U.S. Department of the Interior
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HYDROGEOLOGIC FRAMEWORK, AVAILABILITY OF WATER SUPPLIES, AND SALTWATER INTRUSION, CAPE MAY COUNTY, NEW JERSEY

Water-Resources Investigations Report 01-4246

Prepared in cooperation with the

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

USGS
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by Pierre J. Lacombe and Glen B. Carleton

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West Trenton, New Jersey

2002

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U.S. DEPARTMENT OF THE INTERIOR

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Multiply		By	To obtain
		Length	
inch	(in)	25.4	millimeter
foot	(ft)	.3048	meter
mile	(mi)	1.609	kilometer
		Area	
acre		.4047	hectare
square mile (mi^2)		2.59	square kilometer
square mile (mi^2)		640	acre
		Volume	
gallon	(gal)	3.785	liter
cubic foot	(ft^3)	.0283	cubic meter
gallon	(gal)	7.48	cubic foot
acre foot		326,000	gallons
		Flow	
cubic feet per second	ft^3/s	.02832	cubic meter per second
foot per day	ft/ d	.3048	meter per day
cubic feet per second		449	gallons per minute
cubic feet per second		646,000	gallons per day
cubic feet per second		235.8	million gallons per year
		Hydraulic conductivity	
foot per day (ft/d)		0.3048	meter per day
		Transmissivity	
square foot per day (ft^2/d)[1]		0.09290	square meter per day

Abbreviations used in this report:

ft/yr	feet per year	Mgal/d	million gallons per day
ft/mi	feet per mile	Mgal/mo	million gallons per month
ft^2/d	feet squared per day	Mgal/acre/year	million gallons per acre per year
$ft^3/s/mi^2$	cubic feet per second per square mile	$Mgal/day/mi^2$	million gallons per day per square mile)
$ft^3/s/mi^2$	cubic feet per second per square mile	mg/L	milligrams per liter
gal/min	gallons per minute	µg/L	micrograms per liter
gal/acre/year	gallons per acre per year	µS/cm	microsiemens per centimeter
in/yr	inches per year	1/d	per day
		^oC	degrees Celsius

Vertical datum: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from the 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 $(ft^3/d)/ft^2$ x ft. In this report, this expression is reduced to its simplest form, ft^2/d.

AVALABILITY OF WATER SUPPLIES AND SALTWATER INTRUSION, CAPE MAY COUNTY, NEW JERSEY

by Pierre J. Lacombe and Glen B. Carleton

ABSTRACT

During 1960-90, saltwater intrusion forced the abandonment of at least 10 public-supply wells, 3 industrial-supply wells, and more than 100 domestic-supply wells in Cape May County, N.J. Actual or imminent ground-water contamination caused by land-use practices and human activities has forced the closure of at least six shallow public-supply wells and many domestic-supply wells.

Freshwater in Cape May County flows in many small streams and is held in wetlands and natural and artificial ponds. More importantly, freshwater from precipitation passes through and is stored in five aquifers-- Holly Beach water-bearing zone, estuarine sand aquifer, Cohansey aquifer, Rio Grande water-bearing zone, and Atlantic City 800-foot sand.

Surface-water discharges were measured at 14 stream sites. The Tuckahoe River is the largest stream in Cape May County. The mean annual discharge for the Tuckahoe River at Head of River was 43.8 ft^3/s (cubic feet per second) or 10,800 Mgal/yr (million gallons per year) during the period of record (1969-93). Mean daily discharge ranged from 25 ft^3/s or 16 Mgal/d in September to 73 ft^3/s or 47 Mgal/d in April. Mean daily discharge at the eight largest streams wholly within the county ranged from 15.9 to 3.05 ft^3/s (3,750 to 720 Mgal/yr).

Total water use in the county was about 8,600 Mgal/yr in 1990, including about 25 Mgal/yr of surface water, 3,000 Mgal/yr from the Holly Beach water-bearing zone, 1,000 Mgal/yr from the estuarine sand aquifer, 2,200 Mgal/yr from the Cohansey aquifer, 200 Mgal/yr from the Rio Grande water-bearing zone, and 2,200 Mgal/yr from the Atlantic City 800-foot sand.

Water-level data collected during April 1991 for more than 200 wells show that in some locations ground-water flow directions and rates have changed when compared with those shown on historical potentiometric-surface maps. In 1991, water levels in the Holly Beach water-bearing zone were nearly identical to levels prior to development. A cone of depression has developed in the estuarine sand aquifer; the water-level altitude near the center of the cone was about -5 ft in 1991. An extensive cone of depression has developed in the Cohansey aquifer; the water-level altitude near the center of the cone was about -20 ft. A small cone of depression has developed in the Rio Grande water-bearing zone; the altitude near the center was -5 ft. An elongated cone of depression has developed in the Atlantic City 800-foot sand; the water-level altitude was about -70 ft in Ocean City and -20 ft in Stone Harbor. Water-level maps from predevelopment, 1958, 1978, 1983, and 1988 show that the cones of depression are getting deeper and are expanding in the Atlantic City 800-foot sand.

The 250-mg/L (milligram per liter) line of equal chloride concentration and 50 mg/L line of equal sodium concentration have moved inland, possibly since the early 1900's. Chloride concentrations have increased in many wells in the confined aquifers along the coastline in the southern part of the county. Nitrate concentrations greater than 1 mg/L were present in water samples collected from 10 wells that tap the Holly Beach water-bearing zone. Concentrations of nitrate greater than 10 mg/L in samples collected in Lower, Middle, Upper, and Dennis Townships may result from effluent from septic systems or from agricultural activities.

A water budget shows that the mean annual precipitation is about 42 in., and about 119,000 Mgal falls each year on uplands and freshwater wetlands in the county. About 63,600 Mgal/yr is evapotranspired, 8,200 Mgal/yr becomes overland flow, and 47,200 Mgal/yr recharges the Holly Beach water-bearing zone. In northern Cape May

County, most recharge ultimately is discharged to streams. In southern Cape May County, about 20 percent of recharge is diverted to withdrawal wells.

Because saltwater intrusion has occurred in the confined aquifers along the Atlantic and Delaware Bay coastlines, new supply wells placed along the axis of the peninsula would likely provide freshwater for the longest period of time. The supply wells could be coupled with observation wells placed at or near the saltwater front in the aquifers. The observation wells could be used to obtain water-quality samples and water-level measurements to observe any changes in the location of the saltwater front that might result from withdrawals.

INTRODUCTION

At the turn of the 21st century, the supply of freshwater available in Cape May County, N.J., (fig. 1) has diminished from the quantity available 100 years before. In 1900, the barrier islands were used primarily for cattle grazing, and county land was given away to theater patrons in Philadelphia to entice them to live on the Cape May peninsula. Ground water flowed freely from many of the deep wells when the aquifers were first tapped for water supply. Today, ocean front property on the barrier islands is likely the most limited and most expensive real estate in southern New Jersey. Water levels in nearly all the confined aquifers have deceased to below sea level. Saltwater has intruded into the heavily used aquifers near the shoreline in the county. Water from the water-table aquifer has been rendered non-potable in some areas because of contamination from land-use practices and other human activities.

Geography, climate, and hydrogeology constrain the availability of water resources in Cape May County. The southern part of the 263-mi^2 county is a peninsula that protrudes into the salty waters of Delaware Bay and the Atlantic Ocean. About 38 percent of the county is covered by saltwater wetlands that flood twice daily with seawater. The county typically receives from 40 to 45 inches of precipitation each year, but precipitation that falls on saltwater wetlands and ponds is unusable for water supply. Hydrogeology controls the recharge, flow, discharge, and distribution of the fresh and salty ground water. In this report, freshwater is defined as water with a chloride concentration of less than 250 mg/L; saltwater is water with a chloride concentration of 250 mg/L or greater. The saltwater front is defined as the location of the 250-mg/L line of equal chloride concentrations.

The distribution of fresh and salty water in the aquifers differs with location within the county. In most parts of the county, freshwater is present in five aquifers from land surface to as deep a 900 feet. In many of the saltwater wetlands and barrier islands on the east side of the county and north of Wildwood, however, the shallow aquifers contain salty water, and it is necessary to drill more than 700 ft to reach freshwater. In communities in the southern part of the county, no freshwater is available at any depth along the shore. As a result of the county’s geography and hydrogeology, when compared with the other counties of the New Jersey Coastal Plain, Cape May County has the least amount of land that is suitable for recharging precipitation into the aquifers. In addition, the county has the smallest reliable supply of fresh ground water of all the counties of the New Jersey Coastal Plain.

The quantity and quality of the water supply in Cape May County has been greatly affected by land use, population increases, and tourism. During the past 100 years, the small inland community of Woodbine has withdrawn less than 125 Mgal/yr. No appreciable cone of depression is present in any aquifer in this area, nor has the water quality been degraded. During the same period, large shoreline communities, such as Ocean City, Sea Isle City, and Avalon, whose populations swell during the summer, have withdrawn from 450 to 1,100 Mgal/yr for the last decade. Subsequently, an extensive cone of depression has developed in the Atlantic City 800-foot sand aquifer. Though the cone of depression is from 50 to 80 ft below sea level, the water quality is still as good as it was in the early 1900’s. In contrast, communities such as Cape May City, Cape May Point, and Villas have withdrawn from 25 to 400 Mgal/yr from the Cohansey Aquifer. Small cones of depression have developed nearby that are only 5 to 20 ft below sea

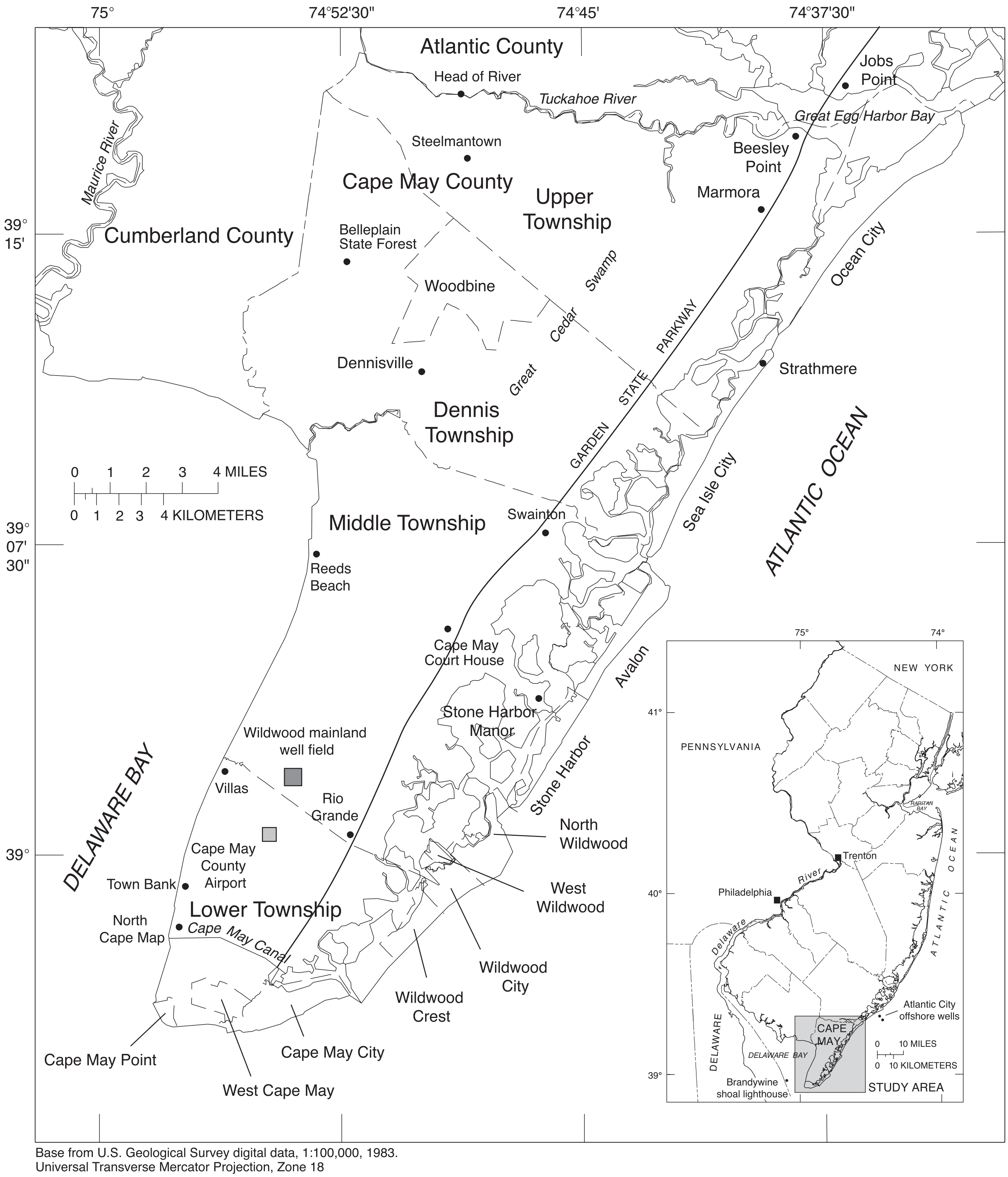


Figure 1. Location of Cape May County, New Jersey, and vicinity.

level; yet the subsequent increases in chloride concentrations in the ground-water supply have forced the abandonment of at least four public-supply wells, two industrial-supply wells, and hundreds of domestic-supply wells (Lacombe and Carlton, 1992).

Land use also affects the quality and quantity of available freshwater. The dredging of the Cape May Canal in the 1940's lowered the water table near the canal and increased the potential for the intrusion of salty water along either side of the canal. The initial dredging operation and subsequent maintenance dredging have moved saltwater-rich sediments from the canal bottom to spoil piles and caused saltwater contamination of nearby domestic-supply wells. Residential communities, septic systems, roadways, industrial sites, parking lots, landfills, service stations, fertilized farm fields, and hazardous waste sites have all altered the recharge, discharge, and quality of the water in the shallow aquifer. Fortunately, in most of the county the water is potable, and water levels are high or stable; in some areas, however, the water quality has been degraded, and the amount of water in storage has decreased.

The U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP), conducted a study of the freshwater supply in Cape May County to provide information on water quality and water availability so that residents and officials in local and state government agencies can effectively manage the water resources of the county into the 21st century. A comprehensive analysis of Cape May County's water resources was needed to evaluate alternative water supplies, such as fresh surface water, and salty ground water and to improve the understanding of the natural and human-related factors that govern the intrusion of saltwater into the five aquifers in Cape May County. The NJDEP promotes the philosophy that effective water-resource management requires a definition of the resource in conjunction with an understanding of the diverse effects that result from using the resource. Effective water management will maximize the beneficial and minimize adverse effects of using this resource.

Purpose and Scope

This report describes the freshwater resources of the 5 freshwater aquifers, the Tuckahoe River, and 13 small streams in Cape May County and vicinity. Specifically, this report describes the hydrostratigraphy of the study area and the hydraulic characteristics of the five aquifers and five confining units. Water-level and water-quality data are presented in maps, graphs, and tables. This report also describes the stream flow, discharge areas, and water quality of the surface-water system in the county. A water budget showing past and present water recharge, withdrawal, and discharge is included. This report describes the availability of freshwater supplies within the county.

The hydrostratigraphy was developed from more than 80 borehole and well logs, and from marine seismic data. The hydrostratigraphic framework is presented in structure and thickness maps and hydrogeologic sections. The hydraulic characteristics were determined from the compilation of the results of aquifer tests, soil permeability tests, well acceptance tests, and computer simulations. Water-level data from eight county-wide water-level synoptic studies are presented in maps, and water-level data from 27 continuous water-level observation wells are presented in hydrographs. Water-withdrawal data also are presented in tables and graphs. Surface-water discharge measurements for 13 stream sites along with predicted discharge are presented in tables and graphs. The results of water-quality analyses of samples collected from 80 wells during 1989-92 are presented in maps, tables, and graphs. Monthly and annual ground-water-withdrawal rates are presented in tables and graphs.

Location and Extent of Study Area

Cape May County is the southernmost county in New Jersey (fig. 1). The Atlantic Ocean lies to the east of this peninsular county and Delaware Bay lies to the west and south. Cape May County is south of and separated from Atlantic County by the Tuckahoe River and Great Egg Harbor Bay. Cumberland County borders Cape May County on the northwest. Cape May County can be divided into three geographic areas--mainland, barrier islands, and tidal saltwater wetlands. The mainland covers about 163 mi^2; land uses on the mainland include forested, agricultural, residential, commercial, and freshwater wetland. Four barrier islands cover about 25 mi^2 along the Atlantic shoreline. The barrier islands are heavily developed with residences and tourist accommodations. The tidal wetlands cover about 75 mi^2 and include saltwater marshlands and ponds to the west of the barrier islands, along Delaware Bay and along the Tuckahoe River.

Climate

Moderate temperatures and mild winters characterize the climate of Cape May County. Annual precipitation in Cape May Court House during 1958-87 ranged from 31.17 to 56.10 in (fig. 2) with a mean of about 40.62 in. (fig. 3, table 1). In Belleplain State Forest, annual precipitation ranged from 28.63 to 59.14 in., with a mean of 43.15 in. (table 1). Mean monthly precipitation in Cape May Court House during 1958-87 ranged from 3.00 to 3.98 in. The minimum and maximum monthly precipitation values were 0.17 and 11.62 in. (table 1). Mean monthly precipitation in Belleplain State Forest during 1958-87 ranged from 3.21 to 4.61 inches. The minimum and maximum monthly precipitation values were 0.02 and 16.64 inches.

Severe storms such as northeasters and hurricanes occur infrequently. When they do occur, they cause severe flooding with seawater. The area that likely will flood during a 100-year flood is shown in figure 4 (Federal Emergency Management Agency, 1996). Evapotranspiration (ET) exceeds rainfall during summer, but during winter, precipitation exceeds ET. This occurs across the State of New Jersey.

Previous Investigations

Many reports have been published which describe or discuss some aspects of the water resources of Cape May County. The major sources of information on the hydrostratigraphy, hydraulic characteristics of the aquifers and confining units, water levels, water withdrawals, and water quality are listed in table 2. The publications are divided into Coastal Plain regional studies, which focus on the Coastal Plain of New Jersey; county-wide studies, which focus on a large part of the county; and local studies, which focus on a well, waste site, or part of a township. The reports are loosely categorized to indicate the focus of the study.

Numbering System for Streamflow Gaging Stations and Wells, and Well Information

The stream-gaging station numbering system used in maps and tables in this report is based on the system used by the U.S. Geological Survey in New Jersey since 1950. All stations are numbered on each river in downstream order. Stations on a tributary that enters between two stations on a mainstream are given a number between the two mainstream stations. A representative stream gaging station number is 01411400 for Fishing Creek at Rio Grande, N.J.

The well-numbering system in the maps, tables, and figures in this report is based on the numbering system used by the U.S. Geological Survey in New Jersey since 1978. The well number consists of a county code number and a sequence number assigned to the well within the county. Code numbers for the counties in the study area are 1, Atlantic County; 9, Cape May County; and 11, Cumberland County.

A representative well number is 9-181, which designates the 181st well inventoried by the USGS in Cape May County. The USGS used other numbering systems in reports published prior to 1978. These previous well numbers are cross referenced in the text where appropriate. Figures 5 to 8 are the index maps showing the location of wells and a well number for each aquifer in the study. Well-construction and other well information is contained in appendix 1.

Methods of Investigation

Most framework, water-level, water-quality, and water-use data used in this study were compiled, analyzed, and interpreted from October

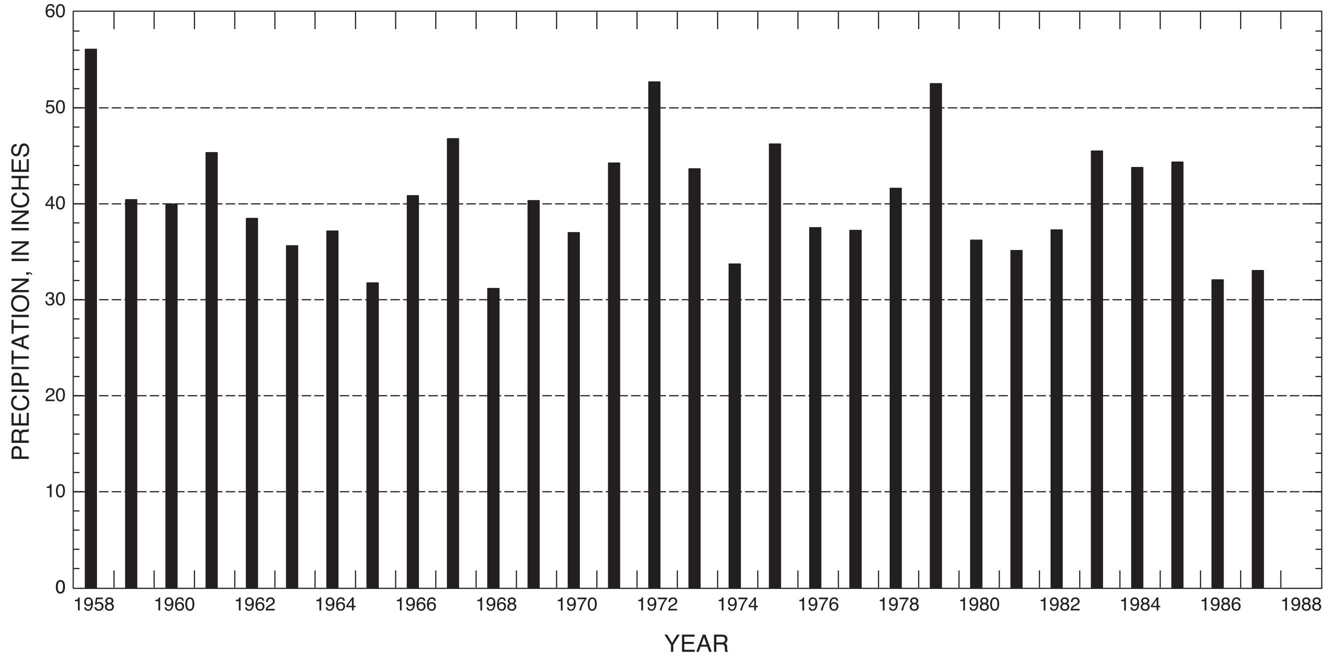


Figure 2. Annual precipitation at Cape May Court House, 1958-87.

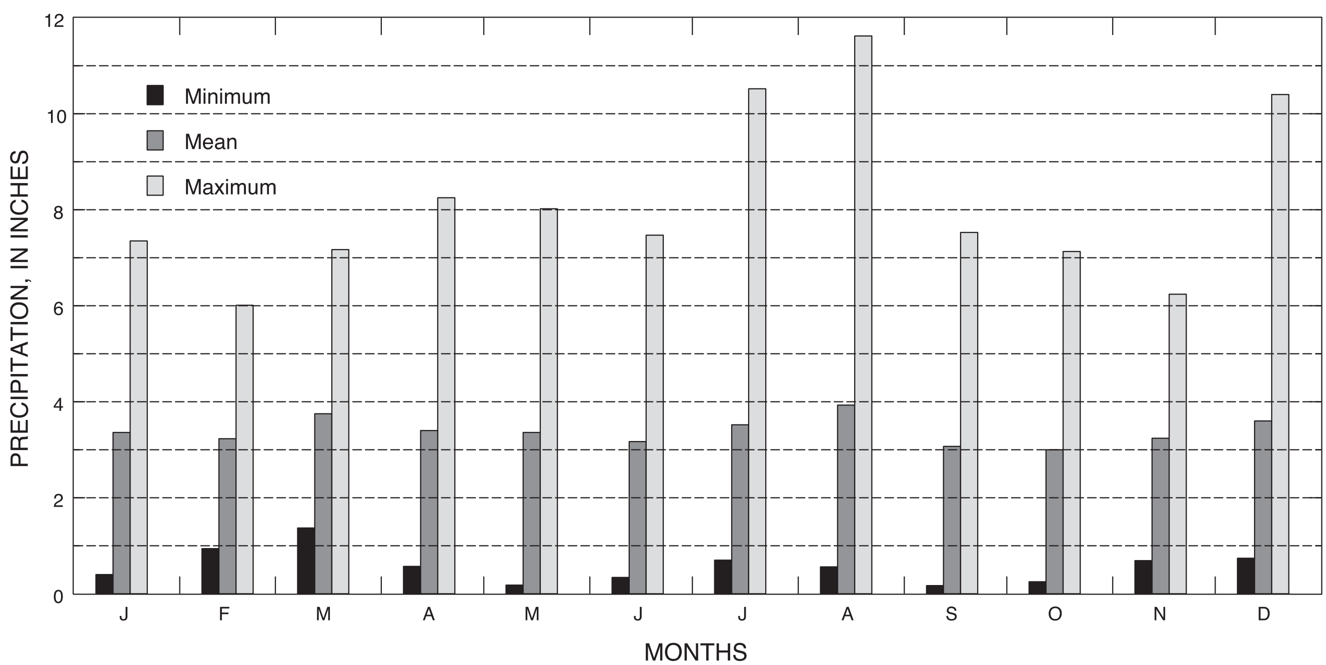


Figure 3. Minimum, mean, and maximum monthly precipitation at Cape May Court House, 1958-87.

Table 1. Monthly and annual precipitation at Cape May Court House and Belleplain State Forest, New Jersey, 1958-87

[in inches; -- data not collected; Min, minimum; Max, maximum; location of stations shown in figure 1]

Cape May Court House

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1958	2.86	4.98	5.86	5.84	5.48	2.66	7.21	11.34	2.74	2.49	2.29	2.38	56.10
1959	1.14	1.85	3.05	3.98	1.69	.98	10.52	6.13	.25	3.49	5.13	2.36	40.42
1960	2.62	3.98	2.04	1.80	3.23	1.40	5.67	4.63	7.52	2.65	1.43	3.08	39.98
1961	2.83	5.65	4.87	3.25	4.15	5.06	3.38	2.65	3.62	4.01	1.74	4.12	45.33
1962	3.45	3.73	3.51	2.61	1.82	4.24	3.98	1.17	3.06	1.58	5.31	3.99	38.47
1963	2.68	2.11	7.17	.59	2.64	2.29	2.62	2.11	4.68	.25	5.56	2.98	35.63
1964	6.20	4.25	4.17	6.79	.18	1.13	2.12	2.22	4.02	2.34	1.05	2.69	37.16
1965	3.39	1.75	4.27	2.59	1.51	2.31	6.00	5.14	2.32	.76	.69	1.03	31.76
1966	2.98	4.45	1.72	4.31	5.34	4.21	.75	1.38	6.71	3.58	1.82	3.63	40.85
1967	.98	3.12	2.24	2.73	5.98	7.15	4.16	11.62	2.01	.85	1.02	4.98	46.78
1968	2.82	.98	5.06	1.47	4.04	3.30	2.43	1.98	.98	2.11	3.32	2.79	31.17
1969	3.81	2.80	3.35	3.22	1.30	1.60	6.14	4.16	2.67	1.08	3.43	6.77	40.33
1970	2.07	2.81	4.07	4.06	2.54	4.13	1.56	1.57	.63	4.83	5.70	3.02	36.99
1971	2.73	4.42	2.34	2.88	4.62	.34	3.17	6.43	4.29	7.13	3.13	2.76	44.24
1972	2.64	5.99	1.98	4.27	4.26	6.88	2.03	2.32	4.31	5.50	6.18	6.34	52.69
1973	3.01	3.09	1.59	3.34	3.98	4.55	4.42	3.63	2.32	1.63	1.75	10.40	43.64
1974	3.11	3.01	3.98	1.76	4.70	2.98	.98	3.44	3.09	2.29	.98	3.66	33.73
1975	5.03	3.19	3.69	4.74	3.13	3.75	5.19	2.98	4.77	2.54	2.67	3.60	46.22
1976	3.25	2.98	2.11	1.35	2.11	1.69	2.71	5.42	6.24	5.71	1.33	2.67	37.51
1977	2.81	2.50	2.11	1.98	1.76	1.77	1.32	2.69	2.98	4.05	6.24	7.03	37.23
1978	6.45	1.86	5.77	2.73	5.63	1.28	3.02	4.41	.17	3.16	3.35	3.78	41.61
1979	7.35	6.01	4.40	3.51	3.98	2.86	3.76	7.15	4.73	2.76	5.36	1.72	52.51
1980	3.40	1.27	6.63	3.68	1.81	3.31	2.37	.79	2.84	6.02	3.04	1.05	36.21
1981	.40	3.25	1.71	3.59	3.40	7.47	1.43	2.55	2.10	3.46	1.67	4.10	35.13
1982	3.23	2.65	3.43	5.17	2.82	3.42	3.70	2.30	1.19	2.72	4.43	2.21	37.27
1983	2.27	2.88	6.33	8.25	4.09	3.21	.70	3.80	2.56	--	5.12	4.27	--
1984	3.06	3.64	7.04	5.29	8.02	2.20	3.98	2.60	1.25	2.73	2.44	1.61	43.77
1985	3.58	2.74	2.78	.57	4.13	5.80	5.36	7.59	4.98	1.52	4.56	.74	44.34
1986	4.05	3.24	1.37	2.68	.47	.99	2.19	3.32	.98	2.77	4.37	5.71	32.08
1987	6.51	1.98	3.98	3.03	2.12	2.24	2.83	.56	2.25	3.02	2.00	2.65	33.04
Mean	3.36	3.23	3.75	3.40	3.36	3.17	3.52	3.98	3.07	3.00	3.24	3.60	40.62
Min	0.40	0.98	1.37	0.57	0.18	0.34	0.70	0.56	0.17	0.25	0.69	0.74	31.17
Max	7.35	6.01	7.17	8.25	8.02	7.47	10.52	11.62	7.52	7.13	6.24	10.40	56.10

Belleplain State Forest

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1958	2.63	5.19	6.74	4.98	4.66	3.84	7.98	10.40	3.40	3.18	3.29	2.73	58.98
1959	1.60	2.45	3.87	2.86	1.17	1.19	16.64	5.98	.53	4.00	4.88	3.32	48.49
1960	3.49	5.12	4.08	2.72	3.44	1.98	7.52	3.82	4.05	1.50	1.60	3.06	42.31
1961	--	--	--	--	3.23	4.45	5.06	1.23	2.88	5.06	2.86	2.85	--
1962	3.45	3.16	3.22	3.63	1.98	3.78	2.98	.98	3.05	1.32	5.06	5.07	38.15
1963	2.98	1.84	6.27	.98	4.47	3.05	1.84	5.03	4.40	.02	6.80	2.85	40.41
1964	5.01	4.03	3.04	7.07	1.64	2.98	5.23	1.30	4.44	2.98	1.13	3.24	42.98
1965	3.30	2.19	3.81	2.15	1.84	1.59	3.52	3.46	3.98	1.03	.71	1.12	28.63
1966	3.31	3.81	1.39	2.67	3.78	2.78	2.86	2.37	8.12	4.19	1.15	4.25	40.68
1967	.64	2.99	2.85	2.63	4.35	1.88	3.80	10.47	1.52	2.37	2.04	4.99	40.53
1968	2.81	1.87	4.42	1.19	4.22	4.98	2.05	.87	1.78	3.09	3.23	3.64	34.10
1969	2.07	3.01	3.47	4.46	1.87	1.37	6.56	4.70	7.60	1.98	3.61	7.03	42.73
1970	1.35	2.85	3.81	5.48	2.09	4.59	3.57	1.07	1.04	5.98	4.09	3.11	38.99
1971	2.62	5.98	1.87	1.24	2.02	.88	2.41	14.18	5.26	5.16	4.28	3.55	49.38
1972	3.66	5.59	2.31	4.43	4.09	7.33	3.82	1.05	4.31	7.19	9.45	5.98	59.14
1973	3.45	2.72	2.41	5.25	4.55	3.47	4.36	2.15	3.22	2.31	1.41	5.54	40.79
1974	3.46	2.07	4.98	2.03	4.45	2.98	1.01	9.68	3.36	2.23	1.04	4.60	41.80
1975	5.86	3.63	4.22	4.28	4.12	5.98	6.10	1.74	5.98	3.18	2.98	2.10	50.01
1976	5.62	2.76	1.45	1.03	2.42	1.63	3.10	7.60	3.77	8.04	.85	2.58	40.85
1977	3.15	2.63	2.04	2.44	1.14	2.81	2.01	6.25	1.83	4.57	6.71	6.20	41.78
1978	6.10	1.14	5.98	2.32	8.70	1.82	5.37	7.24	.87	2.28	3.29	5.61	50.72
1979	6.62	6.61	4.02	3.98	2.83	3.52	4.39	6.10	4.33	3.13	3.98	1.98	51.27
1980	2.98	1.23	6.59	5.77	2.46	7.06	3.44	1.57	1.80	5.17	2.81	1.09	41.98
1981	.57	3.59	1.72	5.07	3.13	4.66	1.83	5.62	3.83	2.62	1.98	3.87	38.43
1982	3.75	2.65	3.16	3.76	2.53	3.17	3.70	4.98	1.81	1.87	4.60	2.84	38.78
1983	2.78	4.14	7.21	9.50	4.61	4.16	.43	3.41	2.99	4.82	6.76	4.77	55.59
1984	2.48	3.07	6.05	5.19	7.47	2.62	3.83	2.76	1.34	3.26	1.56	1.74	41.39
1985	2.88	2.10	2.30	.65	4.04	2.33	3.04	6.53	5.37	1.63	2.44	.98	34.23
1986	4.02	3.12	1.33	4.05	1.22	.98	4.19	3.99	--	3.85	4.36	6.88	--
1987	4.32	1.72	3.59	3.98	1.84	1.98	5.50	1.65	3.01	3.98	2.22	1.62	35.18
Mean	3.34	3.21	3.73	3.64	3.34	3.18	4.27	4.61	3.44	3.40	3.37	3.63	43.15
Min	0.57	1.14	1.33	0.65	1.14	0.88	0.43	0.87	0.53	0.02	0.71	0.98	28.63
Max	6.62	6.61	7.21	9.50	8.70	7.33	16.64	14.18	8.12	8.04	9.45	7.03	59.14

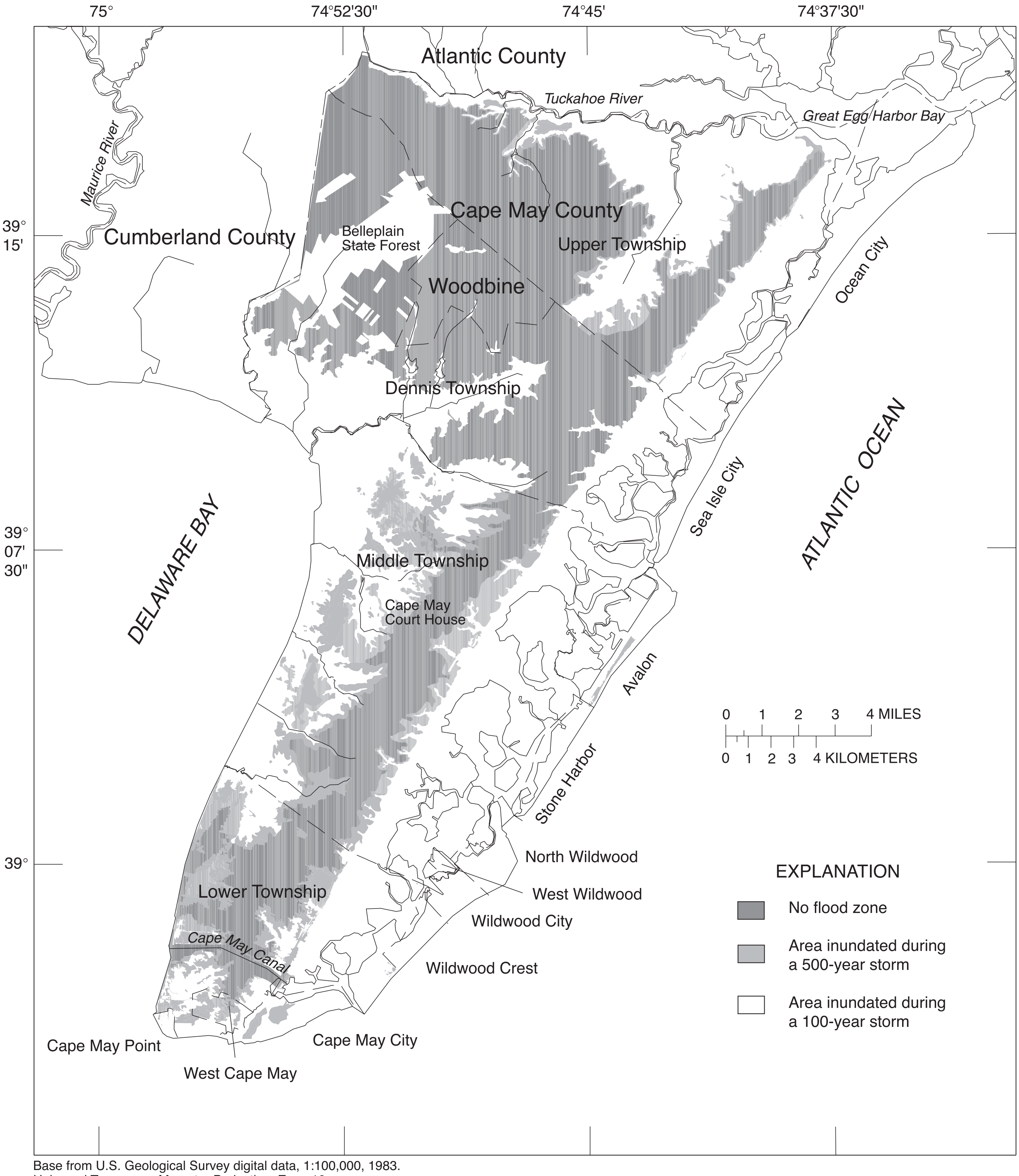
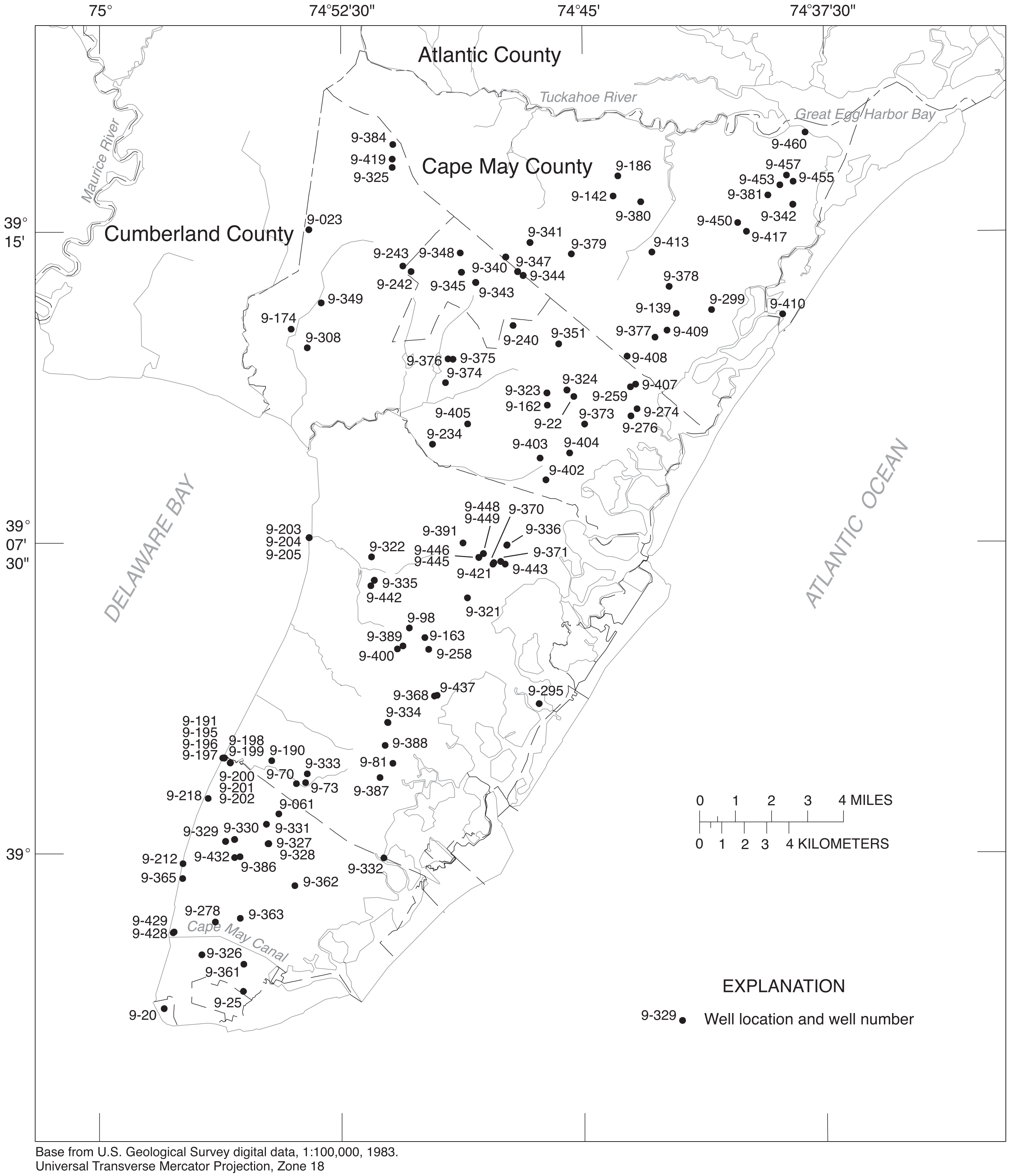


Figure 4. Location of areas inundated during a 100-year storm, Cape May County, New Jersey, and vicinity. (Data from the Federal Emergency Management Agency, 1996.)

Table 2. Previous hydrologic investigations in Cape May County

Type of study	Reference
	Coastal Plain regional studies
Water levels and withdrawals	Zapecza, Voronin, and Martin, 1987
1978 water levels	Walker, 1983
1983 water levels	Eckel and Walker, 1986
1988 water levels	Rosman, Lacombe, and Storck, 1996
1993 water levels	Lacombe and Rosman, 1997
Hydrogeologic framework	Zapecza, 1989
Ground-water supplies	Thompson, 1928
Simulation of ground-water flow	Leahy, 1979
Simulation of ground-water flow	Martin, 1990
Simulation of ground-water flow	Voronin, Spitz, and McAuley, 1996
Simulation of ground-water flow	Pope and Gordon, 1999
	County-wide studies
Water resources	Gill, 1962a
Well records and logs	Gill, 1962b
Simulation of ground-water flow	Spitz and Barringer, 1992
Hydrologic feasibility	Spitz, 1996
Simulation of ground-water flow, saltwater intrusion	Spitz, 1998
Hydrogeology and saltwater intrusion	Schuster and Hill, 1995
Water resources	Geraghty and Miller, 1971
Water-supply study	Jarmer, 1982
Water management and conservation	Kay, 1962
Water-supply potential	Webster, 1963
Water-quality management plan	Cape May County Planning Board, 1979
Desalination study	U.S. Corps of Engineers, 1992
	Local studies
Saltwater intrusion	Epstein, 1986, 1988, 1989
Artificial recharge	Lacombe, 1996
Saltwater intrusion	Lacombe and Carleton, 1992
Public-supply conservation	Scott, 1992
Plume of contamination	Lawler, Matuskey, and Skelly, 1992
Land fill siting	Hart Engineers, 1989
Compendium of contamination sites	N.J. Department of Environmental Protection



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 5. Location of selected wells screened in the Holly Beach water-bearing zone, Cape May County, New Jersey.

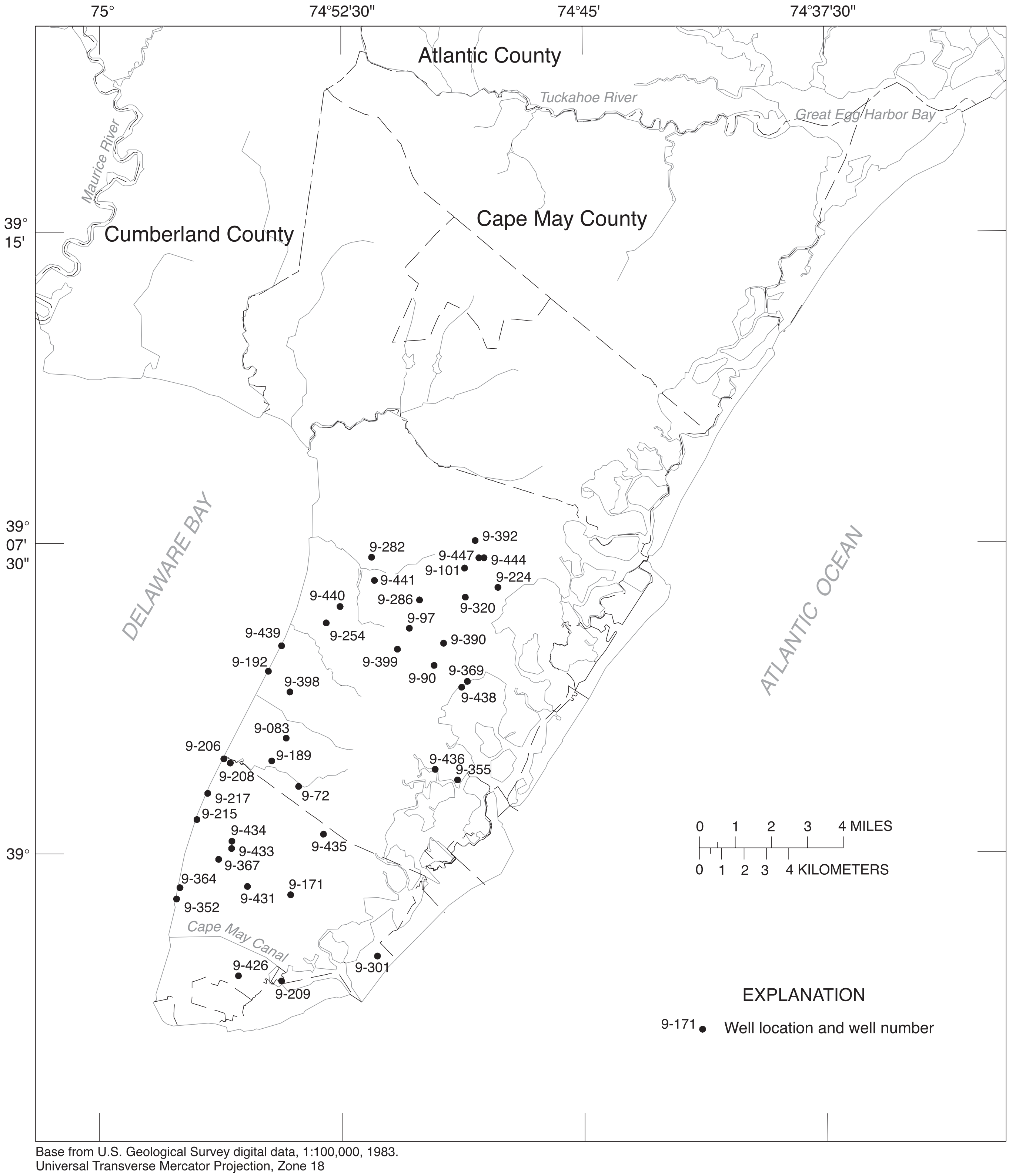


Figure 6. Location of selected wells screened in the estuarine sand aquifer, Cape May County, New Jersey.

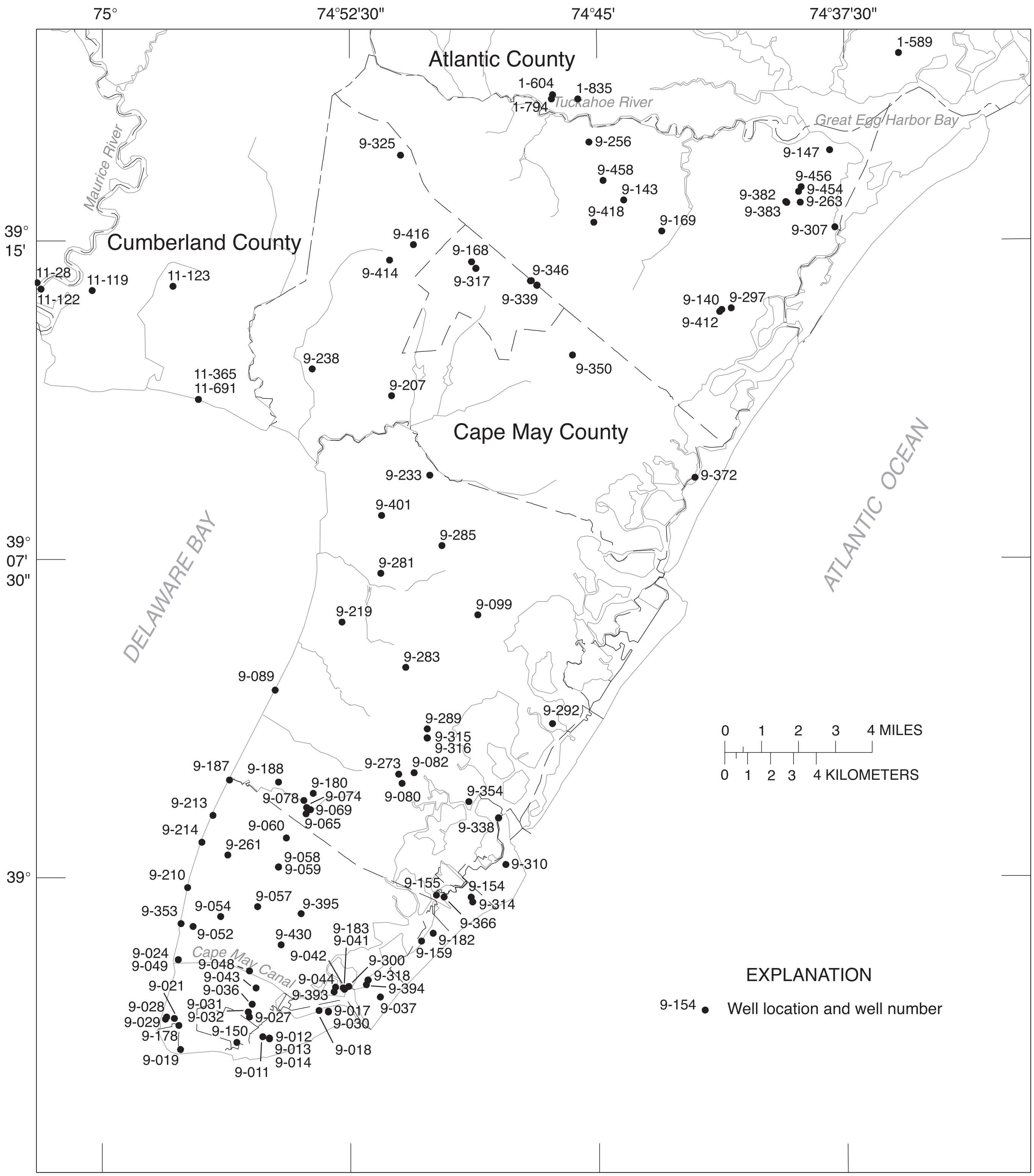


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Figure 7. Location of selected wells screened in the Cohansey aquifer, Cape May County, New Jersey.

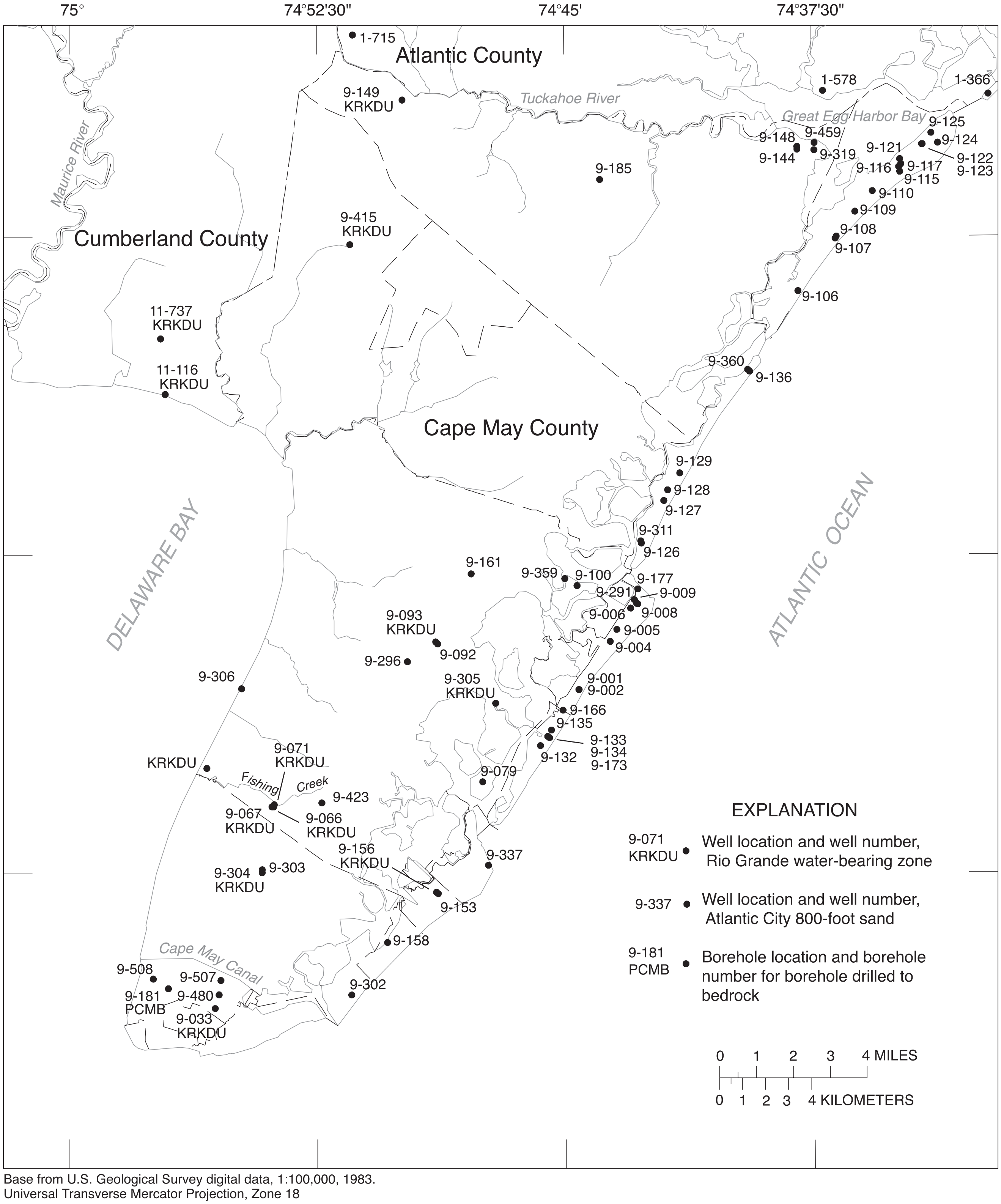


Figure 8. Location of selected borehole and wells screened in the Rio Grande water-bearing zone, Atlantic City 800-foot sand, and deeper zones, Cape May County, New Jersey.

1988 through September 1993. Data from a few water-quality samples that were collected and analyzed during 1993-99 are included in this report. Fieldwork, including well drilling, water sampling, water-level measurements, and interviews with representatives of the major water suppliers, was conducted to augment the available water-resource data.

Discharge measurements were made at 13 freshwater streams within the study area, and historical records provided streamflow data for the gaging station on the Tuckahoe River at Head of River. Additional data on fresh surfacewater were obtained from wetland maps prepared by the NJDEP, (1996).

The hydrostratigraphic interpretation was developed from data in more than 80 geophysical, geologic, and well-completion logs of boreholes and wells and from marine seismic reflection data. This information, together with hydrostratigraphic interpretations provided by Zapecza (1989) and Gill (1962a), was used to develop the structure maps, thickness maps, and sections of the five aquifers and five confining units in the study area. Hydraulic characteristics of the aquifers and confining units were determined from the results of 15 aquifer tests and 15 well-acceptance tests conducted by commercial drillers and USGS personnel prior to this study. The hydraulic characteristics are complemented by results of computer simulations obtained from USGS reports. Hydraulic characteristics are horizontal values for the aquifers and vertical values for the confining units.

The water-withdrawal component of this investigation was developed from ground-water-withdrawal records from about 50 public-supply, 20 industrial-supply, and 20 irrigation-supply wells, and from 3 mining-supply ponds. The water-withdrawal data were compiled by Zapecza and others (1987) and obtained from NJDEP files. Estimates of withdrawals and consumptive use were made for domestic-supply wells.

The ground-water-flow component was developed from synoptic water-level measurements of about 210 wells and continuous ground-water-level measurements in at least 27 wells. This information, together with previous water-level interpretations provided by Walker (1983), Eckel and Walker (1986), Rosman and others (1996), Zapecza and others (1987), and Gill (1962a and b) was used to develop the water-level maps, potentiometric-surface maps, and hydrogeologic sections that in turn were used to determine the ground-water flow directions. Long-term water-level hydrographs were used to show the seasonal water-level fluctuations and trends in the study area.

Ground-water quality was investigated by collecting and analyzing about 80 ground-water samples for chemical constituents. The samples were collected during 1987-92 and analyzed at the USGS National Water Quality Laboratory in Colorado. This investigation focused on the concentrations of chloride, sodium, iron, and nitrate in the ground water. Results of these chemical analyses are stored in the USGS water-quality database at the New Jersey District office in W. Trenton, N.J., in the databases of public water-supply purveyors, and in the Cape May County Health Department database. Water-quality interpretations by Gill (1962a) and Lacombe and Carleton (1992) also were used to map the potable water supply. The location of the saltwater/freshwater interface was determined from chloride concentrations measured in water samples from wells. Information on land use, hazardous waste sites, landfills, and underground storage tanks was used to delineate areas where the water quality of the water-table aquifer is or may become degraded.

The water budget was developed in part from data on precipitation, areal distribution of land types, areal distribution of aquifers, surface-water discharge, calculations of evapotranspiration, estimated and measured flow into and out of the aquifers, and reported and estimated ground-water withdrawals. This information, together with ground-water flow directions and applications of Darcy's Law, supplied the information needed to develop the water budget for the aquifers of Cape May County.

Acknowledgments

The authors thank the water purveyors who operate the public- and industrial-supply wells in Cape May County for allowing access to their wells and records. In addition, the authors acknowledge the assistance of the Cape May County Water Policy Advisory Committee and the League of Women Voters who insured that forums were held for discussion between residents of the county and personnel of USGS and NJDEP. Many well drillers freely gave their time and information on local well-drilling situations, and many land owners granted permission to access their wells for the purpose of measuring water levels and collecting water samples. The authors also thank the following people and their employers who helped in this study. Typically these people were involved in discussions and in more than one water related organization: David Carrick, Cape May City Water Department; Kimberly Cenno, NJDEP; Del Clark, Clark Well Drilling; Ira Dillyn, Stone Harbor Water Department; Robert Fathergill, Lower Township Municipal Utilities Authority (MUA); Peggy Haskins, League of Women Voters; Robert Kecskes, NJDEP; Pasquale LaRosa, Sea Isle City Water Department; Edward Lightcap, private citizen; Larry Newbold, Rutgers Cooperative Extension; Michael Shouvlin, private citizen; Roger Smith, Smith Well Drilling; Thurmond Thompson, Wildwood Water Department; Grover Webber, Cape May County Health Department; and Wayne Winner, New Jersey American Water Company.

SURFACE WATER AND WETLANDS

Surface-water bodies and wetlands dominate the geography of Cape May County. The county is almost surrounded by saltwater. The Atlantic Ocean is to the east and south, Delaware Bay is to the west, Great Egg Harbor and tidal parts of the Tuckahoe River are to the north, and saltwater wetlands lie between the barrier islands and the mainland and at the mouth of all the streams that drain into Delaware Bay (fig. 9). In addition, many freshwater streams, ponds, and wetlands cover the inland part of the county. About 38 percent (100 mi^2) of the area of the county is classified as saltwater wetlands. Freshwater ponds, streams, and wetlands account for 21 percent (55 mi^2) of the area within the county, and the remaining 41 percent (108 mi^2) of the land is upland and barrier islands.

Surface-water bodies and wetland areas that contain freshwater are potential sources of potable water. From the early 1900's to as late as 1984, Cape May City and Wildwood used shallow--less that 50 ft deep--public-supply wells that were located in wetlands. These wells were specifically designed to tap the Holly Beach water-bearing zone in freshwater wetlands. During the mid-1990's, at least two farms used surface water for irrigation.

The freshwater wetlands, saltwater wetlands, barrier islands, and upland areas of the county are shown in figure 9 (New Jersey Department of Environment Protection, 1996). The four land use areas were delineated from aerial photographs taken in 1986. Freshwater wetlands are differentiated from saltwater wetlands by the type and extent of saltwater tolerant vegetation that is present and by the extent of saltwater tide. Wetland areas are differentiated from upland areas on the basis of degree of flooding, soil saturation, wetland vegetation (hydrophytes), and soil types. Barrier island areas are differentiated from upland areas on the basis of their location with respect to the Atlantic Ocean and saltwater wetland areas.

Freshwater Wetlands, Streams, and Ponds

Freshwater wetlands, such as streams, ponds, marshes, and swamps, are wet most of the year. Freshwater wetlands also include forested land and other areas where the water table is at or near land surface for only a few weeks of the year. Freshwater wetlands in the county are in areas with low or flat topography, poor or no drainage, relatively impermeable soils, and dammed ponds. Most of the 55 mi^2 of freshwater wetland are swamps, marshes, and forested wetlands that form broad boarders along freshwater streams. Historically, some of the freshwater wetlands along the coastline of Delaware Bay in Middle Township (fig. 1) were saltwater wetlands, but they

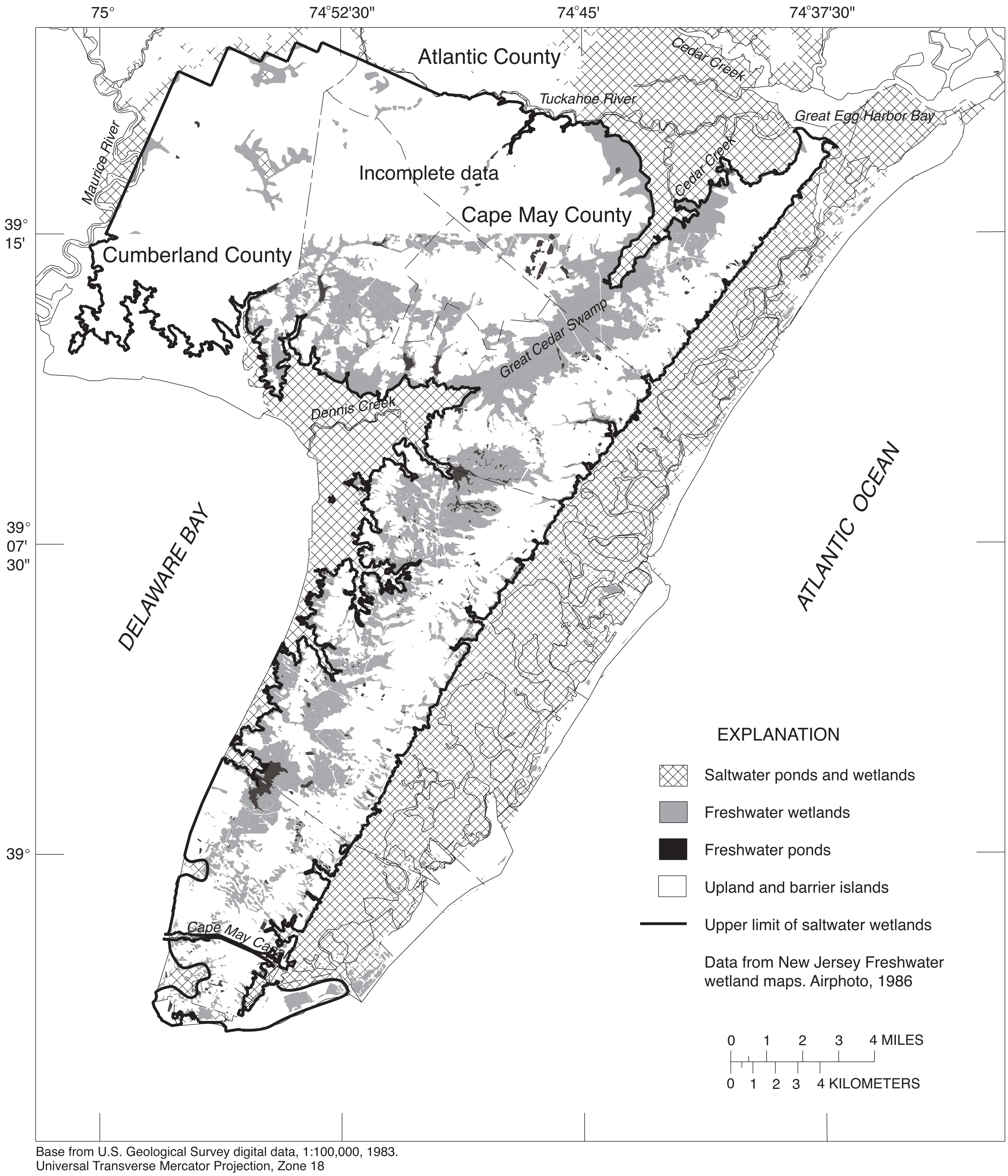


Figure 9. Saltwater ponds and wetlands, freshwater ponds and wetlands, and upland areas and barrier islands, Cape May County, New Jersey.

were diked and fitted with tide gates in the early 1900's to prevent saltwater flooding during high tide.

Cape May County has approximately 15 small freshwater streams that could be sources of potable water. All streams discharge into the Atlantic Ocean, Delaware Bay, Great Egg Harbor Bay, or a saltwater tidal wetland. Freshwater outflow from the streams maintains the position of the freshwater/saltwater interface in tidal part of the stream. On the major streams in the county, there are eight large dammed ponds that range in size from 20 to 60 acres and many small dammed ponds that cover less than 20 acres. Historically, these ponds served as reservoirs for mills run by waterpower. Today, the ponds have the potential for use as small water-supply reservoirs.

Tuckahoe River Permanent Gaging Station

The Tuckahoe River forms the northern border of Cape May County and is the largest river in the county (fig. 10). It flows approximately 13 miles from its headwaters along the Cumberland and Atlantic County border to a weir at Head of River, N.J., where the USGS maintains a streamflow-gaging station. The river is tidal downstream from the gaging station to its outlet into Great Egg Harbor Bay, a distance of approximately 13 miles. From its headwaters to Head of River, the river drops approximately 90 ft, for an average gradient of 7 ft/mi. The area of the basin upstream from the gaging station at Head of River is 30.8 mi^2; the basin consists of relatively flat land with gentle hills and highly permeable soils. Wetlands are present only in areas near the river in the upper reaches, but are more extensive in the lower reaches of the river.

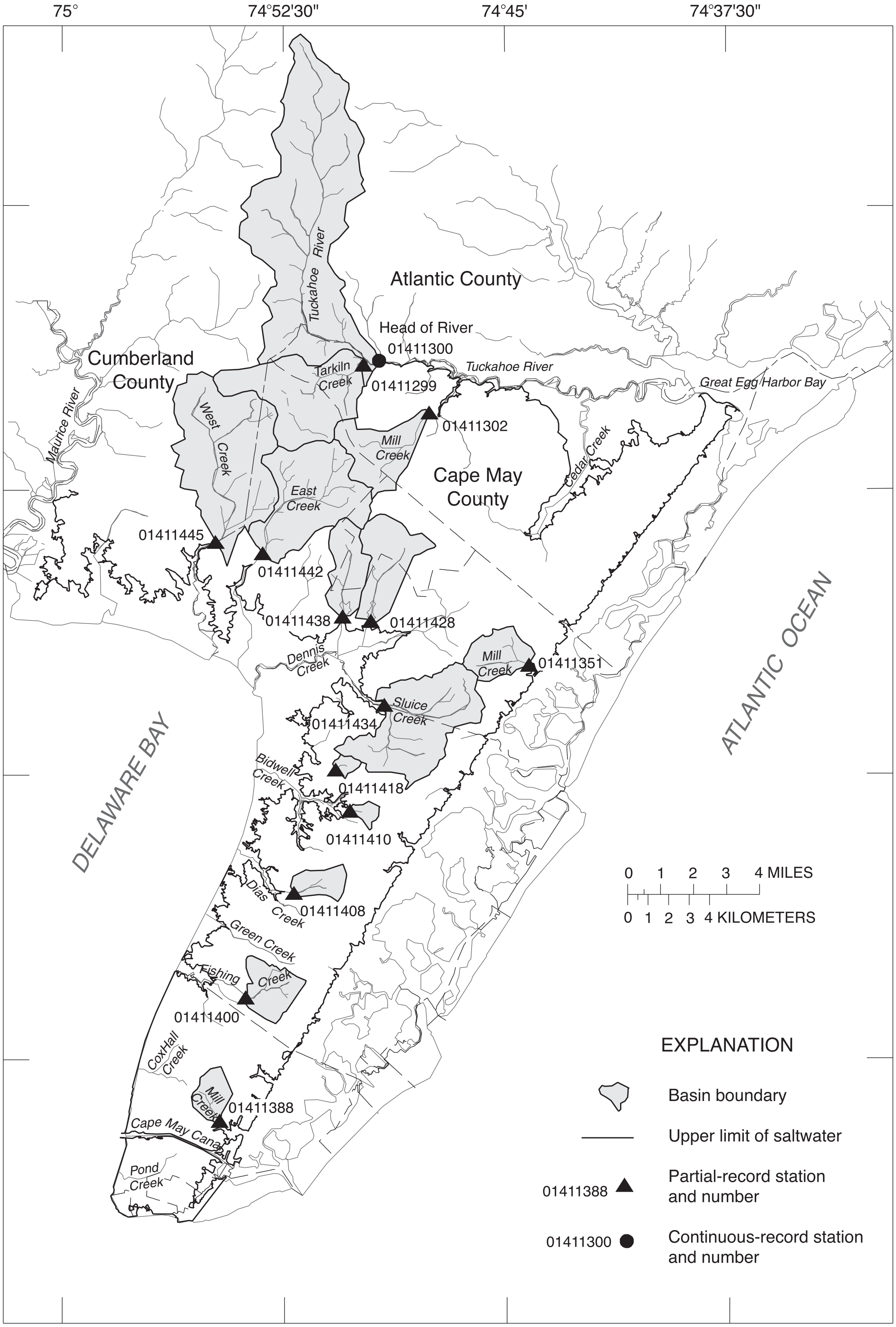
The USGS has collected continuous stream-discharge data on the Tuckahoe River at Head of River since December 1969. The mean annual discharge is 43.8 ft^3/s or about 28 Mgal/d. The discharge is 45 percent (equivalent to 19.34 in.) of the mean annual precipitation at Belleplain State Forest. The 7-day, 10-year low flow discharge is 6.0 ft^3/s or about 4 Mgal/d. The 1-day, 10-year low flow discharge is 5.1 ft^3/s or about 3 Mgal/d (table 3). Mean monthly discharge ranges from about 23 ft3/s or about 15 Mgal/d in September to 70 ft^3/s or about 45 Mgal/d in April (fig. 11).

The total discharge from the Tuckahoe River at Head of River is divided into base flow and direct runoff. Base flow is the ground-water contribution to streamflow, and direct runoff is the surface-water contribution. Both increase following precipitation, but direct runoff decreases to zero within hours, whereas base flow decreases much more gradually. Sloto (1988) describes three techniques for separating total discharge into base flow from direct runoff. The sliding interval technique is considered to be the most accurate for the Tuckahoe River at Head of River because of the highly permeable soils in the basin. The estimated mean annual base flow of the Tuckahoe River at Head of River is 37.0 ft^3/s (16.4 in.)--about 24 Mgal/d--or 85 percent of the mean annual discharge. Annual precipitation at Belleplain State Forest, and annual base flow and direct runoff of the Tuckahoe River at Head of River from 1971 through 1992 are shown in figure 12.

Small Stream Partial-record Stations

Flow rates at 13 partial-record stations on 13 small streams were estimated by using periodic discharge measurements from each partial-record station and same-day discharge rates from the Tuckahoe River at Head of River. Stream discharge measured at the partial-record station was correlated with discharge at Head of River (an index station) to establish a relation between the two sites. For this study, five discontinued partial-record stations were re-activated and eight new stations were established (fig. 10). Discharge was measured 11 times during September 1990 to March 1992 (Bauersfeld and others, 1991; 1992; 1993).

Continuous-record data from the Maurice River at Norma, the Great Egg Harbor River at Folsom, and the Tuckahoe River at Head of River were correlated with the same-day discharge rates for quality control. The data from the three index stations were similar, but the estimated discharge at the partial-record station was less at the Maurice



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 10. Locations of partial-record stations and the continuous-record gaging station on the Tuckahoe River at Head of River, Cape May County, New Jersey.

Table 3. Correlation equations relating base flow at partial-record stations to base flow at Tuckahoe River at Head of River, Cape May County, New Jersey

Q_{pr}, estimated discharge at the partial record station; Q_I, discharge at the index station Tuckahoe River at Head of River; E, Excellent; G, Good; F, Fair; yr, year; mi^2, square mile]

Low flow station number	Index station name	Drainage area (mi^2)	Discharge (Q_I) cubic feet per second 1-day 10-yr	7-day 10-yr	Mean base flow	Mean annual flow	Base flow per mi^2
01411300	Tuckahoe River at Head of River	30.8	5.1	6.0	37.0	43.8	1.2

Low flow station number	Partial Record Station	Drainage area (mi^2)	Correlation Coeffi-cient	Rating	Equation	Estimated discharge (Q_{pr}) in cubic feet per second 1-day 10-yr	7-day 10-yr	Mean base flow	Mean annual flow	Base flow $ft^3/s/mi^2$
01411299	Tarkiln Brook near Head of River	7.40	0.977	E	$Q_{pr} = 1.064X10^{-2}\ Q_I^{1.7748}$	0.2	0.3	6.5	8.7	0.9
01411302	Mill Creek near Steelmantown	3.82	.975	E	$Q_{pr} = 3.537X10^{-4}\ Q_I^{2.54}$	.0	.0	3.4	5.2	.9
01411351	Mill Creek at outlet Magnolia Lake at Ocean View	2.28	.905	E	$Q_{pr} = 5.816X10^{-2}\ Q_I^{1.0869}$	.3	.4	2.9	3.5	1.3
01411388	Mill Creek at Cold Spring	1.34	.952	E	$Q_{pr} = 4.21X10^{-3}\ Q_I^{1.4951}$	.0	.1	.9	1.2	.7
01411400	Fishing Creek at Rio Grande	2.29	.950	E	$Q_{pr} = 3.26X10^{-3}\ Q_I^{1.7091}$	.1	.1	1.6	2.1	.7
01411408	Dias Creek near Cape May Court House	1.27	.841	G	$Q_{pr} = 1.34X10^{-5}\ Q_I^{3.0765}$	.0	.0	.9	1.5	.7
01411410	Bidwell Creek tributary near Cape May Court House	.41	.874	G	$Q_{pr} = 5.41X10^{-5}\ Q_I^{2.3441}$	.0	.0	.3	.4	.6
01411418	Goshen Creek at Goshen	.33	.945	E	$Q_{pr} = 1.605X10^{-6}\ Q_I^{3.2573}$	.0	.0	.2	.4	.6
01411428	Dennis Creek tributary at Dennisville	4.00	.953	E	$Q_{pr} = 2.41X10^{-3}\ Q_I^{2.0711}$	.1	.1	4.3	6.0	1.1
01411434	Sluice Creek at outlet Clint Mill Pond, at South Dennis	8.47	.780	F	$Q_{pr} = 1.4X10^{-8}\ Q_I^{5.6713}$	.0	.0	11.0	28.5	1.3
01411438	Dennis Creek tributary near North Dennis	2.74	.902	E	$Q_{pr} = 4.71X10^{-5}\ Q_I^{3.0226}$	.0	.0	2.6	4.3	.9
01411442	East Creek at East Creek Pond, near Eldora	8.10	.951	E	$Q_{pr} = 1.532X10^{-2}\ Q_I^{1.7371}$	.3	.3	8.1	10.9	1.0
01411445	West Creek at Pickle factory pond, near Eldora	11.9	.887	G	$Q_{pr} = 1.46X10^{-3}\ Q_I^{2.5292}$	.1	.1	13.5	20.7	1.1

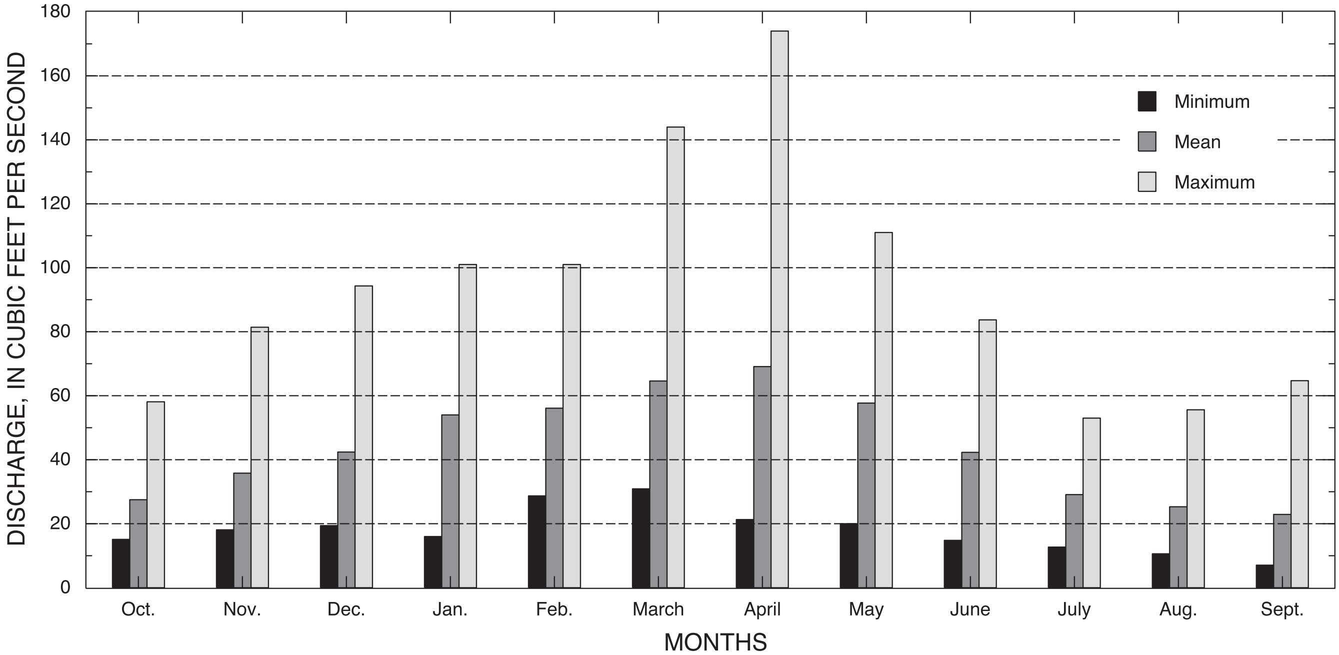


Figure 11. Minimum, mean, and maximum monthly discharge at the continuous-record gaging station, Tuckahoe River at Head of River, Cape May County, New Jersey, 1969-92.

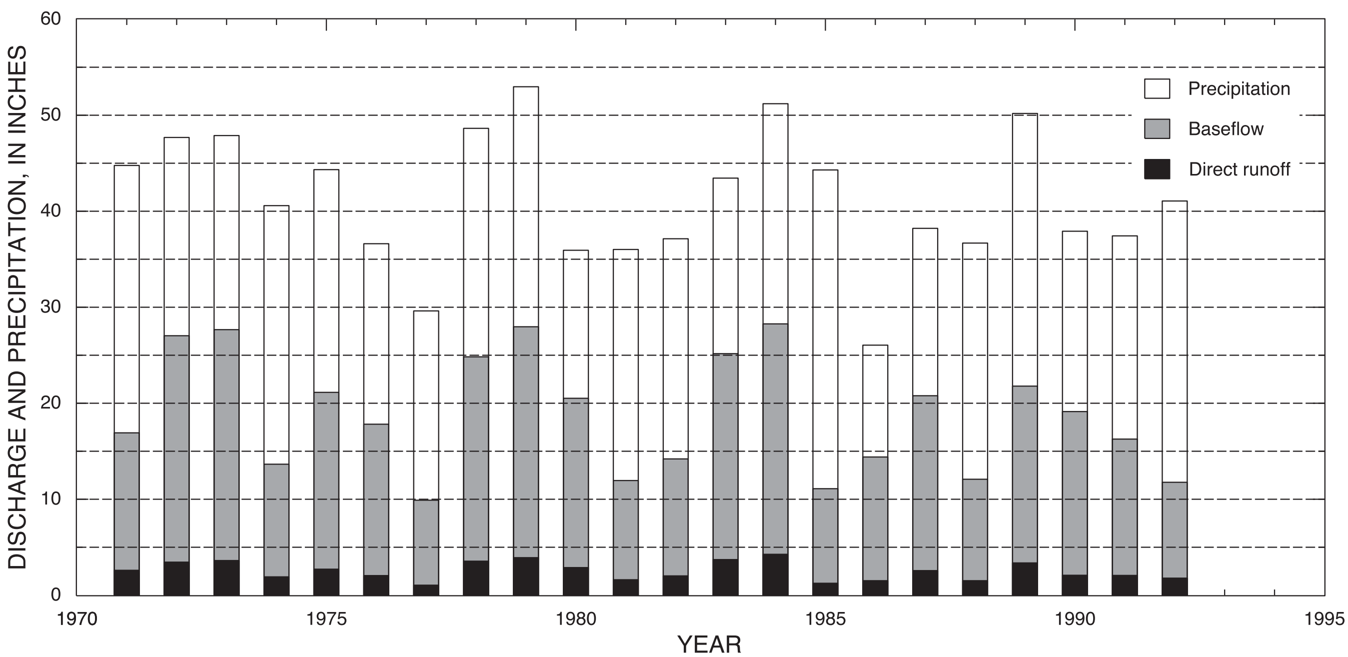
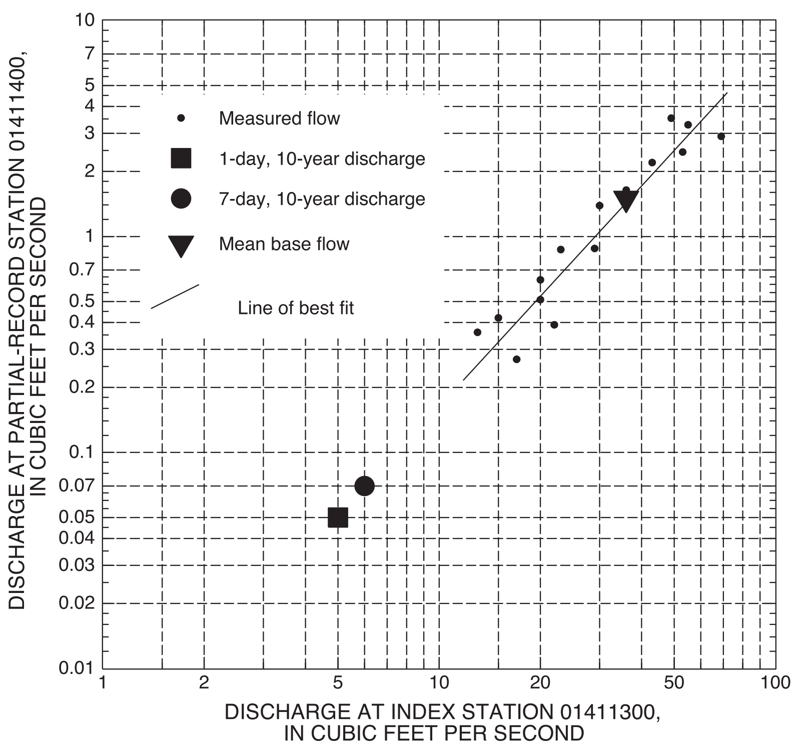


Figure 12. Annual precipitation at Belleplain State Forest and total annual discharge, divided into base flow and direct runoff components for the Tuckahoe River at Head of River, Cape May County, New Jersey, water years 1971-92.

River at Norma and at Great Egg Harbor River at Folsom stations than at the Tuckahoe River station because those two stations have larger drainage areas. Therefore, only the comparison of discharge at the 13 partial-record stations and discharge at Tuckahoe River at Head of River will be discussed here.

The discharge at the partial-record station was plotted against the same-day discharge at the Tuckahoe River at Head of River station on a log-log scale, and the best-fit line through these data was determined by using Maintenance Of Variance Extension, type 1 (Hirsch, 1982)(fig. 13; table 3). Discharge at the partial-record station can be computed from discharge at the Tuckahoe River at Head of River index station. The correlation coefficient, a number between 0 and 1, indicates the degree of correlation between the estimated discharge and the discharge of the Tuckahoe River at Head of River. Each correlation is rated excellent, good, or fair on the basis of the correlation coefficient. Correlation coefficients that are greater than 0.9 are rated excellent. Correlations for eight partial-record stations are rated excellent. Correlation analyses of 0.8 to 0.899 are rated good. Correlation for stations at Dias (1411408), Bidwell (01411410), and Goshen (01411418) Creeks are rated good because of the lower correlation coefficients and (or) because during one or more site visits the creeks were not flowing. The correlation for West Creek (014114340) is rated good, not excellent, in part because of the high rate of error (more than 5 percent) of the discharge measurements. The correlation for Sluice Creek (01411434) is rated fair because of the correlation coefficient (0.78) and high rate of error (more than 8 percent) of the discharge measurements. The higher percentage of wetlands in the Sluice Creek Basin than in the Tuckahoe River Basin probably adversely affected the correlation.

An example of a low flow correlation rated excellent is shown in figure 13. The correlations between measured discharges of the 13 partial-record stations and discharge of the Tuckahoe River at Head of River are shown in table 3.



Discharge		
Date	Qi	Qpr
02-30-70	69	2.91
04-13-71	49	3.53
04-12-72	55	3.29
09-07-72	20	0.51
09-26-90	20	0.63
11-01-90	22	0.39
01-24-91	53	2.46
02-27-91	36	1.64
04-09-91	43	2.20
05-22-91	29	0.88
07-11-91	17	0.27
09-12-91	13	0.36
10-25-91	15	0.42
12-17-91	23	0.87
03-16-92	30	1.39

Qi - Discharge measured at index station, Tuckahoe River at Head of River

Qpr- Discharge measured at partial-record station, Fishing Creek at Rio Grande

Discharge, in cubic feet per second

Correlation equation: $Qpr = 0.00326Qi^{1.7091}$

Correlation coefficient: 0.950

Figure 13. Relation of low flow at Fishing Creek at Rio Grande, station 01411400, to low flow at Tuckahoe River at Head of River, station 01411300, Cape May County, New Jersey, 1970-92.

The 1-day, 10-year low flow; 7-day, 10-year low flow; mean annual base flow; and mean annual discharge at the partial-record stations (table 3) were estimated by using the corresponding same-day discharge of the Tuckahoe River at Head of River in the correlation equation. The Tuckahoe River and other streams in Cape May County are assumed to have flow characteristics that are similar, including a base flow that is about 85 percent of the mean annual flow.

Base flow per square mile at the partial-record stations is computed by dividing the base flow by the area of the basin upstream from the station. Mean annual base flow per mi^2 (base flow/mi^2) for the Tuckahoe River at Head of River is 1.2 $ft^3/s/mi^2$ (table 3). Base flow/mi^2 for the 13 partial-record stations ranges from 0.6 to 1.3 $ft^3/s/mi^2$ (table 3). Average base flow/mi^2 of streams in the southern part of the county (stations 01411388, 01411400, 01411408, 01411410, and 01411418) is 0.7 $ft^3/s/mi^2$, and average base flow/mi^2 in the northern part of the county (station 01411299, 01411302, 01411428, 01411438, 01411442, 01411445) is 1.0 $ft^3/s/mi^2$. Base flow/mi^2 is lower in streams in the southern part of the county than in streams in the northern part of the county. Base flow/mi^2 for stations 01411351 and 01411434 is 1.3 $ft^3/s/mi^2$. The lower values in the south could result from the following factors. (1) Less recharge is entering the basin because there is 6 percent less precipitation in the southern part of the county. (2) A higher percentage of ground water discharges directly to tidal wetlands and bypasses the streams. (3) Discharge from the water-table aquifer is induced into deeper aquifers as a result of ground-water withdrawals. (4) Subtly different basin characteristics decrease the amount of recharge to the water-table aquifer.

Saltwater Wetlands

About 38 percent of Cape May County is covered with saltwater wetlands, ponds, and creeks, and the county has more than 60 mi of ocean and bay shoreline. The major saltwater wetlands are in the tidal marshes between the barrier islands and on the mainland, and at the mouth of Dennis Creek and Cedar Creek (fig. 9). Water in the water-table aquifer in saltwater wetlands is too salty to be potable. Freshwater recharge to these areas from precipitation and stream flow becomes salty upon contact. Therefore, saltwater wetlands are not potential freshwater recharge areas in the county.

A minor but important problem in the county is the destruction of freshwater recharge areas and creation of saltwater wetlands due to shoreline erosion. Nordstrom and others (1986, p. 54 and 62) report that the Delaware Bay shoreline in Cape May County has eroded at an average rate of 4 ft per year from 1812 to 1957 and that the shoreline at the Coast Guard Base in Cape May City has eroded at a rate of 20 ft per year. A monument near the Lighthouse at Cape May Point shows that the shoreline has eroded about 20 ft per year during 1940-90. This natural conversion of upland and freshwater wetland to saltwater wetland or ocean decreases the area available for freshwater recharge and storage.

HYDROSTRATIGRAPHIC FRAMEWORK

The Coastal Plain consists of an eastward thickening wedge of sediments composed principally of unconsolidated gravels, sand, silts, and clays with variable amounts of shells. The sedimentary wedge in New Jersey is generally devoid of hard rocks although some cementation is present locally (Zapecza, 1989).

The deposits in Cape May County extend from land surface to about 6,400 feet below sea level. Beneath the sediment is crystalline bedrock (table 4). The arous layers of deposits are virtually flat with a dip of less than one degree (10 to 60 ft/mi) to the southeast and a strike that is northeast-southwest.

The deepest sediments were deposited about 100 million years ago during the Cretaceous period, and some of the shallowest sediments were deposited within the past 10,000 years. The sediments were deposited in fluvial, beach, continental shelf, and deep-marine environments that were created during transgressions and regressions of the Atlantic Ocean onto eastern North America. Thick and areally extensive gravel and coarse-sand deposits make the most productive

Table 4. Hydrostratigraphy, thickness, and water-bearing characteristics of the aquifers in Cape May County, New Jersey
[Fm, Formation; --, no data]

SYSTEM	SERIES	GEOLOGIC UNIT	MAJOR AQUIFER	AQUIFERS & CONFINING UNITS	LITHOLOGY	THICK-NESS, IN FEET	WATER-BEARING CHARACTERISTICS	WATER-QUALITY CHARACTERISTICS
Quaternary	Holocene	Alluvial deposits	Kirkwood-Cohansey aquifer system	unsaturated zone	Sand, medium to coarse grained: pebbly	0-10	Highly transmissive	Freshwater on interior mainland and barrier island. Locally may be contaminated by human activities. Locally high iron and nitrate. Saltwater flooding during storms
		Beach sand and gravel		Holly Beach water-bearing zone	Sand, medium to coarse grained, pebbly numerous clay lenses in northern part of county	10-195	Sand is thicker in the center of the peninsula and in northern parts of the county are capable of yielding large quantities of water	
	Pleistocene	Cape May Formation						
Tertiary	Miocene	Bridgeton Formation		Confining unit	Clay, silt, more silty north and south of Airport	25-100	Clay thicker under airport (fig.1); unit is more permeable north and south of airport	--
				Estuarine sand aquifer	Sand, medium to coarse grained, pebbly	25-160	Yields large quantities of water in Middle and Lower Townships (fig.1)	Freshwater on mainland in Middle and Lower Townships. High iron in most areas. Saltwater intrusion in Villas
		Cohansey Formation		Confining unit	Silty clay	10-75	Leaky confining unit in most areas; mapped only in Cape May County	--
				Cohansey aquifer	Sand, medium to coarse grained, pebbly, local clay lenses	60-180	Yields large quantities of water on mainland	Freshwater on interior mainland. High iron in most areas. Saltwater intrusion in southern coast from Wildwood to Cape May Point. Rising chloride in Villas and Beesleys Point (fig. 1)
		Kirkwood Formation		Confining unit	Clay, massive regional	54-225	Regional confining unit; thins in southern Lower Township	--
			Kirkwood Formation aquifers	Rio Grande water- Bearing zone	Sand, fine to medium grained	30-170	Two supply wells tap the aquifer, aquifer is much thicker in southern part of county	Freshwater in the four wells that tap the aquifer
				Confining unit	Clay, massive regional	40-190	Regional confining unit. Thins in southern Lower Township	--
				Atlantic City 800-foot sand	Sand, fine- to medium-grained, silt, clay, discontinuous confining unit separates upper from lower Atlantic City 800-foot sand	125-150	Yields large quantities of water from Stone Harbor to Ocean City and on mainland from Middle to Upper Township	Freshwater in all communities north of Wildwood and Lower Townships. Saltwater intrusion in the Wildwood communities. High sodium concentration south of Middle Township and Avalon
				Confining unit	Clay, massive, regional	150-160	Regional confining unit; thins in southern Lower Township	Probable source of high sodium concentrations found in Middle Township, Stone Harbor, and Avalon wells that tap the Atlantic City 800-foot sand
	Eocene	Piney Point Formation		Piney Point aquifer	Silt, sandy	~200	Not used in Cape May County; used in western Atlantic and Cumberland County and Delaware	Saltwater in Cape May County. Freshwater where it is used
		Manasquan-Hornerstown		Confining unit	Clay, silty	~400	--	--
Cetaceous	Lower and Upper Cretaceous	Wenonah Fm. Mount Laurel Fm. Marshalltown Fm. Merchantville Fm. Woodbury Fm. Magothy Fm. Raritan Fm. Potomac Fm.	Deep saltwater aquifers and confining units	Wenonah-Mt Laurel aquifer,	Sand, silty	~200	Not used in Cape May County	Saltwater in Cape May County
				Confining unit	Clay, silty	~100	--	--
				Potomac-Magothy-Raritan aquifer systems	Sand, silty	~2,200	Not used in Cape May County	Saltwater in Cape May County
pre Cretaceous	pre Cretaceous	Triassic Jurassic Paleozoic age rocks	Basement	Unnamed aquifers and confining units	Sand gravel, clay, schist, granites	~1,800	Not used in Cape May County	--

Modified from Zapecza, 1989, table 2

aquifers. These sediments typically are deposited in fluvial or beach environments. Thick and areally extensive sand and silt layers can make good aquifers. Sand and silt usually are deposited in near-shore environments. Thick and areally extensive clay and silt deposits make regional confining units. These sediments typically are deposited in deep water, such as on the middle or outer continental shelf.

The geologic units (table 4) are time-stratigraphic units defined by the fossil assemblage within each unit. The aquifers and confining units (table 4) are hydrostratigraphic units defined by the water transmitting characteristics of the sediments. An aquifer or a confining unit may be composed of multiple geologic units, parts of two geologic units, or a part of only one geologic unit. On the New Jersey Coastal Plain, the Kirkwood-Cohansey aquifer system includes the uppermost sands of the Kirkwood Formation and all overlying sands; within southern Cape May County, however, the Kirkwood-Cohansey aquifer system contains two locally extensive clay confining units. As a result, the Kirkwood-Cohansey aquifer system has been divided into the Holly Beach water-bearing zone, the estuarine sand, and the Cohansey aquifer. The geologic unit labeled the Kirkwood Formation is divided into five hydrostratigraphic units. The uppermost, sand-rich part of it is the basal part of the Kirkwood-Cohansey aquifer system. Beneath the uppermost sand of the Kirkwood Formation is a confining unit, a thin sand unit that is regionally referred to as the Rio Grande water-bearing zone, a second confining unit, a thick sand unit that is regionally referred to as the Atlantic City 800-foot sand, and a third confining unit. The aquifer names used in this report are similar to the names used by Gill (1962a), but the thickness and extent of each aquifer is modified to reflect the hydrostratigraphic units rather than the geologic formations as described by Gill (1962a).

Aquifers containing freshwater and saltwater underlie Cape May County (table 4). The aquifers are divided into (1) shallow aquifers containing both freshwater and saltwater; (2) deep aquifers, containing both freshwater and saltwater; and (3) very deep aquifers, containing only saltwater. The shallow aquifers are the Holly Beach water-bearing zone, estuarine sand aquifer, and Cohansey aquifer on the peninsula and the Holly Beach water-bearing zone and the Cohansey aquifer in northern Cape May County. The deep aquifers are the Rio Grande water-bearing zone and the Atlantic City 800-foot sand. These aquifers are regional aquifers and extend from central Ocean County to Cape May County. The very deep, saltwater aquifers of Cape May County are the Piney Point aquifer, the Wenonah-Mount Laurel aquifer, and the Potomac-Raritan-Magothy aquifer system. In Cape May County these aquifers produce salty water and will not be discussed further in this report.

Maps showing the altitude of the top and the thickness of each aquifer and confining unit (figs. 14-28) are based on more than 80 well and borehole logs. The structural data related to the altitude of the top and bottom of an aquifer are from individual logs. In many cases, the top or bottom of an aquifer is a zone of transition from clay-rich to sand-rich sediments. Therefore, the zone of transition is not at an exact altitude but may be as much as 10 ft higher or lower than the altitude shown. As a result, in some places on the structure maps, the altitude of the top or bottom of an aquifer may not be exactly within the contours. These areas are usually delineated with dashed contour lines. Sections A-A’, B-B’, and C-C’ (figs. 29-30) show the relative thickness and extent of the aquifers and confining units in the county. The extent of freshwater is discussed in the water-quality section of this report. Hydraulic characteristics based on aquifer tests, laboratory tests, and ground-water flow simulations are listed in **table 5** to complement the geohydrologic framework and water budgets.

Shallow Aquifers and Confining Units

The Kirkwood-Cohansey aquifer system as defined by Zapecza (1989) consists of sediments that are part of the upper Kirkwood Formation, Cohansey Formation, Cape May Formation, and, where present, overlying younger sediments. Regionally, these geologic units are combined into one aquifer system because the individual geologic units are for the most part lithologically and hydrologically indistinguishable over the extent of the New Jersey Coastal Plain. In this report, the

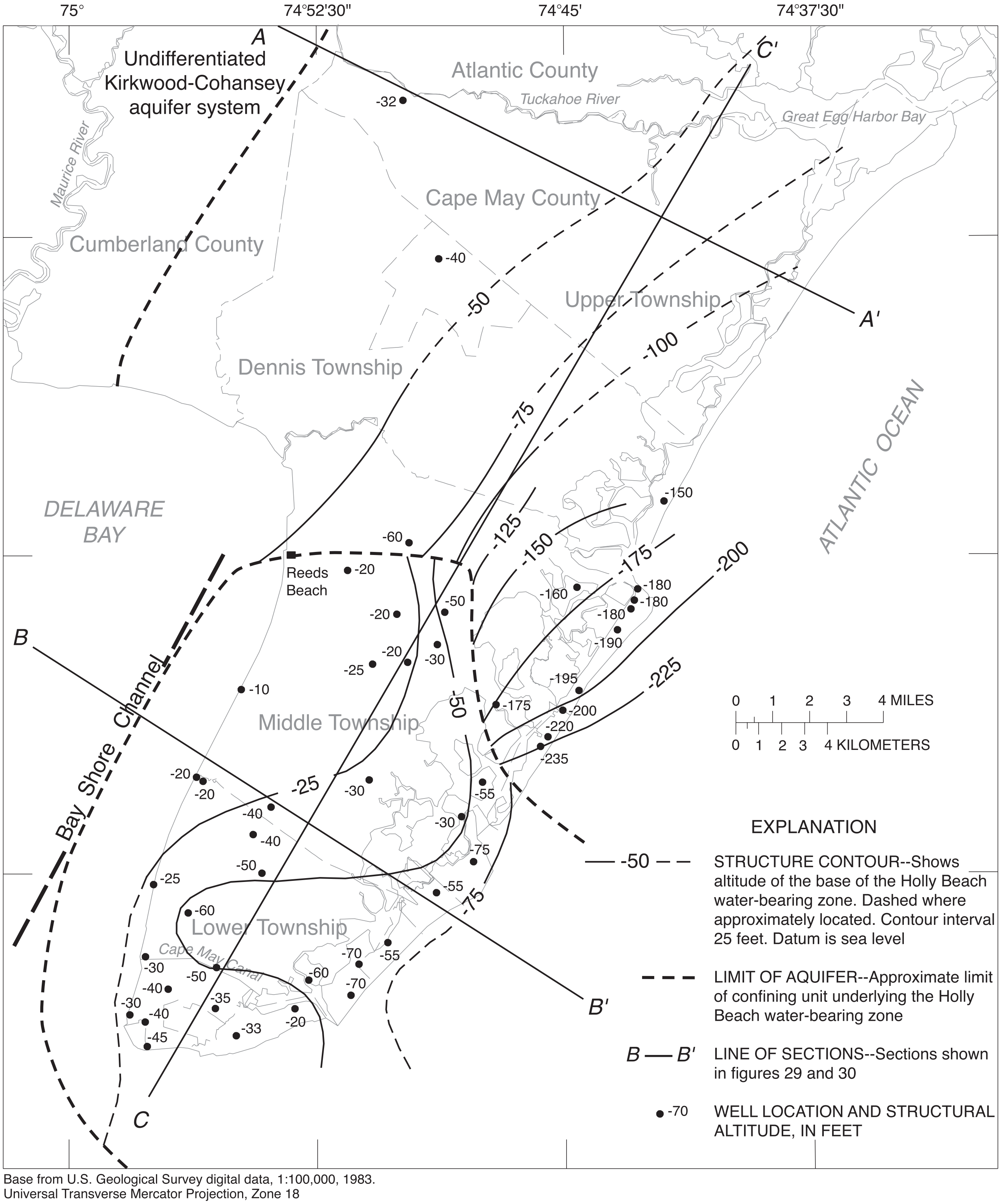


Figure 14. Altitude of the base of the Holly Beach water-bearing zone, Cape May County, New Jersey.

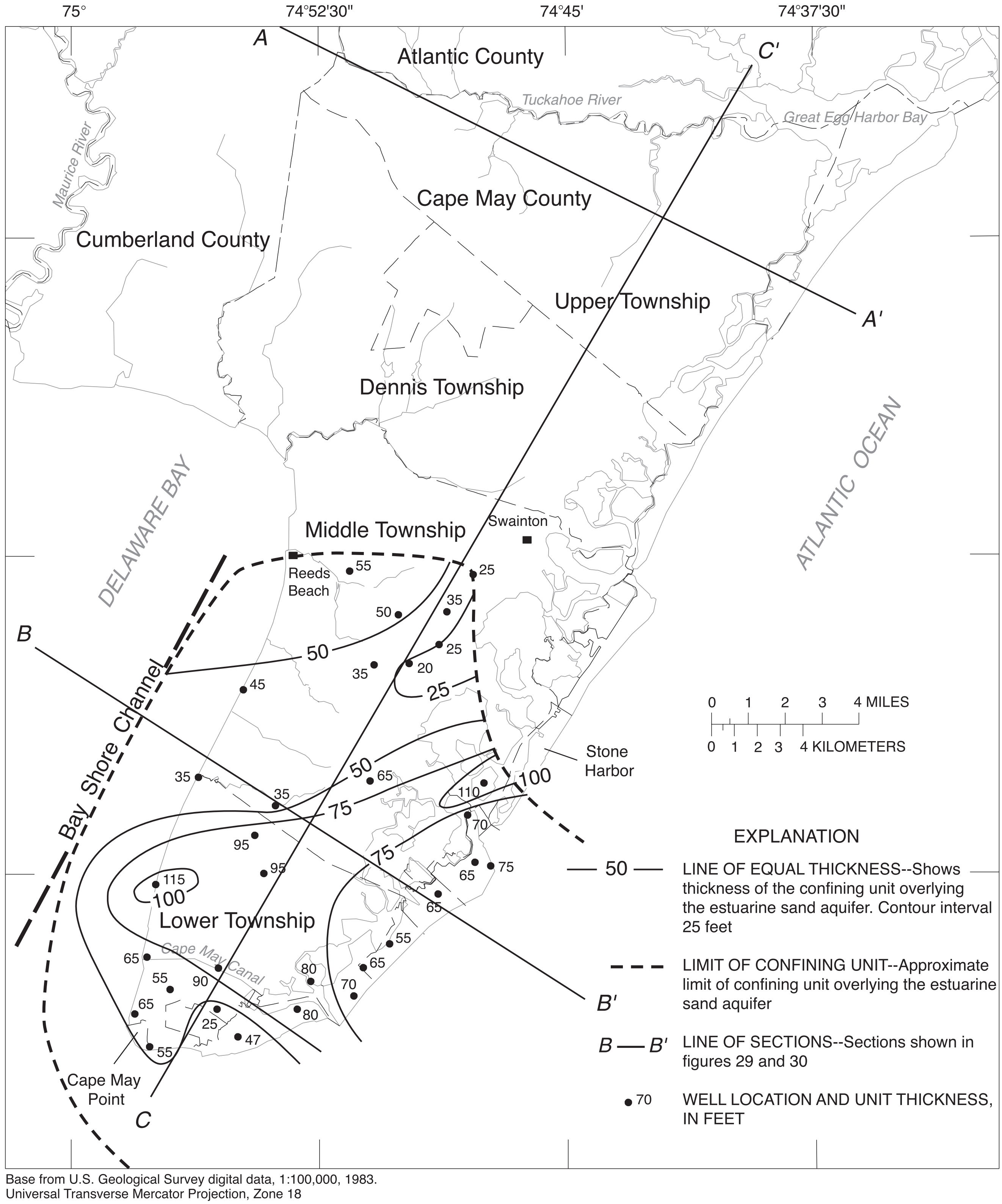


Figure 15. Thickness of the confining unit overlying the estuarine sand aquifer, Cape May County, New Jersey.

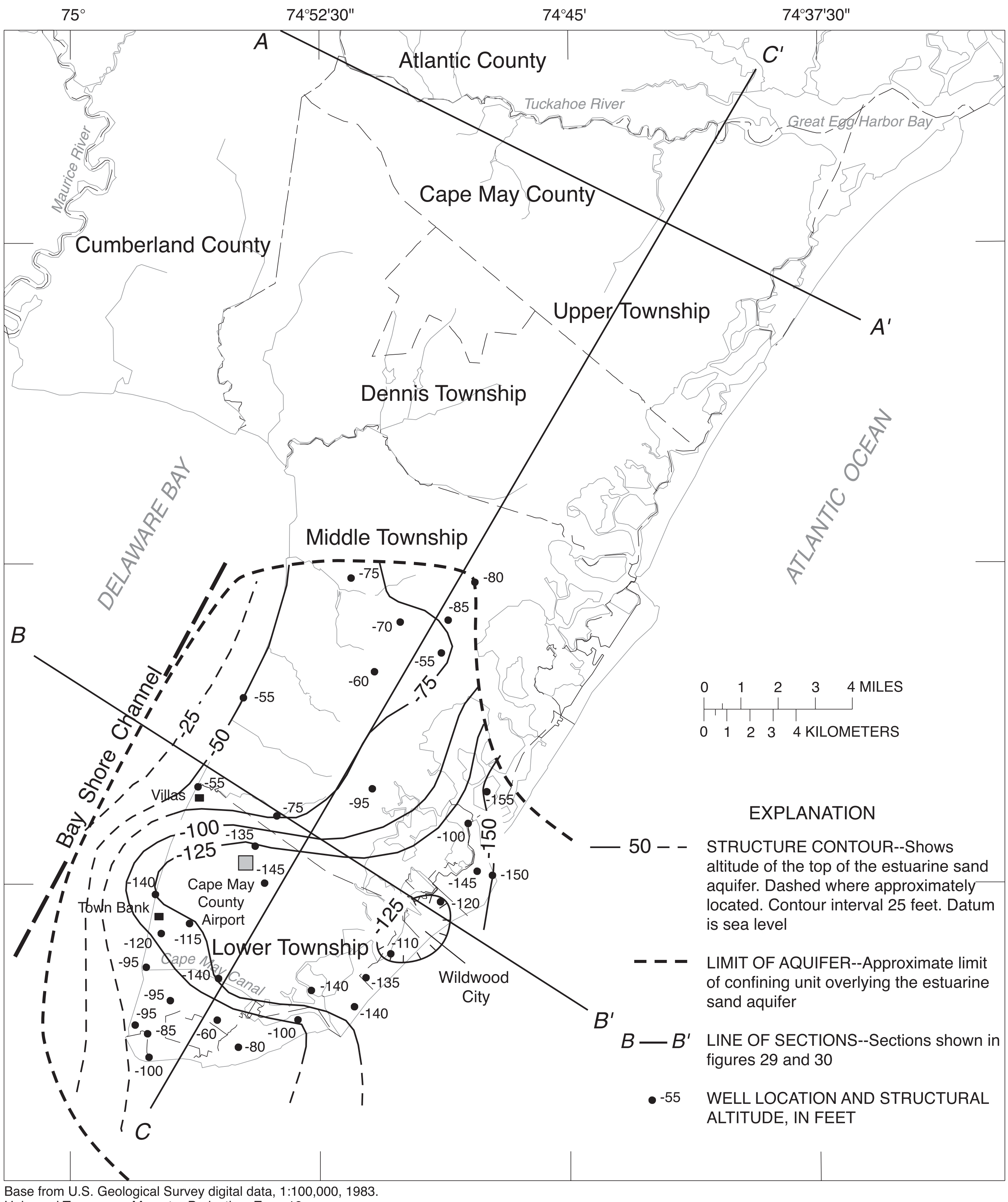
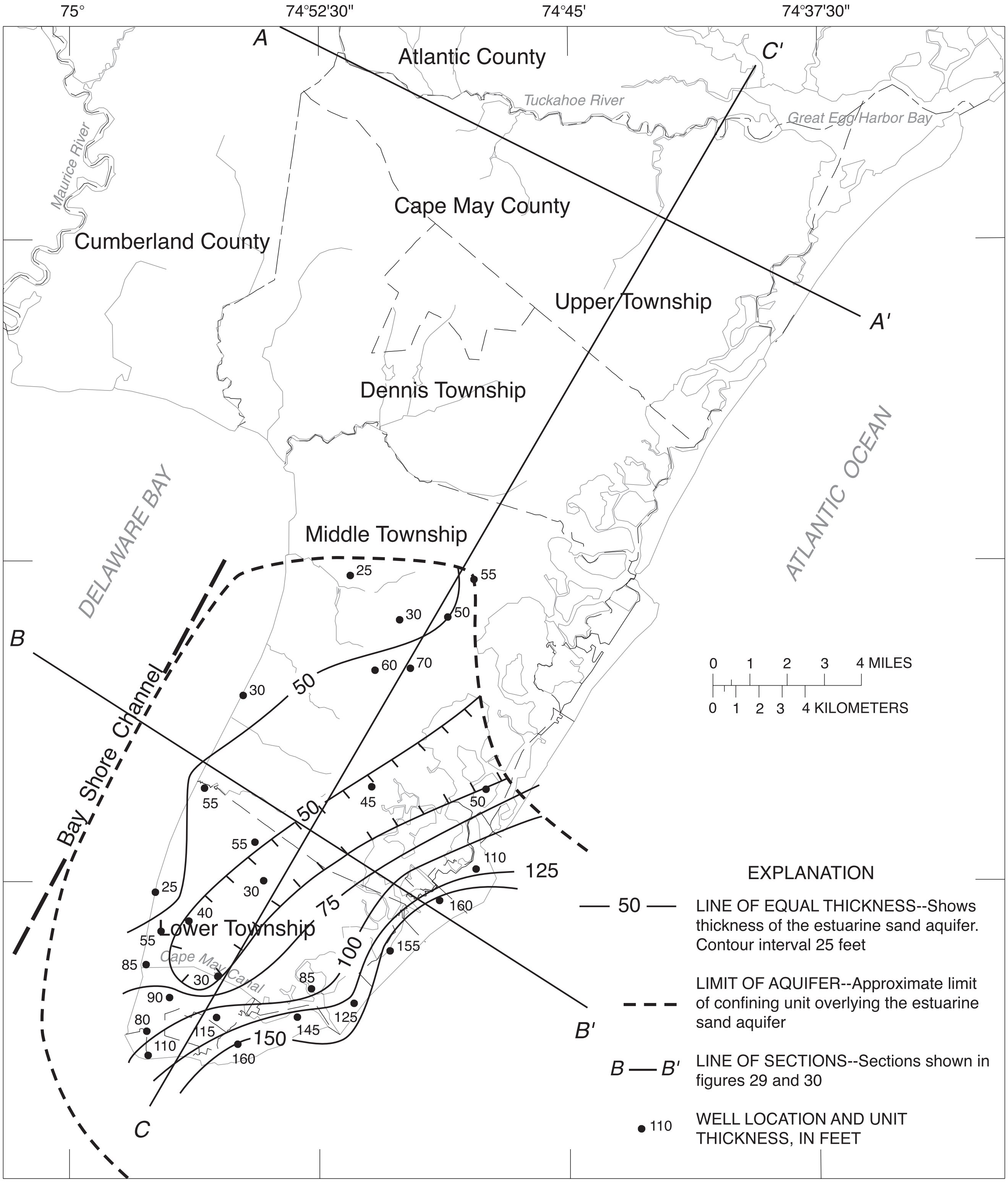


Figure 16. Altitude of the top of the estuarine sand aquifer, Cape May County, New Jersey.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 17. Thickness of the estuarine sand aquifer, Cape May County, New Jersey.

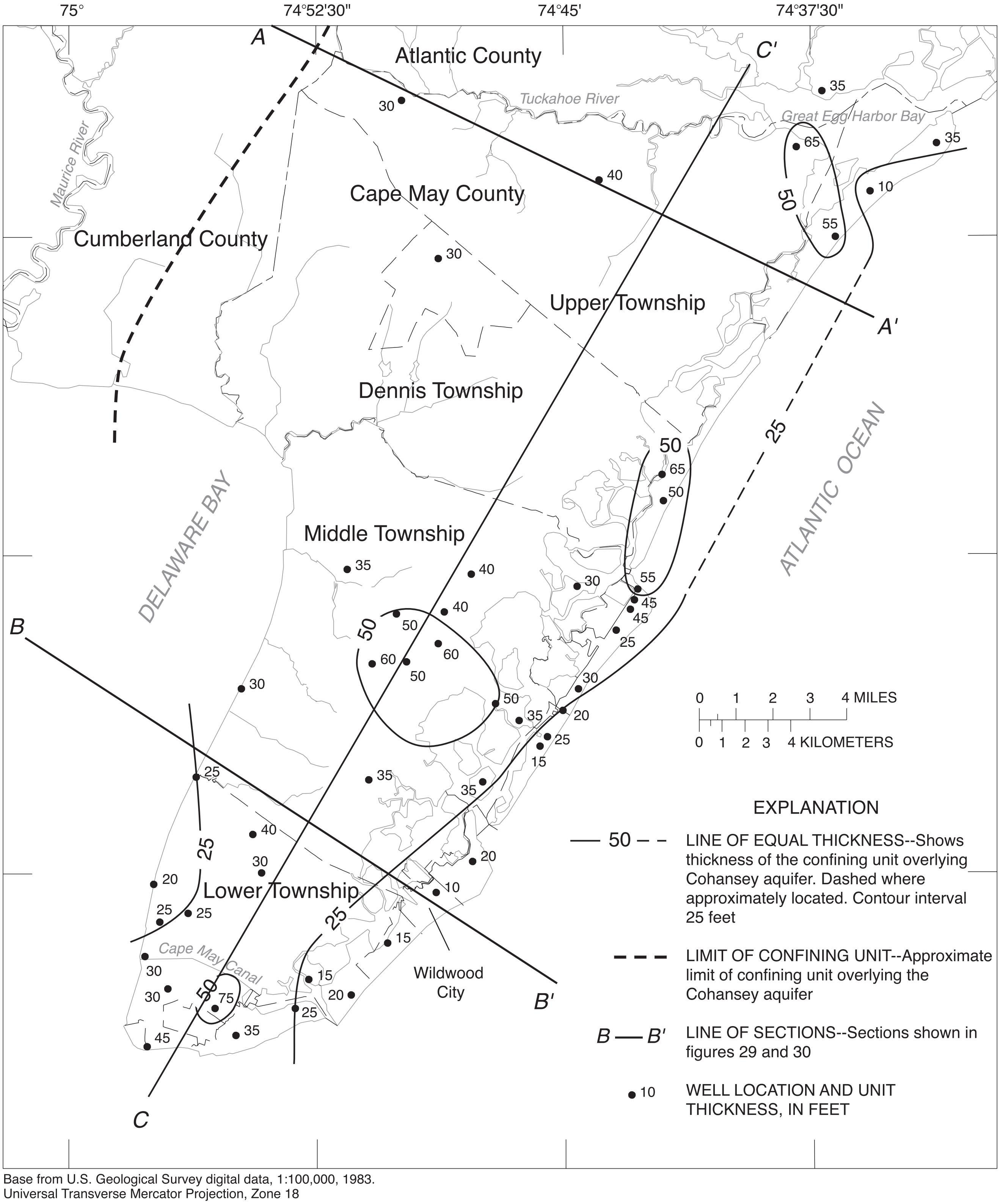


Figure 18. Thickness of the confining unit overlying the Cohansey aquifer, Cape May County, New Jersey.

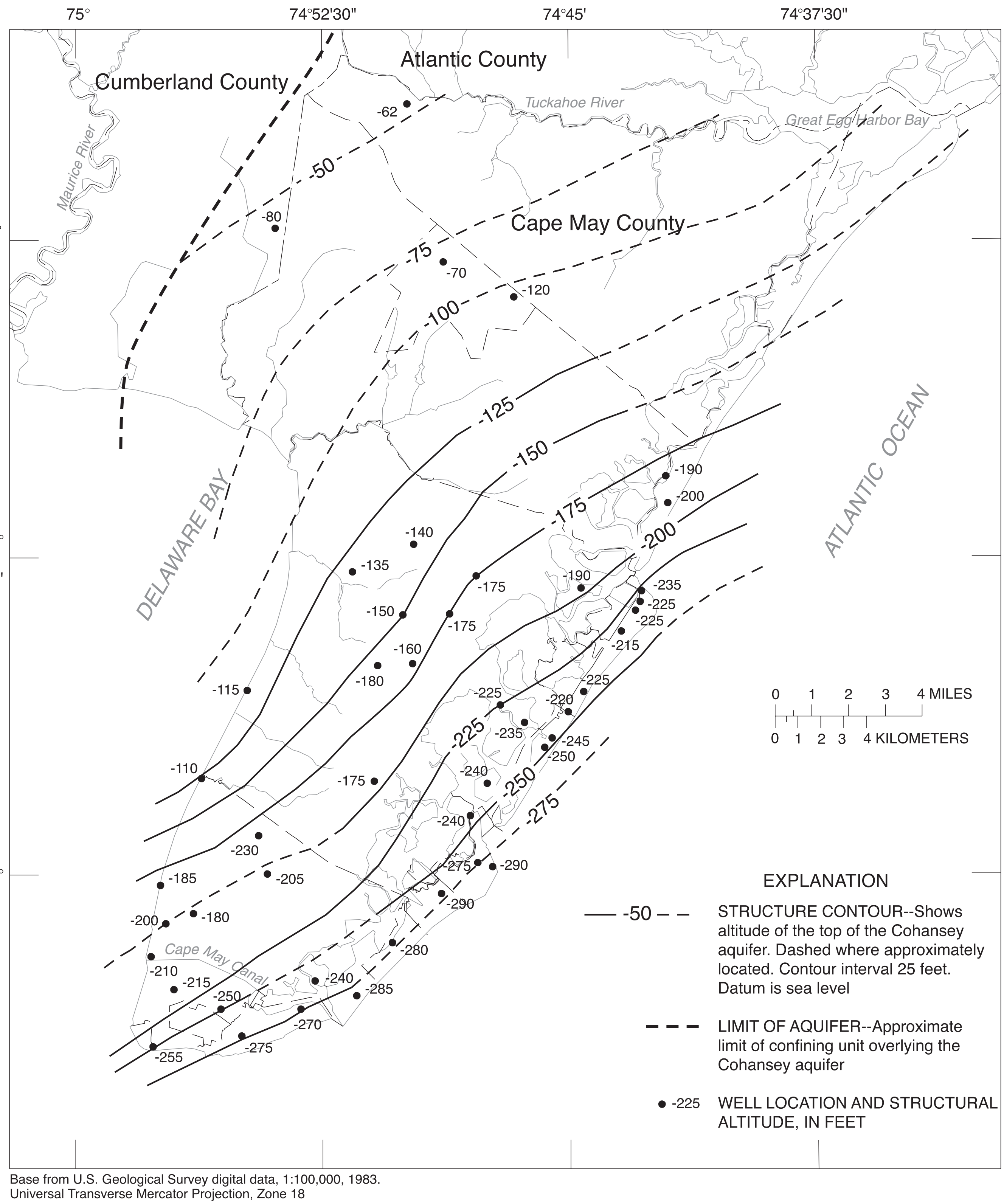


Figure 19. Altitude of the top of the Cohansey aquifer, Cape May County, New Jersey, and vicinity.

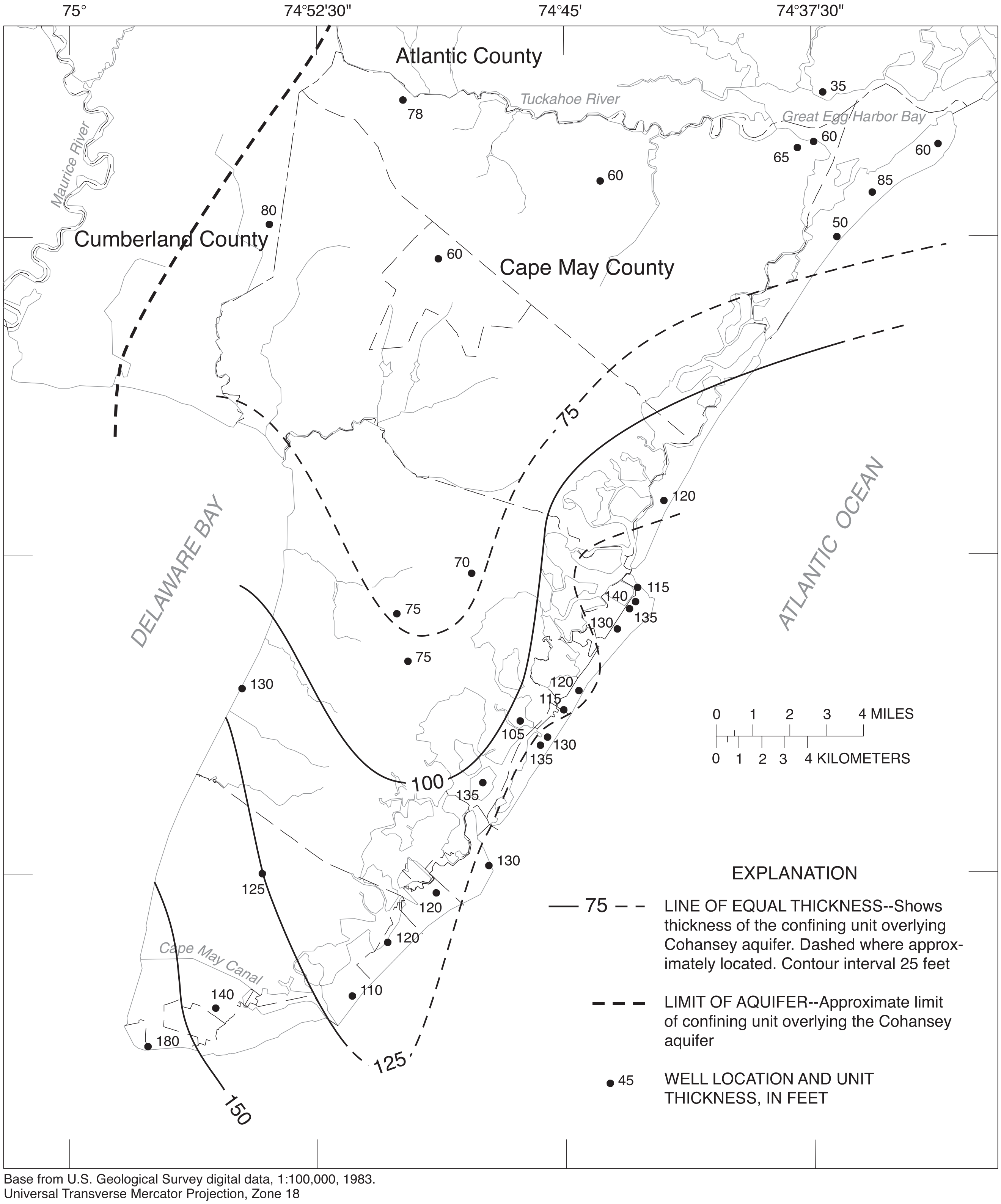


Figure 20. Thickness of the Cohansey aquifer, Cape May County, New Jersey.

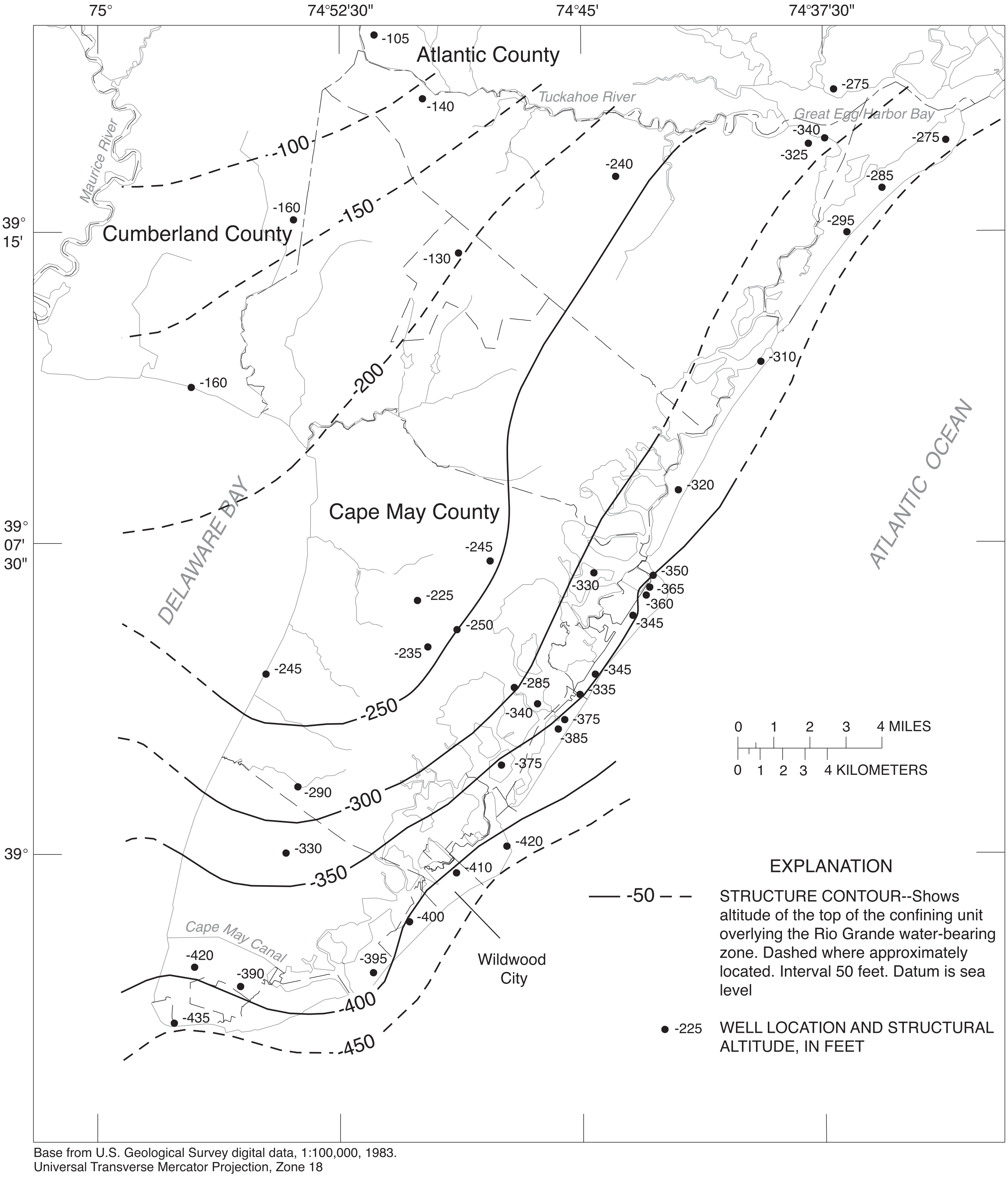


Figure 21. Altitude of the top of the confining unit overlying the Rio Grande water-bearing zone, Cape May County, New Jersey.

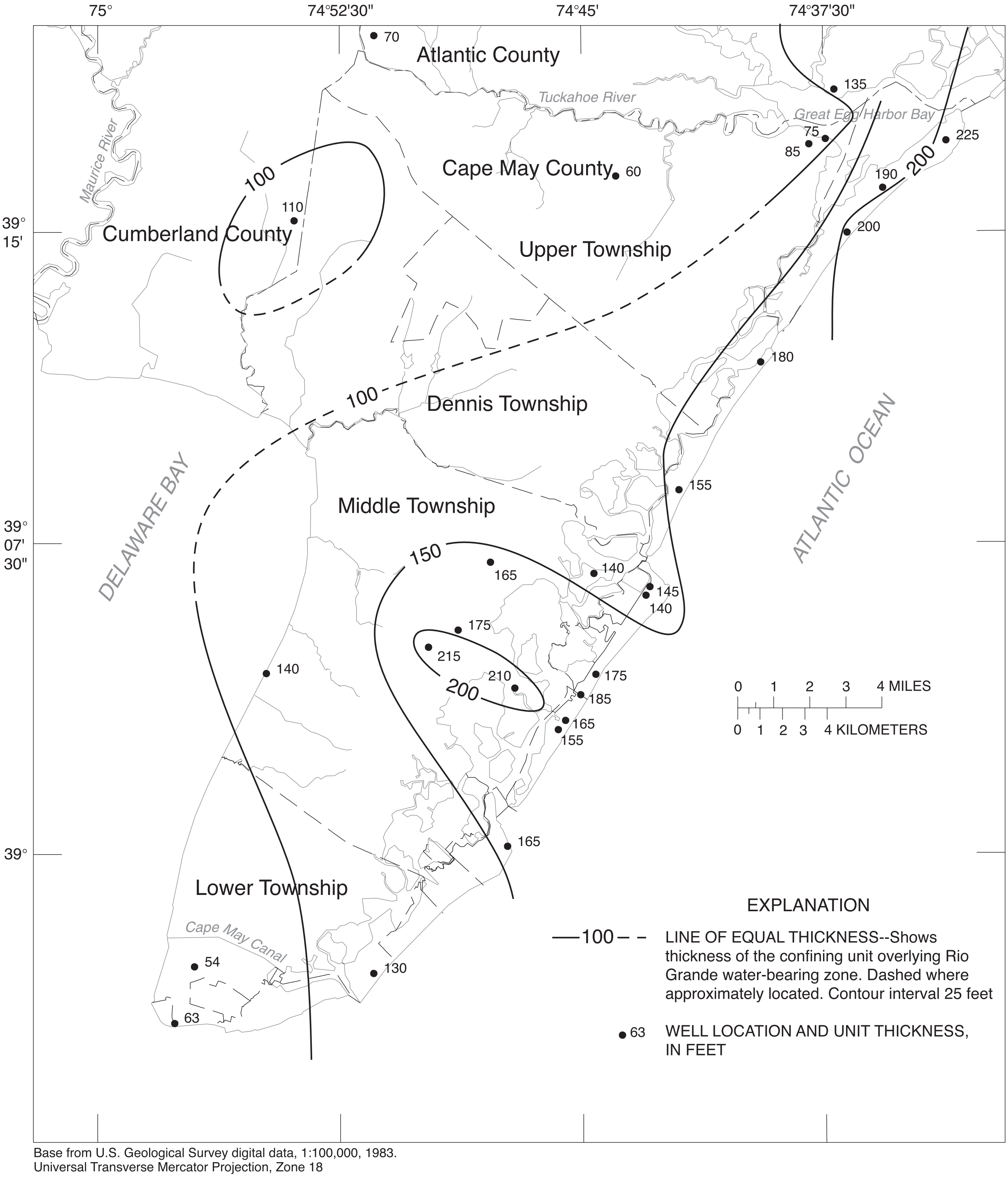


Figure 22. Thickness of the confining unit overlying the Rio Grande water-bearing zone, Cape May County, New Jersey, and vicinity.

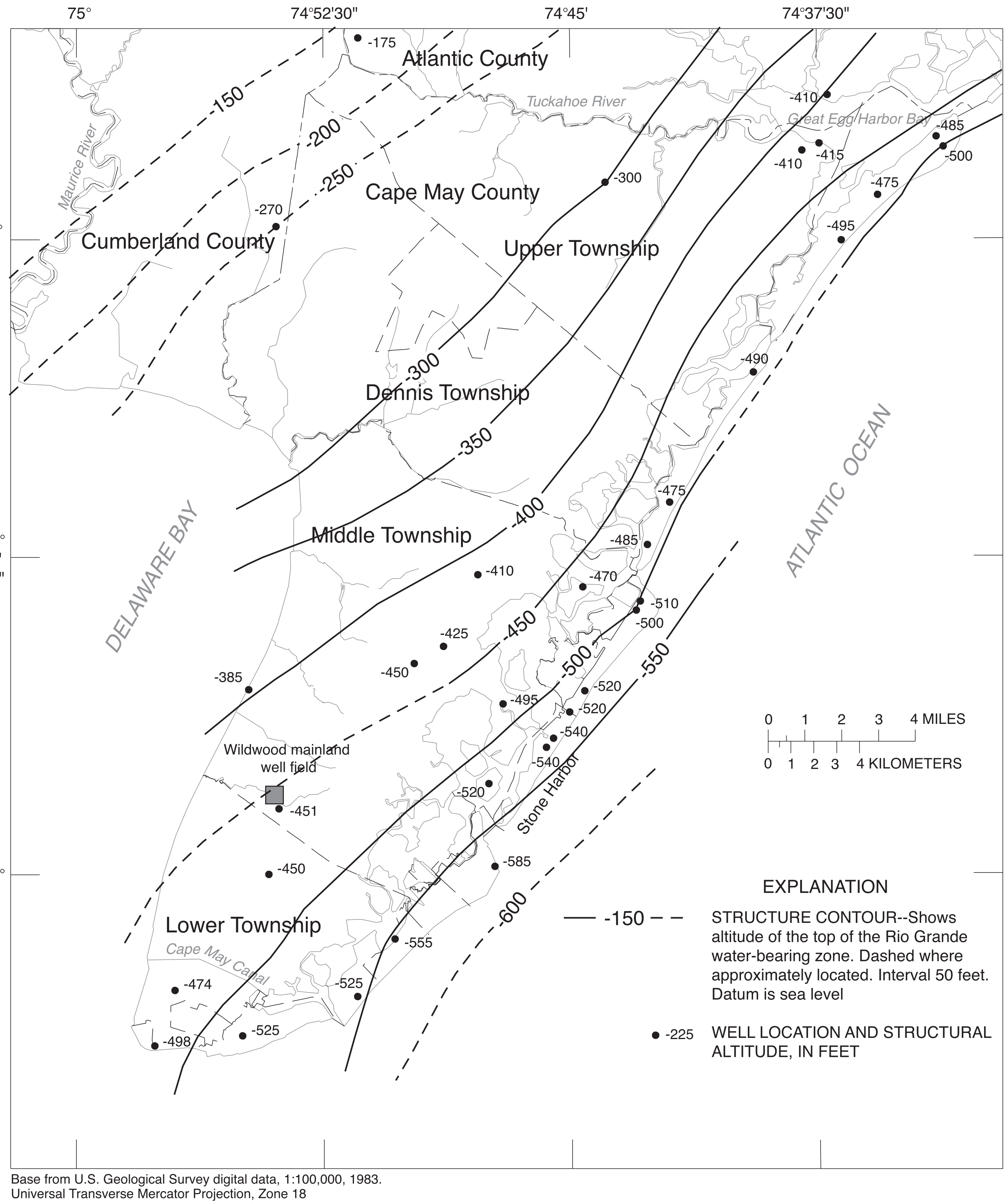


Figure 23. Altitude of the top of the Rio Grande water-bearing zone, Cape May County, New Jersey, and vicinity.

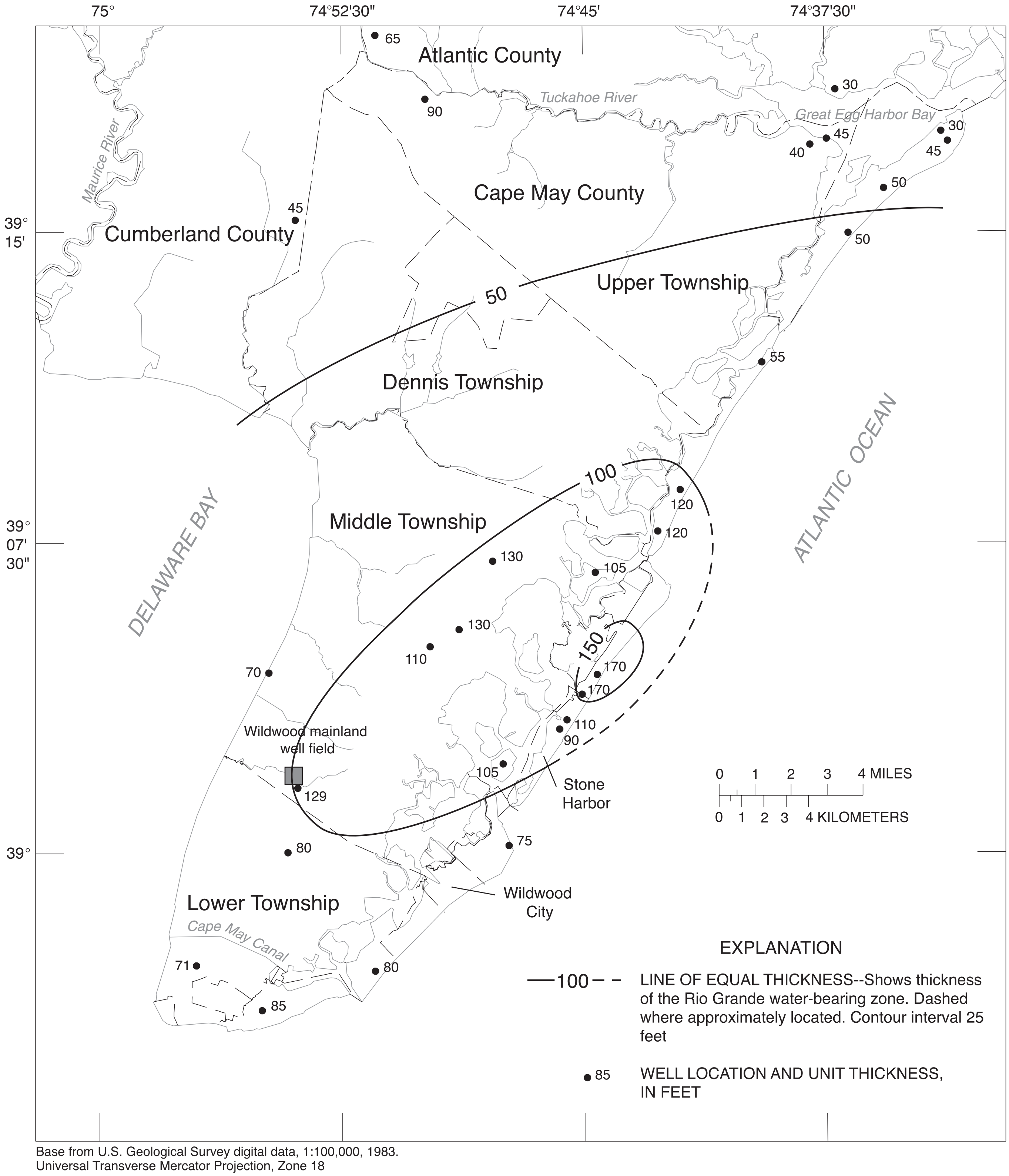
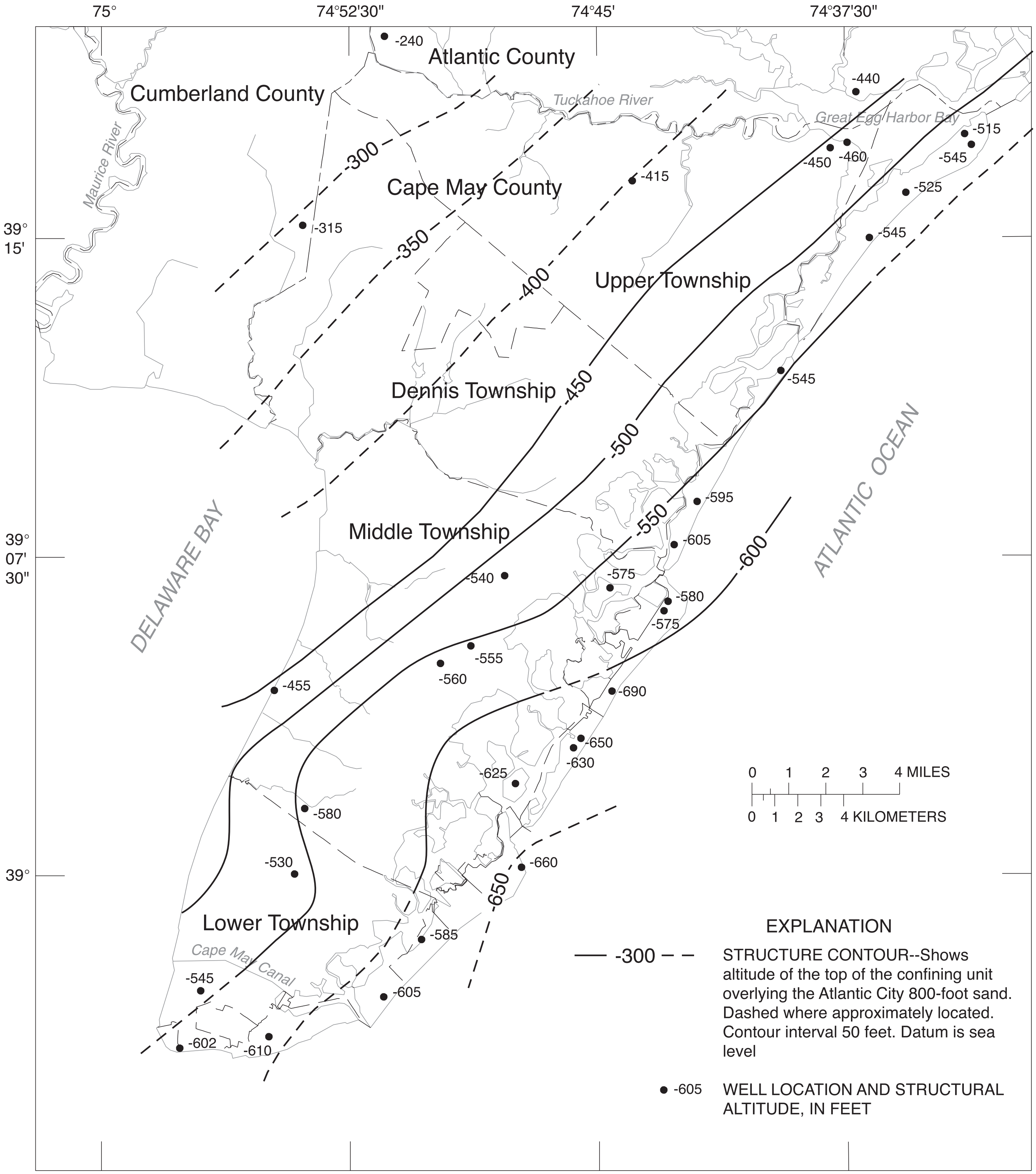


Figure 24. Thickness of the Rio Grande water-bearing zone, Cape May County, New Jersey.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 25. Altitude of the top of the confining unit overlying the Atlantic City 800-foot sand, Cape May County, New Jersey, and vicinity.

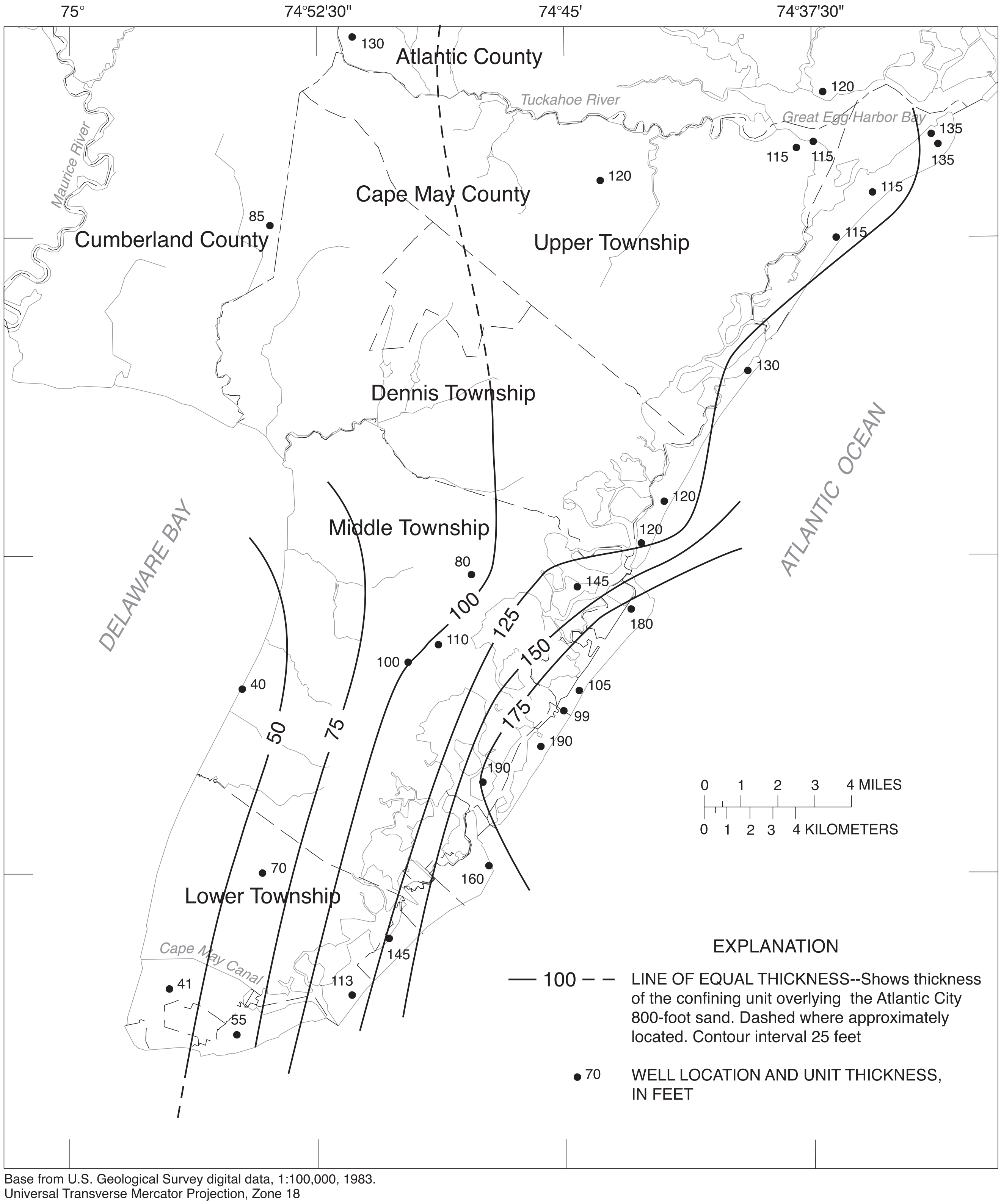


Figure 26. Thickness of the confining unit overlying the Atlantic City 800-foot sand, Cape May County, New Jersey, and vicinity.

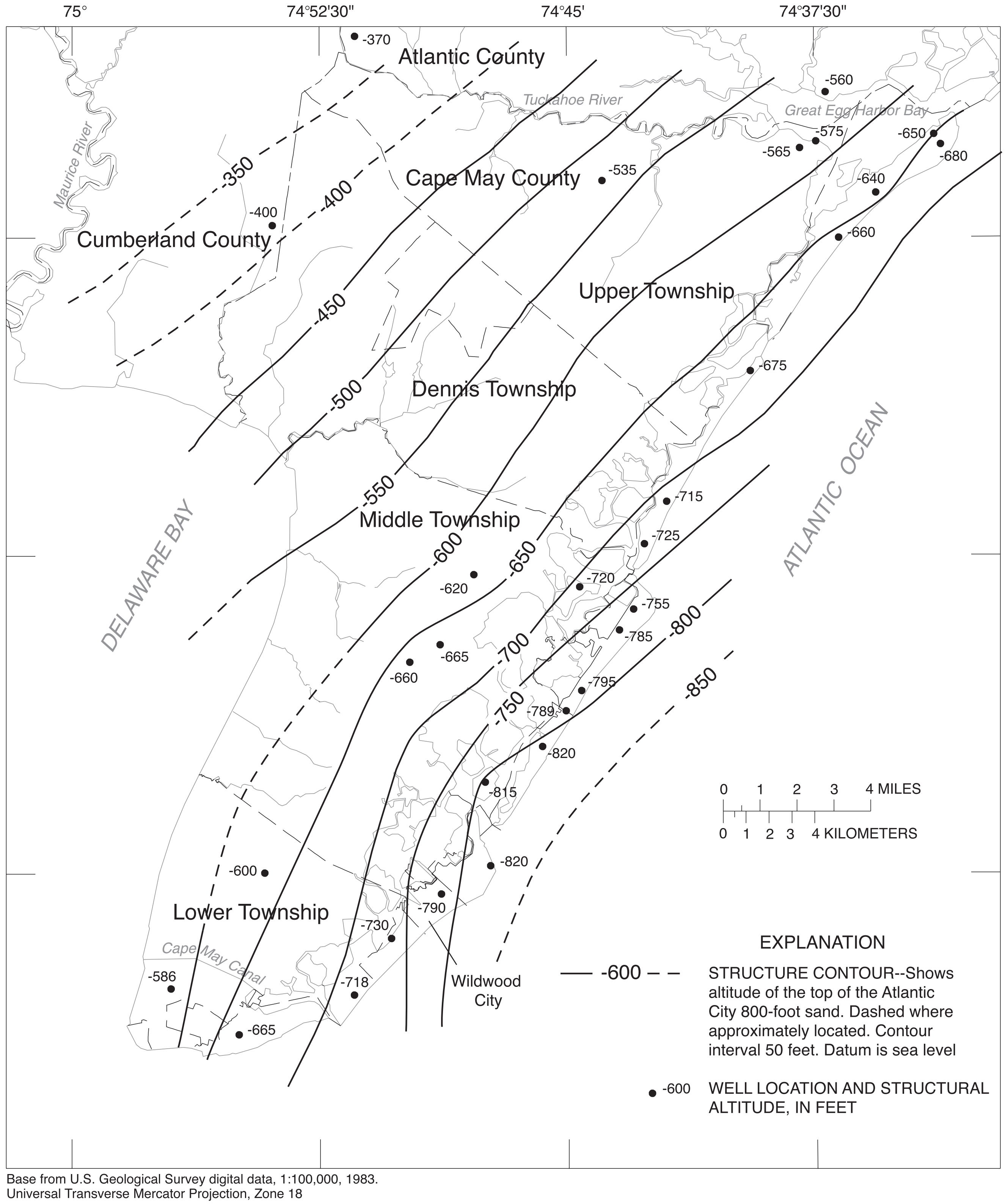


Figure 27. Altitude of the top of the Atlantic City 800-foot sand, Cape May County, New Jersey, and vicinity.

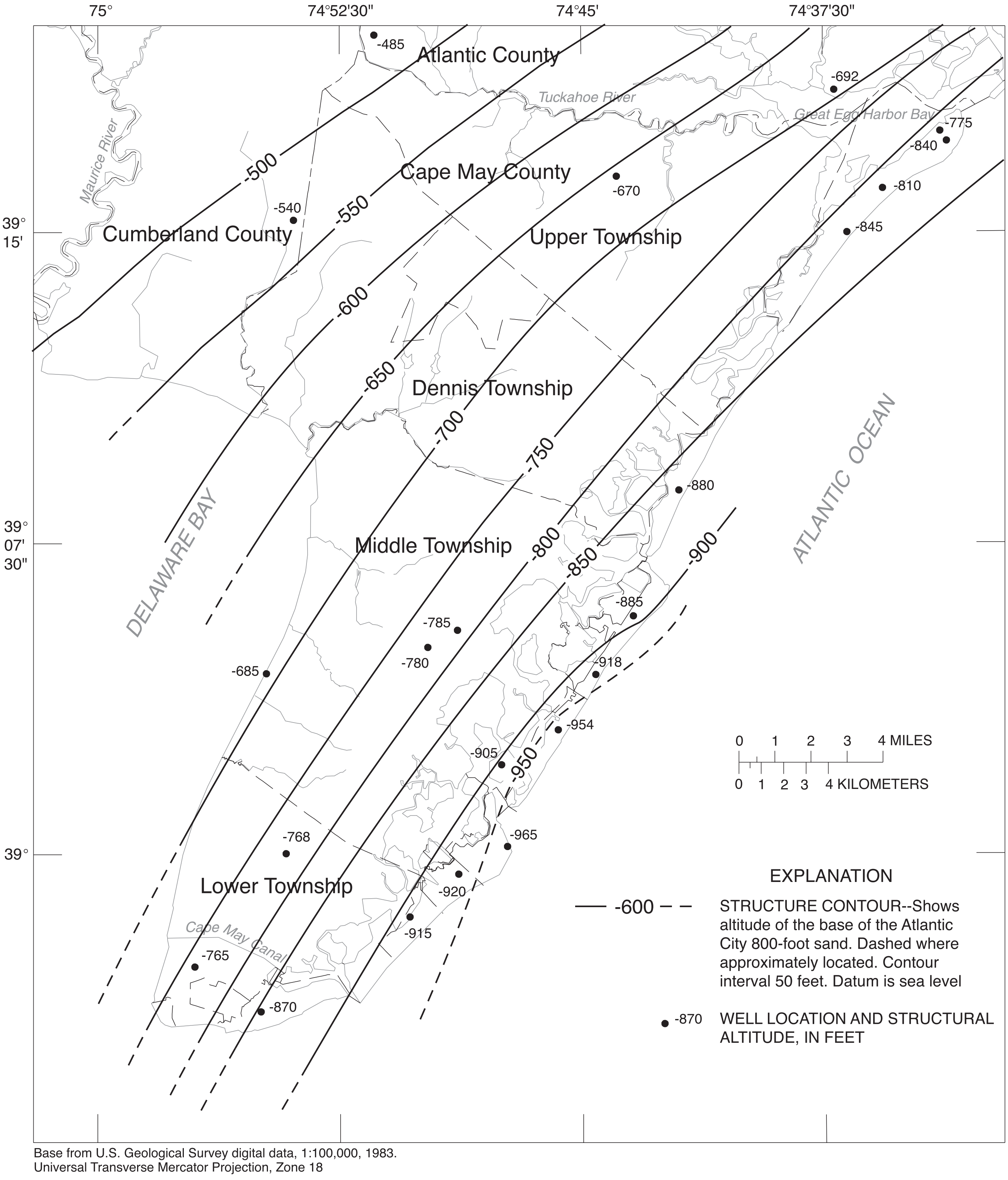


Figure 28. Altitude of the base of the Atlantic City 800-foot sand, Cape May County, New Jersey, and vicinity.

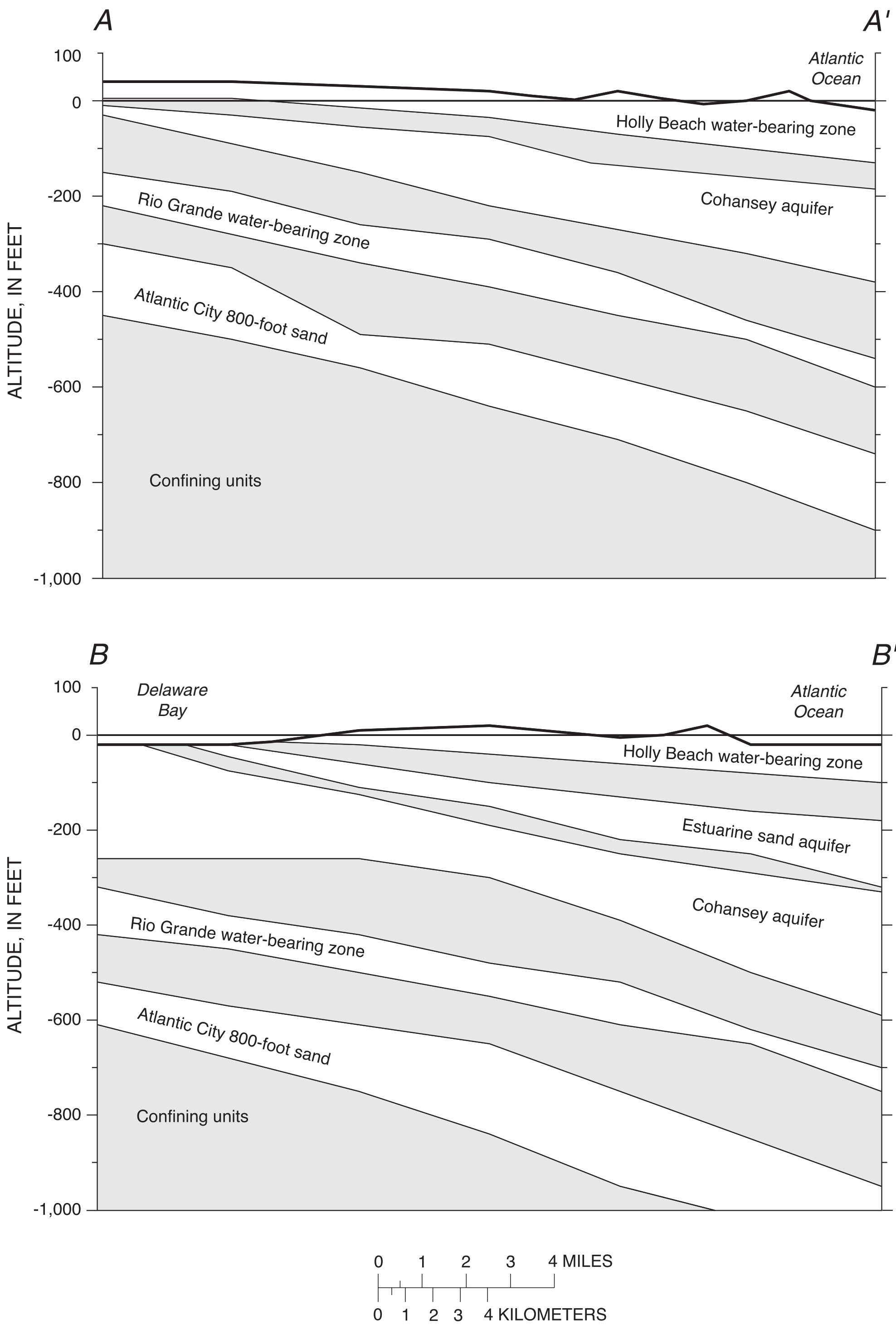


Figure 29. Section *A-A′* and *B-B′* showing the hydrostratigraphy in Cape May County, New Jersey. (Lines of section are shown in figures 14 to 18.)

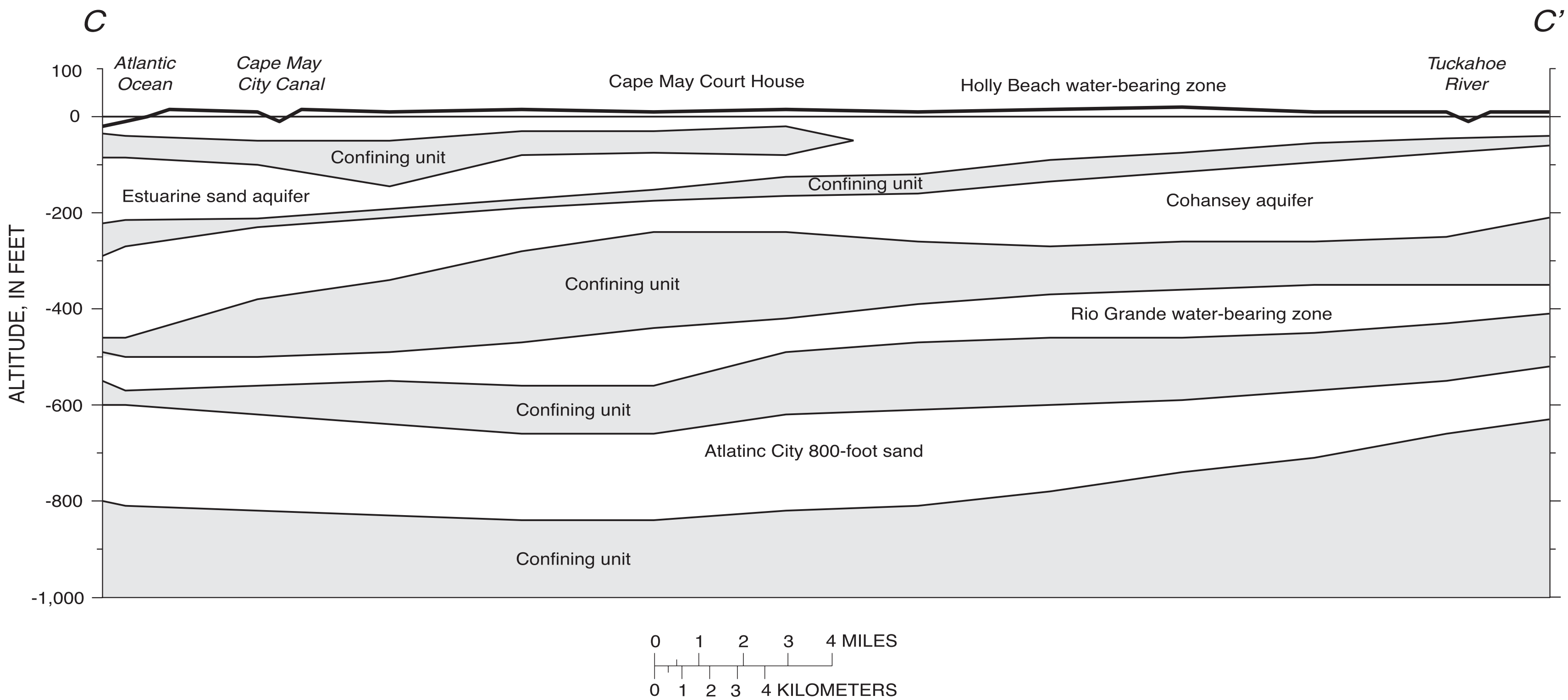


Figure 30. Section *C-C'* showing the hydrostratigraphy in Cape May County, New Jersey. (Lines of section are shown in figures 14 to 18.)

Table 5a. Transmissivity, hydraulic conductivity, and storage coefficient for the aquifers in Cape May County, New Jersey
[Reports and data are stored at N.J. District office, U.S. Geological Survey, West Trenton N.J.; --, no data; USGS, U.S. Geological Survey; ft / d, feet per day; ft^2 / d, feet squared per day]

Transmissivity (ft^2/d)	Hydraulic conductivity(ft/d)	Storage coefficient (dimensionless)	Type of test	Location of test	Reference
			Holly Beach water-bearing zone		
2,000	--	--	Specific conductivity test	Field test	Gill, 1962a, p. 55
5,200- 7,800	--	--	Simulation	County	Martin, 1990, p. 111
7,770- 63,700	520	2.5×10^{-1}	Simulation	County	Spitz and Barringer, 1992
34,000	--	7.0×10^{-3}	Simulation	County	Spitz and Barringer, 1992
			Estuarine sand aquifer		
9,100- 11,450	150- 290	4.3×10^{-4} to 1.0×10^{-5}	Aquifer test	Bidwell Ditch	J.G. Rooney, USGS written commun., 1968
600- 4,900	30	1.0×10^{-5}	Simulation	County	Spitz and Barringer, 1992
1,900-11,790	278-1,680	4.2×10^{-2} to 8.4×10^{-4}	Aquifer test	Marmora	N.J. American Corp., 1990, p. 32
			Cohansey aquifer		
5,500- 8,400	86-130	2.2×10^{-4} to 4.9×10^{-4}	Aquifer test	Cape May City	Gill, 1962a, p. 49
5,350- 9,090	119-167	2.2×10^{-3} to 8.1×10^{-4}	Aquifer test	Rio Grande	Gill, 1962a, p. 49
7,350-11,630	163-257	2.6×10^{-4} to 2.8×10^{-3}	Aquifer test	Rio Grande	Gill, 1962a, p. 49
3,610-4,260	53-63	1.2×10^{-4} to 2.2×10^{-4}	Aquifer test	Coast Guard	Gill, 1962a, p. 49
150- 1,180	5	1.0×10^{-5}	Simulation	County	Spitz and Barringer, 1992
			Kirkwood-Cohansey aquifer system		
1,920- 3,090	20	--	Aquifer test	Marmora	USGS files, 1990
			Rio Grand water-bearing zone		
270- 11,700	--	--	Simulation	County	Martin, 1990, p. 111
2,900-3,285	--	2.9×10^{-4} to 4.3×10^{-4}	Aquifer test	Rio Grande	Van Note-Harvey, Assoc., 1994
			Atlantic City 800-foot sand aquifer		
1,860	12	--	Single well acceptance test	Avalon	USGS files, 1976
4.480	32	--	Single well acceptance test	Avalon	USGS files, 1976
7,970- 14,200	49-89	--	Single well acceptance test	Ocean City	USGS files, 1976
3,260- 5,430	19-32	--	Single well acceptance test	Ocean City	USGS files, 1976
5,210- 7,750	32-48	--	Single well acceptance test	Ocean City	USGS files, 1976
620- 990	4-6	--	Single well acceptance test	Nummy Island	USGS files, 1976
3,850- 7,060	42-47	--	Single well acceptance test	Sea Isle	USGS files, 1976
5720	43	--	Single well acceptance test	Stone Harbor	USGS files, 1976
3,400- 3,600	38-41	8.5×10^{-5}	Aquifer test	Stone Harbor	Gill, 1962a, p. 47
860- 10,000	--	--	Simulation	County	Martin, 1990, p. 111
7,840-14,600	--	--	Aquifer test	Beesley's Point	ECT, 1992

Table 5b. Hydraulic properties of the unsaturated zone and confining units, Cape May County, New Jersey

[in/yr, inch per year; 1/d, per day; ft/day, feet per day; --, no data]

Recharge in./yr	Vertical leakage 1/d	Hydraulic conductivity ft/d	Type of test	Location of test	Reference
			Unsaturated zone		
17-19	0.98	--	Simulated	County	Spitz and Barringer, 1992
--	--	0.4-12	Soil Permeability	County	Markley, 1977
			Confining unit overlying the estuarine sand aquifer		
--	--	2.0×10^{-5} to 8.6×10^{-4}	Simulation	County	Spitz and Barringer, 1992
--	--	9.0×10^{-5}	Simulation	County	Spitz and Barringer, 1992
--	--	2×10^{-7} to 5.7×10^{-2}	Simulation	County	Spitz and Barringer, 1992
			Confining unit overlying the Cohansey aquifer		
--	--	6.0×10^{-4} to 5.7×10^{-2}	Simulation	County	Spitz and Barringer, 1992
--	--	5.0×10^{-3}	Simulation	County	Spitz and Barringer, 1992
			Confining unit overlying the Rio Grande water-bearing zone		
--	--	3.0×10^{-8} to 1×10^{-6}	Simulation	County	Martin, 1990
--	--	5.0×10^{-3}	Simulation	County	Voronin and others, 1996
			Confining unit overlying the Atlantic City 800-foot sand		
--	--	3.0×10^{-8} to 1×10^{-6}	Simulation	County	Martin, 1990
--	--	5.0×10^{-3}	Simulation	County	Voronin and others, 1996
			Confining unit underlying the Atlantic City 800-foot sand		
--	--	2×10^{-5} to 5.2×10^{-5}	Laboratory test	County	Nemickas and Carswell, 1976

Kirkwood-Cohansey aquifer system in northern Cape May County is divided into the Holly Beach water-bearing zone and the Cohansey aquifer. A semi-confining unit separates these aquifers. The two aquifers may not exist everywhere in the northern townships. In many remote areas of northern Cape May County and in contiguous parts of Cumberland and Atlantic Counties, there is a paucity of well-log data. In addition, there is little stress on the aquifers; therefore, it is not possible to differentiate the aquifers on the basis of water-level data. In this report, the Kirkwood-Cohansey aquifer system in southern Cape May County is divided into three aquifers --the Holly Beach water-bearing zone, estuarine sand aquifer, and Cohansey aquifer. Gill (1962a) first divided the shallow freshwater/saltwater strata into these three aquifers. Zapecza (1989) incorporated Gill's division of the strata into his hydrostratigraphic framework. The three shallow aquifers are well defined on the peninsula, but are poorly defined under Delaware Bay and the Atlantic Ocean because of insufficient data.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone is the water-table aquifer in Cape May County (table 4). The aquifer includes the upper part of the Cape May Formation, where present the Bridgeton Formation, and in northern parts of the county the upper part of the Cohansey Formation. The aquifer is composed of gravel interbedded with coarse- to fine-grained sand. Silt, clay, and organic muck can predominate in some parts of the saltwater-wetland areas. In the northern part of the county, clay and silt lenses form local confining units within the Holly Beach water-bearing zone. The aquifer contains freshwater in interior Cape May County, freshwater and saltwater beneath the saltwater wetlands and barrier islands, and saltwater beneath the Atlantic Ocean and Delaware Bay.

The top of the aquifer, the water table, is present at land surface in wetlands, but it can be present at depths of more than 10 ft below land surface in upland areas. The altitude of the top of the aquifer ranges from about +40 ft in northwestern Cape May County to 0 ft along the shore. The altitude of the base of the aquifer ranges from about 0 to -195 ft in the northern part of the county and from -10 to -75 ft in the southern part of the county (figs. 14 and 30). The thickness of the freshwater part of the aquifer ranges from less than 10 to 195 ft in the northern part of the county and from less than 10 to 80 ft in the southern part of the county.

In addition to hydrostratigraphy, the hydraulic characteristics of the unsaturated zone control the rate of movement of shallow ground water. The soil permeability of the unsaturated zone overlying the Holly Beach water-bearing zone ranges from 0.4 to 12 ft/d (Markley, 1977) (table 5). Specific capacity field tests indicated that the transmissivity of the aquifer is about 2,000 ft^2/d. Computer simulations of ground-water flow in the aquifer show that the transmissivity ranges from 5,200 to 63,700 ft^2/d, hydraulic conductivity is 520 ft/d, and the storage coefficient is 0.25. Specific capacities of wells that tap the aquifer ranged from less than 1 to 100 gal/min/ft of drawdown. The yield from wells ranged from 3 to 300 gal/min (Gill 1962a and data on file with the USGS District office, Trenton, N.J.)

Confining Unit Overlying the Estuarine Sand Aquifer

The confining unit that overlies the estuarine sand aquifer is limited to the peninsular part of Cape May County. It is composed of fine-grained marine clay and silt. These sediments were deposited in an ancestral channel of the Delaware River during an interglacial Pleistocene transgression of the Atlantic Ocean. The confining unit probably crops out on the floor of Delaware Bay between the western shore of the peninsula and Bay Shore Channel and from about Reeds Beach to south of Cape May Point (fig. 15). The northern extent of the confining unit lies along a line from about 1 mile north of Reeds Beach through Swainton to Stone Harbor. North of the line, the confining unit exists as thin discontinuous lenses within the Holly Beach water-bearing zone. The estimated southern limit of the confining unit is a few miles south of Cape May Point. No data are available to determine the exact location of the southern limit; however, well-log data indicate that the confining unit extends south of the peninsula. Delaware Bay bathymetry data indicate that the main channel in Delaware Bay cuts the confining unit. Therefore, the southern limit of the confining unit lies between the shoreline and the main channel of Delaware Bay. The confining unit probably is thin or terminates a short distance from shore; the estuarine sand aquifer produces salty water in coastal Cape May City and Cape May Point. The eastern limit of the confining unit extends east of Wildwood. The location of the eastern limit is based on water-quality data, water-level data, and well logs. The eastern limit of the confining unit in the Stone Harbor area is about 1 mile west of Stone Harbor determined on the basis of well logs, water-levels, and water-quality data from USGS wells 9-292 to 9-295.

The altitude of the top of the confining unit on the peninsula coincides with the base of the Holly Beach water-bearing zone (fig. 14) and ranges from approximately -10 to -75 ft. The thickness of the confining unit ranges from 25 ft to more than 100 ft (fig. 15). The altitude of the base of the confining unit ranges from about -50 to about -150 ft (fig. 16). The confining unit is thickest along the ancestral sediment-filled channel of the Delaware River in the area from Villas through the airport to the Wildwood communities **(fig. 1)**. Computer simulations indicated that the vertical hydraulic conductivity of the confining unit ranges from 2.0 x 10^{-5} to 8.6 x 10^{-4} ft/d (table 5).

Estuarine Sand Aquifer

The estuarine sand aquifer is limited to the peninsula of the Cape May County. It is the shallowest confined aquifer in the southern part of the county. The extent of the aquifer is defined by the confining unit that overlies it as described in the previous section. The aquifer consists of gravel and coarse- to fine-grained sand of the lower strata of the Cape May Formation and upper strata of the Cohansey Formation. The top of the aquifer ranges in altitude from approximately -50 ft along the Delaware Bay shoreline to as much as -150 ft in the Wildwood communities (fig. 16). The thickness of the aquifer ranges from 25 to 160 ft (fig. 17). The altitude of the bottom of the aquifer ranges from -75 ft to -275 ft. Aquifer tests indicated that the transmissivity ranges from 9,100 to 11,450 ft^2/d, the hydraulic conductivity ranges from 150 to 290 ft/d, and the storage coefficient ranges from 4.3 x 10^{-4} to 1.0 x 10^{-5} (table 5). Spitz and Barringer (1992) give smaller values for each hydraulic characteristic on the basis of computer simulation. Specific capacities of wells screened in the aquifer ranged from 1 to 13 gal/min/ft of drawdown. Yields of these wells ranged from 3 to 230 gal/min (table 5).

Confining Unit Overlying the Cohansey Aquifer

The confining unit that overlies the Cohansey aquifer is composed of fine-grained silt and clay strata that are near the middle of the Cohansey Formation. The northern limit of the confining unit as it is defined in this report is north of the Tuckahoe River. Zapecza (1989) and Gill (1962a) strictly limited the Cohansey aquifer to southern Cape May County; however, in this study, well-log data indicate that the Cohansey aquifer is present in most of Cape May County. The western limit of the confining unit is between the Maurice River and the Cumberland-Cape May County boundary. The precise location of the limit is unknown because few wells are present in this area. The western limit of the confining unit in Delaware Bay is probably 4 to 5 miles west of the Cape May peninsula; the location is based on marine seismic data (seismic data are on file at the USGS, N.J. District office, West Trenton, N.J.) and data from the well log of the Brandywine Lighthouse in Delaware Bay, about 8 miles west of North Cape May (fig. 1). The southern limit of the confining unit is south of Cape May City and north of the main channel of the Delaware River. Well and borehole logs indicate that the confining unit becomes thinner south of the canal, and water-quality data indicate that the concentrations of chloride increase along the southern shore of the cape. Therefore, the confining unit is probably thin and leaky south of Cape May Point and Cape May City. The confining unit extends an unknown distance east of the Wildwood communities. It is probably continuous in northern Cape May County; however, this premise is uncertain due to the paucity of borehole and well data.

The altitude of the top of the confining unit ranges from about +10 ft in Upper Township to about -275 ft in the Wildwood area. The thickness ranges from 10 to 75 ft (fig. 18). The altitude of the base of the confining unit, which coincides with the top of the Cohansey aquifer, ranges from -62 ft in Upper Township to -275 ft in Wildwood (fig. 19). Spitz and Barringer (1992) determined on the basis of computer simulations that the vertical hydraulic conductivity ranges from 6.0 x 10^{-4} to 5.7 x 10^{-2} ft /d (table 5).

Cohansey Aquifer

The Cohansey aquifer is the uppermost confined aquifer in northern Cape May County and the second confined aquifer in southern Cape May County (table 4). The aquifer is made up of the lower strata of the Cohansey Formation and the sand-rich uppermost strata of the Kirkwood Formation. It is composed of gravel and coarse- to fine-grained sand. The altitude of the top of the aquifer in the county ranges from -62 to -290 ft (fig. 19), and the thickness ranges from about 60 to 180 ft in the county (fig. 20). The altitude of the base of the aquifer ranges from -100 to -400 ft in the county (fig. 21). Aquifer tests conducted on the Cohansey aquifer indicate that the transmissivity generally ranged from 3,600 to 11,600 ft^2/d, the horizontal hydraulic conductivity ranged from 53 to 257 ft/d, and the storage coefficient ranged from 2.2 x 10^{-3} to 8.1 x 10^{-4} (table 5). A computer simulation of the aquifer produced a lower transmissivity and hydraulic conductivity than the aquifer tests (table 5). Specific capacities of wells in the aquifer ranged from 1 to 13 gal/min/ft of drawdown. Yields of wells ranged from 5 to 700 gal/min. The Cohansey aquifer underlying most of the mainland part of the county, part of the Wildwood communities, and nearshore areas in Delaware Bay contains freshwater, but it contains saltwater under offshore parts of Delaware Bay, the northern barrier islands, northern backbays, and Atlantic Ocean.

Deep Aquifers and Confining Units

The Rio Grande water-bearing zone and the Atlantic City 800-foot sand are deep aquifers within the Kirkwood Formation in Cape May County. These aquifers are separated from each other and from higher and lower strata by major confining units. In Cape May County a continuous, thin, leaky clay layer within the Atlantic City 800-foot sand divides the aquifer into upper and lower parts.

In this report, the Rio Grande water-bearing zone is the same aquifer that Gill (1962a) referred to as both the upper aquifer of the Kirkwood Formation and the Rio Grande water-bearing zone. The Atlantic City 800-foot sand in this report is the same aquifer that Gill (1962a) referred to as both the lower aquifer in the Kirkwood Formation and the Atlantic City 800-foot sand.

Confining Unit Overlying the Rio Grande Water-Bearing Zone

The confining unit that overlies the Rio Grande water-bearing zone is composed of a massive clay layer within the Kirkwood Formation. The altitude of the top of the confining unit ranges from -140 ft in northwestern Cape May County to -435 ft in the Wildwood communities (fig. 21). The thickness of the confining unit ranges from 54 to 225 ft (fig. 22). The altitude of the base of the confining unit coincides with the top of the Rio Grande water-bearing zone and ranges from -300 ft in Upper Township to -585 ft in Wildwood (fig. 23). The simulated vertical hydraulic conductivity of the confining unit is 3 x 10^{-8} to 1 x 10^{-6} ft/d (table 5).

Rio Grande Water-Bearing Zone

The Rio Grande water-bearing zone consists of strata of sand near the middle of the Kirkwood Formation. The aquifer is tapped by one well owned by the Wildwood Water Department at its mainland well field and by a well owned by a marina west of Stone Harbor in Middle Township. Otherwise, the aquifer is unused in Cape May County. The altitude of the top of the aquifer ranges from -300 to -585 ft (fig. 23). The thickness of the aquifer ranges from 30 to 170 ft (fig. 24). The altitude of the base of the aquifer ranges from about -300 to -660 ft (fig. 25).

The aquifer is composed of coarse- to fine-grained sand. An aquifer test completed in 1994 shows the aquifer has a transmissivity of 2,900 to 3,285 ft^2/d and a storage coefficient of 2.9×10^{-4} to 4.3×10^{-4} (table 4). The supply well in the Wildwood mainland well field yields as much as 1,100 gal/min. Zapecza (1989) reported that the Rio Grande water-bearing zone is thicker and more productive in southern Cape May County than in any other location in the New Jersey Coastal Plain.

Confining Unit Overlying the Atlantic City 800-Foot Sand

The confining unit that overlies the Atlantic City 800-foot sand is composed of massive clay and silt layers. Some of the thin silt layers in the lower part of the confining unit are lithified. The altitude of the top of the confining unit ranges from about -300 ft in northwestern Cape May County to -660 ft in the Wildwood communities (fig. 25). The thickness of the confining unit ranges from 40 to 190 ft (fig. 26). The base of the confining unit coincides with the top of the Atlantic City 800-foot sand. The altitude of the base ranges from about -350 ft in northwestern Cape May County to -820 ft in Wildwood (fig. 27). The simulated vertical hydraulic conductivity of the confining unit is 3×10^{-8} to 1×10^{-6} ft/d (table 5).

Atlantic City 800-Foot Sand

The Atlantic City 800-foot sand is composed of coarse- to fine-grained sand. The altitude of the top of the aquifer ranges from about -350 to -820 ft (fig. 27) and the altitude of the base ranges from about -500 to -965 ft (fig. 28). The approximate thickness ranges from 125 to 150 ft (fig. 27 and 28). Aquifer and well completion tests of the upper part of the Atlantic City 800-foot sand show that the transmissivity ranges from 620 to 14,600 ft^2/d with a mean of approximately 5,000 ft^2/d **(table 5)**. The horizontal hydraulic conductivity ranges from 4 to 89 ft/d with a mean of approximately 45 ft/d. The storage coefficient ranges from 8.5×10^{-5} to 1.7×10^{-6}. The specific capacity of supply wells in the aquifer ranges from 10 to 50 gal/min per ft of drawdown. Yields of public-supply wells typically range from 600 to 900 gal/min, but for some wells it exceeded 1,000 gal/min (table 5).

A semi-confining unit that is 25 to 50 ft thick separates the upper part from the lower part of the Atlantic City 800-foot sand. This semi-confining unit in Cape May County is described by Zapecza (1989) and is preliminarily mapped in Atlantic and Cape May Counties by Lloyd Mullikin (N.J. Geological Survey, written commun., 1992). The thin semi-confining unit within the Atlantic City 800-foot sand is rich in diatoms, indicating that the sediments were deposited in a marine environment much like that of the other confining units within the Kirkwood Formation. The altitude of the top of the semi-confining unit ranges from -450 ft in northwestern Cape May County to -850 ft in the Wildwood communities.

Confining Unit Underlying the Atlantic City 800-Foot Sand

The confining unit underlying the lower part of the Atlantic City 800-foot sand is the Alloway Clay member of the Kirkwood Formation or its equivalent as described by Nemickas and Carswell (1976). Boreholes 9-181 and 9-304 (fig. 8) fully penetrate the confining unit in Cape May County. The altitude of the top of the confining unit ranges from -500 ft in northwestern Cape May County to -965 ft in the Wildwood communities (fig. 28). The thickness of the confining unit is 165 ft in Lower Township and about 150 ft in southern Atlantic County. The simulated vertical hydraulic conductivity of the confining unit is 2×10^{-5} to 5.2×10^{-5} ft/d (table 5).

WATER WITHDRAWAL

Freshwater withdrawals from Cape May County totaled about 8,550 Mgal/yr during 1960-90; 50 Mgal/yr was withdrawn from surface-water sources and 8,500 Mgal/yr was withdrawn from ground-water sources. Untold billions of gallons of fresh and salty surface water are used for swimming, boating, fishing, bird migration, ecotourism, and power generation, but these uses are not discussed in this report. Measured and estimated freshwater-withdrawal data for 1960-90 are presented in tables 6 and 7 and in graphs and maps that show water withdrawals by aquifer and type of use. Water-withdrawal data are stored in the USGS State Water Use Data System (SWUDS).

Surface-water Withdrawals

Surface-water withdrawals for agricultural and golf purposes are used predominantly for irrigation (table 7a). A produce farm in Upper Township reported using about 15 Mgal/yr from the Tuckahoe River for irrigation (table 7). A blueberry farm north of Belleplain began irrigating with water from Tarkiln Branch in the late 1980's; the estimated maximum withdrawal is 42 Mgal/yr. Golf courses occasionally will use surface water ponds on streams for irrigation. Estimated consumptive use for irrigation is 80 percent of withdrawals (Solley and others, 1988). Many small irrigators in the county dig ponds in lowland or wetland areas and pump water from the ponds for irrigation. The source of the water from these ponds is classified as ground water from the Holly Beach water-bearing zone, not surface water.

Historically, surface water was used primarily for grist and saw mills. Dorwart (1992, p. 67) shows the sites of 15 mills that operated near dams that impounded streams in the county. By 1930, electric and diesel power replaced the streams as a source of energy. From the 1960's to the early 1980's, cranberry growers used large volumes of surface water, but the amounts were not reported. The cranberry bogs are no longer in operation in Cape May County.

Ground-Water Withdrawals

Fresh ground water is withdrawn from five aquifers in the county and is used for public, domestic, semi-public (trailer parks and campgrounds), irrigation, industrial, and mining supply. A graph of water withdrawals by aquifer (fig. 31a) shows that of the 8,500 Mgal/yr withdrawn in 1990, about 3,000 Mgal/yr was from the Holly Beach water-bearing zone, 1,000 Mgal/yr from the estuarine sand aquifer, 2,200 Mgal/yr from the Cohansey aquifer, 180 Mgal/yr from the Rio Grande water- bearing zone, and 2,200 Mgal/yr from the Atlantic City 800-foot sand. A graph of withdrawals by type of user (fig. 31b) shows more than 4,200 Mgal/yr was withdrawn for public supply in 1990, 1,300 Mgal/yr for domestic- and semi-public supply, less than 300 Mgal/yr for irrigation and industrial supply, and 2,500 Mgal/yr for mining. Water used for mining activities (sand and gravel quarries) is recirculated pond water. It is estimated that the quarries use about 15 Mgal/d; however, the water is recycled daily. Water for most other uses is withdrawn from the aquifer, used once, then disposed of through public sewers that lead to a treatment plant and ultimately to the ocean by pipeline. Most domestic self-supplied ground water and some industrial self-supplied and semi-public self-supplied ground water is disposed of through septic tanks. Most of this water infiltrates to the water-table aquifer. Water withdrawals in 1990, less water used for mining, totaled about 6,000 Mgal/yr. Consumptive water use varies with respect to aquifer and type of water use.

Holly Beach Water-Bearing Zone

Water withdrawals from the Holly Beach water-bearing zone during 1960-90 increased from 800 to 3,000 Mgal/yr (fig. 31a). The main use categories in 1990 were domestic, irrigation, and mining supply. The location of selected wells screened in the Holly Beach water-bearing zone are shown in figure 5.

Withdrawals for domestic- and semi-public supply primarily occurred in Dennis and Upper Townships; some domestic water withdrawals also occurred in Middle and Lower Townships (fig. 32a). On the basis of the average annual population, the estimated domestic- and semi-public water use in Dennis and Upper Townships in 1990 was 190 and 283 Mgal/yr, respectively (table 6). Consumptive water use in the two townships was 20 percent of withdrawals (Solly

Table 6. Population by season and type of supply, and withdrawals for domestic self-supply use, by aquifer on the basis of population, Cape May County, New Jersey, 1970-90

[Estimated per capita water use of 65 gal/d, 1970-90. Water use is in million gallons per year; Twp, Township; --, no data]

	Population								
	Year-round Residents[1]			Estimated summer residents[2]			Weighted average of annual residents		
Location	1970	1980	1990	1970	1980	1990	1970	1980	1990
Upper Twp	3,413	6,713	10,681	11,923	15,295	18,213	4,831	8,143	11,936
Dennis Twp	2,635	3,989	5,574	16,048	18,115	20,352	4,870	6,343	8,037
Middle Twp	8,725	11,373	14,771	40,307	48,399	55,103	13,988	17,544	21,493
Lower Twp	10,154	17,105	20,820	47,587	53,278	59,426	16,393	23,133	27,254

	Annual average population by supply type					
	Public supply			Domestic self-supply		
Location	1970	1980	1990	1970	1980	1990
Upper Twp	0	0	0	4,831	8,143	11,936
Dennis Twp	0	0	0	4,870	6,343	8,037
Middle Twp[3]	2,000	2,100	2,192	11,988	15,444	19,301
Lower Twp[4]	8,000	9,000	10,000	8,392	14,133	17,254

	Withdrawals for domestic self supply on the basis of population					
	Holly Beach			Estuarine sand aquifer		
Location	1970	1980	1990	1970	1980	1990
Upper Twp	114.6	193.2	283.2	--	--	--
Dennis Twp	115.5	150.5	190.7	--	--	--
Middle Twp[3]	--	--	--	284.4	366.4	457.9
Lower Twp[4]	--	--	--	199.1	335.3	409.4

Sources: [1] U. S. Census Bureau.
[2] Cape May County Planning Board (1979).
[3] New Jersey American Water Co. Conservation Plan (1990).
[4] Robert Fathergill, oral commun., Lower Township Municipal Utilities Authority (1992).

Table 7a. Water withdrawals for irrigation use by source, Cape May County, New Jersey, 1975-90

[Source of data: U.S. Geological Survey State Water Use Data System (SWUDS); use in million gallons per year; --, use not reported; number below irrigator name is well identification number, wnu, well number unknown]

	Surface water		Holly Beach water-bearing zone									
Year	Deluzio Tuckahoe River	Nove- sack pond	Nove- sack 9-22	Buganski 9-174	Wuerker[1] wnu	Hand 9-63	Hoff[1] wnu	McClain[1] wnu	Taylor[1] wnu	Taylor[1] wnu	Howell 9-83	USDA[1] wnu
1975	14.2	--	29.9	--	8.0	--	--	--	--	--	1.2	--
1976	15.5	--	54.8	--	11.6	--	--	--	--	--	.7	--
1977	34.0	--	56.5	--	11.3	--	--	--	--	--	3.2	--
1978	17.5	--	56.2	--	2.3	--	--	--	--	--	.4	--
1979	17.5	--	22.9	--	7.4	--	--	--	--	--	--	--
1980	24.4	--	64.6	--	15.0	--	--	--	--	--	5.0	--
1981	24.4	--	50.7	--	15.0	--	--	--	--	--	2.0	--
1982	17.8	--	54.5	--	10.4	--	--	--	--	--	2.0	--
1983	34.9	--	63.8	--	7.4	--	--	--	--	--	1.7	--
1984	16.4	31.6	52.3	11.7	17.4	5.0	4.9	6.3	--	1.1	.4	13.8
1985	19.6	97.0	48.0	7.2	4.0	--	2.6	.9	0.1	.3	.5	6.4
1986	26.0	159.1	66.1	20.0	4.0	--	.7	--	.1	.6	.4	11.2
1987	27.3	.2	59.5	25.7	3.6	--	2.4	--	.1	.6	--	13.8
1988	--	--	56.3	29.6	13.2	--	--	--	--	.4	--	12.3
1989	--	--	45.3	2.7	--	--	--	--	--	--	--	1.7
1990	--	--	--	--	--	--	--	--	--	--	--	--

	Holly Beach water-bearing zone							
Year	Legate[1] wnu	Conover[1] wnu	Rice[1] wnu	Shiver[1] wnu	Matteria[1] wnu	Wheller[1] wnu	Nagatsuka1 9-137	Total
1975	--	--	--	--	--	--	1.9	41.0
1976	--	--	--	--	--	--	.8	67.9
1977	--	--	--	--	--	--	1.3	72.3
1978	--	--	--	--	--	--	1.4	60.3
1979	--	--	--	--	--	--	.7	31.0
1980	--	--	--	--	--	--	.6	85.2
1981	--	--	--	--	--	--	.5	68.2
1982	--	--	--	--	--	--	.4	67.3
1983	--	--	--	--	--	--	1.3	74.4
1984	8.3	21.3	3.6	4.8	8.7	40.2	.7	231.3
1985	9.1	16.5	6.4	--	2.0	40.0	1.3	221.1
1986	12.5	23.7	8.4	--	5.7	42.4	1.2	352.5
1987	14.5	10.0	13.0	--	9.2	41.5	--	139.1
1988	12.0	8.4	4.5	--	4.6	--	--	48.9
1989	3.4	--	--	--	--	--	--	53.1
1990	8.9	--	--	--	--	--	--	8.9

	Cohansey aquifer					
Year	Novesack 9-162	Betts 9-169	WW Golf 9-315	Bohm 9-101	Cordes 9-62	Total
1975	--	14.6	--	0.1	0.9	15.6
1976	--	32.0	--	.1	.6	32.7
1977	--	38.4	--	.1	.8	39.2
1978	--	16.5	--	.1	3.4	20.0
1979	--	11.5	--	.1	--	11.6
1980	--	31.0	--	.1	.3	31.3
1981	--	31.0	--	.1	--	31.1
1982	--	31.0	21.2	.1	--	52.3
1983	--	31.0	17.2	.1	.2	48.5
1984	41.8	63.2	73.3	26.5	.1	204.9
1985	45.4	34.0	24.8	25.9	.2	130.3
1986	45.5	34.0	18.2	22.2	.3	120.2
1987	52.9	30.0	20.7	--	.1	103.7
1988	53.1	30.0	--	--	--	83.1
1989	49.0	--	--	--	--	49.0
1990	--	--	--	--	--	--

[1] Source of water may be multiple wells or ponds.

Table 7b. Water withdrawals for mining use by source, Cape May County, New Jersey, 1975-90

[Source of data: U.S. Geological Survey State Water Use Data System (SWUDS); use in million gallons per year; --, use not reported]

	Holly Beach water-bearing zone			
Year	Pond	Pond	Pond	Total
1975	--	--	--	--
1976	--	--	--	--
1977	--	--	--	--
1978	--	--	--	--
1979	--	--	--	--
1980	--	--	--	--
1981	--	--	--	--
1982	--	--	--	--
1983	--	--	--	--
1984	25.5	514.6	--	540.1
1985	25.5	912.9	--	938.4
1986	20.0	1870.3	0.5	1890.8
1987	41.4	1228.3	1.6	1271.3
1988	54.1	1768.5	520.9	2343.5
1989	43.7	1657.6	1206.9	2908.2
1990	32.7	1445.6	1016.0	2494.3

Table 7c. Water withdrawals for industrial use by aquifer, Cape May County, New Jersey, 1975-90

[Source of data: U.S. Geological Survey State Water Use Data System (SWUDS); use in million gallons per year; --, use not reported; wnu, well number unknown]

	Holly Beach water-bearing zone wells			Estuarine sand aquifer well
Year	9-299	wnu	Total	9-90
1975	--	--	--	17.8
1976	--	--	--	4.3
1977	--	--	--	5.4
1978	--	--	--	5.3
1979	--	--	--	4.6
1980	--	--	--	1.7
1981	--	--	--	--
1982	--	--	--	--
1983	--	--	--	--
1984	4.1	--	4.1	--
1985	4.8	--	4.8	--
1986	4.5	--	4.5	--
1987	4.1	3.0	7.1	--
1988	--	2.0	2.0	--
1989	--	3.5	3.5	--
1990	--	4.9	4.9	--

	Cohansey aquifer wells											Atlantic City 800-foot sand wells		
Year	9-42	9-183	9-58	9-59	9-28	9-29	9-300	9-82	9-297	9-182	Total	9-144	9-148	Total
1975	44.1	--	16.8	14.3	135.8	57.9	--	4.6	--	22.2	295.7	27.0	95.8	122.8
1976	16.0	--	26.0	1.4	126.8	68.3	--	2.5	--	21.8	262.8	71.9	63.0	144.9
1977	25.6	--	20.4	23.9	63.4	121.2	--	5.1	--	22.8	282.4	57.6	66.5	124.1
1978	24.1	--	20.4	26.9	72.3	142.1	--	2.4	--	22.2	310.4	59.9	65.0	124.9
1979	40.2	--	5.4	31.8	235.9	.1	--	5.0	--	25.8	344.2	95.6	41.6	137.2
1980	35.3	--	5.4	23.8	172.0	.1	--	4.9	--	5.3	246.8	60.2	71.5	131.7
1981	37.5	--	5.4	23.8	--	--	--	4.9	--	.0	71.6	48.5	81.5	130.0
1982	25.8	--	5.4	23.8	--	--	--	20.0	--	1.1	76.1	68.4	65.1	133.5
1983	29.6	--	5.6	22.2	--	--	--	16.5	--	8.3	82.2	83.3	74.1	157.4
1984	24.8	33.3	14.2	--	--	--	--	18.1	--	30.3	120.7	95.8	60.9	156.7
1985	42.5	16.9	8.5	--	--	--	9.9	15.8	--	33.3	126.9	61.3	83.1	144.4
1986	28.3	25.6	.9	3.0	--	--	7.2	14.8	8.1	35.2	120.1	59.2	56.5	115.7
1987	27.7	28.0	6.7	5.5	--	--	--	15.6	6.4	33.0	122.9	66.6	71.0	137.6
1988	13.7	35.4	4.2	7.6	--	--	3.0	15.0	--	32.9	172.7	61.1	62.3	123.4
1989	15.3	39.4	4.0	4.6	--	--	6.2	13.2	--	34.1	116.8	65.0	67.9	132.9
1990	17.3	44.5	6.2	6.9	--	--	14.5	13.7	--	27.5	130.6	60.0	62.2	122.2

Table 7d. Water withdrawals for public-supply use by user and aquifer, Cape May County, New Jersey, 1960-90

[Source of data: U.S. Geological Survey State Water Use Data System (SWUDS); use in million gallons per year; number below Water Department is well identification number; --, use not reported; WD, Water Department; MUA, Municipal Utilities Authority; ABAND, abandoned; WBZ, water-bearing zone]

	Cape May City WD wells					Cape May Point WD wells	Lower Township MUA wells[1]				Woodbine WD wells
	Cohansey aquifer					Cohansey aquifer and Rio Grande WBZ	Cohansey aquifer				Cohansey aquifer
Year	9-14	9-27	9-36	9-43	Total	9-21	9-52	9-54	9-57	Total	9-168
1960	283.8	283.8	--	--	567.6	30.2	34.5	--	--	34.5	60.0
1961	299.9	299.9	--	--	599.8	27.9	36.2	--	--	36.2	76.8
1962	ABAND	627.6	--	--	627.6	23.9	23.9	23.9	--	47.8	83.2
1963	--	601.2	--	--	601.2	29.3	28.5	28.5	--	57.0	72.0
1964	--	568.0	--	--	568.0	27.4	41.0	41.0	--	82.0	58.6
1965	--	111.1	--	--	362.5	26.6	46.3	46.3	--	92.6	57.9
1966	--	128.8	179.0	--	307.8	31.5	47.6	47.6	--	95.3	--
1967	--	30.8	252.6	70.7	354.1	24.7	50.4	50.4	--	100.9	--
1968	--	--	175.4	161.6	337.0	29.9	65.3	65.3	--	130.6	--
1969	--	--	283.8	82.0	365.8	33.1	66.3	66.3	--	132.7	--
1970	--	5.7	102.8	294.0	402.5	26.4	82.8	82.8	--	165.6	--
1971	--	68.9	86.4	264.6	419.9	25.5	72.6	72.6	--	145.2	--
1972	--	--	157.2	222.1	379.3	8.7	74.5	74.5	--	149.0	--
1973	--	44.0	199.4	132.4	375.8	--	75.8	75.8	--	151.6	--
1974	--	--	217.8	140.8	358.6	--	60.7	60.7	60.7	182.1	--
1975	--	--	221.4	162.5	383.9	--	57.7	57.7	57.7	173.2	55.1
1976	--	--	270.9	132.4	403.3	--	62.3	62.3	62.3	186.1	58.1
1977	--	20.0	265.0	225.4	510.4	--	67.9	67.9	67.9	213.6	71.5
1978	--	5.0	318.3	157.6	480.9	--	59.7	59.7	59.7	179.1	72.0
1979	--	.5	183.5	228.6	412.6	--	60.4	60.4	60.4	181.1	130.2
1980	--	.8	243.8	185.6	430.2	--	64.8	64.8	64.8	194.3	144.4
1981	--	51.4	233.9	251.0	536.3	--	63.2	63.2	63.2	189.6	113.3
1982	--	51.4	282.7	205.0	539.1	--	64.3	64.3	64.3	192.8	116.0
1983	--	28.2	296.1	175.0	499.3	--	67.2	67.2	67.2	201.7	122.6
1984	--	6.8	273.9	115.7	396.4	--	66.1	66.1	66.1	198.5	101.4
1985	--	16.6	238.1	152.1	406.8	--	72.5	72.5	72.5	217.4	108.3
1986	--	15.5	135.2	275.6	426.3	--	83.6	83.6	83.6	250.9	107.3
1987	--	22.9	132.0	287.3	442.2	--	88.6	68.9	75.1	232.6	109.1
1988	--	8.3	114.7	298.9	421.9	--	100.3	59.6	108.7	268.6	114.1
1989	--	.7	93.2	298.1	392.0	--	147.5	39.9	88.8	276.2	106.0
1990	--	.8	117.5	273.1	391.4	--	172.6	42.8	79.0	294.4	110.4

	Wildwood WD mainland wells[1]					Cape May Court House wells		
	Holly Beach water-bearing zone[2]	Estuarine sand[3]	Cohansey aquifer[4]	Rio Grande water-bearing zone[5]	Total	Holly Beach water-bearing zone	Atlantic City 800-foot sand	
						9-163	9-92	9-296
1960	--	160.8	645.1	-	805.9	41.2	--	--
1961	--	158.4	633.5	--	791.9	43.0	--	--
1962	--	169.2	676.4	--	845.6	50.1	--	--
1963	--	177.6	710.4	--	888.0	55.6	--	--
1964	--	185.0	738.8	--	923.8	60.7	--	--
1965	--	183.0	733.4	--	916.4	66.4	--	--
1966	--	187.0	746.1	--	933.1	60.1	--	--
1967	--	190.2	760.2	--	950.4	34.2	21.1	--
1968	--	193.4	773.4	--	966.8	--	61.2	--
1969	38.7	163.9	809.1	--	1011.7	--	61.1	--
1970	40.4	211.7	737.1	--	989.2	--	67.4	--
1971	30.8	164.1	827.0	--	1021.9	--	73.8	--
1972	22.4	197.3	815.6	--	1035.3	--	59.5	--
1973	19.5	144.8	1012.5	--	1176.8	--	62.3	--
1974	24.5	142.3	1135.6	--	1302.4	--	65.2	--
1975	42.0	169.8	961.5	92.1	1265.4	--	69.4	--
1976	56.5	144.9	1139.1	114.7	1455.2	--	74.2	--
1977	51.4	108.2	1114.0	109.3	1382.9	--	84.5	--
1978	53.5	136.8	1133.2	116.3	1439.8	--	84.5	--
1979	61.8	161.1	1220.3	100.1	1543.3	--	94.2	--
1980	71.0	178.7	1266.2	115.4	1631.3	--	92.9	--
1981	78.2	161.9	1233.3	119.2	1592.6	--	90.1	--
1982	83.0	176.0	1291.4	110.1	1660.5	--	97.6	--
1983	87.6	162.0	1225.1	104.7	1579.4	--	102.6	--
1984	51.8	201.3	1285.8	74.3	1613.2	--	107.0	--
1985	--	173.0	1258.8	126.3	1558.1	--	102.7	--
1986	--	120.8	1270.5	120.7	1512.0	--	112.1	--
1987	--	94.5	1326.2	106.1	1526.8	--	132.3	--
1988	--	140.2	1270.0	90.9	1501.1	--	135.4	--
1989	--	150.5	1223.1	166.8	1540.4	--	99.5	50.1
1990	--	130.2	1215.0	182.6	1527.8	--	9.0	154.5

Footnotes are at the end of the table.

Table 7d. Water withdrawals for public-supply use by user and aquifer, Cape May County, New Jersey, 1960-90--Continued

Year	Avalon wells[1] Atlantic City 800-foot sand [6]9-8	9-1	9-6	9-4	9-2	9-5	9-291	Total	Avalon Manor wells Atlantic City 800-foot sand 9-100	Strathmere wells Atlantic City 800-foot sand 9-136
1960	91.1	91.1	--	--	--	--	--	182.2	--	12.9
1961	67.4	67.4	67.4	--	--	--	--	202.1	--	11.9
1962	47.6	47.6	47.6	--	--	--	--	143.0	--	11.9
1963	38.6	38.6	38.6	--	--	--	--	115.7	--	12.9
1964	42.6	42.6	42.6	--	--	--	--	128.3	0.7	17.2
1965	52.1	52.1	52.1	--	--	--	--	156.3	.9	15.8
1966	46.6	46.6	46.6	--	--	--	--	139.9	1.4	19.7
1967	50.2	50.2	50.2	--	--	--	--	150.5	1.5	19.7
1968	41.9	41.9	41.9	41.9	--	--	--	167.5	1.7	32.5
1969	41.1	41.1	41.1	41.1	--	--	--	184.2	1.8	23.6
1970	65.3	--	65.3	65.3	--	--	--	196.8	1.7	18.8
1971	53.1	--	53.1	53.1	53.1	--	--	212.3	4.1	21.8
1972	51.8	--	51.8	51.8	51.8	--	--	207.2	4.5	28.1
1973	51.9	--	51.9	65.9	65.7	--	--	235.4	4.4	21.7
1974	61.4	--	--	101.5	80.5	--	--	243.4	6.0	19.6
1975	99.9	--	--	73.6	67.9	--	--	241.4	5.2	18.4
1976	37.7	--	--	125.1	103.9	--	--	266.7	6.0	22.6
1977	18.1	--	--	92.0	109.2	78.7	--	298.0	6.4	34.0
1978	7.1	--	--	97.3	78.2	80.9	--	263.5	5.2	11.0
1979	.5	--	--	77.2	78.1	118.5	--	274.3	5.5	10.2
1980	.1	--	--	114.3	73.3	114.2	--	301.8	8.5	11.8
1981	--	--	--	147.9	69.3	82.6	--	299.8	5.6	13.2
1982	4.5	--	--	159.5	61.5	120.3	--	345.8	6.1	15.5
1983	10.9	--	--	124.2	76.0	106.2	--	317.3	7.2	16.9
1984	33.4	--	--	112.2	49.8	114.2	--	309.6	9.5	15.1
1985	29.8	--	--	110.1	53.5	104.1	--	297.5	6.8	17.9
1986	--	--	--	107.8	107.8	107.8	--	323.5	7.3	12.6
1987	--	--	--	106.9	106.9	106.9	--	320.8	5.6	16.5
1988	--	--	--	93.5	90.5	93.9	37.0	314.9	--	--
1989	--	--	--	76.0	77.8	93.7	80.2	327.6	--	--
1990	--	--	--	96.8	59.1	56.9	24.3	237.1	--	--

Year	Sea Isle City wells[1] Atlantic City 800-foot sand 9-128	9-129	9-127	9-126	Total	Stone Harbor wells[1] Atlantic City 800-foot sand [7]9-133	9-135	9-132	9-66	9-173	Total
1960	41.9	41.9	41.9	41.9	164.3	38.3	38.3	38.3	--	--	119.5
1961	46.7	46.7	46.7	46.7	180.7	45.0	45.0	45.0	--	--	135.0
1962	46.6	46.6	46.6	46.6	180.3	46.8	46.8	46.8	--	--	140.3
1963	39.9	39.9	39.9	39.9	159.6	46.7	46.7	46.7	--	--	137.0
1964	39.7	39.7	39.7	39.7	158.9	48.6	48.6	48.6	--	--	145.8
1965	38.3	38.3	38.3	38.3	153.3	61.1	61.1	61.1	--	--	183.3
1966	39.2	39.2	39.2	39.2	156.7	47.9	47.9	47.9	--	--	143.6
1967	40.9	40.9	40.9	40.9	163.6	44.3	44.3	44.3	--	--	132.9
1968	39.9	39.9	39.9	39.9	159.7	51.4	51.4	51.4	--	--	155.6
1969	41.7	41.7	41.7	41.7	166.8	49.2	49.2	49.2	--	--	147.5
1970	45.7	45.7	45.7	45.7	178.3	50.7	50.7	50.7	--	--	152.1
1971	43.6	43.6	43.6	43.6	174.4	50.3	50.3	50.3	--	--	151.0
1972	46.0	46.0	46.0	46.0	184.1	52.3	52.3	52.3	--	--	157.0
1973	61.1	61.1	61.1	61.1	244.3	63.0	63.0	63.0	--	--	189.2
1974	61.5	61.5	61.5	61.5	246.1	58.9	58.9	58.9	--	--	176.8
1975	64.8	64.8	64.8	64.8	259.3	59.1	59.1	59.1	--	--	177.4
1976	57.8	57.8	57.8	57.8	231.3	47.3	47.3	47.3	47.3	--	189.4
1977	59.6	59.6	59.6	59.6	238.5	51.1	51.1	51.1	51.1	--	204.5
1978	48.7	48.7	48.7	48.7	195.0	48.7	48.7	48.7	48.7	--	194.7
1979	47.8	47.8	47.8	47.8	191.5	46.7	46.7	46.7	46.7	--	186.6
1980	56.7	56.7	56.7	56.7	226.9	49.4	49.4	49.4	49.4	--	197.7
1981	52.1	52.1	52.1	52.1	208.6	--	47.2	47.2	47.2	47.2	188.8
1982	80.8	80.8	80.8	80.8	323.3	--	48.3	48.3	48.3	48.3	193.3
1983	86.4	86.4	86.4	86.4	345.7	--	52.4	52.4	52.4	52.4	209.7
1984	97.0	97.0	97.0	97.0	388.0	--	55.5	55.5	55.5	55.5	222.0
1985	108.7	108.7	108.7	108.7	434.6	--	48.2	48.2	48.2	48.2	192.8
1986	110.7	110.7	110.7	110.7	442.9	--	54.2	54.2	54.2	54.2	216.8
1987	80.4	80.4	80.4	80.4	321.5	--	51.4	51.4	51.4	51.4	205.6
1988	38.8	133.1	96.4	46.1	314.4	--	48.1	48.1	48.1	48.1	192.5
1989	35.7	121.7	88.3	42.0	287.7	--	44.6	44.6	44.6	44.6	178.2
1990	40.7	138.9	100.8	47.9	328.4	--	46.3	46.3	46.3	46.3	185.3

Table 7d. Water withdrawals for public supply use by user and aquifer, Cape May County, New Jersey, 1960-90--Continued

	Ocean City wells[1] Atlantic City 800-foot sand												
Year	[8]9-121	9-123	9-107	9-122	9-106	9-116	9-109	9-117	9-125	9-110	9-124	9-108	Total
1960	158.7	52.9	52.9	52.9	52.9	52.9	52.9	52.9	--	--	--	--	529.7
1961	162.9	54.3	54.3	54.3	54.3	54.3	54.3	54.3	--	--	--	--	543.8
1962	119.2	59.6	59.6	59.6	59.6	59.6	59.6	59.6	59.6	--	--	--	596.5
1963	125.0	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	--	--	--	625.3
1964	127.6	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	--	--	--	638.3
1965	133.6	66.8	66.8	66.8	66.8	66.8	66.8	66.8	66.8	--	--	--	668.3
1966	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	--	--	741.7
1967	71.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	--	--	710.7
1968	77.9	77.9	77.9	77.9	77.9	77.9	77.9	77.9	77.9	77.9	--	--	779.7
1969	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	--	--	749.0
1970	--	52.6	52.6	52.6	52.6	52.6	52.6	52.6	52.6	52.6	52.6	--	526.0
1971	--	93.0	--	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	930.0
1972	--	82.9	--	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9	829.7
1973	--	78.8	--	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	788.6
1974	--	87.5	--	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	875.7
1975	--	91.5	--	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	914.7
1976	--	102.3	--	102.3	102.3	102.3	102.3	102.3	102.3	102.3	102.3	102.3	1023.8
1977	--	107.7	--	107.7	107.7	107.7	107.7	107.7	107.7	107.7	107.7	107.7	1077.0
1978	--	94.4	--	94.4	94.4	94.4	94.4	94.4	94.4	94.4	94.4	94.4	944.2
1979	--	96.7	--	96.7	96.7	96.7	96.7	96.7	96.7	96.7	96.7	96.7	967.9
1980	--	110.3	--	110.3	110.3	110.3	110.3	110.3	110.3	110.3	110.3	110.3	1103.9
1981	--	112.4	--	112.4	112.4	112.4	112.4	112.4	112.4	112.4	112.4	112.4	1124.0
1982	--	98.1	--	98.1	98.1	98.1	98.1	98.1	98.1	98.1	98.1	98.1	980.6
1983	--	101.8	--	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	1018.1
1984	--	107.4	--	107.4	107.4	107.4	107.4	107.4	107.4	107.4	107.4	107.4	1074.3
1985	--	111.7	--	111.7	111.7	111.7	111.7	111.7	111.7	111.7	111.7	111.7	1117.1
1986	--	112.9	--	112.9	112.9	112.9	112.9	112.9	112.9	112.9	112.9	112.9	1128.6
1987	--	115.4	--	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4	1153.7
1988	--	120.1	--	120.1	120.1	120.1	120.1	120.1	120.1	120.1	120.1	120.1	1200.6
1989	--	113.8	--	113.8	113.8	113.8	113.8	113.8	113.8	113.8	113.8	113.8	1137.7
1990	--	113.3	--	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	1133.1

[1] Water withdrawal was reported cumulatively and has been divided among the extant wells.
[2] Four wells in the Holly Beach water-bearing zone.
[3] Two wells in the estuarine sand.
[4] Six or seven wells in the Cohansey aquifer.
[5] One well in the Rio Grande water-bearing zone.
[6] Well 9-7 and 9-9 are within 200 feet of well 9-8 and withdrawals are combined.
[7] Wells 9-133 is within 100 feet of well 9-134 and withdrawals are combined.
[8] Sealed wells 9-118, 9-119, and 9-120 are within 1,000 feet of well 9-121, and withdrawals are combined.

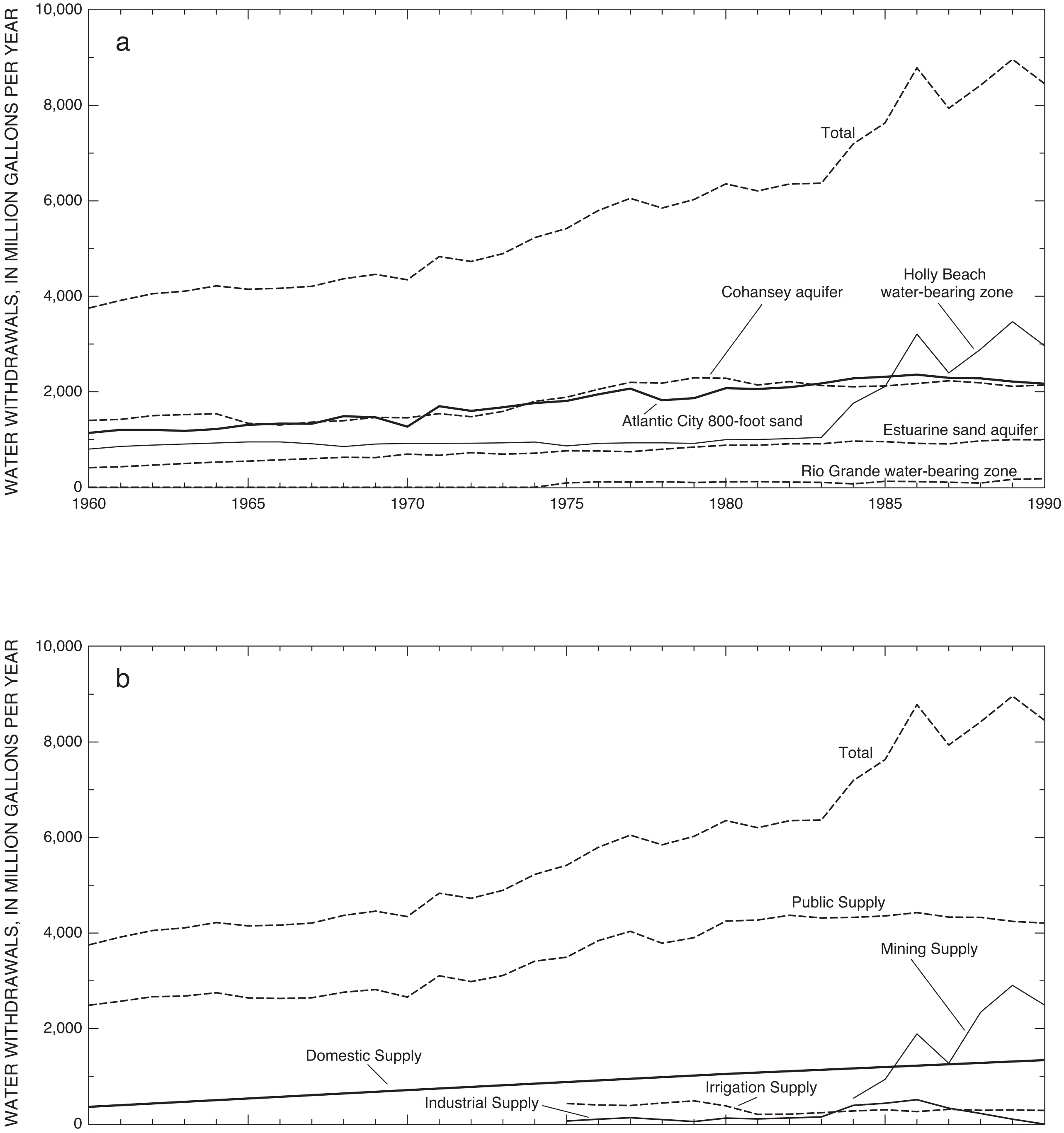


Figure 31. Total water withdrawals and water withdrawals by (a) aquifer and (b) type of use, 1960-90, Cape May County, New Jersey.

and others, 1988) or 38 and 57 Mgal/yr, respectively. The remaining water was returned to the aquifer through domestic septic systems.

Estimated water use for irrigation in 1957 was 180 Mgal/yr (Gill, 1962a, p.79). The NJDEP collected extensive irrigation water-use data in 1986. Reported irrigation use at 23 farms during 1984-88 averaged 385 Mgal (table 7a). It is not always clear which aquifer a farmer used for irrigation supply because well records are not always available for irrigation wells, and withdrawal data from various sources is often commingled. On the basis of conversations with some farmers and the Rutgers Cooperative Agricultural Agent, Lawrence Newbold, however, it was determined that most farmers probably used the water-table aquifer. Water withdrawal for irrigation use in 1990 was estimated to be 400 Mgal/yr. Consumptive water use for irrigation was 80 percent or about 320 Mgal/yr. The remaining 80 Mgal/yr was returned to the water-table aquifer.

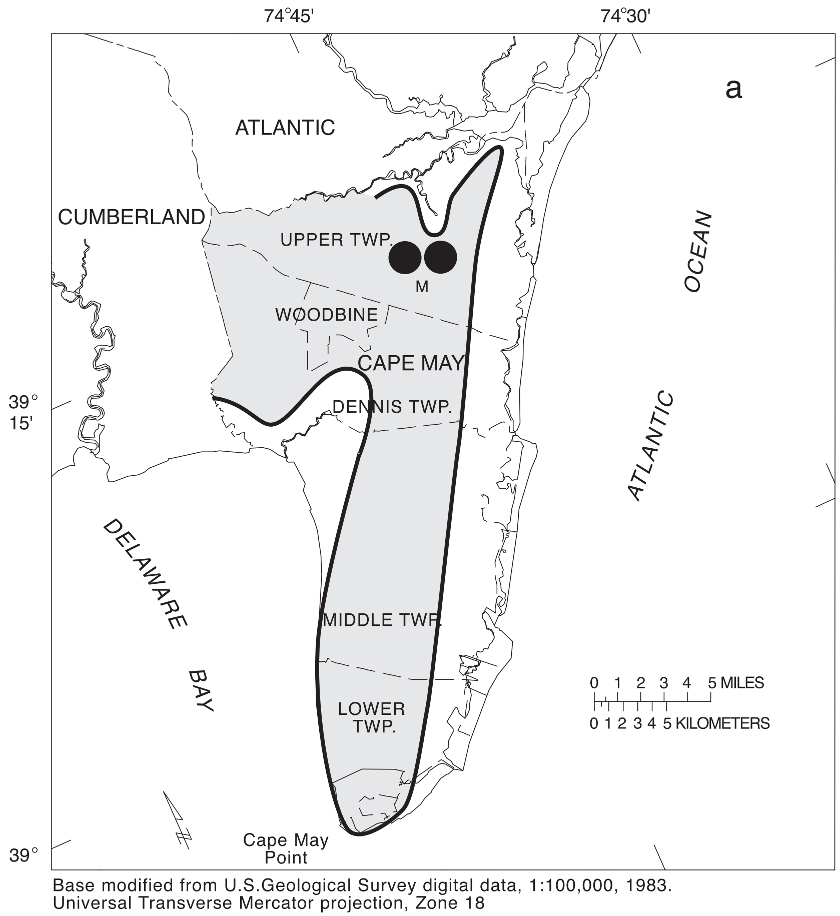
Water withdrawal for mining use has been reported only since 1984, which explains the sharp rise in total water use after 1983-84 (figs. 31a and 31b). In 1990, three sand and gravel operations reported using 2,494 Mgal (table 7b). Water from the gravel pits is recirculated many times in order to mine, then wash, the sand and gravel. During an 8-hour production day, using a 3,000-gal/min dredging pump, a mine will recirculate about 1.44 Mgal. The main loss of water at a sand and gravel mine is through evaporation from the pond surface. An estimated 32 in/yr of water (about 860,000 gal/acre/yr) is lost by evaporation (Veihmeyer, 1964, p. 11-9). Annual consumptive water use as a result of increased evaporation is estimated at 0.86 Mgal/acre/yr, or more than 100 Mgal/yr for the three major mining firms.

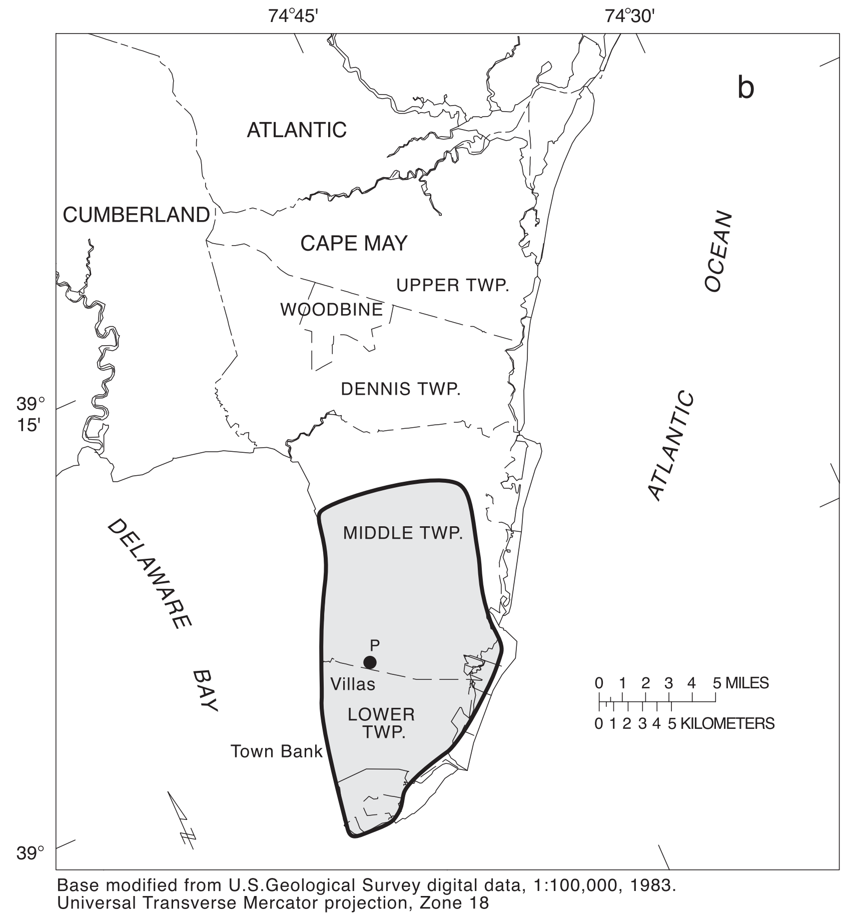
Water withdrawals for public supply from the Holly Beach water-bearing zone has all but ceased in Cape May County. Cape May Court House stopped withdrawing from the aquifer in 1984 (table 7d). Its maximum reported withdrawal was about 66 Mgal/yr in 1965. Wildwood Water Utility stopped using the aquifer in 1984. Its maximum reported withdrawal was about 87 Mgal/yr in 1983. Wildwood Water Department abandoned the wells that tap the aquifer in 1984 after a tanker truck loaded with petroleum overturned near the well field. No withdrawals have been reported for industrial supply.

Estuarine Sand Aquifer

Water is withdrawn from the estuarine sand aquifer only in Middle and Lower Townships (fig. 32b). Water withdrawals during 1960-90 ranged from 400 to 1,000 Mgal/yr (fig. 31a). Withdrawals are used for domestic, public, semi-public, and industrial supply. On the basis of average annual population served by domestic supply, (table 6) withdrawals in 1990 were estimated to be 867 Mgal/yr. Withdrawals for public supply at the Wildwood mainland well field near Rio Grande were 130.2 Mgal in 1990. Maximum withdrawals were 211.7 Mgal in 1970 (table 7c). Water for industrial use was withdrawn by one company, which used about 5 Mgal/yr prior to 1980. The locations of selected wells screened in the estuarine sand aquifer are shown in figure 6.

The Wildwood Water Department mainland well field has two public-supply wells that tap the aquifer. This is the largest water-withdrawal site for this aquifer. Hundreds of domestic-supply wells are concentrated in Villas and Town Bank, and hundreds of other domestic-supply wells are dispersed throughout the upland regions of Lower and Middle Townships. A broad cone of depression with water levels below sea level has resulted from withdrawals from the estuarine sand aquifer and from induced leakage from the estuarine sand aquifer into the cone of depression in the underlying Cohansey aquifer. Water withdrawn from the aquifer for public supply generally is disposed of in public sewers that eventually discharge to the ocean. Water withdrawn from the estuarine sand aquifer for domestic supply is disposed of in septic systems that then discharge to the Holly Beach water-bearing zone. Therefore, water consumption from the aquifer can be considered 100 percent.





EXPLANATION

Area of water withdrawals

M Mining supply

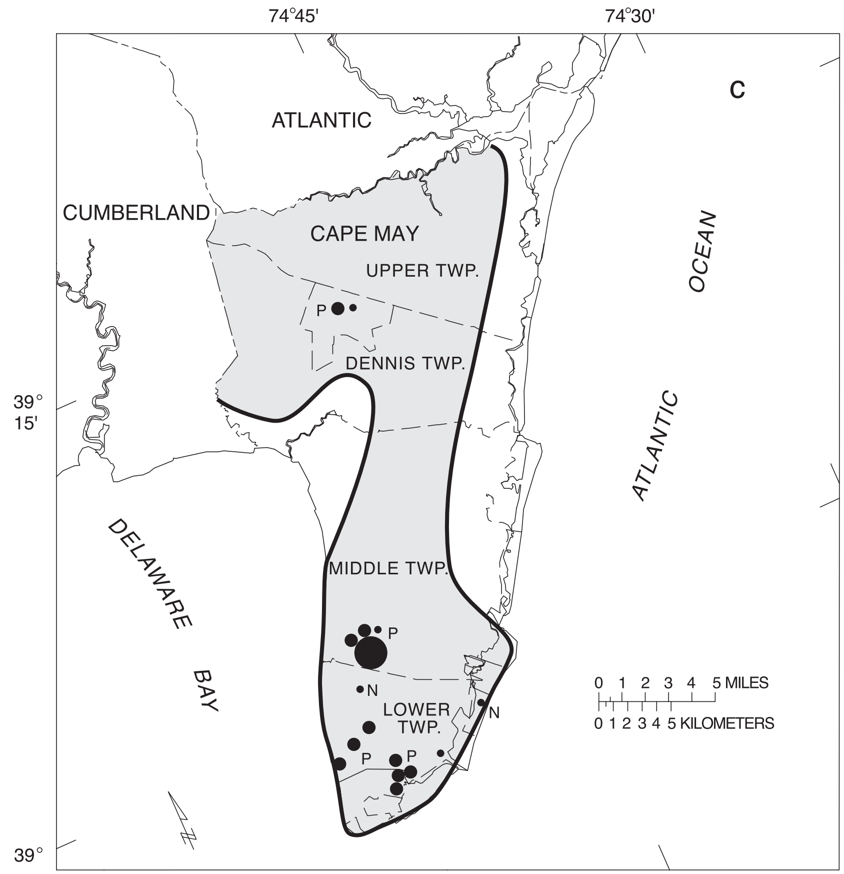
P Public supply

Water withdrawal, in million gallons per year

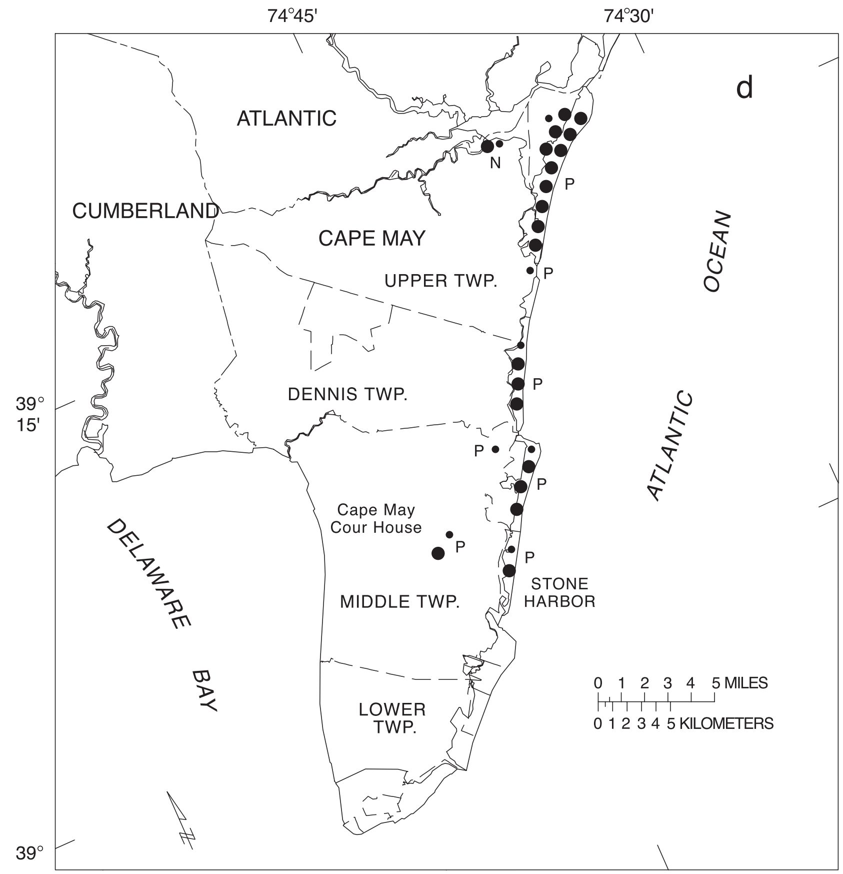
0 - 50 | 50 - 100 | 100 - 1,000

Figure 32a. Approximate area of water withdrawals for domestic and irrigation supply and location of mining-supply wells screened in the Holly Beach water-bearing zone, Cape May County, New Jersey, 1990.

Figure 32b. Approximate area of water withdrawals for domestic, irrigation, and industrial supply and location of a public-supply well screened in the estuarine sand aquifer, Cape May County, New Jersey,1990.



Base modified from U.S.Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator projection, Zone 18



Base modified from U.S.Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator projection, Zone 18

EXPLANATION

Area of water withdrawals

N Industrial supply

P Public supply

Water withdrawal, in million gallons per year

0 - 50 50 - 100 100 - 1,000

Figure 32c. Approximate area of water withdrawals for domestic, irrigation, and industrial supply and location of public-supply wells screened in the Cohansey aquifer, Cape May County, New Jersey, 1990.

Figure 32d. Location of water domestic, industrial, and public-supply wells screened in the Atlantic City 800-foot sand, Cape May County, New Jersey, 1990.

Cohansey Aquifer

Water withdrawal from the Cohansey aquifer during 1960-90 increased from 1,300 to 2,200 Mgal/yr (fig. 31a). The major users in 1990 withdrew the water for public and industrial supply. Water for public supply in 1990 was withdrawn primarily in upland regions of Middle Township, Lower Township, and Woodbine (fig. 32c). In 1990, Wildwood Water Department withdrew 1,215 Mgal/yr from its wells in Middle Township, Cape May City Water Department withdrew 391 Mgal/yr from its wells in Lower Township, and Lower Township Municipal Utilities Authority (MUA) withdrew 294 Mgal/yr, and Woodbine Water Department withdrew 110 Mgal/yr (table 6) from their respective communities. Wildwood Water Department, Lower Township MUA, and Woodbine Water Department have increased withdrawals from the Cohansey aquifer since 1960. Cape May City Water Department has decreased water withdrawals from the Cohansey aquifer from a maximum of 627 Mgal/yr in 1962 to 391 Mgal/yr in 1990 (table 7c). Withdrawals were decreased because saltwater intrusion has forced the closing of supply wells (Lacombe and Carleton, 1992). Cape May Point stopped withdrawals in 1972 because saltwater intrusion made the water nonpotable. Some trailer parks and campgrounds have semi-public-supply wells that tap the Cohansey aquifer, but the amount of water withdrawn is thought to be small. Withdrawals from the Cohansey aquifer for semi-public supply are included with the estimated domestic-supply withdrawals from the Holly Beach water-bearing zone and estuarine sand aquifer. Industrial- supply withdrawals are reported by the fishing industry and the county government, which withdraws water from two wells at the industrial complex on county airport property in Lower Township. Withdrawals for industrial use in 1990 totaled 130.6 Mgal/yr (table 7b). A commercial laundry company in Wildwood Crest stopped using the Cohansey aquifer in 1990 because of saltwater intrusion. A company that extracted magnesite from sea water ceased using the Cohansey aquifer when the plant closed in 1980. Water from the Cohansey aquifer could not be used in the plant because of high chloride levels.

Water withdrawn from the Cohansey aquifer during July and August 1990 totaled nearly three times the water withdrawn during January and February (fig. 33a). Water withdrawals in July totaled 300 Mgal/yr and in February, 108 Mgal/yr. The seasonal fluctuation in water withdrawals results from seasonal fluctuations in the tourist population.

Water withdrawn from this aquifer is processed in one of the county's sewage treatment plants and disposed of in the ocean or disposed of in a septic system and discharged to the water-table aquifer. Therefore, water use is 100 percent consumptive for the Cohansey aquifer.

Rio Grande Water-Bearing Zone

Water is withdrawn from the Rio Grande water-bearing zone by one public-supply well in the Rio Grande well field and one well at a small marina in eastern Middle Township. Annual water withdrawals for public supply during 1960-90 increased from 0 to 182 Mgal/yr (fig. 7c). Estimated annual water withdrawals at the marina totaled less than 0.02 Mgal/yr.

Most of the water is withdrawn during the summer for public supply for the tourists. Water withdrawn from the aquifer is processed in a sewage-treatment plant and discharged to the ocean; therefore, withdrawal is 100 percent consumptive for this aquifer.

Atlantic City 800-Foot Sand

Water is withdrawn from the Atlantic City 800-foot sand predominantly on the barrier islands, but two public-supply wells, one semi-public-supply well in Middle Township, two industrial-supply wells at the electric plant in Upper Township, and two or three domestic-supply wells in Upper Township also withdraw water from this aquifer (fig. 32d). Water withdrawals from the aquifer during 1960-90 increased from about 1,100 to 2,100 Mgal/yr. Withdrawals during 1990 for Ocean City totaled 1,113 Mgal/yr; Sea Isle City, 328 Mgal/yr; Avalon, 237 Mgal/yr; Stone Harbor, 185 Mgal/yr; Cape May Court House, 163 Mgal/yr; Strathmere, less than 20 Mgal/yr; and

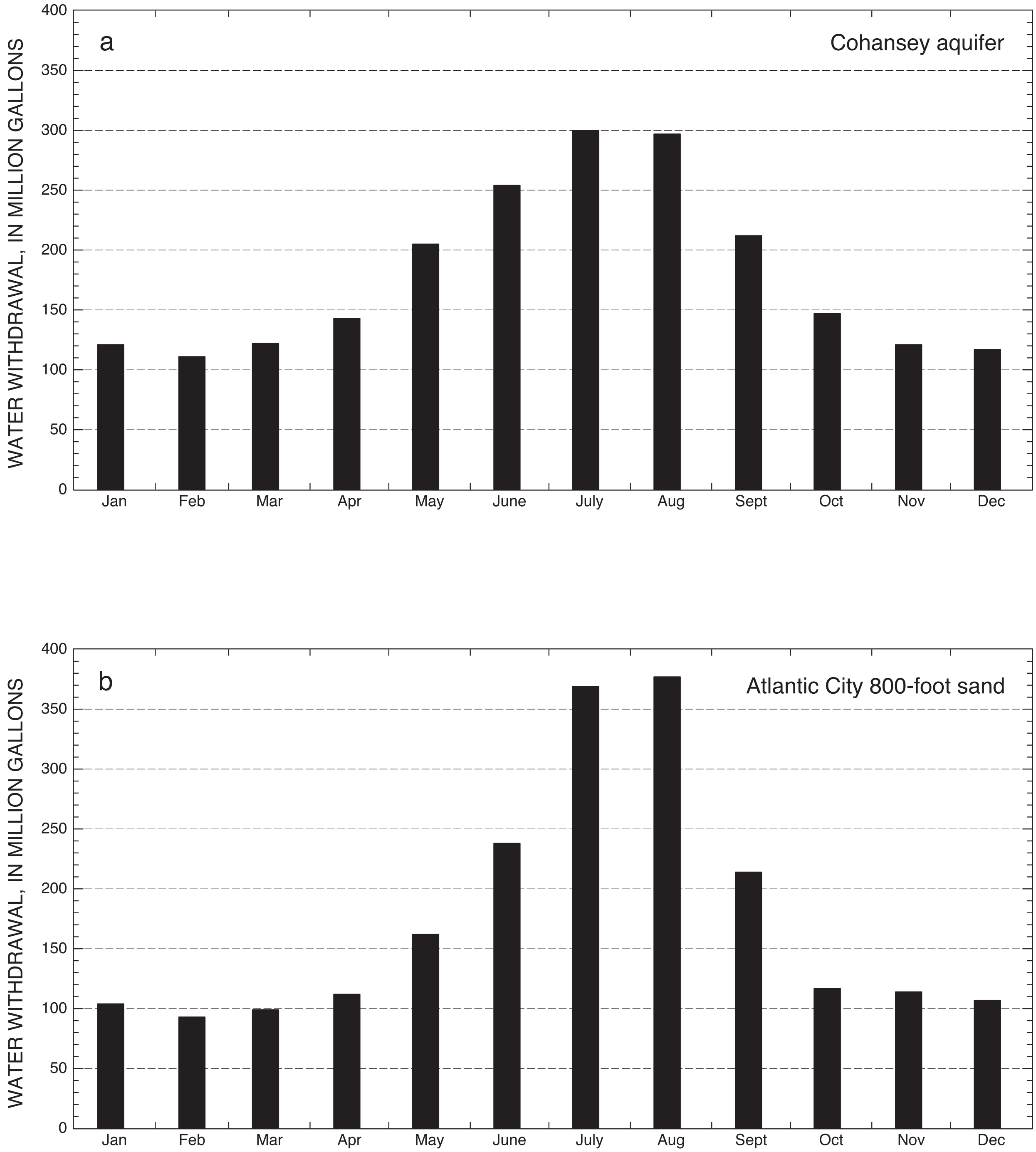


Figure 33. Average monthly water withdrawals for the (a) Cohansey aquifer and (b) Atlantic City 800-foot sand, Cape May County, New Jersey, 1985-90.

Middle Township Water Department in Avalon Manor, less than 10 Mgal/yr (table 7c). Monthly water withdrawals from the Atlantic City 800-foot sand during 1985-90 ranged from less than 100 Mgal/mo in February to 375 Mgal/mo in August (fig. 33). Industrial water use is limited to the electric generation plant in Upper Township. Water withdrawals at the plant began in 1962 when the plant first opened. Water withdrawals at the plant totaled 122 Mgal/yr in 1990 with a maximum withdrawal of 157 Mgal/yr in 1983 (table 7b). Public-supply water withdrawn from the Atlantic City 800-foot sand is sent to one of the regional sewage-treatment plants; therefore, consumptive use is 100 percent. The electric company plant discharges much of the water to the atmosphere as steam; therefore, its consumptive use is 100 percent.

GROUND-WATER LEVELS AND FLOW DIRECTIONS

Historical and recent water-level hydrographs, maps, and sections for the aquifers of Cape May County are used to determine (1) changes in water levels, (2) changes in flow directions, (3) the source areas of ground-water supplies, and (4) ground-water flow paths between and within aquifers. Water-level hydrographs show long-term, seasonal, and daily fluctuations of water levels.

Long-term changes in water levels result from lengthy and large increases or reductions in withdrawals, injections of water, and multi-year droughts. Seasonal water-level fluctuations result from increased evapotranspiration and increased ground-water withdrawals during the summer. Daily water-level fluctuations can be the result of tides or daily changes in withdrawals. Long-term and seasonal fluctuations are of greatest interest in this study; daily fluctuations are of lesser interest, but must be considered when interpreting the water-level data.

Tide-influenced water-level fluctuations in the aquifers typically ranged from 6 ft near the shore in the water-table aquifer (about the same as the tide) to negligible changes in inland areas and in deeper aquifers. Well 9-89, screened in the Cohansey aquifer and located less than 50 ft from Delaware Bay, shows tide influenced water-level fluctuations of about 3.5 ft (fig. 34a). Well 9-99, also screened in the Cohansey aquifer but about 1 mile from a tidal salt marsh, shows tidal fluctuations of less than 0.1 ft (fig. 34b). Well 9-79, screened in the Atlantic City 800-foot sand and located in a salt marsh, shows tidal fluctuations as great as 2 ft (fig. 34c).

The water levels shown on the potentiometric maps are not adjusted for tidal fluctuations. Therefore, water levels near the coast may be as much as 3 ft higher or lower than the daily mean water level. Adjustments were made for daily fluctuations in water levels that result from pumping by measuring the water level only after the pump had been off and water levels had recovered for 1 hour.

In the early 1900's, prior to significant ground-water withdrawals, the water levels of the aquifers of Cape May County were at or above sea level. In the three shallower aquifers, water flowed from areas of ground-water recharge toward the nearest stream, the ocean, or the bay. In the two deep aquifers, water flowed from recharge areas in Atlantic and Cumberland Counties through Cape May County to the ocean or bay. Water levels and flow directions have remained the same in the less developed parts of the shallow aquifers. In deep, heavily developed aquifers, water levels have declined, and water now flows radially inward toward the withdrawal wells.

Holly Beach Water-Bearing Zone

The April 1991 water-level contour map for the Holly Beach water-bearing zone (fig. 35) was developed from water levels measured in 82 wells, from water levels in about 50 streams and ponds, from data on the landward limit of tide, and from water-level data on topographic maps. The water-table was drawn to reflect land-surface topography where water-level data is lacking. This map shows high water levels typical for the spring of each year.

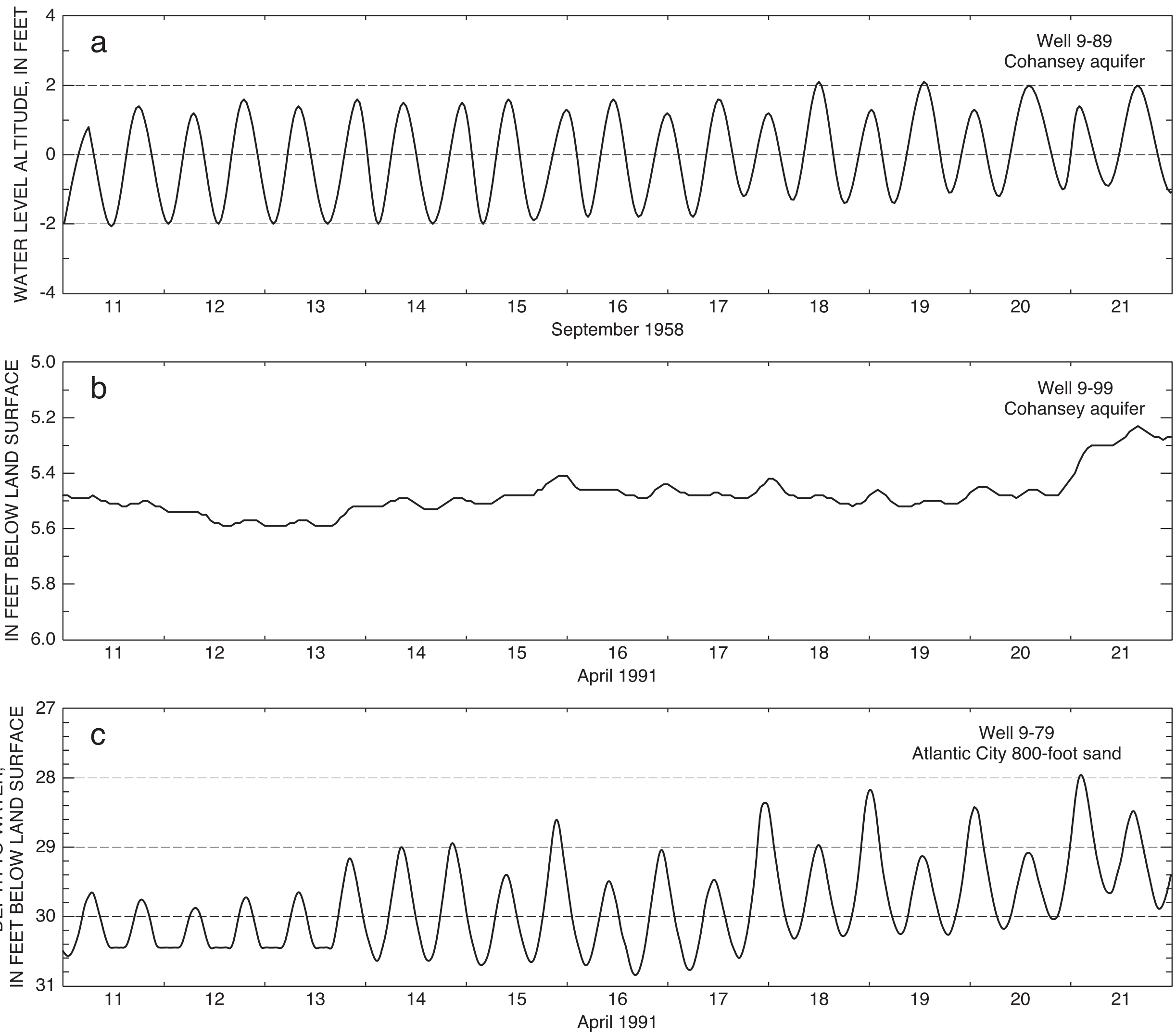


Figure 34. Daily tidal fluctuations in wells screened in the Cohansey aquifer and in the Atlantic City 800-foot sand, Cape May County, New Jersey.

The water-table altitude ranged from 0 to +20 ft south and east of Great Cedar Swamp. The highest water-level altitudes on the peninsula ranged from +10 to +20 ft along a half-mile-wide area on either side of the topographic divide. The gradient of the water table on the peninsula is about 5 to 15 ft/mi, and ground-water discharges primarily to tidal wetlands and small streams. The steeper gradients are toward the ocean, and the shallower gradients are toward Delaware bay.

Northwest of the Great Cedar Swamp, water-level altitudes are 0 to +45 ft, with the highest water levels coinciding with the topographic divide. Water-table gradients range from 5 to 20 ft/mi and generally are steeper in the northern part of the county than on the peninsula. Ground water northwest of the Great Cedar Swamp discharges primarily to streams and rivers. Less ground water is discharged to tidal wetlands in the northern part of the county than on the peninsula because fewer tidal wetlands are present in the north.

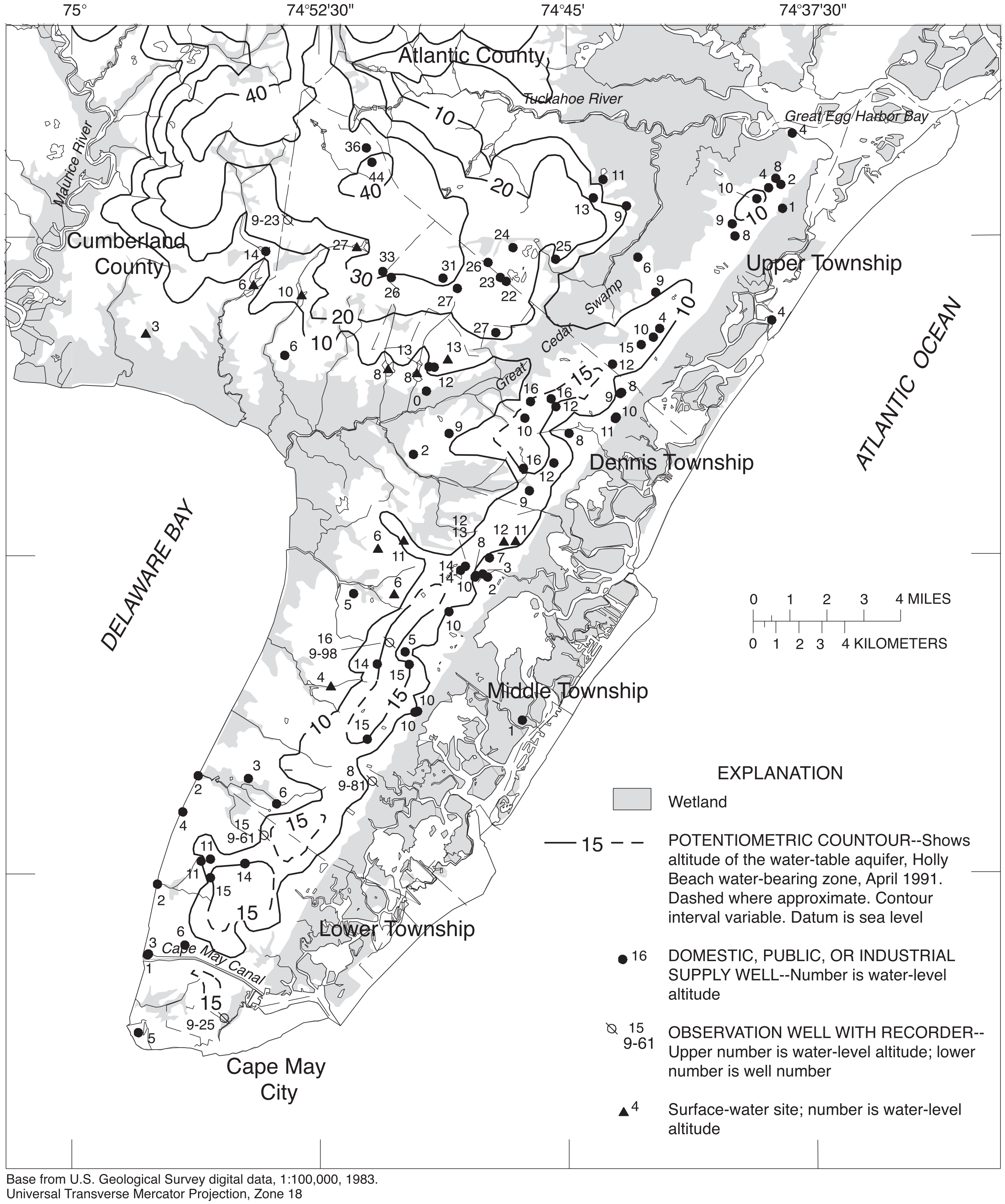


Figure 35. Potentiometric surface of the Holly Beach water-bearing zone, Cape May County, New Jersey, April 1991.

Hydrographs from wells 9-23, 9-25, 9-61, 9-81 and 9-98 (fig. 36) show mean monthly water levels during 1957-92. The hydrographs show a relatively constant mean water level that is above sea level at all times. Annual water-level fluctuations ranged from 2 ft in wells 9-25 and 9-61 to 5 ft in wells 9-81 and 9-98.

The water-level hydrographs used in conjunction with the April 1991 water-level map show that in the upland areas, water levels can be as much as 5 ft lower during August and September than the rest of the year but are about the same throughout the year in the wetland areas. Water levels decline during the summer because of increased evapotranspiration, increased water withdrawals, and reduced recharge. Recharge is reduced because precipitation from summer thunderstorms typically results in less infiltration than winter precipitation.

Annual withdrawals from the aquifer for domestic and irrigation supply total less than 600 Mgal/yr. About 80 percent of the water used for domestic purposes and about 20 percent of the water used for irrigation is returned to the aquifer. Domestic and irrigation withdrawals do not affect ground-water levels or flow directions for long periods of time.

The 1991 water-level map (fig. 35) is similar to the 1958 water-level map (Gill, 1962a, p 132). Water levels shown in both maps subtly mimic the land surface topography. The shapes of the contour lines in both maps closely reflect predevelopment flow directions and rates, except in areas where the land surface has been significantly altered since predevelopment. Ground-water levels near mill ponds became elevated permanently after dams were constructed during the 1700’s and 1800’s. Ground-water levels near the public-supply wells that tap the water-table aquifer in Cape May Court House, Cape May City, and the Wildwood mainland well fields temporarily and locally declined during 1910-60 while the wells were in operation. Water-level altitudes along the Cape May Canal declined permanently from +15 ft to sea level after the canal was constructed in 1942. Since the 1950’s, increased land development with associated impermeable structures, such as paved areas and buildings probably led to decreased infiltration by precipitation, resulting in less recharge to the ground-water system. None-the-less, ground-water levels measured in April 1991 were similar in altitude and flow pattern to those in 1958.

During predevelopment, ground water flowed downward from the recharge areas, then most water flowed laterally and discharged upward into the ocean and bay (fig. 37a and 38a). A minor amount of water flowed downward from the Holly Beach water-bearing zone into the estuarine sand aquifer in the peninsular part of the county (fig. 37a) or into the Cohansey aquifer in the northern part of the county (fig. 38b). The ground-water flow section for 1991 for the peninsular part of the county (fig. 37b) shows the same general flow pattern in the Holly Beach water-bearing zone; however, the water-level declines in the estuarine sand aquifer indicate an increase in the rates of downward flow and an increase in the size of the area where downward flow occurs. This interpretation is developed from the water-level map of the estuarine sand aquifer that shows a large cone of depression in the area (fig. 39a) and from stream-discharge data that show that streams in the southern part of the county have a flow rate per unit area that is about 80 percent of flow rate of streams in the northern part of the county. In the northern part of the county, the flow patterns are nearly identical to those during predevelopment. The conversion of the land from predeveloped, forested land to agricultural, residential, and commercial land use in the 1990’s has not significantly changed the flow paths northwest of Great Cedar Swamp.

Estuarine Sand Aquifer

The potentiometric-surface map for the estuarine sand aquifer is based on water levels measured in 28 wells during April 1991 when the annual water levels were highest (fig. 39a). The shape of the contour lines was refined to show the locations of natural and artificial recharge and discharge areas. The potentiometric surface for 1991 shows a regional cone of depression. The center of the cone of depression underlies the Wildwood mainland well field. The regional

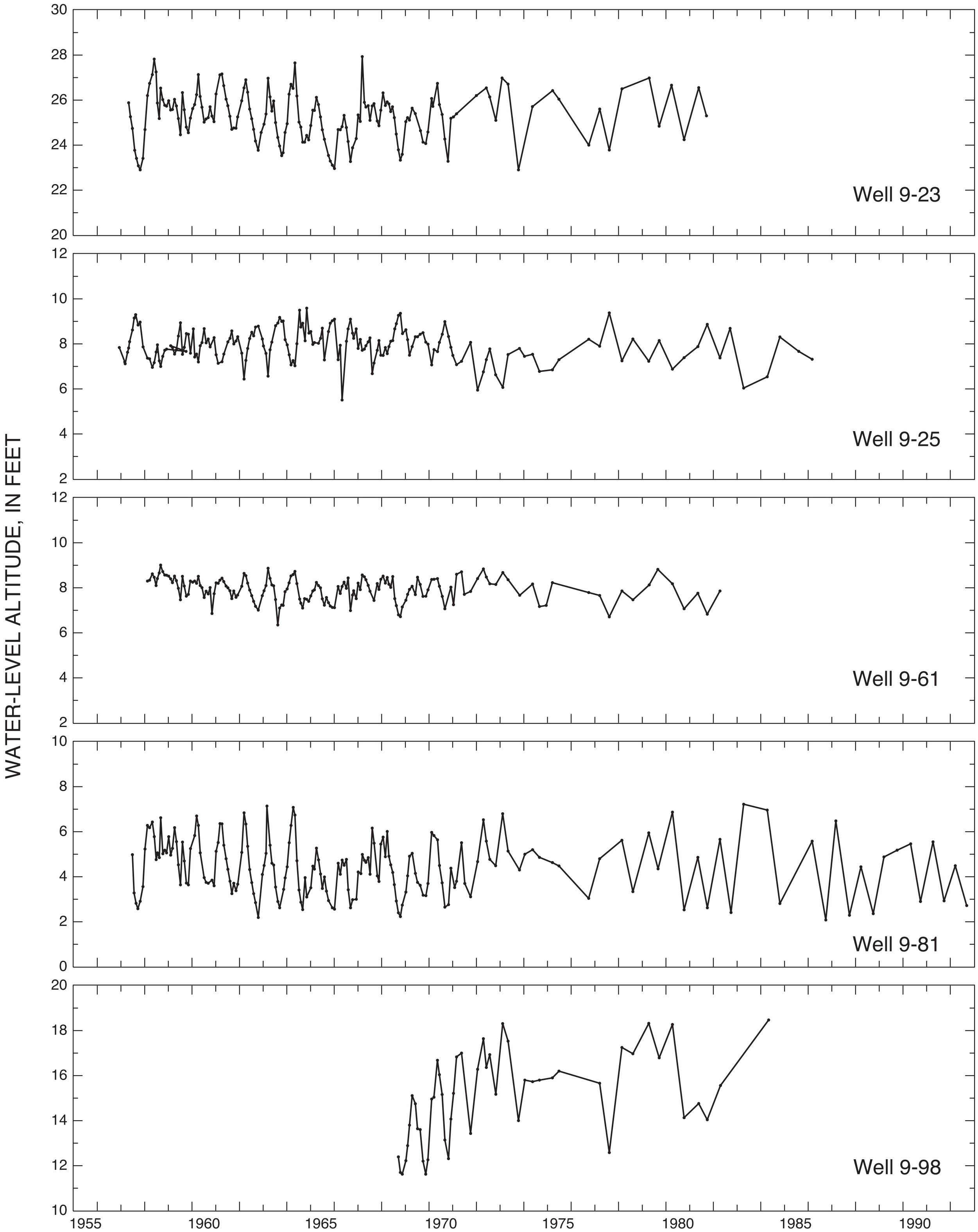


Figure 36. Monthly mean water levels in wells screened in the Holly Beach water-bearing zone, Cape May County, New Jersey.

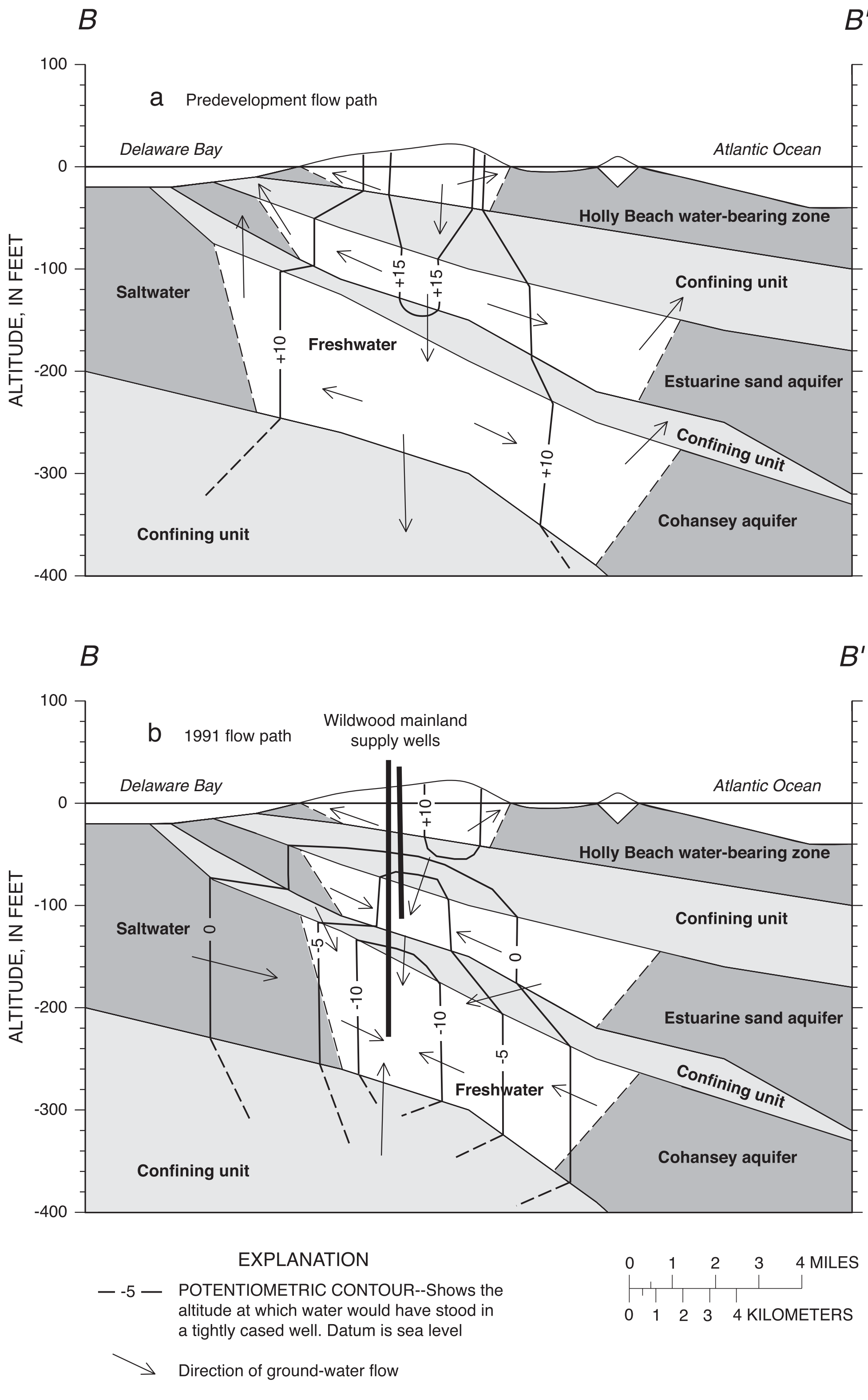


Figure 37. Section *B-B′* showing vertical and horizontal ground-water flow directions during (a) pre-development, and (b) 1991, in the shallow aquifers of Cape May County, New Jersey.

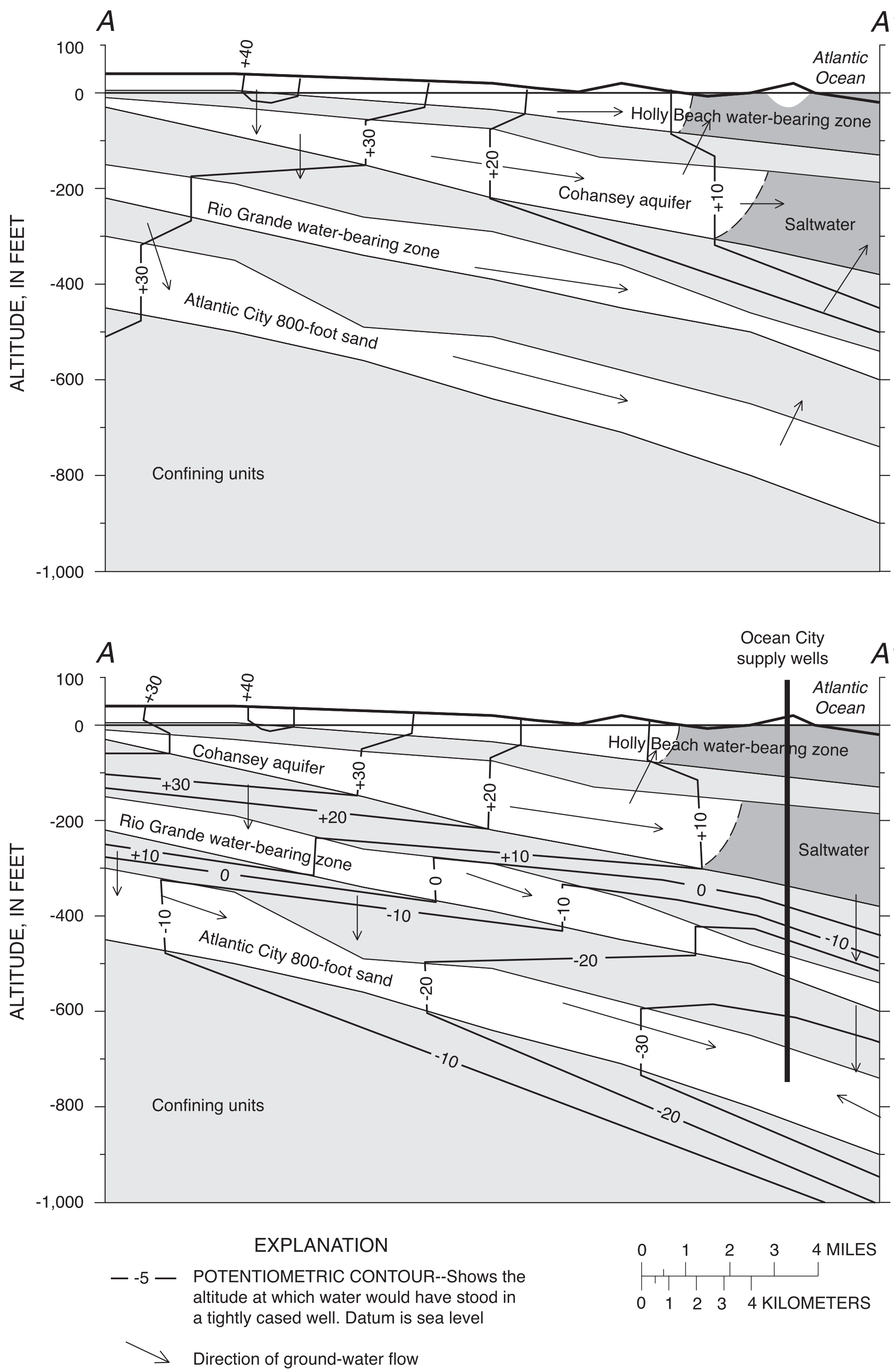


Figure 38. Section *A-A'* showing vertical and horizontal ground-water flow directions (a) during pre-development, and (b) 1991, in the fresh-water aquifers of northern Cape May County, New Jersey.

ground-water flow direction is radially inward toward the well fields. The highest measured water-level altitude, +10 ft, was measured in northern Middle Township. In this area, withdrawals from the aquifer are limited, and the overlying confining unit thins and pinches out. The lowest water-level altitude, -8 ft, was measured in the Wildwood Water Department mainland well field. In the well field, about 150 Mgal/yr is withdrawn from the estuarine sand aquifer, causing a local cone of depression. In addition, about 1,200 Mgal/yr is withdrawn from the Cohansey aquifer, which induces leakage from the estuarine sand aquifer into the Cohansey aquifer, thereby increasing the size of the cone of depression in the estuarine sand aquifer. Ground-water flow gradients in the cone of depression ranged from 5 to 7 ft/mi near the Wildwood mainland supply wells and were 2 ft/mi in much of Lower Township. In parts of Lower and Middle Township that are not near public-supply wells, water levels in the aquifer were near or below sea level, in part, because of extensive withdrawals from domestic-supply wells.

Water levels in the Wildwood communities are above sea level during ground-water injection (Lacombe,1996). An aquifer storage and recovery system used by the Wildwood Water Department has a seasonal effect on water levels in the estuarine sand and Cohansey aquifers. Water is injected or “stored” in the aquifer during periods of low demand (mid-September to mid-May) and withdrawn or “recovered” during periods of high demand. As a result, higher ground-water levels occur during the storage phase. Water-level altitudes during the recharge season are about +2 ft. Water-level altitudes in the aquifer decline to a minimum of about -20 ft in the Wildwood mainland well field as a result of pumping during the summer.

Water-level hydrographs for wells 9-26, 9-97, 9-189, 9-206, and 9-215 (fig. 40) show measured water-level altitudes during 1957-90. Hydrographs for wells 9-26 and 9-97 show that mean annual water-level altitudes have been constant since about 1955. Water-level altitudes have decreased in well 9-189 from about 0 to -4 ft, in well 9-206 from about +1 to -2 ft; and in well 9-215 from 0 to -2 ft. The decrease in water levels in these wells is caused, in part, by ground-water withdrawals in the Villas and Town Bank areas and by the Wildwood Water Department.

Water levels in well 9-26, about 500 ft from the public-supply wells for Cape May City, were below sea level (-4 to -6 ft). The low water levels can be attributed to induced leakage from the estuarine sand aquifer into the Cohansey aquifer.

Well 9-97, which is screened in the estuarine sand aquifer, and well 9-98, which taps the Holly Beach water- bearing zone, are two wells of a three-well well nest. Water levels in well 9-98 (fig. 36) ranged in altitude from +11 to +18 ft. Water-levels altitudes in well 9-97 screened in the estuarine sand aquifer ranged from +6 to +11 ft. The 5- to 6-ft gradient across the confining unit indicates that the flow of water from the Holly Beach water-bearing zone into the estuarine sand aquifer is impeded.

Seasonal water-level fluctuations ranged from 2 to 11 ft in the five observation wells (fig. 40). Water levels in the aquifer in southern Middle and in Lower Townships have the highest seasonal fluctuation. The lowest water levels during the summer are a result of increased withdrawals from the aquifer and of increased induced leakage into the Cohansey aquifer where withdrawals also have increased. The hydrographs show maximum seasonal water-level declines of 7 ft in well 9-189 and of 6 ft in well 9-206. Seasonal fluctuations in well 9-26 were about 2 ft, slightly less than the fluctuations in the Holly Beach water-bearing zone.

The 1958 potentiometric-surface map (fig. 39b) shows water levels during the non-tourist season (modified from Gill, 1962a p. 129). The contours in figure 39b are modified for clarity. Water-level altitudes in 1958 ranged from -2 to +11 ft. A small cone of depression was centered below Villas, and water levels were depressed throughout the Wildwood Water Department well field. The cone of depression shows that water flowed radially toward the Villas and Wildwood Water Department supply wells. In addition, the map shows that in northern Middle Township the predevelopment flow pattern prevailed.

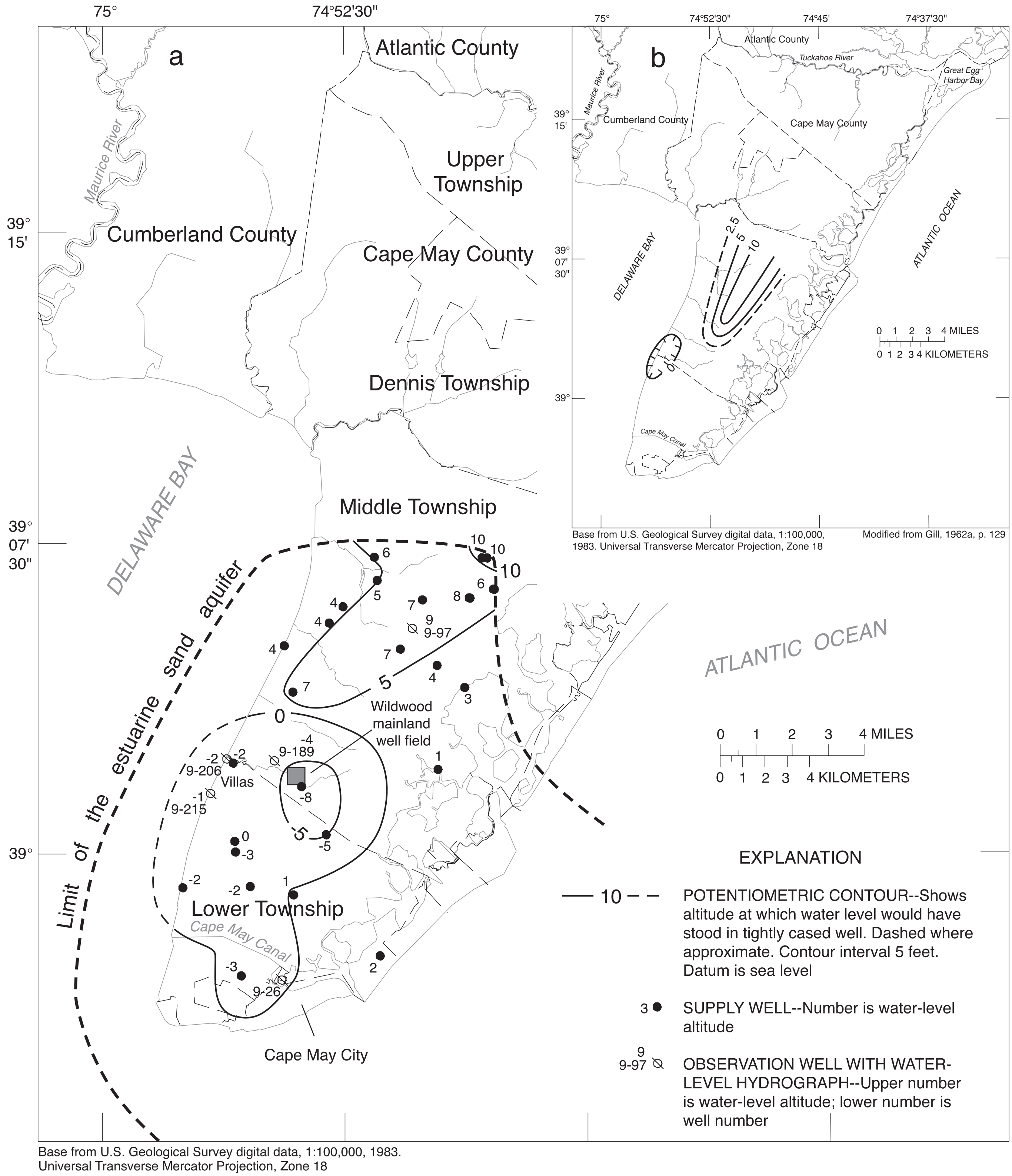


Figure 39. Potentiometric surface of the estuarine sand aquifer in Cape May County, New Jersey, in (a) April 1991 and (b) March 8, 1958.

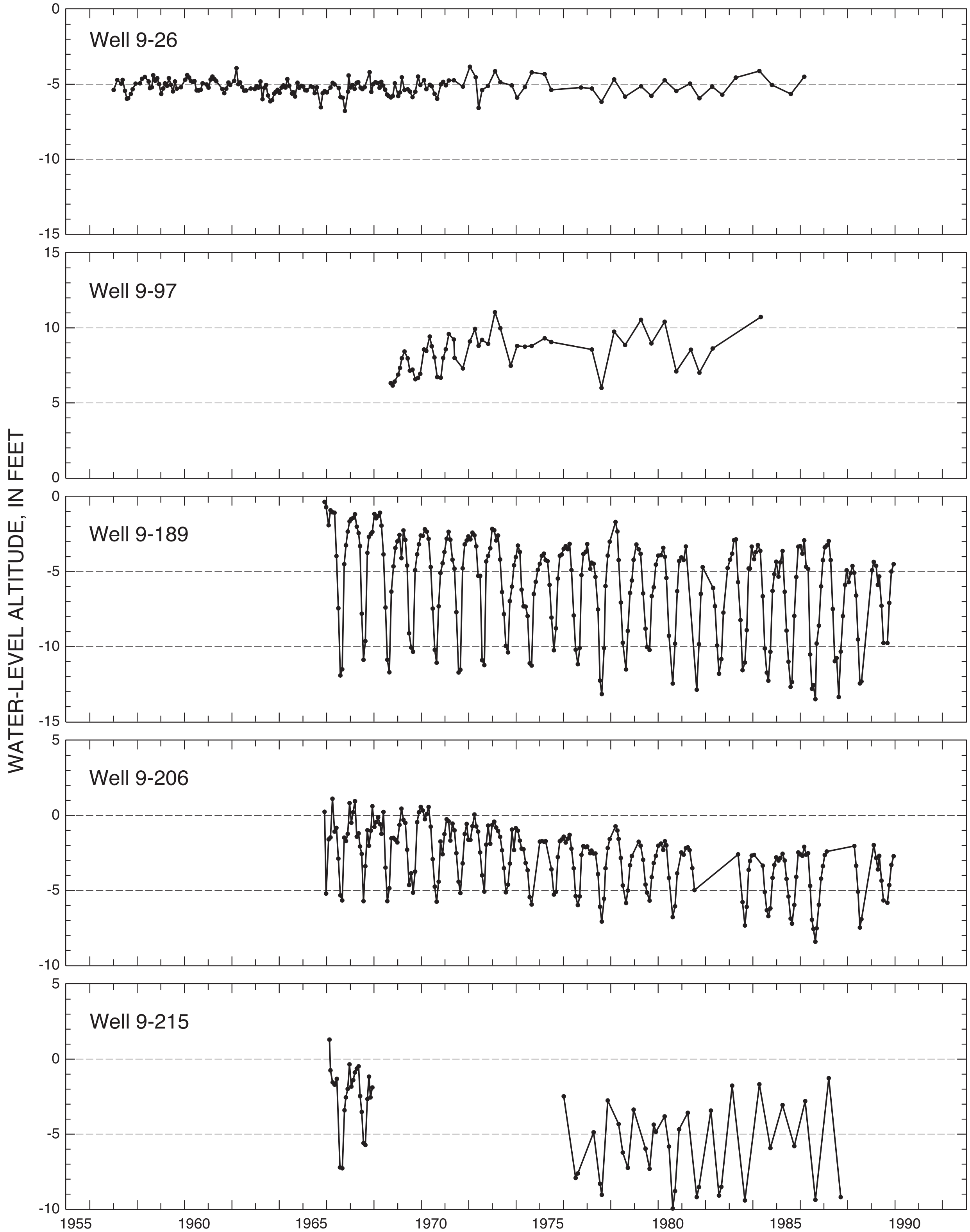


Figure 40. Monthly mean water levels in wells screened in the estuarine sand aquifer, Cape May County, New Jersey.

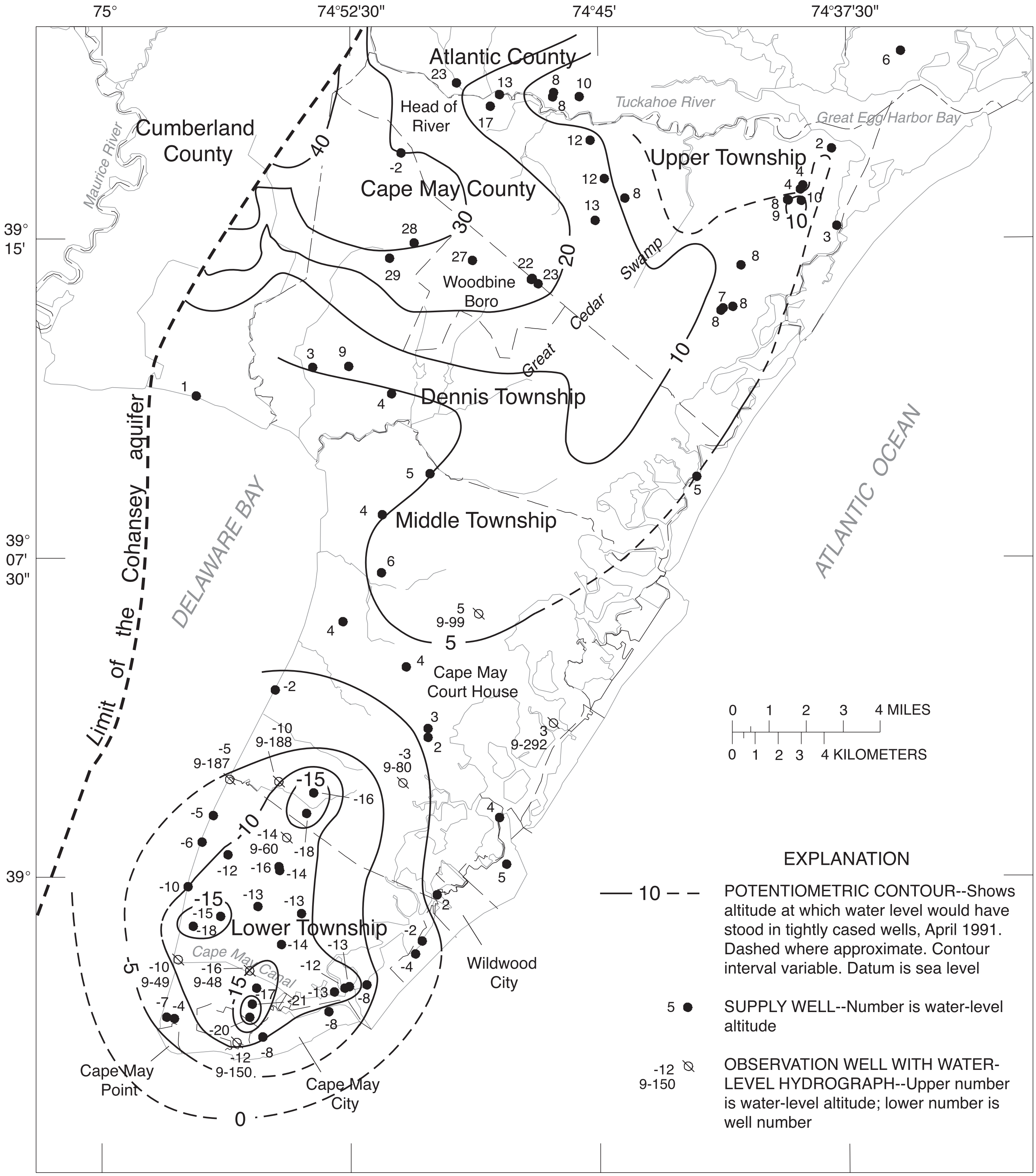
Prior to development, about 1900, ground water in the Holly Beach water-bearing zone flowed from the center of the peninsula downward into the estuarine sand, laterally toward the bay and ocean, and upward near the shoreline (fig. 37a). Flow was downward along the axis of the freshwater zone, which separates the saltwater fronts that are under the bay and the ocean. Flow was upward along the saltwater fronts. The potentiometric surface for the estuarine sand aquifer was at or slightly above sea level prior to development and was similar to the predevelopment potentiometric surface for the Cohansey aquifer in southern Cape May County (fig. 41a).

Cohansey Aquifer

The potentiometric-surface map of the Cohansey aquifer shows water levels during April 1991 (fig. 41) when they were typically at their annual highest. The map is based on water-level data from 61 wells. The shapes of the contours are refined to show the effects of pumping at the major supply wells screened in the Cohansey aquifer and to show areas of greater and lesser leakage from the overlying aquifers. The water levels in the aquifer ranged from +40 ft in Dennis Township to -20 ft in Lower Township. The regional cone of depression in the southern half of the peninsula with water levels below sea level is the result of withdrawals from the aquifer. Within the regional cone of depression are four local cones of depression, which center on the supply wells for the Wildwood Water Department, Lower Township MUA, Cape May City Water Department, and the fishing industry wells located in eastern Lower Township. Water levels in the aquifer in the northern part of the county typically were within 5 ft of the water levels in the Holly Beach water-bearing zone at most locations. Water levels in wells screened in the Cohansey aquifer near Head of River, however, were 14 ft above land surface and 15 ft or more above the water table. Upward flow gradients of this magnitude can occur in some areas adjacent to major streams. Lateral flow gradients ranged from 10 ft/mi or more near the four pumping centers in Lower and Middle Townships to less than 2 ft/mi in Middle and Dennis Townships (fig. 41). Water levels in the northern part of the county, where no well data are available, are contoured as a subdued version of the water-table aquifer. Also water-level data collected prior to development in northern Cape May County by Gill (1962a) (fig. 42a) are similar to water-level data collected in 1991 (fig. 41). The data are similar because no substantial withdrawals were made that would change conditions. In the southern part of the county, the Cohansey aquifer is separated from surficial recharge and discharge areas by two confining units that are thicker and less permeable than the single confining unit in the northern part of the county. As a result, natural downward leakage into and upward discharge out of the aquifer is less in the southern part of the county than in the northern part of the county. Because natural recharge and discharge are controlled by overlying confining units, a lobe of freshwater formed prior to development in the southern part of the county where the confining units are thicker and more extensive (Gill, 1962a) (fig. 41a).

Water-level hydrographs for wells 9-60, 9-80, 9-99, 9-187, and 9-292 in northern Lower Township and southern Middle Township show a mean annual water-level decline of 1 to 6 ft during the period of record, starting as early as 1957 (fig. 43). Ground-water withdrawals from the Cohansey aquifer in this area have increased since 1960. Therefore, water levels continued to decline in the area. During 1966-92, the largest mean annual water-level declines for each of nine observation wells were from 2 to 7 ft. During each summer the water levels declined from 2 to 25 ft below annual high water levels.

Water-level hydrographs for wells 9-48, 9-49, and 9-150 in southern Lower Township (fig. 43) show that mean annual water levels declined during the late 1950's to the 1960's, stabilized during the 1970's, then increased in the 1980's and early 1990's. These trends are related to changes in the location and volume of withdrawals from the Cohansey aquifer in the area. The decrease in water levels during the 1950's and early 1960's was the result of increased water withdrawals from public-supply wells south of the Cape May Canal (fig. 1). The rise in mean annual water-level altitudes in well 9-150 from -18 to -14 ft from 1964



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 41. Potentiometric surface of the Cohansey aquifer, Cape May County, New Jersey, April 1991.

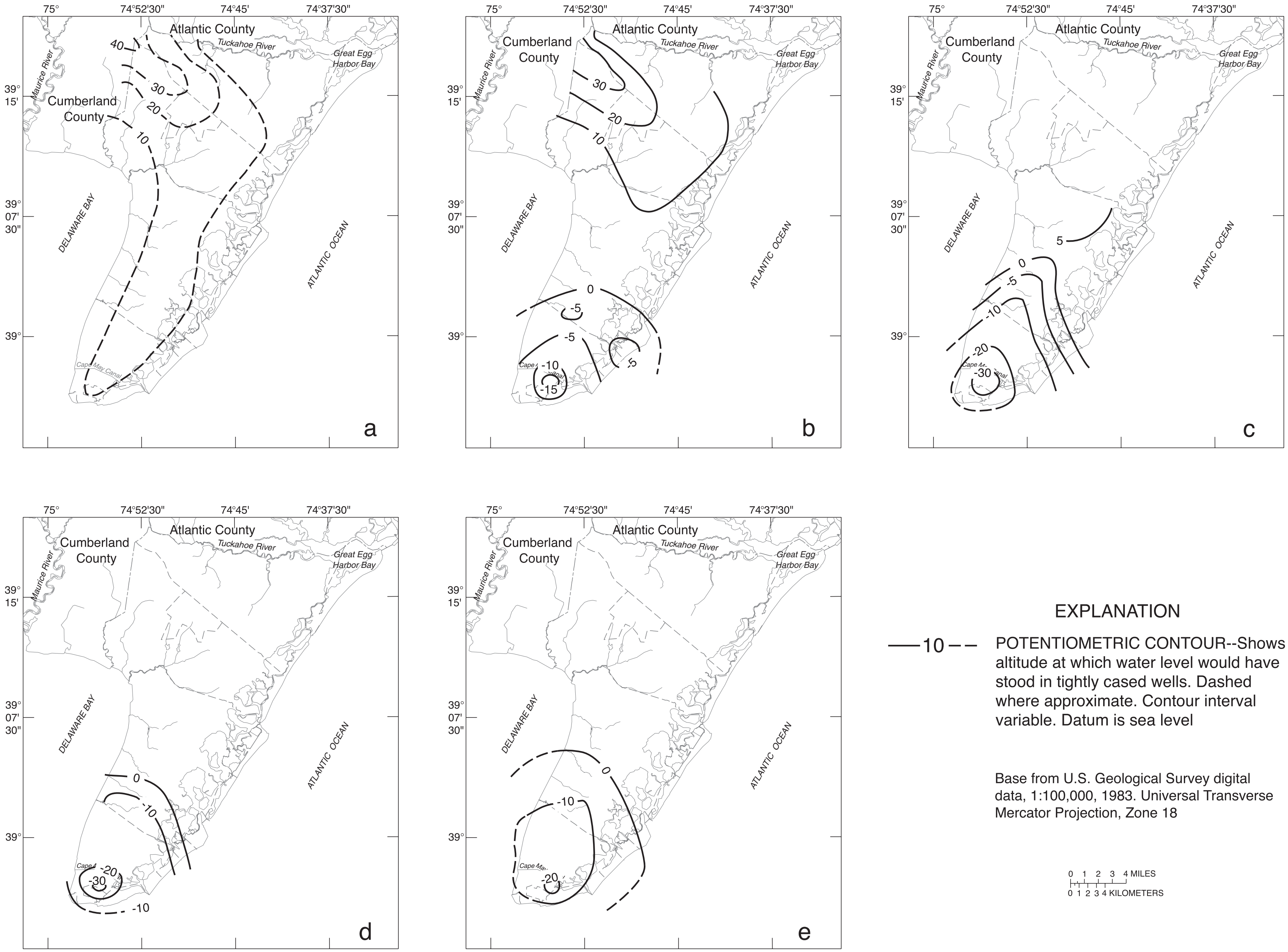


Figure 42. Potentiometric surface of the Cohansey aquifer (a) prior to 1900, (b) January 1958, (c) fall 1978, (d) fall 1983, and (e) fall 1988.

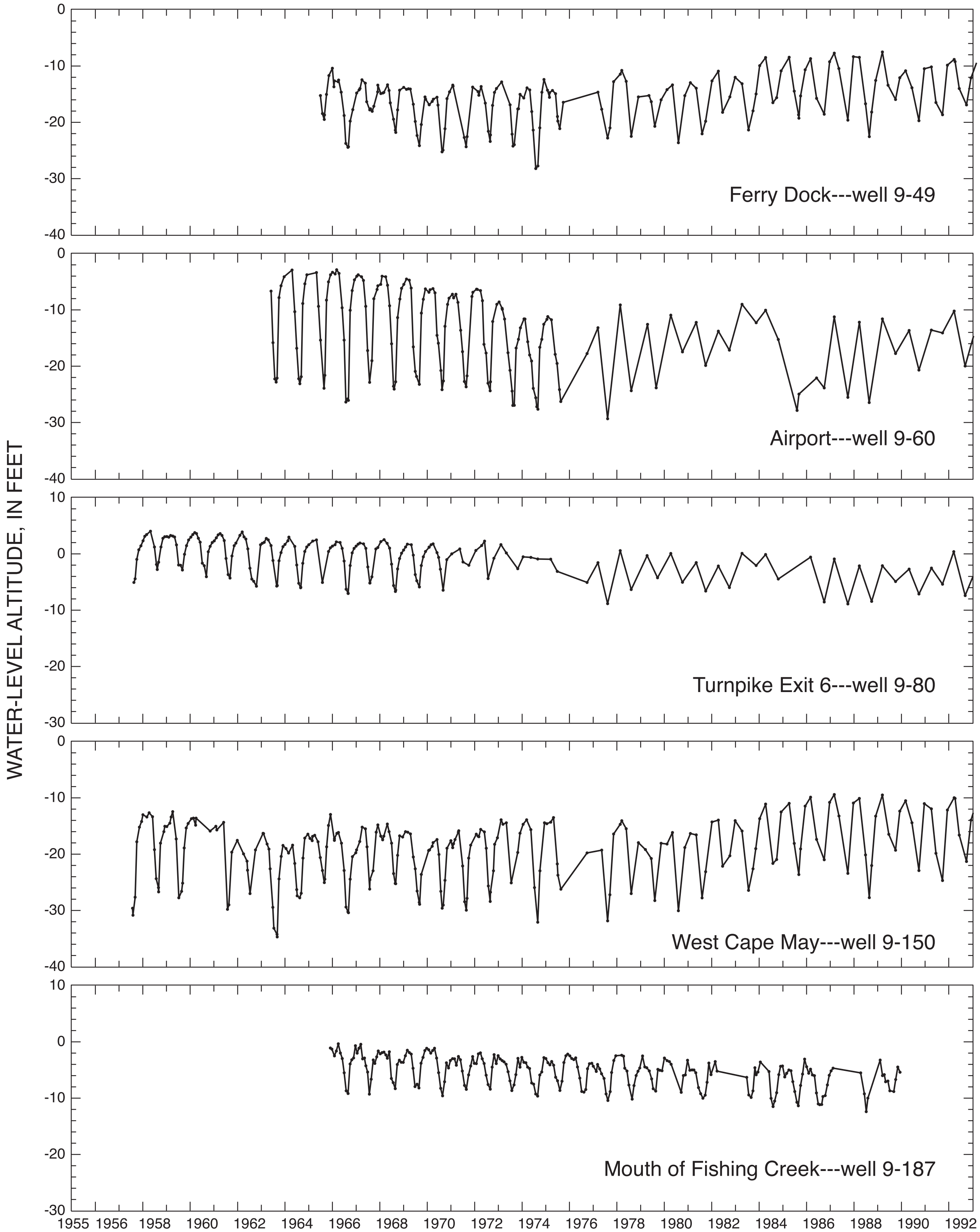


Figure 43. Monthly mean water levels in wells screened in the Cohansey Aquifer, Cape May County, New Jersey. (Well locations shown in figure 40)

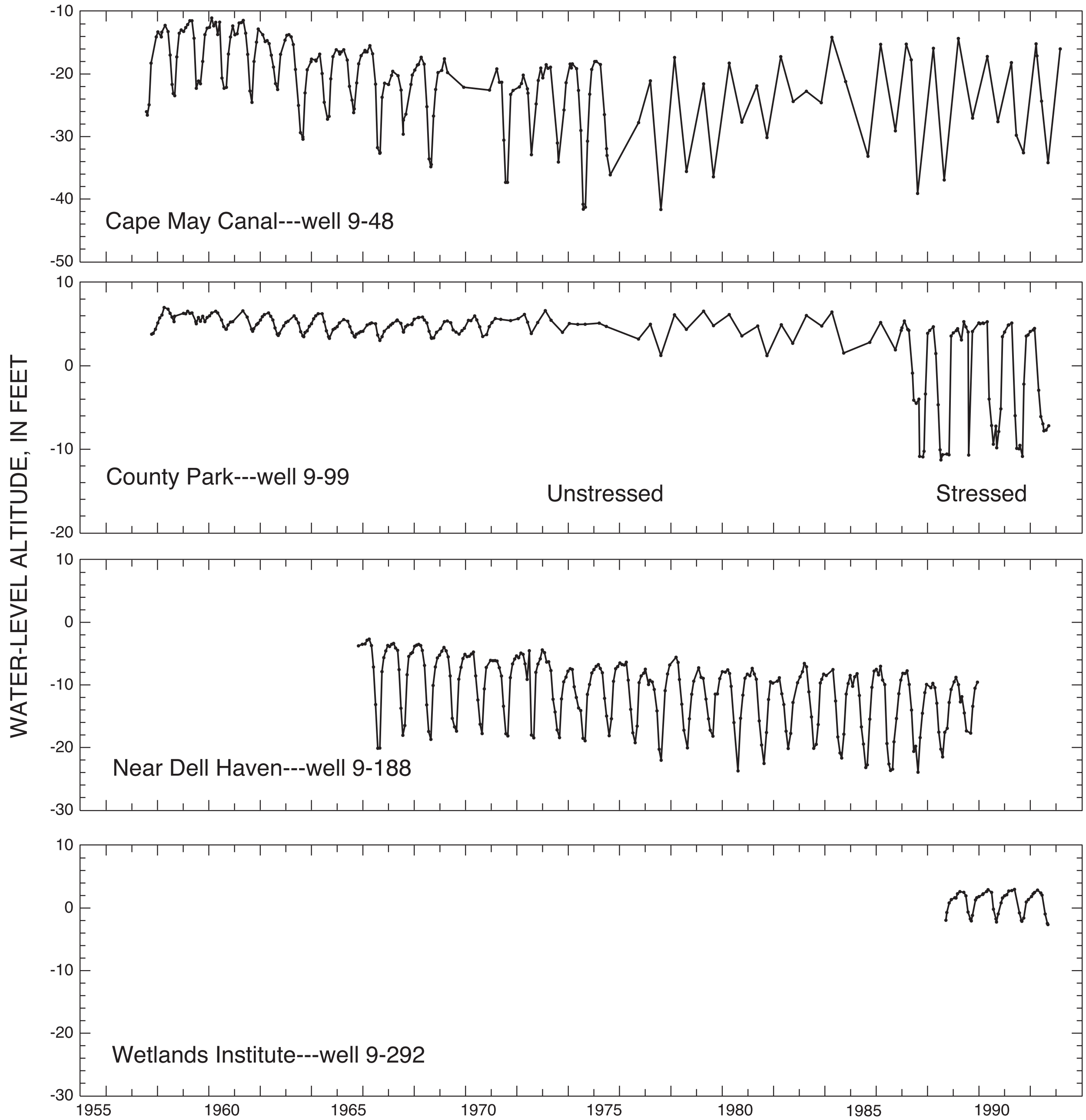


Figure 43. Monthly mean water levels in wells screened in the Cohansey Aquifer, Cape May County, New Jersey. (Well locations shown in figure 40)--Continued.

to the 1970's was a result of (1) the end of the regional drought during the early 1960's, (2) the abandonment of Cape May Point's public-supply wells, and (3) a decrease in withdrawals by Cape May City from its southernmost public-supply well (well 9-14). The increase in mean annual water-level altitudes to -10 ft in the 1980's was caused by the cessation of pumping from industrial-supply wells 9-28 and 9-29 (fig. 7). Water-levels in well 9-49 decreased until 1970, then stabilized because withdrawals from Lower Township MUA supply well 1 (well 9-52) increased until 1970, then remained constant. Mean annual water levels increased in the early 1980's in observation well 9-49 because nearby industrial-supply wells 9-28 and 9-29 were shut off. Water levels decreased in the late 1980's and 1990's when withdrawals from well 9-52 were increased (Cape May City supply well 5). During summer, water levels south of the canal are from 15 to 25 ft lower than water levels during the rest of the year. Summer water withdrawals lowered water-level altitudes to -25 ft in observation well 9-150, -30 ft in well 9-48, and -20 ft in well 9-49 during 1985-90. Seasonal water-level fluctuations in the aquifer north and west of Great Cedar Swamp (fig. 1) likely follow the water-table fluctuations. Water levels in wells screened in the Cohansey aquifer that are more than about 2 miles from supply wells fluctuated about 2 to 3 ft per year during 1955-85 (for example well 9-99, fig. 42).

Prior to development in the early 1900's, ground water in the Cohansey aquifer in the northern part of the county flowed downward from the recharge area along the topographic divides of the county; then laterally into the Tuckahoe River, the ocean, and the bay; and finally upward into these surface-water bodies. In the early 1990's, nearly all water in the aquifer in the northern part of the county continued to flow along this same route. Prior to development in the southern part of the county, ground water flowed downward near the center of the peninsula from recharge areas, then laterally toward the ocean and bay, and finally upward into these water bodies. To summarize, prior to development, ground-water flowed downward along the axis of the peninsula from the recharge areas and upward along the saltwater interface (fig. 37).

The progression of potentiometric-surface maps of the aquifer for 1958, 1978, 1983, and 1988 (fig. 42b-e) shows the northward expansion of the regional cone of depression on the peninsula, the deepening of the cone of depression in the Wildwood mainland well field, and the elimination of the cone of depression originally caused by the pumping of supply wells in the Wildwood island communities. The northward expansion and deepening of the cone of depression is the result of withdrawals from the Wildwood Water Department mainland wells, Lower Township MUA wells, and industrial- and domestic-supply wells. The elimination of the cone of depression under the Wildwood communities is the result of a reduction in withdrawals from the Cohansey aquifer by the Wildwood communities and injection of water into the Cohansey aquifer for storage and recovery.

Rio Grande Water-Bearing Zone

The potentiometric-surface map of the Rio Grande water-bearing zone during April 1991 was developed from water-level measurements made in six wells (fig. 44). This is the first potentiometric-surface map published for the aquifer. Water levels in the aquifer in northwestern Cape May County were above land surface; water in well 9-149 flowed at a slow rate. In eastern Cape May County, an elongated cone of depression is centered below the barrier island communities, and an almost circular cone of depression is centered below the Wildwood mainland well field. The elongated cone of depression under the barrier islands is derived from water levels measured in well 9-305 and reflects the large area over which induced leakage of water from the Rio Grande water-bearing zone into the Atlantic City 800-foot sand occurs. As a result, this elongated cone of depression is categorized as a sympathetic cone of depression. The circular cone of depression centered below the Wildwood Water Department mainland well field was caused by the pumping of well 9-67 (fig. 8).

Annual water-level altitudes in well 9-304 (fig. 45) ranged from -7 ft to -24 ft during 1990-91. In spring 1991, water-levels in well 9-71 declined from -9 ft to about -45 ft.

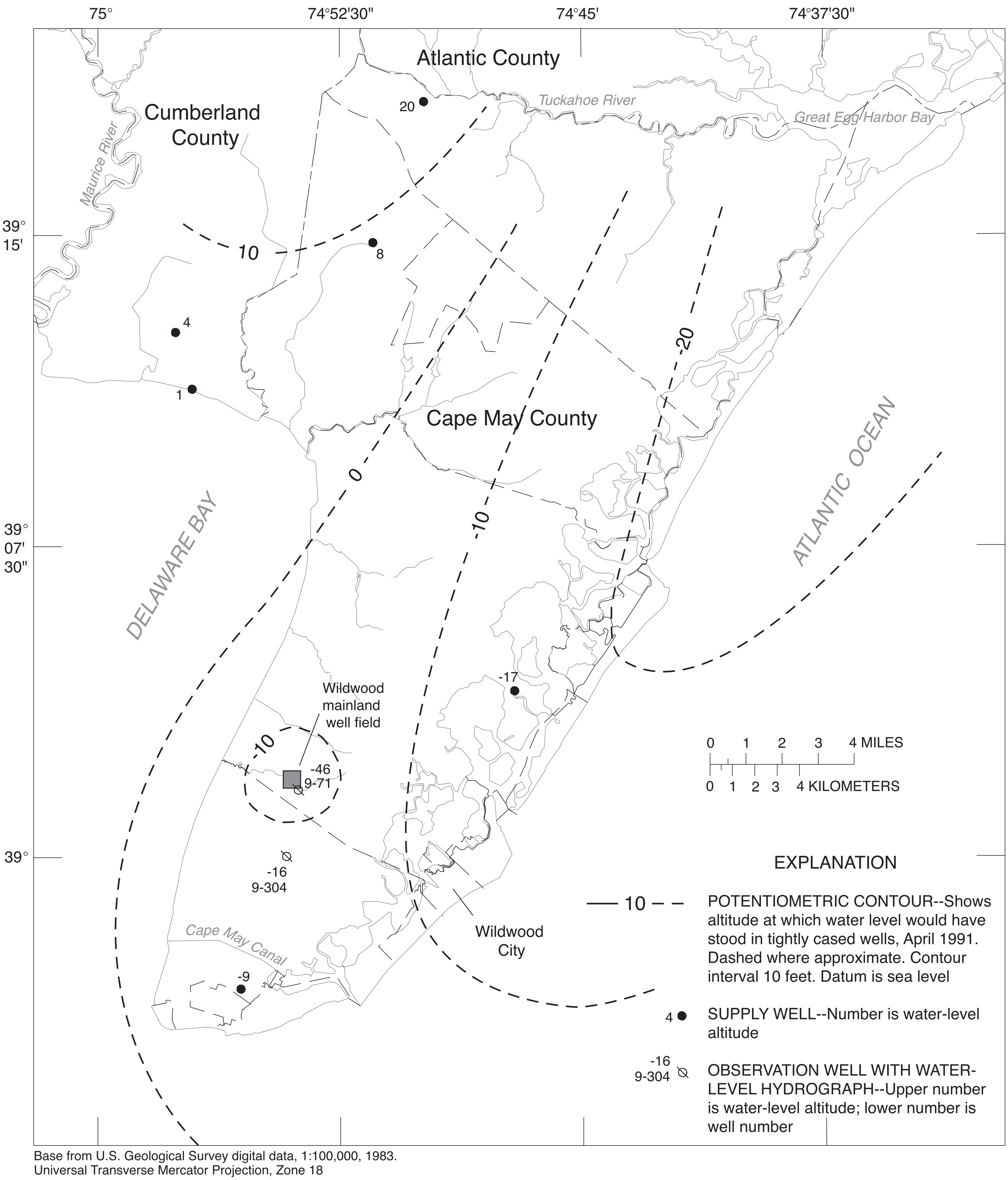


Figure 44. Potentiometric surface of the Rio Grande water-bearing zone, Cape May County, April 1991.

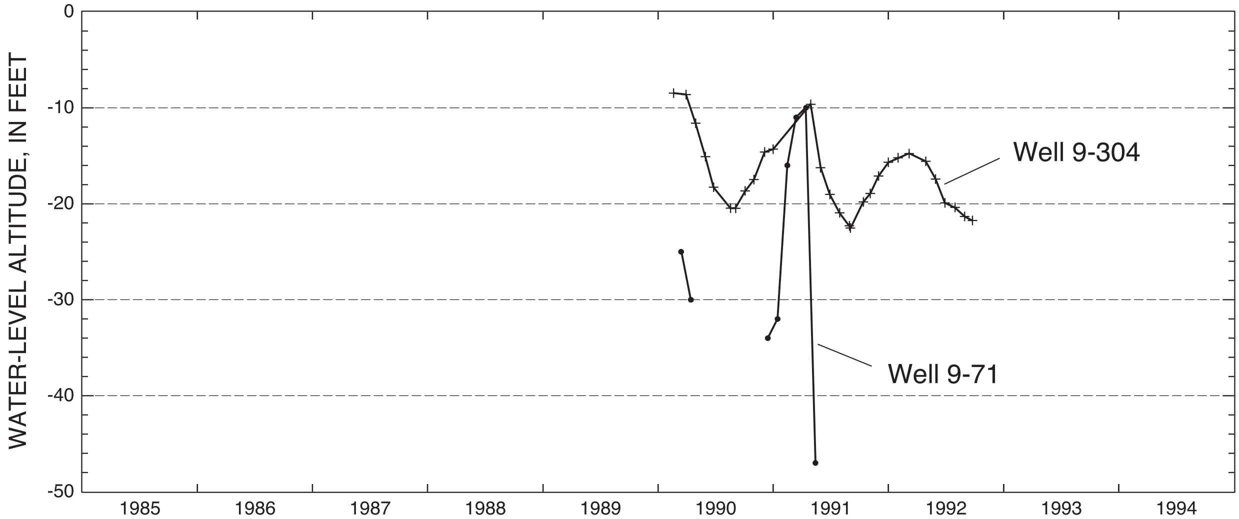


Figure 45. Monthly mean water levels in wells screened in the Rio Grande water-bearing zone, Cape May County, New Jersey.

The sectional view of predevelopment ground-water flow (fig. 38a) shows a general flow path from recharge areas in Cumberland and western Atlantic County toward the ocean and bay, then upward into the ocean and bay. The map view (fig. 44) and sectional view (fig. 38b) for 1991 show that water in the aquifer in northern Cape May County flows radially toward the barrier islands, then downward into the Atlantic City 800-foot sand. Ground water in southern Cape May County flows radially inward toward public-supply well 9-67 at the Wildwood Water Department mainland well field (figs. 8 and 44). The ground-water flow gradient between observation wells 9-304 and 9-71 ranged from 1.5 to 20 ft/mi annually as a result of fluctuations in annual withdrawals at the Wildwood mainland well field.

Atlantic City 800-Foot Sand

The direction of ground-water flow in the Atlantic City 800-foot sand prior to development was from recharge areas in the interior of Cumberland and Atlantic Counties toward the ocean and bay, then upward into the ocean and bay (Zapecza and others, 1987, p114). The potentiometric surface prior to development was above sea level. When wells were first drilled in the aquifer in the early 1890's the water-level altitude was +24 ft in Ocean City and +15 ft in Wildwood (fig. 46a). Four potentiometric-surface maps of the aquifer show that water-level altitudes declined in 1958, 1978, 1983, and 1988 as a result of development (Gill, 1962a; Walker, 1983; Eckel and Walker, 1986; Rosman and others, 1996, respectively) (fig. 46b-e). The elongated cone of depression that underlies the barrier islands was first evident in the 1958 potentiometric-surface map (fig. 46b). At that time, the water-level altitudes in Avalon and Ocean City were about -42 and -49 ft. The -40-ft contour that surrounds selected supply wells on the barrier islands can be used as a reference line to indicate the expansion of the cone of depression around these communities. The fall 1978 potentiometric-surface map (fig. 46c) shows that the -40-ft contour line has expanded and encompasses the northern barrier island communities. The fall 1983 and 1988 maps (figs. 46d and 46e) show that the -40-ft-contour has continued to expand to include more of the barrier island communities. The expanded cone of depression resulted from increased drawdown due to increased water withdrawals. Withdrawals increased from 1,100 Mgal/yr in 1960 to about 2,000 Mgal/yr in 1978, and during 1978-88, water withdrawals increased to 2,200 Mgal/yr (fig. 31a).

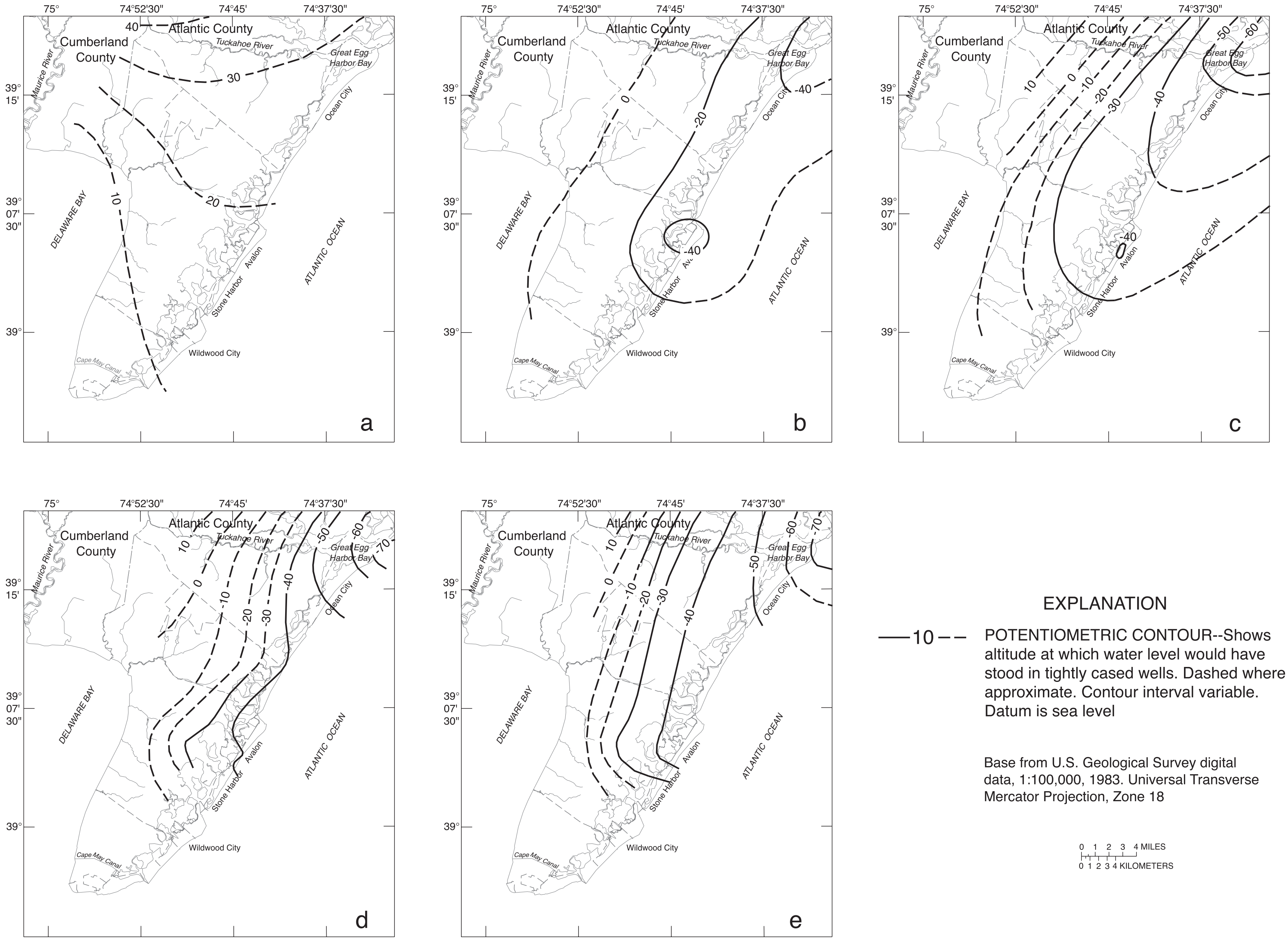


Figure 46. Potentiometric surface of the Atlantic City 800-ft sand during (a) predevelopment, (b) January 1958, (c) fall 1978, (d) fall 1983, and (e) fall 1988.

The potentiometric-surface map for April 1991 (fig. 47) was developed from water levels measured in 34 wells. Twenty-five wells in Ocean City, Sea Isle City, Upper Township, and Middle Township are screened in the upper part of the aquifer. Six wells in Stone Harbor and Avalon are screened in the lower part of the aquifer, and the remaining wells are screened in both the upper and lower part of the aquifer. The solid line (fig. 47) shows the potentiometric surface in the upper part of the aquifer, and the dashed line shows the potentiometric surface in the lower part of the aquifer. The map is intended to show the probable vertical movement between the upper and lower parts of the Atlantic City 800-foot sand. In Ocean City, the vertical gradient between the upper and lower parts is upward because all the supply wells in Ocean City tap the upper part of the Atlantic City 800-foot sand. In Avalon and Stone Harbor the vertical gradient is downward because all wells tap the lower part of the Atlantic City 800-foot sand. Horizontal flow is radially inward toward the public-supply wells of the barrier island communities.

During September 5-9, 1989, water levels were measured to define the potentiometric surface for the aquifer at the end of the summer pumping season (fig. 48). Water levels were lowest and the cone of depression was broadest and deepest during that time of the year. The measurements show that water-level altitudes declined in the Stone Harbor-Avalon area to about -60 ft and in the Ocean City area to about -100 ft. During summer, the lateral ground-water flow gradient in the aquifer was about 6 ft/mi. During fall, winter, and spring, the gradient decreased to about 2 ft/mi.

Long-term water levels in the study area show a general decline since the 1890’s. In 1893, water-level altitudes in Ocean City were +24 ft and in Sea Isle City were +16 ft (Zapecza and others, 1987). The hydrographs for wells 9-115 and 9-131 show water-level altitudes in 1930 in Ocean City ranged from -30 to -50 ft, and in Sea Isle City they ranged from 0 to -5 ft (fig. 49). Therefore, water levels declined as much as 74 ft in Ocean City and as much as 21 ft in Sea Isle City from 1893 to 1930. The average annual decline during this time was about 2 ft/yr for Ocean City and about 0.6 ft/yr for Sea Isle City. The hydrographs for wells 9-115 and 9-131 show relatively constant water levels from about 1928 to 1946 (fig. 49). This may be the result of constant annual water withdrawals or at least no annual increase in withdrawals during the Great Depression and World War II. During 1946-60, the annual high water level declined to about -20 ft in Ocean City. This is an annual rate of decline of about 1.4 ft/yr.

The seasonal water levels in well 9-115 fluctuated about 30 ft during 1950-56. The large seasonal fluctuations resulted from high-volume pumping at a nearby public-supply well. Seasonal water-level fluctuations in well 9-115 decreased with the installation of additional production wells in Ocean City in 1957. The water-level recorder was removed from well 9-115 in 1959. A water-level recorder was installed on well 1-578 in 1959 at Jobs Point, Atlantic County, 2 mi northwest of Ocean City (fig. 8). High water levels during 1959-92 ranged from -21 to -50 ft, and low water levels ranged from -35 to -75 ft (fig. 49). The decline during the early 1960’s could be the result of increased water withdrawals during the drought of the early 1960’s.

Hydrographs for observation wells 9-302, 9-306, and 9-79 (fig. 49) show the summer decline in water levels that resulted from increased water withdrawals. The closer the observation well is to the public-supply wells, the greater the seasonal range in water levels. Well 9-79 (fig. 8) is less than 3 miles from the public-supply wells of Stone Harbor, and water-level altitudes fluctuated seasonally about 20 ft from -30 to -50 ft (fig. 49). Well 9-306 is 12 miles from the public-supply wells, and water-level altitudes fluctuated seasonally about 2 ft from -17 to -19 ft (fig. 49).

Section A-A’ shows the predevelopment water levels and ground-water flow path for the deep freshwater aquifers (fig. 38a). During predevelopment, ground-water flow began in the interior part of the New Jersey Coastal Plain, moved toward the ocean and bay, then upward.

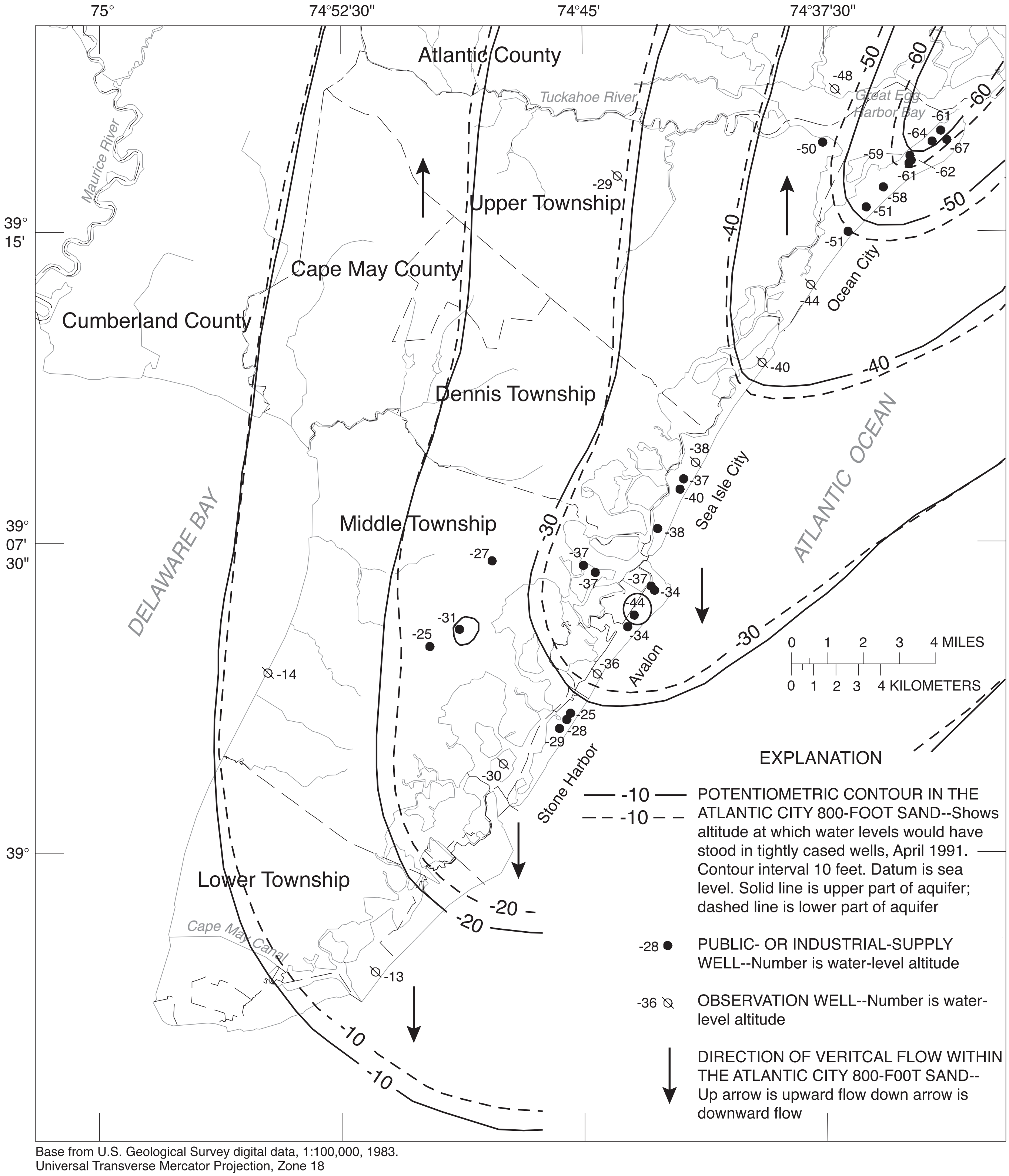


Figure 47. Potentiometric surfaces of the upper and lower parts of the Atlantic City 800-foot sand, Cape May County, New Jersey, April 1991.

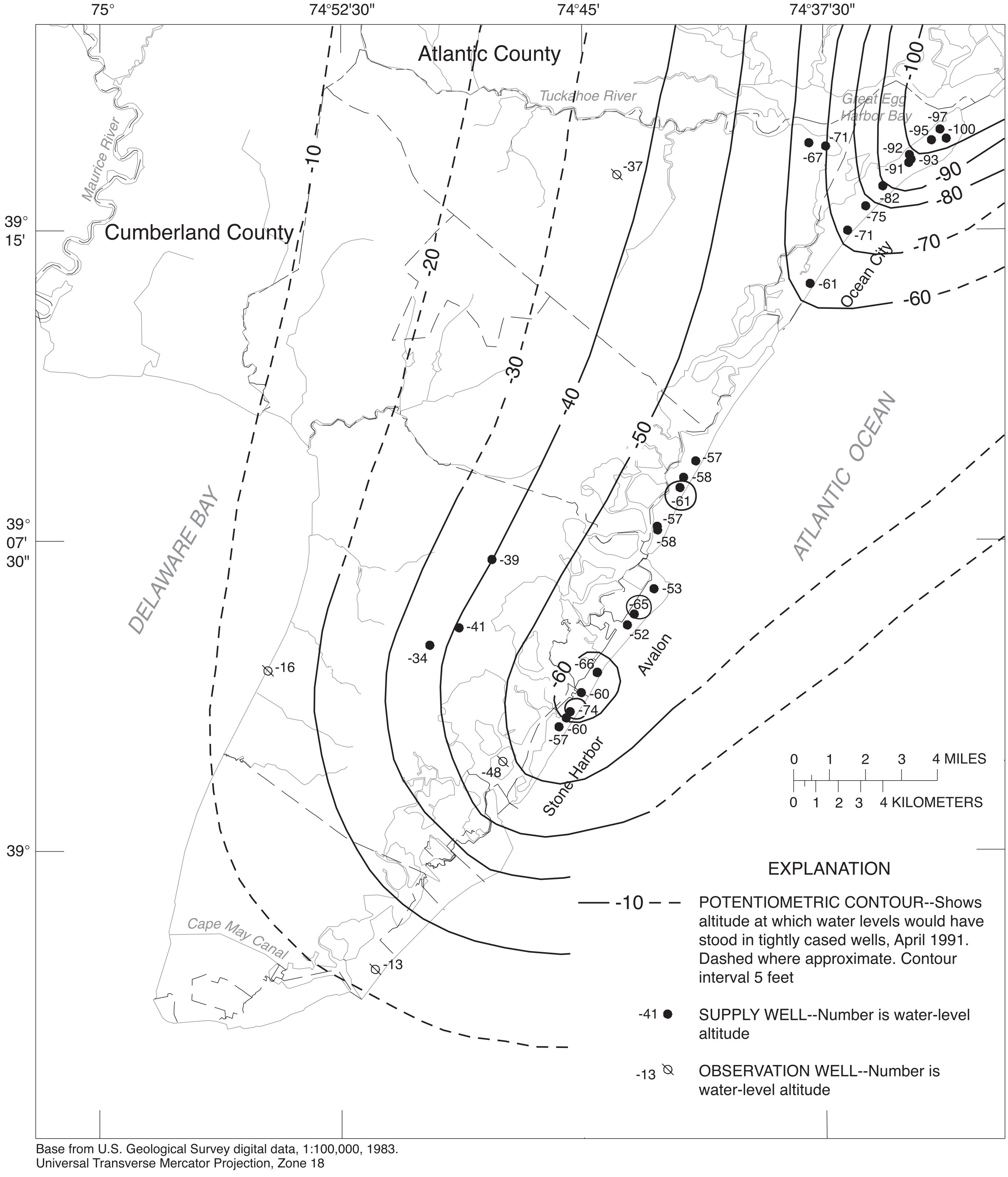


Figure 48. Potentiometric surface of the Atlantic City 800-foot sand, Cape May County, New Jersey, September 5-9, 1989.

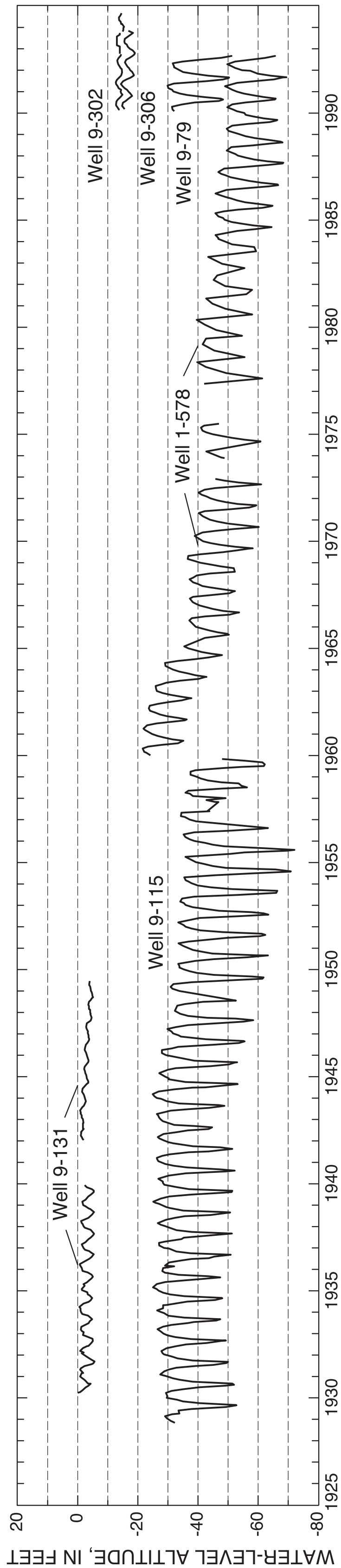


Figure 49. Monthly mean water levels in wells screened in the Atlantic City 800-foot sand, Cape May County, New Jersey, 1925-95.

WATER QUALITY AND SALTWATER INTRUSION

Results of analyses of ground-water samples were used to (1) map the location of the saltwater front and determine areas where active saltwater intrusion is occurring in the five aquifers, (2) delineate areas of high iron concentrations (greater than 0.3 mg/L) in the five aquifers, and (3) delineate areas of high nitrate concentrations (greater than 10 mg/L) in the water-table aquifer. The location of the saltwater front in each aquifer was determined by plotting the concentrations of chloride, then interpolating the position of the 250-mg/L line of equal chloride concentration. The location of the saltwater front is supplemented by plotting the concentrations of sodium in selected wells and interpolating the position of the 50-mg/L line of equal sodium concentration. These concentrations are the NJDEP secondary maximum contaminant levels for drinking water. The saltwater front is defined in this report as the location of the 250-mg/L contour line for chloride. Active saltwater intrusion in the aquifers is considered to be occurring in areas where the chloride concentration has increased during the 1900’s. Chloride concentrations greater than 250-mg/L cause the taste of the water to be objectionable and contribute to the deterioration of domestic and public plumbing. The health effects of elevated sodium concentrations are controversial; however, persons placed on low-sodium diets must include sodium concentrations from drinking water in an assessment of their daily intake (Sheridan, 1997).

Iron is ubiquitous in the aquifers of the county. The NJDEP secondary maximum contaminant level for iron is 300 µg/L. Higher values compromise the aesthetic potability of the water by causing a bitter, astrigent or metallic taste and by causing red staining of clothes, washbasins, and other surfaces that it comes in contact with. In addition, iron can cause encrustation of supply wells, thereby, reducing their specific capacity (Sheridan, 1997).

Nitrate at concentrations greater than 10 mg/L as nitrogen, the NJDEP maximum contaminant level, was found only within the Holly

Beach water-bearing zone. High concentrations of nitrate, when ingested, have demonstrated adverse toxic effects on infants (Sheridan, 1997). In Cape May County, high concentrations of nitrate may be indicative of contamination from farming activities and from septic systems.

The NJDEP maintains a database of known ground-water contamination sites (New Jersey Department of Environmental Protection, 1994). These sites were avoided when water-quality samples were collected from the Holly Beach water-bearing zone. Water-quality samples were collected in heavily populated areas, agricultural areas, and near the Cape May Canal, but attempts were made to avoid areas of known or obvious contamination.

Water samples were collected and analyzed to develop a base line to assess possible changes in water quality that could result from human activity. Selected water-quality data are presented in this report in tables, maps, and graphs. Additional water-quality data are published in a series of USGS reports, Water Resources Data, New Jersey, Water Year 1960-94. Data on major ions, trace elements, pH, temperature, dissolved oxygen, alkalinity, and nutrients are collected by USGS personnel and stored in the National Water Information Service water-quality database at the New Jersey District office in West Trenton.

Water-quality data for each constituent for which a primary and (or) secondary drinking water standard for public drinking-water supplies has been established are not presented in this report. Much of this data is available from the NJDEP Bureau of Safe Drinking Water or from the well owners.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone is the most easily recharged, but also the most easily contaminated, aquifer in Cape May County. The water is fresh and potable in most upland areas; however, chloride and sodium levels have increased in some areas where there is a high density of septic systems, in parts of Villas because of saltwater intrusion, and near spoils piles along the Cape May Canal. Iron concentrations are higher on the peninsula than on the mainland, and nitrate concentrations can be high in agricultural areas and in areas with a high density of septic systems.

In the saltwater wetlands, the top of the aquifer is flooded with seawater during each tidal cycle, thereby, keeping at least the upper part of the aquifer salty. In freshwater wetlands, in lowland areas, and on the barrier islands, the top of the aquifer may be flooded with seawater for a short time during storms. In freshwater wetlands that are located upland or far inland, the top of the aquifer is rarely flooded with seawater. Flooding with seawater and the heavily developed nature of the barrier islands preclude the use of the Holly Beach water-bearing zone on the barrier islands as a source of potable water. None-the-less, some water withdrawn from the aquifer on the barrier islands is still used for irrigation.

Contamination of freshwater in the water-table aquifer may be naturally occurring or may result from human activities. The contamination may be site specific (point source) or area wide (nonpoint source). Point sources of ground-water contamination typically cover five acres or less and include hazardous waste sites, industrial sites, illegal dump sites, accidental spills of chemicals and oils, and leaking underground storage tanks. Point sources typically contaminate relatively small volumes of the aquifer; however, a point source can have a wide variety of contaminants at concentrations much greater than background levels. Nonpoint source ground-water contamination sites typically are densely populated communities with or without domestic septic systems, agricultural areas that frequently or excessively use fertilizer, and coastal areas that experience seawater flooding during storm events. The Cape May Canal, a sea level canal dug in the mid-1940’s, can be considered to be a nonpoint source of ground-water contamination. Nonpoint sources typically contaminate large areas, and the contaminants can be present in either low or high concentrations.

There are 104 known ground-water contamination sites in Cape May County (New Jersey department of Environmental Protection, 1994). The following list itemizes the number of known ground-water contamination sites by community.

Avalon Borough	4
Sea Isle City	3
Cape May City	6
Stone Harbor Borough	1
Cape May Point Borough	0
Upper Township	14
Dennis Township	4
West Cape May Borough	1
Lower Township	14
Wildwood City	12
Middle Township	25
Wildwood Crest Borough	2
North Wildwood City	1
Woodbine Borough	3
Ocean City	14

The history of these sites along with the type, location, and movement of contamination, and remediation efforts at each of these sites is discussed in the various investigative reports available from the Site Remediation Program of the NJDEP.

Chloride, Sodium, and Saltwater Intrusion

To map ongoing saltwater intrusion, ground-water samples have been collected and their chloride concentrations have been analyzed and recorded by the USGS since Gill's (1962) investigation of the water resources in the county. Concentrations of dissolved chloride in water samples from 62 wells ranged from less than 1 to 22,000 mg/L (table 8). Additional water-quality data for the Holly Beach water-bearing zone are available from the USGS. (Data are on file at the USGS, N.J. District office in West Trenton) The location of selected wells, the chloride concentration at each well, the limit of the marine and estuarine wetland areas, and the location of the saltwater front (250-mg/L chloride contour) are shown in figure 50. Water in the Holly Beach water-bearing zone inland of the 250-mg/L chloride contour is fresh, and ground water seaward of the 250-mg/L chloride contour typically is salty but may be fresh in some areas. Freshwater lenses in the Holly Beach water-bearing zone exist under the barrier islands and in certain parts of the saltwater marshland. The freshwater lenses under the islands are used by some land owners for non-potable purposes such as watering lawns and washing cars. Additional small areas of freshwater in the Holly Beach water-bearing zone beneath saltwater wetlands resulted from local clay lenses that extend from the mainland to below the saltwater wetlands; however, without fine-scale hydrogeologic framework information and water-quality data, it is difficult to pinpoint the location of these small freshwater lenses.

Chloride concentrations of 50 to 1,400 mg/L were measured in ground-water samples from seven sites on the mainland (fig. 50). Water samples collected in Marmora and Cape May Court House were 110 and 81 mg/L, respectively; these high chloride concentrations probably were caused by effluent from nearby septic systems. The high chloride concentration (91 mg/L) in southern Middle Township is likely the result of seawater flooding during storms because the well is within 100 ft of a tidal estuary. Water samples from five observation wells along Delaware Bay in Lower Township and Cape May Point contained chloride concentrations in excess of 250 mg/L, which is most likely the result of seawater intrusion.

Since 1980, the owner of one pond and a few domestic well owners near the Cape May Canal and many domestic well owners in Villas have reported excessive chloride in water from wells that tap the Holly Beach water-bearing zone. The pond is on a sod farm in western Dennis Township. The pond owner reported that during Hurricane Gloria in 1985, one irrigation pond filled with water from Delaware Bay (Mr. Bohm, Bohm Sod Farm, oral commun., 1990). The chloride concentration in the pond water was not measured after the hurricane but was thought to be the same as that in Delaware Bay, about 17,000 mg/L. Because the water was too salty for sod irrigation, the sod farm discontinued use of the pond. The

Table 8. Water-quality constituents in samples from selected wells screened in the Holly Beach water-bearing zone, Cape May County, New Jersey

[Additional water-quality data are published in a series of reports from 1960 to 1993, Water Resources Data, New Jersey; number below constituent name is parameter code used to identify the constituent, property, or characteristic in the U.S. Geological Survey water-quality database (NWIS); µS/cm, microsiemens per centimeter at 25^o Celsius; mg/L milligrams per liter; µg/L, micrograms per liter; g/L, grams per liter]

Station Number	Date	Spe-cific con-duct-ance (µS/cm) 00095	pH, water, whole field (Stand-ard units) 00400	Chlo-ride, dis-solved (mg/L as Cl) 00940	Sodium, dis-solved (mg/L as Na) 00930	Calcium, dis-solved (mg/L as Ca) 00915	Nitro-gen, NO^2+NO^3, dis-solved (mg/L as N) 00631	Sulfate, dis-solved (g/L as SO4) 00945	Iron, dis-solved (µg/L as Fe) 01046	Manga-nese, dis-solved (µg/L as Mn) 01056
090020	03-19-92	1,907	6.5	580	251.7	--	--	--	--	--
090070	08-07-90	228	5.8	26	--	--	--	--	--	--
090081	03-18-92	309	5.2	91	50	4	<0.05	17	1,600	58
090098	08-25-92	123	5.4	6	4	13	--	37	480	120
090190	05-27-87	91	5.7	17	--	--	--	--	--	--
090191	05-27-87	700	--	130	--	--	--	--	--	--
090195	05-20-87	498	6.6	95	--	--	--	--	--	--
090196	05-21-87	1,460	6.9	370	--	--	--	--	--	--
090197	05-21-87	1,380	7.2	330	--	--	--	--	--	--
090198	05-12-87	255	6.0	38	--	--	--	--	--	--
090199	05-12-87	215	4.8	19	--	--	--	--	--	--
090200	05-13-87	185	6.0	30	--	--	--	--	--	--
090201	05-13-87	162	7.7	19	--	--	--	--	--	--
090202	05-13-87	980	9.0	330	--	--	--	--	--	--
090203	05-14-87	13,800	7.3	6,300	--	--	--	--	--	--
090204	05-15-87	7,100	--	2,700	--	--	--	--	--	--
090205	05-15-87	4,500	--	1,600	--	--	--	--	--	--
090212	03-17-92	4,290	6.9	1,400	812.5	--	--	--	--	--
090218	03-17-92	3,680	6.8	730	392	--	--	--	--	--
090234	07-30-92	101	4.8	15	9	2	.75	6.7	69	15
090240	08-13-92	117	4.8	24	10	3	.92	7.1	9	310
090278	09-02-92	371	6.9	31	69	.19	1.7	33	58	3
090295	09-07-90	48,000	6.9	21,000	11,000	110	--	2100	6,100	260
090321	03-19-92	193	8.4	10	7	30	<.05	8.4	39	130
090322	04-08-92	122	6.2	9	5	3.3	.07	8.6	4,800	230
090323	06-24-92	115	5.1	17	8	5.3	1.6	16	5	30
090325	07-30-92	163	4.8	18	13	7.3	10	1.0	9	8
090326	07-27-92	491	8.0	32	33	52	12	92	10	65
090327	06-23-92	307	5.8	34	20	16	5.6	29	5	310
090329	06-23-92	172	4.5	10	6	15	1.2	47	9	47
090331	07-28-92	116	5.7	9	7	4.7	.34	23	310	55
090332	07-28-92	52,000	6.9	22,000	11,000	--	--	--	--	--
090333	07-28-92	152	6.3	13	7	14	<.05	12	2,600	200
090334	06-23-92	154	4.9	15	11	7.7	.05	31	7	40
090335	07-29-92	89	5.2	9	5	4.8	.47	14	14	47
090336	06-24-92	155	5.7	9	8	10	6.2	14	4	4
090340	06-24-92	74	4.7	5	4	1	<.05	11	<3	5
090342	06-25-92	140	5.7	23	14	--	--	--	--	--
090345	06-22-92	127	4.3	19	9.2	3.1	3.50	12	<3.0	110
090347	06-24-92	63	4.6	7	4	.24	.4	4.1	71	11
090348	07-29-92	143	4.5	16	10	5.2	1.2	25	12	31
090349	09-05-90	83	5.8	6	4	1.5	<.1	10	5,000	130
090351	10-08-92	62	5.5	6	8	.59	--	5	16	10
090361	09-03-92	179	5.9	11	8	15	5.3	22	180	15
090362	09-03-92	185	5.2	16	15	12	1.4	36	9	110
090363	09-02-92	231	5.5	22	37	.02	4.5	32	6	<1
090365	09-02-92	156	5.3	26	16	2.6	.59	13	20	100
090368	09-04-92	249	7.0	20	13	25	<.05	47	8,200	260
090371	07-27-92	1,050	6.7	89	92	8.8	1.00	.30	33,000	59
090373	08-12-92	--	5.1	11	9	.70	.51	6.5	9	41
090374	08-10-92	63	4.7	7	4	1.0	.92	5.1	4	13
090375	08-11-92	147	4.6	.1	14	4.9	3.6	9.7	7	12
090377	08-12-92	69	4.9	12	7	.82	<.05	1.2	10	6
090378	08-11-92	174	4.8	.1	6	8.0	5.5	<.10	10	42
090379	08-12-92	60	4.6	7	4	.43	.16	4.6	14	5
090380	08-13-92	182	4.5	28	12	3.2	3.7	14	62	27
090381	08-11-92	414	4.8	110	28	16	.55	23	15	530
090384	10-15-92	78	5.1	9	4	1.9	.96	1.0	23	3
090386	09-02-92	239	5.3	44	26	8.6	2.4	24	21	80
090387	09-03-92	172	5.2	29	16	4.6	.65	18	59	140
090388	09-09-92	64	5.3	10	6	1.7	<.05	9.0	50	2
090389	09-02-92	347	5.2	81	43	9.3	2.9	15	30	360
090391	08-13-92	69	5.9	5	4	2.8	.36	9.6	2,100	17
090421	08-13-92	58	4.7	4	2	2.6	.27	9.6	7	16

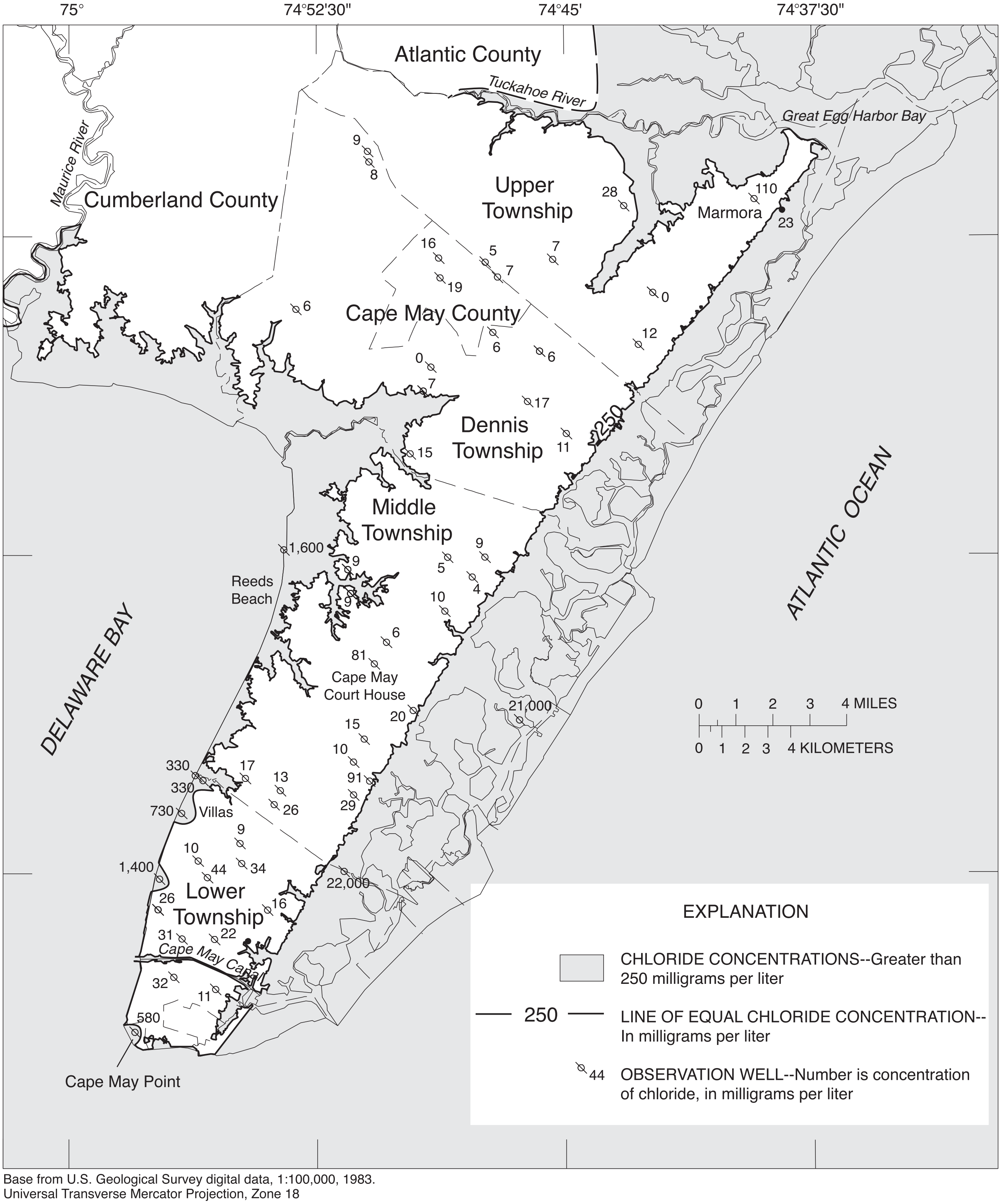


Figure 50. Chloride concentrations in ground-water samples from the Holly Beach water-bearing zone, Cape May County, New Jersey, 1989-92.

chloride concentration of the water in the pond could have decreased since then. Saltwater contamination of domestic wells on the south side of Cape May Canal 2.2 miles from Delaware Bay side of the canal was reported by the Cape May County Health Department (Raymond Chadwick, Cape May County Health Department, written commun., 1992). Water from domestic-supply wells became salty after saltwater-laden spoils from canal dredging operations were deposited on land adjacent to the wells. In 1990, prior to the dredging and spoils disposal, the chloride concentration of water from the domestic-supply wells was less than 50 mg/L. In 1992, about 2 months after the canal dredging began, the chloride concentration increased to more than 1,000 mg/L. The county and personnel involved in the dredging operation are studying ways to prevent this from reoccurring in future dredging operations. Saltwater contamination in Villas was first reported by the Cape May County Health Department and Planning Board (1985) after a number of domestic-well owners in the Villas complained of salty tasting water during the late 1960's. Most domestic wells in Villas tap the Holly Beach water-bearing zone and the estuarine sand aquifer. Many of these wells near Delaware Bay are contaminated with chloride concentrations of more than 200 mg/L. The county report does not differentiate between the aquifers nor does it conclude whether the well water is contaminated by seawater or by salty effluent from the septic systems in the densely settled community of Villas. The high chloride concentrations in ground water may be a combination of both factors.

Water samples were collected at three drive-point locations. Drive points 9-195 to 9-197 and 9-198 to 9-202 are located at two sites in northern Villas. The chloride concentrations in the water samples increased with depth at both of these sites. This shows that freshwater overlies saltwater, and it could indicate that the wedge of saltwater is moving from the bay into the aquifer. Drive points 9-203 to 9-205 are located at a site near Reeds Beach; chloride concentrations here decreased with depth. This indicates that freshwater is discharging some distance off shore, and it could indicate that the frequent tidal floods and storms introduce chloride to the aquifer when salty surface water moves vertically downward from land surface.

Concentrations of dissolved sodium in the Holly Beach water-bearing zone ranged from 2 to 11,000 mg/L (table 8). The locations of the ground-water-sampling sites, the sodium concentration in each water sample, the location of the 50-mg/L sodium contour line, and the areas where sodium concentrations are greater than and less than 50 mg/L are shown in figure 51. The 50-mg/L sodium contour line and the 250-mg/L chloride contour line are in the same location (fig. 50 and 51). Ground water inland from the 50-mg/L sodium line meets the NJDEP secondary maximum contaminant level for sodium, and ground water seaward of the 50-mg/L sodium line exceeds the NJDEP standard. Sodium concentrations in most areas of the mainland ranged from 2 to almost 40 mg/L. Water samples collected from seven of the sites contained sodium concentrations greater than 40 mg/L. Two sites in Middle Township that had high chloride concentrations also had high sodium concentrations. These sites were also affected by seawater or effluent from septic systems. The site in Lower Township with a sodium concentration of 69 mg/L is close to septic systems (fig. 51). Two sites along the Delaware Bay shoreline in Lower Township and one in Cape May Point had sodium concentrations of 250 to 810 mg/L. These sites also had high concentrations of chloride, probably as a result of seawater intrusion.

A ground-penetrating radar survey was conducted on the dirt access road to Reeds Beach to show the configuration of the saltwater-freshwater interface in the aquifer. The top of the interface is where the saltwater wetlands meet the forest edge and the interface becomes deeper in the inland direction. The interface meets the base of the Holly Beach water-bearing zone about 600 ft from the edge of the forest (Data are on file at the USGS, New Jersey District office in West Trenton).

Gill (1962a, p.138) shows that the chloride concentrations in the Holly Beach water-bearing zone were less than 50 mg/L except in Cape May Point and in the saltwater wetlands. Data on

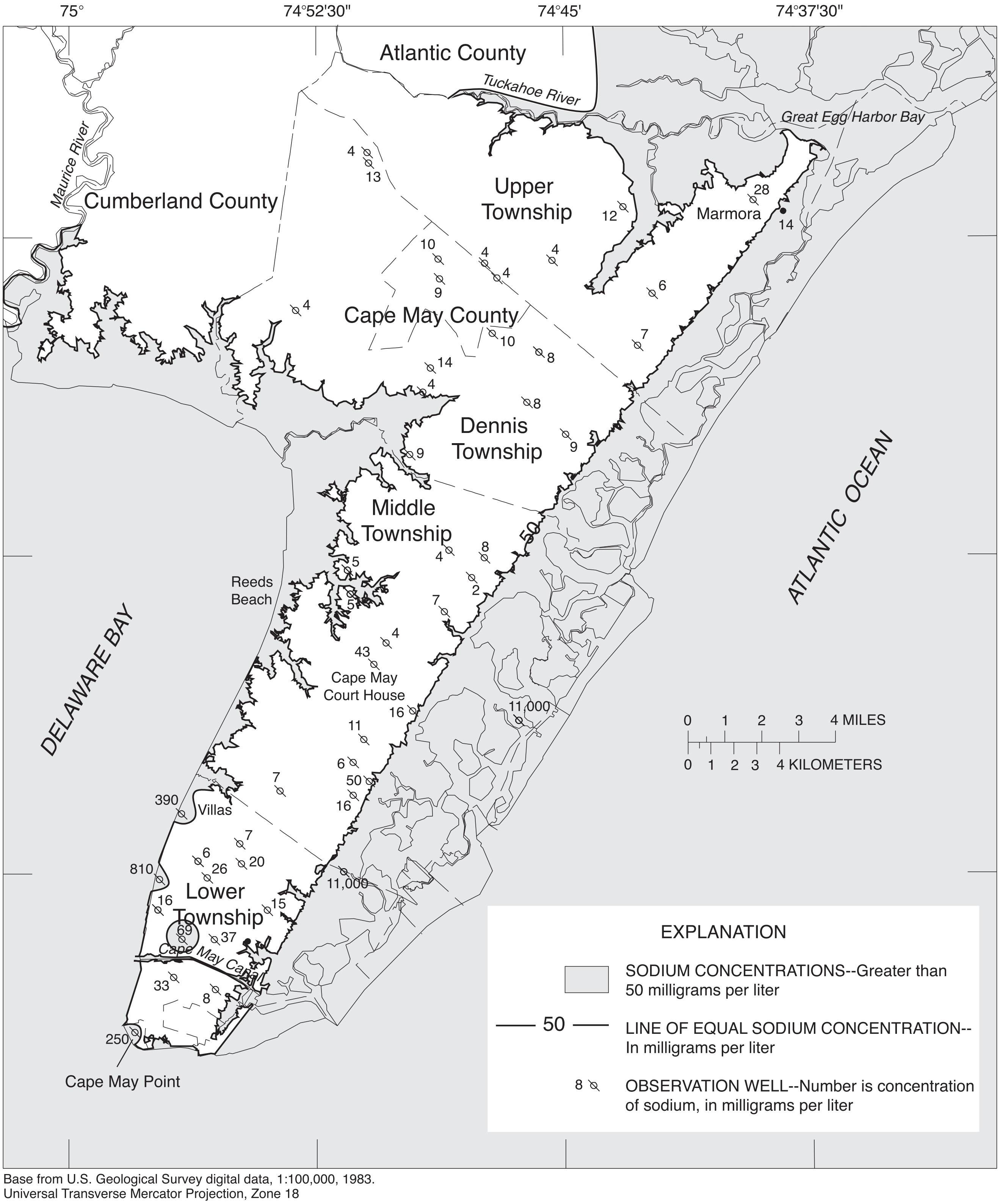


Figure 51. Sodium concentrations in ground-water samples from the Holly Beach water-bearing zone, Cape May County, New Jersey, 1989-92.

chloride and sodium concentrations, and water-levels indicate that the saltwater front in the Holly Beach water- bearing zone has not moved inland in most parts of the county since 1960. The only exception is a small area in Villas that has been affected by induced movement of saltwater in the Holly Beach water- bearing zone.

Iron

The iron concentrations in ground water at 44 wells ranged from less than 3 to 33,000 µg/ L (table 8). The locations of the sampling sites and the concentration of dissolved iron at each site are shown in figure 52. Water from eight freshwater wells contained iron concentrations greater than 300 µg/L, which exceeds the NJDEP secondary maximum contaminant level. Seven of those sites are on the peninsula. Gill (1962a, p. 74) presents water-quality data that indicate that high iron concentrations were present in the Holly Beach water-bearing zone in 1960. The source of the iron is the sediments of the aquifer.

Nitrate

Concentrations of nitrate as nitrogen in ground-water samples collected from 40 wells ranged from less than 0.05 to 12.0 mg/L (table 8). Areas with concentrations greater than 1 mg/L could have been affected by effluent from septic systems and infiltration from agricultural areas. The NJDEP maximum contaminant level for nitrate is 10 mg/L. The locations of the sampling sites and the nitrate concentration at each site are shown in figure 53. Water samples from 16 of the 40 wells contain nitrate in concentrations greater than 1 mg/L. Some of these sites are in agricultural areas and other sites are in areas with domestic septic systems. Water from two wells contained nitrate concentrations greater than 10 mg/L. The site in Lower Township, south of the canal, is in a field that has been used for farming since before 1950. The site in Middle Township is in a septic field owned by a food processing company. The water at both of these sites has been compromised by high nitrate concentrations. High nitrate concentrations which are associated with agriculture and septic systems appear to have affected only a few specific areas.

Estuarine Sand Aquifer

The water of the estuarine sand aquifer is protected from surficial contamination by a confining unit that is 10 to 75 ft thick. Saltwater intrusion appears to be the primary form of human induced contamination. It occurs in shoreline areas as the result of ground-water withdrawals. High iron concentrations are present locally. Nitrate concentrations did not exceed NJDEP primary drinking-water standard and are not shown in this report. During 1987-94, water samples from 18 wells that tap the estuarine sand aquifer were collected and analyzed, and the results were recorded by the USGS (table 9). Additional water-quality data for the aquifer in Cape May County are stored in the USGS, New Jersey District, water-quality database.

Chloride, Sodium, and Saltwater Intrusion

Concentrations of dissolved chloride and dissolved sodium in the estuarine sand aquifer were measured in samples from 19 wells in Cape May County during 1987-94. The locations of the ground-water sampling sites, the concentrations of chloride and sodium at each site, and the present-day locations of the 250-mg/L chloride contour line and the 50-mg/L sodium contour line are shown in figures 54 and 55. Ground water inland of the 250-mg/L chloride line is fresh, and ground water seaward of the 250-mg/L chloride line is salty.

Chloride concentrations in water samples from the freshwater part of the aquifer ranged from 5 to 210 mg/L, and sodium concentrations ranged from 5 to 45 mg/L. Chloride concentrations in excess of 250 mg/L, or sodium concentrations in excess of 50 mg/L were present in samples from four sites. Two of the sites are in the Villas area, one is in Cape May City, and one is near the bay in western Middle Township. Water-quality data collected before 1960 are limited. Gill (1962a, p. 131) reported that the chloride concentrations of water from two unnamed wells in the Villas area were 11 and 12 mg/L in 1958. He also reported that the quality of water from 11 wells in the Villas-Del

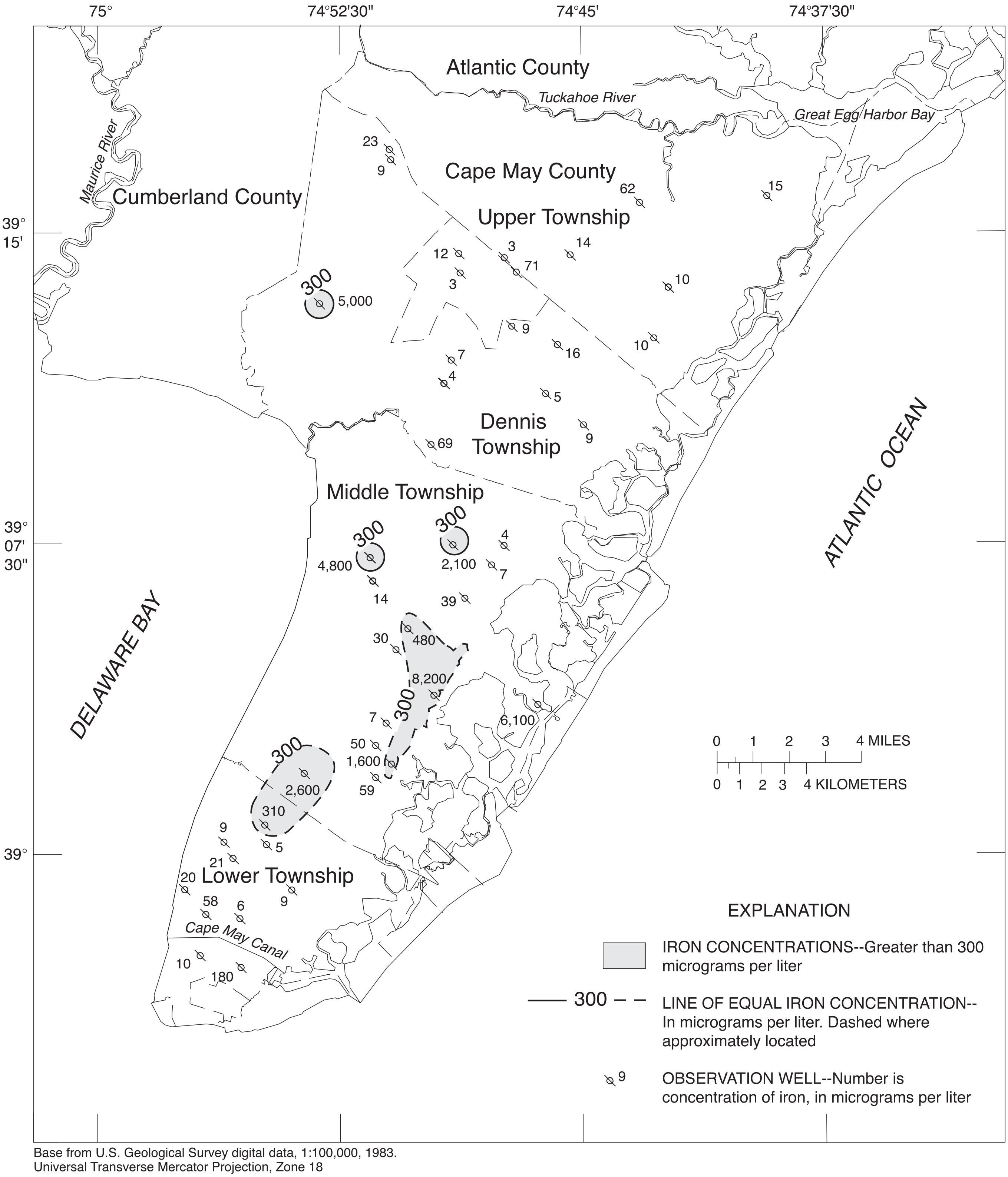


Figure 52. Iron concentrations in ground-water samples from the Holly Beach water-bearing zone, Cape May County, New Jersey, 1989-92.

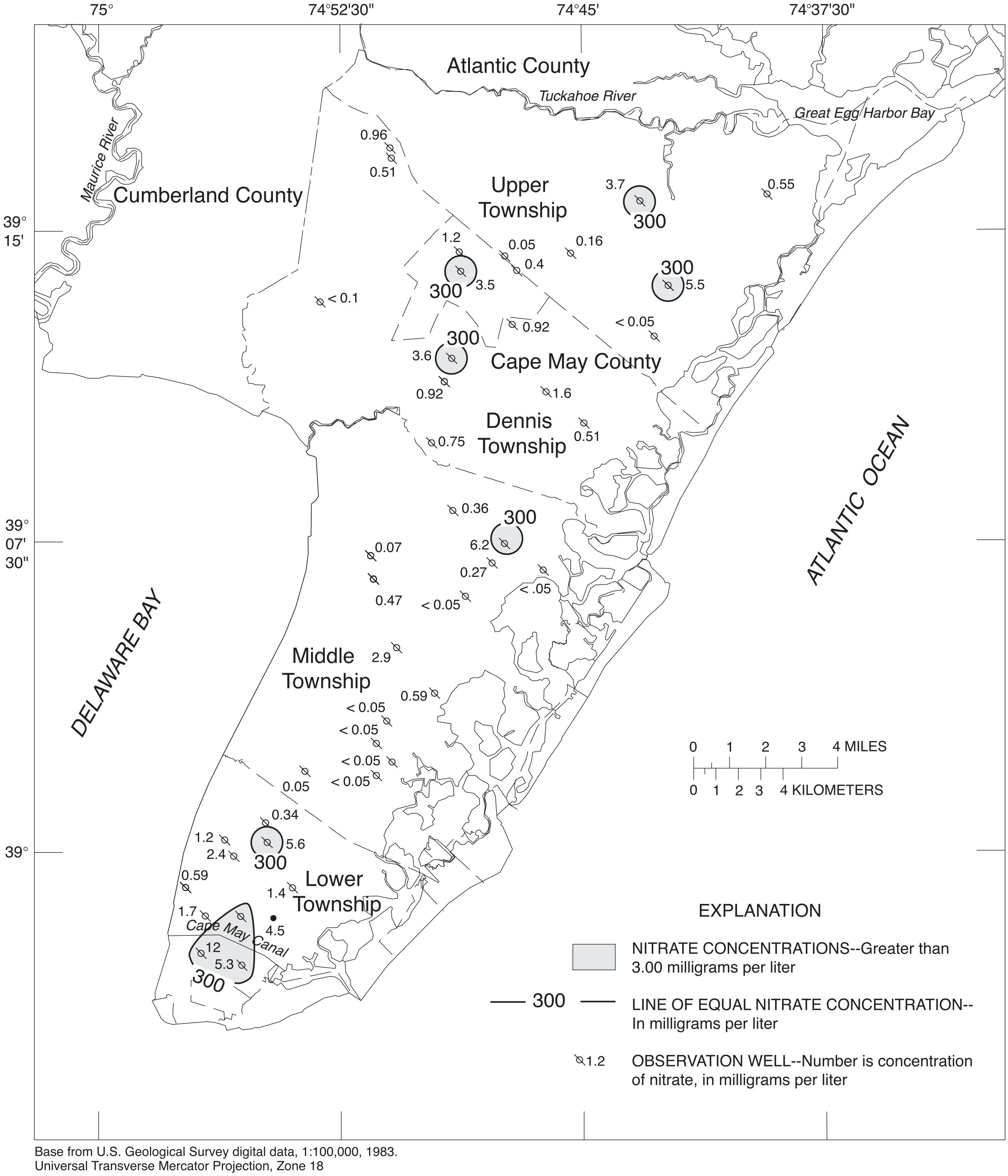


Figure 53. Nitrate concentrations in ground-water samples from the Holly Beach water-bearing zone, Cape May County, New Jersey, 1989-92.

Table 9. Water-quality constituents in samples from selected wells screened in the confined aquifers, Cape May County New Jersey, 1987-94

[Additional water-quality data are published in a series of reports from 1960 to 1993, Water Resources Data, New Jersey; number below constituent name is parameter code used to identify the constituent, property, or characteristic in the U.S. Geological Survey water-quality database (NWIS); µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Station number	Date collected	Specific Conductance (µS/cm) 00095	pH water, whole field (Standard Units) 00400	Chloride, dissolved (mg/L as Cl) 00940	Sodium, dissolved (mg/L as Na) 00930	Calcium, dissolved (mg/L as Ca) 00915	Potassium, dissolved (mg/L as K) 00935	Sulfate, dissolved (mg/L as SO_4) 00945	Iron, dissolved (µg/L as Fe) 01046	Manganese, dissolved (µg/L as Mn) 01056
					Estuarine sand aquifer					
090072	08-30-91	208	--	14	8	29	1.2	4	480	73
090097	08-25-92	137	7.3	8	6	16	.8	8	5,400	130
090189	08-26-94	231	7.9	15	9	33	1.2	10	250	40
090192	08-27-91	828	7.5	210	100	60	2.6	35	740	160
090206	09-17-87	--	--	300	--	--	--	--	--	--
090208	08-18-94	2,440	7.3	660	370	73	9.1	61	1,400	250
090209	08-23-91	1,010	--	300	45	130	3.1	5	4,700	740
090215	09-17-87	--	--	12	--	--	--	--	--	--
090217	03-17-92	1,240	7.4	370	160	--	--	--	--	--
	08-30-94	1,720	7.5	450	190	85	7.1	54	10,000	1,300
090282	04-08-92	159	8.2	10	5	21	3.4	.4	250	130
090320	03-19-92	192	8.3	9	6	28	2.2	.2	12	120
090352	08-25-94	232	7.5	6	20	13	11	.5	120	95
090355	10-14-92	194	7.2	25	16	17	2.1	6	1,600	130
090364	07-28-92	225	7.7	7	19	--	--	--	--	--
090367	09-02-92	227	--	10	24	8	12	<.1	330	100
090369	06-23-92	156	7.4	9	7	--	--	--	--	--
090390	09-02-92	195	6.12	17	10	13	1.2	45	10,000	270
090392	08-13-92	147	7.2	9	7	19	.8	15	1,500	76
090435	09-04-92	298	7.7	21	10	48	2.1	46	500	54
					Cohansey aquifer					
090011	04-15-92	3,340	7.3	1,100	510	55	7	42	3,800	420
090017	08-29-91	940	--	220	120	28	10	3.9	430	32
090018	08-29-91	351	--	35	62	7.7	6.7	.7	440	29
	09-10-92	368	7.8	43	61	--	--	--	--	--
090027	08-27-91	808	--	180	130	17	12	13	670	71
	09-10-92	889	7.5	180	140	--	--	--	--	--
090036	08-27-91	718	--	150	100	20	12	7.1	660	74
	09-10-92	863	7.5	180	120	--	--	--	--	--
090041	09-03-91	330	--	38	49	11	7.5	.9	270	30
090043	08-27-91	298	--	21	29	15	8.5	3	300	30
	09-10-92	292	7.6	19	31	--	--	--	--	--
090044	08-26-87	305	7.7	20	--	--	--	--	--	--
090048	04-06-92	294	7.8	17	22	--	--	--	--	--
	09-13-94	301	7.9	17	22	20	9.7	2.5	50	14
090049	09-05-85	278	7.8	15	49	4.6	8	3.5	38	11
	04-07-92	268	8	13	46	--	--	--	--	--
090052	08-28-91	261	--	15	35	13	6.8	2.7	15	23
	08-12-92	256	7.9	14	33	--	--	--	--	--
090054	08-28-91	272	--	16	25	16	6.7	3.3	190	41
	08-12-92	252	7.9	18	25	--	--	--	--	--
090057	08-28-91	209	--	9	18	14	5.3	2.8	42	34
	08-13-92	197	7.8	9	17	--	--	--	--	--
090069	08-30-91	191	--	13	8	19	2.3	2.9	610	35
090074	08-12-92	240	7.5	36	13	--	--	--	--	--
090078	08-23-88	142	7.7	10	--	--	--	--	--	--
090080	03-18-92	153	7.2	12	8	17	1.3	3.7	1,700	77
090089	09-06-90	163	8	9	7	16	2.6	4.3	640	36
090099	03-19-92	167	8.8	9	9	21	2.2	1	88	23
090150	04-07-92	1,810	8	390	360	--	--	--	--	--
	09-08-94	1,830	7.9	380	330	14	15	27	280	63
090154	08-23-88	682	7.6	140	--	--	--	--	--	--

Table 9. Water-quality constituents in samples from selected wells screened in the confined aquifers, Cape May County New Jersey, 1987-94--Continued

Station number	Date collected	Specific conductance (µS/cm) 00095	pH water whole field (Standard units) 00400	Chloride, dissolved (mg/L as Cl) 00940	Sodium, dissolved (mg/L as Na) 00930	Calcium, dissolved (mg/L as Ca) 00915	Potassium, dissolved (mg/L as K) 00935	Sulfate, dissolved (mg/L as SO_4) 00945	Iron, dissolved (µg/L as Fe) 01046	Manganese, dissolved (µg/L as Mn) 01056
				Cohansey aquifer--Continued						
090168	09-04-90	120	4.9	15	10	1.5	2.8	22	1,800	34
090187	11-18-86	320	7	60	15	28	6.2	5.5	1,900	94
	08-18-94	664	7.1	160	29	51	8.1	5.8	4,100	130
	01-28-99	1,280	7.1	340	67	99	12	13	7,600	246
090188	08-26-94	144	7.2	9	10	9.9	3.5	3.4	1,800	39
090207	08-21-90	47	4.9	9	4	.86	1.2	1.3	5	28
	08-26-94	144	7.2	9	10	9.9	3.5	3.4	1,800	39
090210	03-17-92	182	7.9	10	--	--	--	--	--	--
	08-25-94	201	8.4	8	17	16	5	1.9	61	25
090213	03-17-92	178	8	10	12	--	--	--	--	--
	08-30-94	192	8.4	9	12	19	3.2	2.8	100	31
090214	09-17-87	--	--	17	--	--	--	--	--	--
090256	04-09-92	72	6.3	5	4	2.6	3	7	3,200	57
090281	04-08-92	153	7.9	9	13	13	3	.4	2,700	53
090292	09-07-90	3,990	7.1	1,300	440	190	35	3	8,200	500
090297	08-18-95	43	5.3	8	5	.64	1	2	<3	2
090307	09-05-90	92	5.6	15	8	2	2	7	1,400	25
090317	12-15-89	--	--	12	8	1.3	2	13	1,300	18
090338	08-31-94	1,730	7.3	470	160	110	11	18	1,600	150
090350	10-08-92	78	6.0	5	9	2	3	7	830	48
090353	10-06-92	249	7.7	11	36	13	6	4	26	28
090354	10-14-92	886	7.2	210	100	40	6	34	760	130
090366	08-14-92	445	7.3	71	46	--	--	--	--	--
090372	08-26-92	2,470	6.4	690	280	78	15	33	48,000	1,100
090382	08-11-92	94	5.8	13	8	3.2	1	7	2,300	53
110691	09-04-90	167	6.7	15	16	9.9	3	11	2,000	70
090182	--	--	--	1,700	--	--	--	--	--	--
				Rio Grande water-bearing zone						
090033	08-08-90	2,240	8	540	410	30	16	27	270	4
090067	08-12-92	520	8.2	77	73	--	--	--	--	--
090304	09-05-90	620	8.2	84	120	12	8	12	16	11
090305	12-14-89	702	7.9	150	68	54	14	8	14	2
	08-09-90	839	--	170	<.2	<.02	12	6.6	<3	<1
090395	08-29-95	198	7.5	80	--	--	--	--	--	--
11-691	09-04-90	167	6.7	15	16	9.9	3.3	11	2,000	70
				Atlantic City 800-foot sand						
090002	08-27-90	250	8.7	14	44	9.7	4.1	18	15	<1
090004	08-15-91	375	8.7	51	65	--	--	--	--	--
090005	03-19-85	231	8.4	12	34	13	3.8	16	10	<1
	08-27-87	255	8.5	13	--	--	--	--	--	--
090008	08-27-90	315	8.4	36	50	12	4.8	17	40	<1
	08-26-92	326	8.5	40	54	--	--	--	--	--
090079	08-08-90	438	9.0	48	81	4.3	4.4	18	16	2
090092	03-19-85	325	8.5	37	52	14	5	16	6	<1
090106	09-21-89	206	7.7	10	29	11	3.1	11	23	2
	08-13-92	206	7.9	12	30	--	--	--	--	--
090108	08-30-90	202	7.9	12	31	10	3	11	26	4
090124	08-30-90	199	7.7	11	29	<9.7	3	12	<24	<4
	08-13-92	201	7.8	10	30	--	--	--	--	--
090126	08-27-90	237	8.5	14	30	13	4.9	17	22	<1
	08-26-92	237	8.4	15	31	--	--	--	--	--
090127	08-30-89	252	8.4	14	33	15	4.6	13	6	<1
090128	08-27-87	255	8.4	14	--	--	--	--	--	--
090129	08-27-90	232	8.4	13	32	12	3.9	15	21	<1
	08-15-91	234	8.4	15	32	--	--	--	--	--
090132	08-08-90	350	8.5	34	68	7.9	4.7	17	<3	<1

Table 9. Water-quality constituents in samples from selected wells screened in the confined aquifers, Cape May County New Jersey, 1987-94--Continued

Station number	Date collected	Specific conductance (µS/cm) 00095	pH water whole field (Standard Units) 00400	Chloride, dissolved (mg/L as Cl) 00940	Sodium, dissolved (mg/L as Na) 00930	Calcium, dissolved (mg/L as Ca) 00915	Potassium, dissolved (mg/L as K) 00935	Sulfate, dissolved (mg/L as SO_4) 00945	Iron, dissolved (µg/L as Fe) 01046	Manganese, dissolved (µg/L as Mn) 01056
Atlantic City 800-foot sand--Continued										
	08-26-92	359	8.7	39	66	--	--	--	--	--
090135	03-20-85	290	8.8	20	57	6.6	4	18	15	<1
	08-27-87	305	8.7	17	--	--	--	--	--	--
090136	03-19-85	212	8.1	12	36	9.7	3.1	13	87	<1
090161	08-09-90	526	--	59	54	32	10	26	92	3
090166	08-08-90	347	8.3	34	65	9.3	4.7	17	29	<1
090173	03-20-85	303	8.7	20	56	8	4	18	11	3
	08-15-91	302	8.7	23	55	--	--	--	--	--
090185	09-05-90	197	9.2	5	19	14	4.3	11	12	<1
090291	08-15-91	320	8.6	36	52	--	--	--	--	--
[1]090296	03-04-92	--	--	35	--	--	--	--	--	--
090302	09-06-90	3,000	8.1	570	390	16	15	41	110	7
090306	09-06-90	425	8.1	48	64	13	7.5	17	290	49
090337	04-16-92	560	8.7	85	95	10	6.5	23	60	9
090158	08-12-26	--	--	352	284	28	--	33	200	2.5
090013	12-30-57	5,180	7.4	1510	1080	51	49	125	1,500	25

[1]Water quality data are from NJDEP database.

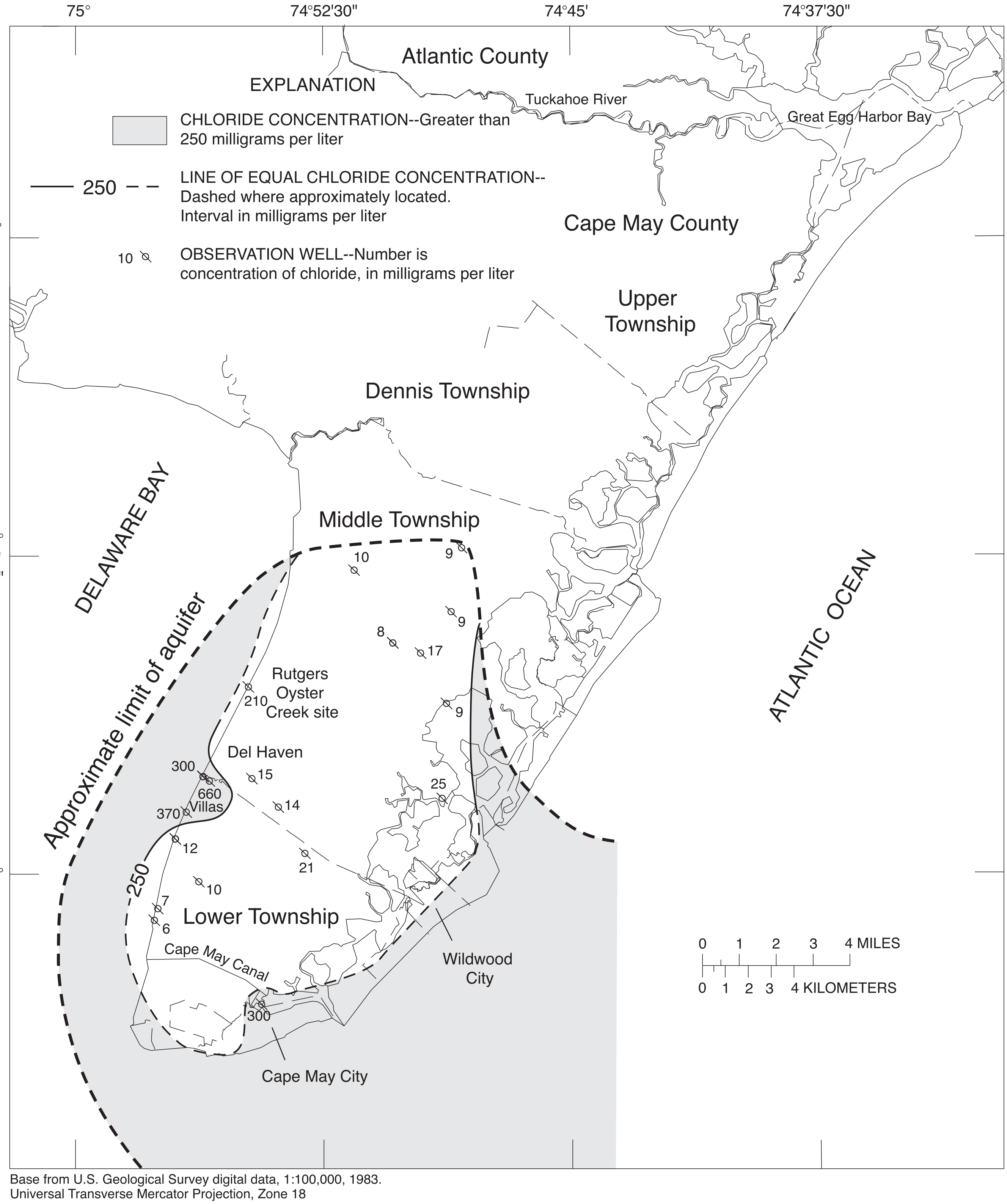
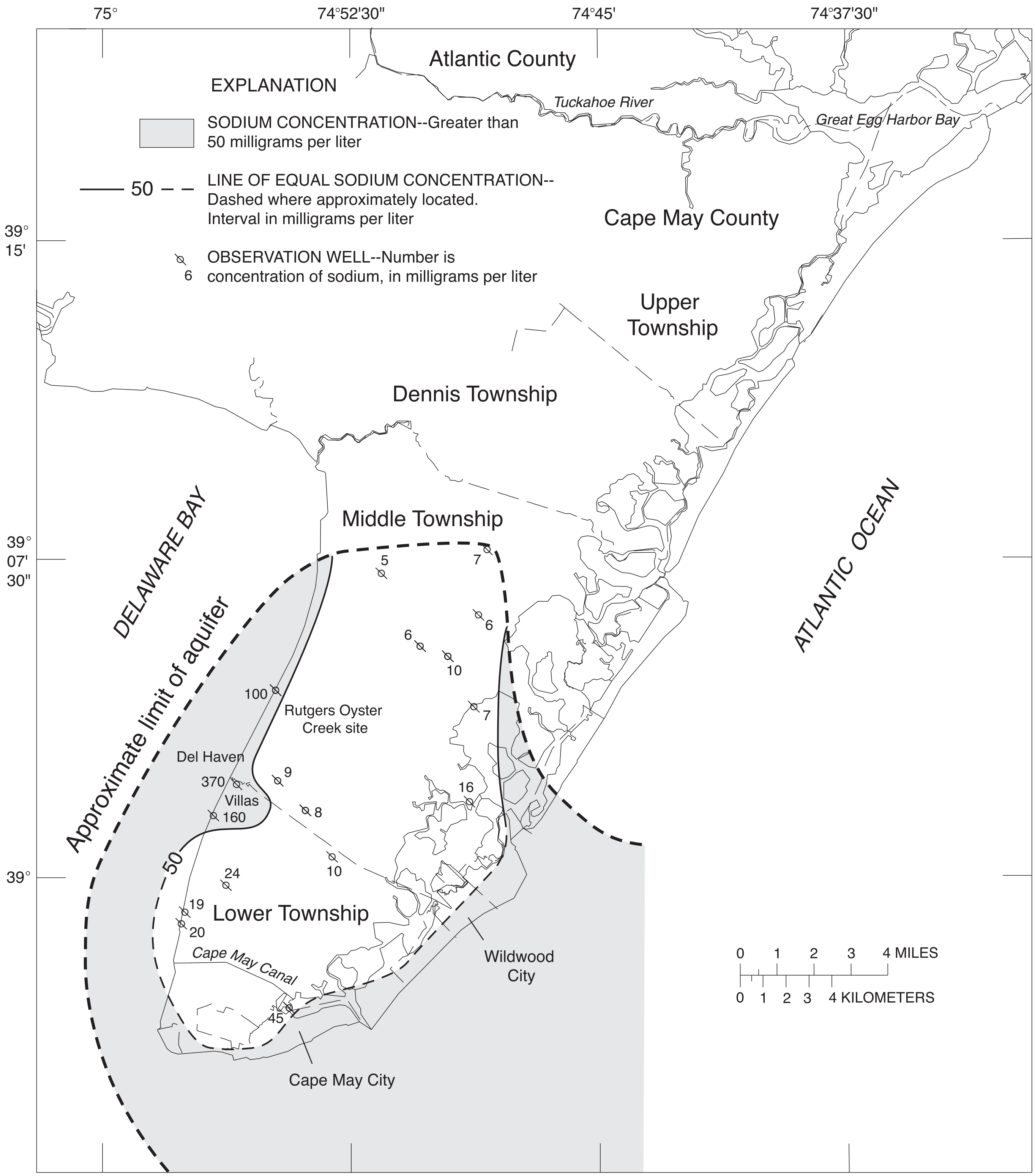


Figure 54. Chloride concentrations in ground-water samples from the estuarine sand aquifer, Cape May County, New Jersey, 1989-92.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 55. Sodium concentrations in ground-water samples from the estuarine sand aquifer, Cape May County, New Jersey, 1989-92.

Haven area was good (Gill, 1962a, p. 161, wells 11Es to 22Es) and that water from 3 wells at Sunray Beach (Del Haven) was brackish or salty (Gill, 1962a, p. 161, wells 23Es, 24Es, and 25Es). Seaber (1963) shows no wells completed in the estuarine sand aquifer in that area. In the late 1960's, homeowners in Villas first complained of salty water from their wells (Woodward Jarmer, Cape May County Planning Department, oral commun., 1990). Cape May County Health Department and Planning Board (1985) conducted a study of chloride concentrations in the Villas area after more local residents complained about salty-tasting well water. The Health Department collected water samples from about 220 domestic wells. Chloride concentrations in the samples ranged from less than 10 mg/L to more that 1,050 mg/L. Lacombe and Carleton (1992) incorporated the chloride data from Gill (1962a), the Cape May County Health Department and Planning Board (1985) investigation, and the USGS water-quality and well-records databases to show that the average, apparent, horizontal rate of movement of the 250-mg/L chloride front in the Villas area was 220 ft per year during 1965-84.

By using a digital model of the aquifer, Spitz and Barringer (1992) showed the rate of movement for the chloride front with a density of half seawater-half freshwater (referred to as the half-seawater front) was about 5 to 15 ft per year. This rate is much slower than the apparent movement rate of the 250-mg/L chloride front for two reasons. First, the half-seawater front is far from the center of the cone of depression near the Wildwood mainland well field; therefore, the radial inward ground-water flow velocities are slower at the distal locations. Second, the movement rate of the half-seawater front is an average rate for a large section of the aquifer near the Delaware Bay shoreline, whereas the movement rate of the 250-mg/L chloride front is calculated for the small area of the aquifer with the fastest movement rate (Lacombe and Carleton, 1992, fig. 6). Saltwater from under the bay is migrating eastward toward the domestic-supply wells in Villas and the public-supply wells in the Wildwood Water Department mainland well field (figs. 1 and 38).

The chloride concentration of 300 mg/L in water samples collected near the Cape May City public-supply wells is much higher than the chloride concentration of 17 mg/L reported in 1958 (Gill, 1962a, p. 131). The confining unit overlying the estuarine sand aquifer is thin south of the canal; therefore, the downward flow of salty water is less impeded here than in many other parts of the county. In addition, the high chloride concentrations in this area may be caused by saltwater migration toward the cone of depression centered on the Cape May City Water Department supply wells (fig. 38). More than a dozen homeowners in southwestern Lower Township and a few in Cape May Point use the estuarine sand aquifer for domestic supply. The water in that area was not analyzed for chloride, but it is likely that the water contains less than 250 mg/L of chloride because none of the homeowners registered a complaint.

The chloride concentration in water from well 9-192 at the Rutgers Oyster Research laboratory was 12 mg/L in 1958 (Gill, 1962a, p. 131), but had increased to 210 mg/L in 1992. The increase could be the result of many years of ground-water withdrawals at the research laboratory. The wells of many summer homes along the shoreline of Delaware Bay in Middle Township tap the aquifer. The chloride concentration of well water serving these homes was not determined, but only local, heavy users of the aquifer could create a cone of depression of sufficient size for a period long enough to induce the movement of salty ground water.

Freshwater in the estuarine sand aquifer underlies West Wildwood, North Wildwood, and parts of easternmost Delaware Bay (figs. 54 and 55). Hydrostratigraphic data indicate that the confining unit is 100 ft thick (fig. 15). The thick confining unit has impeded the immediate discharge of the fresh ground water at the shoreline, thus supporting the formation of a lens of freshwater from the center of the mainland to the bay and ocean. In areas north and south of the thick confining layer, the freshwater lens does not extend as far east and west of the mainland.

Iron

The iron concentrations in ground water from 15 wells ranged from 12 to 10,000 µg/L (table 9, fig. 56). Water from 11 of the wells contained iron concentrations greater than 300 µg/L, a level at which potability is compromised. The source of the iron probably is the Pleistocene-age sediments (Gill, 1962a; Owens and Minard, 1979).

Cohansey Aquifer

The water quality of the Cohansey aquifer is protected from sources of contamination at land surface by the overlying confining units and aquifers that have a combined thickness of 50 to 250 ft. Saltwater intrusion appears to be human induced because it occurs only in areas near withdrawal wells. During 1987-94, water samples from 43 wells that tap the Cohansey aquifer were collected, analyzed, and recorded by the USGS (table 9). Additional water-quality data used in this report are stored in the USGS, New Jersey District, water-quality database.

Chloride, Sodium, and Saltwater Intrusion

Concentrations of dissolved chloride and dissolved sodium in the Cohansey aquifer were measured in samples from 42 wells in Cape May County during 1987-94 (table 9). The locations of the ground-water sampling sites, the concentrations of chloride and sodium at each site, and the locations of the 250-mg/L chloride contour line and the 50-mg/L sodium contour line are shown in figures 57 and 58.

Chloride concentrations in samples from the freshwater part of the aquifer ranged from 5 to 220 mg/L; the highest concentration of chloride in samples from the saltwater part of the aquifer was 1,300 mg/L. A laundry company in Wildwood Crest reported, however, that chloride concentrations in their supply well rose to 1,700 mg/L in 1987 (Mr. Stockes, Wildwood Laundry Co., oral commun., 1987).

Water from 15 wells contained chloride concentrations in excess of 50 mg/L. Eight of the wells are east of the mainland, in the saltwater wetlands and on the barrier islands; five wells are in the Cape May City area, and one well is in Villas. Saltwater intrusion has been documented in North Wildwood, Cape May City, Cape May Point, and southern Lower Township (Gill, 1962a, p. 117-127; Lacombe and Carleton, 1992).

In the eastern part of the county, from Ocean City to Wildwood and in the back bays, chloride concentrations in wells screened in the Cohansey aquifer ranged from 71 to 1,300 mg/L, and sodium concentrations ranged from 100 to 4,400 mg/L. No chloride data are available for wells that tap the Cohansey aquifer to show the movement of the 250-mg/L chloride contour in the area from Ocean City to Stone Harbor. It is likely that little movement of the front has occurred in this area because there is no significant cone of depression in the aquifer. The 250-mg/L chloride contour is closer to the mainland in northern Middle Township and Dennis and Upper Townships than it is in southern Middle and Lower Townships. The 250-mg/L chloride contour is closer to the mainland because the confining unit that overlies the Cohansey aquifer has greater transmissivity in the northern townships than in the southern townships. As a result, freshwater from the mainland discharges upward more easily in the northern townships.

Chloride concentrations in samples from wells near the Wildwood communities ranged from 71 to 1,700 mg/L. Active saltwater intrusion that occurred during the 1950's in North Wildwood probably has ceased. The ice company and cement company in North Wildwood were out of business by 1970; therefore, they no longer withdrew water from the aquifer. The only known user of the water in North Wildwood is a commercial marina. Only small abmounts of water are pumped from the marina's supply well (well 9-338). The water had a chloride concentration of 470 mg/L in 1994. Gill (1962a, p. 158) reported the chloride concentration of water from well 40Cc at the same site as well 9-338 was 610 mg/L in 1958. Wildwood Water Utility began injecting water into well 9-310 in North Wildwood in 1986. This well is one of four

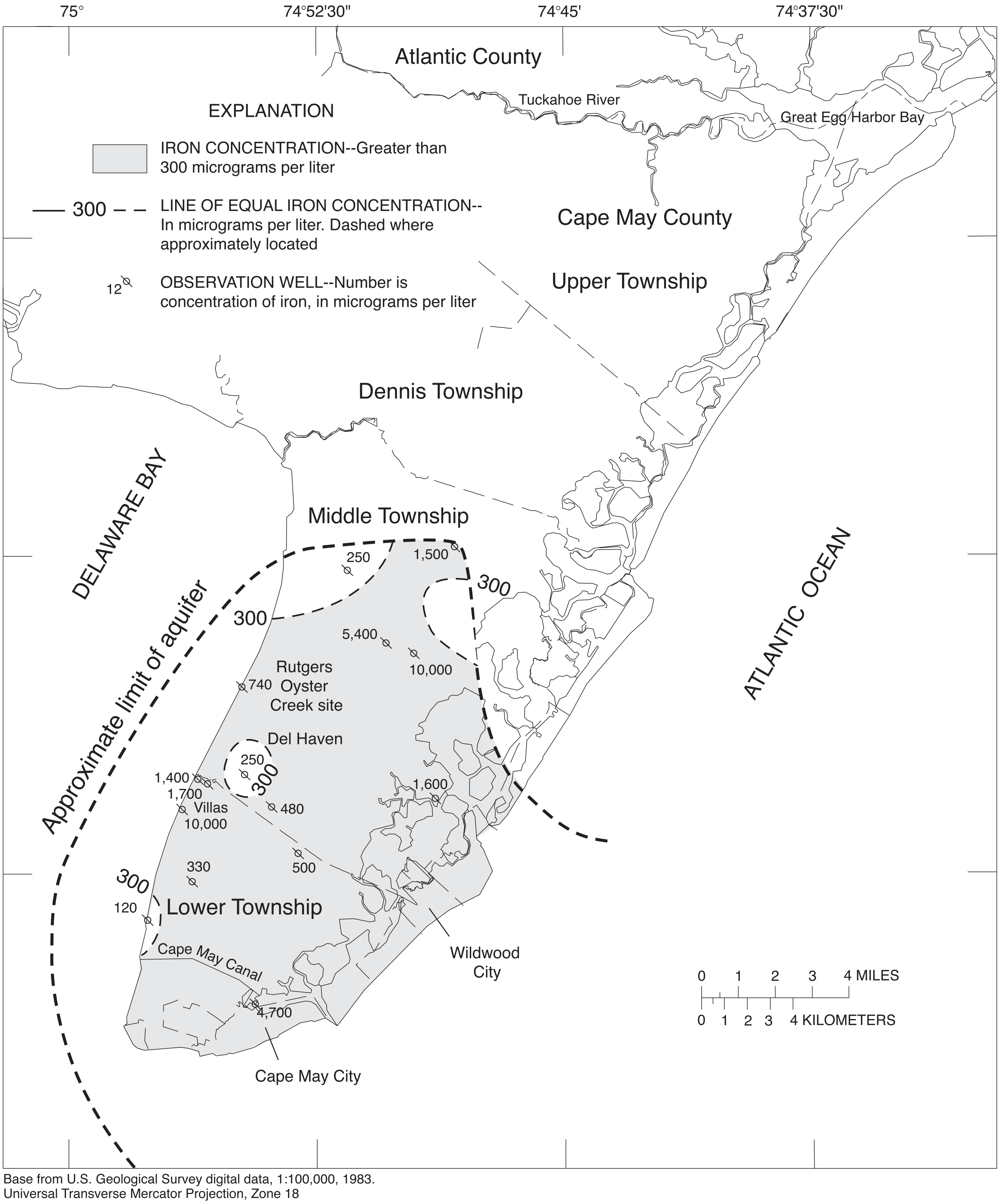
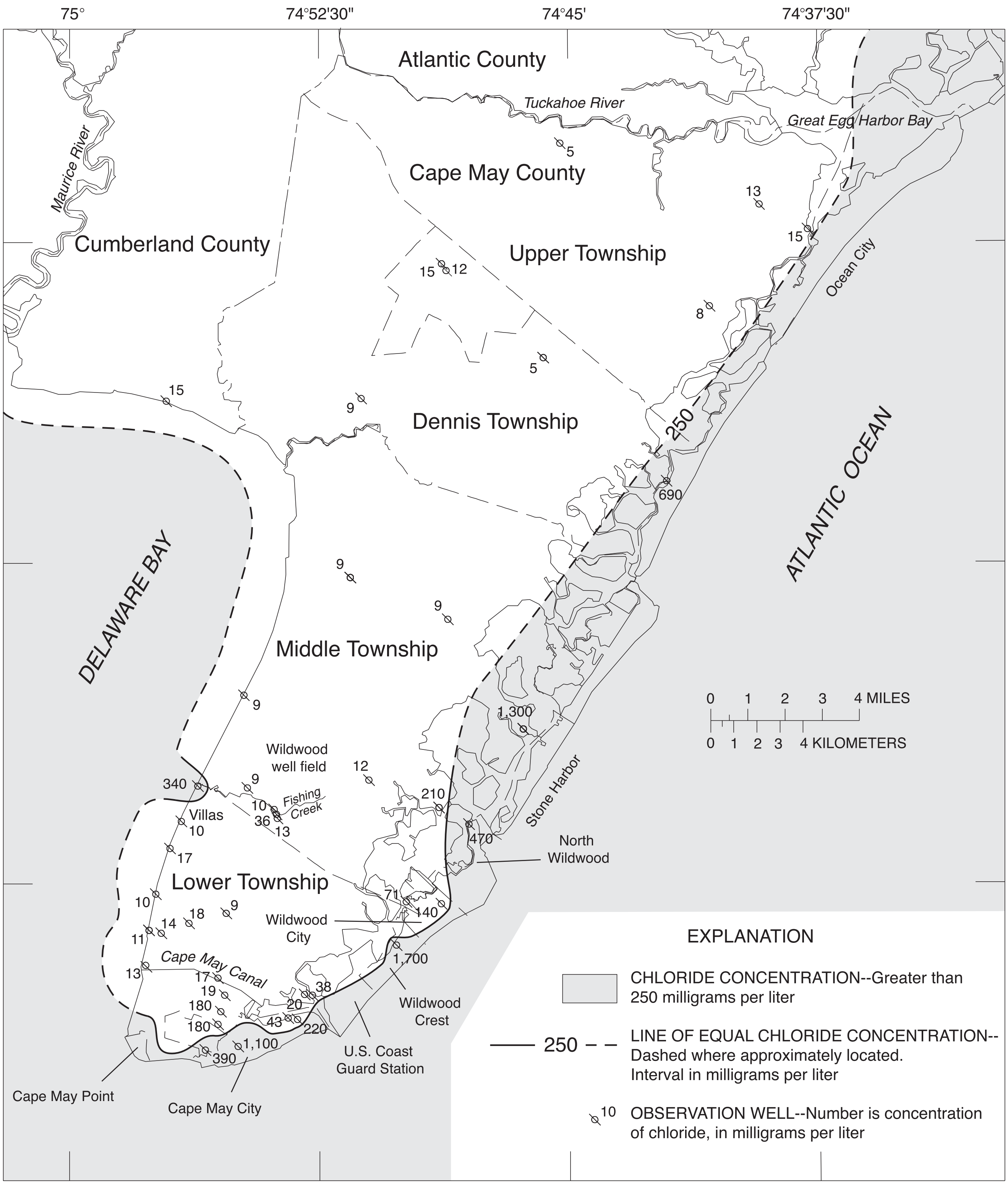
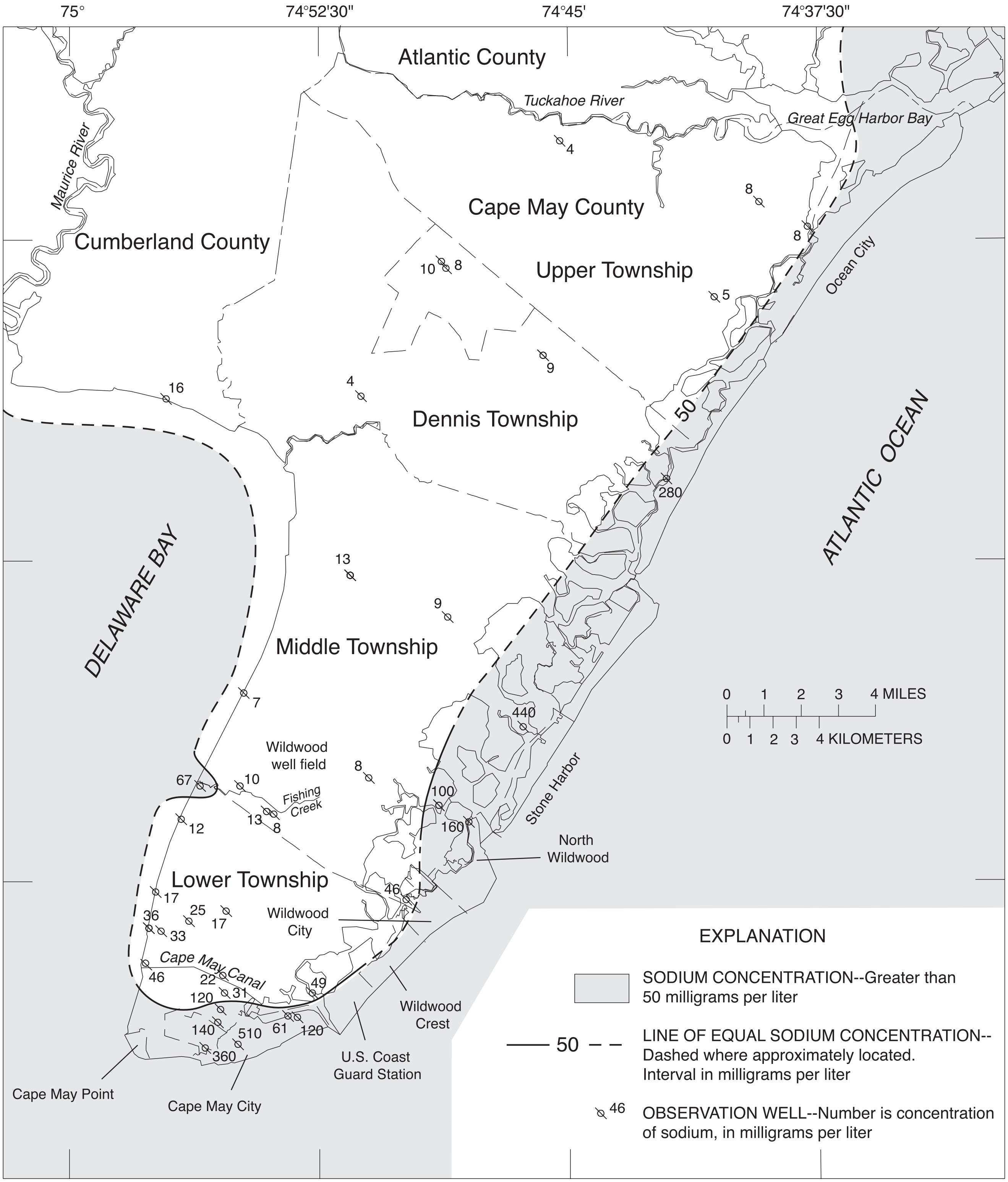


Figure 56. Iron concentrations in ground-water samples from the estuarine sand aquifer, Cape May County, New Jersey, 1989-92.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 57. Chloride concentrations in ground-water samples from the Cohansey aquifer, Cape May County, New Jersey, 1989-92.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 58. Sodium concentrations in ground-water samples from the Cohansey aquifer, Cape May County, New Jersey, 1987-99.

used on the island for artificial recharge for storage and recovery (Lacombe, 1997). The injected water has a chloride concentration of about 35 mg/L, and injection causes the water level in the aquifer near the well to increase. As a result of the changes in aquifer use in North Wildwood, the chloride concentrations and water withdrawals have decreased, and water levels have increased.

Chloride concentrations in well 9-154 in Wildwood (well 28Cc in Gill, 1962a, p. 158) were static during 1940-60 at about 80 to 120 mg/L (Gill, 1962a, p. 124). Active saltwater intrusion in Wildwood started sometime during 1960's to early 1980's and caused the chloride concentrations in the aquifer to increase to 140 mg/L by 1988. Well 9-154 has been sealed and replaced with well 9-314, a well used for artificial recharge for storage and recovery. No other withdrawal wells are known to be active in Wildwood or West Wildwood. Saltwater intrusion has likely slowed significantly because water levels have risen as a result of the injection of water into the storage and recovery well.

Saltwater intrusion in Wildwood Crest caused the closure and sealing of the water-supply well (well 9-182) for a commercial laundry in 1987. Sometime during early 1987, the owners of the commercial laundry realized soap was not reacting properly with the water and tested the water. The chloride concentration of the water was 1,700 mg/L. The company chose to seal the well and purchase water from the Wildwood Water Utility. The only other active wells in Wildwood Crest are wells 9-159 and 9-176. They are used for artificial recharge for storage and recovery. Because these wells are used to increase the water level for much of the year, intrusion of saltwater from the east probably has slowed. Lacombe (1996) showed that water injected into well 9-176 during the non-summer months had a chloride concentration of about 35 mg/L; however, as water was withdrawn during the summer, the chloride concentration increased so that by early September the chloride concentration was 65 mg/L. This indicates that the concentration of chloride outside the volume of injected water is closer to 149 mg/L, as was reported for water from well 9-37 in 1956 (well 21Cc in Gill, 1962a, p. 63).

Saltwater intrusion occurred at the former U.S. Coast Guard Station in Lower Township during the late 1950's to early 1960's. The chloride concentration in water from well 9-037 (well 21Cc in Gill, 1962a; and well Cm164 in Seaber, 1963) was 149 mg/L in 1958. A new well (well Cm162 in Seaber, 1963) drilled at the station produced water with chloride concentrations in excess of 3,700 mg/L in samples collected in 1960 and 1961. Therefore, the chloride concentrations increased from about 150 to 3,700 mg/L during 1958-60. These two wells have been sealed. A restaurant located about 2,500 feet northwest of the U.S. Coast Guard Station had a well that produced water that met the County Health Department water-quality standards in early 1990. Although the well water never became salty, the owner connected his restaurant to the Wildwood Water Utility to insure a potable water supply.

Saltwater intrusion in the Cape May City and Cape May Point area has been documented by Lacombe and Carleton (1992), Gill (1962a), Seaber (1963), and David Carrick (Water Superintendent, Cape May City, written commun., 1993). The chloride concentrations in water from five public-supply wells increased during 1940-95 (fig. 59). The chloride concentrations increased in Supply Well 1 (9-12) (fig. 7) from about 60 to 250 mg/L during 1945-51 and in Well 2 (9-14) from about 30 to 250 mg/L during 1950-64. Well 2 was abandoned in 1961 and sealed in about 1965. The chloride concentrations in water from Well 3 (9-27) rose slowly from about 20 to about 50 mg/L during 1951-66, then increased to 100 mg/L in 1967. This sharp rise occurred soon after Supply Wells 1 and 2 were abandoned and withdrawal increased in Supply Well 3. The increased withdrawals caused the saltwater front to move more rapidly toward Supply Well 3. In 1977, the Cape May City Water Department decreased withdrawals from Well 3 because the chloride concentration in Supply Well 4 (9-36) was increasing. The Water Department believed that pumping both Wells 3 and 4 would increase the rate of saltwater intrusion. Since 1985, the Water Department primarily depends on water from Well 5 for public supply. Wells 3 and 4 are pumped but are stringently monitored for chloride concentrations on a weekly basis to insure

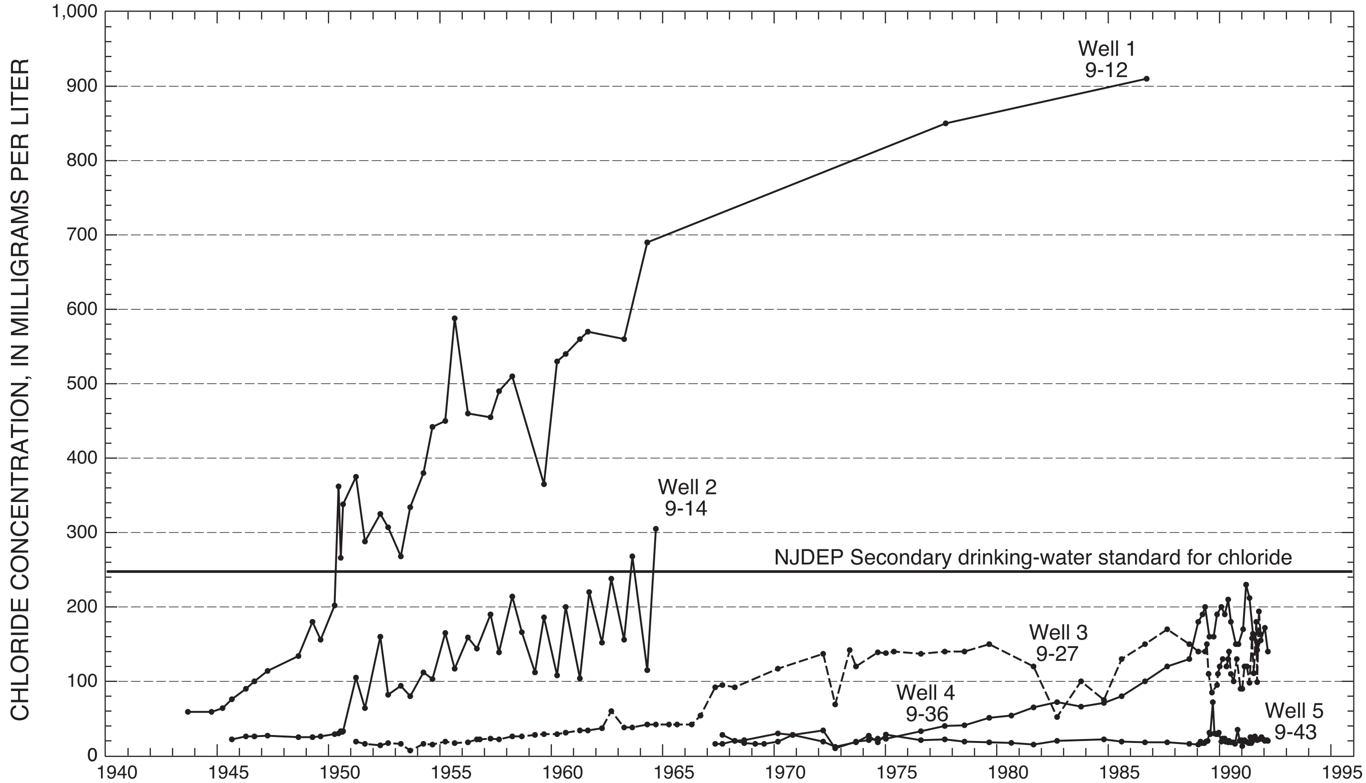


Figure 59. Chloride concentrations in ground-water samples from the five public-supply wells of Cape May City, New Jersey, 1941-94. (NJDEP is New Jersey Department of Environmental Protection.)

potability. If chloride concentrations approach 250 mg/L, Well 3 or 4 is rested for as long as 2 or 3 months so that the chloride concentration will decrease (David Carrick, oral and written commun., 1987-94).

The saltwater front has been moving through the Cape May City well field since the 1940's. This movement is shown episodically for each decade from 1940 through 1990 (fig. 60). The volume of ground water withdrawn is shown at the top of each well during each decade. The distance between the 50 and 250 or 500 mg/L chloride contours increased during each succeeding decade. This could indicate that the saltwater front is becoming more diffuse as it intrudes.

Lacombe and Carleton (1992) incorporate the chloride data from Gill (1962a) and Seaber (1963) and from USGS, NJDEP, and Cape May City Water Department databases to show that the average rate of movement of the saltwater front was 92 ft per year from 1950 to 1963; 143 ft per year from 1963 to 1985, and 272 ft per year from 1985 to 1991. Spitz and Barringer (1992) used a ground-water flow model to show that the average rate of movement of the half-seawater front in the entire Cohansey aquifer ranged from 5 to 15 ft per year. Spitz (1998) used measured chloride values to recalibrate a ground-water flow model to match the movement of the 250-mg/L chloride front. In their report, Lacombe and Carleton (1993) discuss one small area and the movement of the 250-mg/L line of equal chloride concentration; Spitz and Barringer (1992) discuss, in generic terms, the half-seawater front everywhere in the county; and Spitz (1998) discusses the use of a refined model to replicate the observed movement of the 250-mg/L line of equal chloride concentrations.

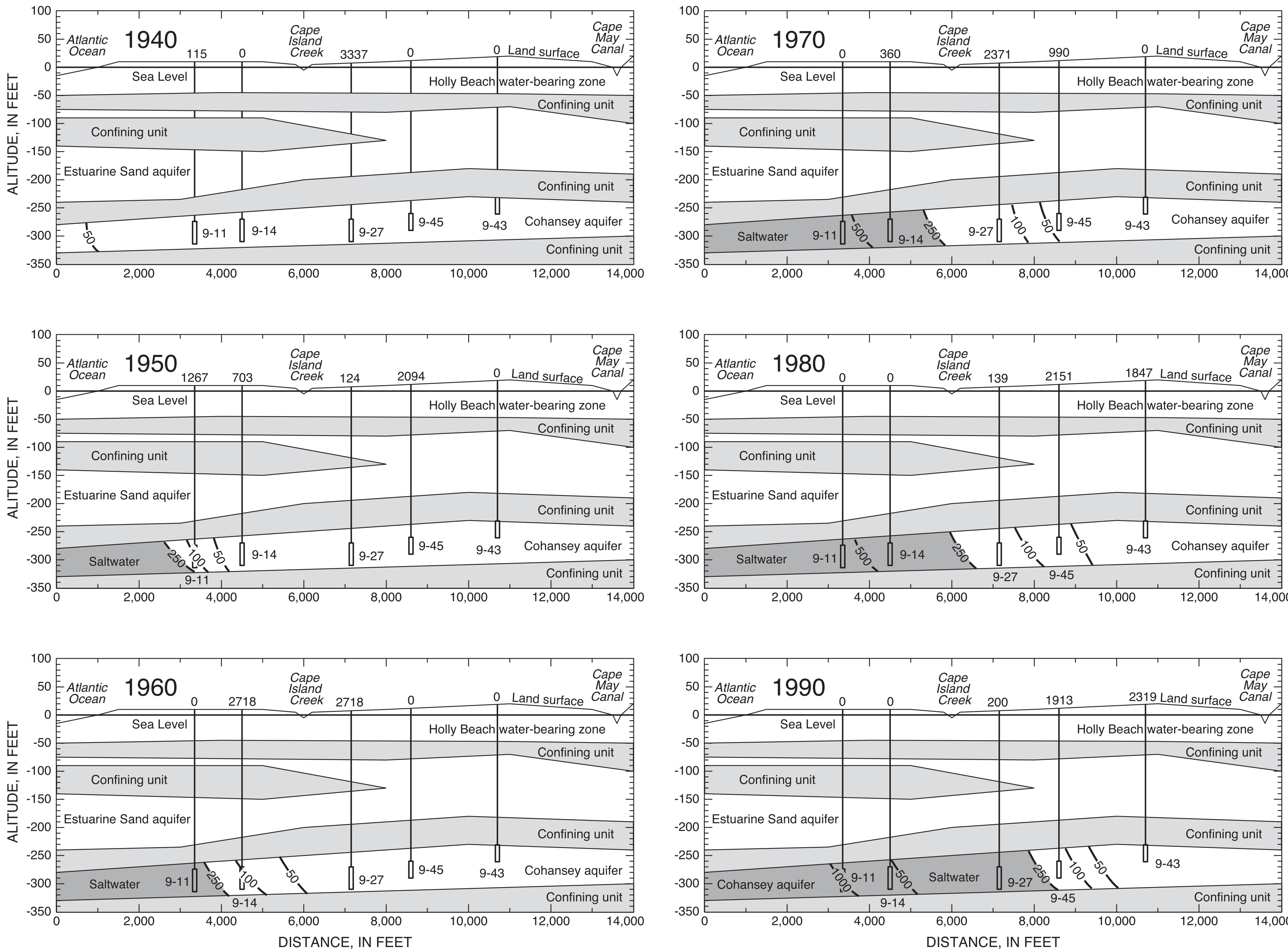


Figure 60. Sections showing chloride concentrations and reported withdrawals for each decade in the Cape May City well field, Cohansey aquifer, Cape May County, New Jersey, 1940-90. (Number shown at top of each well location is average annual withdrawal, in million gallons per year. Number at well screen is the well number. Number with contour line is chloride concentration, in milligrams per liter.)

Lacombe and Carleton (1992) describe the movement of saltwater through the Cape May Point well field. Well 1 (well 9-19; well 1Kc in Gill, 1962a, p.155) was drilled in 1916. The initial chloride concentration in water from the well is unknown. The well was screened in both the Cohansey aquifer and the Rio Grande water-bearing zone. In 1945, the concentration of chloride was 555 mg/L (well Cm148 in Seaber, 1963, p. 152). The saltwater front probably moved slowly landward in the Cape May Point area in 1916. At the onset of World War II (about 1940), the U.S. military stationed soldiers at Cape May Point to build a cement observation bunker. It has been proposed that there was a substantial increase in water withdrawals to supply the troops and to build the cement bunker, thereby causing saltwater intrusion in well 9-19. Cape May Point's Well 2 (9-21; well 5Cc in Gill, 1962a, p.157) was completed in 1958; water from it contained a chloride concentration of 130 mg/L at that time. In 1972, Cape May Point began to purchase water from Cape May City because water in Well 2 was salty. Lacombe and Carleton (1992) show that the front moved at a rate of 121 ft/yr during 1943-72 between Cape May Point Wells 1 and 2.

Two industrial wells used for the manufacturing of magnesite and located in southern Lower Township just north of Cape May Point experienced saltwater intrusion. The first supply well (well 9-29; well Cm116 in Seaber, 1963, p. 107) completed in 1942 could have had an initial chloride concentration of 60 to 80 mg/L similar to the initial chloride concentrations of the second supply well (9-128; well Cm117 in Seaber, 1963, p. 107). The chloride concentration in well 9-29 increased to 269 mg/L by 1954. Well 9-28 was installed in 1953, and the chloride concentration in water samples were 79 mg/L in 1954. The water in well 9-28 became salty in 1978. Lacombe and Carleton (1992) show that the saltwater front moved at a rate of 138 ft/yr during 1954-78 at the company wells. Since 1978 no public- or industrial-supply wells have been active in the Cape May Point area. As a result, the present rate of moment of the saltwater front is significantly slower than it was during the 1940's-70's.

Saltwater intrusion is occurring in well 9-187 located at the mouth of Fishing Creek just north of Villas (fig. 61). Chloride concentrations in water samples collected from the well from the early 1960's to early 1970's ranged from 10 to 30 mg/L. By the mid-1980's the chloride concentration had risen to 50 mg/L. In 1994, the chloride concentration was 160 mg/L. Well 9-187 is a key well for documenting saltwater movement from the bay toward the Wildwood Water Department mainland well field.

With the exception of the Villas area, the saltwater front in the Cohansey aquifer on the bay side of the cape is offshore, possibly only a short distance (less than 1 mi). The saltwater front is moving landward in areas where water levels have declined, particularly where water levels are below sea level. The saltwater front has moved inshore in Villas as a result of withdrawals in the Wildwood Mainland well field. The USGS installed observation well 9-353 (fig. 7) on the shoreline west of Lower Twp MUA Well 1 (well 9-52) to assess the movement of saltwater toward the MUA's supply wells. The chloride concentration in well 9-353 was 11 mg/L in 1992.

Iron

During 1985-95, water samples were collected from 39 wells and analyzed for dissolved iron (table 9). Dissolved iron concentrations in the freshwater part of the aquifer ranged from 5 to 3,200 µg/L.

Twenty-two wells scattered throughout the county contain water with dissolved iron concentrations greater than the NJDEP secondary maximum contaminant level of 300 µg/L (fig. 62). The iron occurs naturally in the Cohansey Formation.

Changes in the concentrations of iron have been noted in the artificial recharge wells in North Wildwood and in Cape May City. The injected water in North Wildwood well 9-310 has an iron concentration of about 0.3 mg/L; however, late in the recovery season the iron concentration is greater than 0.4 mg/L. As a result, late in the season the injected water cannot be used. In Cape

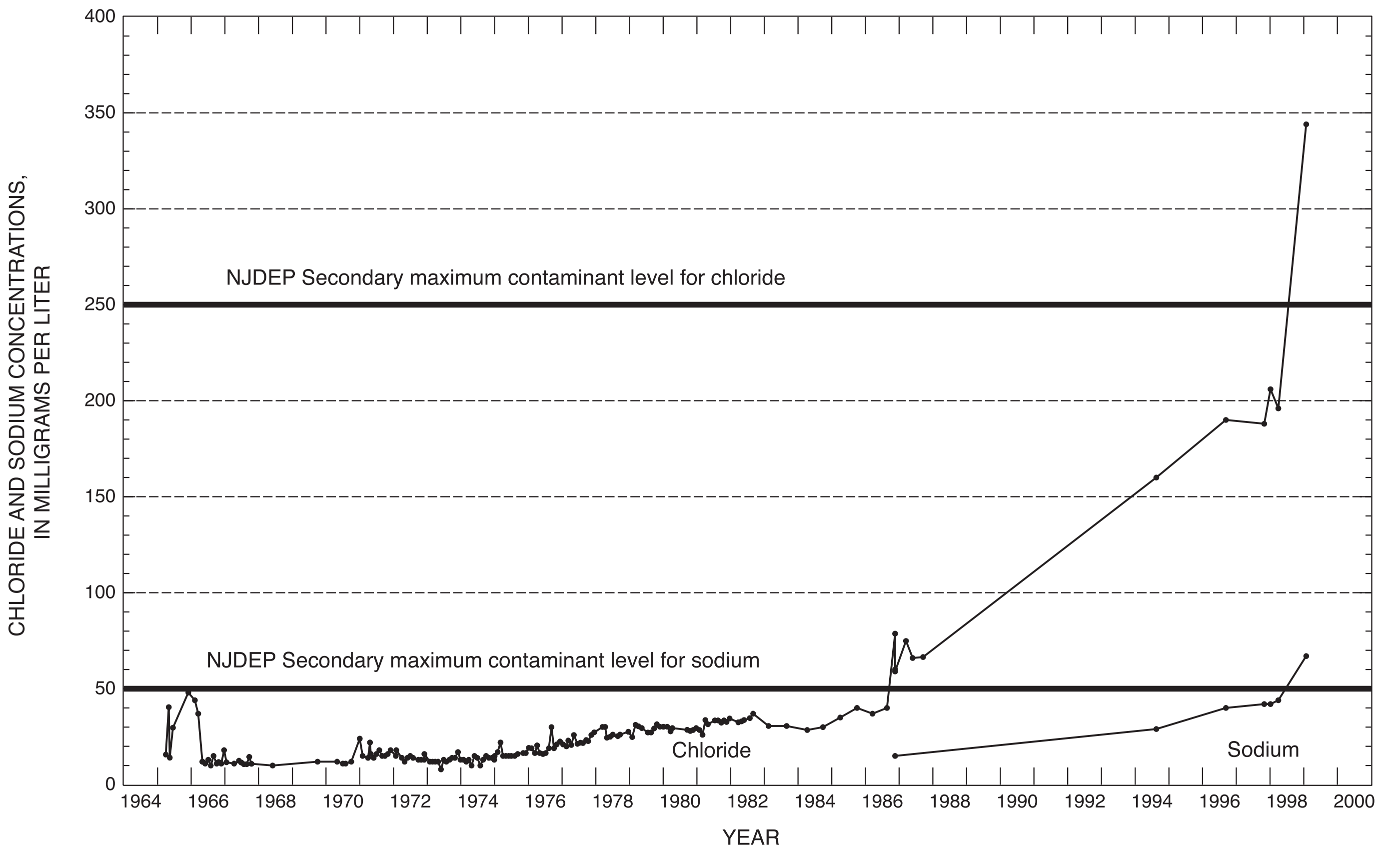


Figure 61. Chloride and sodium concentrations in samples from well 9-187 screened in the Cohansey aquifer at the mouth of Fishing Creek, Lower Township, Cape May County, New Jersey, 1964-99. (NJDEP is New Jersey Department of Environmental Protection.)

May City, well 9-27 is also used for recharge. The recharge water has an iron concentration of 0.03 mg/L; however, when the water is withdrawn, it is virtually free of iron (Dave Carrick, Cape May City Water Department, oral and written commun., 1994). As a result, the well screen and gravel pack become clogged and must be cleaned more frequently than those of the recharge wells of the Wildwood Water Department.

Rio Grande Water-Bearing Zone

The water quality of the Rio Grande water-bearing zone is for all practical purposes unaffected by contamination from land surface. The two sources of contamination, barring leakage from a breach in a well casing or a poorly constructed well, are saltwater intrusion from the saltwater part of the aquifer and dissolution of elements that are native to the aquifer and confining-unit materials.

Water samples were collected from five wells in the study area. The dissolved chloride concentrations in the aquifer ranged from 77 to 540 mg/L during 1989-95 (table 9). The chloride concentrations in samples from six wells in the study area and the location of the saltwater front (250-mg/L chloride contour) show that water in most of the aquifer is fresh (fig. 63). The location of the saltwater front is close to the location shown in Gill (1962a, p. 107). The chloride concentration in the aquifer at the Wildwood mainland well field has remained constant at about 80 mg/L since Gill (1962a, p. 107) sampled it in 1958.

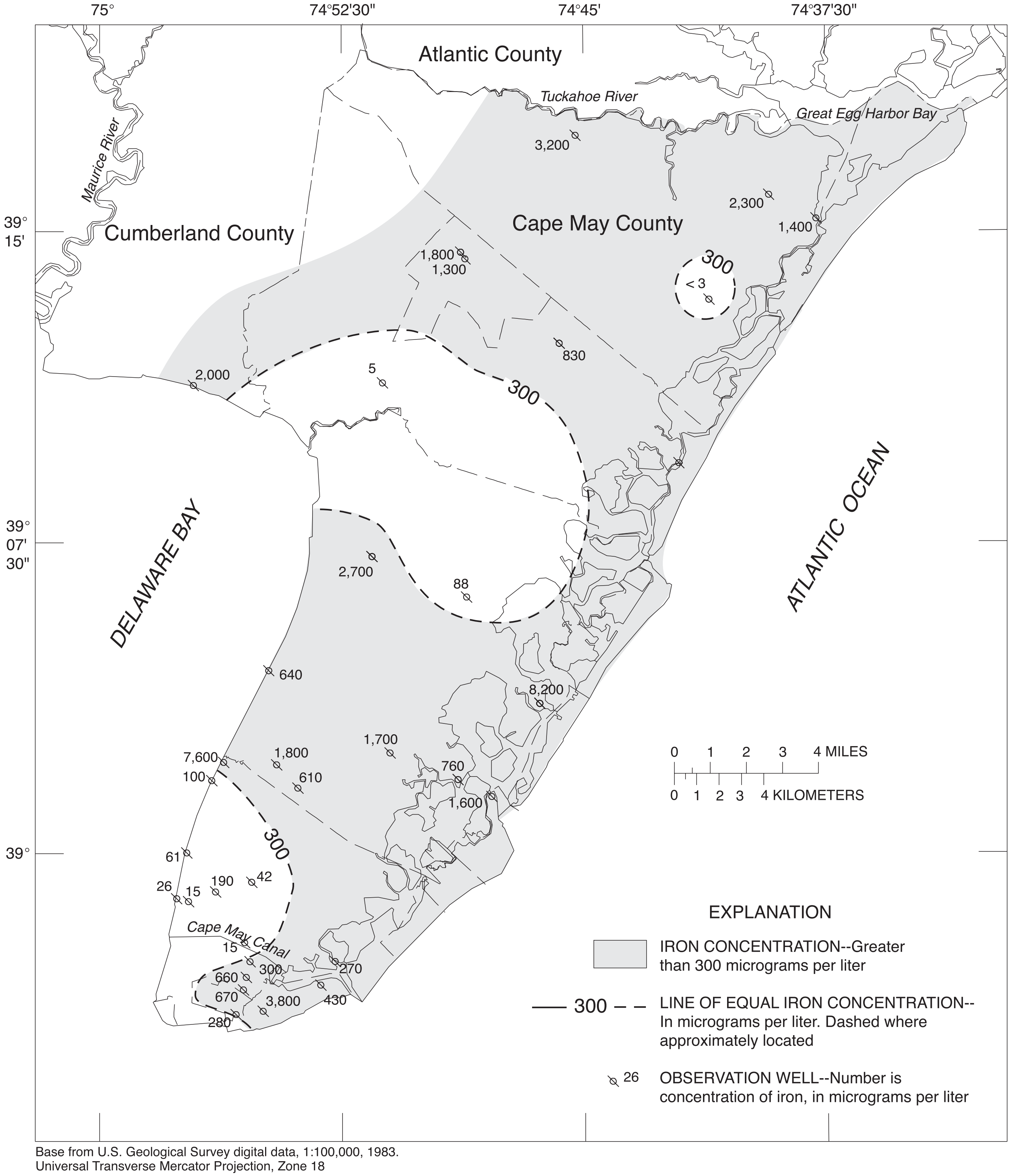
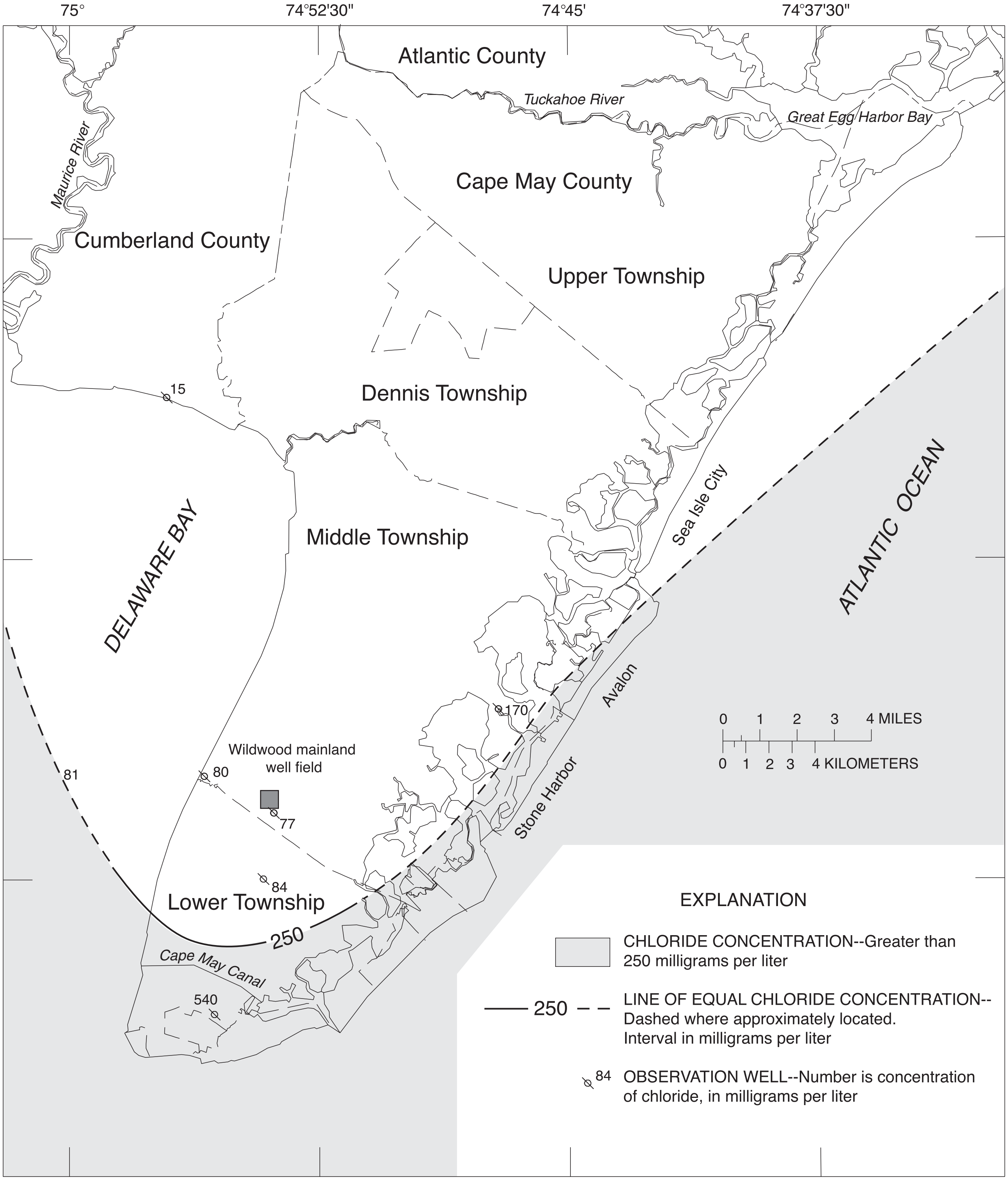


Figure 62. Iron concentrations in water samples from the Cohansey aquifer, Cape May County, New Jersey, 1987-99.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Universal Transverse Mercator Projection, Zone 18

Figure 63. Chloride concentrations in water samples from the Rio Grande water-bearing zone, Cape May County, New Jersey, 1989-92.

Concentrations of dissolved sodium in the samples collected during 1989-92 ranged from 68 to 410 mg/L. The locations of the five wells sampled, the sodium concentration at each well, and the location of the 50-mg/L sodium contour are shown in figure 64.

On the basis of water-quality data from wells in the study area and of the interpretation of electric logs, the aquifer contains freshwater in the mainland from Cape May Canal northward and under the barrier islands from the communities north of Sea Isle City to Delaware Bay. The aquifer contains salty water under the barrier islands south of Avalon and south of the canal (fig. 63; table 9).

Iron concentrations in water samples from the five wells in Cape May County and well 11-691 in Cumberland County ranged from <3 to 270 µg/L during 1989-92. Water in this aquifer had a lower concentration of dissolved iron than water in the shallower aquifers. As a result, the water may have a better taste and may not stain clothing or plumbing fixtures like the water from the shallower aquifers.

Atlantic City 800-Foot Sand

The water quality of the Atlantic City 800-foot sand is unaffected by contamination from land surface. The two sources of natural contamination in the aquifer, barring leakage from a breach in a well casing or a poorly constructed well, are saltwater intrusion from the saltwater part of the aquifer or dissolution of iron or other trace elements and compounds that are native to the aquifer material.

Chloride, Sodium, and Saltwater Intrusion

Water samples were collected by the USGS or by the well owner from 28 wells and analyzed for chloride and sodium (table 9, figs. 65 and 66). The chloride concentrations in water from supply wells from Ocean City to Stone Harbor and on the mainland north of Rio Grande ranged from 5 to 51 mg/L. The chloride concentration in water samples from observation wells south of Stone Harbor and Rio Grande ranged from 85 to 570 mg/L. The location of the 250-mg/L chloride contour (fig. 65) is based on these water-quality data. The location of the 250-mg/L chloride contour in the aquifer east of Cape May County is based on chloride data from the wells in Cape May County and from the two observation wells located 1.9 and 5 miles east of Atlantic City (fig. 1). The location of the 250-mg/L chloride contour in Delaware Bay is based on the projected location of the subcrop of the Atlantic City 800-foot sand in the bay and on water-quality data for the Brandywine Lighthouse well (fig. 1). Patrick (1944) suggests that during the 1940's the water in the Atlantic City 800-foot sand at the Brandywine shoal lighthouse in Delaware Bay, 7 mi west of the Cape May Canal (fig. 1), was too salty to be potable.

Chloride data collected during 1988-92 indicate that the location of the saltwater front is generally consistent with its location in the 1960's (Gill, 1962a, p. 103). One exception is it's location on the west side of the peninsula and under Delaware Bay. No chloride data for the west side of the peninsula were available for the late 1950's to 1960's to accurately determine the location of the saltwater front. On the basis of 1988-92 data, the saltwater front located along the west side of the cape is about 4 miles north of where Gill (1962a, p. 103) mapped it. The change in location is not indicative of saltwater movement but rather this is a refinement of the location based on newer data.

The concentration of chloride increases gradually from north to south along the barrier islands between Ocean City and Cape May Canal (fig. 67a). Chloride concentrations were at background values of 10 to 15 mg/L in Ocean City, Strathmere, and Sea Isle City. At the transition zone in Middle Township, Avalon, and Stone Harbor, the concentrations of chloride ranged from 35mg/L to more than 50 mg/L or 2 to 3 times higher than chloride concentrations in barrier island communities to the north. Chloride concentrations increase to 85 mg/L in North Wildwood and 530 mg/L in Lower Township. Data for the late 1950's for Wildwood Crest and Cape May City show chloride concentrations of about 350 and 1,500 mg/L, respectively (Gill, 1962a, fig.

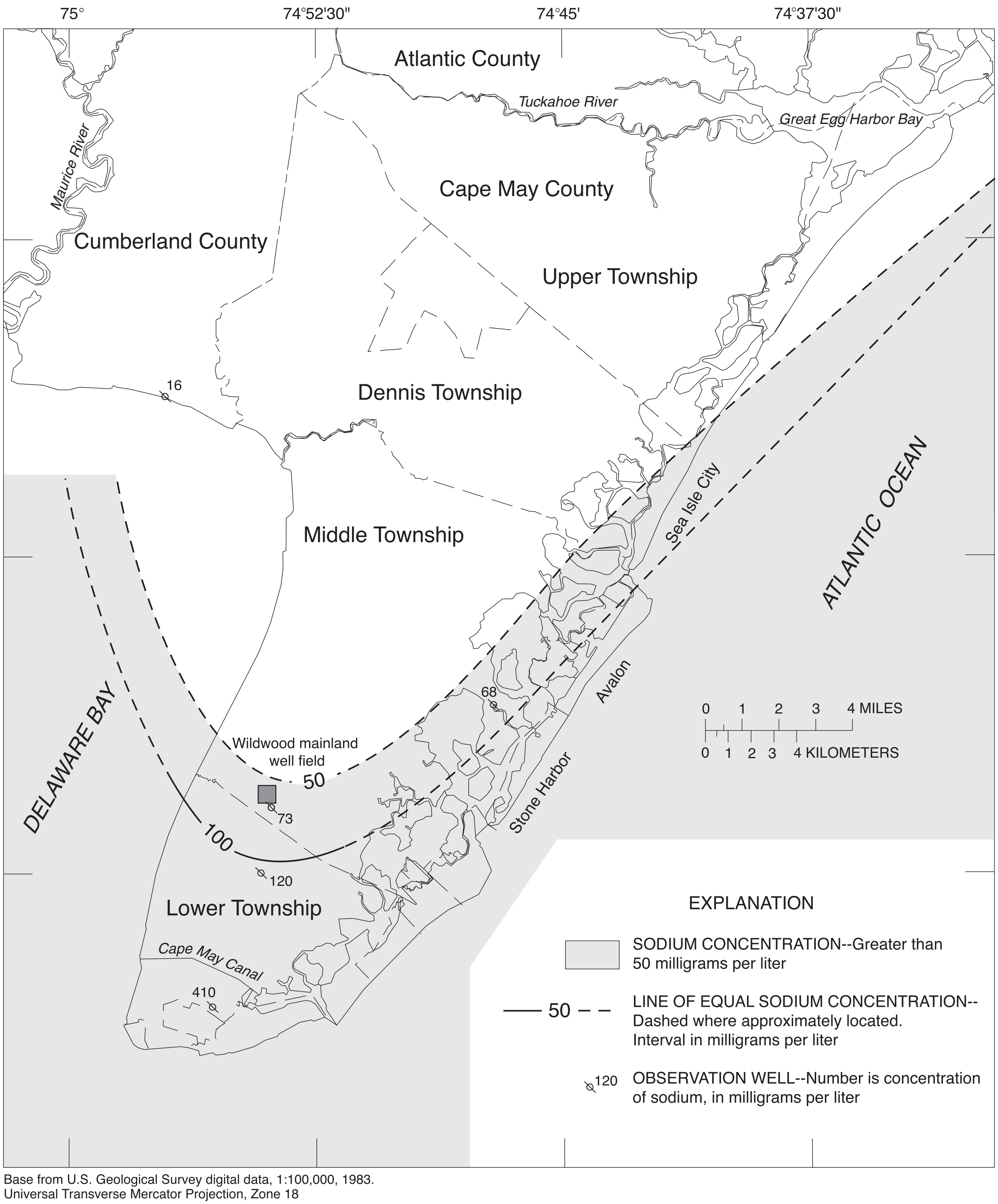


Figure 64. Sodium concentrations in water samples from the Rio Grande water-bearing zone, Cape May County, New Jersey, 1989-92.

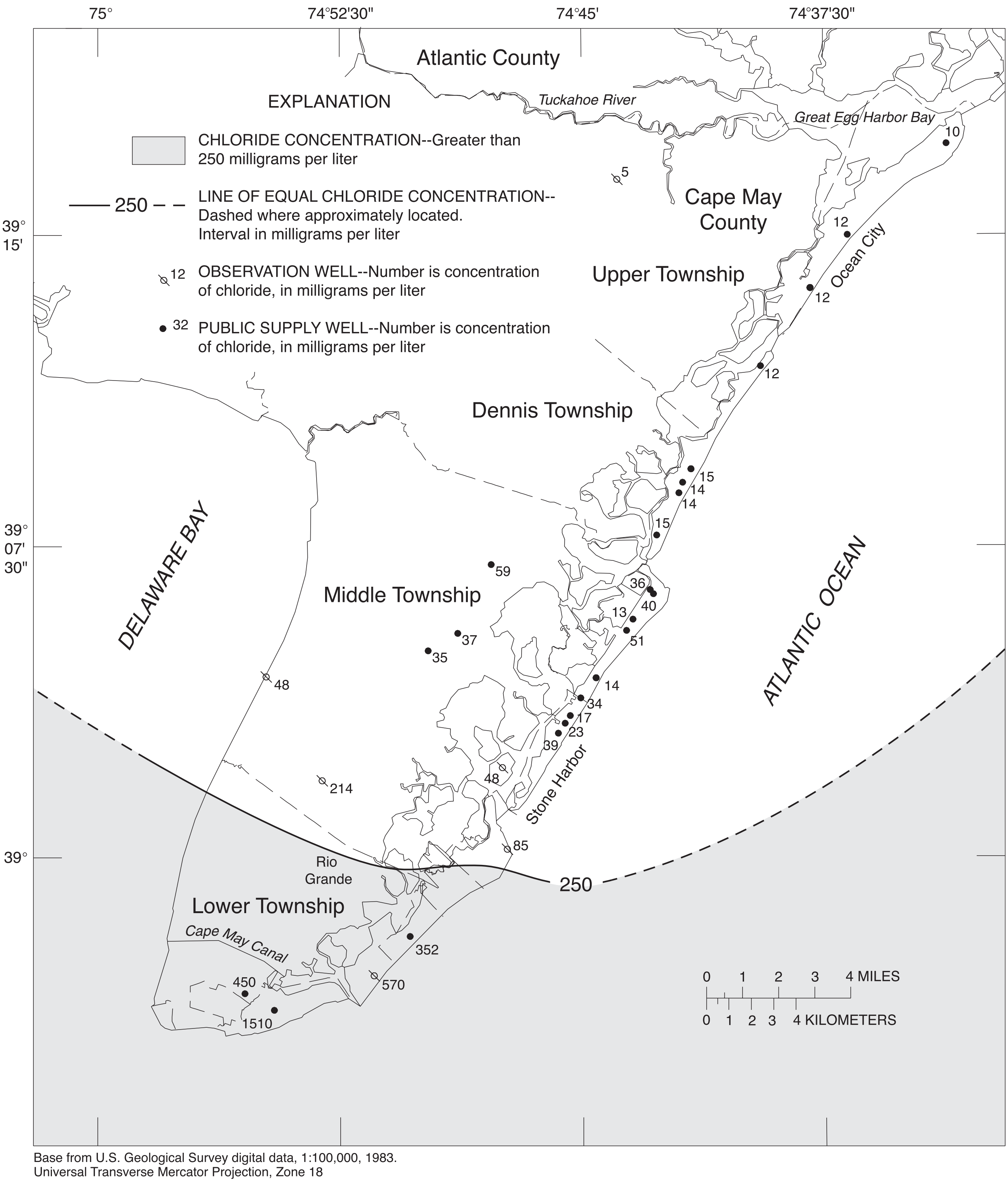


Figure 65. Chloride concentrations in water samples from the Atlantic City 800-foot sand aquifer, Cape May County, New Jersey, 1989-92.

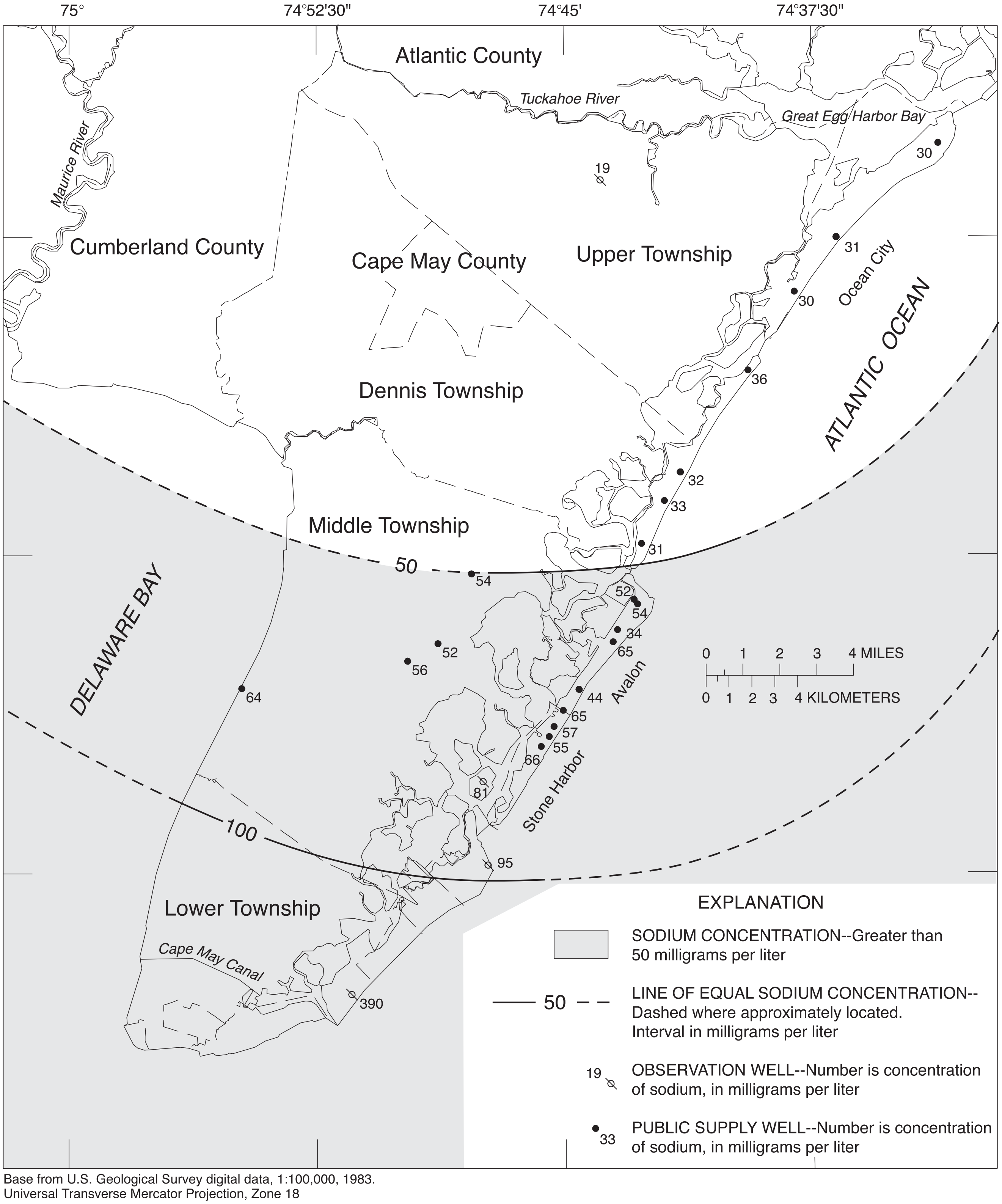


Figure 66. Sodium concentrations in water samples from the Atlantic City 800-foot sand aquifer, Cape May County, New Jersey, 1989-92.

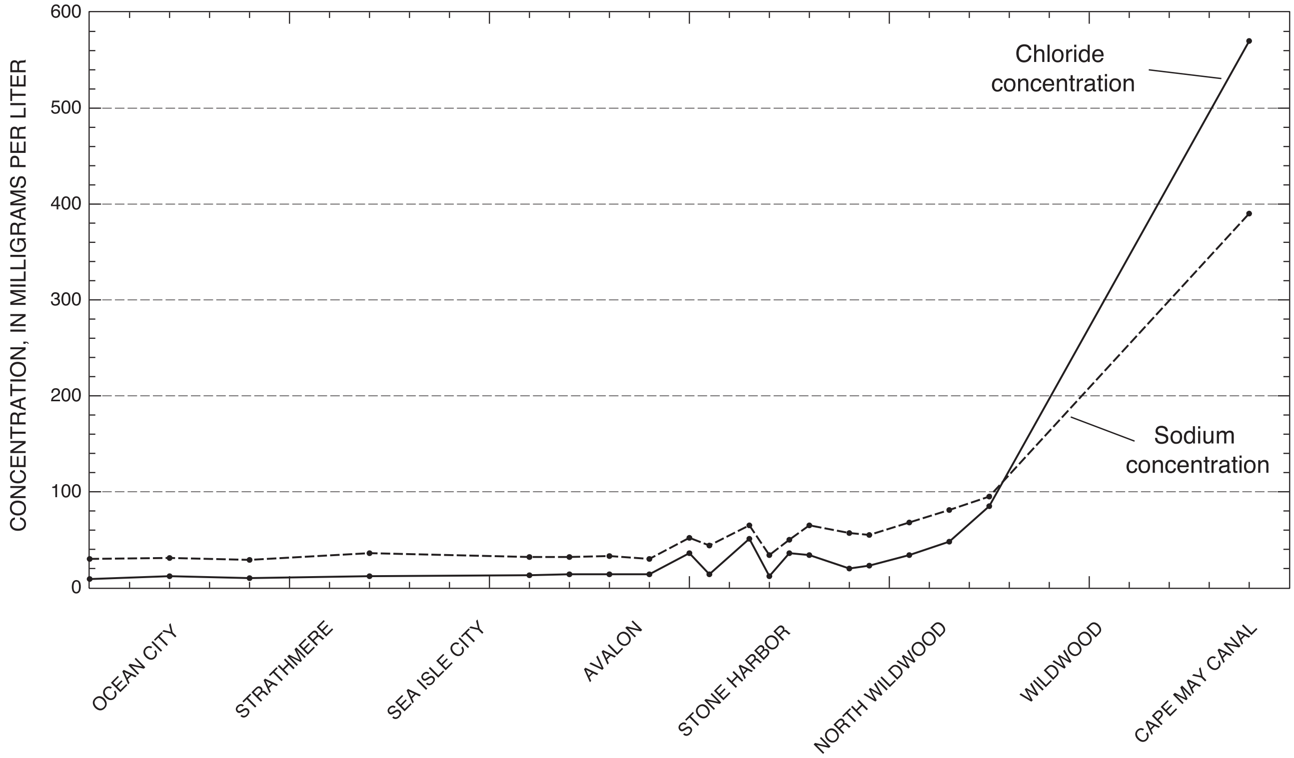


Figure 67a. Chloride and sodium concentrations in water samples from the Atlantic City 800-foot sand from Ocean City to the Cape May Canal along the barrier islands, Cape May County, New Jersey, 1990.

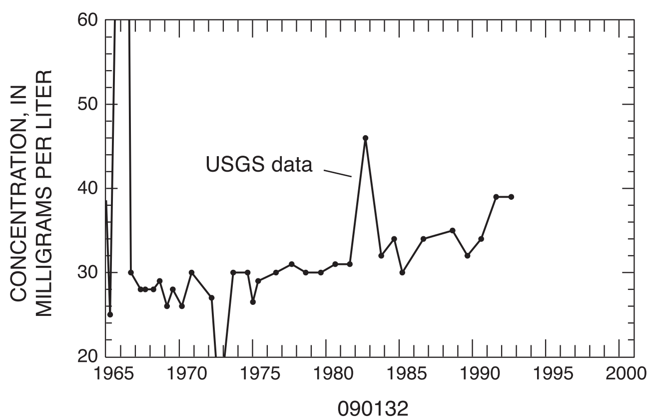


Figure 67b. Chloride concentrations in water samples from well 9-132 screened in the Atlantic City 800-foot sand, Stone Harbor, New Jersey, 1965-93. (USGS U.S. Geological Survey)

27, table 15). These higher chloride concentrations have been reported since the 1920's when wells were first drilled in these communities (Seaber, 1963, p. 141-148); therefore, the elevated chloride concentrations are not the result of recent seawater intrusion. The elevated chloride concentrations in Avalon and Stone Harbor may be a relief of the last interglacial period when the sea level was about 16 ft higher during recent times. During the last interglacial period, highly mineralized ground water was located more landward than it is during recent times, and the mineralized ground water left a chloride and sodium residue in the sediments that is slowly being released into the ground water. It is also plausible that the elevated chloride and sodium concentrations are a result of a subtle elevation of these ions in the chemical makeup of the sediments. None-the-less, the area is on the leading edge of a very broad transition zone from freshwater to saltwater.

Chloride data indicate that the saltwater front has moved northward about 2, 000 ft in Wildwood during 1958-71. Lacombe and Carleton (1992) calculated that the rate of movement was 154 ft/yr during that time. Simulation of ground-water flow in the Atlantic City 800-foot sand showed that the flow of salty water from the aquifer in the Wildwood area to the Stone Harbor public-supply wells will probably take hundreds of years (Voronin and others, 1996, p. 22).

The source of saltwater for intrusion in the Atlantic City 800-foot sand is much different from that in the Cohansey aquifer. As a result, the rate of saltwater intrusion is much slower in the Atlantic City 800-foot sand. The source of saltwater is a broad saltwater zone between the 250-mg/L chloride line, and the 10,000 mg/L, or the half-seawater line (Lacombe and Rosman 1997). This broad saltwater zone in the Atlantic City 800-foot sand is more than 5 miles wide, whereas the zone in the Cohansey aquifer is probably much less than 1 mile wide. As a result, saltwater intrusion in the Atlantic City 800-foot sand occurs at a slow rate for a long time. The rate of increase is perhaps 0.5 to 2 mg/L per year; that rate of movement can last for many decades. Chloride concentrations in samples from well 9-132 in Stone Harbor show that chloride concentrations in the Atlantic City 800-foot sand have increased from about 30 to 48 mg/L during 1973-93 (fig. 76b).

Concentrations of dissolved sodium ranged from 19 to 390 mg/L during 1985-92. The location of the 50-mg/L sodium contour line (fig. 66) is about 3 miles north of the 250-mg/L chloride line (fig. 65). Samples from nine public-supply wells contained sodium concentrations in excess of the NJDEP secondary drinking-water standard of 50 mg/L. Elevated concentrations of sodium probably are caused by the same conditions that caused the elevated concentrations of chloride.

Iron

The concentration of iron was determined for water samples from 21 wells during 1985-92 (table 9, fig. 68). Dissolved iron concentrations in the public-supply wells ranged from 6 to 92 µg/L. The iron concentrations in a sample from observation well 9-302 was 290 µg/L (table 9). No public-supply wells that tap the aquifer had iron concentrations in excess of the NJDEP secondary drinking-water standard of 300 µg/L.

WATER BUDGETS

A water budget is calculated to quantify the volume of water passing through the components of the flow system. Knowledge of the volumetric amounts of the budget components can be particularly useful in gaining perspective on the relative importance of various parts of the flow system and can aid in the management of water resources.

The five components of the water budget of a hydrologic flow system are (1) precipitation; (2) evapotranspiration; (3) flow paths in, through, and out of the aquifers; (4) discharge to freshwater and saltwater bodies; and (5) withdrawals from wells.

The water budgets for the three shallow and the two deep aquifers in Cape May County are presented as a schematic flow-path diagram for a time prior to development and for 1990.

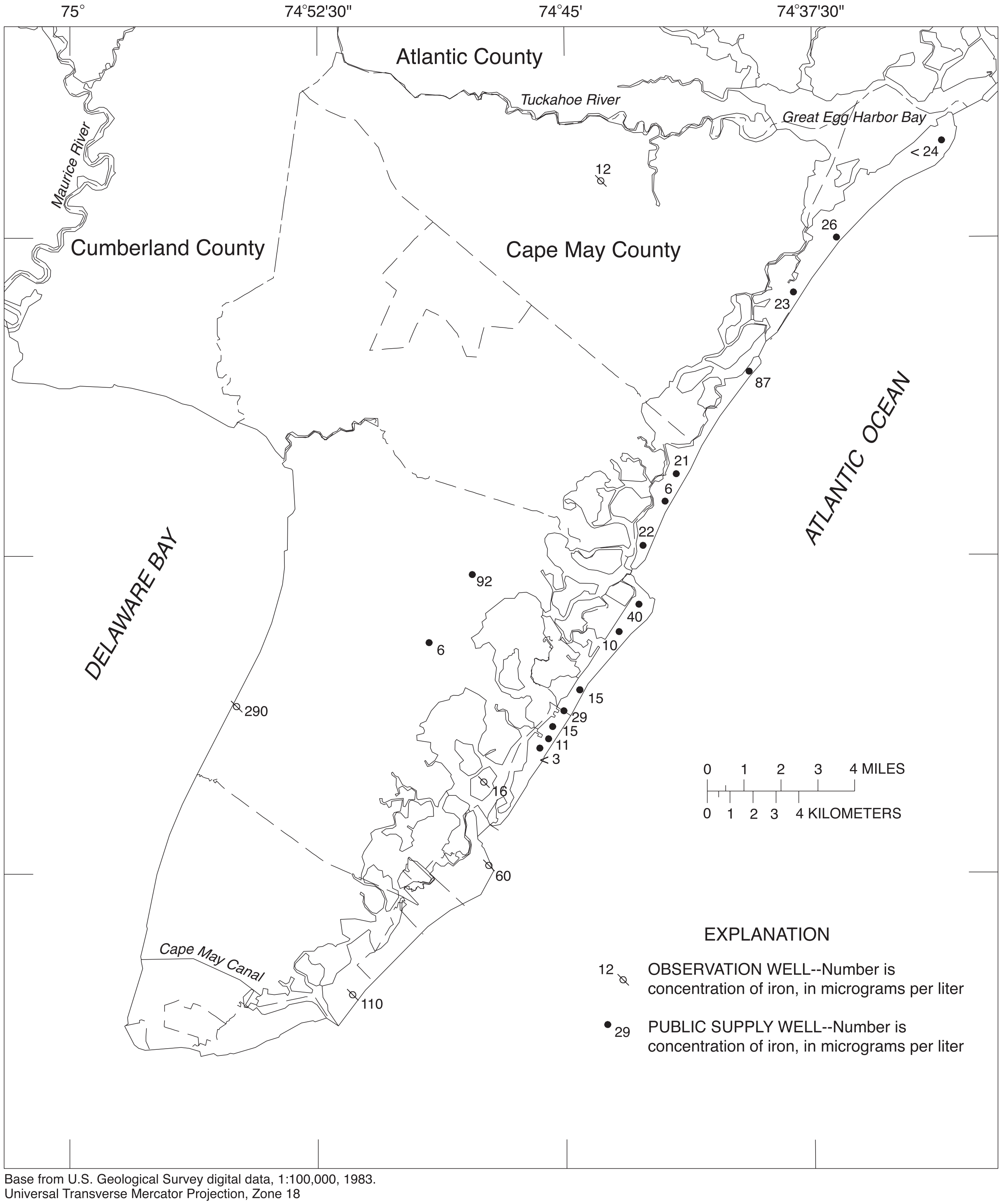


Figure 68. Iron concentrations in water samples from the Atlantic City 800-foot sand, Cape May County, New Jersey, 1989-92.

The empirical equation for the water budget for land surface is

$$P = ET + Q_d + R ,$$

for the water-table aquifer is

$$R = Q_{bf} + L' + W ,$$

and for a confined aquifer is

$$L = Q_l + L' + W,$$

where

P is precipitation,

ET is evapotranspiration,

Q_d is direct/overland discharge to a surface-water body,

R is recharge to the water-table aquifer from land surface,

Q_{bf} is base-flow discharge to a surface-water body,

L is leakage into a confined aquifer,

L' is leakage out of an aquifer through a confining unit,

W is water withdrawal, and

Q_l is lateral discharge from the confined aquifer to salty water.

For each of these budget equations, it is assumed that the ground-water system is at steady-state, meaning that no substantial change in ground-water levels occurs.

Shallow Aquifer System Prior To Development

Average annual precipitation in Cape May County during 1890-1910 and 1958-87 was 41.9 in. (table 1). When 41.9 in/yr is converted to common units for this budget, about 192,000 Mgal/yr of freshwater fell on Cape May County (fig. 69). The county covers 263 mi^2, of which 55 mi^2 is freshwater wetlands, 108 mi^2 is upland area, and 100 mi^2 is saltwater wetlands. Precipitation that falls on saltwater wetland --about 73,000 Mgal/yr-- becomes non-potable water as a consequence of saltwater contamination and is removed from the available freshwater in the budget.

The average amount of precipitation that falls on freshwater wetlands is about 40,200 Mgal/yr and on upland areas is about 78,800 Mgal/yr. Precipitation that falls onto land surfaces in these areas will (1) evapotranspire (ET), (2) become direct overland discharge (Q_d) to streams and wetland areas with outflows, or (3) recharge (R) the Holly Beach water-bearing zone. Average potential ET is 25 in/yr based on Thorntwaite's method for calculating ET (Chow, 1964). The amount of water available for ET also can be determined by subtracting the average annual stream discharge and the estimated annual downward leakage from the Holly Beach water-bearing zone to the confined aquifers from the average annual precipitation. Average stream discharge for the county is 19.3 in/yr, or about 54,800 Mgal/yr, and estimated downward leakage into deeper aquifers is about 600 Mgal/yr. Therefore, the amount of available ET from the freshwater wetland and the upland area is 22.4 in/yr, or 21,500 Mgal/yr evapotranspired from freshwater wetlands and 42,100 Mgal/yr evapotranspired from upland areas.

The direct discharge to streams calculated by using the base-flow separation methods is discussed in the surface-water supply section of this report. Of the annual average stream discharge, 15 percent, or about 8,200 Mgal/yr, is direct discharge, and 85 percent, or about 46,600 Mgal/yr, is base-flow discharge. It is likely that 100 percent of direct discharge is from freshwater wetland areas.

During predevelopment, recharge to the Holly Beach water-bearing zone from freshwater wetland areas was about 10,500 Mgal/yr. The recharge was precipitation that fell on freshwater wetland and did not evapotranspire nor discharge directly to the streams. Recharge to the aquifer from the upland areas was about 36,700 Mgal/yr and consisted of precipitation that was not evapotranspired. Total annual recharge to the Holly Beach water-bearing zone was 47,200 Mgal/yr.

The recharge water that entered the Holly Beach water-bearing zone flowed through the aquifer, then left it as (1) baseflow to streams, an

WATER BUDGET OF THE SHALLOW AQUIFER SYSTEM DURING PREDEVELOPMENT

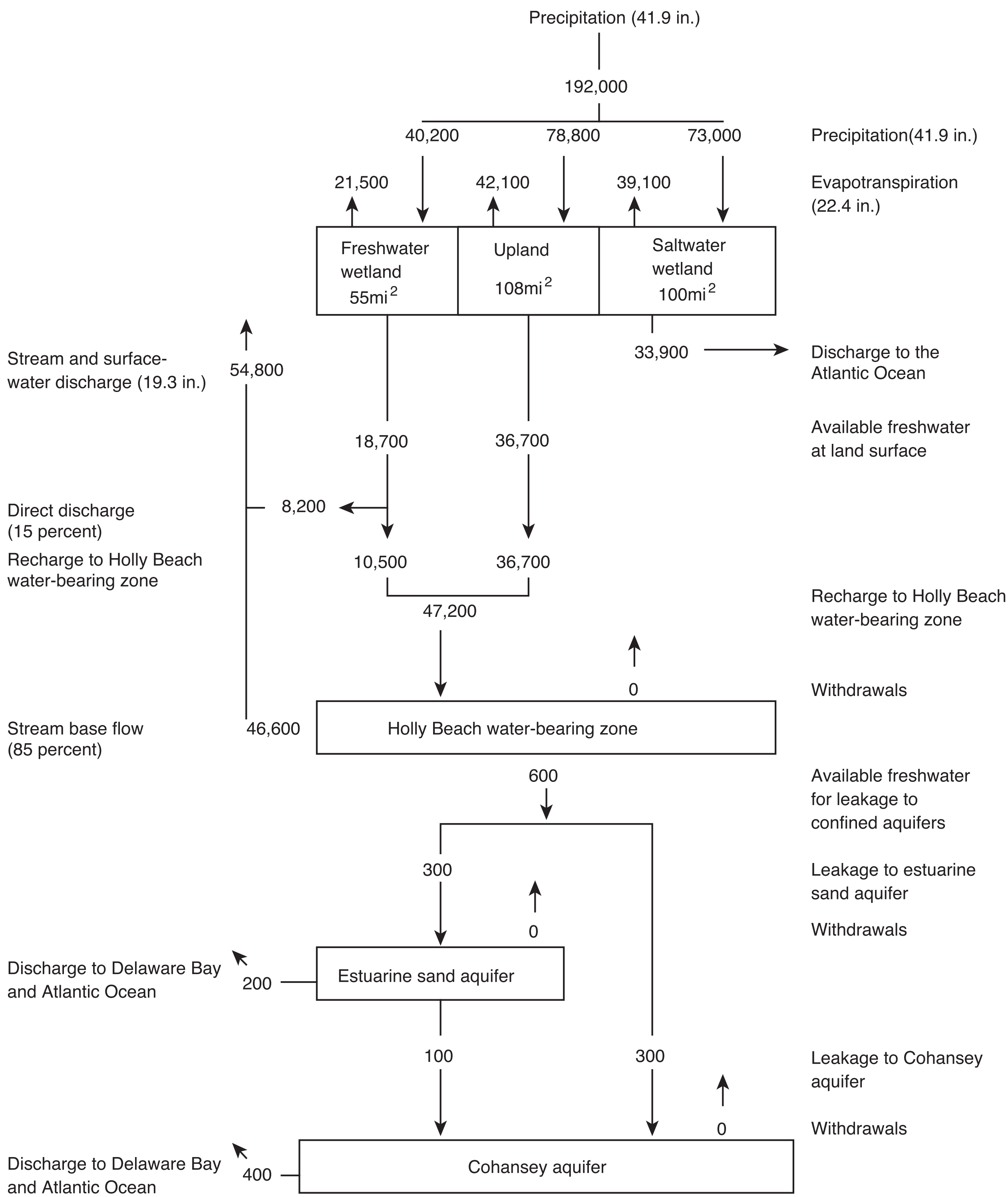


Figure 69. Annual average water budget, in million gallons, for the shallow aquifer system during pre-development. (Precipitation (41.9) is inches of water over the study area; (85 percent) is percent of annual average stream flow.)

amount of about 46,600 Mgal/yr, or (2) leakage to deeper aquifers, an amount of about 600 Mgal/yr. The leakage can be estimated by using Darcy's Law,

$$Q = KAf\ \Delta h/\Delta l\ ,$$

where

- Q is the aquifer discharge as leakage to a deeper aquifer in Mgal/yr;
- K is a hydraulic conductivity, 0.4 ft/yr,
- A is the area of the aquifer base, 163 mi^2,
- Δh is the difference in head, 2 ft,
- Δl is the length of the flow path (thickness of confining unit), 50 ft, and
- f is a constant 208.5 to convert the units to Mgal/yr.

By using Darcy's Law, it is estimated that about half the water, or 300 Mgal/yr, that leaked out of the base of the Holly Beach water-bearing zone recharged the estuarine sand aquifer, and about half leaked into the Cohansey aquifer in the northern half of the county.

The water budget for the estuarine sand aquifer can be estimated by using Darcy's Law, pre-pumping water levels, and approximate values for aquifer characteristics (K = 0.4 ft/yr, A = 50 mi^2, Δh = 1 ft, Δl = 50 ft, f = 208.5). On the basis of Darcy's Law, about 100 Mgal/yr leaked from the estuarine sand aquifer into the Cohansey aquifer in southern Cape May County. The remainder of the water, about 200 Mgal/yr, probably discharged laterally to the ocean and bay.

The water budget for the Cohansey aquifer prior to development shows that the aquifer received about 300 Mgal/yr from the Holly Beach water-bearing zone in northern Cape May County and about 100 Mgal/yr from the estuarine sand aquifer. The recharge water discharged to the ocean and bay.

Spitz and Barringer (1992) used a ground-water flow model to show that about 1.5 percent of the recharge into the Holly Beach water-bearing zone leaked into the estuarine sand aquifer, and 20 percent of the recharge into the estuarine sand aquifer recharged the Cohansey aquifer. In this report it is estimated that 2 percent of the recharge into the Holly Beach water-bearing zone leaked into the estuarine sand aquifer and that 40 percent of the recharge into the estuarine sand aquifer leaked into the Cohansey aquifer. The percentages produced by these two methods are different, but the volumes are about equal.

Shallow Aquifer System During 1990

During 1960-90 the average annual precipitation was 41.9 in. or 192,000 Mgal (fig. 70). The extent of the three land area types, and the rates of ET and surface-water discharge likely are the same as those prior to development. During 1990, water withdrawals from the Holly Beach water-bearing zone totaled 3,000 Mgal; from the estuarine sand aquifer, 1,000 Mgal; and from the Cohansey aquifer, 2,200 Mgal (fig. 31). Water withdrawals from these aquifers resulted in reduced base flow to streams, discharge to surface water, and freshwater storage within the aquifer by measurably lowering water levels and decreasing stream discharges in the southern part of the county.

Withdrawals of freshwater from the Holly Beach water-bearing zone and induced leakage from the Holly Beach water-bearing zone into the estuarine sand aquifer and the Cohansey aquifer results in decreased base flow to streams (fig. 70).

The largest water users of the Holly Beach water-bearing zone are the sand and gravel mining firms in Dennis and Upper Townships. The water they withdraw is recycled many times, and therefore, it is difficult to assess how much of the water is reused. If reported water use is considered to be withdrawn once and discharged to a tributary of the Great Cedar Swamp (fig. 1), ground-water discharge to surface-water bodies is bypassed. Therefore, the stream base-flow component of the water budget is reduced by 2,700 Mgal to account for direct withdrawal from the Holly Beach water-bearing zone.

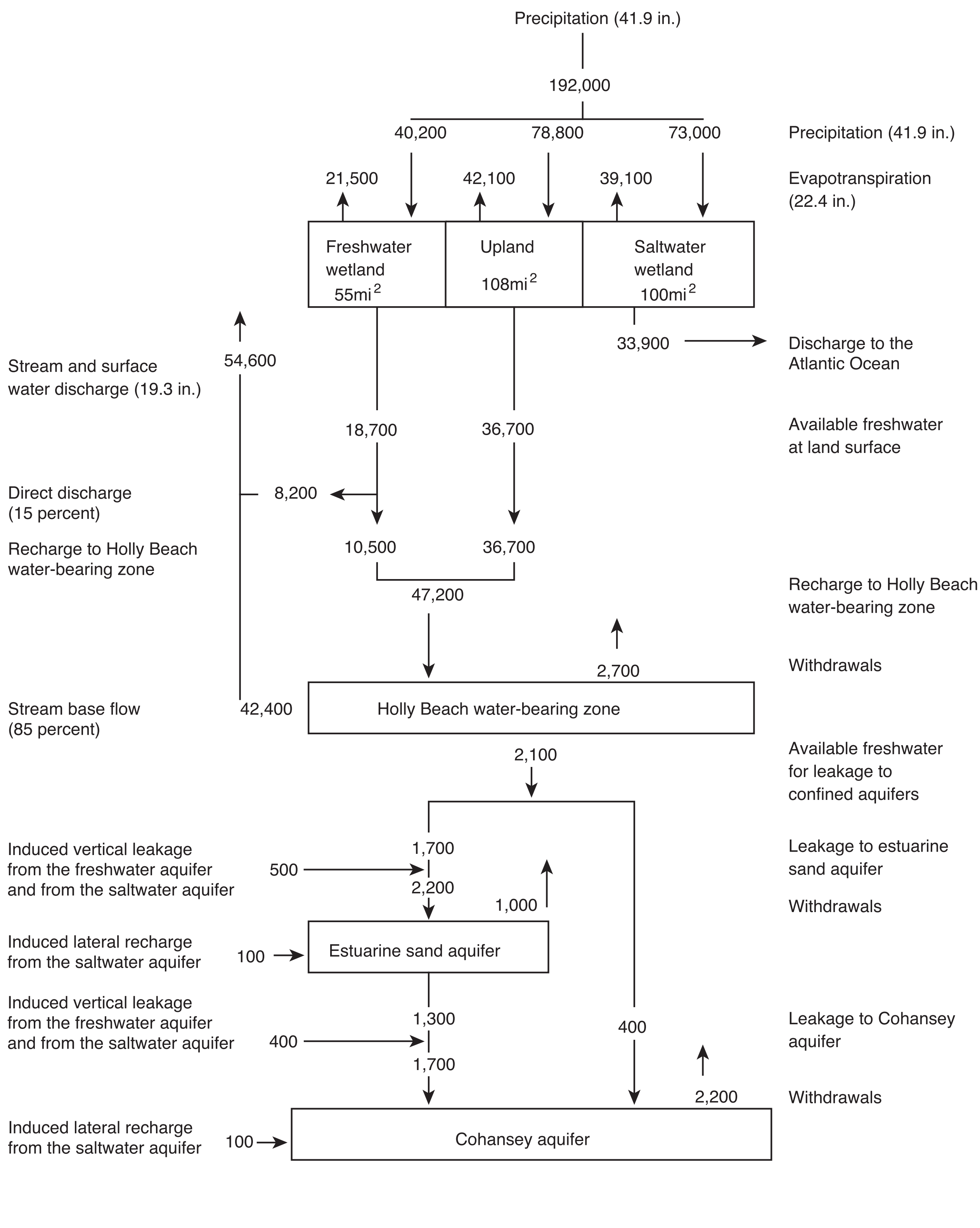


Figure 70. Annual average water budget, in million gallons, for the shallow aquifer system during 1990. (Precipitation (41.9) is inches of water over the study area; (85 percent) is percent of annual average stream flow.)

The source of water that is directly and indirectly withdrawn from the estuarine sand aquifer is induced leakage of either freshwater or saltwater from the Holly Beach water-bearing zone and storage within the estuarine sand aquifer (fig. 70). Two methods can be used to estimate induced leakage, (1) Darcy's Law and data from potentiometric-surface maps and hydrogeology, and (2) interpretations of reduced stream discharge in areas of the cone of depression. Darcy's Law and data from potentiometric-surface maps show that induced leakage of freshwater and saltwater into the cone of depression (areas where water-level altitudes are zero or less) of the estuarine sand aquifer is about 1,300 Mgal (K = 0.4 ft/yr, A = 50 mi^2, Δh = 15 ft, Δl = 50 ft, f = 208.5).

Stream discharge per square mile in southern Cape May County is about 85 percent of stream discharge in northern Cape May County. Unit discharge measurements in small basins are not as accurate as unit discharge measurements in large basins. Therefore, a potential exists for a 15 percent decrease in discharge in the area of the cone of depression in the estuarine sand aquifer. The areal extent of the cone is about 50 mi^2; therefore, a 15 percent decrease in the stream discharge is 2,500 Mgal.

The two methods used to calculate induced leakage yield values of 1,300 and 2,500 Mgal. The average is about 1,900 Mgal. About twenty-five percent of the cone of depression in the estuarine sand aquifer is overlain by saltwater in the Holly Beach water-bearing zone or surficial saltwater; therefore, about 25 percent of the induced leakage is saltwater (about 500 Mgal) and 75 percent is freshwater (about 1,400 Mgal).

The decrease in storage of the estuarine sand aquifer is, on the basis of the Theim equation, less than 100 Mgal (K = 14,000 ft/yr, b = 50 ft, Δh = 10, r' = 4 mi, r" = 10 ft). Therefore, lateral intrusion of saltwater into the estuarine sand aquifer is not as significant as vertical leakage of saltwater from areas where the Holly Beach water-bearing zone is salty. These calculations indicate that nearly twice as much water leaks into the estuarine sand aquifer than is directly withdrawn from the aquifer; therefore, withdrawals from the Cohansey aquifer induce water to flow from the estuarine sand aquifer and, in part, cause the cone of depression in the estuarine sand aquifer.

The source of the water that is withdrawn from the Cohansey aquifer in northern Cape May County is induced leakage directly from the Holly Beach water-bearing zone because the estuarine sand aquifer is not present in the northern half of the county. The source of water that is withdrawn from the Cohansey aquifer in southern Cape May County is induced leakage that must pass through the estuarine sand aquifer to the Cohansey aquifer.

Prior to development, an estimated 300 Mgal/yr leaked into the Cohansey aquifer from the Holly Beach water-bearing zone in northern Cape May County. The major water user in northern Cape May County is the Woodbine Water Department, which withdraws about 100 Mgal/yr. The source of water withdrawn by the Woodbine Water Department is induced leakage from the Holly Beach water-bearing zone. Therefore, in 1990, the leakage in northern Cape May County from the Holly Beach water-bearing zone into the Cohansey aquifer was about 400 Mgal.

Induced leakage from the freshwater and saltwater parts of the estuarine sand aquifer into the Cohansey aquifer can be calculated by using Darcy's Law, the 1990 potentiometric-surface value, and framework data. The induced leakage is about 1,700 Mgal (K = 0.4 ft/yr, A = 100 mi^2, Δh = 10 ft, Δl = 50 ft, f = 208.5). About 40 percent of the cone of depression in the Cohansey aquifer is overlain by saltwater in the estuarine sand aquifer; however, the difference between the potentiometric-surface values at areas where saltwater overlies the freshwater part of the Cohansey aquifer is small, less than 5 ft. About 25 percent of the leakage is salty water, 400 Mgal, and about 75 percent is freshwater, 1,300 Mgal. The decrease in storage of the Cohansey aquifer on the basis of the Theim equation is 100 Mgal (K = 14,000 ft/yr, b = 125 ft, Δ h = 10, r' = 4 mi, and r" = 10 ft). On the basis of this result, lateral intrusion of saltwater into the Cohansey aquifer is not as significant as vertical leakage of saltwater from the estuarine sand aquifer.

Water withdrawals from the Cohansey aquifer have been relatively stable at 2,200 Mgal per year from 1975 through 1990. Potentiometric-surface maps show that the cone of depression has not expanded or deepened appreciably during those years. Therefore, the cone of depression can be considered to be stable, and very little of the water that is withdrawn from the Cohansey aquifer is from lateral flow in the aquifer.

Spitz and Barringer (1992) show that about 9 percent of the recharge into the Holly Beach water-bearing zone leaked into the estuarine sand aquifer and 120 percent of the recharge into the estuarine sand aquifer recharged the Cohansey aquifer. For this report, it is estimated that 3 percent of the recharge into the Holly Beach water-bearing zone leaked into the estuarine sand aquifer and that 70 percent of the recharge into the estuarine sand aquifer leaked into the Cohansey aquifer.

Deep Aquifer System Prior To Development

The source of water to the Rio Grande water-bearing zone and the Atlantic City 800-foot sand in Cape May County is recharge from the upland areas of Cumberland County and western Atlantic County (fig. 71). Predevelopment potentiometric-surface maps, hydrostratigraphic maps, and Darcy's Law were used to estimate that 200 Mgal/yr flowed through the Atlantic City 800-foot sand in Cape May County and discharged to the ocean or bay (K =14,000 ft/yr, b = 125 ft, A = 15 mi., Δh = 15 ft, and Δl = 15 mi^2). By using Darcy's Law, discharge through the confining unit overlying the Atlantic City 800-foot sand was estimated to be 200 Mgal/yr (K = 0.2 ft/yr, A = 150 mi^2, Δh = 10 ft, Δl = 300 ft, and f = 208.5).

Little is known about the water levels in the Rio Grande water-bearing zone prior to development. The Rio Grande water-bearing zone is half as thick as the Atlantic City 800-foot sand. Therefore, it probably has half as much flow as the Atlantic City 800-foot sand, or about 100 Mgal/yr.

Deep Aquifer System During 1990

The source of water to the Rio Grande water-bearing zone and the Atlantic City 800-foot sand is recharge from the upland areas of Cumberland County and western Atlantic County and storage in the aquifer in areas under the Atlantic Ocean and Delaware Bay (fig. 71). The vertical leakage through the confining units overlying the Rio Grande water-bearing zone and underlying the Atlantic City 800-foot sand is small enough to be insignificant; therefore, for the water budget, it is considered to be zero.

Withdrawals from the Atlantic City 800-foot sand totaled about 2,200 Mgal in 1990. Water was withdrawn primarily along the Atlantic coastline in Cape May County and has caused a measurable decrease in water levels in the aquifer. The Darcy equation was used with data from the 1990 potentiometric-surface map to calculate that about 2,200 Mgal flowed through the Atlantic City 800-foot sand in Cape May County. The source of the freshwater was induced flow from the west and totaled about 1,200 Mgal (K = 14,000 ft/yr, b = 125 ft, s = 15 mi, Δh = 60 ft, and Δl = 10 mi). The decrease in storage in the eastern and southern parts of the county amounted to about 800 Mgal (K = 14,000 ft/yr, b = 125 ft, s = 15 mi, Δh = 60 ft, and Δl = 15 mi). Potential leakage from the Rio Grande water-bearing zone was about 900 Mgal (K = 0.2 ft/yr, A = 300 mi^2, Δh = 42 ft, Δl = 100 ft and f = 208.5).

AVAILABILITY OF FRESHWATER SUPPLIES

The availability of supplies of freshwater in Cape May County depends on the quality and quantity of water that is needed by the user and on the location and time of year of the withdrawal. The five major types of water users in the county have water quality and quantity requirements categorized as high, medium, or low based on NJDEP drinking-water standards and their annual withdrawal rate (fig. 72).

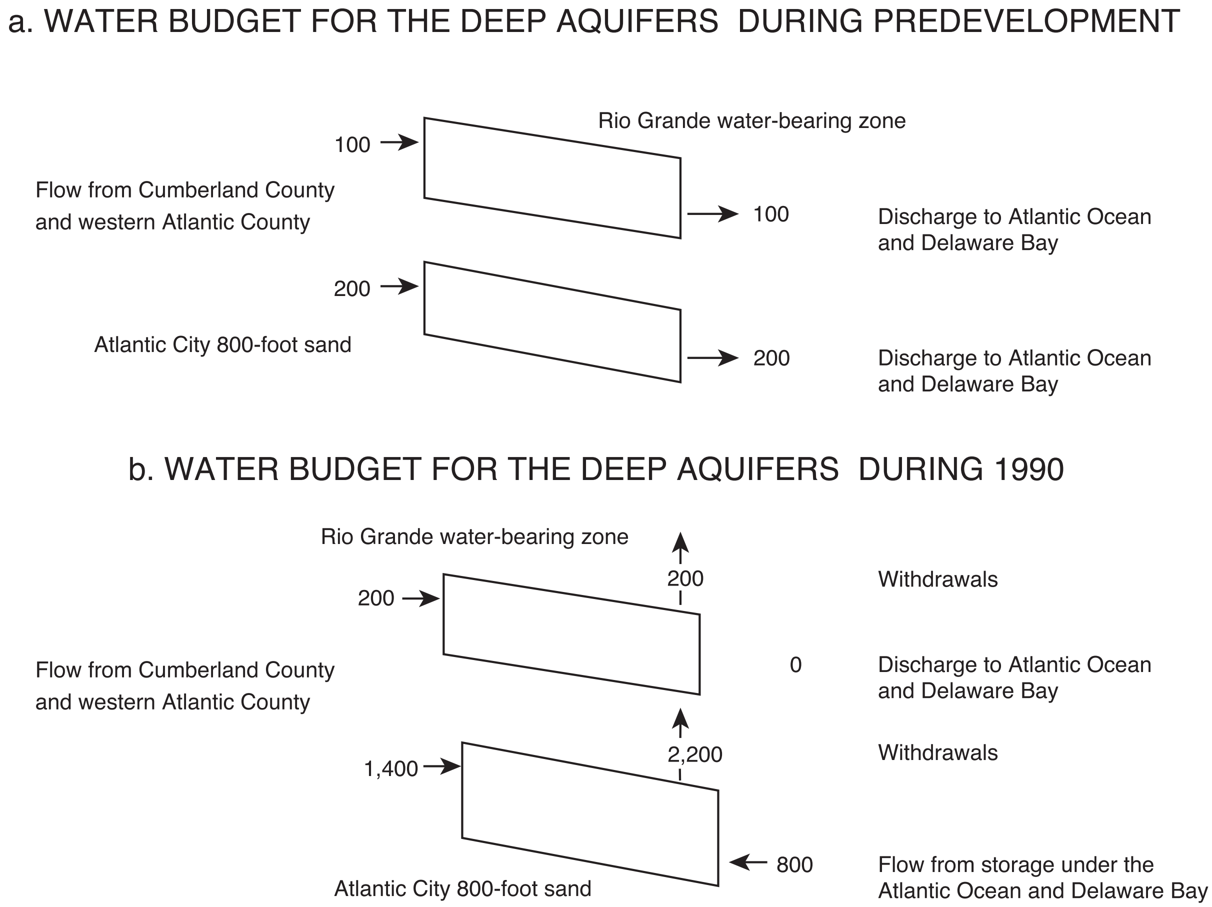


Figure 71. Annual average water budget, in million gallons, for the deep aquifer system during (a) predevelopment and (b) 1990.

		Annual withdrawal rate		
		High	Medium	Low
NJDEP drinking-water standards	High	**Public Supply**	**Industrial Supply**	**Domestic Supply**
	Medium	**Irrigation Supply**		
	Low	**Mining Supply**		

Figure 72. Types of water supply based on NJDEP water-quality standards and withdrawal rates. (NJDEP is New Jersey Department of Environmental Protection)

Public-supply water is mandated to be of high quality, and typically, public-supply well owners require high quantities of water. Domestic-supply users also require high-quality water, but typically they need only low quantities of water. Industrial-supply users, such as the electric generation and fishing industries of Cape May County, usually need high quality water though they only require medium quantities of water. Irrigation-supply users do not usually need water that meets NJDEP drinking-water standards, and the quantity of water needed during the summer growing season depends on rainfall. Mining-supply users typically use large quantities of water, but the quality of the water is of little concern.

The availability of water also is based on location, such as the source of water and geographic location of the stream intake or well, and on the time of year. The major sources of freshwater are the Tuckahoe River, mill ponds with discharges that are greater than 400 Mgal/yr, and the five aquifers in the county. Small quantities of high-quality water are available in most parts of the county. The focus of this section is to define the location of areas where large quantities of freshwater are available. Such areas have the greatest potential to safely sustain withdrawal of freshwater for public supply for a long time.

Cape May County's annual demand for public-, domestic-, and industrial-water supply was about 5,400 Mgal/yr in 1990. The monthly demand in August was 675 Mgal but only 200 Mgal in February. Water availability decreases greatly during the summer as a result of evapotranspiration and is much higher in the other three seasons. As a result, months of high water demand are also months of low water availability, and months of low water demand are the months of high water availability.

Surface-Water Supply

Surface-water discharge is greater for the Tuckahoe River than for any other stream in Cape May County. Mean annual discharge during the period of record was 10,300 Mgal/yr (43.8 ft^3/s) (table 3), and mean monthly discharge ranged from 465 Mgal (23 ft^3/s) in September to 1,360 Mgal (68 ft^3/s) in April (fig. 11). In Cape May County, the mean annual discharge at a pond or at the head of tide for the 10 largest streams (fig. 10) is shown in table 10.

The amount of fresh surface water that is available for withdrawal is based on NJDEP regulations (NJAC 7:9-4.5 C2) which permit withdrawals of surface water such that a flow of 0.125 $Mgal/d/mi^2$ of basin area remains in the stream at the point of withdrawal. The annual available water for withdrawal from the Tuckahoe River at Head of River is 8,923 Mgal, or 86 percent of annual flow (table 3). The total annual volume of water available for withdrawal from Fishing Creek at Rio Grande is 391 Mgal, or about 79 percent of the annual discharge.

The amount of fresh surface water available for supply is greatest during late winter and spring, when streamflows are greatest, and least during the summer, when streamflows are reduced as a result of evapotranspiration. In other areas of the New Jersey Coastal Plain, water suppliers have built surface-water reservoirs to store water during periods of high flow; this stored water is released during periods of high use. Potential locations for surface-water reservoirs in Cape May County are one or more of the ponds that have formed behind dams built on local streams (table 10).

Shallow Aquifer Water Supply

Freshwater withdrawn from the shallow aquifers--the Holly Beach water-bearing zone, estuarine sand aquifer, and Cohansey aquifer--is replenished by precipitation or replaced by saltwater intrusion. By 1990, saltwater intrusion had affected each of the shallow aquifers (figs. 50, 54, and 57). Future withdrawals at 1990 withdrawal rates will remove additional water from storage, and saltwater intrusion will continue.

The replenishment of the freshwater supply has been exceeded by withdrawals since 1960 and possibly earlier for the shallow aquifers in parts of southern Cape May County. These withdrawals have caused intrusions of saltwater along the shoreline in at least six areas in the southern part of the county and one area in northern part of the

Table 10. Mean annual discharge of, and water available for withdrawal from, the ten largest streams in Cape May County, N.J.
[ft^3/s, cubic feet per second; Mgal/yr, million gallons per year]

Source	Mean annual discharge in Mgal/yr	Mean annual discharge in ft^3/s	Water available for withdrawal in Mgal/yr
Tuckahoe River at Head of River	10,328	43.8	8,923
Sluice Creek as Clint Mill pond	6,720	28.5	6,334
West Creek at Pickle Factory pond	4,881	20.7	4,338
East Creek at East Creek pond	2,570	10.9	2,201
Tarnkiln Brook near Head of River	2,051	8.7	1,714
Dennis Creek tributary at Johnsons Mill pond	1,415	6.0	1,232
Mill Creek at Steelmantown	1,226	5.2	1,052
Mill Creek tributary at Ludlams pond	1,041	4.3	889
Mill Creek at Magnolia Lake	825	3.5	721
Fishing Creek at Pumping House pond	495	2.1	391

county. Saltwater intrusion had forced the abandonment of four industrial- and public-supply wells prior to 1960, and six industrial- and public-supply wells during 1960-90 (Lacombe and Carleton, 1992).

The optimal locations for high-volume public- and industrial-supply wells that tap the shallow aquifers would be along a line about mid-way between the 250-mg/L chloride contour for the Atlantic Ocean and the contour for Delaware Bay (figs. 73 to 75). Such a location makes the wells equidistant from the two saltwater fronts. In conjunction with the supply wells, an array of observation wells could be installed near the shoreline and inside and parallel to the existing 250-mg/L chloride contour for each aquifer. The suite of production wells, observation wells, and previously installed wells could be used to monitor withdrawal rates, water levels, and concentrations of chloride, sodium, and other constituents. The size and shape of the cones of depression could be correlated with the ground-water withdrawal rates and with saltwater intrusion rates and locations. Existing domestic-supply wells could continue withdrawals in most areas without significant adverse effects. If adverse effects, such as increases in chloride and sodium concentrations, were identified in water samples, withdrawals from large capacity supply wells could be adjusted to decrease flow of saltwater into the aquifers.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone typically contains freshwater on the mainland above the high-tide line (fig. 50). Domestic-supply users who withdraw only a couple hundred gallons per day and reside in a sparsely settled area where use of agricultural chemicals is limited, where septic systems are functioning properly, that is distant from the saltwater front, and that is distant from listed or unlisted hazardous waste sites could have a copious supply of high-quality water for their limited withdrawal needs. Domestic-supply users in a densely settled area, near areas where agricultural chemicals are heavily used, or near a listed or unlisted waste site could eventually experience degradation in the quality of the shallow water supply.

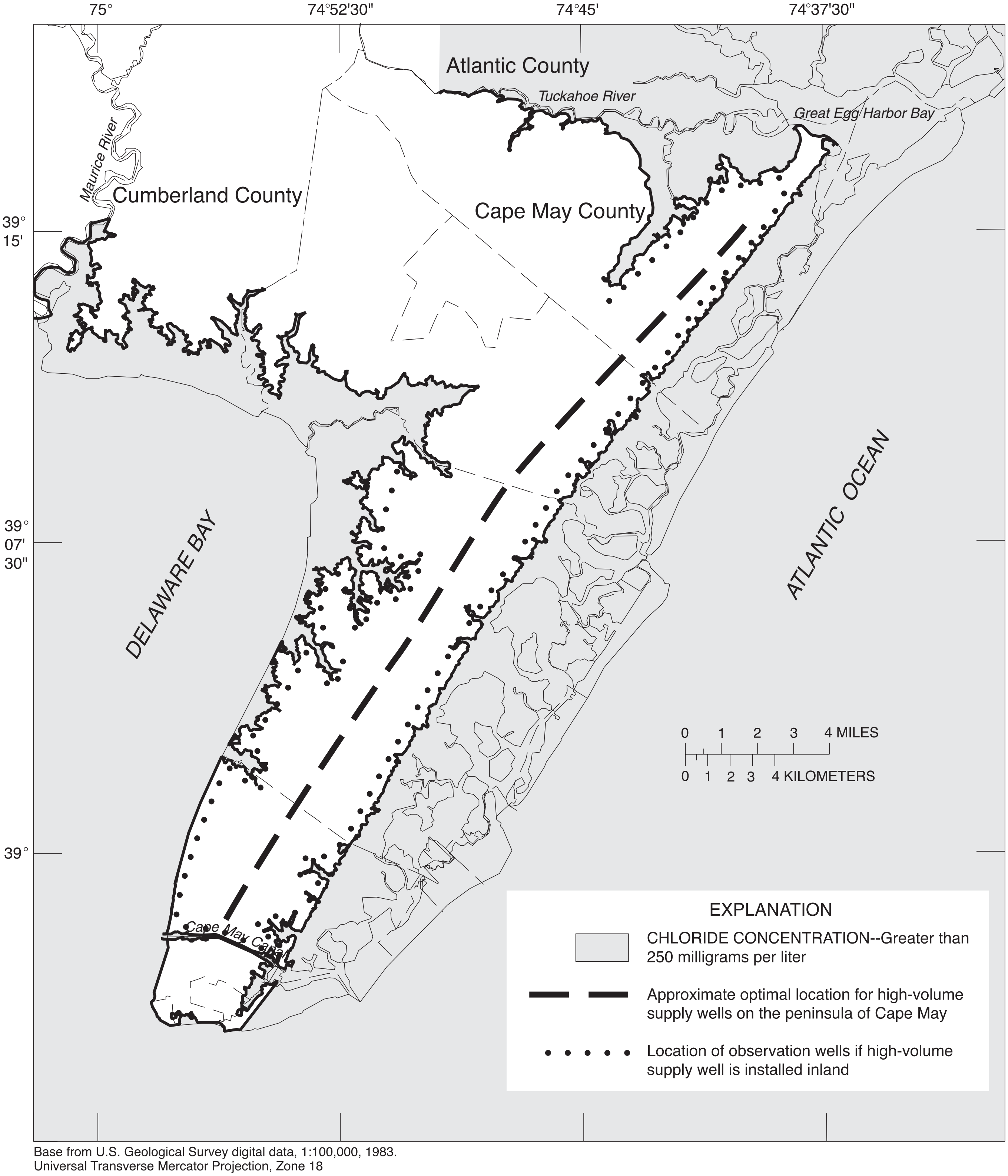


Figure 73. Line of approximate optimal locations of high-volume supply wells and corresponding observation wells in the Holly Beach water-bearing zone, Cape May County, New Jersey.

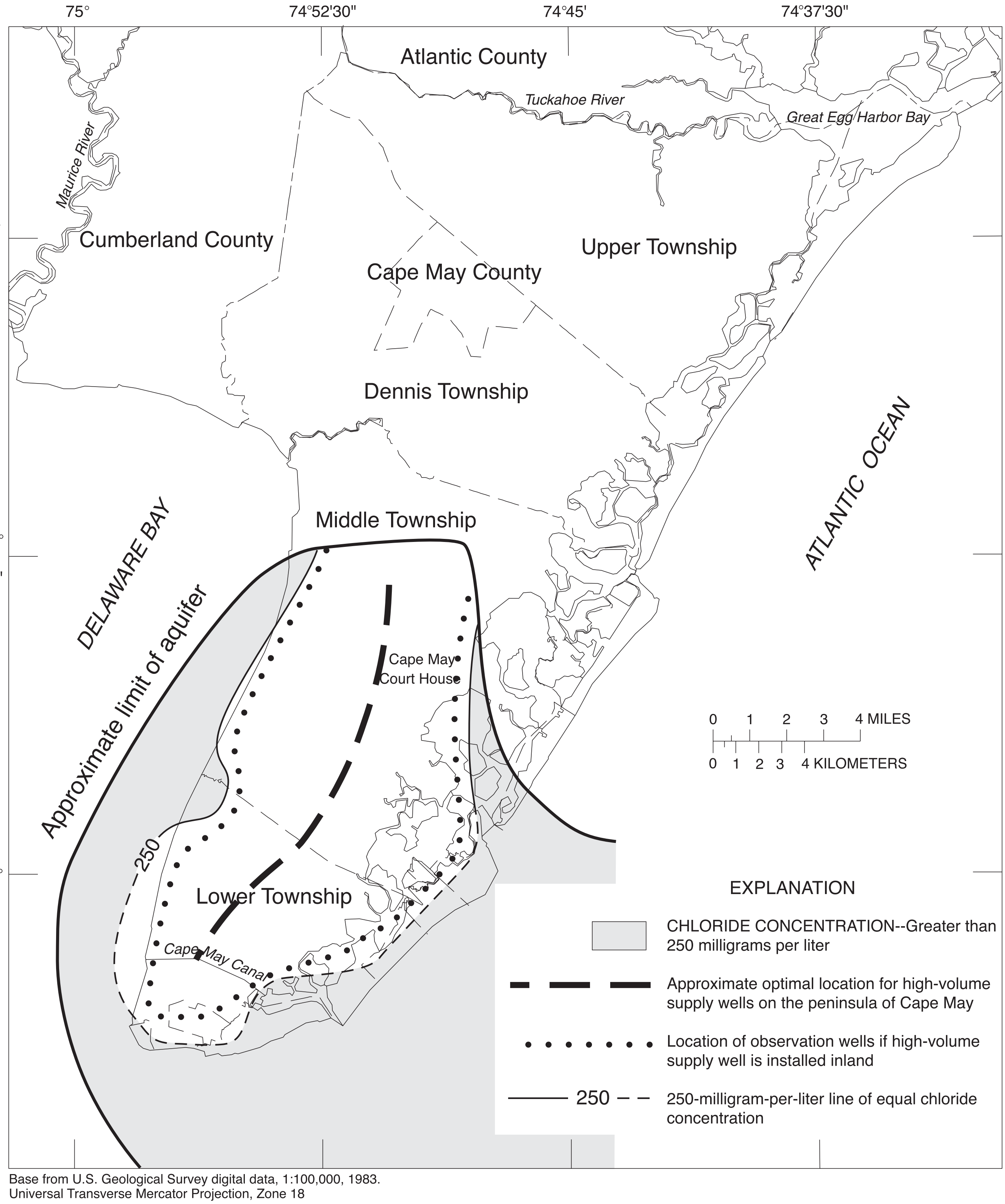


Figure 74. Line of approximate optimal locations of high-volume supply wells and corresponding observation wells in the estuarine sand aquifer, Cape May County, New Jersey.

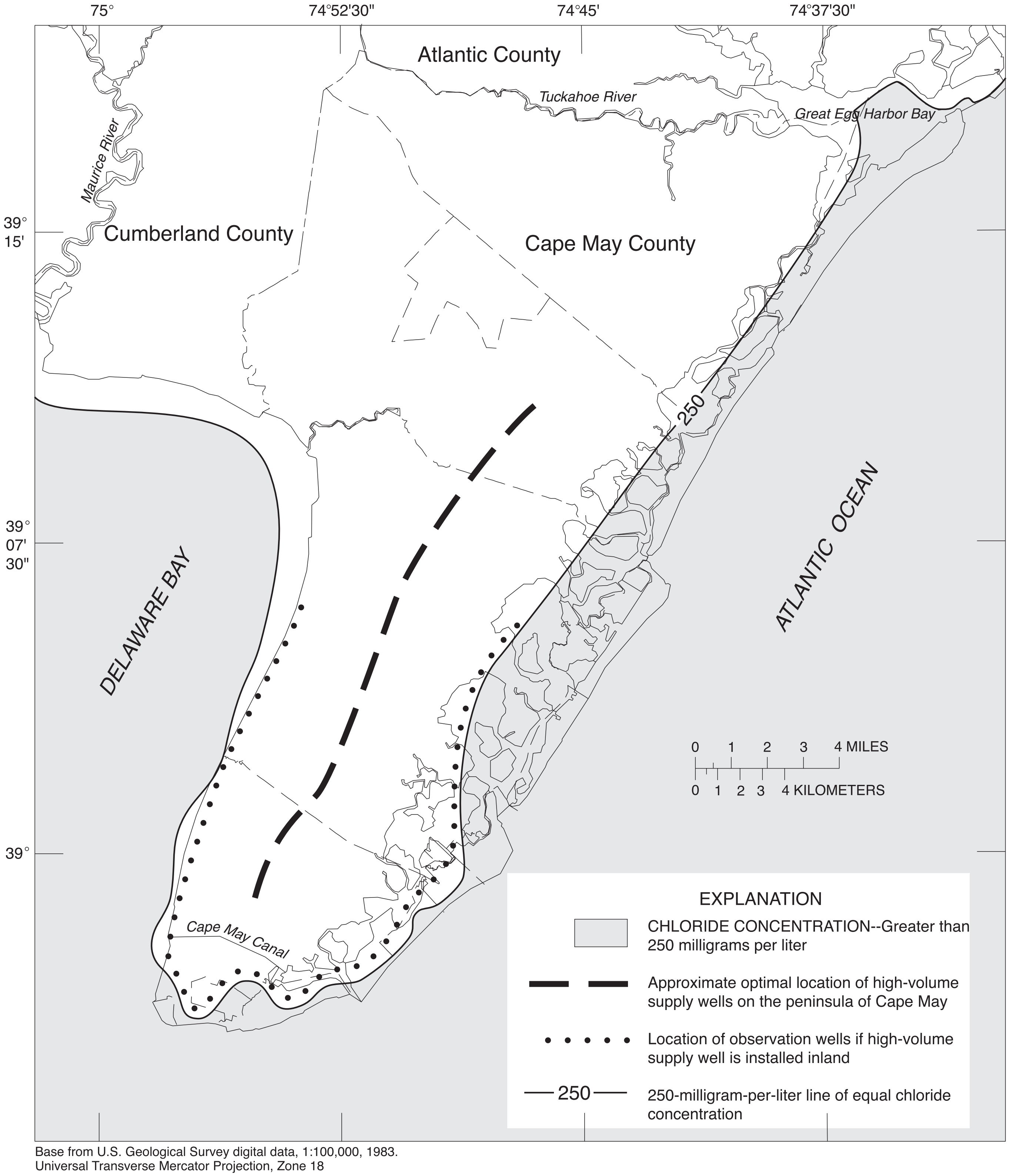


Figure 75. Line of approximate optimal locations of high-volume supply wells and corresponding observation wells in the Cohansey aquifer, Cape May County, New Jersey.

Public-supply wells that tap the Holly Beach water-bearing zone are subject to the same influences as domestic wells. Large withdrawals from the Holly Beach water-bearing zone will cause local cones of depression and possibly accelerate the movement of contaminated ground water toward the well. Large withdrawals also will tend to decrease flow in nearby streams and lower water levels in nearby wells.

The center line between the 250-mg/L chloride contour on the Atlantic Ocean side of the peninsula and on the Delaware Bay side of the peninsula is the optimal location for large volume production wells (fig. 73) because they are equidistant from the saltwater fronts. Generally, the best locations for supply wells in these areas are far from (1) salty surface water, (2) saltwater parts of the Holly Beach water-bearing zone, (3) landfills, (4) waste-disposal areas, (5) agricultural land, (6) high-density residential areas, and (7) areas with high background iron levels in the water. These optimal sites would probably produce the largest quantity of high-quality water from the Holly Beach water-bearing zone.

The greatest volume of freshwater from the Holly Beach water-bearing zone is available during autumn after the leaves have fallen, during winter, and during spring prior to new growth because there is little evapotranspiration and slightly higher precipitation. About three times more water recharges the Holly Beach water-bearing zone during late fall to early spring than during summer. This is shown by both increased water levels of 2 to 3 ft in the Holly Beach water-bearing zone during winter and increased stream discharge during winter. The water supply is more readily available north of the Great Cedar Swamp (fig. 1) than on the peninsula because northern Cape May County is not surrounded by saltwater and less water is withdrawn.

Water availability is limited from the Holly Beach water-bearing zone on the barrier islands. The limited supply has been developed in some areas on the islands for landscape irrigation during the summer. This small nonpotable water supply could be expanded for additional lawn irrigation. It is not suitable for human consumption, however, because the water quality has or can be easily degraded by intensive high-density residential and commercial land use, and frequent flooding with saltwater during storms. In addition, saltwater intrusion probably would occur if the aquifer is pumped heavily.

Estuarine Sand Aquifer

Supplies of freshwater are limited for large-volume supply wells in shoreline areas in the estuarine sand aquifer because of the proximity of saltwater (fig. 54 and 55); however, freshwater supplies are sufficient for large-volume supply wells in inland areas where the threat of saltwater intrusion is diminished. Concentrations of iron in many shoreline and inland areas exceed the NJDEP secondary drinking-water standard (fig. 56), and thus, further constrain the locations where high quality water is readily available for public and domestic supply. These water-quality conditions do not preclude use of the water, but they do constrain the amount of water that can be withdrawn without causing saltwater intrusion, and diminish the amount of water that can be used without treatment.

Small withdrawals from most areas of the aquifer will not induce saltwater intrusion. Large withdrawals from the estuarine sand aquifer and the Cohansey aquifer have caused a regional cone of depression to develop and saltwater intrusion to occur in Villas. (fig. 38). The cone of depression in the estuarine sand aquifer has induced saltwater leakage from the Holly Beach water-bearing zone and lateral movement of saltwater from salty parts of the estuarine sand aquifer (fig. 54). The cone of depression extends into the saltwater part of the estuarine sand aquifer and below the saltwater part of the Holly Beach water-bearing zone. The greatest rate of saltwater intrusion occurs where the water levels in the saltwater part of the aquifer are below sea level. Saltwater intrusion in the estuarine sand aquifer has occurred and continues to occur in and near Villas, the Wildwood communities, and Cape May Point; it is expected to continue if the present patterns of large-volume withdrawals continue.

In the future, the volume of freshwater available in the aquifer will depend on well placement, pumpage rates, and the aquifer response to withdrawal. Given that saltwater intrusion has occurred along both the east and west shorelines, the optimal placement of high-volume supply wells is along the long axis of the peninsula (fig. 74). Such placement may assure the largest volume of freshwater for the longest period of time. Observation wells could be placed east and west of the supply wells along the shoreline inside the 250-mg/L chloride line to monitor water levels and chloride concentrations. To optimize the freshwater supply in the estuarine sand aquifer, the water levels at the saltwater front should stay above sea level, and chloride concentrations should not rise above ambient levels at each observation well.

Cohansey Aquifer

Freshwater available from the Cohansey aquifer is limited by the closeness of the 250-mg/L chloride or sodium lines to the high volume supply wells (figs. 57 and 58). In many areas, the concentration of iron (fig. 59) exceeds the NJDEP secondary drinking water-standard of 0.3 mg/L, which also limits the availability of high-quality water for public and domestic supply. This water-quality condition does not preclude use of the water, but diminishes its utility without treatment.

Small withdrawals such as those from domestic-supply wells probably will not induce saltwater intrusion. Large withdrawals from the aquifer, such as those in the Wildwood mainland, Lower Township MUA, and Cape May City well fields, have expanded and deepened the cone of depression (figs. 40 and 41). Withdrawals have induced lateral movement of saltwater from saltwater parts of the Cohansey aquifer and caused saltwater to leak from the estuarine sand aquifer into the Cohansey aquifer.

In the southern part of the county, the extent of the cone of depression is greater than the extent of the freshwater in the aquifer, and lateral saltwater intrusion has occurred where water levels in the aquifer are below sea level. In addition, leakage from the saltwater part of the estuarine sand aquifer is occurring where the water levels in the Cohansey aquifer are lower than water levels in the estuarine sand aquifer. Saltwater intrusion in the aquifer has been detected in Villas, the Wildwood communities, Cape May City, Cape May Point, and Beesley's Point. Ongoing saltwater intrusion will continue if the present pattern of large volume withdrawals continues in the southern part of the county.

An additional but limited supply of freshwater is available from the Cohansey aquifer from Cape May Court House to Marmora because water levels in this area are still above sea level (fig. 40). Water-quality and water-level data collected in the area indicate that saltwater intrusion probably has not begun in this area.

The volume of freshwater available in the Cohansey aquifer depends on well placement, pumpage rate, and aquifers response to withdrawal. The confining units that separate the Cohansey from the estuarine sand aquifer and the Holly Beach water-bearing zone are thinner and more permeable north of Lower Township than in Lower Township. As a result, there is increased potential for leakage from the estuarine sand aquifer and the Holly Beach water-bearing zone. Given that saltwater intrusion has occurred along both sides of the peninsula and at Beesleys Point, the optimal placement of supply wells is along the axis of the peninsula from Rio Grande to Marmora (fig. 75). This would likely result in the ability to withdraw high volumes of freshwater for the longest period of time. Observation wells could be placed along each shoreline and inside the 250-mg/L chloride contour. The observation wells could be used to monitor water levels and chloride and sodium concentrations. Water levels in wells near the 250-mg/L chloride line should be maintained above sea level to keep chloride concentrations at existing levels.

Deep Aquifer Water Supply

Freshwater is available from the Rio Grande water-bearing zone and Atlantic City 800-foot sand of the Kirkwood Formation. High chloride concentrations caused the abandonment and sealing of a well that tapped the Rio Grande water-bearing zone in Stone Harbor Manor during the 1950's. Chloride concentrations have risen slowly in two wells in Wildwood and one well in Stone Harbor, all of which are screened in the Atlantic City 800-foot sand (Lacombe and Carleton, 1992). If withdrawals continue at the 1990 withdrawal rates, the slow rates of saltwater intrusion could continue.

The water supply provided by wells completed in the aquifers of the Kirkwood Formation is quite extensive and could last many generations (Voronin and others, 1996). Non-public, low-use wells completed in the aquifers could still withdraw water without significant adverse effects. The collection and analysis of water samples from the observation well network would provide an early warning if the chloride concentrations increased. Users could then adjust withdrawals to control the intrusion.

Rio Grande Water-Bearing Zone

Freshwater is available from the Rio Grande water-bearing zone, but it is limited by the proximity of a supply well to the 250 mg/L chloride and 50 mg/L sodium contour (figs. 63 and 64). In 1960, small increases in chloride concentrations were detected in water from a public-supply well in Stone Harbor Manor (fig. 63). Withdrawals of about 180 Mgal/yr from the Wildwood mainland well field may have caused a small movement of the 250-mg/L chloride line. Observation wells that monitor saltwater intrusion have been in place only since 1989. Saltwater movement could continue at an extremely slow rate if the present pattern and rates of ground-water withdrawals continue.

Freshwater supply is available from the Rio Grande water-bearing zone in all areas of the mainland north of Lower Township. The confining unit that separates the Rio Grande water-bearing zone from the shallower aquifers is nearly impermeable; therefore, saltwater leakage from overlying aquifers is limited.

The volume of freshwater available will depend on well placement, pumpage rates, and aquifer response to withdrawal. Because saltwater intrusion has occurred in one area along the Atlantic coastline, the optimal placement of the supply wells to obtain the largest volume of freshwater for the longest period of time is along center line of the peninsula and halfway between the 250-mg/L chloride contour on the east and west sides of the cape (fig. 76). Observation wells could be placed at the shoreline or inland of the 250-mg/L chloride contour east and west of each supply well. The observation wells could be used to measure water levels and to collect water samples to monitor the concentrations of chloride. Water levels near the 250-mg/L chloride contour should be maintained above sea level to prevent chloride concentrations from rising above background levels.

Atlantic City 800-Foot Sand

Freshwater available from the Atlantic City 800-foot sand is limited by the proximity of high volume supply wells to the 250-mg/L chloride contour (figs. 65 and 66). The future use of the aquifer in the lower part of the county depends on maintaining the 1990 positions of the 250-mg/L chloride and the 50-mg/L sodium contours.

Large-volume withdrawals during 1975-95, such as those on the barrier island communities from Stone Harbor northward (fig. 32d), have caused a slight movement of the saltwater front. By 1975, a slow rate of saltwater intrusion was measured in the wells at Wildwood (Lacombe and Carleton, 1992). Saltwater intrusion possibly is occurring in the aquifer southwest, south, and east of the elongated cone of depression (fig. 48) that is centered on the barrier island communities. Saltwater intrusion probably will continue at an extremely slow rate if present withdrawal patterns continue. A change in the location or quantity of water withdrawals can increase or decrease the rate of movement of the saltwater front.

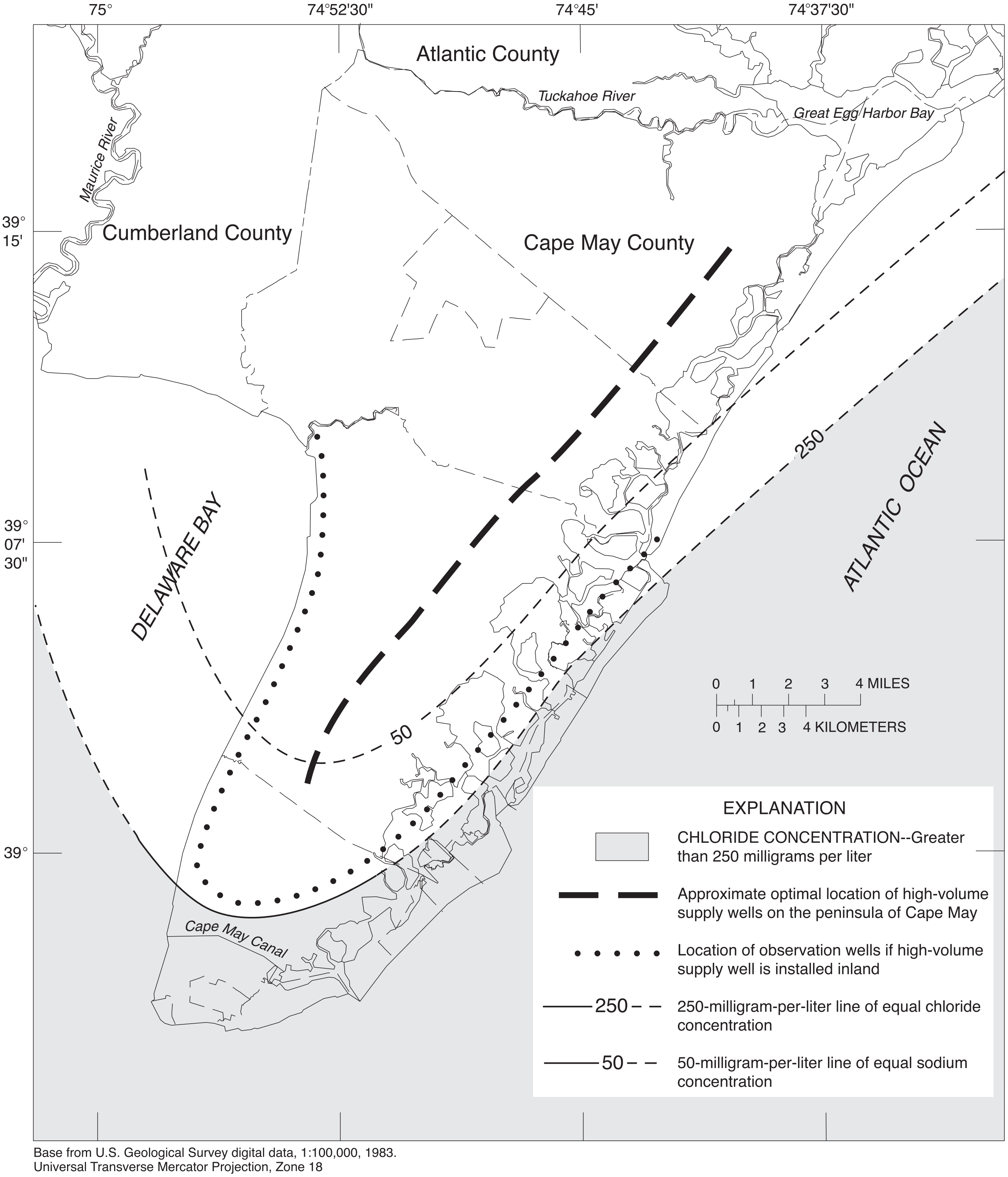


Figure 76. Line of approximate optimal locations of high-volume supply wells and corresponding observation wells in the Rio Grande water-bearing zone, Cape May County, New Jersey.

Water with chloride concentrations less than 250 mg/L is available from the Atlantic City 800-foot sand from all wells north of Lower-Middle Township boundary. Water containing low concentrations of sodium (less than 50 mg/L) is available from the upper and lower parts of the Atlantic City 800-foot sand in areas north of Middle Township and Avalon (fig. 66). The confining unit that separates the Atlantic City 800-foot sand from the Rio Grande water-bearing zone and shallower aquifers has low permeability; therefore, leakage of saltwater from above the aquifer is unlikely.

The volume of freshwater available will depend on well placement, pumpage rate, and aquifer response to withdrawal. Given that saltwater intrusion has begun in Wildwood and could be occurring on all three sides of the cape, then optimal placement of new supply wells to obtain the largest volume of freshwater for the longest period of time is along the axis of the peninsula (fig. 77). Observation wells would need be placed only along the west side of the cape at the shoreline. Wells on the barrier islands previously used for supply also could be used as observation wells to monitor water levels and chloride considerations. Water levels at the 250-mg/L chloride contour should be maintained at or near sea level to prevent chloride concentrations from rising above present concentrations.

SUMMARY

This report describes the discharge rate and use of surface-water, and the hydrostratigraphy, water use, ground-water flow, water quality, and water budgets for the five aquifers in Cape May County, N.J. Surface water is not a principal source of water supply for Cape May County, but it is used extensively for irrigation of some farms and golf courses. The surface-water system is composed of 12 small streams that flow a short distance, beginning near the ground-water divide in the county and emptying into the Atlantic Ocean, back bays, and Delaware Bay. The Tuckahoe River the largest potential source of fresh surface water in the county, flows along the Cumberland-Atlantic County boundary in the upper reaches and the Atlantic-Cape May boundary in the lower reaches. The mean annual discharge of the Tuckahoe River at Head of River is 42.8 ft^3/s (cubic feet per second). Other potential sources of surface-water supply and their mean annual flows are Sluice Creek, 28.5 ft^3/s; West Creek, 20.7 ft^3/s; and East Creek, 10.9 ft^3/s.

The principal sources of ground-water supply for the county are the Holly Beach water-bearing zone, the estuarine sand aquifer, the Cohansey aquifer, the Rio Grande water-bearing zone, and the Atlantic City 800-foot sand. The top of the Holly Beach water-bearing zone is at or near land surface; the altitude of the base of the freshwater part of the aquifer is -10 to -75 ft on the peninsula and -32 to -180 ft in the northern part of the county. The altitude of the top of the freshwater part of the estuarine sand aquifer is about -50 to -145 ft, and the thickness is about 50 ft. The confining unit that overlies the estuarine sand aquifer ranges in thickness from about 50 to 100 ft and is thickest in the northern part of Lower Township. Less vertical recharge enters the estuarine sand aquifer in this area than in other areas of the county. The altitude of the top of the Cohansey aquifer ranges from -62 to -290 ft, and the thickness ranges from 60 to 180 ft. The confining unit that overlies the Cohansey aquifer ranges from 10 to 75 ft thick in most areas that contain freshwater. Because the confining units are thicker in northern Lower Township, less vertical recharge enters the Cohansey aquifer in this area than in other parts of the county. The altitude of the top of the Rio Grande water-bearing zone is -400 ft in Woodbine and -550 ft in central Middle Township, and the thickness is 50 to 100 ft. The thickness of the confining unit that overlies the freshwater part of the aquifer is about 150 to 200 ft. The altitude of the top of the Atlantic City 800-foot sand is -600 to -750 ft along the eastern half of the county from Upper Township to the Middle-Lower Township boundary, and the confining unit is 100 to 150 ft thick. A 10- to 20-ft thick clay bed in the middle of the Atlantic City 800-foot sand aquifer divides the aquifer into upper and lower parts. The confining unit that overlies the Atlantic City 800-foot sand is about 100 ft thick. All the aquifers probably crop out in, or the subcrops terminate in, the Delaware Bay.

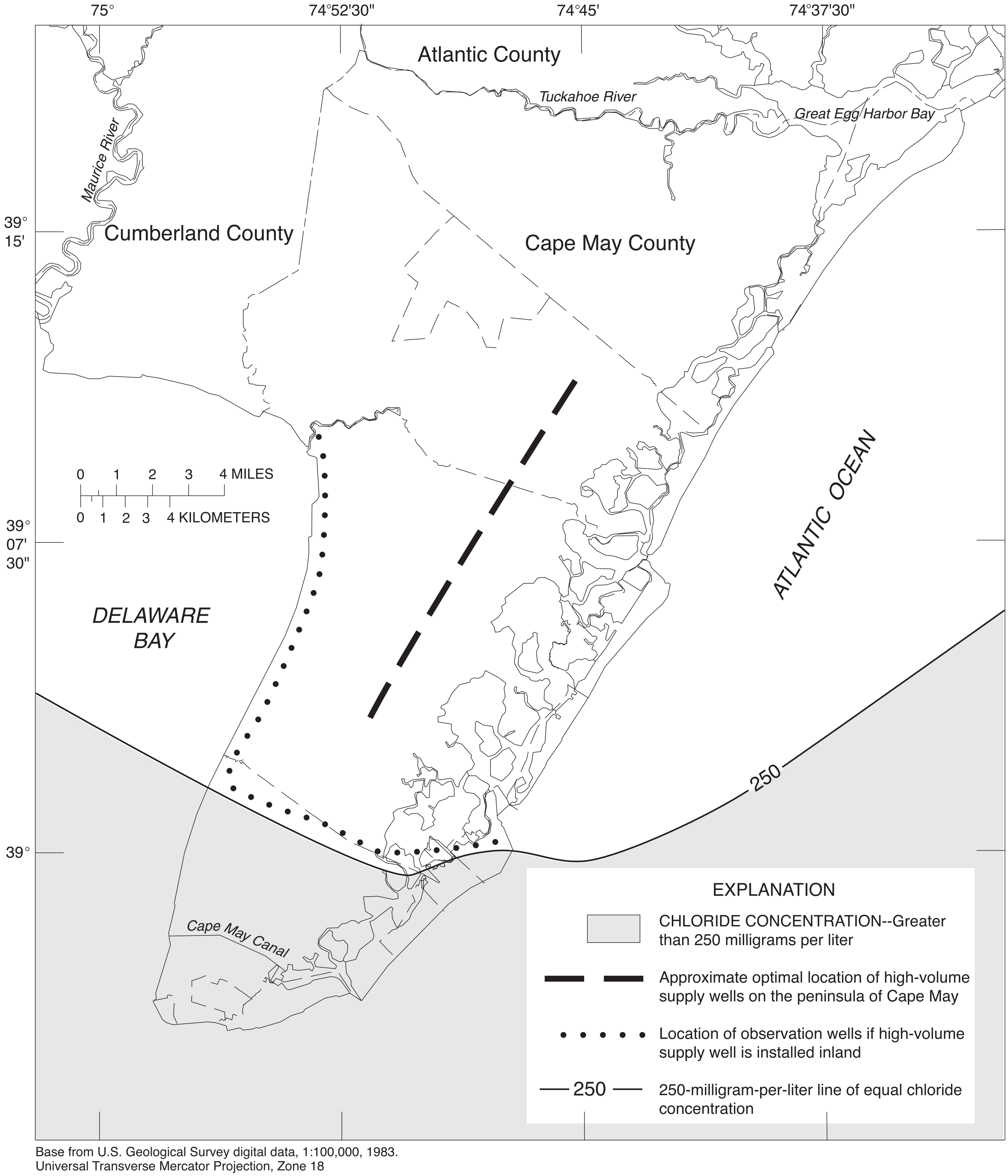


Figure 77. Line of approximate optimal locations of high-volume supply wells and corresponding observation wells in the Atlantic City 800-foot sand, Cape May County, New Jersey.

Water-level hydrographs and maps for the Holly Beach water-bearing zone show that water levels have generally remained constant since the 1950's. Water-level maps and sections indicate that in general, ground water flows from land surface downward, then towards the bay or ocean; locally it flows toward streams and wetlands. The greatest decline in water levels in the Holly Beach water-bearing zone has been along the Cape May Canal, where water-level altitudes dropped from +15 ft to sea level at the time the canal was dredged.

Potentiometric-surface maps and sections and water-level hydrographs for the estuarine sand aquifer show that water levels have declined and have been below sea level since 1958, especially in the southern part of the county. Water levels in the interior of the county are 4 to 13 ft below sea level, but more significantly the water levels were 14 to 23 ft below the water-table aquifer. Therefore, a large volume of freshwater from the Holly Beach water-bearing zone flows into the estuarine sand aquifer near the center of the cone of depression. Beneath Delaware Bay, water-level altitudes in the aquifer are 2 to 8 ft below sea level. The low water levels in the aquifer induce the flow of saltwater from Delaware Bay into the aquifer.

Potentiometric-surface maps and sections of the Cohansey aquifer prior to development, in 1958, and in 1991 show that the direction and gradient of ground-water flow in northern Cape May County remains the same. The greatest decline in water-level altitudes in the Cohansey aquifer has been from +10 ft to -15 ft near the four pumping centers of the water department for Cape May City, Wildwood, and Lower Township, and near the fishing industry supply wells at the southern tip of the peninsula. The direction of ground-water flow in southern Cape May County reversed from the flow direction prior to development, and now ground water flows radially inward toward the pumping centers on the peninsula. The inflowing water is fresh in many areas, but salty in most offshore and shoreline areas. Water from the estuarine sand aquifer leaks vertically into the Cohansey aquifer.

Potentiometric-surface maps and sections for the Rio Grande water-bearing zone show that in 1991, along the barrier islands, ground water flowed radially inward toward the barrier islands, then downward into the Atlantic City 800-foot sand, forming an elongated sympathetic cone of depression in eastern Cape May County. Near the Wildwood mainland well field, ground water flows radially toward the supply wells. Since withdrawals began in the late 1890's, water-level altitudes in the Rio Grande water-bearing zone have declined from about +20 ft to about -20 ft.

Potentiometric-surface maps and sections of the Atlantic City 800-foot sand prior to development show the ground-water flow direction was toward the Atlantic Ocean and Delaware Bay. Potentiometric-surface maps from 1958 through 1991 show that the flow directions reversed, and now ground water flows radially inward toward the pumping centers on the barrier islands. Since withdrawals began in the late 1890's, water-level altitudes in the Atlantic City 800-foot sand have declined from about +20 ft to -60 ft in winter and to -80 ft during summer. The inflowing water is fresh in most areas, but salty in the Wildwood, Lower, and Cape May communities.

The potability of water in the freshwater part of the three shallow aquifers differs from place to place on the basis of (1) the extent of saltwater intrusion, (2) the effect of land use, and (3) background concentrations of iron. Iron concentrations in each aquifer ranged from less than 0.3 mg/L (N.J. Department of Environmental Protection secondary maximum contaminant level) in all aquifers to more than 2,500 mg/L in the Holly Beach water-bearing zone, 1 mg/L in the estuarine sand aquifer and Cohansey aquifer, and more than 250 mg/L in the Rio Grande water-bearing zone and Atlantic City 800-foot sand. Contamination caused by industrial, commercial, agricultural, and residential waste is documented at 104 hazardous waste sites in the county. The contamination has degraded the water quality in the Holly Beach water-bearing zone at each site. No evidence has been found to indicate that contamination has degraded the water quality in the estuarine sand aquifer, Cohansey aquifer, Rio Grande water-bearing zone, or Atlantic City 800-foot sand. All other water-quality constituents in the public-supply wells in confined aquifers fall within the NJDEP primary drinking-water standard limits, and most fall within the NJDEP secondary drinking-water standard limits.

Contamination caused by saltwater intrusion in the confined aquifers is documented for areas along the Delaware Bay, the Atlantic Ocean, and the Great Egg Harbor Bay. In the estuarine sand and Cohansey aquifer near Villas, the chloride concentration has increased from less than 50 mg/L to more than 200 mg/L during 1960-90. In the Cohansey aquifer at Cape May Point, Cape May City, and the Wildwood communities, the chloride concentration has increased from less than 50 mg/L to more than 500 mg/L. In the Cohansey aquifer at Upper Township next to Great Egg Harbor Bay, the chloride concentration increased from less than 20 mg/L to more than 40 mg/L. In the Rio Grande water- bearing zone, the chloride concentrations at Stone Harbor Manor increased from less than 50 mg/L to more than 200 mg/L. In the Atlantic City 800-foot sand at the Wildwood communities, the chloride concentration increased from less than 50 mg/L to more than 200 mg/L. In each location the increase in the concentration of chloride is a direct result of ground-water withdrawals.

Withdrawals of ground water in the county exceeded 8,000 Mgal in 1990 with about 4,000 Mgal/yr used for public supply, 2,000 Mgal/yr used for domestic, irrigation, and industrial supply, and 2,000 Mgal/yr used for mining supply. The major public-supply withdrawal sites and the respective withdrawal rates are Wildwood mainland well field, 1,500 Mgal/yr; Lower Township well field, 300 Mgal/yr; Cape May City well field, 390 Mgal/yr; Ocean City well field, 1,100 Mgal/yr; and Stone Harbor-Avalon-Sea Isle City well fields, 840 Mgal/yr.

The water budget shows that the county receives about 192,000 Mgal/yr of precipitation. Historically, all water is evapotranspired or discharged to the ocean and bay by various surface-water or ground-water pathways. The predevelopment water budget quantifies each of the 15 or so major pathways, including evapotranspiration; overland discharge to the ocean and bay; ground-water discharge to streams; recharge to the aquifers; and discharge to streams, ocean, and bay. The water budget for 1990 includes all of the same pathways, but the quantities are increased for ground-water withdrawals from each aquifer and recharge to the aquifer, and decreased proportionately for ground-water discharge to streams, ocean, and bay

Given the hydraulic characteristics of the aquifers and confining units and the location of the freshwater-saltwater interface, the optimal locations for new supply wells for each aquifer would be along the predevelopment ground-water divide for each aquifer. The divide is about halfway between the saltwater fronts on the east and west sides of the peninsula. Observation wells could be used to monitor water levels and water quality, and to assess the effects of withdrawals on the aquifers.

CONCLUSIONS

Each of the five significant freshwater aquifers of Cape May County are in close proximity to saltwater. The Holly Beach water-bearing zone is in direct connection with seawater. Other aquifers contain saltwater and have a distant connection to the Atlantic Ocean or Delaware Bay. Historical and ongoing water withdrawals have caused the formation of many potentiometric cones of depression in these aquifers. This condition favors saltwater intrusion by lateral movement and by downward leakage. Saltwater intrusion is the most significant threat to the water supply of Cape May County.

Saltwater intrusion in the five aquifers has been ongoing since development of the aquifer began. Construction of the Cape May Canal has virtually removed the possibility of obtaining potable water from the Holly Beach water-bearing zone along the 4-mile length of the canal. Erosion of the Delaware Bay shoreline has removed aquifer material, thereby increasing the rate of saltwater intrusion. The estuarine sand aquifer has shown evidence of saltwater intrusion in Villas since the 1960's. Communities immediately north and south of Villas are susceptible to saltwater intrusion in the future. Saltwater intrusion has occurred in the Cohansey aquifer at North Wildwood, Wildwood, and Wildwood Crest, and the Atlantic Ocean beach in Lower Township. Saltwater intrusion also has occurred at Cape May City, Cape May Point, and areas of Lower Township immediately north of Cape May Point. Intrusion also has occurred in Lower Township in the Villas area. If withdrawals continue at the same rate as in 1990, saltwater intrusion could occur in Lower Township near North Cape May, and in Town Bank before 2025. Saltwater intrusion in the Rio Grande water-bearing zone has occurred in Stone Harbor Manor and could occur in the Villas area if the rate of withdrawals is increased at the Wildwood mainland well field. Saltwater intrusion in the Atlantic City 800-foot sand has occurred in the Wildwood and North Wildwood areas. High background levels of chloride concentrations are present in areas south of the village of Rio Grande. Saltwater intrusion is not expected to affect Stone Harbor for more than a century.

The optimal location for future water-supply development is along the axis of the peninsular part of the county. The southernmost location for a major supply well for each aquifer depends on location of the saltwater front in the aquifer.

Surface water in the northern part of the county can provide limited quantities of potable water to nearby communities. Quantities from the surface-water sources probably are not large enough during the summer though to provide water to the southern part of the county when it is most needed.

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Appendix I

Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey
[Boro, Borough; Twp, Township; --, no data]

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090001	390420	744435	AVALON WATER DEPT	4-48/N2/SEALED	5	802-870	1948	KRKDL	37-00001	AVALON BORO	AVALON	--	--
090002	390420	744435	AVALON WATER DEPT	2R-71/NEW 7	5	821-861	1971	KRKDL	37-00280	AVALON BORO	AVALON	4-11	-35
090004	390528	744338	AVALON WATER DEPT	6	10	880-920	1968	KRKDL	37-00265	AVALON BORO	AVALON	4-11	-33
090005	390545	744326	AVALON WATER DEPT	5-76/NEW 8	8	784-839	1976	KRKDL	37-00313	AVALON BORO	AVALON	4-11	-43
090006	390615	744301	AVALON WATER DEPT	5-61/L1/SEALED	5	845-895	1961	KRKDL	37-00219	AVALON BORO	AVALON	--	--
090007	390621	744251	AVALON WATER DEPT	2-10	10	905-955	1910	KRKDL	--	AVALON BORO	AVALON	--	--
090008	390621	744248	AVALON WATER DEPT	3	10	845-925	1930	KRKDL	--	AVALON BORO	AVALON	4-11	-33
090009	390622	744250	AVALON WATER DEPT	1-98	10	875-925	1898	KRKDL	56-00092	AVALON BORO	AVALON	--	--
090011	385612	745457	CAPE MAY C W D	CMCWD 1 OBS	7	281-321	1940	CNSY	57-04898	CAPE MAY CITY	CAPE MAY	--	--
090012	385613	745457	CAPE MAY C W D	COLUMBIA 1	10	--	1940	CNSY	--	CAPE MAY CITY	CAPE MAY	--	--
090013	385613	745457	CAPE MAY CITY WATER DEPT	TEST 10	10	835-865	1958	CKKD	37-00184	CAPE MAY CITY	CAPE MAY	--	--
090014	385615	745509	CAPE MAY CITY WATER DEPT	LAFAYETTE 2	12	282-322	1945	CNSY	--	CAPE MAY CITY	CAPE MAY	--	--
090017	385651	745310	US COAST GUARD	USCG 1	11	292-322	1943	CNSY	--	CAPE MAY CITY	CAPE MAY	4-	-8
090018	385652	745327	US COAST GUARD	USCG 2	11	295-325	1943	CNSY	--	CAPE MAY CITY	CAPE MAY	--	--
090019	385557	745738	CAPE MAY POINT WATER DEPT	LIGHTHOUSE 1/SEALED	6	260-300	1916	CNSY	57-00036	CAPE MAY POINT BORO	CAPE MAY	--	--
090019	385557	745738	CAPE MAY POINT WATER DEPT	LIGHTHOUSE 1/SEALED	6	552-592	1916	CNSY	--	CAPE MAY POINT BORO	CAPE MAY	--	--
090020	385616	745800	US GEOLOGICAL SURVEY	TRAFFIC CIRCLE OBS	9	15-20	1960	HLBC	--	CAPE MAY POINT BORO	CAPE MAY	4-8	5
090021	385631	745741	CAPE MAY PT W D	SUNSET 2/ SEALED	13	250-280	1958	CNSY	--	CAPE MAY POINT BORO	CAPE MAY	--	--
090022	391100	744521	NOVASACK BROS	1 (NOVASACK 1)	25	56-112	1965	ESRNS	37-00229	DENNIS TWP	WOODBINE	4-10	12
090023	391504	745330	US GEOLOGICAL SURVEY	CAPE MAY 55/SEALED	33	15-18	1957	HLBC	--	DENNIS TWP	PORT ELIZABETH	--	--
090024	385804	745742	US GEOLOGICAL SURVEY	HIGBEE 2/SEALED	9	240-250	1957	CNSY	37-00156	LOWER TWP	CAPE MAY	--	--
090025	385641	745533	US GEOLOGICAL SURVEY	CAPE MAY 1A	11	35-38	1956	HLBC	--	LOWER TWP	CAPE MAY	--	--
090026	385641	745533	US GEOLOGICAL SURVEY	CAPE MAY 1B	11	90 96	1957	CPMY	--	LOWER TWP	CAPE MAY	--	--
090027	385643	745533	CAPE MAY C W D	CMCWD 3	10	277-306	1950	CNSY	37-00013	LOWER TWP	CAPE MAY	4-	-20
090028	385641	745749	NW MAGNESITE CO	NW MAG 2/SEALED	10	235-265	1953	CNSY	37-00038	LOWER TWP	CAPE MAY	4-	-4
090029	385640	745805	NW MAGNESITE CO	NW MAG 1/SEALED	10	296-321	1942	CNSY	--	LOWER TWP	CAPE MAY	4-	-7
090030	385650	745310	US GEOLOGICAL SURVEY	TEST 6	11	305-325	1957	CNSY	--	CAPE MAY CITY	CAPE MAY	--	--
090031	385650	745535	CAPE MAY C W D	BROADWAY 3	12	270-300	1927	CNSY	--	LOWER TWP	CAPE MAY	--	--
090032	385650	745535	CAPE MAY C W D	BROADWAY 1	12	270-300	1927	CNSY	--	LOWER TWP	CAPE MAY	--	--
090033	385650	745535	CAPE MAY C W D	BROADWAY 2	12	587-600	1902	KRKDU	--	LOWER TWP	CAPE MAY	4-8	-8
090036	385701	745528	CAPE MAY C W D	CMCWD 2/ CMCWD 4 (NEW)	10	174--282	1966	CNSY	--	LOWER TWP	CAPE MAY	4-	-21
090037	385711	745136	US COAST GUARD	USCG-NEW/ SEALED	--	--	--	CNSY	--	LOWER TWP	WILDWOOD	--	--
090041	385722	745241	SNOW CANNING	SNOW 2/ SEALED	10	--	1957	CNSY	37-00134	LOWER TWP	CAPE MAY	--	--
090042	385723	745240	BORDON CO(SNOW)	SNOW 3	5	259--289	1969	CNSY	37-00268	LOWER TWP	CAPE MAY	4-	-13
090043	385724	745521	CAPE MAY C W D	CMCWD 5	18	246-276	1965	CNSY	57-00011	LOWER TWP	CAPE MAY	4-	-17
090044	385725	745257	SNOW CANNING	SNOW 1	5	--	1965	CNSY	--	LOWER TWP	CAPE MAY	--	--
090048	385748	745533	US GEOLOGICAL SURVEY	CANAL 5 OBS	17.48	242-252	1957	CNSY	37-00159	LOWER TWP	CAPE MAY	4-	-16
090049	385804	745742	US GEOLOGICAL SURVEY	HIGBEE BEACH 3 OBS	6	241-250	1957	CNSY	--	LOWER TWP	CAPE MAY	4-	-10
090052	385851	745715	LOWER TWP MUA	LTMUA 1	18	241-262	1956	CNSY	37-00113	LOWER TWP	CAPE MAY	4-	-18
090054	385905	745625	LOWER TWP MUA	LTMUA 2	14	212--247	1962	CNSY	37-00223	LOWER TWP	CAPE MAY	4-	-15
090057	385919	745518	LOWER TWP MUA	LTMUA 3	20	262-302	1974	CNSY	37-00293	LOWER TWP	CAPE MAY	4-	-13
090058	390015	745440	CAPE MAY COUNTY	1	20	248-275	1942	CNSY	57-00012	LOWER TWP	RIO GRANDE	4-	-16
090059	390015	745440	CAPE MAY COUNTY	2	20	252-278	1942	CNSY	57-00013	LOWER TWP	RIO GRANDE	4-	-14
090060	390056	745426	US GEOLOGICAL SURVEY	AIRPORT 7 OBS	13.11	242-257	1957	CNSY	--	LOWER TWP	RIO GRANDE	4-	-14
090061	390058	745427	US GEOLOGICAL SURVEY	CAPE MAY 74	12.85	24-27	1957	HLBC	--	LOWER TWP	RIO GRANDE	--	--

[1]HLBC and CPMY, Holly beach water-bearing zone; CNSY, Cohansey aquifer; KRKDU, Rio Grande water bearing zone; PCMB, Precambrian; ESRNS, Estuarine sand aquifer; CKKD, Kirkwood-Cohansey aquifer, Undifferentiated; KRKDL, Atlantic City 800-foot sand

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090062	391048	744321	CORDES, WILLIAM	LOWER TWP	10	--	--	CPMY	--	DENNIS TWP	SEA ISLE CITY	--	--
090063	390052	745300	HAND, HOLMES N	2 1958	20	--	1958	CPMY	--	MIDDLE TWP	RIO GRANDE	--	--
090065	390130	745350	WILDWOOD WATER DEPT	RIO GRANDE 34	12	172-242	1966	CNSY	37-00235	MIDDLE TWP	RIO GRANDE	4-	-18
090066	390135	745349	WILDWOOD WATER DEPT	RIO GRANDE 22	8	462-512	1957	KRKDU	--	MIDDLE TWP	RIO GRANDE	--	--
090067	390135	745352	WILDWOOD WATER DEPT	RIO GRANDE 38	10	461-590	1969	KRKDU	37-00271	MIDDLE TWP	RIO GRANDE	--	--
090069	390136	745342	WILDWOOD WATER DEPT	RIO GRANDE 33	9	236-260	1966	CNSY	37-00234	MIDDLE TWP	RIO GRANDE	--	--
090070	390137	745352	WILDWOOD WATER DEPT	RIO GRANDE 36	10	48-63	1967	HLBC	37-00242	MIDDLE TWP	RIO GRANDE	--	--
090071	390138	745348	WILDWOOD WATER DEPT	RIO GRANDE 23 OBS	8	473-523	1926	KRKDU	--	MIDDLE TWP	RIO GRANDE	4-8	-9
090072	390138	745350	WILDWOOD WATER DEPT	RIO GRANDE 31	10	108-135	1950	ESRNS	37-00012	MIDDLE TWP	RIO GRANDE	4-16	-8
090073	390139	745349	WILDWOOD WATER DEPT	RIO GRANDE 27	7	--	1967	CPMY	--	MIDDLE TWP	RIO GRANDE	4-16	12
090074	390139	745349	WILDWOOD WATER DEPT	RIO GRANDE 29	9	191-231	1947	CNSY	57-00007	MIDDLE TWP	RIO GRANDE	--	--
090078	390149	745354	WILDWOOD WATER DEPT	RIO GRANDE 30	9	229-250	1948	CNSY	37-00002	MIDDLE TWP	RIO GRANDE	--	--
090079	390210	744730	HALLER, LEE	NUMMY IS 2 OBS	2	833-876	1968	KRKDL	--	MIDDLE TWP	STONE HARBOR	4-9	-29
090080	390213	745056	US GEOLOGICAL SURVEY	CAPE MAY 42 OBS	13.67	242-252	1957	CNSY	--	MIDDLE TWP	STONE HARBOR	4-	-3
090081	390211	745055	US GEOLOGICAL SURVEY	CAPE MAY 23 OBS	14.90	23-26	1956	HLBC	--	MIDDLE TWP	STONE HARBOR	4-16	6
090082	390228	745034	CAPE MAY CANNER	1-1969	10	229-260	1969	CKKD	37-00269	MIDDLE TWP	STONE HARBOR	--	--
090083	390248	745413	HOWELL, HOWARD N	HOWELL 1	5	--	--	ESRNS	--	MIDDLE TWP	RIO GRANDE	--	--
090086	390331	744604	STONE HARBOR WD	SHWD 1/SEALED	8	--	1957	KRKDU	--	MIDDLE TWP	STONE HARBOR	--	--
090089	390425	745446	US GEOLOGICAL SURVEY	OYSTER LAB 4 OBS	7.37	195-210	1957	CNSY	37-00158	MIDDLE TWP	RIO GRANDE	4-	-3
090090	390433	744938	KEUFFEL & ESSER CO	MIDDLE TWP	15	100-120	1954	ESRNS	37-00080	MIDDLE TWP	STONE HARBOR	4-18	4
090092	390525	744851	NJ WATER CO	NEPTUNUS 7	17	681-791	1967	KRKDL	37-00240	MIDDLE TWP	STONE HARBOR	4-16	-30
090093	390525	744851	NJ WATER CO	NEPTUNUS TW1	17	659-674	1966	KRKDU	--	MIDDLE TWP	STONE HARBOR	--	--
090097	390527	745024	US GEOLOGICAL SURVEY	BDWLL DCH 31ES	18.54	117-121	--	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-17	9
090098	390527	745024	US GEOLOGICAL SURVEY	BDWLL DCH 31HB	18.50	21-25	1968	HLBC	--	MIDDLE TWP	STONE HARBOR	4-17	16
090099	390611	744838	US GEOLOGICAL SURVEY	CAPE MAY CO PK 8 OBS	10.73	214-230	1957	CNSY	35-00680	MIDDLE TWP	STONE HARBOR	4-	5
090100	390647	744438	MIDDLE TWP W D	AVALON M WW 1	5	763-815	1963	KRKDL	37-00224	MIDDLE TWP	AVALON	4-11	-36
090101	390654	744841	BOHM, LAWRENCE H	1	20	40-92	1969	ESRNS	35-00982	MIDDLE TWP	STONE HARBOR	--	--
090106	391343	743755	NJ WATER CO	SHORE DIV 7	8	760-810	1924	KRKDL	56-00006	OCEAN CITY	SEA ISLE CITY	4-16	-43
090107	391457	743647	NJ/AMERICAN WATER CO	SHORE DIV 6	5	--	1923	KRKDL	--	OCEAN CITY	SEA ISLE CITY	--	--
090108	391500	743645	NJ WATER CO	SHORE DIV 14	7	774-840	1970	KRKDL	36-00412	OCEAN CITY	SEA ISLE CITY	4-11	-50
090109	391535	743611	NJ WATER CO	SHORE DIV 9	8	749-809	1946	KRKDL	56-00008	OCEAN CITY	OCEAN CITY	4-11	-50
090110	391604	743539	NJ WATER CO	SHORE DIV 12	7	759-814	1965	KRKDL	36-00373	OCEAN CITY	OCEAN CITY	4-11	-57
090115	391636	743428	NORMANDIE	OCEAN AVE AND 9TH ST	10	762-812	1902	KRKDL	--	OCEAN CITY	OCEAN CITY	--	--
090116	391638	743451	NJ WATER CO	SHORE DIV 8	7	760-810	1937	KRKDL	56-00007	OCEAN CITY	OCEAN CITY	4-11	-60
090117	391642	743447	NJ WATER CO	SHORE DIV 10	5	746-798	1950	KRKDL	36-00017	OCEAN CITY	OCEAN CITY	4-11	-61
090118	391644	743447	OCEAN CITY WTRS	10TH & HAVEN	8	--	1893	KRKDL	--	OCEAN CITY	OCEAN CITY	--	--
090119	391647	743442	OCEAN CITY WTRS	9TH & HAVEN	8	--	1896	KRKDL	--	OCEAN CITY	OCEAN CITY	--	--
090120	391648	743452	OCEAN CITY WTRS	1	8	762-812	1902	KRKDL	--	OCEAN CITY	OCEAN CITY	--	--
090121	391649	743449	NJ WATER CO	SHORE DIV 4	8	--	1910	KRKDL	56-00004	OCEAN CITY	OCEAN CITY	4-11	-58
090122	391710	743408	NJ WATER CO	SHORE DIV 5	6	--	1923	KRKDL	56-00005	OCEAN CITY	OCEAN CITY	4-11	-63
090123	391710	743409	OCEAN CITY WTRS	2	8	745-795	1911	KRKDL	--	OCEAN CITY	OCEAN CITY	--	--
090124	391712	743340	NJ WATER CO	SHORE DIV 13	8	774-840	1970	KRKDL	36-00413	OCEAN CITY	OCEAN CITY	4-11	-66
090125	391726	743352	NJ WATER CO	SHORE DIV 11	10	--	1962	KRKDL	36-00314	OCEAN CITY	OCEAN CITY	4-11	-60
090126	390747	744241	SEA ISLE CITY WATER DEPT	SICWD 5	7	736-802	1957	KRKDL	37-00162	SEA ISLE CITY	SEA ISLE CITY		
090127	390847	744200	SEA ISLE CITY WATER DEPT	SICWD 4	7	742-830	1954	KRKDL	37-00064	SEA ISLE CITY	SEA ISLE CITY	4-8	-39

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090128	390902	744153	SEA ISLE CITY WATER DEPT	SICWD 3	7	800-870	1930	KRKDL	57-00010	SEA ISLE CITY	SEA ISLE CITY	4-8	-36
090129	390926	744131	SEA ISLE CITY WATER DEPT	SICWD 2/SEALED	7	801-861	1926	KRKDL	57-00009	SEA ISLE CITY	SEA ISLE CITY	4-8	-37
090130	390926	744131	SEA ISLE CITY WATER DEPT	CENTRAL AVE	7	--	1896	KRKDL	56-00098	SEA ISLE CITY	SEA ISLE CITY	--	--
090131	390928	744135	SEA ISLE CITY WATER DEPT	SICWD 1	5	--	1912	KRKDL	--	SEA ISLE CITY	SEA ISLE CITY	--	--
090132	390301	744545	STONE HARBOR WATER DEPT	SHWD 4	10	830-880	1955	KRKDL	37-00079	STONE HARBOR BORO	STONE HARBOR	4-12	-28
090133	390314	744532	STONE HARBOR WATER DEPT	SHWD 2/ SEALED	10	--	1924	KRKDL	--	STONE HARBOR BORO	STONE HARBOR	--	--
090134	390314	744532	STONE HARBOR WATER DEPT	SHWD 1/ SEALED	6	--	1902	KRKDL	--	STONE HARBOR BORO	STONE HARBOR	--	--
090135	390323	744525	STONE HARBOR WATER DEPT	SHWD 3	9	837-877	1949	KRKDL	37-00009	STONE HARBOR BORO	STONE HARBOR	4-12	-24
090136	391152	743927	CORSONS INLET WATER DEPT	CIWC 1	7	802-834	1904	KRKDL	56-00147	UPPER TWP	SEA ISLE CITY	--	--
090137	391238	744159	NAGATSUKA, JOHN K	NAG 3	20	--	--	CPMY	--	UPPER TWP	SEA ISLE CITY	--	--
090139	391250	744212	NAGATSUKA, JOHN K	NAG 2	20	--	--	CPMY	--	UPPER TWP	SEA ISLE CITY	4-9	4
090140	391422	744041	US AIR FORCE	PALERMO 1/SEALED	15	--	1950	CNSY	--	UPPER TWP	SEA ISLE CITY	4-	8
090142	391555	744412	GIEBERSON, FRED	2	30	25-45	1973	CPMY	37-00287	UPPER TWP	MARMORA	4-19	13
090143	391557	744411	GIEBERSON, FRED	1	25	110-140	1973	CNSY	37-00286	UPPER TWP	MARMORA	4-	8
090144	391703	743756	ATL CITY ELEC	ACEC 5	9	650-690	1975	KRKDL	36-00451	UPPER TWP	MARMORA	--	--
090147	391707	743756	ATL CITY ELEC	ACEC 2R-LAYNE3	9	125-145	1962	CKKD	36-00319	UPPER TWP	MARMORA	4-	2
090148	391707	743756	ATL CITY ELEC	ACEC 3-LAYNE 4	9	645-675	1964	KRKDL	36-00364	UPPER TWP	MARMORA	--	--
090149	391814	744954	MORRIS APRIL BR	MORRIS	20	250-290	1948	KRKDU	37-00005	UPPER TWP	TUCKAHOE	4-19	20
090150	385607	745556	US GEOLOGICAL SURVEY	WESTCAPE MAY 1 OBS	6.60	283-293	1957	CNSY	37-00155	WESTCAPE MAY BORO	CAPE MAY	4-	-12
090153	385932	744851	WILDWOOD WATER DEPT	WWD 1/ SEALED	8	--	1894	KRKDL	--	WILDWOOD CITY	WILDWOOD	--	--
090154	385932	744851	WILDWOOD WATER DEPT	WWD 2/SEALED	10	293-354	1928	CNSY	57-00008	WILDWOOD CITY	WILDWOOD	--	--
090155	385935	744954	WILDWOOD CLAM C	3-1971/SEALED	5	311-331	1971	CNSY	37-00276	WILDWOOD CITY	WILDWOOD	4-	2
090156	385934	744854	AMERICAN PIPE C	1895/ SEALED	8	--	--	KRKDU	57-00040	WILDWOOD CITY	WILDWOOD	--	--
090157	385841	745000	STOKES LAUNDRY	1/ SEALED	7	312-338	1966	CNSY	37-00232	WILDWOOD CREST BORO	WILDWOOD	--	--
090158	385823	745023	WILDWOOD WATER DEPT	OLD WELL/ SEALED	9	810-937	1926	KRKDL	57-00041	WILDWOOD CREST BORO	WILDWOOD	--	--
090159	385830	745021	WILDWOOD WATER DEPT	WWD 35	8	249-360	1967	CNSY	37-00241	WILDWOOD CREST BORO	WILDWOOD	4-	4
090161	390704	744750	EASTERN SHORE CONVALES CTR	1	15.70	639-654	1983	KRKDL	--	MIDDLE TWP	STONE HARBOR	4-15	-26
090162	391044	744617	NOVASACK BROS	2	30	90-138	1966	ESRNS	38-00238	DENNIS TWP	WOODBINE	4-10	10
090163	390513	744955	NJ WATER CO	NEPTUNUS 6	15	27-43	1955	HLBC	37-00093	MIDDLE TWP	STONE HARBOR	4-16	5
090166	390351	744504	STONE HARBOR WATER DEPT	SHWD 5	7	820-860	1976	KRKDL	37-00312	STONE HARBOR BORO	STONE HARBOR	--	--
090168	391430	744848	WOODBINE W C	6	45	135-157	1967	CKKD	37-00239	WOODBINE BORO	WOODBINE	--	--
090169	391513	744302	BETTS, WALTER	36-394	10	116-160	1968	CNSY	36-00394	UPPER TWP	MARMORA	--	--
090171	385901	745405	LOWER TWP BD ED	1	10	149-161	1973	ESRNS	37-00289	LOWER TWP	CAPE MAY	4-17	1
090172	385756	745509	CAPE MAY C WATER DEPT	TEST 11	15	295-325	1978	CKKD	37-00326	LOWER TWP	CAPE MAY	--	--
090173	390314	744532	STONE HARBOR WATER DEPT	SHWD 6	10	810-860	1981	KRKDL	37-00579	STONE HARBOR BORO	STONE HARBOR	4-12	-27
090174	391240	745403	BUGANSKI, ANTHY	IRR-1979	12	45-75	1979	CKKD	35-01863	DENNIS TWP	HEISLERVILLE	--	--
090175	391539	744343	KOHLER, JOHN	1	23	90-140	1979	CNSY	36-01019	UPPER TWP	MARMORA	--	--
090176	385830	745021	WILDWOOD WATER DEPT	WWD 35A	8	252-338	1978	CNSY	37-00319	WILDWOOD CREST BORO	WILDWOOD	--	--
090177	390642	744248	WONDER ICE CO	ABANDONED	--	--	--	KRKDL	56-00093	AVALON BORO	AVALON	--	--
090178	385643	745803	NW MAGNESITE CO	STEAM PLT	10	121-128	--	CNSY	--	LOWER TWP	CAPE MAY	--	--
090180	390159	745337	WILDWOOD WATER DEPT	RIO GRANDE 42	15	--	1979	CNSY	37-00375	MIDDLE TWP	RIO GRANDE	4	-16
090181	385718	745700	ANCHOR GAS CO	DICKINSON 1	22	--	1963	PCMB	--	LOWER TWP	CAPE MAY	--	--
090182	385841	745000	STOKES LAUNDRY	2/ SEALED	7	320-350	1980	CNSY	37-00484	WILDWOOD CREST BORO	WILDWOOD	4-	-2
090183	385724	745243	BORDEN CO(SNOW)	4	5	260-290	1979	CNSY	37-00403	LOWER TWP	CAPE MAY	4-	-12
090184	391544	744347	UPPER TWP BD ED	2	15	110-140	1984	CKKD	36-04557	UPPER TWP	MARMORA	--	--

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level Date in 1987	Water level Altitude in feet
090185	391621	744355	US GEOLOGICAL SURVEY	MACNAMARA W A	15	640-650	1985	KRKDL	--	UPPER TWP	MARMORA	4-9	-28
090186	391621	744354	US GEOLOGICAL SURVEY	USGS AC 14 OBS	14	19.5-22.5	1985	CKKD	36-06189	UPPER TWP	MARMORA	4-11	11
090187	390218	745609	CAPE MAY COUNTY	CAPE MAY F-35	10	186-190	1965	CNSY	--	LOWER TWP	RIO GRANDE	4-	-5
090188	390215	745440	CAPE MAY COUNTY	CAPE MAY F-36	5.5	229-233	1965	CNSY	--	MIDDLE TWP	RIO GRANDE	4-	-10
090189	390215	745440	CAPE MAY COUNTY	CAPE MAY F-37	5.5	83-87	1965	ESRNS	--	MIDDLE TWP	RIO GRANDE	4-12	-3
090190	390215	745440	WILDWOOD CITY	CAPE MAY F-40	5	21.5-30.5	1971	HLBC	--	MIDDLE TWP	RIO GRANDE	4-12	3
090191	390219	745611	US GEOLOGICAL SURVEY	FISHING CREEK HB-1	10	14-17	1987	HLBC	37-02472-8	LOWER TWP	RIO GRANDE	4-12	2
090192	390425	745446	RUTGERS UNIVERSITY	RUTGERS OYSTER LAB	7	64-71	1954	ESRNS	--	MIDDLE TWP	RIO GRANDE	--	--
090195	390219	745608	US GEOLOGICAL SURVEY	FC-1 DRIVEPOINT	8.48	15-17	1987	HLBC	37-02472-8	LOWER TWP	RIO GRANDE	--	--
090196	390219	745608	US GEOLOGICAL SURVEY	FC-2 DRIVEPOINT	8.48	25-27	1987	HLBC	37-02472-8	LOWER TWP	RIO GRANDE	--	--
090197	390219	745608	US GEOLOGICAL SURVEY	FC-3 DRIVEPOINT	8.48	46-48	1987	HLBC	37-02472-8	LOWER TWP	RIO GRANDE	--	--
090198	390212	745557	US GEOLOGICAL SURVEY	BSR-1 DRIVEPOINT	6.85	10-12	1987	HLBC	37-02473-6	LOWER TWP	RIO GRANDE	--	--
090199	390212	745557	US GEOLOGICAL SURVEY	BSR-2 DRIVEPOINT	6.85	20-22	1987	HLBC	37-02473-6	LOWER TWP	RIO GRANDE	--	--
090200	390212	745557	US GEOLOGICAL SURVEY	BSR-3 DRIVEPOINT	6.85	28-30	1987	HLBC	37-02473-6	LOWER TWP	RIO GRANDE	--	--
090201	390212	745557	US GEOLOGICAL SURVEY	BSR-4 DRIVEPOINT	6.85	39-41	1987	HLBC	37-02473-6	LOWER TWP	RIO GRANDE	--	--
090202	390212	745557	US GEOLOGICAL SURVEY	BSR-5 DRIVEPOINT	6.85	54-56	1987	HLBC	37-02473-6	LOWER TWP	RIO GRANDE	--	--
090203	390738	745330	US GEOLOGICAL SURVEY	RB-1 DRIVEPOINT	10	10-12	1987	HLBC	35-06513-3	MIDDLE TWP	HEISLERVILLE	--	--
090204	390738	745330	US GEOLOGICAL SURVEY	RB-2 DRIVEPOINT	10	40-42	1987	HLBC	35-06513-3	MIDDLE TWP	HEISLERVILLE	--	--
090205	390738	745330	US GEOLOGICAL SURVEY	RB-3 DRIVEPOINT	10	50-52	1987	HLBC	35-06513-3	MIDDLE TWP	HEISLERVILLE	--	--
090206	390218	745609	CAPE MAY COUNTY	CAPE MAY F-7	10	108-112	1965	ESRNS	--	LOWER TWP	RIO GRANDE	4-12	-1
090207	391121	745114	US GEOLOGICAL SURVEY	JAKES LANDING-1	10.48	80-90	1987	CNSY	35-06772-1	DENNIS TWP	WOODBINE	4-	4
090208	390212	745557	US GEOLOGICAL SURVEY	BSR-6	6.92	98-108	1987	ESRNS	37-02602-0	LOWER TWP	RIO GRANDE	4-17	-1
090209	385656	745422	COLD SPRING PACKING CO	COLD SPRING PACKING 1	5	90-110	1985	ESRNS	37-01425	LOWER TWP	CAPE MAY	--	--
090210	385946	745725	CAPE MAY COUNTY	CAPE MAY C-1	11.03	216-221	1965	CNSY	--	LOWER TWP	CAPE MAY	4-	-10
090212	385946	745725	CAPE MAY COUNTY	CAPE MAY C-3	11.41	45-50	1965	HLBC	--	LOWER TWP	CAPE MAY	4-12	2
090213	390128	745639	CAPE MAY COUNTY	CAPE MAY F-41	12.23	203-208	1965	CNSY	--	LOWER TWP	RIO GRANDE	4-	-5
090214	390050	745659	CAPE MAY COUNTY	CAPE MAY F-44	19.86	205-210	1965	CKKD	--	LOWER TWP	RIO GRANDE	--	--
090215	390050	745659	CAPE MAY COUNTY	CAPE MAY F-45	20.23	120-125	1965	ESRNS	--	LOWER TWP	RIO GRANDE	--	--
090216	390050	745659	CAPE MAY COUNTY	CAPE MAY F-46	20.62	45-50	1965	HLBC	--	LOWER TWP	RIO GRANDE	--	--
090217	390128	745639	CAPE MAY COUNTY	CAPE MAY F-42	13.17	96-100	1965	ESRNS	--	LOWER TWP	RIO GRANDE	4-24	0
090218	390128	745639	CAPE MAY COUNTY	CAPE MAY F-43	12.76	46-50	1965	CPMY	--	LOWER TWP	RIO GRANDE	4-24	4
090219	390601	745245	BAYSHORE ASSOCIATES	1982-200 HAND & RT 47	19	150-200	1982	CNSY	35-03380	MIDDLE TWP	RIO GRANDE	4-18	4
090224	390626	744739	CAPE MAY CO MUA SLDG CMPST	1	9	105-115	1983	ESRNS	35-03718	MIDDLE TWP	STONE HARBOR	4-17	6
090233	390929	745005	HAZLET, JAMES	1985 IRR	12	120-170	1985	CKKD	35-04815	MIDDLE TWP	WOODBINE	4-11	5
090234	390953	744940	STITES, JOHN	1985 IRR	12	43-68	1985	CKKD	35-04970	DENNIS TWP	WOODBINE	4-18	2
090238	391159	745338	BOHM, DAVID	BOHM SOD FARM	7.5	60-100	1984	CKKD	35-04183	DENNIS TWP	HEISLERVILLE	4-	3
090240	391245	744710	COLLIGAN, WALLACE	1985 IRR	35	27-57	1985	CKKD	35-04764	DENNIS TWP	WOODBINE	4-11	27
090242	391403	745020	CAROL LYNN RESORT	1981 BATHHOUSE REPLCMNT	35	35-45	1981	CKKD	35-03070	WOODBINE BORO	WOODBINE	4-11	26
090243	391411	745035	MACLEOD, JOHN N	1984 IRR	43	30-60	1984	CKKD	35-04108	DENNIS TWP	WOODBINE	4-19	33
090254	390535	745258	MYERS & ROBBINS FARM	1984 DIAZ CREEK M&R FARM	10	60-100	1984	ESRNS	35-03381	MIDDLE TWP	RIO GRANDE	4-28	4
090256	391719	744514	TUCKAHOE FIRE CO	TUCKAHOE FIRE CO	25	138-158	1981	CNSY	36-01106	UPPER TWP	TUCKAHOE	4-	12
090258	390456	744948	SOUTH JERSEY FUEL	SOUTH JERSEY FUEL RS-4	25	8-18	1986	HLBC	35-05683-5	MIDDLE TWP	STONE HARBOR	4-18	15
090259	391118	744324	LUTHERAN HOME,OCEANVIEW	LUTHERAN HOME	25	6-31	1985	CPMY	36-05968	DENNIS TWP	SEA ISLE CITY	4-8	9
090261	390032	745612	CAPE MAY CO LIBRARY	LIBRARY 1024	10	145-160	1982	CNSY	37-00665	LOWER TWP	RIO GRANDE	4	-12
090263	391553	743850	GRACE OIL CO	FOSBENNERS TEXACO DEEP	35	140-150	1984	CNSY	36-04054	UPPER TWP	MARMORA	4-	10

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090272	391409	744732	CAPE MAY CITY MUA	CAPE MAY COMUA W-1	37.5	19.5-24.5	1982	CPMY	35-03141	WOODBINE BORO	WOODBINE	--	--
090273	390226	745102	GARDEN LAKE MOBILE HOMES	GARDEN LK PK 1985	15	220-260	1985	CNSY	37-01613	MIDDLE TWP	STONE HARBOR	4-	0
090274	391043	744333	NEW JERSEY HIGHWAY AUTHORITY	SEAVILLE SERV AREA 1	15	62.5-83.8	1954	CPMY	37-00075	DENNIS TWP	SEA ISLE CITY	4-10	10
090276	391045	744332	NEW JERSEY HIGHWAY AUTHORITY	SEAVILLE SERV AREA 2	15	62.3-83.7	1954	CPMY	37-00074	DENNIS TWP	SEA ISLE CITY	4-10	10
090278	385851	745638	COLD SPRING APARTMENTS	CHANNEL APTS	20	31-41	1983	HLBC	37-00848	LOWER TWP	CAPE MAY	0-0	6
090281	390710	745134	SOIL CONSERVATION SERVICE	BD-21CH	11	176-181	1967	CNSY	37-00254	MIDDLE TWP	STONE HARBOR	4-	6
090282	390710	745134	SOIL CONSERVATION SERVICE	BD-21ES	11	90-95	1967	ESRNS	37-00250	MIDDLE TWP	STONE HARBOR	4-12	6
090283	390457	745049	SOIL CONSERVATION SERVICE	BD-22CH	17.20	200-205	1967	CNSY	37-00255	MIDDLE TWP	STONE HARBOR	4-	5
090285	390749	744943	SOIL CONSERVATION SERVICE	BD-20CH-2	17.10	201-206	1967	CNSY	37-00256	MIDDLE TWP	WOODBINE	--	--
090286	390608	745005	SOIL CONSERVATION SERVICE	BD-23ES	19	92.5-97.5	1967	ESRNS	37-00253	MIDDLE TWP	STONE HARBOR	4-12	7
090289	390330	745010	GARDEN LAKE MOBILE HOMES	GARDEN LK PK 1981	15	237-257	1981	CNSY	37-00595	MIDDLE TWP	STONE HARBOR	4-	3
090291	390627	744254	AVALON WATER D	AVALON WD 9	7	764-941	1988	KRKDL	36-09846	AVALON BORO	AVALON	4-11	-36
090292	390337	744623	US GEOLOGICAL SURVEY	WETLANDS 1 OBS	5	251-261	1988	CNSY	37-03035	MIDDLE TWP	STONE HARBOR	4-	3
090293	390337	744623	US GEOLOGICAL SURVEY	WETLANDS 2 OBS	5	155-165	1988	ESRNS	37-03036	MIDDLE TWP	STONE HARBOR	--	--
090294	390337	744623	US GEOLOGICAL SURVEY	WETLANDS 3 OBS	5	105-115	1988	ESRNS	37-03037	MIDDLE TWP	STONE HARBOR	--	--
090295	390337	744623	US GEOLOGICAL SURVEY	WETLANDS 4 OBS	5	80-90	1988	HLBC	37-03038	MIDDLE TWP	STONE HARBOR	4-9	0
090296	390500	744946	NJ WATER CO-SHORE DIST	HAND AVE 8	20	682-812	1986	KRKDL	35-06073	MIDDLE TWP	STONE HARBOR	4-16	-24
090297	391324	744056	SHORE ACRES	SHORE ACRES A	10	145-180	1986	CNSY	36-06829	UPPER TWP	SEA ISLE CITY	4-	8
090299	391307	744100	STATE OFNJ-HIGHWAY GSP	NJHA-GSPUPPER 1-A	5	62-65	1977	HLBC	36-00478	UPPER TWP	SEA ISLE CITY	--	--
090300	385726	745233	LUNDS FISHERIES	LUNDS FISHERIES 2	5	261-286	1976	CNSY	37-00314	LOWER TWP	CAPE MAY	--	--
090301	385732	745124	WILDWOOD W D	WILDWOOD 44-RECHARGE 4	2	190-245	1983	CNSY	37-00831	LOWER TWP	WILDWOOD	4-17	-1
090302	385709	745128	US GEOLOGICAL SURVEY	COAST GUARD 800 OBS	5	883-893	1989	KRKDL	37-03628-9	LOWER TWP	WILDWOOD	4-9	-12
090303	390002	745410	US GEOLOGICAL SURVEY	AIRPORT DOE 36	25	--	1978	KRKDL	57-00044	LOWER TWP	RIO GRANDE	--	--
090304	390002	745410	US GEOLOGICAL SURVEY	AIRPORT RIO GRANDE OBS	25	495-505	1989	KRKDU	37-03763-3	LOWER TWP	RIO GRANDE	4-8	-7
090305	390401	744706	SCOTCH BONNET WATER	SCOTCH BONNET MARINA	5	--	1960	KRKDU	37-00214	MIDDLE TWP	STONE HARBOR	4-18	-16
090306	390422	745447	US GEOLOGICAL SURVEY	OYSTER 800 OBS	6	656-666	1989	KRKDL	35-00239	MIDDLE TWP	RIO GRANDE	4-8	-13
090307	391518	743747	ALL SEASONS MARINA	ALL SEASONS MARINA	5	95-120	1984	CKKD	36-04376	UPPER TWP	MARMORA	4-	3
090308	391213	745333	BOHM, DAVID	BOHM SOD FARM 1987	12	58-98	1987	CKKD	35-06359	DENNIS TWP	HEISLERVILLE	4-10	6
090310	390018	744748	WILDWOOD W D	RIO GRANDE39 NEW-RECHRG4	7	279-357	1986	CNSY	37-01781	NORTHWILDWOOD	STONE HARBOR	4-	5
090311	390750	744242	SEA ISLE C W D	SICWD 6-1989	8	732-896	1989	KRKDL	36-10378	SEA ISLE CITY	SEA ISLE CITY	4-8	-37
090313	390726	745329	SWIERCZYNSKI, STEPHEN	REEDS BEACH BAY FRONT 1	14	7-105	1953	ESRNS	37-00048	MIDDLE TWP	RIO GRANDE	--	--
090314	385930	744852	WILDWOOD CITY	RECHARGE 3	10	212-325	1982	CNSY	37-00640	WILDWOOD CITY	WILDWOOD	--	--
090315	390317	745010	WILDWOOD GOLF	GOLF CLUB 2-1975-OW 3	10	228-248	1975	CNSY	35-01373	MIDDLE TWP	STONE HARBOR	4-10	2
090316	390317	745010	WILDWOOD GOLF	GOLF CLUB 1-1975-OW 2	10	229-247	1975	CNSY	37-00306	MIDDLE TWP	STONE HARBOR	--	--
090317	391421	744840	WOODBINE MUA	WOODBINE MUA 7	42	135-158	1981	CKKD	35-02729	WOODBINE BORO	WOODBINE	4-	27
090318	385735	745158	TWO MILE INN	TWO MILE INN NR N BNDRY	5	260-292	1984	CNSY	37-01141	LOWER TWP	WILDWOOD	4-	6
090319	391702	743725	PITT, WILLIAM	PITT DOM	8	667-687	1987	KRKDL	36-08518	UPPER TWP	OCEAN CITY	--	--
090320	390611	744838	US GEOLOGICAL SURVEY	BD-24ES COUNTY PARK	10.73	93-95	--	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-9	8
090321	390611	744838	US GEOLOGICAL SURVEY	BD-24HB COUNTY PARK	10.73	20-22	--	HLBC	--	MIDDLE TWP	STONE HARBOR	4-9	10
090322	390710	745134	US GEOLOGICAL SURVEY	BD-21HB	11	20-24	--	HLBC	--	MIDDLE TWP	STONE HARBOR	--	--
090323	391107	744607	NOVASACK, WALTER	MW-2 GRACETOWN RD 1989	30	5-25	1989	CKKD	36-11978	DENNIS TWP	WOODBINE	4-15	16
090324	391111	744530	NOVASACK, WALTER	MW-1 KINGS HWY 1989	34	10-30	1989	CKKD	36-11977	DENNIS TWP	WOODBINE	4-15	16
090325	391701	745057	US GEOLOGICAL SURVEY	FIRETOWER OBS	55	109-119	1992	CKKD	35-13059	DENNIS TWP	TUCKAHOE	--	--
090326	385734	745650	US GEOLOGICAL SURVEY	NEW ENGLAND RD OBS	14	39.7-49.7	1992	HLBC	37-04775	LOWER TWP	CAPE MAY	--	--
090327	390015	745446	CAPE MAY COUNTY	MW-1 AIRPORT1986 OBS	20	12.8-33	1986	HLBC	37-02254-7	LOWER TWP	RIO GRANDE	4-18	15

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level Date in 1987	Water level Altitude in feet
090328	390015	745446	CAPE MAY COUNTY	MW-5 AIRPORT 1986	20	7-27	1986	HLBC	37-02260	LOWER TWP	RIO GRANDE	4-18	14
090329	390018	745606	LOWER TWP MUA	MW-6 1987 LOWER TWP MUA	14.20	7.85-17.8	1987	HLBC	37-02515-5	LOWER TWP	RIO GRANDE	4-17	11
090330	390021	745549	LOWER TWP MUA	MW-9 1987 LOWER TWP MUA	15.53	6.57-16.6	1987	HLBC	37-02512-1	LOWER TWP	RIO GRANDE	4-17	11
090331	390043	745450	US GEOLOGICAL SURVEY	AIRPORT OBS HLBC NW RNWY	21	38.6-48.6	1992	HLBC	37-04770	LOWER TWP	RIO GRANDE	--	--
090332	385954	745112	US GEOLOGICAL SURVEY	CMCMUA SEWAGE OBS	9	40.3-45.3	1992	HLBC	37-04787	MIDDLE TWP	WILDWOOD	--	--
090333	390156	745334	US GEOLOGICAL SURVEY- WILDWOOD WATER DEPT	PUMP POND N OBS	20	28-38	1992	HLBC	37-04769	MIDDLE TWP	RIO GRANDE	--	--
090334	390310	745104	CAPE MAY COUNTY MUA-	TRANSFER STATION	18	14-19	1984	HLBC	37-01139	MIDDLE TWP	STONE HARBOR	4-17	15
090335	390636	745129	US GEOLOGICAL SURVEY	BD-10HB-1992 TICK RD OBS	13	10-20	1992	HLBC	35-13061	MIDDLE TWP	STONE HARBOR	--	--
090336	390727	744722	CAPE MAY COUNTY MUA	SWAINTON	20	--	1987	HLBC	35-07123-1	MIDDLE TWP	STONE HARBOR	4-17	7
090337	390012	744720	US GEOLOGICAL SURVEY	N WILDWOOD 800 OBS	10	910-960	1992	KRKDL	37-04660	NORTHWILDWOOD	STONE HARBOR	--	--
090338	390124	744801	BISHOP MARINA	HEREFD/ BISHOP 2-1986 PVC	7	276-296	1986	CNSY	37-01811	NORTHWILDWOOD	STONE HARBOR	4-	4
090339	391357	744649	CAPE MAY COUNTY MUA	ADMIN BLDG SLF-1984	38	148-158	1984	CKKD	35-04001	UPPER TWP	WOODBINE	4-9	23
090340	391424	744723	CAPE MAY COUNTY MUA	SLF MW-3	29.96	2-22	1984	CKKD	35-04009-2	UPPER TWP	WOODBINE	5-22	26
090341	391445	744638	CAPE MAY COUNTY MUA	MW-12 CMCMUA SLF	27.96	2-27	1984	CKKD	35-04003-3	UPPER TWP	WOODBINE	4-9	24
090342	391539	743828	ACTION SUPPLY	1990 ROOSEVELT BLVD	5	62-72	1990	CKKD	36-13625	UPPER TWP	MARMORA	4-19	1
090343	391347	744819	STATE OF NJ-HUMAN SERV	MW-11DEVEL CTR	37.55	15-35	1989	CKKD	35-09162-2	WOODBINE BORO	WOODBINE	4-10	27
090344	391357	744651	CAPE MAY COUNTY MUA	MW-15 CMCMUA SLF	35.45	12-37	1984	CKKD	35-04016-5	WOODBINE BORO	WOODBINE	4-9	22
090345	391402	744846	STATE OF NJ WOODBINE DEV CTR	MW-10 WOODBINE STATE SCH	41.65	3-23	1989	CKKD	35-09161-4	WOODBINE BORO	WOODBINE	4-10	31
090346	391403	744701	CAPE MAY COUNTY MUA	MAINT BLDG SLF-PROD	34.3	138-148	1984	CKKD	35-04000	WOODBINE BORO	WOODBINE	4-9	22
090347	391403	744701	CAPE MAY COUNTY MUA	MW-14 CMCMUA SLF	33.27	70-90	1984	CKKD	--	WOODBINE BORO	WOODBINE	4-9	23
090348	391430	744848	US GEOLOGICAL SURVEY	MW-1 WOODBINE MUA 1992	43	30.2-40.2	1992	CKKD	35-13019	WOODBINE BORO	WOODBINE	--	--
090349	391318	745307	BELLEPLAIN STATE FOREST	EAST CREEK LODGE	16	36-40	--	CKKD	--	DENNIS TWP	HEISLERVILLE	--	--
090350	391218	744545	US GEOLOGICAL SURVEY-	GRT CEDAR 1-D OBS	16	227-237	1992	CKKD	36-16171	DENNIS TWP	WOODBINE	--	--
090351	391218	744545	US GEOLOGICAL SURVEY-	GRT CEDAR 1-S OBS	16	57-67	1992	CKKD	36-16093	DENNIS TWP	WOODBINE	--	--
090352	385855	745737	US GEOLOGICAL SURVEY-	ROSLYN OBS SHALLOW	20	170 180	1992	ESRNS	37-04872	LOWER TWP	CAPE MAY	--	--
090353	385855	745737	US GEOLOGICAL SURVEY-	ROSLYN AVE OBS DEEP	20	262-272	1992	CNSY	37-04871	LOWER TWP	CAPE MAY	--	--
090354	390147	744855	US GEOLOGICAL SURVEY	GRASSY SOUND 1-D OBS	4.67	230-240	1992	CNSY	37-04873	MIDDLE TWP	STONE HARBOR	--	--
090355	390147	744855	US GEOLOGICAL SURVEY	GRASSY SOUND 1-S OBS	4.59	100-110	1992	ESRNS	37-04874	MIDDLE TWP	STONE HARBOR	--	--
090359	390657	744500	MIDDLE TOWNSHIP WATER DISTRICT	MTWD 2	5	708-773	1986	KRKDL	36-07286	MIDDLE TWP	AVALON	4-11	-35
090360	391152	743927	NJ/AMERICAN WATER CO	CIWC VINCENT AVE STA 2	7	636-836	1991	KRKDL	36-13154	UPPER TWP	SEA ISLE CITY	4-16	-40
090361	385718	745532	EVERITT, EDWARD	EVERITT IRR	15	15-18	1980	HLBC	--	LOWER TWP	CAPE MAY	--	--
090362	385912	745405	CAPE COUNTRY CLUB	MW DRIVEWAY	19	8-18	1990	HLBC	37-03954	LOWER TWP	CAPE MAY	--	--
090363	385825	745538	BARTLE, BOB-TMU WELDING	TMU DOM 1987 SHUNPIKE RD	20	52-55	1987	HLBC	37-02237	LOWER TWP	CAPE MAY	--	--
090364	385911	745731	PENDERS,DENNIS	1990 DOM 28 ENGLEWOOD DR	12	150-160	1990	ESRNS	37-03901	LOWER TWP	CAPE MAY	4-16	-2
090365	385911	745718	PETERSEN, CHARLES	PETERSEN IRR	10	25-30	1989	HLBC	--	LOWER TWP	CAPE MAY	--	--
090366	385940	744954	POST CREEK SEAFOOD INC	1984 788 W MONTGOMERY AV	5	270-290	1983	CNSY	37-01039	WILDWOOD CITY	WILDWOOD	--	--
090367	385949	745620	LONG BROTHERS CONS (O'NIELL)	3120 BUTTERNUT RD 1990	10	168-173	1990	ESRNS	37-03688	LOWER TWP	CAPE MAY	--	--
090368	390348	744937	POWERS, TOM	407 1ST AVE 1990 DOM	12	62-72	1990	HLBC	35-08942	MIDDLE TWP	STONE HARBOR	9-29	10
090369	390405	744846	COOPER, DAVID C	1990 DOM 49 BENNYS LNDG	8	95-105	1990	ESRNS	37-04106	MIDDLE TWP	STONE HARBOR	--	--
090370	390701	744747	EASTERN SHORE CONVALESCENT	MW B-1 1986	15	3.67-13.7	1986	HLBC	35-05294	MIDDLE TWP	STONE HARBOR	4-12	8
090371	390703	744734	AVALON GOLF	MW-3 1989	10	12-22	1989	HLBC	35-09184-3	MIDDLE TWP	STONE HARBOR	4-12	3
090372	390924	744203	BROGDEN, J (LARSEN'S)	1956 BROGDEN WELL	5	294-302	1956	CNSY	--	DENNIS TWP	SEA ISLE CITY	4-8	5
090373	391022	744457	PINE HAVEN CAMPGROUND	1989 AT T-15	20	60-70	1989	CKKD	36-10326	DENNIS TWP	SEA ISLE CITY	4-10	8
090374	391122	744916	WAWA FOOD MARKET	DENNISVILLE 1985	7	53-63	1985	CKKD	35-04388	DENNIS TWP	WOODBINE	4-11	0
090375	391156	744902	DENNIS TOWNSHIP BD OF ED-	MW-1 ELEM SCH 1989	18	3-23	1989	CKKD	35-09289-1	DENNIS TWP	WOODBINE	4-10	12

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090376	391157	744911	DENNIS TOWNSHIP BD OF ED	MW-2 ELEM SCH 1989	18	3-23	1989	CKKD	35-09290	DENNIS TWP	WOODBINE	4-10	13
090377	391227	744245	IOCONA, AUGUSTINE	DOM 23 CALEDONIA DR	28	70-80	1988	CKKD	36-09919	UPPER TWP	SEA ISLE CITY	4-9	15
090378	391341	744219	ENGINEERING DESIGN ASSOC.	DOM RT50 & CAMBR DR	20	50-60	1989	CKKD	36-11779	UPPER TWP	SEA ISLE CITY	4-9	9
090379	391428	744521	ALDON HOMES (BUGNI)	DOM 4 WYNCROFT DR	35	40-50	1989	CKKD	36-10761	UPPER TWP	WOODBINE	4-12	25
090380	391543	744311	NEWBOLD, ROBERT (MARTINELLI)	1923 TUCKAHOE RD	13	35-45	1990	CKKD	36-12720	UPPER TWP	MARMORA	4-19	9
090381	391553	743915	NJ/AMERICAN WATER CO	OBS 3 S STAGECOACH RD	30	78-98	1990	CKKD	36-12777	UPPER TWP	MARMORA	4-16	10
090382	391553	743915	NJ/AMERICAN WATER CO	OBS DEEP 20 FT FM TW	30	190-210	1989	CKKD	36-12681-1	UPPER TWP	MARMORA	4-16	8
090383	391554	743916	NJ/AMERICAN WATER CO	OBS 180FT FM TW	30	190-210	1990	CKKD	36-12680-2	UPPER TWP	MARMORA	4-16	9
090384	391706	745104	GRUMEL, JANE	1989 DOM TARKILN RD	54	70-80	1989	CKKD	35-09824	DENNIS TWP	TUCKAHOE	4-10	36
090385	390154	745332	WILDWOOD CITY	RIO GRANDE 43	15	156-274	1983	CNSY	37-00861	MIDDLE TWP	RIO GRANDE		
090386	385950	745545	ROS-LEN BUILDERS (RAFF)	DOM 155 FISH CR RD	20	25-30	1990	HLBC	37-03656	LOWER TWP	CAPE MAY	4-17	15
090387	390152	745123	STARFARE, R (ADAIR)	DOM 504 BAYVIEW RD	15	31-34	1989	HLBC	37-03266	MIDDLE TWP	STONE HARBOR	--	--
090388	390237	745127	ALBRECHT AND HEUN (HASKINS)	DOM 120 W RALEIGH	15	27-32	1990	HLBC	37-03868	MIDDLE TWP	STONE HARBOR	--	--
090389	390458	745045	R J CONTRACTING (PAGNAN)	2 STAGECOACH RD	20	47-50	1986	HLBC	35-05277	MIDDLE TWP	STONE HARBOR	--	--
090390	390514	744951	ARENBERG-OFFSHORE STORAGE	1985 IRR 27 GOSHEN RD	18	87-90	1985	ESRNS	35-04774	MIDDLE TWP	STONE HARBOR	--	--
090391	390729	744828	US GEOLOGICAL SURVEY	BD-1HB SEIGTOWN RD	19.1	29-31	1966	HLBC	--	MIDDLE TWP	STONE HARBOR	--	--
090392	390729	744828	US GEOLOGICAL SURVEY	BD-1ES SEIGTOWN RD	19.1	110-112	1966	ESRNS	--	MIDDLE TWP	STONE HARBOR	--	--
090393	385718	745300	BREE-ZEE-LEE YACHT BASIN	1982 SEMI-PUBLC OCEAN DR	5	276-296	1982	CNSY	37-00694	LOWER TWP	CAPE MAY	4-17	-13
090394	385729	745201	OTTER HARBOR CLAM CO	2 MILE BOAT DOCK	5	250-275	1979	CNSY	37-00327	LOWER TWP	WILDWOOD	4-16	-8
090395	385909	745359	CRAIG, TOBY-CAPE MAY NATIONAL	CART BLDG 1991	15	255-275	1991	CNSY	37-04368	LOWER TWP	CAPE MAY	4-	-13
090397	390254	745125	LAMONICA BRAND FOODS	MW-4 SEPTIC	23	7-12	--	HLBC	37-01313-1	MIDDLE TWP	STONE HARBOR		
090398	390355	745406	DELSEA WOODS	NO 2 PUBLIC 1986	10	90-100	1985	ESRNS	35-04740	MIDDLE TWP	RIO GRANDE	4-11	7
090399	390457	745049	US GEOLOGICAL SURVEY	BD-22 ES (@ STOKES)	17.20	90-94	1966	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-17	7
090400	390457	745049	US GEOLOGICAL SURVEY	BD-22 HB (@ STOKES)	17.2	20-24	1966	HLBC	--	MIDDLE TWP	STONE HARBOR	4-17	14
090401	390832	745132	KANE, JAMES	GOSHEN L RD IRR NR POND	10	95-150	1976	CKKD	--	MIDDLE TWP	WOODBINE	4-19	4
090402	390901	744609	DRIFTWOOD CAMP GROUNDS	1987 CLERMONT NR SHOWERS	17	110-120	1987	CKKD	36-07750	DENNIS TWP	WOODBINE	4-10	9
090403	390933	744620	THORNBOROUGH, ALBERT HIDDEN ACRES CMPGRD	OLD 1.5 INCH	22	--	--	CKKD	--	DENNIS TWP	WOODBINE	4-11	16
090404	390940	744525	GARCIA, ANDREW	DOM 18 KIMBERLY CT	25	58-65	1990	CKKD	36-13327	DENNIS TWP	WOODBINE	4-19	12
090405	391022	744835	YOUNG, R	832 DVL RD HAND DUG	23	--	--	CKKD	--	DENNIS TWP	WOODBINE	4-11	9
090406	391110	744330	CAMPBELL, CLARE	1984 REPL 182 SHORE RD	20	101-111	1984	CKKD	36-04119	DENNIS TWP	SEA ISLE CITY		
090407	391119	744322	LUTHERAN HOME,OCEAN VIEW	PW 3	23	90-100	1984	CKKD	36-04715	DENNIS TWP	SEA ISLE CITY	4-8	8
090408	391200	744338	ALDON HOMES-CONFALONE	DOM 8 LAURADELL RD	35	45-55	1990	CKKD	36-13350	UPPER TWP	SEA ISLE CITY	4-18	12
090409	391237	744223	PETRELLA, JOSEPH	IRR NEW BRIDGE RD	25	54-64	1988	CKKD	36-10727	UPPER TWP	SEA ISLE CITY	4-9	10
090410	391300	743848	CORSON INLET STATE PARK	OCEAN DR	10	75-85	1989	CKKD	36-12447	OCEAN CITY	SEA ISLE CITY	4-10	4
090411	391318	745307	STATE OF NJ-BELLEPLAIN	E CR MILL POND 1992 DOM	15	260-300	1992	KRKDU	35-12745	DENNIS TWP	HEISLERVILLE		
090412	391319	744117	NJ MARINE SCIENCE	NJMSC 2 REDRILLED	21.62	155-165	1986	CKKD	36-07565	UPPER TWP	SEA ISLE CITY	4-9	7
090413	391431	744251	SUNDANCE HOMES (NIGHTINGALE)	1989 DOM 242 RT50	10	40-50	1989	CKKD	36-11034	UPPER TWP	SEA ISLE CITY	4-9	6
090414	391433	745117	STATE OF NJ-BELLEPLAIN	1973 MEISLE FIELD WELL 2	38	--	--	CKKD	35-01234	DENNIS TWP	WOODBINE	4-25	29
090415	391450	745130	STATE OF NJ-BELLEPLAIN	1973 PICNIC AREA WELL 1	29		1974	KRKDU	35-01233	DENNIS TWP	WOODBINE	4-25	8
090416	391455	745037	STATE OF NJ-BELLEPLAIN	1990 ADMIN BLDG	40	110-115	1990	CKKD	35-10506	DENNIS TWP	WOODBINE	4-9	28
090417	391500	743955	BLOHM, LARRY	1990 DOM	25	65-70	1990	CKKD	36-13885	UPPER TWP	SEA ISLE CITY	4-12	8
090418	391526	744505	JENNINGS, BRIAN	1990 NEW 47 N SUNSET RD	32	95-105	1990	CKKD	36-14048	UPPER TWP	TUCKAHOE	4-9	13
090419	391646	745054	CAPRIONI SEWAGE CAPRIONI 1-	1981	48	--	1981	CKKD	55-00044-4	DENNIS TWP	TUCKAHOE	4-10	44
090420	391716	743502	OCEAN CITY	RT 52 VISITOR CENTER	9	200-220	1989	CKKD	36-11158	OCEAN CITY	OCEAN CITY	--	--
090421	390659	744748	EASTERN SHORE NURSING HOME	MW B-4 1986	16	3-13	1986	HLBC	35-05297-0	MIDDLE TWP	STONE HARBOR	4-12	10

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
090422	391540	743913	AMERICAN WATER WORKS	STAGE COACH RD TW	25	145-205	1990	CKKD	36-12682	UPPER TWP	MARMORA	--	--
090423	390134	745240	ATLANTIC ELECTRIC COMPANY	RIO GRANDE MW 1	20	825-875	1993	KRKDL	37-05244	MIDDLE TWP	RIO GRANDE	--	--
090424	390457	744942	NJ/AMERICAN WATER CO	HAND & FRONT OW4/SEALED	21	--	1932	HLBC	57-00003	MIDDLE TWP	STONE HARBOR	--	--
090425	391440	745132	STATE OF NJ-BELLEPLAIN	COREHOLE @ MNT YD/SEALED	34	--	1991	KRKDU	35-12081	DENNIS TWP	WOODBINE	--	--
090426	385704	745542	BARUFFI, ART	1990 DOM STRAWBERRY LN	12	100-110	1990	ESRNS	37-03971	LOWER TWP	CAPE MAY	4-16	-3
090427	385729	745248	HINCH MARINA	1983COM 989 OCEAN DR REP	5	273-293	1983	CNSY	37-00930	LOWER TWP	CAPE MAY	--	--
090428	385806	745743	DELAWARE RIVER AND BAY	LEWES FERRY MW-2	10	19-24	1987	HLBC	37-02421-3	LOWER TWP	CAPE MAY	4-16	1
090429	385807	745741	DELAWARE RIVER AND BAY	LEWES FERRY MW-1	6	11-16	1987	HLBC	37-02420-5	LOWER TWP	CAPE MAY	4-1	
090430	385825	745435	CAPE ISLAND ASSOCIATES	1988 DOM AT HOUSE	10	234-254	1988	CNSY	37-03223	LOWER TWP	CAPE MAY	4-18	-14
090431	385913	745525	GENEOVESE, IDA	DOM 266 FISH CR RD	20	155-165	1988	ESRNS	37-03163	LOWER TWP	CAPE MAY	4-15	-2
090432	385955	745549	RAFF, LESLIE	IRR 141 FISHING RD	18	20-50	1985	HLBC	37-01406	LOWER TWP	CAPE MAY	4-17	15
090433	390003	745552	ROBINSON, DAVE	1990-2 DOM 217 MARSHALL	15	170-180	1990	ESRNS	37-04190	LOWER TWP	RIO GRANDE	4-29	-3
090434	390019	745554	CAPE MAY CO MUA- LOWER TWP PUMP STA	1989 CO MUA EFFLUENT	20	166-176	1989	ESRNS	37-03504	LOWER TWP	RIO GRANDE	4-18	0
090435	390029	745304	OLSON, DENNIS	1990 DOM 324 MAGNOLIA	17	130-140	1990	ESRNS	35-03640	LOWER TWP	RIO GRANDE	4-16	-5
090436	390202	744937	STATE OF NJ-DEPT OF TRANS	N WILDWOOD BLVD/SEALED	2	--	--	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-17	1
090437	390349	744932	FERACO, TOM AND JEANINE	1990 DOM 404 1ST AVE	10	60-70	1990	HLBC	37-04093	MIDDLE TWP	STONE HARBOR	4-12	10
090438	390401	744846	ELLIOT, JANE	1985 DOM BENNYS LANDING	3	94-104	1985	ESRNS	37-01664	MIDDLE TWP	STONE HARBOR	4-12	3
090439	390502	745422	HOLLINGER, DORIS (JOHNSON)	111 BEACH AVE 1984	8	85-95	1984	ESRNS	35-04198	MIDDLE TWP	RIO GRANDE	4-12	4
090440	390559	745233	HOFF, JOHN	1985 DOM 29 HWY 47 SO	17	90-100	1985	ESRNS	35-04826	MIDDLE TWP	RIO GRANDE	4-11	4
090441	390636	745129	US GEOLOGICAL SURVEY	BD-10-ES	13.5	85-90	1966	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-12	5
090442	390636	745129	US GEOLOGICAL SURVEY	BD-10-HB 1966	12.8	20-24	1966	HLBC	--	MIDDLE TWP	STONE HARBOR	4-12	5
090443	390659	744726	AVALON GOLF	AG&D 1989 PZ-4	12	6-16	1989	HLBC	35-09242	MIDDLE TWP	STONE HARBOR	4-12	2
090444	390709	744805	STATE OF NJ-	WILLIAMS MW-85-2B	16.80	102-112	1986	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-29	10
090445	390709	744815	STATE 0F NJ	WILLIAMS MW-85-1A	19.83	7.7-17.7	1986	HLBC	--	MIDDLE TWP	STONE HARBOR	4-29	14
090446	390709	744815	STATE OF NJ	WILLIAMS MW-85-1B	19.86	48.6-58.6	1986	HLBC	--	MIDDLE TWP	STONE HARBOR	4-29	14
090447	390709	744815	STATE OF NJ	WILLIAMS MW-85-1C	20.05	99.2-109	1986	ESRNS	--	MIDDLE TWP	STONE HARBOR	4-29	10
090448	390714	744806	STATE OF NJ	WILLIAMS MW-90-11A	16.55	24-34	1991	HLBC	35-11385-5	MIDDLE TWP	STONE HARBOR	4-29	12
090449	390714	744806	STATE OF NJ	WILLIAMS MW-90-11B	16.61	68-78	1991	HLBC	35-11380	MIDDLE TWP	STONE HARBOR	4-29	12
090450	391518	743959	CASACCIO, JILL CLAYTON	OLD STGECH&JILL AVE	30	65-80	1991	CKKD	36-14052	UPPER TWP	MARMORA	4-9	9
090451	391552	743851	CARDWELL, TOM	1987 REPL 16 N SHORE RD	35	110-120	1987	CKKD	36-08355	UPPER TWP	MARMORA	--	--
090452	391552	743851	WENDYS RESTAURANT	RT9-N SHORE RD / RS VLT	30	--	1986	CKKD	--	UPPER TWP	MARMORA	--	--
090453	391608	743853	UPPER TWP ELEMENTARY SCH	MARMORA ELEM 100FT	30	75-95	1986	CKKD	36-07486	UPPER TWP	MARMORA	4-19	4
090454	391608	743853	UPPER TWP ELEMENTARY SCH	MARMORA ELEM 200FT	30	180-200	1986	CKKD	36-07300	UPPER TWP	MARMORA	4-19	4
090455	391613	743831	GARVEY, RON	1990 DOM 6 BAY AIRE RD	25	95-105	1990	CKKD	36-13559	UPPER TWP	MARMORA	4-19	2
090456	391615	743848	UPPER TWP SCHOOL DIST	K-2 ELEMENTARY SUPPLY	25	100-130	1989	CKKD	36-12642	UPPER TWP	MARMORA	4-9	4
090457	391621	743840	WALCOTT, DAVID	1987 DOM TEAL ST	15	50-60	1987	CKKD	36-07988	UPPER TWP	MARMORA	4-9	8
090458	391625	744448	SCHWEIBINZ, ROBERT	1987 DOM RT 50	25	87-97	1987	CKKD	36-09259	UPPER TWP	MARMORA	4-10	12
090459	391712	743725	HARBOR RD IMPROVEMENT ASSOC	HRIA 1966	7	--	1966	KRKDL	36-00377	UPPER TWP	OCEAN CITY	4-9	-50
090460	391726	743810	ATLANTIC ELECTRIC COMPANY	BLE-SLAG OBS-1	11.18	20-35	1982	CKKD	56-00430	UPPER TWP	MARMORA	4-8	4
090461	391728	743810	ATLANTIC ELECTRIC COMPANY	ACEC 6 DEEP	8	639-710	1991	KRKDL	36-15182	UPPER TWP	MARMORA	--	--
090462	390927	745113	WHEELER, JOHN H	WHEELER 2	4	--	1968	CKKD	55-00069	MIDDLE TWP	WOODBINE	--	--
090463	385650	745450	TAYLOR, SHEPPARD	TAYLOR IRR 1	8	--	1977	CKKD	57-00058	CAPE MAY CITY	CAPE MAY	--	--
090464	391633	745220	MATTERA, FRANK	MATTERA IRR 1	47	--	1976	CKKD	57-00016	DENNIS TWP	TUCKAHOE	--	--
090465	391633	745220	MATTERA, FRANK	MATTERA IRR 2	47	--	1960	CKKD	57-00017	DENNIS TWP	TUCKAHOE	--	--
090466	391633	745220	MATTERA, FRANK	MATTERA IRR 3	47	--	1975	CKKD	57-00018	DENNIS TWP	TUCKAHOE	--	--
090467	390030	745645	REA FARMS-REA,	LESLIE C REA FARMS 1	15	--	1960	CKKD	57-00054	LOWER TWP	RIO GRANDE	--	--

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level Date in 1987	Water level Altitude in feet
090468	390030	745645	REA FARMS-REA,	LESLIE C REA FARMS 2	15	--	1960	CKKD	57-00055	LOWER TWP	RIO GRANDE	--	--
090469	390030	745645	REA FARMS-REA,	LESLIE C REA FARMS 3	25	--	1960	CKKD	57-00056	LOWER TWP	RIO GRANDE	--	--
090470	390030	745645	REA FARMS-REA,	LESLIE C REA FARMS 4	15	--	1960	CKKD	57-00057	LOWER TWP	RIO GRANDE	--	--
090471	390055	745355	HOFF, EDWARD III & FRANK	HOFF IRR 1	22	--	1967	CKKD	57-00022	LOWER TWP	RIO GRANDE	--	--
090472	390055	745355	HOFF, EDWARD III & FRANK	HOFF IRR 2	22	--	1967	CKKD	57-00023	LOWER TWP	RIO GRANDE	--	--
090473	390055	745355	HOFF, EDWARD III & FRANK	HOFF IRR 3	22	--	1967	CKKD	57-00024	LOWER TWP	RIO GRANDE	--	--
090474	390055	745355	HOFF, EDWARD III & FRANK	HOFF IRR 4	22	--	1967	CKKD	57-00025	LOWER TWP	RIO GRANDE	--	--
090475	390315	745420	SHIVERS, WALTER	W SHIVERS IRR 1	8	--	1952	CKKD	57-00053	MIDDLE TWP	RIO GRANDE	--	--
090476	390927	745113	WHEELER, JOHN	WHEELER 1	4	--	1968	CKKD	55-00068	MIDDLE TWP	WOODBINE	--	--
090477	391433	744527	MORIE COMPANY	MNG 1	20	--	--	CKKD	56-00027	UPPER TWP	WOODBINE	--	--
ATLANTIC COUNTY WELLS													
010039	392329	742348	BRIGANTINE W D	NEW 4	10	733-788	1966	KRKDL	56-00012	BRIGANTINE CITY	OCEANVILLE	--	--
010093	392908	745454	LEVARI, ROBERT	LEVARI 1	100	16-76.0	1967	CKKD	35-00929	BUENA VISTA TWP	FIVE POINTS	--	--
010117	393213	743832	EGG HAR WTR WKS	OW41 5	40	350-432	1964	KRKDL	32-00477	EGG HARBOR CITY	EGG HARBOR CITY	--	--
010180	392754	742701	US GEOLOGICAL SURVEY	OCEANVILLE 1 OBS	27	560-570	1959	KRKDL	36-00294	GALLOWAY TWP	OCEANVILLE	--	--
010227	392710	744440	HAMILTON TWP MUA	HTMUA 5	20	316-347	1966	KRKDL	36-00391	HAMILTON TWP	MAYS LANDING	--	--
010349	394041	744604	STATE OF NJ	MULLICA 2D	59	145-150	1975	CKKD	--	HAMMONTON TOWN	HAMMONTON	--	--
010351	394108	744319	STATE OF NJ	MULLICA 23S/SEALED	39	17-22	1975	CKKD	--	HAMMONTON TOWN	ATSION	--	--
010366	391821	743208	LONGPORT WD	LONGPORT OBS/SEALED	6	753-803	1895	KRKDL	56-00080	LONGPORT BORO	OCEAN CITY	--	--
010367	391859	743122	LONGPORT WD	LONGPORT 2	10	750-800	1947	KRKDL	56-00038	LONGPORT BORO	OCEAN CITY	--	--
010369	391905	743128	LONGPORT WD	LONGPORT 3	10	760-810	1968	KRKDL	36-00402	LONGPORT BORO	OCEAN CITY	--	--
010370	391928	743055	MARGATE CITY WD	MCWD 6/SEALED	10	748-798	1962	KRKDL	36-00318	MARGATE CITY	OCEAN CITY	--	--
010372	391932	743059	MARGATE CITY WD	MCWD 7	5	760-800	1963	KRKDL	36-00326	MARGATE CITY	OCEAN CITY	--	--
010376	392008	743017	MARGATE CITY WD	MCWD 5	10	741-791	1958	KRKDL	36-00278	MARGATE CITY	OCEAN CITY	--	--
010566	392434	743032	ATLANTIC CITY MUA	ACMUA 600	12	-	1925	KRKDL	--	PLEASANTVILLE CITY	PLEASANTVILLE	--	--
010578	391826	743709	US GEOLOGICAL SURVEY	JOBS POINT OBS	10	670-680	1959	KRKDL	36-00295	SOMERS POINT CITY	OCEAN CITY	--	--
010589	391924	743550	NJ AMERICAN WATER CO	NJWC 9	19	129-159	1966	CKKD	36-00388	SOMERS POINT CITY	OCEAN CITY	--	--
010604	391826	744620	CORBIN CITY BD OF ED	CORBIN 1	20	101-111	1980	CKKD	36-02064	CORBIN CITY	TUCKAHOE	--	--
010648	392125	742604	BALLY PARK PLACE	BALLY 1	7	775-835	1979	KRKDL	36-01084	ATLANTIC CITY	ATLANTIC CITY	--	--
010650	392651	744254	HAMILTON TWP WD	HAMILTON WD TEST2-73	20		1973	KRKDL	--	HAMILTON TWP	MAYS LANDING	--	--
010700	392933	744604	US GEOLOGICAL SURVEY	ACGS 4	40	479-539	1984	KRKDL	35-04274	HAMILTON TWP	DOROTHY	--	--
010701	393148	745617	BUENA BORO MUA	BBMUA TW 1	118	410-460	1984	PNPN	35-03992	BUENA BORO	BUENA	--	--
010702	392032	743008	US GEOLOGICAL SURVEY	BURK AVE TW OBS	5	740-750	1985	KRKDL	--	MARGATE CITY	OCEAN CITY	--	--
010704	392343	743733	US GEOLOGICAL SURVEY	EGG HARBOR HS	51	596-606	1985	KRKDL	--	EGG HARBOR TWP	MAYS LANDING	--	--
010710	391726	742221	US GEOLOGICAL SURVEY	ACOW 2 OBS		973-1000	1985	KRKDL	--	ATLANTIC CITY	ATLANTIC CITY	--	--
010711	391955	742507	US GEOLOGICAL SURVEY	ACOW 1 OBS		820-850	1985	KRKDL	--	ATLANTIC CITY	ATLANTIC CITY	--	--
010713	392902	745051	US GEOLOGICAL SURVEY	MIZPAH DEEP	100	525-535	1985	PNPN	35-04656	HAMILTON TWP	DOROTHY	--	--
010715	391946	745124	US GEOLOGICAL SURVEY	PEASLEE TEST HOLE/SEALED	43	-	1985	KRKDL	35-04903	ESTELL MANOR CITY	TUCKAHOE	--	--
010794	391820	744622	CORBIN CITY BD OF ED	AC REGIONAL DAY SCHOOL	20	110-120	1986	CKKD	35-06008	CORBIN CITY	TUCKAHOE	--	--
010834	392017	743002	US GEOLOGICAL SURVEY	MARGATE FIREHOUSE 1 OBS	5	970-991	1988	PNPN	--	MARGATE CITY	OCEAN CITY	--	--
010835	391820	744534	CORBIN CITY BD OF ED	JS HELMBOLD ED CENTER	15	116-126	1984	CNSY	35-05072	CORBIN CITY	TUCKAHOE	--	--
110028	391401	750158	DEL BAY PACKING	PACKING 1	5	215-235	1947	CKKD		COMMERCIAL TWP	PORT NORRIS	--	--

Appendix 1. Records of selected wells screened in the aquifers of Cape May, Cumberland, and Atlantic Counties, New Jersey--Continued

N.J. unique identification number	Latitude	Longitude	Well owner	Local identifier	Land-surface altitude, in feet	Screened interval, in feet	Year drilled	Aquifer[1]	N.J. well permit number	Township	7.5- minute quadrangle	Water level: Date in 1987	Water level: Altitude in feet
110116	391118	745705	MOORES BEACH FD	FIRE DEPT	5	295-315		KRKDU	--	MAURICE RIVER TWP	HEISLERVILLE	--	--
110119	391350	750018	CUMBERLAND COUNTY	HEISLERVILLE 2 OBS	6	125-135	1971	CKKD	--	MAURICE RIVER TWP	PORT NORRIS	--	--
110122	391352	750151	AMERICAN CLAM C	AMER CLAM 2	5	247-267	1963	CKKD	--	MAURICE RIVER TWP	PORT NORRIS	--	--
110123	391356	745751	NJ DEPT OF INST	LEESBURG 3/BAYSIDE PRSN3	13	248-268	1967	CKKD	35-00947	MAURICE RIVER TWP	HEISLERVILLE	--	--
110125	391744	745829	SUZEY-BEL CAN	SUZEY-BEL CANNING 1	5	58-78	1948	CKKD	--	MAURICE RIVER TWP	PORT ELIZABETH	--	--
110132	392512	745212	DE ROSA, SAM	RAGOVIN 3600/SEALED	85	-	1964	MRPA	--	MAURICE RIVER TWP	DOROTHY	--	--
110298	391138	750116	EAST PT W ASSOC	EAST PT 1962	5	-	--	CKKD	--	MAURICE RIVER TWP	PORT NORRIS	--	--
110362	391518	745355	US GEOLOGICAL SURVEY	BELLEPLN ST FO/SEALED	30	-	1985	-	35-04640	MAURICE RIVER TWP	PORT ELIZABETH	--	--
110365	391116	745705	US GEOLOGICAL SURVEY	MOORES BEACH-1	4.21	80-90	1987	CNSY	35-06771-3	MAURICE RIVER TWP	HEISLERVILLE	--	--
110691	391116	745705	US GEOLOGICAL SURVEY	MOORES BEACH-2	3	150-160	1989	CKKD	35-09802-3	MAURICE RIVER TWP	HEISLERVILLE	--	--
110737	391237	745713	LABAR, LELAND	LABAR DOM 1982	10	307-317	1982	KRKDU	35-03449	MAURICE RIVER TWP	HEISLERVILLE	--	--
110738	391522	745849	HAFFELFINGER, JOHN	1986 DOM LEESBURG RD	15	60-70	1986	CKKD	35-05469	MAURICE RIVER TWP	PORT ELIZABETH	--	--

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