outcrop area
		Navesink Formation	Sand, clayey, silty, glauconitic, green and black, medium- to coarse-grained		Low-permeability 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, 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, 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		
		Magothy Formation	Sand, quartz, light gray, fine- to coarse-grained; local beds of dark-gray lignitic clay	Potomac-Raritan-Magothy aquifer system: Upper aquifer	A major aquifer system. The Lower aquifer does not crop out in the study area. The Upper and Middle aquifers crop out in thin bands along the Fall Line. These aquifers are unconfined where they crop out but confined downdip.
				Confining unit	
	Lower Cretaceous	Raritan Formation	Sand, quartz, light gray, fine- to coarse-grained, pebbly, arkosic; red, white, and variegated clay	Middle aquifer	
				Confining unit	
		Potomac Group	Alternating clay, silt, sand, and gravel	Lower aquifer	
Pre-Cretaceous		Bedrock	Precambrian and lower Paleozoic crystalline rocks, locally Triassic basalt, sandstone, and shale and Jurassic diabase	Bedrock confining unit	No wells obtain water from these consolidated rocks, except along the Fall Line.

Table 1-4. Hydraulic properties of aquifers and aquifer systems in the Rancocas Creek study area, New Jersey

[Site locations shown in figure 1-3; ft/d, feet per day; ft²/d, square feet per day; --, data unavailable; Twp, Township; References are listed on sheet 5]

Site number	Site location	Date of aquifer test	Method of evaluation[1]	Horizontal hydraulic conductivity (ft/d)	Transmissivity (ft²/d)	Storage coefficient (dimensionless)	Reference
	Kirkwood-Cohansey aquifer system						
1	Lebanon State Forest, Woodland Twp, Burlington County	8/4/58	Thiem	[2]120	[2]12,000	--	Rhodehamel, 1973
2	Coyle Airport, Woodland Twp, Burlington County	--	Laboratory test	17.42	3,752	--	Rush, 1968
	Vincentown aquifer						
3	Outcrop between Jacobstown and New Egypt, North Hanover Twp, Burlington County	--	Laboratory test	21.44	536	--	Rush, 1968
	Wenonah-Mount Laurel aquifer						
4	Medford Twp, Burlington County	1987	Theis	40.3	1,611	.00026	[3]Database file number 36
4	Medford Twp, Burlington County	1987	Theis recovery	34	1,354	--	[3]Database file number 36
4	Medford Twp, Burlington County	1987	Hantush and Jacob	30.25	1,210	.00061	[3]Database file number 36
5	Southampton Twp, Burlington County	10/29/90	Hantush and Jacob	20.5	1,232	.000272	[3]Database file number 68
--	Outcrop of the Mount Laurel Sand, Burlington County [4]	--	Laboratory test	21.44	1,206-2,144	--	Rush, 1968
--	Coastal Plain [4]	--	--	[5]12.96	[5]430-1,780	[5].0002	Nemickas, 1976
	Englishtown aquifer system						
6	Pemberton Twp, Burlington County	6/30/92	Theis	14	636	.0001	[3]Database file number 38
6	Pemberton Twp, Burlington County	6/30/92	Cooper and Jacob	17	760	.0005	[3]Database file number 38
6	Pemberton Twp, Burlington County	6/30/92	Cooper and Jacob	14	648	.00007	[3]Database file number 38
6A	Pemberton Twp, Burlington County	6/30/92	Theis	20	908	.000087	[3]Database file number 38
6A	Pemberton Twp, Burlington County	6/30/92	Cooper and Jacob	19.4	875	.00077	[3]Database file number 38
6A	Pemberton Twp, Burlington County	6/30/92	Cooper and Jacob	14	648	.0001	[3]Database file number 38
7	Columbus, Mansfield Twp, Burlington County	--	Laboratory test	42.88	2,412	--	Rush, 1968
8	Hartford, Mount Laurel Twp, Burlington County	--	Laboratory test	40.2	2,412	--	Rush, 1968
9	South of Etra, East Windsor Twp, Mercer County		Laboratory test	13.4	670	--	Vecchioli and Palmer, 1962
	Potomac-Raritan-Magothy aquifer system						
10	Jackson Twp, Ocean County	2/16/93	Theis recovery	[7]15.02	[6,7]1,502	--	[3]Database file number 103
10	Jackson Twp, Ocean County	2/16/93	Jacob	[7]15.20	[6,7]1,520	--	[3]Database file number 103
10	Jackson Twp, Ocean County	2/16/93	Papadopulos and Cooper	[7]13.70	[6,7]1,370	--	[3]Database file number 103
10A	Jackson Twp, Ocean County	2/16/93	Jacob	[7]12.37	[6,7]1,237	[7].000137	[3]Database file number 103
10A	Jackson Twp, Ocean County	2/16/93	Theis recovery	[7]14.41	[6,7]1,441	--	[3]Database file number 103
10A	Jackson Twp, Ocean County	2/16/93	Hantush and Jacob	[7]11.76	[6,7]1,176	[7].000175	[3]Database file number 103
10B	Jackson Twp, Ocean County	2/16/93	Theis recovery	[7]27.61	[6,7]2,761	[7].00015	[3]Database file number 103
11	Chesterfield Twp, Burlington County	5/10/94	Hantush and Jacob	[8]50.8	[8]3,050	[8].0000926	[3]Database file number 123
12	Burlington City, Burlington County	--	--	[7]201	[7]22,110	[7].060	Rush, 1968
--	Coastal Plain [4]	--	--	[9]134	[9]6,030	[9].0003	Vecchioli and Palmer, 1962, and Barksdale and others, 1958
	Stockton Formation						
--	Mercer County [4]	--	--	--	134-4,690	.00001-.001	Vecchioli and Palmer, 1962, and Barksdale and others, 1958
13	Penns Neck, West Windsor Twp, Mercer County	--	--	--	1,072	.0002	Vecchioli and Palmer, 1962
14	Plainsboro, Plainsboro Twp, Middlesex County	3/31/86	Theis	100-270	1,740	.0002	Lewis and Spitz, 1987
15	Langhorne, Bucks County, Pennsylvania	6/00/57	--	--	3,100	.0005	Rima and others, 1962

[1]Methods of evaluation are explained in Driscoll (1986)
[2]Average of 20 observations
[3]New Jersey Geological Survey Hydroparameters Database System (unpublished data on file at the New Jersey Geological Survey, New Jersey Department of Environmental Protection, Trenton, N.J.)
[4]No specific location available
[5]Average value from 33 wells
[6]Calculated with an aquifer thickness of 100 feet
[7]Value for the Upper aquifer
[8]Value for the undifferentiated Potomac-Raritan-Magothy aquifer system
[9]Value for the Raritan Formation

Table 1-5. Hydraulic properties of confining units in and near the Rancocas Creek study area, New Jersey

[Site locations shown in figure 1-3; ft, feet; ft/d, feet per day; --, data unavailable; Twp, Township]

Site number	Site location	Depth of core (ft)	Vertical hydraulic conductivity (ft/d)	Reference
	Hornerstown Sand			
16	Outcrop between Arneystown and New Egypt, Upper Freehold Twp, Monmouth County	--	0.0938	Rush, 1968
16A	Outcrop between Arneystown and New Egypt, Upper Freehold Twp, Monmouth County	--	.00268	Rush, 1968
	Red Bank Sand			
17	Outcrop near Arneystown, North Hanover Twp, Burlington County	--	.134	Rush, 1968
	Navesink Formation			
18	Outcrop near Arneystown, North Hanover Twp, Burlington County	--	2.01	Rush, 1968
	Wenonah Formation			
19	Fort Dix, New Hanover Twp, Burlington County	456.0	[1].0000374-.0000598	Nichols, 1977
	Marshalltown Formation			
19A	Fort Dix, New Hanover Twp, Burlington County	390.0	[2].000134-.000259	Nichols, 1977
	Woodbury Clay-Merchantville Formation			
19B	Fort Dix, New Hanover Twp, Burlington County	523.0	[1].000012-.00000763	Nichols, 1977
19B	Fort Dix, New Hanover Twp, Burlington County	546.0	[3].00000276-.00000658	Nichols, 1977
19B	Fort Dix, New Hanover Twp, Burlington County	569.0	[3].0000122-.00000806	Nichols, 1977
	Merchantville Formation			
19C	Fort Dix, New Hanover Twp, Burlington County	625.0	[3].000105-.0000552	Nichols, 1977

[1]Range of three values
[2]Range of two values
[3]Range of four values

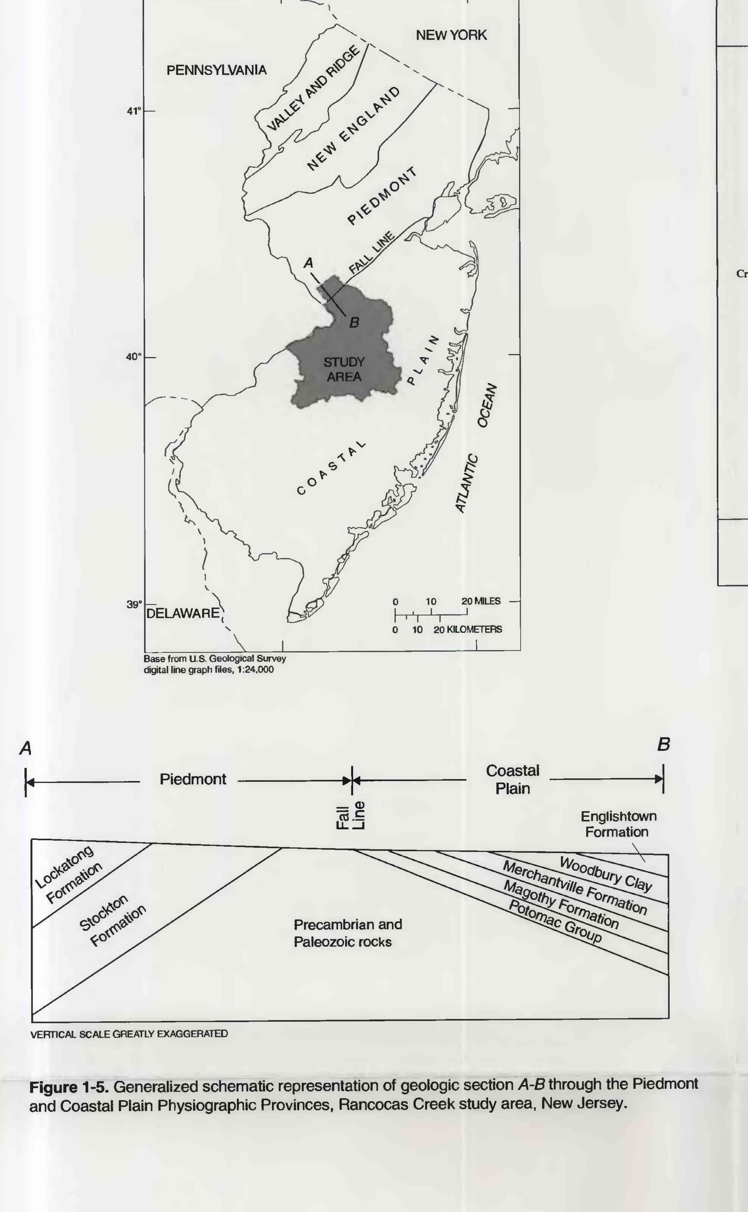


Figure 1-5. Generalized schematic representation of geologic section A-B through the Piedmont and Coastal Plain Physiographic Provinces, Rancocas Creek study area, New Jersey.

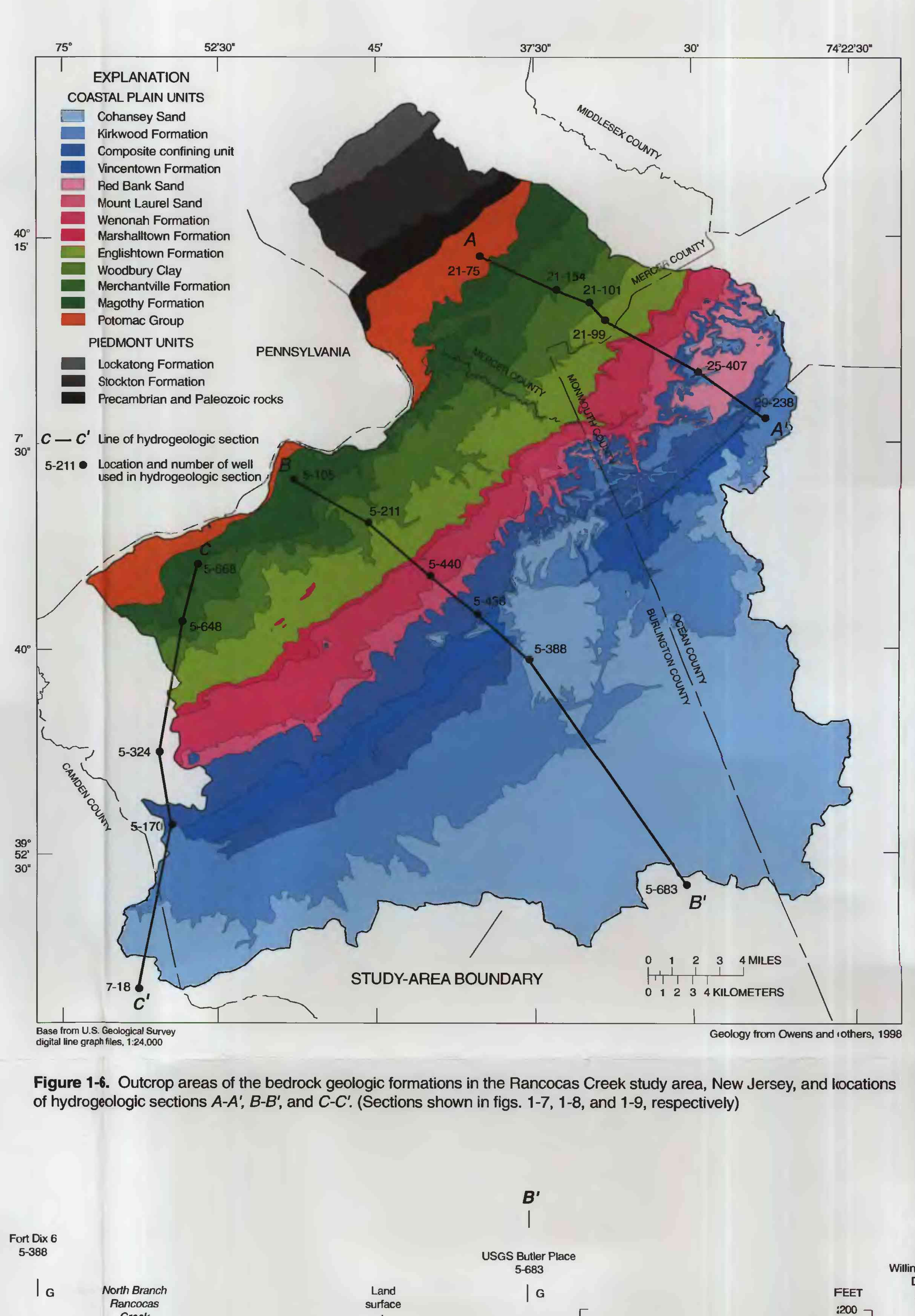
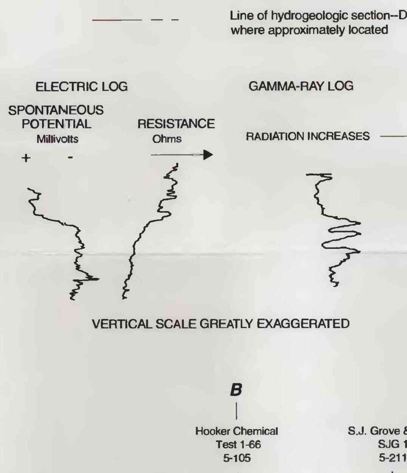


Figure 1-6. Outcrop areas of the bedrock geologic formations in the Rancocas Creek study area, New Jersey, and locations of hydrogeologic sections A-A', B-B', and C-C'. (Sections shown in figs. 1-7, 1-8, and 1-9, respectively)

EXPLANATION
for figures 1-7, 1-8, and 1-9

Fort Dix 6	Local well name and number
5-388	U.S. Geological Survey well number
E	Electric log
G	Gamma-ray log
— —	Line of hydrogeologic section--Dashed where approximately located



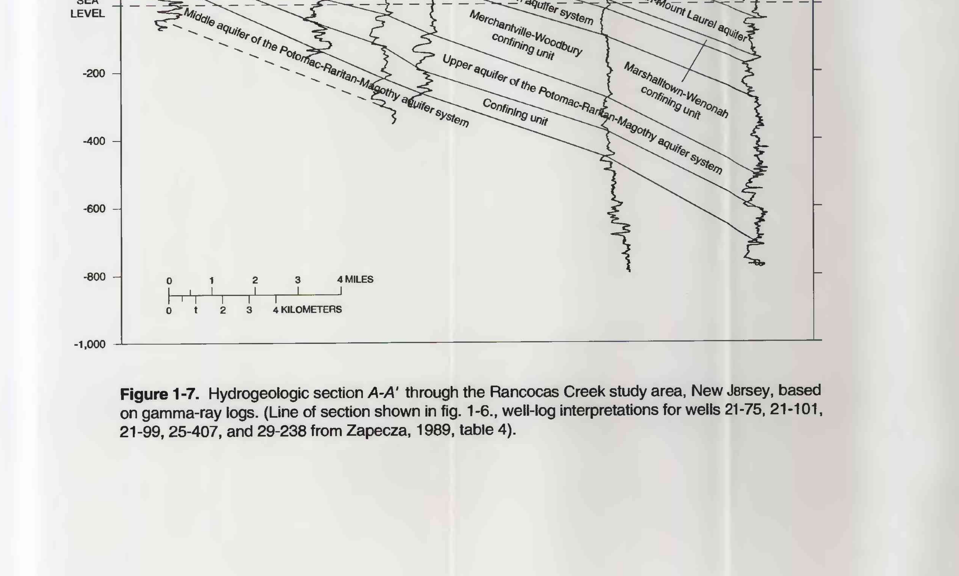


Figure 1-7. Hydrogeologic section A-A' through the Rancocas Creek study area, New Jersey, based on gamma-ray logs. (Line of section shown in fig. 1-6., well-log interpretations for wells 21-75, 21-101, 21-99, 25-407, and 29-238 from Zapecza, 1989, table 4).

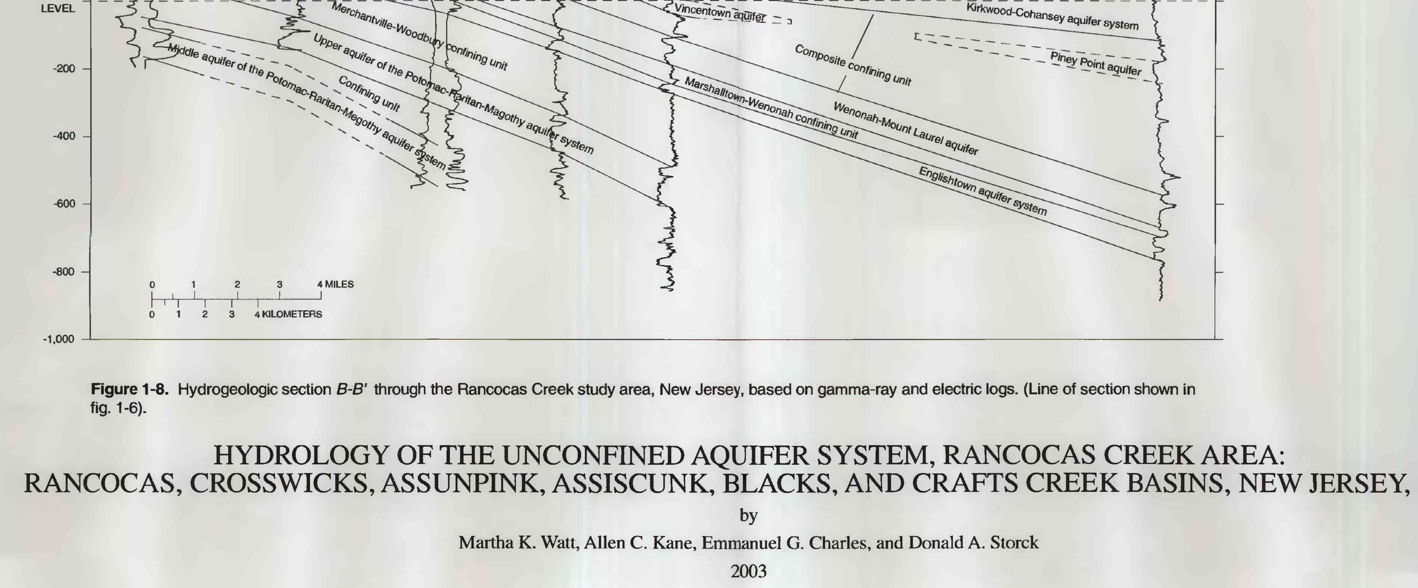


Figure 1-8. Hydrogeologic section B-B' through the Rancocas Creek study area, New Jersey, based on gamma-ray and electric logs. (Line of section shown in fig. 1-6).

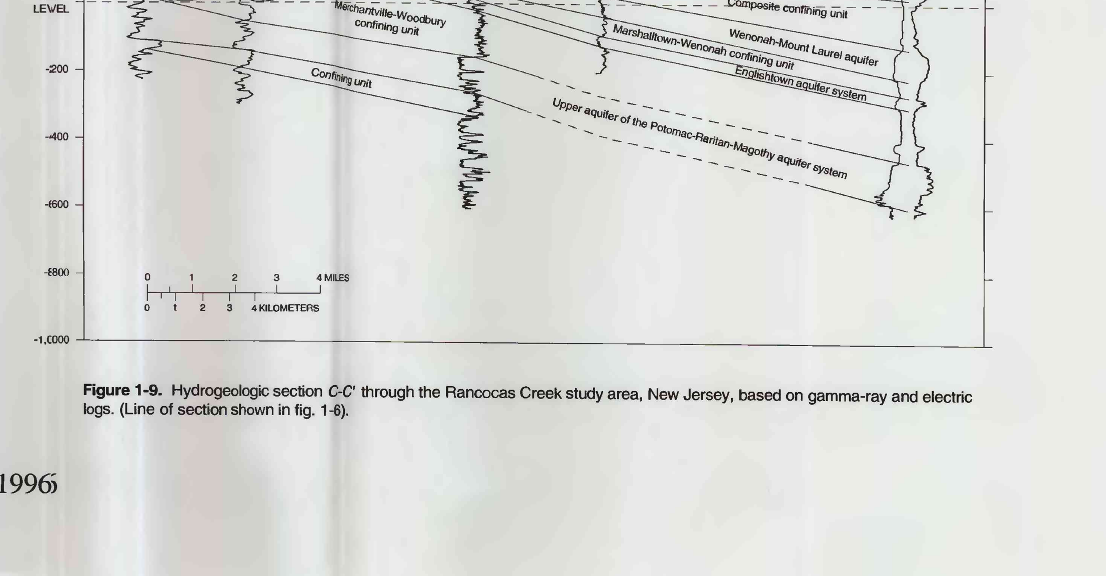


Figure 1-9. Hydrogeologic section C-C' through the Rancocas Creek study area, New Jersey, based on gamma-ray and electric logs. (Line of section shown in fig. 1-6).

HYDROLOGY OF THE UNCONFINED AQUIFER SYSTEM, RANCOCAS CREEK AREA:
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by
Martha K. Watt, Allen C. Kane, Emmanuel G. Charles, and Donald A. Storck
2003