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Simulated Effects of Projected 2010 Withdrawals on Ground-Water Flow and Water Levels in the New Jersey Coastal Plain—A Task of the New Jersey Water Supply Plan, 2006 Revision

Scientific Investigations Report 2007-5134

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U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2007

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Suggested citation:
Gordon, A.D., 2007, Simulated Effects of Projected 2010 Withdrawals on Ground-Water Flow and Water Levels in the New Jersey Coastal Plain—A Task of the New Jersey Water Supply Plan, 2006 Revision: U.S. Geological Survey Scientific Investigations Report 2007-5134, 116 p.

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
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	
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
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)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot [(ft/d)/ft]	1	meter per day per meter

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 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.

Simulated Effects of Projected 2010 Withdrawals on Ground-Water Flow and Water Levels in the New Jersey Coastal Plain—A Task of the New Jersey Water Supply Plan, 2006 Revision

By Alison D. Gordon

Abstract

A ground-water flow model previously developed as part of a Regional Aquifer System Analysis (RASA) of the New Jersey Coastal Plain was used to simulate ground-water flow in eight major confined aquifers to help evaluate ground-water resources in support of the New Jersey Department of Environmental Protection's revision of the New Jersey State Water Supply Plan. This model was calibrated to 1998 steady-state and transient conditions. Withdrawals at wells in operation in 1998 were varied in three scenarios to evaluate their effects on flow directions, water levels, and water budgets in the confined aquifers. The scenarios used to predict changes in pumpage from 1998 to 2010 were based on (1) a continuation of 1990-99 trends in water use, (2) public-supply withdrawals estimated from county population projections, and (3) restricted withdrawals in Water-Supply Critical Areas. Total withdrawals in these three scenarios were approximately 366, 362, and 355 million gallons per day, respectively. The results of these simulations are used by New Jersey water-management officials to help address water-supply concerns for the State.

In the revision of the New Jersey State Water Supply Plan, the eight major confined aquifers of the New Jersey Coastal Plain and their outcrop areas are divided into 41 hydrologic budget areas (HBAs). Simulation results were used to assess the effects of changing ground-water withdrawals on water levels and the flow budgets in each budget area. Simulation results for each scenario were compared with 1998 (baseline) simulated water levels and flow budgets.

The 41 hydrologic budget areas are in areas of large ground-water withdrawals, water-level declines, and (or) saltwater-intrusion potential. Their boundaries are based on various hydrologic, geohydrologic, and withdrawal conditions, such as aquifer extent, location of the 250-milligram-per-liter isochlor, aquifer outcrop area, and ground-water divides. The budget areas include primarily the onshore, freshwater portions of the aquifers. A budget analysis was done for each of the hydrologic budget areas for each scenario. Ground-water withdrawals, leakage to streams, net leakage to overlying and underlying aquifers, lateral flow to adjacent budget areas, and the flow direction at the 250-milligram-per-liter isochlor were evaluated.

Although three different methods were applied to predict future pumping rates, the simulated water levels for scenarios 1 and 2 were generally within 2 feet of each other in most areas in the confined aquifers, but differences of more than 2 feet occurred locally. Differences in values of flow-budget components between scenarios 1 and 2 as a percentage change from 1998 values were generally within 2 percent in most hydrologic budget areas, but values of some budget components in some hydrologic budget areas differed by more than 2 percent. Simulated water levels recovered as much as 4 feet more in northeastern Camden and northwestern Burlington Counties in the Lower Potomac-Raritan-Magothy aquifer, and as much as 3 feet more in the same area in the Upper and Middle Potomac-Raritan-Magothy aquifers when pumpage restrictions were imposed in Critical Area 2 (scenario 3).

In the Wenonah-Mount-Laurel aquifer, water levels declined continually in Monmouth County (HBA 8) downdip from the outcrop (in Critical Area 1) from 1988 to 2010 in all three scenarios, although most of the water levels farther downdip from this area in Critical Area 1 are still recovering because of mandated reductions in pumpage in the 1990s. In the Englishtown aquifer system, water levels declined continually in small areas in HBA 13—in central Monmouth County (in Critical Area 1) and in western Monmouth County downdip from the outcrop from 1988 to 2010 in all three scenarios, although most of the water levels farther downdip from this area are still recovering because of the mandated reductions in pumpage.

In the Upper Potomac-Raritan-Magothy aquifer in Critical Area 1 in Monmouth County (HBA 15), water levels were recovering in 1998, but declined again by 2010 in all

three scenarios when pumpage was increased, but the area of decline was smaller in scenario 3. In Critical Area 2 in central Camden and in Gloucester and western Burlington Counties (HBA 16), water levels were recovering in 1998 in scenarios 1 and 2, but had declined again by 2010 when pumpage was increased. In scenario 3, water levels in this area were still recovering in 2010.

In the Middle Potomac-Raritan-Magothy aquifer, water levels were recovering in 1998, but then declined by 2010 both inside and outside Critical Area 1 downdip from the outcrop in Middlesex, Monmouth, and southeastern Mercer Counties (HBA 18) in scenarios 1 and 2; however, the area of decline in Monmouth County was smaller in scenario 3. In scenario 1, water levels in Critical Area 2 downdip from the outcrop in Camden and Gloucester Counties (HBA 19) were recovering in 1998, but then declined by 2010; however, the area of decline was much smaller in scenario 2 and limited to Gloucester County, and no decline was observed in this area in scenario 3.

In scenario 1, water levels in the Lower Potomac-Raritan-Magothy aquifer in Critical Area 2 in Camden and Gloucester Counties (HBA 22) were recovering in 1998, but then declined by 2010 when pumpage was increased. The area of decline was less extensive in scenario 2, and in scenario 3 water levels were recovering. In scenarios 1 and 2, water levels in a small part of the updip area of Gloucester County declined continually from 1988 to 2010, but the area of decline was smaller in scenario 2. The water levels in the same area were recovering after 1998 in scenario 3.

The model flow budgets for each scenario indicate that the confined aquifers of New Jersey are recharged by vertical and lateral flow caused by recharge from precipitation on the outcrop areas and by vertical flow from overlying or underlying aquifers through confining units of varying leakance. The sources of water to wells as flows to and from the HBAs can be complex and are interdependent. The flow budgets indicate that as pumpage from the confined aquifers increased, inflow from the overlying aquifer usually increased, although some of this inflow became outflow to the underlying aquifer because of pumpage increases in the underlying aquifers. In HBA 16 in the Upper Potomac-Raritan-Magothy aquifer, inflow from the overlying aquifer increased 13, 13, and 9 percent, respectively, in scenarios 1, 2, and 3 from the 1998 simulation, but outflow to the underlying aquifer increased 7, 7, and 6 percent, respectively. In HBA 19 in the Middle Potomac-Raritan-Magothy aquifer, inflow from the overlying aquifer increased 8, 7, and 6 percent, respectively, in scenarios 1, 2, and 3, but outflow to the underlying aquifer increased 5, 4, and 2 percent, respectively, in these scenarios. The flow budgets also indicate that as pumpage from the Atlantic City 800-foot sand in HBA 1 increased (14, 11, and 11 percent, respectively), lateral inflow from the updip unconfined aquifer increased (6, 5, and 5 percent, respectively).

Leakage to streams decreased from baseline conditions in some hydrologic budget areas in the outcrop of the Upper and Middle Potomac-Raritan-Magothy aquifers because of increased pumpage in the budget areas in which the streams are located, or in adjacent budget areas. Leakage to streams in the outcrop areas of these aquifers decreased less in scenario 3 than in scenarios 1 and 2. Simulated leakage to streams in HBA 40 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer in Critical Area 1 decreased 3, 3, and 1 percent, respectively, in scenarios 1, 2, and 3 from the 1998 simulation. Simulated leakage to streams in HBA 44 in the outcrop of the Middle Potomac-Raritan-Magothy aquifer in Critical Area 1 decreased 3, 3, and 2 percent, respectively, in scenarios 1, 2 and 3 from the 1998 simulation. In HBA 42 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer in Critical Area 2, however, induced leakage from the stream to the aquifer occurred in 1998 and in all three scenarios, although the amount of leakage decreased 1, 1, and 3 percent in scenarios 1, 2, and 3, respectively.

In HBA 2 in the Atlantic City 800-foot sand, lateral inflow from the aquifer offshore increased 5, 3, and 3 percent in scenarios 1, 2, and 3, respectively. The 250-milligram-per-liter isochlor is approximately 10 miles offshore to the east of HBA 2, and about 4 to 6 miles inland to the south of HBA 2, and could move farther landward if ground-water withdrawals increase. In HBA 18 in the Middle Potomac-Raritan-Magothy aquifer, simulated inflow updip from the location of the 250-milligram-per-liter isochlor in Ocean County increased 2 percent in all three scenarios.

Introduction

The New Jersey State Water Supply Plan (SWSP), adopted by the New Jersey Department of Environmental Protection (NJDEP) in 1982, is a water-supply management tool that designates planning areas based on various geologic, hydrologic, and withdrawal conditions so that water resources can be evaluated within designated areas that exhibit similar hydrogeologic conditions. The SWSP, last revised in 1996, is currently (2006) being updated by the NJDEP to account for changes in the State’s water-resource demand and supply conditions that have occurred over the past decade.

The 1982 SWSP identified two areas in the New Jersey Coastal Plain where regional cones of depression resulting from ground-water development in populated areas were causing saltwater intrusion and threatening the long-term reliability of the ground-water supply. These areas are referred to as Water-Supply Critical Areas. Critical Area 1 includes the Englishtown aquifer system, the Wenonah-Mount Laurel aquifer, and the Upper and Middle Potomac-Raritan-Magothy aquifers in portions of Monmouth, Ocean, and Middlesex Counties (fig. 1). In Critical Area 1, purveyors with wells that pump 100,000 gal/d or more were required to reduce their withdrawals to 50 percent or less of the 1983 rate (CH2M Hill and others, 1992). These restrictions went into effect in the 1990s (N.J. Department of Environmental Protection, 1996). Since then, water levels in the Englishtown aquifer system

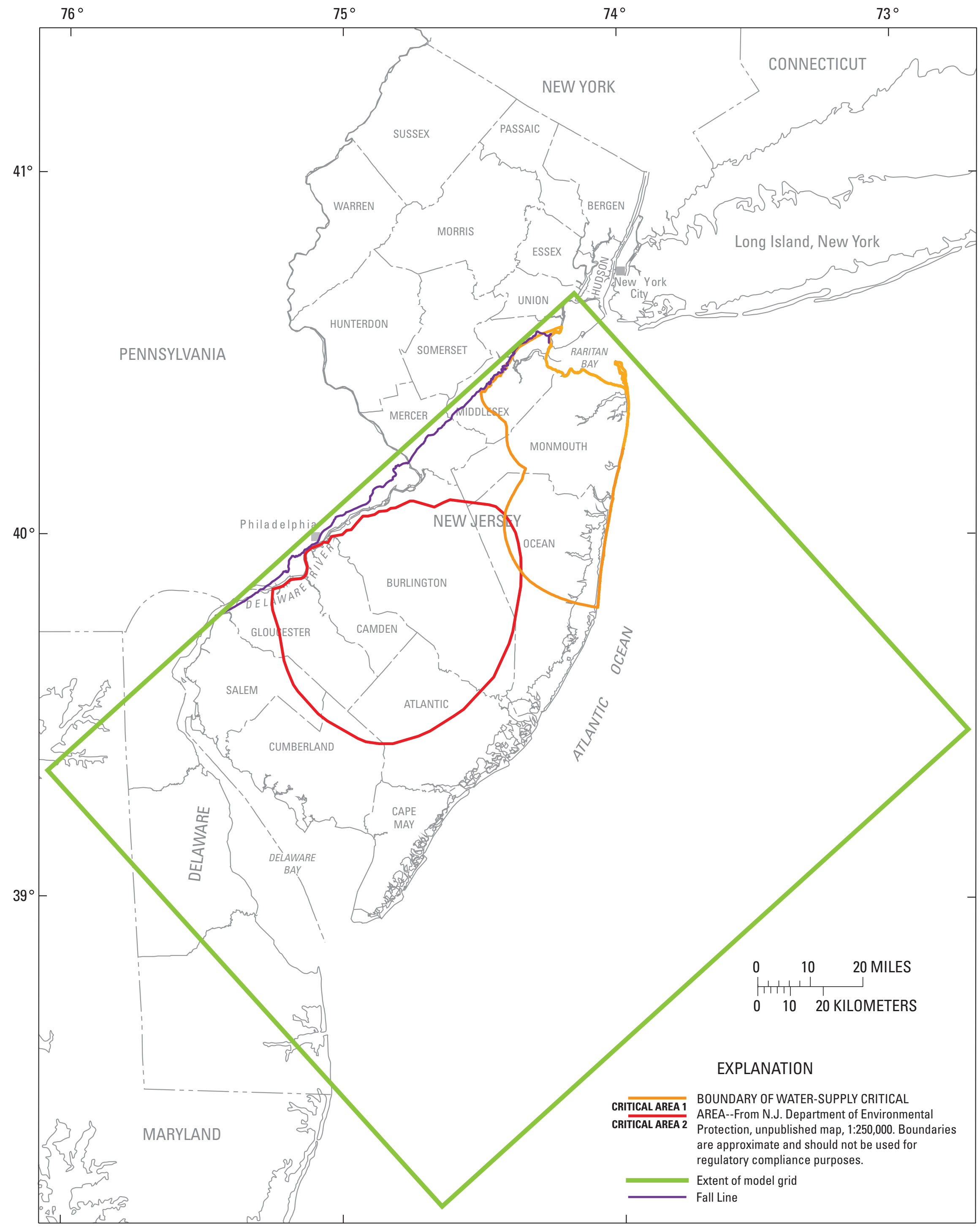


Figure 1. Location of model grid and Critical Areas in the New Jersey Coastal Plain.

and the Wenonah-Mount Laurel aquifer have risen more than 120 ft (Lacombe and Rosman, 2001). Critical Area 2 includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers and is centered on Gloucester, Camden, and Burlington Counties. Withdrawals in Critical Area 2 were reduced by an average of 22 percent (N.J. Department of Environmental Protection, 2005a).

In 2003, the U.S. Geological Survey (USGS), in cooperation with the NJDEP, initiated a study to investigate the effects of projected 2010 withdrawals based on various ground-water-demand scenarios on ground-water flow and water levels in the confined New Jersey Coastal Plain aquifers. This information will be used in the revised water-supply plan to estimate flow budgets within and outside areas of population growth and to quantify changes in simulated water levels in the confined aquifers in the New Jersey Coastal Plain.

Purpose and Scope

This report describes the results of simulations of ground-water flow and water levels that would result from projected 2010 withdrawals done by use of a previously developed Regional Aquifer System Analysis (RASA) ground-water flow model of the New Jersey Coastal Plain. Forty-one hydrologic budget areas were delineated based on hydrologic constraints in each of the eight major confined aquifers of the Coastal Plain. The hydrologic budget areas coincide primarily with areas of large ground-water withdrawals, large water-level declines, and potential saltwater intrusion.

Average 1998 ground-water withdrawals for approximately 2,050 wells are used as a baseline for comparison with simulated water levels and flow budgets for the eight confined aquifers. Three withdrawal scenarios are used to simulate a range of projected increases or decreases in ground-water withdrawals at existing wells from 1998 to 2010. Results of these simulations are used to quantify the effects of projected changes in withdrawals on the ground-water flow system in the hydrologic budget areas. Simulation results are presented in a series of maps showing simulated water levels for 2010, the simulated difference between water levels in 1998 and 2010, and areas of water-level change from 1988 to 1998 and from 1999 to 2010, particularly in the Water-Supply Critical Areas. Flow-budget components in each of the 41 hydrologic budget areas are quantified.

The locations of continuous or manual water-level monitoring wells in 2005 and the locations of wells in which chloride concentrations were measured from 1999 to 2005 are shown in appendix 1 to provide information about water levels and movement of saline water (ground water with chloride concentrations greater than 250 mg/L) in the New Jersey Coastal Plain. This information is included to show areas of current data collection where water levels have been monitored long term, and to indicate areas of potential water-level declines or saltwater intrusion where data are lacking.

Hydrogeologic Setting

The Coastal Plain sediments of New Jersey comprise a seaward-dipping wedge of alternating layers of gravel, sand, silt, and clay overlying crystalline bedrock. The confined aquifers consist predominantly of sand but may also include interbedded silts and clays that range from about 50 to more than 600 ft in thickness and are separated by confining units; the confining units are composed predominantly of silts and clays and range in thickness from 50 to 1,000 ft (Martin, 1998). The aquifers are recharged by precipitation in aquifer outcrop areas. Ground water flows laterally downdip and (or) downward to underlying units. Water in the confined aquifers discharges to wells, to the Raritan or Delaware Bay, or to the Atlantic Ocean. Detailed descriptions of the hydrogeology of the New Jersey Coastal Plain aquifers and confining units are given in Zapecza (1989) and Martin (1998). The aquifers and corresponding geologic units are shown in table 1. A generalized hydrogeologic section through the Coastal Plain (fig. 2) shows the conceptual model of the aquifers and confining units in onshore areas.

Simulation Of Projected 2010 Withdrawals

In this study, a previously developed transient ground-water flow model of the New Jersey Coastal Plain, the RASA model (Martin, 1998), subsequently revised by Voronin (2004), was used to simulate the ground-water flow system in eight confined aquifers from 1999 to 2010 using the MODFLOW model code (Harbaugh and McDonald, 1996). Simulation results were used to evaluate the effects of projected changes in ground-water withdrawals on water levels and to quantify the effects on the flow budgets in the designated hydrologic budget areas.

Description of Ground-Water Flow Model

The ground-water flow model consists of 10 layers that represent 10 aquifers and 9 intervening confining units. The model-grid dimensions are 135 rows by 245 columns. Onshore, the model-grid spacing is 0.25 mi^2 in the northern and southwestern New Jersey Coastal Plain, and 0.31 mi^2 in the southeastern New Jersey Coastal Plain. Offshore, the row spacing increases to a maximum of 3.16 mi^2. The grid is aligned approximately parallel to the Fall Line and the strike of the Coastal Plain hydrogeologic units (fig. 1).

The updip extent of each aquifer layer is a no-flow boundary in the model. The lower boundary of the model represents crystalline bedrock, which underlies the Coastal Plain sediments and is a no-flow boundary. The lateral model boundaries in the northeast and southwest are specified-flux

Table 1. Geologic and hydrogeologic units of the New Jersey Coastal Plain and model units used in this study.

[Modified from Martin (1998, table 2); Zapecza (1989, table 2); and Seaber (1965, table 3); shading indicates adjacent geologic or hydrogeologic unit is not present in the updip or downdip areas]

System	Series	Geologic Unit	Hydrogeologic Unit		Model Units[1]	
					Updip	Downdip
Quaternary	Holocene	Alluvial deposits	Undifferentiated		Upper Kirkwood-Cohansey aquifer (A2)	
		Beach sand and gravel	Undifferentiated		Upper Kirkwood-Cohansey aquifer (A2)	Holly Beach water-bearing zone (A1)
	Pleistocene	Cape May Formation	Kirkwood-Cohansey aquifer system	Undifferentiated		Estuarine clay confining unit (C1)
						Upper Kirkwood-Cohansey aquifer (A2)
Tertiary	Miocene	Pennsauken Formation		Undifferentiated	Upper Kirkwood-Cohansey aquifer and Rio Grande water–bearing zone (A2)	
		Bridgeton Formation	Kirkwood-Cohansey aquifer system	Undifferentiated	Upper Kirkwood-Cohansey aquifer and Rio Grande water–bearing zone (A2)	
		Beacon Hill Gravel	Kirkwood-Cohansey aquifer system	Undifferentiated	Upper Kirkwood-Cohansey aquifer and Rio Grande water–bearing zone (A2)	
		Cohansey Sand	Kirkwood-Cohansey aquifer system		Upper Kirkwood-Cohansey aquifer and Rio Grande water–bearing zone (A2)	
		Kirkwood Formation	Kirkwood-Cohansey aquifer system		Lower Kirkwood-Cohansey aquifer (A3)	Upper Kirkwood-Cohansey aquifer and Rio Grande water–bearing zone (A2)
		Kirkwood Formation	Confining unit			
		Kirkwood Formation	Rio Grande water-bearing zone			
		Kirkwood Formation	Confining unit			Confining unit (C2)
		Kirkwood Formation	Atlantic City 800-foot sand			Atlantic City 800-foot sand (A3)
		Kirkwood Formation	Composite confining unit		Basal Kirkwood confining unit (C3)	
	Oligocene	Piney Point Formation[2]	Composite confining unit	Piney Point aquifer	Piney Point aquifer (A4)	
	Eocene	Shark River Formation	Composite confining unit		Vincentown-Manasquan confining unit (C4)	
		Manasquan Formation	Composite confining unit		Vincentown-Manasquan confining unit (C4)	
	Paleocene	Vincentown Formation	Composite confining unit	Vincentown aquifer	Vincentown aquifer (A5)	Vincentown-Manasquan confining unit (C4)
		Hornerstown Sand	Composite confining unit		Navesink-Hornerstown confining unit (C5)	
Cretaceous	Upper Cretaceous	Tinton Sand	Composite confining unit		Navesink-Hornerstown confining unit (C5)	
		Red Bank Sand	Composite confining unit	Red Bank sand	Navesink-Hornerstown confining unit (C5)	
		Navesink Formation	Composite confining unit		Navesink-Hornerstown confining unit (C5)	
		Mount Laurel Sand	Wenonah-Mount Laurel aquifer		Wenonah-Mount Laurel aquifer (A6)	
		Wenonah Formation	Wenonah-Mount Laurel aquifer		Wenonah-Mount Laurel aquifer (A6)	
		Marshalltown Formation	Marshalltown-Wenonah confining unit		Marshalltown-Wenonah confining unit (C6)	
		Englishtown Formation	Englishtown aquifer system		Englishtown aquifer (A7)	Marshalltown-Wenonah confining unit (C6)
		Woodbury Clay	Merchantville-Woodbury confining unit		Merchantville-Woodbury confining unit (C7)	
		Merchantville Formation	Merchantville-Woodbury confining unit		Merchantville-Woodbury confining unit (C7)	
		Magothy Formation	Potomac-Raritan-Magothy aquifer system	Upper aquifer	Upper Potomac-Raritan-Magothy aquifer (A8)	
		Raritan Formation	Potomac-Raritan-Magothy aquifer system	Confining unit	Confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers (C8)	
		Raritan Formation	Potomac-Raritan-Magothy aquifer system	Middle aquifer	Middle Potomac-Raritan-Magothy aquifer (A9)	
		Potomac Group	Potomac-Raritan-Magothy aquifer system	Confining unit	Confining unit between the Middle and Lower Potomac-Raritan-Magothy aquifers (C9)	
	Lower Cretaceous	Potomac Group	Potomac-Raritan-Magothy aquifer system	Lower aquifer	Lower Potomac-Raritan-Magothy aquifer (A10)	
Pre-Cretaceous		Bedrock	Bedrock confining unit			

[1] 'A' refers to modeled aquifer. 'C' refers to modeled confining unit. Number refers to model unit (Voronin, 2004).

[2] Olsson and others, 1980

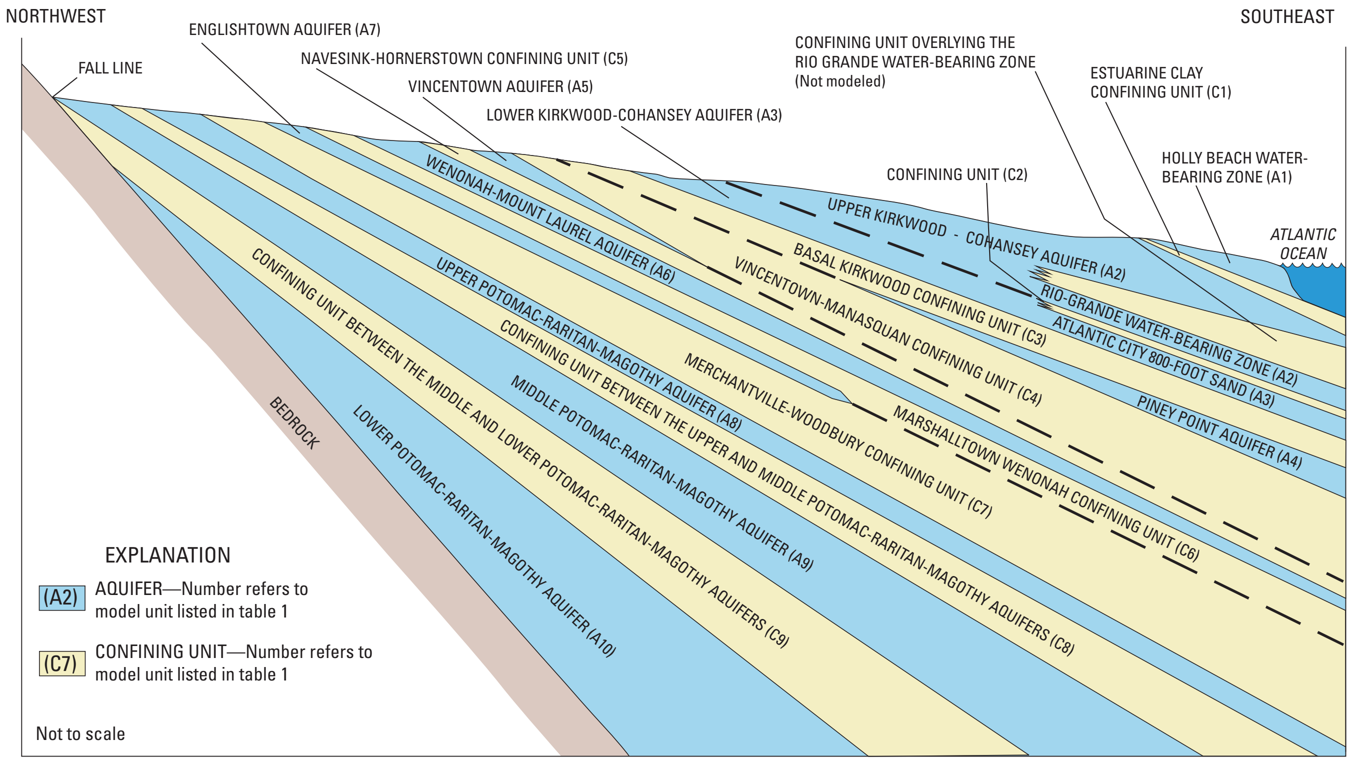


Figure 2. Generalized hydrogeologic section through the onshore part of the New Jersey Coastal Plain. (Modified from Martin, 1998)

boundaries. In offshore areas, the upper boundary is a constant freshwater equivalent water level. In onshore areas, the upper boundary is a variable recharge boundary. In cells that represent stream reaches, the upper boundary of the model is a head-dependent-flux boundary. The southeastern downdip boundaries in the Potomac-Raritan-Magothy aquifer system (model layers 8-10) are stationary no-flow boundaries and are located at the downdip extent of freshwater in the aquifer system as determined by Meisler (1980). The Piney Point, Vincentown, and Wenonah-Mount Laurel aquifers and the Englishtown aquifer system (model layers 4-7) are not continuous throughout the New Jersey Coastal Plain, and in the southeast are modeled as no-flow boundaries. The southeastern boundaries in the upper Kirkwood-Cohansey aquifer system, the Rio Grande water-bearing zone, and the Atlantic City 800-foot sand (model layers 2 and 3) are specified-flux boundaries.

The model design and input data are described in detail in the RASA model documentation (Martin, 1998). The RASA model was updated to 1998 conditions and rediscretized to a finer grid spacing by Voronin (2004). Typically, transmissivity values used for the confined aquifers in the model range from 500 ft^2/d or less in the Wenonah-Mount Laurel aquifer and Englishtown aquifer system to greater than 10,000 ft^2/d in the Potomac-Raritan-Magothy aquifer system and the Atlantic City 800-foot sand. The highest transmissivities— those equal to or greater than 10,000 ft^2/d— are in Camden and Gloucester Counties in the Potomac-Raritan-Magothy aquifer system, in Monmouth and Ocean Counties in the Middle Potomac-Raritan-Magothy aquifer, and in Atlantic County in the Atlantic City 800-foot sand. Typically, vertical leakance values (vertical hydraulic conductivity divided by thickness) range from about $5x10^{-9}$ to greater than $5x10^{-3}$ (ft/d)/ft. Values of vertical leakance typically are greater in updip areas near aquifer outcrop areas than in downdip areas. In this study, minor changes were made to the rediscretized RASA model. The vertical leakance of the confining unit between model layers 3 and 4 (model unit C3, table 1) and the confining unit between layers 5 and 6 (model unit C5, table 1) was modified to improve the representation of the hydrogeologic framework in small updip areas of these confining units.

Ground-Water-Withdrawal Data

Ground-water-withdrawal data for 1998 from more than 2,050 wells were obtained from the site-specific water-use database (SWUDS) of the USGS New Jersey Water Science Center in West Trenton, N.J., and were included in the model input. The database includes all public-supply wells, but also irrigation, commercial, industrial, mining, and power-generation wells. Most domestic wells were not included in the simulations because they are typically screened in surficial (unconfined) aquifers and are small-capacity wells. The withdrawal data in SWUDS were collected from the NJDEP Bureau of Water Allocation.

In 1998, withdrawals from the aquifers of the New Jersey Coastal Plain totaled about 340.3 Mgal/d. More than 70 percent of these withdrawals were from the confined aquifers.

Total 1998 ground-water withdrawals, by well, were used as the baseline pumpage from which withdrawals were increased or decreased to determine projected 2010 demand. Projected changes in withdrawals were input at existing wells and simulated simultaneously in all aquifers. A graph of total withdrawals for the baseline (1998) simulation and each scenario for each confined aquifer is shown in figure 3. Withdrawals for 1988 are shown for comparison.

Some withdrawals are from wells screened in the outcrop (unconfined) areas of the Vincentown and Upper and Middle Potomac-Raritan-Magothy aquifers and the Englishtown aquifer system. These withdrawals are not considered to be from the confined part of the aquifer and are not shown in figure 3. Pumpage from the unconfined Vincentown aquifer was 0.05 Mgal/d in 1998 and in scenarios 2 and 3, and 0.06 Mgal/d in scenario 1. Pumpage from the unconfined Englishtown aquifer system was less than 0.01 Mgal/d in 1998 and in all three scenarios. Pumpage from the unconfined Upper Potomac-Raritan-Magothy aquifer was 20.6 Mgal/d in 1998, 22.0 Mgal/d in scenario 1, 21.3 Mgal/d in scenario 2, and 20.7 Mgal/d in scenario 3. Pumpage from the unconfined Middle Potomac-Raritan-Magothy aquifer was 19.0 Mgal/d in 1998, 20.5 Mgal/d in scenario 1, 20.0 Mgal/d in scenario 2, and 19.9 Mgal/d in scenario 3.

Description of the Hydrologic Budget Areas

To analyze the flow budget for each of the confined aquifers in the New Jersey Coastal Plain, each confined aquifer and its outcrop was divided into Hydrologic Budget Areas (HBAs). The HBAs vary in areal extent and boundaries depending on the hydrologic conditions of the aquifer in which they are located. Almost all non-domestic ground-water withdrawals from the New Jersey Coastal Plain confined aquifers are located within these areas. Only the onshore,

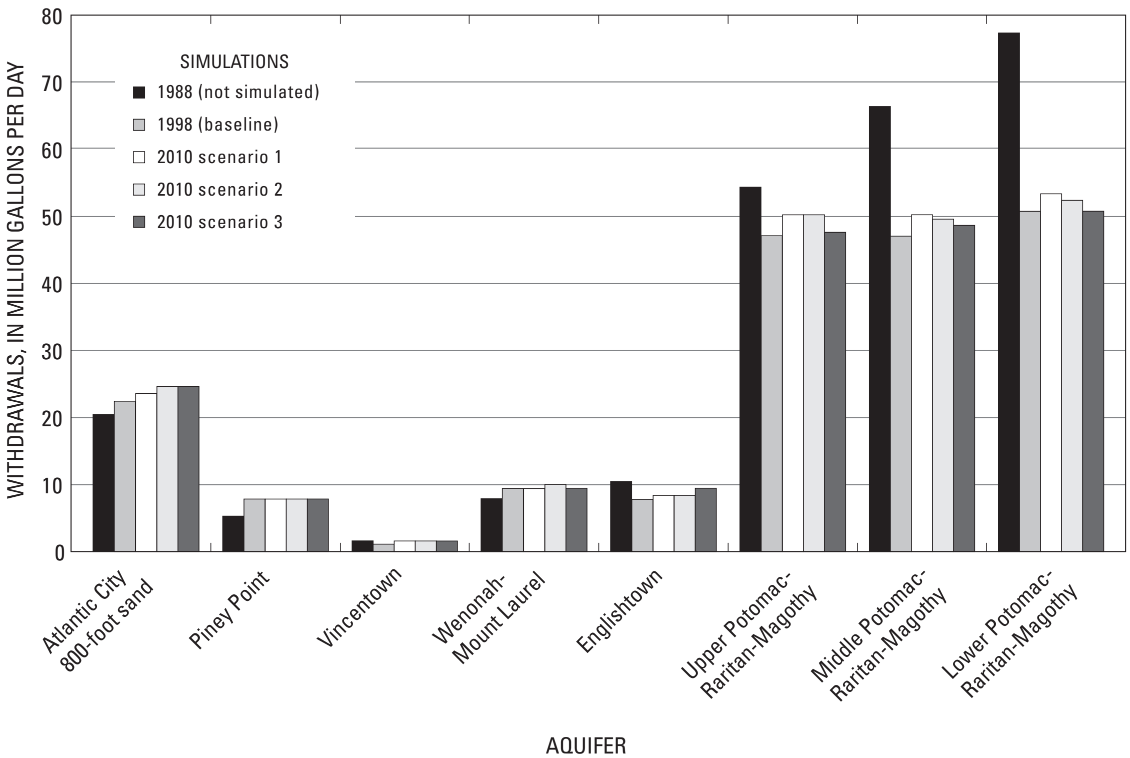


Figure 3. Average annual ground-water withdrawals from confined aquifers in the New Jersey Coastal Plain for 1988 and 1998, and withdrawals input for model scenarios.

freshwater portions of the confined aquifers (areas with chloride concentrations below 250 mg/L as shown in Lacombe and Rosman (2001)) are included in the HBAs, except HBA 3 in the Atlantic City 800-foot sand, HBA 21 in the Middle Potomac-Raritan-Magothy aquifer, and HBA 23 in the Lower Potomac-Raritan-Magothy aquifer; HBAs 3 and 21 have withdrawals in areas where chloride concentrations exceed 250 mg/L. The New Jersey Secondary Drinking Water Standard Recommended Upper Limit (RUL) of 250 mg/L for chloride is the level above which the taste of water may become objectionable to the consumer and may also be associated with the presence of sodium in drinking water (Shelton, 2005). Elevated concentrations of sodium may have an adverse health effect on normal, healthy persons (Shelton, 2005).

Forty-one HBAs have been designated—24 in the confined part of the aquifers (HBAs 1-24) and 17 in the outcrop areas (HBAs 30-46). HBA designations 25 through 29 are not assigned to any area; these numbers are available for any budget areas that may be designated in the future. Each HBA was delineated by various hydrologic boundaries, including aquifer extents, outcrop areas, the 250-mg/L isochlor, Water-Supply Critical Areas, and ground-water divides. The HBAs and their locations are summarized in table 2.

Flow-Budget Terms

A schematic representation of an HBA within an aquifer, illustrating the flow-budget terms, is shown in figure 4. Inflow to a particular HBA can be from (1) overlying aquifers, (2) underlying aquifers, (3) adjacent HBAs, (4) the unconfined part (outcrop) of the aquifer (where present), (5) the offshore area of the aquifer, (6) downdip aquifer areas not associated with an HBA, (7) storage, (8) induced leakage from streams to aquifers in the outcrop areas, and (9) recharge in outcrop areas. (Leakage and recharge are not shown in figure 4.) Inflow to an HBA is designated as a positive value in the flow budgets. Negative values indicate that the flow direction is out of the HBA. Outflow from a particular HBA can be to (1) overlying aquifers, (2) underlying aquifers, (3) adjacent HBAs, (4) the unconfined part (outcrop) of the aquifer (where present), (5) the offshore area of the aquifer, (6) downdip areas of the aquifer not included in any HBA, (7) storage, (8) streams (not shown in figure 4), and (9) withdrawals. Some portions of the confined aquifer are not included in an HBA because withdrawals in these areas are either very small, zero, or downdip from the 250-mg/L isochors and therefore contain nonpotable water; however, these areas are accounted for by flow into or out of the adjacent or updip HBA.

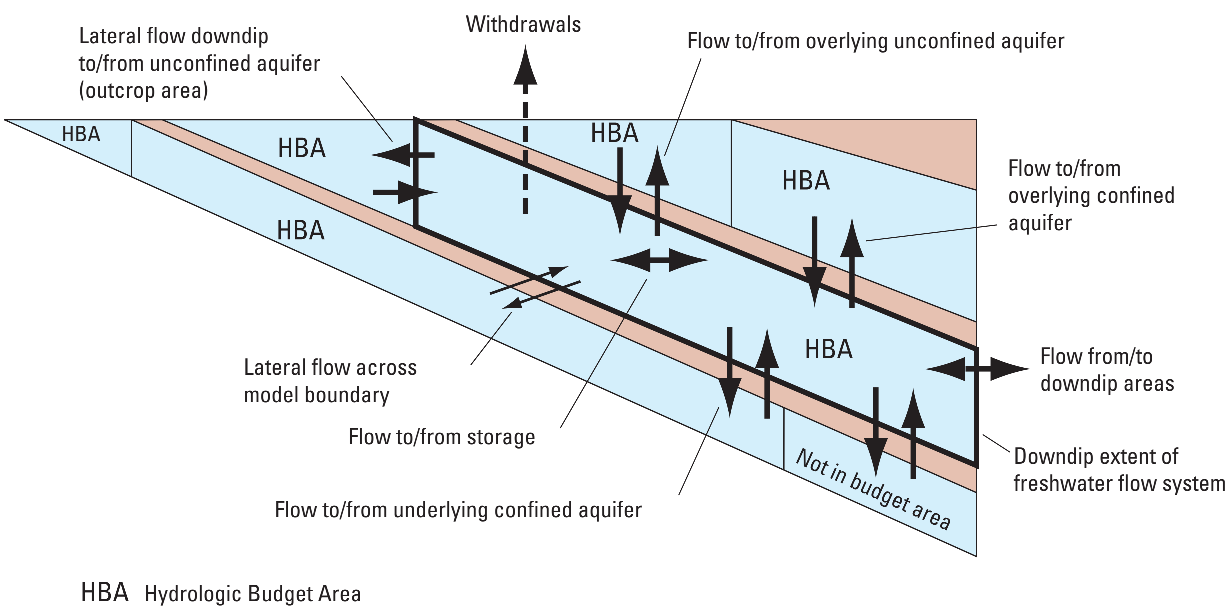


Figure 4. Generalized schematic representation of budget terms used to describe flow in the hydrologic budget areas in the New Jersey Coastal Plain ground-water flow model. Leakage and recharge in unconfined outcrop areas are not shown. (Modified from Pope and Gordon, 1999, p. 40)

Table 2. Hydrologic budget areas in the confined aquifers of the New Jersey Coastal Plain.

[mg/L, milligrams per liter; Y, yes; n/a; not applicable]

Hydrologic budget area number for confined aquifer[1]	Aquifer	County or part of county included in the hydrologic budget area	Hydrologic budget area number for adjacent outcrop area of aquifer	Hydrologic budget area bounded by a 250-mg/L isochlor[2]	Confined aquifer in a Critical Area
1	Atlantic City 800-foot sand	Ocean and Burlington	n/a		
2	Atlantic City 800-foot sand	Atlantic and Cape May	n/a	Y	
3	Atlantic City 800-foot sand	Cape May	n/a	Y	
4	Piney Point	Ocean and Burlington	n/a		
5	Piney Point	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, and Salem	n/a	Y	
6	Vincentown	Monmouth and Ocean	30, 31		
7	Vincentown	Burlington, Camden, Gloucester, and Salem	32		
8	Wenonah-Mount Laurel	Monmouth and Ocean	33		Y
9	Wenonah-Mount Laurel	Burlington, Monmouth, and Ocean	34		
10	Wenonah-Mount Laurel	Burlington	35		
11	Wenonah-Mount Laurel	Camden and Gloucester	36		
12	Wenonah-Mount Laurel	Gloucester and Salem	37		
13	Englishtown aquifer system	Monmouth and Ocean	38		Y
14	Englishtown aquifer system	Atlantic, Burlington, Camden, Cumberland, Gloucester, Monmouth, Ocean, and Salem	39		
15	Upper Potomac-Raritan-Magothy	Mercer, Middlesex, Monmouth, and Ocean	40		Y
16	Upper Potomac-Raritan-Magothy	Atlantic, Burlington, Camden, Gloucester, Mercer, Monmouth, and Salem	41, 42		Y
17	Upper Potomac-Raritan-Magothy	Gloucester and Salem	43	Y	
18	Middle Potomac-Raritan-Magothy	Mercer, Middlesex, Monmouth, and Ocean	44	Y	Y
19	Middle Potomac-Raritan-Magothy	Burlington, Camden, Gloucester, Mercer, Monmouth, and Ocean	45	Y	Y
20	Middle Potomac-Raritan-Magothy	Gloucester and Salem	46	Y	
21	Middle Potomac-Raritan-Magothy	Cumberland and Salem	n/a	Y	
22	Lower Potomac-Raritan-Magothy	Burlington, Camden, and Gloucester	n/a	Y	Y
23	Lower Potomac-Raritan-Magothy	Gloucester	n/a	Y	Y
24	Lower Potomac-Raritan-Magothy	Gloucester and Salem	n/a	Y	

[1] Numbers 25-29 have not been assigned to allow for redefinition or addition of hydrologic budget areas at a later date.

[2] Isochlors from Lacombe and Rosman (2001, figs. 3-3, 4-3, 6-3, 8-3, 9-3, and 10-3).

Simulated Effects Of Projected 2010 Withdrawals

Three scenarios were simulated under transient conditions to evaluate the hydrologic effects of projected 2010 withdrawals. A 1998 model simulation was used as a baseline for comparison to the 2010 simulated water levels and flow budgets. Ground-water-flow conditions during 1998 were simulated by incorporating average 1998 withdrawal stresses. Flow budgets are presented for each scenario for the 41 HBAs. The extent and boundaries of the HBAs in each aquifer are described in the section on scenario 1. The simulations from 1999 through 2010 incorporated three pumping periods of 2, 5, and 5 years in length.

Description of Scenarios and Projected Withdrawals in 2010

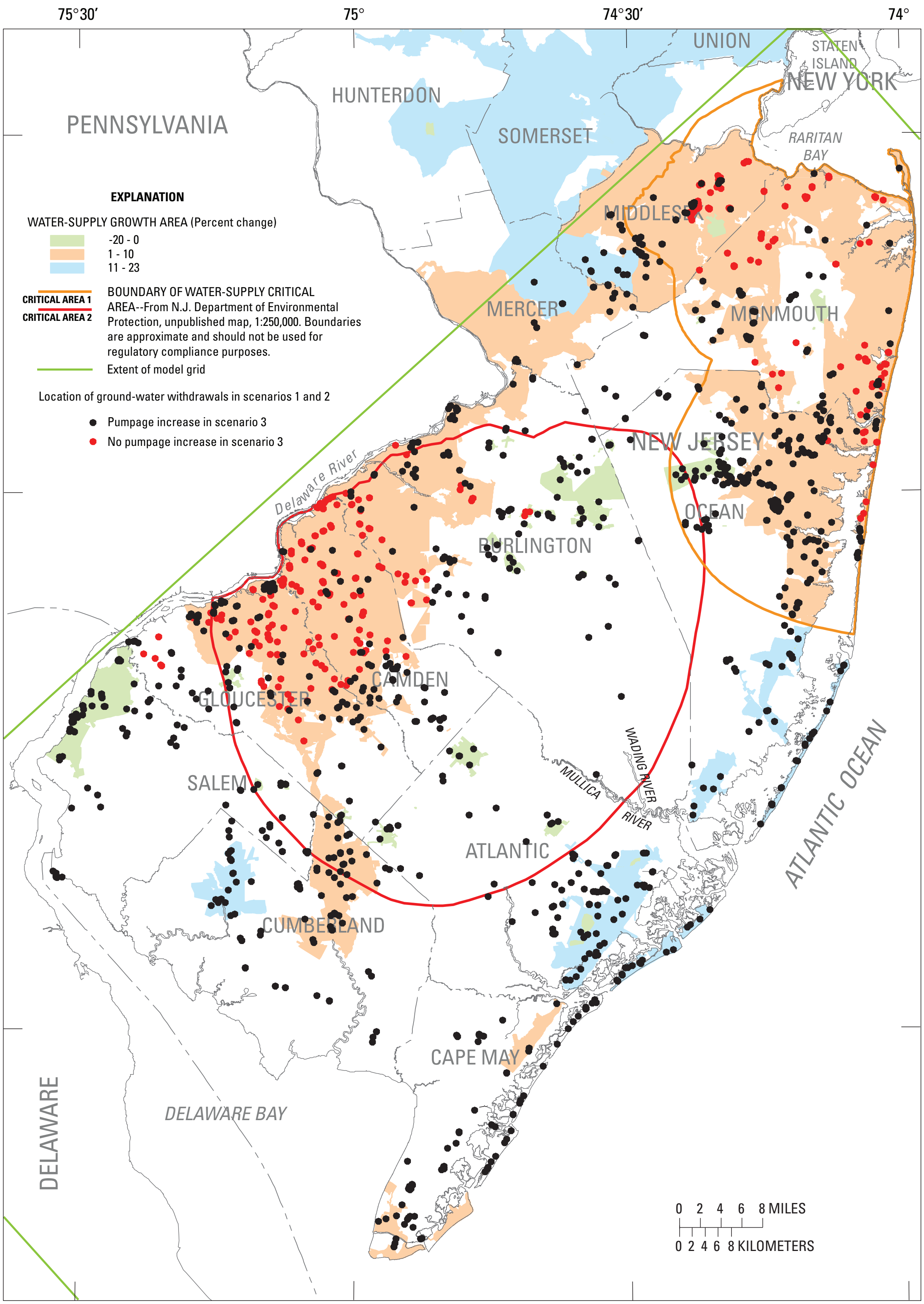
The NJDEP developed three scenarios to represent a range of potential water withdrawals in 2010. The scenarios were based on (1) a continuation of 1990-99 withdrawal trends, (2) county population projections, and (3) pumpage restrictions in Critical Areas 1 and 2 (fig. 1). Scenarios 1 and 2 involved increasing or decreasing ground-water withdrawals at wells in the New Jersey Coastal Plain by water-use category, whereas scenario 3 incorporated restrictions on pumpage at selected public-supply wells in or adjacent to Critical Areas 1 and 2. Public-supply and agricultural water use makes up about 90 percent of the total 1998 withdrawals from the confined aquifers of the New Jersey Coastal Plain.

For the first scenario, it was assumed that 1990-99 annual withdrawal trends would continue to 2010. A straight-line least-squares linear regression equation was calculated by the NJDEP for each county for each water-use category except public supply. The regression equations were used to predict withdrawals in 2010. The 2010 withdrawal was converted into a percentage increase or decrease from the 1999 reported withdrawal for each county. For agricultural and nonagricultural irrigation wells, 1998 withdrawals were decreased or increased by the percentage calculated for the county in which the well is located. Self-supplied industrial withdrawals were not changed, except in Monmouth County where they were increased 44 percent. No change was predicted for mining, power-generation, or self-supplied commercial withdrawals. Public-supply withdrawals can be used for residential, industrial, and commercial purposes. Because these withdrawals can serve multiple counties, water purveyors were divided into 18 similar interconnected groups, referred to as water-supply growth areas, which are located within the State’s previously delineated water-supply regions (N.J. Department of Environmental Protection, 2005b). Trend equations were then developed for each of the water-supply growth areas. The 2010 withdrawal was converted into a percentage increase or decrease from the 1999 reported withdrawal for each water-supply growth area. If the total withdrawal was minimal or if the total number of withdrawal sources was small, no change was assumed. For public-supply wells, 1998 withdrawals were increased or decreased by the percentage calculated for the water-supply growth area in which the well is located (fig. 5). The percentage change ranged from -20 to 23. A generalized summary of changes in withdrawals in scenarios 1 and 2 by water-use category is shown below.

Water-use category	Scenario 1: Percentage increase/decrease by—	Scenario 2: Percentage increase/decrease by—
Public supply	Water-supply growth area	County
Agricultural irrigation	County	County
Non-agricultural irrigation	County	No change
Industrial	Only Monmouth County increased	No change
Commercial, mining, power generation	No change	No change

In scenario 2, a population-based approach was used to predict public-supply withdrawals in 2010. Census data for 2000 and population estimates for 2010 were used to calculate the percentage change in county population (Wu, 2004). Per capita water-use rates were assumed to remain constant and the percentage change in population was assumed to represent the percentage change in water withdrawals. To obtain the 2010 withdrawal rate, the annual rate in 1998, by well, was increased or decreased by the percentage specified for the county in which the well is located. The predicted increase for public-water supply in the New Jersey Coastal Plain ranged from 1 percent (Camden and Salem Counties) to 13 percent (Ocean County). Agricultural withdrawals were assumed to change based on projections provided by the NJDEP (Steven Domber, N.J. Geological Survey, written commun., 2005). Ground-water withdrawals for agricultural irrigation were decreased in all counties except Cumberland, Monmouth, and Salem, for which withdrawals were increased 1, 8, and 4 percent, respectively. For this scenario, the NJDEP assumed no change in withdrawals for non-agricultural irrigation— for example, golf course— or for self-supplied industrial and commercial, mining, and power-generation withdrawals.

Scenario 3 incorporated the withdrawals used in scenario 2, except for selected wells within Critical Areas 1 and 2. For scenario 3, it was assumed that ground-water withdrawals would be supplemented by surface water for purveyors within the Critical Areas that have surface-water alternatives. For these purveyors, the 1998 pumping rate was maintained at their wells. The 1998 pumping rate also was maintained for some wells outside the Critical Areas because a purveyor had a surface-water alternative— for example, a reservoir or the Delaware River. If a purveyor did not have a surface-water alternative, the pumping rate from scenario 2 was used.



Base from U.S. Geological Survey
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Figure 5. Percent of projected change in ground-water withdrawals in water-supply growth areas in the New Jersey Coastal Plain for scenario 1. (Public-supply wells not located within a shaded area were assigned the percentage for the closest shaded area.)

The aquifers for which pumping rates were changed in this scenario include the Wenonah-Mount Laurel and the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers and the Englishtown aquifer system. Wells for which pumping rates in scenario 3 were not changed from 1998 rates are shown in figure 5.

Scenario 1—Continuation of 1990-99 Withdrawal Trends

The 41 HBAs are presented and the extent and boundaries of the HBAs in each aquifer are described. Simulated 2010 water levels and changes in simulated water levels from 1998 to 2010 for scenario 1 are shown by aquifer. Maximum increases and (or) declines in simulated water levels in this scenario and the baseline (1998) simulation are discussed. The flow budget for each HBA also is shown. Budget components that differ (typically more than 0.1 Mgal/d in an HBA) between this scenario and the baseline (1998) simulation are discussed.

Atlantic City 800-Foot Sand

The HBAs in the Atlantic City 800-foot sand (HBAs 1-3; fig. 6) extend to the updip extent of the confining unit overlying the Atlantic City 800-foot sand to the north and northwest. The southeastern boundary is the Atlantic Ocean and the southwesternmost boundary is the Delaware Bay. The boundary between HBAs 1 and 2 is the Mullica River (fig. 5), and the boundary between HBAs 2 and 3 is the location of the 250-mg/L isochlor from Lacombe and Rosman (2001).

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Atlantic City 800-foot sand are shown in figure 6. Ground water is withdrawn from this aquifer predominantly in coastal Ocean, Atlantic, and Cape May Counties. Simulated water levels in HBAs 1 to 3 range from 80 ft below NGVD of 1929 along the coast of Atlantic County to 60 ft above NGVD of 1929 in western Atlantic County. The 250-mg/L isochlor (Lacombe and Rosman, 2001) traverses the tip of Cape May County about 4 to 6 mi inland from its southernmost point, then extends north offshore. Salty water has moved inland in Cape May County because of withdrawals in Atlantic County (McAuley and others, 2001). The change in simulated water levels from 1998 to 2010 is shown in figure 7. The projected increase in withdrawals resulted in a maximum simulated water-level decline of 14 ft in coastal Atlantic County.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 is shown in figure 8. Values of flow-budget components for this scenario are compared with those for the baseline simulation. The flow budgets indicate that in HBAs 1 and 2, recharge to the aquifer is mostly from lateral inflow from the Kirkwood-Cohansey aquifer system updip from the Atlantic City 800-foot sand (fig. 2), and inflow from the overlying aquifer. Changes in the simulated budget indicate that pumpage was increased 0.73 Mgal/d (14 percent) in HBA 1 and 2.2 Mgal (14 percent) in HBA 2. When pumpage was increased, lateral inflow from the updip area increased 0.32 Mgal/d (6 percent) in HBA 1 and 0.6 Mgal/d (4 percent) in HBA 2. Inflow from the overlying aquifer increased 0.31 Mgal/d (6 percent) in HBA 1 and 0.66 Mgal/d (4 percent) in HBA 2. Lateral inflow from the aquifer offshore increased 0.14 Mgal/d (3 percent) in HBA 1 and 0.77 Mgal/d (5 percent) in HBA 2. The 250-mg/L isochlor (Lacombe and Rosman, 2001) is approximately 10 mi offshore from HBA 1 and the eastern part of HBA 2, and is the southern boundary of HBA 2 (locations of water-level and chloride-monitoring wells in this aquifer are shown in appendix 1 (fig. 1-1)). In HBA 2, lateral inflow at the 250-mg/L isochlor was small (0.03 Mgal/d, less than 1 percent). Pumpage in HBA 3, which is south of the 250-mg/L isochlor, was not changed and the changes in the flow-budget components were small (0.04 Mgal/d or less). Water withdrawn from the well in HBA 3 is treated at a nearby desalination plant in Cape May County.

Piney Point Aquifer

The HBAs in the Piney Point aquifer (HBAs 4 and 5; fig. 9) extend to the updip limit of the aquifer to the north. The easternmost boundary is the Atlantic Ocean and the westernmost boundary is the Delaware Bay. The southernmost boundary is the approximate location of the 250-mg/L isochlor (Lacombe and Rosman, 2001). The Mullica and Wading Rivers (fig. 5) separate HBA 4 from HBA 5 to the south, and other smaller surface-water basin boundaries separate them to the west.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Piney Point aquifer are shown in figure 9. Ground water is withdrawn mostly in coastal Ocean and northern Atlantic Counties, with additional withdrawals in southern Camden and western Burlington Counties. Simulated water levels range from 60 ft below NGVD of 1929 at a cone of depression in coastal Ocean County to 120 ft above NGVD of 1929 in western Ocean and eastern Burlington Counties. Water levels are also 60 ft below NGVD of 1929 in the Delaware Bay because of pumping in Delaware. Changes in simulated water levels from 1998 to 2010 are shown in figure 10. The projected increase in withdrawals resulted in a maximum simulated water-level decline of 7 ft in coastal Ocean County near the updip extent of the aquifer.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figure 11. Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. Because the aquifer does not crop out, recharge is from vertical leakage from the overlying aquifer. The simulated budgets indicate that in HBA 4, pumpage was increased 0.36 Mgal/d (8 percent); inflow from the overlying aquifer increased 0.3 Mgal/d (7 percent), and lateral outflow to the aquifer offshore decreased 0.04 Mgal/d (1 percent). In

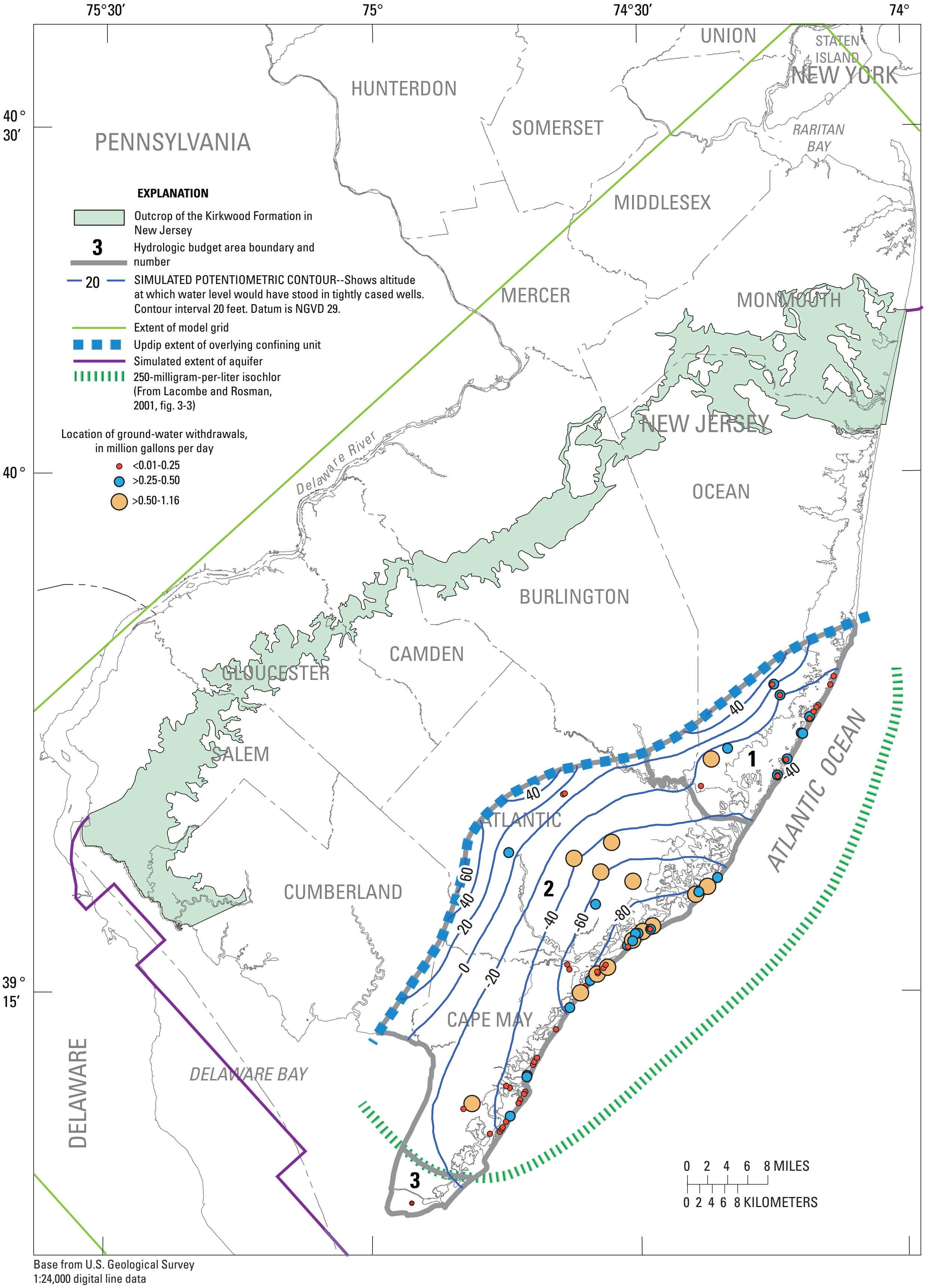


Figure 6. Hydrologic budget areas in the Atlantic City 800-foot sand and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

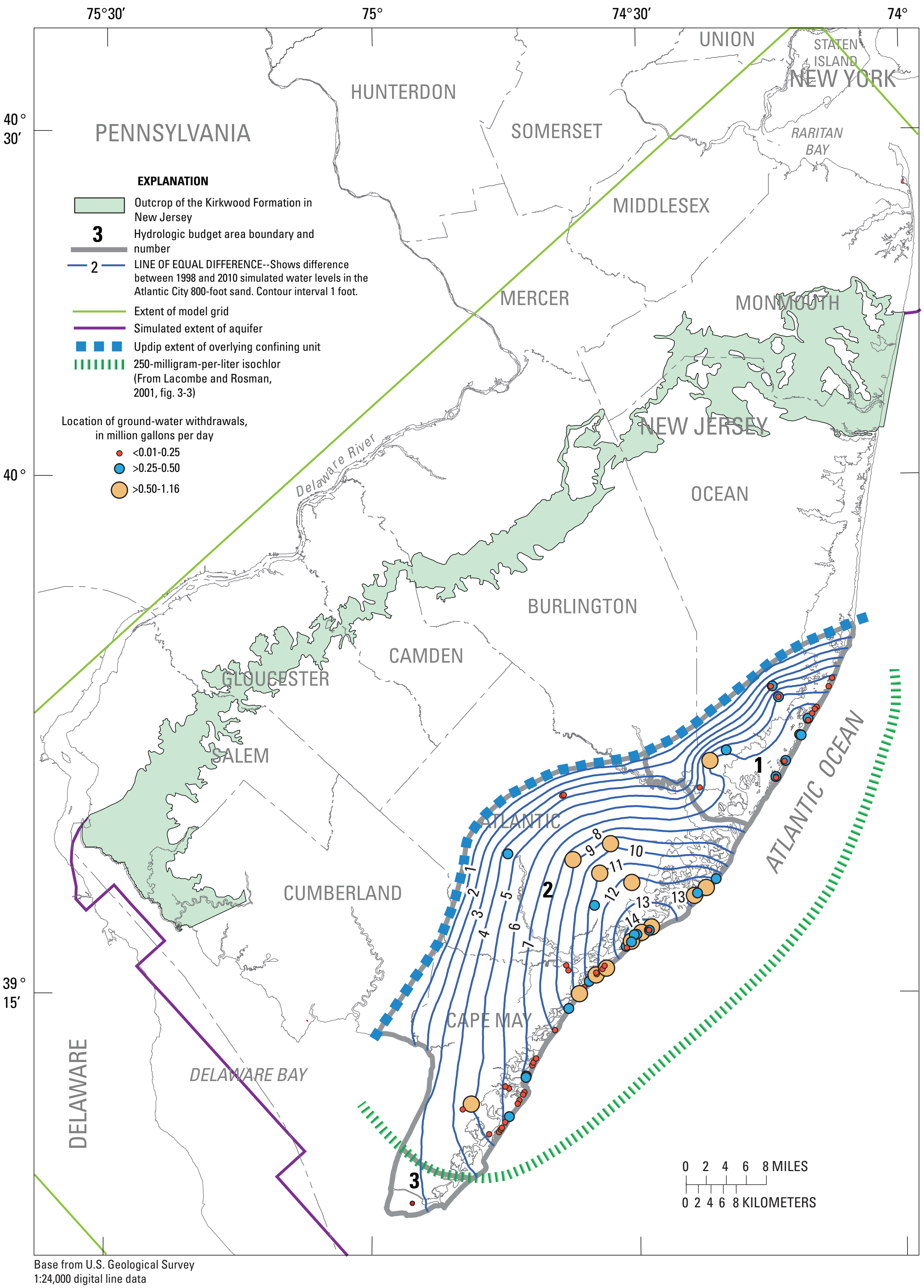
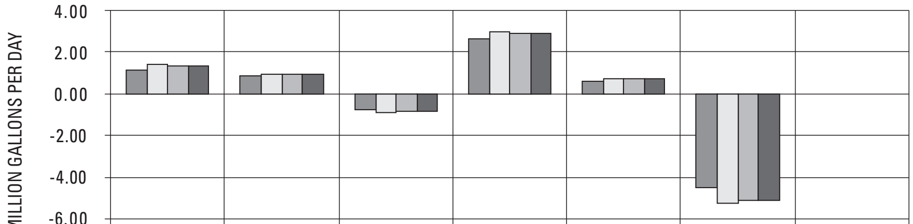


Figure 7. Change in simulated water levels (1998 to 2010) in the Atlantic City 800-foot sand, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a.

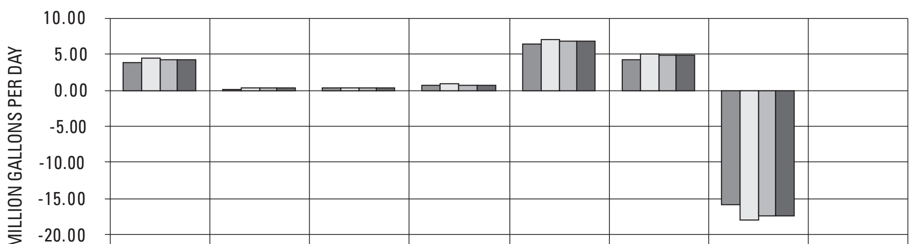
Hydrologic Budget Area 1



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 2	Lateral flow from updip	Lateral flow from offshore	Pumpage	Storage
1998	1.13	0.89	-0.75	2.63	0.62	-4.52	0.00
Scenario 1	1.44	0.95	-0.86	2.95	0.76	-5.25	0.00
Scenario 2	1.36	0.93	-0.80	2.88	0.74	-5.12	0.00
Scenario 3	1.36	0.93	-0.80	2.88	0.74	-5.12	0.00

b.

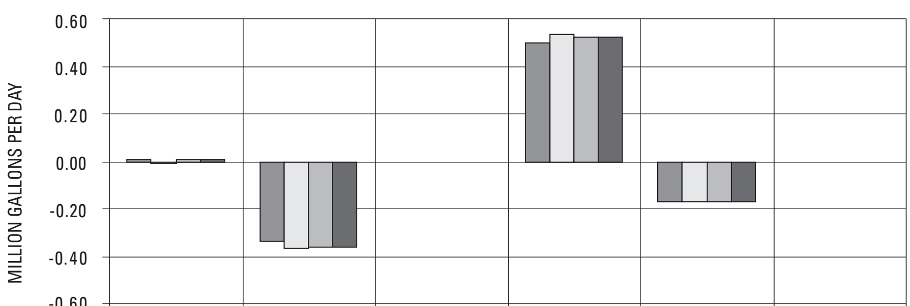
Hydrologic Budget Area 2



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 3	Lateral flow from HBA 1	Lateral flow from updip	Lateral flow from offshore	Pumpage	Storage
1998	3.87	0.21	0.34	0.75	6.39	4.33	-15.90	0.01
Scenario 1	4.53	0.25	0.37	0.86	6.99	5.10	-18.10	0.00
Scenario 2	4.33	0.24	0.36	0.80	6.80	4.83	-17.34	0.00
Scenario 3	4.33	0.24	0.36	0.80	6.80	4.83	-17.34	0.00

c.

Hydrologic Budget Area 3



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 2	Lateral flow from offshore	Pumpage	Storage
1998	0.01	0.00	-0.34	0.50	-0.17	0.00
Scenario 1	-0.01	0.00	-0.37	0.54	-0.17	0.00
Scenario 2	0.01	0.00	-0.36	0.52	-0.17	0.00
Scenario 3	0.01	0.00	-0.36	0.52	-0.17	0.00

Figure 8. Simulated flow budget for hydrologic budget areas (a) 1, (b) 2, and (c) 3 in the Atlantic City 800-foot sand, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

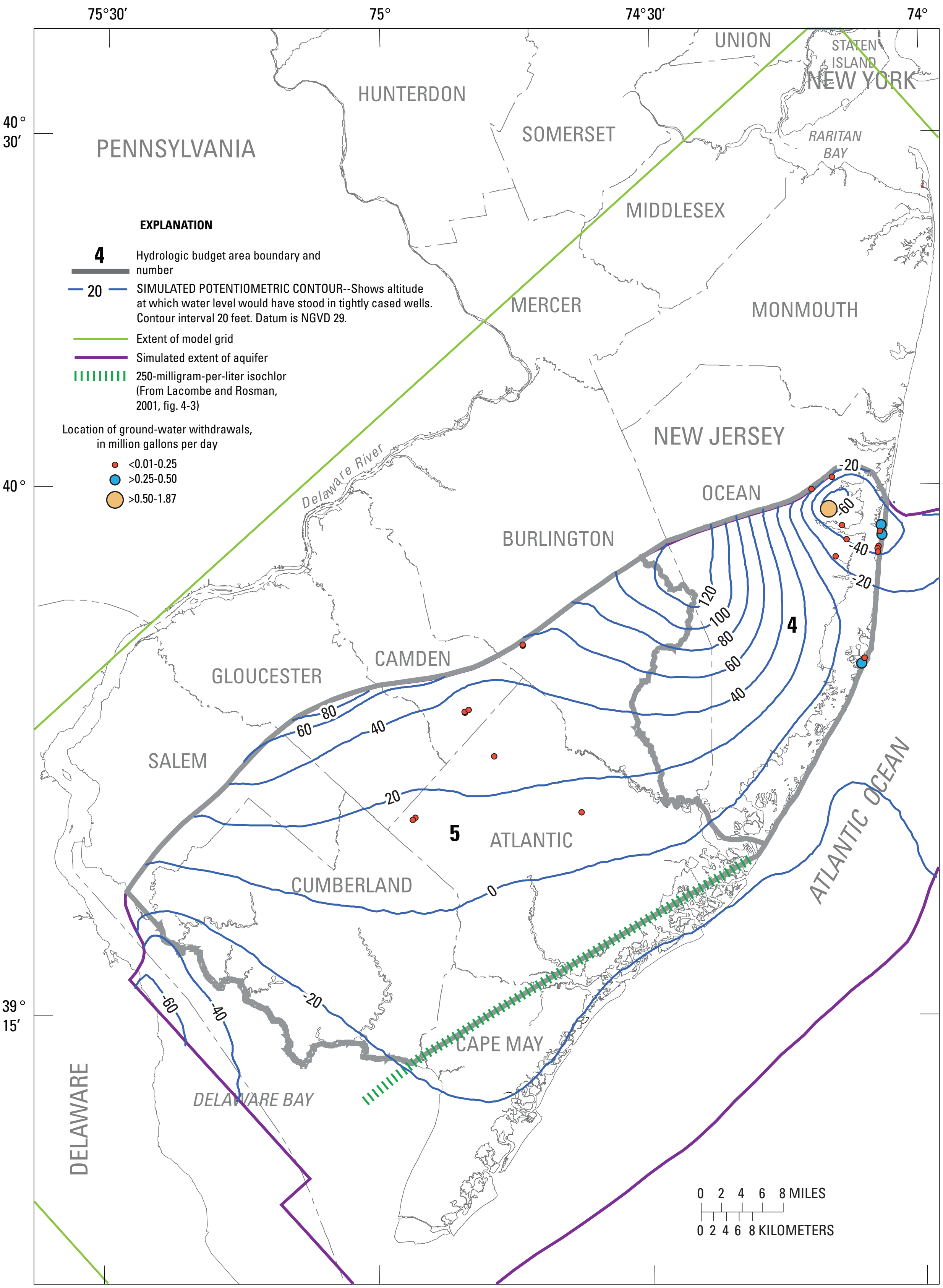


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Figure 9. Hydrologic budget areas in the Piney Point aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

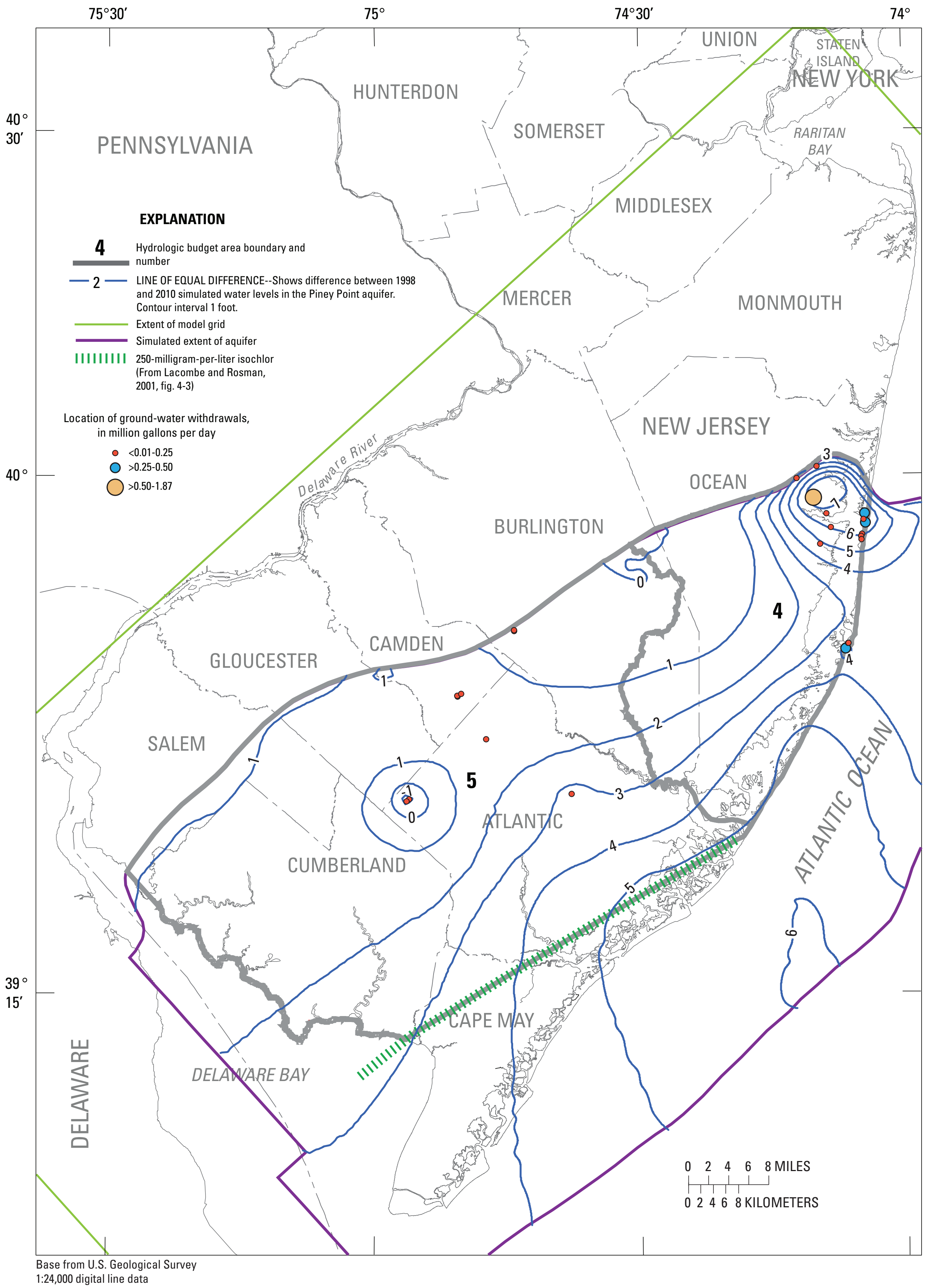


Figure 10. Change in simulated water levels (1998 to 2010) in the Piney Point aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

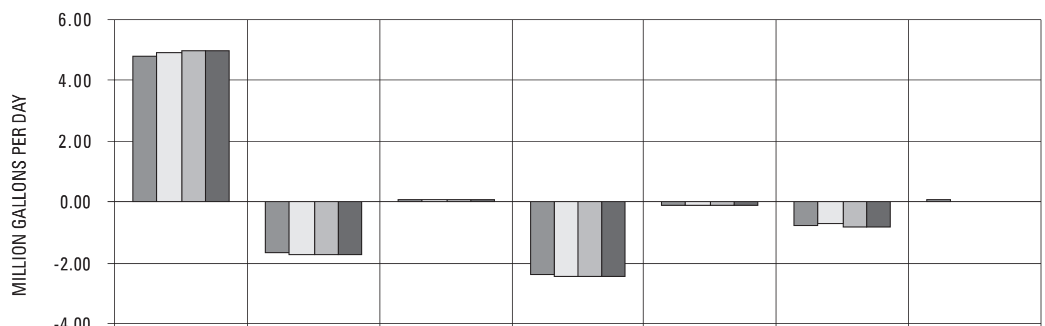
a.

Hydrologic Budget Area 4

	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 5	Lateral flow from offshore	Pumpage	Storage
1998	4.28	-0.19	-0.09	-0.28	-3.74	0.01
Scenario 1	4.58	-0.16	-0.07	-0.24	-4.10	0.00
Scenario 2	4.65	-0.17	-0.08	-0.21	-4.20	0.00
Scenario 3	4.65	-0.17	-0.08	-0.21	-4.20	0.00

b.

Hydrologic Budget Area 5



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 4	Lateral flow from 250-mg/L isochlor	Lateral flow from offshore	Pumpage	Storage
1998	4.78	-1.66	0.09	-2.39	-0.12	-0.75	0.05
Scenario 1	4.92	-1.72	0.07	-2.45	-0.12	-0.70	0.00
Scenario 2	4.96	-1.70	0.08	-2.43	-0.12	-0.81	0.01
Scenario 3	4.96	-1.70	0.08	-2.43	-0.12	-0.81	0.01

Figure 11. Simulated flow budget for hydrologic budget areas (a) 4 and (b) 5 in the Piney Point aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding; mg/L, milligrams per liter.)

HBA 5, pumpage was decreased 0.05 Mgal/d (1 percent), but inflow from the overlying aquifer increased 0.14 Mgal/d (3 percent), and outflow to the underlying aquifer also increased 0.06 Mgal/d (1 percent). The flow direction at the 250-mg/L isochlor is from HBA 5 to the downdip, saltier part of the aquifer not included in any HBA.

Vincentown Aquifer

The HBAs in the confined Vincentown aquifer (HBAs 6 and 7; fig. 12) extend to the outcrop of the aquifer (HBAs 30-32) and to the updip extent of the aquifer to the north. The easternmost boundary is the Atlantic Ocean and the westernmost boundary is a line drawn from the updip extent of the aquifer past the area of pumping in the aquifer. The southern boundary is the downdip extent of the aquifer. A ground-water divide inferred from observed water levels in Lacombe and Rosman (2001) separates HBA 6 from HBA 7.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Vincentown aquifer are shown in figure 12. Ground water is withdrawn mainly in southern Monmouth and northern Ocean Counties, with some additional withdrawals in Gloucester County. Simulated water levels range from 0 to 140 ft above NGVD of 1929. The change in simulated water levels from 1998 to 2010 is shown in figure 13. The simulated water levels are similar to the 1998 baseline simulated water levels; the largest difference is the 2-ft decline in central Camden County as a result of increased withdrawals from the underlying Wenonah-Mount Laurel aquifer.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figures 14 (for the confined part of the aquifer) and 15 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. Pumpage was increased 0.11 Mgal/d (1 percent) in HBA 6; inflow from the overlying aquifer decreased 0.12 Mgal/d (1 percent), but outflow to the underlying Wenonah-Mount Laurel aquifer also decreased 0.22 Mgal/d (2 percent). In HBA 7, pumpage was not changed, but inflow from the overlying aquifer increased 0.32 Mgal/d (1 percent), and outflow to the underlying aquifer also increased 0.33 Mgal/d (1 percent).

Pumpage was increased 0.01 Mgal/d (less than 1 percent) in HBA 30 in the outcrop of the Vincentown aquifer, but there is no pumpage in HBAs 31 and 32, also in the outcrop. The changes between the values of the 1998 and 2010 flow-budget components were small in this aquifer (0.09 Mgal/d or less, less than 1 percent); however, in HBA 32, leakage to streams decreased 0.11 Mgal/d (1 percent), and water from storage decreased 0.18 Mgal/d (1 percent).

Wenonah-Mount Laurel Aquifer

The HBAs in the confined Wenonah-Mount Laurel aquifer (HBAs 8-12; fig. 16) extend to the outcrop of the aquifer (HBAs 33-37) to the north and northwest. The easternmost boundary is the Atlantic Ocean and the westernmost is the Delaware River. The southwestern boundary is at the northernmost location of the 250-mg/L isochlor (Lacombe and Rosman, 2001). The southeastern boundary of HBA 8 coincides with the boundary of HBA 13 in the underlying Englishtown aquifer system. Surface-water basin boundaries separate HBAs 33 to 37 from each other.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Wenonah-Mount Laurel aquifer are shown in figure 16. Ground water is withdrawn in central Salem, Gloucester, Camden, and Burlington Counties, and also in northern Ocean and southern Monmouth Counties. Simulated water levels range from 60 ft below NGVD of 1929 in coastal Monmouth and Ocean Counties to 120 ft above NGVD of 1929 in western Monmouth and northwestern Ocean Counties. The change in simulated water levels from 1998 to 2010 is shown in figure 17. Because the Wenonah-Mount Laurel aquifer has a good hydraulic connection to the underlying Englishtown aquifer system, the effect of withdrawals in one aquifer is similarly observed in the adjacent aquifer. Simulated water levels recovered more than 24 ft in coastal Ocean County within Critical Area 1 and declined 6 ft in central Gloucester County in both aquifers. In Critical Area 1, mandated reductions in withdrawals went into effect in the 1990s (N.J. Department of Environmental, 2005a). Since then, water levels in these two aquifers have recovered more than 120 ft (Lacombe and Rosman, 2001).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figures 18 (for the confined part of the aquifer) and 19 (for the outcrop). Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 8, pumpage was increased 0.07 Mgal/d (1 percent); inflow from the overlying aquifer decreased 0.3 Mgal/d (3 percent), and outflow to storage decreased 0.38 Mgal/d (4 percent). Water levels in HBA 8 are recovering as a result of reductions in withdrawals within Critical Area 1, allowing water to go to storage (outflow); however, when pumpage was increased, less water was available for aquifer storage. In HBA 9, pumpage was decreased 0.2 Mgal/d (4 percent) and inflow from the overlying aquifer decreased 0.25 Mgal/d (5 percent). Pumpage in HBA 10 was not increased and the changes in the flow-budget components were small (0.04 Mgal/d (1 percent) or less). In HBA 11, pumpage was increased 0.29 Mgal/d (3 percent) and inflow from the overlying aquifer increased 0.38 Mgal/d (4 percent), but outflow to the underlying aquifer also increased 0.13 Mgal/d (1 percent). In HBA 12, pumpage was decreased 0.06 Mgal/d (1 percent) and changes between the values of the 1998 and 2010 flow-budget components were small (0.09 Mgal/d (1 percent) or less). There are no withdrawals in the

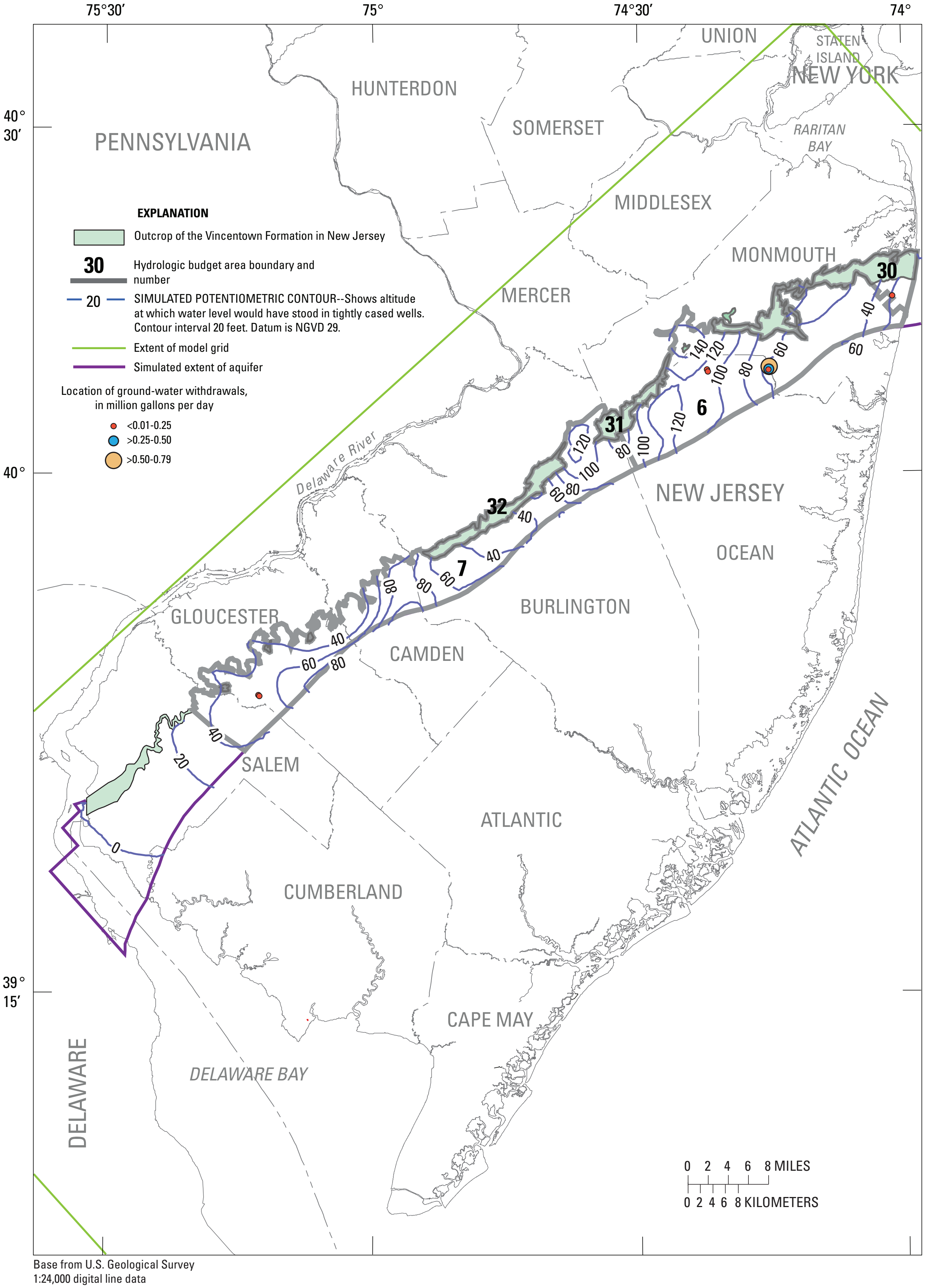


Figure 12. Hydrologic budget areas in the Vincentown aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

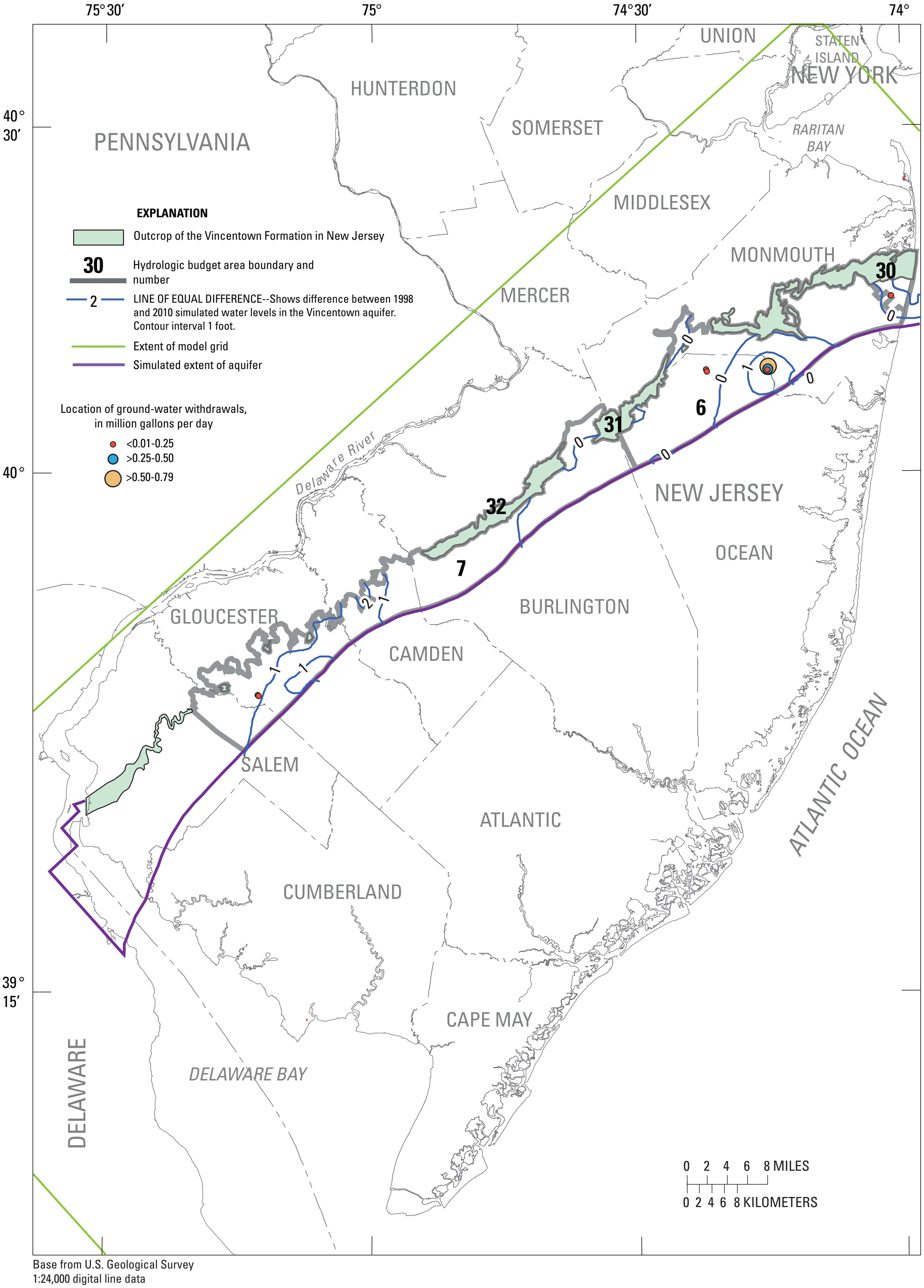
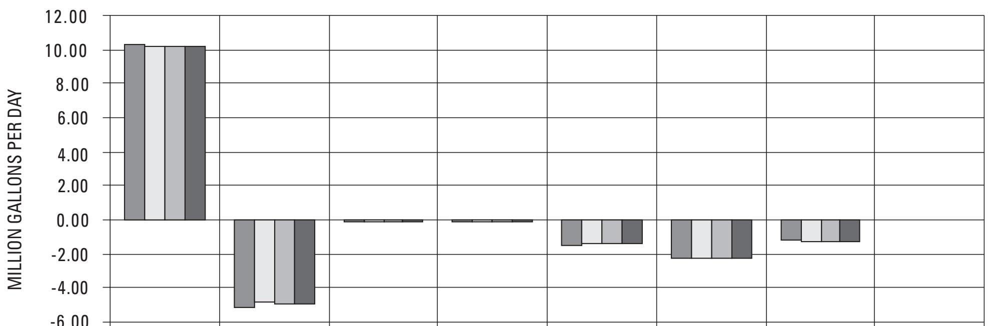


Figure 13. Change in simulated water levels (1998 to 2010) in the Vincentown aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a.

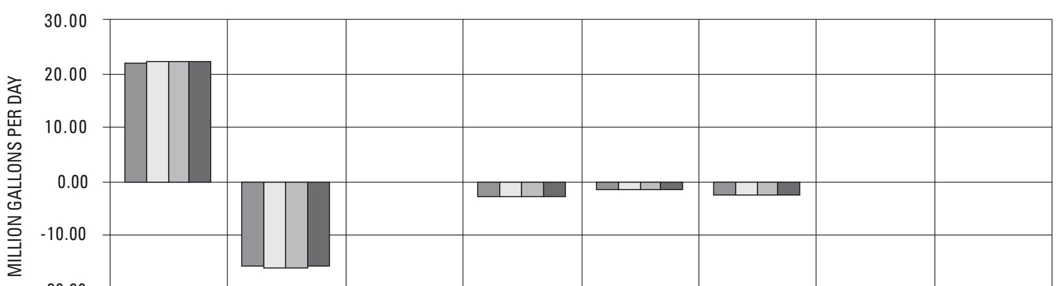
Hydrologic Budget Area 6



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 7	Lateral flow from offshore	Lateral flow from HBA 30	Lateral flow from HBA 31	Pumpage	Storage
1998	10.25	-5.09	-0.08	-0.15	-1.48	-2.25	-1.21	0.00
Scenario 1	10.13	-4.87	-0.08	-0.15	-1.44	-2.26	-1.32	0.00
Scenario 2	10.16	-4.91	-0.08	-0.15	-1.43	-2.26	-1.32	0.00
Scenario 3	10.15	-4.88	-0.08	-0.15	-1.45	-2.26	-1.32	0.00

b.

Hydrologic Budget Area 7

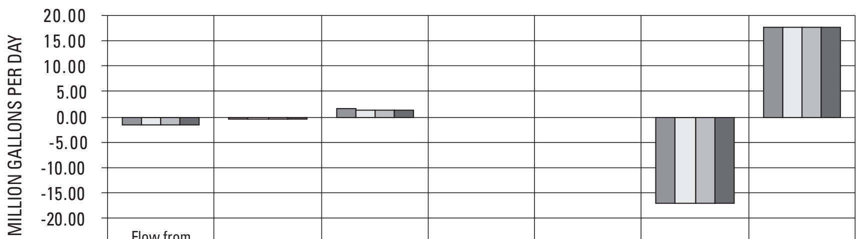


	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 6	Lateral flow from portion of aquifer not in an HBA	Lateral flow from HBA 31	Lateral flow from HBA 32	Pumpage	Storage
1998	21.94	-15.55	0.08	-2.79	-1.30	-2.33	-0.03	0.00
Scenario 1	22.26	-15.88	0.08	-2.74	-1.30	-2.37	-0.03	0.00
Scenario 2	22.26	-15.91	0.08	-2.74	-1.30	-2.35	-0.03	0.00
Scenario 3	22.06	-15.68	0.08	-2.77	-1.30	-2.35	-0.03	0.00

Figure 14. Simulated flow budget for hydrologic budget areas (a) 6 and (b) 7 in the Vincentown aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

a.

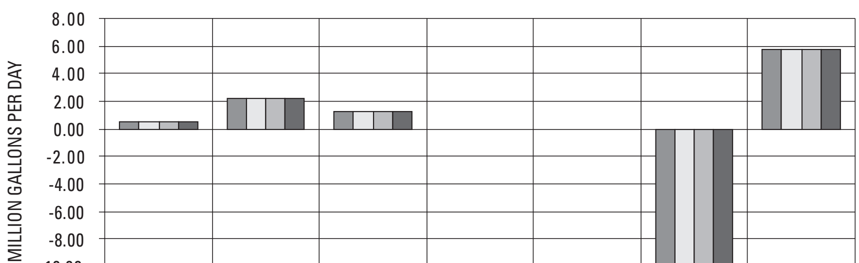
Hydrologic Budget Area 30



	Flow from underlying aquifer	Lateral flow from offshore	Lateral flow from HBA 6	Pumpage	Storage	Stream leakage	Recharge
1998	-1.53	-0.39	1.48	-0.05	-0.10	-17.06	17.65
Scenario 1	-1.47	-0.39	1.44	-0.06	-0.02	-17.15	17.65
Scenario 2	-1.47	-0.39	1.43	-0.05	-0.02	-17.16	17.65
Scenario 3	-1.48	-0.39	1.45	-0.05	-0.03	-17.18	17.65

b.

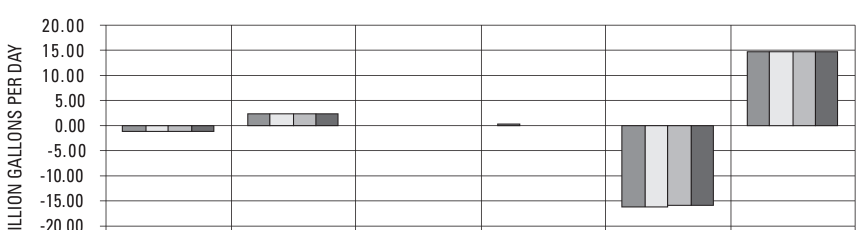
Hydrologic Budget Area 31



	Flow from underlying aquifer	Lateral flow from HBA 6	Lateral flow from HBA 7	Pumpage	Storage	Stream leakage	Recharge
1998	0.54	2.25	1.30	0.00	0.00	-9.79	5.70
Scenario 1	0.55	2.26	1.30	0.00	0.00	-9.81	5.70
Scenario 2	0.54	2.26	1.30	0.00	0.00	-9.79	5.70
Scenario 3	0.54	2.26	1.30	0.00	0.00	-9.79	5.70

c.

Hydrologic Budget Area 32



	Flow from underlying aquifer	Lateral flow from HBA 7	Pumpage	Storage	Stream leakage	Recharge
1998	-1.20	2.33	0.00	0.17	-16.14	14.83
Scenario 1	-1.16	2.37	0.00	-0.01	-16.03	14.83
Scenario 2	-1.28	2.35	0.00	0.03	-15.93	14.83
Scenario 3	-1.26	2.35	0.00	0.02	-15.95	14.83

Figure 15. Simulated flow budget for hydrologic budget areas (a) 30, (b) 31, and (c) 32 in the outcrop of the Vincentown aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

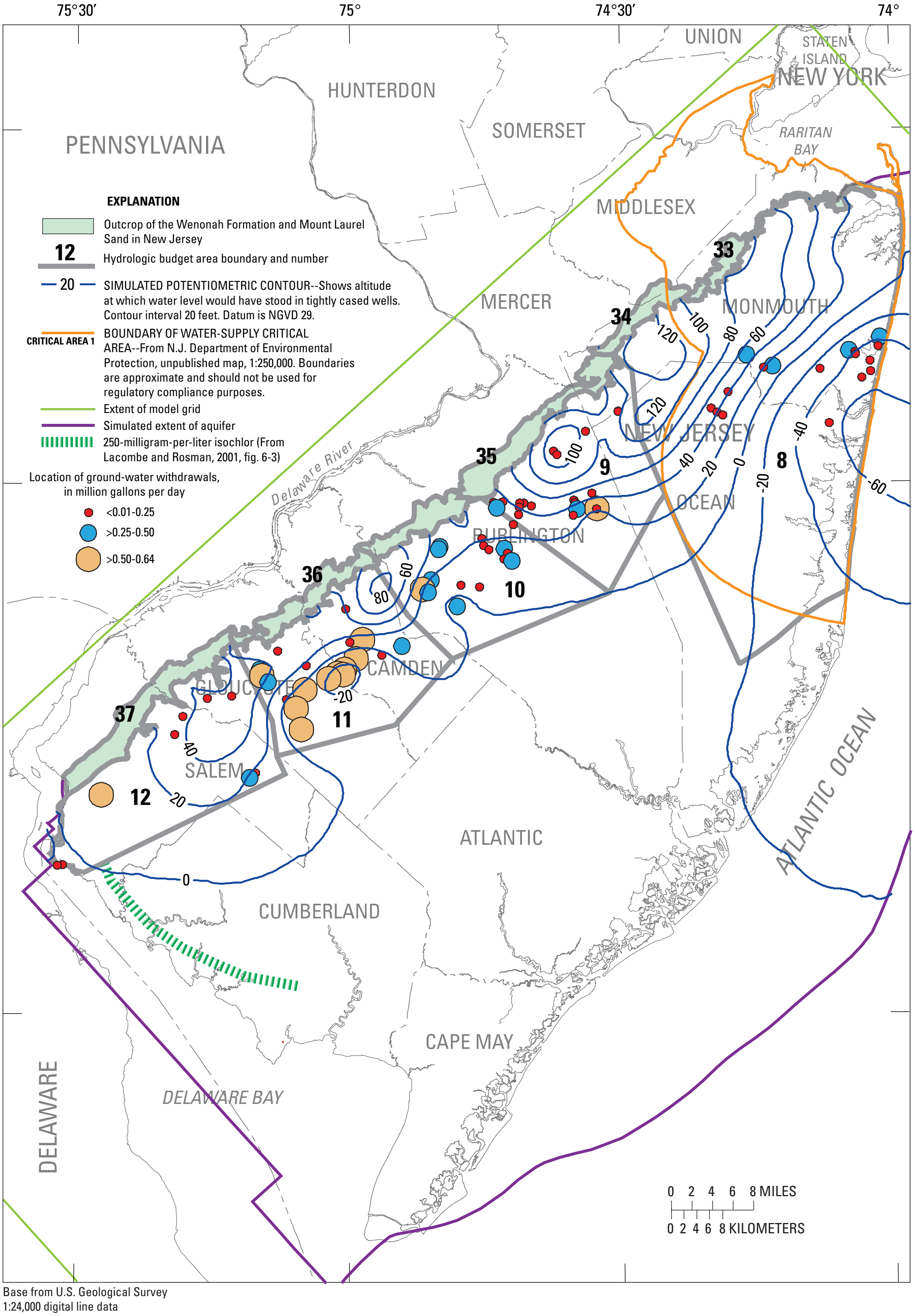


Figure 16. Hydrologic budget areas in the Wenonah-Mount Laurel aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

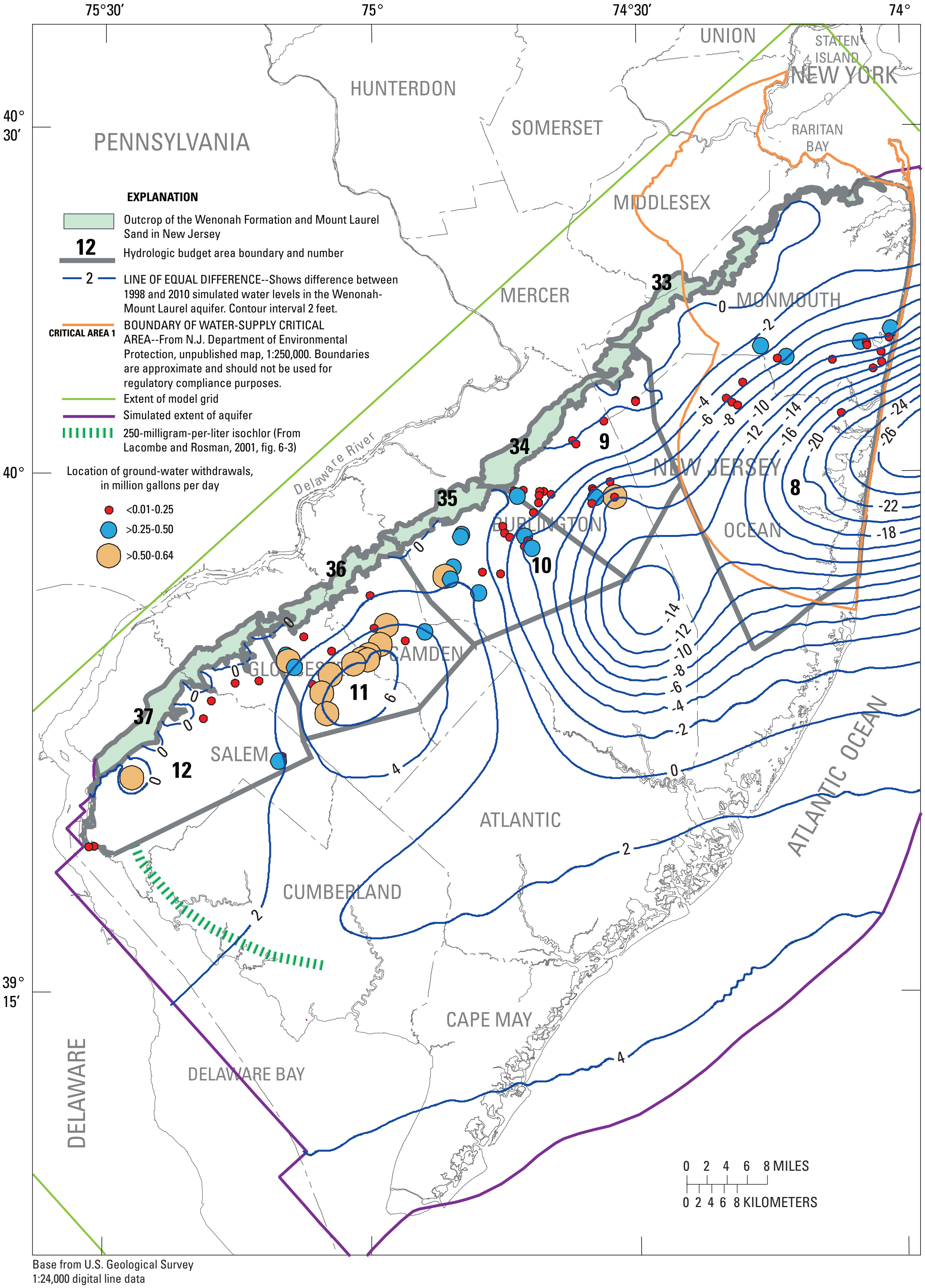
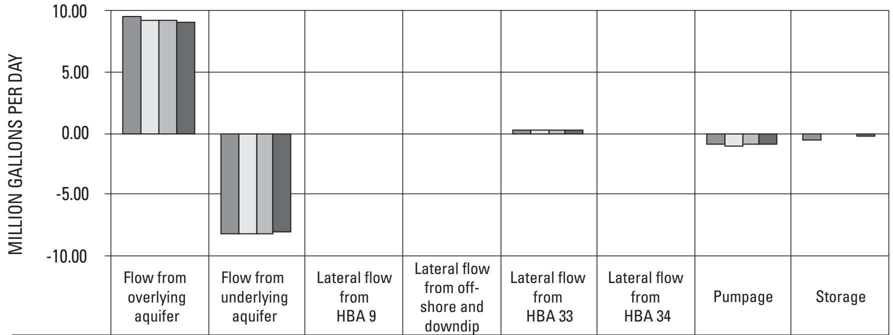


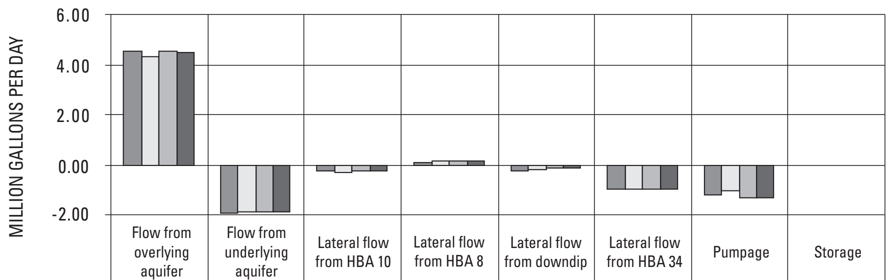
Figure 17. Change in simulated water levels (1998 to 2010) in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a. Hydrologic Budget Area 8



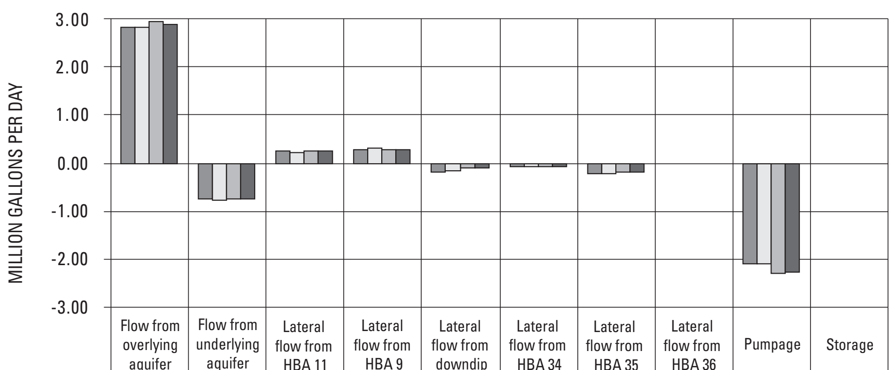
	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 9	Lateral flow from off-shore and downdip	Lateral flow from HBA 33	Lateral flow from HBA 34	Pumpage	Storage
1998	9.52	-8.14	-0.10	-0.11	0.28	-0.01	-0.92	-0.53
Scenario 1	9.22	-8.17	-0.12	-0.06	0.30	-0.01	-0.99	-0.15
Scenario 2	9.22	-8.18	-0.13	-0.08	0.30	-0.01	-0.97	-0.15
Scenario 3	9.08	-8.04	-0.13	-0.09	0.30	-0.01	-0.93	-0.19

b. Hydrologic Budget Area 9



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 10	Lateral flow from HBA 8	Lateral flow from downdip	Lateral flow from HBA 34	Pumpage	Storage
1998	4.55	-1.93	-0.28	0.10	-0.23	-0.98	-1.22	-0.02
Scenario 1	4.30	-1.90	-0.30	0.12	-0.19	-0.98	-1.02	-0.02
Scenario 2	4.53	-1.90	-0.27	0.13	-0.16	-0.98	-1.33	-0.01
Scenario 3	4.48	-1.88	-0.27	0.13	-0.16	-0.97	-1.32	-0.01

c. Hydrologic Budget Area 10

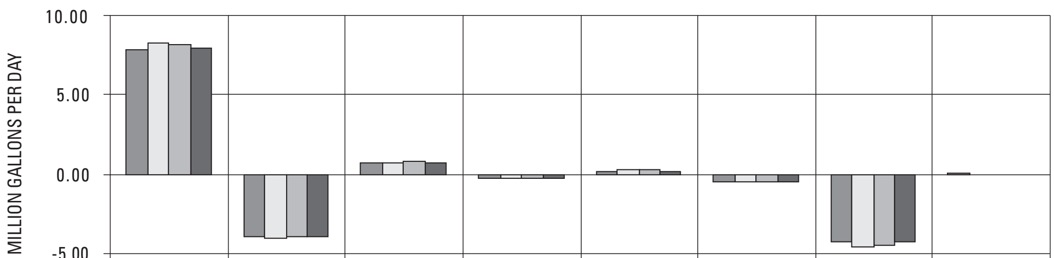


	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 11	Lateral flow from HBA 9	Lateral flow from downdip	Lateral flow from HBA 34	Lateral flow from HBA 35	Lateral flow from HBA 36	Pumpage	Storage
1998	2.83	-0.75	0.25	0.28	-0.19	-0.07	-0.22	-0.01	-2.10	-0.01
Scenario 1	2.81	-0.79	0.23	0.30	-0.15	-0.08	-0.21	-0.01	-2.10	0.00
Scenario 2	2.93	-0.75	0.25	0.27	-0.12	-0.07	-0.20	-0.01	-2.30	0.00
Scenario 3	2.88	-0.74	0.25	0.27	-0.12	-0.07	-0.20	-0.01	-2.26	0.00

Figure 18. Simulated flow budget for hydrologic budget areas (a) 8, (b) 9, (c) 10, (d) 11, and (e) 12 in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

d.

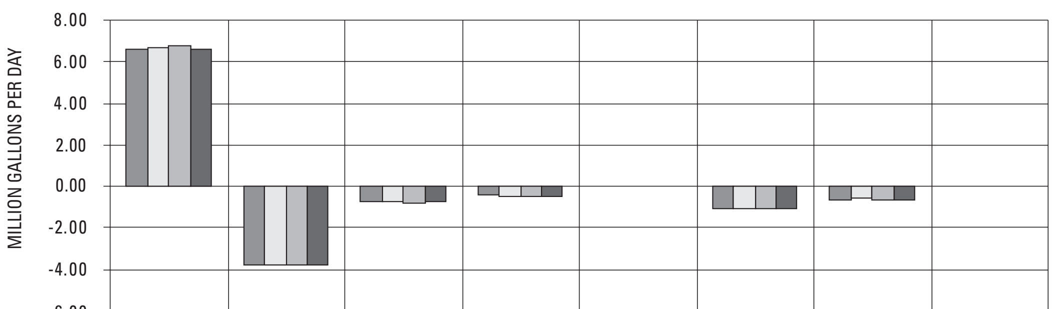
Hydrologic Budget Area 11



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 12	Lateral flow from HBA 10	Lateral flow from downdip	Lateral flow from HBA 36	Pumpage	Storage
1998	7.88	-3.93	0.71	-0.25	0.19	-0.50	-4.24	0.12
Scenario 1	8.26	-4.06	0.76	-0.23	0.25	-0.48	-4.53	0.01
Scenario 2	8.12	-3.95	0.77	-0.25	0.24	-0.48	-4.48	0.01
Scenario 3	7.93	-3.90	0.74	-0.25	0.20	-0.48	-4.25	0.00

e.

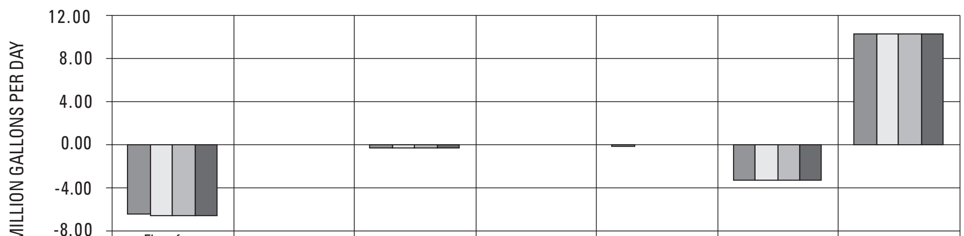
Hydrologic Budget Area 12



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 11	Lateral flow from downdip	Lateral flow from offshore	Lateral flow from HBA 37	Pumpage	Storage
1998	6.59	-3.78	-0.71	-0.43	-0.02	-1.04	-0.63	0.03
Scenario 1	6.68	-3.81	-0.76	-0.47	-0.03	-1.03	-0.57	0.00
Scenario 2	6.74	-3.81	-0.77	-0.46	-0.03	-1.03	-0.63	0.00
Scenario 3	6.64	-3.74	-0.74	-0.46	-0.03	-1.03	-0.63	0.00

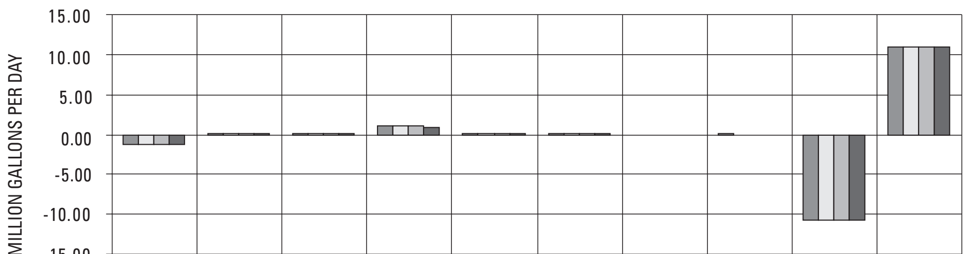
Figure 18. Simulated flow budget for hydrologic budget areas (a) 8, (b) 9, (c) 10, (d) 11, and (e) 12 in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)—Continued

a. Hydrologic Budget Area 33



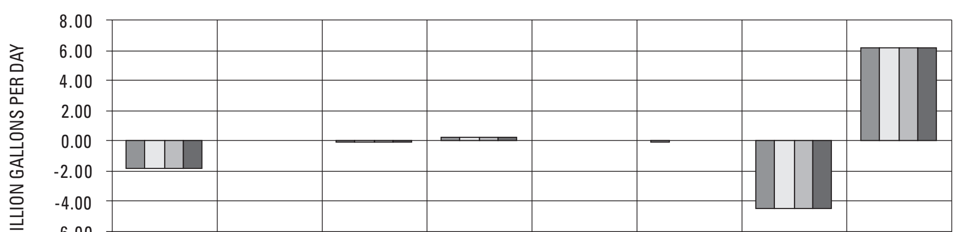
	Flow from underlying aquifer	Lateral flow from HBA 34	Lateral flow from HBA 8	Pumpage	Storage	Stream leakage	Recharge
1998	-6.48	-0.05	-0.28	0.00	-0.13	-3.32	10.26
Scenario 1	-6.61	-0.05	-0.30	0.00	0.01	-3.30	10.26
Scenario 2	-6.60	-0.05	-0.30	0.00	0.00	-3.30	10.26
Scenario 3	-6.56	-0.05	-0.30	0.00	-0.02	-3.33	10.26

b. Hydrologic Budget Area 34



	Flow from underlying aquifer	Lateral flow from HBA 35	Lateral flow from HBA 33	Lateral flow from HBA 9	Lateral flow from HBA 8	Lateral flow from HBA 10	Pumpage	Storage	Stream leakage	Recharge
1998	-1.34	0.11	0.05	0.98	0.01	0.07	0.00	0.01	-10.79	10.90
Scenario 1	-1.31	0.11	0.05	0.98	0.01	0.08	0.00	0.00	-10.81	10.90
Scenario 2	-1.32	0.11	0.05	0.98	0.01	0.07	0.00	0.00	-10.77	10.90
Scenario 3	-1.31	0.11	0.05	0.97	0.01	0.07	0.00	0.00	-10.79	10.90

c. Hydrologic Budget Area 35

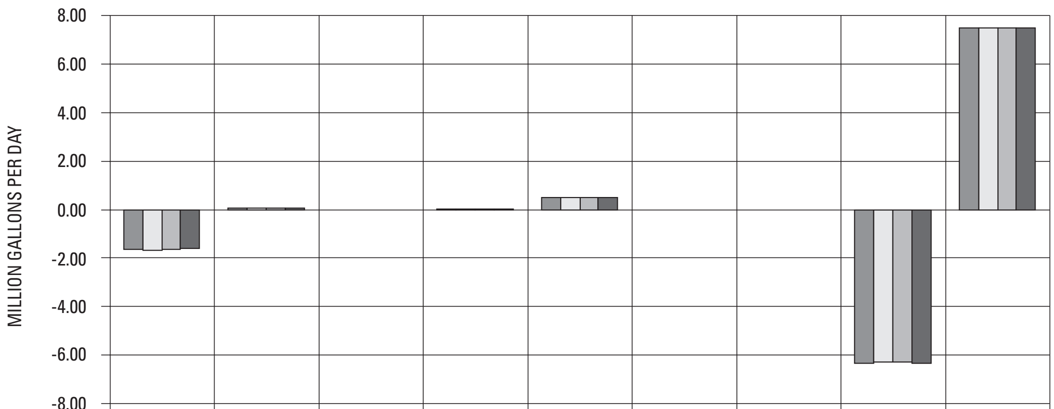


	Flow from underlying aquifer	Lateral flow from HBA 36	Lateral flow from HBA 34	Lateral flow from HBA 10	Pumpage	Storage	Stream leakage	Recharge
1998	-1.81	0.04	-0.11	0.22	0.00	-0.05	-4.42	6.12
Scenario 1	-1.82	0.04	-0.11	0.21	0.00	-0.01	-4.43	6.12
Scenario 2	-1.83	0.04	-0.11	0.20	0.00	-0.01	-4.43	6.12
Scenario 3	-1.79	0.04	-0.11	0.20	0.00	-0.02	-4.45	6.12

Figure 19. Simulated flow budget for hydrologic budget areas (a) 33, (b) 34, (c) 35, (d) 36, and (e) 37 in the outcrop of the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

d.

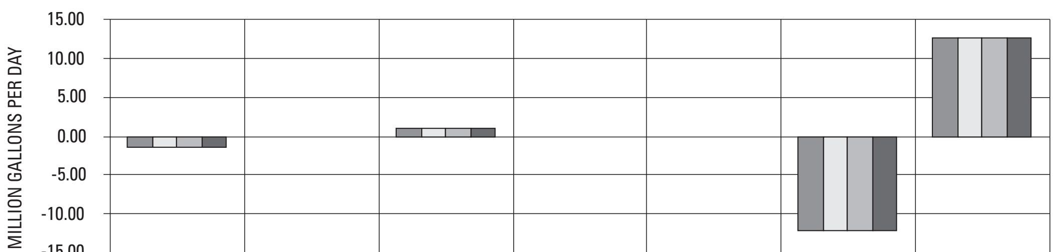
Hydrologic Budget Area 36



	Flow from underlying aquifer	Lateral flow from HBA 37	Lateral flow from HBA 35	Lateral flow from HBA 10	Lateral flow from HBA 11	Pumpage	Storage	Stream leakage	Recharge
1998	-1.65	0.06	-0.04	0.01	0.50	0.00	-0.04	-6.33	7.48
Scenario 1	-1.68	0.05	-0.04	0.01	0.48	0.00	-0.01	-6.28	7.48
Scenario 2	-1.66	0.05	-0.04	0.01	0.48	0.00	-0.02	-6.30	7.48
Scenario 3	-1.62	0.06	-0.04	0.01	0.48	0.00	-0.03	-6.34	7.48

e.

Hydrologic Budget Area 37



	Flow from underlying aquifer	Lateral flow from HBA 36	Lateral flow from HBA 12	Pumpage	Storage	Stream leakage	Recharge
1998	-1.37	-0.06	1.04	0.00	-0.03	-12.12	12.54
Scenario 1	-1.37	-0.05	1.03	0.00	0.00	-12.14	12.54
Scenario 2	-1.36	-0.05	1.03	0.00	0.00	-12.14	12.54
Scenario 3	-1.34	-0.06	1.03	0.00	-0.01	-12.16	12.54

Figure 19. Simulated flow budget for hydrologic budget areas (a) 33, (b) 34, (c) 35, (d) 36, and (e) 37 in the outcrop of the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)—Continued

outcrop area (HBAs 33 to 37). In HBA 33, inflow from the overlying aquifer increased 0.13 Mgal/d (1 percent) and water to storage decreased 0.14 Mgal/d (1 percent). In HBAs 34 to 37, the changes between the values of the 1998 and 2010 flow-budget components were small (0.05 Mgal/d (1 percent) or less).

Englishtown Aquifer System

The HBAs in the confined Englishtown aquifer system (HBAs 13 and 14; fig. 20) extend to the outcrop of the aquifer to the north, which includes HBAs 38 to 39. The easternmost boundary is the Atlantic Ocean and the westernmost boundary is an approximated ground-water divide determined from 1998 observed water levels (Lacombe and Rosman, 2001, fig. 7.3). The southern boundary is the downdip extent of the aquifer. A ground-water divide inferred from observed water levels in Lacombe and Rosman (2001) separates HBA 13 from HBA 14.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Englishtown aquifer system are shown in figure 20. Ground water is withdrawn in Camden, Burlington, Monmouth, and northern Ocean Counties. Simulated water levels range from 80 ft below NGVD of 1929 in coastal Ocean County to 120 ft above NGVD of 1929 in western Monmouth County. The change in simulated water levels from 1998 to 2010 is shown in figure 21. A 6-ft decline in simulated water levels was observed in the southern part of Gloucester County as a result of increased withdrawals from the overlying Wenonah-Mount Laurel aquifer. Simulated water levels recovered more than 26 ft from those in 1998, as a result of mandated reductions in withdrawals from the Englishtown aquifer system and the Wenonah-Mount Laurel aquifer in Critical Area 1 in the 1990s (fig. 21).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figures 22 (for the confined part of the aquifer) and 23 (for the outcrop). Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 13, pumpage was increased 0.39 Mgal/d (3 percent); inflow from the overlying aquifer increased 0.2 Mgal/d (1 percent), but outflow to the underlying aquifer also increased 0.28 Mgal/d (2 percent) because of pumpage from the underlying Upper Potomac-Raritan-Magothy aquifer. Outflow to storage also decreased (0.41 Mgal/d, 3 percent). Water levels in this HBA are recovering as a result of reductions in withdrawals in Critical Area 1, allowing water to go to aquifer storage; however, when the pumpage increased, less water was available for storage. In HBA 14, pumpage was increased 0.12 Mgal/d (1 percent); inflow from the overlying aquifer increased 0.27 Mgal/d (2 percent), but water from storage decreased 0.22 Mgal/d (2 percent).

Pumpage in HBA 38 in the outcrop was not changed but outflow to the underlying aquifer increased 0.19 Mgal/d (1 percent) because of pumpage from the underlying aquifer. There is no pumpage in HBA 39 in the outcrop and leakage to streams increased 0.23 Mgal/d (1 percent), but outflow to storage decreased 0.52 Mgal/d (2 percent).

Upper Potomac-Raritan-Magothy Aquifer

The HBAs in the confined Upper Potomac-Raritan-Magothy aquifer (HBAs 15-17; fig. 24) extend to the outcrop of the aquifer to the north (HBAs 40-43). The easternmost boundary is Raritan Bay and the Atlantic Ocean and the southwesternmost boundary is the location of the 250-mg/L isochlor (Lacombe and Rosman, 2001). In HBA 15, the southern boundary approximates the southern boundary of Critical Area 1. A ground-water divide inferred from observed water levels in Lacombe and Rosman (2001) separates HBA 15 from HBA 16. The southwestern boundary of HBA 16 is approximated by extending the 250-mg/L isochlor in HBA 17 east toward HBA 16.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Upper Potomac-Raritan-Magothy aquifer are shown in figure 24. Ground water is withdrawn in updip areas of Salem and Burlington Counties, Gloucester and Camden Counties, southern Middlesex and Mercer Counties, and Monmouth and northern Ocean Counties. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in Camden County to 60 ft above NGVD of 1929 along the outcrop in Mercer County, and water levels are about 40 ft below NGVD of 1929 in coastal northern Ocean County. The change in simulated water levels from 1998 to 2010 is shown in figure 25. The projected increase in withdrawals resulted in a simulated water-level decline of 2 ft in central Gloucester and Camden Counties in Critical Area 2, and a decline of 5 ft in Middlesex County near the outcrop just outside Critical Area 1.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figures 26 and 27. Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 15, pumpage was increased 1.79 Mgal/d (7 percent); inflow from the overlying aquifer increased 1.49 Mgal/d (6 percent), and lateral inflow from the downdip part of the aquifer (not included in any HBA) increased 0.61 Mgal/d (2 percent). In HBA 16, pumpage was increased 1.92 Mgal/d (6 percent) and inflow from the overlying aquifer increased 4.12 Mgal/d (13 percent), but outflow to the underlying Middle Potomac-Raritan-Magothy aquifer also increased 2.23 Mgal/d (7 percent). Lateral inflow from HBA 42 in the outcrop decreased 0.36 Mgal/d (1 percent), and water to storage decreased 0.46 Mgal/d (2 percent). In HBA 17, pumpage was decreased 0.09 Mgal/d (1 percent); however, inflow from the overlying aquifer increased 0.19 Mgal/d (3 percent) and outflow to the adjacent HBA (HBA 16) also increased 0.17 Mgal/d (2 percent).

In HBA 40 in the outcrop, pumpage was increased 1.45 Mgal/d (2 percent); leakage to streams decreased 2.44 Mgal/d (3 percent), and outflow to the underlying Middle Potomac-Raritan-Magothy aquifer decreased 0.47 Mgal/d (1 percent).

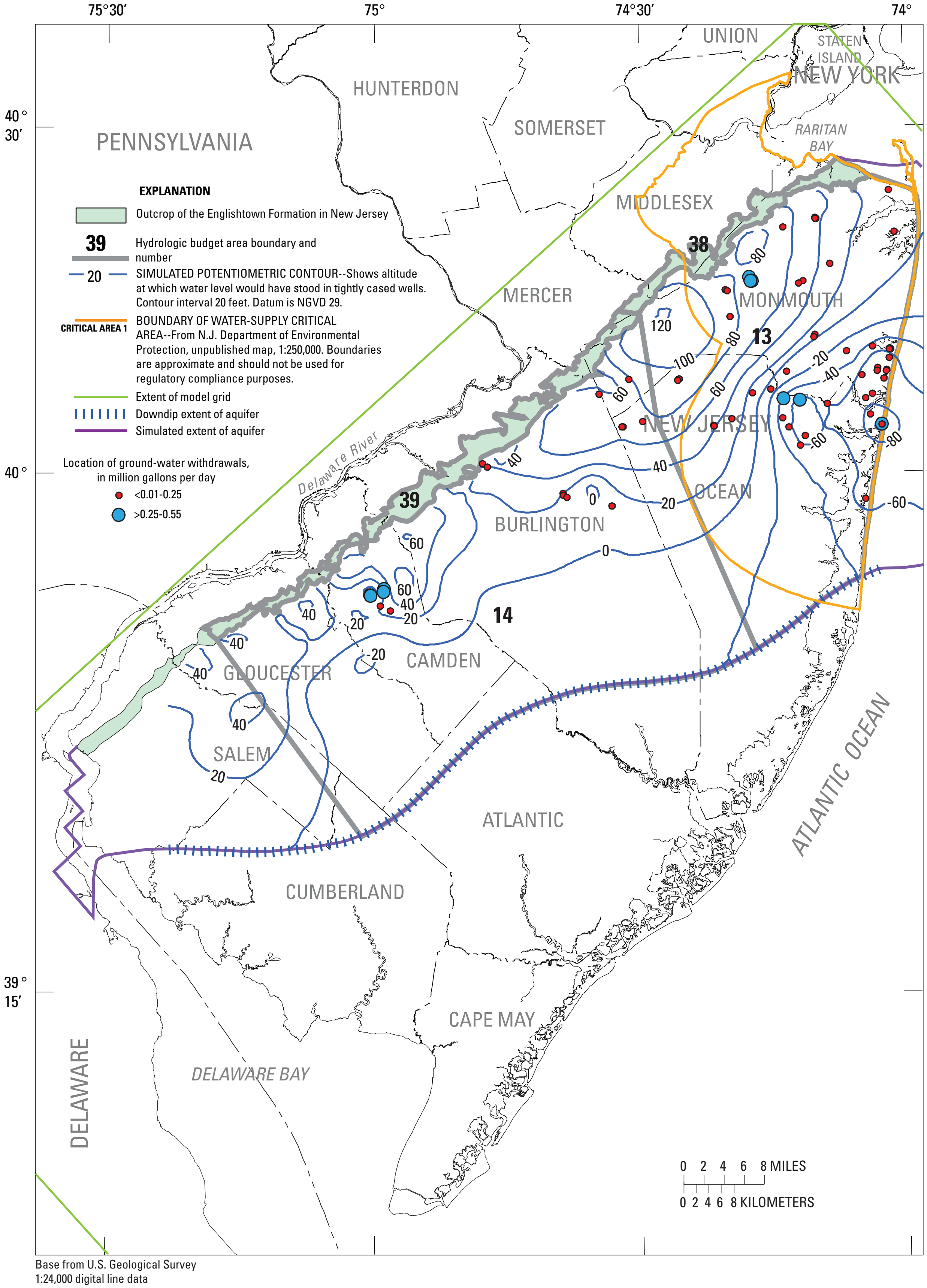
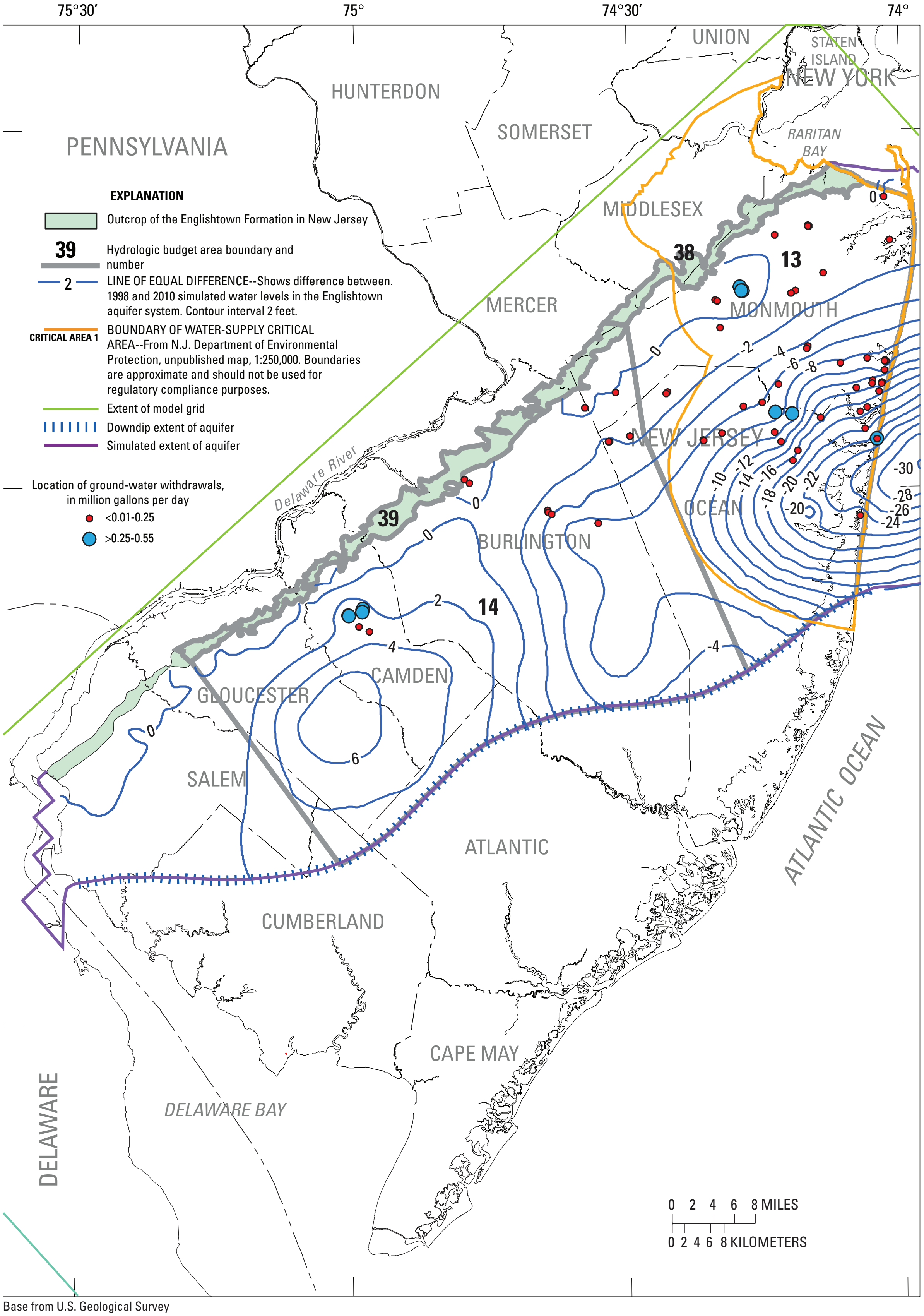


Figure 20. Hydrologic budget areas in the Englishtown aquifer system and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

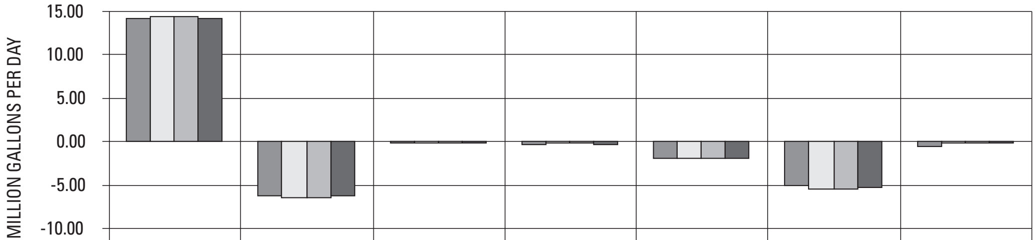


Base from U.S. Geological Survey
1:24,000 digital line data

Figure 21. Change in simulated water levels (1998 to 2010) in the Englishtown aquifer system, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a.

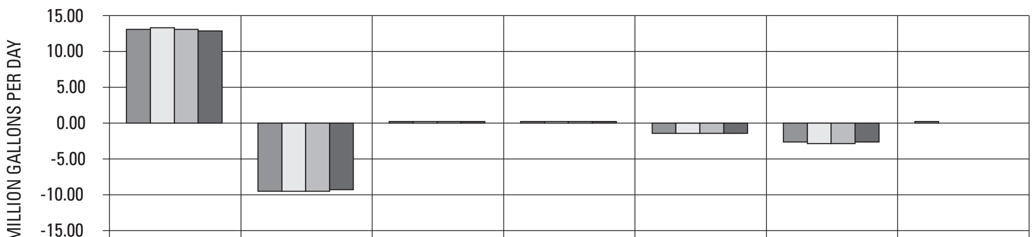
Hydrologic Budget Area 13



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 14	Lateral flow from offshore	Lateral flow from HBA 38	Pumpage	Storage
1998	14.26	-6.20	-0.16	-0.40	-1.88	-5.04	-0.58
Scenario 1	14.46	-6.48	-0.21	-0.25	-1.91	-5.45	-0.17
Scenario 2	14.46	-6.47	-0.21	-0.25	-1.91	-5.48	-0.15
Scenario 3	14.28	-6.35	-0.21	-0.30	-1.93	-5.31	-0.19

b.

Hydrologic Budget Area 14

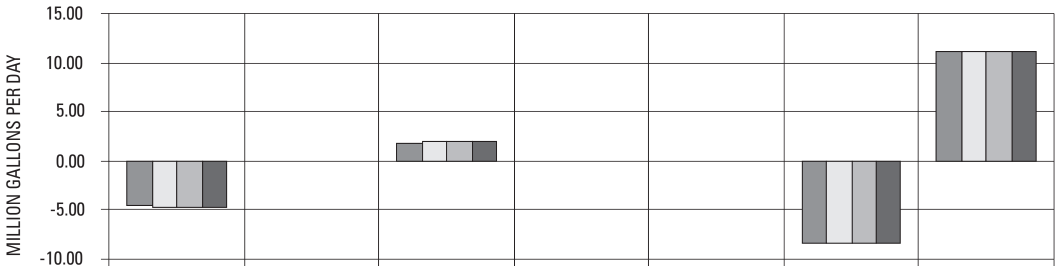


	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 13	Lateral flow from portion of aquifer not in an HBA	Lateral flow from HBA 39	Pumpage	Storage
1998	13.01	-9.51	0.16	0.19	-1.33	-2.71	0.19
Scenario 1	13.28	-9.54	0.21	0.21	-1.31	-2.83	-0.03
Scenario 2	13.14	-9.50	0.21	0.21	-1.31	-2.75	-0.01
Scenario 3	12.91	-9.26	0.21	0.20	-1.32	-2.72	-0.05

Figure 22. Simulated flow budget for hydrologic budget areas (a) 13 and (b) 14 in the Englishtown aquifer system, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

a.

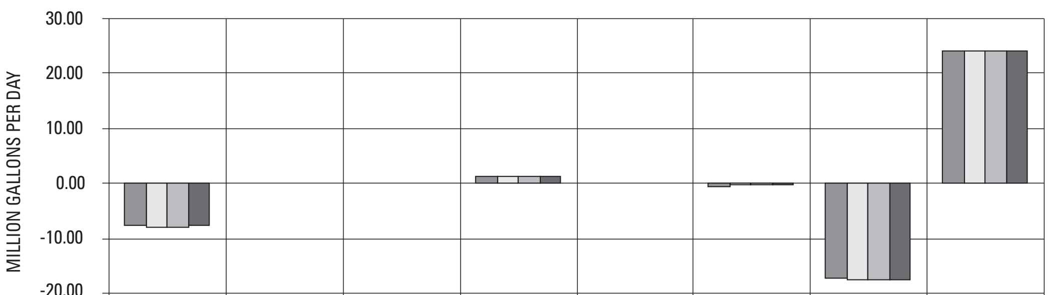
Hydrologic Budget Area 38



	Flow from underlying aquifer	Lateral flow from HBA 39	Lateral flow from HBA 13	Pumpage	Storage	Stream leakage	Recharge
1998	-4.54	-0.03	1.88	-0.01	-0.12	-8.37	11.18
Scenario 1	-4.73	-0.03	1.91	-0.01	0.04	-8.37	11.18
Scenario 2	-4.70	-0.03	1.91	-0.01	0.03	-8.39	11.18
Scenario 3	-4.63	-0.03	1.93	-0.01	0.01	-8.45	11.18

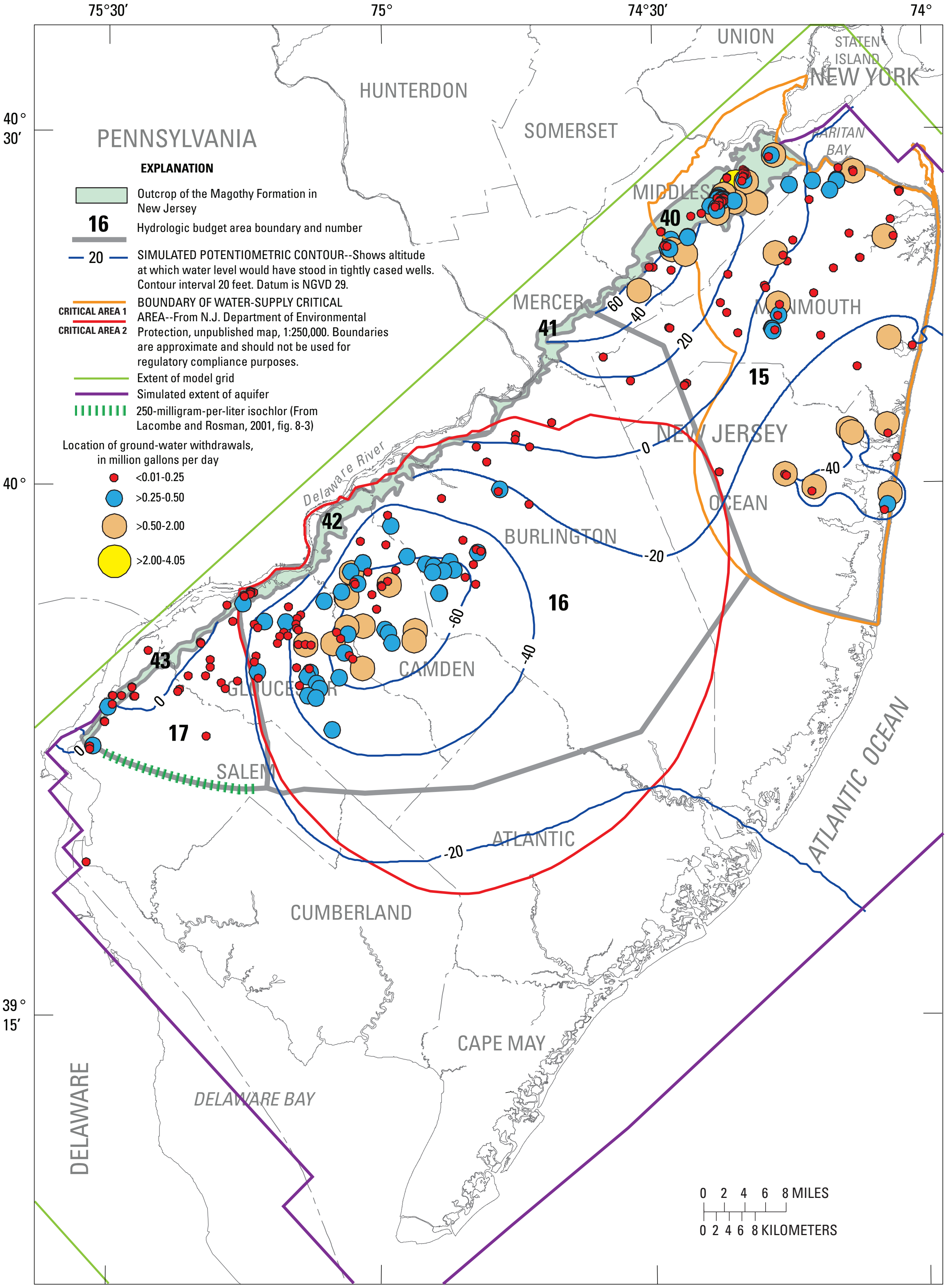
b.

Hydrologic Budget Area 39



	Flow from underlying aquifer	Lateral flow from HBA 38	Lateral flow from outcrop not in an HBA	Lateral flow from HBA 14	Pumpage	Storage	Stream leakage	Recharge
1998	-7.63	0.03	0.03	1.33	0.00	-0.67	-17.23	24.14
Scenario 1	-7.90	0.03	0.03	1.31	0.00	-0.15	-17.46	24.14
Scenario 2	-7.88	0.03	0.03	1.31	0.00	-0.17	-17.46	24.14
Scenario 3	-7.72	0.03	0.03	1.32	0.00	-0.26	-17.54	24.14

Figure 23. Simulated flow budget for hydrologic budget areas (a) 38 and (b) 39 in the outcrop of the Englishtown aquifer system, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 24. Hydrologic budget areas in the Upper Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

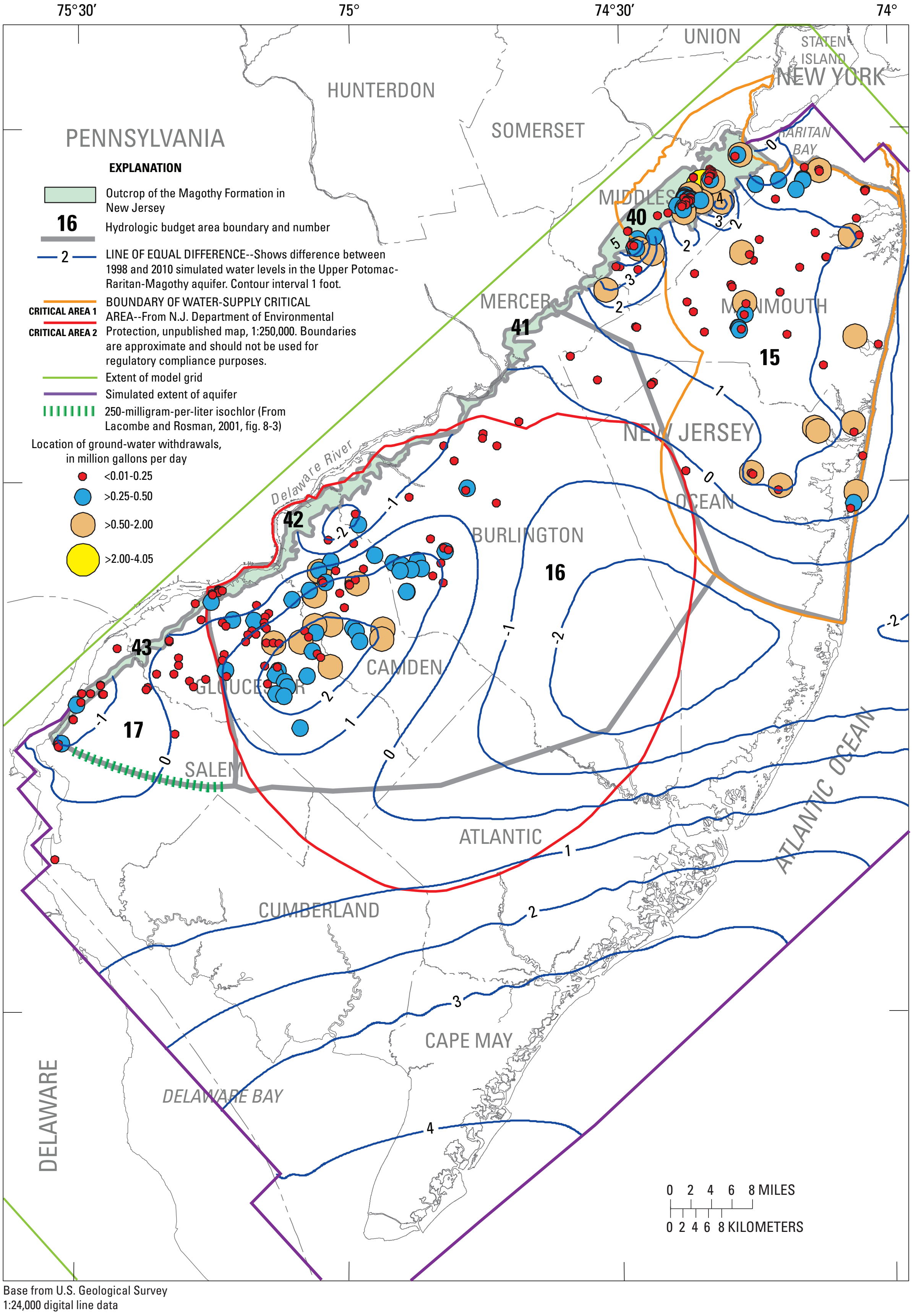
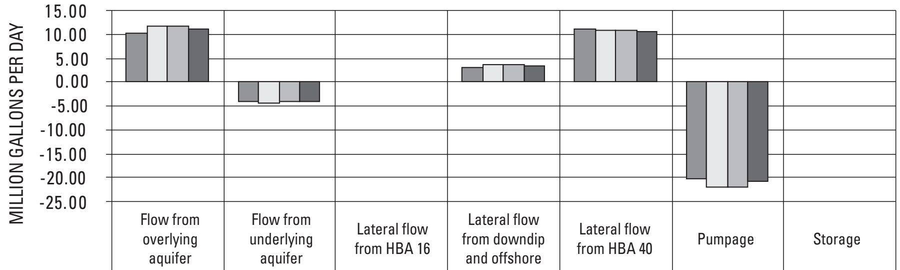


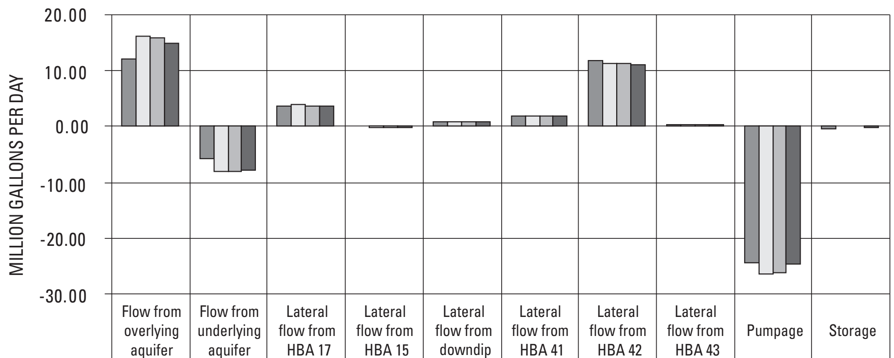
Figure 25. Change in simulated water levels (1998 to 2010) in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a. Hydrologic Budget Area 15



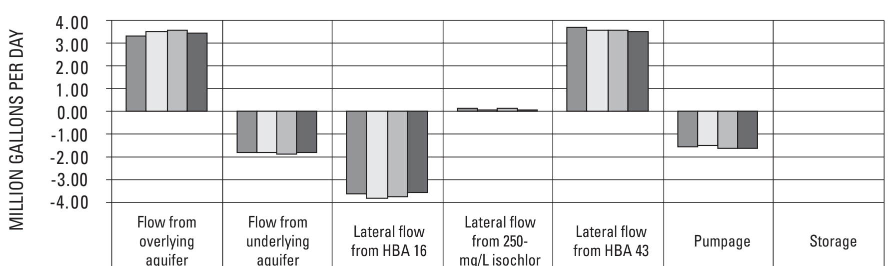
	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 16	Lateral flow from downdip and offshore	Lateral flow from HBA 40	Pumpage	Storage
1998	10.32	-4.20	0.00	3.03	10.99	-20.20	0.07
Scenario 1	11.81	-4.39	0.17	3.62	10.75	-21.99	0.01
Scenario 2	11.61	-4.23	0.18	3.63	10.68	-21.88	0.01
Scenario 3	11.26	-4.25	0.14	3.26	10.47	-20.86	-0.02

b. Hydrologic Budget Area 16



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 17	Lateral flow from HBA 15	Lateral flow from downdip	Lateral flow from HBA 41	Lateral flow from HBA 42	Lateral flow from HBA 43	Pumpage	Storage
1998	11.99	-5.80	3.65	0.00	0.95	1.98	11.81	0.27	-24.41	-0.45
Scenario 1	16.11	-8.03	3.82	-0.17	0.94	1.93	11.45	0.28	-26.33	0.01
Scenario 2	15.88	-7.94	3.77	-0.18	0.92	1.93	11.38	0.28	-26.06	0.01
Scenario 3	14.90	-7.74	3.57	-0.14	0.85	1.89	11.14	0.27	-24.69	-0.06

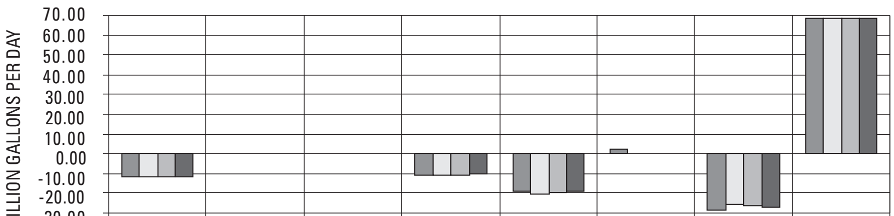
c. Hydrologic Budget Area 17



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 16	Lateral flow from 250-mg/L isochlor	Lateral flow from HBA 43	Pumpage	Storage
1998	3.30	-1.82	-3.65	0.11	3.66	-1.59	-0.03
Scenario 1	3.49	-1.83	-3.82	0.08	3.55	-1.50	0.00
Scenario 2	3.55	-1.85	-3.77	0.10	3.58	-1.63	0.00
Scenario 3	3.46	-1.84	-3.57	0.08	3.49	-1.63	0.00

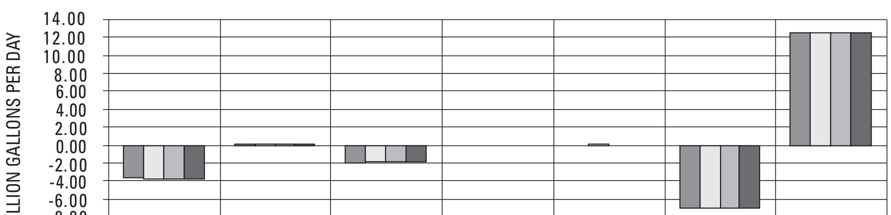
Figure 26. Simulated flow budget for hydrologic budget areas (a) 15, (b) 16, and (c) 17 in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding; mg/L, milligrams per liter.)

a. Hydrologic Budget Area 40



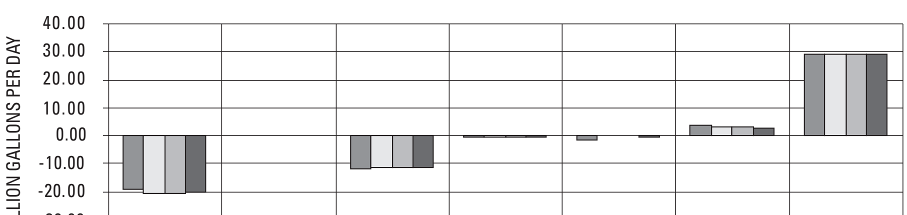
	Flow from underlying aquifer	Lateral flow from HBA 41	Lateral flow from offshore	Lateral flow from HBA 15	Pumpage	Storage	Stream leakage	Recharge
1998	-11.95	-0.12	-0.13	-10.99	-19.09	2.15	-28.25	68.37
Scenario 1	-11.48	-0.12	-0.14	-10.75	-20.54	0.46	-25.81	68.37
Scenario 2	-11.46	-0.12	-0.14	-10.68	-19.86	0.34	-26.45	68.37
Scenario 3	-11.40	-0.12	-0.14	-10.47	-19.21	0.19	-27.23	68.37

b. Hydrologic Budget Area 41



	Flow from underlying aquifer	Lateral flow from HBA 40	Lateral flow from HBA 16	Pumpage	Storage	Stream leakage	Recharge
1998	-3.68	0.12	-1.98	0.00	-0.05	-6.99	12.58
Scenario 1	-3.82	0.12	-1.93	0.00	0.01	-6.97	12.58
Scenario 2	-3.76	0.12	-1.93	0.00	0.00	-7.03	12.58
Scenario 3	-3.75	0.12	-1.89	0.00	0.00	-7.06	12.58

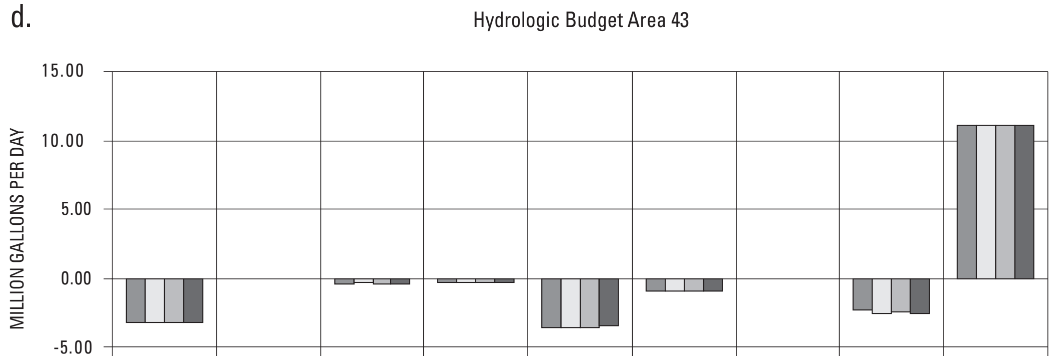
c. Hydrologic Budget Area 42



	Flow from underlying aquifer	Lateral flow from HBA 43	Lateral flow from HBA 16	Pumpage	Storage	Stream leakage	Recharge
1998	-19.26	0.12	-11.81	-0.50	-1.28	3.60	29.14
Scenario 1	-20.61	0.10	-11.45	-0.50	-0.03	3.32	29.14
Scenario 2	-20.43	0.10	-11.38	-0.50	-0.08	3.13	29.14
Scenario 3	-20.08	0.10	-11.14	-0.50	-0.26	2.73	29.14

Figure 27. Simulated flow budget for hydrologic budget areas (a) 40, (b) 41, (c) 42, and (d) 43 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

d.



	Flow from underlying aquifer	Lateral flow from HBA 42	Lateral flow from offshore	Lateral flow from HBA 16	Lateral flow from HBA 17	Pumpage	Storage	Stream leakage	Recharge
1998	-3.21	-0.12	-0.38	-0.27	-3.66	-0.96	-0.08	-2.34	11.04
Scenario 1	-3.21	-0.10	-0.37	-0.28	-3.55	-0.92	0.00	-2.60	11.04
Scenario 2	-3.23	-0.10	-0.39	-0.28	-3.58	-0.97	0.00	-2.50	11.04
Scenario 3	-3.18	-0.10	-0.39	-0.27	-3.49	-0.97	-0.01	-2.62	11.04

Figure 27. Simulated flow budget for hydrologic budget areas (a) 40, (b) 41, (c) 42, and (d) 43 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)—Continued

There also was a decrease in inflow from storage of 1.69 Mgal/d (2 percent). There was no pumpage in HBA 41 in the outcrop but outflow to the underlying aquifer increased 0.14 Mgal/d (1 percent). In HBA 42 in the outcrop, pumpage was not changed; however, outflow to the underlying Middle Potomac-Raritan-Magothy aquifer increased 1.35 Mgal/d (4 percent), but lateral outflow to HBA 16 decreased 0.36 Mgal/d (1 percent) and induced leakage from the stream to the aquifer decreased 0.28 Mgal/d (1 percent). Outflow to storage also decreased 1.25 Mgal/d (4 percent). The decrease in pumpage in HBA 43 was small (0.04 Mgal/d, less than 1 percent), but leakage to streams increased 0.26 Mgal/d (2 percent) and lateral outflow to HBA 17 decreased 0.11 Mgal/d (1 percent).

Middle Potomac-Raritan-Magothy Aquifer

The HBAs in the confined Middle Potomac-Raritan-Magothy aquifer (HBAs 18-21; fig. 28) extend to the outcrop of the aquifer to the north and northwest (HBAs 44-46). The outcrop extends north and northwest to the Fall Line (fig. 1). The easternmost boundary is Raritan Bay and the Atlantic Ocean and the westernmost boundary is the Delaware River. The southern boundary is the approximate location of the 250-mg/L isochlor (Lacombe and Rosman, 2001), except in HBA 21, where it extends farther south to include the pumping areas downdip from the 250-mg/L isochlor in Salem County. Ground-water divides and the approximate boundary of the Critical Areas separate HBA 18 from HBA 19, and HBA 19 from HBAs 20 and 21.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface for the Middle Potomac-Raritan-Magothy aquifer are shown in figure 28. Ground water is withdrawn in updip areas of Salem, Gloucester, Camden, and Burlington Counties, southern Middlesex and Mercer Counties, and Monmouth and northern Ocean Counties. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in Camden County to 80 ft above NGVD of 1929 near the outcrop in Middlesex County. The change in simulated water levels from 1998 to 2010 is shown in figure 29. The projected increase in withdrawals resulted in a simulated water-level decline of 9 ft in Middlesex County near the outcrop adjacent to the boundary of Critical Area 1.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figures 30 (for the confined part of the aquifer) and 31 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 18, pumpage was increased 1.63 Mgal/d (8 percent); lateral inflow from the outcrop (HBA 44) increased 0.82 Mgal/d (4 percent) and lateral inflow at the location of the 250-mg/L isochlor increased 0.5 Mgal/d (2 percent), but inflow from the overlying aquifer decreased 0.33 Mgal/d (2 percent), and outflow to the underlying aquifer decreased 0.23 Mgal/d (1 percent). In HBA 19, pumpage was increased 1.15 Mgal/d (2 percent) and inflow from the overlying aquifer increased 3.8 Mgal/d (8 percent), but outflow to the underlying aquifer also increased 2.47 Mgal/d (5 percent). Water to storage decreased 0.5 Mgal/d (1 percent) and inflow at the 250-mg/L isochlor increased 0.13 Mgal/d (less than 1 percent). In HBA 20, pumpage was decreased 0.07 Mgal/d (1 percent), and the changes in the flow-budget components were small (0.07 Mgal/d (1 percent) or less). In HBA 21, which is

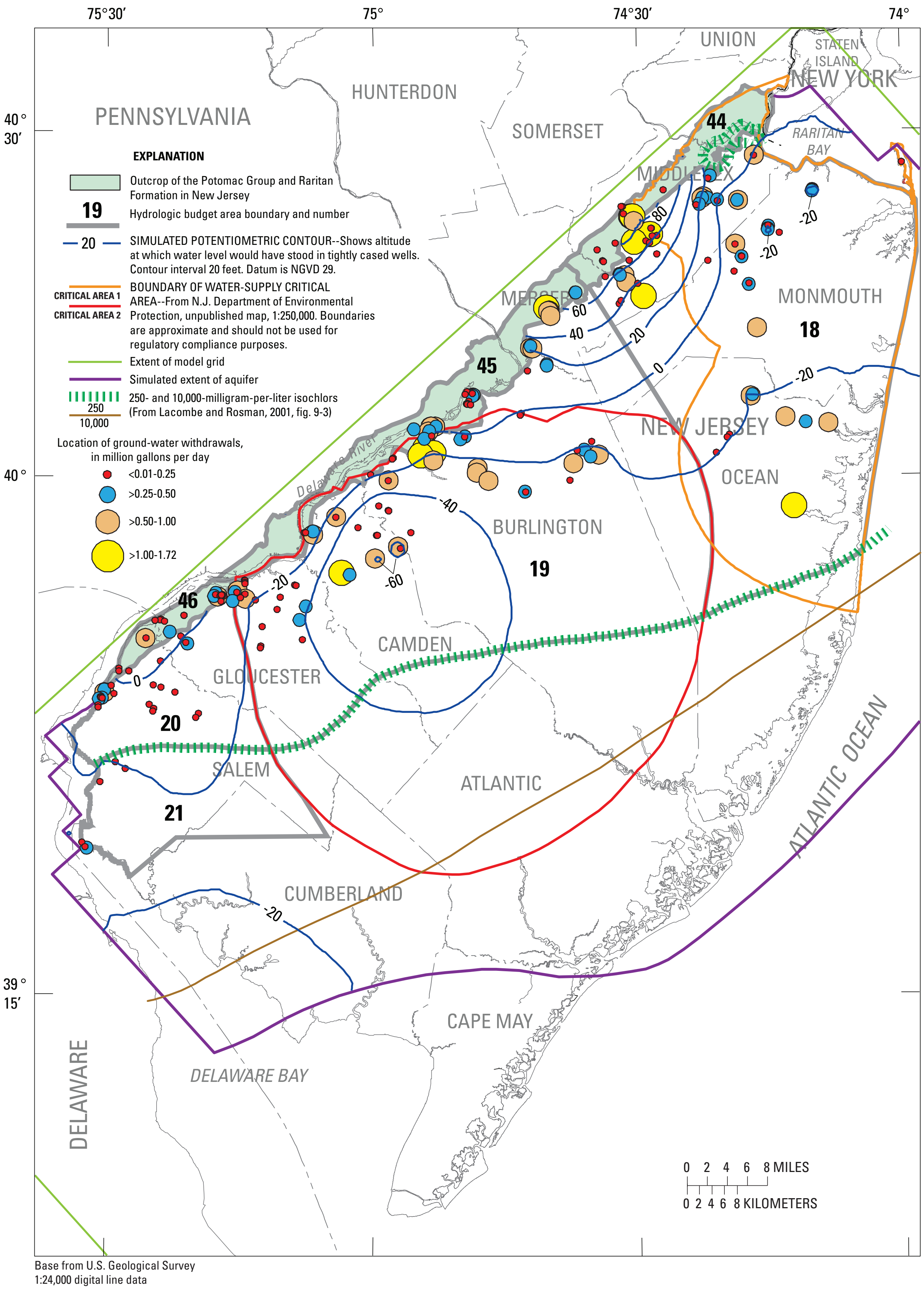
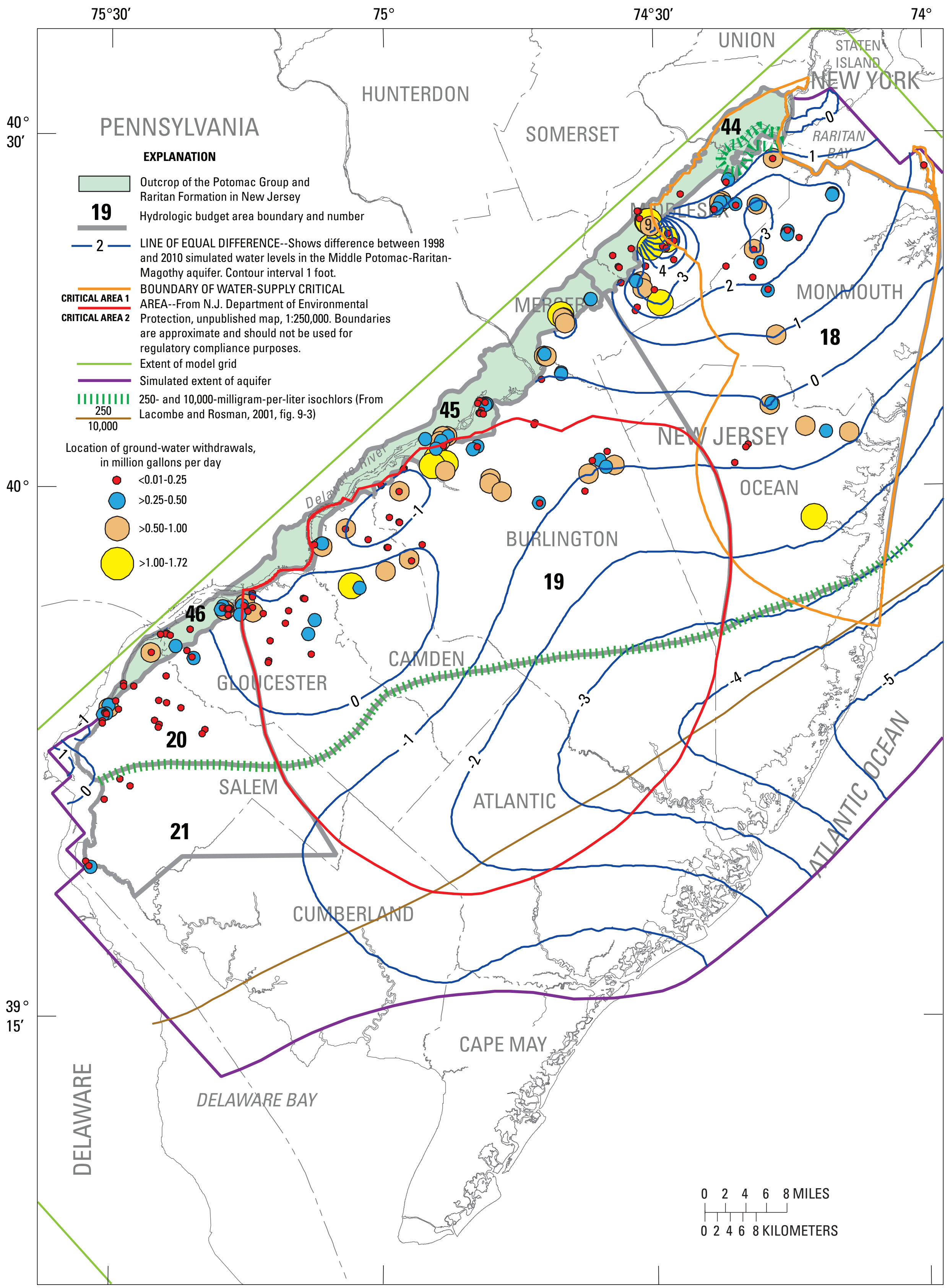


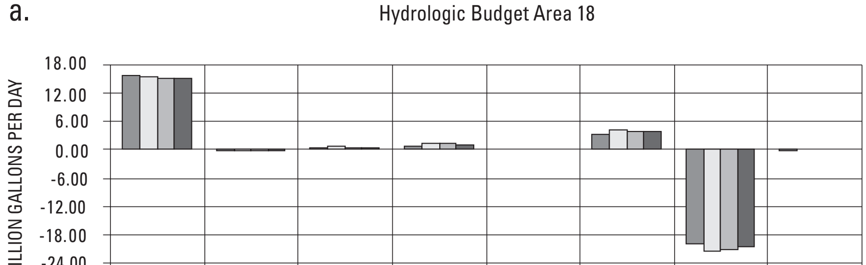
Figure 28. Hydrologic budget areas in the Middle Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.



Base from U.S. Geological Survey
1:24,000 digital line data

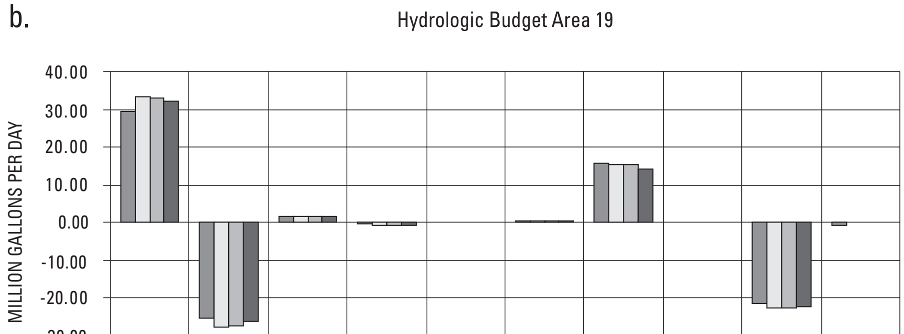
Figure 29. Change in simulated water levels (1998 to 2010) in the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a.



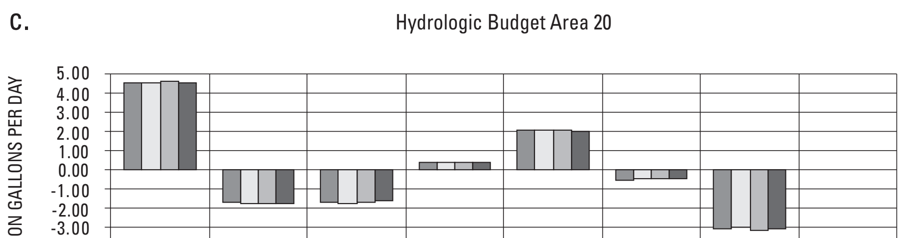
	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 19	Lateral flow from 250-mg/L isochlor	Lateral flow from offshore	Lateral flow from HBA 44	Pumpage	Storage
1998	15.73	-0.30	0.40	0.85	0.00	3.33	-19.88	-0.12
Scenario 1	15.40	-0.07	0.65	1.35	0.00	4.15	-21.51	0.03
Scenario 2	15.26	-0.08	0.57	1.30	0.00	3.99	-21.06	0.02
Scenario 3	15.21	-0.08	0.57	1.19	0.00	3.83	-20.70	-0.01

b.



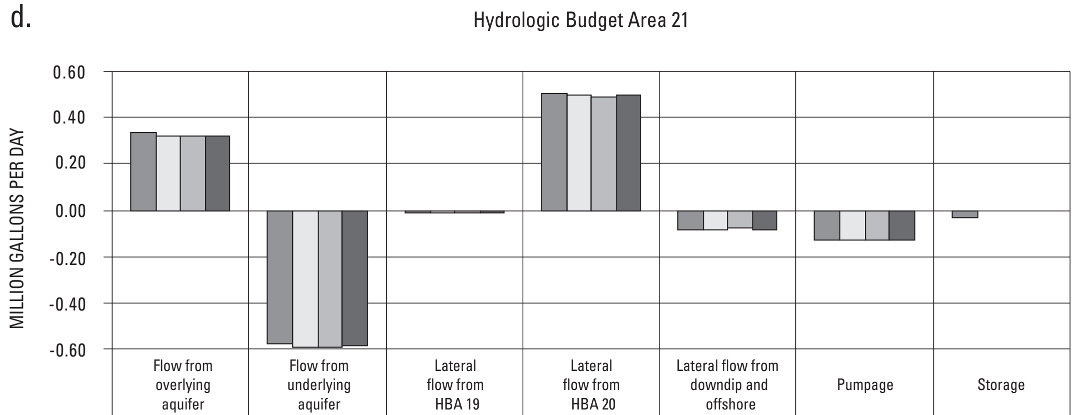
	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 20	Lateral flow from HBA 18	Lateral flow from HBA 21	Lateral flow from 250-mg/L isochlor	Lateral flow from HBA 45	Lateral flow from HBA 46	Pumpage	Storage
1998	29.43	-25.28	1.72	-0.40	0.01	0.32	15.87	0.28	-21.48	-0.49
Scenario 1	33.23	-27.75	1.74	-0.65	0.01	0.45	15.28	0.29	-22.63	0.01
Scenario 2	32.90	-27.21	1.72	-0.57	0.01	0.44	15.17	0.29	-22.75	0.00
Scenario 3	32.30	-26.26	1.65	-0.57	0.01	0.39	14.34	0.28	-22.10	-0.05

c.



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 19	Lateral flow from offshore	Lateral flow from HBA 46	Lateral flow from 250-mg/L isochlor	Pumpage	Storage
1998	4.52	-1.72	-1.72	0.41	2.10	-0.50	-3.06	-0.03
Scenario 1	4.54	-1.77	-1.74	0.40	2.06	-0.50	-2.99	0.00
Scenario 2	4.60	-1.74	-1.72	0.42	2.06	-0.49	-3.14	0.00
Scenario 3	4.55	-1.75	-1.65	0.41	2.00	-0.50	-3.07	0.00

Figure 30. Simulated flow budget for hydrologic budget areas (a) 18, (b) 19, (c) 20, and (d) 21 in the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding; mg/L, milligrams per liter.)



	Flow from overlying aquifer	Flow from underlying aquifer	Lateral flow from HBA 19	Lateral flow from HBA 20	Lateral flow from downdip and offshore	Pumpage	Storage
1998	0.34	-0.58	-0.01	0.50	-0.08	-0.13	-0.03
Scenario 1	0.32	-0.59	-0.01	0.50	-0.08	-0.13	0.00
Scenario 2	0.32	-0.59	-0.01	0.49	-0.08	-0.13	0.00
Scenario 3	0.32	-0.59	-0.01	0.50	-0.08	-0.13	0.00

Figure 30. Simulated flow budget for hydrologic budget areas (a) 18, (b) 19, (c) 20, and (d) 21 in the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding; mg/L, milligrams per liter.)—Continued

south of the 250-mg/L isochlor, pumpage was not changed and the changes between the values of the 1998 and 2010 flow-budget components were small (0.03 Mgal/d (4 percent) or less). The withdrawal wells in HBA 21 are not supply wells.

In HBA 44 in the outcrop, pumpage was increased 0.28 Mgal/d (less than 1 percent) and leakage to streams decreased 2.23 Mgal/d (3 percent). Inflow from storage decreased 1.13 Mgal/d (1 percent), and lateral outflow to HBA 18 increased 0.82 Mgal/d (1 percent) when pumpage was increased there. HBA 44 is underlain by bedrock, which is represented by a no-flow boundary in the New Jersey RASA model (Voronin, 2004); therefore, there is no flow to or from an underlying aquifer. The 250-mg/L isochlor is located onshore near the coast in HBA 44 (fig. 28); however, lateral inflow from the aquifer offshore (not included in any HBA) did not change. In HBA 45 in the outcrop, pumpage was increased 1.18 Mgal/d (1 percent); water to storage decreased 0.67 Mgal/d (1 percent) and outflow to HBA 19 decreased 0.59 Mgal/d (less than 1 percent), but outflow to the underlying aquifer increased 0.26 Mgal/d (less than 1 percent). Pumpage was not changed in HBA 46 in the outcrop and leakage to streams increased (0.64 Mgal/d, 3 percent), but outflow to storage decreased (0.54 Mgal/d, 2 percent).

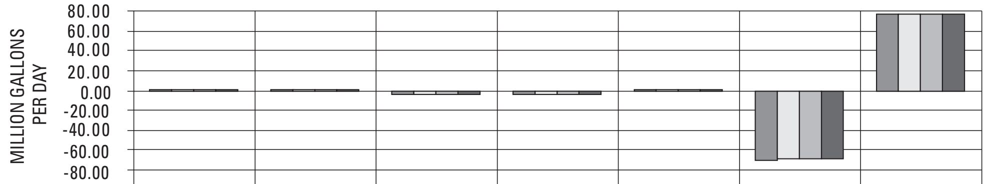
Lower Potomac-Raritan-Magothy Aquifer

The HBAs in the confined Lower Potomac-Raritan-Magothy aquifer (HBAs 22 to 24; fig. 32) extend to the updip extent of the aquifer to the north and east. The Delaware River is the westernmost boundary. The location of the 250-mg/L isochlor (Lacombe and Rosman, 2001) is the southern boundary of HBA 24; the isochlor separates HBA 22 from HBA 23 and HBA 23 from HBA 24. The southern boundary of HBA 23 is approximately at the southernmost location of the 250-mg/L isochlor in HBA 24.

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Lower Potomac-Raritan-Magothy aquifer are shown in figure 32. Ground water is withdrawn in updip areas of Salem, Gloucester, and Camden Counties and northwestern Burlington County. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in central Camden County to NGVD of 1929 near the Delaware River in Salem and Gloucester Counties. Water levels are also 60 ft below NGVD of 1929 in Delaware because of pumping there. The change in simulated water levels from 1998 to 2010 was small (1 ft or less) (fig. 33).

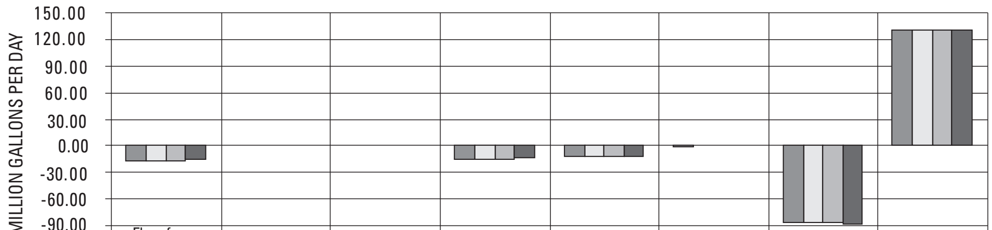
The simulated 2010 flow budget for each HBA in this aquifer for scenario 1 and for the baseline (1998) simulation is shown in figure 34. Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. This aquifer does not crop out in New Jersey and is recharged by flow from the overlying aquifers. In HBA 22, pumpage was increased 2.95 Mgal/d (7 percent); inflow from the overlying aquifer increased 2.75 Mgal/d (6 percent), and lateral inflow from the downdip part of the aquifer (not included in any HBA) increased 0.17 Mgal/d (less than 1 percent). There is no pumpage in HBA 23, which is salty water bounded on the east and west by the 250-mg/L isochlor. Pumpage in HBA 24 was decreased 0.07 Mgal/d (2 percent). Ground water flows from HBA 24 to HBA 23 (fresher to saltier water) and from HBA 23 to HBA 22 (saltier to fresher water). Flow from HBA 23 to HBA 22 increased 0.03 Mgal/d (less than 1 percent) in this scenario.

a. Hydrologic Budget Area 44



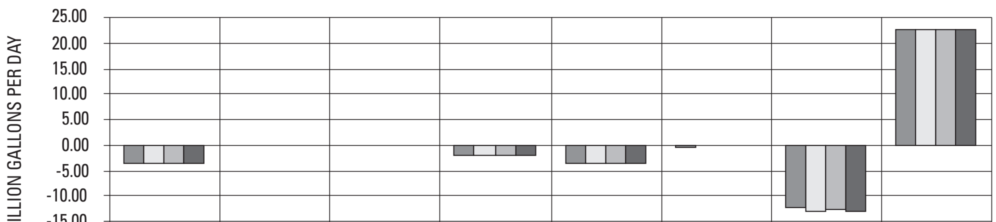
	Lateral flow from HBA 45	Lateral flow from offshore	Lateral flow from HBA 18	Pumpage	Storage	Stream leakage	Recharge
1998	0.08	0.06	-3.33	-3.91	1.21	-70.56	76.45
Scenario 1	0.08	0.06	-4.15	-4.19	0.08	-68.33	76.45
Scenario 2	0.08	0.06	-3.99	-4.18	0.08	-68.50	76.45
Scenario 3	0.08	0.06	-3.83	-4.18	0.07	-68.65	76.45

b. Hydrologic Budget Area 45



	Flow from underlying aquifer	Lateral flow from HBA 46	Lateral flow from HBA 44	Lateral flow from HBA 19	Pumpage	Storage	Stream leakage	Recharge
1998	-16.59	0.01	-0.08	-15.87	-11.41	-0.64	-86.30	130.88
Scenario 1	-16.85	0.01	-0.08	-15.28	-12.59	0.03	-86.13	130.88
Scenario 2	-16.32	0.01	-0.08	-15.17	-12.05	0.01	-87.28	130.88
Scenario 3	-15.79	0.02	-0.08	-14.34	-11.98	-0.06	-88.65	130.88

c. Hydrologic Budget Area 46



	Flow from underlying aquifer	Lateral flow from HBA 45	Lateral flow from HBA 19	Lateral flow from HBA 20	Pumpage	Storage	Stream leakage	Recharge
1998	-3.66	-0.01	-0.28	-2.10	-3.70	-0.54	-12.30	22.61
Scenario 1	-3.62	-0.01	-0.29	-2.06	-3.70	0.00	-12.94	22.61
Scenario 2	-3.65	-0.01	-0.29	-2.06	-3.79	0.00	-12.79	22.61
Scenario 3	-3.55	-0.02	-0.28	-2.00	-3.70	-0.01	-13.06	22.61

Figure 31. Simulated flow budget for hydrologic budget areas (a) 44, (b) 45, and (c) 46 in the outcrop of the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding.)

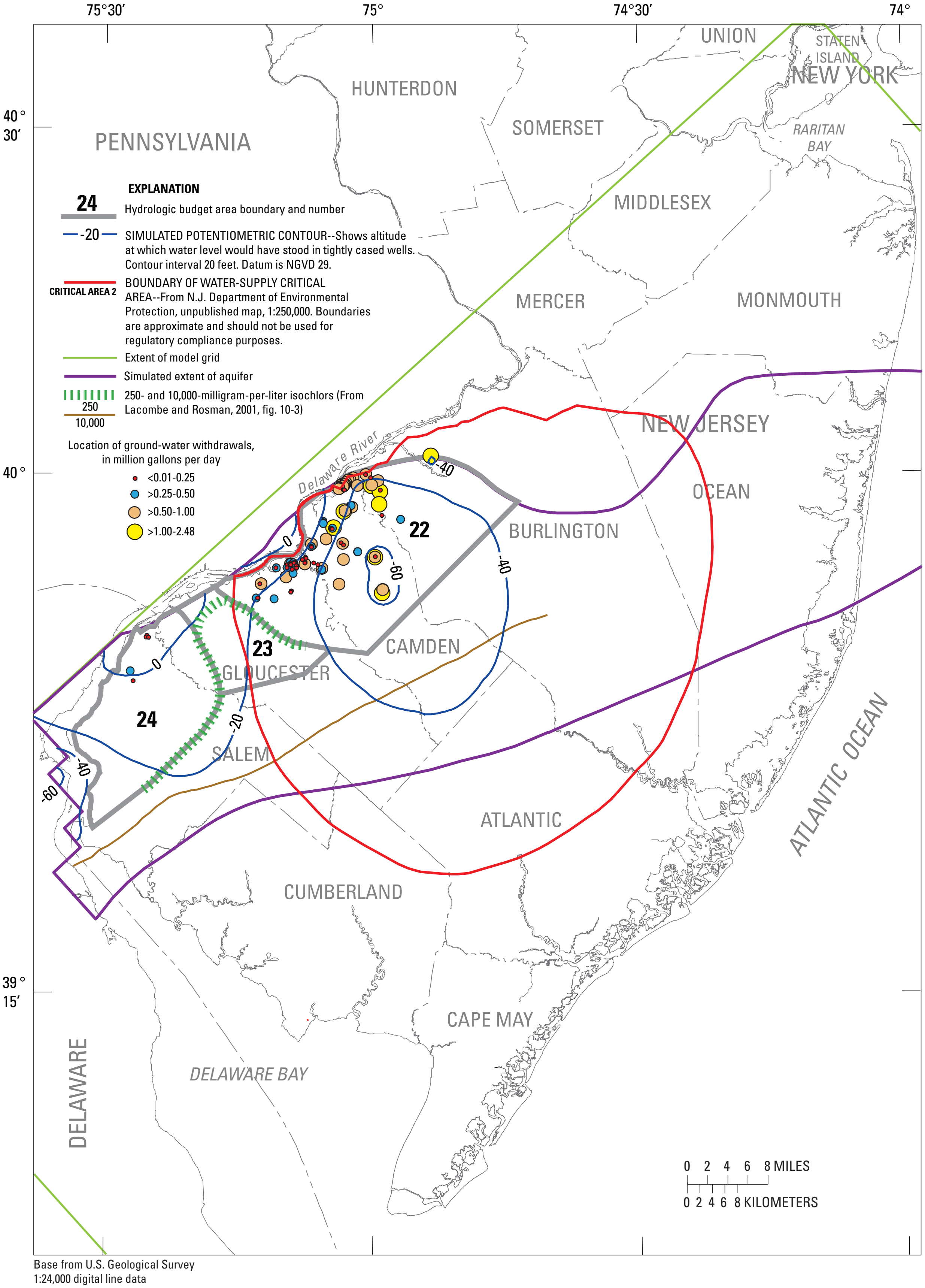


Figure 32. Hydrologic budget areas in the Lower Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 1, New Jersey Coastal Plain.

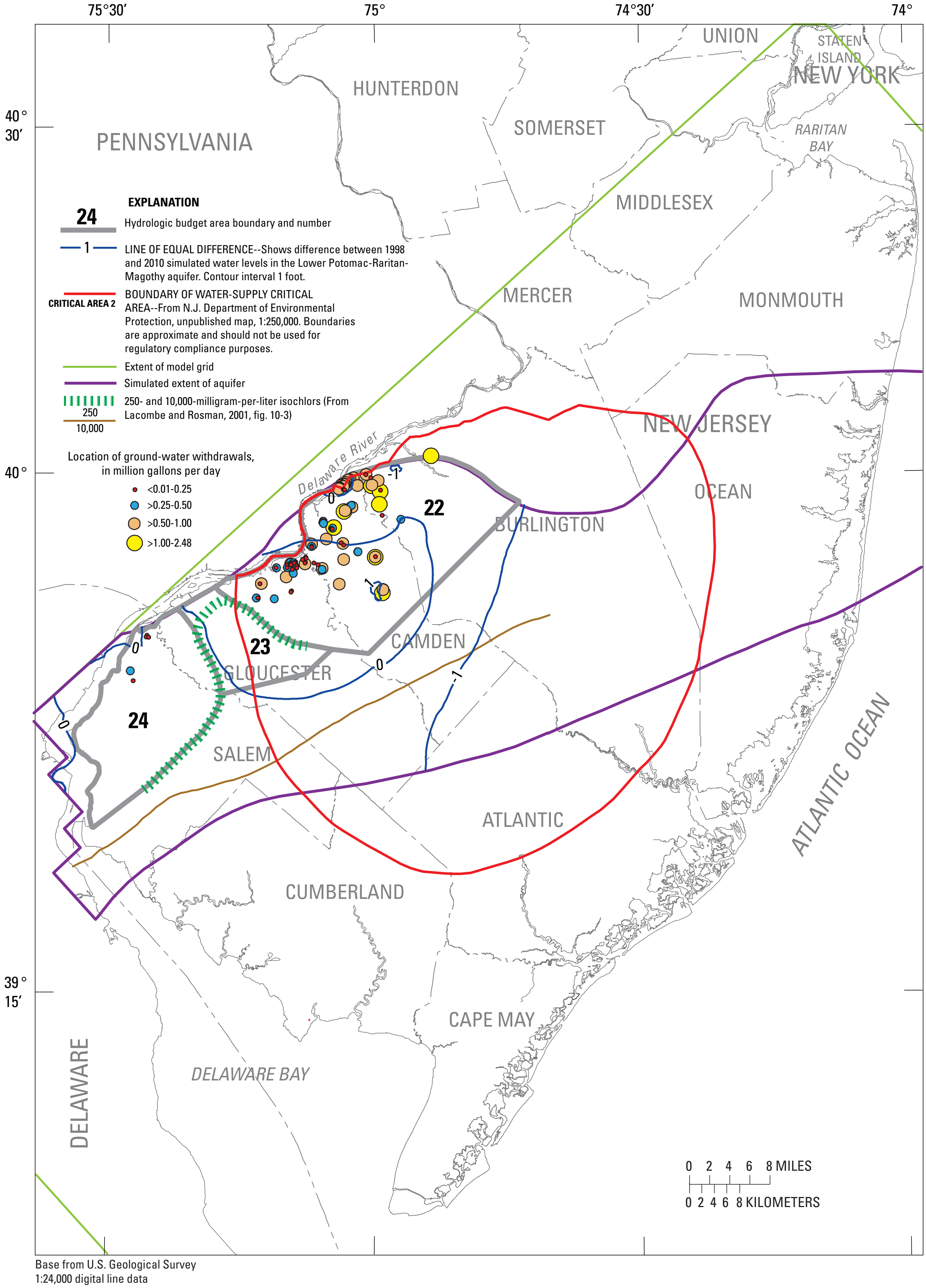
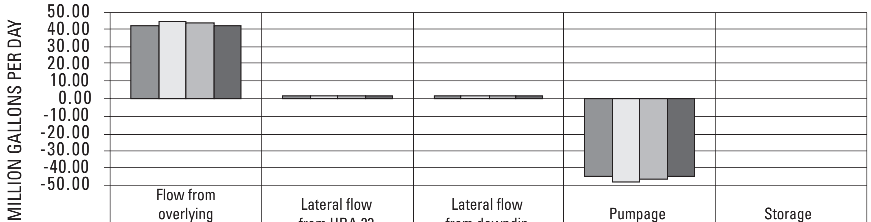


Figure 33. Change in simulated water levels (1998 to 2010) in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Positive value indicates water-level decline.)

a.

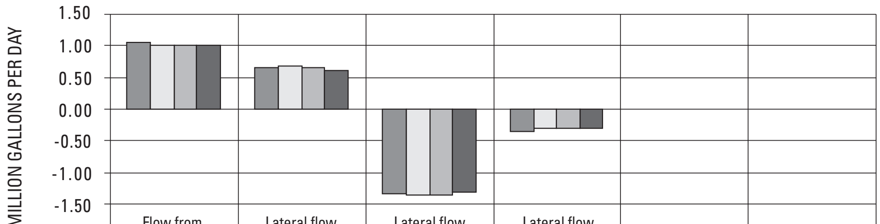
Hydrologic Budget Area 22



	Flow from overlying aquifer	Lateral flow from HBA 23	Lateral flow from downdip	Pumpage	Storage
1998	42.24	1.34	1.48	-45.06	0.00
Scenario 1	44.99	1.37	1.65	-48.01	0.00
Scenario 2	43.94	1.35	1.58	-46.87	0.00
Scenario 3	42.39	1.30	1.52	-45.21	0.00

b.

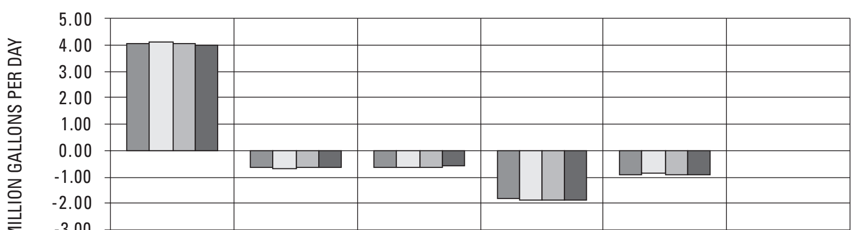
Hydrologic Budget Area 23



	Flow from overlying aquifer	Lateral flow from HBA 24	Lateral flow from HBA 22	Lateral flow from downdip	Pumpage	Storage
1998	1.05	0.65	-1.34	-0.35	0.00	0.00
Scenario 1	1.01	0.69	-1.37	-0.32	0.00	0.00
Scenario 2	1.00	0.66	-1.35	-0.31	0.00	0.00
Scenario 3	1.01	0.62	-1.30	-0.32	0.00	0.00

c.

Hydrologic Budget Area 24



	Flow from overlying aquifer	Lateral flow from HBA 23	Lateral flow from 250-mg/L isochlor	Lateral flow from offshore	Pumpage	Storage
1998	4.03	-0.65	-0.64	-1.82	-0.92	0.00
Scenario 1	4.07	-0.69	-0.63	-1.90	-0.85	0.00
Scenario 2	4.06	-0.66	-0.62	-1.86	-0.92	0.00
Scenario 3	4.01	-0.62	-0.59	-1.88	-0.92	0.00

Figure 34. Simulated flow budget for hydrologic budget areas (a) 22, (b) 23, and (c) 24 in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, for 1998 and scenarios 1, 2, and 3. (A negative value indicates flow out of the hydrologic budget area. Scenario totals may not equal zero as a result of rounding; mg/L, milligrams per liter.)

Scenario 2—Withdrawals Based on Population Projections by County

Simulated 2010 water levels and changes in simulated water levels from 1998 to 2010 for scenario 2 are shown by aquifer in figures 35 to 50. Maximum increases and (or) declines in simulated water levels in this scenario and the baseline (1998) simulation are discussed. Flow-budget components that differ (typically more than 0.1 Mgal/d in an HBA) between this scenario and the baseline simulation are discussed.

Atlantic City 800-Foot Sand

The location of ground-water withdrawals and the simulated potentiometric surface in the Atlantic City 800-foot sand are shown in figure 35. Simulated water levels range from 80 ft below NGVD of 1929 in coastal Atlantic County to 60 ft above NGVD of 1929 near the updip extent of the aquifer in western Atlantic County. The 250-mg/L isochlor (Lacombe and Rosman, 2001) traverses the tip of Cape May from its southernmost point, then extends north offshore. The change in simulated water levels from 1998 to 2010 is shown in figure 36. The projected increase in withdrawals resulted in a simulated water-level decline of 9 ft in coastal Atlantic County—approximately 5 ft less than in scenario 1 in the same area (fig. 7).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figure 8. Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBAs 1 and 2, most recharge to the aquifer is from lateral inflow from the Kirkwood-Cohansey aquifer system updip from the Atlantic City 800-foot sand (fig. 2), and inflow from the overlying aquifer. Pumpage was increased 0.6 Mgal/d (11 percent) in HBA 1 and 1.44 Mgal/d (9 percent) in HBA 2; lateral inflow from the updip area increased 0.25 Mgal/d (5 percent) in HBA 1 and 0.41 Mgal/d (3 percent) in HBA 2; inflow from the overlying aquifer increased 0.23 Mgal/d (4 percent) in HBA 1 and 0.46 Mgal/d (3 percent) in HBA 2; and lateral inflow from the aquifer offshore increased 0.12 Mgal/d (2 percent) in HBA 1 and 0.5 Mgal/d (3 percent) in HBA 2. The 250-mg/L isochlor (Lacombe and Rosman, 2001) is approximately 10 mi offshore of Atlantic County, and could move landward if ground-water withdrawals increase. (Locations of water-level and chloride-monitoring wells are shown in appendix 1 (fig. 1-1)). Pumpage in HBA 3, south of the 250-mg/L isochlor, was not increased and the changes in the flow-budget components were small (0.02 Mgal/d or less).

Pumpage in the flow budget for HBA 2 was 0.76 Mgal/d (5 percent) less in scenario 2 than in scenario 1; inflow from the overlying aquifer was 0.2 Mgal/d (1 percent) less; inflow from the updip area was 0.19 Mgal/d (1 percent) less; and inflow from the aquifer offshore was 0.27 Mgal/d (2 percent) less.

Piney Point Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Piney Point aquifer are shown in figure 37. Simulated water levels range from 60 ft below NGVD of 1929 at a cone of depression in coastal Ocean County to 120 ft above NGVD of 1929 in western Ocean and eastern Burlington Counties. Water levels are also 60 ft below NGVD of 1929 in the Delaware Bay because of pumping in Delaware. The change in simulated water levels from 1998 to 2010 is shown in figure 38. The projected increase in withdrawals resulted in a maximum simulated water-level decline of 11 ft in coastal northern Ocean County near the updip extent of the aquifer— approximately 4 ft more than in scenario 1 in the same area (fig. 10).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figure 11. Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. Pumpage was increased 0.46 Mgal/d (11 percent) in HBA 4 and 0.06 Mgal/d (1 percent) in HBA 5. Inflow from the overlying aquifer increased 0.37 Mgal/d (9 percent) in HBA 4 and 0.18 Mgal/d (4 percent) in HBA 5. Flow at the location of the 250-mg/L isochlor is from HBA 5 to the downdip area of the aquifer (not included in any HBA) increased 0.04 Mgal/d (1 percent).

Vincentown Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Vincentown aquifer are shown in figure 39. Simulated water levels range from NGVD of 1929 near the Delaware River in Salem County to 140 ft above NGVD of 1929 in southwestern Monmouth County. Changes in simulated water levels from 1998 to 2010 are shown in figure 40. The projected increase in withdrawals resulted in a simulated water-level decline of 2 ft in a small area in northern Ocean and southern Monmouth Counties. The simulated water levels in scenario 2 are nearly identical (within 1 ft) to those in scenario 1 (fig. 13).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figures 14 (for the confined part of the aquifer) and 15 (for the outcrop). Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 6, pumpage was increased 0.11 Mgal/d (1 percent); however, inflow from the overlying aquifer decreased 0.09 Mgal/d (1 percent), but outflow to the underlying aquifer also decreased 0.18 Mgal/d (2 percent). Pumpage was not changed in HBA 7, but inflow from the overlying aquifer increased 0.32 Mgal/d (1 percent), and outflow to the underlying aquifer also increased 0.36 Mgal/d (2 percent).

Pumpage was not changed in HBA 30 in the outcrop of the Vincentown aquifer and there is no pumpage in HBAs 31 and 32, also in the outcrop. The change in the flow-budget

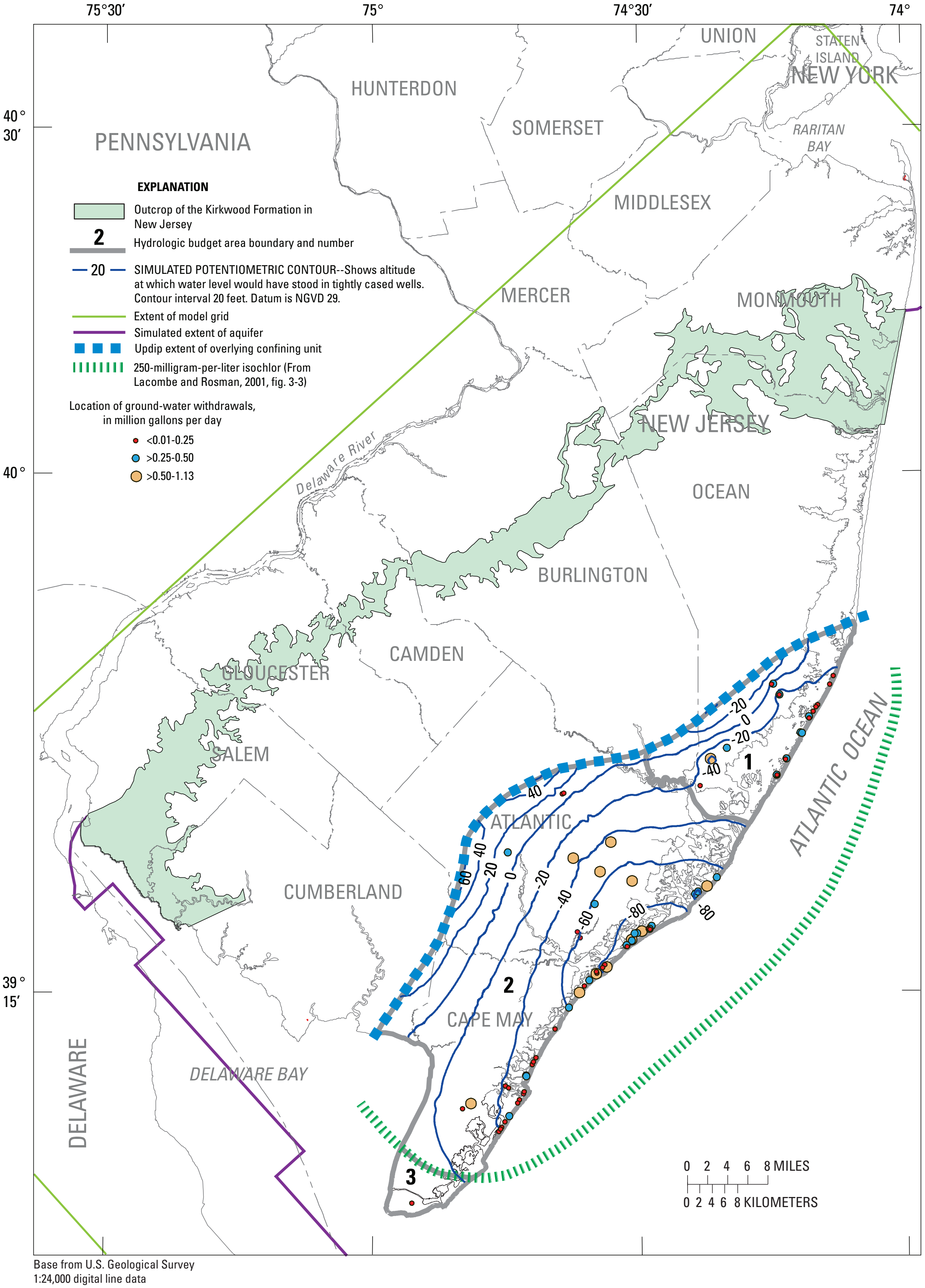


Figure 35. Hydrologic budget areas in the Atlantic City 800-foot sand and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

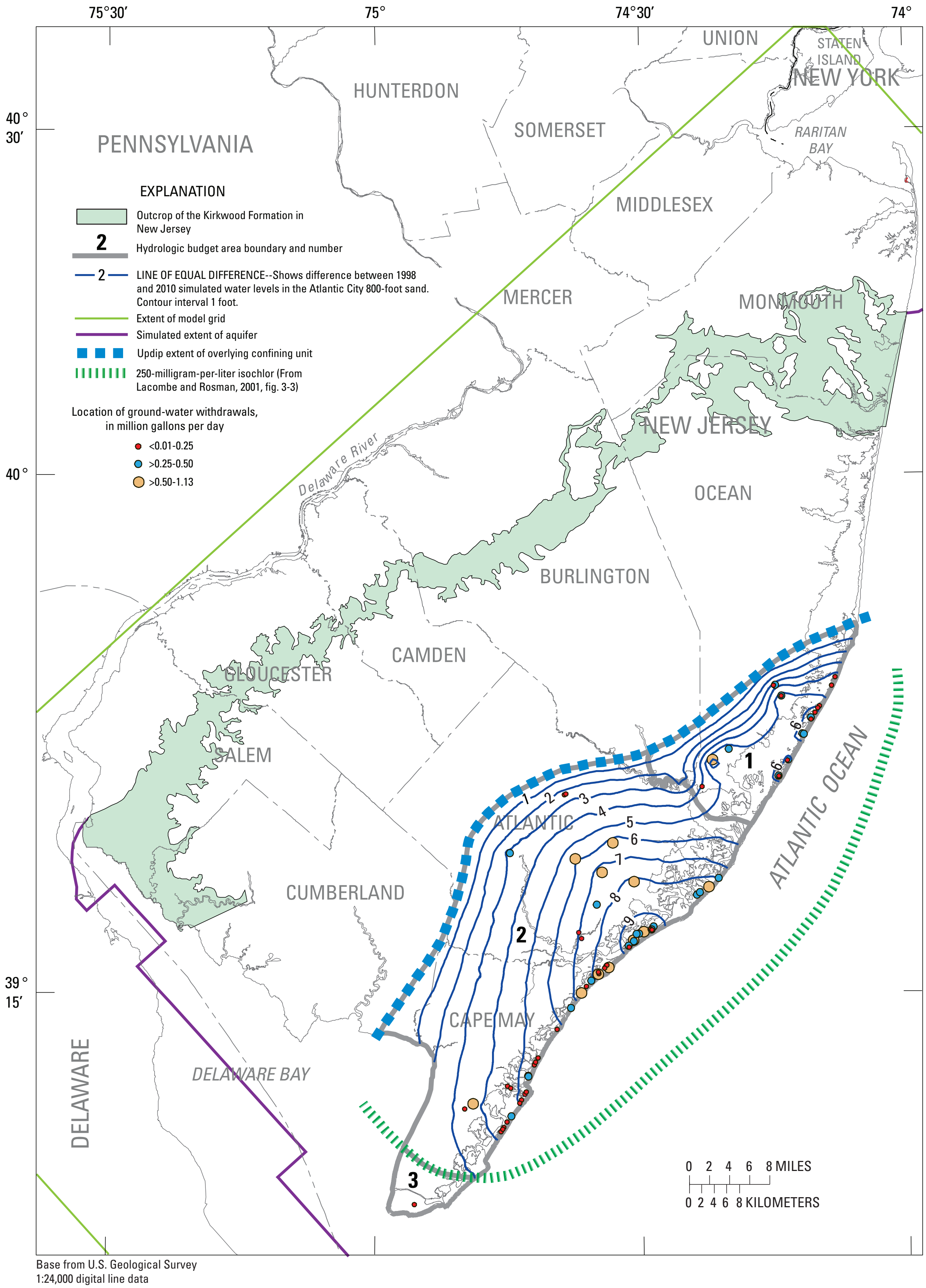


Figure 36. Change in simulated water levels (1998 to 2010) in the Atlantic City 800-foot sand, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

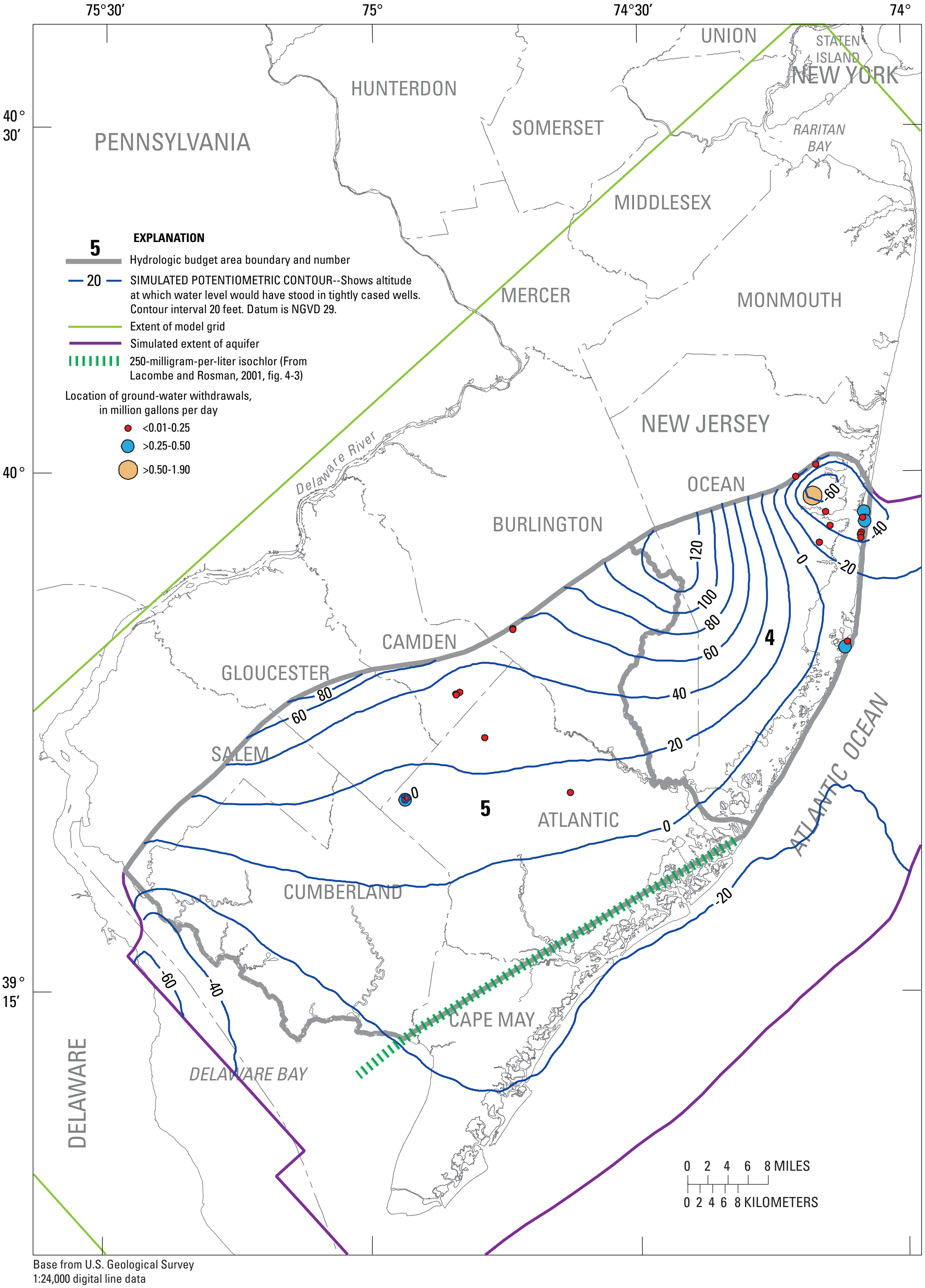


Figure 37. Hydrologic budget areas in the Piney Point aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

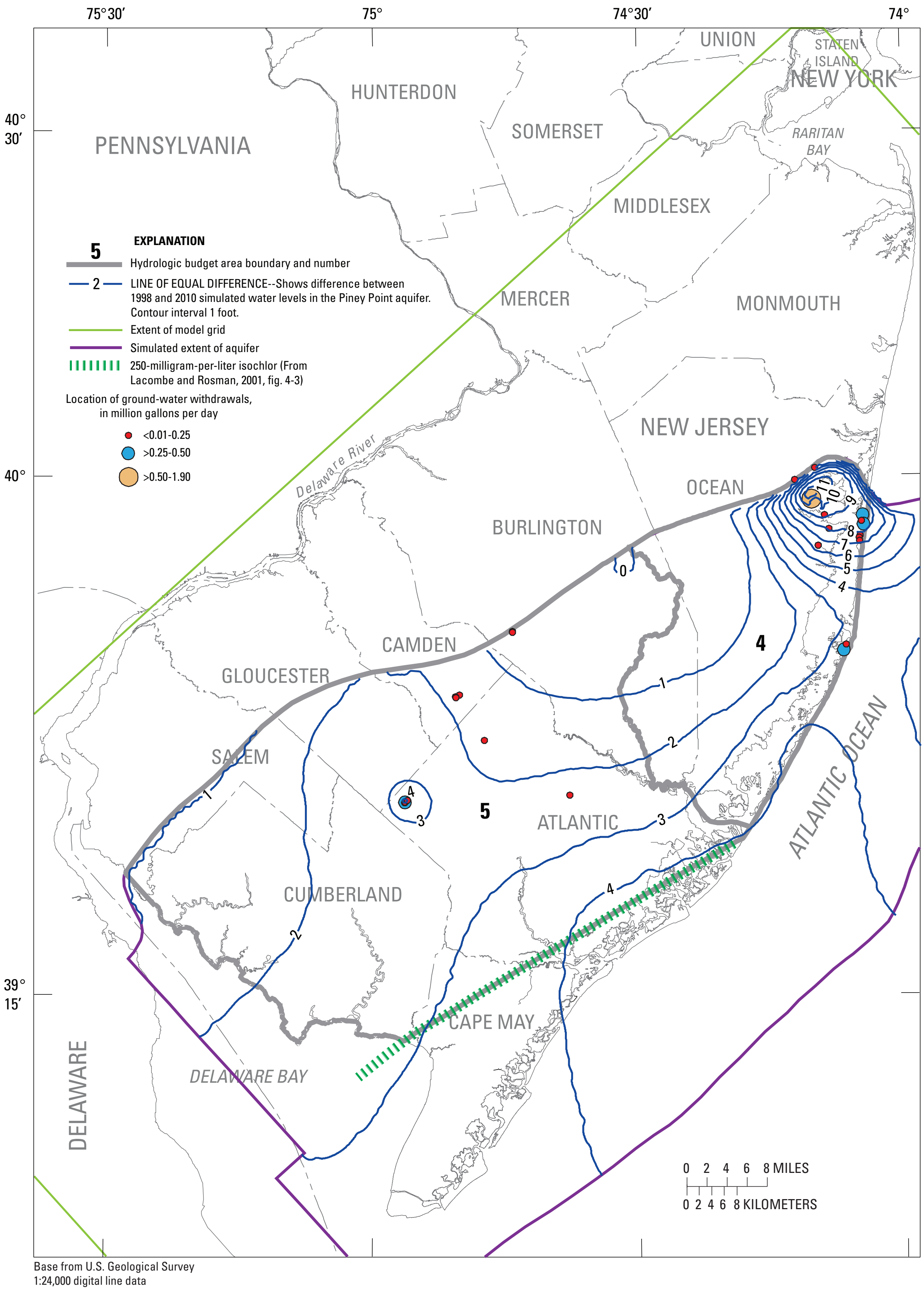


Figure 38. Change in simulated water levels (1998 to 2010) in the Piney Point aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

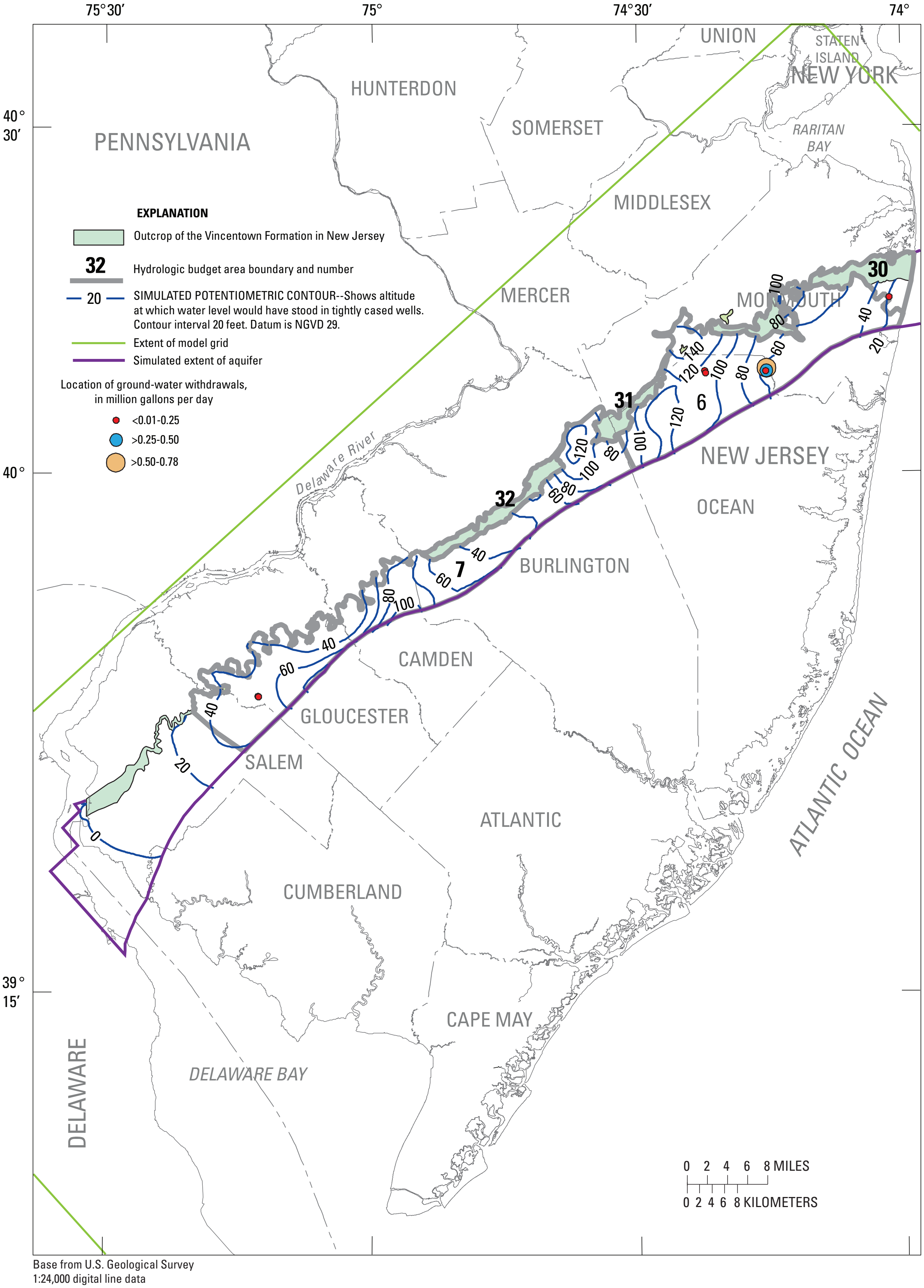
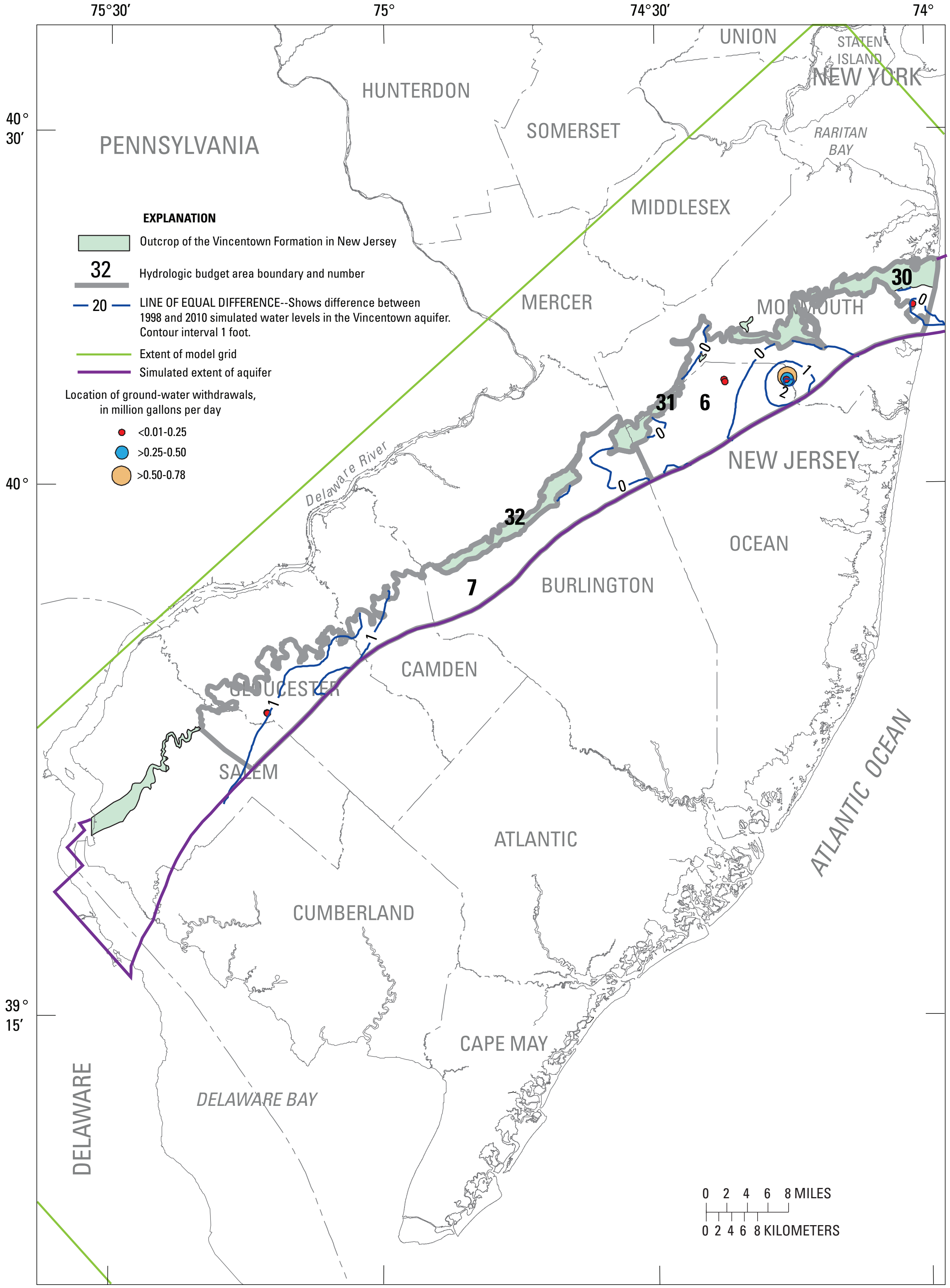


Figure 39. Hydrologic budget areas in the Vincentown aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 40. Change in simulated water levels (1998 to 2010) in the Vincentown aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

components from 1998 to 2010 was small (0.1 Mgal/d (1 percent) or less) in HBAs 30 and 31. In HBA 32, leakage to streams decreased 0.21 Mgal/d (1 percent), and inflow from storage decreased 0.14 Mgal/d (1 percent). The flow-budget components in all HBAs for this aquifer were similar to those in scenario 1.

Wenonah-Mount Laurel Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Wenonah-Mount Laurel aquifer are shown in figure 41. Simulated water levels range from 60 ft below NGVD of 1929 in coastal Ocean County to 120 ft above NGVD of 1929 in western Monmouth County and northwestern Ocean County. Changes in simulated water levels from 1998 to 2010 are shown in figure 42. The simulated water levels in scenario 2 recovered more than 24 ft in coastal Ocean County in Critical Area 1 because of mandated pumpage reductions in Critical Area 1, and declined 6 ft in central Gloucester County. The simulated water levels in scenario 2 recovered 2 ft less in southeastern Burlington County, and as much as 10 ft less in eastern Burlington County, than in scenario 1 (fig. 17).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figures 18 (for the confined part of the aquifer) and 19 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 8, pumpage was increased 0.05 Mgal/d (1 percent); outflow to storage decreased 0.38 Mgal/d (4 percent), but inflow from the overlying aquifer decreased 0.3 Mgal/d (3 percent). In HBA 9, pumpage was increased 0.11 Mgal/d (2 percent), but the changes in the other flow-budget components were small (0.07 Mgal/d (1 percent) or less). In HBA 10, pumpage was increased 0.2 Mgal/d (6 percent) and inflow from the overlying aquifer increased 0.1 Mgal/d (3 percent), but outflow to the downdip part of the aquifer (not included in any HBA) decreased 0.07 Mgal/d (2 percent). In HBA 11, pumpage was increased 0.24 Mgal/d (3 percent) and inflow from the overlying aquifer increased 0.24 Mgal/d (3 percent). Pumpage in HBA 12 was not changed but inflow from the overlying aquifer increased 0.15 Mgal/d (2 percent).

There was no pumpage in the outcrop (HBAs 33-37). However, in HBA 33, outflow to storage decreased 0.13 Mgal/d (1 percent), and outflow to the underlying aquifer increased 0.12 Mgal/d (1 percent). In HBAs 34 to 37, the change in flow-budget components from 1998 to 2010 was small (0.04 Mgal/d (1 percent) or less).

Englishtown Aquifer System

The location of ground-water withdrawals and the simulated potentiometric surface in the Englishtown aquifer system are shown in figure 43. The range in water levels is from 80 ft below NGVD of 1929 in coastal Ocean County to 120 ft above NGVD of 1929 in western Monmouth County. Changes in simulated water levels from 1998 to 2010 are shown in figure 44. Simulated water levels recovered 26 ft from 1998 to 2010 in Critical Area 1, where water levels are recovering from mandated reductions in pumpage that took place in the 1990s. The area of recovery corresponds to a similar area of recovery in the Wenonah-Mount Laurel aquifer. Simulated water levels in the southern part of Gloucester County declined 6 ft as a result of increased withdrawals in the overlying Wenonah-Mount Laurel aquifer.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figures 22 (for the confined part of the aquifer) and 23 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 13, pumpage was increased 0.44 Mgal/d (3 percent); inflow from the overlying aquifer increased 0.2 Mgal/d (1 percent) and outflow to storage decreased 0.43 Mgal/d (3 percent), but outflow to the underlying aquifer increased 0.27 Mgal/d (2 percent). Pumpage in HBA 14 was increased slightly (0.04 Mgal/d, less than 1 percent) and water from storage decreased 0.2 Mgal/d (1 percent), but inflow from the overlying aquifer increased 0.13 Mgal/d (1 percent).

Pumpage was not changed in HBA 38 in the outcrop but outflow to the underlying aquifer increased 0.16 Mgal/d (1 percent). There is no pumpage in HBA 39 in the outcrop, but outflow to storage decreased 0.5 Mgal/d (2 percent), and leakage to streams increased 0.23 Mgal/d (1 percent). The difference in flow-budget components was similar to that observed for this aquifer in scenario 1.

Upper Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Upper Potomac-Raritan-Magothy aquifer are shown in figure 45. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in eastern Gloucester, central Camden, and western Burlington Counties to 60 ft above NGVD of 1929 at the aquifer outcrop in Mercer and Middlesex Counties, and are about 40 ft below NGVD of 1929 in northeastern Ocean County. Changes in simulated water levels from 1998 to 2010 are shown in figure 46. The projected increase in withdrawals resulted in a simulated water-level decline of 5 ft in Middlesex County near the outcrop just outside Critical Area 1. There is a 3-ft recovery in simulated water levels from 1998 to 2010 in northeastern Camden County near the outcrop in Critical Area 2.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figures 26 (for the confined part of the aquifer) and 27 (for the outcrop). Values of simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 15, pumpage was increased 1.68 Mgal/d (7 percent), inflow from the overlying aquifer

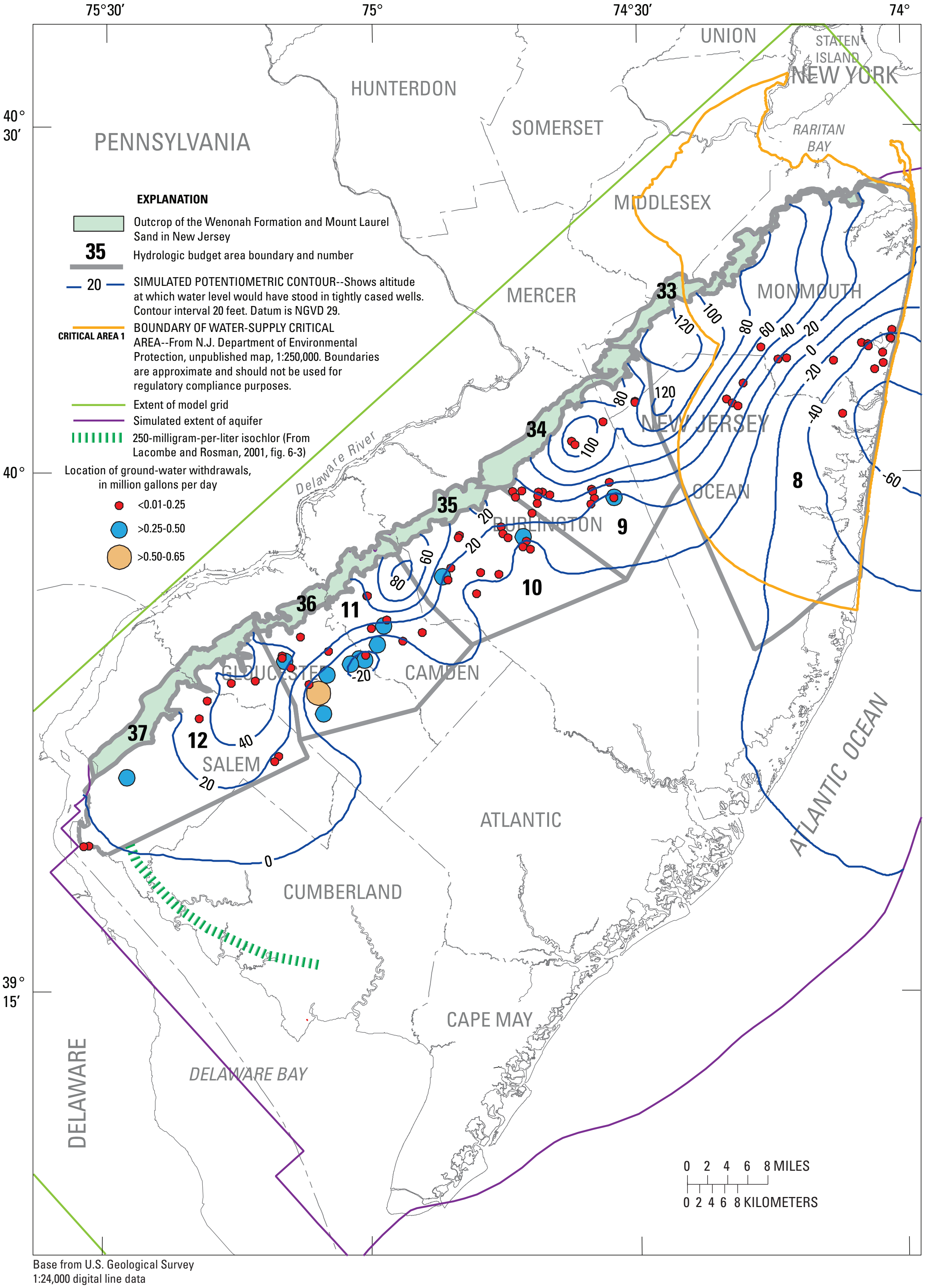


Figure 41. Hydrologic budget areas in the Wenonah-Mount Laurel aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

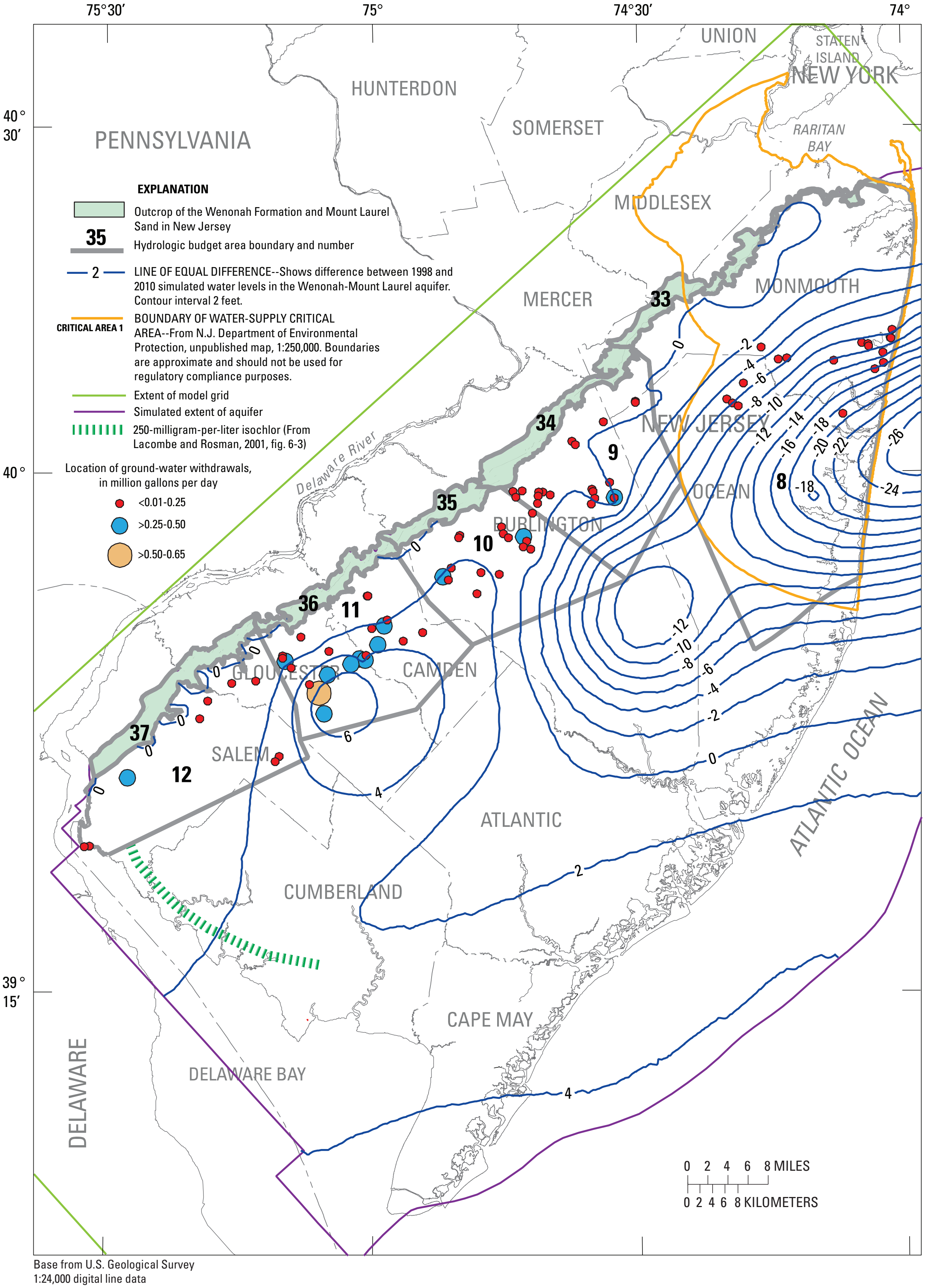


Figure 42. Change in simulated water levels (1998 to 2010) in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

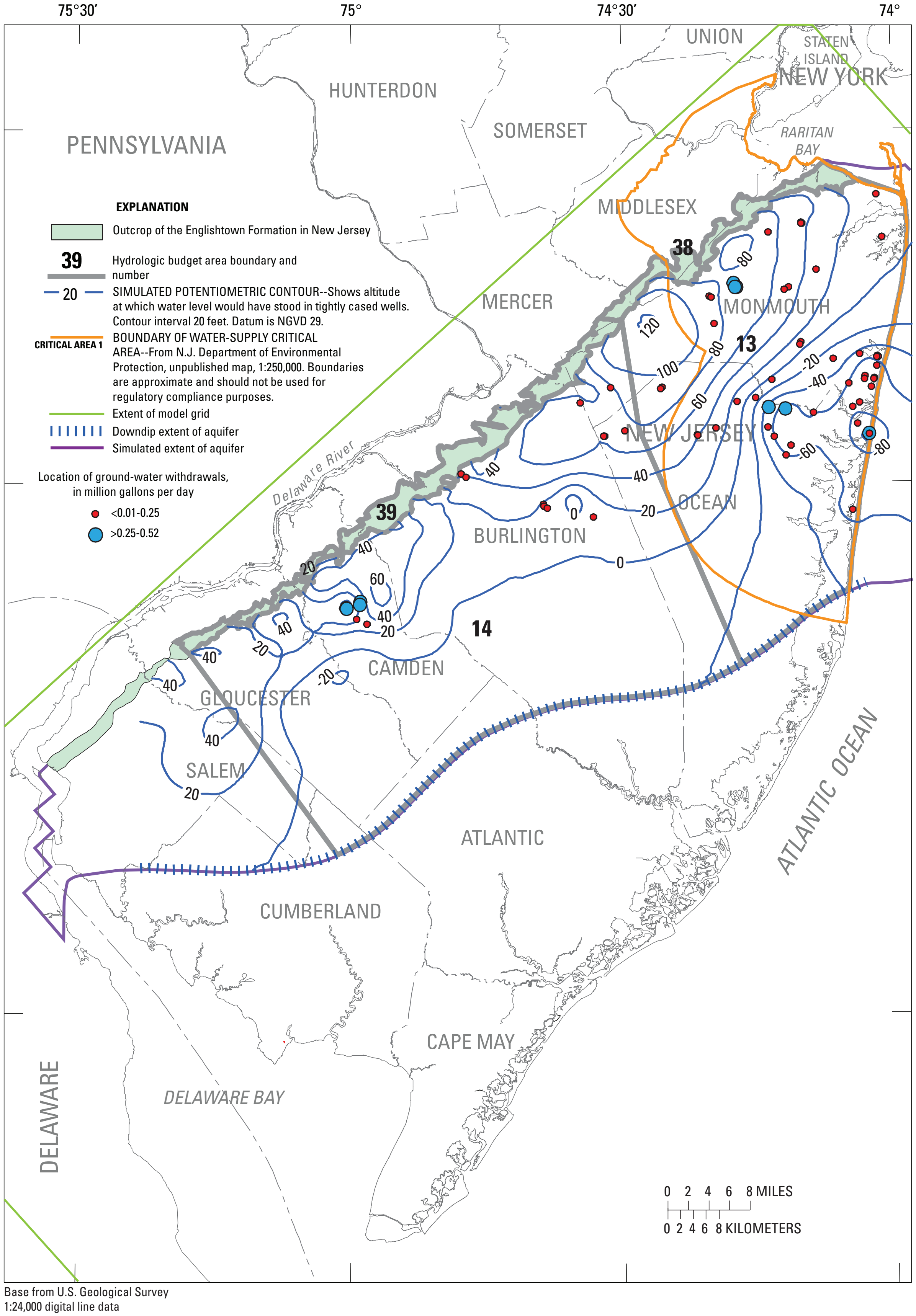


Figure 43. Hydrologic budget areas in the Englishtown aquifer system and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

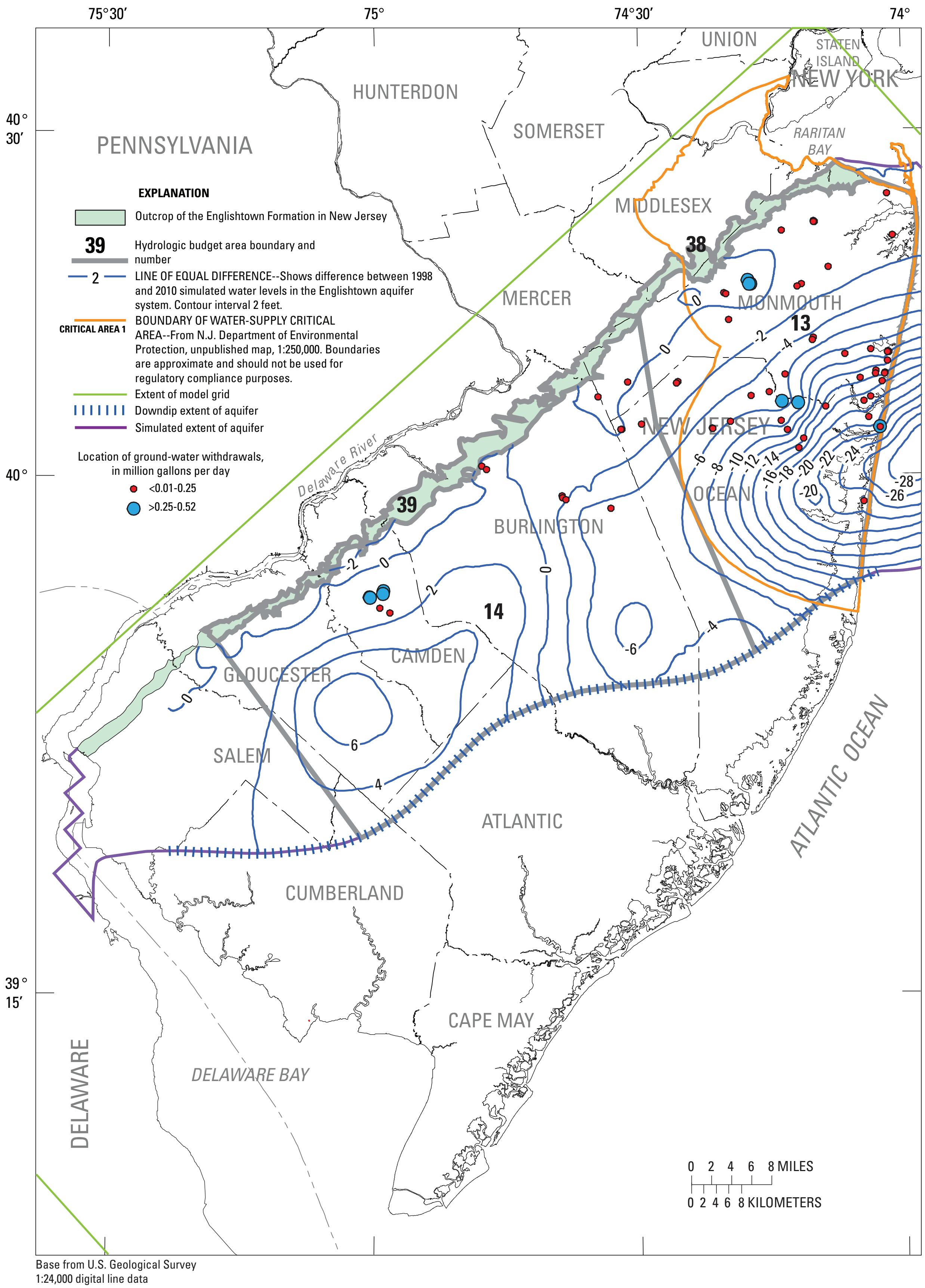


Figure 44. Change in simulated water levels (1998 to 2010) in the Englishtown aquifer system, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

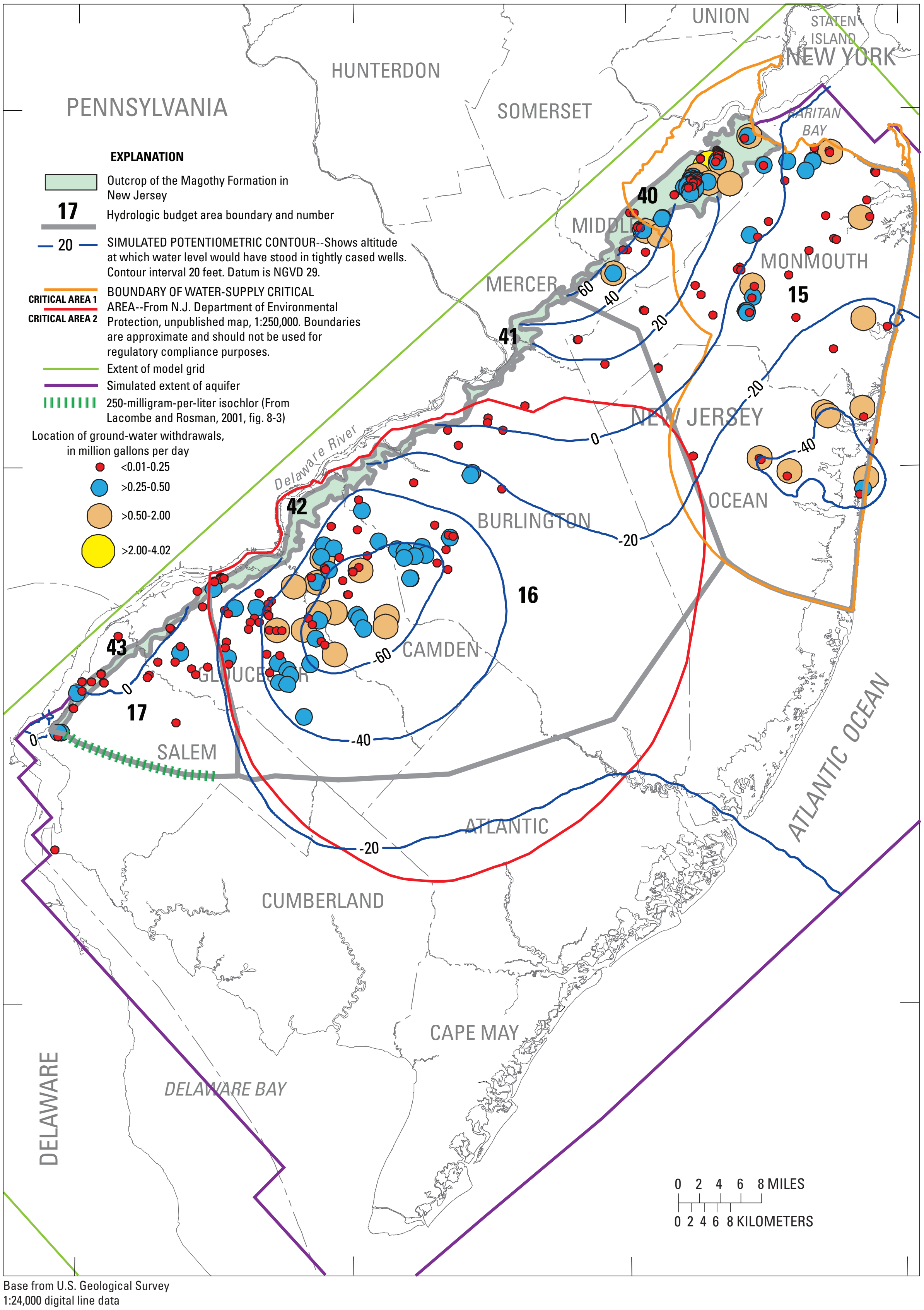


Figure 45. Hydrologic budget areas in the Upper Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

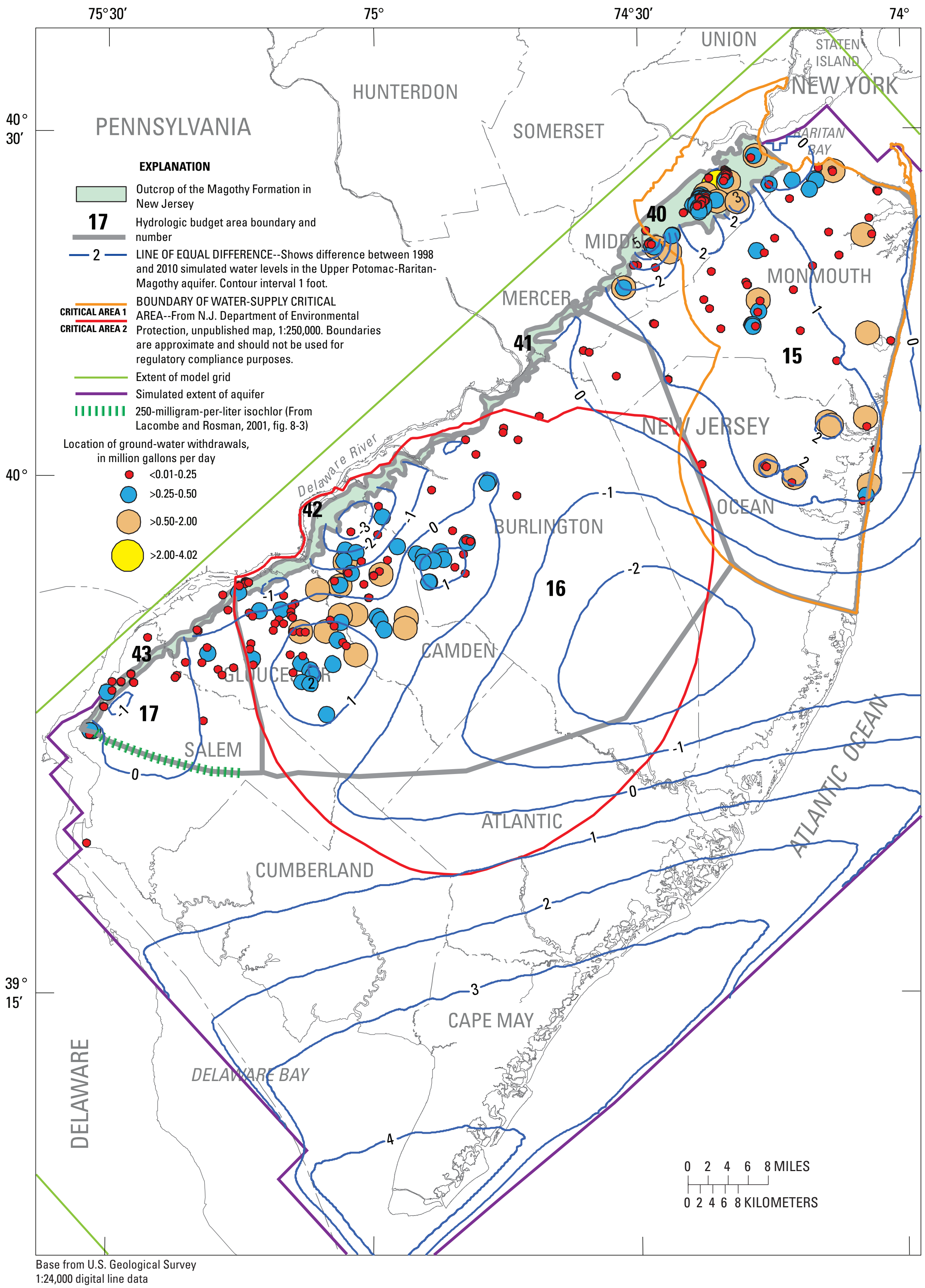


Figure 46. Change in simulated water levels (1998 to 2010) in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

increased 1.29 Mgal/d (5 percent), and lateral inflow from the downdip part of the aquifer (not included in any HBA) increased 0.6 Mgal/d (2 percent). Lateral inflow from the outcrop (HBA 40) decreased 0.31 Mgal/d (1 percent) when pumpage was increased in HBA 40. Pumpage in HBA 16 was increased 1.65 Mgal/d (5 percent); inflow from the overlying aquifer increased 3.89 Mgal/d (13 percent), but outflow to the underlying Middle Potomac-Raritan-Magothy aquifer also increased 2.14 Mgal/d (7 percent). Lateral inflow from HBA 42 in the outcrop decreased 0.43 Mgal/d (1 percent) and water to storage decreased 0.46 Mgal/d (1 percent). Pumpage in HBA 17 was increased slightly (0.04 Mgal/d, 1 percent), and inflow from the overlying aquifer increased 0.25 Mgal/d (4 percent), but outflow to HBA 16 increased 0.12 Mgal/d (2 percent).

Pumpage in HBA 40, in the outcrop in Middlesex County, was increased 0.77 Mgal/d (1 percent); leakage to streams decreased 1.8 Mgal/d (3 percent), inflow from storage decreased 1.81 Mgal/d (3 percent), and outflow to the underlying aquifer decreased 0.49 Mgal/d (1 percent). There is no pumpage in HBA 41 and the change in the flow-budget components was small (0.08 Mgal (1 percent) or less). Pumpage in HBA 42 in the outcrop was not changed, but induced leakage from the stream to the aquifer decreased 0.47 Mgal/d (1 percent); moreover, outflow to the underlying aquifer increased about 1.17 Mgal/d (4 percent) because of the effects of increased pumping in the underlying Middle Potomac-Raritan-Magothy aquifer. Outflow to storage decreased 1.2 Mgal/d (4 percent). In HBA 43 in the outcrop, pumpage was increased slightly (0.01 Mgal/d, less than 1 percent); leakage to streams increased 0.16 Mgal/d (1 percent) and outflow to HBA 17 decreased 0.08 Mgal/d (1 percent).

Changes in the flow budgets for HBAs 41 to 43 are similar to those observed in scenario 1. In HBA 40, however, pumpage was 0.68 Mgal/d (1 percent) less and leakage to streams was 0.64 Mgal/d (less than 1 percent) more than in scenario 1.

Middle Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Middle Potomac-Raritan-Magothy aquifer are shown in figure 47. Simulated water levels range from 40 ft below NGVD of 1929 in Critical Area 2 in eastern Gloucester, Camden, and western Burlington Counties to 80 ft above NGVD of 1929 near the outcrop in Middlesex County. The change in simulated water levels from 1998 to 2010 is shown in figure 48. The projected increase in withdrawals resulted in a simulated water-level decline of 6 ft in Middlesex County near the outcrop and the boundary of Critical Area 1. The decline was 3 ft less than in scenario 1 in this area (fig. 29).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figures 30 (for the confined part of the aquifer) and 31 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 18, pumpage was increased 1.18 Mgal/d (6 percent); lateral inflow from the outcrop (HBA 44) increased 0.66 Mgal/d (3 percent), inflow at the location of the 250-mg/L isochlor increased 0.45 Mgal/d (2 percent), and lateral inflow from HBA 19 increased 0.17 Mgal/d (1 percent), but inflow from the overlying aquifer decreased 0.53 Mgal/d (2 percent). Outflow to the underlying aquifer also decreased 0.22 Mgal/d (1 percent). In HBA 19, pumpage was increased 1.27 Mgal/d (3 percent), and inflow from the overlying aquifer increased 3.47 Mgal/d (7 percent), but outflow to the underlying aquifer also increased 1.93 Mgal/d (4 percent). Outflow to storage decreased 0.49 Mgal/d (1 percent). Also, inflow at the 250-mg/L isochlor increased 0.12 Mgal/d (less than 1 percent). Pumpage in HBA 20 was increased 0.08 Mgal/d (1 percent) and flow-budget components increased or decreased as much as 0.08 Mgal/d (1 percent or less). Pumpage in HBA 21 was not changed, but outflow to storage decreased 0.03 Mgal/d (4 percent).

Changes in the simulated flow budget indicate that in HBA 44 in the outcrop, pumpage was increased 0.27 Mgal/d (less than 1 percent); however, leakage to streams decreased 2.06 Mgal/d (3 percent) because of an increase in pumpage in the adjacent budget area, HBA 18, and inflow from storage decreased 1.13 Mgal/d (1 percent). HBA 44 is underlain by bedrock, which is represented by a no-flow boundary in the New Jersey RASA model (Voronin, 2004); therefore, there is no flow to or from an underlying aquifer. There is a 250-mg/L isochlor located onshore near Raritan Bay in HBA 44 (fig. 47); however, lateral inflow from the aquifer offshore (not included in any HBA) did not change. In HBA 45, pumpage was increased 0.64 Mgal/d (less than 1 percent); outflow to the underlying aquifer decreased 0.27 Mgal/d (less than 1 percent) and lateral outflow to HBA 19 decreased 0.7 Mgal/d (1 percent), but leakage to streams increased 0.98 Mgal/d (1 percent). There also was a decrease in water to storage of 0.65 Mgal/d (less than 1 percent). In HBA 46, pumpage was increased 0.09 Mgal/d (less than 1 percent); leakage to streams increased 0.49 Mgal/d (2 percent), but outflow to storage decreased 0.54 Mgal/d (2 percent).

When the HBA 18 flow budgets for scenarios 1 and 2 are compared, pumpage was 0.45 Mgal/d (2 percent) less in scenario 2 than in scenario 1; lateral inflow from the outcrop (HBA 44) was 0.16 Mgal/d (1 percent) less, and inflow from the overlying aquifer was 0.14 Mgal/d (less than 1 percent) less in scenario 2 than in scenario 1. When the HBA 19 flow budgets for scenarios 1 and 2 are compared, pumpage was 0.12 Mgal/d (1 percent) greater in scenario 2 than in scenario 1, and inflow from the overlying aquifer was 0.33 Mgal/d (1 percent) greater in scenario 2 than in scenario 1. When the HBA 45 flow budgets for scenarios 1 and 2 are compared, pumpage was 0.54 Mgal/d (1 percent) less in scenario 2 than in scenario 1, leakage to streams was 1.15 Mgal/d (1 percent) greater, and outflow to the underlying Lower Potomac-Raritan-Magothy aquifer was 0.53 Mgal/d (less than 1 percent) less in scenario 2 than in scenario 1. Outflow to the underly-

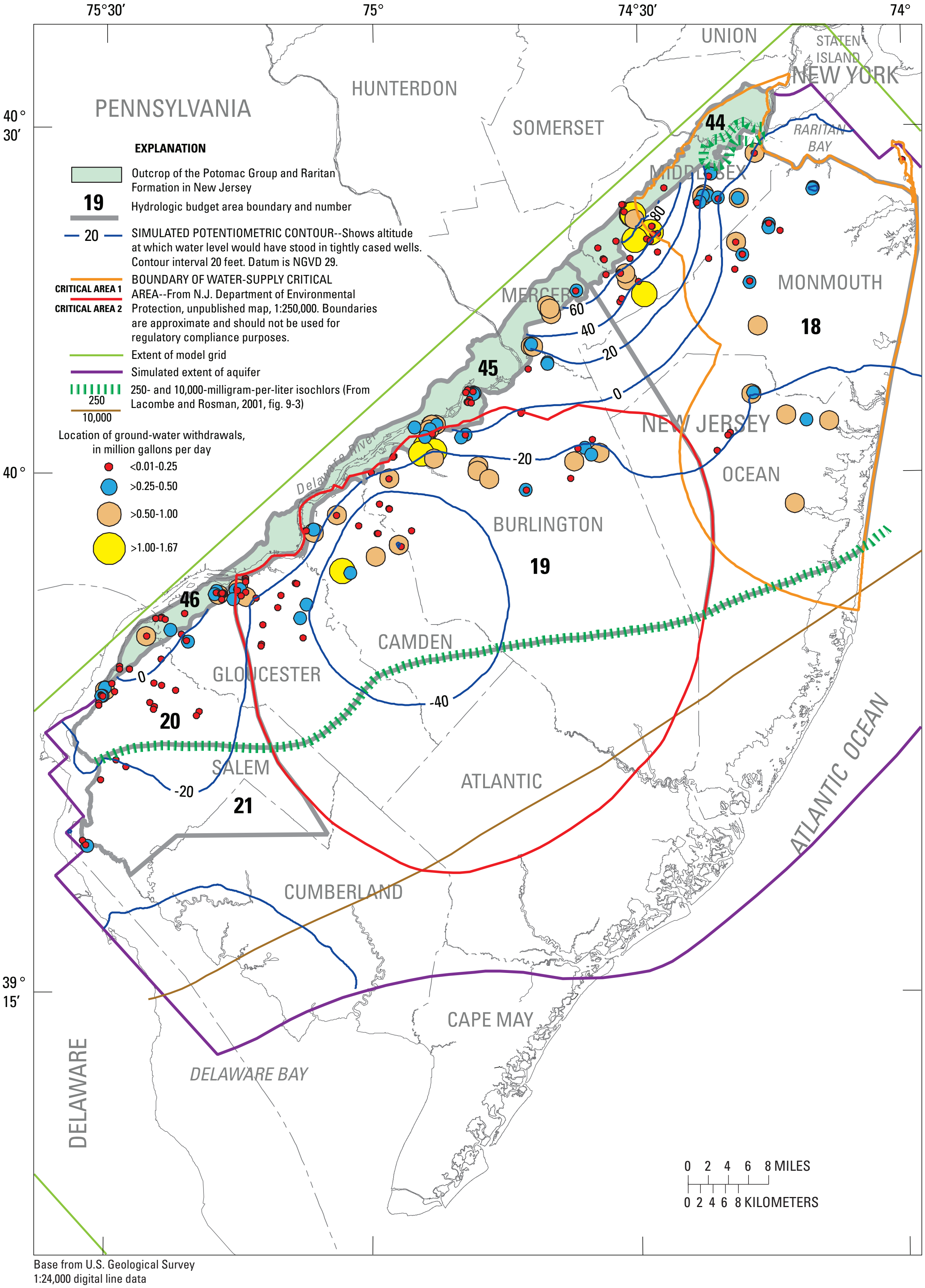


Figure 47. Hydrologic budget areas in the Middle Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

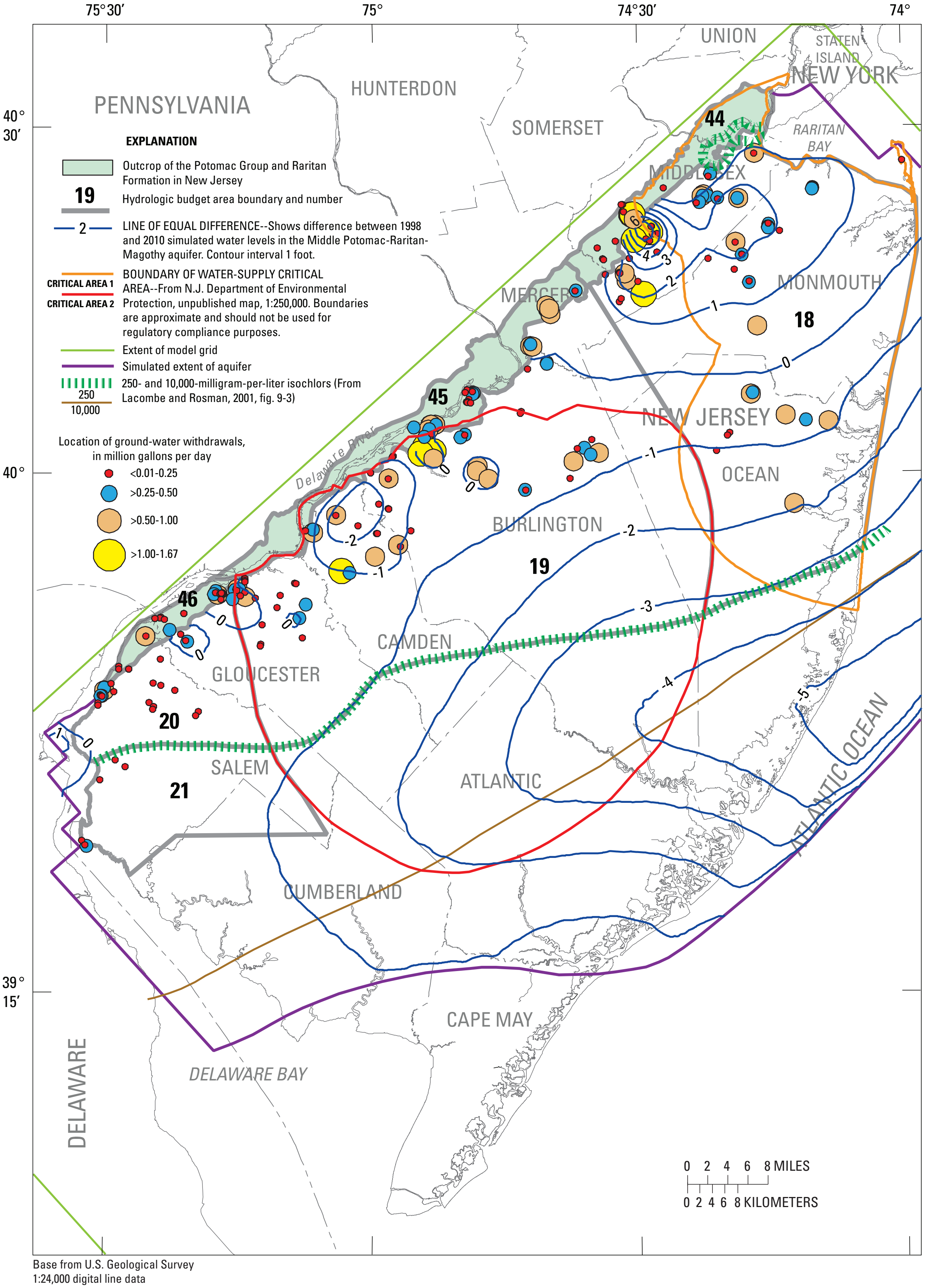


Figure 48. Change in simulated water levels (1998 to 2010) in the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)

ing Lower Potomac-Raritan-Magothy aquifer was less in scenario 2 than in scenario 1 because pumpage in the Lower Potomac-Raritan-Magothy aquifer (HBA 22) was 1.14 Mgal/d (3 percent) less in scenario 2 (fig. 34) than in scenario 1. The flow budgets for HBAs 20 and 21 and HBAs 44 and 46 in the outcrop were similar (0.17 Mgal/d (1 percent) or less) in scenarios 1 and 2.

Lower Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated 2010 potentiometric surface in the Lower Potomac-Raritan-Magothy aquifer are shown in figure 49. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in central Camden County to NGVD of 1929. Changes in simulated water levels from 1998 to 2010 are shown in figure 50. There is a 2-ft recovery in simulated water levels from 1998 to 2010 in northeastern Camden County in Critical Area 2.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 2 and for the baseline (1998) simulation is shown in figure 34. Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 22, pumpage was increased 1.81 Mgal/d (4 percent); inflow from the overlying Middle Potomac-Raritan-Magothy aquifer increased 1.7 Mgal/d (4 percent), and inflow from the downdip part of the aquifer (not included in any HBA) increased 0.1 Mgal/d (less than 1 percent). There is no pumpage in HBA 23, which is bounded by the 250-mg/L isochlor on the east and west. The flow direction at the 250-mg/L isochlor is from HBA 23 (saltier water) to HBA 22 (fresher water), and from HBA 24 (fresher water) to HBA 23 (saltier water). Flow from HBA 23 to HBA 22 increased 0.01 Mgal/d (less than 1 percent) in this scenario. The pumpage in HBA 24 was not changed and the change in flow-budget components was 0.04 Mgal/d (1 percent) or less.

In HBA 22, pumpage was increased 1.14 Mgal/d (3 percent) more in scenario 1 than in scenario 2, resulting in 1.05 Mgal/d (2 percent) less inflow from the overlying aquifer in scenario 2 than in scenario 1. The flow budgets for HBAs 23 and 24 are similar (0.07 Mgal/d (1 percent) or less) in scenarios 1 and 2.

Scenario 3—Restrictions on Withdrawals in Critical Areas

Pumpage in scenario 3 was changed at selected wells in or adjacent to Critical Areas 1 and 2 in the Wenonah-Mount Laurel and Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, and the Englishtown aquifer system. Simulated 2010 water levels for the confined aquifers and changes in simulated water levels from 1998 to 2010 for scenario 3 are shown in figures 51 to 60. Simulated water levels for the Vincentown and Piney Point aquifers and the Atlantic City 800-foot sand in scenario 3 are nearly identical to those in scenario 2 because the pumpage in those two scenarios is equal; therefore, the simulated water levels in these aquifers for scenario 3 are not shown in this report. Flow budgets for scenario 3 are given for all aquifers, however (figs. 8, 11, 14, 15, 18, 19, 22, 23, 26, 27, 30, 31, and 34). Maximum increases and declines in simulated water levels between this scenario and the baseline (1998) simulation, and between scenario 3 and scenario 2, are discussed. The HBAs with the largest changes in flow budgets between scenario 3 and the baseline (1998) simulation, and between scenario 3 and scenario 2, are discussed.

Wenonah-Mount Laurel Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Wenonah-Mount Laurel aquifer are shown in figure 51. Simulated water levels range from 60 ft below NGVD of 1929 in southeastern Monmouth and coastal Ocean Counties to 120 ft above NGVD of 1929 in western Monmouth County and northwestern Ocean County. Changes in simulated water levels from 1998 to 2010 are shown in figure 52. Simulated water levels recovered more than 24 ft as a result of the decrease in withdrawals from the Wenonah-Mount Laurel aquifer and the underlying Englishtown aquifer system in Critical Area 1. The simulated water levels in scenario 3 are similar to those in scenario 2 (fig. 41).

The simulated 2010 flow budget for each HBA in this aquifer for scenario 3 and for the baseline (1998) simulation is shown in figures 18 (for the confined part of the aquifer) and 19 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. Changes from the baseline simulation are largest in HBA 8 in Critical Area 1 and HBA 10 in western Burlington County. In HBA 8, pumpage was increased 0.01 Mgal/d (less than 1 percent), but inflow from the overlying aquifer decreased 0.44 Mgal/d (5 percent); outflow to storage decreased 0.34 Mgal/d (3 percent). In HBA 10, pumpage was increased 0.16 Mgal/d (5 percent) and inflow from the overlying aquifer increased 0.05 Mgal/d (1 percent). There are no withdrawals in the outcrop areas (HBAs 33 to 37), and changes in the flow-budget components were 0.11 Mgal/d (1 percent) or less.

Differences between the flow budgets for scenarios 2 and 3 are largest in HBA 8 in Critical Area 1 and in HBA 11 in Camden and Gloucester Counties. In HBA 8 in scenario 3, pumpage was decreased 0.04 Mgal/d (1 percent); inflow from the overlying aquifer decreased 0.14 Mgal/d (2 percent), and outflow to the underlying aquifer decreased 0.14 Mgal/d (1 percent) from scenario 2. In HBA 11 in scenario 3, pumpage was decreased 0.23 Mgal/d (3 percent); inflow from the overlying aquifer decreased 0.19 Mgal/d (2 percent), and outflow to the underlying aquifer decreased 0.05 Mgal/d (less than 1 percent) from scenario 2.

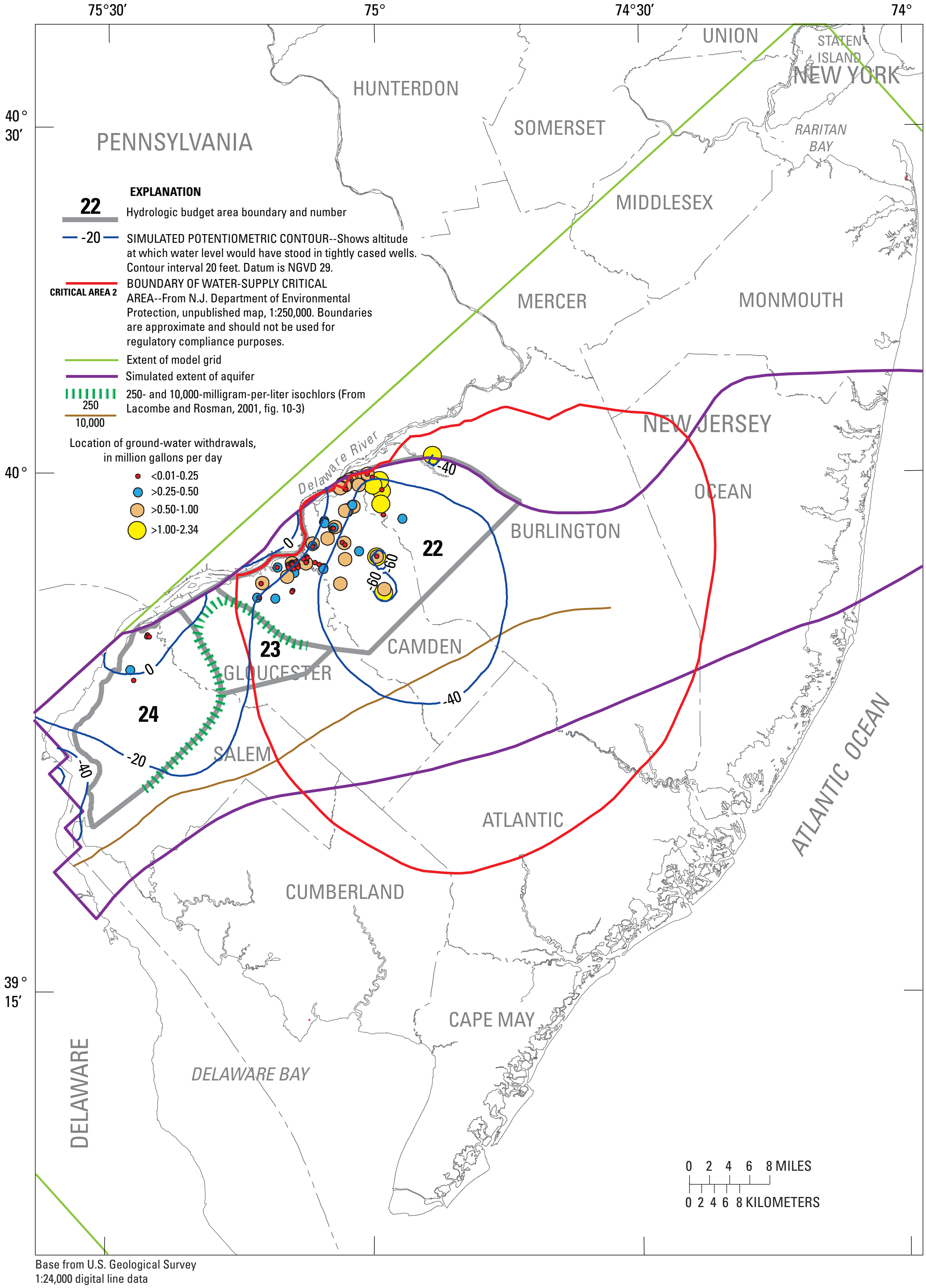


Figure 49. Hydrologic budget areas in the Lower Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 2, New Jersey Coastal Plain.

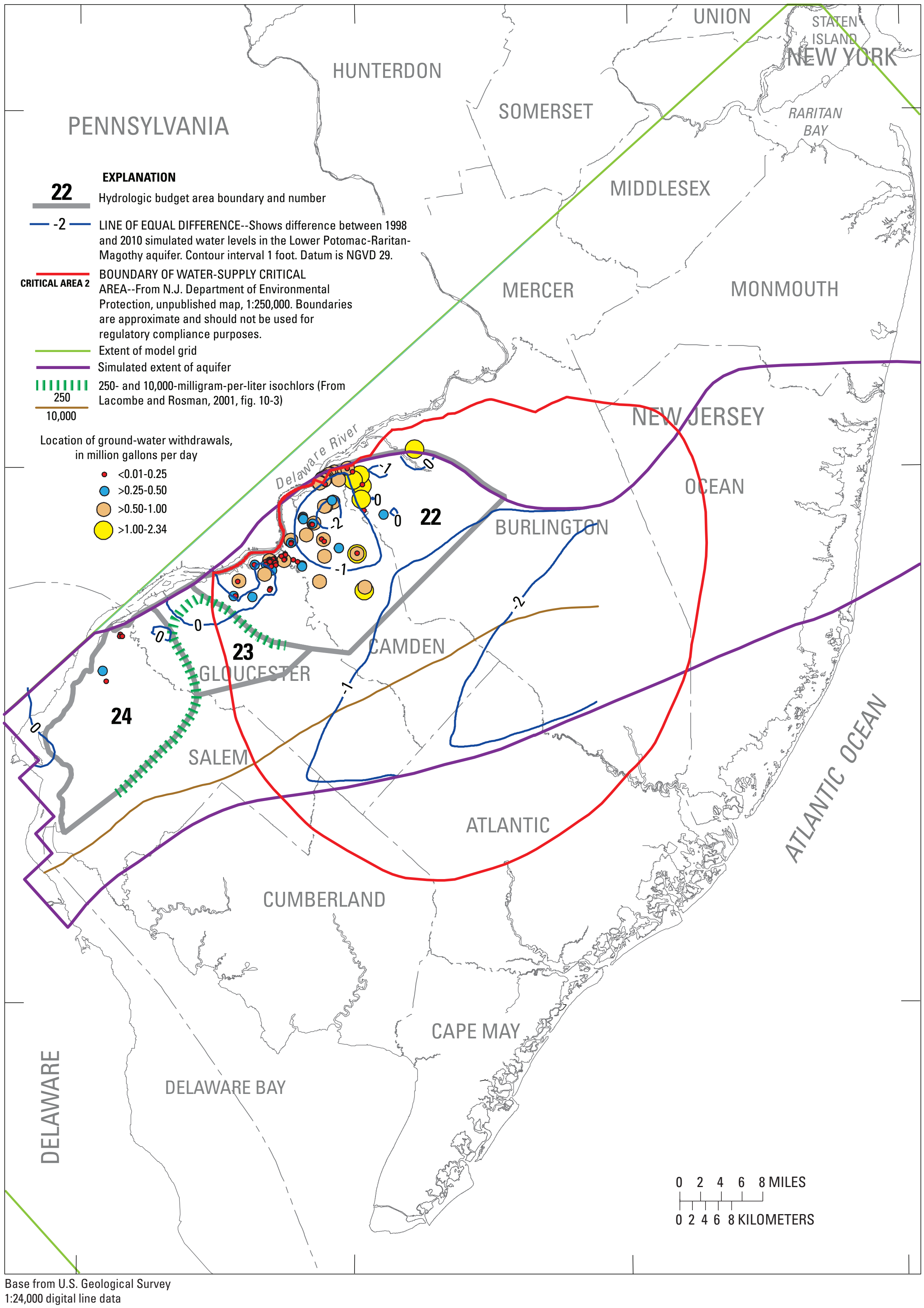
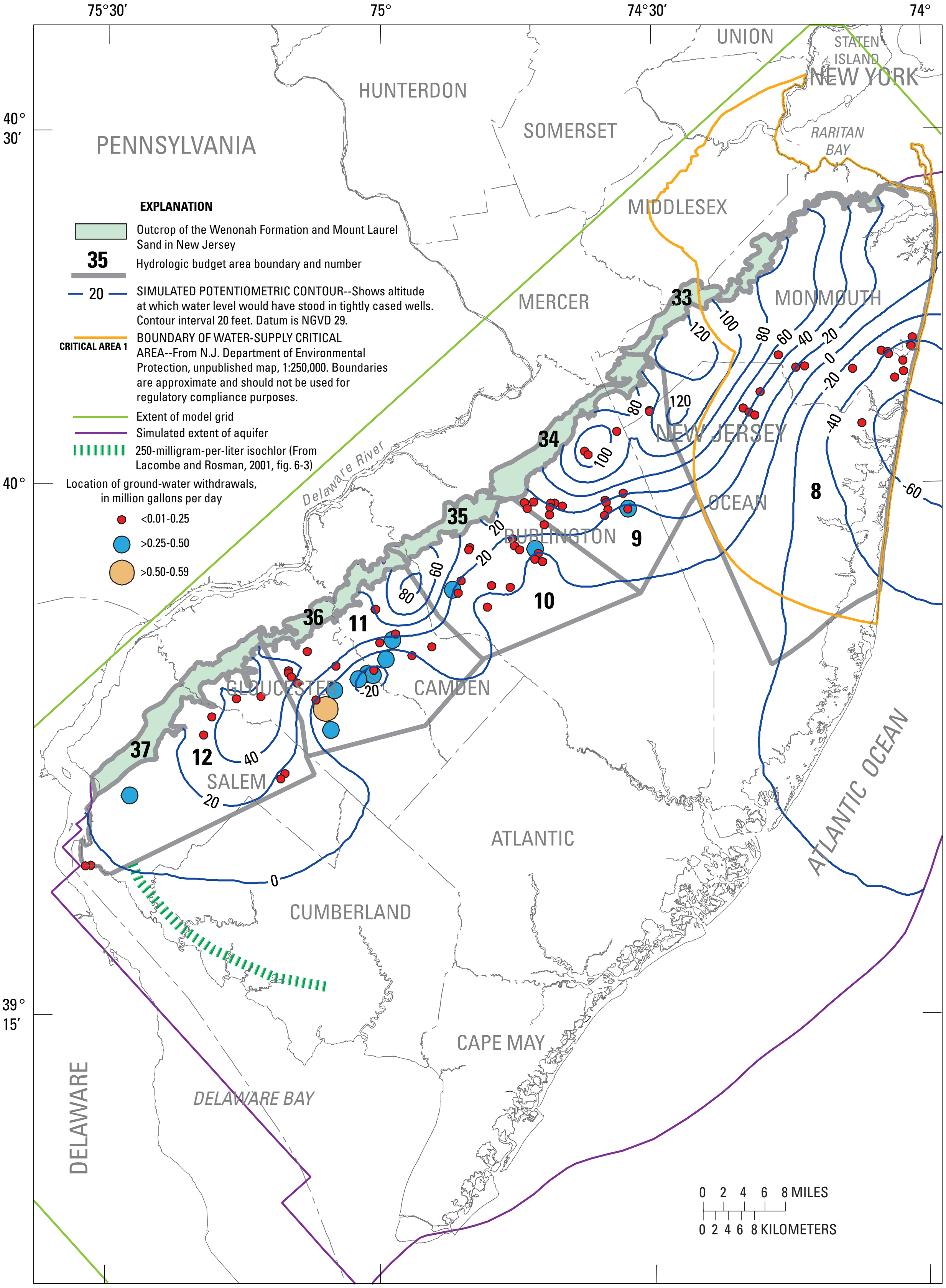


Figure 50. Change in simulated water levels (1998 to 2010) in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Positive value indicates water-level decline.)



Base from U.S. Geological Survey
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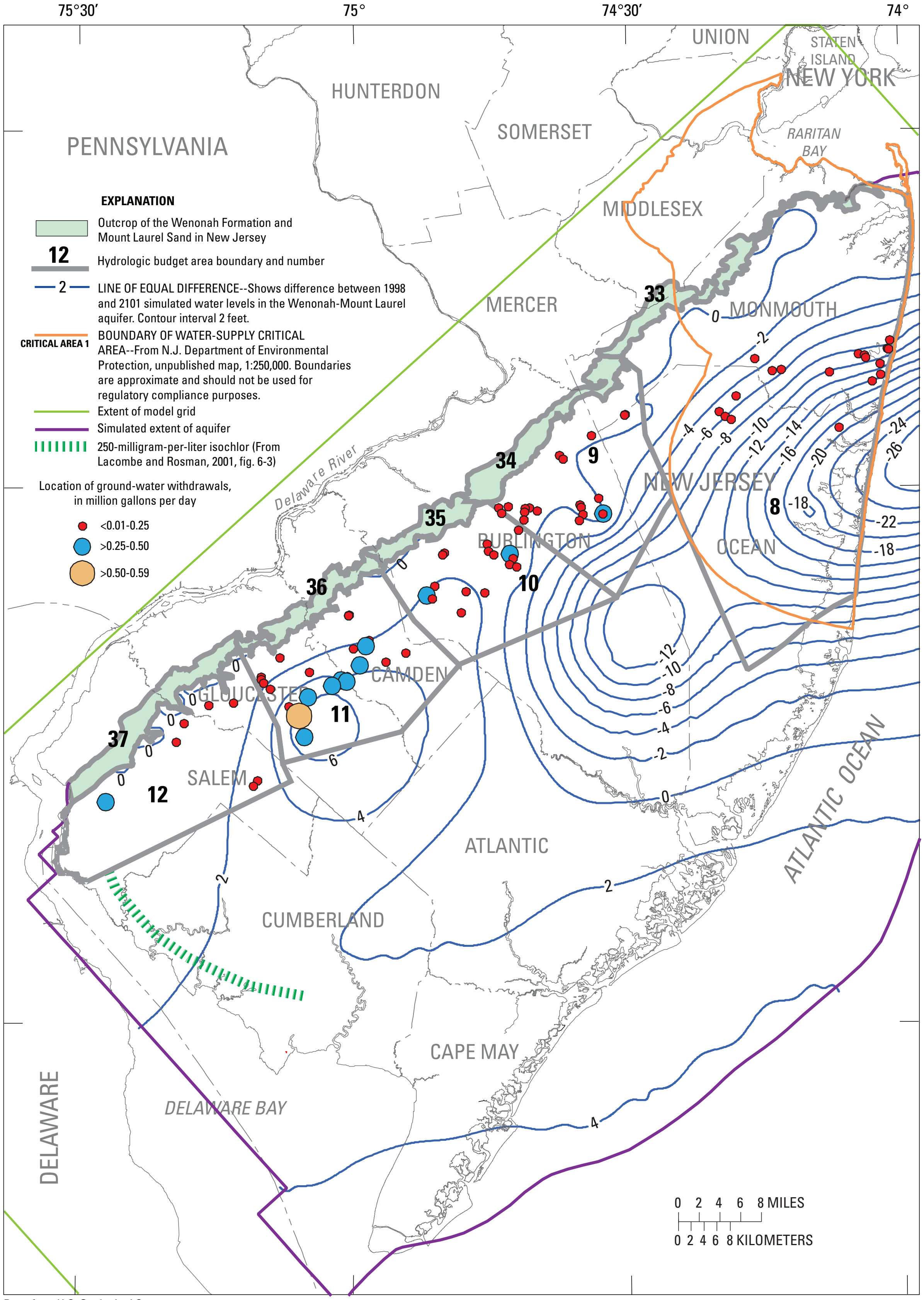
Figure 51. Hydrologic budget areas in the Wenonah-Mount Laurel aquifer and simulated potentiometric surface in 2010 for scenario 3, New Jersey Coastal Plain.



Base from U.S. Geological Survey
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Figure 52. Change in simulated water levels (1998 to 2010) in the Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 3. (Positive value indicates water-level decline.)

Englishtown Aquifer System

The location of ground-water withdrawals and the simulated potentiometric surface in the Englishtown aquifer system is shown in figure 53. Simulated water levels range from 80 ft below NGVD of 1929 in coastal Ocean County to 120 ft above NGVD of 1929 in western Monmouth County. Changes in simulated water levels from 1998 to 2010 are shown in figure 54. Simulated water levels recovered more than 28 ft from 1998 to 2010 in Critical Area 1, where water levels are recovering as a result of restrictions on pumpage that began in the 1990s. Simulated water levels rose 2 ft more in scenario 3 than in scenario 2 (fig. 44) in the same area. In scenario 3, simulated water levels in southern Gloucester County declined 4 ft—2 ft less than in scenario 2 (fig. 44)—from 1998 to 2010.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 3 and for the baseline (1998) simulation is shown in figures 22 (for the confined part of the aquifer) and 23 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. In HBA 13 in Critical Area 1, pumpage was increased 0.27 Mgal/d (2 percent); outflow to storage decreased 0.39 Mgal/d (3 percent), but outflow to the underlying aquifer increased 0.15 Mgal/d (1 percent). In HBA 14, pumpage was increased only 0.01 Mgal/d (less than 1 percent); inflow from the overlying aquifer decreased 0.1 Mgal/d (1 percent), and outflow to the underlying aquifer decreased 0.25 Mgal/d (2 percent).

In HBA 38 in the outcrop, pumpage was not changed, but stream leakage increased 0.08 Mgal/d (1 percent) and outflow to the underlying aquifer increased 0.09 Mgal/d (1 percent). There was a decrease in water to storage of 0.13 Mgal/d (1 percent). There is no pumpage in HBA 39 in the outcrop, but outflow to storage decreased 0.41 Mgal/d (2 percent), and leakage to streams increased 0.31 Mgal/d (1 percent).

The flow budget for HBA 13 in scenario 3 indicates that pumpage was decreased 0.17 Mgal/d (1 percent), inflow from the overlying aquifer decreased 0.18 Mgal/d (1 percent), and outflow to the underlying aquifer decreased 0.12 Mgal/d (1 percent) from scenario 2. In HBA 14, pumpage was decreased 0.03 Mgal/d (less than 1 percent), inflow from the overlying aquifer decreased 0.23 Mgal/d (less than 1 percent), and outflow to the underlying Upper Potomac-Raritan-Magothy aquifer in Critical Area 2 decreased 0.24 Mgal/d (2 percent) from scenario 2. The flow-budget components for HBA 38 in the outcrop in scenario 3 did not change appreciably (0.07 Mgal/d (1 percent) or less) from scenario 2. In HBA 39 in the outcrop, outflow to the underlying aquifer decreased 0.16 Mgal/d (1 percent) from scenario 2.

Upper Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Upper Potomac-Raritan-Magothy aquifer are shown in figure 55. Simulated water levels range from 60 ft below NGVD of 1929 in central Camden and eastern Burlington Counties to 60 ft above NGVD of 1929 near the outcrop in Mercer and Middlesex Counties, and are about 40 ft below NGVD of 1929 in two small areas in northern Ocean County. Changes in simulated water levels from 1998 to 2010 are shown in figure 56. There is a 5-ft decline in simulated water levels from 1998 to 2010 in Middlesex County near the outcrop just outside Critical Area 1 similar to that in scenario 2 (fig. 46). There is a 5-ft recovery in simulated water levels downdip from the outcrop near the boundary between Burlington and Camden Counties in Critical Area 2; a 3-ft recovery was seen in the same area in scenario 2.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 3 and for the baseline (1998) simulation is shown in figures 26 (for the confined part of the aquifer) and 27 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. The change in flow budgets was largest in HBA 15 in Critical Area 1, in HBA 16 in Critical Area 2, and in HBAs 40, 42, and 43 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer. In HBA 15, pumpage was increased 0.66 Mgal/d (3 percent); inflow from the overlying aquifer increased 0.94 Mgal/d (4 percent), lateral inflow from HBA 16 increased 0.14 Mgal/d (1 percent), and lateral inflow from the downdip part of the aquifer (not included in any HBA) increased 0.23 Mgal/d (1 percent), but lateral inflow from the outcrop (HBA 40) decreased 0.52 Mgal/d (2 percent). In HBA 16, pumpage was increased 0.28 Mgal/d (1 percent); outflow to storage decreased 0.39 Mgal/d (1 percent), and inflow from the overlying aquifer increased 2.91 Mgal/d (9 percent), but outflow to the underlying aquifer also increased 1.94 Mgal/d (6 percent), and lateral inflow from the outcrop (HBA 42) decreased 0.67 Mgal/d (2 percent).

In HBA 40 in the outcrop, pumpage was increased 0.12 Mgal/d (less than 1 percent); outflow to the underlying aquifer decreased 0.55 Mgal/d (1 percent), and lateral outflow to HBA 15 decreased 0.52 Mgal/d (1 percent), but leakage to streams decreased 1.02 Mgal/d (1 percent), and inflow from storage decreased 1.96 Mgal/d (3 percent). Changes in the simulated flow budget indicate that although pumpage in HBA 42 in the outcrop in Critical Area 1 was not changed, outflow to HBA 16 downdip from the outcrop decreased 0.67 Mgal/d (2 percent), and induced leakage from the stream to the aquifer decreased 0.87 Mgal/d (3 percent), but outflow to the underlying aquifer increased 0.82 Mgal/d (2 percent). Outflow to storage decreased 1.02 Mgal/d (3 percent). Pumpage in HBA 43 in the outcrop was increased only 0.01 Mgal/d (less than 1 percent); leakage to streams increased 0.28 Mgal/d (3 percent), and outflow downdip to HBA 17 decreased 0.17 Mgal/d (2 percent).

In scenario 3, pumpage in HBA 15 was decreased 1.02 Mgal/d (4 percent); inflow from the overlying aquifer decreased 0.35 Mgal/d (1 percent), inflow from the downdip part of the aquifer (not included in any HBA) decreased 0.37 Mgal/d (1 percent), and lateral inflow from the outcrop (HBA 40) decreased 0.21 Mgal/d (1 percent) from scenario 2 because of pumpage restrictions in Critical Area 1 in the Upper and

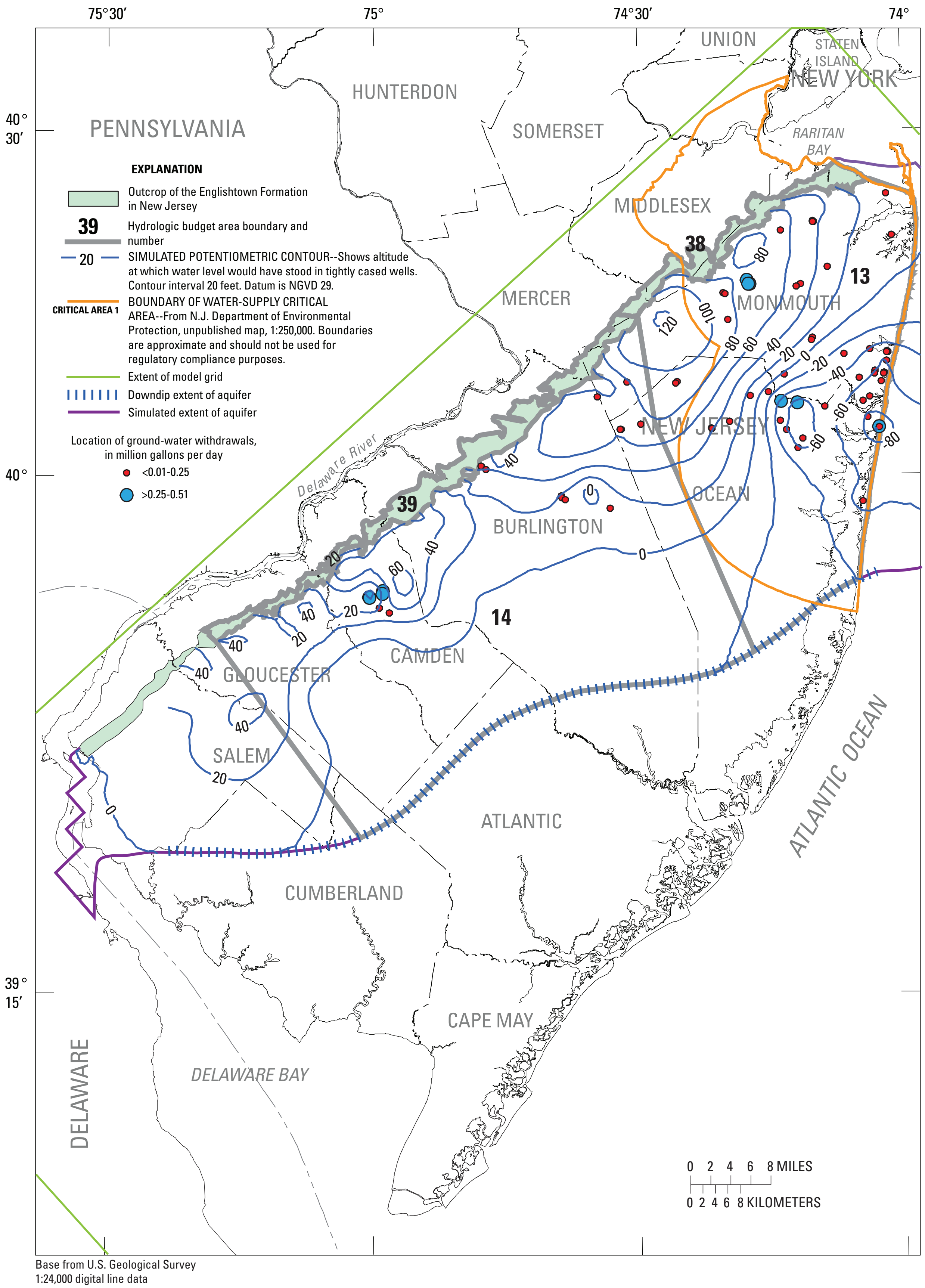
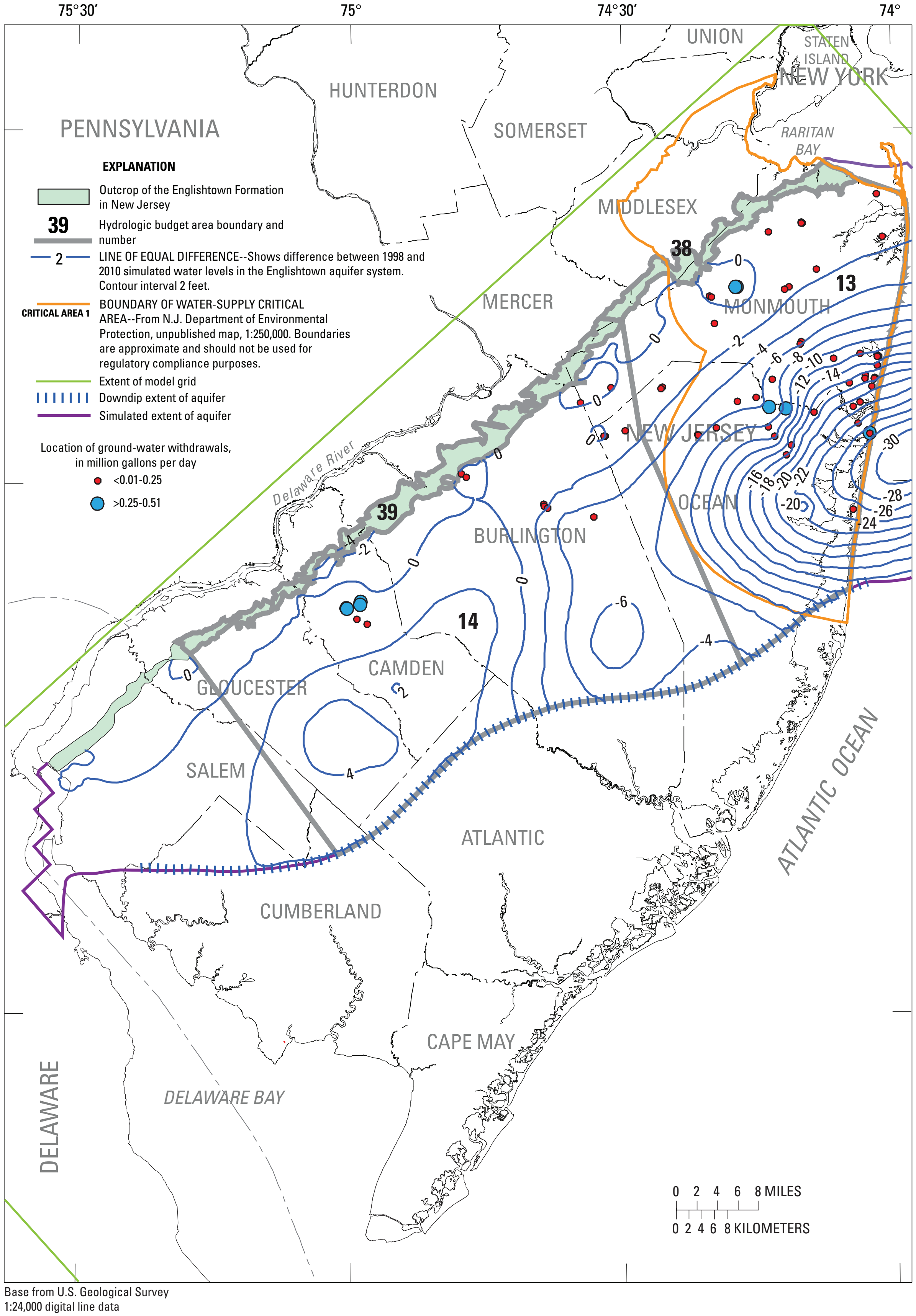


Figure 53. Hydrologic budget areas in the Englishtown aquifer system and simulated potentiometric surface in 2010 for scenario 3, New Jersey Coastal Plain.



Base from U.S. Geological Survey
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Figure 54. Change in simulated water levels (1998 to 2010) in the Englishtown aquifer system, New Jersey Coastal Plain, scenario 3. (Positive value indicates water-level decline.)

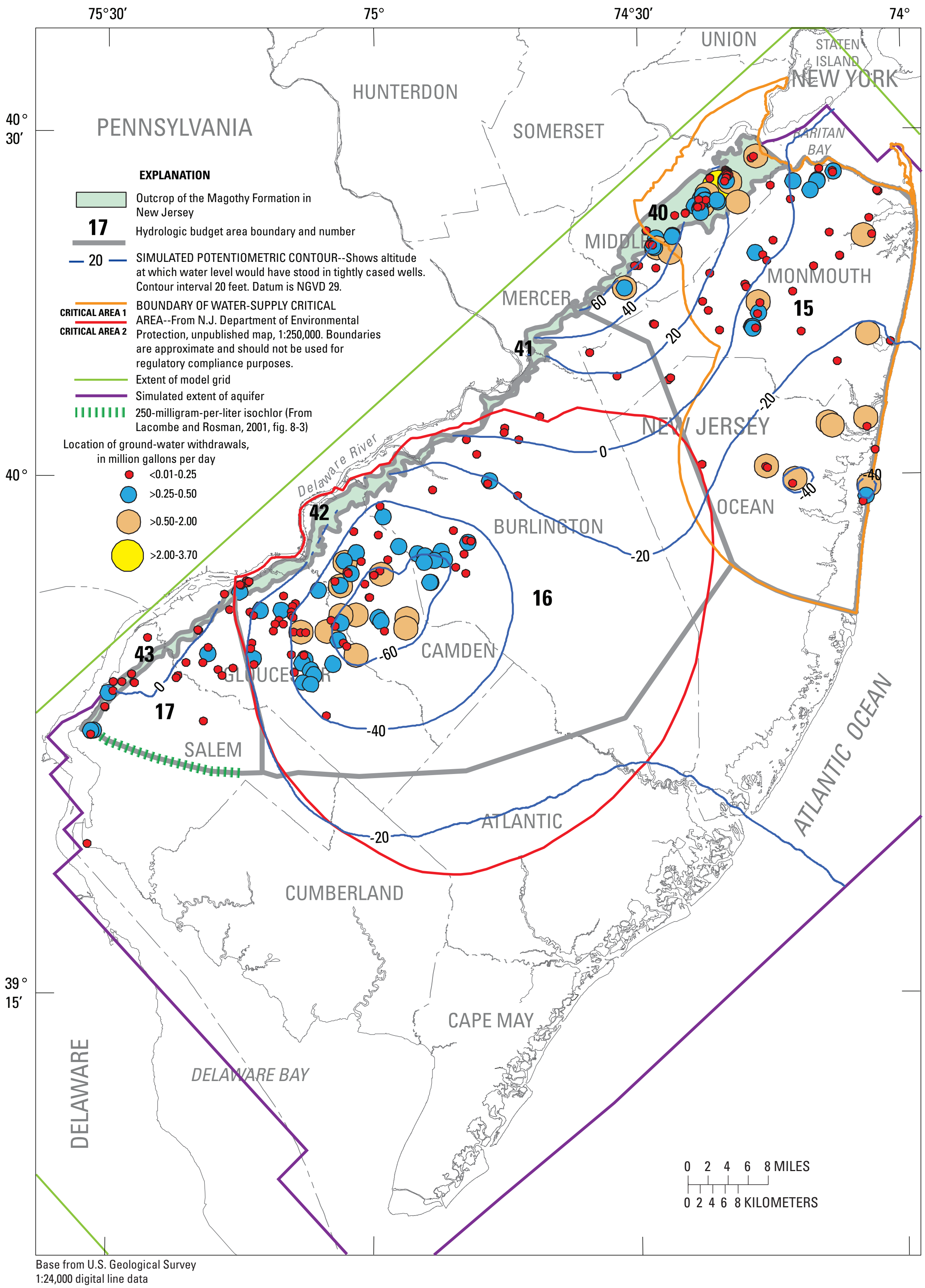
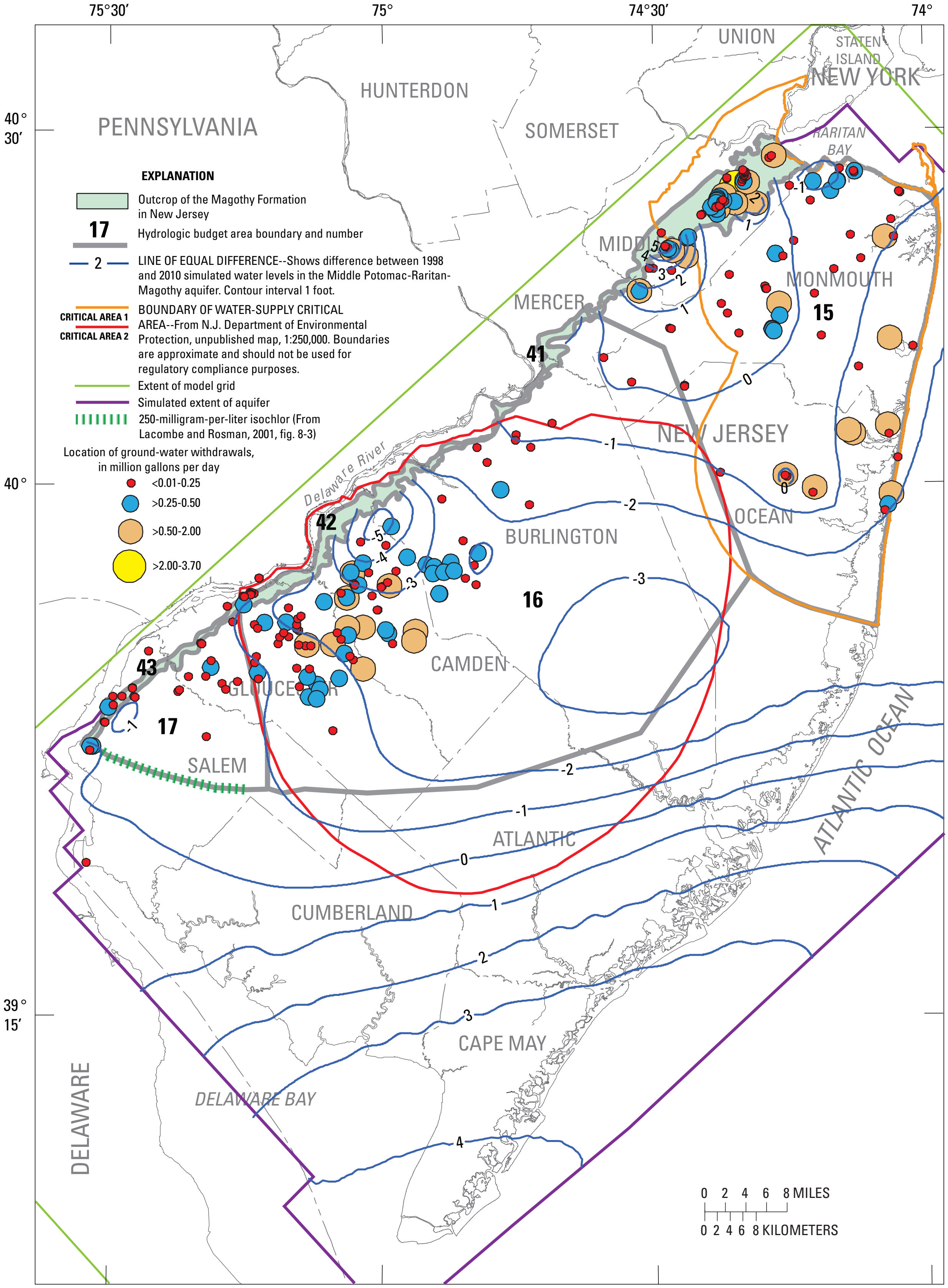


Figure 55. Hydrologic budget areas in the Upper Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 3, New Jersey Coastal Plain.



Base from U.S. Geological Survey
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Figure 56. Change in simulated water levels (1998 to 2010) in the Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3. (Positive value indicates water-level decline.)

Middle Potomac-Raritan-Magothy aquifers in scenario 3. In addition, in HBA 16 in Critical Area 2, pumpage was decreased 1.37 Mgal/d (4 percent); inflow from the overlying aquifer decreased 0.98 Mgal/d (4 percent), lateral inflow from HBA 17 decreased 0.2 Mgal/d (less than 1 percent), lateral inflow from HBA 42 decreased 0.24 Mgal/d (1 percent), and outflow to the underlying aquifer decreased 0.2 Mgal/d (1 percent) from scenario 2.

In HBA 40 in the outcrop in Critical Area 1, pumpage was decreased 0.65 Mgal/d (1 percent) and leakage to streams increased 0.78 Mgal/d (2 percent) from scenario 2. Although pumpage in HBA 42 was not changed from scenario 2 to scenario 3, the induced leakage from the stream to the aquifer decreased 0.4 Mgal/d (2 percent), outflow to HBA 16 decreased 0.24 Mgal/d (1 percent), and outflow to the underlying aquifer decreased 0.35 Mgal/d (2 percent) because of the decrease in pumpage in HBA 16 and in HBA 19 in the underlying Middle Potomac-Raritan-Magothy aquifer (0.65 Mgal/d, 2 percent) in scenario 3.

Middle Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Middle Potomac-Raritan-Magothy aquifer are shown in figure 57. Simulated water levels range from 40 ft below NGVD of 1929 in Critical Area 2 in western Gloucester, Camden, and eastern Burlington Counties to 80 ft above NGVD of 1929 near the outcrop in Middlesex County. Changes in simulated water levels from 1998 to 2010 are shown in figure 58. There is a 9-ft decline in water levels from 1998 to 2010 in Middlesex County near the intersection between the boundary of the outcrop and the boundary of Critical Area 1—3 ft more than in scenario 2 in the same area (fig. 48). There is a 4-ft recovery in northeastern Camden and northwestern Burlington Counties—2 ft more than in scenario 2—from 1998 to 2010.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 3 and for the baseline (1998) simulation is shown in figures 30 (for the confined part of the aquifer) and 31 (for the outcrop). Values of the simulated flow-budget components for this scenario are compared with those for the baseline simulation. The change in flow budgets was largest in HBA 18 in Critical Area 1, in HBA 19 in Critical Area 2, and in HBAs 44, 45, and 46 in the outcrop of the Middle Potomac-Raritan-Magothy aquifer. In HBA 18, pumpage was increased 0.82 Mgal/d (4 percent); inflow from the overlying aquifer decreased 0.52 Mgal/d (3 percent), lateral inflow from HBA 44 in the outcrop increased 0.5 Mgal/d (2 percent), lateral inflow from the 250-mg/L isochlor increased 0.34 Mgal/d (2 percent), and outflow to the underlying aquifer decreased 0.22 Mgal/d (1 percent). In HBA 19, pumpage was increased 0.62 Mgal/d (1 percent); inflow from the overlying aquifer increased 2.87 Mgal/d (6 percent), but lateral inflow from the outcrop (HBA 45) decreased 1.53 Mgal/d (3 percent), and outflow to the underlying aquifer increased 0.98 Mgal/d (2 percent) because of pumpage in the underlying Lower Potomac-Raritan-Magothy aquifer. Outflow to storage decreased 0.44 Mgal/d (1 percent).

In HBA 44 in the outcrop, pumpage was increased 0.27 Mgal/d (less than 1 percent); however, leakage to streams decreased 1.91 Mgal/d (2 percent), and lateral outflow to HBA 18 increased 0.5 Mgal/d (1 percent). Inflow from storage decreased 1.14 Mgal/d (1 percent). In HBA 45 in the outcrop, pumpage was increased 0.57 Mgal/d (less than 1 percent), outflow to the underlying aquifer decreased 0.8 Mgal/d (1 percent), lateral outflow to HBA 19 decreased 1.53 Mgal/d (1 percent), and outflow to storage decreased 0.58 Mgal/d (less than 1 percent); moreover, leakage to streams increased 2.35 Mgal/d (2 percent). In HBA 46 in the outcrop outside Critical Area 2, pumpage was not changed, but leakage to streams increased 0.76 Mgal/d (3 percent), outflow to the underlying aquifer decreased 0.11 Mgal/d (less than 1 percent), and outflow to storage decreased 0.53 Mgal/d (2 percent).

Differences in flow budgets between scenarios 2 and 3 are largest in HBA 19 in Critical Area 2 and HBA 45 in the outcrop. In HBA 19, pumpage was decreased 0.65 Mgal/d (2 percent), inflow from the overlying aquifer decreased 0.6 Mgal/d (1 percent), and lateral inflow from the outcrop (HBA 45) decreased 0.83 Mgal/d (2 percent) from scenario 2. Outflow to the underlying Lower Potomac-Raritan-Magothy aquifer (HBA 22) decreased 0.95 Mgal/d (2 percent) because pumpage in that aquifer was 1.66 Mgal/d (4 percent) less in scenario 3 than in scenario 2 (fig. 34). In HBA 45, pumpage was decreased 0.07 Mgal/d (less than 1 percent), and stream leakage increased 1.37 Mgal/d (1 percent), but lateral outflow to HBA 19 decreased 0.83 Mgal/d (less than 1 percent) from scenario 2. Also, outflow to the underlying aquifer decreased 0.53 Mgal/d (1 percent) because of pumpage restrictions in Critical Area 2 in scenario 3.

Lower Potomac-Raritan-Magothy Aquifer

The location of ground-water withdrawals and the simulated potentiometric surface in the Lower Potomac-Raritan-Magothy aquifer are shown in figure 59. Simulated water levels range from 60 ft below NGVD of 1929 in Critical Area 2 in central Camden County to NGVD of 1929 near the Delaware River. The change in simulated water levels from 1998 to 2010 is shown in figure 60. There is a 4-ft recovery in simulated water levels from 1998 to 2010 in northeastern Camden and northwestern Burlington Counties in Critical Area 2. Simulated water levels recovered as much as 3 ft more in scenario 3 than in scenario 2 (fig. 50) as a result of the pumpage restrictions in Critical Area 2 in scenario 3.

The simulated 2010 flow budget for each HBA in this aquifer for scenario 3 and for the baseline (1998) simulation is shown in figure 34. The change in flow budgets was largest in HBA 22 in Critical Area 2. In HBA 22, pumpage was increased 0.15 Mgal/d (less than 1 percent), and inflow from the overlying aquifer increased 0.15 Mgal/d (less than 1 percent). A comparison with the flow budget for scenario 2 shows that these changes also were largest in HBA 22 in Criti-

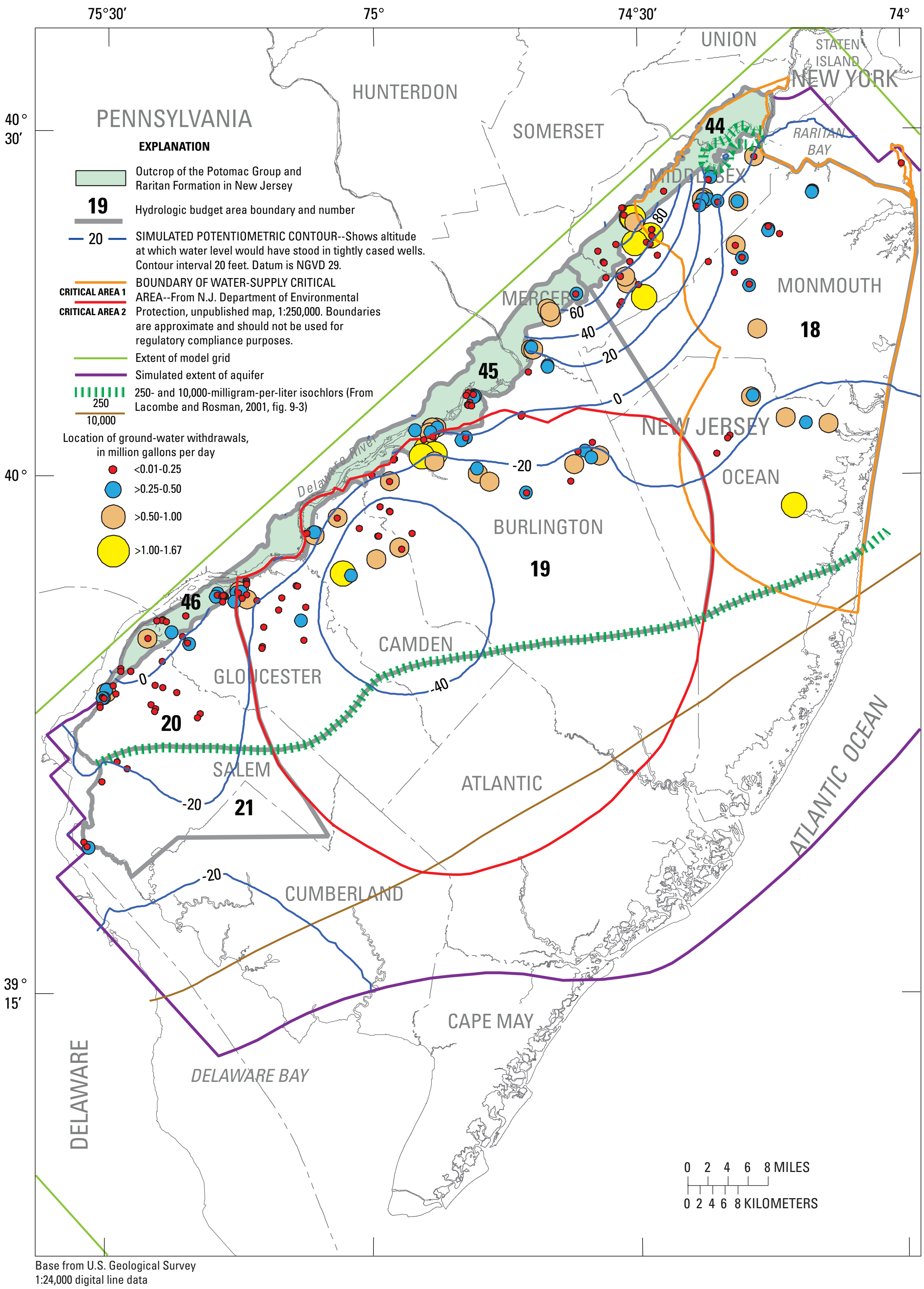


Figure 57. Hydrologic budget areas in the Middle Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 3, New Jersey Coastal Plain.

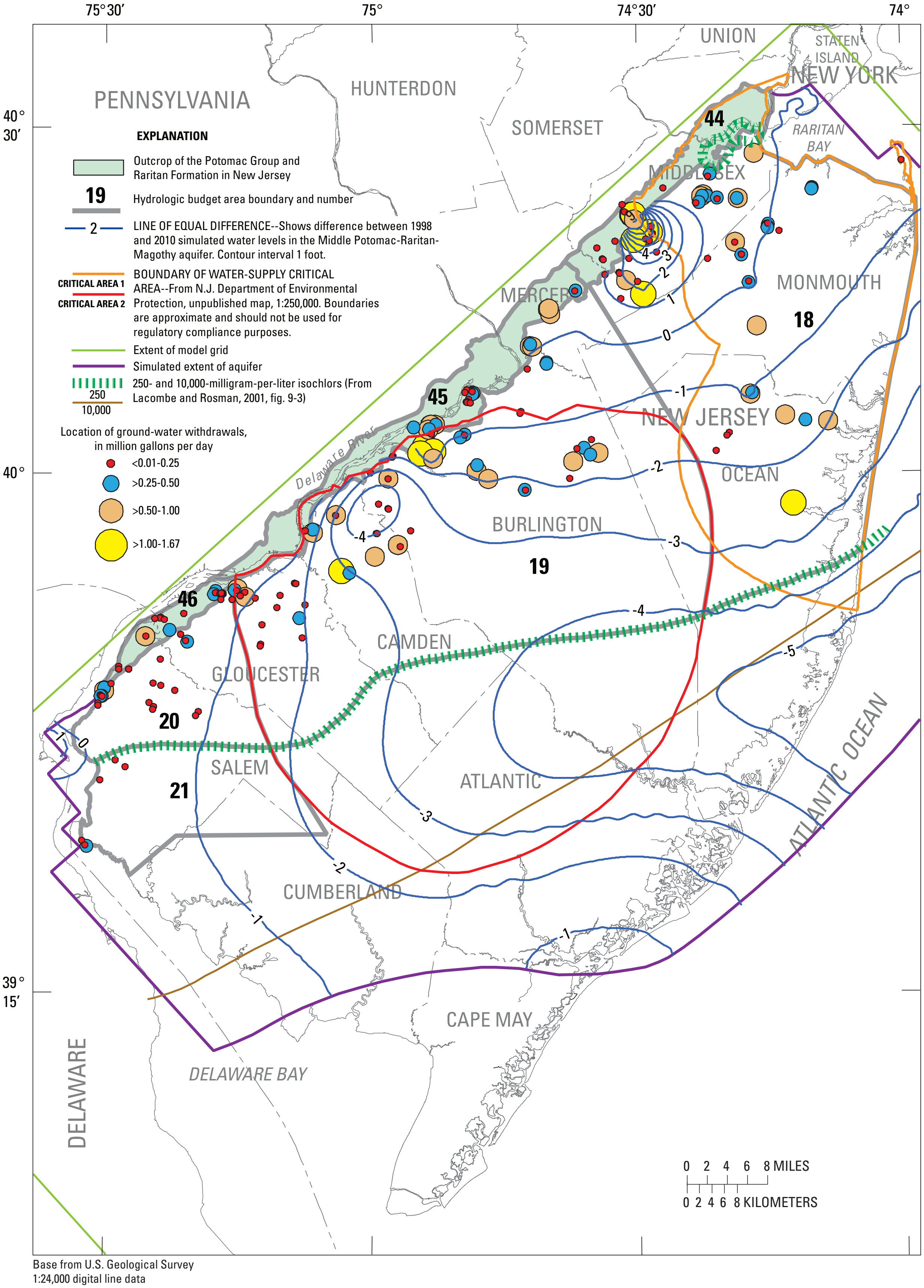


Figure 58. Change in simulated water levels (1998 to 2010) in the Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3. (Positive value indicates water-level decline.)

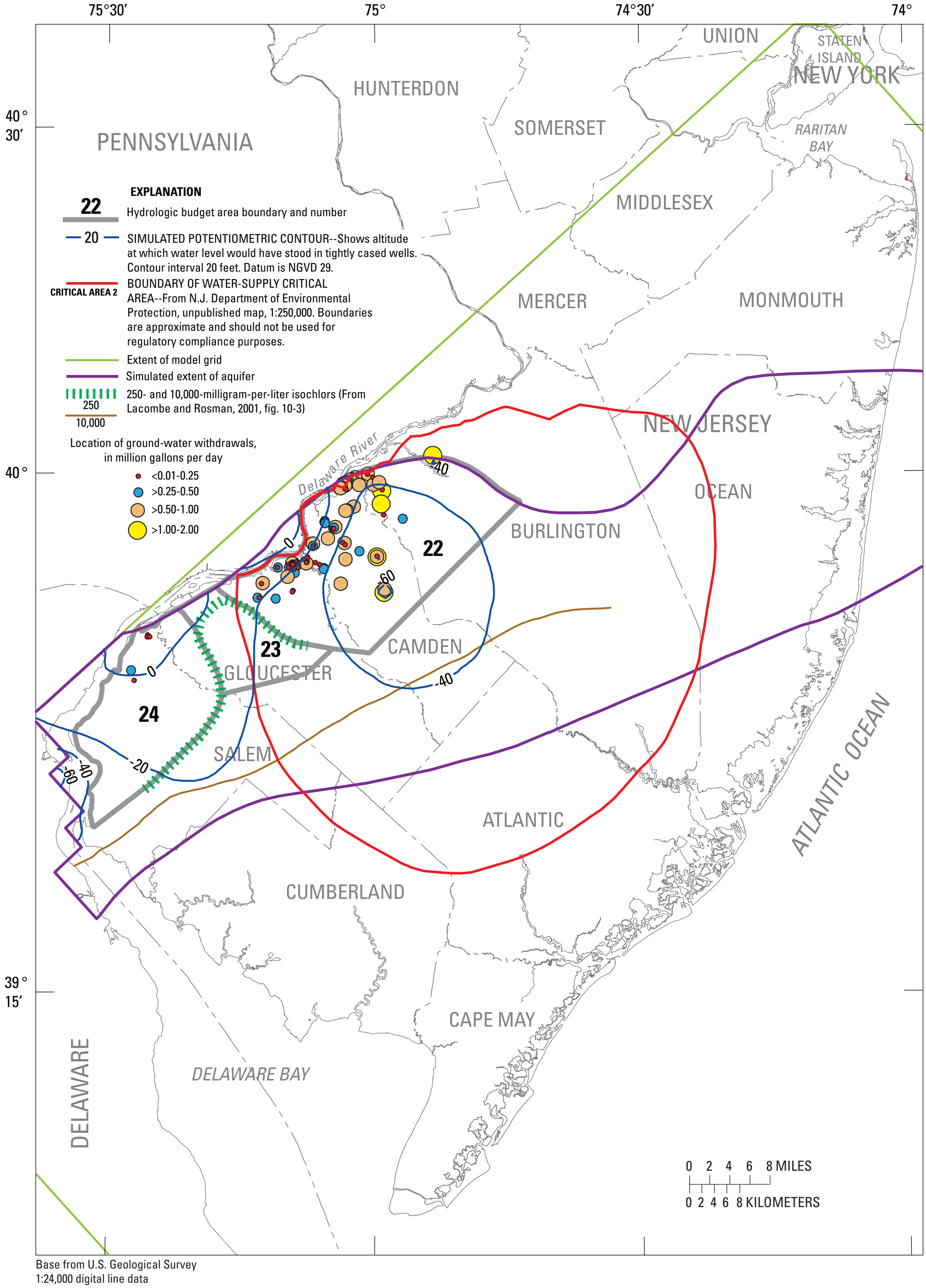


Figure 59. Hydrologic budget areas in the Lower Potomac-Raritan-Magothy aquifer and simulated potentiometric surface in 2010 for scenario 3, New Jersey Coastal Plain.

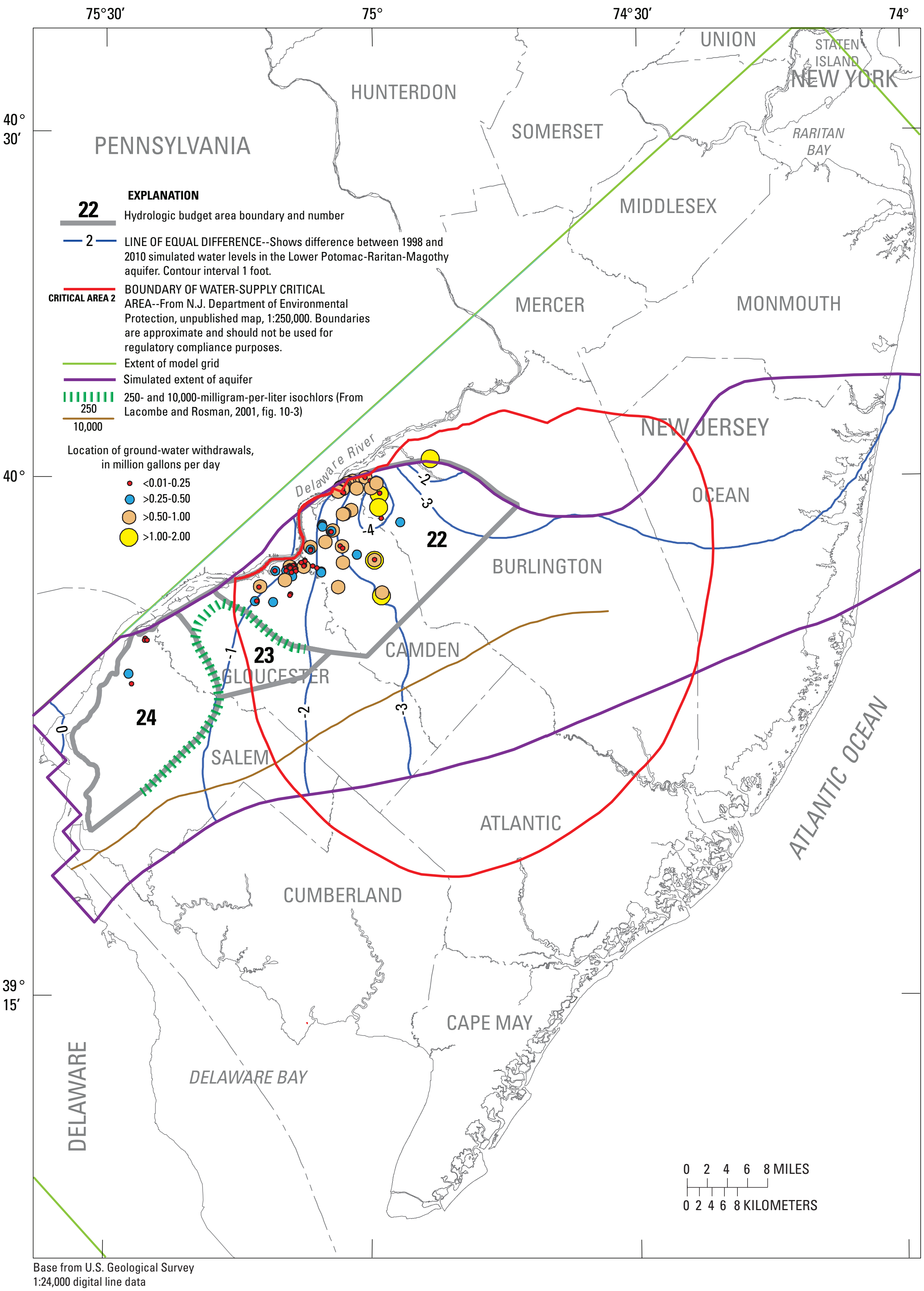


Figure 60. Change in simulated water levels (1998 to 2010) in the Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3. (Positive value indicates water-level decline.)

cal Area 2. In HBA 22, pumpage was decreased 1.66 Mgal/d (4 percent), inflow from the overlying Middle Potomac-Raritan-Magothy aquifer decreased 1.55 Mgal/d (4 percent), and lateral inflow from HBA 23, most of which is inside the 250-mg/L isochlor, decreased 0.05 Mgal/d (less than 1 percent) from scenario 2.

Comparison of Results for Scenarios 1, 2, and 3

The predicted withdrawals in 2010 totaled 365.7 Mgal/d for scenario 1, 361.8 Mgal/d for scenario 2, and 355.4 Mgal/d for scenario 3. The location of pumped wells was not changed from 1998 to 2010 and no new pumping sites were added to the simulations.

Differences in simulated water levels between scenarios 1 and 2 were largest in HBA 2 in the Atlantic City 800-foot sand at the pumping center in Atlantic County (5 ft), in HBA 5 in the Piney Point aquifer in western Atlantic County (5 ft), and in HBA 8 in the Wenonah-Mount Laurel aquifer in eastern Burlington County (10 ft). In scenario 1, water-supply withdrawals were changed based on withdrawal trends from 1990 to 1999 in water-supply growth areas (fig. 5), whereas in scenario 2, water-supply withdrawals were changed by an amount based on the projected increase in population for each county. In the Atlantic City 800-foot sand in coastal Atlantic County, withdrawals at water-supply wells were increased 18 percent in scenario 1, whereas withdrawals in Atlantic County were increased only 11 percent in scenario 2. In the Piney Point aquifer in western Atlantic County, predicted 2010 withdrawals at water-supply wells were decreased 20 percent in scenario 1; in scenario 2, withdrawals in Atlantic County were increased 11 percent. In the Wenonah-Mount Laurel aquifer in eastern Burlington County, predicted 2010 withdrawals at water-supply wells were decreased 20 percent in scenario 1; in scenario 2, withdrawals in Burlington County were increased 11 percent.

Differences in simulated water levels between scenarios 2 and 3 were largest in HBA 18 in the Middle Potomac-Raritan-Magothy aquifer in Middlesex County (3 ft) near the outcrop and boundary of Critical Area 1, and in HBA 22 in the Lower Potomac-Raritan-Magothy aquifer in northeastern Camden and northwestern Burlington Counties (4 ft) in Critical Area 2. Differences occurred in these areas because the method used to predict 2010 withdrawals for scenario 2 was varied at wells in and adjacent to the Critical Areas for scenario 3. In scenario 3, withdrawals in Critical Area 1 were decreased 2.2 Mgal/d from those in scenario 2, whereas in Critical Area 2, withdrawals were decreased 3.8 Mgal/d from those in scenario 2. In scenario 3, withdrawals were decreased 0.4 Mgal/d from those in scenario 2 at wells located adjacent to Critical Area 2 or from aquifers not designated as Critical Area aquifers; however, withdrawals were not decreased at wells located adjacent to Critical Area 1 in scenario 3 (fig. 5).

The largest changes in simulated water levels by aquifer from 1998 to 2010 for scenarios 1, 2, and 3 that equal or exceed 5 ft are shown in table 3. Water levels in the Atlantic City 800-foot sand in Atlantic County (HBA 2) declined 5 ft more in scenario 1 than in scenarios 2 and 3 (figs. 7 and 36). Pumpage was 0.76 Mgal/d more in scenario 1 than in scenarios 2 and 3 (fig. 8). Simulated water levels in the Piney Point aquifer in Ocean County (HBA 4) declined 4 ft more in scenarios 2 and 3 than in scenario 1 (figs. 10 and 38), although pumpage was only 0.1 Mgal/d more in scenarios 2 and 3 than in scenario 1 (fig. 11). In the Wenonah-Mount Laurel aquifer in coastal Ocean County (HBA 8), onshore simulated water levels recovered about 24 ft in all three scenarios in response to mandated pumpage restrictions in Critical Area 1 (figs. 17, 42, and 52). Simulated water levels in the Englishtown aquifer system in the same area (HBA 13) recovered 26 ft or more (figs. 21, 44, and 54).

Although the 2010 pumpage from the Potomac-Raritan-Magothy aquifer system is much greater than that from the other New Jersey Coastal Plain aquifers (fig. 3), the maximum simulated water-level decline is about 9 ft in this aquifer system, less than in the Atlantic City 800-foot sand and Piney Point aquifer, and less than the magnitude of water-level change in the Wenonah-Mount Laurel aquifer and the Englishtown aquifer system. This is probably because the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers

Table 3. Largest changes in simulated water levels by aquifer from 1998 to 2010 for scenarios 1, 2, and 3.

[Mgal/d, million gallons per day; negative sign denotes water-level recovery]

Aquifer	Hydrologic Budget Area	Change in simulated water level (feet)			Increase in withdrawals from 1998 to 2010 (Mgal/d)		
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Atlantic City 800-foot sand	2	14	9	[1]9	2.20	1.44	1.44
Piney Point	4	7	11	[1]11	.44	.54	.54
Wenonah-Mount Laurel	8	-24	-24	-24	.07	.05	.01
Englishtown	13	-26	-26	-28	.41	.44	.27
Upper Potomac-Raritan-Magothy	15	5	5	5	1.79	1.68	.66
Middle Potomac-Raritan-Magothy	18	9	6	9	1.63	1.18	.82

[1] These simulated differences are not shown in figures in the report.

typically are thicker and more transmissive, and the vertical leakance of their intervening confining units is greater, than for the Englishtown aquifer system and the Wenonah-Mount Laurel, Vincentown, and Piney Point aquifers (Martin, 1998; Pope and Gordon, 1999).

Simulated flow budgets for each HBA varied with the stress conditions specified for each scenario. The sources of water to wells as flows to and from the HBAs can be complex and are interdependent. In each HBA, withdrawals can be derived from leakage to streams in the outcrop areas; vertical leakage through overlying and underlying confining units; lateral flow from adjacent HBAs, and from downdip and offshore areas not in any HBA; and (or) storage. Lateral flows vary by HBA because of areal differences in transmissivity, stream conductance, vertical conductance, and withdrawals. The model flow budgets indicate that the confined aquifers of New Jersey are recharged by vertical and lateral flow caused by recharge from precipitation on the outcrop areas and by vertical flow from overlying or underlying aquifers through confining units of varying leakance. The flow budgets indicate that as pumpage from the confined aquifers increased, inflow from the overlying aquifer usually increased, although some of this inflow became outflow to the underlying aquifer because of pumpage increases there, such as in HBA 16 in the Upper Potomac-Raritan-Magothy aquifer, and in HBA 19 in the Middle Potomac-Raritan-Magothy aquifer. The flow budgets also indicate that lateral flow from the updip unconfined aquifer increased with increased pumpage from the Atlantic City 800-foot sand in HBAs 1 and 2 (fig. 2).

In HBA 16 in the Upper Potomac-Raritan-Magothy aquifer, inflow from the overlying aquifer increased 4.12, 3.89, and 2.91 Mgal/d, respectively (13, 13, and 9 percent, respectively) in scenarios 1 to 3, when withdrawals were increased 1.92, 1.65, and 0.28 Mgal/d, respectively (6, 5, and 1 percent, respectively); however, outflow to the underlying aquifer also increased 2.23, 2.14, and 1.94 Mgal/d, respectively (7, 7, and 6 percent, respectively). In HBA 19 in the Middle Potomac-Raritan-Magothy aquifer, inflow from the overlying aquifer increased 3.8, 3.47, and 2.87 Mgal/d, respectively (8, 7, and 6 percent, respectively) in scenarios 1 to 3, when withdrawals were increased 1.15, 1.27, and 0.62 Mgal/d, respectively (2, 3, and 1 percent, respectively); however, outflow to the underlying aquifer also increased 2.47, 1.93, and 0.98 Mgal/d, respectively (5, 4, and 2 percent, respectively). In HBA 1 in the Atlantic City 800-foot sand, inflow from the overlying aquifer increased 0.31, 0.23, and 0.23 Mgal/d, respectively (6, 4, and 4 percent, respectively) in scenarios 1 to 3, and lateral inflow from updip increased 0.32, 0.25, and 0.25 Mgal/d, respectively (6, 5, and 5 percent, respectively), in response to an increase in withdrawals of 0.73, 0.6, and 0.6 Mgal/d, respectively (14, 11, and 11 percent, respectively). In HBA 2 in the Atlantic City 800-foot sand, inflow from the overlying aquifer increased 0.66, 0.46, and 0.46 Mgal/d, respectively (4, 3, and 3 percent, respectively) in scenarios 1 to 3, and lateral inflow from updip increased 0.6, 0.41, and 0.41 Mgal/d, respectively (4, 3, and 3 percent, respectively), in response to an increase in withdrawals of 2.2, 1.44, and 1.44 Mgal/d, respectively (14, 9, and 9 percent, respectively).

In the outcrop (unconfined) areas of the confined aquifers, continued declines in water levels can reduce ground-water discharge to streams and, in some areas of pumping, may induce water to flow from the stream to the aquifer. In HBA 40, in the outcrop of the Upper Potomac-Raritan-Magothy aquifer in Critical Area 1, leakage to streams decreased 2.44 Mgal/d (3 percent) in scenario 1, 1.8 Mgal/d (3 percent) in scenario 2, and 1.02 Mgal/d (1 percent) in scenario 3 compared to the 1998 simulation in response to an increase in pumpage from baseline conditions of 1.45 Mgal/d (2 percent) in scenario 1, 0.77 Mgal/d (1 percent) in scenario 2, and 0.12 Mgal/d (less than 1 percent) in scenario 3. In HBA 44, in the Middle Potomac-Raritan-Magothy aquifer in Critical Area 1, leakage to streams was reduced by 2.23 Mgal/d (3 percent) in scenario 1, 2.06 Mgal/d (3 percent) in scenario 2, and 1.91 Mgal/d (2 percent) in scenario 3 in response to an increase in pumpage from baseline conditions of 0.28 Mgal/d (less than 1 percent) in scenario 1 and 0.27 Mgal/d (less than 1 percent) in scenarios 2 and 3 in HBA 44 and an increase in pumpage from baseline conditions of 1.63 Mgal/d (8 percent) in scenario 1, 1.18 Mgal/d (6 percent) in scenario 2, and 0.82 Mgal/d (4 percent) in scenario 3 in HBA 18, downdip from HBA 44. In HBA 42 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer in Critical Area 2, however, induced leakage from the stream to the aquifer occurred in 1998 and in all three scenarios, although the amount of leakage decreased 0.28 Mgal/d (1 percent) in scenario 1, 0.47 Mgal/d (1 percent) in scenario 2, and 0.87 Mgal/d (3 percent) in scenario 3. Pumpage was not changed from baseline conditions in HBA 42 in the three scenarios, and lateral outflow to HBA 16, downdip from HBA 42, decreased 0.36 Mgal/d (1 percent) in scenario 1, 0.43 Mgal/d (1 percent) in scenario 2, and 0.67 Mgal/d (2 percent) in scenario 3.

In HBA 2 in the Atlantic City 800-foot sand, lateral inflow from the offshore part of the aquifer (not included in any HBA) increased 0.77, 0.5, and 0.5 Mgal/d (5, 3, and 3 percent) in scenarios 1, 2, and 3, respectively, when pumpage was increased 2.2, 1.44, and 1.44 Mgal/d (14, 9, and 9 percent), respectively. The 250-mg/L isochlor is about 10 mi offshore from the pumping center in Atlantic County, is about 5 mi offshore from the pumping center in Cape May County, and curves onshore and traverses the southern part of Cape May County and is the southern boundary of HBA 2. Lateral inflow at the location of the onshore isochlor is small, 0.03 Mgal/d in scenario 1 and 0.02 Mgal/d in scenarios 2 and 3 (less than 1 percent in all three scenarios). In HBA 5 in the Piney Point aquifer, the flow direction at the 250-mg/L isochlor is toward the downdip, saltier part of the aquifer (not included in any HBA). In HBA 17 in the Upper Potomac-Raritan-Magothy aquifer, there was a small decrease in lateral inflow at the location of the onshore isochlor in Salem County of 0.03 Mgal/d in scenario 1, 0.01 Mgal/d in scenario 2, and 0.03 Mgal/d in scenario 3 (less than 1 percent in all three scenarios). In HBA 18 in the Middle Potomac-Raritan-Magothy aquifer, simulated flow toward the aquifer at the location of the 250-mg/L isochlor in Ocean County increased 0.5, 0.45, and 0.34 Mgal/d (2 percent in all three scenarios) when pumpage was increased 1.63, 1.18 and 0.82 Mgal/d (8, 6, and 4 percent), respectively, in scenarios 1, 2, and 3. Pumped wells in the downdip portion of HBA 18 are more than 7 mi updip from the location of the 250-mg/L isochlor. In the coastal part of HBA 44, in the outcrop of the Middle Potomac-Raritan-Magothy aquifer, the 250-mg/L isochlor is located onshore. Lateral inflow from the offshore part of the aquifer (not included in any HBA) is 0.06 Mgal/d under baseline conditions and in all three scenarios.

Water-Level Decline and Recovery in the Hydrologic Budget Areas

Decades of increasingly larger ground-water withdrawals in populated areas of the New Jersey Coastal Plain have created cones of depression of regional extent in several confined aquifers. Since 1978, the USGS has conducted synoptic water-level measurements every 5 years at wells in the New Jersey Coastal Plain to document changes in levels (Walker, 1983; Eckel and Walker, 1986; Rosman and others, 1995; Lacombe and Rosman, 1997 and 2001). To identify areas of water-level decline and (or) recovery since withdrawals were restricted in Critical Areas 1 and 2 beginning in the 1990s, the simulated 2010 water levels were compared with 1988 synoptic water levels (Rosman and others, 1995).

Areas of observed recovery or decline from 1988 to 1998, simulated recovery or decline from 1999 to 2010, and percent remaining recovery for 1988 to 1998 and 1999 to 2010 for scenarios 1, 2, and 3 for the hydrologic budget areas in the five confined aquifers of the New Jersey Coastal Plain included as part of Critical Areas 1 and 2 were determined. Areas of recovery or decline from 1988 to 1998 were determined from the difference between the measured potentiometric surfaces in 1988 and 1998 (Rosman and others, 1995; Lacombe and Rosman, 2001). Areas of recovery or decline from 1998 to 2010 were calculated as the difference between 1998 and 2010 simulated water levels. The remaining recovery is the percentage of the water-level recovery from 1988 to 1998 that is remaining in 2010. These areas are shown in figures 61 to 75. The following matrix shows the colors used to depict the areas of water-level change in these figures and indicate the region where synoptic water-level measurements were conducted.

	1999-2010	
1988-98	**Recovery**	**Decline**
Recovery	yellow	red or pink
Decline	blue	green

The predicted increase or decrease in pumpage from 1999 to 2010 for counties within Critical Areas 1 and 2 is shown in the following table. For scenario 3, the predicted change was designated by water purveyor with wells located in Critical Areas 1 and 2.

County in Critical Area 1	Scenario 1 (percent)	Scenario 2 (percent)
Middlesex	10	9
Monmouth	[1]9 and 10	7
Ocean (eastern)	9	13
Ocean (northwestern)	-20	13

Selected[2] County in Critical Area 2	Scenario 1 (percent)	Scenario 2 (percent)
Burlington (eastern)	-20	11
Burlington (northwestern)	7	11
Camden	7	1
Gloucester	7	10

[1] Nine percent in southern and coastal Monmouth County; 10 percent in northern Monmouth County

[2] These counties are selected because most of their withdrawals are from wells located in and adjacent to Critical Area 2

In the Wenonah-Mount Laurel aquifer (fig. 61), water levels were recovering in 1998 but then declined again by 2010 near the outcrop in western Monmouth (HBA 9), northern Burlington (HBAs 9-10), northwestern Gloucester (HBAs 11-12), and northeastern Salem (HBA 12) Counties, and in a small portion of central Camden County (HBA 11) in scenario 1. These areas of decline also were observed in scenarios 2 and 3 (figs. 62 and 63), except that the area of decline in northeastern Burlington County was larger in these scenarios. Water levels declined continually from 1988 to 2010 throughout most of this aquifer in Salem, Gloucester, and Camden Counties, and in Monmouth County in Critical Area 1 adjacent to the outcrop (HBA 8) in all three scenarios. Water levels in the remainder of Critical Area 1 and in eastern Burlington and northwestern Ocean Counties recovered from 1988 to 2010 in all three scenarios. Water levels declined from 1988 to 1998, then recovered from 1999 to 2010 in central Burlington County, and in several small areas in northwestern Ocean County and Monmouth County in all three scenarios.

In the Englishtown aquifer system, water levels in scenario 1 were recovering in 1998, but declined by 2010 in several small areas near the outcrop in western Gloucester, eastern Salem, and northern Burlington Counties (HBA 14) and in western Monmouth County (HBAs 13-14) in all three scenarios (fig. 64 to 66). The area of decline was smaller in eastern Salem and western Gloucester Counties in scenario 3. Water levels declined continually from 1988 to 2010 in eastern Gloucester, central Camden, and western Burlington Counties in all three scenarios. There was a continual decline in water levels in two small areas in western and in central Monmouth County (HBA 13) downdip from the outcrop from 1988 to 2010 in all three scenarios. Water levels declined from 1988 to 1998, then recovered from 1999 to 2010 in an area adjacent to the outcrop in Gloucester, Camden, and northwestern Burlington Counties, in northeastern Burlington and northwestern Ocean Counties, and in northern Monmouth County in all three scenarios. Water levels in most of the downdip and

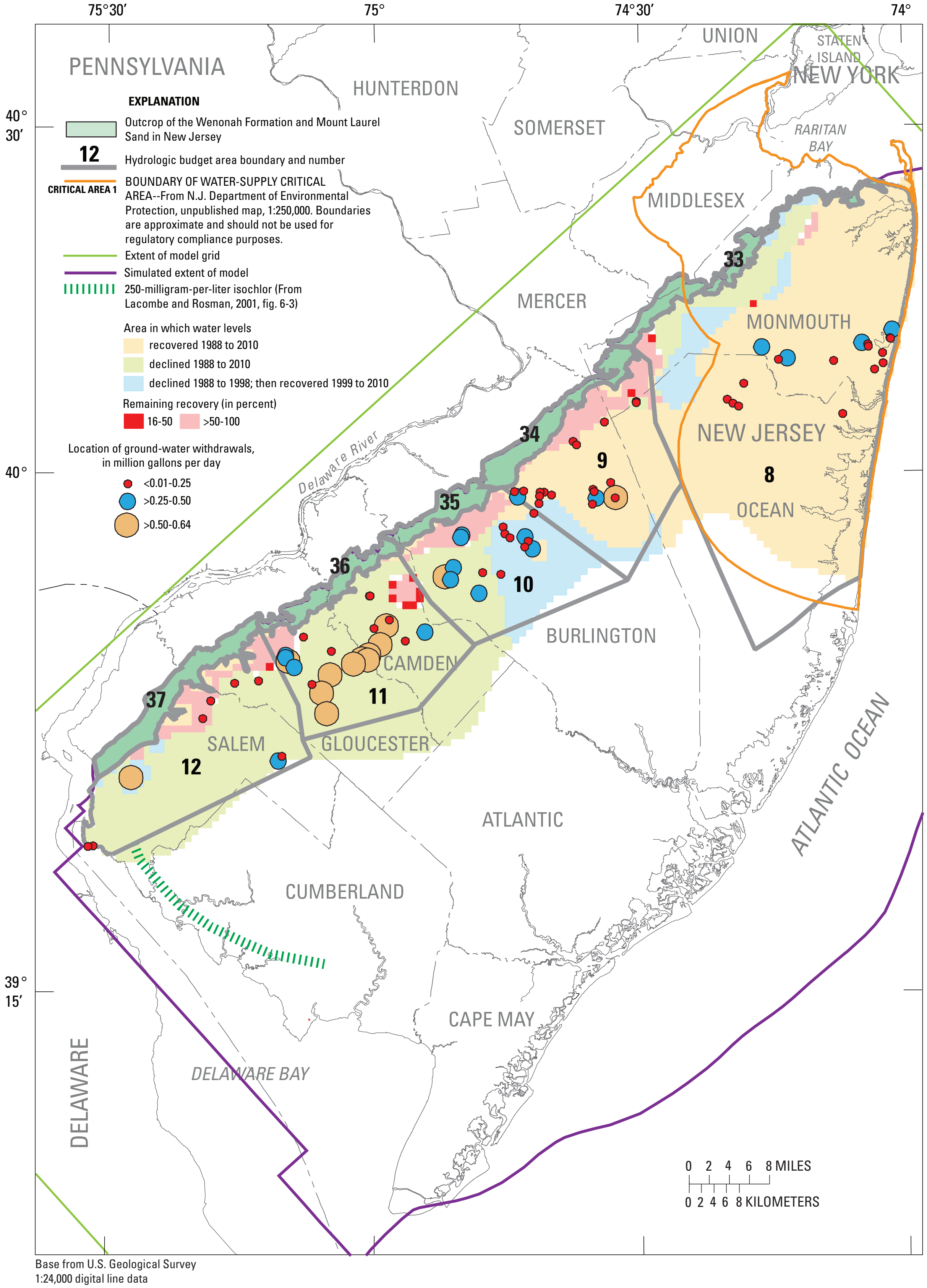


Figure 61. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 1. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

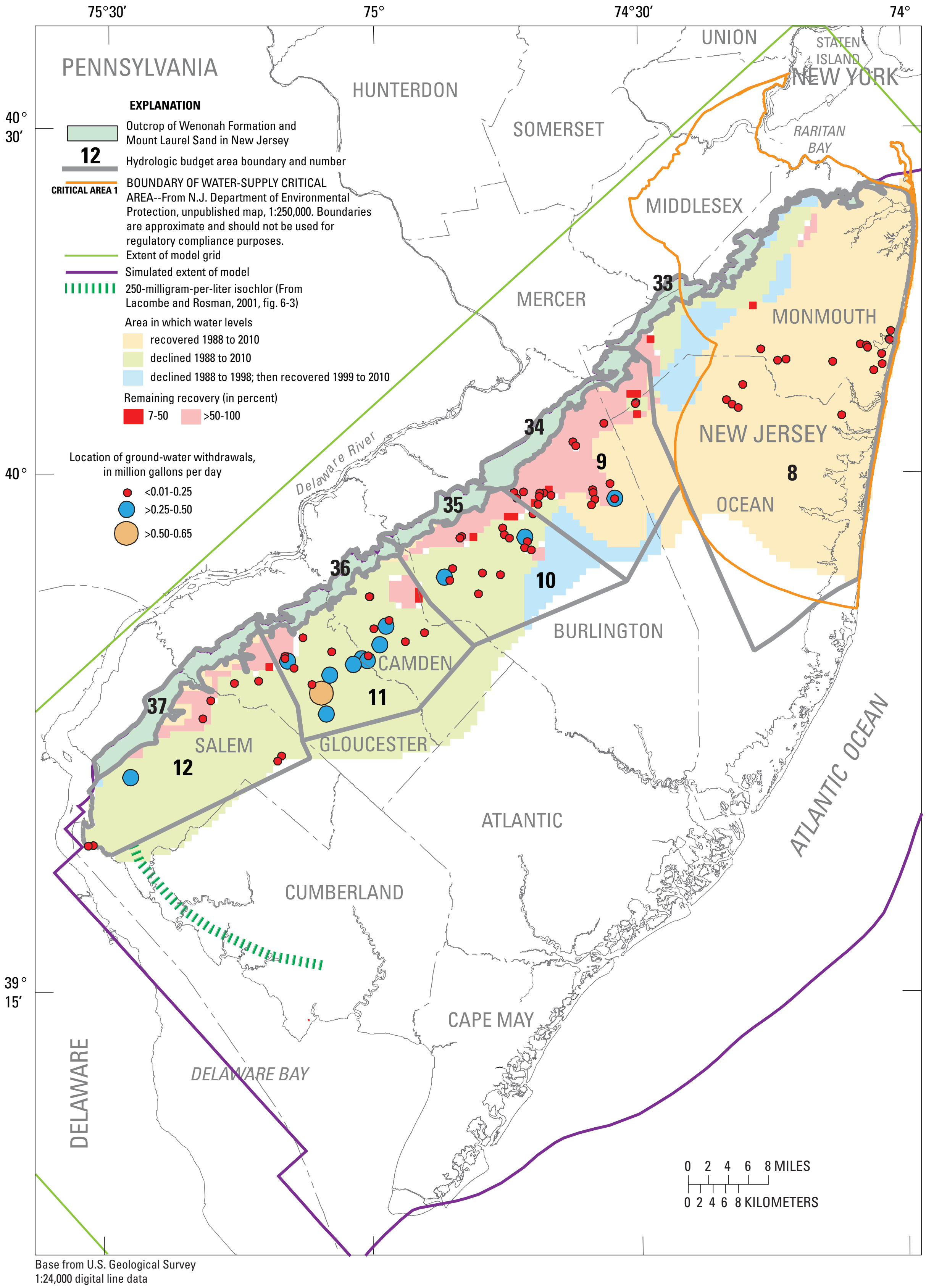


Figure 62. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999- 2010, Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 2. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

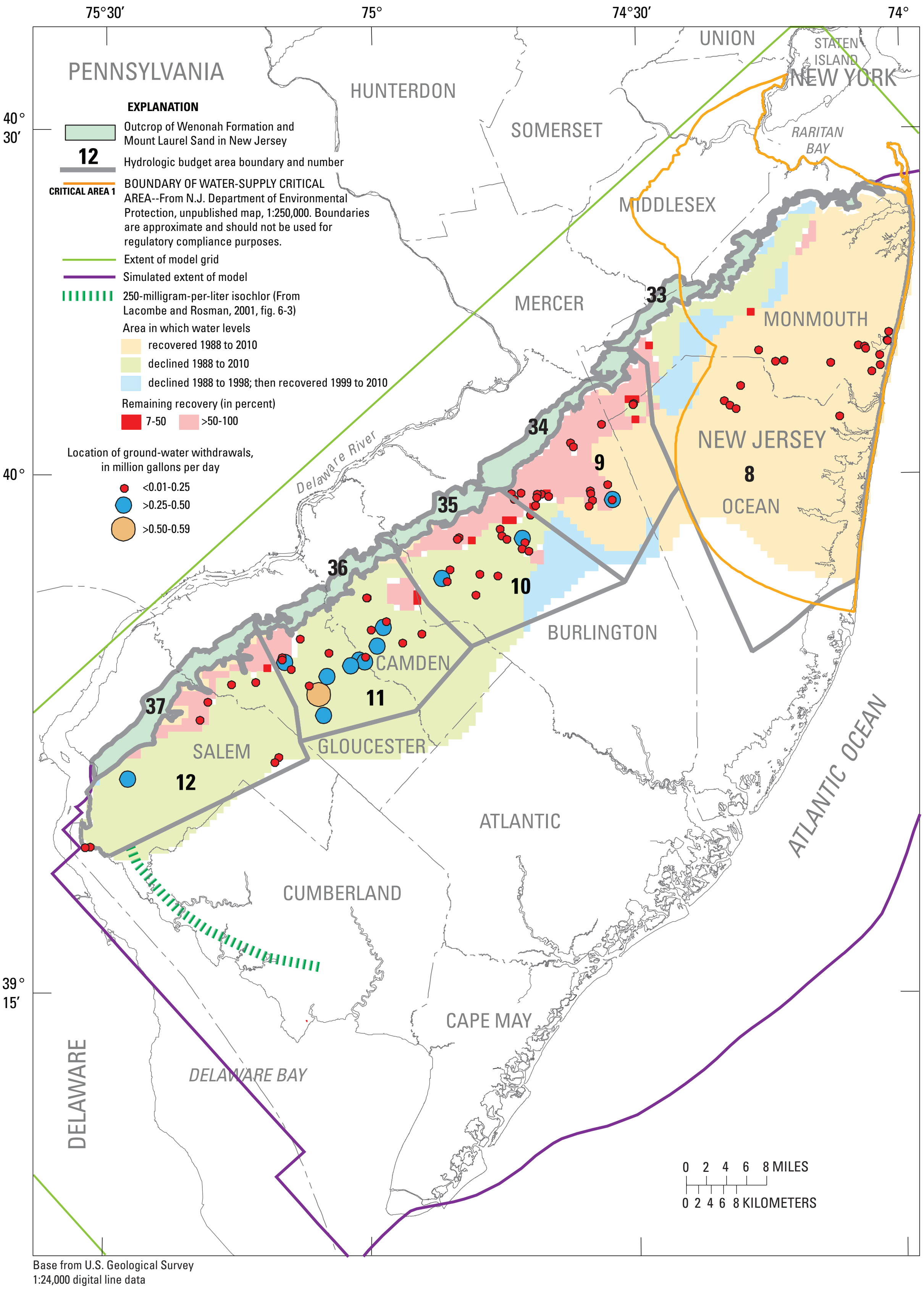


Figure 63. Areas in which water levels recovered (yellow), declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Wenonah-Mount Laurel aquifer, New Jersey Coastal Plain, scenario 3. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

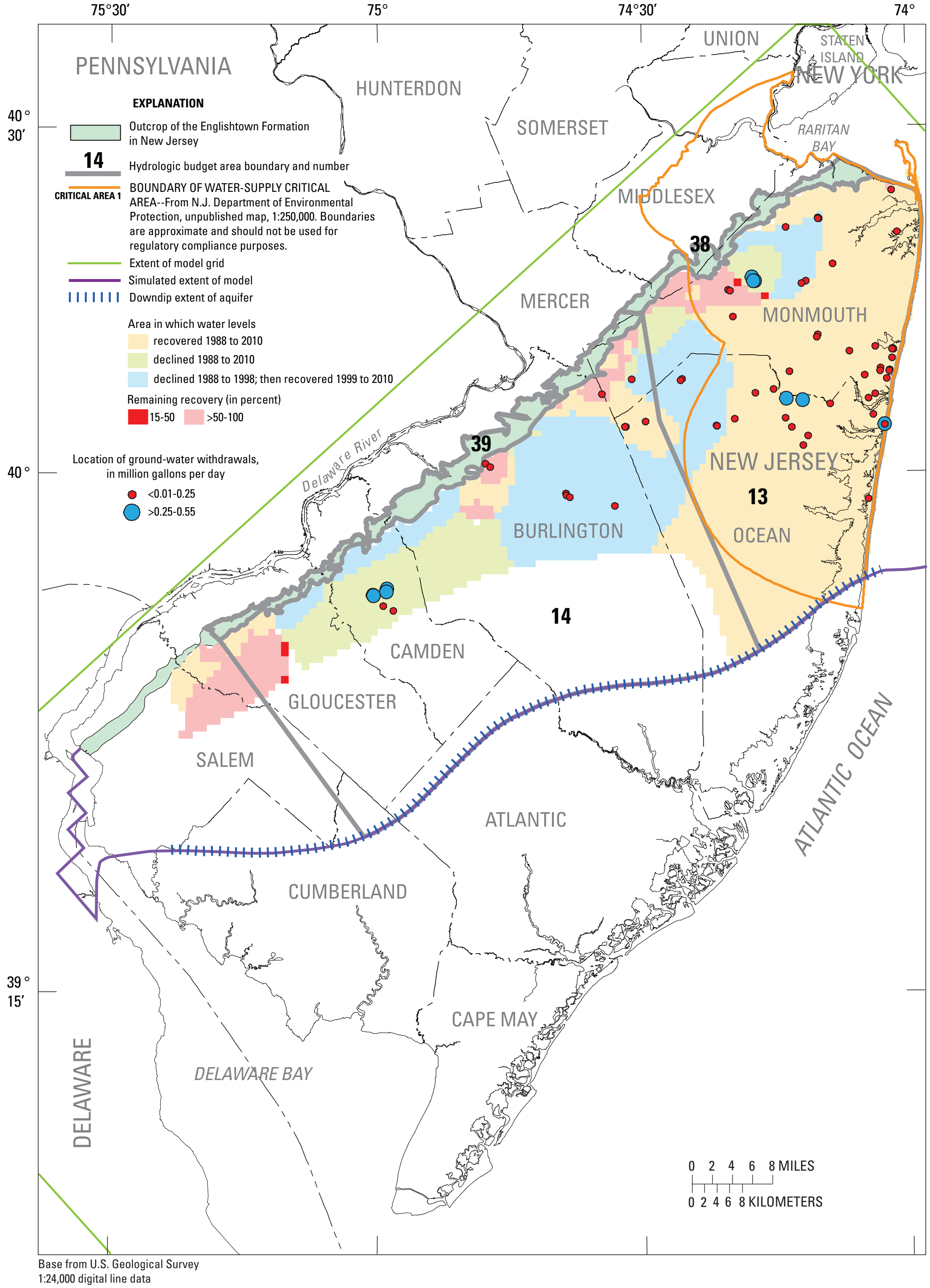


Figure 64. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Englishtown aquifer system, New Jersey Coastal Plain, scenario 1. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

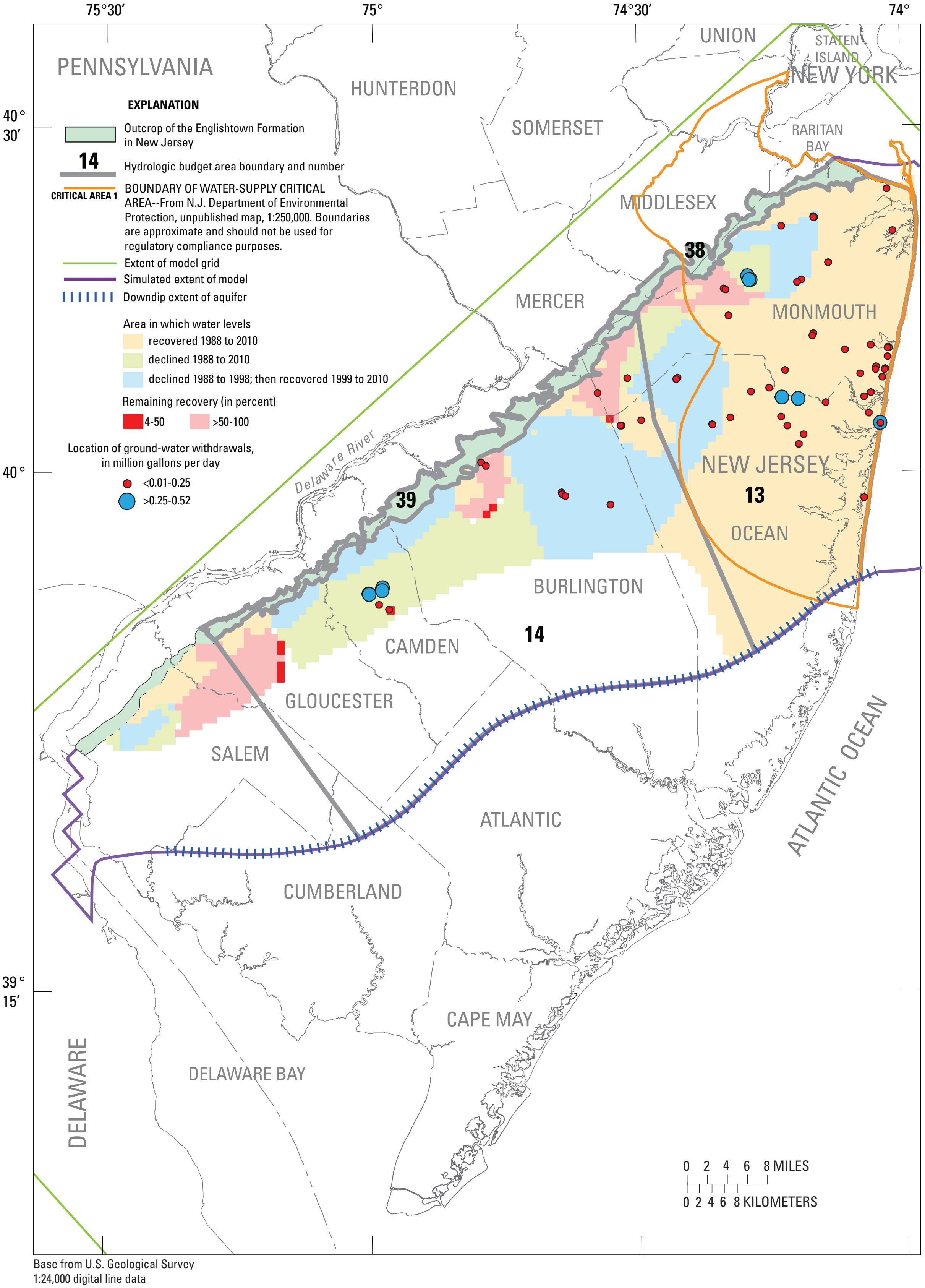
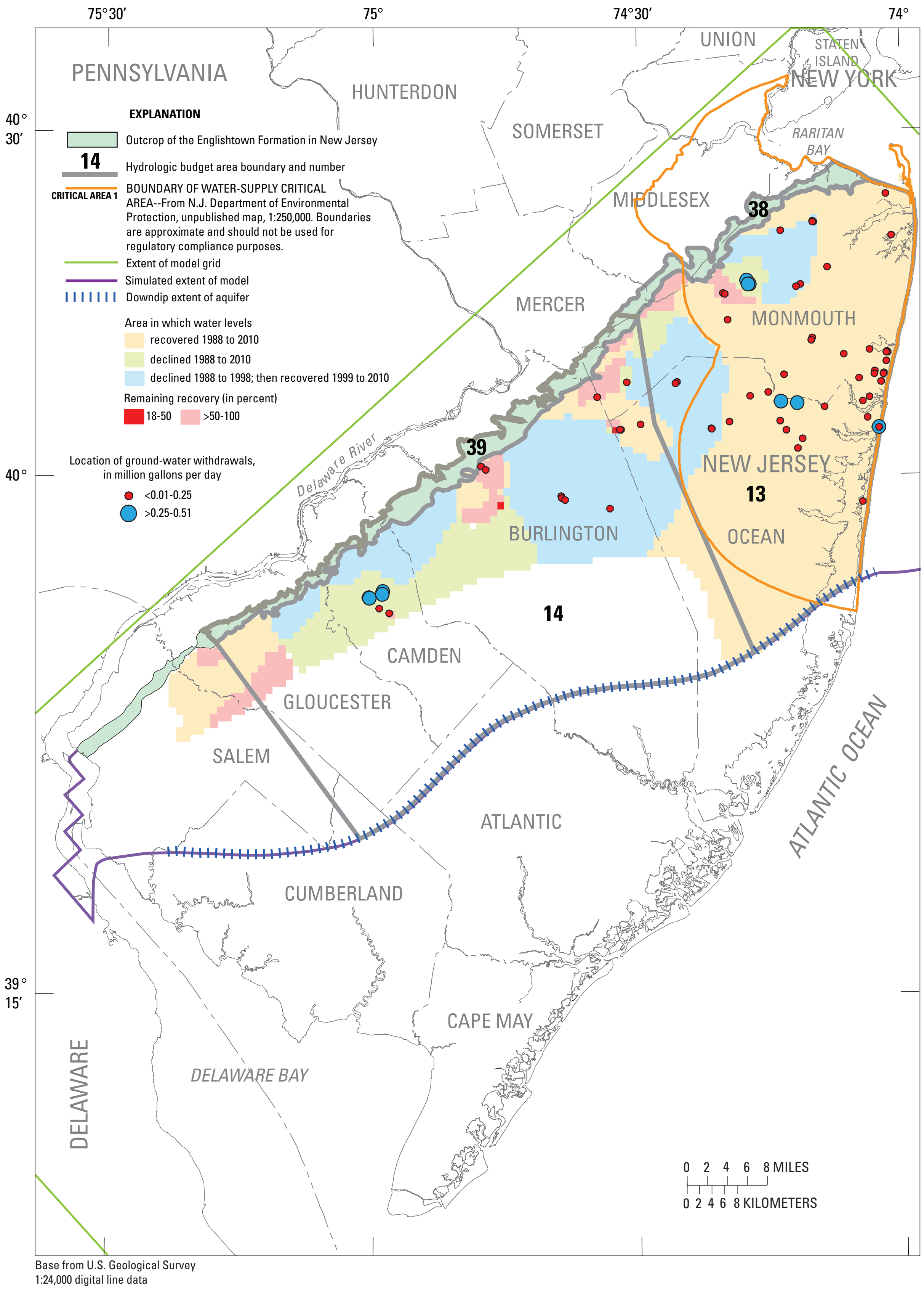


Figure 65. Areas in which water levels recovered (yellow), declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Englishtown aquifer system, New Jersey Coastal Plain, scenario 2. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 66. Areas in which water levels recovered (yellow), declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Englishtown aquifer system, New Jersey Coastal Plain, scenario 3. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

coastal area of Critical Area 1 recovered from 1988 to 2010 in scenarios 1 to 3.

In the Upper Potomac-Raritan-Magothy aquifer in scenario 1, water levels were recovering in 1998 in Critical Area 1 in Monmouth County (HBA 15) but declined by 2010 as a result of the projected increases in pumpage; the same pattern occurred in this area in scenario 2 and, to a lesser degree, in scenario 3, where water levels continued to recover in the eastern part of the county (figs. 67 to 69). In scenarios 1 and 2, water levels were recovering in 1998 in Critical Area 2, in Gloucester, central Camden, and part of western Burlington Counties (HBA 16) but, by 2010, they declined again in these areas; however, in scenario 3, water levels recovered from 1988 to 2010. Water levels in most of the updip area of Critical Area 2 in Gloucester, Camden, and Burlington Counties (HBA 16) and Salem County (HBA 17) recovered from 1988 to 2010 in scenarios 1 and 2. In scenarios 1 and 2, water levels declined continually from 1988 to 2010 in northern Ocean County in Critical Area 1 (HBA 15); in scenario 3, water levels in this area generally declined from 1988 to 1998, and then recovered from 1999 to 2010. In scenarios 1 and 2, water levels declined continually from 1988 to 2010 in an area adjacent to Critical Area 2 in Salem County; in scenario 3, the area of continual decline was smaller and farther from the Critical Area 2 boundary. Water levels declined continually from 1988 to 2010 in an area adjacent to the outcrop near the boundary of Critical Area 1 in southern Middlesex County (HBA 15) in all three scenarios.

In the Middle Potomac-Raritan-Magothy aquifer, water levels in scenarios 1 and 2 were recovering in 1998, but then declined by 2010 inside and outside Critical Area 1 downdip from the outcrop in Middlesex, Monmouth, and southeastern Mercer Counties (HBA 18) (figs. 70 and 71). The area of decline was smaller in scenario 3 (fig. 72). In Critical Area 2 downdip from the outcrop in Camden and Gloucester Counties (HBA 19), water levels were recovering in 1998, but declined by 2010 in scenario 1; the area of decline was much smaller in scenario 2 and was limited to Gloucester County, and no decline was observed in this area in scenario 3. Water levels continually declined from 1988 to 2010 in a very small area adjacent to the outcrop in southern Mercer County in all three scenarios, and in a small area in central Burlington County in scenario 2 only. Water levels declined from 1988 to 1998, then recovered from 1999 to 2010 in three isolated areas in northeastern Salem, southern Gloucester, and northern Burlington Counties in all three scenarios. Water levels continually recovered from 1988 to 2010 in the downdip area of Critical Area 1 in all three scenarios.

In the Lower Potomac-Raritan-Magothy aquifer, most water levels in Critical Area 2 in Camden and Gloucester Counties (HBA 22 and 23) were recovering in 1998, but then declined by 2010 (fig. 73) in scenario 1. This area was much smaller in scenario 2 (fig. 74) and was absent in scenario 3 (fig. 75). In scenario 1, water levels declined continually from 1988 to 2010 in a small central updip part of Gloucester County. This area was smaller in scenario 2, and was absent in scenario 3. Water levels declined from 1988 to 1998, then recovered from 1999 to 2010 in Salem County and in smaller areas in northern Gloucester County in all three scenarios. Water levels continually recovered from 1988 to 2010 in small areas in northwestern Gloucester, northeastern Camden, and northwestern Burlington Counties in scenario 1, and in northern Camden County, most of northeastern Burlington County, and the remainder of Gloucester County in scenario 2, but water levels recovered continually in Burlington and Camden Counties, and the remainder of Gloucester County in scenario 3.

Model Limitations

The RASA model is a regional ground-water flow model based on a conceptual hydrogeologic framework of the confined aquifers of the New Jersey Coastal Plain that is a simplified representation of a complex heterogeneous system. Local-scale heterogeneities or hydrologic features not represented in the regional model may affect the results of the simulations. Assumptions made in this model, such as isotropy and vertical homogeneity within each layer, may not be entirely satisfied and thus be a source of simulation error. Model parameters such as transmissivity, ground-water withdrawals, and recharge rates represent averages over the model area. Model parameters were estimated in areas where data, such as transmissivity and water-level measurements, were lacking. Variations in water levels resulting from seasonal variations in ground-water withdrawals or recharge rates were not simulated; however, the regional gradients are accurately simulated.

Ground-water discharge to streams is quantified in outcrop areas in the model by stream leakage, which is used to indicate areas of streamflow depletion. Because the RASA model is used to evaluate ground-water flow in confined aquifers, discretization errors may be associated with streams and stream leakances input to the model. However, differences in simulated water levels and in the magnitude and direction of flows between the baseline simulation and each of the three scenarios are considered to be reliable and to provide a reasonable estimate of the sources of water in the outcrop areas.

Steady-State Simulation

Ground-water systems are dynamic and adjust over periods of decades or greater to pumping and other stresses (Alley, 2006). A steady-state simulation was run using 2010 withdrawals from scenario 2 to determine the time required for steady-state conditions to be reached in the New Jersey Coastal Plain with 2010 withdrawal stresses. The ground-water system adjusts to the 2010 stresses by adjusting inflows and outflows until a new equilibrium in the flow system is achieved. Steady-state conditions are assumed when water levels do not change over time or when changes in the storage contribution to the water budget cease for given withdrawal

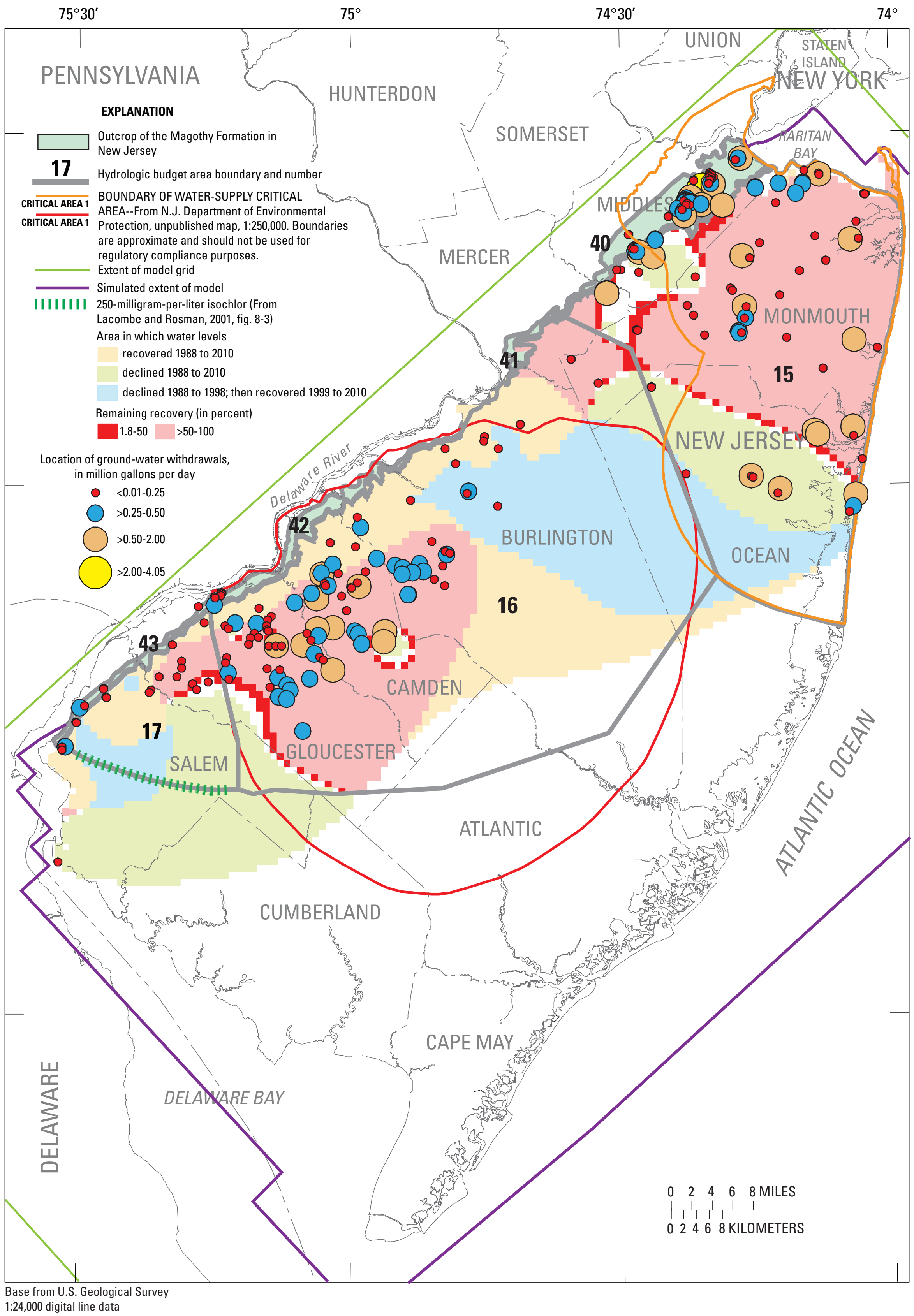


Figure 67. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

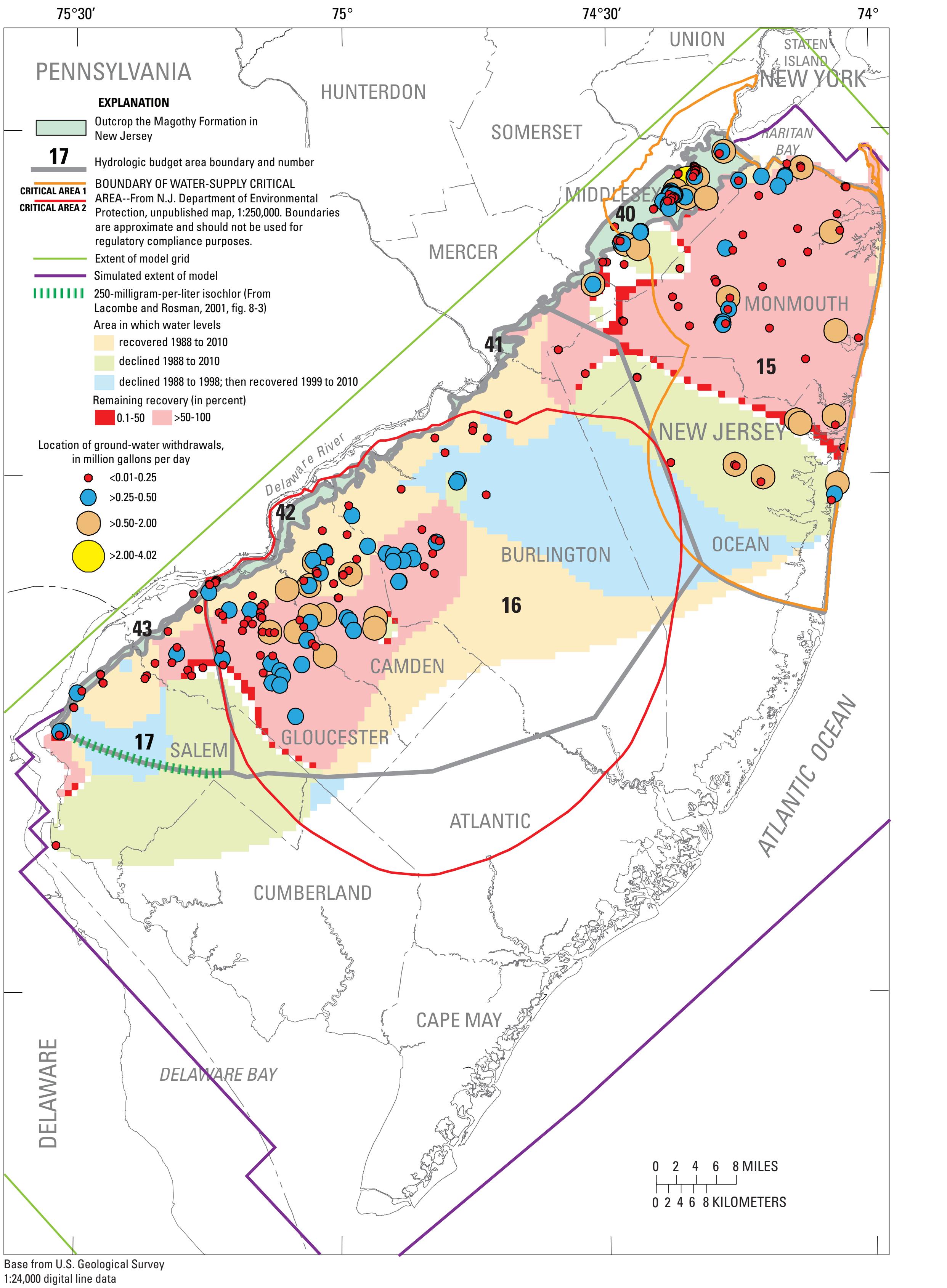


Figure 68. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

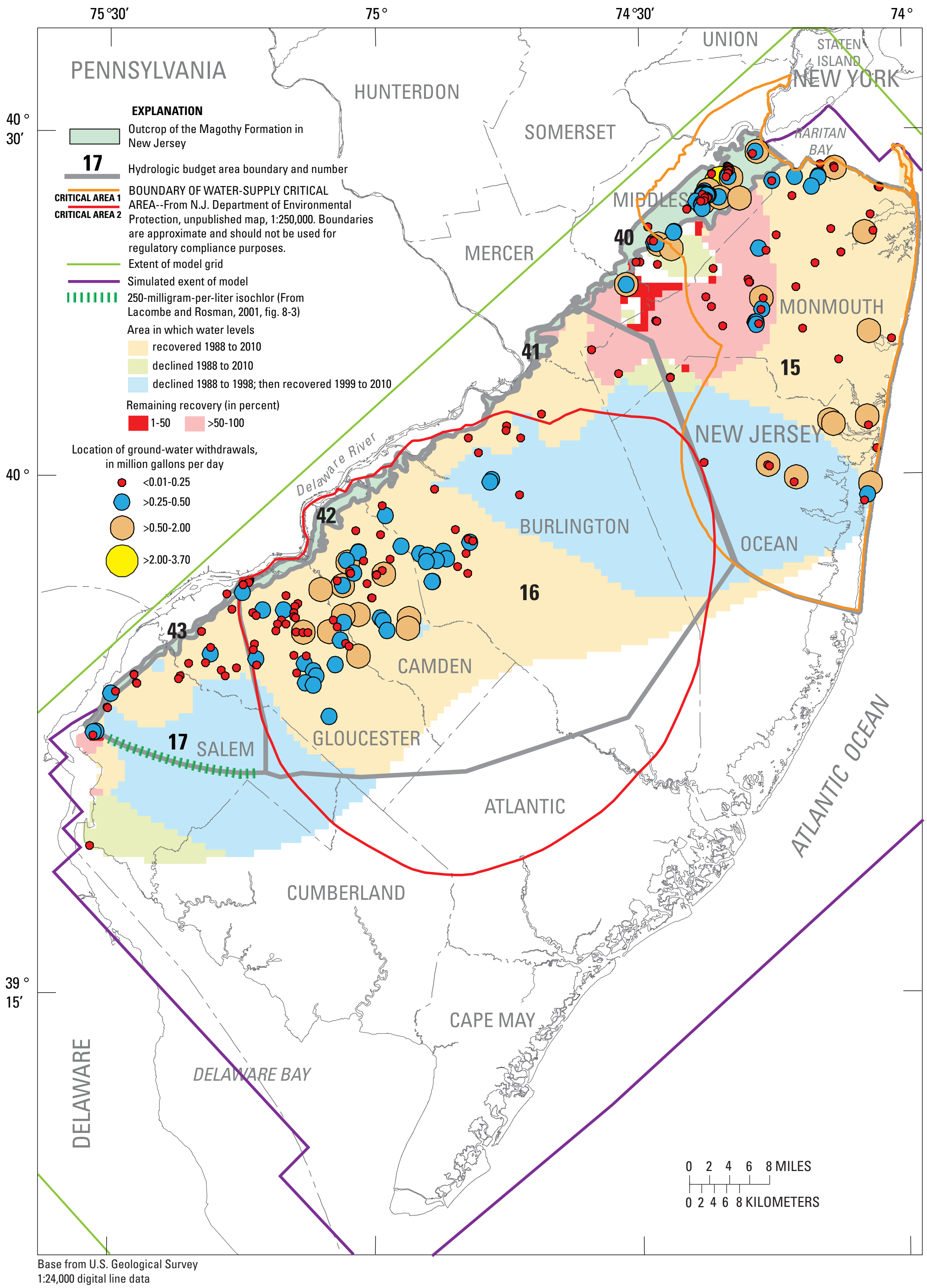


Figure 69. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

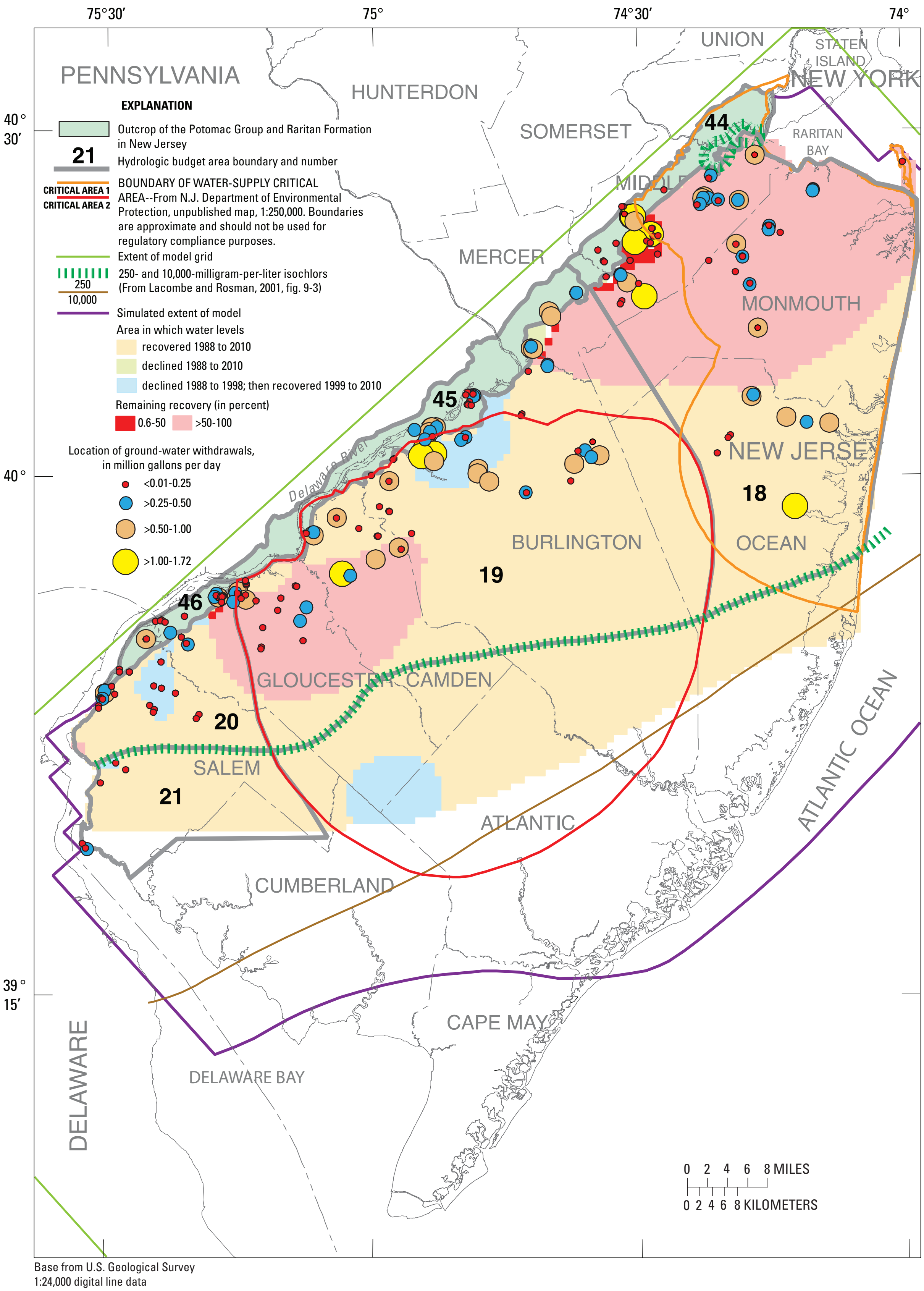


Figure 70. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

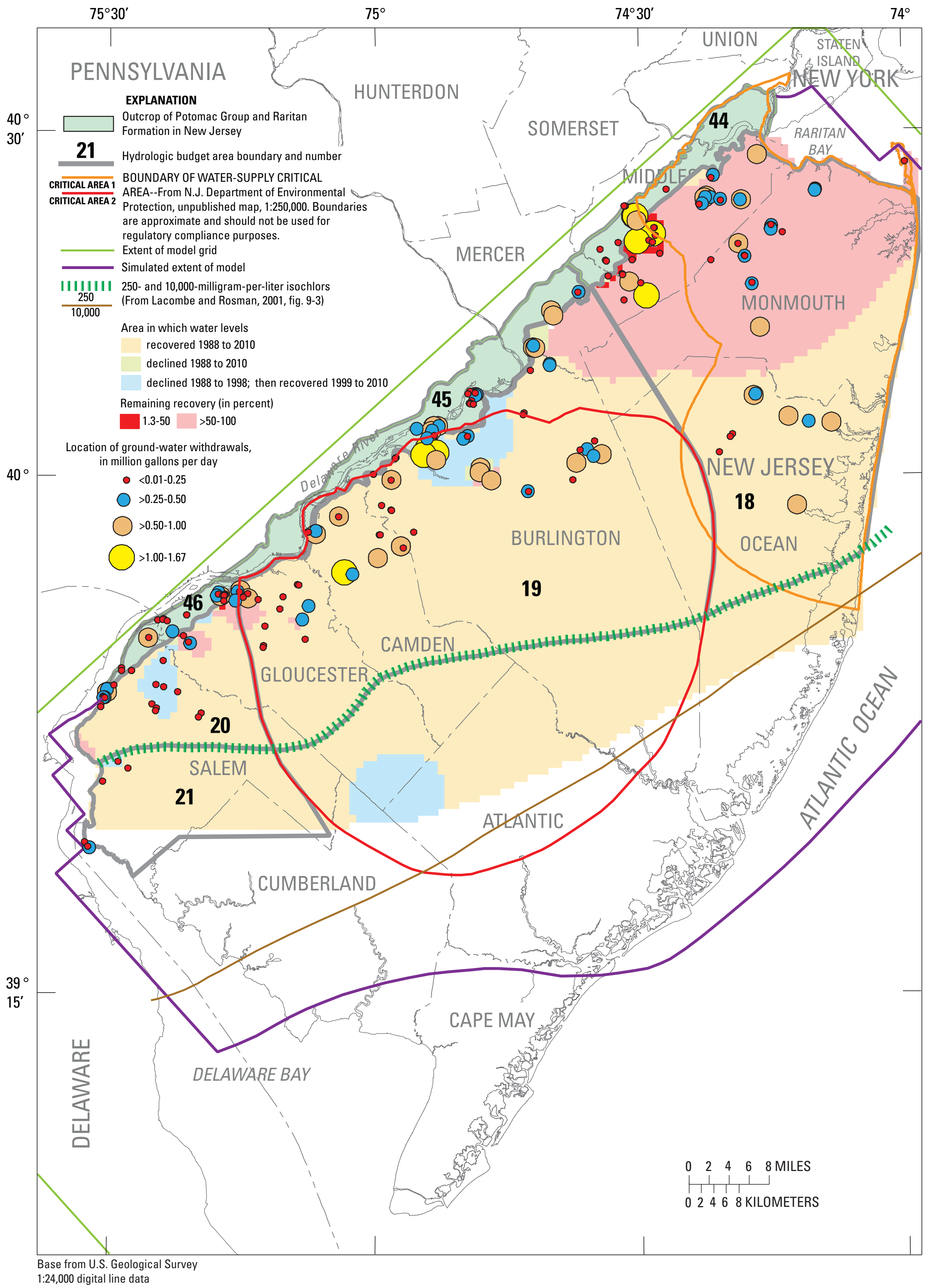


Figure 71. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

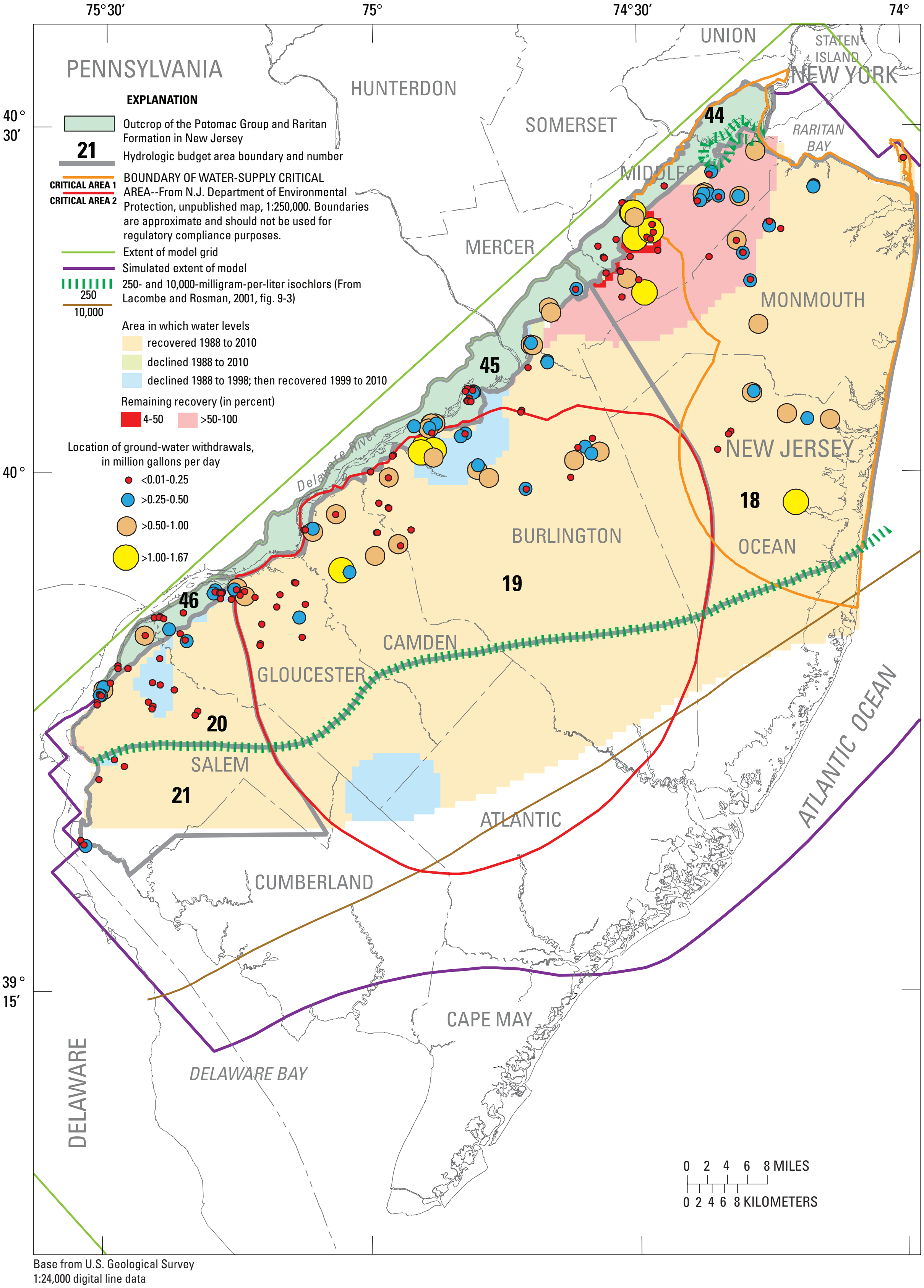


Figure 72. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

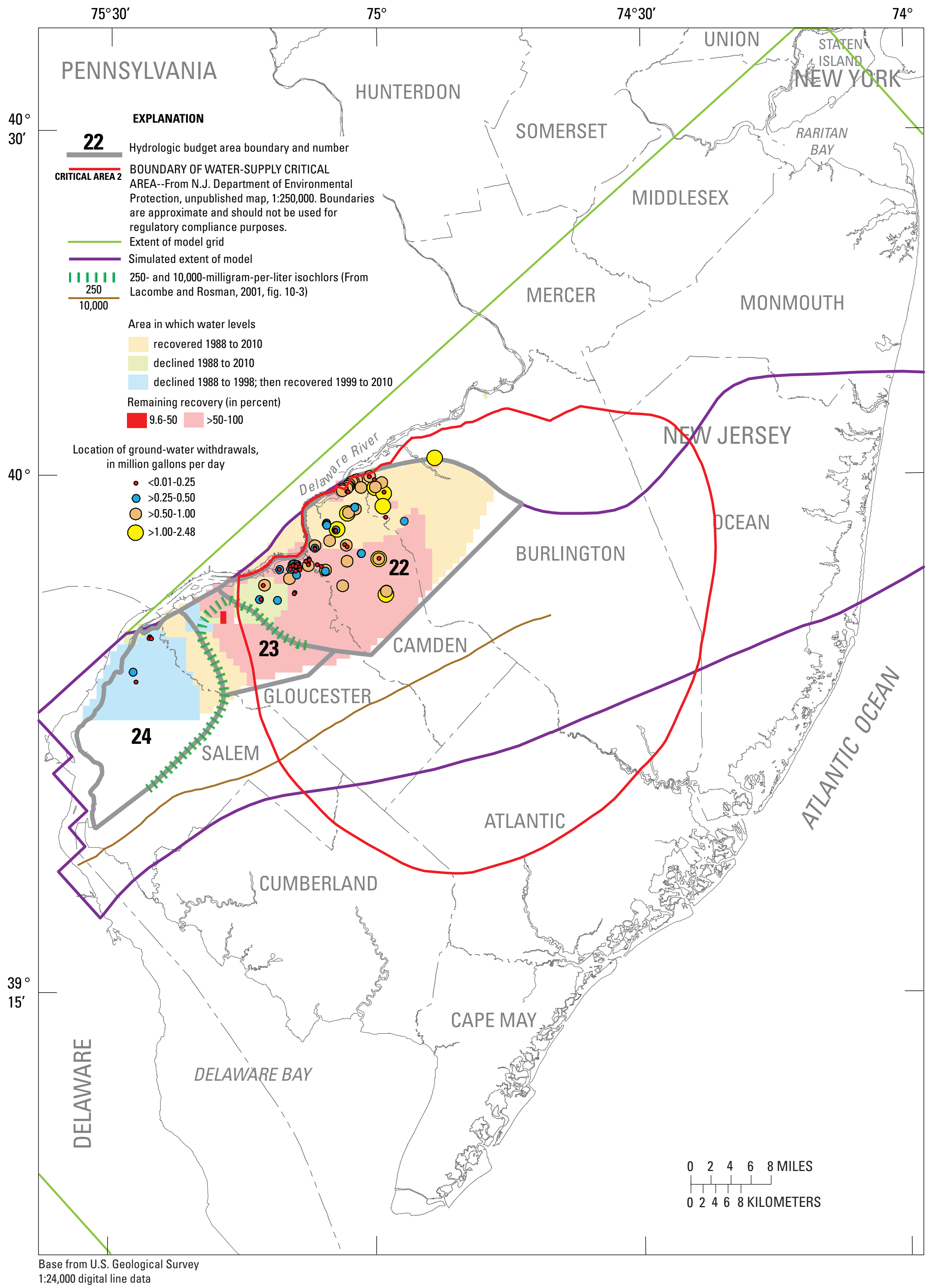


Figure 73. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 1. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)

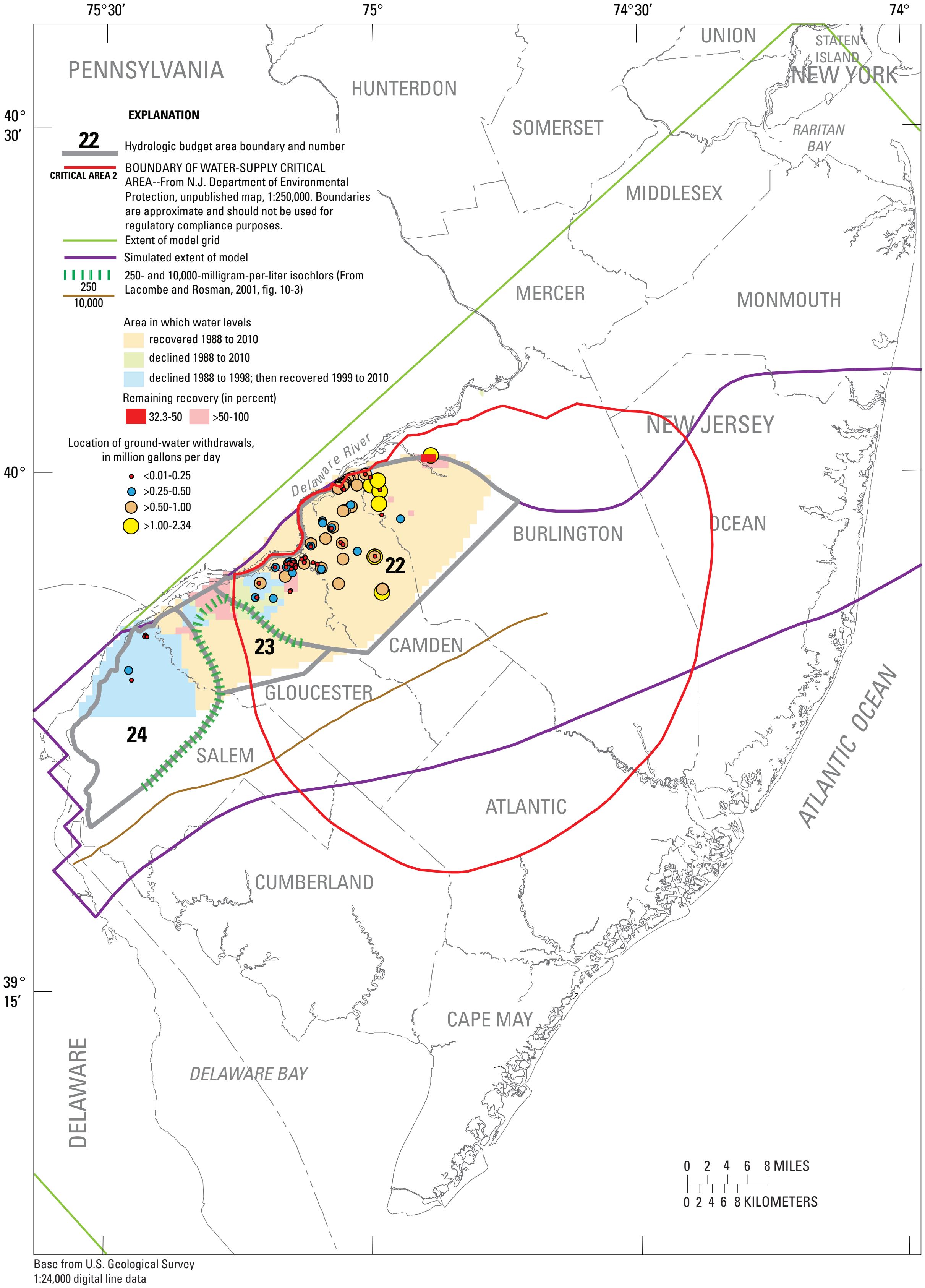
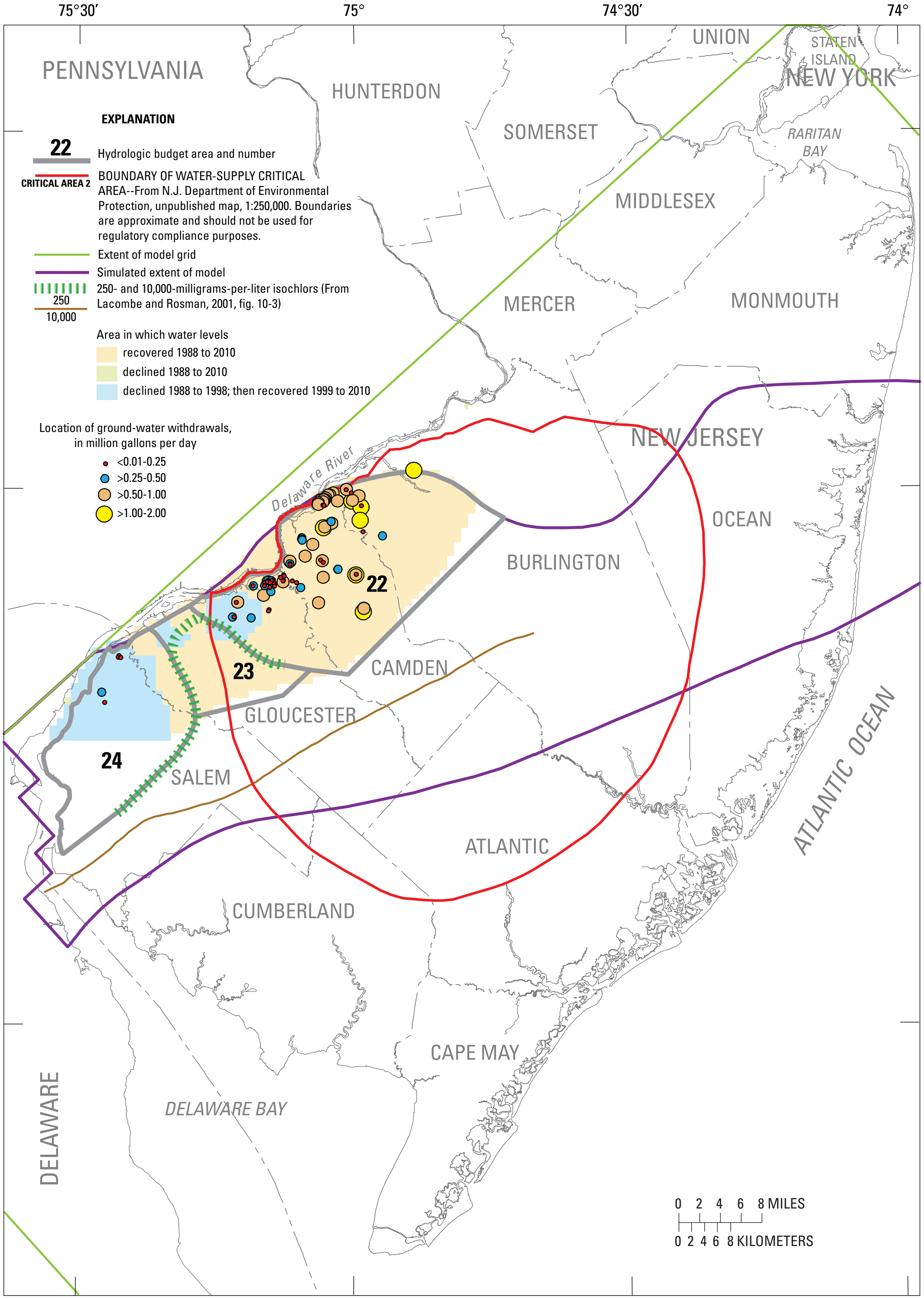


Figure 74. Areas in which water levels recovered (yellow); declined (green); declined, then recovered (blue); and recovered, then declined (red or pink), 1988-98 and 1999-2010, Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 2. (Small white areas adjacent to areas of water-level recovery or decline represent areas where water levels did not change. Remaining recovery is percentage of water-level recovery during 1988-98 that is remaining in 2010.)



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 75. Areas in which water levels recovered (yellow); declined (green); and declined, then recovered (blue), 1988-98 and 1999-2010, Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain, scenario 3.

conditions. For this simulation, conducted using the RASA model with continued 2010 withdrawals, the system was assumed to be at approximately steady-state conditions when the storage term was very low (less than 0.1 Mgal/d) and simulated water-level changes were less than 1 ft. For most of the confined aquifers in the New Jersey Coastal Plain, this state was achieved within 5 years, except in some parts of Ocean County. In Ocean County, more than 0.1 Mgal/d remained in storage in the Upper Potomac-Raritan-Magothy aquifer after 5 years. Also, water levels in the Wenonah-Mount Laurel aquifer and the Englishtown aquifer system did not stabilize for more than 40 years. As previously mentioned, these aquifers are hydraulically connected and their transmissivities can be more than an order of magnitude lower than the transmissivities of the Potomac-Raritan-Magothy aquifer system and the Piney Point, Vincentown, and Atlantic City 800-foot sand aquifers. (See “Description of ground-water flow model.”)

Summary and Conclusions

The New Jersey State Water Supply Plan (SWSP) is a tool devised by the NJDEP for assessing the State’s water-supply resources by delineating planning areas and evaluating water resources within each of them. The NJDEP is currently (2006) revising the SWSP. With each revision, the level of detail of investigation of water-supply issues in the State is refined. The current 2006 revision includes the delineation of planning areas for the eight confined aquifers of the New Jersey Coastal Plain. Forty-one water-budget areas in the confined aquifers and their outcrop were delineated by approximating boundaries based on various hydrologic, geohydrologic, and withdrawal conditions, such as aquifer extents, location of the 250-mg/L isochlor, aquifer outcrops, ground-water divides, and areas of large ground-water withdrawals.

An existing Regional Aquifer System Analysis (RASA) ground-water flow model of the New Jersey Coastal Plain was used to simulate ground-water flow in eight major confined aquifers of the region. A baseline simulation was run using 1998 withdrawals to establish water-level and flow conditions in 1998. Three scenarios were used to simulate the effects of pumpage in the Coastal Plain in 2010 predicted using three different methods. The methods, provided by the NJDEP, included (1) a continuation of 1990-99 water-use trends, (2) population projections by county, and (3) pumpage restrictions in Critical Areas 1 and 2. In scenario 1, estimated changes in withdrawals for public supply in water-supply growth areas in water-supply regions ranged from -20 to 23 percent. In scenario 2, estimated changes in withdrawals for public supply by county ranged from 1 to 13 percent. In scenario 3, the withdrawals from scenario 2 were modified for some wells located in or, in some cases, adjacent to, Critical Areas 1 and 2, depending on whether a water purveyor had access to a surface-water alternative. The projections were applied to wells that were in operation in 1998— mainly water-supply and agricultural wells, because about 90 percent of the total 1998 withdrawals from wells in the confined aquifers in the New Jersey Coastal Plain were used for public supply or agriculture.

The simulation results were used to assess the effects of the projected 2010 withdrawals on water levels, flow budgets for 41 hydrologic budget areas (HBAs), and areas of water-level recovery and decline. Continued declines in water levels in the confined aquifers can pose a threat to the long-term availability of ground water in some areas as a result of ground-water depletion and (or) saltwater intrusion. In the outcrop (unconfined) areas of the confined aquifers, continued declines in water levels can reduce ground-water discharge to streams and, in some areas of pumping, may induce water to flow from the stream to the aquifer.

In scenarios 1, 2, and 3, simulated water-level declines from 1998 to 2010 were largest in the Atlantic City 800-foot sand in coastal Atlantic County (14 ft in scenario 1 and 9 ft in scenarios 2 and 3) and in the Piney Point aquifer in Ocean County near the updip extent of the aquifer (7 ft in scenario 1 and 11 ft in scenarios 2 and 3). In scenarios 1, 2, and 3, simulated water levels in the Wenonah-Mount Laurel aquifer and Englishtown aquifer system in coastal Monmouth and Ocean Counties are still recovering in 2010 because of mandated reductions in withdrawals in Critical Area 1 beginning in the 1990s. Although the Potomac-Raritan-Magothy aquifers are the most heavily pumped aquifers in the New Jersey Coastal Plain, the magnitude of the water-level change in these aquifers from 1998 to 2010 was generally smaller, because the transmissivity and thickness of the Potomac-Raritan-Magothy aquifers are generally greater than those of the Piney Point, Vincentown, and Wenonah-Mount Laurel aquifers, and the Englishtown aquifer system.

A flow-budget analysis was completed for the 41 water-budget areas in the confined aquifers and their outcrops for scenarios 1 to 3 and the baseline simulation. The sources of water to wells as flows to and from the HBAs can be complex and are interdependent. Water for withdrawals in each HBA can be derived from leakage to streams in the outcrop areas; vertical leakage through overlying and underlying confining units; lateral flow from adjacent HBAs, and from downdip and offshore areas not in any HBA; and (or) storage. Changes in simulated flow budgets result from changes in pumpage within a budget area, but also from changes in pumpage in adjacent budget areas and in overlying and underlying aquifers. Lateral flows vary by HBA because of areal differences in transmissivity, stream conductance, vertical conductance, and withdrawals. The flow budgets indicate that as withdrawals increase in a confined aquifer, leakage from the overlying confined aquifer through the intervening confining unit increases; only the Atlantic City 800-foot sand (HBAs 1-2) also received increased inflow from the underlying aquifer with increased pumpage. In some outcrop areas of the Vincentown, Wenonah-Mount Laurel, and Upper and Middle Potomac-Raritan-Magothy aquifers, increased ground-water withdrawals reduced leakage to streams. Increases in ground-water withdrawals in the Atlantic City 800-foot sand and the Middle Potomac-Raritan-Magothy aquifer induced landward or updip movement of saltwater.

The flow budgets for the areas with the largest declines in simulated water levels for scenarios 1, 2, and 3 show that in HBA 2 in the Atlantic City 800-foot sand, inflow from the overlying aquifer increased 0.66, 0.46, and 0.46 Mgal/d, respectively (4, 3, and 3 percent, respectively) in scenarios 1 to 3, and lateral inflow from the offshore part of the aquifer (not included in any HBA) increased 0.77, 0.5, and 0.5 Mgal/d (5, 3, and 3 percent, respectively), in response to an increase in withdrawals of 2.2, 1.44, and 1.44 Mgal/d, respectively (14, 9, and 9 percent, respectively). The 250-mg/L isochlor is about 10 mi offshore from the pumping center in Atlantic County, is about 5 mi offshore from the pumping center in Cape May County, and curves onshore and traverses the southern boundary of HBA 2. In HBA 4 in the Piney Point aquifer, inflow from the overlying aquifer increased 0.3, 0.37, and 0.37 Mgal/d, respectively (7, 9, and 9 percent, respectively), in scenarios 1 to 3, in response to an increase in withdrawals of 0.36, 0.46, and 0.46 Mgal/d, respectively (8, 11, and 11 percent, respectively). In HBA 16 in the Upper Potomac-Raritan-Magothy aquifer, inflow from the overlying aquifer increased 4.12, 3.89, and 2.91 Mgal/d, respectively (13, 13, and 9 percent, respectively) in scenarios 1 to 3, when withdrawals were increased 1.92, 1.65, and 0.28 Mgal/d, respectively (6, 5, and 1 percent, respectively); however, outflow to the underlying aquifer also increased 2.23, 2.14, and 1.94 Mgal/d, respectively (7, 7, and 6 percent, respectively). In HBA 18 in the Middle Potomac-Raritan-Magothy aquifer, when withdrawals increased 1.63, 1.18, and 0.82 Mgal/d, respectively (8, 6, and 4 percent, respectively), in scenarios 1 to 3, lateral inflow from the outcrop (HBA 44) increased 0.82, 0.66, and 0.5 Mgal/d, respectively (4, 3, and 2 percent, respectively), and inflow downdip at the 250-mg/L isochlor in Ocean County increased 0.5, 0.45, and 0.34 Mgal/d, respectively (2 percent for each scenario). Pumped wells in the downdip portion of HBA 18 are more than 7 mi updip from the location of the 250-mg/L isochlor.

Leakage to streams decreased from baseline conditions in some HBAs in the outcrop of the Upper and Middle Potomac-Raritan-Magothy aquifers because of increased pumpage in the budget areas in which the streams are located, or in adjacent budget areas. For example, in HBA 40, in the outcrop of the Upper Potomac-Raritan-Magothy aquifer in Critical Area 1, leakage to streams decreased 2.44 Mgal/d (3 percent) in scenario 1, 1.8 Mgal/d (3 percent) in scenario 2, and 1.02 Mgal/d (1 percent) in scenario 3 compared to the 1998 simulation in response to an increase in pumpage from baseline conditions of 1.45 Mgal/d (2 percent) in scenario 1, 0.77 Mgal/d (1 percent) in scenario 2, and 0.12 Mgal/d (less than 1 percent) in scenario 3. In HBA 44 in the Middle Potomac-Raritan-Magothy aquifer in Critical Area 1, leakage to streams decreased 2.23, 2.06, and 1.91 Mgal/d, respectively (3, 3, and 2 percent, respectively), in scenarios 1 to 3 in response to an increase in pumpage from baseline conditions of 0.28, 0.27, and 0.27 Mgal/d, respectively (less than 1 percent for each scenario), in HBA 44 and an increase in pumpage from baseline conditions of 1.63, 1.18, and 0.82 Mgal/d, respectively (8, 6, and 4 percent, respectively), in HBA 18, downdip from HBA 44. In HBA 42 in the outcrop of the Upper Potomac-Raritan-Magothy aquifer (in Critical Area 2), there was induced leakage from the stream to the aquifer in the 1998 simulation and scenarios 1 to 3. Pumpage was not changed from baseline conditions in HBA 42 in the three scenarios, and lateral outflow to HBA 16, downdip from HBA 42, decreased 0.36 Mgal/d (1 percent) in scenario 1, 0.43 Mgal/d (1 percent) in scenario 2, and 0.67 Mgal/d (2 percent) in scenario 3; moreover, the induced leakage from the stream to the aquifer decreased 0.28, 0.47, and 0.87 Mgal/d (1, 1, and 3 percent, respectively).

In the Wenonah-Mount Laurel aquifer, water levels declined continually in Monmouth County (HBA 8) downdip from the outcrop (in Critical Area 1) from 1988 to 2010 in all three scenarios, although most of the water levels in the downdip area of Critical Area 1 are still recovering because of mandated reductions in pumpage in the 1990s. In the Englishtown aquifer system, water levels declined continually in two small areas in HBA 13—in central Monmouth County (in Critical Area 1) and in western Monmouth County downdip from the outcrop from 1988 to 2010 in all three scenarios, although most of the water levels in the downdip area of Critical Area 1 are still recovering because of the mandated reductions in pumpage. In the Upper Potomac-Raritan-Magothy aquifer in Critical Area 1 in Monmouth County (HBA 15), water levels were recovering in 1998, but declined again by 2010 in all three scenarios, but the area of decline was smaller in scenario 3. In the Upper Potomac-Raritan-Magothy aquifer in Critical Area 2 in central Camden and in Gloucester and western Burlington Counties (HBA 16), water levels were recovering in 1998 in scenarios 1 and 2, but had declined again by 2010. In scenario 3, water levels in this area were still recovering in 2010.

In the Middle Potomac-Raritan-Magothy aquifer, water levels were recovering in 1998, but then declined by 2010 both inside and outside Critical Area 1 downdip from the outcrop in Middlesex, Monmouth, and southeastern Mercer Counties (HBA 18) in scenarios 1 and 2; however, in scenario 3, the area of decline was smaller. In scenario 1, water levels in Critical Area 2 downdip from the outcrop in Camden and Gloucester Counties (HBA 19) were recovering in 1998, but then declined by 2010; however, the area of decline was less extensive in scenario 2, and water levels in the same area did not decline after 1998 in scenario 3.

In scenario 1, water levels in the Lower Potomac-Raritan-Magothy aquifer in Critical Area 2 in Camden and Gloucester Counties (HBA 22) were recovering in 1998, but then declined by 2010 when pumpage was increased. The area of decline was less extensive in scenario 2, and in scenario 3 water levels were recovering. In scenarios 1 and 2, water levels in a small part of the updip area of Gloucester County declined continually from 1988 to 2010, but the area of decline was smaller in scenario 2. The water levels in this area were recovering after 1998 in scenario 3.

Total withdrawals were 340.3 Mgal/d for 1998, 365.7 Mgal/d for scenario 1, 361.8 Mgal/d for scenario 2, and 355.4 Mgal/d for scenario 3. The simulated water levels for scenarios 1 and 2 were generally within 2 ft of each other in most areas in the confined aquifers, but differences of more than 2 ft occurred locally. Differences in values of flow-budget components between scenarios 1 and 2 as a percentage change from 1998 values were generally within 2 percent in most hydrologic budget areas, but values of some budget components in some hydrologic budget areas differed by more than 2 percent.

Simulated water levels in Critical Areas 1 and 2 continued to recover more in scenario 3 than in scenarios 1 and 2 because mandated pumpage restrictions in the 1990s within the Critical Areas were maintained in scenario 3. Moreover, simulated water levels in the Upper and Middle Potomac-Raritan-Magothy aquifers in Critical Areas 1 and 2 generally declined less in scenario 3 than in scenarios 1 and 2. The flow budgets in scenario 3 indicate that leakage to streams in the outcrop area of the Upper Potomac-Raritan-Magothy aquifer (HBA 40) decreased as much as 2 percent less than in scenarios 1 and 2. The flow budgets in scenario 3 also indicate that inflow from the overlying aquifer was as much as 6 percent smaller in the Lower Potomac-Raritan-Magothy aquifer (HBA 22), and 4 percent smaller in the Upper Potomac-Raritan-Magothy aquifer (HBA 16) than in scenarios 1 and 2.

The three scenarios used to quantify the effects in withdrawals on the ground-water flow system in the New Jersey Coastal Plain did not incorporate pumpage at additional or possible new withdrawal sites, but did include areas with current water-supply management concerns. The flow-budget values indicate that the sources of water to or from a particular HBA change when stresses change in an HBA, but also can change as the stresses in the underlying, overlying, and adjacent HBAs change. Effects of additional, future changes in withdrawal stresses on water levels and ground-water flow in the confined aquifers of the New Jersey Coastal Plain can be estimated by reevaluation of the flow budgets in each of the hydrologic budget areas as part of the SWSP.

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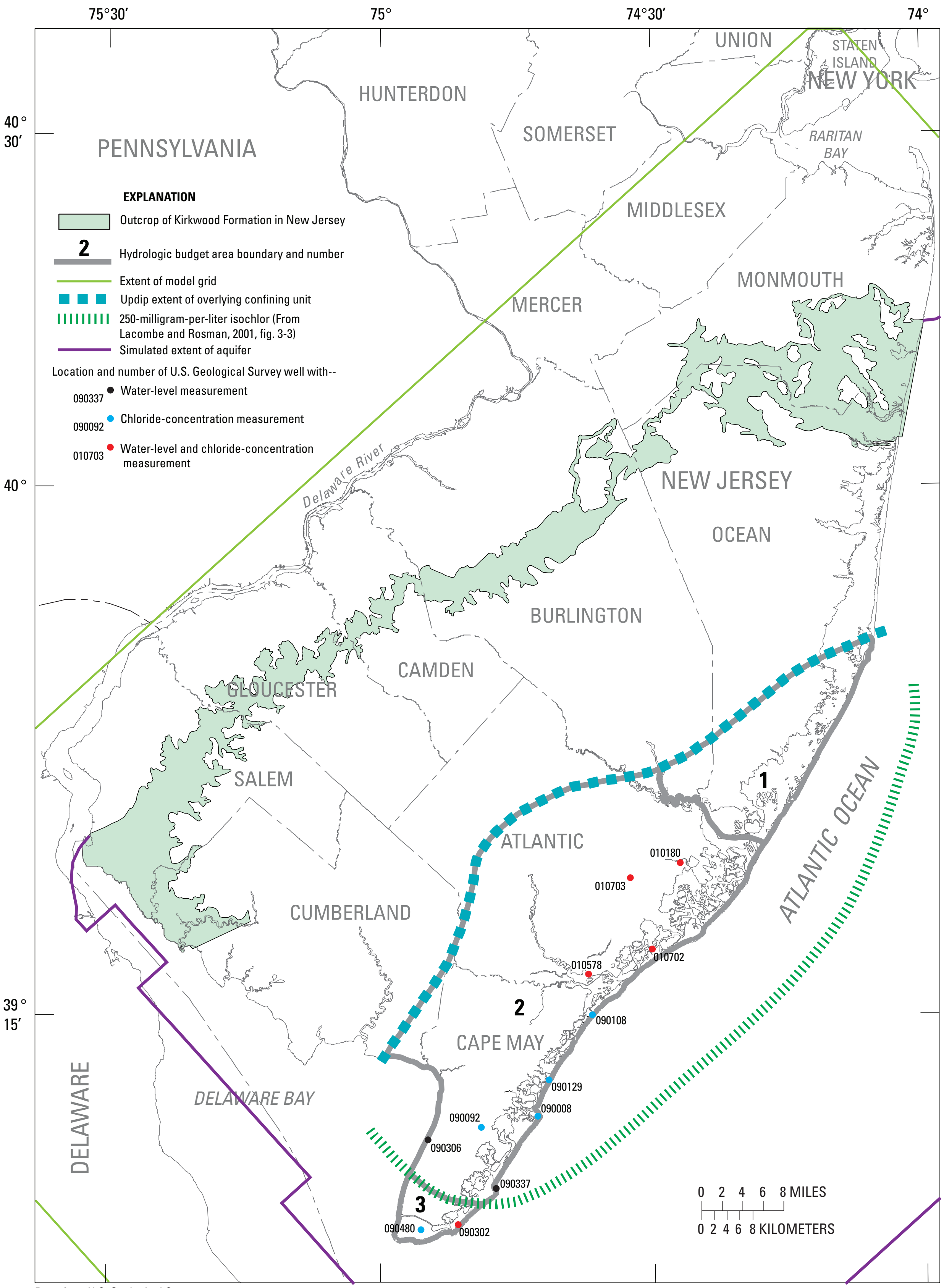
Appendix 1—Water-Level Monitoring Wells (2005) and Chloride-Measurement Wells (1999–2005), New Jersey Coastal Plain

Water-level and chloride-concentration data are collected by the USGS at various wells in the New Jersey Coastal Plain. The locations of these wells are shown in figures for each aquifer in this appendix. Well-construction and chloride-concentration information for these wells is also given here. These data are important for determining areas at risk for saltwater intrusion, areas of declining water levels, and areas where available information is limited and additional data collection may be warranted. All data were obtained from the USGS New Jersey Water Science Center in West Trenton, N.J.



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 1-1. Location of wells with water-level measurements (2005) and chloride-concentration measurements (1999-2005), Atlantic City 800-foot sand, New Jersey Coastal Plain.

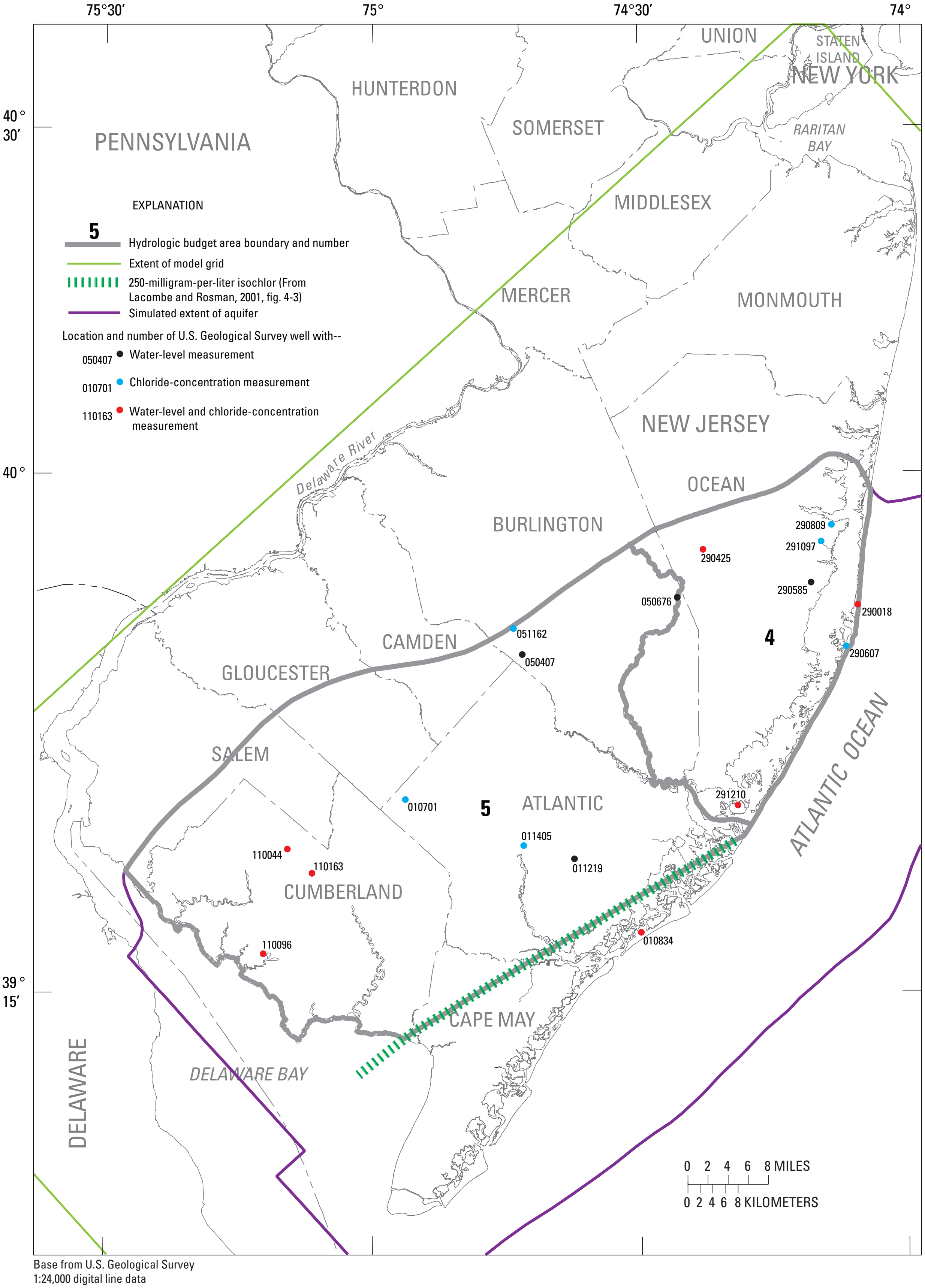


Figure 1-2. Location of wells with water-level measurements (2005) and chloride-concentration measurements (2000-2005), Piney Point aquifer, New Jersey Coastal Plain.

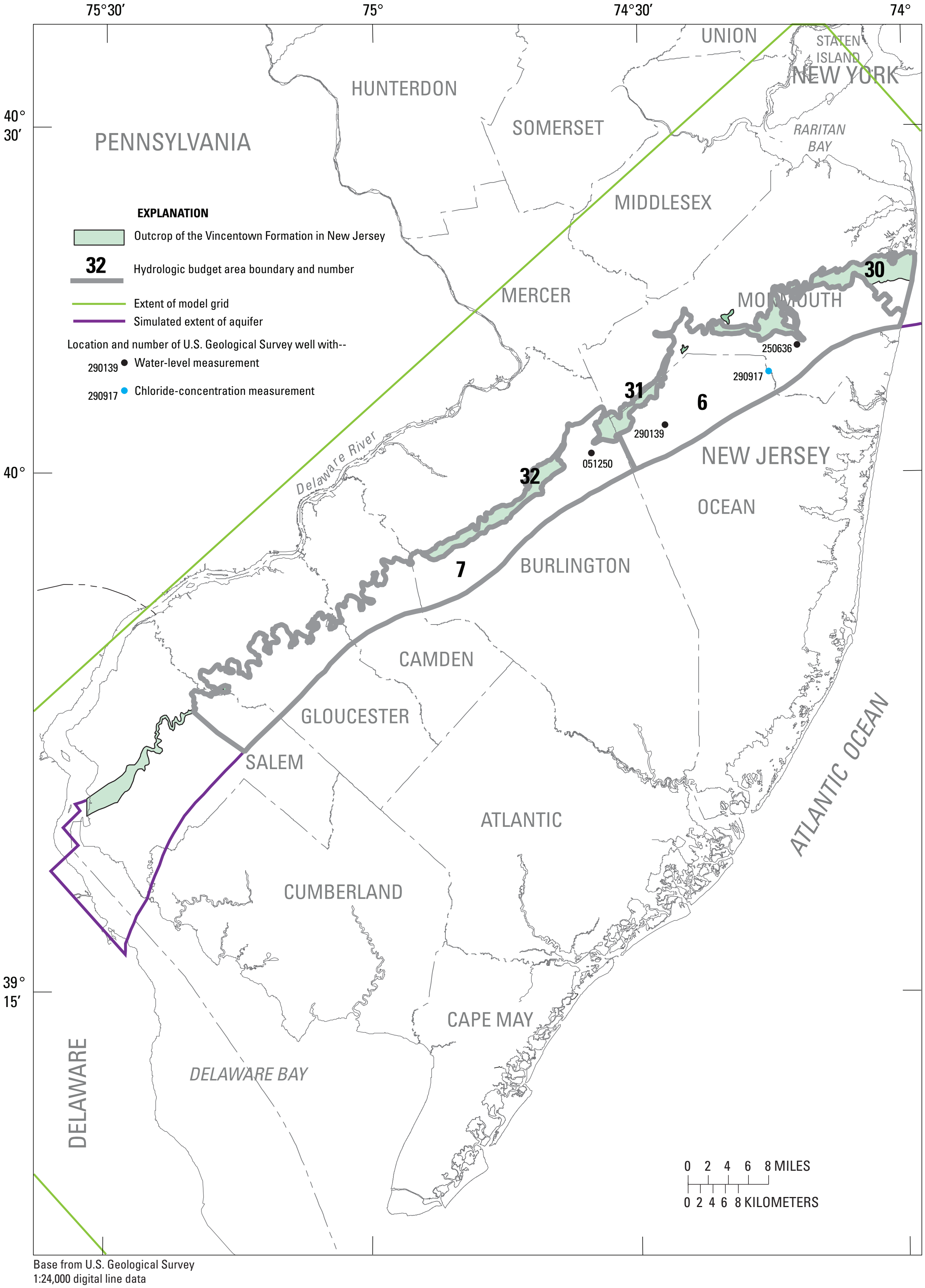


Figure 1-3. Location of wells with water-level measurements (2005) and chloride-concentration measurements (2000-2005), Vincentown aquifer, New Jersey Coastal Plain.

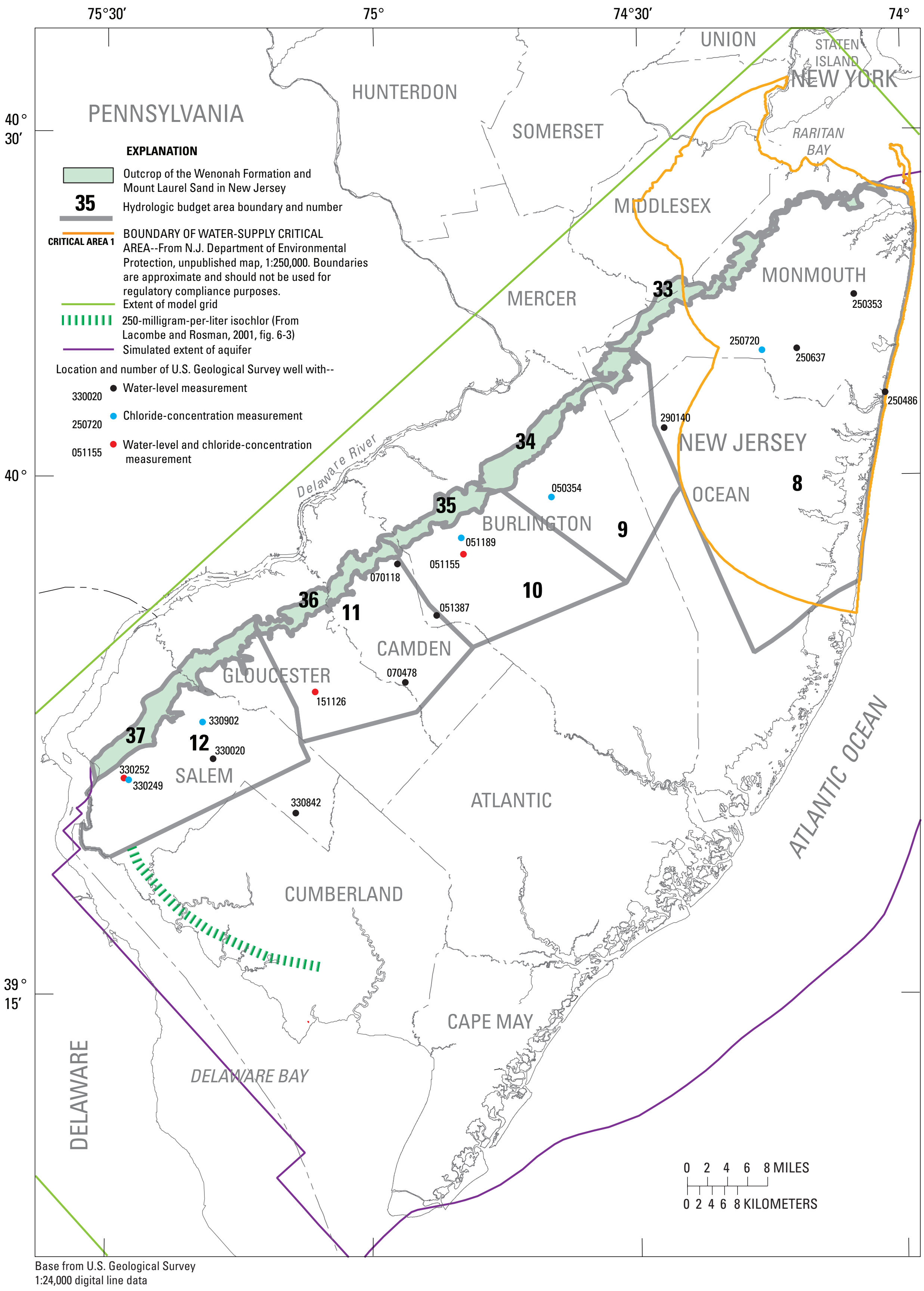


Figure 1-4. Location of wells with water-level measurements (2005) and chloride-concentration measurements (2000-2005), Wenonah-Mount-Laurel aquifer, New Jersey Coastal Plain.

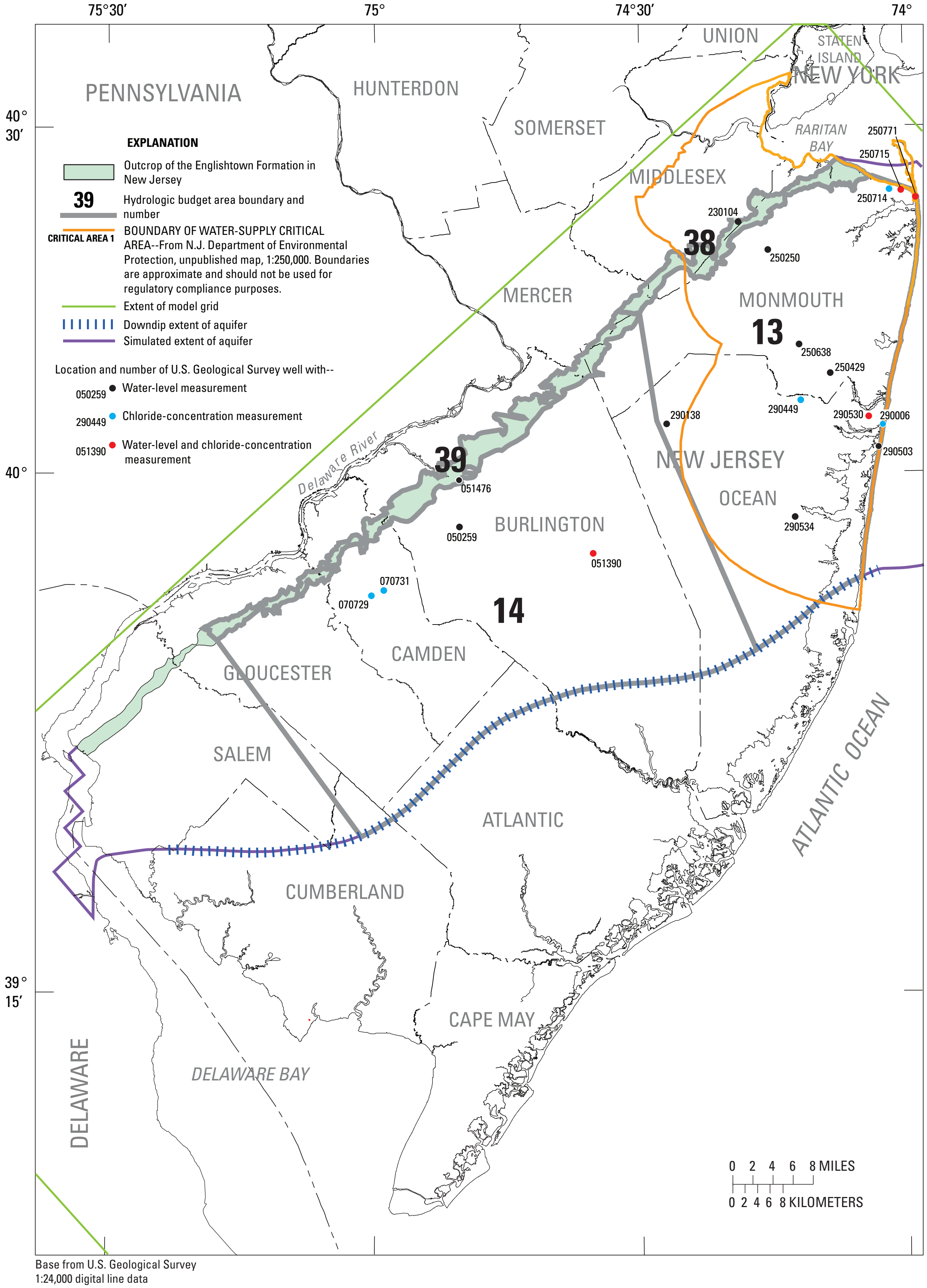


Figure 1-5. Location of wells with water-level measurements (2005) and chloride-concentration measurements (1999-2005), Englishtown aquifer system, New Jersey Coastal Plain.

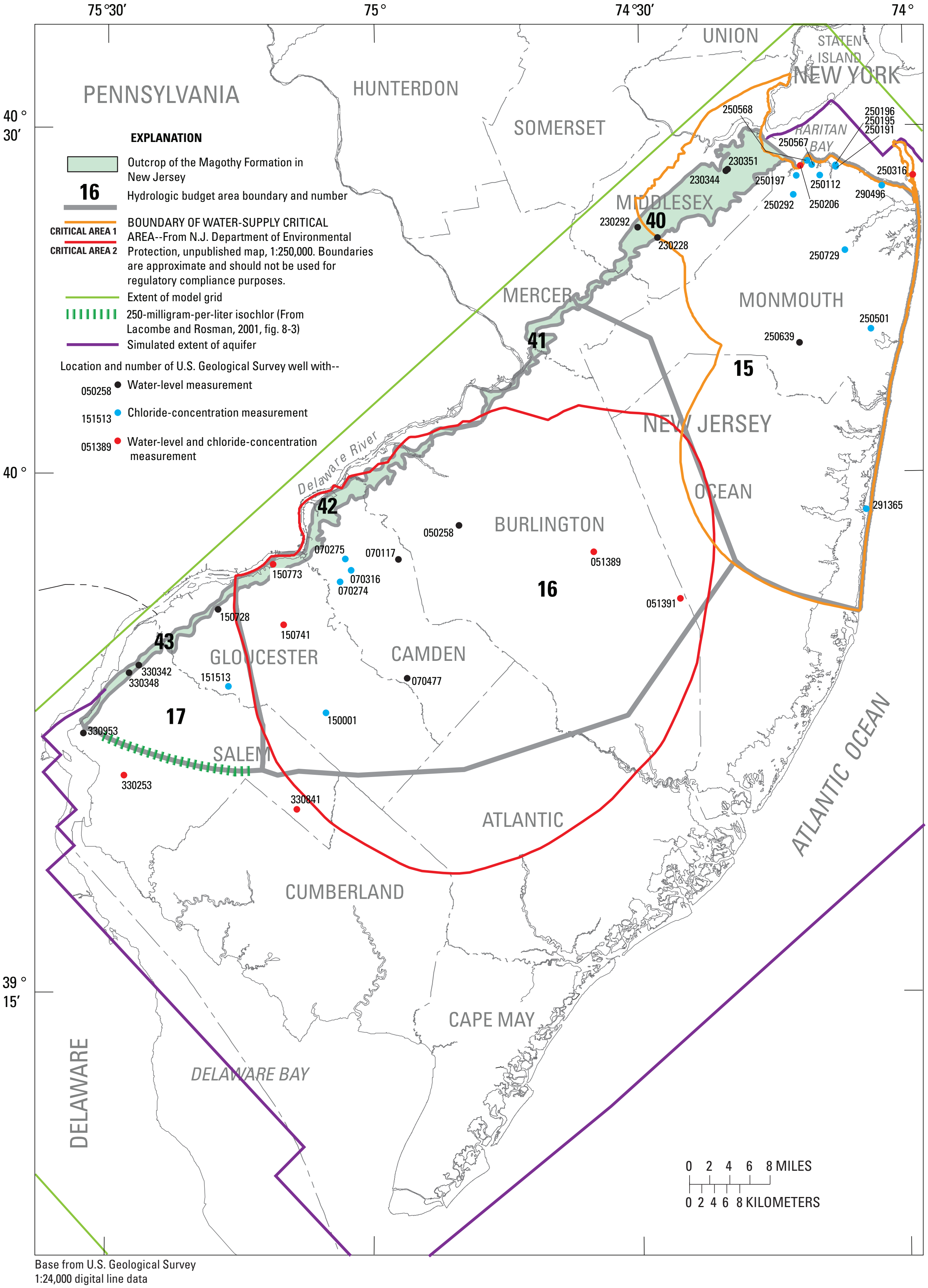
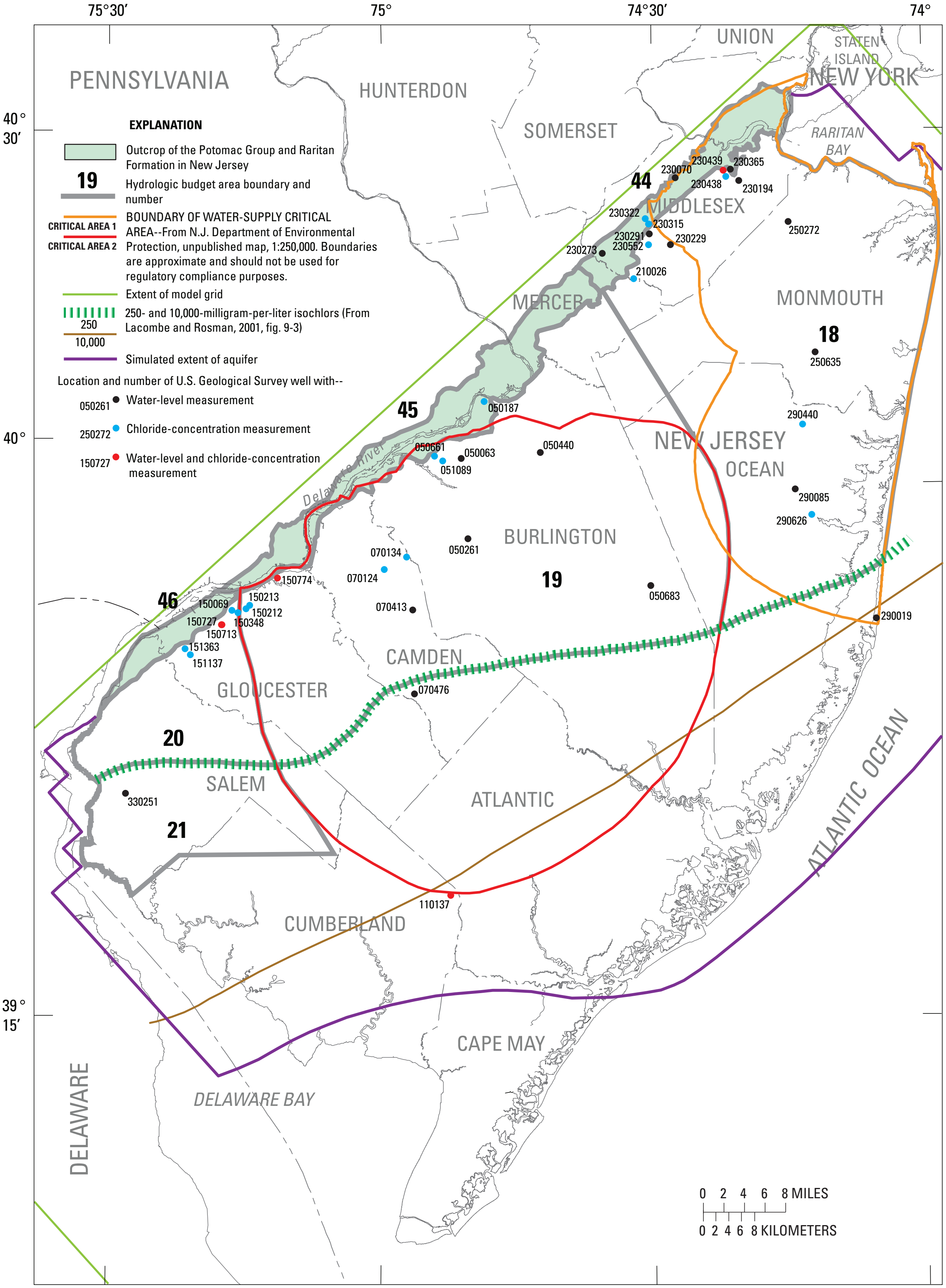
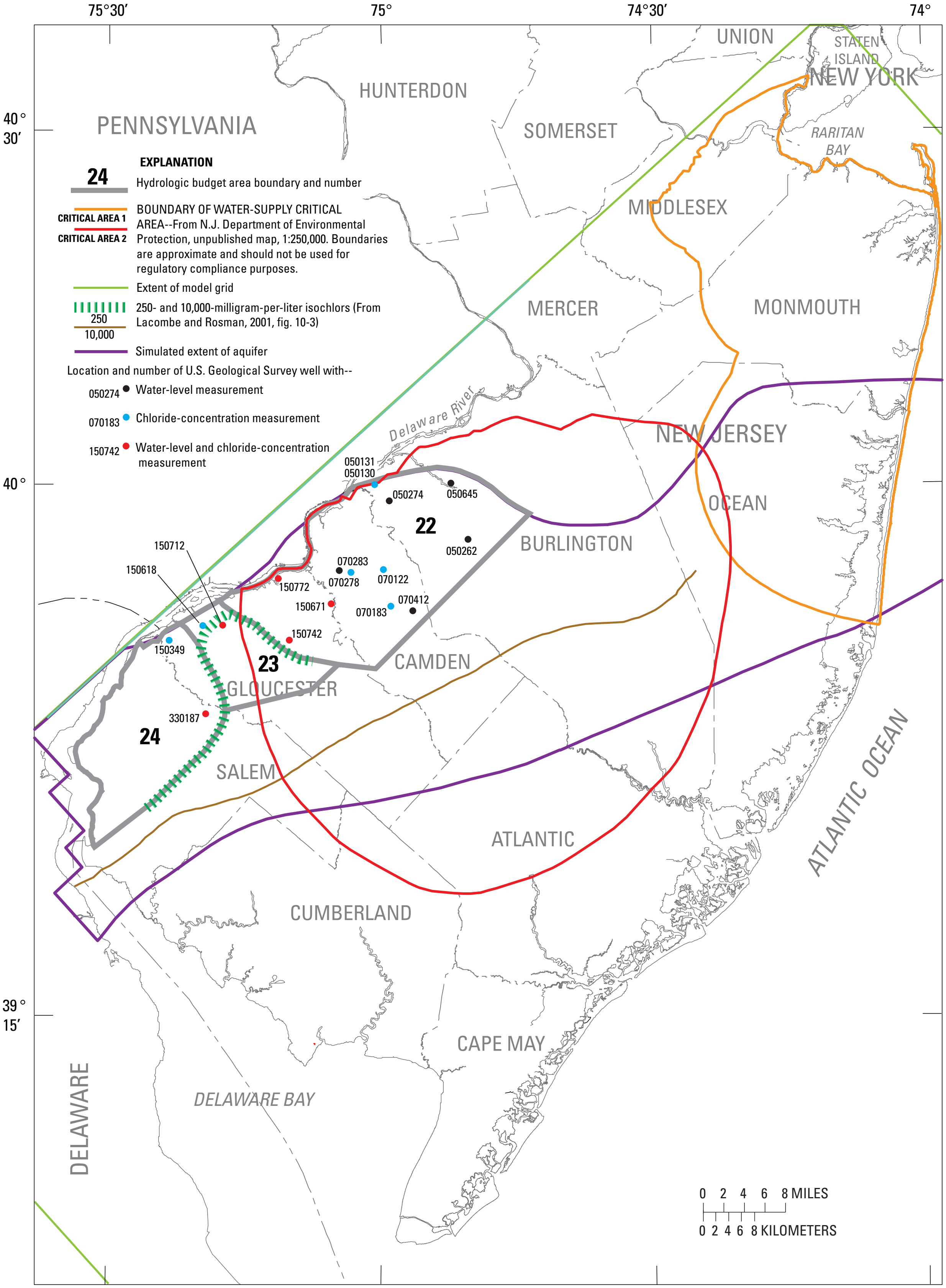


Figure 1-6. Location of wells with water-level measurements (2005) and chloride-concentration measurements (1999-2005), Upper Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain.



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 1-7. Location of wells with water-level measurements (2005) and chloride-concentration measurements (1999-2005), Middle Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain.



Base from U.S. Geological Survey
1:24,000 digital line data

Figure 1-8. Location of wells with water-level measurements (2005) and chloride-concentration measurements (1999-2005), Lower Potomac-Raritan-Magothy aquifer, New Jersey Coastal Plain.

Table 1-1. Wells with continuous or manual water-level measurements, New Jersey Coastal Plain, 2005.

[Well number prefaced by county identifier: 01, Atlantic; 05, Burlington, 07, Camden; 09, Cape May; 11, Cumberland; 15, Gloucester; 23, Middlesex; 25, Monmouth; 29, Ocean; or 33, Salem; latitude and longitude are referenced to the North American Datum of 1927]

U.S. Geological Survey well number	Latitude	Longitude	Screened interval (feet below land surface)	Beginning year of record
Atlantic City 800-foot sand				
010180	392754	742701	560 - 570	1959
010578	391826	743709	670 - 680	1959
010702	392032	743008	740 - 750	1988
010703	392639	743232	560 - 570	1985
090302	385709	745128	883 - 893	1989
090306	390422	745447	656 - 666	1990
090337	390012	744720	910 - 960	1992
Piney Point aquifer				
010834	392017	743002	970 - 990.7	1988
011219	392640	743724	722 - 742	1996
050407	394422	744309	240 - 260	1963
050676	394914	742546	530 - 540	1962
110044	392732	750929	361 - 376	1972
110096	391829	751208	365 - 375	1972
110163	392526	750643	463 - 473	1973
290018	394829	740535	468 - 474	1962
290425	395322	742252	[1]348	1962
290585	395028	741044	412 - 422	1984
291210	393115	741910	860 - 880	1997
Vincentown aquifer				
051250	400148	743520	45 - 55	1996
250636	401105	741202	85.1 - 95.3	1987
290139	400414	742702	161 - 171	1964
Wenonah-Mount Laurel aquifer				
051155	395315	744946	120 - 180	1992
051387	394800	745246	335 - 355	1997
070118	395229	745712	137 - 147	1967
070478	394215	745617	520 - 530	1961
151126	394119	750627	328 - 338	1995
250353	401542	740530	321 - 327	1984
250486	400711	740202	604 - 614	1984
250637	401105	741202	307.1 - 317.3	1987
290140	400414	742702	257 - 267	1964
330020	393534	751752	[1]283	1958
330252	393348	752755	91 - 96	1965
330842	393055	750835	675 - 695	1997
Englishtown aquifer system				
050259	395524	745025	253 - 263	1963
051390	395309	743521	615 - 635	1997
051476	395928	745027	9 - 14	2003
230104	402143	741849	0 - 11	1923
250250	401918	741529	185 - 215	1971
250429	400834	740834	623 - 633	1964
250638	401105	741202	482.8 - 493	1987
250715	402426	740019	350 - 360	1991
250771	402350	735839	258 - 278	1997
290138	400414	742702	417 - 427	1964
290503	400210	740310	845 - 906	1983
290530	400452.8	740413.3	730 - 790	1988
290534	395609	741240	1,080 - 1,146	1965
Upper Potomac-Raritan-Magothy aquifer[2]				
050258	395524	745025	400 - 410	1963
051389	395309	743521	900 - 920	1997
051391	394904	742536	1,416 - 1,436	1997
070117	395229	745712	552 - 562	1967
070477	394215	745617	829 - 839	1961
150728	394808	751724	46 - 56	1987
150741	394652	751004	293 - 313	1987
150773	395206	751118	30 - 50	2000
230228	402015	742757	128 - 138	1961

[1] Well depth; screened interval not available

[2] Includes wells designated in the Old Bridge aquifer

[3] Includes wells designated in the Farrington and the undifferentiated Potomac-Raritan-Magothy aquifers

[4] Multiple well screens

Table 1-1. Wells with continuous or manual water-level measurements, New Jersey Coastal Plain, 2005.—Continued.

[Well number prefaced by county identifier: 01, Atlantic; 05, Burlington, 07, Camden; 09, Cape May; 11, Cumberland; 15, Gloucester; 23, Middlesex; 25, Monmouth; 29, Ocean; or 33, Salem; latitude and longitude are referenced to the North American Datum of 1927]

U.S. Geological Survey well number	Latitude	Longitude	Screened interval (feet below land surface)	Beginning year of record
230292	402109	743012	93 - 104	1961
230344	402558	742013	31 - 37	1968
230351	402605	741959	76 - 82	1968
250206	402625	741145	225 - 249	1978
250316	402536	735905	371 - 397	1965
250639	401105	741202	891.2 - 901.2	1988
330253	393348	752755	335 - 340	1965
330342	394236	752724	46 - 51	2005
330348	394317	752619	[1]18	1959
330841	393055	750835	1,005 - 1,025	1997
330953	393724.83	753224.9	109 -114	2002
Middle Potomac-Raritan-Magothy aquifer[3]				
050063	400213	745108	284 - 294	1966
050261	395525	745025	740 - 750	1968
050440	400243	744223	603 - 613	1968
050683	395122	743017	2,102 - 2,117	1964
070413	394922	745630	706 - 717	1963
070476	394215	745617	1,485 - 1,495	1960
110137	392514	745217	2,083 - 2,093	1974
150713	394808	751724	125 - 155	1987
150727	394808	751724	[4]195 - 216	1987
150774	395206	751118	93 - 113	2000
230070	402555	742719	0 - 21	1936
230194	402536	742018	[4]201 - 281	1930
230229	402015	742757	319 - 330	1965
230273	401932	743529	70 - 75	1970
230291	402109	743013	192 - 203	1961
230365	402633	742120	148 - 160	1931
230439	402633	742200	121 - 126	1968
250272	402208	741452	670 - 680	1973
250635	401105	741202	[4]1,225.6 - 1,330.3	1987
290019	394829	740535	2,736 - 2,756	1962
290085	395929	741420	1,460 - 1,480	1968
330251	393348	752755	699 - 709	1965
Lower Potomac-Raritan-Magothy aquifer				
050262	395524	745025	1,125 - 1,145	1968
050274	395841	745905	241 - 262	1972
050645	400010	745216	431 - 441	1966
070283	395246	750434	445 - 455	1963
070412	394922	745630	1,082 - 1,092	1963
150671	394957	750530	650 - 670	1986
150712	394808	751724	275 - 290	1987
150742	394652	751004	757.2 - 777.2	1986
150772	395206	751118	196 - 216	2000
330187	394037	751914	664 - 672	1959

[1] Well depth; screened interval not available

[2] Includes wells designated in the Old Bridge aquifer

[3] Includes wells designated in the Farrington and the undifferentiated Potomac-Raritan-Magothy aquifers

[4] Multiple well screens

Table 1-2. Wells with measured chloride concentrations, New Jersey Coastal Plain, 1999-2005.

[Well number prefaced by county identifier: 01, Atlantic; 05, Burlington, 07, Camden; 09, Cape May; 11, Cumberland; 15, Gloucester; 23, Middlesex; 25, Monmouth; 29, Ocean; or 33, Salem; latitude and longitude are referenced to the North American Datum of 1927; mg/L; milligrams per liter]

U.S. Geological Survey well number	Latitude	Longitude	Screened interval (feet below land surface)	Date of most recent sample	Chloride concentration (mg/L)
Atlantic City 800 foot sand					
010180	392754	742701	560 - 570	7/27/2005	1.69
010578	391826	743709	670 - 680	7/26/2005	3.92
010702	392032	743008	740 - 750	7/25/2005	22.1
010703	392639	743232	560 - 570	7/22/2004	2.59
090008	390621	744248	845 - 925	9/29/1999	27.5
090092	390524.3	744856	681 - 791	9/28/1999	40.1
090108	391458.7	743645.4	774 - 840	9/24/1999	10.2
090129	390926	744131	801 - 861	9/23/1999	13.0
090302	385709	745128	883 - 893	8/5/2005	406
090480	385643.3	745532.7	[1]621 - 820	9/27/1999	480
Piney Point aquifer					
010701	393148.4	745618.4	410 - 460	4/18/2000	28.1
010834	392017	743002	970 - 990.7	11/1/2002	321
011405	392748.4	744305.1	545 - 620	12/20/2002	58.3
051162	394635.7	744410.5	215 - 235	5/15/2000	2.16
110044	392732	750929	361 - 376	11/15/2001	51.7
110096	391829	751208	365 - 375	11/28/2001	4.47
110163	392526	750643	463 - 473	11/22/2002	168
290018	394829	740535	468 - 474	8/3/2005	7.64
290425	395322	742252	[2]348	7/19/2005	2.67
290607	394453.9	740655.4	596.75 - 661.92	8/28/2001	2.98
290809	395527	740826	330 - 370	4/19/2000	2.89
291097	395400	740937	345 - 445	4/19/2000	2.50
291210	393115	741910	860 - 880	7/21/2005	131
Vincentown aquifer					
290917	400849.6	741516.2	126 - 186	7/12/2000	3.12
Wenonah-Mount Laurel aquifer					
050354	395813.1	743949.6	178 - 198	9/26/2000	2.63
051155	395315	744946	120 - 180	6/23/2000	2.93
051189	395441	745000	87.58 - 127.58	5/8/2000	5.71
151126	394119	750627	328 - 338	7/30/2004	1.36
250720	401053	741558	235 - 255	11/14/2000	8.31
330249	393342.4	752718	110 - 150	7/19/2000	63.3
330252	393348	752755	91 - 96	5/26/2005	91.1
330902	393844.9	751904.9	100 - 143	6/6/2001	3.45
Englishtown aquifer system					
051390	395309	743521	615 - 635	6/20/2000	1.36
070729	394925	750021	204 - 224	8/22/2000	1.58

Table 1-2. Wells with measured chloride concentrations, New Jersey Coastal Plain, 1999-2005.—Continued.

[Well number prefaced by county identifier: 01, Atlantic; 05, Burlington, 07, Camden; 09, Cape May; 11, Cumberland; 15, Gloucester; 23, Middlesex; 25, Monmouth; 29, Ocean; or 33, Salem; latitude and longitude are referenced to the North American Datum of 1927; mg/L; milligrams per liter]

U.S. Geological Survey well number	Latitude	Longitude	Screened interval (feet below land surface)	Date of most recent sample	Chloride concentration (mg/L)
070731	394950.8	745857.4	216 - 236	8/2/1999	1.76
250714	402424.1	740144.4	198 - 248	6/5/2001	5.20
250715	402426	740019	350 - 360	8/8/2005	5.74
250771	402350	735839	258 - 278	7/20/2005	15,200
290006	400405	740244	778 - 818	8/10/1999	0.81
290449	400614.3	741157.2	569 - 698	8/10/1999	1.25
290530	400453	740413	730 - 790	8/11/2005	1.5
		Upper Potomac-Raritan-Magothy aquifer[3]			
051389	395309	743521	900 - 920	6/30/2005	1.05
051391	394904	742536	1,416 - 1,436	2/12/2004	1.27
070274	395032.5	750345.8	269 - 349	7/28/1999	0.34
070275	395230.4	750311.6	236 - 267	8/3/1999	1.88
070316	395131.4	750230.9	271 - 348	8/22/2000	1.41
150001	393912.4	750519	[1]746 - 800	1/6/1999	152
150741	394652	751004	293 - 313	8/24/2004	23.9
150773	395206	751118	30 - 50	7/13/2005	130
151513	394126	751613	357- 367	12/19/2005	9.9
250112	402537.8	740935.8	312 - 352	5/21/2003	1.99
250191	402620	740741	302 - 362	6/10/2003	650
250195	402620.8	740744.2	290 - 350	6/10/2003	226
250196	402628	740744	308 - 348	6/10/2003	194
250197	402536	741215	304 - 354	5/21/2003	16.4
250206	402625	741145	225 - 249	6/9/2003	419
250292	402358.5	741234.4	341 - 414	9/5/2000	1.58
250316	402536	735905	371 - 397	6/13/2003	21.2
250496	402441	740233	510 - 543	5/23/2003	1.26
250501	401215	740358	1,000 - 1,075	9/5/2000	1.66
250567	402630	741029	[1]250 - 270	6/5/2003	278
250568	402652	741100	245 - 265	5/29/2003	4,120
250729	401907.1	740649.3	575 - 655	8/14/2000	2.90
291365	395636.6	740443.2	[1]1,389 - 1,580	10/16/2001	1.33
330253	393348	752755	335 - 340	8/12/2004	697
330841	393055	750835	1,005 - 1,025	7/1/2005	3,320
		Middle Potomac-Raritan-Magothy aquifer[4]			
050187	400703	744832	119 - 134	7/11/2001	12.3
050661	400225	745402	147 - 199	9/14/1999	25.0
051089	400201	745309.9	176 - 251	5/9/2000	12.9
070124	395249.4	745935.5	[1]483 - 626	7/27/1999	1.90
070134	395353	745708	454 - 488	8/4/1999	0.65
110137	392514	745217	2,083 - 2,093	1/21/2004	11,300

Table 1-2. Wells with measured chloride concentrations, New Jersey Coastal Plain, 1999-2005.—Continued.

[Well number prefaced by county identifier: 01, Atlantic; 05, Burlington, 07, Camden; 09, Cape May; 11, Cumberland; 15, Gloucester; 23, Middlesex; 25, Monmouth; 29, Ocean; or 33, Salem; latitude and longitude are referenced to the North American Datum of 1927; mg/L; milligrams per liter]

U.S. Geological Survey well number	Latitude	Longitude	Screened interval (feet below land surface)	Date of most recent sample	Chloride concentration (mg/L)
150069	394920	751619	108 - 168	8/7/2000	20.4
150137	394535	752054	158 - 208	9/13/2000	23.4
150212	394929	751447	192 - 220	5/16/2000	20.9
150213	394947.2	751421.5	135 - 175	5/16/2000	22.5
150348	394909.6	751540.7	105 - 135	6/14/2000	27.0
150713	394808	751724	125 - 155	5/17/2004	14.2
150727	394808	751724	[1]195 - 216	6/7/2004	213
150774	395206	751118	93 - 113	7/13/2005	26.9
151363	394608	752128	121 - 143	9/27/2000	30.9
210026	401725	743159	260 - 290	7/16/2001	11.4
230315	402204	743024	103 - 138	4/25/2000	23.8
230322	402230	743040	95.4 - 115.4	4/24/2000	26.2
230438	402600.4	742143.2	132 - 182	8/9/2000	18.8
230439	402633	742200	121 - 126	5/27/2004	34.4
230552	402017.5	743021.2	[1]116 - 166	9/11/2001	5.12
290440	400501.3	741326.2	[1]1,357 - 1,602	8/9/1999	1.45
290626	395721.1	741229.5	[1]1,700 - 1,875	5/31/2000	1.02
		Lower Potomac-Raritan-Magothy aquifer			
050130	395959.8	750040.9	167 - 198	9/26/2000	16.4
050131	400002	750044	145 - 176	8/1/2000	18.8
070122	395252	745943	[1]684 - 741	7/26/1999	3.63
070183	394945	745855	923 - 1,011	8/2/1999	7.72
070278	395237.7	750315.4	452 - 594	8/3/1999	4.07
150349	394650	752316	170 - 220	7/1/2004	143
150618	394804	751933	230 - 240	6/30/2004	253
150671	394957	750530	650 - 670	7/27/2004	11.8
150712	394808	751724	275 - 290	5/13/2004	580
150742	394652	751004	757.2 - 777.2	7/15/2004	147
150772	395206	751118	196 - 216	7/13/2005	30.1
330187	394037	751914	664 - 672	7/13/2004	153

[1] Multiple well screens

[2] Well depth; screened interval not available

[3] Includes wells designated in the Old Bridge aquifer

[4] Includes wells designated in the Farrington and the undifferentiated Potomac-Raritan-Magothy aquifers

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