Prepared in cooperation with the New Jersey Department of Environmental Protection

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Scientific Investigations Report 2013–5232

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Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above or below the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Water-Level Conditions in the Confined Aquifers of the New Jersey Coastal Plain, 2008

by Vincent T. DePaul and Robert Rosman

Abstract

Groundwater-level altitudes in 10 confined aquifers of the New Jersey Coastal Plain were measured and evaluated to provide an overview of regional groundwater conditions during fall 2008. Water levels were measured in more than 900 wells in New Jersey, eastern Pennsylvania, and northern Delaware and potentiometric surface maps prepared for the confined Cohansey aquifer of Cape May County, the Rio Grande water-bearing zone, the Atlantic City 800-foot sand, the Piney Point, Vincentown, and the Wenonah-Mount Laurel aquifers, the Englishtown aquifer system, and the Upper, Middle, and Lower aquifers of the Potomac-Raritan-Magothy aquifer system. In 2008, the highest water-level altitudes were observed in the Vincentown aquifer (median, 78 ft) and the lowest in the Atlantic City 800-foot sand (median, -45 ft). Persistent, regionally extensive cones of depression were present within the potentiometric surfaces of the Englishtown aquifer system in east-central New Jersey, the Wenonah-Mount Laurel aquifer in east-central and southern New Jersey, the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in southern New Jersey, and the Atlantic City 800-foot sand in the southeastern part of the State. Cones of depression in the potentiometric surfaces of the Upper Potomac-Raritan-Magothy and the Piney Point aquifers in east-central and southwestern New Jersey had broadened and deepened since 2003.

Declining water levels in many of New Jersey's confined Coastal Plain aquifers intensified during the late 1970s and early 1980s, prompting the designation of two water-supply Critical Areas by the New Jersey Department of Environmental Protection; Critical Areas 1 and 2 continued to be of concern. To address that concern, water-level changes were assessed in nearly 800 wells measured during the fall of 2003 and 2008, and potentiometric-surface difference maps for each aquifer were constructed and evaluated. In addition, water-level trends were calculated for 77 wells for the periods 2003–8 and 1998–2008 and for 73 wells for the period 1978–2008.

From 2003 to 2008 small to moderate water-level changes were observed in many Coastal Plain aquifers in New Jersey, but in places, groundwater levels continued to decline substantially as a result of pumping. Groundwater levels in the Atlantic City 800-foot sand were lower in 2008 than in 2003; declines were greatest near pumping centers in eastern Atlantic County. Changes were less pronounced in Cape May County where water levels were, on average, 1 to 3 feet (ft) lower than those during the previous study (2003), except near Rio Grande where a localized cone of depression had formed as a result of increased withdrawals. Large and widespread declines occurred in the Piney Point aquifer in Cumberland County where water levels in and around the city of Bridgeton had fallen in excess of 100 ft since 2003, and by 30 ft to more than 60 ft in surrounding areas. Groundwater levels in the Wenonah-Mount Laurel aquifer and Englishtown aquifer system continued to recover in east-central New Jersey; however, groundwater levels in the Wenonah-Mount Laurel aquifer throughout the southern part of the State continued to decline.

In the Upper Potomac-Raritan-Magothy aquifer, groundwater levels were substantially lower than in 2003 in parts of northern Ocean County but were stable in the area adjacent to Raritan Bay (Critical Area 1), and water levels continued to recover in southern New Jersey. In the Middle Potomac-Raritan-Magothy aquifer, water levels rose near Raritan Bay in Middlesex County; however, modest declines were recorded in interior areas of Monmouth and Ocean Counties. Groundwater levels in both the Middle and Lower Potomac-Raritan-Magothy aquifers were stable or rising within the regional cone of depression in Critical Area 2; beyond the critical area in southern New Jersey, however, water levels were slightly lower than in 2003.

Analyses of long-term water-level changes indicate that from 1978 to 2008 downward trends occurred at 20 wells (27 percent), upward trends at 27 wells (37 percent), and trends at 26 wells (36 percent) were insubstantial. Sustained, long-term declines were observed most often at wells within the Atlantic City 800-foot sand and at wells in the Piney Point aquifer in southern New Jersey, in which rates of decline were as great as 1.4 feet/year. Upward water-level trends were observed frequently at wells screened in the Englishtown aquifer system and the Wenonah-Mount Laurel aquifer in Critical Area 1 in east-central New Jersey, and in the Potomac-Raritan-Magothy aquifer system in parts of Critical Area 1 and throughout most of Critical Area 2 in southern New Jersey. Annual rates of upward change were as great as 3.9

and 5.6 ft/yr in the Englishtown aquifer system and Wenonah-Mount Laurel aquifer, respectively. Among the units of the Potomac-Raritan-Magothy aquifer system, annual rates of recovery were greatest in the Lower aquifer.

From 1998 to 2008, downward water-level trends were observed at 22 wells (29 percent), upward trends were observed at 21 wells (27 percent), and insubstantial trends at 34 wells (44 percent). Downward trends were detected most often at wells open to the Piney Point aquifer and the Atlantic City 800-foot sand. Upward water-level trends were most frequent in wells open to the Englishtown aquifer system in Critical Area 1 and in wells within the Potomac-Raritan-Magothy aquifer system in southern New Jersey.

Introduction

The Coastal Plain aquifers of New Jersey provide an important source of water for more than 2 million people. Groundwater withdrawals from Coastal Plain aquifers have steadily increased from less than 50 million gallons per day (Mgal/d) prior to 1920 to more than 300 Mgal/d in the late 1980s and early 1990s (unpublished data on file at the U.S. Geological Survey (USGS), New Jersey Water Science Center). As a result, water levels in the confined aquifers have steadily declined, and regional cones of depression have formed. In addition to the loss of storage, declining water levels in these aquifers have caused reversals in natural hydraulic gradients that have, in some areas, induced the movement of brackish or saline water from estuaries, bays, and adjacent aquifers to freshwater aquifers.

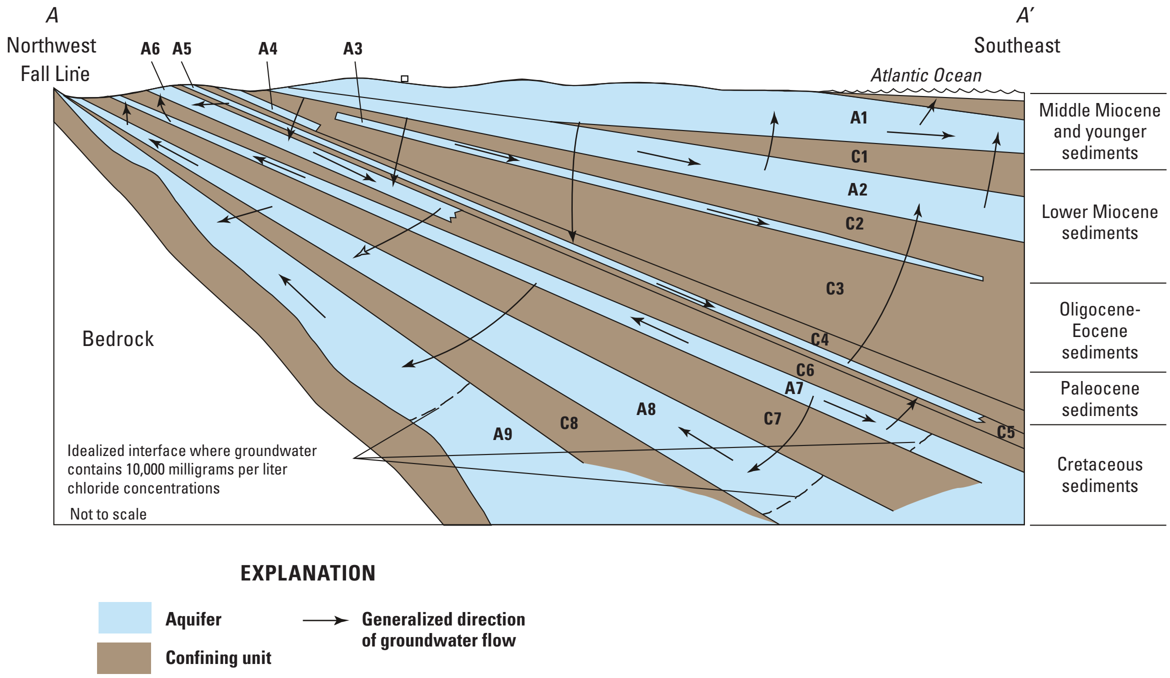
Prior to 1978, groundwater levels were measured and cones of depression were mapped in response to local hydrologic issues. To provide water-supply managers, regulators, and scientists with a regional assessment of groundwater conditions in multiple aquifers, the USGS, in cooperation with the New Jersey Department of Environmental Protection (NJDEP), initiated a plan in 1978 to map the potentiometric surfaces of the major confined aquifers on a 5-year cyclical basis. Such assessments provide a broad view of the effects of groundwater development and are an essential component to managing and sustaining the region's water supply. In 1988, the plan of study was expanded to include selected water-level measurements in Delaware in order to better define cones of depression that propagated beneath the Delaware River and Bay. To date, potentiometric surfaces in 1978, 1983, 1988, 1993, 1998, and 2003 have been mapped.

In 1985, concern over the long-term decline in water levels in areas where groundwater was the primary or sole source of supply prompted the NJDEP to designate two water-supply Critical Areas in the New Jersey Coastal Plain. Critical Area 1 is in the east-central part of the State and Critical Area 2 is in the Camden County area of southern New Jersey. Each Critical Area is composed of a depleted zone and a threatened margin. The boundary of the depleted zone corresponds to the average -30-feet potentiometric contour in each of the regulated aquifers, which is based on the 1983 maps by Eckel and Walker (1986). A 3-mile-wide buffer, known as the threatened margin, surrounds the depleted zone of each aquifer and addresses the potential for saltwater intrusion as a result of this decline in water levels. Critical Area boundaries shown on maps in this report are composites that include the largest surface extents of both the depleted zone and the threatened margin of each of the affected aquifers.

Critical Area 1, designated in 1985, encompasses parts of Middlesex, Monmouth, and Ocean Counties (fig. 1). Regulated aquifers within Critical Area 1 apply to, in increasing order of depth, the Wenonah-Mount Laurel aquifer, the Englishtown aquifer system, and the Upper and Middle Potomac-Raritan-Magothy aquifers (PRM). Mandatory reductions in groundwater withdrawals from production wells within the depleted zones of the Wenonah-Mount Laurel aquifer, the Englishtown aquifer system, and the Middle PRM aquifer were set at 50 percent relative to 1983 volumes, whereas those in the Upper PRM aquifer were set at 40 percent of 1983 volumes. Within the threatened margin, allocated withdrawals remained at 1983 volumes (New Jersey Administrative Code 7:19-8.4, 2005). Critical Area 1 restrictions were implemented in 1989, but because access to alternate water supplies was not initially available, compliance by most individual purveyors was deferred until 1991.

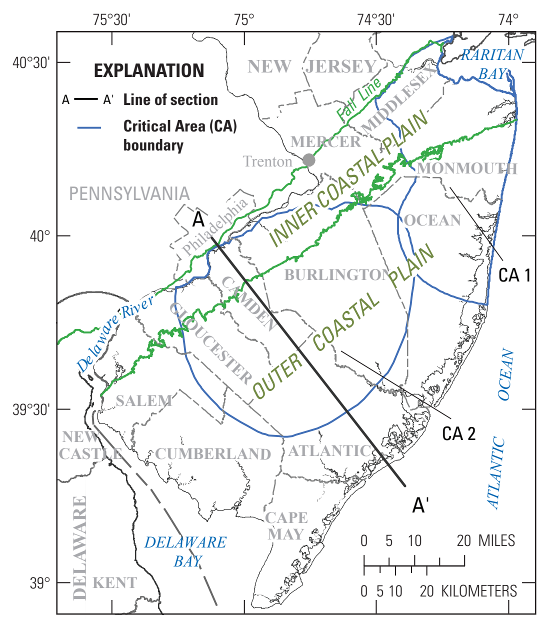
Prior to the recovery and subsequent stabilization of water levels during the early 1990s throughout Critical Area 1, water levels declined by as much as 135, 260, and 300 feet relative to predevelopment conditions in the Middle PRM aquifer, Wenonah-Mount Laurel aquifer, and Englishtown aquifer system, respectively. Upon completion of the Manasquan Reservoir in 1991, which can supply the region with approximately 30 million gallons per day (Mgal/d) of surface water (New Jersey Water Supply Authority, 2005), withdrawals from confined Coastal Plain aquifers in this area were reduced and replaced with surface-water withdrawals and, to a lesser extent, withdrawals from shallower, unconfined aquifers (Watt, 2000), initiating a reversal in the long-term decline in water levels. As of 2008, water levels have recovered from lows observed during 1983–88 by as much as 67, 150, and 187 ft in the Middle PRM aquifer, the Wenonah-Mount Laurel aquifer, and the Englishtown aquifer system, respectively.

In an effort to improve the management of groundwater resources of the PRM aquifer system in southern New Jersey, Critical Area 2 was designated in 1993. Groundwater availability issues within the region included widespread declining water levels and loss of storage associated with development of groundwater resources for public supply and the potential for movement of saline water from Gloucester County and downdip areas toward the Camden area cone of depression. The management area encompasses Camden, most of Burlington and Gloucester, and parts of Atlantic, Cumberland, Ocean, Monmouth, and Salem Counties (fig. 1), although regulations are most applicable to the first three counties. Restrictions on groundwater withdrawals apply only to the



Hydrogeologic unit

A1	Upper unconfined Kirkwood-Cohansey aquifer
C1	Confining unit overlying the lower Kirkwood Formation aquifer (Atlantic City 800-foot sand); also contains the Rio Grande water-bearing zone
A2	Confining lower Kirkwood Formation aquifer (Atlantic City 800-foot sand)
C2	Basal Kirkwood Formation confining unit; the upper part of the composite confining unit
A3	Confined Piney Point aquifer
C3	Composite confining unit
A4	Vincentown aquifer
C4	Navesink-Hornerstown confining unit
A5	Wenonah-Mount Laurel aquifer
C5	Marshalltown-Wenonah confining unit
A6	Englishtown aquifer system
C6	Merchantville-Woodbury confining unit
A7	Upper Potomac-Raritan-Magothy aquifer
C7	Confining unit between the Middle and Upper Potomac-Raritan-Magothy aquifers
A8	Middle Potomac-Raritan-Magothy aquifer
C8	Confining unit between the Lower and Middle Potomac-Raritan-Magothy aquifers
A9	Lower Potomac-Raritan-Magothy aquifer



Base modified from U.S. Geological Survey digital data, 1:24,000 Universal Transverse Mercator Projection, Zone 18, NAD 83

Figure 1. Location of the study area and generalized representation of simulated prepumping flow in a hydrogeologic section through the Coastal Plain of southern New Jersey.

aquifers of the PRM and were initiated in 1996. Groundwater withdrawals in the depleted zone were reduced by an average of 22 percent relative to 1983 volumes, whereas within the threatened margin, withdrawals were limited to the maximum annual volume between 1983 and 1991 (New Jersey Administrative Code 7:19-8.5, 2005). Development of shallower, non-restricted aquifers was encouraged and specific conservation measures introduced to curtail groundwater withdrawals within the region including the use of the Tri-County Pipeline, which began operation in 1996 and can provide more than 30 Mgal/d of water from the Delaware River to users within Burlington, Camden, and Gloucester Counties. In addition, parts of Burlington County were recognized as a Water Allocation Credit Receiving Area, whereby allocated withdrawals may be transferred locally to developing areas based on formulae set forth by the NJDEP (New Jersey Administrative Code, 7:19-8.5, 2005). Reductions in groundwater withdrawals coupled with the use of alternative surface-water sources have resulted in substantial rises in water levels in Critical Area 2, and as of 2008, water levels have recovered from lows observed during 1988–93 by as much as 53, 40, and 50 ft in the Upper, Middle, and Lower PRM aquifers, respectively.

Purpose and Scope

The scope and objectives of this report are to characterize 2008 groundwater conditions within selected confined aquifers of the New Jersey Coastal Plain and to evaluate groundwater-level changes in each during selected time periods using potentiometric-surface and water-level-change maps and simple trend statistics. Hydrographs that illustrate seasonal variations and the long-term effects of groundwater withdrawals are provided for 83 wells. Groundwater withdrawals from the 10 confined aquifers in New Jersey are compiled for 1978 to 2008 and presented in various maps, graphs, and tables throughout the report. Basic well-characteristic and water-level data are included in the appendixes. This report is the seventh in the series of reports that show the potentiometric surfaces for the major confined aquifers of the New Jersey Coastal Plain.

Description of Study Area

The study area encompasses the Coastal Plain Physiographic Province of New Jersey, eastern Pennsylvania, and parts of the Coastal Plain in Delaware. Although the study area extends offshore and beneath the continental shelf, the primary focus of the study was on the emerged parts of the Coastal Plain in the three States, an area of approximately 5,400 square miles (mi^2). The study area, shown in figure 1, is bounded on the west by the Fall Line and on the east by the Atlantic Ocean. This investigation focuses on the counties of Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Monmouth, Ocean, Salem, and parts of Mercer and Middlesex in New Jersey but includes limited parts of Kent and New Castle Counties in Delaware and parts of Philadelphia County in Pennsylvania. Topography within the study area is relatively flat; altitudes range from 0 ft along estuaries, bays, and the Atlantic coastline to nearly 400 ft at the transition of the inner and outer Coastal Plain sub-provinces in western Monmouth County, New Jersey. For purposes of geographic comparison, the New Jersey counties of Mercer, Middlesex, Monmouth, and Ocean are referred to in this report as the northern counties within the Coastal Plain; the remaining counties within the Coastal Plain—Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, and Salem—are referred to as the southern counties.

Groundwater has historically been the primary source of potable supply throughout much of the study area. The broad, flat stream valleys characteristic of the low-relief topography of the Coastal Plain generally are not practical for surface-water impoundments. A thick sequence of unconsolidated sands and gravels that underlie the study area, however, provide an abundant source of freshwater, enabling the development of many areas within the Coastal Plain for moderate to large populations. In recent years, declining water levels and instances of saltwater intrusion initiated a shift toward alternate sources of supply. From 1985 to 2008 surface water as a percentage of the total public supply among Coastal Plain populations increased from 11 to nearly 25 percent. As a result, declining groundwater levels in threatened aquifers began, and continue, to recover.

Hydrogeologic Framework

The hydrogeologic framework used in this report was developed for the New Jersey Coastal Plain Regional Aquifer System Analysis (RASA) study by Zapecza (1989) and consists of a southeastward dipping and thickening wedge of unconsolidated deposits of sand, silt, and clay of Cretaceous to Tertiary age underlain by basement rocks and overlain by a veneer of locally occurring Quaternary sediments. Coastal Plain sediments were deposited in various shelf, marginal marine, near shore or coastal beach, and deltaic environments, the extent of which fluctuated in response to relative changes in sea level. Units composed of distinctly less permeable sediments (predominantly clays and fine-grained silts) form the confining units, and coarser, more permeable sand and gravel units, which readily produce water, form the aquifers. These deposits are less than 50 ft thick along the western limit of the Coastal Plain (Fall Line) and thicken to more than 6,500 ft in southern Cape May County. Coastal Plain sediments of Cretaceous and Tertiary age generally strike northeast-southwest and dip 10 to 60 feet per mile (ft/mi) to the southeast (Zapecza, 1989); overlying Quaternary deposits are flat. Many of these units crop out near the Fall Line parallel to strike, transitioning into unconfined aquifers; others such as the Piney Point aquifer are confined throughout the study area. The aquifers and confining units discussed in this report range in age from Lower Cretaceous to Miocene (table 1). A brief description of each aquifer is included in sections devoted to

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

[Aquifers in **bold** print are those discussed in report. Modified from Zapecza, 1989, and Sugarman, 2001]

System	Series	Geologic unit	Hydrogeologic unit	
Quaternary	Holocene	Alluvial deposits	Undifferentiated	
		Beach sand and gravel		
	Pleistocene	Cape May Formation	Kirkwood-Cohansey aquifer system	
Tertiary	Miocene	Pennsauken Formation		
		Bridgeton Formation		
		Beacon Hill Gravel		
		Cohansey Sand	Kirkwood-Cohansey aquifer system	
		Kirkwood Formation	"Upper" Wildwood-Belleplain confining unit	
			Rio Grande water-bearing zone	
			"Lower" Wildwood-Belleplain confining unit	
			Atlantic City 800-foot sand	
	Oligocene	Piney Point Formation / Shark River Formation	Composite confining unit	**Piney Point aquifer**
	Eocene			
		Manasquan Formation		
	Paleocene	Vincentown Formation		**Vincentown aquifer**
		Hornerstown Sand		Hornerstown Sand[1]
Cretaceous	Upper Cretaceous	Tinton sand		
		Red Bank Sand		Red Bank Sand
		Navesink Formation		
		Mount Laurel Sand	**Wenonah-Mount Laurel aquifer**	
		Wenonah Formation		
		Marshalltown Formation	Marshalltown-Wenonah confining unit	
		Englishtown Formation	**Englishtown aquifer system**	
		Woordbury Clay	Merchantville-Woodbury confining unit	
		Merchantville Formation		
		Magothy Formation	**Potomac-Raritan-Magothy aquifer system**	**Upper aquifer**
		Raritan Formation		Confining unit
				Middle aquifer
		Potomac group		Confining unit
	Lower Cretaceous			**Lower aquifer**
Pre Cretaceous		Bedrock	Bedrock confining unit	

[1]Not designated as a formal aquifer by Zapecza (1989).

individual aquifers; for a more detailed discussion, Zapecza (1989) and Sugarman and others (2005) describe the hydrogeology of New Jersey and Vroblesky and Fleck (1991), the hydrogeology of Delaware.

Well Numbering System

In this report, wells are listed by their USGS identification numbers. For wells located in New Jersey and Pennsylvania, the well-numbering system consists of a county code number followed by a sequence number for wells within that county. For example, well number 15-123 is the 123rd well inventoried in Gloucester County. In Maryland, the numbering system consists of a county code, followed by the 5-minute quadrangle code and a number indicating the order in which the well was inventoried in that quadrangle. For example, well CO Bd 53 is located in Caroline County as indicated by “CO,” is in the 5-minute quadrangle “Bd,” and is the 53rd well mapped in that quadrangle. County codes for New Jersey, Pennsylvania, and Maryland are listed in table 2. Well identifiers in Delaware are assigned by the Delaware Geological Survey and are numbered on the basis of a coordinate system using 5-minute quadrangles of latitude and longitude.

Table 2. County prefix codes used in well-numbering systems in New Jersey, Pennsylvania, and Maryland.

County name	Code	County name	Code
New Jersey			
Atlantic	01	Mercer	21
Burlington	05	Middlesex	23
Camden	07	Monmouth	25
Cape May	09	Ocean	29
Cumberland	11	Salem	33
Gloucester	15		
Pennsylvania			
Philadelphia	P		
Maryland			
Cecil	CE		
Caroline	CO		

Previous Investigations

Various regional studies describe groundwater-level data, potentiometric surfaces, and groundwater flow in the New Jersey Coastal Plain. Previous potentiometric surface maps in this series present groundwater levels in the study area at 5-year intervals from 1978 through 2003: 1978, Walker (1983); 1983, Eckel and Walker (1986); 1988, Rosman and others (1996); 1993 and 1998, Lacombe and Rosman (1997, 2001); and 2003, DePaul and others (2009). The confined-aquifer water-level map series is supplemented by water-table maps for the unconfined aquifers within the following basins of the New Jersey Coastal Plain: Mullica River Basin (Johnson and Watt, 1996); Salem River, Raccoon, Oldmans, Alloway, and Stow Creek Basins (Johnson and Charles, 1997); Upper Maurice River Basin (Lacombe and Rosman, 1995); Great Egg Harbor River Basin (Watt and Johnson, 1992); Rancocas, Crosswicks, Assunpink, Blacks, and Crafts Creek Basins (Watt and others, 2003); and the Toms River, Metedeconk River, and Kettle Creek Basins (Watt and others, 1994).

Countywide water-resources studies were conducted by Barksdale and others (1943), Jablonski (1968), and Anderson and Appel (1969) for Middlesex, Monmouth, and Ocean Counties, respectively. Rush (1968), Farlekas and others (1983), Hardt and Hilton (1969), Rosenau and others (1969), Gill (1962), and Lacombe and Carleton (2002) completed water-resource studies for the southern counties of Burlington, Camden, Gloucester, Salem, and Cape May, respectively.

Simulations of groundwater flow from a regional perspective within the New Jersey Coastal Plain are described in Martin (1998), Pope and Gordon (1999), and Voronin (2004). Pucci and others (1994), Navoy and Carleton (1995), and McAuley and others (2001) did detailed studies, including groundwater-flow models of Critical Area 1, Critical Area 2, and the Atlantic City area, respectively. In Critical Area 2, Navoy and others (2005) simulated the vulnerability of public-supply wells open to the Potomac-Raritan-Magothy aquifer system to saltwater intrusion, and Navoy (1994) simulated the effects of projected withdrawals on water levels in the Wenonah-Mount Laurel aquifer. Groundwater-level recovery in Critical Area 1 and Critical Area 2 is discussed in Spitz and others (2008) and Spitz and DePaul (2008).

Simulations of the effects of allocated and projected withdrawals on water levels in the Potomac-Raritan-Magothy aquifer system in Gloucester and Salem Counties are reported by Charles and others (2011). Voronin and others (1996), Spitz (1998), and Lacombe and others (2009) simulated groundwater flow in confined aquifers in Cape May County. Pope (2006) simulated effects of increased withdrawals on water levels in the Atlantic City 800-foot sand.

Data Collection and Analysis

Static groundwater-level altitudes were measured in 926 wells in New Jersey and Pennsylvania by USGS personnel. Water levels were measured in additional wells in Delaware by personnel of the Delaware Department of Natural Resources and Environmental Control (DNREC). Water levels used in this study, most of which were measured during late October to mid-December 2008, are assumed to represent the 2008 average annual water level in that aquifer at that location within the study area; in some cases water levels were recovering from high summer withdrawal rates and had not yet reached the mean annual water level, but the difference from mean annual, where it exists, is generally small. Water levels measured at about the same time of year once every 5 years can be compared to each other to reveal long-term trends whether or not they are exactly the mean annual water levels for the respective years.

Water levels were measured at observation wells and production wells used for industrial, commercial, irrigation, domestic, and public supply; wells used for measurement were generally chosen on the basis of areal distribution within each aquifer. Measurements made at observation wells constitute about one-third of the dataset, and in order to maximize the geographic distribution and to capture low water levels associated with withdrawals, the network was augmented with production wells. Measurements were made using steel or electric tapes graduated to hundredths of a foot, which are the most accurate devices, or using an airline, which is less accurate. The airline method was used in limited instances and only at wells that were inaccessible for measuring by either electric or steel tape. Pumps in high-capacity supply wells were turned off for a minimum of 1 hour before measurement of the water level in the well. In addition, nearby pumping was controlled at the time of measurement; pumps in all other high-capacity production wells screened in the same aquifer within 0.25 mi of the measured well were idle for at least 1 hour prior to measurement of the water level. In accordance with USGS methods for the collection of water-level data, measurements were made in each well until two consecutive measurements within 0.05 ft were obtained at least 5 minutes apart. The resulting water-level measurement was considered representative of static or near-static conditions. Importantly, "static" in this report is not intended to mean unaffected by withdrawals but rather representative of water levels in the area, not of those influenced by the very local effects of individual withdrawals. Water-level data are presented in appendixes 1 through 9.

Groundwater in three observation wells measured in this study had chloride concentrations in excess of 5,000 milligrams per liter (mg/L). Water levels in these wells were converted from a measured saltwater hydraulic head to a calculated freshwater head. The conversion equation follows a modification of the Ghyben-Herzberg relation (Todd, 1980) to determine the equivalent length of freshwater in a well filled with saltwater:

$$l_f = (p_s / p_f)\, l_s,$$

where

l_f is length of the freshwater column in the well casing,

p_s is the density of saltwater,

p_f is the density of freshwater, and

l_s is the length of saltwater column in the well casing.

The density of freshwater is 1.00 gram per cubic centimeter (g/cm^3), and the density of water increases with increasing solute concentrations. Adjusted water levels were used to contour the potentiometric surfaces; both the measured water levels and their freshwater equivalents are presented in the appendixes of the report.

The water level in a well represents the hydraulic head in the part of the aquifer to which the well is open. Hydraulic heads at each well were calculated by subtracting the water level, in feet below land surface, from the land-surface altitude, in feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). In confined aquifers, this level typically stands above the top of the aquifer as a result of increases in pressure with depth and the presence of overlying, relatively impermeable strata. Maps depicting the areal distribution of hydraulic head within each aquifer then were constructed; lines of equal hydraulic head are represented on these maps by potentiometric-surface contours. From these maps groundwater flow in each aquifer can be inferred, as general flow directions are assumed to be perpendicular to the potentiometric-surface contours and in the direction of decreasing head. Although most of the data used in this study are composed of measurements made in the confined parts of the aquifers, in some cases, measurements made in the unconfined parts are included in order to guide placement of potentiometric contours at the aquifer outcrops.

On the plate maps accompanying this report, the symbol for an observation well applies not only to the original use of the well, but to wells that had not been pumped during the 7 days prior to measurement. Prior to 1998, reports in this series applied the term "observation well" to a well that had not been pumped within the 24 hours prior to measurement. Because of wide variations in the hydraulic characteristics among the aquifers within the study area, the residual effects of pumping stresses also differ greatly, and therefore, this "idle period" for observation-well classification was lengthened to 7 days.

Groundwater-level-change maps for selected aquifers were constructed by comparing the potentiometric surfaces and groundwater-level measurements from 2003 and 2008. Water-level-change values were calculated as the difference between the 2003 and 2008 groundwater-level altitudes, except where continuous or semi-continuous hydrograph data were available; in those cases, a calculated slope was used to determine water-level change. In limited cases, water levels measured during 2008 that were not measured during prior studies were compared to an estimated water level derived from the earlier potentiometric surface map at that location. In addition, where measurements were sparse or absent, particularly in downdip areas of some units, points representing the differences in the potentiometric surface at the intersections of two contours were used to provide additional spatial coverage. The water-level-change values were plotted on digital base maps and initially contoured by using geographic information systems (GIS) software to provide an unbiased interpolation of the data. The contours were then manually adjusted to reflect the understanding of the groundwater system. Raster datasets were constructed from the resulting "difference" contours and points in order to provide estimates of groundwater-level change in areas lacking measurements. While these maps provide a spatial perspective in assessing water-level change throughout individual aquifers over a given time period, interpretations based on these maps are best viewed with some caution. In most cases, the density of data throughout a given aquifer may be insufficient to support the interpretation and use on a local scale. Additionally, many of the data points used in the construction of these maps are based on two measurements that represent a long-term net change in water levels; in the absence of continuous long-term water-level data, the direction and rate of change during intervening time periods may fluctuate and not be known, and cannot be resolved through use of intermittent data points. Further, uncertainty may be introduced by the relative positions of the compared water-level measurements on the annual hydrograph. Finally, equivalent gradational scales were used on all maps to maintain consistency; a change of -5 to +5 ft is classified as "no substantial change," and lesser water-level changes are not shown.

Water-level data from wells with at least 15 years of record were used to produce the hydrographs shown in various figures throughout this report, with the exception of those for the Rio Grande water-bearing zone, where water levels were collected intermittently. In many cases, hydrographs show periods of record beyond 15 years, and many span the 30-year period from 1978 to 2008. The water-level data used to construct the hydrographs are a combination of continuous measurements and manual measurements collected on a seasonal basis. These data illustrate seasonal variations in water levels; the long-term effects of artificial stresses, such as pumping; and in some cases, the development and recovery of depressions in the potentiometric surface. Where temporal density and continuity of long-term water-level measurements were sufficient, trends were statistically analyzed by using the Mann-Kendall trend test, a commonly used method to assess monotonic change in time-series data (Mann, 1945; Helsel and Hirsch, 2002). The Mann-Kendall method is a nonparametric trend test that determines whether a statistically significant positive or negative change in a constituent (in this case, depth to water) has occurred over the period of interest. The method, however, does not imply whether change is linear nor does it determine the magnitude of change. Calculation of Sen's slope for each of the test periods was used to quantify the magnitude of annual water-level change (Sen, 1968; Gilbert, 1987). Because water levels may vary throughout the year as a result of seasonal demand and withdrawal patterns, a modified test that accounts for seasonality in the data, determined from Wilcoxon scores, was used (Hirsch and Slack, 1984; Winkler, 2004). For the purposes of this study, an upward or downward change over a given period of time was considered statistically significant if the Mann-Kendall trend test had a 95-percent confidence level (*p* value of 0.05) and if the average yearly change, as indicated by the slope of the line, was greater than or equal to 0.2 feet per year (ft/yr). If the slope was less than 0.2 ft/yr, the indicated yearly change was considered insubstantial. Analyses focused on the 5-year period from 2003 to 2008, the decadal period of 1998 through 2008, and the 30-year period from 1978 to 2008. The 30-year period coincides with the duration of the individual water-level synoptic studies in this series and is used to illustrate long-term trends not dominated by short-term variations in climate or withdrawal patterns. Because trends observed in many of the wells were not always unidirectional from the beginning to the end of a cycle, trends in different directions may cancel each other out, leading to the conclusion of an "insignificant trend" for a given time period.

In addition to trend tests on long-term water-level data, hypothesis tests were performed on the medians of paired differences between the 2003 and 2008 and the decadal (1998–2008) measurements using the non-parametric Wilcoxon signed-rank test (Wilcoxon, 1945; Helsel and Hirsch, 2002). The null hypothesis for each test was that the median difference between paired measurements is equal to zero or that no statistical difference exists between compared measurements. Because the ranks of differences rather than the actual values are used, the magnitude of the differences does not affect the outcome of the test. Differences were considered significant if a *p*-value of less than or equal to (≤) 0.05 (95-percent confidence level) was attained, that is, a 1 in 20 chance of obtaining this correlation by random occurrence. As the *p*-value decreases, evidence for rejecting the null hypothesis increases. Tests were performed on data grouped according to aquifer, aquifer and county, and aquifer and selected management-area boundaries.

The location of the 10,000-mg/L line of equal chloride concentration (approximately half that of seawater) was simulated for selected aquifers in the New Jersey Coastal Plain by use of the USGS SHARP model (Pope and Gordon, 1999). The locations of these lines (hereafter referred to as isochlor) on selected plates represent the toe of the saltwater interface, that is, the intersection of the interface with the bottom of the aquifer, generally its farthest landward or updip position. Because of disequilibrium of the flow system with present day sea level, the position of the interface is more closely related to predevelopment rather than current groundwater conditions, and despite future scenarios of increasing withdrawals and deepening cones of depression, numerical simulations indicate little to no movement (Pope and Gordon, 1999). As such, these boundaries likely have not moved substantially in response to changing groundwater conditions observed throughout past study cycles and, therefore, have not been updated. The locations of the 10,000-mg/L isochlors for the aquifers of the Delaware Coastal Plain are based on maps by Vroblesky and Fleck (1991). The location of the 250-mg/L isochlor, which designates the limit of potable water in each aquifer as defined by NJDEP secondary drinking-water standards (New Jersey Administrative Code, 2004), is based on published maps that are cited for each aquifer. If no map was available to show the location of the 250-mg/L isochlor in a particular aquifer, the line was determined from chloride data stored in the USGS National Water Information System database (NWIS) and the NJDEP quarterly monitoring database. Modifications from previously published maps in this report series were made to these 250-mg/L isochlors as current (2003–8) water-quality data warranted.

Groundwater-withdrawal data for central and southern New Jersey were tabulated and mapped in order to assess volumes of water pumped from each of the aquifers. Data were compiled from permitted data only, that is, wells in which daily withdrawals meet or exceed 100,000 gallons for a period of more than 30 days in a consecutive 365-day period. Such wells include those used for public-supply, large-scale agriculture (irrigation), and commercial or industrial purposes. No attempt was made to estimate withdrawals from numerous smaller-capacity production wells, such as those used for domestic supply, which is a limitation of the analysis. Withdrawal data cited in this report were obtained from data reported to the New Jersey Department of Environmental Protection and were quality reviewed and incorporated into the water-use database of the USGS New Jersey Water Science Center. Additional withdrawal data from the late 1970s were obtained from Zapecza and others (1987).

Cohansey Aquifer

The Cohansey aquifer in Cape May County is the youngest and uppermost confined aquifer considered in this study. The aquifer is composed of gravel and coarse- to fine-grained sands and includes the lower part of the Cohansey Formation and the sand-rich uppermost section of the Kirkwood Formation (Zapecza, 1989). Throughout Cape May County, Pleistocene deposits of sand and clay overlie the Cohansey aquifer, providing effective confinement from surficial recharge. In northern Cape May County, the Cohansey aquifer underlies the Holly Beach water-bearing zone and is confined by one or more discontinuous clay deposits, whereas in the southern part of the county two intervening widespread and uniform confining units and the estuarine sand aquifer overlie the Cohansey aquifer. The aquifer in Cape May County ranges in thickness from 50 ft near Ocean City to more than 150 ft near the southern tip of the peninsula (Lacombe and Carleton, 2002). The limit of confinement is in northern Cape May County, approximately bounded by the Tuckahoe River and a northeast-trending line from the mouth of the Maurice River at Delaware Bay to the intersection of Cape May, Cumberland, and Atlantic Counties.

The Cohansey aquifer contains freshwater throughout most of the extent underlying mainland Cape May County; however, saline water is present in the aquifer beneath the extreme southern part of the peninsula, beneath the back bays and barrier islands north of Wildwood, and beneath near-shore and offshore areas of the Atlantic Ocean and the Delaware Bay (pl. 1). Additionally, saltwater has migrated into freshwater parts of the aquifer along the western coast of the peninsula, west of the village of Rio Grande. The saltwater-freshwater interface (hereafter referred to as saltwater front), as indicated by 250-mg/L isochlor, was originally mapped by Gill (1962) and updated by Lacombe and Rosman (2001), Lacombe and Carleton (2002), and DePaul and others (2009). The estimated position of the saltwater front is mapped farther inland than in previous studies, near Villas, Cape May County, reflecting the rapidly rising chloride concentrations observed in well 9-187, which increased from 190 mg/L in 1996 to 805 mg/L in 2005. A groundwater sample collected in early 2010 yielded a chloride concentration of 1,150 mg/L, confirming the 70-mg/L annual rate of increase. The chemistry of the water from this well is consistent with seawater intrusion into coastal fresh groundwaters. The composition of the groundwater is that of a calcium-chloride type, indicative of base-exchange reactions with aquifer materials, whereby the uptake of sodium into the solid phase (primarily on clay minerals and organic matter within the aquifer matrix) is enhanced, replacing calcium ions that are subsequently released to solution (Vengosh, 2003). This results in low molar ratios of sodium to chloride relative to seawater (< 0.86), as well as low ratios of both sulfate and boron to chloride. Lacombe and others (2009) indicate that withdrawals at the Rio Grande well field are a possible cause of intrusion in this area. Similarly, chloride concentrations in well 9-89, along the western coast of the peninsula and 2.8 miles to the north of well 9-187, have increased linearly since 2003; sodium to chloride molar ratios in groundwater from this well also have decreased during the same time period, indicating a mix of seawater with fresher groundwaters. Immediately to the south of Villas, however, the groundwater remains fresh along the western coast of the peninsula where chloride concentrations are typically less than 15 mg/L, and no sustained increases have been observed during the past decade. Approximately 2 mi to the east of well 9-187, at the Rio Grande well field (fig. 2), chloride concentrations in a production well have increased from about 15 mg/L to as high as 83 mg/L during 1998–2009. Although concentrations in this well are typically around 50 mg/L, decreasing sodium to chloride ratios along with increasing chloride concentrations indicate the possible movement of water from the Delaware Bay.

Water withdrawals

The distribution of withdrawals from the Cohansey aquifer in Cape May County is shown in figure 2. Groundwater withdrawals are most common in the southern part of the peninsula in upland areas of Middle and Lower Townships, although smaller-capacity production wells are located throughout the central and northern parts of the county. During 2008, approximately 4 Mgal/d (75 percent of total withdrawals) were withdrawn for public supply, lesser amounts were withdrawn for industrial, irrigation, and other purposes. In 2008, the Wildwood Water Utility (WWU), the largest user of groundwater from the Cohansey aquifer, withdrew an average of 2.0 Mgal/d. Most of the withdrawals were concentrated at the well field at Rio Grande and accounted for 50 percent of public-supply withdrawals from the aquifer in 2008. The second largest user of the Cohansey aquifer, Lower Township

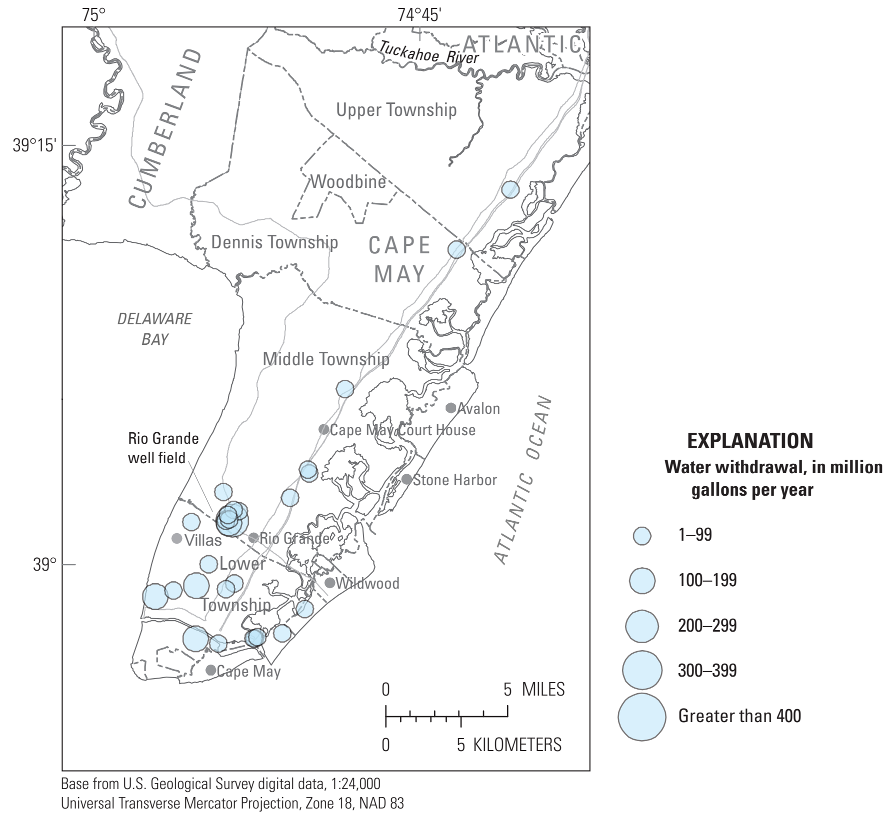


Figure 2. Location and volume of groundwater withdrawals from the confined Cohansey aquifer, southern Cape May County, New Jersey Coastal Plain, 2008.

Municipal Utilities Authority (LTMUA), accounted for an additional 1.1 Mgal/d.

From 1978 to 2008, estimated withdrawals from the Cohansey aquifer ranged from 3.8 to 6.9 Mgal/d. By 1982, withdrawals were at their peak and remained greater than 6 Mgal/d throughout the 1980s (fig. 3). During 1991–92 withdrawals decreased by 14 percent, and throughout the 1990s, average withdrawal rates were about 5.5 Mgal/d. Following a brief increase from 1996 to 1998, withdrawals decreased with the introduction of Cape May City Water Department (CMCWD) wells tapping the Atlantic City 800-foot sand and supplying water to the desalination plant completed in 1998. From 1998 to 1999, withdrawals from the Cohansey aquifer decreased by 24 percent, the largest such reduction from any given year to the next. Withdrawal rates increased during 2000–1, but from 2003 to 2008 withdrawals were further reduced by an additional 20 percent. Withdrawals of 3.8 Mgal/d in 2008 were the lowest since this series of studies commenced in 1978 (fig. 3; table 3).

Withdrawals by the two major utilities remained relatively constant from the early the 1980s to 2006; however, farther to the south substantial reductions occurred in Cape May City, coinciding with the use of production wells open to the Atlantic City 800-foot sand. LTMUA slightly reduced withdrawals during 2006–7; however, they returned to antecedent withdrawal rates in 2008. From 2007 to 2008, WWU reduced withdrawals from the Cohansey aquifer at the Rio Grande well field by nearly 1 Mgal/d and replaced those by using withdrawals from deeper, less vulnerable aquifers.

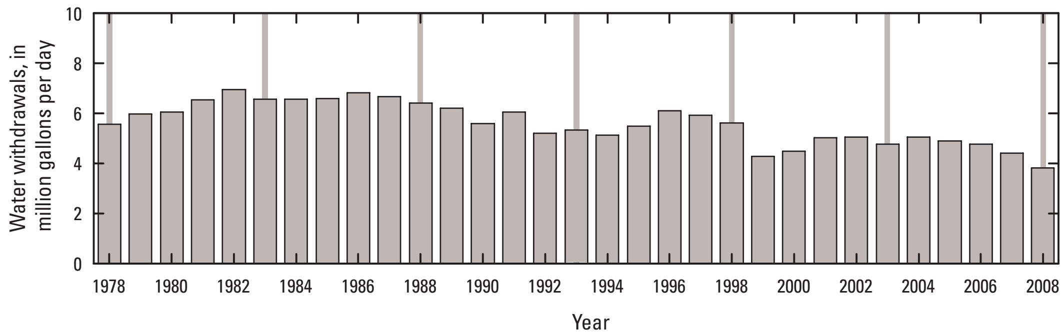


Figure 3. Estimated groundwater withdrawals from the confined Cohansey aquifer in Cape May County, New Jersey Coastal Plain, 1978–2008. (Thin vertical bars denote 5-yr data collection periods)

Table 3. Groundwater withdrawals by county and aquifer from selected confined aquifers of the New Jersey Coastal Plain, 2008.

[Withdrawals are in million gallons per day; only permitted and reported values included; <, less than; --, not applicable]

County	Aquifer									
	Cohansey[1]	Rio Grande water-bearing zone	Atlantic City 800-foot sand	Piney Point	Vincen-town	Wenonah-Mount Laurel	English-town aquifer system	Upper Potomac-Raritan-Magothy	Middle Potomac-Raritan-Magothy	Lower Potomac-Raritan-Magothy
Atlantic	--	--	11.8	0.6	--	--	--	--	--	--
Burlington	--	--	--	0.03	<0.01	2.8	0.9	4.5	18.0	9.5
Camden	--	--	--	0.02	--	2.1	1.4	8.1	6.5	24.4
Cape May	3.8	0.3	8.7	--	--	--	--	--	--	--
Cumberland	--	--	--	0.5	--	--	--	0.1	--	--
Gloucester	--	--	--	--	0.1	1.4	0.04	8.7	6.0	2.8
Mercer	--	--	--	--	--	--	--	0.8	9.0	--
Middlesex	--	--	--	--	--	--	--	15.8	8.4	--
Monmouth	--	--	--	--	0.6	0.6	2.9	8.6	7.3	--
Ocean	--	0.3	6.2	4.7	0.4	0.14	2.0	7.0	7.0	--
Salem	--	--	--	--	0.03	1.2	--	1.5	2.7	0.6
Total	3.8	0.6	26.8	5.8	1.1	8.2	7.2	55.1	64.9	37.2

[1]Cape May County only.

Water levels

The potentiometric surface map for fall and early winter 2008 for the confined Cohansey aquifer is shown on plate 1 (fig. 1-1); supporting water-level data used to construct this map are presented in appendix 1-1. Because water-level altitudes in the northern part of Cape May County did not change appreciably since pumping began, the potentiometric surface of the aquifer underlying only the southern half of the Cape May peninsula was mapped. The configuration of the groundwater surface shows a broad cone of depression centered beneath major withdrawal locations in the southern part of the peninsula, encompassing all of Lower Township, Cape May, and West Cape May, as well as large parts of Middle Township and Wildwood Crest. The highest measured water-level altitudes in the confined Cohansey aquifer occurred in central and western Middle Townships and in areas to the north, ranging from about 4 to 6 ft. The lowest groundwater-level altitudes occurred in central and southern Lower Township in the vicinity of the LTMUA and CMCWD well fields, ranging from -9 to -17 ft. In comparison, withdrawals from the WWU Rio Grande well field to the north are substantially greater than those from the LTMUA and CMCWD Cohansey aquifer wells (82 percent), yet heads are slightly higher. Lower observed groundwater levels to the south and west are consistent with a decrease in transmissivity toward the southwestern part of the peninsula and greater recharge in Middle Township and to the north. The groundwater surface within the study area slopes concentrically inward toward potentiometric lows in central and southern Lower Township, and flow is radially inward from the north and south, as well as from the Atlantic Ocean and Delaware Bay coastlines. The configuration of the potentiometric surface is similar to that of 2003; however, the area encompassed by the -10-ft contour has contracted slightly from its previous extent as a result of reductions in Cohansey aquifer withdrawals at the WWU Rio Grande well field.

Vertical head differences were calculated as the differences in groundwater altitude between each aquifer and adjacent hydrogeologic units. These head differences are an indication of the direction and magnitude of hydraulic gradients that affect the vertical component of flow and provide insight into the potential for inter-aquifer flow. Calculation of such differences is predicated on the collection of accurate head data from multiple aquifers at individual wells or at wells in close proximity to one another. However, data of this type are limited throughout the study area, and estimated groundwater altitudes were compared to those in adjacent units above and below each aquifer to supplement the analysis. Because the Cohansey aquifer is the uppermost aquifer in this study and a recent potentiometric surface has not been constructed for the overlying estuarine sand aquifer, comparison could be made only with the underlying unit, the Rio Grande water-bearing zone. Throughout the study area, water levels within the Cohansey aquifer are greater than those in the Rio Grande water-bearing zone. The potential for downward flow from the aquifer is strongest throughout the central part of Cape May County, where vertical head differences are typically 20 to 25 ft, and probably weakest toward the southern tip of the peninsula.

Small to moderate net water-level changes were measured in most wells during 2008; from a regional perspective, however, water levels generally remained about the same relative to those observed in 2003. Results of the Wilcoxon signed-rank test indicate that no statistically significant difference is present among 38 matched data pairs measured in 2003 and 2008. Water levels increased in 21 wells (55 percent), were unchanged in 4 wells (11 percent), and decreased in 13 wells (34 percent). Water-level changes range from declines of 2 to 3 ft at the northeastern and southwestern edges of the cone of depression to rises of 2 to 9 ft in central and northern Lower Township (fig. 4). For the 10-year period 1998–2008, results indicate that there was a statistically significant rise in water levels.

Long-term water-level trends in the Cohansey aquifer were evaluated both graphically and statistically. The magnitude of groundwater-level changes in the Cohansey aquifer, as well as the other confined aquifers throughout the Coastal Plain, depends upon changes in storage within the aquifer, which is a function of its hydraulic properties, and the distribution and changes in patterns of recharge and discharge (including withdrawals). Climatic variations affect water levels in confined aquifers only indirectly and are not considered in this report.

Hydrographs of four wells located within and at the edges of the cone of depression in southern Cape May County are shown in figure 5. Each hydrograph depicts water-level altitudes at or below 0 ft since the initial study in 1978. The hydrographs also show the response of water levels to seasonal changes in withdrawals; these fluctuations were as much as 19 ft, with wells located closest to pumping centers (9-60 and 9-150) exhibiting the greatest annual variability. The water level in well 9-80, located near the northeastern edge of the cone of depression, shows the least annual variability. The net change in water levels in this well during the 5-year (2003–8), the decadal, and the 30-year periods was negligible. The hydrograph of observation well 9-150, which is located near the southern tip of the peninsula, shows rising water levels from 1979 through the mid-1980s, stabilization through the mid-1990s, and rising levels again from 1998 to 2003. From 2004 through 2008, the near-zero slope of the hydrograph indicates stable groundwater levels. The recovery in water levels in well 9-150 during 1979–86 resulted from the abandonment of public-supply wells in Cape May Point and a decrease in withdrawals from Cape May City's southernmost supply well (Lacombe and Carleton, 2002); rising water levels and the lower amplitude of seasonal fluctuations observed between 1998 and 2004 were the result of further reductions in withdrawals by Cape May City. From 2005 to 2008, annual variability again increased, although this may be an artifact of an increase in data-collection frequency. The net change during 2003–5 in the water level in well 9-150 was negligible. Well 9-60, located in northern Lower Township near LTMUA production wells and less than 1 mi from the WWU Rio Grande well field, had annual high water levels of -7 to -12 ft and seasonal fluctuations of 10 to 19 ft; the summer level was nearly 20 ft below the annual high. Although measurements in this well were made at a rate of only 2 to 3 times per year, an upward slope in the hydrograph can be observed during 2005–8, indicating a rise in water levels corresponding to reductions in withdrawals from the Cohansey aquifer at the well field. Withdrawals from the nearby pumping center remained relatively constant from 1980 through 2006, averaging 3.2 Mgal/d; consequently, the water level in this well shows neither a distinct upward nor downward trend during that period.

Results of the Mann-Kendall trend analysis are listed in appendix 10-1. Temporal density of the data for well 9-60 was not sufficient, and trends were not calculated. No significant upward or downward trends were observed in the remaining Cohansey aquifer wells for the 5-year period from 2003 to 2008; however, a slight downward trend was indicated for well 9-150 during 1998–2008. In contrast, an upward trend was indicated for the 30-year period. Although upward and downward trends were detected at the 95-percent confidence level during several periods at wells 9-49 and 9-80, the slopes of the hydrographs during these periods were negligible, and the magnitude of change was not considered important.

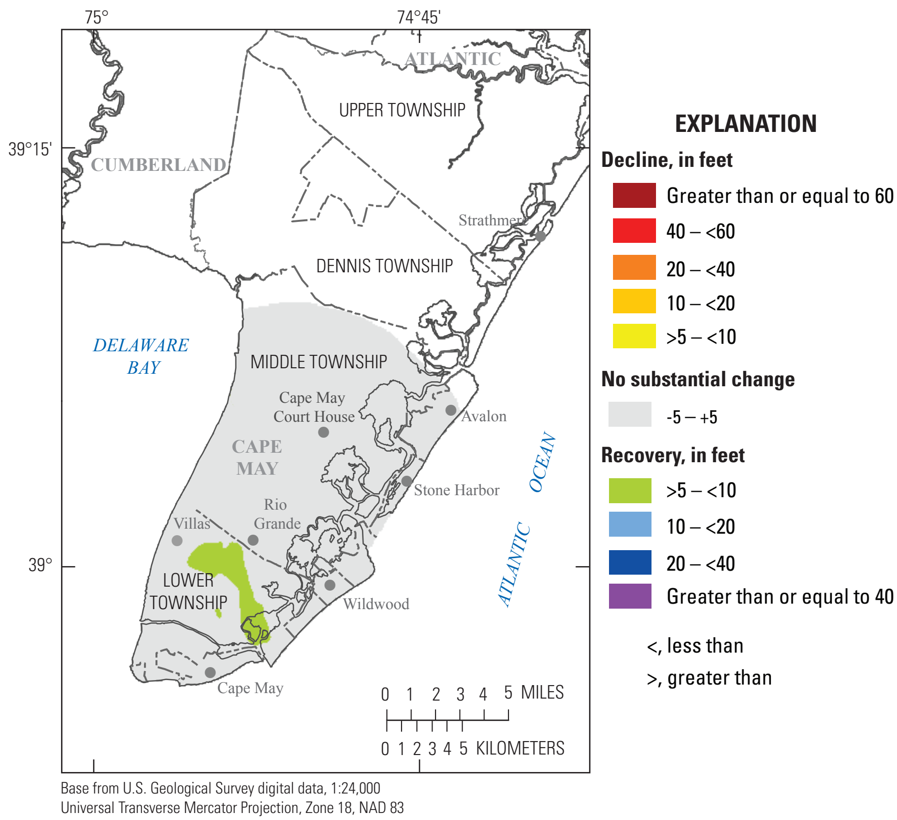


Figure 4. Water-level changes in the confined Cohansey aquifer, Cape May County, New Jersey Coastal Plain, 2003–8.

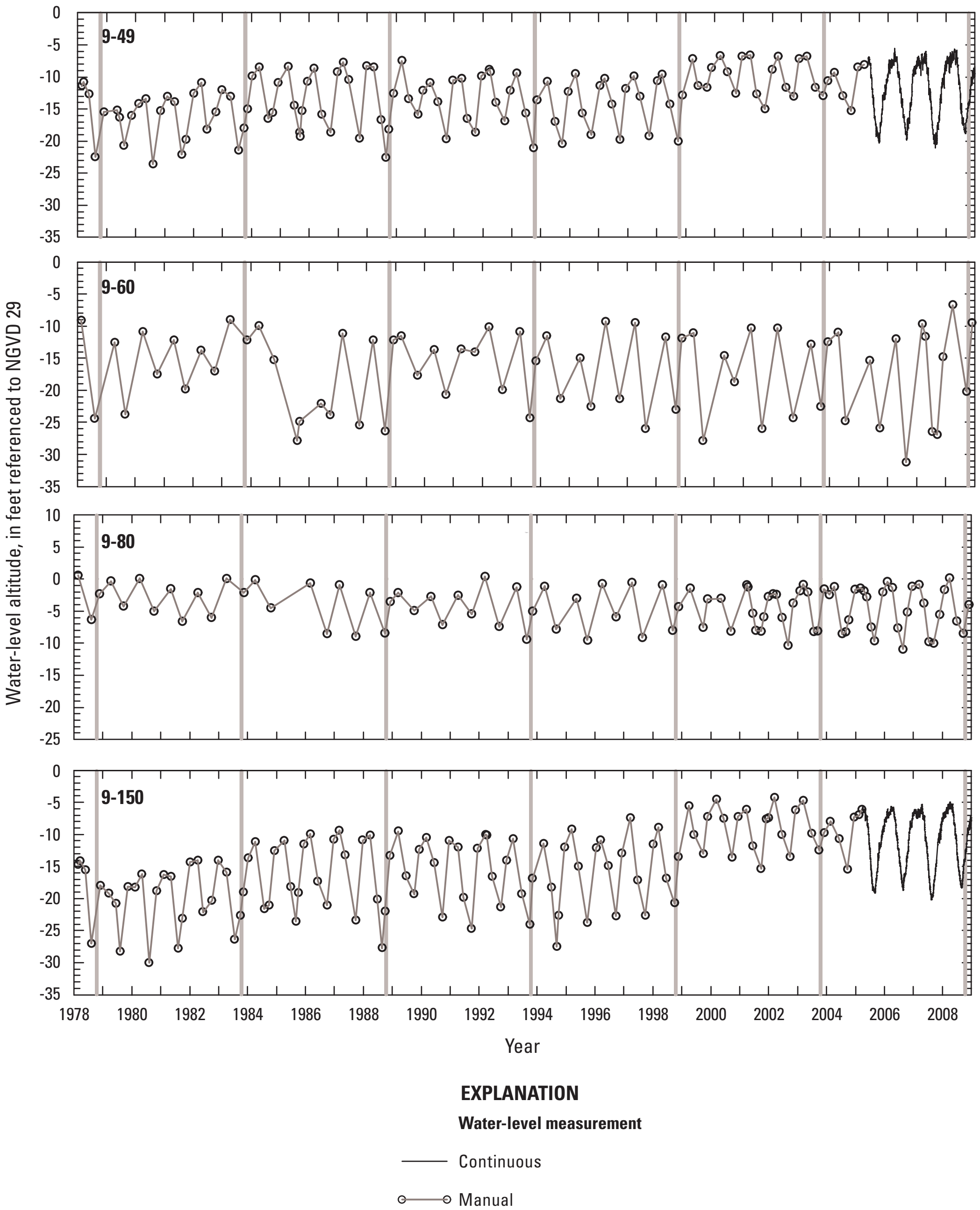


Figure 5. Water-level hydrographs for selected observation wells screened in the confined Cohansey aquifer, Cape May County, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 1-1)

Rio Grande Water-Bearing Zone

The Rio Grande water-bearing zone, as described by Zapecza (1989), is a relatively thin unit composed of coarse- to fine-grained sand situated midway within the confining unit that overlies the Atlantic City 800-foot sand. The updip extent of the Rio Grande water-bearing zone approximately coincides with that of the Atlantic City 800-foot sand, though it is slightly eastward, extending from southern Ocean County through eastern Cumberland County (fig. 1-2 on pl. 1). The Rio Grande water-bearing zone is laterally continuous from Cape May to the southern Ocean County mainland and barrier island beaches; however, the formation pinches out in Egg Harbor Township, Atlantic County, and is generally not recognizable farther updip in this area (Sugarman and Miller, 1997; Zapecza, U.S. Geological Survey, written commun., 2011). The water-bearing zone is approximately 40 ft thick throughout its extent in coastal Ocean and Atlantic Counties (Zapecza, 1989) but thickens considerably in southeastern Cape May where, near Stone Harbor, it is as great as 170 ft thick (Lacombe and Carleton, 2002). Although water levels differ from those in the underlying Atlantic City 800-foot sand, demonstrating substantial hydraulic separation between the aquifers, Lacombe (U.S. Geological Survey, written commun., 2011) showed that geophysical and driller's logs collected at the WWU Rio Grande well field were not definitive regarding the depth and thickness of the confining unit separating the Rio Grande water-bearing zone from the Atlantic City 800-foot sand, resulting in two wells intended for the lower part of the Rio Grande water-bearing zone being installed instead in the upper part of the Atlantic City 800-foot sand.

Fresh groundwater is present within the aquifer underlying coastal regions of the mainland and the barrier islands from its northwestern limit in southern Ocean County southward through most of mainland Cape May County. The aquifer contains saline water south of the canal in southern Cape May County and likely beneath the back bays, barrier islands, and near shore areas along the Atlantic Coast from Avalon to the city of Cape May. Limited available water-quality data provide no evidence of increasing chloride concentrations through 2008. The location of the 10,000-mg/L isochlor has not been determined for this aquifer but may be near the location of the 10,000-mg/L isochlor in the underlying Atlantic City 800-foot sand.

Water Withdrawals

The Rio Grande water-bearing zone is of minor importance as a source of potable water in New Jersey and is the least utilized of the aquifers included in this study (table 3). Withdrawals from the aquifer totaled approximately 225 million gallons (0.6 Mgal/d) during 2008. Withdrawals are made primarily by water purveyors in Long Beach and Little Egg Harbor Townships in southern Ocean County and in Middle Township in Cape May County (fig. 6*A*). Several smaller-capacity production wells withdraw water from the aquifer, although the amounts are not thought to be substantial; these wells are located in parts of northern Cape May and eastern Cumberland Counties. Average withdrawals from 1978 to 2008 were less than 1 Mgal/d (fig. 7*A*). Withdrawal amounts were apportioned equally between Ocean and Cape May Counties from 1978 to 1988 (approximately 0.3 to 0.4 Mgal/d); thereafter, withdrawals generally were greater in Cape May County.

Water Levels

Groundwater-level data used in preparing the 2008 potentiometric surface for the Rio Grande water-bearing zone are presented in appendix 1-2. The groundwater surface configuration is an elongated cone of depression centered beneath coastal New Jersey extending from the Cape May peninsula northward to Ship Bottom in southern Ocean County (fig. 1-2 on pl. 1). Water levels within the Rio Grande water-bearing zone ranged from a low of -27 ft (well 9-67) in southern Cape May to a maximum of 16 ft (well 9-149) in northwestern Cape May County. As noted by Lacombe and Rosman (2001), the configuration of the regional cone of depression is consistent with the configuration of, and sustained head decline of the cone of depression in, the underlying Atlantic City 800-foot sand, and low water levels observed in downdip parts of the Rio Grande water-bearing zone probably result from downward flow to the Atlantic City 800-foot sand. Locally, withdrawals from the Rio Grande water-bearing zone at the Rio Grande well field in southern Cape May contribute to the low water levels in this vicinity. Water levels at the Rio Grande well field rose by as much as 9 ft relative to 2003 levels as a result of reductions in groundwater withdrawals that began in 2006. In contrast, the water level in well 9-526, 2.2 mi to the west, was 8 ft lower than in 2003 despite the absence of withdrawals from the aquifer (fig. 8*A*). Elsewhere, most water levels measured in the Rio Grande water-bearing zone showed small to moderate declines from 2003 (fig. 8*A*), although withdrawal data indicate little change during the same period. Despite the absence of wells and data, groundwater levels most likely declined throughout eastern and coastal Atlantic County in response to declines in the underlying Atlantic City 800-foot sand. Water-level altitudes in the Rio Grande water-bearing zone were greater than those in the Atlantic City 800-foot sand throughout the study area; vertical differences increased where heads were most depressed in the underlying aquifer in central and eastern Atlantic County and, to a lesser extent, in southern Cape May County. An upward vertical gradient from the Atlantic City 800-foot sand to the Rio Grande water-bearing zone previously observed at the Rio Grande well field reversed and as of 2008 is downward.

Hydrographs for two observation wells located in Cape May County are shown in figure 9. Water-level data were collected intermittently at these two wells, and distinct long-term

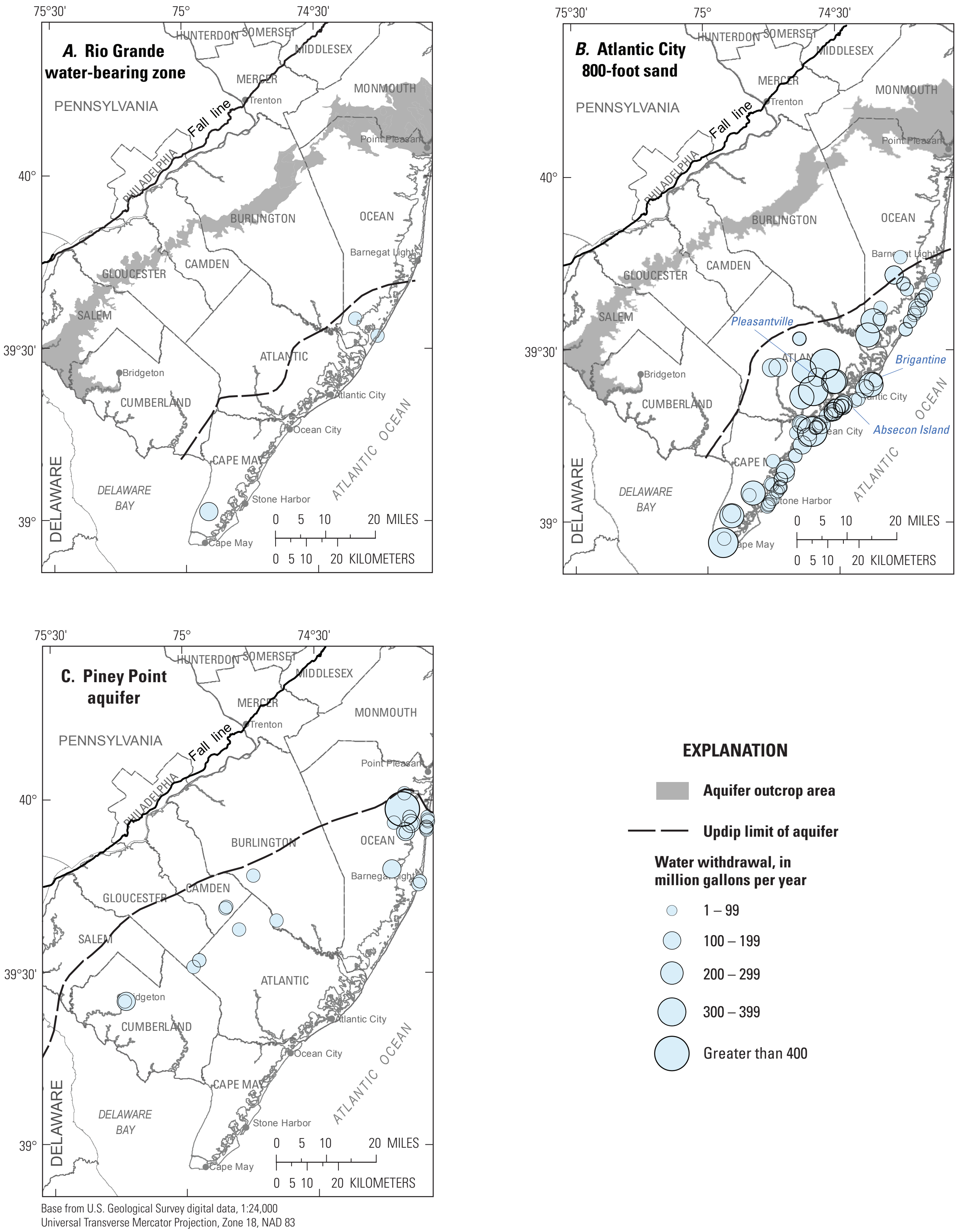


Figure 6. Location and volume of groundwater withdrawals from *A*, the Rio Grande water-bearing zone, *B*, the Atlantic City 800-foot sand, and *C*, the Piney Point aquifer, New Jersey Coastal Plain, 2008.

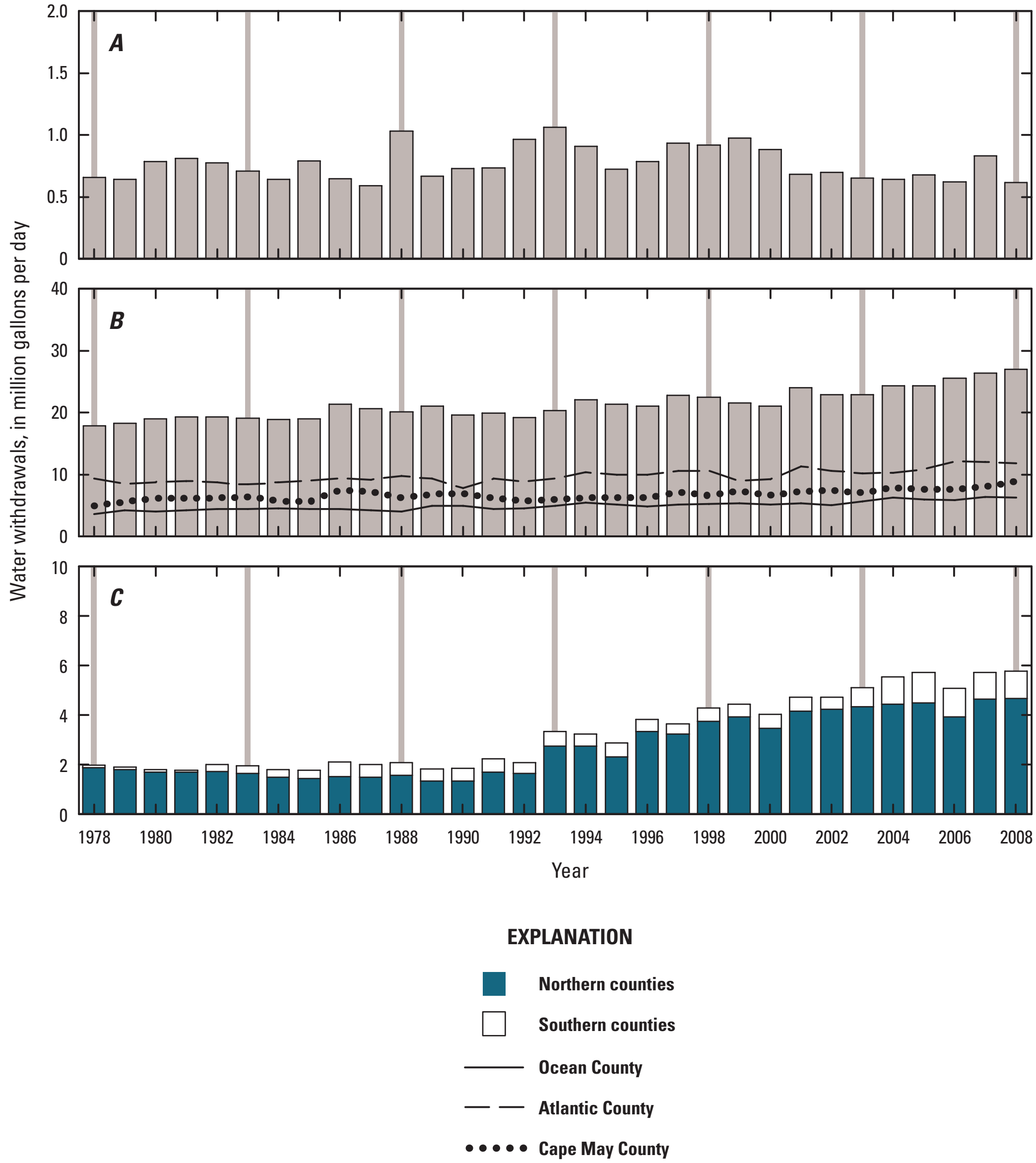


Figure 7. Estimated groundwater withdrawals from *A*, the Rio Grande water-bearing zone, *B*, the Atlantic City 800-foot sand, and *C*, the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008. [Thin vertical bars denote 5-yr data collection periods; note different vertical scaling]

trends are difficult to evaluate. Seasonal fluctuations in water levels are evident at both wells during the early 1990s but are more pronounced in well 9-71 because of its location among production wells at the Rio Grande well field. Data were collected more frequently at well 9-304 than at well 9-71. From 2003 to 2008, the change in the water level in well 9-304 was negligible, but for the period of record, a decline a nearly 7 ft was observed.

Results of the Wilcoxon signed-rank test indicate no significant change in paired samples from 2003 to 2008 (app. 10-2). Water levels increased in 2 wells (17 percent), were unchanged in 1 well (8 percent), and decreased in 9 wells (75 percent). One Rio Grande water-bearing zone well had sufficient data for the Mann-Kendall trend test (app. 10-1). Water levels from 2003 to 2008 did not significantly change; from 1998 through 2008, however, there was a statistically significant downward trend, although the annual rate of decline of 0.12 ft/yr was considered insubstantial. Additional wells within the aquifer need to be identified and data collected in order for substantive interpretations to be made.

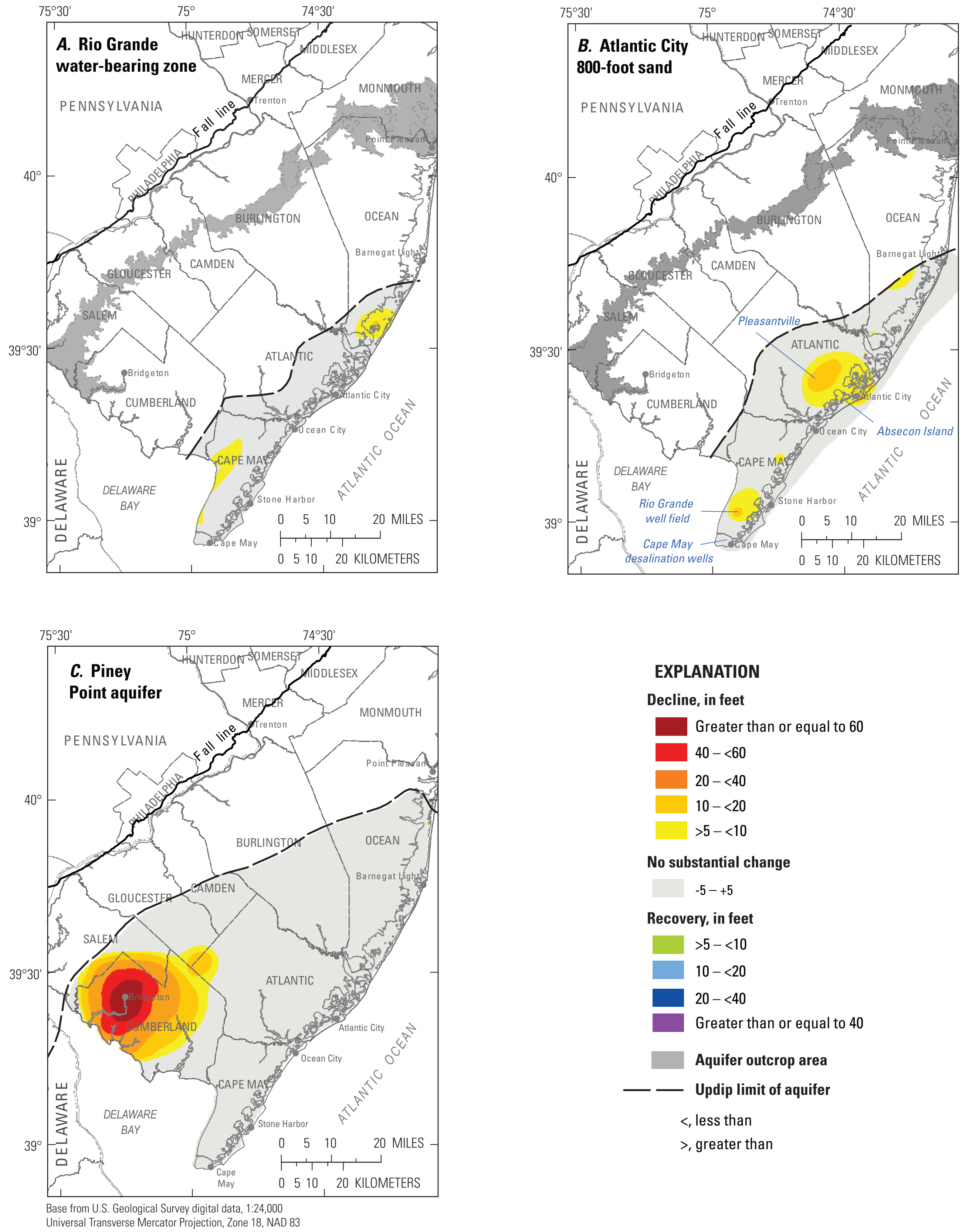


Figure 8. Groundwater-level changes in *A*, the Rio Grande water-bearing zone, *B*, the Atlantic City 800-foot sand, and *C*, the Piney Point aquifer, New Jersey Coastal Plain, 2003–8.

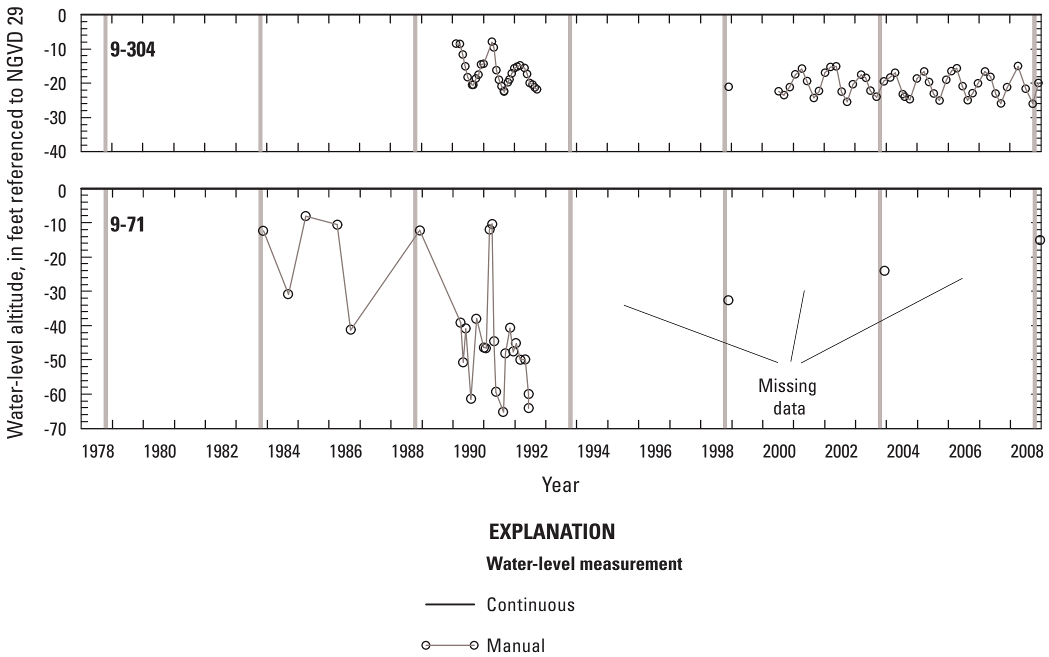


Figure 9. Water-level hydrographs for selected observation wells screened in the Rio Grande water-bearing zone, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 1-2)

Atlantic City 800-Foot Sand

The Atlantic City 800-foot sand, originally named for the depth of production wells in the Atlantic City area, is a major confined aquifer within the Kirkwood Formation. The aquifer is composed of medium- to coarse-grained quartz sands with interspersed shell material. The updip limit of the aquifer is based on the updip limit of the overlying confining unit; however, this confining unit is poorly defined in places. The updip boundary extends, from northeast to southwest, from southern Ocean County 1.7 mi north of Barnegat Light to eastern Cumberland County (pl. 2). The downdip limit of the aquifer is offshore from Ocean, Atlantic, and Cape May Counties. The aquifer thickens downdip and southward from a thickness of 40 ft near Barnegat Light to more than 200 ft at Cape May City (McAuley and others, 2001). Recharge is through vertical flow from the overlying Kirkwood-Cohansey aquifer throughout the extent of the aquifer, although recharge is more substantial near the updip limit where the confining unit is leaky or where the aquifers are in direct contact (Pope, 2006). Recharge also occurs via lateral flow from the Kirkwood-Cohansey aquifer near the updip boundary.

The Atlantic City 800-foot sand contains freshwater throughout southern Ocean, Atlantic, and northern Cape May Counties where dissolved chloride concentrations typically range from 2 to 20 mg/L. Proceeding south from Avalon, however, the groundwater becomes progressively more chloride-rich, and near the southern tip of the Cape May Peninsula, concentrations range from 400 mg/L to more than 1,500 mg/L. The estimated position of the 250-mg/L isochlor is approximately 4 mi to the south-southeast of production wells at Stone Harbor. Concentrations of chloride in groundwater from observation well 9-337, located between the saltwater front and the Stone Harbor pumping center have not increased. At the Stone Harbor production wells nearest the front, chloride concentrations have remained largely constant over time. From the mid-1960s through 2008, concentrations generally ranged from 30 to 40 mg/L, only occasionally exceeded these values, and subsequently returned to antecedent levels. Recently reported chloride concentrations were as high as 87 mg/L, as low as 26 mg/L, and fluctuated with pumping. The highest concentrations typically occurred during the late summer or early fall. Concentrations decreased during the winter and spring. Moreover, recent flow simulations indicate that the 250-mg/L isochlor will not intersect production wells at Stone Harbor for at least 720 years under various water-allocation scenarios (Pope, 2006). Farther to the north and offshore of Atlantic County, the saltwater front is estimated to be about 9.6 and 8 mi to the southeast of production wells in Ventnor and Brigantine, respectively. Dissolved chloride in samples from production wells at Brigantine remained at concentrations consistently below 8 mg/L for the period of record through 2008. Similarly, data from production wells at Ventnor showed little or no sustained increase in dissolved chloride concentrations through 2008; for the period 1998 to 2008, reported values only infrequently exceeded 10 mg/L and were typically below this value. Farther to the south, the estimated saltwater front bisects the southern part of the Cape May peninsula, trending approximately east-west from Wildwood to the south of Villas. South of this line, chloride concentrations in groundwater at or near pumping centers increased modestly from 1998 to 2008; concentrations at wells 9-508 and 9-302, although elevated, have remained stable. The estimated location of the 10,000-mg/L isochlor is approximately 36 mi offshore and to the southeast of Atlantic City.

Water Withdrawals

The Atlantic City 800-foot sand is the principal confined aquifer supplying water to New Jersey's barrier island communities from Harvey Cedars in southern Ocean County to Cape May City and as far inland as Mays Landing and Egg Harbor City in Atlantic County. Withdrawals from the aquifer ranged from 17.9 to 27 Mgal/d during 1978 to 2008 (fig. 7*B*). Withdrawals have gradually increased since 1978; from any given year to the next increases ranged from 2 to 14 percent, with intervening periods of reduction of generally a few percent or less. Increases of 5 percent or more from the previous year occurred in 1986, 1993 to 1994, 1997, 2001, and 2004. Withdrawals in 2008 averaged nearly 27 Mgal/d, the greatest of the 30-year period from 1978 to 2008. Withdrawal amounts were greatest in Atlantic County and least in Ocean County, where the aquifer thins and becomes less transmissive. From 1978 to 2008, average withdrawals in Atlantic County ranged from 7.8 to 12.0 Mgal/d, gradually increasing throughout the 30-year period; nearly 60 percent of withdrawals occurred along the barrier islands. Three major pumping centers are within Atlantic County: Absecon Island, Brigantine, and Pleasantville (fig. 6*B*). The Pleasantville pumping center is composed of well fields of the Atlantic City Municipal Utility Authority and New Jersey American Water Company-Atlantic and includes several supply wells in eastern Hamilton Township. During 2008, average daily withdrawals from Pleasantville of 5.9 Mgal were greatest among the three pumping centers. Withdrawals ranged from a low of 2 Mgal/d in 1985 to the highs in 2008. Increases of more than 20 percent from a given year to the next occurred in 1996, 2001, and 2005–6. The Absecon Island pumping center, which includes Atlantic City, Margate, Ventnor, and Longport, historically accounted for a greater percentage of withdrawals than the other pumping centers. During the 1980s, withdrawals from Absecon Island center were equal to the combined withdrawals from the other two centers. In 2005 withdrawals at the Pleasantville and Absecon Island centers were nearly equal, and while withdrawals at the former have since increased, those at the latter decreased. Withdrawals at the Absecon Island pumping center were relatively constant from 1980 to 2006; average withdrawals generally fluctuated between 4 and 5 Mgal/d, until reductions during 2007–8. At Brigantine, average withdrawals in 2008 were 1.8 Mgal/d. Withdrawals increased from 1.5 to 2 Mgal/d during 1980–86; thereafter, combined withdrawals from all wells were approximately 2 Mgal/d.

In Cape May County, most of the groundwater withdrawals were distributed throughout the barrier islands, although substantial withdrawals were also made near Cape May Court House and near Cape May City at the southern end of the peninsula (fig. 6*B*). From 1978 to 2008, average withdrawals ranged from 5.0 to 8.9 Mgal/d. Withdrawals decreased during 1986–92 from 7.5 Mgal/d to less than 6 Mgal/d; however, during 1992–2003 withdrawals increased by more than 20 percent. In early 1998, a desalination plant in lower Cape May County began operation to augment existing groundwater supply, and by 2003, associated withdrawals from the aquifer were approximately 1 Mgal/d. During 2003–8, withdrawals throughout the county further increased by 25 percent. In 2008, withdrawals of 8.7 Mgal/d represented the greatest total during 1978–2008.

In southern Ocean County, withdrawals from the aquifer were made over nearly the entire length of the barrier island complex; the largest volumes were withdrawn within the mainland communities of Stafford and Little Egg Harbor Townships. Average withdrawals in Ocean County during 2008 were 6.2 Mgal/d, a 9 percent increase from 2003 volumes.

Water Levels

The 2008 potentiometric surface of the Atlantic City 800-foot sand is shown on plate 2; groundwater-level measurements used in the preparation of this map are presented in appendix 2. Long-term groundwater withdrawals have created a large, elongated cone of depression that aligns along the general strike of the Kirkwood Formation and extends beneath the coastal barrier island communities from Barnegat Light in Ocean County south to Cape May City. Water levels within the Atlantic City 800-foot sand range in altitude from greater than 40 ft near the updip boundary in central Atlantic County to more than 90 ft below NGVD 29 within the deepest part of the cone, beneath the eastern Atlantic County municipalities of Atlantic City, Margate, and Ventnor. At the northern end of the cone of depression, south of Barnegat Light, water levels ranged from -29 ft near the northern limit of the confined aquifer to -35 ft (well 29-9) near the southern end of Long Beach Island. Southwest from the center of the regional cone, water levels were progressively higher toward the southern end of the Cape May peninsula, where the highest water level measured in coastal Cape May County was -24 ft. Two small cones of depression are present in southern Cape May County at the Cape May City (wells 9-479 and 9-480) and WWU well fields.

Groundwater levels measured in 72 wells in 2003 and 2008 were compared to evaluate water-level changes in the Atlantic City 800-foot sand and to map the potentiometric differences (fig. 8*B*). In 2008, water levels declined in 64 wells (89 percent), were unchanged in 4 wells (5.5 percent), and rose in 4 wells (5.5 percent). Owing to the substantial increase in withdrawals at the Pleasantville pumping center, groundwater decline was greatest in Atlantic County in an area near the center of the cone of depression, extending throughout the mainland communities of Egg Harbor Township and the city of Pleasantville to the barrier island communities of Brigantine, Atlantic City, and Ventnor. From 2003 to 2008 throughout eastern Atlantic County, groundwater-level declines were typically about 9 ft but as great as 16 ft. To the north and east, small to moderate declines were observed throughout much of southern Ocean County, were greatest at and near mainland pumping centers, and were smallest along the barrier island. In Cape May County, groundwater-level declines were greatest in the vicinity of the Rio Grande well field. Because not all wells measured in 2008 were available during the 2003 study, water-level data were compared to estimates derived from the 2003 potentiometric surface at those locations, resulting in apparent declines of nearly 25 ft at the Rio Grande well field. These values may overestimate the 5-year decline, whereas the measured change of -7 ft at an observation well 1 mile (mi) to the east probably underestimates the overall decline in the vicinity of the well field (fig. 8*B*). In the vicinity of the Cape May City desalination wells, interspersed but modest declines and rises relative to 2003 were observed.

Results of the Wilcoxon signed-rank test indicate statistically significant differences (declines) in paired measurements during both the 5- and 10-year periods across the aquifer. Given recently (2003–8) declining water levels throughout Atlantic County, this relationship was strongest during the 5-year period. Differences (declines) are considered statistically significant among paired measurements throughout the counties of Atlantic, Ocean, and Cape May for the 5-year period, and in Atlantic and Cape May Counties for the 10-year period (appendix 10-2, fig. 8*B*).

Results of the Mann-Kendall statistical trend test are listed in appendix 10-1. Supporting hydrographs for seven observation wells that depict long-term and seasonal trends in the Atlantic City 800-foot sand from 1978 to 2008 are shown in figure 10**.** Water-level trends during 2003–8 were downward at six wells; data from the seventh well (1-37) were insufficient for testing. Downward trends were strongest at wells in eastern Atlantic County at and near the center of the cone of depression (wells 1-180, 1-578, and 1-702) and weakest on the western side of the Cape May peninsula (well 9-306). From 1998 to 2008, trends were downward at four wells (1-578, 9-302, 9-306, and 9-337) and insignificant at the remaining three wells (1-37, 1-180, and 1-702). For the 30-year period, significant downward trends were observed at all seven wells. Trend tests for each were run for the periods of record, and trends were downward with rates of decline ranging from 0.5 to 1 ft/yr.

Photograph was provided by U.S. Geological Survey field personnel

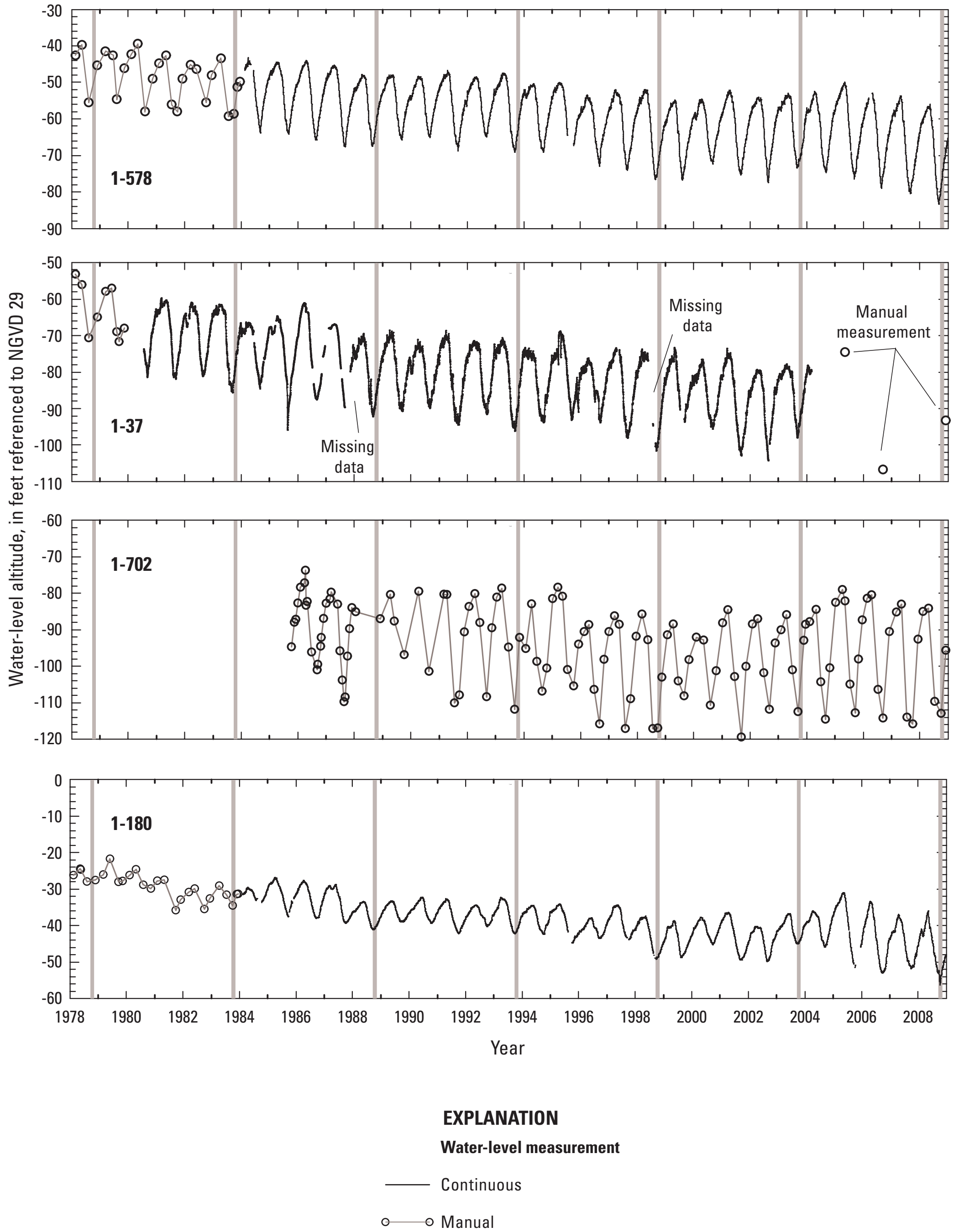


Figure 10. Water-level hydrographs for selected observation wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 2)

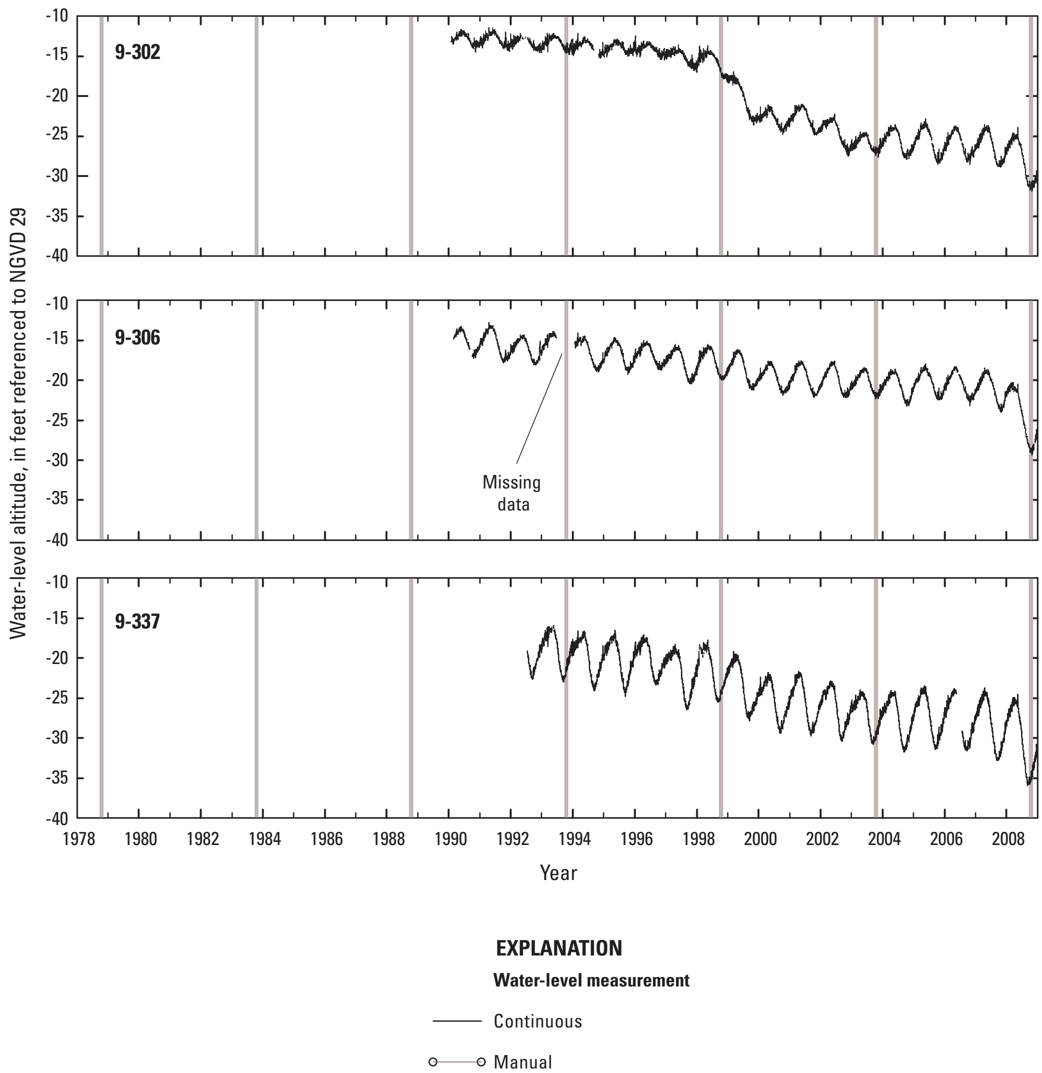


Figure 10. Water-level hydrographs for selected observation wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 2)—Continued

Piney Point Aquifer

The Piney Point aquifer, of middle to late Eocene age, is composed of fine- to coarse-grained glauconitic sands interspersed with shell material. The Piney Point aquifer does not crop out within the study area and, therefore, cannot be recharged directly by precipitation; recharge occurs by leakage through confining layers, primarily from the overlying aquifer. The updip limit of the aquifer is in central Ocean, Burlington, Camden, Gloucester, and Salem Counties and approximately near the downdip limit of the Vincentown aquifer. Near this updip limit, the aquifer is generally 40 ft thick. There are two areas within the aquifer extent in New Jersey of substantial sand accumulation (Zapecza, 1989)—southern Burlington and Ocean Counties where thicknesses can exceed 130 ft and, to the southwest, in southern Cumberland County where maximum thicknesses are greater than 200 ft. In the former, a greater percentage of coarse-grained materials readily permits the transmission of water and is favorable to development, and in the latter, thin clay beds and clay-silt in the aquifer matrix limit productivity (Sugarman and others, 2005). In Delaware, the Piney Point aquifer is composed of two geologic units, the Piney Point Formation and the basal sand of the Calvert Formation, that together function as a single hydrologic unit (McLaughlin and Velez, 2006). The Piney Point aquifer in Delaware is predominantly an upward coarsening, shelly quartz sand containing glauconite that grades to a muddier facies north and west of the city of Dover. The updip limit of the aquifer is in central Kent County, and the downdip limit extends into southeastern Sussex County (Vroblesky and Fleck, 1991). The maximum thickness of the aquifer in Delaware, approximately 250 ft, occurs near the city of Dover.

Groundwater in the Piney Point aquifer is typically a calcium-sodium or sodium-bicarbonate type water that evolves to a sodium-chloride type water in downdip areas. Owing to recharge via vertical flow through the upper confining unit, ion-exchange reactions are likely important determinants of the water chemistry of the aquifer, as evidenced by the enrichment of sodium and potassium relative to chloride (Lettini and others, 2003). Sodium to chloride molar ratios range from 1.8:1 to more than 100:1 with highest ratios present in updip sections and beneath the barrier island complex of central Ocean County, indicative of the greater capacity for cation-exchange within the aquifer in these areas. In many areas of the aquifer, sodium concentrations exceeded the NJDEP secondary maximum contaminant level of 50 mg/L. Chloride concentrations in groundwater ranged from 2 to 10 mg/L throughout much of Ocean and central Burlington Counties but increased to the south and seaward where concentrations exceeded 300 mg/L in groundwater in coastal Atlantic County. In southern and southwestern New Jersey, concentrations ranged from 1 to 200 mg/L and increased with decreasing distance to the Delaware Bay. Historical data indicate possible saltwater intrusion into wells at bay front communities in southern Cumberland County; owing to the lack of supporting chemical data, it is unclear whether increases in chloride concentrations resulted from lateral intrusion from the Delaware Bay or from vertical leakage from the overlying aquifer via compromised annular well seals. Further, recent (2008) water-quality data for the aquifer in this area were not available.

For this study, the location of the 250-mg/L isochlor in New Jersey was modified from Schaefer (1983) and Lacombe and Rosman (2001); in Delaware, the location was mapped by Woodruff (1969) and modified by Lacombe and Rosman (2001). The location of the onshore part of the line extends from eastern Atlantic County southwest to northern Cape May County. To the north, the position of this line was estimated by Lacombe and Rosman (2001) to be 12 mi downdip from production wells at Barnegat Light; however, neither observed nor simulated data were available to substantiate this estimate. The simulated 10,000-mg/L isochlor is located offshore, approximately 8 mi from production wells at Barnegat Light (Pope and Gordon, 1999). Measured chloride concentrations in production wells at Barnegat Light ranged from 5 to 15 mg/L but were typically 10 mg/L or less; sustained increases have not occurred during 1998–2008. Similarly, chloride concentrations in groundwater from observation wells near the saltwater front have not increased substantially, and the extent of freshwater remains similar to that in 2003. In Delaware, the position of the front is approximately 10 mi downdip from the major pumping center at Dover.

Water Withdrawals

In New Jersey, groundwater withdrawals from the Piney Point aquifer were made predominantly in the coastal region of Ocean County, particularly in the central Barnegat Bay region, in Buena Borough in western Atlantic County, and in and around the city of Bridgeton in southern Cumberland County where water-quality issues in the overlying Kirkwood-Cohansey aquifer have spurred recent development of the Piney Point aquifer (fig. 6*C*). Withdrawals from the Piney Point aquifer also are made in the updip parts of the aquifer in southeastern Burlington and Camden Counties in locations where yields are favorable to development. In Delaware, the Piney Point aquifer is a major source of groundwater in Kent County and has long been utilized for supply in and around the city of Dover.

Average withdrawals in New Jersey from the Piney Point aquifer ranged from less than 2 to 5.8 Mgal/d during 1978–2008 (fig. 7*C*). Withdrawals from the Piney Point aquifer were relatively minor from 1978 to 1992 at 2 Mgal/d with most withdrawals in Ocean County and negligible amounts in Atlantic and Cumberland Counties. Withdrawals increased by more than 50 percent from 1992 to 1993, largely owing to increasing development in the Toms River area. From 1993 to 2002, development of the aquifer in Ocean County continued to expand, and by 2003 withdrawals there accounted for 90 percent (4.3 Mgal/d) of all withdrawals from the Piney Point aquifer within New Jersey. Combined withdrawals in Atlantic, Burlington, Camden, and Cumberland Counties ranged from 0.1 to 0.6 Mgal/d from 1978 through 2002, followed by increases of 56 and 41 percent in 2003 and 2004, respectively, as withdrawals in the Bridgeton area began.

Water Levels

The potentiometric surface of the Piney Point aquifer during late fall 2008 in New Jersey and Delaware is shown on plate 3; the groundwater-level data that were used in the analysis are listed in appendix 3. The maximum groundwater altitude within the Piney Point aquifer (118 ft in well 29-425) occurred near the up-dip extent along the border of Burlington and Ocean Counties, and the minimum (less than -150 ft, various wells) occurred in south-central Cumberland County, New Jersey. The configuration of the 2008 potentiometric surface indicates the presence of six distinct cones of depression. The northernmost cone underlies Seaside Park in Ocean County near the area where the aquifer is most heavily utilized in New Jersey; the minimum water level at the center of this cone of depression was -45 ft (well 29-1681). To the south, the cone of depression centered beneath Barnegat Light had a potentiometric minimum of -39 ft (well 29-607).

A cone of depression in coastal Atlantic County is consistent with sustained head decline in the overlying Atlantic City 800-foot sand. The Piney Point aquifer is unused in this area, and the presence of this cone indicates upward leakage in response to lower water levels in the overlying aquifer. Above the Atlantic City 800-foot sand, a cone of depression in the infrequently used Rio Grande water-bearing zone also is an indicator of hydraulic stress propagating through the hydrogeologic section in this area. The 2008 water level at the center of this cone (-38 ft, well 1-834) was approximately 4 ft lower than that observed during the previous study. Water levels in the overlying Atlantic City 800-foot sand declined as much as 16 ft in this area from the previous study.

Development of the aquifer in Bridgeton, Cumberland County, after 2003 caused a deep and regionally extensive cone of depression to form within an area already characterized by persistent potentiometric lows and long-term gradual declines in water levels as a result of withdrawals at Dover, Delaware. Yields within the Piney Point aquifer vary at different locations because of variations in hydraulic conductivity that result from facies changes within the Piney Point Formation. The depth and extent of this cone are greater than expected given the relatively small amounts of groundwater withdrawn. Measured water level altitudes at the pumping center in Bridgeton ranged from -154 to -157 ft; a subsequent review of purveyor-collected data reported throughout 2009 confirmed these observations (NJDEP, 2012). With the introduction of the supply wells in Bridgeton and the deepening of the cone of depression, the hydraulic gradient was somewhat reversed, forming a groundwater divide within the aquifer beneath the Delaware Bay. Groundwater that previously flowed beneath the bay from New Jersey toward pumping centers in Dover is now partially captured by production wells at Bridgeton.

In Delaware, a cone of depression, with a minimum water-level altitude of -138 ft (well Jd14-15) persists in and around the city of Dover. This cone is the most regionally extensive within the Piney Point aquifer in the study area. Substantial long-term withdrawals in Dover placed significant hydraulic stress on the aquifer with the breadth of effects extending throughout a large area beneath the Delaware Bay and into southern New Jersey. Until 2004, the long-term withdrawals were the primary cause of declining water levels in the Piney Point aquifer in Cumberland County. The potentiometric surface shows a slight deepening and apparent movement of the center of the cone to the north; this change is probably a result of spatial shifts in the withdrawal patterns or the configuration of the water levels relative to those of previous studies.

In updip areas of the aquifer, vertical head differences between the overlying Kirkwood- Cohansey aquifer and the Piney Point aquifer were greatest in Camden, Gloucester, Cumberland, and western Atlantic Counties, and flow is downward, recharging the aquifer. A downward vertical gradient to the Piney Point aquifer persists throughout much of Ocean County; however, in southern Burlington County estimated heads were generally higher in the Piney Point aquifer, particularly in low-lying areas near the Batsto and Mullica Rivers, resulting in a strong upward vertical gradient that is demonstrated by the presence of flowing artesian wells. Vertical head differences between the Piney Point and the Wenonah-Mount Laurel aquifers indicate strong downward gradients and the potential for flow out of the Piney Point aquifer in central Burlington, Camden, and Gloucester Counties, particularly in areas where the underlying Wenonah-Mount Laurel aquifer is stressed, such as in Winslow and Monroe Townships (Williamstown quadrangle). Vertical water-level differences range from 60 to 80 ft in this area, and maximum differences may exceed 100 ft. In south-central Cumberland County, estimated vertical differences within the regional cone of depression exceed 150 ft both above and below the Piney Point aquifer; thus there is the potential for induced flow from both the underlying and overlying units into the Piney Point aquifer.

In the northern extent of the aquifer, vertical differences between the Piney Point and Wenonah-Mount Laurel aquifers diminish in the downdip direction, and the potential for a downward gradient lessens. At the northernmost cone of depression in the Piney Point aquifer in Ocean County, the vertical gradient reverses, and flow is upward into the Piney Point aquifer. At Barnegat Light and immediately to the south, a potential downward vertical gradient into the Piney Point aquifer from the transitional area of the Kirkwood-Cohansey aquifer system and the Atlantic City 800-foot sand is present. From Harvey Cedars and proceeding down the coast, the gradient reverses and strengthens. Near Atlantic City, vertical head differences are as great as 60 ft, and flow is upward from the Piney Point aquifer into the overlying Atlantic City 800-foot sand. This potential upward gradient weakens south and to the west; however, vertical head differences between the two units remain substantial throughout Cape May County (where Piney Point aquifer water levels are believed to be higher than -20 ft and Atlantic City 800-foot sand water levels are known to be generally lower than -20 ft and as low as -60 ft).

Of the confined aquifers included in this study, groundwater levels in the Piney Point aquifer changed more from 2003 to 2008 than water-levels in other units in terms of mean (-14 ft) and maximum (-136 ft) change. Although water levels were essentially unchanged or had recovered throughout much of the State (fig. 8*C*), declines exceeding 130 ft were observed in southern New Jersey. Of the 50 wells measured in both 2003 and 2008, groundwater levels declined in 38 (76 percent), remained about the same in 4 (8 percent), and rose in 8 (16 percent) wells. Stable groundwater levels to a slight recovery of groundwater levels were observed throughout southern Ocean, Burlington, and parts of northern Atlantic Counties. Moderate to large declines were most common at the cones of depression in western Atlantic and Cumberland Counties in New Jersey and Kent County in Delaware (fig. 8*C*). In Bridgeton, Cumberland County, moderate withdrawals created a deep cone of depression and caused groundwater levels to decline more than 130 ft at the center of the cone and from 25 to 60 ft through much of Cumberland County. In western Atlantic County, the cone of depression centered beneath the Borough of Buena widened and deepened as groundwater levels declined 17 ft relative to 2003 levels. Although withdrawals from borough wells increased during 2003–8, declining groundwater levels probably were, to some degree, affected by the expansion of the area with water levels below NGVD 29 throughout Cumberland County.

Moderate groundwater-level declines were observed in most wells in Kent County, Delaware. Near Dover, declines ranged from 9 ft to 17 ft with the largest declines occurring near the center of the cone of depression and the most temperate declines to the south and west.

Results of the Wilcoxon signed-rank test indicate significant differences in the paired water-level measurements throughout the dataset as a whole for both the 5-year and the decadal period. Given steeply declining groundwater levels in southern New Jersey during 2004–8, this relation was strongest for the 5-year period. Repeated measurements made at individual wells were not available in sufficient numbers to group and test by county, except for Ocean County, where no differences were detected during either period, indicating that statistical significance is attained on the basis of changes observed in wells in southern New Jersey.

Results of the Mann-Kendall statistical trend test are listed in appendix 10-1. Hydrographs for 13 observation wells that show long-term and seasonal trends for the Piney Point aquifer in New Jersey and Delaware are provided in figures 11 and 12. Downward trends during 2003–8 were observed at seven wells, most notably at wells in southern Cumberland County—11-44, 11-96 and 11-163—where annual rates of decline exceeded 9, 6, and 7 ft/yr, respectively. Slight downward trends were observed at wells 1-834, 5-407, 29-18, and 29-585 located in downdip areas of Atlantic, Burlington, and Ocean Counties, respectively. At two wells located in updip and mid-dip areas of Burlington and Ocean Counties (5-676 and 29-425), no significant upward or downward trend was observed. Results were similar for the 10- and 30-year periods; statistically significant downward trends were detected at observation wells in Atlantic and Cumberland Counties. No significant trend was detected at well ID55-01, located near Dover, Delaware, for the period 2003 to 2008; however, downward trends were observed for both the 10-year and 30-year periods.

Photograph was provided by U.S. Geological Survey field personnel

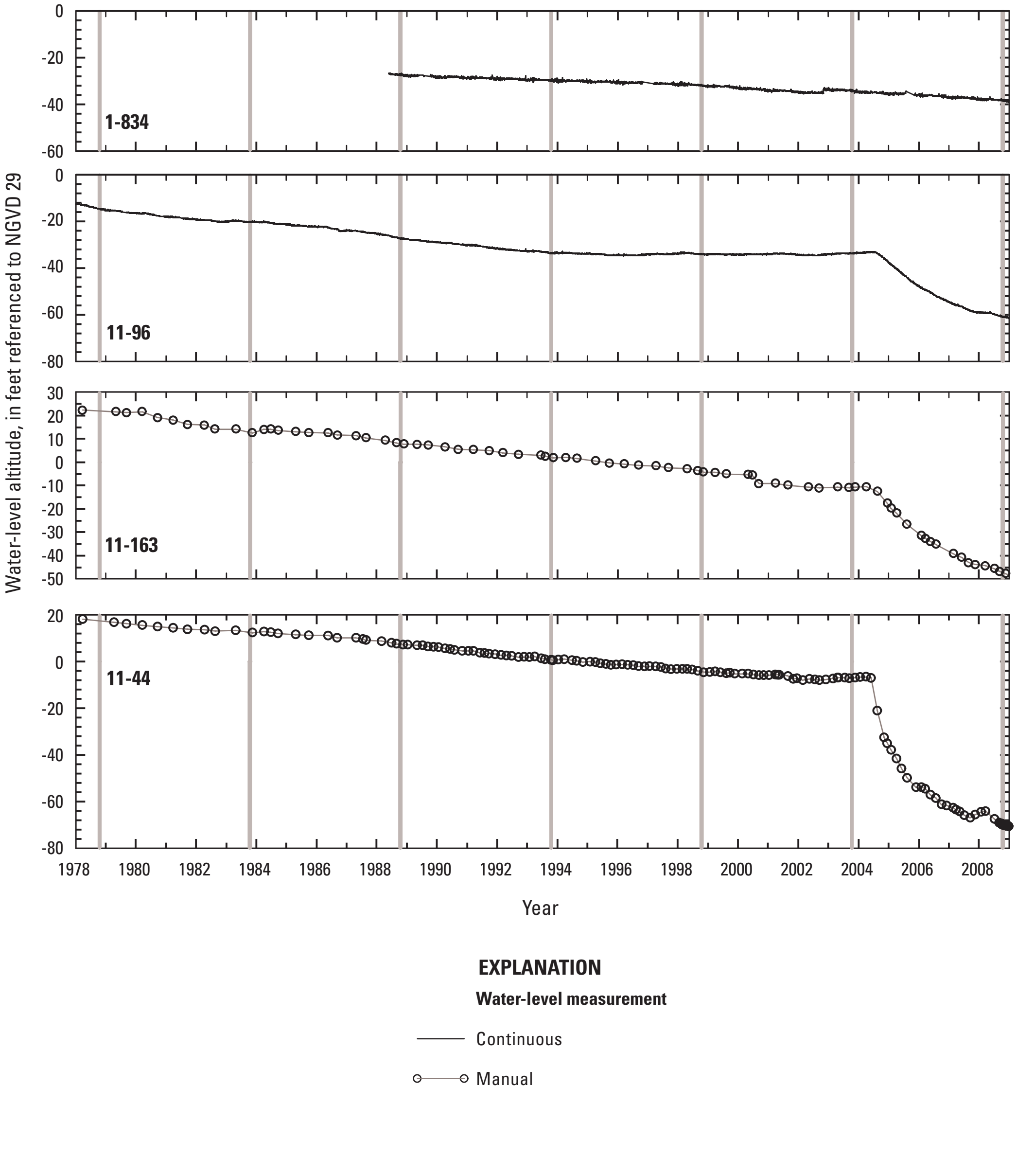


Figure 11. Water-level hydrographs for selected observation wells screened in the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 3)

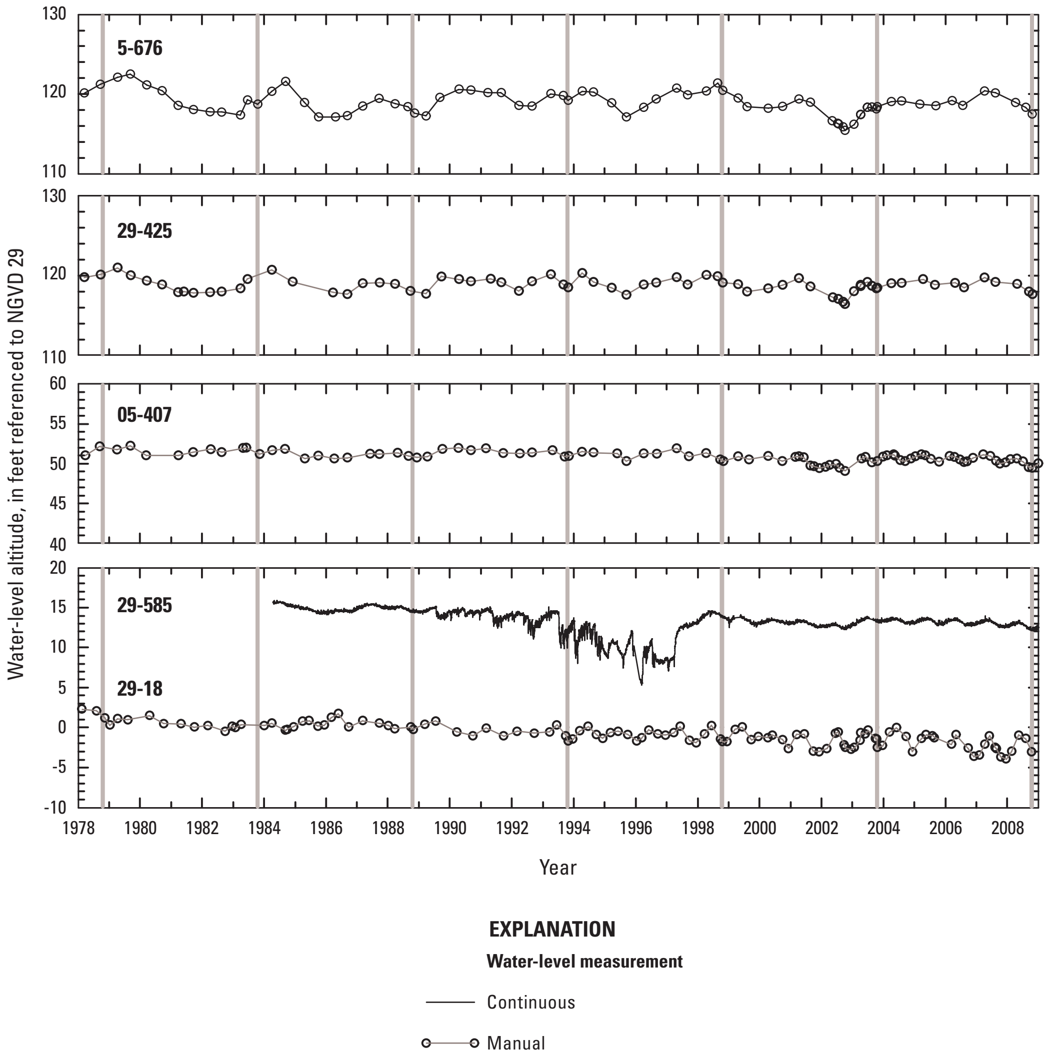


Figure 11. Water-level hydrographs for selected observation wells screened in the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 3)—Continued

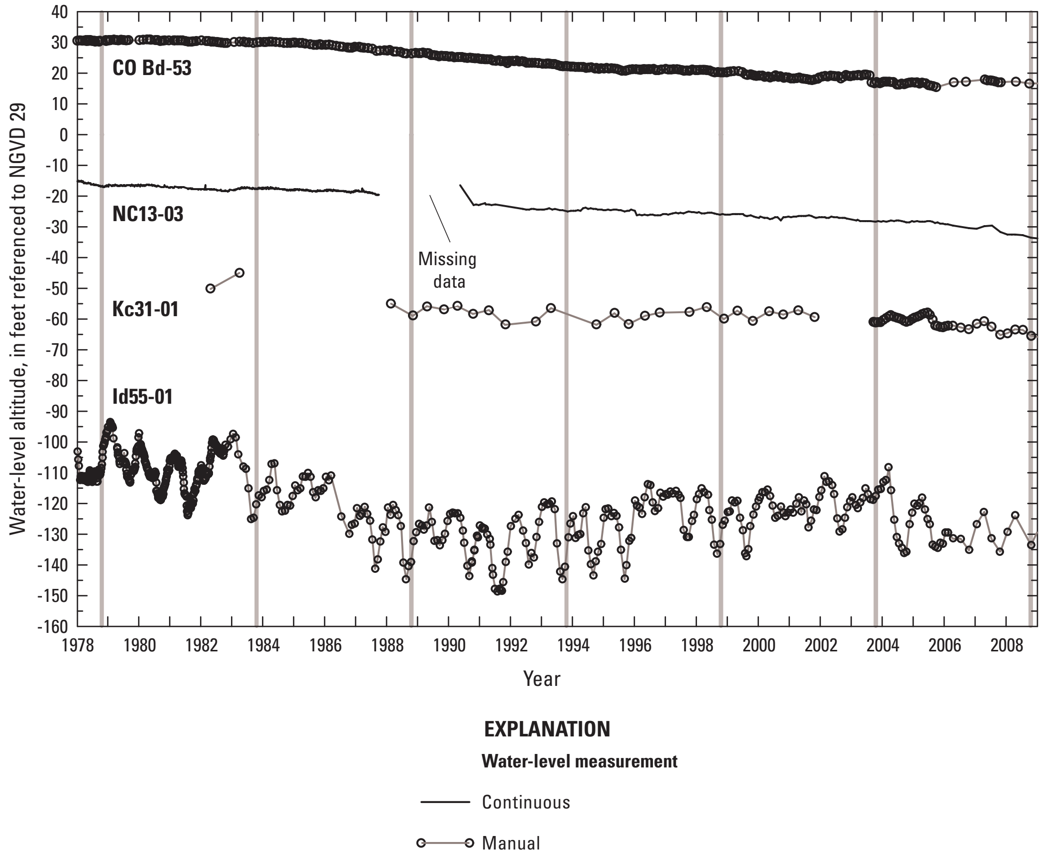


Figure 12. Water-level hydrographs for selected observation wells screened in the Piney Point aquifer, Delaware and eastern Maryland, 1978–2008. (Vertical bars denote 5-yr data collection cycles; well locations shown on pl. 3)

Vincentown Aquifer

The Vincentown aquifer is composed of the sandy parts of the Paleocene Vincentown Formation. Within the outcrop and from 8 mi to 10 mi downdip, the Vincentown Formation can yield quantities of groundwater capable of sustaining small production and domestic-supply wells; beyond this extent, it functions primarily as a confining unit (Zapecza, 1989). In the outcrop and the shallow subsurface, the formation is composed primarily of a massive quartzose sand containing abundant glauconite, mica, and shell material. The formation grades to silty sand then to silt downdip from the outcrop (Sugarman, 1992). The formation is thickest (more than 100 ft thick) in Monmouth County, the area where it is most often used for water supply. The aquifer is well defined in northern Ocean and southern Monmouth Counties but is less well defined in the rest of the Coastal Plain. Beyond Monmouth and Ocean Counties, the Vincentown Formation is silty and produces appreciable quantities of water only locally; the Vincentown Formation is not a significant source of water in any part of southwestern or south-central New Jersey.

The Vincentown aquifer is recharged by direct infiltration of rainfall on outcrop areas and in areas where the overlying confining unit is thin or absent. The aquifer also receives recharge from the lower part of the Kirkwood-Cohansey aquifer where the overlying confining unit is thin or leaky. The Vincentown aquifer contains freshwater throughout its confined extent. Chloride concentrations range from 1 to 20 mg/L throughout the northern counties; in southern counties, concentrations range from 1 to 25 mg/L. Locally, greater concentrations are present in groundwater within the outcrop, likely owing to anthropogenic sources such as road deicers, agricultural chemicals, and septic system effluent. Despite presumed hydraulic contact between the aquifer and the Atlantic Ocean and the aquifer and the lower Delaware River, no evidence of saltwater intrusion exists. Because of the low to moderate chloride concentrations in groundwater, the 250-mg/L isochlor was not determined for the Vincentown aquifer.

Water Withdrawals

Groundwater withdrawals from the Vincentown aquifer are most common in Monmouth County and parts of northern Ocean County. The aquifer in this area is used for public supply, but it also is an important source for domestic and irrigation supply (fig. 13*A*). Withdrawals for self supply and irrigation are made from the sandy parts of the aquifer in Salem and Burlington Counties and, to a lesser extent, in Gloucester and Camden Counties. Groundwater withdrawals from the Vincentown aquifer ranged from 0.8 to 1.5 Mgal/d from 1978 to 2008 (fig. 14*A*). From any given year to the next, withdrawals increased or were reduced by relatively large percentages, ranging from 5 to 44 percent. Average withdrawals during 2008 were 1.1 Mgal/d with more than 95 percent occurring throughout Ocean and Monmouth Counties. Production wells located in close proximity to the Metedeconk River, which forms the border between northern Ocean and southern Monmouth Counties, accounted for nearly 65 percent (0.7 Mgal/d) of total reported withdrawals from the aquifer.

Water Levels

The 2008 potentiometric surface map for the Vincentown aquifer is shown on plate 4; supporting water-level data are presented in appendix 4. Where water-level data were sparse, particularly in southwestern New Jersey, previously published potentiometric surface maps (DePaul and others, 2009), as well as simulated water levels from Voronin (2004), were used to estimate the position and shape of the contours. The configuration of the potentiometric surface for the Vincentown aquifer is nearly identical to that interpreted for 2003; however, small declines in water-level altitudes are indicated by a slight updip and northeastern shift in the mapped contours relative to 2003. The highest groundwater-level altitudes occurred near the updip limit in western Monmouth and northwestern Ocean County in areas of greatest topographic relief; the lowest observed water-level altitudes occurred in coastal Monmouth and Salem Counties in the northeastern and southwestern extent of the aquifer, respectively. A potentiometric high in northern Ocean County, indicated by the 160 ft-contour, reflects prevailing water-table altitudes in the outcrop. Groundwater flow in Monmouth, Ocean, and northern Burlington Counties is generally to the east-southeast from areas of high water-level altitudes near the updip boundary in the west toward areas of discharge to pumped wells and the Atlantic Ocean and toward the eastern areas at the downdip limit of the aquifer where flow recharges the underlying Wenonah-Mount Laurel aquifer.

The lack of accessible wells in Burlington and Camden Counties precluded mapping of 2008 conditions, although the infrequent usage of the aquifer here would indicate that water levels remain essentially unchanged and the potentiometric surface has a configuration similar to that simulated by Martin (1998). The limited water-level data for central Gloucester County indicate that a local potentiometric high, originally mapped by Hardt and Hilton (1969) and confirmed by DePaul and others (2009), is present. Potentiometric lows of near 0 ft observed during previous studies where the aquifer underlies the Salem River and Delaware estuary were not confirmed in 2008 owing to the loss of observation wells in southwestern Salem County. Reported static water levels at several irrigation wells (not shown on map) during 2008, however, confirm the presence of low water-level altitudes in Salem County. Groundwater altitudes progressively decrease to the southwest of the potentiometric high in Gloucester County, indicating regional flow toward the Delaware River.

Vertical water-level differences between the Vincentown aquifer and the overlying Kirkwood-Cohansey aquifer are generally less than 20 ft in Monmouth and Ocean Counties; a weak to moderate downward hydraulic gradient to the Vincentown aquifer from the water-table aquifer is present and increases in the downdip direction toward the east. In central and southern New Jersey, vertical water-level differences are as great 60 ft, indicating a downward gradient from the water-table aquifer to the Vincentown aquifer. A downward vertical gradient is present from the Vincentown to the Wenonah-Mount Laurel aquifer throughout most of Monmouth and Ocean Counties, strengthening toward the downdip boundary of the Vincentown aquifer where water-level altitudes ranged from 40 to 80 ft higher than in the underlying Wenonah-Mount Laurel aquifer. In areas where localized potentiometric highs in the Wenonah-Mount Laurel aquifer coincide with the downdip boundary of the Vincentown aquifer, groundwater-level altitudes are similar and vertical gradients are nearly neutral. At limited observation wells in southern New Jersey, a downward gradient that weakens to the southwest was apparent.

Substantive interpretations of water-level changes could not be made for the extent of the aquifer in 2008, given the spatial limitations of the data collected at individual wells during both studies. Of the 21 wells measured during both the 2003 and 2008 studies, water levels declined in 15 (72 percent), remained the same in 3 (14 percent) and rose in 3 (14 percent) of wells. Water-level changes were minor, owing to the relative constancy of withdrawals, and generally declined or rose by 1 to 3 ft. Declines of 5 or 6 ft occurred at four wells, but no spatial patterns are apparent. Declines were not always associated with withdrawals from the aquifer (fig. 13, 15*A*).

Results of the Wilcoxon signed-rank test indicate significant declines in the paired water-level measurements throughout the dataset as a whole for the 5-year period, but no significant change was observed for the 10-year period (appendix 10-2). Long-term water-level data collected at three wells open to the Vincentown aquifer are represented in figure 16; results of the trend test are provided in appendix 10-1. No significant upward or downward trends were detected at any well for the 5-, 10-, or 30-year periods.

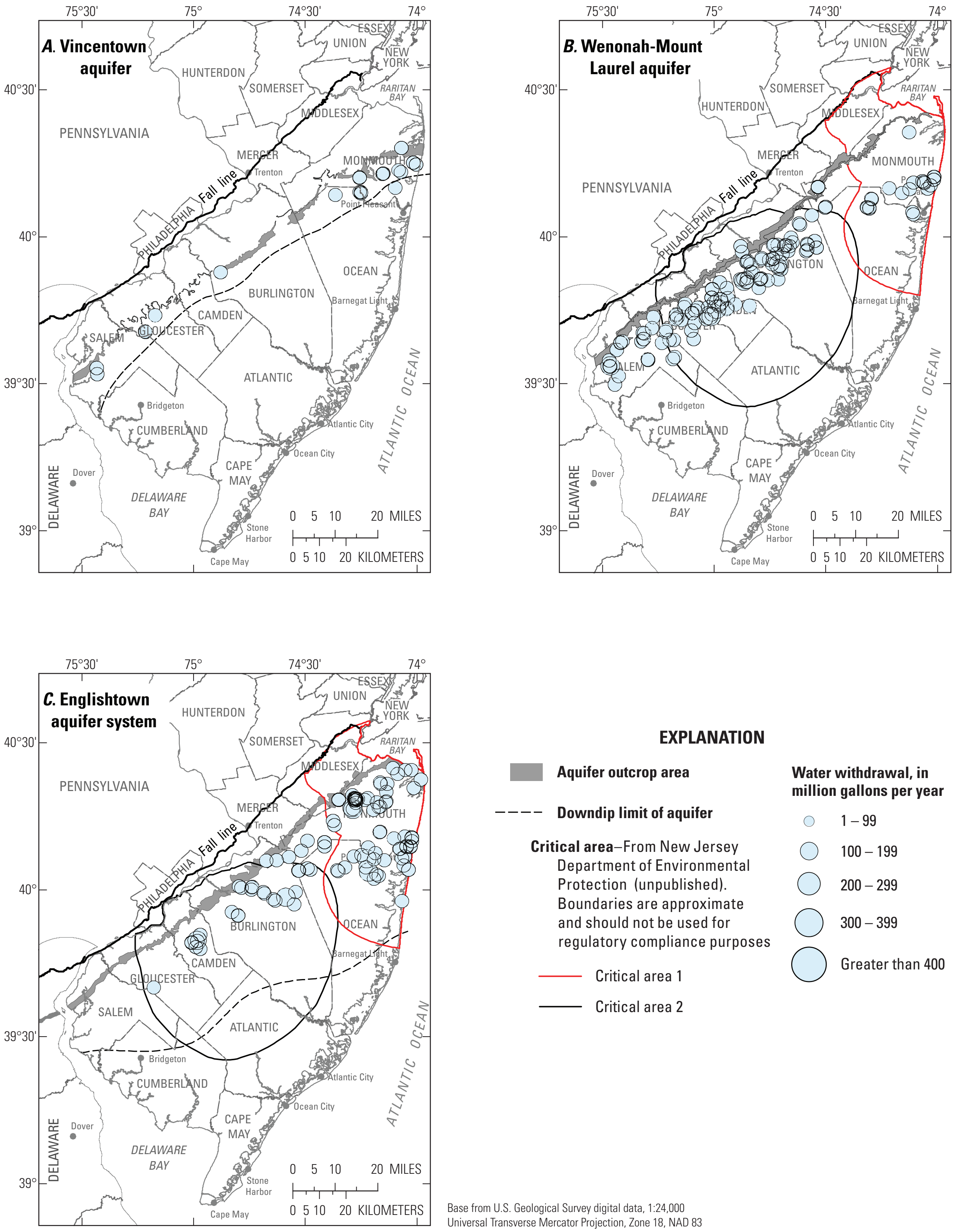


Figure 13. Location and volume of groundwater withdrawals from *A*, the Vincentown aquifer, *B*, Wenonah-Mount Laurel aquifer, and *C*, the Englishtown aquifer system, New Jersey Coastal Plain, 2008.

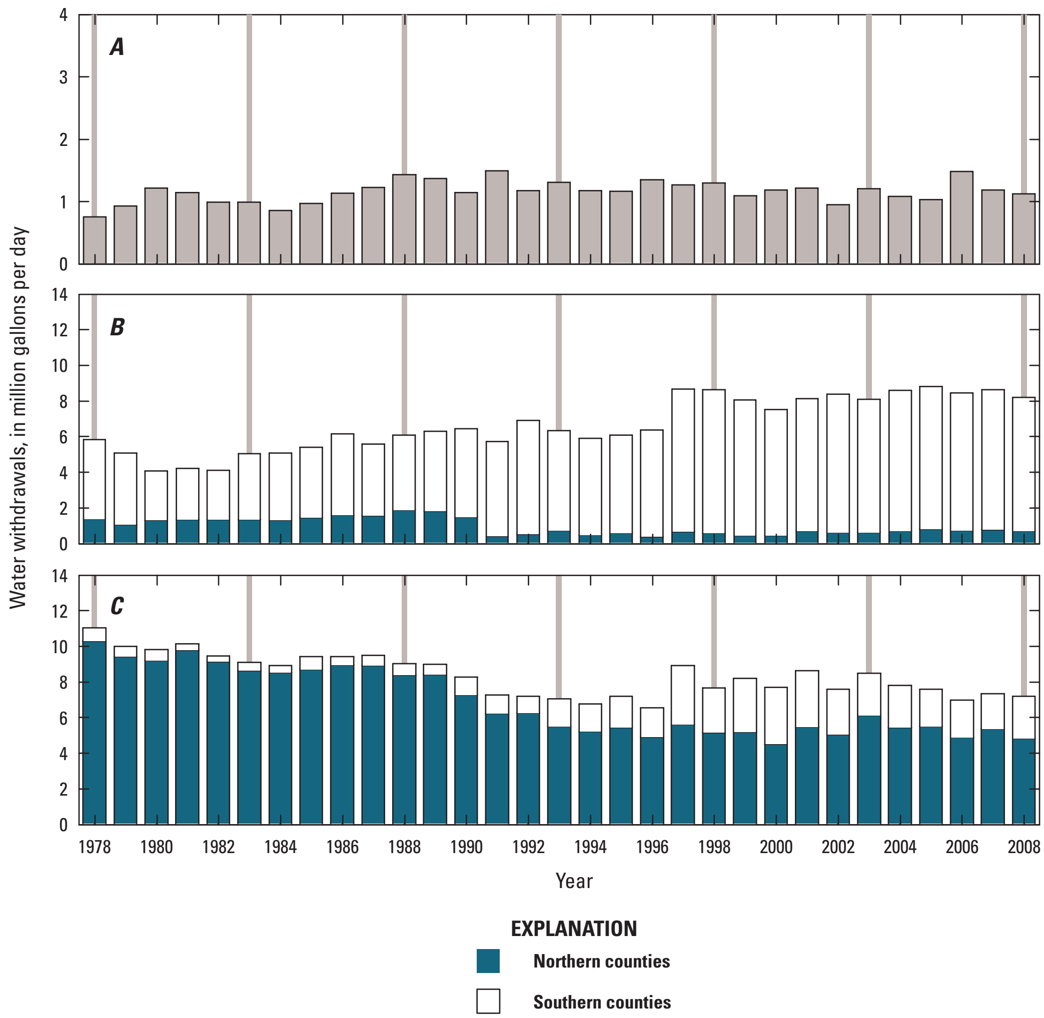


Figure 14. Estimated groundwater withdrawals from *A*, the Vincentown aquifer, *B*, the Wenonah-Mount Laurel aquifer, and *C*, the Englishtown aquifer system, New Jersey Coastal Plain, 1978–2008. (Thin vertical bars denote 5-yr data collection periods; note different vertical scaling)

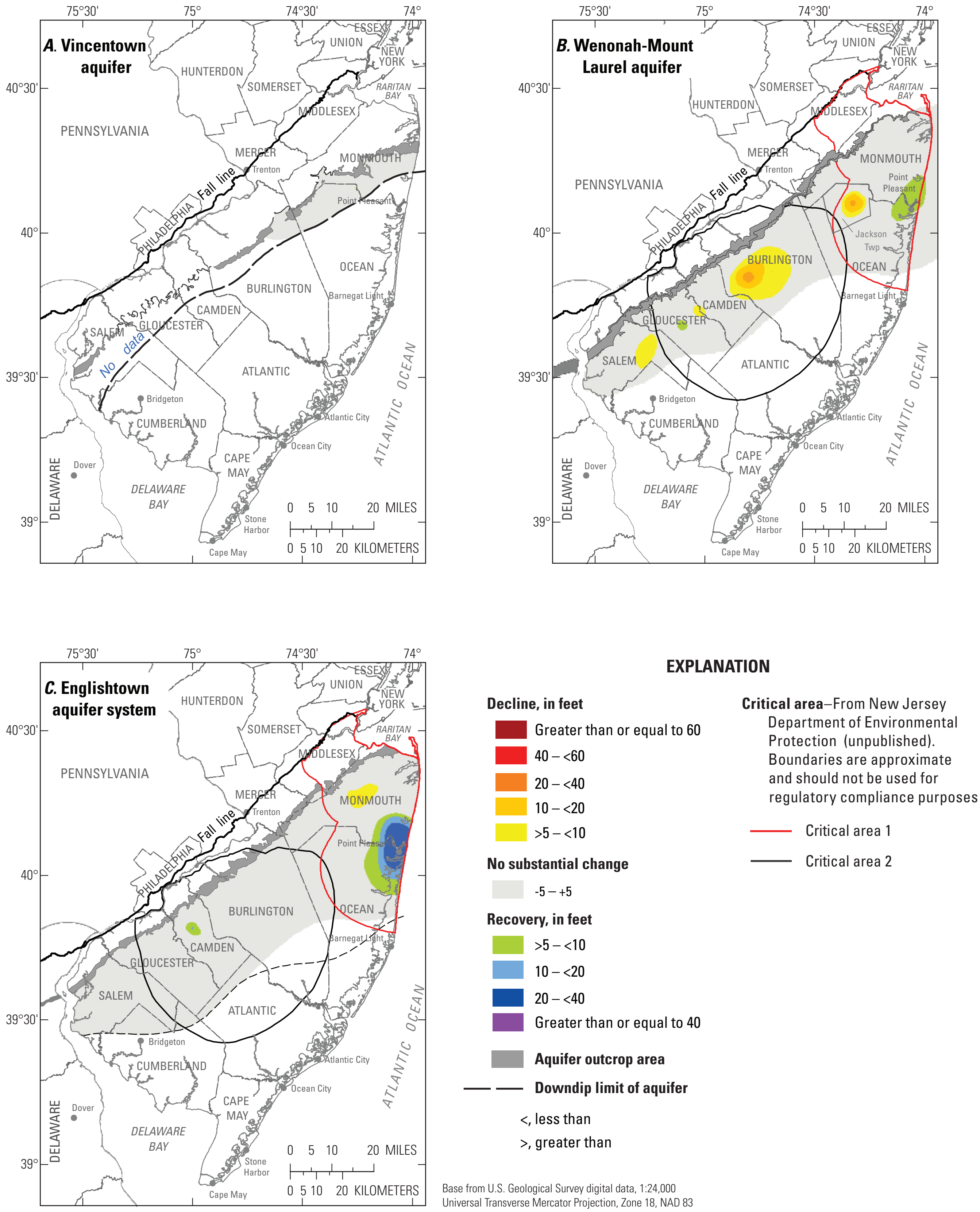


Figure 15. Groundwater level changes in *A*, the Vincentown aquifer, *B*, the Wenonah-Mount Laurel aquifer, and *C*, the Englishtown aquifer system, New Jersey Coastal Plain, 2003–8.

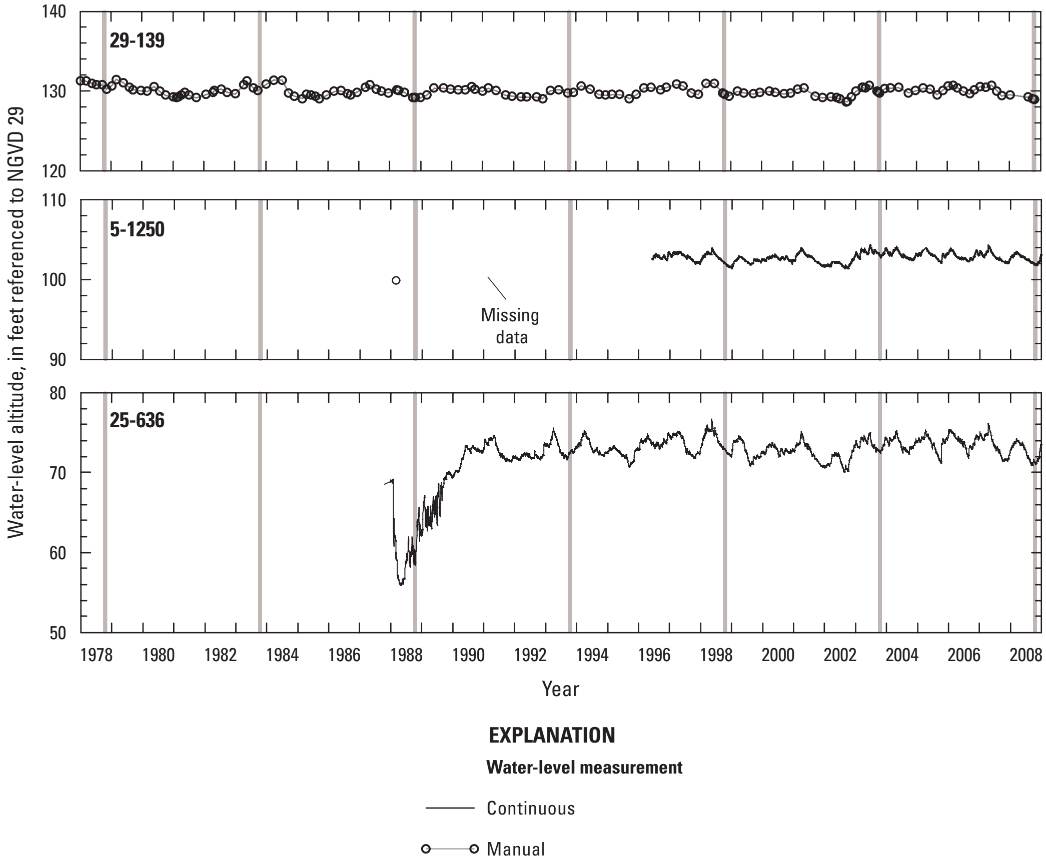


Figure 16. Water-level hydrographs for selected observation wells screened in the Vincentown aquifer, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 4)

Wenonah-Mount Laurel Aquifer

The Wenonah-Mount Laurel aquifer is composed of the sand of the Mount Laurel Formation and, locally, the upper part of the Wenonah Formation where the latter is not composed predominantly of silt. The Mount Laurel Formation is a slightly glauconitic, micaceous quartz sand; shell beds are fairly common throughout. The upper part of the Wenonah Formation consists of slightly glauconitic, clayey fine sand or silt containing abundant lignite fragments and occasional pyrite (Owens and others, 1970); at its base, the formation grades to a silt. The aquifer crops out within the exposures of the Mount Laurel and Wenonah Formations from Monmouth and Middlesex Counties in the northeastern part of the Coastal Plain to Salem County in the southwest (pl. 5). The downdip limit of the aquifer is offshore of Monmouth and Ocean Counties; in the southern New Jersey counties—Atlantic, Cumberland, and Cape May—this limit is poorly defined. The productivity at any location is based on the thickness and silt content of the materials composing the aquifer. The aquifer is thickest in southwestern New Jersey (western Salem, and central Gloucester and Camden Counties) where it is most often used for water supply. In this area, thicknesses of 100 ft to 200 ft are common (Zapecza, 1989). In Salem County, the silt content increases, and the productive sands decrease accordingly. In the northeastern part of the Coastal Plain, the aquifer is used for water supply in central and eastern Monmouth and northern Ocean Counties; the aquifer here is generally 60 ft to 80 ft thick (Zapecza, 1989), although thicknesses may exceed 100 ft in some areas of Monmouth County.

The Wenonah-Mount Laurel aquifer contains freshwater throughout much of its confined extent. In the northern part of the study area, chloride concentrations in groundwater generally range from 2 to 20 mg/L with concentrations increasing in the downdip direction. The highest chloride concentrations along the coast in Monmouth County typically were less than 25 mg/L. Occasional elevated concentrations were observed in close proximity to outcrop areas where recently recharged groundwater may discharge to pumped wells finished in the confined aquifer. In southern Cumberland and Salem Counties, a zone of saline groundwater is present along the Delaware estuary, extending approximately 2 mi inland in the southwestern part of Salem County (pl. 5). Elevated chloride concentrations (50 to greater than 100 mg/L) also are present in groundwater in and near the city of Salem. During 1990–2004, chloride concentrations in some supply wells increased to more than 150 mg/L, with the greatest annual rates of increase occurring during 2000–2. Concentrations have since stabilized at approximately 100 mg/L. Elsewhere in southern New Jersey, in areas where the aquifer is used, the groundwater is generally fresh, and chloride concentrations are typically less than 25 mg/L.

Water Withdrawals

Groundwater withdrawals from the Wenonah-Mount Laurel aquifer occur mostly in southern New Jersey where the aquifer is confined throughout a narrow band from central Burlington County to central Salem County from the outcrop to less than 10 mi downdip (fig. 13). Groundwater is also withdrawn in eastern Monmouth County, along and within 10 mi of the Atlantic coast. From 1978 to 2008, withdrawals ranged from 4.1 to 8.8 Mgal/d; in 2008, withdrawals averaged 8.2 Mgal/d (fig. 14*B*, table 3). During 2008, most of the groundwater (7.5 Mgal/d, 91 percent) was pumped from the aquifer underlying the southern counties of New Jersey and, during most years, was typically greater by an order of magnitude than that pumped in the north. Withdrawals in the northern counties decreased from about 1.4 Mgal/d in 1978 to 0.7 Mgal/d in 1993 with the largest reduction occurring in 1991 as a result of the implementation of Critical Area 1 cutbacks. During the same period, groundwater withdrawals in the southern counties increased only marginally; thereafter, withdrawals increased to more than 8 Mgal/d with peak volumes occurring during 1997–98 and 2005 (fig. 14*B*). From 1996 to 1997, average withdrawals from the aquifer in southern counties increased by 34 percent in an effort to supplement lost allocation from the regulated PRM aquifers in Critical Area 2.

Water Levels

The potentiometric surface map, depicting water levels during the fall and early winter 2008 for the Wenonah-Mount Laurel aquifer, is shown in plate 5; supporting water-level data used to construct this map are presented in appendix 5. The 2008 potentiometric surface shows high groundwater altitudes near the outcrop in northern New Jersey Coastal Plain counties, a potentiometric low near the outcrop in north-central Burlington County, and three cones of depression within the aquifer. The highest groundwater altitudes were observed near the outcrop in Monmouth County (147 ft in well 25-412); the lowest were observed in coastal Monmouth County and along the border of central Camden and Gloucester Counties. The northernmost cone of depression, located in the coastal region of Monmouth and Ocean Counties, is elongate in shape; is centered beneath the boroughs of Point Pleasant, Brielle, and Spring Lake Heights; and extends throughout a broad area from Seaside Park in northern Ocean County north to Long Branch in Monmouth County and west toward Lakewood. The configuration and shape of the cone of depression is similar to that in the underlying Englishtown aquifer system, though the generally lower transmissivity of the aquifer produces a cone that is narrower. Simulated contours (Voronin, 2004) were used to guide the closure of contours at the eastern or offshore edge of the cone. At the deepest part of the cone, groundwater-level altitudes ranged from -63 to -68 ft, a rise of 6 to 8 ft from levels observed in 2003. Within the area encompassed by the 0–ft contour, groundwater withdrawals from the aquifer in 2008 were estimated to be approximately 0.4 Mgal/d. Given the depth and breadth of this cone, this amount is not substantial; the relatively low transmissivity of the aquifer of 500 to 700 square feet per day (ft^2/d) (Martin, 1998), coupled with long-term withdrawals and low potentiometric head in the underlying Englishtown aquifer system, contribute to the size and persistence of the cone.

The central cone of depression, the smallest of the three, is centered beneath the community of Browns Mills and has a minimum water-level altitude of -27 ft (well 5-367). Average groundwater withdrawals during 2008 from 10 wells in the Browns Mills area were modest at 0.54 Mgal/d. Since 1980, average withdrawals ranged from 0.5 to 1.2 Mgal/d, peaking in the early 1990s and generally decreasing thereafter. Notable reductions in withdrawals of more than 15 percent from the previous year occurred in 1994, 1996, and 2006.

The southern cone of depression underlies parts of central Burlington, Camden, and Gloucester Counties. This elongated cone of depression began to form after 1983. Two smaller cones of depression have since merged to form the larger, more regionally extensive feature present in 2008, extending approximately 30 mi along the direction of the strike of the Wenonah and Mount Laurel Formations. The northernmost “center” of the cone underlying Medford Lakes has a potentiometric-surface low of -55 ft (well 5-1253), a decline of more than 20 ft from the previous study. The southernmost “center” underlies an area straddling the border between Camden and Gloucester Counties; its length is approximately 8 mi along the direction of strike. The low water level of -82 ft (well 7-847) represents a decline of 11 ft from 2003. Each center is characterized by steep, lateral hydraulic gradients in their respective updip areas, ranging from 42 to 50 ft/mi.

Vertical head differences between the Piney Point and the Wenonah-Mount Laurel aquifers indicate a moderate to strong downward gradients in central Burlington, Camden, and Gloucester Counties, particularly in areas where the Wenonah-Mount Laurel aquifer is experiencing pumping stresses, such as Winslow and Monroe Townships (Williamstown quadrangle). Potentiometric differences range from 60 to 80 ft in this area, with maximum differences exceeding 100 ft. Throughout much of the mid-dip and updip areas of the aquifer, a downward hydraulic gradient is present from the Wenonah-Mount Laurel aquifer to the underlying Englishtown aquifer system. At the deep cone of depression in the Wenonah-Mount Laurel aquifer in coastal Ocean and Monmouth Counties, water-level differences between the two units can be substantial, although along the eastern and northern edges, these differences moderate and, in places, are neutral.

Groundwater-level changes in the Wenonah-Mount Laurel aquifer from 2003 to 2008 are shown in figure 15*B*. Most groundwater levels measured showed small to moderate changes relative to 2003, although large declines were indicated in a few areas. Water levels declined in 84 wells (74 percent), recovered in 21 wells (19 percent), and remained about the same in 8 wells (7 percent). Water levels, in general, rose 5 to 10 ft near the center of the regional cone of depression underlying eastern Monmouth County (fig. 15*B*), continuing the long-term trend of recovery in this area. This rise in water-levels can be attributed to a reduction in withdrawals and corresponding recovery in the underlying Englishtown aquifer system, as the volume of, and year to year changes in, withdrawals from the Wenonah-Mount Laurel are minor. Away from the center of the cone of depression, changes in groundwater levels were subtle, and declines or rises of 2 to 3 feet were most common. Beyond the 0-ft contour and to the north and west, the potentiometric surface showed little to no change from 2003. In central Jackson Township, however, water levels were as much as 20 ft lower than in 2003 despite modest increases in withdrawals of less than 10 percent.

Throughout the southern counties, water levels measured in 2003 and 2008 declined in 66 percent of wells, recovered in 10 percent, and remained about the same in 24 percent. Within the Browns Mills cone of depression, water levels remained about the same as in 2003, reflecting stable trends in withdrawals. Groundwater levels in central Burlington County declined from 2 to 23 ft in response to increasing withdrawals in the vicinity of Medford Lakes. In comparison, water-level declines near the Camden/Gloucester County line were more moderate, and stable to rising water levels were observed in surrounding municipalities, reflecting an 11 percent decrease in withdrawals since 2003.

Results of the Wilcoxon signed-rank test indicate a statistically significant difference (decline) in paired water-level measurements in the dataset as a whole (app. 10-2) from 2003 to 2008. A similar relation was observed in measurements throughout Critical Area 2; however, no significant difference among compared measurements throughout Critical Area 1 was indicated. Significant decreases between paired measurements were observed for Burlington, Camden, Ocean, and Salem Counties, but not for Monmouth or Gloucester Counties. From 1998 to 2008, significant differences between paired measurements were not observed.

Results of the Mann-Kendall statistical trend test are listed in appendix 10-1. Supporting hydrographs for eight observation wells that show long-term and seasonal trends in the Wenonah-Mount Laurel aquifer from 1978 to 2008 are provided in figures 17 and 18. From 2003 to 2008, statistically significant downward trends were observed for 5 wells (7-118, 7-478, 29-140, 33-20, and 33-252), and upward trends were observed for 2 wells (25-486 and 25-637). Downward trends were strongest for wells 7-478 and 33-20 and weakest for wells nearest the outcrop (33-252 and 7-118). No significant upward or downward trend was observed for well 25-353. From 1998 to 2008, significant downward trends were observed for two wells, 7-478 and 29-140. Observation well 7-478 is located near the border between Camden and Gloucester Counties and along the downdip side of the southern cone of depression. Following a 70-ft water-level decline over an 18-year period (1983–2001), water levels stabilized, then rose during 2004–5, but have since declined. Well 29-140, located in the mid-dip section of the aquifer in northern Ocean County, shows only a modest decline for the 10-year period, as well as for the period of record. Upward trends were observed for wells 25-353, 25-486, and 25-637 for their respective periods of record; in contrast, downward trends were observed for wells 7-478 and 33-20 from 1978 to 2008.

Photograph was provided by U.S. Geological Survey field personnel

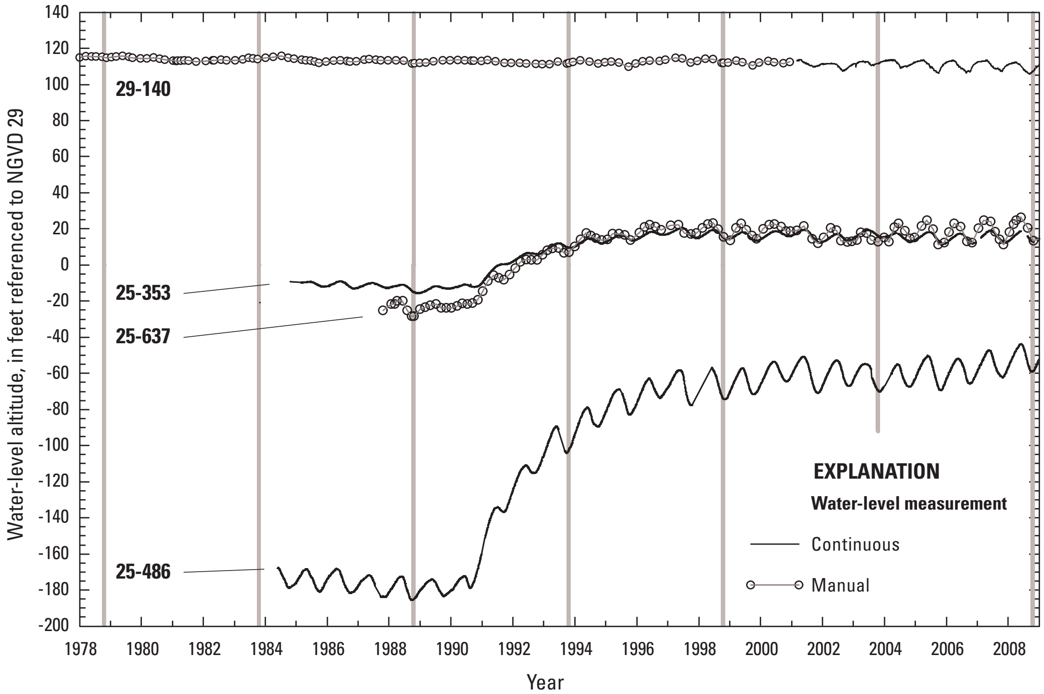


Figure 17. Water-level hydrographs for selected observation wells screened in the Wenonah-Mount Laurel aquifer in the northern counties of the New Jersey Coastal Plain, 1978–2008. (Vertical bars denote 5-yr data collection cycles; well locations shown on pl. 5)

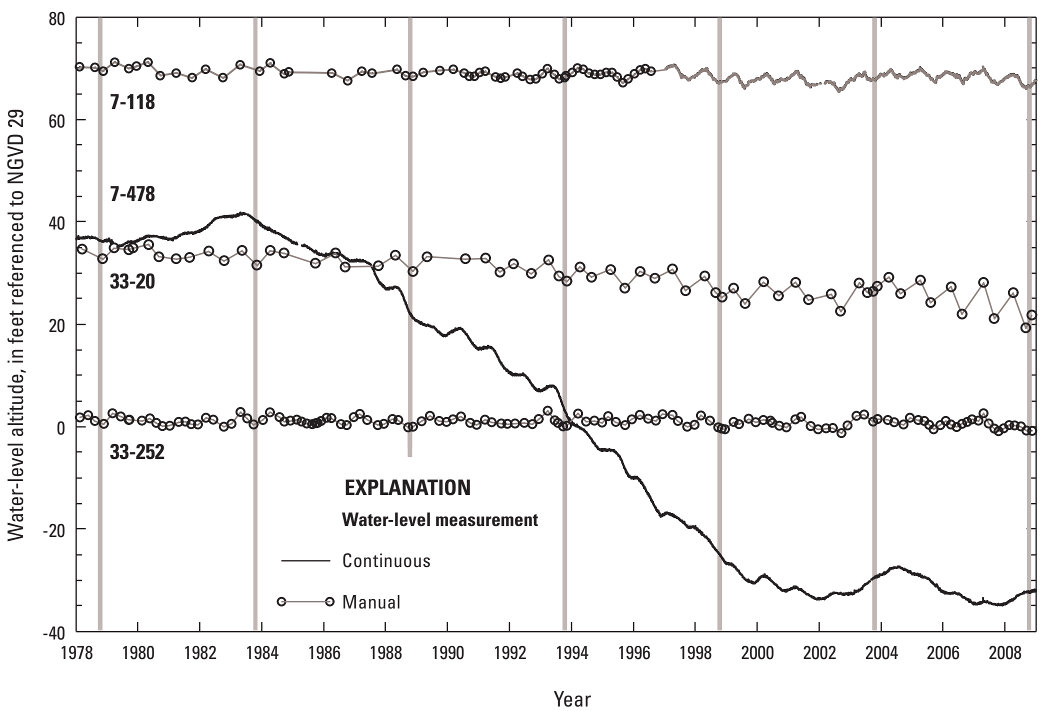


Figure 18. Water-level hydrographs for selected observation wells screened in the Wenonah-Mount Laurel aquifer in the southern counties of the New Jersey Coastal Plain, 1978–2008. (Vertical bars denote 5-yr data collection cycles; well locations shown on pl. 5)

Englishtown Aquifer System

The Englishtown Formation is a fine- to medium-grained feldspathic quartzose sand that in some places grades to a silt. The formation is thickest (200 ft) in Monmouth County and remains sandy and thick a substantial distance downdip from the outcrop; therefore, the aquifer yields large quantities of water in Monmouth and Ocean County. In central and southern Ocean County, a confining unit partitions the Englishtown aquifer system into upper and lower aquifers. The aquifer system is underlain by the Merchantville-Woodbury confining unit, which is the most extensive confining unit in the Coastal Plain. The Englishtown Formation thins considerably to the southwest, where sandy units are discontinuous and silt beds predominate (Zapecza, 1989). The approximate downdip limit of the aquifer system is shown on plate 6; it extends from the Forked River in Ocean County, southwest through Hammonton and Buena in Atlantic County, then along an east-west trending line through Bridgeton in Cumberland County to the Delaware Estuary in Salem County. The distance from outcrop to the downdip boundary is approximately 34 mi in Ocean County, but to the southwest, the lateral extent of the confined aquifer decreases to about 12 mi in southern Salem County. To the south and east the aquifer is not recognized on geophysical logs that penetrate the section (Zapecza, 1989). Transmissivity in the Englishtown aquifer system decreases substantially to the southwest as geologic material composing the aquifer matrix becomes finer-grained (Nichols, 1977), and little water is produced from the aquifer in the southwestern part of the State (Zapecza, 1989).

Most of the confined part of the Englishtown aquifer system contains fresh groundwater, except in a limited area at and surrounding the Sandy Hook observation well (25-771) in northeastern Monmouth County where chloride concentrations exceed 15,000 mg/L. The geochemical imprint on the groundwater from this well indicates a direct connection to, and mixing with, seawater. The saline water is present below a 5-ft-thick clay lens, however, and is effectively segregated from the upper part of the aquifer where the groundwater is fresh and used for potable supply.

In updip and mid-dip sections of the confined aquifer, calcium and bicarbonate are the predominant ionic species, and concentrations of chloride are low, ranging from 1 to less than 10 mg/L, except in northern Monmouth County where concentrations at times exceed 10 mg/L. In far downdip areas of northern Ocean County, sodium is the predominant cation, and the groundwater exhibits high sodium to chloride molar ratios, ranging from 5:1 to 100:1, evidence of substantial amounts of cation exchange. Concentrations of chloride in groundwater from the lower part of the confined aquifer in these areas occasionally exceeded 15 mg/L and have been observed to be as high as 40 mg/L but are most often less than the former. No evidence of upward trends has been observed.

Chloride concentrations in the Englishtown aquifer system in southern New Jersey generally ranged from less than 1 to 9 mg/L throughout the confined aquifer, although higher concentrations were observed within and near outcrop areas. Chloride concentrations showed no apparent increase with increasing distance in the downdip direction; however, most of the chloride data from the southern counties are from wells within 10 mi of the outcrop. Water-quality data farther downdip are sparse, and substantive conclusions about the evolution of groundwater toward this boundary could not be made. Chloride data for individual wells through time also are rare, and temporal trends could not be determined.

Water Withdrawals

Withdrawals from the Englishtown aquifer system are made primarily in Monmouth and northern Ocean Counties and in central Camden County; however, smaller-capacity production wells are present throughout north-central Burlington County (fig. 13*C*). The aquifer is used locally in eastern Mercer County and near the outcrop in Salem and Gloucester Counties where withdrawals are made primarily for domestic self-supply. Average withdrawals from the Englishtown aquifer system in 2008 were approximately 7.2 Mgal/d (table 3); withdrawals from the northern counties accounted for 67 percent of this volume. Withdrawals decreased from approximately 11 Mgal/d in 1978 to less than 7 Mgal/d by 1996 (fig. 14*C*) as a result of mandated cutbacks in Critical Area 1 and, beginning in 1991, the use of the Manasquan Reservoir as an alternative source of water. Reductions during 1989–91 (26 percent) were the most notable. In 1997 withdrawals increased to nearly 9 Mgal/d and, during the ensuing decade, ranged from 7 to 8.5 Mgal/d. In northern Coastal Plain counties, withdrawals averaged nearly 9 Mgal/d during the 1980s, 5.7 Mgal/d during the 1990s, and from 2000 to 2008, 5.2 Mgal/d.

Withdrawals from the aquifer system in the southern counties were constant at approximately 0.5 Mgal/d from 1978 through 1987 (fig.14*C*); in 1988 withdrawals began to increase gradually. By 1996, average withdrawals were nearly 1.7 Mgal/d; a sharp increase to 3.3 Mgal/d followed in 1997. In 1997 in Camden County, estimated withdrawals more than doubled from the previous year because of new wells brought on line in the county. This increase in the use of the Englishtown aquifer system was a consequence of restrictions placed on withdrawals from the underlying PRM aquifer system in 1996. From 1998 to 2001 withdrawals averaged approximately 3 Mgal/d. In 2002, withdrawals from the aquifer system in the southern Coastal Plain began a gradual decline, then leveled at approximately 2 Mgal/d. In 2008 average withdrawals throughout the southern Coastal Plain counties were 2.3 Mgal/d.

Water Levels

The potentiometric surface during the fall and early winter of 2008 for the Englishtown aquifer system is shown on plate 6; supporting water-level data used to construct this map are presented in appendix 6. The highest groundwater altitudes within the confined aquifer exceeded 100 ft and occurred near the outcrop in western Monmouth County, roughly coinciding with areas of greatest topographic relief. The lowest groundwater altitudes (-84 to -101 ft) occurred along the Monmouth/Ocean County boundary and are associated with pumping centers near Point Pleasant and Lakewood. The dominant feature of the groundwater flow system is a prominent cone of depression underlying northeastern Ocean and eastern Monmouth Counties (pl. 6). This regionally extensive cone of depression has been well documented; a 1958 potentiometric surface map by Seaber (1965) shows water levels in this area in excess of 100 ft below NGVD 29. Nichols (1977) similarly documents declines in water levels from 1900 to 1959 of greater than 100 ft near the border of Monmouth and Ocean Counties; from 1959 to 1983, groundwater levels in this region declined an additional 150 ft.

The location and configuration of this cone is similar to that in the overlying Wenonah-Mount Laurel aquifer; vertical leakance through the confining unit allows good hydraulic connection between the two aquifers. Closed contours on the seaward side of the cone were mapped on the basis of simulations by Voronin (2004). The lateral hydraulic gradient on the updip side of the cone of depression is relatively steep, ranging from 12 to 30 ft/mi; on the downdip side this gradient is generally less than 5 ft/mi. The cone of depression is composed of several smaller cones underlying pumping centers located at Point Pleasant, Spring Lake, and Lakewood, the largest of which underlies coastal communities from Mantoloking in northern Ocean County to Belmar in southern Monmouth County. Lowest water-level altitudes in this area (< -80 ft) were measured in production wells at Point Pleasant.

The remaining local cones underlie areas near the town of Lakewood. Each is radially small but deep, and each is associated with either a single well or two wells. This area is characterized by a potentiometric head of less than -70 ft, with the minimum groundwater altitude (-101 ft) observed in the northern part of the municipality, near the Metedeconk River.

A local depression in the potentiometric surface at Freehold (well 25-727) is indicated on the map (pl. 6) by the upswept 80-ft contour in the southeastern part of the Freehold quadrangle. This feature was initially included on the 1993 potentiometric map and verified during the 1998 and 2003 studies (Lacombe and Rosman, 2001; DePaul and others, 2009). A measured water-level altitude near this feature was 62 ft, a decline from the previous study of 6 ft. In the southern counties, groundwater altitudes ranged from a high of 96 ft in northern Burlington County to a low of -38 ft where a small, localized cone of depression is present in central Burlington County beneath the community of Browns Mills.

Vertical head differences between the Englishtown aquifer system and the Upper PRM aquifer are significant in updip and mid-dip areas of western Monmouth, northeastern Ocean, and Camden Counties. Groundwater altitudes during 2008 in the Englishtown aquifer system were as much as 117, 115, and 104 ft higher in Monmouth, Ocean, and Camden Counties, respectively, and the potential for downward flow out of the Englishtown aquifer system is greatest in these areas. In eastern Monmouth and northeastern Ocean County, however, groundwater altitudes are higher in the Upper PRM aquifer than in the Englishtown aquifer system. Despite heads that are more than 40 ft higher in the Upper PRM aquifer than in the Englishtown aquifer system beneath the cone of depression in eastern Monmouth and Ocean Counties, upward flow is impeded owing to the thickness and low permeability of the underlying Merchantville-Woodbury confining unit in that area (Martin, 1998).

Water-level differences between the Englishtown aquifer system and the Wenonah-Mount Laurel aquifer are generally less than those between the Upper PRM aquifer and the Englishtown aquifer system. Water-level differences range from 10 to 25 ft in updip areas of Monmouth and Ocean County; however, in mid-dip areas where the Englishtown aquifer system is used for supply, water levels may be as much as 45 ft lower than those in the overlying Wenonah-Mount Laurel aquifer. Along the western edge of the cone of depression in coastal Monmouth and Ocean Counties, water-level differences are as much as 60 ft, and the Englishtown aquifer system receives downward recharge from the overlying Wenonah-Mount Laurel aquifer, contributing to the sustained potentiometric lows in the Wenonah-Mount Laurel aquifer. Flow from the Wenonah-Mount Laurel aquifer to the Englishtown aquifer system may be substantial in areas where vertical gradients are strong because of the relatively high leakance of the Marshalltown-Wenonah confining unit (Martin, 1998). Water-level differences decrease toward the east and north of the cone of depression, ranging from 5 to 20 ft.

Water-level changes from 2003 to 2008 were calculated for the 76 wells open to the Englishtown aquifer system and measured in both years. A map showing these water-level changes is provided in figure 15C. Of the wells measured in both 2003 and 2008, water levels declined in 40 (53 percent), recovered in 32 (42 percent), and remained the same in 4 (5 percent). Water-level declines ranged from 1 to 23 ft and were most common in central Monmouth County to the north and updip from the regional cone of depression, and in updip and mid-dip areas of northwestern Ocean and Burlington Counties. In mid-dip areas of north-central Ocean County, groundwater levels did not change. The largest changes were observed at and near the center of the regional cone of depression where a 40-percent reduction in withdrawals relative to 2003 volumes caused water levels to recover by 28 to 38 ft. On the western and updip side of the cone of depression, water levels were stable or had recovered by 3 to 18 ft. At the southern edge of the cone of depression, water levels were unchanged or modestly recovered.

In central Camden County in southern New Jersey, water levels were as much as 20 ft higher than those observed in 2003. Rising water levels occurred throughout several small municipalities as a result of a 20-percent reduction in withdrawals during this period.

Results of the Wilcoxon signed-rank test indicate that, from 2003 to 2008 and from 1998 to 2008, the differences in paired water-level measurements throughout the aquifer were not significant (appendix 10-2). In Critical Area 1, water levels recovered during 1998–2008 and 2003–8, although during 2003–8, rises are not statistically significant at the 95-percent confidence level. Evaluated by county, water-level rises from 2003 to 2008 in Ocean County were significant, and declines in Burlington County were significant during the same period. There were no significant changes in other counties during 2003–8 and no significant changes in any county during 1998–2008.

Results of the Mann-Kendall statistical trend test are listed in appendix 10-1. Supporting hydrographs for nine observation wells that graphically depict long-term and seasonal trends in the Englishtown aquifer system from 1978 to 2008 are shown in figure 19. The hydrographs for wells 23-104 and 25-715 show little to no change in water levels during the periods of record, whereas the hydrograph for well 29-138 shows periods of modest decline and subsequent recovery. Wells 23-104 and 25-715 are located in updip areas, and well 29-138 is within the mid-dip section of the aquifer system. These wells are distant from the regional cone of depression along the coast.

The water level in well 25-715, located near Sandy Hook Bay in northern Monmouth County, has remained relatively constant since the well was installed in 1991. Withdrawals from the aquifer are made 1.25 mi to the west but are minor; therefore, the range in seasonal fluctuations is small, from 2 to less than 4 ft, and the long-term water-level change is barely perceptible. Temporal fluctuations observed in well 23-104 show responses to changes in precipitation and subsequent recharge; this well is located away from the influence of pumping wells and within the outcrop where infiltration is rapid and recharge paths are relatively short. From 1978 to 2008, the water level in this well has remained essentially unchanged. Results of trend testing indicated a near-zero slope for the periods of record (1978–2008) at both wells.

The hydrograph for well 29-138 (fig. 19) shows a gradual decline of 7 ft during 1978–93, followed by a rise of 8 ft through 1998; thereafter, annual high-water levels generally stabilized at 66 ft. During the latter part of the period of record, a slight downward trend was observed, and the water level declined by nearly 4 ft from 2003 to 2008.

Observation wells 25-250 and 5-259 are located in updip areas of western Monmouth and Burlington Counties, respectively, far from major cones of depression but near areas where the aquifer is pumped. From 2003 to 2008 a slight, downward trend was observed at well 5-259. A calculated slope of -0.46 indicates a water-level decline of 2 to 3 ft during this period. In comparison, the trend observed at well 25-250 was statistically insignificant. For the 10-year period, however, a slight upward trend was observed in well 25-250, and for the 30-year period, the trend, though insubstantial, was slightly downward.

Water-level change within the aquifer was more dynamic at wells located nearer the regional cone of depression. Well 29-530 is located near the center of the cone, and proceeding updip, in order of increasing distance, are wells 25-429 and 25-638. Water-level trends observed in each of the wells parallel one another, and with increasing distance inland, the slopes of the hydrographs become shallower, groundwater altitudes increase, and the seasonal variability is tempered. Owing to Critical Area conservation strategies introduced in the late 1980s, water levels rose sharply in all three wells from 1990 to 1996; the magnitude of recovery during this period was greatest in well 29-530 at approximately 100 ft. From 1998 to 2008, despite a brief decline during 2001–3, an upward trend in water levels occurred for wells 25-429 and 29-530. From 1998 to 2008, results of the Mann Kendall trend test indicate that no change occurred in the water levels in well 25-638; however, for the 5-year period 2003 to 2008, an upward trend is indicated. Both graphical and statistical analyses of data from well 29-534 indicate a trend similar to those in wells described above; however, the position of the well on the southern edge of the depression, distant from withdrawal centers, and the depth of its screened interval contribute to the moderation in both decline and recovery. Water levels in this well lack seasonality, and the inflection point indicating recovery lagged others by nearly 3 years. Results of the Mann Kendall trend test indicate significant upward trends for the 5-, 10-, and 30-year periods.

Photograph was provided by U.S. Geological Survey field personnel

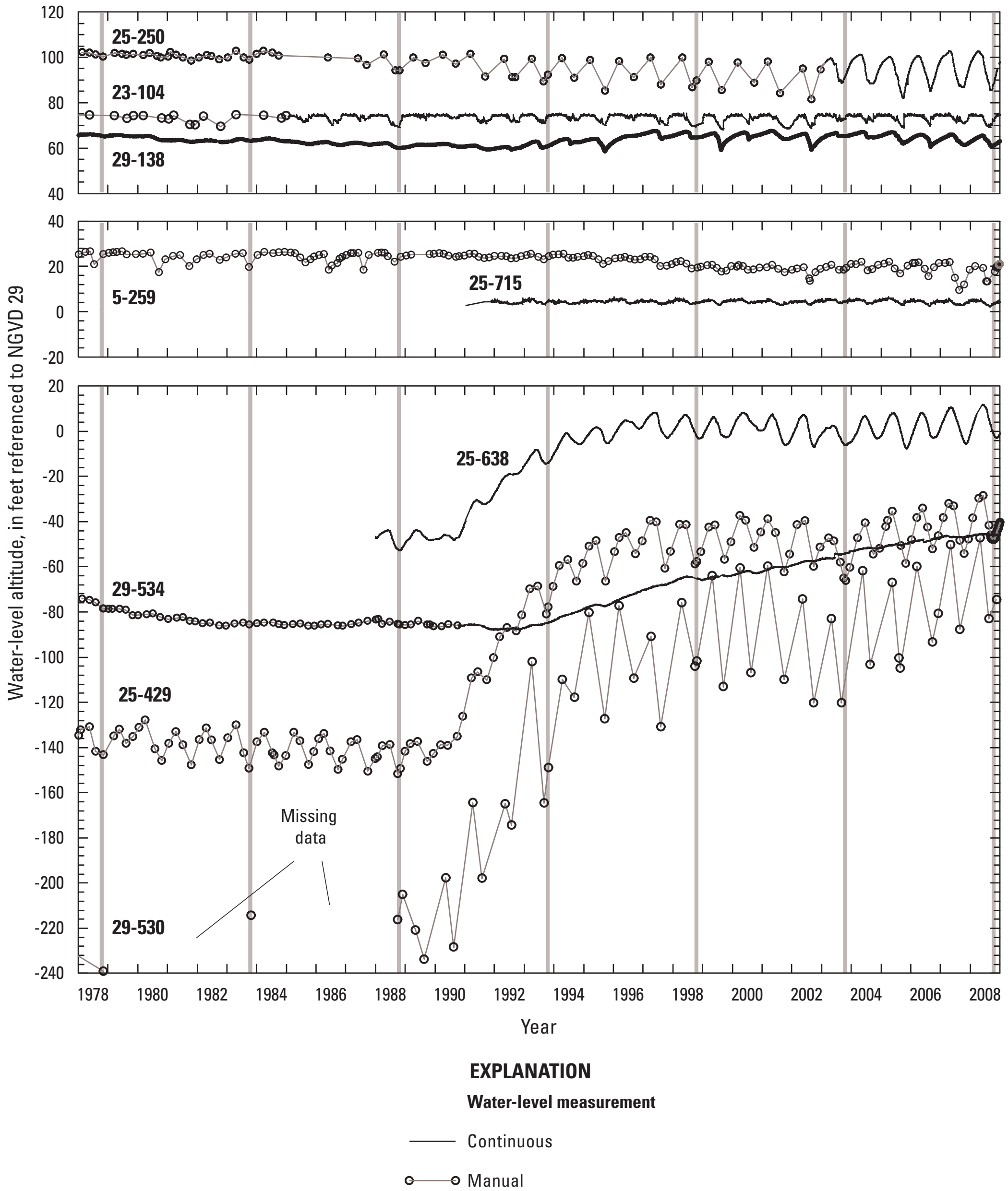


Figure 19. Water-level hydrographs for selected observation wells screened in the Englishtown aquifer system, New Jersey Coastal Plain, 1978–2008. (Hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 6)

Potomac-Raritan-Magothy Aquifer System

The PRM aquifer system includes the most productive aquifers in the New Jersey Coastal Plain. In order of increasing depth they are the Upper, Middle, and Lower PRM aquifers. The Upper PRM aquifer generally corresponds to the Magothy Formation in New Jersey (Zapecza, 1989) and is the most extensive unit within the aquifer system. In Monmouth and Middlesex Counties, the aquifer is locally referred to as the Old Bridge aquifer. The aquifer consists of coarse-grained permeable sands with thin interbedded clay and clayey silt layers present locally. The outcrop extends in a northeast to southwest trending band from the Raritan Bay to the Delaware River adjacent to Salem County and is mostly coincident with the outcrop of the Magothy Formation. The downdip part of the aquifer is well defined offshore of Monmouth and Ocean Counties but less well defined in Atlantic, Cumberland, and Cape May Counties. The thickness of the sand interval ranges from more than 200 ft in eastern Monmouth County to about 50 ft in Cape May County. Recharge to the aquifer is mainly from outcrop areas in Mercer, Middlesex, and Monmouth Counties and from the overlying Englishtown aquifer system, but water also enters the system from outcrop areas in Burlington, Camden, and Gloucester Counties because long-term withdrawals and cones of depression in these areas have altered the natural flow paths, converting areas formerly receiving discharge into recharge areas. The overlying confining unit, ranging in thickness from 200 to 300 ft throughout Monmouth, Ocean, and southern Burlington Counties, is relatively impermeable and effectively impedes vertical flow in downdip areas (Zapecza, 1989). Transmissivity of the aquifer is greatest in the eastern part of Monmouth County, although the sand bodies remain highly conductive throughout western Monmouth County, as well as in western Camden and Gloucester Counties.

The Middle and undifferentiated aquifer of the PRM aquifer system extends from the Raritan Bay in the northeastern part of the study area to Maryland in the southwest. Northeast of Burlington County, the aquifer is locally referred to as the Farrington aquifer. The aquifer in this area is well defined from the outcrop area to about 20 mi downdip; beyond this distance the aquifer cannot be separated from the underlying sediments within the PRM aquifer system. Zapecza (1989) refers to the aquifer in eastern Middlesex County and western Monmouth County as the undifferentiated PRM aquifer. Similarly, in southern New Jersey the aquifer can be traced in the subsurface from the outcrop to an area extending approximately 10 mi to 12 mi downdip, beyond which the aquifer is indistinguishable from the Lower PRM aquifer. Where the confining unit between the Lower and Middle aquifers is absent, the aquifer unconformably overlies bedrock or weathered bedrock. The transmissivity of the aquifer is greatest in northern Ocean County (greater than 16,000 ft^2/d), but the aquifer is most productive in Burlington, Camden, and Gloucester Counties in, and within a short distance from, the outcrop area where the transmissivity ranges from 6,000 ft^2/d to more than 10,000 ft^2/d (Martin, 1998). To the southwest, discontinuous silt and clay beds within the Middle aquifer in Salem County inhibit its productivity. The Middle PRM aquifer is continuous into Delaware where it is composed of the sandy parts within the upper part of the Potomac Formation. The updip limit of the aquifer in Delaware is within the outcrop of the Potomac Formation in northern New Castle County. The downdip limit of the freshwater-saltwater interface, as indicated by the 10,000 mg/L isochlor, extends into eastern Sussex County, Delaware.

The Lower PRM aquifer is the lowermost aquifer within the Coastal Plain of New Jersey and Delaware. The aquifer does not crop out in New Jersey but is entirely overlain by the confining bed separating the Middle and the Lower PRM aquifers. The aquifer is recognizable about 8 to 12 mi downdip from the outcrop area of the Potomac and Raritan Formations (Zapecza, 1989); beyond this limit the aquifer cannot be differentiated from the overlying sediments of the Middle PRM aquifer. The transmissivity of the aquifer is highest in northwestern and central Camden County and adjoining areas in Gloucester and Burlington Counties; this is where the aquifer is most productive. The Lower PRM is continuous into Delaware, coinciding with the lower part of the Potomac Formation. The updip limit of the aquifer in Delaware lies between the western edge of the Coastal Plain sediments and the updip limit of the Middle PRM aquifer; the downdip limit is in northern Kent County (Vroblesky and Fleck, 1991).

Extent of Saline Water

The PRM aquifer system contains saline water throughout a broad area of southern New Jersey (2,490 mi^2), extending from the banks of the Delaware River in Salem and Gloucester Counties east through southern Ocean County and to the south, encompassing parts of Burlington, Camden, and Ocean Counties, much of Gloucester and Salem Counties, and all of Atlantic, Cumberland, and Cape May Counties (fig. 20). The presence of saline water in the aquifer system throughout much of southern New Jersey largely resulted from past seawater incursions and the subsequent deposition of paleoseawaters that accompanied eustatic rises in sea level. Long residence times and continued reaction with minerals in the aquifer matrix, particularly in far downdip areas in southern New Jersey, resulted in a dense, highly mineralized, and geochemically mature groundwater. These waters have not yet been flushed with more dilute groundwater from northern recharge areas owing to low freshwater heads at and near the transitional zone. The saltwater front arcs in the updip direction and toward the Delaware River in southern Gloucester County, reflecting predevelopment flow paths and movement of groundwater toward predevelopment discharge areas. Chloride concentrations in the groundwater range from 1 mg/L to more than 20,000 mg/L, generally increasing in the seaward

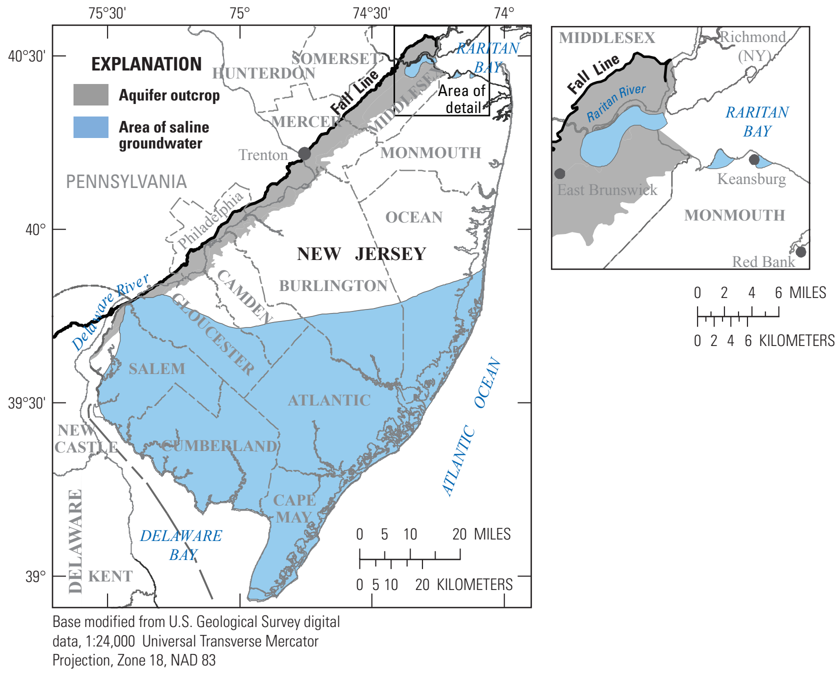


Figure 20. Area of saline groundwater, Potomac-Raritan-Magothy aquifer system, New Jersey, 2008.

direction and with depth throughout the aquifer system. Although saline groundwater in deeper parts of the aquifer system in Salem, Gloucester, and Cumberland Counties occasionally exhibits geochemical properties similar to those of seawater (sodium and bromide to chloride ratios of 0.86 and 1.5×10^{-3}, respectively), the composition of the groundwater generally indicates a reverse base-exchange reaction, whereby calcium and magnesium ions are lost to sodium-bearing exchange sites, resulting in sodium enrichment of the groundwater (Meisler, 1989). As sodium enrichment progresses, calcium-magnesium to chloride ratios decrease relative to those for seawater. Concurrent increases in boron to chloride ratios in the groundwater relative to seawater are consistent with desorption from clay confining units (Pucci and others, 1997; DePaul and Szabo, 2007; Vinson and others, 2011). Because the aquifer system is in good hydraulic connection with the Delaware River in Camden, Gloucester, and to a lesser degree in Salem County (Navoy and others 2005), induced infiltration during periods of drought and low river discharge may also be a source of chloride contamination in southern New Jersey.

In the northern parts of the Coastal Plain, the PRM aquifer system underlying Middlesex and Monmouth Counties is hydraulically connected to the Raritan and South Rivers, the Washington Canal, and the Raritan Bay, permitting saline water to recharge the aquifer system where prevailing hydraulic gradients are landward (Pucci and others, 1994).

Within the Upper PRM aquifer, freshwater is present throughout much of the updip extent, but saline water is present in Salem County, east through southern Ocean County and south, encompassing most of Atlantic and all of Cumberland and Cape May Counties (pl. 7). Chloride concentrations in the Upper aquifer range from 1 mg/L to more than 4,000 mg/L. The lowest concentrations occurred in mid-dip and downdip areas of the aquifer throughout Monmouth, Middlesex, northern Ocean, Burlington, and Camden Counties, where values are less than 10 mg/L. In updip areas adjacent to the aquifer outcrop, concentrations are typically higher, ranging from 2 to 92 mg/L, likely resulting from anthropogenic sources such as road deicers and agricultural runoff in nearby recharge areas. The highest concentrations of chloride were observed in the downdip areas of Salem and Gloucester Counties and in areas of limited extent near the Raritan Bay in northern Monmouth County.

In areas adjacent to, and where the Upper PRM is in good hydraulic connection with, the Raritan Bay, saline water recharges the aquifer underlying parts of Keyport, Union Beach, and Keansburg. Increasing chloride concentrations and the related chemical quality of groundwater during the past decade (1998–2008) indicate continued active saltwater intrusion in this area. From 1998 to 2008 chloride concentrations in wells 25-206 and 25-567 increased at rates of more than 60 mg/L per year. In southern New Jersey, saline groundwater is present within the aquifer throughout large parts of southern Salem, central and western Gloucester, and southern Camden Counties. Saline groundwater occurs throughout all of Cumberland County and points south and likely beneath much of Atlantic and parts of southern Burlington and Ocean Counties. Water-quality data for the area east of Gloucester County is limited, and the location of the freshwater-saltwater interface is inferred from water-quality data for wells located to the north and by the relative position of this interface within the underlying Middle PRM aquifer. Chloride concentrations ranged from less than 1 mg/L to 30 mg/L in and around the Camden cone of depression to as high as 250 mg/L in central Gloucester County. At observation wells in the downdip direction of the saltwater front, chloride concentrations are as high as 3,300 mg/L. Trends in chloride concentrations are most often upward along this line in the direction of the Camden cone of depression, particularly at production wells in Glassboro and Clayton, although annual rates of increase typically are small.

Within the Middle PRM aquifer, groundwater is generally fresh throughout the northern counties, except in areas where the aquifer underlies or is adjacent to the Raritan and South Rivers in Middlesex County. The recent movement of the saltwater front in the Raritan River and Bay area and the extent of saline groundwater are not fully known because of the lack of current data and wells open to the aquifer; therefore, the mapped location of this line has not changed during the past several data-collection cycles. Recent (2006–8) water-quality data for a limited number of observation wells, however, indicate that moderate to highly saline groundwater (500–4,800 mg/L) is still (2008) present in the Sayreville area of Middlesex County. Within the southern extent of the Middle PRM aquifer, the saltwater front roughly bisects southern New Jersey from Salem County in the west to southern Ocean County in the east. In similar fashion to the geographic pattern of saltwater occurrence in the Upper aquifer, a tongue of saline groundwater arcs in an updip direction toward areas of higher potentiometric head in central Gloucester County (pl. 8). To the west of this line in Salem County, trends in dissolved chloride in groundwater were not significant or, in some cases, were downward for 1998 to 2008. Northeast of this line, toward the Camden cone of depression but in areas where chloride concentrations are low to moderate (15 to 60 mg/L), slight upward trends were sometimes observed for production wells.

The extent of freshwater within the Lower PRM aquifer is shown on plate 9. The location of the saltwater front, based on previously published works by Barksdale and others (1958), Gill and Farlekas (1976), and Schaefer (1983), was updated by using recent water-quality data (DePaul and others, 2009). Chloride concentrations in groundwater from the Lower PRM aquifer ranged from less than 2 mg/L to more than 11,000 mg/L. The lowest concentrations, which generally did not exceed 20 mg/L, occurred in downdip areas of Burlington and Camden Counties and away from the Delaware River. Highest concentrations of chloride are present in the aquifer underlying much of western Gloucester County and northwestern Salem County and areas to the south and east, where concentrations ranged from 143 to 850 mg/L. The presence of chloride concentrations in excess of 22,000 mg/L has also been determined in groundwater in eastern Cumberland County where, in the undifferentiated part of the system, highly concentrated brines are encountered at depths of 3,000 ft or greater. The simulated 10,000 mg/L isochlor trends northeast to southwest from southern Burlington to southern Salem County (Pope and Gordon, 1999). This line, along with the 250-mg/L isochlor, approximately defines the transition or dispersion zone, whereby fresh and saline groundwater mix primarily through the process of diffusion but by advection and mechanical dispersion as well. The simulated location of this line is 2 mi in the downdip direction from the 250-mg/L isochlor in Gloucester and 3 mi distant in southern Salem County, indicating a laterally narrow zone of dispersion in places.

Groundwater Flow System

Groundwater flow in the Potomac-Raritan-Magothy aquifer system is discussed in detail in Martin (1998) and Voronin (2004), and for the Camden area, in Navoy and Carleton (1995). Prior to water-supply development (pre-1900), groundwater flow within the PRM aquifer system was controlled primarily by variations in hydraulic properties of the saturated sediments, as well as by land-surface topography. The aquifer system was recharged by precipitation at outcrop areas in Mercer and Middlesex Counties and by leakage from the overlying Englishtown aquifer system. Groundwater flowed to the east and southeast from topographic highs in Mercer, Monmouth, and Middlesex Counties toward topographic low points near the Raritan Bay and the Atlantic Ocean. Groundwater in the shallow part of the system followed short flow paths and discharged locally to surface-water bodies; water that entered the deeper, regional groundwater flow system followed intermediate and relatively long flow paths toward discharge points beneath the Raritan Bay and Atlantic Ocean. Longer flow paths curved toward the southwest, trending arcuately across, then up the aquifer dip, discharging to the Delaware River and other low-lying surface-water bodies in outcrop areas of Camden, Gloucester, and Salem Counties (Martin, 1998; Spitz and DePaul, 2008).

After development, potentiometric surfaces and groundwater flow patterns in the PRM aquifer system were substantially altered by the location and magnitude of groundwater withdrawals. Withdrawals throughout the system had increased, causing groundwater levels to decline and large cones of depression to form. Long flow paths indicative of the unstressed system were supplanted by short and intermediate flow paths in many places, with groundwater discharging to pumped wells. By the early 1980s, cones of depression had formed in both the Upper and Middle aquifers in the northern section of the Coastal Plain, marked by water levels below -50 ft in both the Upper and Middle aquifers, and water levels in the Middle aquifer were below -100 ft in northern Monmouth County. In southern New Jersey, regional cones of depression underlying central Camden County extended more than 45 miles in the downdip direction and encompassed all three aquifers. By the late 1980s and early 1990s, groundwater levels in the Upper, Middle, and Lower PRM aquifers had reached minima of -109, -92, and -107 ft , respectively. Owing to this decline, groundwater flow patterns were reversed such that recharge and discharge were redistributed throughout the system, and areas that once supplied recharge to downdip areas of the aquifer now (2008) supply discharge to production wells. Moreover, areas of discharge, such as those in the southwestern part of the State adjacent to the Delaware River, were converted to recharge areas.

With the establishment of the Critical Areas and associated management strategies, the progressive, long-term declines in groundwater levels began to stabilize and subsequently recover. By 2008 groundwater levels typically recovered from 10 ft to more than 30 ft in the Upper and Middle aquifers across much of Monmouth County, with maximum recoveries of 37 ft and 51 ft, respectively. In Middlesex County, recovery of groundwater levels in the Middle aquifer typically ranged from less than 10 ft to 40 ft but was as much as 67 ft. Recovery in northern Ocean County was less dynamic and ranged from 2 ft to 25 ft. In places, water levels continued to decline in the Upper aquifer. In southern New Jersey groundwater levels recovered by as much as 53, 40, and 50 ft in the Upper, Middle, and Lower aquifers, respectively.

A more detailed discussion of groundwater-level recovery in the PRM aquifers as a result of Critical Area management strategies is provided in Spitz and others (2008), DePaul and others (2009), and Spitz and DePaul (2008). Groundwater-level conditions in the PRM aquifer system during fall 2008 are discussed in the following sections.

Upper Potomac-Raritan-Magothy Aquifer

Water Withdrawals

Withdrawals from the Upper PRM aquifer are made in Middlesex, Monmouth, and northern Ocean Counties from upland recharge areas to the Atlantic coastline **(**fig. 21*A***)**; however, in the southern part of the study area from Burlington County south to Salem County, withdrawals are confined to a narrow band extending from the aquifer outcrop to about 12 mi downdip. Beyond this limit, depth to the top of the aquifer is substantial and elevated (higher than background) dissolved solids in the groundwater prompts the use of shallower aquifers. The primary pumping centers are located in eastern Middlesex County within and near the outcrop of the Magothy Formation and in central Camden and Gloucester Counties. Substantial withdrawals also are made in northwestern Burlington, northern Ocean, and throughout Monmouth County. Minor withdrawals are made in Mercer County and in Salem County within close proximity to the up dip limit of the aquifer.

Estimated groundwater withdrawals from the Upper PRM aquifer during 1978–2008 ranged from 54.4 to 80.5 Mgal/d; average withdrawals during 2008 were 55.1 Mgal/d (fig. 22*A*; table 3). Withdrawals peaked during the early to mid-1980s prior to emplacement of mandatory restrictions and alternative sources of supply. From 1989 to 1995, withdrawals were relatively constant, ranging from 65 to 69 Mgal/d, and were followed by a reduction of 8 Mgal/d or 12 percent during 1994–95. From 1996 to 2008 withdrawals ranged from 54.4 to 62.9 Mgal/d with reductions occurring in successive years, except for 2000–1, 2004–5 and 2006–7. Average withdrawals throughout the aquifer during 2008 were about the same as in 2003.

Upper PRM aquifer withdrawals were highest in Middlesex, Gloucester, and Monmouth Counties, at 15.8, 8.7, and 8.6 Mgal/d, respectively (table 3). Throughout the northern counties average withdrawals during 2008 were 32 Mgal/d, nearly 30 percent greater than those in the southern counties (table 3, fig. 22*A*). Combined withdrawals from the northern counties peaked from 1981 to 1984 (approximately 47 Mgal/d); from 1984 to 2000, withdrawals generally decreased in successive years with the largest reductions occurring during 1988–89. A marked increase occurred during 2001 when withdrawals were 17 percent greater than during the previous year. Withdrawals decreased again by 2003 and were followed by modest increases in 2005 and 2007. In the southern counties, water withdrawals generally were stable (approximately 30–32 Mgal/d) from 1978 through 1995; in 1996 withdrawals decreased to 27 Mgal/d, or by 16 percent, from the year prior. Mandatory restrictions on withdrawals from the Upper PRM aquifer further reduced these amounts, and from 1997 to 2008, withdrawals ranged from 23 to 27 Mgal/d. Average withdrawals during 2008 (23 Mgal/d) were at the low end of this range.

Water Levels

The potentiometric surface map for 2008 for the Upper PRM aquifer is shown on plate 7; supporting water-level data used to construct this map are provided in appendix 7. The dominant feature of the potentiometric surface is the extensive cone of depression that extends from the Raritan Bay in the northeastern part of the study area to Salem and Cumberland Counties in the southwest. The highest groundwater altitudes occurred in and near the outcrop area in eastern Mercer and Middlesex Counties; the lowest groundwater altitudes occurred in northern Ocean and central Camden Counties. Previous water-level studies documented low water levels extending into northern Delaware and eastern Maryland (Lacombe and Rosman, 2001; DePaul and others, 2009). Because of the unavailability of data during 2008, groundwater conditions in the Upper PRM aquifer in Delaware were not determined.

The regional cone of depression can be divided into two sub-regional segments, northeastern and southwestern segments. The northeastern sub-regional depression encompasses most of Ocean and Monmouth Counties. This cone of depression has expanded and deepened since the 2003 study as a result of continued increases in groundwater withdrawals. The well-defined center of the cone is beneath pumping centers

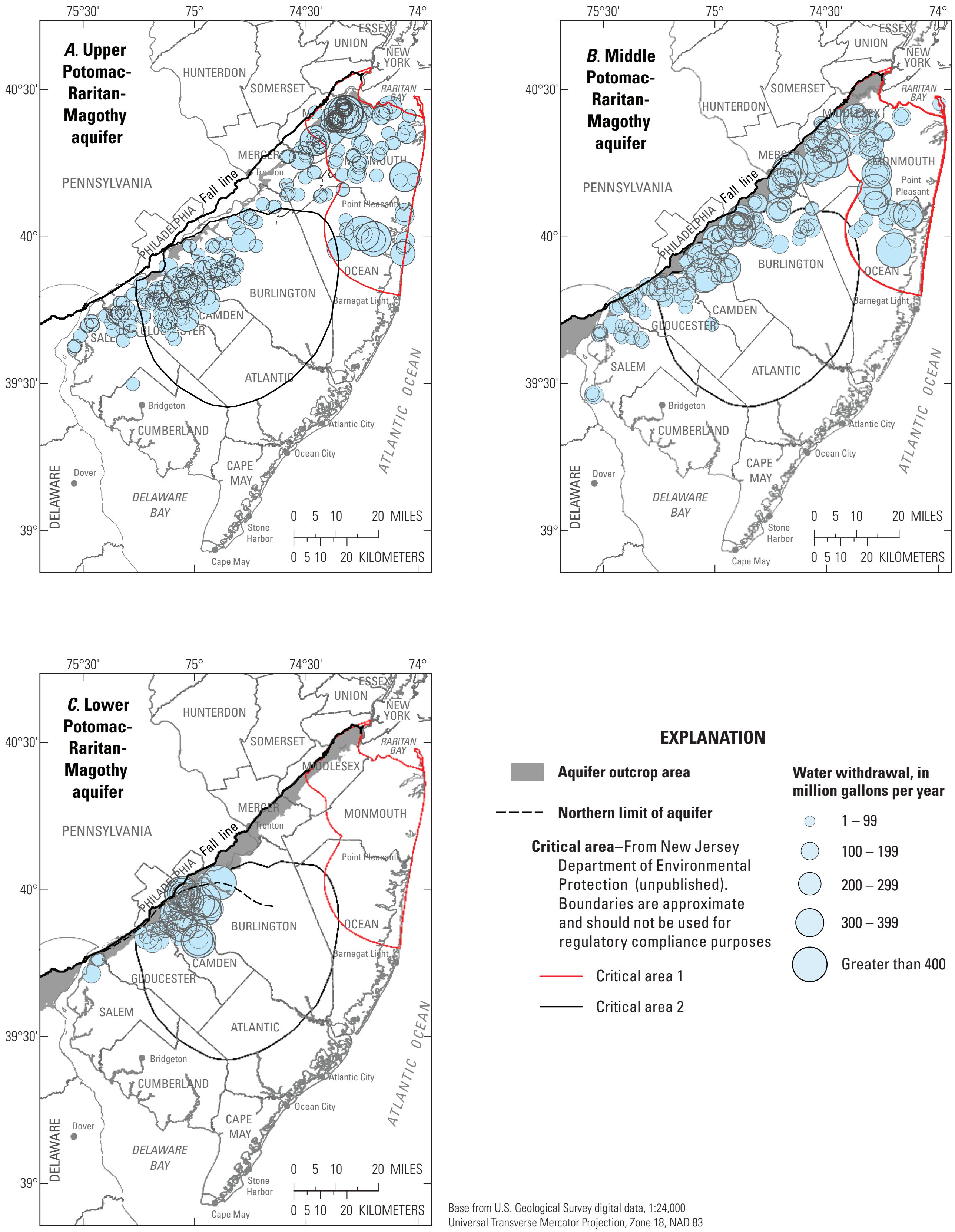


Figure 21. Location and volume of groundwater withdrawals from *A*, the Upper Potomac-Raritan-Magothy aquifer, *B*, the Middle Potomac-Raritan-Magothy aquifer, and *C*, the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 2008.

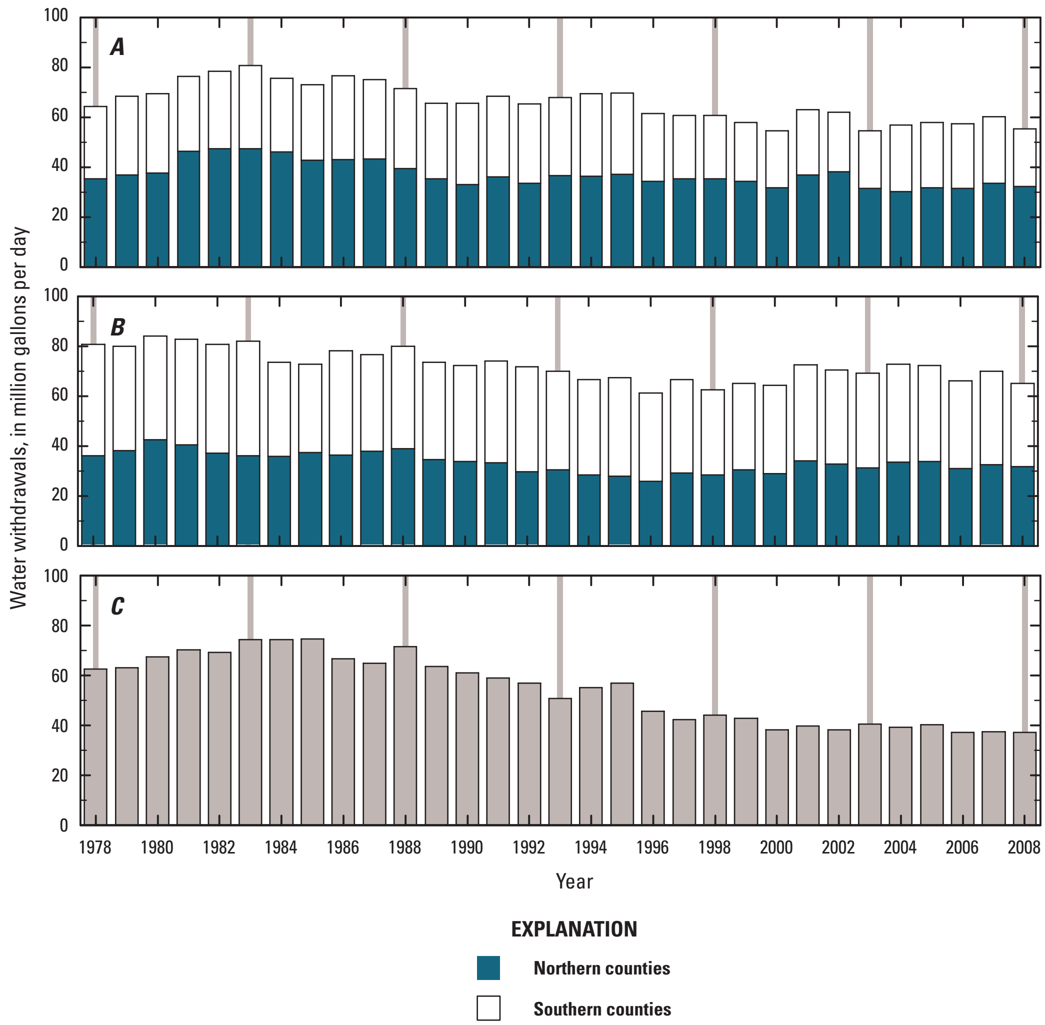


Figure 22. Estimated groundwater withdrawals from *A*, the Upper Potomac-Raritan-Magothy aquifer, *B*, the Middle Potomac-Raritan-Magothy aquifer, and *C*, the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008. (Thin vertical bars denote 5-yr data collection periods)

in Manchester and Toms River Townships and Lakehurst Borough; groundwater altitudes in this area ranged from -81 to -95 ft. Lateral hydraulic gradients are steeper on the updip side of this cone (because of proximity to recharge at and near the outcrop) than on the downdip side; therefore, hydraulic stress extends eastward and beneath the Barnegat Bay, encompassing pumping centers on the barrier island from Mantoloking to Seaside Heights. Moreover, despite constant or decreasing withdrawals on the barrier islands, water levels were generally lower than in 2003 and likely were affected by increases in groundwater withdrawals to the west. The small, localized cone near Seaside Heights has deepened, and water levels throughout the barrier islands declined by 6 ft to as much as 15 ft. Approximately 15 mi to the southwest, the water level in well 5-1391 declined by nearly 10 ft to -35 ft, and the area of aquifer encompassed by the -30 ft potentiometric contour became contiguous with that in southern New Jersey.

Elsewhere throughout the northern counties, water levels ranged from -37 to 76 ft with high altitudes near the outcrop in Mercer and Middlesex Counties and low altitudes at the center of a localized depression near Asbury Park. Such localized depressions were more common in the potentiometric surfaces during previous studies; however, owing to rising water levels in central and northern Monmouth County coupled with declining water levels in southern Monmouth and northern Ocean Counties, such depressions are no longer evident.

The southern segment of the regional cone of depression encompasses much of Burlington, Camden, Gloucester, and eastern Salem Counties. In areas where data are sparse or absent, simulated potentiometric contours by Voronin (2004) were adapted to close the contours on the downdip edge of the regional cone. Groundwater-level altitudes in this segment ranged from highs of 0–19 ft in extreme updip areas of Burlington and Salem Counties to lows of -70 to -91 ft at and near the center of the cone in Berlin, Pine Hill, and Clementon in Camden County and Medford Lakes in Burlington County. From 2003 to 2008, water levels in this central segment, in general, remained stable or had recovered modestly; however, water levels at the center of the cone were as much as 16 ft higher in 2008.

Water-level differences between the Upper and Middle PRM aquifers are generally small to moderate near the outcrop and to about 8 mi downdip, ranging from near neutral to approximately 20 ft and indicating the potential for downward flow out of the Upper PRM aquifer. Vertical head differences in the southwest in Salem County are locally as much as 30 ft along the Delaware River and, in the northeast within and along the outcrop of the Magothy Formation in Middlesex and western Monmouth Counties, range from 20 ft to as much as 50 ft above the potentiometric low in the Middle PRM aquifer. The potential for downward flow from the outcrop to the underlying Middle aquifer is greatest in this area, and the natural flow patterns have been altered such that recharge to the Middle aquifer is enhanced, reducing the volume of groundwater in the Upper aquifer that formerly flowed to the south and east. Because of the reduction of groundwater flow in the Upper aquifer, coupled with the loss of upward discharge beneath the Raritan Bay from both the Upper and Middle PRM aquifers, refreshening of the aquifer in the Union Beach area cannot progress. In eastern Monmouth County, the vertical gradient reverses; groundwater altitudes in the Upper PRM aquifer are as much as 25 feet lower than in the underlying Middle PRM aquifer in the Red Bank, Monmouth County, and area. In north-central Ocean County within the cone of depression near Lakehurst, vertical head differences between the Upper and Middle aquifers increase to nearly 70 ft, and the potential for vertical flow is upward into the Upper PRM. In southern New Jersey, near the cone of depression in Camden and Burlington Counties, vertical head differences range from 10 to 20 ft, and flow is upward from the Middle aquifer. To the south and southeast (downdip) from the cone of depression, vertical head differences are uncertain owing to the limited amount of data in these areas.

Vertical head differences between the Upper PRM aquifer and the Englishtown aquifer system are substantially greater than those between the Upper and Middle PRM aquifers. Head differences and potential for downward flow into the aquifer are greatest in updip and mid-dip areas. Estimated vertical head differences in 2008 were as much as 104 ft in Camden, 117 ft in Western Monmouth, and 115 ft in northwestern Ocean County. In eastern Monmouth and northeastern Ocean County, however, groundwater altitudes are higher in the Upper PRM than in the Englishtown aquifer system. Despite differences of more than 40 ft between the Upper PRM and the Englishtown aquifer system beneath the cone of depression in eastern Monmouth and Ocean Counties, upward flow is probably limited because of the thickness and low permeability of the overlying Merchantville-Woodbury confining unit (Martin, 1998).

The mapped difference in the potentiometric surfaces of the Upper PRM aquifer from 2003 to 2008 is shown in figure 23*A*. Of 182 wells measured in 2003 and 2008, water levels declined in 110 (60 percent) wells in 2008; declines of 5 ft or greater were observed in 50 wells (27 percent) and declines of 10 ft or more in 21 wells (12 percent). In contrast, water levels rose in 61 wells (34 percent); rises of 5 ft or greater were observed in 27 wells (15 percent), and rises of 10 ft or more were observed in 6 wells (3 percent). Water levels remained about the same in 11 wells (6 percent). Results of the Wilcoxon signed-rank test indicate that, on an aquifer-wide basis, water levels were statistically lower in 2008 than in 2003 (appendix 10-2). When grouped by county, this relation held for Monmouth, Ocean, and Salem Counties but was strongest for Monmouth and Ocean, providing further evidence of declining groundwater levels in these areas as shown in figure 23*A*. In Burlington, Gloucester, and Middlesex Counties, differences in water levels from 2003 to 2008 are not significant; however, differences in Camden County were substantially higher. Similarly, water levels, grouped according to management area, declined in Critical Area 1 but recovered in Critical Area 2. For the 10-year period, significant declines occurred in Critical Area 1, as well as in the sub-regional group of Middlesex, Monmouth, and Ocean Counties. Water-level increases occurred in Critical Area 2, as well as in the sub-regional group of Burlington, Camden, and Gloucester Counties.

Results of the Mann-Kendall trend analysis are listed in appendix 10-1; supporting water-level hydrographs for the northern and southern counties are shown in figures 24 and 25, respectively. In the northern counties, water levels followed an upward trend from 2003 to 2008 at two wells (23-292 and 23-228). Trends were insignificant at 3 wells (23-351 25-206, 25-316), and a downward trend was observed at 1 well (25-639). Observation well 25-639 is located in southern Monmouth County at the northern edge of the expanding sub-regional depression. In the southern counties, upward trends from 2003 to 2008 were observed at 2 wells (5-258 and 7-117), and insubstantial trends were observed at 2 wells (7-477 and 15-741). Downward trends were observed at two wells (15-728 and 33-253); both are located beyond the boundary of Critical Area 2. Downward trends for wells in the southern counties, though statistically significant, were generally small with annual rates of decline of less than 0.6 ft that are sometimes difficult to see graphically. The absence of nearby withdrawals and the lack of distinct seasonality in water levels in well 33-253, much like those in observation wells in Delaware, indicate regional influences from withdrawals and sustained head declines in adjacent aquifers on both sides of the Delaware Bay (DePaul and others, 2009).

From 1998 to 2008, for observation wells in the northern counties, trends were similar to those observed during the 5-year period; trends were upward in 2 wells (23-228 and 23-292), insignificant in 3 wells (23-351, 25-206, and 25-316), and downward in well 25-639 along the periphery of the cone

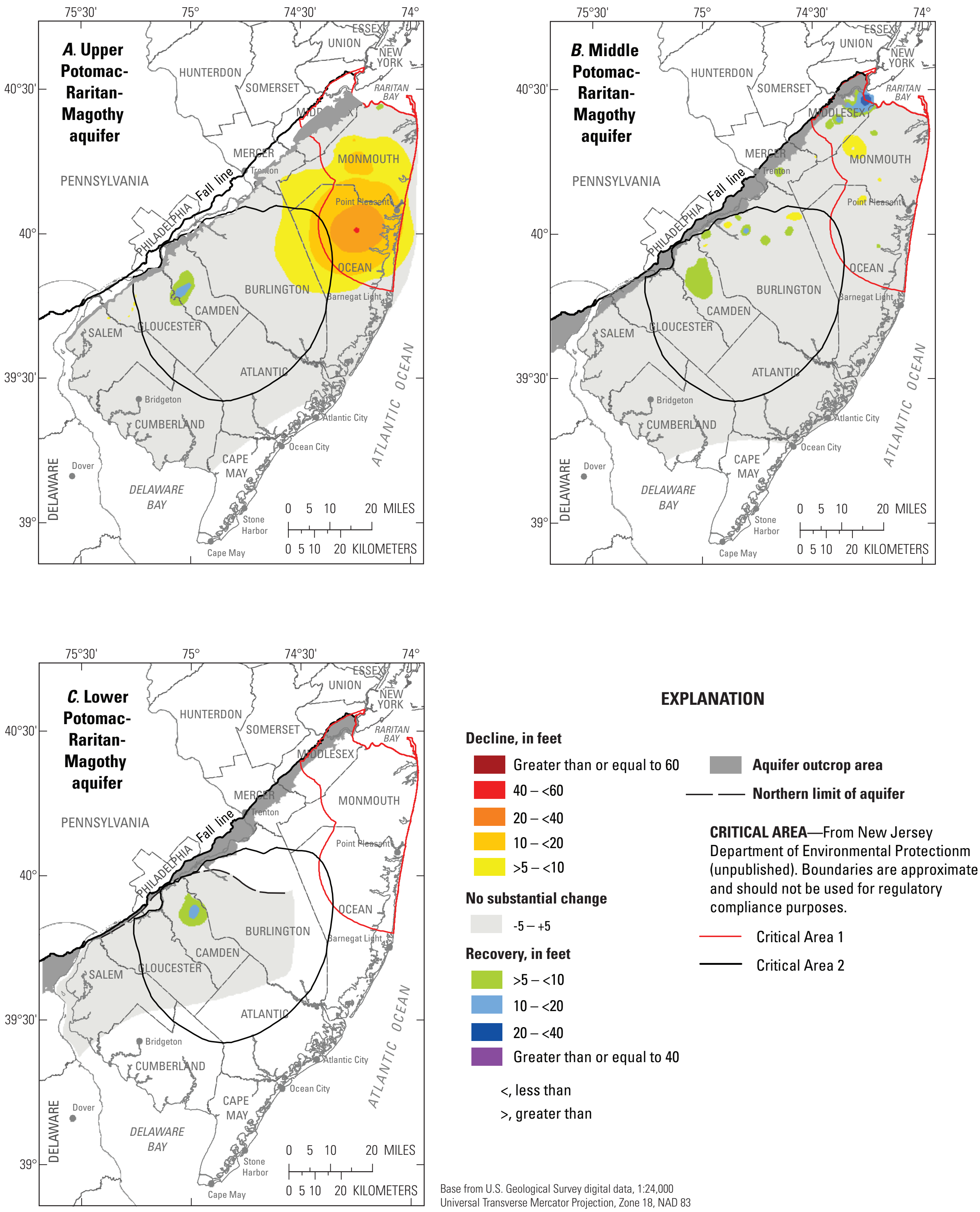


Figure 23. Groundwater-level changes in the *A*, Upper Potomac-Raritan-Magothy aquifer, *B*, Middle Potomac-Raritan-Magothy aquifer, and *C*, Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 2003–8.

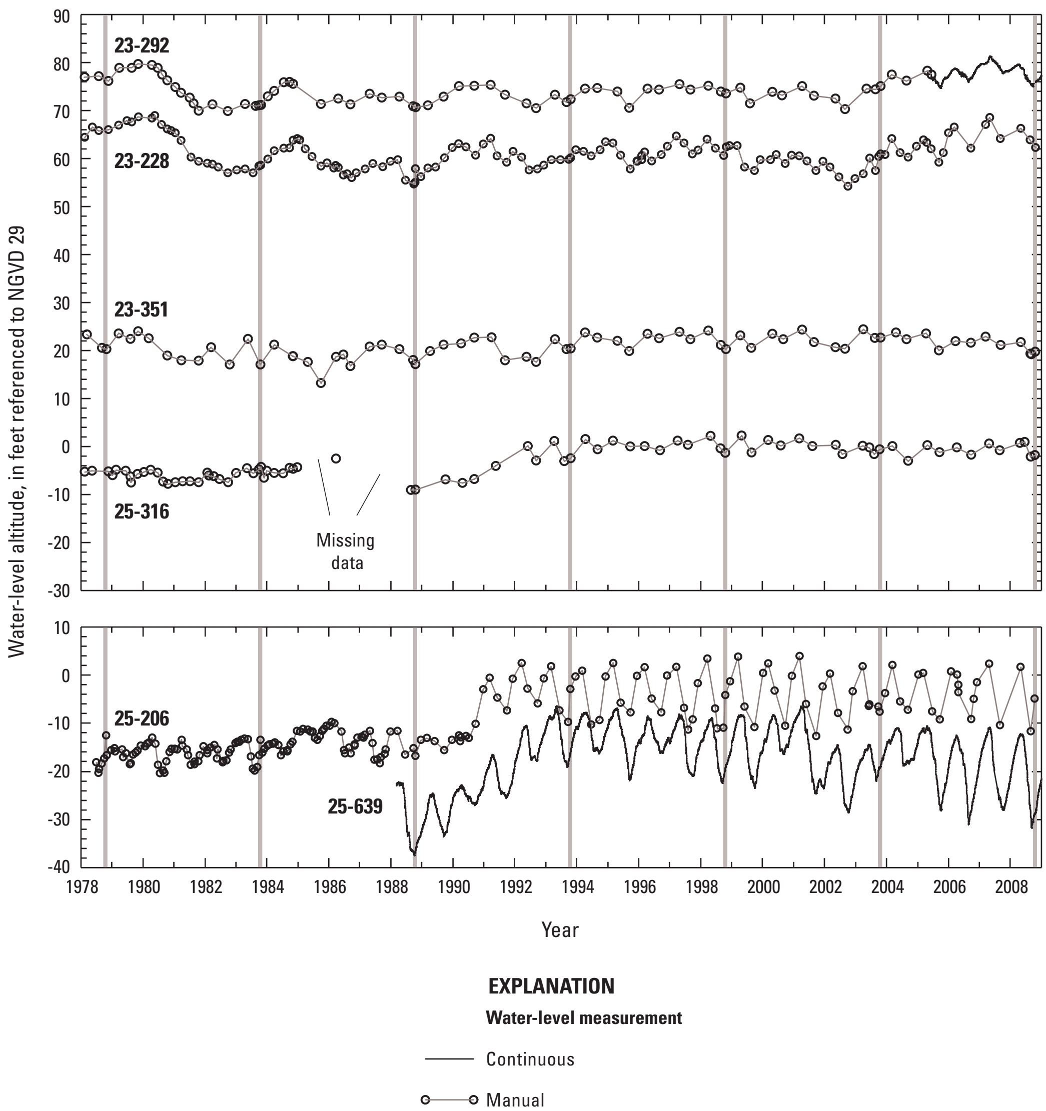


Figure 24. Water-level hydrographs for selected observation wells screened in the Upper Potomac-Raritan-Magothy aquifer in the northern counties, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 7)

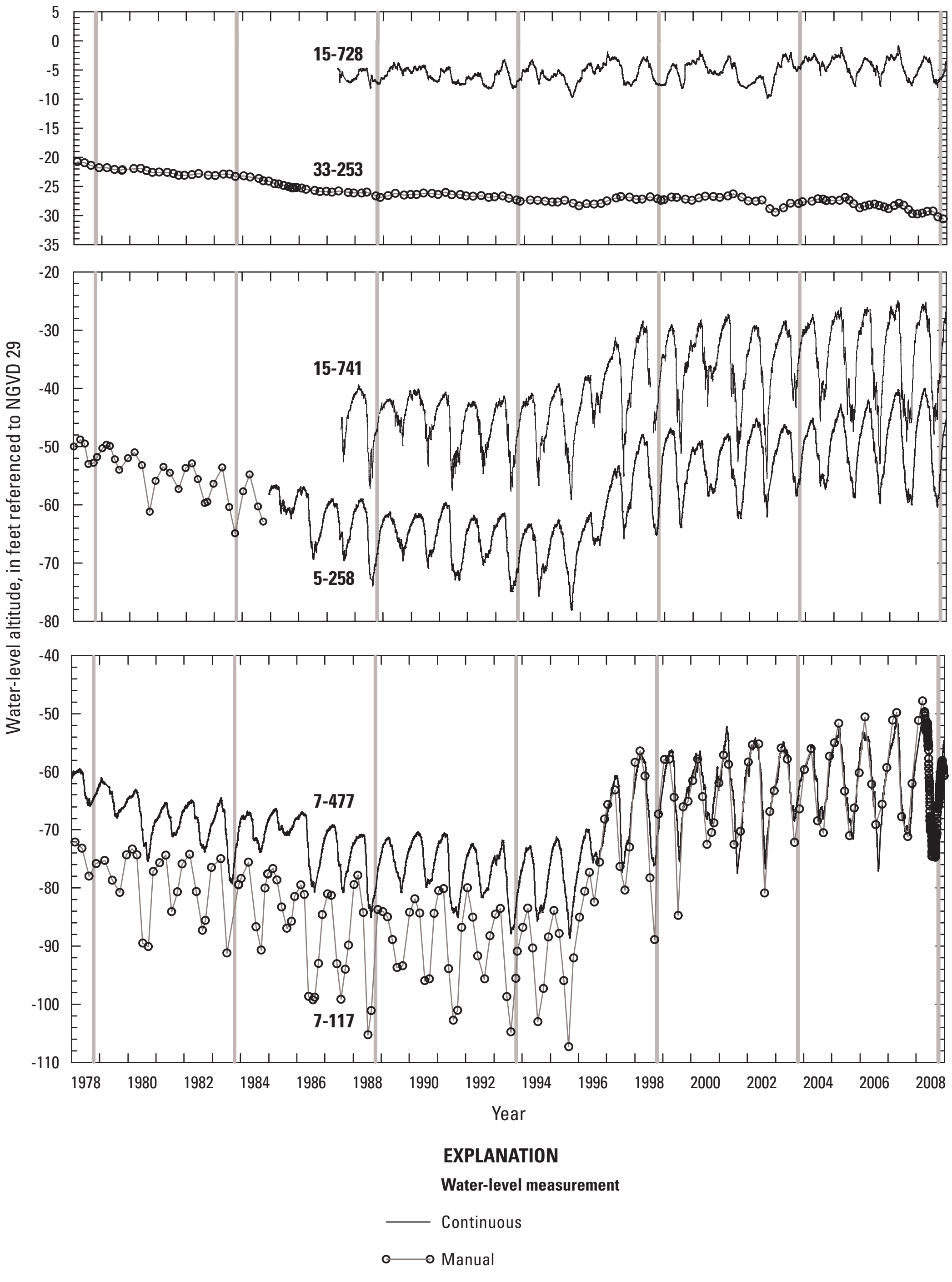


Figure 25. Water-level hydrographs for selected observation wells screened in the Upper Potomac-Raritan-Magothy aquifer in the southern counties, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 7)

of depression. For observation wells in the southern counties, trends were upward at four wells (5-258, 7-117, 7-477, and 15-741). The 10-year trend at well 15-728 was considered insignificant; a downward trend was indicated for well 33-253.

In the northern Coastal Plain counties from 1978 to 2008 upward water-level trends were observed at 3 wells (23-292, 25-206 and 25-316), and water-level change was insubstantial at 3 wells (23-228, 23-351, and 25-639) (app. 10-1). The upward trend at well 25-206 was attained largely through a substantial rise in water levels during 1990–92, which corresponds to the cessation of withdrawals from the aquifer. In the southern counties, upward trends in water levels were determined for four wells (same as those for the 10-year period); rates of recovery ranged from 0.36 to 1.13 ft/yr. Results also indicate slightly increasing water levels in well 15-728; however, the annual rate of recovery was considered insubstantial. The highest annual rates of recovery coincided with the steepest lateral hydraulic gradients on the updip side of the regional cone of depression; annual rates of recovery were lower on the northern and downdip sides of the depression. A downward trend was observed for well 33-253 for the 30-year period; the net change in the water level in this well was 9 ft.

Middle Potomac-Raritan-Magothy Aquifer

Water Withdrawals

Groundwater withdrawals from the Middle and undifferentiated PRM aquifer occurred throughout its extent from the Raritan Bay to Salem County. Primary pumping centers in the aquifer's northern extent are located in eastern Middlesex, northern Monmouth, and northern Ocean Counties and, in the south, Burlington, Camden, Gloucester, and Salem Counties. The distribution of withdrawals is similar to that in the Upper PRM aquifer in that withdrawals are made in the updip and mid-dip areas of the aquifer throughout the northern counties of New Jersey, but withdrawals are confined to a relatively narrow band extending from the outcrop to approximately 8 mi downdip in the southern counties (fig. 21*B*). Beyond this limit, the presence of elevated concentrations of dissolved solids in the groundwater inhibits development of the aquifer.

Groundwater withdrawals from the Middle PRM aquifer from 1978 to 2008 ranged from 61 to 84 Mgal/d (fig. 22*B*). Withdrawals peaked during the early 1980s, but from 1984 to 2000, withdrawals were reduced by 18 Mgal/d (22 percent) as a result of mandated Critical Area cutbacks. From 2001 to 2005, however, withdrawals increased by 13 percent. By 2008 average withdrawals throughout the aquifer declined again, and the reported withdrawals of nearly 65 Mgal/d represent a 6-percent decrease from 2003, the year of the last regional water-level study (table 3).

In the northern counties of New Jersey, average withdrawals ranged from 26 to 43 Mgal/d from 1978 to 2008. Withdrawals generally decreased during 1980–96; Critical Area restrictions triggered notable single-year reductions from 1988 to 1989 and again from 1991 to 1992. From 1997 to 2002, withdrawals again increased and by 2005 were approximately 34 Mgal/d. Withdrawals across the northern counties subsequently declined and in 2008 were at 32 Mgal/d, nearly 1 Mgal/d greater than the 2003 withdrawals. In the northern counties in 2008, average groundwater withdrawals were greatest in Mercer County (9 Mgal/d), followed by Middlesex, Monmouth, and Ocean Counties at 8.4, 7.3, and 7.0 Mgal/d, respectively (table 3). Historically, withdrawals among the northern counties were greatest in Middlesex County and, at their maximum in 1980, exceeded 15 Mgal/d. Declining water levels and saltwater encroachment along tidal reaches of the Raritan River and its tributaries led to the systematic reduction of withdrawals in this area, and by 1990, average withdrawals were approximately 8 Mgal/d. Since 1991, however, average withdrawals throughout Middlesex County increased and receded during successive short 1- to 3-year periods. During 1998–2008, average withdrawals in Middlesex County peaked in 2004 at 11.2 Mgal/d, but withdrawals decreased during 2005–8. In Ocean County, average withdrawals decreased by approximately 7.2 Mgal/d or 58 percent during 1980–98; thereafter, average withdrawals ranged from 6 to 8 Mgal/d. Withdrawals in Monmouth County followed a similar trend with the smallest annual volumes withdrawn during 1992–97. Withdrawals increased slightly in 1998 and, from 1999 to 2000, ranged from 5.7 to 7.3 Mgal/d. In comparison, withdrawals from the aquifer in Mercer County were relatively constant during the 1980s, ranging from 7 to 8 Mgal/d, increased in 1991, and stabilized through the early 2000s until peaking in 2007 at 9.5 Mgal/d.

Withdrawals from the aquifer in the southern counties were slightly greater on average than those in northern counties during 1978–2008. Average groundwater withdrawals in the southern counties ranged from 33.3 to 46.1 Mgal/d during the 30-period. Groundwater withdrawals in the combined southern counties peaked in 1983, decreased by nearly 9 Mgal/d to 37 Mgal/d in 1984 and were relatively constant from 1986 to 2007, alternately increasing or decreasing in any given year by 1 to 10 percent. Average withdrawals in 2008 of approximately 33 Mgal/d were at their lowest levels since 1978. Withdrawals from the aquifer in southern New Jersey were greatest in Burlington County and least in Salem County.

Water Levels

Water-level data from 173 wells open to the Middle and undifferentiated PRM aquifer are provided in appendix 8; the 2008 potentiometric surface is shown on plate 8. The highest groundwater-level altitudes in the Middle PRM aquifer occurred near the updip limit in Mercer and Middlesex County, New Jersey. This potentiometric high coincides with groundwater highs in the overlying Upper PRM aquifer and is where the aquifer historically received most of the recharge. The lowest groundwater-level altitudes occurred in central Camden County where they are associated with the long-term regional cone of depression and in southwestern Salem County, adjacent to the Delaware Estuary. The major feature of the potentiometric surface is the regionally extensive cone of depression that encompasses much of the study area and extends from the Raritan Bay in the northeast to Salem in the southwest. Much like the regional cone of depression in the Upper PRM aquifer, several discrete sub-regional cones or areas of low potentiometric head are present within the northern, north-central, central, and southwestern parts of the larger cone.

The northern segment underlies eastern Middlesex County and part of northwestern Monmouth County in New Jersey and is within Critical Area 1. Groundwater altitudes in the northern segment of the regional cone ranged from -11 ft (well 23-194) to -36 ft (well 25-545) in 2008; water levels were lowest along the Raritan Bay front and inland and south to about 6 mi. Groundwater altitudes increased toward the outcrop because of topographic influences. The north-central area of the regional cone of depression includes much of southeastern Monmouth County and is within Critical Area 1. Groundwater altitudes in this segment ranged from -11 to -33 ft (wells 23-194 and 25-272); lowest altitudes occurred near pumping centers in and around Freehold, with groundwater altitudes increasing to the north and west.

The central segment of the regional cone of depression underlies a broad area of the New Jersey Coastal Plain, extending from Ocean County southwest to Gloucester County and eastward to Atlantic County; it includes substantial parts of Burlington and Camden Counties. Water-level altitudes in this segment ranged from 0 ft to -66 ft; the lowest water levels were observed in central Camden County and in the vicinity of Marlton in Burlington County. The shape and orientation of the cone of depression is similar to that in the overlying Upper PRM aquifer, though groundwater altitudes generally were higher in the Middle aquifer near its center and on the downdip side, indicating the potential for upward flow out of the aquifer. Lateral hydraulic gradients on the updip side of the cone of depression of nearly 8 ft/mi are steeper than those in either the Upper or Lower aquifers, although at 1 to 2 ft/mi on the downdip side, the gradients are similar to those of the Upper aquifer and slightly less than those of the Lower aquifer. Large areas of low hydraulic head are present in central Camden County despite the absence of withdrawals from the Middle aquifer; substantial withdrawals from both the Upper aquifer and the underlying Lower PRM aquifer likely induce leakage through adjacent confining layers, contributing to the depth of the cone of depression here. Near the southeastern edge of this central segment, depths to the top of the aquifer are considerable, and the groundwater is highly mineralized; consequently, few wells are open to the aquifer. Observation well 11-137 in eastern Cumberland County, New Jersey, is the farthest downdip well open to the aquifer included in this study; total dissolved solids in the groundwater are such that the density of the groundwater is substantially greater than fresher waters within other parts of the aquifer. Correcting for density, the measured groundwater altitude of -52 ft yields a freshwater equivalent of -29 ft. In northern Ocean County, at the northeastern edge of this segment, water levels ranged from -16 ft (well 29-626) to -39 ft (well 29-576); the lowest water levels were measured at or near production wells throughout Jackson Township.

The southwestern segment of the regional cone of depression encompasses Salem County in New Jersey and most of New Castle County in Delaware. Groundwater altitudes in Salem County ranged from -20 ft (wells 33-305 and 33-166) to -75 ft (well 33-934). Groundwater altitudes were estimated to be highest in the south-central part of Salem County, and measured water levels were lowest along the Delaware River and estuary where localized cones of depression are present in Pennsville and on Artificial Island. Previous studies documented potentiometric lows extending beneath the Delaware Bay and into northern Delaware and eastern Maryland (Lacombe and Rosman, 2001; DePaul and others, 2009). Water-level data for a comparable time period were not available, and groundwater conditions could not be determined.

Water-level differences were small to moderate near the outcrop of the Middle aquifer and to about 8 mi downdip; higher groundwater altitudes in the Middle aquifer indicate a weak downward vertical gradient and the potential for flow into the Lower aquifer. Despite the relatively small vertical head differences between the two aquifers, flow rates between the two may be substantial owing to high leakance of the intervening confining unit (Martin, 1998). On the downdip side of the cone of depression, estimated heads may be higher in the Lower aquifer than in the Middle aquifer, by as much as 15 ft, indicating the potential for upward flow into the Middle PRM aquifer. Water-level differences between the Upper PRM aquifer and Middle PRM aquifer are presented in detail in the previous section. In brief, a downward hydraulic gradient is present from the Upper to the Middle PRM aquifer in most places along, and for short distances downdip from, the western boundary of the Upper PRM aquifer. In parts of Monmouth and north-central Ocean County where the Upper PRM aquifer is stressed, the potential for flow is upward through the top of the Middle aquifer. In southern New Jersey, within the regional cone of depression, flow is generally upward through the top of the Middle aquifer.

The 5-year change in water levels in the Middle PRM aquifer is shown in figure 23*B*. Of 151 wells measured in both 2003 and 2008, water levels declined in 71 (47 percent) wells in 2008. Declines of 5 ft or greater were observed in 15 wells (10 percent) and of 10 ft or more in only 3 wells. In contrast, water levels recovered in 63 wells (42 percent); rises of 5 ft or greater were observed in 29 wells and of 10 ft or greater in 5 wells (19 percent). Water levels remained about the same in 17 wells (11 percent). Stable or rising water levels were most often associated with the regional cone of depression in Critical Area 2 but were also observed throughout eastern Middlesex and northern Monmouth Counties. Moderate declines were observed in central Monmouth and northern Ocean Counties and in updip areas of Burlington, Gloucester, and Salem Counties, beyond the boundary of Critical Area 2.

Groundwater levels in northern Ocean and southern Monmouth Counties were generally at or slightly below those observed during 2003 with declines of 1 to 6 ft typical. In northwestern Monmouth County groundwater levels declined by 5 to 10 ft since 2003, but near the Raritan Bay and in updip sections in Middlesex County, water levels were stable or had recovered. Near the Raritan and South Rivers, water levels showed modest to substantial recovery, ranging from 2 to 8 ft, as a result of continued reduction in groundwater withdrawals. Semi-annual water-level data collected from observation wells in this area confirm small to moderate rises from 2003 to 2008 (U.S Geological Survey, 2010). Mapped recovery near the Raritan Bay in Sayreville (greater than 20 ft) was based on observations at a single well (23-401); however, a review of reported static water-level measurements from nearby production wells during this period indicated rises of at least as much. Such large differences may be an artifact of residual pumping effects during the earlier measurement period; however, rising groundwater levels are likely because withdrawals from the Middle aquifer were discontinued in this area by 2004, and those from the Upper aquifer were minor.

In the central segment and within Critical Area 2, small to moderate recovery of water levels was observed in most wells (range of 2–11 ft), except for scattered wells located along the updip side of the cone and beyond the depleted zone of Critical Area 2. Although withdrawals typically decreased and water levels recovered throughout much of the area, withdrawals at individual wells or small groups of wells have increased since 2003 as a result of temporal and spatial shifts in local pumping patterns, resulting in local declines in groundwater levels. Near the center of the cone of depression, water levels rose 3 to 8 ft in 10 wells and were unchanged in 3 wells. On the downdip side of the cone, water levels recovered slightly. Adjacent to the outcrop in and around Camden, N.J., unchanged water levels or rises of 2 to 4 ft were most common, although combined withdrawals from the Middle and Lower aquifers remained at 2003 volumes. In eastern Cumberland County, far from withdrawal centers, the water level in well 11-137 did not change. Within the southwestern segment of the cone, water levels declined 1 to 5 ft throughout southern Gloucester County and central Salem County.

Results of the Wilcoxon signed-rank test indicate that, from 2003 to 2008, the differences in water levels between paired measurements throughout the aquifer were not significant (app. 10-2). A similar result was calculated for paired measurements from Critical Area 1; however, within Critical Area 2, a significant increase was observed. Significant increases are also indicated for Camden and Middlesex Counties and significant decreases for Gloucester and Salem Counties. Water levels in Monmouth, Ocean, Burlington, and Mercer Counties did not appreciably change. For the period 1998 to 2008, a statistically significant rise in water levels was observed in the study area as a whole, as well as in Critical Area 2; however, differences between paired measurements were not significant throughout Critical Area 1. Results indicate significant increases in water levels in Burlington and Gloucester Counties, significant decreases in water levels throughout Monmouth and Salem Counties, and no significant difference in the paired measurements for Camden, Middlesex, and Ocean Counties.

Water-level hydrographs for seven wells screened in the Middle and undifferentiated aquifer of the PRM aquifer system in the northern counties of New Jersey are shown in figure 26; well locations are shown on plate 8. From 2003 to 2008, statistically significant downward trends in water levels were detected at wells 29-19 and 29-85 (app. 10-1). Changes were subtle, at -0.28 ft/yr at well 29-19 and -0.38 ft/yr at well 29-85 and were, in part, responses to the increased withdrawals and the deepening cone of depression within the Upper PRM aquifer. Water levels in wells 25-635 and 23-291 showed no significant change during this period; however, trend test results indicated a significant rise in the water level in well 25-272. Limited water-level data during targeted periods precluded a statistical analysis of wells 23-97, 23-273, and 23-439. During 1998–2008, downward trends were detected at three observation wells (29-19, 29-85, and 25-635), and an upward trend was detected at well 23-291. No significant upward or downward trends were observed at well 25-272. The water level in observation well 29-19 declined during this period. Although results of the Mann-Kendall produced a p-value of less than 0.001 for well 29-19, the annual rate of decline was less than 0.2 ft and, therefore, was considered unimportant for the purposes of this discussion. During the 30-year period, 1978–2008, upward trends were detected at five wells (23-291, 23-439, 25-272, 25-635, and 29-85); neither an upward nor a downward trend was determined for well 29-19.

Groundwater hydrographs for 10 wells open to the Middle aquifer and the undifferentiated part of the PRM aquifer system in southern counties of New Jersey are shown in figure 27; observation well locations are shown on plate 8. For the southern counties from 2003 to 2008, upward trends were indicated for 6 wells, and downward trends were indicated for 3 wells. The geographic patterns of both downward and upward trends are consistent with observations based on the water-level-change maps. Upward trends were detected at observation wells within the depleted zone of Critical Area 2, and downward trends were detected beyond the Critical Area 2 boundary and to the southwest in Gloucester and Salem Counties. Seasonal water-level fluctuations and the annual rate of recovery were greatest at wells nearest the cone's center (7-413 and 5-261) and more temperate on the northern and southeastern sides of the cone. Annual rates of decline were highest in mid-dip areas in Salem County (wells 33-187 and 33-251) and moderate in updip areas of Gloucester County. The wider seasonal fluctuations observed in well 33-187 show the effects of nearby production wells at Woodstown; the absence of distinct seasonality in water levels in wells 11-137 and 33-251 illustrate long-term regional trends that are not dominated by the effects of local withdrawals.

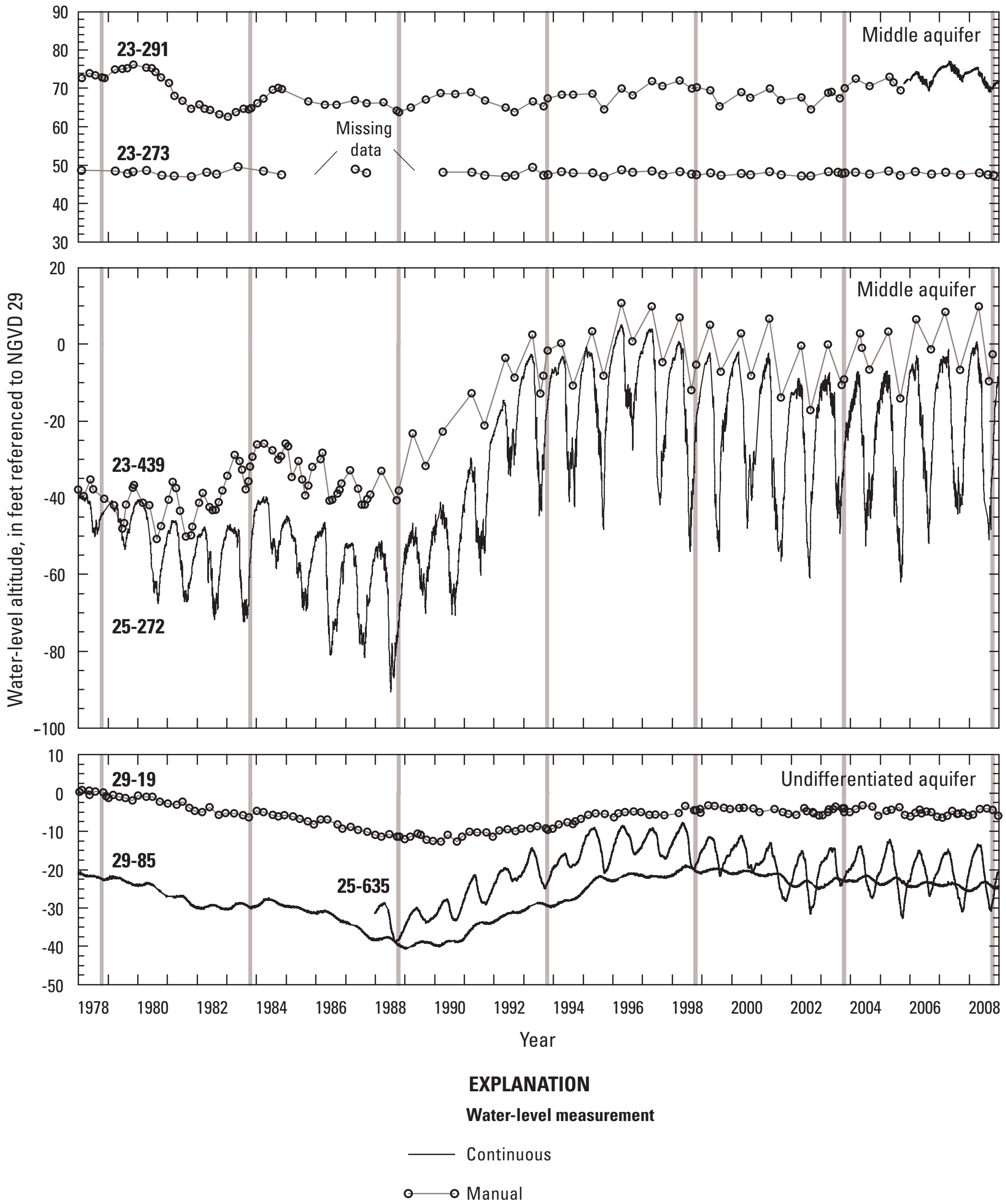


Figure 26. Water-level hydrographs for selected observation wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer in the northern counties, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 8)

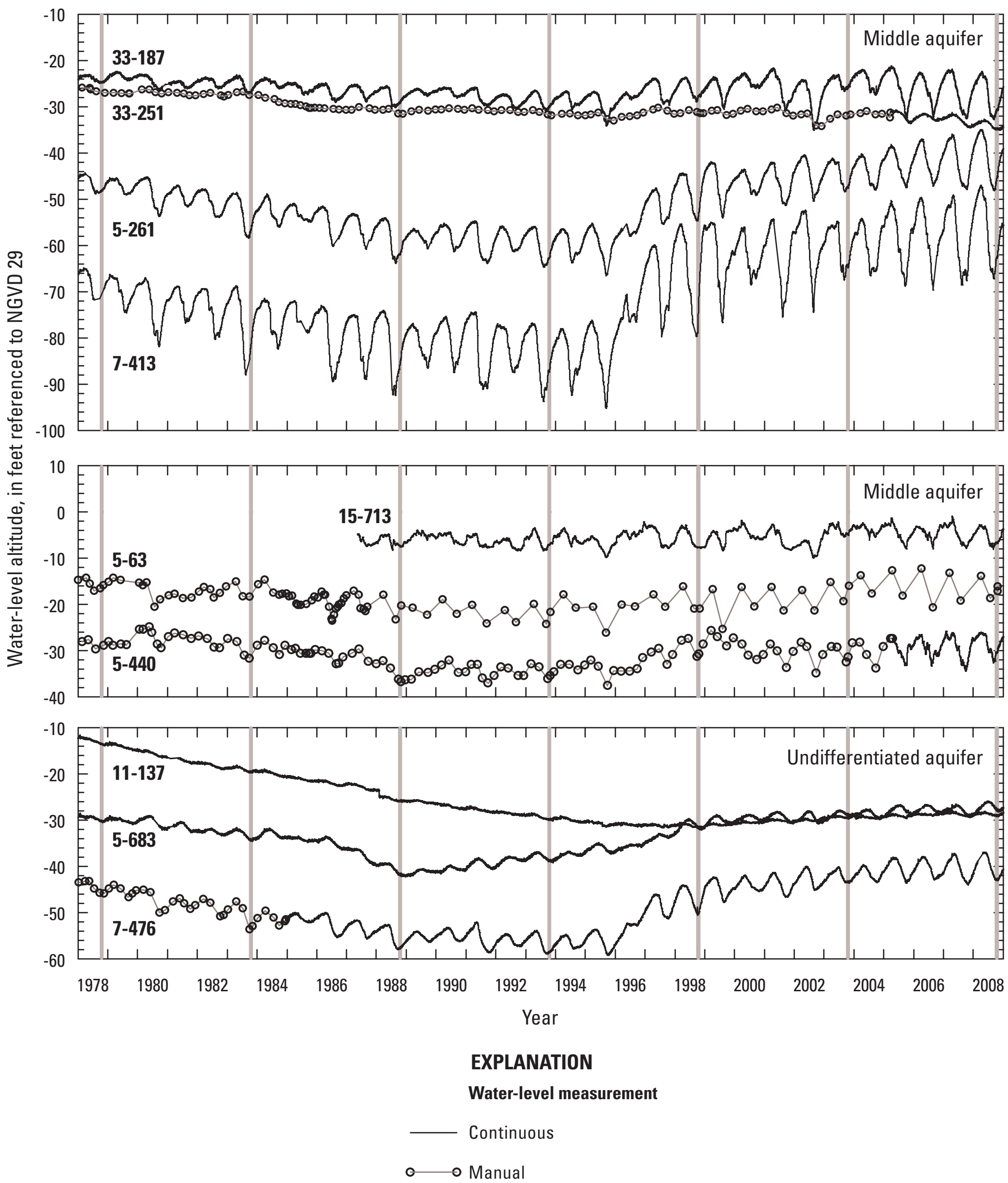


Figure 27. Water-level hydrographs for selected observation wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer in the southern counties, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; well 11-37 corrected for density; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 8)

Lower Potomac-Raritan-Magothy Aquifer

Water Withdrawals

Groundwater withdrawals from the Lower PRM aquifer in New Jersey were made predominantly in areas adjacent to the Delaware River, with most (approximately 24.4 Mgal/d or 66 percent) in Camden County (table 3). Most withdrawals were made in the northwestern part of the county near the eastern bank of the Delaware River, although pumping centers are located as far as 11 mi downdip in the central part of the county (fig. 21*C*). Substantial withdrawals (9.5 Mgal/d) were made in Burlington County along the Camden border and near the northern limit of the aquifer. In Salem and Gloucester Counties, withdrawals were made in the extreme updip parts of the aquifer owing to the presence of saline water in downdip areas. Groundwater withdrawals from the aquifer in Delaware were most common within or near the outcrop area of the Potomac Formation; however, production wells are also located in downdip areas adjacent to the Delaware River (Delaware City).

From 1978 to 2008, average withdrawals from the Lower PRM aquifer ranged from 37 to 75 Mgal/d (fig. 22*C*). Withdrawals peaked in the early and mid-1980s; thereafter, withdrawals generally decreased until 2000 and, from 2000 to 2005, remained constant at approximately 38 to 40 Mgal/d. In 2006, groundwater withdrawals were further reduced by 1 Mgal/d to 37 Mgal/d. In 2008, average withdrawals were 37 Mgal/d with 66 percent occurring in Camden County. In Camden County, most withdrawals were made by the Camden City Water Department (United Water Camden), the Merchantville-Pennsauken Water Commission, and New Jersey American Water; together these utilities accounted for 78 percent of withdrawals in the county during 2008.

Trends in withdrawals throughout Camden and Gloucester Counties were similar to regional trends, and although the percentage of reductions was higher in Gloucester County, reductions in volume were much greater in Camden County. Reductions of 20 percent or greater from the previous year occurred in 1989, 1991, 2000, and 2006 in Gloucester County; in Camden County, reductions of 10 percent or greater occurred in 1986, 1989, 1993, 1996, and 2006. In Burlington County, withdrawals generally increased from 1978 through 1990, and during the ensuing decade withdrawals were relatively constant, ranging from 8 to 10 Mgal/d. During 2001–4 withdrawals nominally decreased, and during 2005–8, withdrawals increased by nearly 30 percent. These large increases were associated with the city of Camden wells located along, but just beyond, the boundary of Critical Area 2. In Salem County, withdrawals were limited because of the widespread presence of saline groundwater. Withdrawals were relatively small at approximately 1 Mgal/d from 1982 to 2006, although withdrawals in Salem County peaked during the early 1990s at nearly 1.5 Mgal/d. Notable reductions in withdrawals (20 percent or greater) from any given year to the next occurred during 1985, 1994, 2000, and 2007.

Withdrawals from the aquifer in Delaware ranged from approximately 3.5 to more than 8 Mgal/d during 1978–2001 and peaked during 1999–2001 (DePaul and others, 2009). Recent data (2002–8) for this aquifer in Delaware were not tabulated for this study.

Water Levels

The potentiometric surface map for fall and early winter 2008 for the Lower Potomac-Raritan-Magothy aquifer is shown on plate 9; water-level data used to construct this map are listed in appendix 9. Most of the water-level measurements were made at wells located within New Jersey (80); 8 wells in Delaware and 3 in Pennsylvania were included. Despite the limited availability of water-level data, interpretation of the potentiometric surface was extended into northeastern Delaware, given the lateral flow beneath the bay and the effect of long-term withdrawals in Delaware on low water levels observed in southwestern New Jersey In addition, the cone of depression in Delaware historically has been well documented and mapped.

The configuration of the potentiometric surface in New Jersey is a generally ovate depression, slightly elongated from northeast to southwest along strike and centered beneath the Camden County community of Gibbsboro. The location and configuration of the cone of depression are similar to those in the overlying Middle and Upper PRM aquifers, though the Lower aquifer is shallower at its center and slightly updip from the Middle aquifer. Lateral hydraulic gradients on the updip side of the cone of approximately 8 ft/mi are similar to those of the Middle aquifer along the same hydrogeologic section; the estimated lateral gradient of 2.5 ft/mi on the downdip side is slightly greater than that of the Middle aquifer.

During 2008, water-level altitudes ranged from 4 ft to -66 ft throughout southern New Jersey. Throughout the aquifer, groundwater altitudes typically were at or below 0 ft; water levels greater than 0 ft occurred adjacent to the Delaware River along the northwestern boundary of the aquifer in Burlington County and immediately adjacent to the updip boundary in New Castle County, Del. The lowest water levels were observed in central Camden County. The general direction of lateral groundwater flow is dominated by the large cone of depression in central Camden and is similar to that in the southern extents of the Upper and Middle PRM aquifers; flow moves radially from the updip and downdip margins of the aquifer toward potentiometric lows at pumping centers. A groundwater divide is present approximately along the border between Gloucester and Salem Counties; beyond this divide, groundwater flow is to the southwest and beneath the Delaware Bay toward the regional cone of depression in Delaware. Water-level differences between the Middle and Lower PRM aquifers are discussed in the previous section, which describes water levels within the Middle PRM aquifer in detail.

The 5-year change in water levels in the Lower PRM aquifer is shown in figure 23*C*. Of the 84 wells measured in both 2003 and 2008, water levels in 2008 were lower in

22 of the wells (26 percent); however, all declines in New Jersey were typically less than 5 ft (water levels in one well in Delaware declined by 6 ft) and are represented as no substantial change in figure 23*C*. Water levels increased in 54 wells (64 percent) and remained the same in 8 (10 percent). Water levels increased in 12 wells by more than 5 ft relative to 2003; these changes occurred primarily in wells in north-central Camden County and southwestern Burlington County.

Results of the Wilcoxon signed-rank test indicate increasing water levels from 2003 to 2008 in the Lower aquifer as a whole, in Critical Area 2, and in Camden County (app. 10-2). Test results indicate differences in water levels throughout Burlington and Gloucester Counties were insignificant likely because scattered, modest declines and rises within the aquifer offset one another. For 1998–2008, a statistically significant increase was observed in the aquifer as a whole, in Critical Area 2, and in Burlington, Camden, and Gloucester Counties.

Groundwater hydrographs for seven monitoring wells in southern New Jersey and northern Delaware are presented in figures 28 and 29; well locations are shown on plate 9. Results of the Mann Kendall trend test (app. 10-1) indicate that, from 2003 to 2008 upward trends were observed for four wells (5-262, 7-412, 15-671, and Dc34-05). A downward trend was indicated for 1 well (15-712), and water-level changes were insignificant for 2 wells. Much like recent trends in the Upper and Middle PRM aquifers, upward trends observed within Critical Area 2 were strongest for wells located nearest the center of the cone of depression. Water levels observed at Dc34-05, located within the outcrop of the Potomac Formation on the northeastern side of the cone of depression in east-central New Castle County, Del., followed a pattern similar to that observed in Db33-17. From 1984 to 2003, water levels in both wells, despite numerous brief periods of decline and recovery, generally did not change, and from 2003 to 2008, water levels recovered slightly. On the other hand, water levels in well Ec32-07, located on the southern side of the cone of depression, declined from the early 1980s through 2007, followed by rising water levels in 2008.

During 1998–2008, upward trends were indicated for 3 wells (5-262, 7-412, and 15-671), a downward trend was indicated for 1 well (Ec32-07), and an insubstantial trend was indicated for well 15-712. For the 30-year period, water-level trends were upward for 4 wells, downward for 1 well, and insubstantial for 1 well (appendix 10-1).

Photograph was provided by U.S. Geological Survey field personnel

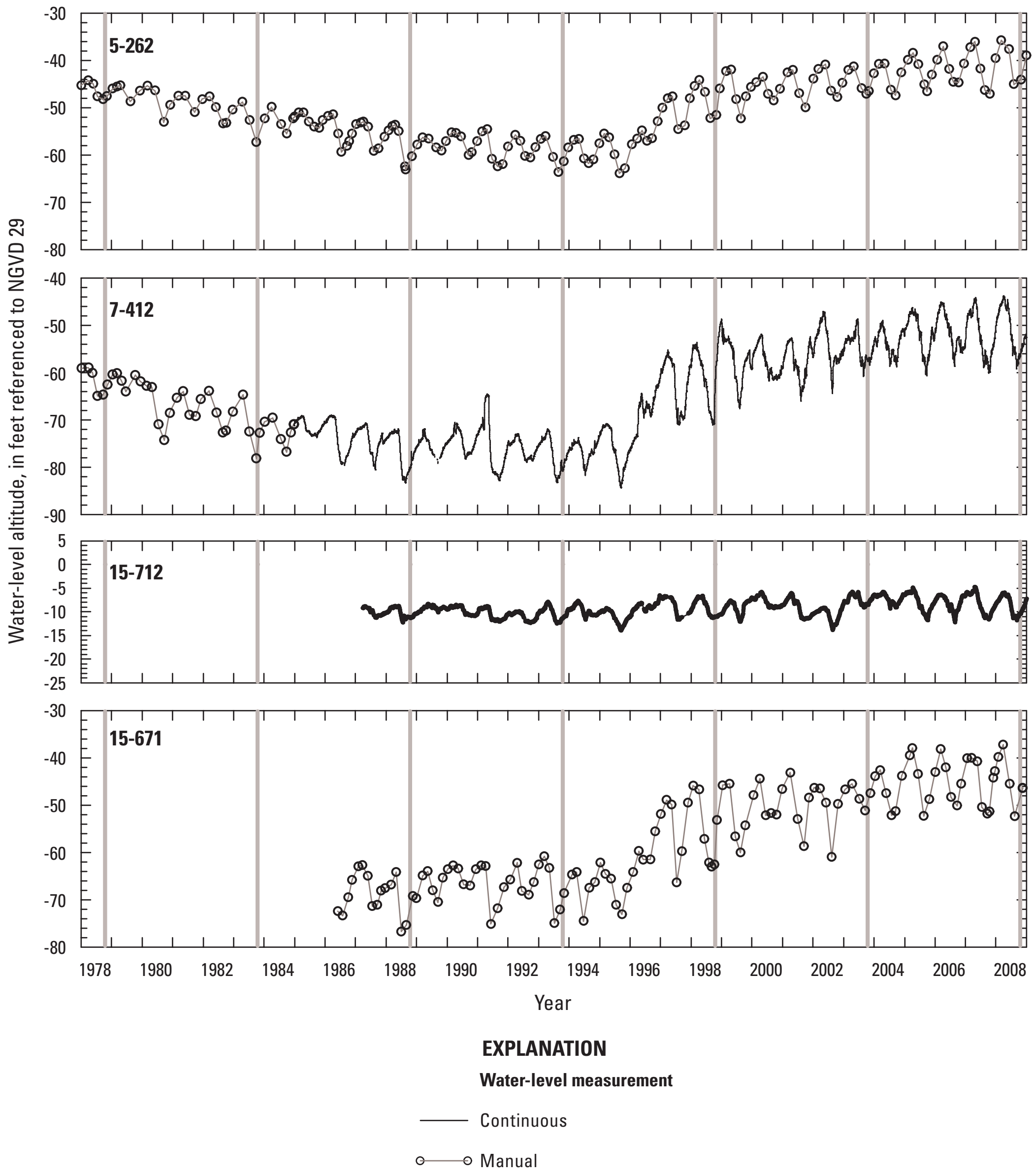


Figure 28. Water-level hydrographs for selected observation wells screened in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 9)

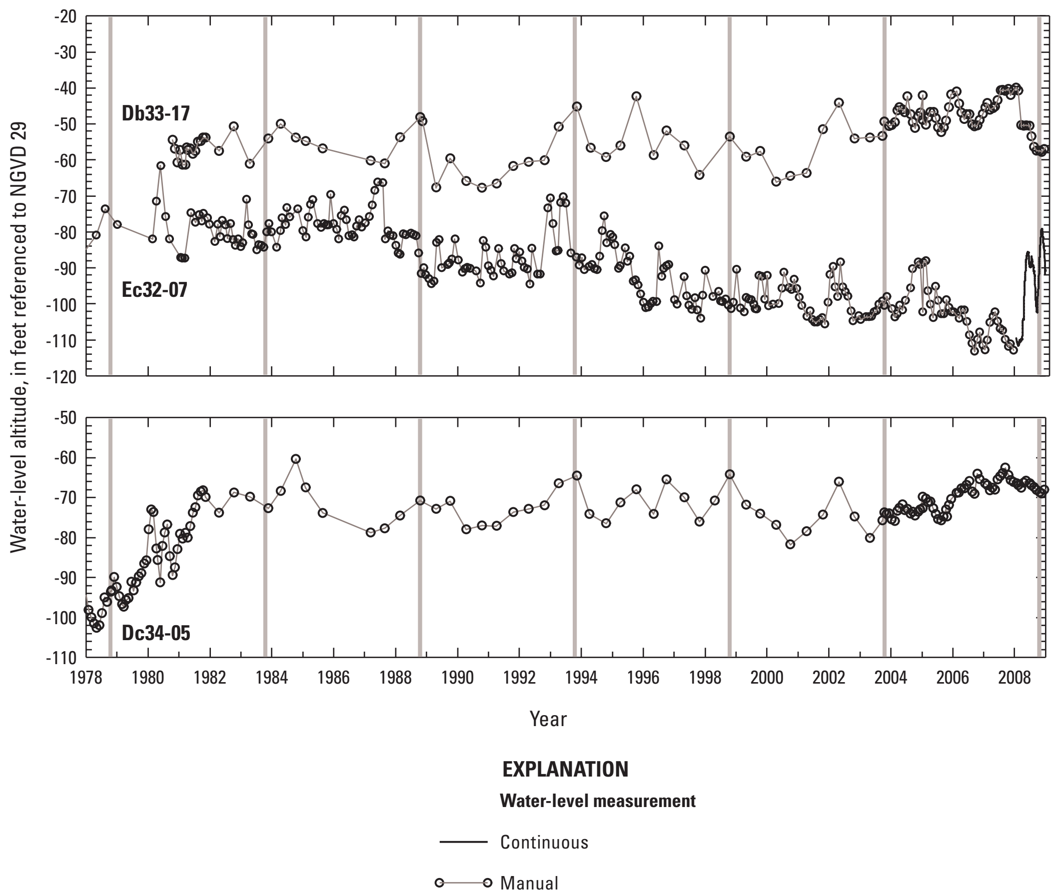


Figure 29. Water-level hydrographs for selected observation wells screened in the Lower Potomac-Raritan-Magothy aquifer, Delaware Coastal Plain, 1978–2008. (All hydrographs are at the same scale; vertical bars denote 5-yr data collection cycles; well locations shown on pl. 9)

Potentiometric Heads in Relation to the Tops of Aquifers

Withdrawals from confined aquifers can reduce the pressure head, resulting in a lowering of the potentiometric surface, but in most cases do not cause a dewatering of the aquifer. Desaturation of confined aquifers can lead to adverse effects, such as the compression of the aquifer materials (resulting in decreased porosity and hydraulic conductivity) and the deterioration of water quality by enhanced leakage through confining units of poor water quality, as well as through potential oxidation reactions with the aquifer matrix. In order to identify areas within selected confined aquifers that are potentially unsaturated, the altitudes of the 2008 potentiometric surfaces were compared to digital surfaces of the associated hydrogeologic unit-top altitudes. Raster datasets representing the differences between the two surfaces were created and contoured by using GIS software. The contours of the differences were then manually adjusted on the basis of the current understanding of the hydrogeologic framework of the Coastal Plain. Analyses were conducted for aquifers characterized by persistent potentiometric lows: the Atlantic City 800-foot sand, the Piney Point aquifer, the Wenonah-Mount Laurel aquifer, the Englishtown aquifer system, and the Upper, Middle, and Lower aquifers of the PRM aquifer system. Selected analyses and maps (fig. 30) are provided for informative purposes only and are best not applied at a local scale. In the updip areas of the aquifers, the height of hydraulic head above the unit top approaches zero as distance from the outcrop decreases and is presumed to be at or near zero at the downdip edge of the outcrop. Given the presence of an unsaturated zone throughout much of the extent of the outcrops, this difference is expected to be less than zero within the outcrop, except at discharge points near lakes, streams, and major rivers. Because water-level measurements from wells at the downdip edges of the aquifer outcrops are generally not made during data-collection cycles, the density and configuration of available water-level data in these areas are not sufficient for substantive interpretation. In downdip areas of confined aquifers, however, a negative value would indicate that the potentiometric surface is below the unit top and thus, the

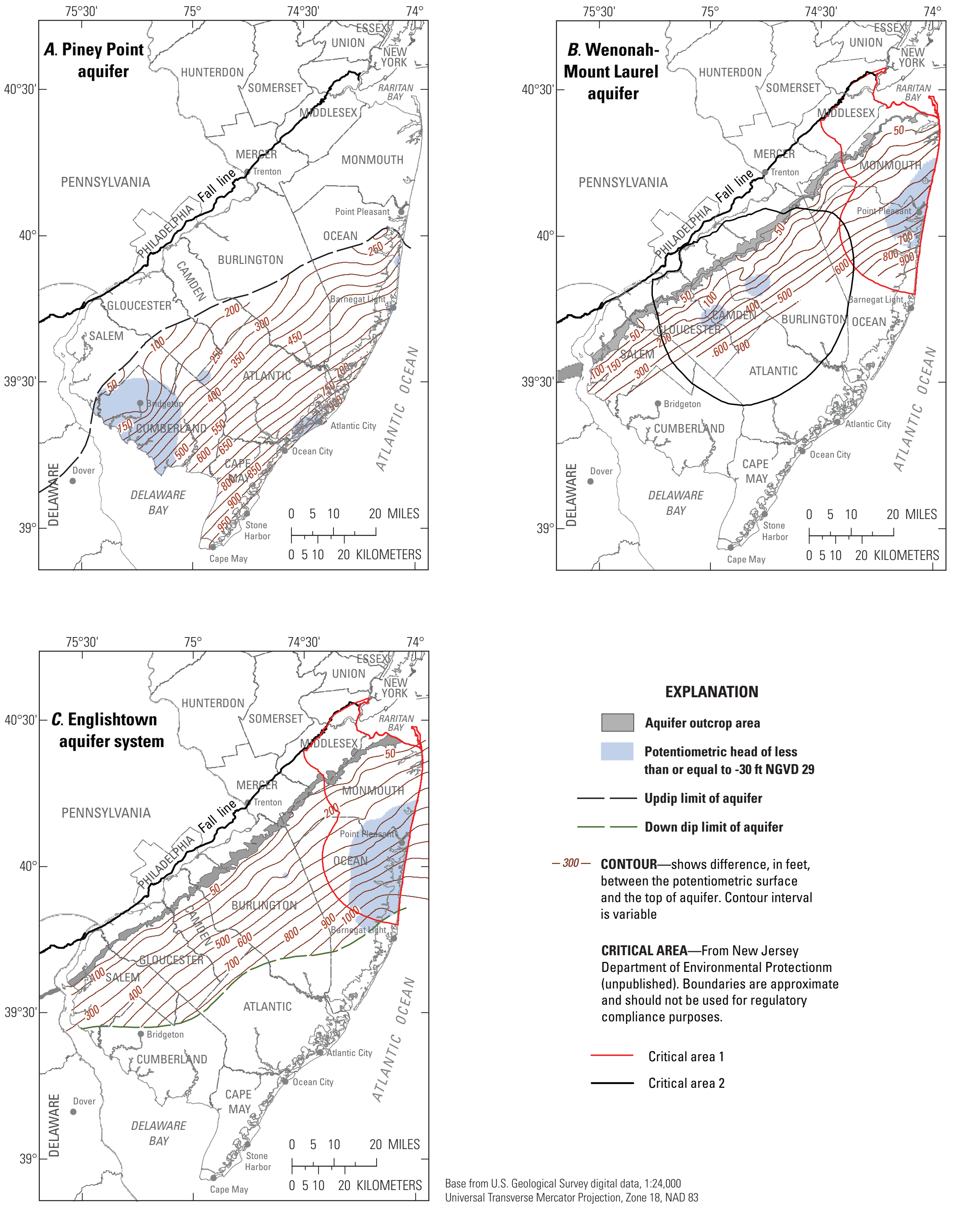


Figure 30. Available feet of potentiometric head above the top of the *A*, Piney Point aquifer, *B*, Wenonah-Mount Laurel aquifer, and *C*, Englishtown aquifer system, central and southern New Jersey, 2008.

aquifer is potentially desaturated. On the basis of these comparisons, altitudes of selected 2008 potentiometric surfaces do not approach unit-top altitudes in areas away from outcrops. In areas of extreme potentiometric lows, such as the Piney Point aquifer in Cumberland County, the minimum available head above the top of the aquifer was approximately 50 ft where the cone of depression intersected the updip boundary, and available head averaged more than 150 ft throughout the deepest part of the cone (fig. 30). In comparison, within the deep cones of depression in the Englishtown aquifer system and Wenonah-Mount Laurel aquifer, minimum available head above the unit tops was 310 ft and 230 ft, respectively (along the updip edge of the -30 ft contour for 2008), and available heads averaged 680 ft and 470 ft, respectively. Even at their lowest historical levels during the mid-1980s, potentiometric heads within the Englishtown aquifer system and Wenonah Mount Laurel aquifer exceeded the unit-top altitudes by a minimum of 275 ft and 145 ft, respectively. Within the Critical Area 2 cones of depression, as defined by the -30 ft contour for the Lower PRM aquifer, groundwater altitudes in the PRM aquifer system exceeded unit-top altitudes on average by more than 370 ft for each of the three units (371, 560, and 860 ft; Upper, Middle, and Lower aquifers, respectively). Minimum available potentiometric heads during 2008, observed near the updip edges of the cones of depression, were 42, 75, and 195 ft in the Upper, Middle, and Lower PRM aquifers, respectively.

Summary

Groundwater levels measured in 936 wells in New Jersey, eastern Pennsylvania, eastern Maryland, and northern Delaware during fall 2008 were used to map the potentiometric surfaces of 10 confined aquifers in the New Jersey Coastal Plain. Potentiometric surface maps were prepared for the confined Cohansey aquifer in Cape May County, the Rio Grande water-bearing zone, the Atlantic City 800-foot sand, the Piney Point aquifer, the Vincentown aquifer, the Wenonah-Mount Laurel aquifer, the Englishtown aquifer system, and the Upper, Middle, and Lower aquifers of the Potomac-Raritan-Magothy (PRM) aquifer system.

Water-level differences, evaluated in 800 wells measured during the fall of 2003 and 2008, indicate small to moderate changes in many Coastal Plain aquifers in New Jersey. Groundwater levels stabilized or had recovered, but in places, water levels continued to decline as a result of withdrawals. In the confined Cohansey aquifer in Cape May, groundwater altitudes generally did not change. Groundwater levels in the Atlantic City 800-foot sand typically were below those in 2003; declines were greatest near pumping centers in coastal Atlantic County. Changes were less pronounced in Cape May County, and water levels were, on average, less than 3 ft lower than those measured during the previous study in 2003, except near Rio Grande, N.J., where a localized cone of depression had formed as a result of increased withdrawals. Large and widespread water-level declines were observed in the Piney Point aquifer in Cumberland County where water levels fell in excess of 100 ft in and around Bridgeton and by 30 to 60 ft in surrounding areas. Groundwater levels in the Wenonah-Mount Laurel aquifer and Englishtown aquifer system continued to recover in Critical Area 1. In Critical Area 2 water levels in the Wenonah-Mount Laurel aquifer continued to decline.

In the Upper Potomac-Raritan-Magothy aquifer, groundwater levels were substantially lower than those observed in 2003 in parts of northern Ocean County but did not change appreciably in the Raritan Bay area, and water levels continued to recover in Critical Area 2. In the Middle Potomac-Raritan-Magothy aquifer, water levels recovered near the Raritan and South Rivers in Middlesex County; however, modest declines occurred in the interior parts Monmouth and Ocean Counties. Groundwater levels in both the Middle and Lower PRM aquifers were stable to recovering in Critical Area 2. Beyond Critical Area 2 in southern New Jersey, however, water levels were slightly lower than in 2003.

Water-level trends were calculated for 73 wells for the 30-year period (1978–2008) and for 77 wells for both the 10-year (1998–2008) and 5-year (2003–8) periods. Results of analyses of long-term water-level changes show that, during 1978–2008, trends were downward at 20 wells (27 percent), upward at 27 wells (37 percent), and were insubstantial or insignificant at 26 wells (36 percent). Declining water levels were observed most often in wells screened within the Atlantic City 800-foot sand where rates of decline ranged from less than 0.1 to 1 foot per year (ft/yr) and in wells in the Piney Point aquifer in southern New Jersey where rates of decline were as much as 1.4 ft/yr. Upward water-level trends were observed commonly for wells in the Englishtown aquifer system and the Wenonah-Mount Laurel aquifer in Critical Area 1 and in the PRM aquifer system in parts of Critical Area 1 and most of Critical Area 2. Annual rates of increase ranged from 1.1 to 5.6 ft in the Englishtown aquifer system and Wenonah-Mount Laurel aquifer. For the aquifers of the PRM aquifer system, annual rates of recovery were greatest in the Lower aquifer.

From 1998 to 2008, downward water-level trends were observed for 22 wells (29 percent), upward trends for 21 wells (27 percent), and insubstantial trends for 34 wells (44 percent). Downward water-level trends were observed most often for wells open to the Piney Point aquifer and the Atlantic City 800-foot sand; rates of decline ranged from less than 0.2 to 7.6 ft/yr. Upward trends were observed mostly for wells open to the Englishtown aquifer system in Critical Area 1 and for wells within the PRM aquifer system in Critical Area 2 and southern New Jersey.

From 2003 to 2008, downward trends were observed for 30 wells (39 percent), upward trends for 20 wells (26 percent), and insubstantial or insignificant trends for 27 wells (35 percent). The geographic pattern of water-level trends for the 30-year period was similar to that for the 10-year period (1998–2008); however, annual rates of decline markedly increased throughout the Atlantic City 800-foot sand and the

Piney Point aquifer in southern New Jersey where water levels declined by as much as 9.4 ft/yr.

Long-term withdrawals from confined aquifers of the New Jersey Coastal Plain have resulted in the lowering of the potentiometric surface in places but have not caused aquifer dewatering within the study area. In areas of persistent low water levels and deep cones of depression, available potentiometric head above the tops of the aquifers is sufficient, and no evidence of desaturation was observed.

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Appendixes 1–10.

Tables

Appendix 1-1. Water-level data for wells screened in the confined Cohansey aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
9-11	57-04898	Cape May	-74.91545	38.93678	281–321	7	--	-20	-14	-17	-15	-11	-10	1	12/8/2008
9-18	--	Cape May	-74.89045	38.94789	295–325	4	--	--	--	--	--	-14	-14	0	12/8/2008
9-27	37-00013	Cape May	-74.92556	38.94520	277–306	10	-21	-27	-17	-21	-18	-11	-12	-1	12/8/2008
9-30	--	Cape May	-74.88573	38.94733	305–325	11	--	--	--	--	-14	-13	-14	-1	12/8/2008
9-36	--	Cape May	-74.92406	38.95039	174–282	10	-26	-33	-20	-26	-17	-15	-16	-1	12/8/2008
9-42	37-00268	Cape May	-74.87739	38.95650	259–289	5	--	-18	-12	--	-16	-19	-11	8	12/7/2008
9-43	57-00011	Cape May	-74.92217	38.95645	246–276	18	--	-25	-13	-21	-16	-8	-9	-1	12/8/2008
9-48	37-00159	Cape May	-74.92545	38.96345	242–252	17	--	-22	-17	-21	-17	-12	-10	2	12/3/2008
9-49	**--**	**Cape May**	**-74.96129**	**38.96789**	**241–250**	**6**	**-16**	**-15**	**-13**	**-14**	**-13**	**-11**	**-9**	**2**	**12/4/2008**
9-52	37-00113	Cape May	-74.95306	38.98164	241–262	18	--	-15	-16	-22	-19	-14	-17	-3	12/8/2008
9-54	37-00223	Cape May	-74.93937	38.98508	212–247	14	--	-18	-16	-20	-21	-17	-16	1	12/7/2008
9-60	**--**	**Rio Grande**	**-74.90684**	**39.01567**	**242–257**	**13**	**--**	**-12**	**-12**	**-15**	**-12**	**-13**	**-9**	**4**	**12/3/2008**
9-74	57-00007	Rio Grande	-74.89670	39.02756	191–231	9	--	--	--	--	-13	--	-12	--	12/15/2008
9-78	37-00002	Rio Grande	-74.89787	39.03034	229–250	9	--	--	--	--	--	--	-7	--	12/15/2008
9-80	**--**	**Stone Harbor**	**-74.84850**	**39.03706**	**242–252**	**14**	**-2**	**-2**	**-4**	**-5**	**-4**	**-2**	**-4**	**-2**	**12/3/2008**
9-89	37-00158	Rio Grande	-74.91239	39.07372	195–210	7	-2	-2	-2	-1	-0	-2	0	2	12/3/2008
9-99	35-00680	Stone Harbor	-74.81017	39.10317	214–230	11	4	5	4	3	4	5	4	-1	12/4/2008
9-150	**37-00155**	**Cape May**	**-74.93184**	**38.93539**	**283–293**	**7**	**-18**	**-19**	**-13**	**-17**	**-14**	**-10**	**-9**	**1**	**12/4/2008**
9-159	37-00241	Wildwood	-74.83900	38.97417	249–360	8	--	-8	-8	-11	-8	-6	-6	0	11/24/2008
9-180	37-00375	Rio Grande	-74.89359	39.03345	--	15	--	--	--	--	--	--	-5	--	12/15/2008
9-187	--	Rio Grande	-74.93545	39.03845	186–190	10	--	--	-6	-7	-3	-4	-5	-1	12/7/2008
9-188	--	Rio Grande	-74.91073	39.03761	229–233	6	--	--	-10	-11	-9	-7	-5	2	12/7/2008
9-207	35-06772-1	Woodbine	-74.85350	39.18928	80–90	10	--	--	--	--	--	5	5	0	12/16/2008
9-210	--	Cape May	-74.95656	38.99622	216–221	11	--	--	-8	-13	-12	-10	-9	1	12/8/2008
9-213	--	Rio Grande	-74.94378	39.02456	203–208	12	--	--	--	-8	-7	-5	-3	2	12/7/2008
9-219	35-03380	Rio Grande	-74.87878	39.10039	150–200	19	--	--	--	2	3	5	14	9	12/16/2008
9-281	37-00254	Stone Harbor	-74.85906	39.11956	176–181	11	--	--	5	5	4	6	5	-1	12/7/2008
9-292	37-03035	Stone Harbor	-74.77266	39.06039	251–261	5	--	--	1	2	1	0	2	2	12/7/2008
9-301	37-00831	Wildwood	-74.85622	38.96003	190–245	2	--	--	--	--	-11	-10	-9	1	12/15/2008
9-310	37-01781	Stone Harbor	-74.79664	39.00514	279–357	7	--	--	1	0	2	3	5	2	11/24/2008
9-314	37-00640	Wildwood	-74.81375	38.99242	212–325	7	--	--	--	-1	0	1	3	2	11/24/2008
9-315	35-01373	Stone Harbor	-74.83572	39.05484	228–248	10	--	--	--	--	--	7	6	-1	12/15/2008

Appendix 1-1. Water-level data for wells screened in the confined Cohansey aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
9-353	37-04871	Cape May	-74.95990	38.98206	262–272	20	--	--	--	-12	-12	-8	-11	-3	12/8/2008
9-354	37-04873	Stone Harbor	-74.81575	39.02992	230–240	5	--	--	--	2	2	4	4	0	12/7/2008
9-358	37-02274	Stone Harbor	-74.83156	39.06567	240–270	15	--	--	--	--	-0	2	-1	-3	12/4/2008
9-366	37-01039	Wildwood	-74.83128	38.99456	270–290	5	--	--	--	--	-3	-2	-1	1	12/15/2008
9-385	37-00861	Rio Grande	-74.88934	39.03250	156–274	15	--	--	--	--	-14	-10	-5	5	12/15/2008
9-394	37-00327	Wildwood	-74.86656	38.95817	250–275	5	--	--	--	--	-9	-11	-7	4	12/7/2008
9-395	37-04368	Cape May	-74.89934	38.98595	255–275	15	--	--	--	-17	-15	-15	-12	3	12/8/2008
9-492	35-16575	Woodbine	-74.78017	39.13650	105–135	22	--	--	--	--	--	7	6	-1	12/15/2008
9-505	37-00508	Stone Harbor	-74.86203	39.03197	260–280	20	--	--	--	--	--	--	-3	--	12/15/2008
9-518	36-24677	Marmora	-74.73222	39.26194	245–265	30	--	--	--	--	--	--	8	--	12/10/2008
9-525	--	Rio Grande	-74.91317	39.00089	–260	20	--	--	--	--	--	-22	-13	9	12/8/2008
9-630	37-09436	Wildwood	-74.85647	38.95986	148–254	4	--	--	--	--	--	--	-8	--	12/8/2008
9-662	37-09403	Rio Grande	-74.91028	39.00417	245–275	20	--	--	--	--	--	--	-13	--	12/8/2008

Appendix 1-2. Water-level data for wells screened in the Rio Grande water-bearing zone, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
9-67	37-00271	Rio Grande	-74.89684	39.02650	461–590	10	--	--	--	--	-46	-33	-27	6	12/8/2008
9-71	**--**	**Rio Grande**	**-74.89628**	**39.02734**	**473–523**	**8**	**--**	**-12**	**-12**	**--**	**-33**	**-24**	**-15**	**9**	**12/15/2008**
9-149	37-00005	Tuckahoe	-74.83139	39.30425	250–290	20	--	20	18	--	18	18	16	-2	12/15/2008
9-304	**37-03763-3**	**Rio Grande**	**-74.90239**	**39.00067**	**495–505**	**25**	**--**	**--**	**--**	**--**	**-21**	**-19**	**-20**	**-1**	**12/3/2008**
9-415	35-01233	Woodbine	-74.85795	39.24734	–306	29	--	--	--	--	6	7	5	-2	12/16/2008
9-519	36-22762	Marmora	-74.65444	39.26506	478–498	31	--	--	--	--	--	-25	-26	-1	12/3/2008
9-526	37-05559	Rio Grande	-74.93583	39.03833	578–598	10	--	--	--	--	--	-18	-26	-8	12/7/2008
11-737	35-03449	Heislerville	-74.95323	39.21039	307–317	10	--	--	--	--	2	1	0	-1	12/15/2008
29-775	32-08715	New Gretna	-74.38348	39.56120	293–318	5	--	-8	-6	--	-2	-1	-1	0	11/26/2008
29-813	32-11971	Tuckerton	-74.34670	39.58595	307–337	20	--	--	-3	--	1	3	-3	-6	12/16/2008
29-1621	33-40378	Tuckerton	-74.26297	39.53528	417–456	5	--	--	--	--	--	-19	-24	-5	11/14/2008

Appendix 2. Water-level data for wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
1-37	**56-00071**	**Atlantic City**	**-74.41598**	**39.36428**	**782–837**	**10**	**-65**	**-70**	**-80**	**-83**	**-88**	**-85**	**-93**	**-8**	**12/2/2008**
1-39	56-00012	Oceanville	-74.39598	39.39156	733–788	10	-60	-65	-74	-68	-78	-74	-90	-16	12/2/2008
1-117	32-00477	Egg Harbor City	-74.64180	39.53692	350–432	41	23	21	19	20	17	18	14	-4	11/17/2008
1-180	**36-00294**	**Oceanville**	**-74.44987**	**39.46512**	**560–570**	**27**	**-28**	**-32**	**-39**	**-41**	**-47**	**-43**	**-50**	**-7**	**12/2/2008**
1-367	56-00038	Ocean City	-74.52207	39.31648	750–800	10	-66	-68	-75	-80	-86	-81	-82	-1	12/2/2008
1-369	36-00402	Ocean City	-74.52371	39.31817	760–810	10	--	--	--	--	--	--	-76	--	12/2/2008
1-376	36-00278	Ocean City	-74.50432	39.33567	741–791	10	--	--	--	--	--	--	-86	--	12/1/2008
1-565	36-00014	Pleasantville	-74.51293	39.41067	610–660	10	--	--	--	--	--	--	-74	--	12/11/2008
1-578	**36-00295**	**Ocean City**	**-74.61877**	**39.30734**	**670–680**	**10**	**-45**	**-51**	**-55**	**-59**	**-66**	**-64**	**-69**	**-5**	**12/2/2008**
1-593	36-00372	Atlantic City	-74.48076	39.34181	740–790	9	--	-75	-96	--	--	-87	-98	-11	12/2/2008
1-599	56-00015	Atlantic City	-74.48257	39.34234	800–830	9	--	--	--	--	--	--	-91	--	12/1/2008
1-600	56-00016	Atlantic City	-74.47718	39.34601	750–810	8	-69	-73	-79	-83	-93	-88	-88	0	12/2/2008
1-637	32-05113	Egg Harbor City	-74.63996	39.53720	335–425	35	--	--	--	--	--	--	5	--	11/17/2008
1-648	36-01084	Atlantic City	-74.43404	39.35706	775–835	7	--	-74	-80	--	--	-83	-94	-11	12/3/2008
1-650	--	Mays Landing	-74.71461	39.44762	–380	22	--	--	16	19	16	16	13	-3	12/10/2008
1-683	36-02091	Brigantine Inlet	-74.37398	39.40312	725–775	8	--	--	-64	-70	-71	-70	-70	0	12/2/2008
1-702	**--**	**Ocean City**	**-74.50182**	**39.34234**	**740–750**	**5**	**--**	**--**	**-87**	**-92**	**-103**	**-93**	**-96**	**-3**	**12/2/2008**
1-703	36-05092	Pleasantville	-74.54182	39.44428	560–570	38	--	--	-45	-46	-58	-47	-63	-16	11/26/2008
1-704	--	Mays Landing	-74.62544	39.39539	596–606	51	--	--	-38	-37	-49	-50	-61	-11	11/26/2008
1-706	36-04982-1	Pleasantville	-74.52460	39.49262	520–530	41	--	--	-25	-25	-35	-30	-39	-9	12/3/2008
1-889	36-11871	Ocean City	-74.50274	39.33426	735–795	8	--	--	--	-86	-94	-87	-87	0	12/1/2008
1-967	36-13010	Brigantine Inlet	-74.35565	39.41559	702–776	5	--	--	--	-62	-64	-60	-62	-2	12/2/2008
1-990	36-19288	Pleasantville	-74.58916	39.38562	496–652	30	--	--	--	--	-55	-50	-66	-16	12/3/2008
1-991	36-16204	Pleasantville	-74.57003	39.41922	492–642	63	--	--	--	--	-55	-48	-61	-13	12/3/2008
1-1218	36-17655	Mays Landing	-74.62738	39.43901	520–610	67	--	--	--	--	-48	-47	-55	-8	12/10/2008
1-1220	36-17339	Pleasantville	-74.61627	39.44651	552–603	66	--	--	--	--	-51	-49	-58	-9	12/10/2008
1-1252	32-20165	Egg Harbor City	-74.64055	39.53664	337–441	41	--	--	--	--	--	16	13	-3	11/17/2008
1-1253	36-16750	Pleasantville	-74.54452	39.46384	344–598	55	--	--	--	--	-43	-36	-50	-14	12/3/2008
1-1256	36-17667	Ocean City	-74.51504	39.32573	649–796	6	--	--	--	--	--	-94	-88	6	12/1/2008
1-1456	36-21156	Pleasantville	-74.50724	39.41389	602–652	5	--	--	--	--	--	-64	-71	-7	12/11/2008

Appendix 2. Water-level data for wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
1-1974	36-32164	Marmora	-74.63422	39.37097	356–660	65	--	--	--	--	--	--	-62	--	12/3/2008
1-1975	36-22085	Pleasantville	-74.50714	39.43122	550–650	21	--	--	--	--	--	--	-67	--	12/4/2008
1-1976	36-22109	Pleasantville	-74.50756	39.47842	531–631	42	--	--	--	--	--	--	-38	--	12/3/2008
1-2037	--	Atlantic City	-74.47103	39.36553	--	8	--	--	--	--	--	--	-87	--	12/4/2008
9-2	37-00280	Avalon	-74.74305	39.07247	821–861	5	-36	-40	-46	-44	-49	-50	-51	-1	12/4/2008
9-4	37-00265	Avalon	-74.72791	39.09081	880–920	10	-40	-42	-40	-43	-51	-48	-50	-2	12/4/2008
9-79	--	Stone Harbor	-74.79128	39.03622	833–876	2	--	--	--	-36	-46	-41	-44	-3	12/7/2008
9-92	37-00240	Stone Harbor	-74.81517	39.09020	681–791	17	-32	-31	-34	-38	-41	-42	-45	-3	12/4/2008
9-106	56-00006	Sea Isle City	-74.63149	39.22859	760–810	8	-46	-46	-51	-54	-62	-61	-62	-1	12/4/2008
9-108	36-00412	Sea Isle City	-74.61221	39.24975	774–840	7	--	-57	-58	-88	-70	-67	-69	-2	12/4/2008
9-109	56-00008	Ocean City	-74.60260	39.25998	749–809	8	-49	-56	-57	--	-69	-65	-70	-5	12/3/2008
9-116	56-00007	Ocean City	-74.58038	39.27714	760–810	7	--	-62	-64	-74	-75	-74	-75	-1	12/3/2008
9-125	36-00314	Ocean City	-74.56421	39.29112	–800	10	--	--	-66	-76	-87	-73	-76	-3	12/4/2008
9-135	37-00009	Stone Harbor	-74.75655	39.05650	838–878	9	-30	-34	-31	-38	-43	-40	-43	-3	12/15/2008
9-136	56-00147	Sea Isle City	-74.65713	39.19778	802–834	7	--	-45	-45	-47	-54	-54	-58	-4	12/4/2008
9-144	36-00451	Marmora	-74.63472	39.28925	650–690	9	-47	-54	-50	-60	-70	-66	-70	-4	12/11/2008
9-161	--	Stone Harbor	-74.79667	39.11817	639–654	16	--	-26	-32	-35	-38	-37	-41	-4	12/8/2008
9-185	37-01340-8	Marmora	-74.73181	39.27261	640–650	15	--	--	-35	--	-41	-41	-45	-4	12/4/2008
9-291	36-09846	Avalon	-74.71438	39.10834	764–941	7	--	--	--	-45	-49	-49	-51	-2	12/4/2008
9-296	35-06073	Stone Harbor	-74.82825	39.08334	682–812	20	--	--	-27	-33	-35	-36	-41	-5	12/4/2008
9-302	**37-03628-9**	**Wildwood**	**-74.85739**	**38.95261**	**883–893**	**5**	**--**	**--**	**--**	**-14**	**-18**	**-27**	**-31**	**-4**	**12/4/2008**
9-306	**35-09239**	**Rio Grande**	**-74.91267**	**39.07289**	**656–666**	**6**	**--**	**--**	**--**	**-17**	**-19**	**-22**	**-27**	**-5**	**12/3/2008**
9-311	36-10378	Sea Isle City	-74.71202	39.13025	732–896	8	--	--	--	-46	-50	-48	-51	-3	12/12/2008
9-337	**37-04660**	**Stone Harbor**	**-74.78850**	**39.00345**	**910–960**	**10**	**--**	**--**	**--**	**-20**	**-24**	**-28**	**-32**	**-4**	**12/4/2008**
9-359	36-07286	Avalon	-74.74952	39.11559	708–773	5	--	--	--	-46	-52	-50	-52	-2	12/7/2008
9-423	37-05244	Rio Grande	-74.87658	39.02678	825–875	20	--	--	--	-19	-21	-23	-30	-7	12/16/2008
9-459	36-00377	Ocean City	-74.62294	39.28692	–620	7	--	--	--	--	-67	-66	-70	-4	12/2/2008
9-479	37-06313	Cape May	-74.92431	38.94339	655–825	7	--	--	--	--	-17	-37	-42	-5	12/8/2008
9-480	37-06314	Cape May	-74.92537	38.94547	621–820	14	--	--	--	--	-17	-49	-42	7	12/8/2008
9-481	36-17001	Marmora	-74.65416	39.26487	603–738	33	--	--	--	--	--	-55	-58	-3	12/3/2008

Appendix 2. Water-level data for wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
9-482	36-20238	Sea Isle City	-74.69216	39.15723	724–884	8	--	--	--	--	--	-49	-53	-4	12/12/2008
9-507	37-06563	Cape May	-74.92234	38.95642	615–810	18	--	--	--	--	--	-33	-34	-1	12/7/2008
9-508	37-06564	Cape May	-74.95917	38.95789	585–765	10	--	--	--	--	--	-23	-24	-1	12/7/2008
9-521	37-07541	Stone Harbor	-74.76172	39.05072	830–953	10	--	--	--	--	--	-40	-42	-2	12/15/2008
9-522	37-07594	Rio Grande	-74.89444	39.02472	570–664	12	--	--	--	--	--	--	-59	--	12/11/2008
9-523	37-07593	Rio Grande	-74.89472	39.02917	563–653	10	--	--	--	--	--	--	-59	--	12/15/2008
9-527	36-23696	Sea Isle City	-74.74016	39.18150	660–790	20	--	--	--	--	--	--	-60	--	12/12/2008
9-613	36-28902	Sea Isle City	-74.69444	39.14639	722–815	5	--	--	--	--	--	--	-55	--	12/12/2008
29-9	53-00031	Beach Haven	-74.24181	39.56298	572–656	5	-28	-30	-31	-32	-34	-33	-35	-2	11/13/2008
29-111	33-01180	Ship Bottom	-74.14305	39.69290	465–500	9	-22	-52	-23	-27	-30	-26	-28	-2	11/13/2008
29-112	33-00674	Ship Bottom	-74.13511	39.70518	451–493	5	-20	-36	-24	-27	-29	-26	-29	-3	11/13/2008
29-457	33-01275	Beach Haven	-74.22392	39.58606	551–650	8	-26	-27	-26	--	--	-43	-37	6	11/14/2008
29-549	33-01723	Ship Bottom	-74.18105	39.64690	528–588	5	--	--	--	--	--	--	-35	--	11/14/2008
29-561	33-01268	Ship Bottom	-74.16478	39.66340	520–562	10	-25	-28	-24	-20	-30	-28	-31	-3	11/12/2008
29-597	32-05858	Tuckerton	-74.33881	39.60289	400–500	25	--	-6	-3	--	--	-18	-19	-1	11/26/2008
29-598	33-00967	Ship Bottom	-74.20214	39.70061	--	2	--	--	-21	-25	-26	-26	-28	-2	11/13/2008
29-814	32-12329	New Gretna	-74.38515	39.54787	512–552	10	--	--	--	-24	-26	-24	-32	-8	11/12/2008
29-936	33-24693	Beach Haven	-74.19689	39.62384	528–594	9	--	--	-25	-25	-26	-31	-33	-2	11/14/2008
29-1063	32-15207	Tuckerton	-74.36409	39.58856	475–521	33	--	--	-24	-25	-27	-28	-27	1	11/26/2008
29-1077	33-25686	Ship Bottom	-74.17283	39.65406	514–574	7	--	--	--	--	--	--	-25	--	11/12/2008
29-1078	33-26875	Ship Bottom	-74.24967	39.69365	366–429	24	--	--	--	--	26	28	22	-6	11/13/2008
29-1421	32-22507	Tuckerton	-74.33831	39.59348	405–511	12	--	--	--	--	--	-19	-20	-1	11/26/2008
29-1433	33-41143	West Creek	-74.26947	39.72675	375–415	58	--	--	--	--	--	48	40	-8	11/12/2008
29-1624	33-42213	Ship Bottom	-74.18111	39.64448	501–582	5	--	--	--	--	--	-35	-35	0	11/14/2008
29-1729	33-40839	Beach Haven	-74.21022	39.60419	518–634	6	--	--	--	--	--	-33	-36	-3	11/14/2008
29-1730	32-25614	Tuckerton	-74.36583	39.58667	460–521	35	--	--	--	--	--	--	-27	--	11/26/2008
29-1731	32-23935	West Creek	-74.33639	39.62611	416–514	63	--	--	--	--	--	--	-16	--	11/26/2008
29-1774	33-41391	Ship Bottom	-74.24806	39.69611	365–431	23	--	--	--	--	--	--	20	--	11/13/2008
29-1779	33-39413	Beach Haven	-74.20861	39.60917	541–616	5	--	--	--	--	--	--	-35	--	11/13/2008
29-1803	32-27684	Tuckerton	-74.33437	39.62641	403–520	78	--	--	--	--	--	--	-28	--	11/26/2008

Appendix 2. Water-level data for wells screened in the Atlantic City 800-foot sand, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
29-2007	33-42856	Ship Bottom	-74.16736	39.66067	500–550	11	--	--	--	--	--	--	-29	--	11/13/2008
29-2056	33-45394	Ship Bottom	-74.23564	39.67858	379–421	8	--	--	--	--	--	--	10	--	11/13/2008
29-2057	P200905744	West Creek	-74.27018	39.72529	356–432	64	--	--	--	--	--	--	-45	--	11/13/2008
29-2058	32-28028	Tuckerton	-74.338	39.59327	406–509	10	--	--	--	--	--	--	-22	--	11/12/2008

Appendix 3. Water-level data for wells screened in the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	State-issued permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
1-270	31-03648	Newtonville	-74.78931	39.62028	390–410	93	--	33	33	31	22	18	19	1	11/20/2008
1-700	35-04274	Dorothy	-74.76739	39.49262	479–539	40	--	--	17	12	18	18	17	-1	11/17/2008
1-701	35-03992	Buena	-74.93806	39.53023	410–460	120	--	--	--	--	--	-26	-43	-17	11/12/2008
1-713	35-04656	Dorothy	-74.84711	39.48401	525–535	100	--	--	-2	-4	-6	-8	-9	-1	11/17/2008
1-834	**--**	**Ocean City**	**-74.50015**	**39.33817**	**970–991**	**5**	**--**	**--**	**-28**	**-30**	**-32**	**-34**	**-38**	**-4**	**12/2/2008**
1-1219	36-16546	Pleasantville	-74.62294	39.44456	722–742	68	--	--	--	-14	-16	-18	-19	-1	11/26/2008
1-1238	55-00008	Buena	-74.93086	39.53081	391–463	108	--	--	--	--	-31	-17	-34	-17	11/12/2008
1-1405	36-23678	Mays Landing	-74.71769	39.46355	545–620	23	--	--	--	--	--	-6	-8	-2	12/10/2008
1-1445	35-22078	Buena	-74.95903	39.51153	360–540	99	--	--	--	--	--	-29	-45	-16	11/12/2008
5-407	**--**	**Atsion**	**-74.71877**	**39.73956**	**240–260**	**47**	**52**	**51**	**51**	**51**	**50**	**50**	**49**	**-1**	**10/21/2008**
5-488	32-00913	Atsion	-74.64847	39.64583	419–449	37	51	50	50	54	48	47	47	0	11/17/2008
5-676	**--**	**Woodmansie**	**-74.42904**	**39.82067**	**530–540**	**199**	**121**	**119**	**118**	**119**	**120**	**118**	**117**	**-1**	**10/21/2008**
5-800	32-04454	Medford Lakes	-74.75683	39.79234	200–210	85	--	73	72	73	72	73	72	-1	11/5/2008
5-1162	32-05879	Indian Mills	-74.73585	39.77670	215–235	60	--	--	--	--	--	--	53	--	11/7/2008
7-572	31-14078	Hammonton	-74.84119	39.68239	304–314	108	--	60	55	53	50	51	50	-1	12/9/2008
7-980	31-09893	Hammonton	-74.84266	39.68584	274–294	102	--	--	--	--	--	49	42	-7	12/9/2008
7-1147	31-64921	Williamstown	-74.88472	39.68056	–390	139	--	--	--	--	--	--	71	--	12/30/2008
7-1280	31-72548	Hammonton	-74.84111	39.68240	290–320	108	--	--	--	--	--	--	43	--	12/9/2008
11-44	**35-01197**	**Bridgeton**	**-75.15768**	**39.45900**	**361–376**	**82**	**17**	**12**	**7**	**0**	**-5**	**-7**	**-70**	**-63**	**11/19/2008**
11-92	--	Ben Davis Point	-75.25241	39.29623	397–417	5	--	-28	-37	-44	-44	-46	-75	-29	12/9/2008
11-96	**34-00852**	**Cedarville**	**-75.20185**	**39.30817**	**365–375**	**10**	**-15**	**-20**	**-28**	**-34**	**-34**	**-34**	**-61**	**-27**	**11/19/2008**
11-163	**35-01196**	**Millville**	**-75.11157**	**39.42400**	**463–473**	**80**	**22**	**13**	**8**	**2**	**-4**	**-11**	**-48**	**-37**	**11/19/2008**
11-341	34-00991	Ben Davis Point	-75.32228	39.32683	300–357	4	--	-35	-44	-49	-50	-50	-81	-31	12/9/2008
11-349	34-01463	Cedarville	-75.23958	39.28189	380–410	5	--	-28	-35	-42	-42	-44	-70	-26	12/10/2008
11-1151	34-01814	Cedarville	-75.20886	39.26383	466–476	5	--	--	--	--	-40	-42	-66	-24	12/9/2008
11-1220	34-06736	Bridgeton	-75.22003	39.40900	235–375	29	--	--	--	--	--	-22	-154	-132	12/8/2008
11-1221	34-06556	Bridgeton	-75.21081	39.41092	250–390	36	--	--	--	--	--	-21	-157	-136	12/8/2008
11-1571	34-06557	Bridgeton	-75.21713	39.41067	245–390	42	--	--	--	--	--	--	-155	--	12/8/2008
15-1592	31-58699	Buena	-74.90919	39.58997	290–350	101	--	--	--	--	--	--	-2	--	11/20/2008

Appendix 3. Water-level data for wells screened in the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	State-issued permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
15-1593	31-58698	Buena	-74.96125	39.61933	335–405	118	--	--	--	--	--	--	22	--	11/20/2008
15-1757	31-70478	Buena	-74.96061	39.61978	290–350	119	--	--	--	--	--	--	21	--	11/20/2008
29-2	33-01206	Barnegat Light	-74.10958	39.75623	597–654	7	--	-40	-33	-38	--	-38	-35	3	11/13/2008
29-18	**--**	**Barnegat Light**	**-74.09264**	**39.80818**	**468–474**	**9**	**1**	**0**	**-0**	**-2**	**-2**	**-3**	**-3**	**0**	**10/17/2008**
29-23	33-01494	Seaside Park	-74.08230	39.90634	490–527	7	--	--	--	-57	-58	-43	-40	3	12/2/2008
29-116	53-00020	Toms River	-74.14764	39.94484	267–293	3	--	-1	-1	-2	-22	-13	-13	0	11/24/2008
29-425	**--**	**Whiting**	**-74.38070**	**39.88956**	**348–348**	**128**	**--**	**--**	**--**	**119**	**119**	**118**	**118**	**0**	**10/22/2008**
29-537	53-00001	Seaside Park	-74.07753	39.94320	400–430	4	--	-35	-30	-35	-58	-17	-19	-2	12/2/2008
29-582	33-04511	Seaside Park	-74.07558	39.92995	435–485	12	--	--	--	-51	--	-48	-37	11	12/3/2008
29-585	**--**	**Forked River**	**-74.17847**	**39.84123**	**412–422**	**15**	**--**	**15**	**15**	**12**	**14**	**14**	**12**	**-2**	**10/30/2008**
29-607	33-07876	Long Beach NE	-74.11497	39.74843	597–662	5	--	-41	-34	-38	-44	-40	-39	1	11/14/2008
29-616	53-00005	Toms River	-74.13878	39.92440	340–360	7	--	-6	-12	--	--	-17	-16	1	11/25/2008
29-739	33-01247	Lakewood	-74.16525	40.01233	200–220	20	--	13	11	13	8	11	10	-1	11/10/2008
29-808	33-06595	Seaside Park	-74.07891	39.93540	395–475	5	--	--	-29	-46	-76	-30	-31	-1	12/2/2008
29-1096	33-29653	Toms River	-74.16136	39.89940	345–440	32	--	--	--	--	-1	-9	-7	2	12/3/2008
29-1114	29-24912	Point Pleasant	-74.05736	40.01292	206–276	10	--	--	--	--	-3	1	-1	-2	11/5/2008
29-1210	36-20855	Tuckerton	-74.31903	39.52095	860–880	6	--	--	--	--	-14	-16	-19	-3	10/22/2008
29-1215	33-31998	Toms River	-74.17264	39.96706	196–258	25	--	--	--	--	--	--	-16	--	12/4/2008
29-1217	33-29690	Forked River	-74.18486	39.86433	468–583	32	--	--	--	--	--	17	15	-2	11/25/2008
29-1579	33-41928	West Creek	-74.26803	39.72931	595–645	61	--	--	--	--	--	25	24	-1	11/13/2008
29-1675	33-40849	Toms River	-74.21089	39.90275	335–445	72	--	--	--	--	--	--	19	--	12/3/2008
29-1681	33-40235	Seaside Park	-74.08297	39.91442	459–503	5	--	--	--	--	--	--	-45	--	12/2/2008
29-1999	33-41870	Toms River	-74.20556	39.92778	301–386	62	--	--	--	--	--	--	8	--	11/25/2008
					Delaware and Maryland										
De-KE-10400	10040	Wyoming	-75.5781	39.0044	--	54	--	--	--	--	--	--	-66	--	12/23/2008
DE-KE-11221	112218	Wyoming	-75.5661	39.0381	--	49	--	--	--	--	--	--	-86	--	12/16/2008
DE-KE-225743	225743	Wyoming	-75.5858	39.0894	--	55	--	--	--	--	--	--	-103	--	12/30/2008
CO Bd 53	**CO73-0541**	**Goldsboro**	**-75.7835**	**39.0409**	**300–312**	**60**	**30**	**30**	**26**	**22**	**20**	**17**	**17**	**0**	**3/31/2009**
Id55-01	**10225**	**Dover**	**-75.5133**	**39.1739**	**329–349**	**20**	**--**	**--**	**-132**	**-128**	**-127**	**-115**	**-128**	**-13**	**1/15/2009**

Appendix 3. Water-level data for wells screened in the Piney Point aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	State-issued permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
Jd14-15	10211	Dover	-75.5192	39.1547	370–450	21	--	--	--	--	-155	-121	-138	-17	12/17/2008
Jd25-03	--	Dover	-75.5086	39.1458	327–484	20	--	--	--	--	-130	-117	-132	-15	12/18/2008
Jd34-18	D010208	Dover	-75.5325	39.1247	330–337	20	--	--	--	--	-177	-116	-125	-9	12/17/2008
Je12-03	D031640	Little Creek	-75.4827	39.1557	340–502	22	--	--	--	--	-123	-114	-131	-17	12/18/2008
Kc31-01	**--**	**Marydel**	**-75.6541**	**39.0401**	**370–380**	**55**	**--**	**--**	**--**	**--**	**-56**	**-61**	**-66**	**-5**	**2/5/2009**
Nc13-03	**10223**	**Greenwood**	**-75.6161**	**38.8264**	**620–630**	**62.7**	**--**	**--**	**--**	**--**	**-26**	**-29**	**-34**	**-5**	**1/15/2009**

Appendix 4. Water-level data for wells screened in the Vincentown aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-1250	**28-20189-2**	**New Egypt**	**-74.58849**	**40.03011**	**45–55**	**112**	**--**	**--**	**--**	**--**	**102**	**103**	**103**	**0**	**12/29/2008**
5-1720	28-10989	New Egypt	-74.59613	40.05081	118–126	123	--	--	--	--	--	--	110	--	11/4/2008
15-123	31-00216	Pitman West	-75.15944	39.71494	121–150	140	--	--	--	--	75	77	78	1	12/9/2008
15-1005	30-03319	Pitman West	-75.22397	39.67906	140–156	148	--	--	70	--	62	70	64	-6	12/9/2008
15-1360	31-42096	Pitman West	-75.13417	39.72972	166–191	120	--	--	--	--	78	80	80	0	12/3/2008
15-1544	31-32489	Pitman West	-75.14222	39.71889	130–140	138	--	--	--	--	--	83	86	3	12/1/2008
25-448	29-04725	Asbury Park	-74.12236	40.19289	219–235	125	--	--	--	--	70	72	69	-3	10/24/2008
25-636	**29-18404-5**	**Farmingdale**	**-74.20014**	**40.18484**	**85–95**	**112**	**--**	**--**	**59**	**--**	**73**	**73**	**71**	**-2**	**10/22/2008**
25-685	29-13792	Marlboro	-74.13125	40.28567	68–76	80	--	--	--	--	--	--	70	--	12/2/2008
25-691	29-15843-5	Farmingdale	-74.18542	40.18456	5–25	50	--	--	43	--	45	46	45	-1	11/3/2008
25-702	29-09528	Asbury Park	-74.04669	40.22753	129–140	45	--	--	--	--	44	42	43	1	10/24/2008
25-703	29-11712	Asbury Park	-74.11389	40.22147	167–187	80	--	--	--	--	70	70	70	0	10/22/2008
25-717	29-28188	Adelphia	-74.33348	40.17956	38–43	150	--	--	--	--	131	133	130	-3	10/30/2008
25-788	29-36417	Long Branch	-74.02086	40.25192	120–166	50	--	--	--	--	29	31	29	-2	11/12/2008
25-789	29-06311	Farmingdale	-74.18625	40.18317	–198	70	--	--	--	--	--	46	45	-1	10/29/2008
25-847	29-23330	Farmingdale	-74.15861	40.21389	88–118	87	--	--	--	--	--	--	83	--	10/24/2008
25-1065	29-05506	Adelphia	-74.25467	40.15078	110–195	97	--	--	--	--	--	--	79	--	11/6/2008
29-139	**28-04784**	**Cassville**	**-74.45015**	**40.07067**	**161–171**	**136**	**--**	**129**	**129**	**--**	**130**	**130**	**129**	**-1**	**10/22/2008**
29-230	28-05038	Cassville	-74.39456	40.12344	85–100	150	--	--	130	--	132	133	129	-4	10/23/2008
29-241	29-07425	Adelphia	-74.26067	40.15286	115–165	82	--	--	--	--	--	83	77	-6	10/27/2008
29-658	29-08966	Lakehurst	-74.31237	40.11678	202–215	115	--	--	96	--	94	94	89	-5	10/30/2008
29-698	28-11275	Cassville	-74.41508	40.10008	120–132	152	--	--	141	--	137	137	134	-3	10/22/2008
29-916	29-13024	Adelphia	-74.27903	40.14734	139–155	125	--	--	106	--	111	110	106	-4	11/5/2008
29-917	29-16962	Adelphia	-74.25409	40.14722	126–186	75	--	--	75	--	63	69	65	-4	10/28/2008
33-292	30-00397	Woodstown	-75.25574	39.63734	190–218	142	--	--	--	--	--	43	37	-6	12/9/2008

Appendix 5. Water-level data for wells screened in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-257	51-00156	Mount Holly	-74.84969	39.92081	–90	80	27	25	27	54	50	54	52	-2	10/28/2008
5-354	32-00103	Pemberton	-74.66338	39.97042	178–198	62	40	39	36	40	36	39	36	-3	11/20/2008
5-355	52-00004	Pemberton	-74.68530	39.97400	155–185	81	39	38	38	41	39	42	39	-3	11/4/2008
5-359	32-00539	Pemberton	-74.68710	39.95695	181–242	70	36	35	37	34	37	42	36	-6	11/6/2008
5-365	32-00386	Browns Mills	-74.58177	39.96475	290–330	95	18	-3	-11	-12	0	6	4	-2	11/5/2008
5-367	32-00818	Browns Mills	-74.54377	39.96539	308–338	90	--	--	--	--	--	--	-27	--	11/6/2008
5-427	32-00749	Pemberton	-74.70099	39.89175	260–348	70	11	-8	-13	-5	-5	3	-8	-11	11/5/2008
5-464	32-00637	Medford Lakes	-74.75997	39.85392	--	120	--	--	--	--	--	--	-45	--	11/13/2008
5-695	32-01240	Browns Mills	-74.62182	39.89123	428–496	102	24	18	15	9	7	8	-2	-10	11/5/2008
5-711	31-05707	Medford Lakes	-74.79377	39.85789	260–275	75	--	--	--	--	--	-12	-35	-23	11/6/2008
5-718	32-00361	Browns Mills	-74.50960	39.96012	376–388	95	--	--	--	--	-8	-4	-3	1	11/5/2008
5-724	32-03118	Pemberton	-74.70763	39.90403	199–275	43	18	15	6	6	-6	-1	-8	-7	11/5/2008
5-725	48-00021	New Egypt	-74.61902	40.03692	142–162	145	128	126	125	126	125	126	125	-1	11/4/2008
5-744	32-00520	Whiting	-74.49742	39.94425	–456	100	9	-13	-21	-21	-9	-6	-6	0	11/6/2008
5-1004	32-08631	Pemberton	-74.67010	39.95400	209–254	84	--	--	29	36	36	31	26	-5	11/6/2008
5-1082	31-19052	Mount Holly	-74.79197	40.00036	82–92	48	--	--	22	23	18	24	23	-1	10/29/2008
5-1087	32-09937	Pemberton	-74.74433	39.89261	227–232	55	--	--	11	9	-2	5	-7	-12	11/5/2008
5-1155	31-39849	Mount Holly	-74.82939	39.88767	120–180	46	--	--	--	31	23	25	18	-7	10/27/2008
5-1165	32-00490	Browns Mills	-74.58866	39.98220	275–307	120	--	--	--	6	14	17	17	0	11/11/2008
5-1166	28-17342	New Egypt	-74.56463	40.07514	119–129	135	--	--	--	100	97	100	98	-2	11/05/2008
5-1178	32-13264	Pemberton	-74.73688	39.92784	140–180	40	--	--	--	30	19	21	15	-6	10/21/2008
5-1186	32-15968	Browns Mills	-74.55152	39.98745	267–358	90	--	--	--	-27	-6	-1	-1	0	11/6/2008
5-1245	52-00082	Mount Holly	-74.75238	39.91400	--	39	--	--	--	--	10	19	10	-9	10/29/2008
5-1253	31-46953	Medford Lakes	-74.80155	39.82789	357–417	118	--	--	--	--	-47	-32	-55	-23	11/7/2008
5-1387	31-40373	Clementon	-74.87908	39.80000	335–355	119	--	--	--	--	2	1	-6	-7	11/7/2008
5-1414	31-49988	Medford Lakes	-74.85461	39.84789	199–259	65	--	--	--	--	--	-12	-30	-18	11/7/2008
5-1415	31-50015	Medford Lakes	-74.85033	39.86292	162–212	50	--	--	--	--	--	3	-13	-16	11/13/2008
5-1449	32-12425	Pemberton	-74.69639	39.94333	160–198	45	--	--	--	--	--	27	19	-8	10/29/2008
5-1475	32-18506	Browns Mills	-74.58654	39.97623	276–326	110	--	--	--	--	7	12	4	-8	11/5/2008
5-1495	32-06317	Whiting	-74.47800	39.93550	512–522	120	--	--	--	--	2	5	5	0	11/6/2008

Appendix 5. Water-level data for wells screened in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-1776	31-38296	Medford Lakes	-74.87444	39.82778	295–305	90	--	--	--	--	--	--	-1	--	02/23/2009
7-22	31-00513	Clementon	-74.93650	39.79378	310–360	147	34	--	11	-7	4	3	0	-3	11/3/2008
7-118	**31-04898**	**Clementon**	**-74.95294**	**39.87484**	**137–147**	**158**	**69**	**69**	**68**	**68**	**68**	**68**	**67**	**-1**	**11/7/2008**
7-308	51-00014	Runnemede	-75.00536	39.82464	–126	77	57	58	56	55	49	50	48	-2	12/23/2008
7-391	31-05628	Clementon	-74.96453	39.77839	315–335	168	36	37	16	2	-14	-9	-12	-3	11/14/2008
7-401	31-02371	Clementon	-74.96905	39.78956	–267	85	36	43	23	9	-6	-3	-2	1	11/6/2008
7-414	51-00010	Clementon	-74.94136	39.82303	237–275	150	60	52	36	51	58	52	49	-3	11/19/2008
7-421	--	Clementon	-74.95378	39.85261	220–234	175	91	91	89	89	87	88	86	-2	11/3/2008
7-449	31-04749	Clementon	-74.90297	39.77159	420–460	159	20	19	-4	--	-10	-9	-12	-3	11/6/2008
7-478	**--**	**Williamstown**	**-74.93767**	**39.70428**	**520–530**	**111**	**36**	**40**	**21**	**3**	**-25**	**-29**	**-32**	**-3**	**11/7/2008**
7-513	31-07766	Clementon	-74.93933	39.75900	410–460	166	--	--	-4	-19	-31	-34	-27	7	11/21/2008
7-685	31-22273	Williamstown	-74.98686	39.75370	322–427	144	--	--	--	-20	-62	-50	-51	-1	12/2/2008
7-847	31-36246	Pitman East	-75.02128	39.73317	329–380	150	--	--	--	--	-81	-71	-82	-11	12/3/2008
7-1079	31-22832	Runnemede	-75.01961	39.80400	120–130	67	--	--	--	--	--	51	50	-1	11/20/2008
7-1086	31-61104	Clementon	-74.99722	39.77889	299–389	180	--	--	--	--	--	--	-16	--	12/2/2008
7-1202	31-62243	Medford Lakes	-74.84016	39.76678	495–525	114	--	--	--	--	--	--	-13	--	11/21/2008
15-687	31-22088	Woodbury	-75.19683	39.77542	5.5–23.5	28	--	--	--	--	--	--	22	--	11/25/2008
15-910	30-02454	Pitman West	-75.23686	39.69800	140–160	108	--	--	82	81	78	85	81	-4	12/9/2008
15-953	31-06570	Runnemede	-75.10073	39.78845	86–100	81	--	--	56	55	54	55	52	-3	11/20/2008
15-1009	31-22018	Pitman East	-75.10836	39.74078	149–178	100	--	--	65	62	58	62	59	-3	12/02/2008
15-1040	30-05046	Woodstown	-75.30658	39.71595	77–87	120	--	--	77	79	78	81	78	-3	12/3/2008
15-1060	31-30571	Pitman East	-75.09804	39.68339	335–386	136	--	--	--	20	-47	-23	3	26	12/2/2008
15-1104	30-02422-6	Woodstown	-75.32074	39.73067	–40	102	--	--	--	81	79	82	79	-3	12/04/2008
15-1126	31-34033-4	Pitman East	-75.10712	39.68873	328–338	146	--	--	--	--	-22	-3	8	11	11/14/2008
15-1203	31-34604	Pitman East	-75.08128	39.70956	298–308	147	--	--	--	--	-31	-3	-2	1	1/8/2009
15-1206	31-39283	Pitman West	-75.16125	39.72781	195–215	139	--	--	--	--	--	82	86	4	12/3/2008
15-1223	31-33093-2	Pitman East	-75.08795	39.65345	485–495	137	--	--	--	--	--	-7	-13	-6	1/8/2009
15-1349	31-33937	Pitman East	-75.03350	39.72428	680–690	160	--	--	--	--	--	-63	-60	3	11/20/2008
15-1357	31-25418	Pitman East	-75.09823	39.68261	340–390	137	--	--	--	--	--	-23	2	25	12/2/2008
15-1384	31-45999	Pitman East	-75.03231	39.72231	342–382	160	--	--	--	--	--	-47	-65	-18	1/8/2009

Appendix 5. Water-level data for wells screened in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
15-1387	51-00215	Woodbury	-75.12914	39.76211	70–100	45	--	--	--	--	--	--	37	--	11/25/2008
15-1452	31-36292	Pitman West	-75.14231	39.71886	198–258	142	--	--	--	--	--	74	78	4	12/1/2008
15-1517	30-11753	Pitman West	-75.22208	39.72372	112–132	88	--	--	--	--	65	67	64	-3	12/9/2008
15-1524	31-22318	Runnemede	-75.07989	39.76484	174–225	90	--	--	--	--	--	66	65	-1	12/2/2008
15-1634	31-56244	Pitman West	-75.17639	39.65056	340–370	140	--	--	--	--	--	--	26	--	12/12/2008
25-14	49-00017	Asbury Park	-74.02233	40.19386	424–504	20	-153	-170	-210	-91	-85	-67	-60	7	10/23/2008
25-88	29-05886	Adelphia	-74.28289	40.24456	143–163	150	--	--	114	112	113	113	110	-3	11/25/2008
25-95	29-04709	Freehold	-74.27848	40.27178	128–140	162	--	--	--	133	134	133	131	-2	10/28/2008
25-166	29-04381	Farmingdale	-74.23448	40.16450	336–396	123	--	--	-29	21	21	23	22	-1	10/22/2008
25-168	29-03105	Farmingdale	-74.22103	40.16597	354–440	160	-46	-44	-56	--	-2	11	0	-11	10/2/2008
25-185	29-02607	Farmingdale	-74.17320	40.24400	229–250	119	59	60	56	65	66	65	59	-6	10/29/2008
25-335	--	Asbury Park	-74.06875	40.20428	465–480	90	-110	-118	-136	-56	-59	-38	-37	1	10/22/2008
25-353	**--**	**Long Branch**	**-74.09125**	**40.26178**	**321–327**	**140**	**--**	**-21**	**-15**	**10**	**15**	**16**	**13**	**-3**	**10/17/2008**
25-391	29-07506	Asbury Park	-74.03617	40.15798	485–561	25	-190	-161	-215	-104	-83	-72	-68	4	10/23/2008
25-396	28-06896	New Egypt	-74.52599	40.11622	92–102	122	85	85	83	86	83	86	82	-4	11/3/2008
25-405	--	Roosevelt	-74.48654	40.16817	–124	158	127	128	126	127	145	147	145	-2	10/23/2008
25-412	28-05835	Roosevelt	-74.47206	40.17967	100–140	194	153	152	151	152	150	150	147	-3	10/23/2008
25-443	29-02871	Asbury Park	-74.06428	40.18161	435–465	75	-147	-158	--	--	--	-63	-55	8	10/23/2008
25-486	**--**	**Point Pleasant**	**-74.03347**	**40.11984**	**604–614**	**10**	**--**	**--**	**-185**	**-102**	**-74**	**-69**	**-59**	**10**	**10/17/2008**
25-533	29-05113	Farmingdale	-74.22570	40.13789	349–365	120	--	-61	-74	-21	-16	-8	-21	-13	11/25/2008
25-542	--	Asbury Park	-74.12431	40.16425	430–450	68	--	-99	-115	-51	-34	-25	-25	0	10/23/2008
25-637	**29-18400-2**	**Farmingdale**	**-74.20014**	**40.18484**	**307–317**	**112**	**--**	**--**	**-28**	**7**	**16**	**13**	**13**	**0**	**10/22/2008**
25-687	29-15008	Long Branch	-74.04747	40.30217	177–187	20	--	--	1	8	11	11	8	-3	11/5/2008
25-698	29-17963	Asbury Park	-74.07203	40.18789	421–451	75	--	--	--	--	--	--	-58	--	10/23/2008
25-720	29-16821	Adelphia	-74.26570	40.18150	235–255	120	--	--	--	--	--	--	80	--	11/6/2008
25-829	29-36936	Farmingdale	-74.16169	40.14233	395–402	61	--	--	--	--	--	-32	-26	6	10/24/2008
25-897	29-17602	Farmingdale	-74.14792	40.22456	288–298	95	--	--	--	--	--	--	45	--	11/3/2008
25-976	29-45800	Long Branch	-74.09208	40.30733	--	61	--	--	--	--	--	--	28	--	11/4/2008
29-31	29-04663	Lakewood	-74.13678	40.04294	605–625	13	-117	-124	-133	-120	-73	-59	-54	5	11/10/2008
29-36	29-06021	Lakewood	-74.15339	40.07058	518–548	30	--	-131	-146	-115	-75	-63	-57	6	10/31/2008

Appendix 5. Water-level data for wells screened in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
29-37	29-04283	Point Pleasant	-74.11464	40.07511	576–591	20	-136	-141	-155	-129	-90	-76	-68	8	11/24/2008
29-49	29-06022	Point Pleasant	-74.11772	40.08439	556–586	29	--	-135	-149	-122	-82	-69	-63	6	11/10/2008
29-140	**28-04785**	**Cassville**	**-74.45015**	**40.07067**	**257–267**	**135**	**115**	**--**	**112**	**112**	**112**	**112**	**107**	**-5**	**10/22/2008**
29-227	29-05007	Lakehurst	-74.32029	40.10175	–358	110	42	38	--	47	46	39	19	-20	10/31/2008
29-234	28-08255	Roosevelt	-74.42515	40.13595	180–200	140	123	130	122	121	121	119	114	-5	10/24/2008
29-699	28-07966	Roosevelt	-74.39181	40.15483	214–226	160	--	124	121	123	122	118	109	-9	10/23/2008
29-713	28-10063	Lakehurst	-74.35015	40.11011	318–324	130	--	83	82	84	84	78	58	-20	10/27/2008
29-740	29-08522	Lakehurst	-74.35483	40.05897	340–380	105	--	41	39	42	52	53	46	-7	11/3/2008
29-781	29-09069	Lakehurst	-74.33209	40.10623	302–325	110	--	--	40	36	42	59	38	-21	11/3/2008
29-782	29-09348	Lakehurst	-74.25653	40.11928	375–381	120	--	--	--	--	--	-1	-2	-1	11/5/2008
29-783	29-09681	Adelphia	-74.29967	40.12950	310–325	112	--	49	39	39	48	46	42	-4	11/6/2008
29-784	29-10449	Lakehurst	-74.30181	40.09734	341–347	90	--	--	2	4	9	6	-10	-16	11/7/2008
29-786	29-08581	Lakehurst	-74.29126	40.10845	364–379	110	--	-0	-3	4	13	9	-3	-12	10/30/2008
29-926	28-18902	Cassville	-74.45737	40.10289	127–160	105	--	--	109	110	110	110	107	-3	11/5/2008
29-1138	28-23392	New Egypt	-74.50265	40.10456	100–120	95	--	--	--	--	96	97	93	-4	11/3/2008
29-2055	28-56401	Adelphia	-74.37000	40.14806	249–269	157	--	--	--	--	--	--	101	--	11/3/2008
33-2	--	Alloway	-75.27463	39.53400	462–472	85	--	22	20	19	14	15	10	-5	12/15/2008
33-8	30-00030	Alloway	-75.30608	39.55819	322–345	62	--	--	12	10	7	9	4	-5	12/5/2008
33-20	**--**	**Alloway**	**-75.29741**	**39.59289**	**–283**	**77**	**33**	**32**	**30**	**28**	**25**	**27**	**22**	**-5**	**11/14/2008**
33-22	31-04612	Elmer	-75.17179	39.59273	460–500	105	28	30	27	20	6	14	3	-11	12/5/2008
33-50	--	Salem	-75.44381	39.59319	73–97	20	5	6	4	5	6	7	5	-2	12/8/2008
33-56	--	Salem	-75.42308	39.60186	–93	25	7	7	7	7	7	8	6	-2	12/8/2008
33-249	50-00042	Salem	-75.45464	39.56189	110–150	5	0	-2	-5	--	--	-6	-6	0	12/9/2008
33-252	**--**	**Salem**	**-75.46467**	**39.56370**	**91–96**	**3**	**1**	**0**	**-0**	**0**	**-1**	**1**	**-1**	**-2**	**11/20/2008**
33-381	30-01505	Salem	-75.45214	39.58150	85–125	10	--	-0	1	1	-0	1	0	-1	12/9/2008
33-384	30-01356	Salem	-75.41664	39.52722	–320	15	--	1	--	0	-1	1	0	-1	12/9/2008
33-407	34-01600	Salem	-75.43353	39.50258	250–300	5	--	--	--	--	-7	-2	-2	0	12/15/2008
33-456	31-19206	Elmer	-75.17940	39.58548	443–503	125	--	28	27	22	8	9	8	-1	12/5/2008
33-664	30-01454	Woodstown	-75.35269	39.62622	123–166	70	--	--	--	--	36	38	36	-2	12/9/2008
33-842	35-17374	Elmer	-75.14268	39.51539	675–695	77	--	--	--	--	--	--	18	--	11/19/2008

Appendix 5. Water-level data for wells screened in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
33-886	30-06741	Pitman West	-75.22742	39.63106	358–378	144	--	--	--	--	--	38	31	-7	12/15/2008
33-902	30-09510	Woodstown	-75.31766	39.64592	100–143	48	--	--	--	--	36	38	36	-2	12/5/2008
33-904	30-05669	Pitman West	-75.23525	39.64997	300–310	143	--	--	--	--	--	48	40	-8	12/2/2008
33-932	30-05631	Salem	-75.42425	39.60108	70–80	30	--	--	--	--	9	11	9	-2	12/9/2008
33-937	30-08556	Alloway	-75.28458	39.57298	318–338	102	--	--	--	--	--	15	9	-6	12/5/2008
33-938	34-00970	Taylors Bridge	-75.52944	39.46208	270–290	18	--	--	--	--	2	3	5	2	12/10/2008
33-973	30-05372	Alloway	-75.36419	39.55892	230–240	39	--	--	--	--	--	14	11	-3	12/5/2008

Appendix 6. Water-level data for wells screened in the Englishtown aquifer system, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
5-195	31-01164	Mount Holly	-74.84458	39.97606	70–74	60	25	23	22	26	22	22	21	-1	10/31/2008
5-197	31-01191	Mount Holly	-74.82211	39.94817	148–159	41	26	25	19	26	24	26	22	-4	10/31/2008
5-256	31-01399	Mount Holly	-74.84956	39.92078	–440	79	--	--	--	--	19	20	18	-2	10/28/2008
5-259	**--**	**Mount Holly**	**-74.83989**	**39.92345**	**253–263**	**73**	**25**	**--**	**24**	**24**	**20**	**19**	**18**	**-1**	**10/27/2008**
5-375	32-00276	Pemberton	-74.64321	39.96873	343–378	72	19	29	25	20	12	21	26	5	11/5/2008
5-387	32-01103	Pemberton	-74.68849	39.99539	208–228	50	52	54	49	52	49	48	49	1	11/10/2008
5-437	28-03831	Columbus	-74.69349	40.03622	94–105	74	62	61	61	66	58	62	59	-3	10/29/2008
5-754	--	Browns Mills	-74.54619	39.99483	419–447	100	50	46	43	37	32	31	29	-2	11/4/2008
5-1390	32-21804	Browns Mills	-74.58877	39.88595	615–635	107	--	--	--	--	10	11	7	-4	10/21/2008
5-1427	27-11807	Bristol	-74.79516	40.01456	40–60	55	--	--	--	--	--	51	47	-4	10/23/2008
5-1437	28-11130	New Egypt	-74.57543	40.11456	165–245	170	--	--	--	--	--	100	96	-4	10/27/2008
5-1476	31-55694	Mount Holly	-74.84044	39.99122	9–14	17	--	--	--	--	--	12	10	-2	10/27/2008
5-1482	32-18441	Browns Mills	-74.58793	39.97623	431–511	113	--	--	--	--	--	--	-38	--	11/6/2008
5-1492	32-22557	Browns Mills	-74.55182	39.98761	411–451	88	--	--	--	--	23	23	21	-2	11/6/2008
5-1493	32-22560	Browns Mills	-74.55024	39.98773	430–470	100	--	--	--	--	--	28	30	2	11/6/2008
5-1762	31-65897	Mount Holly	-74.80000	39.91472	249–279	55	--	--	--	--	--	--	12	--	10/28/2008
5-1763	31-70362	Mount Holly	-74.79944	39.91694	231–281	55	--	--	--	--	--	--	10	--	10/28/2008
7-166	31-01202	Clementon	-74.96828	39.80225	367–457	150	0	47	11	15	13	10	19	9	12/3/2008
7-529	31-13543	Clementon	-74.98711	39.80900	250–283	55	1	50	26	3	0	4	20	16	10/31/2008
7-672	31-24779	Runnemede	-75.00611	39.82458	195–215	76	--	--	49	46	28	3	23	20	12/23/2008
7-673	31-24778	Runnemede	-75.00617	39.82461	195–215	76	--	--	50	--	--	6	24	18	12/23/2008
7-731	31-29319	Clementon	-74.98222	39.83089	216–236	69	--	--	--	52	46	27	10	-17	12/23/2008
15-676	--	Woodbury	-75.19681	39.77542	68–78	28	--	--	30	30	30	30	30	0	11/25/2008
23-104	**--**	**Freehold**	**-74.31320**	**40.36205**	**0–11**	**77**	**--**	**--**	**69**	**74**	**70**	**73**	**72**	**-1**	**10/20/2008**
23-211	28-07520	Jamesburg	-74.37942	40.30558	43–49	105	90	93	91	--	95	94	93	-1	10/21/2008
25-9	49-00050	Sandy Hook	-74.04236	40.41150	--	15	10	11	5	10	9	--	8	--	10/22/2008
25-16	29-00045	Asbury Park	-74.02961	40.17611	563–594	20	-188	-196	-202	-91	-68	-68	-52	16	10/23/2008
25-28	29-05292	Point Pleasant	-74.07447	40.10659	770–820	90	-219	-220	-207	-119	-93	-100	-63	37	11/13/2008
25-30	29-00069	Point Pleasant	-74.06197	40.11256	690–750	33	-233	-249	-225	-116	-91	-100	-62	38	11/13/2008
25-46	29-04196	Marlboro	-74.20542	40.29650	212–232	122	70	68	61	--	58	52	41	-11	11/7/2008

Appendix 6. Water-level data for wells screened in the Englishtown aquifer system, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
25-63	29-04386	Farmingdale	-74.17170	40.19659	420–460	75	--	--	-83	-39	-27	-29	-11	18	10/29/2008
25-80	29-05417	Adelphia	-74.24987	40.23761	294–334	120	75	78	73	73	78	75	68	-7	11/25/2008
25-96	29-04435	Freehold	-74.25015	40.27344	327–356	200	87	88	81	74	68	70	60	-10	10/27/2008
25-144	49-00031	Marlboro	-74.16556	40.36200	–154	104	--	--	59	--	57	58	57	-1	11/25/2008
25-162	29-07043	Farmingdale	-74.17820	40.13761	500–560	69	-114	-120	-125	-66	-48	-51	-48	3	11/5/2008
25-165	29-05346	Farmingdale	-74.22289	40.14500	363–550	135	--	--	-94	-46	-36	-30	-53	-23	11/6/2008
25-250	**29-04437**	**Freehold**	**-74.25765**	**40.32178**	**185–215**	**139**	**100**	**99**	**95**	**92**	**90**	**92**	**89**	**-3**	**10/20/2008**
25-277	29-00030	Keyport	-74.24242	40.37528	138–152	180	--	--	--	--	92	91	90	-1	10/15/2008
25-365	29-04513	Long Branch	-74.01764	40.34622	268–333	8	--	--	--	6	2	8	6	-2	11/12/2008
25-383	49-00014	Asbury Park	-74.03533	40.14703	631–711	15	--	--	--	--	--	--	-61	--	10/23/2008
25-389	29-00398	Asbury Park	-74.05180	40.14920	660–711	60	-203	-232	-224	-109	-83	-96	-65	31	10/23/2008
25-408	28-06655	Allentown	-74.53321	40.16872	96–119	105	--	100	100	99	--	99	100	1	10/24/2008
25-428	29-02869	Asbury Park	-74.08197	40.13956	689–740	100	--	--	--	--	--	--	-74	--	10/23/2008
25-429	**29-04140**	**Farmingdale**	**-74.14236**	**40.14289**	**623–633**	**98**	**-143**	**-149**	**-149**	**-78**	**-58**	**-66**	**-47**	**19**	**10/30/2008**
25-441	29-05289	Asbury Park	-74.10975	40.17500	549–649	120	-162	-163	-170	-74	-65	-73	-50	23	10/23/2008
25-442	49-00032	Asbury Park	-74.06144	40.18114	627–657	70	--	-177	--	--	--	-67	-50	17	10/23/2008
25-638	**29-18401-1**	**Farmingdale**	**-74.20014**	**40.18484**	**483–493**	**112**	**--**	**--**	**-53**	**-14**	**-3**	**-6**	**-2**	**4**	**10/22/2008**
25-686	29-15362	Marlboro	-74.13125	40.29928	320–340	80	--	--	--	31	--	27	28	1	12/2/2008
25-697	29-13591	Long Branch	-74.07522	40.32836	247–277	77	--	--	25	28	29	29	26	-3	11/5/2008
25-704	29-15337	Adelphia	-74.30848	40.24733	290–320	195	--	--	105	107	107	106	102	-4	11/7/2008
25-710	29-16728	Lakewood	-74.15267	40.10181	594–644	45	--	--	-164	-96	-70	-71	-60	11	10/30/2008
25-714	29-25383	Sandy Hook	-74.02858	40.40680	198–248	80	--	--	--	--	--	10	4	-6	10/28/2008
25-715	**29-25384**	**Sandy Hook**	**-74.00486**	**40.40733**	**350–360**	**229**	**--**	**--**	**--**	**5**	**4**	**5**	**4**	**-1**	**10/15/2008**
25-727	29-24425	Freehold	-74.29315	40.27922	149–206	112	--	--	--	--	--	68	62	-6	10/27/2008
25-733	29-28556	Marlboro	-74.19764	40.27233	316–366	135	--	--	--	--	47	48	39	-9	11/7/2008
25-735	29-26191	Marlboro	-74.23042	40.35091	140–191	140	--	--	--	33	83	84	82	-2	11/7/2008
25-771	29-36217	Sandy Hook	-73.97708	40.39733	258–278	8	--	--	--	--	-1	2	0	--	10/15/2008
25-771	29-36217	Sandy Hook		Freshwater equivalent			--	--	--	--	4	6	5	-1	10/15/2008
25-782	28-14424	Allentown	-74.52015	40.13539	215–245	150	--	--	--	--	--	104	92	-12	10/29/2008
25-786	29-30436	Marlboro	-74.13681	40.30039	233–273	87	--	--	--	--	32	33	30	-3	11/20/2008

Appendix 6. Water-level data for wells screened in the Englishtown aquifer system, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
25-787	28-36906	Allentown	-74.52606	40.18197	90–100	133	--	--	--	--	113	114	113	-1	10/22/2008
25-837	29-26791	Adelphia	-74.32917	40.20667	243–318	118	--	--	--	--	--	--	96	--	11/6/2008
25-1002	29-45380	Marlboro	-74.22376	40.31317	--	123	--	--	--	--	--	--	76	--	11/25/2008
29-5	49-00002	Point Pleasant	-74.04480	40.06839	750–834	4	-232	-225	-208	-159	-110	-100	-70	30	11/5/2008
29-138	**--**	**Cassville**	**-74.45015**	**40.07067**	**417–427**	**137**	**65**	**63**	**60**	**61**	**65**	**65**	**61**	**-4**	**10/22/2008**
29-236	29-03883	Adelphia	-74.25870	40.14011	541–577	170	--	-43	-53	-16	-56	-7	-9	-2	10/27/2008
29-430	29-05721	Lakewood	-74.19820	40.03876	752–817	104	--	-182	-176	-105	--	-76	-76	0	11/12/2008
29-433	29-05110	Lakewood	-74.18839	40.05253	673–741	45	-207	-202	-184	-105	-78	-75	-71	4	11/12/2008
29-434	29-04304	Lakewood	-74.22106	40.06114	697–757	123	-189	-160	--	-93	-68	-72	-64	8	11/6/2008
29-438	29-04834	Lakewood	-74.23484	40.07750	600–758	78	-152	-170	-161	-112	-79	-90	-91	-1	11/5/2008
29-441	29-05068	Lakewood	-74.18686	40.08478	726–736	30	-136	-141	-140	-112	-70	-61	-53	8	11/5/2008
29-450	29-03324	Lakewood	-74.22978	40.10653	520–582	70	-135	-153	-133	-87	-61	-70	-65	5	11/5/2008
29-451	29-02207	Lakehurst	-74.25376	40.11011	510–530	60	-102	-108	-103	-64	-52	-54	-51	3	11/5/2008
29-452	--	Seaside Park	-74.07625	39.96181	1,120–1,180	11	--	-115	-104	-85	--	-51	-51	0	11/24/2008
29-454	--	Seaside Park	-74.07189	39.96876	1,009–1,136	5	-119	-118	-107	-85	-85	-43	-37	6	11/24/2008
29-503	29-01325	Point Pleasant	-74.05236	40.03623	845–906	5	--	-194	-194	-133	-98	-94	-66	28	11/5/2008
29-518	--	New Egypt	-74.53293	40.06706	218–238	75	--	--	61	62	62	54	51	-3	10/21/2008
29-530	**29-04530**	**Point Pleasant**	**-74.07036**	**40.08133**	**730–790**	**17**	**-236**	**-211**	**-202**	**-146**	**-99**	**-102**	**-74**	**28**	**11/20/2008**
29-532	49-00075	Point Pleasant	-74.06605	40.08303	748–798	10	--	-259	-216	--	--	-115	-84	31	11/20/2008
29-534	**33-01117**	**Toms River**	**-74.21070**	**39.93595**	**1,080–1,146**	**18**	**-79**	**-86**	**-86**	**-85**	**-66**	**-54**	**-46**	**8**	**10/30/2008**
29-938	28-20499	Lakehurst	-74.35584	40.06600	487–527	123	--	--	-15	0	15	16	16	0	10/31/2008
29-1316	29-26316	Lakehurst	-74.32681	40.07789	512–553	105	--	--	--	--	4	2	3	1	11/3/2008
29-1336	28-34164	Cassville	-74.49353	40.07483	305–355	130	--	--	--	--	76	76	71	-5	10/29/2008
29-2013	28-41494	Roosevelt	-74.42071	40.14150	378–398	144	--	--	--	--	--	--	100	--	10/24/2008
29-2023	29-55507	Lakewood	-74.19867	40.10414	533–700	55	--	--	--	--	--	--	-101	--	11/5/2008
33-168	30-00029	Penns Grove	-75.37378	39.66119	113–124	40	--	--	--	--	17	19	16	-3	12/3/2008
33-581	30-01467	Penns Grove	-75.37736	39.65881	95–115	22	--	--	16	11	--	15	13	-2	12/3/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-116	28-02847	Columbus	-74.64294	40.11900	247–253	102	7	6	3	4	5	-1	0	1	10/29/2008
5-165	31-05458	Moorestown	-74.90469	39.87498	464–500	121	-64	-70	-94	-93	-74	-74	-70	4	11/9/2008
5-167	31-07883	Mount Holly	-74.86411	39.87959	478–548	46	-74	-83	-88	-92	-73	-77	-72	5	1/8/2009
5-212	28-03560	Columbus	-74.68544	40.08761	290–310	83	-13	-15	-18	-18	-17	-21	-22	-1	10/30/2008
5-218	--	Columbus	-74.74766	40.12178	–100	65	3	1	1	3	2	3	-2	-5	10/30/2008
5-229	31-08922	Moorestown	-74.98228	39.94217	160–200	40	-47	-57	-56	-53	-48	-37	-35	2	11/3/2008
5-249	31-05282	Medford Lakes	-74.84502	39.86889	523–541	55	-65	-75	-84	-86	-68	-60	-64	-4	11/13/2008
5-254	31-10560	Mount Holly	-74.81527	39.90675	451–471	32	--	--	--	-77	-66	-60	-60	0	10/29/2008
5-258	**31-04627**	**Mount Holly**	**-74.83989**	**39.92345**	**400–410**	**71**	**-52**	**-65**	**-66**	**-69**	**-59**	**-54**	**-52**	**2**	**10/27/2008**
5-317	31-00212	Moorestown	-74.88794	39.98067	192–222	45	--	--	-45	-46	-46	-32	-29	3	12/9/2008
5-438	--	Bristol	-74.76738	40.03844	220–230	41	-22	-23	--	--	--	-23	-25	-2	10/24/2008
5-707	31-14627	Moorestown	-74.91733	39.89561	405–441	100	--	-86	-94	--	-71	-67	-64	3	11/9/2008
5-728	--	Pemberton	-74.72766	39.97206	485–500	55	-31	-31	-37	-42	-43	-33	-36	-3	11/5/2008
5-731	--	Trenton East	-74.70738	40.12761	118–128	93	5	4	3	3	3	2	1	-1	11/3/2008
5-745	27-05937	Bristol	-74.80489	40.03261	260–290	102	-18	-17	-21	-23	-23	-20	-21	-1	10/23/2008
5-759	31-16976	Medford Lakes	-74.82572	39.85956	593–672	65	--	--	--	--	--	-86	-91	-5	11/7/2008
5-795	31-09595	Moorestown	-74.89325	39.88595	416–463	60	-79	-96	-97	-97	-76	-74	-76	-2	11/10/2008
5-820	31-06841	Clementon	-74.89175	39.84603	545–591	87	--	-81	-83	--	--	-78	-73	5	11/10/2008
5-1157	28-28845	Columbus	-74.72544	40.05344	251–266	45	--	--	--	-25	--	-27	-26	1	11/3/2008
5-1159	28-15286	Bristol	-74.75199	40.06297	165–205	50	--	--	--	-9	-9	-9	-12	-3	10/21/2008
5-1170	27-10144	Bristol	-74.82377	40.05372	140–215	58	--	--	--	--	--	--	-10	--	10/22/2008
5-1181	31-41329	Mount Holly	-74.78050	39.99325	313–343	19	--	--	--	-79	-53	-48	-49	-1	10/21/2008
5-1183	28-28543	Bristol	-74.77433	40.05928	200–220	75	--	--	--	-16	-14	-14	-16	-2	10/22/2008
5-1194	31-29146	Moorestown	-74.89506	39.93047	300–310	80	--	--	--	-64	-53	-48	-44	4	11/04/2008
5-1389	32-22005	Browns Mills	-74.58877	39.88595	900–920	107	--	--	--	--	-42	-38	-43	-5	10/21/2008
5-1391	32-21805	Woodmansie	-74.42626	39.81790	1,416–1,436	187	--	--	--	--	-32	-26	-35	-9	10/21/2008
5-1490	31-17792	Mount Holly	-74.82266	39.94761	364–376	41	--	--	--	--	-57	-50	-50	0	10/31/2008
5-1499	31-55693	Camden	-75.00573	39.97067	44–49	18	--	--	--	--	--	--	-12	--	11/19/2008
7-13	51-00032	Runnemede	-75.10956	39.87281	111–160	31	--	-46	-44	-39	-30	-27	-25	2	11/18/2008
7-15	31-06208	Clementon	-74.93866	39.78095	675–745	150	-78	-89	-97	-97	--	-90	-74	16	11/3/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
7-18	31-02079	Clementon	-74.93675	39.79417	650–713	147	--	--	-93	-96	-100	-76	-74	2	11/3/2008
7-115	31-00051	Clementon	-74.98545	39.86372	400–420	70	--	-84	-101	-95	-62	-58	-56	2	11/13/2008
7-117	**31-04897**	**Clementon**	**-74.95294**	**39.87484**	**552–562**	**158**	**-75**	**-79**	**-84**	**-91**	**-67**	**-66**	**-61**	**5**	**11/7/2008**
7-131	31-05096	Moorestown	-74.95183	39.89817	–342	71	-74	-87	-83	-86	-54	-65	-59	6	12/23/2008
7-249	31-02703	Runnemede	-75.06203	39.79870	426–447	65	--	--	-86	-86	-63	-64	-51	13	12/2/2008
7-252	31-05581	Runnemede	-75.03139	39.80042	407–477	65	-83	-94	-91	-96	-66	-68	-56	12	12/2/2008
7-274	31-05226	Runnemede	-75.06234	39.84220	269–349	55	-86	-92	-86	-91	-58	-63	-63	0	11/19/2008
7-275	31-03375	Camden	-75.05284	39.87522	236–267	60	-77	-78	-81	-72	--	-61	-47	14	11/20/2008
7-279	31-04798	Camden	-75.05412	39.87731	224–275	65	-76	-72	-77	--	-47	-53	-47	6	11/18/2008
7-285	31-03308	Camden	-75.07601	39.87967	144–191	37	-50	-51	-51	-45	-29	-29	-27	2	11/18/2008
7-299	21-02570	Camden	-75.03239	39.88956	206–246	65	--	--	--	--	--	--	-54	--	11/12/2008
7-311	31-04723	Runnemede	-75.00703	39.82428	395–473	75	-80	-86	-91	-88	-63	-72	-56	16	12/23/2008
7-316	31-05100	Runnemede	-75.04153	39.85884	271–348	75	--	-87	-83	-79	-52	-59	-51	8	11/19/2008
7-322	31-04283	Camden	-75.07889	39.89981	101–112	33	--	-53	-50	-46	-34	-31	-28	3	11/19/2008
7-398	31-06646	Clementon	-74.98586	39.79078	668–698	200	-81	-96	-97	--	--	-75	-68	7	11/14/2008
7-404	31-03307	Runnemede	-75.07128	39.84889	297–339	67	-78	-83	-82	-75	-50	-54	-51	3	11/18/2008
7-410	31-02360	Runnemede	-75.01528	39.84486	–441	95	-90	-95	-94	-93	-63	-69	-63	6	11/18/2008
7-422	31-03306	Clementon	-74.99770	39.85772	379–421	71	-84	-88	-104	-109	-58	-62	-56	6	11/19/2008
7-423	--	Clementon	-74.99795	39.85789	–459	70	--	--	--	--	-61	-65	-59	6	11/19/2008
7-477	**--**	**Williamstown**	**-74.93767**	**39.70428**	**829–839**	**111**	**-64**	**-73**	**-77**	**-81**	**-70**	**-62**	**-63**	**-1**	**11/7/2008**
7-521	31-12301	Clementon	-74.99286	39.79600	600–629	186	--	--	-97	-98	-81	-78	-80	-2	11/14/2008
7-573	--	Philadelphia	-75.12686	39.89892	–89	11	--	-10	-9	-5	-3	-2	-2	0	11/19/2008
7-727	31-31110	Moorestown	-74.98956	39.91545	175–202	40	--	--	--	-70	-53	-52	-45	7	11/19/2008
7-824	31-37826	Clementon	-74.98561	39.77836	590–665	150	--	--	--	--	-90	-72	-74	-2	11/6/2008
7-1234	31-63874	Clementon	-74.92489	39.85039	475–505	31	--	--	--	--	--	--	-67	--	11/21/2008
15-3	31-06676	Pitman East	-75.09981	39.67045	670–740	140	-63	-33	-71	-74	-62	-53	-51	2	12/3/2008
15-8	51-00101	Woodbury	-75.13668	39.77450	244–307	21	-50	-53	-61	--	-52	-46	-41	5	11/19/2008
15-28	30-00432	Woodbury	-75.22363	39.79847	191–216	70	-21	-23	-23	-27	-24	-19	-20	-1	11/25/2008
15-60	31-02358	Pitman West	-75.13240	39.70178	562–612	150	-60	-70	-66	-70	-63	-65	-47	18	12/2/2008
15-63	31-04176	Pitman East	-75.11648	39.71900	549–599	150	-59	-65	-64	-67	-57	-63	-58	5	12/2/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
15-127	31-03280	Pitman West	-75.16531	39.72969	–524	140	-46	-49	-50	--	-45	-37	-35	2	12/9/2008
15-187	--	Woodbury	-75.12906	39.76206	325–355	45	--	--	-69	-66	--	-53	-53	0	11/15/2008
15-194	31-05309	Woodbury	-75.17651	39.79220	230–265	10	-42	-47	-45	-46	-35	-34	-40	-6	12/03/2008
15-238	50-00036	Woodstown	-75.30885	39.74381	217–240	30	--	--	--	--	--	--	-22	--	12/05/2008
15-240	30-00973	Bridgeport	-75.31019	39.75289	190–231	32	-21	-19	-21	-21	-19	-16	-19	-3	11/17/2008
15-248	51-00029	Pitman East	-75.07564	39.72856	559–618	125	-63	-68	-80	-73	--	-54	-53	1	11/21/2008
15-274	51-00065	Woodbury	-75.14995	39.79528	273–310	80	--	--	--	--	--	--	-41	-	12/30/2008
15-275	31-00170	Woodbury	-75.15137	39.79736	268–310	59	-42	-44	-53	-54	-57	-36	-34	2	12/30/2008
15-276	31-04567	Woodbury	-75.17321	39.80575	242–289	60	-39	-44	-46	-48	-40	-32	-30	2	1/8/2008
15-281	31-03021	Woodbury	-75.17318	39.81975	227–243	61	-35	-40	-37	-38	-30	-25	-27	-2	11/21/2008
15-303	--	Woodbury	-75.20963	39.84178	84–114	10	-6	-8	-9	-8	-7	-4	-5	-1	11/20/2008
15-330	31-06356	Woodbury	-75.14604	39.81620	190–235	40	-44	-50	-49	-47	-38	-31	-30	1	11/20/2008
15-339	30-01161	Woodstown	-75.31908	39.73067	247–267	90	-19	-19	-20	-21	-20	-18	-22	-4	12/4/2008
15-346	30-01565	Woodbury	-75.22683	39.75728	267–343	80	--	-24	-29	-35	-27	-21	-26	-5	11/25/2008
15-355	30-01426	Woodbury	-75.21318	39.80595	205–245	42	-28	-30	-28	-28	-29	-19	-19	0	11/25/2008
15-378	--	Bridgeport	-75.26907	39.75650	–239	105	--	--	-21	-21	-19	-15	-18	-3	12/9/2008
15-433	31-17801	Runnemede	-75.08789	39.77475	512–552	149	--	-55	-64	-68	-53	-51	-45	6	11/21/2008
15-617	30-03533-3	Bridgeport	-75.32074	39.77706	60–70	31	--	--	-7	-7	-8	-4	-8	-4	11/12/2008
15-728	**30-04549**	**Bridgeport**	**-75.28963**	**39.80234**	**46–56**	**4**	**--**	**--**	**-7**	**-7**	**-8**	**-4**	**-6**	**-2**	**11/12/2008**
15-741	**--**	**Woodbury**	**-75.16740**	**39.78122**	**293–313**	**82**	**--**	**--**	**-44**	**-46**	**-38**	**-31**	**-32**	**-1**	**11/14/2008**
15-773	31-26238	Woodbury	-75.18796	39.86845	30–50	10	--	--	-7	-1	0	2	1	-1	11/12/2008
15-779	31-26239	Woodbury	-75.18847	39.87283	25–35	5	--	--	-8	-1	-1	0	0	0	12/12/2008
15-1000	31-21614	Runnemede	-75.10823	39.77956	354–359	75	--	--	-71	-70	-56	-52	-57	-5	11/20/2008
15-1031	30-03412	Bridgeport	-75.32185	39.76484	95–105	47	--	--	-9	-10	-9	-6	-10	-4	11/12/2008
15-1088	50-00050	Pitman West	-75.22602	39.73567	–285	35	--	--	--	--	--	-18	-25	-7	11/24/2008
15-1089	31-37705	Runnemede	-75.10470	39.83778	198–258	45	--	--	--	--	-45	-42	-39	3	11/21/2008
15-1105	30-04335	Woodstown	-75.28269	39.71234	357–377	145	--	--	--	-25	-22	-19	-20	-1	12/4/2008
15-1106	30-07949	Woodbury	-75.21467	39.85422	101–111	10	--	--	--	-9	-9	-6	-7	-1	11/20/2008
15-1346	30-03764	Bridgeport	-75.26935	39.80734	60–90	10	--	--	--	--	-11	-7	-9	-2	11/17/2008
15-1365	31-45998	Pitman East	-75.03234	39.72234	628–712	160	--	--	--	--	--	-62	-59	3	11/20/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
15-1483	30-12606	Woodstown	-75.33630	39.74261	186–216	102	--	--	--	--	-17	-12	-14	-2	12/3/2008
15-1513	30-05444	Woodstown	-75.27019	39.69067	357–367	78	--	--	--	--	-33	-30	-31	-1	12/4/2008
15-1528	30-12878	Pitman West	-75.24713	39.74067	210–280	45	--	--	--	--	--	--	-32	--	11/24/2008
15-1531	30-13147	Woodstown	-75.26419	39.74644	206–256	59	--	--	--	--	--	--	-25	--	11/24/2008
15-1543	31-62302	Pitman East	-75.05073	39.72567	616–703	150	--	--	--	--	--	-67	-64	3	11/20/2008
15-1545	30-06144	Pitman West	-75.23581	39.68594	476–486	130	--	--	--	--	--	-35	-36	-1	12/9/2008
15-1577	31-61731	Runnemede	-75.08639	39.79528	–	80	--	--	--	--	--	--	-38	--	11/21/2008
15-1755	31-60817	Pitman East	-75.01278	39.70421	700–820	150	--	--	--	--	--	--	-60	--	11/20/2008
21-1	--	Allentown	-74.51394	40.23025	285–315	125	--	--	--	--	36	35	31	-4	10/22/2008
21-19	28-05897	Hightstown	-74.56632	40.26966	133–181	90	71	68	69	70	71	69	68	-1	10/20/2008
21-46	28-02489	Trenton East	-74.63571	40.18872	138–141	60	32	--	-70	--	26	35	32	-3	10/28/2008
21-84	48-00063	Hightstown	-74.52440	40.27250	181–205	84	61	54	51	56	57	56	55	-1	10/20/2008
23-15	48-00064	Hightstown	-74.51468	40.31172	–110	95	59	65	64	67	69	68	67	-1	10/22/2008
23-98	28-01426	Jamesburg	-74.43412	40.34739	99–120	50	47	44	41	45	42	46	46	0	10/22/2008
23-108	48-00194	New Brunswick	-74.37932	40.38150	87–107	23	--	--	--	--	--	--	1	--	10/21/2008
23-109	--	New Brunswick	-74.38182	40.38400	–101	24	1	-2	-2	-2	17	7	14	7	10/21/2008
23-142	49-29698	South Amboy	-74.30848	40.39622	199–249	90	8	4	9	8	--	2	3	1	10/17/2008
23-143	--	South Amboy	-74.34348	40.39650	81–91	30	--	5	5	7	6	8	5	-3	10/15/2008
23-173	--	South Amboy	-74.27147	40.40178	173–193	60	-4	-7	-8	1	-1	-0	-1	-1	10/16/2008
23-180	--	South Amboy	-74.35765	40.41066	57–67	19	4	4	4	5	4	5	4	-1	10/15/2008
23-182	--	South Amboy	-74.30487	40.41372	66–71	31	17	15	13	16	17	16	15	-1	10/16/2008
23-213	28-06470	Jamesburg	-74.39414	40.31319	195–198	100	--	--	--	--	15	16	12	-4	10/21/2008
23-228	**28-04251**	**Jamesburg**	**-74.46543**	**40.33761**	**128–138**	**147**	**66**	**58**	**55**	**60**	**62**	**61**	**62**	**1**	**10/24/2008**
23-292	**28-04250**	**Hightstown**	**-74.50293**	**40.35261**	**93–104**	**107**	**76**	**71**	**71**	**72**	**74**	**75**	**76**	**1**	**10/24/2008**
23-344	--	South Amboy	-74.33654	40.43288	31–37	22	15	13	14	17	16	17	15	-2	10/20/2008
23-351	**--**	**South Amboy**	**-74.33265**	**40.43483**	**76–82**	**35**	**20**	**17**	**17**	**20**	**20**	**23**	**20**	**-3**	**10/20/2008**
23-490	28-08490	Jamesburg	-74.43860	40.32350	287–325	167	51	--	--	--	--	49	47	-2	10/23/2008
23-508	--	Hightstown	-74.53142	40.30036	–90	105	68	65	63	65	66	65	63	-2	10/20/2008
23-565	28-11720	Jamesburg	-74.46932	40.33602	165–197	137	--	52	--	--	56	54	56	2	10/23/2008
23-569	29-11861	South Amboy	-74.28242	40.46066	102–132	100	--	--	--	--	--	--	46	--	10/16/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
23-581	28-08423	South Amboy	-74.34311	40.45978	24–44	80	--	--	--	--	--	--	61	--	10/16/2008
23-775	28-11436	Jamesburg	-74.45514	40.28825	182–190	118	--	--	--	--	39	39	35	-4	10/21/2008
23-1156	29-12379	Freehold	-74.30586	40.37650	230–238	60	--	--	-4	4	3	1	0	-1	11/4/2008
23-1159	29-19607-8	South Amboy	-74.33015	40.45566	95–105	86	--	--	--	--	--	--	44	--	10/21/2008
23-1172	29-19614-1	South Amboy	-74.32070	40.46288	68–78	103	--	--	--	--	--	--	42	--	10/21/2008
23-1200	28-17439	Jamesburg	-74.49933	40.30308	166–176	111	--	--	--	--	66	65	63	-2	10/21/2008
23-1358	29-45498	South Amboy	-74.26265	40.43983	50–55	50	--	--	--	--	--	--	8	--	10/16/2008
25-4	28-08915	Allentown	-74.59013	40.18111	212–262	68	--	21	--	--	26	20	15	-5	10/28/2008
25-6	49-00049	Sandy Hook	-74.04292	40.41039	519–582	20	--	--	--	--	--	--	0	--	10/28/2008
25-13	29-07461	Asbury Park	-74.02230	40.19367	1,105–1,165	29	-16	-27	-29	-15	-17	-15	-24	-9	10/23/2008
25-37	29-04068	Marlboro	-74.20169	40.26889	686–706	137	-30	-35	-21	-14	-18	-15	-22	-7	11/7/2008
25-56	28-05400	Freehold	-74.35965	40.29530	363–384	70	9	1	18	16	12	14	7	-7	10/23/2008
25-62	29-03492	Farmingdale	-74.17014	40.19289	831–885	80	-20	-34	-29	-11	-15	-16	-25	-9	10/29/2008
25-91	29-05708	Freehold	-74.25792	40.25456	632–685	140	-38	-47	-34	-13	-15	-15	-25	-10	10/27/2008
25-97	29-04708	Freehold	-74.24987	40.27372	596–656	195	-42	-47	-38	-19	-23	-19	-29	-10	10/27/2008
25-103	29-07494	Freehold	-74.29317	40.27933	478–575	107	-53	-36	-39	-14	-17	-11	-20	-9	10/27/2008
25-112	29-03096	Keyport	-74.15953	40.42727	312–352	44	-41	-36	-39	-14	-12	-20	-14	6	10/30/2008
25-116	29-03509	Sandy Hook	-73.98605	40.40000	600–660	10	-15	-18	-16	--	-4	-5	-5	0	10/16/2008
25-154	29-04207	Keyport	-74.17153	40.41261	400–430	73	--	--	--	--	--	--	-15	--	10/30/2008
25-175	29-05851	Adelphia	-74.25462	40.21289	681–762	102	-27	-32	-38	--	--	-12	-27	-15	10/29/2008
25-195	29-01297	Keyport	-74.12853	40.43922	290–350	15	--	-35	-32	-21	-18	-19	-13	6	10/30/2008
25-197	29-08379	Keyport	-74.20376	40.42664	304–354	35	-27	-26	-25	-10	-10	-12	-10	2	10/30/2008
25-206	**--**	**Keyport**	**-74.19542**	**40.44039**	**225–249**	**14**	**-13**	**-14**	**-15**	**-3**	**-4**	**-8**	**-5**	**3**	**10/15/2008**
25-214	21-07184	Adelphia	-74.36248	40.24286	585–641	195	-1	0	--	--	8	8	-1	-9	10/23/2008
25-218	--	Jamesburg	-74.38793	40.26594	510–527	250	20	13	12	--	22	22	27	5	10/23/2008
25-220	28-06114	Freehold	-74.33672	40.26017	539–569	125	-16	-24	-24	-5	-8	-7	-16	-9	10/27/2008
25-244	29-05790	Freehold	-74.25109	40.31344	524–594	161	-34	-42	-47	-19	-25	-18	-26	-8	10/30/2008
25-259	29-00073	Marlboro	-74.24053	40.34286	508–593	155	-18	-26	-27	-5	-5	-5	-8	-3	11/7/2008
25-284	29-01731	Keyport	-74.24645	40.42122	231–271	90	-7	-7	-11	4	4	0	3	3	10/15/2008
25-290	--	Keyport	-74.21236	40.40081	–353	71	--	--	--	--	--	-8	-11	-3	10/20/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
25-292	29-03729	Keyport	-74.20914	40.39969	341–414	87	-33	-33	-34	--	--	-12	-15	-3	10/20/2008
25-303	29-05164	Marlboro	-74.13570	40.35178	527–600	70	--	--	-61	-19	-14	-22	-24	-2	11/10/2008
25-316	**29-04299**	**Sandy Hook**	**-73.98430**	**40.42678**	**371–397**	**11**	**-5**	**-4**	**-9**	**-2**	**-1**	**-1**	**-2**	**-1**	**10/15/2008**
25-322	28-01842	Roosevelt	-74.40459	40.19928	667–697	210	4	-2	-4	7	7	5	-3	-8	10/24/2008
25-334	29-00137	Asbury Park	-74.06486	40.20400	1,013–1,065	23	-21	-37	-37	--	-29	-41	-34	7	10/22/2008
25-341	--	Asbury Park	-74.01648	40.20955	–	19	--	--	--	--	--	--	-23	--	10/22/2008
25-360	29-07941	Long Branch	-74.05492	40.34847	668–759	146	-31	-34	-34	--	--	-33	-27	6	10/29/2008
25-436	29-06193	Asbury Park	-74.12364	40.16417	990–1,033	60	-26	-41	-43	-17	-21	-19	-30	-11	10/23/2008
25-456	29-08092	Keyport	-74.15070	40.44455	277–316	17	--	--	--	--	--	--	-12	--	10/15/2008
25-459	29-09335	Long Branch	-74.05975	40.37186	551–612	80	--	-24	-25	-15	-19	-13	-15	-2	11/5/2008
25-493	29-07784	Farmingdale	-74.19014	40.20872	–860	115	--	-35	-38	-17	-19	-19	-29	-10	10/23/2008
25-496	29-10478	Sandy Hook	-74.04195	40.41183	510–543	16	--	--	--	--	--	--	-6	--	10/28/2008
25-500	28-12215	Allentown	-74.56753	40.14722	270–305	88	--	4	0	--	4	2	-4	-6	10/27/2008
25-501	29-11335	Asbury Park	-74.06569	40.20428	1,000–1,075	30	--	--	--	--	--	--	-37	--	10/23/2008
25-502	29-11033	Adelphia	-74.26873	40.23689	616–671	117	--	-59	-51	--	-28	-22	-32	-10	10/27/2008
25-509	28-12280	Roosevelt	-74.46943	40.22108	390–430	167	--	26	24	34	33	31	25	-6	10/23/2008
25-514	29-12732	Keyport	-74.15264	40.44483	266–312	14	--	-26	-27	-15	-9	-16	-12	4	10/15/2008
25-550	29-13610	Adelphia	-74.27431	40.21622	636–656	105	--	--	-39	-12	-16	-13	-25	-12	10/27/2008
25-567	29-15851	Keyport	-74.17431	40.44177	250–270	10	--	--	-23	-9	-7	-14	-11	3	10/20/2008
25-568	29-16343	Keyport	-74.18292	40.44789	245–265	10	--	--	-12	-2	-0	-5	-1	4	10/20/2008
25-568	29-16343	Keyport	Freshwater equivalent				--	--	--	--	--	-4	0	4	10/20/2008
25-639	**29-18403-7**	**Farmingdale**	**-74.20014**	**40.18484**	**891.2–901.2**	**112**	**--**	**--**	**-35**	**-16**	**-19**	**-19**	**-29**	**-10**	**10/22/2008**
25-712	29-21610	Long Branch	-74.11556	40.31697	598–668	43	--	--	--	--	--	-21	-27	-6	10/20/2008
25-721	29-15170	Asbury Park	-74.08600	40.19184	999–1,149	130	--	--	--	--	-17	-15	-27	-12	10/22/2008
25-724	29-17817	Freehold	-74.25828	40.32317	446–551	120	--	--	--	-12	-18	-13	-29	-16	10/30/2008
25-729	29-21611	Long Branch	-74.11328	40.31875	575–655	35	--	--	--	-17	-18	-17	-24	-7	10/20/2008
25-736	29-21612	Long Branch	-74.11911	40.31886	569–669	40	--	--	-31	--	--	-21	-27	-6	10/20/2008
25-749	48-00045	Allentown	-74.53988	40.14567	–350	100	--	--	--	--	-0	-2	-9	-7	10/24/2008
25-823	29-49204	Long Branch	-74.07228	40.34636	605–700	40	--	--	--	--	--	-14	-22	-8	10/29/2008
25-828	29-44304	Keyport	-74.16675	40.41181	399–428	63	--	--	--	--	--	-20	-12	8	10/30/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
25-830	28-18879	Allentown	-74.54172	40.17361	330–340	102	--	--	--	--	--	16	10	-6	10/22/2008
25-1063	29-55195	Keyport	-74.12814	40.44136	312–352	12	--	--	--	--	--	--	-14	--	10/30/2008
25-1083	29-53160	Freehold	-74.31489	40.33469	334–354	126	--	--	--	--	--	--	2	--	10/30/2008
29-70	33-01159	Seaside Park	-74.06611	39.98509	1,375–1,495	5	-21	-28	-26	-22	-27	-29	-44	-15	11/5/2008
29-134	29-03570	Lakehurst	-74.32881	40.05803	846–962	97	-22	-26	-29	-41	-50	-42	-65	-23	10/28/2008
29-238	28-08229	Roosevelt	-74.44248	40.13889	584–648	130	-10	-4	--	-5	-14	-7	-18	-11	10/27/2008
29-504	29-03142	Point Pleasant	-74.05230	40.03645	1,263–1,368	5	-18	-27	-25	-18	-22	-23	-35	-12	11/05/2008
29-531	29-03345	Point Pleasant	-74.07028	40.08125	1,256–1,342	18	-19	-33	-29	-18	-25	-22	-32	-10	11/13/2008
29-577	33-05553	Seaside Park	-74.07639	39.96173	1,394–1,498	7	--	-22	-20	-20	-21	-33	-47	-14	11/25/2008
29-1040	29-23401	Lakehurst	-74.25351	40.01095	1,013–1,184	38	--	--	--	-27	-38	-49	-95	-46	10/31/2008
29-1309	33-37783	Toms River	-74.20823	39.99070	–1,340	75	--	--	--	--	--	-47	-81	-34	12/4/2008
29-1365	33-37776	Seaside Park	-74.07825	39.94362	1,389–1,580	4	--	--	--	--	-27	-60	-66	-6	12/2/2008
29-1380	32-39030	Lakehurst	-74.32598	40.01012	937–1,024	65	--	--	--	--	-32	-52	-82	-30	10/30/2008
29-1381	29-41029	Lakehurst	-74.32545	40.01076	928–984	64	--	--	--	--	--	--	-82	--	10/30/2008
29-1577	29-48781	Lakehurst	-74.32431	40.02878	905–985	78	--	--	--	--	--	-40	-67	-28	10/31/2008
[1]29-1623	29-48193	Point Pleasant	-74.06769	40.06928	1,190–1,283	8	-20	-33	-30	--	--	-25	-34	-9	11/20/2008
29-2011	28-41493	Roosevelt	-74.42071	40.14150	692–712	144	--	--	--	--	--	--	-7	--	10/24/2008
33-76	30-00661	Penns Grove	-75.41242	39.72456	118–123	27	3	0	2	1	1	3	0	-3	12/3/2008
33-111	30-01253	Penns Grove	-75.49825	39.62956	190–235	10	-14	-15	-17	-19	-20	-21	-21	0	11/18/2008
33-253	**--**	**Salem**	**-75.46473**	**39.56375**	**335–340**	**3**	**-22**	**-23**	**-27**	**-28**	**-27**	**-28**	**-31**	**-3**	**11/20/2008**
33-342	--	Penns Grove	-75.45670	39.71059	46–51	18	-5	1	-1	-1	3	9	5	-4	11/20/2008
33-348	--	Penns Grove	-75.43883	39.72197	–	25	--	--	--	--	--	--	19	--	11/20/2008
33-355	--	Woodstown	-75.32463	39.65400	–360	58	-29	-22	-24	-17	-24	-22	-26	-4	12/5/2008
33-361	30-01815	Penns Grove	-75.44942	39.70109	44–54	13	-9	-8	-9	-6	1	4	2	-2	11/24/2008
33-671	30-05148	Wilmington South	-75.50345	39.66514	87–102	7	--	--	--	-3	-7	-3	-4	-1	11/18/2008
33-697	30-01113	Penns Grove	-75.44808	39.70125	47–62	12	--	--	--	--	--	2	0	-2	11/24/2008
33-841	35-17766	Elmer	-75.14268	39.51539	1,005–1,025	77	--	--	--	--	-48	-43	-43	0	11/19/2008
33-920	30-11400	Woodstown	-75.36689	39.71075	184–204	79	--	--	--	--	--	-6	-17	-11	12/4/2008
33-952	30-13727	Delaware City	-75.54236	39.61356	147–152	24	--	--	--	--	--	-8	-9	-1	11/20/2008
33-953	30-13726	Delaware City	-75.54027	39.62356	109–114	7	--	--	--	--	--	2	0	-2	11/20/2008

Appendix 7. Water-level data for wells screened in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
33-955	--	Wilmington South	-75.50581	39.65820	124–134	6	--	--	--	--	--	--	-2	--	11/20/2008
33-956	--	Penns Grove	-75.49671	39.66426	140–150	17	--	--	--	--	--	--	-7	--	11/20/2008
P10116	--	Philadelphia	-75.14184	39.91206	60–75	9.4	--	--	--	--	-6	-7	-6	1	11/19/2008

[1]Formerly well 29-524.

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-63	**--**	**Bristol**	**-74.85183**	**40.03706**	**284–294**	**45**	**-16**	**-16**	**-21**	**-21**	**-21**	**-16**	**-17**	**-1**	**10/24/2008**
5-70	27-05259	Bristol	-74.83405	40.05372	140–200	60	-13	-11	-16	--	-16	-17	-8	9	10/22/2008
5-87	27-03694	Beverly	-74.87964	40.06872	50–60	10	--	-8	-13	-9	-11	-16	-11	5	10/29/2008
5-114	28-02901	Columbus	-74.65599	40.10178	388–392	85	-7	-8	-12	-13	-11	-11	-13	-2	11/3/2008
5-119	28-04082	Trenton East	-74.64544	40.13928	–305	100	--	--	--	--	8	6	3	-3	10/24/2008
5-122	28-05042	Trenton East	-74.67049	40.16136	337–367	75	4	0	-1	-4	-0	-1	-1	0	10/29/2008
5-126	31-04276	Moorestown	-74.98939	39.99125	157–196	73	-8	-15	-16	-16	-15	-13	-5	8	11/20/2008
5-127	31-04697	Moorestown	-74.96906	39.99400	179–229	35	--	--	--	--	--	--	-10	--	11/18/2008
5-128	31-04733	Moorestown	-74.96903	39.99392	–225	35	--	--	--	--	--	-16	-10	6	11/18/2008
5-214	--	Columbus	-74.74136	40.09169	–319	60	-10	--	-13	-12	-12	-18	-20	-2	11/3/2008
5-232	31-06020	Moorestown	-74.98700	39.95714	210–270	9	-40	-46	-44	-46	-46	-36	-44	-8	11/3/2008
5-261	**--**	**Mount Holly**	**-74.83989**	**39.92372**	**740–750**	**73**	**-48**	**-58**	**-61**	**-62**	**-51**	**-47**	**-44**	**3**	**10/27/2008**
5-265	31-04727	Moorestown	-74.96811	39.95064	248–288	24	-56	-65	-65	--	-54	-51	-46	5	11/3/2008
5-284	31-03806	Moorestown	-74.91414	39.99356	298–338	62	-26	-29	-28	--	-28	-23	-19	4	10/31/2008
5-290	31-06674	Mount Holly	-74.78116	39.99342	545–615	15	-55	-57	-63	-60	-48	-45	-45	0	10/21/2008
5-297	31-01610	Moorestown	-74.90308	39.92411	441–457	51	--	--	-68	-66	-54	-49	-46	3	11/4/2008
5-330	52-00008	Browns Mills	-74.61485	39.99700	1,056–1,086	140	-49	-51	-65	-65	-59	-53	-41	12	11/4/2008
5-332	48-00269	New Egypt	-74.62188	40.01828	1,064–1,104	150	-39	-42	-52	-51	-39	-33	-28	5	11/4/2008
5-333	32-07668	New Egypt	-74.61482	40.02456	1,030–1,051	128	-50	-51	-64	--	-49	-42	-36	6	11/4/2008
5-336	28-00795	New Egypt	-74.57382	40.03064	1,036–1,089	105	--	--	-55	-63	-53	-43	-35	8	11/4/2008
5-385	32-03778	Pemberton	-74.71322	39.97761	747–823	30	--	-52	-61	-70	-52	-51	-41	10	11/4/2008
5-388	52-00009	Pemberton	-74.62810	39.99428	1,090–1,140	160	-42	-47	-62	-50	-52	-38	-36	2	11/4/2008
5-436	--	Columbus	-74.66905	40.02178	757–800	96	--	--	--	-42	-33	-31	-31	0	10/29/2008
5-440	**28-05128**	**Columbus**	**-74.70639**	**40.04528**	**603–613**	**72**	**-29**	**-29**	**-36**	**-35**	**-30**	**-31**	**-30**	**1**	**10/21/2008**
5-634	47-00001	Bristol	-74.80225	40.01086	–516	55	-56	-58	-60	-64	-77	-72	-42	30	10/21/2008
5-683	**--**	**Chatsworth**	**-74.50432**	**39.85623**	**2,102–2,117**	**141**	**-30**	**-34**	**-42**	**-39**	**-32**	**-29**	**-28**	**1**	**10/21/2008**
5-726	28-08443	New Egypt	-74.61466	40.03686	667–732	140	--	--	-41	-36	-37	-23	-25	-2	11/4/2008
5-749	31-07140	Moorestown	-74.92706	39.91903	–425	75	-60	-69	-75	-73	-61	-54	-51	3	11/4/2008
5-801	27-06877	Frankford	-75.02017	40.00567	5–25	20	--	0	-1	-4	-3	-1	1	2	10/22/2008
5-1089	27-08534	Beverly	-74.88569	40.03372	176–251	19	--	--	-25	-25	-35	-15	-23	-8	10/21/2008

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
5-1158	28-28844	Columbus	-74.72572	40.05456	450–460	45	--	--	--	-28	-24	-26	-25	0	11/3/2008
5-1172	28-20985	Bristol	-74.75711	40.12039	270–290	42	--	--	--	--	1	-0	-2	-2	10/23/2008
5-1430	28-35104	Trenton East	-74.73155	40.13705	160–170	55	--	--	--	--	--	8	7	-1	10/27/2008
5-1472	27-10750	Beverly	-74.89631	40.01425	190–240	25	--	--	--	--	--	-25	-27	-2	10/22/2008
5-1484	27-14624	Beverly	-74.88875	40.04711	215–253	39	--	--	--	--	-17	-12	-14	-2	10/21/2008
5-1524	27-15940	Beverly	-74.95295	40.01956	155–175	70	--	--	--	--	--	6	8	2	10/21/2008
5-1525	28-19074	New Egypt	-74.58654	40.05011	800–820	130	--	--	--	--	--	-27	-41	-14	11/4/2008
5-1527	27-15342	Bristol	-74.79111	40.09417	70–110	47	--	--	--	--	--	1	-3	-4	10/24/2008
5-1546	27-12676	Bristol	-74.82750	40.06194	168–178	82	--	--	--	--	--	--	-7	--	10/23/2008
5-1702	31-26455	Moorestown	-74.94767	39.97928	176–254	79	--	--	--	--	--	--	-10	--	10/31/2008
5-1806	28-54748	New Egypt	-74.61461	40.03686	660–725	140	--	--	--	--	--	--	-30	--	11/4/2008
7-39	51-00060	Camden	-75.11065	39.91597	123–163	21	--	--	--	--	--	--	-13	--	11/17/2008
7-124	31-07020	Moorestown	-74.99281	39.88050	483–626	77	-77	-84	-92	-85	-55	-60	-52	8	11/19/2008
7-132	31-05095	Moorestown	-74.95183	39.89817	–500	71	-82	-81	-81	--	-53	-66	-66	0	11/20/2008
7-135	31-05218	Moorestown	-74.95047	39.89797	443–493	72	--	--	-73	-81	-50	-64	-66	-2	11/20/2008
7-142	31-04098	Camden	-75.01723	39.91070	321–378	32	--	--	-66	-64	-48	-44	-38	6	11/19/2008
7-186	--	Clementon	-74.98156	39.83067	–35	70	-77	-85	-88	-89	-64	-65	-57	8	12/23/2008
7-304	31-05108	Camden	-75.03350	39.90122	307–372	50	--	--	-72	-75	-59	-46	-42	4	11/12/2008
7-329	31-04836	Camden	-75.06795	39.94072	110–140	16	-36	-31	-34	-29	-21	-17	-13	4	11/18/2008
7-413	**31-04561**	**Clementon**	**-74.94128**	**39.82289**	**706–717**	**149**	**-69**	**-78**	**-82**	**-85**	**-66**	**-63**	**-59**	**4**	**11/12/2008**
7-476	**--**	**Williamstown**	**-74.93767**	**39.70428**	**1,485–1,495**	**111**	**-46**	**-53**	**-57**	**-58**	**-49**	**-43**	**-43**	**0**	**11/7/2008**
7-726	31-31111	Moorestown	-74.98853	39.91470	276–422	40	--	--	--	-70	-53	-52	-45	7	11/19/2008
7-733	31-40817	Runnemede	-75.04153	39.85850	452–535	75	--	--	--	-82	-53	-61	-53	8	11/19/2008
7-734	31-40970	Runnemede	-75.05012	39.87170	333–499	55	--	--	--	--	-54	-58	-51	7	11/18/2008
7-986	31-43797	Camden	-75.06878	39.94178	102–180	28	--	--	--	--	-25	-19	-15	4	11/18/2008
7-1007	31-58577	Camden	-75.04194	39.96542	99–109	33	--	--	--	--	--	-12	-10	2	11/19/2008
7-1022	31-58628	Camden	-75.04978	39.98286	63–73	25	--	--	--	--	--	--	-14	--	11/18/2008
7-1040	31-59619	Camden	-75.04239	39.96231	105–115	40	--	--	--	--	--	-15	-14	1	11/19/2008
7-1057	31-59365	Camden	-75.05967	39.97167	78–83	66	--	--	--	--	--	-8	-7	1	11/10/2008
7-1264	31-60880	Camden	-75.06583	39.90194	305–407	50	--	--	--	--	--	--	-4	--	11/12/2008

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
11-137	--	Dorothy	-74.87100	39.42067	2,083–2,093	85	-37	-43	-49	-53	-55	-53	-52	1	11/19/2008
11-137	--	Dorothy		Freshwater equivalent			-14	-19	-25	-30	-32	-30	-29	1	11/19/2008
15-24	31-05513	Runnemede	-75.11784	39.85409	282–345	35	-53	-55	-51	-45	-36	-33	-32	0	11/21/2008
15-135	30-01314	Marcus Hook	-75.37769	39.75456	130–180	7	--	-1	-2	-2	-3	-1	-4	-3	11/10/2008
15-140	30-01248	Bridgeport	-75.35936	39.76900	132–184	6	2	-1	-2	-11	-2	-1	-2	-1	11/12/2008
15-213	30-00602	Woodbury	-75.23893	39.82989	135–175	10	-10	-10	-10	-10	-10	-6	-8	-2	11/19/2008
15-236	30-01177	Woodstown	-75.31105	39.74292	241–312	75	-21	-20	-22	-12	-20	-19	-19	0	12/5/2008
15-348	30-01776	Bridgeport	-75.26093	39.81945	105–135	20	-9	-10	-11	-10	-10	-7	-10	-3	11/12/2008
15-374	31-13385	Runnemede	-75.12420	39.81503	430–486	50	--	-65	-63	-63	-50	-46	-43	3	11/21/2008
15-415	31-14478	Woodbury	-75.17851	39.80956	287–307	40	--	-42	-39	-42	-34	-27	-29	-2	11/21/2008
15-444	30-02032	Marcus Hook	-75.39519	39.79900	65–70	16	--	--	--	--	-8	-7	-7	0	11/20/2008
15-569	30-02405	Bridgeport	-75.34744	39.75936	161–201	32	--	--	-12	-9	-8	-5	-8	-3	11/24/2008
15-585	30-02522	Bridgeport	-75.34908	39.78456	79–89	8	--	--	1	1	-1	1	1	0	11/12/2008
15-616	30-03532-5	Bridgeport	-75.32074	39.77706	230–240	31	--	--	-8	-8	-8	-5	-8	-3	11/12/2008
15-620	30-03677	Bridgeport	-75.32547	39.80122	131–141	7	--	--	2	2	1	4	2	-2	11/12/2008
15-679	30-03624	Bridgeport	-75.26963	39.82956	118–128	10	--	--	-3	-7	-5	-2	-3	-1	11/18/2008
15-713	30-04348	Bridgeport	-75.28963	39.80234	125–155	6	--	--	-8	-7	-7	-4	-6	-2	11/12/2008
15-727	30-04548	Bridgeport	-75.28963	39.80234	195–205	5	--	--	-8	-8	-8	-5	-7	-2	11/12/2008
15-774	31-26241	Woodbury	-75.18796	39.86845	93–113	10	--	--	-1	--	--	-1	-1	0	11/12/2008
15-780	31-26244	Woodbury	-75.18768	39.87317	75–85	5	--	--	-2	-5	-4	-3	-1	2	12/12/2008
15-998	--	Pitman East	-75.10194	39.67533	820–837	141	--	--	-64	--	-56	-47	-46	1	12/3/2008
15-1015	--	Bridgeport	-75.29074	39.82900	137–142	5	--	--	--	--	--	-4	-5	-1	11/12/2008
15-1036	31-22504	Woodbury	-75.13523	39.79472	259–319	60	--	--	--	-63	-51	-45	-48	-3	11/21/2008
15-1176	31-43251	Woodbury	-75.17081	39.82506	174–184	44	--	--	--	--	-27	-21	-21	0	11/21/2008
15-1484	30-12608	Woodstown	-75.33630	39.74289	280–300	104	--	--	--	--	-14	-14	-16	-2	12/3/2008
15-1485	31-48720	Woodbury	-75.14129	39.84372	160–306	30	--	--	--	--	-33	-29	-28	1	11/19/2008
15-1504	30-12671	Bridgeport	-75.26074	39.75761	458–478	92	--	--	--	--	-29	-27	-28	-1	12/5/2008
15-1530	30-13148	Woodstown	-75.26324	39.74539	376–396	52	--	--	--	--	--	--	-25	--	11/24/2008
15-1540	--	Woodbury	-75.23794	39.84411	130–140	16	--	--	--	--	--	-4	-5	-1	11/26/2008
15-1728	30-13075	Bridgeport	-75.37500	39.77778	30–40	10	--	--	--	--	--	--	1	--	11/24/2008

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
21-12	28-07034	Jamesburg	-74.48776	40.26019	520–560	115	28	27	23	25	37	32	27	-5	10/29/2008
21-22	28-05440	Hightstown	-74.51790	40.28411	337–367	103	50	45	35	41	47	46	43	-3	10/20/2008
21-25	28-01262	Hightstown	-74.56404	40.28816	205–226	100	65	64	67	64	64	64	63	0	10/22/2008
21-43	28-05409	Trenton East	-74.69724	40.18378	118–138	6	--	2	4	4	3	3	2	-1	10/28/2008
21-54	28-04602	Trenton East	-74.65491	40.21842	194–243	85	--	--	--	40	39	36	43	7	10/28/2008
21-73	28-02927	Trenton East	-74.66819	40.23891	128–144	80	--	--	--	47	40	45	47	2	10/28/2008
21-101	28-06030	Allentown	-74.57864	40.21153	366–421	140	35	42	40	43	42	41	37	-4	10/21/2008
21-120	28-05368	Hightstown	-74.61757	40.26555	96–121	74	71	69	57	--	68	71	70	-1	10/22/2008
21-122	28-06455	Hightstown	-74.61618	40.26511	75–126	75	--	--	--	--	67	71	69	-2	10/22/2008
21-561	28-14731	Hightstown	-74.52189	40.25508	230–270	113	--	--	--	--	--	56	57	1	10/20/2008
21-706	--	Hightstown	-74.52496	40.27280	–400	83	--	--	--	--	--	--	44	--	10/20/2008
23-9	28-00180	Hightstown	-74.53631	40.30064	250–280	98	69	--	62	65	65	67	64	-3	10/20/2008
23-16	28-07800	Hightstown	-74.51504	40.31172	230–260	95	66	60	58	62	63	63	61	-2	10/22/2008
23-17	28-04589	Hightstown	-74.51439	40.31183	268–298	98	67	61	60	--	65	64	62	-2	10/22/2008
23-70	--	New Brunswick	-74.45487	40.43205	0–21	73	57	56	56	57	57	58	56	-2	10/20/2008
23-97	--	New Brunswick	-74.41710	40.37983	236–301	39	2	2	6	29	27	18	24	6	10/21/2008
23-106	--	New Brunswick	-74.37959	40.38094	–132	27	--	--	--	4	13	7	9	2	10/21/2009
23-107	--	New Brunswick	-74.37904	40.38122	311–334	28	--	-3	-0	--	8	6	9	3	10/21/2008
23-114	--	New Brunswick	-74.37904	40.38872	225–237	26	--	--	--	--	--	--	0	--	10/21/2008
23-132	--	South Amboy	-74.35959	40.39316	262–267	25	-44	-38	-36	-3	4	13	11	-2	10/15/2008
23-147	29-04998	South Amboy	-74.31051	40.39780	425–475	80	--	-79	-65	-16	-18	-28	-18	10	10/17/2008
23-171	48-00208	South Amboy	-74.36687	40.40111	240–300	20	--	--	--	--	--	--	-10	--	10/21/2008
23-176	29-06429	South Amboy	-74.32293	40.40205	321–363	45	-61	--	--	--	--	-29	-20	9	10/17/2008
23-194	--	South Amboy	-74.33793	40.42677	201–281	18	-76	-46	-59	-8	-14	-17	-11	6	10/20/2008
23-273	**--**	**Hightstown**	**-74.59099**	**40.32566**	**70–75**	**76**	**--**	**--**	**--**	**47**	**47**	**48**	**47**	**-1**	**10/24/2008**
23-291	28-04249	Hightstown	-74.50321	40.35261	192–203	107	73	65	64	67	70	70	70	0	10/24/2008
23-365	--	South Amboy	-74.35515	40.44261	148–160	5.7	-52	-43	-51	-9	-14	--	-1	--	12/22/2008
23-401	29-05352	South Amboy	-74.27420	40.46244	254–288	44	-75	-80	-77	--	-14	-38	-13	25	10/16/2008
23-439	28-05987	South Amboy	-74.36626	40.44261	121–126	21	-40	-32	-38	-2	-5	-9	-3	6	10/20/2008
23-482	**--**	**Perth Amboy**	**-74.27098**	**40.54510**	**44–76**	**11**	**-3**	**9**	**10**	**10**	**10**	**10**	**10**	**0**	**10/15/2008**

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
23-552	28-10991	Hightstown	-74.50549	40.33830	116–166	105	--	--	59	88	68	64	60	-4	10/21/2008
23-1160	28-20882-0	South Amboy	-74.33015	40.45566	210–230	86	--	--	-54	-13	-13	-19	-11	8	10/21/2008
23-1181	29-19615-9	South Amboy	-74.31793	40.46177	127–137	70	--	--	--	-24	-20	-25	-23	2	10/21/2008
23-1346	28-40082	Jamesburg	-74.46928	40.33606	276–337	130	--	--	--	--	44	41	41	0	10/22/2008
23-1500	28-45485	Jamesburg	-74.45272	40.32506	444–514	155	--	--	--	--	--	--	35	--	12/2/2008
23-1501	28-50046	Jamesburg	-74.48283	40.30330	350–445	117	--	--	--	--	--	--	42	--	12/2/2008
25-153	29-05942	Keyport	-74.16889	40.41222	635–690	65	-47	-75	-116	-20	-21	-21	-24	-4	10/30/2008
25-230	29-06353	Freehold	-74.31481	40.33461	580–670	125	-41	-36	-49	-14	-16	-13	-18	-5	11/12/2008
25-247	29-04285	Freehold	-74.30179	40.31680	762–832	146	-26	-34	-48	-8	-16	-14	-24	-10	10/30/2008
25-262	29-05023	Marlboro	-74.23073	40.35091	730–810	141	-36	--	--	--	--	-22	-16	6	11/7/2008
25-268	29-06361	Freehold	-74.25203	40.35628	632–698	114	-40	-50	-64	-12	9	-24	-20	4	10/30/2008
25-272	**29-06527**	**Marlboro**	**-74.24737**	**40.36900**	**670–680**	**117**	**-44**	**-55**	**-73**	**-17**	**-21**	**-29**	**-33**	**-4**	**10/20/2008**
25-320	29-48826	Sandy Hook	-73.99931	40.45150	838–878	14	-4	-9	-10	-1	-1	0	2	2	10/16/2008
25-495	--	Long Branch	-74.05003	40.31417	–1,000	10	--	--	-11	-3	-2	-2	-2	0	10/29/2008
25-545	29-13277	Keyport	-74.16848	40.41177	–712	60	--	--	--	--	--	--	-36	--	10/30/2008
25-562	29-13329	Keyport	-74.20342	40.42791	500–555	30	--	--	--	--	--	-37	-32	5	10/30/2008
25-634	29-16237	Freehold	-74.28626	40.25567	877–914	170	--	--	--	-22	-20	-25	-30	-5	11/5/2008
25-635	**29-18402-9**	**Farmingdale**	**-74.20014**	**40.18484**	**1,226–1,330**	**111**	**--**	**--**	**-38**	**-23**	**-18**	**-22**	**-28**	**-6**	**10/22/2008**
25-711	29-14303	Freehold	-74.31709	40.29555	649–756	90	--	--	-35	-4	-8	-7	-11	-4	10/30/2008
25-728	28-21488	Freehold	-74.35948	40.29533	541–621	70	--	--	-24	-1	-3	-4	-10	-6	10/23/2008
25-731	28-22008	Freehold	-74.36625	40.31131	541–628	71	--	--	--	--	3	2	-3	-5	10/23/2008
25-1064	29-24446	Adelphia	-74.27442	40.21729	921–976	100	--	--	--	--	--	--	-33	--	10/28/2008
29-19	**--**	**Barnegat Light**	**-74.09264**	**39.80818**	**2,736–2,756**	**9**	**0**	**-6**	**-11**	**-10**	**-5**	**-5**	**-4**	**1**	**10/17/2008**
29-47	--	Lakewood	-74.14261	40.07489	1,709–1,749	8	-36	-41	-65	-45	-40	-17	-21	-4	11/4/2008
29-85	**--**	**Toms River**	**-74.23848**	**39.99151**	**1,460–1,480**	**67**	**-23**	**-29**	**-40**	**-30**	**-20**	**-23**	**-25**	**-2**	**10/30/2008**
29-118	29-04322	Lakehurst	-74.35237	40.03345	1,397–1,583	96	-27	-28	-41	-29	-41	-23	-27	-4	10/31/2008
29-132	29-03726	Lakehurst	-74.32912	40.05803	1,606–1,728	98	-30	-34	-48	-42	-38	-29	-32	-3	10/28/2008
29-440	29-06549	Lakewood	-74.22353	40.08381	1,357–1,602	72	-20	-31	-44	-29	-20	-21	-24	-3	11/6/2008
29-490	33-01343	Keswick Grove	-74.35844	39.98658	1,436–1,636	100	-30	-47	-33	-18	-19	-21	-22	-1	11/5/2008
29-576	29-08936	Lakehurst	-74.28740	40.11475	1,276–1,462	135	-32	-35	-48	-40	-36	-33	-39	-6	10/27/2008

Appendix 8. Water-level data for wells screened in the Middle and undifferentiated Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft) 1978	1983	1988	1993	1998	2003	2008	2003–2008 change (ft)	2008 measurement date
29-581	48-00056	Roosevelt	-74.44498	40.14061	876–976	130	-1	-16	-26	-17	-14	-12	-9	3	10/27/2008
29-588	29-09259	Lakewood	-74.18486	40.07737	1,410–1,620	73	--	-24	-53	-33	-21	-25	-24	1	11/12/2008
29-595	29-08356	Lakewood	-74.13486	40.07095	1,565–1,800	25	--	--	--	--	--	--	-4	--	11/4/2008
29-626	33-10224	Toms River	-74.20778	39.95598	1,700–1,875	9	--	-23	-33	-23	-14	-24	-16	8	11/25/2008
29-779	29-12006	Lakewood	-74.14153	40.07595	1,700–1,860	34	--	--	--	--	--	--	-21	--	11/4/2008
29-1113	29-25859	Point Pleasant	-74.05733	40.01295	1,852–1,974	10	--	--	--	--	-7	-7	-10	-3	11/5/2008
29-1659	29-34751	Adelphia	-74.29139	40.15389	1,100–1,300	142	--	--	--	--	--	--	-15	--	10/28/2008
29-1781	29-44970	Adelphia	-74.29444	40.15750	1,100–1,325	150	--	--	--	--	--	--	-13	--	10/28/2008
33-65	--	Penns Grove	-75.40964	39.65345	501–512	30	-14	-15	-18	--	-18	-17	-22	-5	12/5/2008
33-106	--	Salem	-75.48770	39.58734	359–365	5	--	--	--	-31	-31	-31	-34	-3	12/15/2008
33-119	30-00018	Wilmington South	-75.51145	39.66917	210–230	7	-46	-39	-43	-44	-38	-46	-48	-2	11/20/2008
33-158	30-00763	Woodstown	-75.33575	39.64678	562–575	62	--	--	-25	-17	-25	-23	-26	-3	12/5/2008
33-166	--	Penns Grove	-75.37575	39.66178	568–578	47	-14	-15	-18	--	-18	-16	-20	-4	11/5/2008
33-187	**--**	**Woodstown**	**-75.32036**	**39.67714**	**664–672**	**73**	**-25**	**-26**	**-28**	**-29**	**-28**	**-25**	**-29**	**-4**	**11/14/2008**
33-251	**--**	**Salem**	**-75.46467**	**39.56370**	**699–709**	**3**	**-27**	**-28**	**-32**	**-32**	**-31**	**-32**	**-35**	**-3**	**11/20/2008**
33-305	30-01083	Penns Grove	-75.41603	39.67039	381–457	14	-13	-14	-16	--	-16	-15	-20	-5	12/5/2008
33-918	34-01512	Taylors Bridge	-75.53594	39.46414	1,115–1,135	12	--	--	--	--	--	-44	-43	1	12/10/2008
33-933	30-13120	Woodstown	-75.31880	39.64617	535–670	48	--	--	--	--	-33	-31	-33	-2	12/5/2008
33-934	34-04055	Taylors Bridge	-75.52979	39.46214	826–836	16	--	--	--	--	-60	-70	-75	-5	12/10/2008
33-972	30-12165	Wilmington South	-75.50525	39.67181	202–264	11	--	--	--	--	--	--	-51	--	11/20/2008
P10105	--	Philadelphia	-75.17212	39.89511	–101	9	-9	--	-7	-4	-4	-6	-4	2	11/19/2008

Appendix 9. Water-level data for wells screened in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
5-123	31-05321	Camden	-75.00245	39.98461	226–261	25	-10	-12	-16	-16	-16	-12	-8	4	11/18/2008
5-125	31-03835	Moorestown	-74.98884	39.99114	239–281	79	-11	-15	-16	-19	-17	-15	-10	5	11/18/2008
5-129	27-04844	Camden	-75.00267	39.99595	–174	60	--	--	--	--	--	-0	3	3	11/12/2008
5-130	31-04576	Frankford	-75.01098	40.00006	167–198	70	-4	-3	-14	-12	-14	-9	-6	3	11/18/2008
5-146	27-03080	Beverly	-74.96809	40.02292	89–130	25	3	2	0	--	--	5	4	-1	11/18/2008
5-228	31-08923	Moorestown	-74.98234	39.94206	440–500	40	-47	-51	-60	-53	-55	-38	-42	-4	11/3/2008
5-262	**--**	**Mount Holly**	**-74.83989**	**39.92345**	**1,125–1,145**	**72**	**-48**	**-58**	**-60**	**-61**	**-52**	**-47**	**-44**	**3**	**10/27/2008**
5-274	31-03674	Moorestown	-74.98434	39.97817	241–262	40	-20	-26	-29	-31	-28	-25	-19	6	11/7/2008
5-645	--	Bristol	-74.87072	40.00289	431–441	40	-31	-35	-41	-41	-38	-30	-29	1	10/27/2008
5-648	--	Beverly	-74.90217	40.01736	306–316	34	-20	-23	-29	-28	-29	-19	-22	-3	10/21/2008
5-746	31-12925	Moorestown	-74.98739	39.95736	389–450	13	-29	-41	-43	-43	-38	-32	-29	3	11/3/2008
5-819	31-19212	Moorestown	-74.94595	39.93531	499–590	20	--	-59	-68	-65	--	-47	-47	0	11/3/2008
5-823	--	Moorestown	-74.92122	39.93819	590–640	35	-48	-62	-75	-64	-50	-50	-47	3	11/3/2008
5-1075	31-26130	Moorestown	-74.93250	39.94253	528–644	40	--	--	-63	-61	--	-43	-42	1	11/3/2008
5-1811	31-64874	Camden	-75.05490	39.99261	–119	1	--	--	--	--	--	--	-13	--	11/17/2008
5-1813	31-64870	Camden	-75.05128	39.99261	–122	15	--	--	--	--	--	--	-5	--	11/17/2008
7-12	31-02687	Runnemede	-75.10979	39.87272	334–359	31	-57	-60	-52	-50	-41	-36	-33	3	11/18/2008
7-68	31-00904	Camden	-75.09287	39.93267	185–225	24	--	--	--	--	--	--	-14	--	11/17/2008
7-111	31-03456	Camden	-75.08854	39.95686	139–170	9	--	--	-26	--	-10	-7	-8	-1	11/18/2008
7-121	--	Moorestown	-74.99333	39.88092	672–729	76	-89	-98	-107	--	-59	-73	-57	16	11/19/2008
7-122	31-07021	Moorestown	-74.99489	39.88122	684–741	80	--	--	--	--	--	--	-51	--	11/19/2008
7-130	31-05077	Moorestown	-74.95183	39.89817	743–748	71	-67	-75	-80	-79	-52	-59	-51	8	11/20/2008
7-144	31-00684	Camden	-75.01695	39.91145	491–527	39	-60	-64	-67	-65	-49	-42	-38	4	11/19/2008
7-157	31-05033	Camden	-75.00839	39.93284	376–427	45	--	--	--	--	-43	-37	-32	5	11/19/2008
7-163	31-04051	Camden	-75.00764	39.93606	371–453	39	-46	-51	-53	-45	-36	-35	-26	9	11/19/2008
7-171	31-04797	Camden	-75.08717	39.90736	224–313	15	--	--	--	--	--	--	-17	--	11/13/2008
7-172	31-04799	Camden	-75.08534	39.90781	218–312	10	-46	-40	-37	-38	--	-35	-8	27	11/13/2008
7-175	31-00079	Camden	-75.07687	39.92089	266–306	21	-55	-52	-51	--	-38	-31	-29	2	11/13/2008
7-185	--	Clementon	-74.98156	39.83067	940–950	70	--	--	--	--	--	--	-63	--	12/23/2008
7-188	31-05950	Clementon	-74.98258	39.83059	934–986	65	--	--	-89	-97	-62	-69	-66	3	12/23/2008

Appendix 9. Water-level data for wells screened in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
7-221	--	Philadelphia	-75.12694	39.89894	162–170	11	-39	-35	-30	-26	-22	-18	-16	2	11/19/2008
7-273	31-04756	Runnemede	-75.06234	39.84222	612–712	54	-78	-77	-83	-82	-61	-59	-56	3	11/19/2008
7-278	31-02434	Camden	-75.05389	39.87725	452–594	65	-72	-76	-82	--	-50	-56	-49	7	11/20/2008
7-283	31-04282	Camden	-75.07573	39.87956	445–455	24	-62	-64	-64	-61	-48	-43	-40	3	11/18/2008
7-284	31-05054	Camden	-75.07601	39.87981	–484	30	--	--	-66	-61	-45	-44	-40	4	11/18/2008
7-302	31-02130	Camden	-75.02745	39.88867	523–572	21	-76	-83	-89	-95	-62	-55	-52	3	11/12/2008
7-320	31-04642	Camden	-75.05289	39.94733	245–285	69	-33	-36	-34	-32	-26	-18	-15	3	11/18/2008
7-335	31-02915	Camden	-75.03934	39.95545	243–278	61	-33	-35	-35	-34	-29	-27	-20	7	11/18/2008
7-341	31-01417	Camden	-75.06915	39.96533	115–145	45	-22	-20	-19	-21	-10	-7	-6	1	11/19/2008
7-350	51-00064	Camden	-75.02189	39.96742	232–257	12	--	--	--	--	-23	-18	-15	3	11/18/2008
7-368	51-00053	Camden	-75.06292	39.97983	106–126	10	-13	-22	-17	--	--	-12	-9	3	11/17/2008
7-372	31-05110	Camden	-75.03498	39.98153	195–230	68	--	--	-23	-20	-16	-13	-12	1	11/18/2008
7-412	**31-09560**	**Clementon**	**-74.94128**	**39.82289**	**1,082–1,092**	**149**	**-62**	**-72**	**-78**	**-80**	**-58**	**-58**	**-55**	**3**	**11/12/2008**
7-523	31-12315	Runnemede	-75.09217	39.86434	458–557	81	-56	-58	-61	-58	-43	-38	-38	0	11/18/2008
7-528	31-08526	Camden	-75.05061	39.97686	140–180	20	-23	-28	-32	-22	-14	-13	-11	2	11/17/2008
7-541	31-15720	Camden	-75.09573	39.93650	215–253	20	--	-34	-31	-26	-19	-14	-10	4	11/17/2008
7-547	31-18944	Camden	-75.08231	39.95881	155–195	35	--	--	-32	--	-12	-10	-7	3	11/18/2008
7-597	31-20270	Camden	-75.08684	39.95503	136–176	11	--	--	-30	--	-11	-8	-8	0	11/18/2008
7-723	31-28896	Camden	-75.05484	39.90036	418–470	64	--	--	--	--	-49	-43	-42	1	11/10/2008
7-739	31-38319	Moorestown	-74.99406	39.88178	695–754	85	--	--	--	--	--	--	-51	--	11/19/2008
7-932	31-43420	Camden	-75.07092	39.96656	125–145	29	--	--	--	--	-11	-7	-5	2	11/17/2008
7-933	31-45075	Camden	-75.02128	39.96900	177–182	28	--	--	--	--	-22	-19	-16	3	10/10/2008
7-965	31-26140-0	Camden	-75.03323	39.99345	85–105	19	--	--	--	--	-12	-7	-5	2	10/28/2008
7-1006	31-58576	Camden	-75.04192	39.96539	250–260	33	--	--	--	--	--	-16	-14	2	11/18/2008
7-1027	31-58626	Camden	-75.04972	39.98283	148–158	26	--	--	--	--	--	--	-15	--	11/18/2008
7-1042	31-59990	Camden	-75.05303	39.96475	265–275	89	--	--	--	--	--	--	-10	--	11/10/2008
7-1043	31-59991	Camden	-75.05306	39.96472	210–220	89	--	--	--	--	--	--	-11	--	11/10/2008
7-1055	31-59303	Camden	-75.05961	39.97161	210–220	67	--	--	--	--	--	-9	-8	1	11/10/2008
7-1070	31-56691	Camden	-75.05639	39.98839	93–120	11	--	--	--	--	--	--	-10	--	11/17/2008
7-1085	31-59128	Camden	-75.06028	39.90167	355–445	51	--	--	--	--	--	-40	-39	1	11/10/2008

Appendix 9. Water-level data for wells screened in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
15-133	30-01222	Marcus Hook	-75.37852	39.75289	317–367	20	--	--	-2	-4	-4	1	2	1	11/10/2008
15-139	30-01223	Bridgeport	-75.35936	39.76900	301–345	7	-10	-10	-11	-1	-11	-9	-11	-2	11/12/2008
15-282	31-07056	Woodbury	-75.18443	39.82034	388–450	55	-30	--	-34	-32	-51	-19	-19	0	11/21/2008
15-308	--	Woodbury	-75.21047	39.84483	231–271	10	-14	-15	-19	-41	-26	-13	-15	-2	11/20/2008
15-312	51-00063	Woodbury	-75.16243	39.85189	322–372	20	-58	-55	-56	-45	-52	-29	-25	4	11/21/2008
15-321	31-00028	Woodbury	-75.14767	39.87225	237–277	13	--	-57	-61	--	--	-34	-30	4	11/20/2008
15-326	31-05689	Woodbury	-75.12723	39.87134	243–277	12	--	--	--	--	--	--	-34	--	12/14/2008
15-331	31-04259	Woodbury	-75.15225	39.83175	405–457	35	-44	-47	-53	-49	-42	-34	-32	2	11/19/2008
15-349	--	Marcus Hook	-75.38741	39.78067	170–220	6	-5	-5	-8	-5	-6	-4	-5	-1	11/10/2008
15-357	--	Bridgeport	-75.29324	39.83261	–105	4	-4	-4	--	--	--	-6	-7	-1	11/12/2008
15-430	31-17788	Woodbury	-75.16167	39.86514	256–328	15	--	-49	-53	--	--	-19	-20	-1	11/20/2008
15-615	30-03530-9	Bridgeport	-75.32074	39.77706	378–388	29	--	--	-15	-16	-15	-12	-15	-3	11/12/2008
15-618	30-03531-7	Bridgeport	-75.32547	39.80122	230–240	7	--	--	-7	-7	-8	-5	-7	-2	11/12/2008
15-671	**--**	**Runnemede**	**-75.09128**	**39.83261**	**650–670**	**35**	**--**	**--**	**-69**	**-69**	**-53**	**-47**	**-46**	**1**	**11/14/2008**
15-678	30-03625	Bridgeport	-75.26963	39.82956	194–204	9	--	--	-8	-5	-8	-5	-6	-1	11/18/2008
15-680	30-03602	Bridgeport	-75.26768	39.84400	186–196	9	--	--	-5	-6	-5	-2	-5	-3	11/18/2008
15-712	**30-04347**	**Bridgeport**	**-75.28963**	**39.80234**	**275–290**	**7**	**--**	**--**	**-11**	**-11**	**-11**	**-8**	**-10**	**-2**	**11/12/2008**
15-738	30-03612-7	Bridgeport	-75.25630	39.83011	188–198	5	--	--	-9	-9	-9	-6	-7	-1	11/18/2008
15-742	31-25266-4	Woodbury	-75.16740	39.78122	757–777	84	--	--	-37	-37	-32	-26	-26	0	11/14/2008
15-770	31-26237-6	Woodbury	-75.18712	39.86734	204–224	10	--	--	-25	-21	-17	-12	-10	2	11/12/2008
15-772	31-26242	Woodbury	-75.18796	39.86845	196–216	10	--	--	--	--	--	-12	-11	1	11/12/2008
15-778	31-26245	Woodbury	-75.18856	39.87278	170–190	5	--	--	--	--	-17	-13	-8	5	12/12/2008
15-1004	--	Pitman East	-75.10073	39.73928	1,038–1,206	80	--	--	--	-63	-55	-49	-48	1	12/3/2008
15-1125	30-04112	Bridgeport	-75.29074	39.82706	186–196	15	--	--	--	-3	-4	-3	-3	0	11/12/2008
15-1201	30-11328	Woodbury	-75.24685	39.84011	235–245	12	--	--	--	--	--	-5	-6	-1	11/18/2008
15-1487	30-12609	Woodstown	-75.33630	39.74261	495–525	104	--	--	--	--	-15	-16	-17	-1	12/3/2008
15-1726	30-13076	Bridgeport	-75.37528	39.77722	180–200	10	--	--	--	--	--	--	-6	--	11/24/2008
33-86	30-01139	Marcus Hook	-75.42269	39.76595	169–189	13	-10	-12	-11	-17	-14	-12	-13	-1	11/17/2008
33-330	50-00098	Penns Grove	-75.44947	39.70139	–394	16	-38	-15	-23	-40	-34	-34	-38	-4	11/24/2008
33-335	30-01133	Penns Grove	-75.46203	39.70314	270–430	13	--	-30	-33	--	--	-32	-36	-4	12/5/2008

Appendix 9. Water-level data for wells screened in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft, feet; --, data not available; **blue** type indicates well with accompanying hydrograph; horizontal datum is North American Datum of 1983; vertical datum is National Geodetic Vertical Datum of 1929; positive differences in water-level change indicate a rise in water levels from 2003 to 2008, whereas negative values indicate a decline in water levels from 2003 to 2008]

USGS well identifier	New Jersey permit number	USGS quadrangle	Longitude	Latitude	Screened interval (ft)	Altitude of land surface (ft)	Water-level altitude (ft)							2003–2008 change (ft)	2008 measurement date
							1978	1983	1988	1993	1998	2003	2008		
33-843	30-12116	Woodstown	-75.31741	39.64567	825–855	42	--	--	--	--	--	--	-38	--	12/5/2008
33-951	30-08958	Marcus Hook	-75.41217	39.78144	130–150	22	--	--	--	--	--	--	-8	--	11/17/2008
P10113	--	Philadelphia	-75.17740	39.90234	--	6	-7	--	-5	-4	-3	-3	-1	2	11/19/2008
P10114	--	Philadelphia	-75.14157	39.91261	122–167	10	--	--	-8	-6	-6	-5	-5	0	11/19/2008
Delaware and Maryland															
Db15-05	8006	Newark East	-75.6708	39.6548	216–238	20	--	--	--	--	-1	0	0	0	1/13/2009
Db33-17	10398	Wimington South	-75.6194	39.6262	185–189	48	--	--			-40	-51	-57	-6	12/17/2008
Dc34-05	--	Wimington South	-75.6130	39.6321	574–579	28	--	--	-68	-65	-64	-74	-68	6	12/17/2008
Dc53-07	--	St Georges	-75.6310	39.5976	534–539	55	--	--	--	--	--	--	-110	--	12/16/2008
DE-NC 10058	10058	St Georges	-75.6358	39.5715	--	--	--	--	--	--	--	--	-138	--	12/16/2008
DE-NC 53066	53066	Delaware City	-75.6046	39.5734	--	--	--	--	--	--	--	--	-121	--	12/16/008
Ec32-07	--	St Georges	-75.6336	39.5442	586–596	9	--	--	-93	-87	-101	-102	-90	12	1/12/2009

Appendix 10-1. Results of the Mann-Kendall trend test on water levels from selected observation wells, New Jersey Coastal Plain, 1978–2008.

[USGS, U.S. Geological Survey; ft/yr, feet per year; **blue** indicates statistically significant upword trend; **red** indicates statistically significant downword trend; $p = 0.05$, slope ≥ |0.2|; Insubstantial, $p = 0.05$ and slope < |0.2|; NA, not applicable; --, amount of data insufficient for analysis; <, less than; ≥, greater than or equal to]

USGS well identifier	Name	Aquifer	2003 to 2008				1998 to 2008				1978 to 2008			
			Trend	*p*	Sen's slope (ft/yr)	Season-ality	Trend	*p*	Sen's slope (ft/yr)	Season-ality	Trend	*p*	Sen's slope (ft/yr)	Season-ality
9-49	Higbee Beach 3 Obs	Cohansey	insignificant	0.061	NA	x	insubstantial	0.033	-0.16	x	insubstantial	<0.001	0.13	x
9-80	Cape May 42 Obs	Cohansey	insignificant	1	NA	x	insignificant	0.402	NA	x	insubstantial	<0.001	-0.06	x
9-150	West Cape May 1	Cohansey	insignificant	1	NA	x	decreasing	0.004	-0.22	x	increasing	<0.001	0.29	x
9-304	Airport Rio Grande obs	Rio Grande wbz	insignificant	0.791	NA	x	insubstantial	0.003	-0.12	x	--	--	--	
1-37	Galen Hall Obs	Atlantic City 800-foot sand	--	--	--		insignificant	0.524	NA	x	decreasing	<0.001	-0.82	x
1-180	Oceanville 1 Obs	Atlantic City 800-foot sand	decreasing	<0.001	-1.58	x	insignificant	0.137	NA	x	decreasing	<0.001	-0.55	x
1-578	Jobs Point Obs	Atlantic City 800-foot sand	decreasing	<0.001	-1.56	x	decreasing	<0.001	-0.31	x	decreasing	<0.001	-0.62	x
1-702	Burk Ave TW Obs	Atlantic City 800-foot sand	decreasing	<0.001	-1.38	x	insignificant	0.128	NA	x	[1]decreasing	<0.001	-0.45	x
9-302	Coast Guard 800	Atlantic City 800-foot sand	decreasing	<0.001	-0.38	x	decreasing	<0.001	-0.67	x	[1]decreasing	<0.001	-0.97	
9-306	Oyster 800 Obs	Atlantic City 800-foot sand	decreasing	<0.001	-0.32	x	decreasing	<0.001	-0.29	x	[1]decreasing	<0.001	-0.38	x
9-337	N Wildwood 800 Obs	Atlantic City 800-foot sand	decreasing	<0.001	-0.43	x	decreasing	<0.001	-0.56	x	[1]decreasing	<0.001	-0.72	x
1-834	Margate Firehouse Obs	Piney Point	decreasing	<0.001	-0.75		decreasing	<0.001	-0.57		[1]decreasing	<0.001	-0.52	
5-407	Atsion 1 Obs	Piney Point	insubstantial	0.012	-0.11	x	insignificant	0.574	NA	x	insubstantial	<0.001	-0.05	x
5-676	Coyle Airport Obs	Piney Point	insignificant	0.5224	NA		insignificant	0.419	NA		insignificant	0.072	NA	
11-044	Vocational Sch 3 Obs	Piney Point	decreasing	<0.001	-9.41		decreasing	<0.001	-7.55		decreasing	<0.001	-1.39	
11-096	Jones Island 2 Obs	Piney Point	decreasing	<0.001	-6.41		decreasing	<0.001	-2.75		decreasing	<0.001	-1.02	
11-163	Fair Grounds 3 Obs	Piney Point	decreasing	0.0043	-7.82		decreasing	<0.001	-5.01		decreasing	<0.001	-1.44	
29-18	Island Beach 2 Obs	Piney Point	decreasing	<0.001	-0.32	x	insubstantial	0.003	-0.13	x	insubstantial	<0.001	-0.11	x
29-425	Webbs Mills 2 Obs	Piney Point	insignificant	0.836	NA	x	insignificant	0.092	NA	x	insubstantial	0.007	-0.04	x
29-585	DOE-Forked River	Piney Point	insubstantial	<0.001	-0.15	x	insubstantial	<0.001	-0.05	x	[1]insubstantial	<0.001	-0.09	
COBd-53	COBd-53	Piney Point	decreasing	0.02	-0.33		decreasing	<0.001	-0.48		decreasing	<0.001	-0.57	
ID55-01	ID55-01	Piney Point	insignificant	0.078	NA	x	decreasing	0.024	-0.54	x	decreasing	<0.001	-0.97	x
Kc31-01	Kc31-01	Piney Point	decreasing	<0.001	-0.85730		decreasing	<0.001	-0.69		--	--	--	
Nc13-03	Nc13-03	Piney Point	decreasing	<0.001	-0.59110		decreasing	<0.001	-0.46		decreasing	<0.001	-0.49	
5-1250	McGuire 08-MW-5	Vincentown	insubstantial	<0.001	-0.13	x	insubstantial	0.016	0.05	x	--	--	--	
25-636	Howell Twp 2 Ob	Vincentown	insubstantial	0.004	-0.16	x	insubstantial	0.003	0.09	x	[1]insubstantial	<0.001	0.10	x
29-139	Colliers Mills 2 Obs	Vincentown	insubstantial	0.019	-0.12	x	insubstantial	0.002	0.06	x	insignificant	0.737	NA	x
7-118	Hutton Hill 2 Obs	Wenonah-Mt. Laurel	decreasing	<0.001	-0.24	x	insubstantial	0.002	0.08	x	insubstantial	<0.001	-0.05	x
7-478	New Brooklyn Pk 3	Wenonah-Mt. Laurel	decreasing	<0.001	-1.50		decreasing	<0.001	-0.44		decreasing	<0.001	-3.21	
25-353	Fort Monmouth 1	Wenonah-Mt. Laurel	insignificant	0.361	NA	x	insubstantial	<0.001	-0.13	x	[1]increasing	<0.001	1.35	x

Appendix 10-1. Results of the Mann-Kendall trend test on water levels from selected observation wells, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft/yr, feet per year; **blue** indicates statistically significant upword trend; **red** indicates statistically significant downword trend; $p = 0.05$, slope ≥ |0.2|; Insubstantial, $p = 0.05$ and slope < |0.2|; NA, not applicable; --, amount of data insufficient for analysis; <, less than; ≥, greater than or equal to]

USGS well identifier	Name	Aquifer	2003 to 2008				1998 to 2008				1978 to 2008			
			Trend	p	Sen's slope (ft/yr)	Season-ality	Trend	p	Sen's slope (ft/yr)	Season-ality	Trend	p	Sen's slope (ft/yr)	Season-ality
25-486	DOE-Sea Girt Obs	Wenonah-Mt. Laurel	increasing	<0.001	2.46	x	increasing	<0.001	1.11	x	[1]increasing	<0.001	5.57	x
25-637	Howell Twp 3 Ob	Wenonah-Mt. Laurel	increasing	0.003	0.66	x	insignificant	0.13	NA	x	[1]increasing	<0.001	1.11	x
29-140	Colliers Mills 3 Obs	Wenonah-Mt. Laurel	decreasing	<0.001	-0.47	x	decreasing	<0.001	-0.22	x	insubstantial	<0.001	-0.13	x
33-020	Horner Obs	Wenonah-Mt. Laurel	decreasing	0.005	-0.93	x	insignificant	0.078	NA	x	decreasing	<0.001	-0.36	x
33-252	Salem 2 Obs	Wenonah-Mt. Laurel	decreasing	0.0065	-0.34		insignificant	0.202	NA		insubstantial	<0.001	-0.04	x
5-259	Medford 2 Obs	Englishtown	decreasing	0.001	-0.46	x	insignificant	0.132	NA	x	decreasing	<0.001	-0.25	x
23-104	Morrell 1 Obs	Englishtown	insignificant	1	NA	x	insubstantial	0.038	0.03	x	insignificant	0.64	NA	x
25-250	Village 215 Obs	Englishtown	insignificant	0.151	NA	x	increasing	0.004	0.31	x	insubstantial	<0.001	-0.15	x
25-429	Allaire State Pk Obs	Englishtown	increasing	<0.001	2.94	x	increasing	<0.001	1.37	x	increasing	<0.001	3.86	x
25-638	Howell Twp 4 Ob	Englishtown	increasing	<0.001	1.09	x	insignificant	0.072	NA	x	[1]increasing	<0.001	1.58	x
25-715	Atlantic Highlands B	Englishtown	insubstantial	<0.001	-0.17	x	insignificant	0.317	NA	x	--	--	--	
29-138	Colliers Mills 1 Obs	Englishtown	decreasing	<0.001	-0.62	x	decreasing	<0.001	-0.20	x	insubstantial	<0.001	0.06	x
29-530	Pt Pleasant 6 Obs	Englishtown	increasing	0.038	5.06	x	increasing	0.004	3.33	x	--	--	--	--
29-534	Toms River 2 Obs	Englishtown	increasing	<0.001	1.67		increasing	<0.001	2.24		increasing	<0.001	2.14	
5-258	Medford 1 Obs	Potomac-Raritan-Magothy, upper	increasing	0.001	0.76	x	increasing	<0.001	0.71	x	increasing	<0.001	0.59	x
7-117	Hutton Hill 1 Obs	Potomac-Raritan-Magothy, upper	increasing	0.015	0.71	x	increasing	<0.001	0.69	x	increasing	<0.001	1.13	x
7-477	New Brooklyn Pk 2	Potomac-Raritan-Magothy, upper	insignificant	0.357	NA	x	increasing	<0.001	0.40	x	increasing	<0.001	0.36	x
15-728	Stefka 4 Obs	Potomac-Raritan-Magothy, upper	decreasing	<0.001	-0.31	x	insignificant	0.084	NA	x	[1]insubstantial	<0.001	0.09	x
15-741	Mantua Shallow	Potomac-Raritan-Magothy, upper	insignificant	1	NA	x	increasing	<0.001	0.36	x	[1]increasing	<0.001	0.74	x
23-228	Forsgate 3 Obs	Potomac-Raritan-Magothy, upper	increasing	0.0258	0.83		increasing	<0.001	0.63		insubstantial	0.012	0.07	x
25-206	Keyport 4 Obs	Potomac-Raritan-Magothy, upper	insignificant	0.371	NA	x	insignificant	0.742	NA	x	increasing	<0.001	0.41	x
23-292	Forsgate 2 Obs	Potomac-Raritan-Magothy, upper	increasing	0.011	0.44	x	increasing	<0.001	0.57	x	increasing	<0.001	0.20	x
23-351	Sayreville 1 Obs	Potomac-Raritan-Magothy, upper	insignificant	0.08	NA		insignificant	0.928	NA		insubstantial	0.01	0.12	x
25-316	Sandy Hook SP 1 Obs	Potomac-Raritan-Magothy, upper	insignificant	0.617	NA	x	insignificant	0.089	NA	x	increasing	<0.001	0.21	
25-639	Howell Twp 5 Obs	Potomac-Raritan-Magothy, upper	decreasing	<0.001	-1.15	x	decreasing	<0.001	-0.57	x	[1]insignificant	0.852	NA	x
33-253	Salem 3 Obs	Potomac-Raritan-Magothy, upper	decreasing	0.026	-0.59		decreasing	<0.001	-0.26		decreasing	<0.001	-0.25	
5-063	Willingboro 1 Obs	Potomac-Raritan-Magothy, middle	insignificant	0.12	NA	x	increasing	0.011	0.49	x	insignificant	0.137	NA	x
5-261	Medford 5 Obs	Potomac-Raritan-Magothy, middle	increasing	<0.001	0.80	x	increasing	<0.001	0.74	x	increasing	<0.001	0.39	x
5-440	Rhodia 1 Obs	Potomac-Raritan-Magothy, middle	increasing	0.029	0.28	x	insignificant	0.078	NA	x	insubstantial	<0.001	0.10	x

Appendix 10-1. Results of the Mann-Kendall trend test on water levels from selected observation wells, New Jersey Coastal Plain, 1978–2008.—Continued

[USGS, U.S. Geological Survey; ft/yr, feet per year; **blue** indicates statistically significant upword trend; **red** indicates statistically significant downword trend; p = 0.05, slope ≥ |0.2|; Insubstantial, p = 0.05 and slope < |0.2|; NA, not applicable; --, amount of data insufficient for analysis; <, less than; ≥, greater than or equal to]

USGS well identifier	Name	Aquifer	2003 to 2008				1998 to 2008				1978 to 2008			
			Trend	*p*	Sen's slope (ft/yr)	Season-ality	Trend	*p*	Sen's slope (ft/yr)	Season-ality	Trend	*p*	Sen's slope (ft/yr)	Season-ality
5-683	Butler Place 1 Obs	Potomac-Raritan-Magothy, middle	increasing	**<0.001**	0.26	x	increasing	**<0.001**	0.31	x	increasing	**<0.001**	0.27	
7-413	Elm Tree 3 Obs	Potomac-Raritan-Magothy, middle	increasing	**<0.001**	0.79	x	increasing	**<0.001**	0.68	x	increasing	**<0.001**	0.71	x
7-476	New Brooklyn Pk 1	Potomac-Raritan-Magothy, middle	increasing	**<0.001**	0.26	x	increasing	**<0.001**	0.58	x	increasing	**<0.001**	0.57	x
15-713	Stefka 2 Obs	Potomac-Raritan-Magothy, middle	decreasing	**<0.001**	-0.30	x	insubstantial	0.039	0.09	x	[1]insubstantial	<0.001	0.09	x
23-291	Forsgate 1 Obs	Potomac-Raritan-Magothy, middle	insignificant	0.472	NA	x	increasing	**0.002**	0.60	x	increasing	**<0.001**	0.23	x
23-439	South River 2 Obs	Potomac-Raritan-Magothy, middle	insignificant	0.121	NA	x	insignificant	0.839	NA	x	increasing	**<0.001**	1.51	x
25-272	Marlboro 1 Obs	Potomac-Raritan-Magothy, middle	increasing	**<0.001**	1.10	x	insignificant	0.103	NA	x	increasing	**<0.001**	0.90	x
25-635	Howell Twp 1 Ob	Potomac-Raritan-Magothy, middle	insignificant	0.117	NA	x	decreasing	**<0.001**	-0.56	x	[1]increasing	**0.002**	0.25	x
29-19	Island Beach 3 Obs	Potomac-Raritan-Magothy, middle	decreasing	**<0.001**	-0.28	x	insubstantial	<0.001	-0.17	x	insubstantial	0.004	0.05	x
29-085	Toms River 84 Obs	Potomac-Raritan-Magothy, middle	decreasing	**<0.001**	-0.38		decreasing	**<0.001**	-0.44		increasing	**<0.001**	0.26	
33-187	Point Airy Obs	Potomac-Raritan-Magothy, middle	decreasing	**<0.001**	-0.74	x	insignificant	0.255	NA	x	insubstantial	<0.001	-0.05	x
33-251	Salem 1 Obs	Potomac-Raritan-Magothy, middle	decreasing	**<0.001**	-0.66		decreasing	**<0.001**	-0.31	x	insubstantial	<0.001	-0.19	
11-137	Ragovin 2100 Obs	Potomac-Raritan-Magothy, undiff	insubstantial	<0.001	0.18		increasing	**<0.001**	0.27		decreasing	**<0.001**	-0.52	
5-262	Medford 4 Obs	Potomac-Raritan-Magothy, lower	increasing	**<0.001**	0.80	x	increasing	**<0.001**	0.74	x	increasing	**<0.001**	0.68	x
7-412	Elm Tree 2 Obs	Potomac-Raritan-Magothy, lower	increasing	**0.004**	0.58	x	increasing	**<0.001**	0.83	x	[1]increasing	**<0.001**	1.05	x
15-671	Deptford Deep Obs	Potomac-Raritan-Magothy, lower	increasing	**0.05**	0.40	x	increasing	**<0.001**	0.75	x	[1]increasing	**<0.001**	1.32	x
15-712	Stefka 1 Obs	Potomac-Raritan-Magothy, lower	decreasing	**<0.001**	-0.27	x	insubstantial	0.024	0.09	x	insubstantial	<0.001	0.13	x
Dc34-05	Dc34-05	Potomac-Raritan-Magothy, lower	increasing	**<0.001**	1.78		--	--	--		increasing	**<0.001**	0.68	
Ec32-07	Ec32-07	Potomac-Raritan-Magothy, lower	insignificant	0.061	NA		decreasing	**0.002**	-0.66		decreasing	**<0.001**	-1.08	

[1] period of record only

Appendix 10-2. Results of the Wilcoxon signed-rank test for paired water levels.

[**blue** indicates significant difference (increase); **red** indicates significant difference (decrease); $p = 0.05$; <, less than; --, no data]

Aquifer	All		Atlantic		Burlington		Camden		Cape May		Cumberland		Gloucester	
	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08
Cohansey	0.103	<0.0001	--	--	--	--	--	--	0.103	<0.0001	--	--	--	--
Rio Grande wbz	0.170	--	--	--	--	--	--	--	--	--	--	--	--	--
Atlantic City 800-ft sand	<0.0001	<0.0001	<0.0001	0.040	--	--	--	--	<0.0001	0.0028	--	--	--	--
Piney Point	<0.0001	0.017			--	--	--	--	--	--	--	--	--	--
Vincentown	0.001	0.410	--	--	--	--	--	--	--	--	--	--	--	--
Wenonah-Mt. Laurel	<0.0001	0.315	--	--	<0.0001	0.287	0.027	0.677	--	--	--	--	0.890	0.129
Englishtown	0.521	0.300	--	--	0.042	0.193	--	--	--	--	--	--	--	--
Potomac-Raritan-Magothy, Upper	0.001	0.563	--	--	0.496	0.043	<0.0001	0.0002	--	--	--	--	0.418	<0.0001
Potomac-Raritan-Magothy, Middle	0.585	0.033	--	--	0.118	<0.0001	0.0005	0.147	--	--	--	--	0.004	<0.0001
Potomac-Raritan-Magothy, Lower	0.000	<0.0001	--	--	0.091	0.002	<0.0001	<0.0001	--	--	--	--	0.715	<0.0001

Aquifer	Mercer		Middlesex		Monmouth		Ocean		Salem		Critical Area 1		Critical Area 2	
	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08	2003–8	1998–08
Cohansey	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rio Grande wbz	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Atlantic City 800-ft sand	--	--	--	--	--	--	0.012	--	--	--	--	--	--	--
Piney Point	--	--	--	--	--	--	0.587	0.424	--	--	--	--	--	--
Vincentown	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wenonah-Mt. Laurel	--	--	--	--	0.841	0.669	0.051	0.348	<0.0001	0.359	0.553	0.535	<0.0001	0.802
Englishtown	--	--			0.812	0.674	0.027	0.117	--	--	0.054	0.0483	0.854	0.735
Potomac-Raritan-Magothy, Upper	--	--	0.1187	0.015	<0.0001	<0.0001	0.001	0.004	0.0005	--	<0.0001	<0.0001	<0.0001	<0.0001
Potomac-Raritan-Magothy, Middle	0.375	0.820	0.029	0.729	0.135	0.003	0.204	0.850	0.002	0.004	0.353	0.175	0.0004	<0.0001
Potomac-Raritan-Magothy, Lower	--	--	--	--	--	--	--	--	--	--	--	--	<0.0001	<0.0001

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