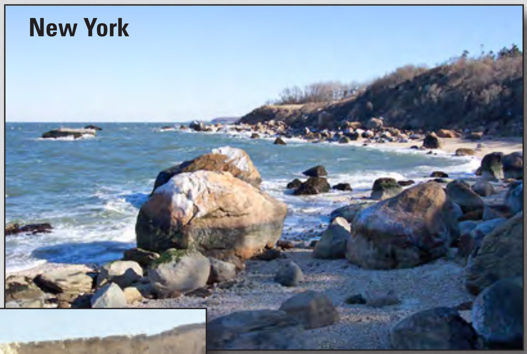
Water Availability and Use Science Program

Digital Elevations and Extents of Regional Hydrogeologic Units in the Northern Atlantic Coastal Plain Aquifer System From Long Island, New York, to North Carolina



Data Series 996

Version 1.1, December 2020

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs (top to bottom). The shore of Long Island Sound at Rock Point, East Marion, **New York**. Glacial deposits shown are a remnant of the Roanoke Point moraine (Christopher Schubert, USGS, 2003).

USGS hydrologist measuring the radioactivity at the base of the Bridgeton Formation, at the contact with the underlying Cohansey sand, **New Jersey** (Otto Zapecza, USGS, 1991).

Ditched stream through soybean fields in Kent County, **Delaware** (Mark Nardi, USGS, 2010).

Cross section at Calvert Cliffs on the shore of the Chesapeake Bay in Calvert County, **Maryland**, showing Coastal Plain geologic layers and seeps of groundwater along contacts (David Butts, Maryland Department of Natural Resources, 2015).

USGS wire-line coring rig used to obtain continuous core of sediment and basement bedrock from within the Chesapeake Bay impact crater, Bayside, Mathews County, **Virginia**. The lower Chesapeake Bay and adjacent tidal marsh are in the background (E. Randolph McFarland, USGS, 2001).

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Supplemental Information

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

Unit name descriptors such as “lower” and “upper” are shown without capital letters for internal consistency in this report, except for Lower Cretaceous, which corresponds to a formal geologic unit name. This format may differ from the source references.

Abbreviations

DEM	digital elevation model
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
NACP	Northern Atlantic Coastal Plain
NED	National Elevation Dataset
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
ppm	parts per million
TIN	triangular irregular network
USGS	U.S. Geological Survey

Digital Elevations and Extents of Regional Hydrogeologic Units in the Northern Atlantic Coastal Plain Aquifer System From Long Island, New York, to North Carolina

By Jason P. Pope,[1] David C. Andreasen,[2] E. Randolph McFarland,[1] and Martha K. Watt[1]

Abstract

Digital geospatial datasets of the extents and top elevations of the regional hydrogeologic units of the Northern Atlantic Coastal Plain aquifer system from Long Island, New York, to northeastern North Carolina were developed to provide an updated hydrogeologic framework to support analysis of groundwater resources. The 19 regional hydrogeologic units were delineated by elevation grids and extent polygons for 20 layers: the land and bathymetric surface at the top of the unconfined surficial aquifer, the upper surfaces of 9 confined aquifers and 9 confining units, and the bedrock surface that defines the base of all Northern Atlantic Coastal Plain sediments. The delineation of the regional hydrogeologic units relied on the interpretive work from source reports for New York, New Jersey, Delaware and Maryland, Virginia, and North Carolina rather than from re-analysis of fundamental hydrogeologic data. This model of regional hydrogeologic unit geometries represents interpolation, extrapolation, and generalization of the earlier interpretive work. Regional units were constructed from available digital data layers from the source studies in order to extend units consistently across political boundaries and approximate units in offshore areas.

Though many of the Northern Atlantic Coastal Plain hydrogeologic units may extend eastward as far as the edge of the Atlantic Continental Shelf, the modeled boundaries of all regional hydrogeologic units in this study were clipped to an area approximately defined by the furthest offshore extent of fresh to brackish water in any part of the aquifer system, as indicated by chloride concentrations of 10,000 milligrams per liter. Elevations and extents of units that do not exist onshore in Long Island, New York, were not included north of New Jersey. Hydrogeologic units in North Carolina were included primarily to provide continuity across the Virginia-North Carolina State boundary, which was important for defining the southern edge of the Northern Atlantic Coastal Plain study area.

[1]U.S. Geological Survey.

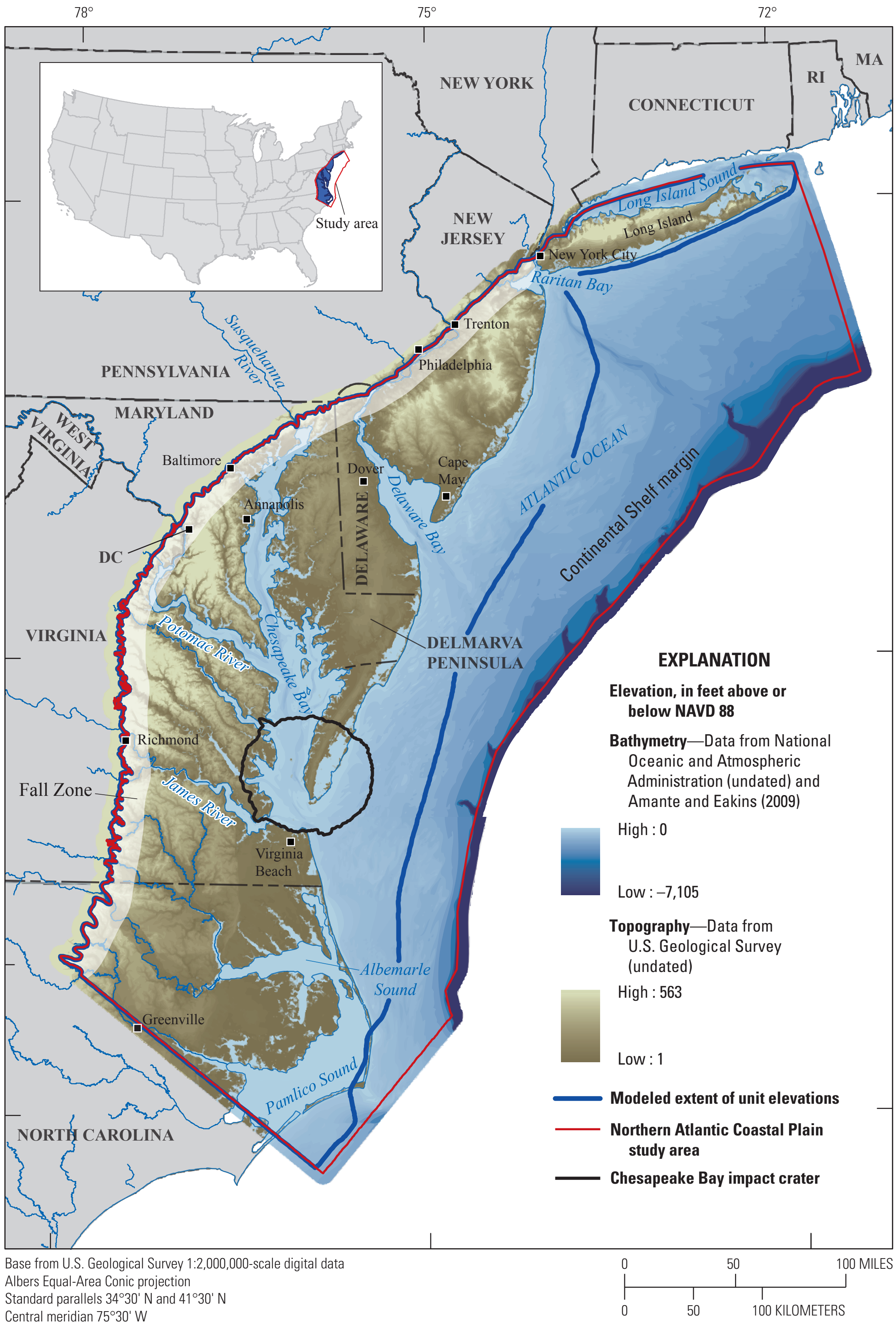
[2]Maryland Geological Survey.

Introduction

The U.S. Geological Survey (USGS) Northern Atlantic Coastal Plain (NACP) aquifer system groundwater availability study is part of a national assessment of groundwater availability conducted through the USGS Groundwater Resources Program. A major goal of these studies is to provide updated information about the current status of groundwater resources in principal aquifers and to develop tools and datasets to assist State, county, municipal, and water-management agencies with making long-term groundwater-management decisions (Reilly and others, 2008).

Although the NACP (fig. 1) aquifer system is one of the smallest by area of the 66 principal aquifer systems in the Nation recognized by the U.S. Geological Survey (Miller, 2000), it ranks 13th overall in terms of total groundwater withdrawals (Reilly and others, 2008). Despite abundant precipitation (about 45 inches per year [in/yr]), the supply of fresh surface water in this region is limited because many of the coastal surface waters are brackish estuaries. As a result, many communities in the NACP rely heavily on groundwater to meet their water demand. These groundwater resources, however, can be limited by the amount of available drawdown, drought, saltwater intrusion, and agricultural and industrial contamination.

Increases in population and changes in land use during the past 100 years have resulted in diverse, increased demands for freshwater throughout the NACP. Substantial groundwater withdrawals had begun in the northern part of the study area by the late 1800s. By 1900, about 100 million gallons per day (Mgal/d) of water was pumped from the NACP aquifer system (Masterson and others, 2016b). Groundwater serves as a vital source of drinking water for the approximately 20 million people who live in the region and accounts for about 40 percent of the drinking water supply (Kenny and others, 2009). Total groundwater withdrawal in 2005 was estimated to be about 1,500 Mgal/d in the study area and included withdrawals for industrial and commercial use, irrigation, self-supplied domestic, and many other purposes in addition to municipal water supply (Masterson and others, 2013).



Base from U.S. Geological Survey 1:2,000,000-scale digital data
Albers Equal-Area Conic projection
Standard parallels 34°30' N and 41°30' N
Central meridian 75°30' W
North American Datum of 1983

Figure 1. Location and extent of the Northern Atlantic Coastal Plain study area, showing elevation and bathymetry.

The effects of these large withdrawals include extensive declines in water levels and resulting changes in the aquifers of the NACP, many of which extend across State lines and create the potential for a variety of interstate and regional groundwater-management issues. A groundwater availability study of the NACP was conducted primarily to address the regional challenges in analyzing and understanding groundwater resources. As part of the study, the hydrogeology and hydrologic conditions of the NACP aquifer system are discussed in detail by Masterson and others (2013). The analyses of groundwater flow and availability in the NACP aquifer system are detailed in Masterson and others (2016a) and were based on a regional groundwater model of the aquifer system documented in Masterson and others (2016b).

A fundamental component of understanding groundwater flow in this region is the detailed delineation of the various aquifers and confining units that make up this complex system. At the regional level, this delineation involves correlation of hydrogeologic units described and mapped at the state level, as well as some generalization of these units to fit the scale of the regional hydrogeologic model. In a comprehensive study of the NACP aquifer system as part of the USGS Regional Aquifer-System Analysis (RASA) program, the regional hydrogeologic framework was described in detail by Trapp (1992). The report by Trapp (1992) also outlines about a century of previous investigations contributing to understanding the hydrogeology of the NACP aquifer system. Information on the geometry of the aquifer system, however, is available only on paper maps, not in digital form. In addition, approximately two decades of subsequent investigations have contributed substantially to the cumulative knowledge about the NACP aquifer system.

The various revisions to the delineation of the NACP regional aquifer system are described in detail in Masterson and others (2013) and include much more data than previously published on unit geometries and a substantially improved understanding of unit correlations across State boundaries. Various recent state-level studies by the USGS and cooperating agencies have redefined several of the aquifers and confining units in the system. Among other details, the understanding of spatial differences within the Potomac aquifer system from north to south has been considerably enhanced (Andreasen and others, 2013; McFarland, 2013). Also, substantial recent work has described the geometry and characteristics of the Chesapeake Bay impact crater buried within the Coastal Plain of Virginia, which has had a tremendous effect on the aquifer system and groundwater flow in that area (McFarland and Bruce, 2006). In addition to incorporating the results of many additional studies, the revisions to the NACP regional aquifer system include updates to regional names for aquifers and confining units that are more consistent with local names in the NACP focus area of New York, New Jersey, Delaware, Maryland, and Virginia. Also, important advancements in computer mapping technology during the two decades since the last NACP framework report have resulted in the ability to better map, visualize, and understand the aquifer system in three dimensions. State-level datasets delineating hydrogeologic unit geometries have been published in several state-level studies, but the current data series report and accompanying data release include the first comprehensive digital dataset describing the geometry of the entire NACP aquifer system.

Purpose and Scope

This report describes spatially referenced digital datasets delineating the regional hydrogeologic units of the NACP aquifer system, which are provided in a related data release (Pope and others, 2016). The 19 regional hydrogeologic units are delineated by elevation grids and extent polygons for 20 layers: the land and bathymetric surface at the top of the unconfined surficial aquifer, the upper surfaces of 9 confined aquifers and 9 interlayered confining units, and the bedrock surface defining the base of all NACP sediments. Polygons defining the extents of the regional hydrogeologic units are also described and included. Except for the layer defining the land surface and bathymetric elevations, each of the regional hydrogeologic unit top elevation layers corresponds to the base of one or more other units, so that unit thicknesses may be determined by comparison of the various overlapping surfaces, depending on the units present at any particular location.

The regional hydrogeologic units presented here and available in the data release are described in detail in a report on the hydrogeology and hydrologic conditions of the NACP aquifer system (Masterson and others, 2013), which introduces and supports a recent comprehensive analysis of groundwater availability in this aquifer system (Masterson and others, 2016a). That NACP groundwater availability study relied on analyses from a regional NACP groundwater flow model (Masterson and others, 2016b), for which the regional hydrogeologic units presented in the current report are a fundamental component.

This report, along with the NACP hydrologic conditions report by Masterson and others (2013), updates the NACP regional framework information provided by Trapp (1992), incorporating more than two decades of additional work in various parts of the study area. The report synthesizes information from state-level investigations in New York (Smolensky and others, 1989), New Jersey (Zapecza, 1989; Voronin, 2003), Maryland and Delaware (Andreasen and others, 2013), Virginia (McFarland and Bruce, 2006; McFarland, 2013), and North Carolina (Gellici and Lautier, 2010) and is dependent on these investigations for definition and interpretation of hydrogeologic units. The associations between the state-level units and the regional hydrogeologic units included in this report are shown in figure 2.

The construction of the regional hydrogeologic unit elevations and extents adhered as closely as possible to the referenced state-level data, combining units vertically where necessary and appropriate for regional representation and joining units and unit extents smoothly across boundaries.

<table>
<tr><th>NACP</th><th>New York (Long Island)</th><th>New Jersey</th><th>Delaware</th><th>Maryland</th><th>Virginia</th><th>North Carolina</th></tr>
<tr><td>surficial</td><td>upper glacial</td><td>Holly Beach,
unconfined upper Kirkwood-Cohansey</td><td colspan="4">surficial</td></tr>
<tr><td>upper Chesapeake</td><td rowspan="13">absent</td><td>Holly Beach</td><td colspan="2">upper Chesapeake</td><td>Yorktown</td><td>Yorktown</td></tr>
<tr><td>upper Chesapeake</td><td>confined upper Kirkwood-Cohansey</td><td>Pocomoke,
Manokin</td><td>Pocomoke,
Ocean City,
Manokin</td><td>Yorktown-Eastover</td><td>Yorktown</td></tr>
<tr><td>lower Chesapeake</td><td>unnamed</td><td colspan="3">Saint Marys</td><td>Pungo River</td></tr>
<tr><td>lower Chesapeake</td><td>lower Kirkwood-Cohansey,
confined Kirkwood</td><td>Milford,
Frederica,
Federalsburg,
Cheswold</td><td>Choptank,
Calvert</td><td>Saint Marys</td><td>Pungo River</td></tr>
<tr><td>Calvert</td><td>basal Kirkwood</td><td colspan="3">Calvert</td><td>Castle Hayne</td></tr>
<tr><td>Piney Point</td><td colspan="4">Piney Point</td><td>Castle Hayne</td></tr>
<tr><td>Nanjemoy-Marlboro</td><td>Vincentown-Manasquan</td><td colspan="3">Nanjemoy-Marlboro*</td><td>Beaufort</td></tr>
<tr><td>Aquia</td><td>Vincentown</td><td>Rancocas</td><td colspan="2">Aquia*</td><td>Beaufort</td></tr>
<tr><td>Monmouth-Mount Laurel</td><td>Navesink-Hornerstown</td><td colspan="2">Severn</td><td colspan="2">Peedee</td></tr>
<tr><td>Monmouth-Mount Laurel</td><td>Wenonah-Mount Laurel</td><td>Mount Laurel</td><td>Monmouth</td><td colspan="2">Peedee</td></tr>
<tr><td>Matawan</td><td>Marshalltown-Wenonah</td><td colspan="2">Matawan</td><td>Virginia Beach</td><td>Black Creek</td></tr>
<tr><td>Matawan</td><td colspan="2">Englishtown</td><td>Matawan</td><td>Virginia Beach</td><td>Black Creek</td></tr>
<tr><td>Magothy</td><td>Merchantville-Woodbury</td><td colspan="2">Matawan-Magothy</td><td rowspan="2">absent</td><td>Cape Fear</td></tr>
<tr><td>Magothy</td><td>Magothy</td><td>upper Potomac-Raritan-Magothy</td><td>Magothy</td><td>Magothy</td><td>upper Cape Fear,
lower Cape Fear</td></tr>
<tr><td>Potomac</td><td>Raritan</td><td>unnamed</td><td colspan="2">Magothy-Patapsco</td><td>Potomac,*
upper Cenomanian</td><td>upper Cenomanian</td></tr>
<tr><td>Potomac-Patapsco</td><td>Lloyd</td><td>middle Potomac-Raritan-Magothy</td><td colspan="2">upper Patapsco,
lower Patapsco</td><td>Potomac*</td><td>Lower Cretaceous</td></tr>
<tr><td>Potomac-Patuxent</td><td rowspan="2">absent</td><td>unnamed</td><td colspan="2">Arundel Clay</td><td rowspan="2">absent</td><td rowspan="2">absent</td></tr>
<tr><td>Potomac-Patuxent</td><td>lower Potomac-Raritan-Magothy</td><td>Patuxent,
Waste Gate</td><td>Patuxent,
Waste Gate</td></tr>
<tr><td colspan="7">bedrock basement</td></tr>
</table>

Figure 2. Regional hydrogeologic units and corresponding state-level hydrogeologic units for the Northern Atlantic Coastal Plain (NACP) aquifer system. Unit names for New York are from Smolensky and others (1989); for New Jersey, from the U.S. Geological Survey New Jersey Water Science Center (unpub. data, 2011); for Virginia, from McFarland and Bruce (2006); and for North Carolina, from Gellici and Lautier (2010). Units for Delaware and Maryland are from Andreasen and others (2013), but the units in Delaware were not the primary focus of that report. Regional units are from Masterson and others (2013) and this report. Units shaded in gray are confining units; units that are unshaded are aquifer units. Aquifers and associated confining units indicated with an asterisk are truncated in part of Virginia by sediments related to the Chesapeake Bay impact crater. Hydrogeologic units shown in bold italic font are those in southern Maryland that extend across the State border into northern Virginia. Unit name descriptors such as "lower" and "upper" are shown without capital letters for internal consistency in this report, except for Lower Cretaceous, which corresponds to a formal geologic unit name. This format may differ from the source references.

The goal was to produce consistent regional hydrogeologic units to support regional analyses and groundwater modeling. Individual state-level datasets and publications should remain the preferred sources of data for studies at more detailed scales.

The extents of all regional hydrogeologic units were clipped to an area approximately defined by the furthest offshore extent (in any unit) of the 10,000 milligram per liter (mg/L) chloride concentration contour (Charles, 2016). This delineation was chosen because it is approximately the half-way point between the chloride concentration in freshwater and modern sea water. Relatively little data on hydrogeologic unit elevations are available in offshore or saline areas of the aquifer system, and several of the source reports for this regional study defined a limited offshore extent. Extending the regional hydrogeologic units as presented here involves some extrapolation of unit elevations from source reports. However, some brackish parts of the aquifer system adjacent to the Chesapeake Bay impact crater in Virginia are important for groundwater supply and have been the subject of intensive recent investigation (McFarland and Bruce, 2006); therefore, inclusion of these brackish areas in the regional extent was important. Furthermore, the entire area around the impact crater was included in the selected extent even though most of the groundwater in the crater-fill units is very saline, because the identification of the impact-crater units represents a substantial addition to the knowledge of local and regional hydrogeology (McFarland and Bruce, 2006), and these units are known to substantially influence regional groundwater flow (Heywood and Pope, 2009). Units on Long Island that are not reported to exist onshore are not included north of Raritan Bay in the regional dataset because information on offshore extents and elevations are extremely sparse in that area.

The study area for this investigation includes only the northeastern part of North Carolina because the focus of this analysis is the NACP hydrogeologic system from Long Island to the Virginia-North Carolina border. The hydrogeology and hydrogeologic conditions in the Coastal Plain of North Carolina and South Carolina were separately described in a previous groundwater availability study by Campbell and Coes (2010). Regional hydrogeologic units in North Carolina are included only to provide continuity across the Virginia-North Carolina State boundary, which was important for defining the southern edge of the NACP study area.

Location and Physical Setting

The part of the NACP that was included in this investigation occupies a land area of more than 30,000 square miles and a total area of about 50,000 square miles along the eastern seaboard of the United States from Long Island, New York, southward to the northeastern part of North Carolina (fig. 1). A seaward-dipping wedge of mostly unconsolidated stratified sediments composed of clay, silt, sand, and gravel underlies this area, ranging in age from Early Cretaceous to Holocene. This sedimentary wedge forms a complex groundwater system in which layers of sand and gravel function predominantly as aquifers, and layers of silt and clay function as confining units. The western limit of the NACP is the Fall Zone, the transition between older consolidated bedrock near land surface and the unconsolidated sedimentary deposits of the NACP. From the Fall Zone, the bedrock dips beneath the sedimentary wedge to constitute the basement that underlies the entire study area (McFarland and Bruce, 2006).

The NACP sedimentary wedge is aligned approximately parallel to the Fall Zone and dips and thickens to the east and south from a thin edge in the Fall Zone. Sediments in the NACP are typically thousands of feet thick along the coast, with a maximum thickness of about 10,000 feet (ft) near the edge of the Continental Shelf. Coastal Plain sediments are continuous along the entire Continental Shelf, from Newfoundland in the north to Honduras in the south, but are entirely submerged north of Cape Cod, Massachusetts (Trapp, 1992). The eastern end of Long Island is considered the northern limit of the continuous exposure of Coastal Plain sediments.

The complex and variable topography of the NACP—reflecting rising and falling sea levels, erosion and deposition by major rivers, and several episodes of glaciation on Long Island—is described in detail in Masterson and others (2013). Land-surface elevations are relatively low, ranging from a few hundred feet above the North American Vertical Datum of 1988 (NAVD 88) in the Fall Zone to approximately zero along the coastline. Ocean depth generally is less than a few hundred feet across most of the offshore parts of the study area, though it increases to thousands of feet at the edge of the Continental Shelf.

Methods Used

Definitions and dimensions of regional hydrogeologic units described in this report were constructed from the most current, available data from state-level reports. These data vary in their composition, but all included (at a minimum) hydrogeologic unit elevations in the form of contour lines and defined unit extents delineated by polygon boundaries. These datasets were the fundamental building blocks of the regional hydrogeologic units described in this report. The development of hydrogeologic unit elevations for the various source reports typically involved the construction of unit elevation contours from point data (commonly well logs) interpreted by hydrologists and geologists. However, log data were not used for the delineation of the regional hydrogeologic units described in this report, of which construction relied almost entirely on the hydrogeologic unit layer contours described in the source reports.

Sources of Data

The regional hydrogeologic units presented here primarily were derived from the most recently published spatial data available for States and subregions within the NACP (table 1). These publications outline the history of the development of hydrogeologic interpretations in the individual areas.

Digital hydrogeologic data for Long Island, New York, were obtained from the USGS New York Water Science Center as digitized versions of files described in the report by Smolensky and others (1989). The data used for the current study consisted of elevation contours and extents for the primary regional hydrogeologic units present on Long Island, which do not include a series of units located between the surficial aquifer and the Magothy aquifer elsewhere in the study area (fig. 2). The report by Smolensky and others (1989) mentions the reported presence of these additional Coastal Plain units offshore of Long Island, but includes no spatial information regarding the exact location or geometry of these units.

Table 1. Primary sources of information for hydrogeologic units in States within the Northern Atlantic Coastal Plain.

Geographic area	Source of data
New York (Long Island)	Smolensky and others, 1989
New Jersey	Zapecza, 1989; U.S. Geological Survey, unpub. data, 2011
Maryland-Delaware	Andreasen and others, 2013
Virginia	McFarland and Bruce, 2006; McFarland, 2013
North Carolina	Gellici and Lautier, 2010; McFarland, 2013

For New Jersey, digital data on the New Jersey hydrogeologic framework were obtained from the USGS New Jersey Water Science Center (unpub. data, 2011). These data include updates to Voronin (2003) and to the New Jersey hydrogeologic framework described by Zapecza (1989). The digital data obtained from New Jersey included unit elevation contours and extents, as well as unit elevation rasters.

Digital data for Maryland and Delaware and adjacent areas of Virginia were obtained from the Maryland Coastal Plain Aquifer Information System (MCPAIS), which was developed cooperatively by the Maryland Geological Survey and the USGS Maryland-Delaware-District of Columbia Water Science Center. The MCPAIS, documented in a report by Andreasen and others (2013), is a geographic-information-system tool that includes hydrogeologic unit elevation contours and rasters, as well as polygon unit extents and a variety of other related hydrogeologic data. Hydrogeologic unit elevations for Delaware and northern Virginia were included in the MCPAIS for continuity with Maryland, but were not the focus of the MCPAIS (Andreasen and others, 2013). The MCPAIS hydrogeologic data were used for Delaware because the scale of the data was more appropriate for regional analysis than local-scale information otherwise available for Delaware.

Data for Virginia and adjacent areas of Maryland and North Carolina were obtained from a recent publication by McFarland and Bruce (2006) on the hydrogeologic framework of the Virginia Coastal Plain. Available digital data include extents, elevation contours, and elevation rasters, along with a variety of other hydrogeologic information. Several of the Virginia hydrogeologic units described in the current report extend into northeastern North Carolina. A subsequent investigation, specifically focused on the extent and characteristics of the Potomac aquifer in Virginia, also was useful in the correlation of hydrogeologic units across the Virginia-North Carolina border (McFarland, 2013). Information from Andreasen and others (2013) was used to supplement hydrogeologic information in northern Virginia because that report includes the most recent analysis of hydrogeologic units along the Maryland-Virginia border.

Hydrogeologic data obtained for the northeastern corner of the North Carolina Coastal Plain are documented by Gellici and Lautier (2010) as part of the recent groundwater availability study for the Atlantic Coastal Plain of North and South Carolina (Campbell and Coes, 2010). The report by McFarland (2013) incorporates information from more recent publications to revise and update the understanding of some of the correlations between Virginia and North Carolina Coastal Plain hydrogeologic units, and the unit delineations in the current report reflect that revised understanding.

Delineation of Regional Hydrogeologic Units

The correlation of hydrogeologic units across State boundaries was based on previous regional studies, such as Trapp (1992), as well as the cooperative work of individual authors of the source data, which includes studies across State boundaries. The regional units for the current report aggregate the units described in the various source reports with the correlation of equivalent units across State boundaries, the combination of multiple local units into more generalized regional units, the interpolation of individual units across State boundaries, and the extrapolation of individual units into offshore areas not included in source datasets.

Elevation contours and unit extent polygons were assembled and adjusted for each of the regional hydrogeologic units listed in figure 2, except for the elevation dataset describing the land and bathymetric surface. A uniform regional dataset of basement surface elevation contours was assembled from state-level source data to define the bottom of the NACP aquifer system.

Elevations for the land and bathymetric surface—which define the top of the surficial aquifer—were obtained from a digital elevation model (DEM) assembled at a horizontal resolution of 100 ft and a vertical resolution of 1 ft for the entire study area. Land-surface elevation data for the project DEM were obtained from the USGS National Elevation Dataset (NED) at 30-meter (1 arc second) resolution (U.S. Geological Survey, n.d.), and bathymetric elevation data were assembled from two sources: the National Oceanic and Atmospheric Administration (NOAA) 90-meter (3 arc second) U.S. Coastal Relief model (National Oceanic and Atmospheric Administration, n.d.) and the NOAA ETOPO1 1 arc minute global relief model (Amante and Eakins, 2009). The higher-resolution terrestrial NED was used as the basis for the topographic and bathymetric model, and NED elevations were rounded systematically to the nearest integer, in feet. Elevations greater than zero were defined as terrestrial areas, and all NED elevations between zero and 1 ft were rounded up to a value of 1. Areas with NED values of zero or less were defined as submerged areas, and the two bathymetric datasets were used to fill in the defined submerged areas with elevations at or below NAVD 88. The resulting combined DEM, with a horizontal resolution of 100 ft, became the baseline for the initial analyses of all other hydrogeologic unit elevations. This regional 100-ft topographic and bathymetric DEM is provided with the data release for this report (Pope and others, 2016), with the file name nacp_dem100ft (table 2).

For each of the remaining hydrogeologic units and the basement surface, combined elevation contours were converted to triangular irregular networks (TINs) as a simple linear interpolation of the contours, and the TINs were then converted to rasters at the desired resolution of 100 ft, with raster cells coincident with the project topographic and bathymetric DEM. A series of comparisons between the hydrogeologic unit elevation rasters were conducted to eliminate vertical conflicts (intersections) between elevations in different hydrogeologic unit layers and produce an internally consistent elevation model of all the hydrogeologic units in the NACP aquifer system. Extent polygons of individual hydrogeologic units were used to constrain the horizontal extents of the unit rasters to their defined areas, and systematic

Table 2. Names of digital data files for elevations and extents of regional hydrogeologic units of the Northern Atlantic Coastal Plain (NACP) aquifer system available in Pope and others (2016).

[Files for each unit include elevation rasters in GRID format, elevation data in ASCII (.txt) format, and unit extents in polygon shapefile (.shp) format]

Layer	Hydrogeologic unit	Elevation raster file	Elevation ASCII file	Extent polygon file
1	Surficial aquifer	nacp_aq01surf	nacp_aq01surf.txt	nacp_hyd_unit_bound.shp
2	Upper Chesapeake confining unit	nacp_cu01	nacp_cu01.txt	nacp_cu01_ext.shp
3	Upper Chesapeake aquifer	nacp_aq02upch	nacp_aq02upch.txt	nacp_aq02upch_ext.shp
4	Lower Chesapeake confining unit	nacp_cu02	nacp_cu02.txt	nacp_cu02_ext.shp
5	Lower Chesapeake aquifer	nacp_aq03loch	nacp_aq03loch.txt	nacp_aq03loch_ext.shp
6	Calvert confining unit	nacp_cu03	nacp_cu03.txt	nacp_cu03_ext.shp
7	Piney Point aquifer	nacp_aq04pipt	nacp_aq04pipt.txt	nacp_aq04pipt_ext.shp
8	Nanjemoy-Marlboro confining unit	nacp_cu04	nacp_cu04.txt	nacp_cu04_ext.shp
9	Aquia aquifer	nacp_aq05aq	nacp_aq05aq.txt	nacp_aq05aq_ext.shp
10	Monmouth-Mount Laurel confining unit	nacp_cu05	nacp_cu05.txt	nacp_cu05_ext.shp
11	Monmouth-Mount Laurel aquifer	nacp_aq06moml	nacp_aq06moml.txt	nacp_aq06moml_ext.shp
12	Matawan confining unit	nacp_cu06	nacp_cu06.txt	nacp_cu06_ext.shp
13	Matawan aquifer	nacp_aq07mtwn	nacp_aq07mtwn.txt	nacp_aq07mtwn_ext.shp
14	Magothy confining unit	nacp_cu07	nacp_cu07.txt	nacp_cu07_ext.shp
15	Magothy aquifer	nacp_aq08mgty	nacp_aq08mgty.txt	nacp_aq08mgty_ext.shp
16	Potomac confining unit	nacp_cu08	nacp_cu08.txt	nacp_cu08_ext.shp
17	Potomac-Patapsco aquifer	nacp_aq09popt	nacp_aq09popt.txt	nacp_aq09popt_ext.shp
18	Potomac-Patuxent confining unit	nacp_cu09	nacp_cu09.txt	nacp_cu09_ext.shp
19	Potomac-Patuxent aquifer	nacp_aq10_popx	nacp_aq10_popx.txt	nacp_aq10popx_ext.shp
20	Basement	nacp_cu10bsmt	nacp_cu10bsmt.txt	nacp_hyd_unit_bound.shp
NA	Topography and bathymetry (100 feet)	nacp_dem100ft	nacp_dem100ft.txt	nacp_area_bnd_fmwk.shp

comparisons between unit elevations were used to make final adjustments to individual unit elevations. The project DEM described previously was used as the ultimate upper boundary of all unit elevations because data for elevations at the surface of the earth generally are more accurate than for any of the subsurface units defined primarily by relatively sparse well-log and outcrop data.

The model of hydrogeologic unit dimensions created by this process (at 100-ft horizontal resolution) was then sampled into a regional MODFLOW groundwater model (with 1-mile horizontal resolution) as a part of a project to further investigate and understand groundwater flow and availability in the study area (Masterson and others, 2016a, 2016b). During the subsequent process of simulation and analysis of groundwater flow, adjustments and corrections to the regional hydrogeologic unit extents and elevations were made in some parts of the study area to correct previous errors and represent the best understanding of flow-system geometry. In order to represent the incorporated changes and to reflect the most appropriate resolution of the final three-dimensional model of hydrogeologic unit elevations, the unit elevations from the groundwater model were exported to uniform rasters at a resolution of 2,640 ft (0.5 mile). Systematic comparisons between regional hydrogeologic unit elevations at this scale produced the final regional hydrogeologic units published in this report. The final resolution characterizes the generalized regional nature of this model of hydrogeologic units and is sufficient to preserve the resolution of the source interpretive reports. Elevation values in the final rasters are interpolated to decimal feet from the integer values of the higher-resolution working files.

As components of a model of hydrogeologic unit elevations, the published digital unit elevations and extents (Pope and others, 2016) adhere to some basic guidelines used in the construction of the unit layers. The tops of all units have been assigned elevations across their entire regional extents, as defined from the extents in the various state-level source reports. However, the unit elevations in many of the source reports were not always referenced against land-surface or bathymetric elevations at the resolution of the best available topographic and bathymetric data. This means that contoured unit top elevations may be truncated by topographic and bathymetric elevations or, in some instances, by the elevations of other hydrogeologic units. This is common for units that crop out or subcrop in the Fall Zone, where land-surface elevations are highly variable. It is also common for many units in areas where river channels deeply incise the NACP and where land-surface elevations vary substantially across the river valleys.

Where topographic or bathymetric surface elevations conflicted with modeled elevations of hydrogeologic units, the topographic and bathymetric elevations were used, and the topographic or bathymetric elevations were assigned to the intersected units in the regional framework. This resulted in several hydrogeologic units with areas of zero thickness and top elevations equal to topographic or bathymetric elevations; in some instances, several consecutive units were affected. The result may be hydrogeologic units that are highly variable or intermittently absent (thickness of zero) within their defined extents. Although this circumstance may seem to be the result of data artifacts, it actually provides a reasonable model of the affected hydrogeologic units, some of which have been observed to be widely sculpted by erosion, creating windows or channels to deeper units that have not been altered or truncated entirely (McFarland and Bruce, 2006). Regardless, even at a relatively coarse resolution, representation of the complexity of the interlayered NACP aquifer system is challenging, particularly when interpolating thin units across large areas.

GIS Formats for Digital Datasets

Geographic information system (GIS) software (ArcGIS 10.1 from Environmental Systems Research Institute) was used to construct the digital raster surfaces representing the top elevations of the regional hydrogeologic units, as well as the polygons of unit extents. The 20 elevation rasters—the tops of each of the 19 units and the regional basement—have a common horizontal resolution of 2,640 ft (0.5 mile) and are aligned to the same base raster, though the rasters may define units that have different spatial extents. Land surface, bathymetric, and unit elevation values are in integer feet, relative to the NAVD 88. Raster files are provided in both ESRI GRID format and in an American Standard Code for Information Interchange (ASCII) format that can be read by a wide variety of GIS systems. Polygon features delineating the extents of the various hydrogeologic units are provided in shapefile (.shp) format.

The higher resolution (100 ft) DEM of the topographic and bathymetric surface described in the Methods section of this report is also included with the digital data (table 2). This raster dataset, with elevations to the nearest integer foot, is not used to define the regional hydrogeologic units described in this report but is provided for use in other possible applications in the NACP at greater detail than the NACP regional hydrogeology.

All geospatial datasets use a custom Albers Equal-Area Conical projected coordinate system with a central meridian of –75.5 degrees and standard parallels of 34.5 and 41.5 degrees. The horizontal datum is the North American Datum of 1983 (NAD 83).

Regional Hydrogeologic Unit Elevations and Extents

The delineation of regional hydrogeologic units requires recognition of unit equivalents across state boundaries. Furthermore, the use of the regional framework data requires an understanding of the relations between the regional hydrogeologic units and those in individual States. The NACP regional hydrogeologic units are described by Masterson and others (2013); brief discussions in the current report primarily provide details regarding the relations between the regional and State units in the construction of the digital data. The unit relations are outlined in the chart in figure 2.

Bedrock Basement

The bedrock basement defines the bottom of the entire NACP aquifer system, and the approximate intersection of the basement surface with the land surface defines the western edge of the NACP in the Fall Zone where Coastal Plain sediments approach a thickness of zero (fig. 1). The basement itself is not a hydrogeologic unit but instead serves as a relatively impermeable lower boundary for the aquifer system and is included here for this reason. The bedrock basement is readily distinguished from the various sediments across the extent of the NACP, but data delineating the basement surface are highly variable and generally sparse. Few wells penetrate to basement in the eastern part of the study area, and the lack of offshore data required substantial extrapolation of elevation contours beyond the coastline. Nevertheless, the various data sources used for the definition of the regional surface showed general agreement regarding the slope and elevation of the basement surface with areas of higher definition where more supporting data were available.

Potomac-Patuxent Aquifer

The Potomac-Patuxent regional aquifer is the lowermost hydrogeologic unit in the NACP aquifer system, and it directly overlies the regional basement in a large part of the study area (fig. 3). The regional aquifer includes the lower Potomac-Raritan-Magothy aquifer system in New Jersey, and the Patuxent and Waste Gate aquifers in Delaware, Maryland, and northern Virginia (fig. 2). Its presence in the northern part of the Virginia Coastal Plain is indicated by Andreasen and others (2013). In Delaware, Maryland, and northern Virginia, this regional aquifer combines two aquifers that have been locally differentiated and may have somewhat different hydrologic conditions: the overlying Patuxent aquifer and the deeper Waste Gate aquifer (Andreasen and others, 2013).

The Potomac-Patuxent aquifer is absent beneath Long Island, New York, and most of the Coastal Plain of Virginia and North Carolina within the study area (fig. 3). In these areas, stratigraphically similar sediments do not exist, have not been differentiated from shallower units, or are not separated from the overlying Potomac-Patapsco aquifer by a regional confining unit. In these areas, the Potomac-Patapsco aquifer is the lowermost unit in the NACP aquifer system.

The Potomac-Patuxent regional aquifer is bounded by an overlying confining unit over much of its extent, but the aquifer crops out or subcrops in the Fall Zone, where it approaches land surface, and it may be hydrologically continuous with sediments of the surfical aquifer.

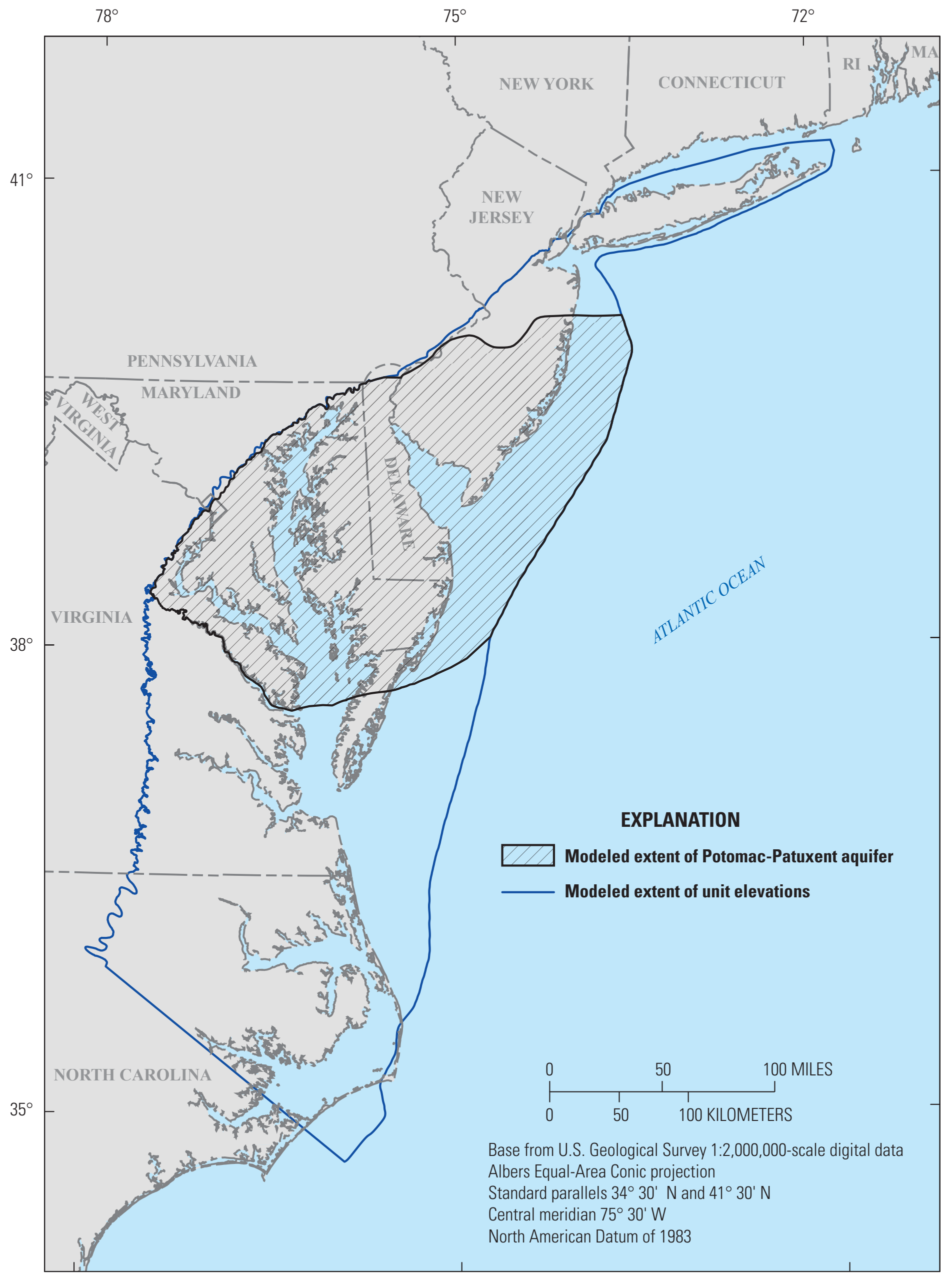


Figure 3. Location and extent of the Potomac-Patuxent regional aquifer.

Potomac-Patuxent Confining Unit

The Potomac-Patuxent regional confining unit (fig. 4) overlies the Potomac-Patuxent aquifer and separates the aquifer from the Potomac-Patapsco aquifer above. The regional confining unit includes the unnamed confining unit overlying the lower Potomac-Raritan-Magothy aquifer in New Jersey and the Arundel Clay confining unit in Delaware, Maryland and northern Virginia (fig. 2). The Potomac-Patuxent confining unit is composed of hard clays and silts within the fluvial-deltaic Potomac and Raritan Formations in New Jersey, Delaware, Maryland, and northern Virginia (Trapp, 1992). Its presence in the northern part of the Virginia Coastal Plain is indicated by Andreasen and others (2013).

The confining unit ranges in thickness from a thin western edge in the Fall Zone to more than 1,000 ft along the Atlantic coast in Delaware and pinches out south of the Potomac River in Virginia (Andreasen and others, 2013; McFarland, 2013). Regionally, this confining unit separates the underlying Potomac-Patuxent aquifer from the Potomac-Patapsco aquifer above.

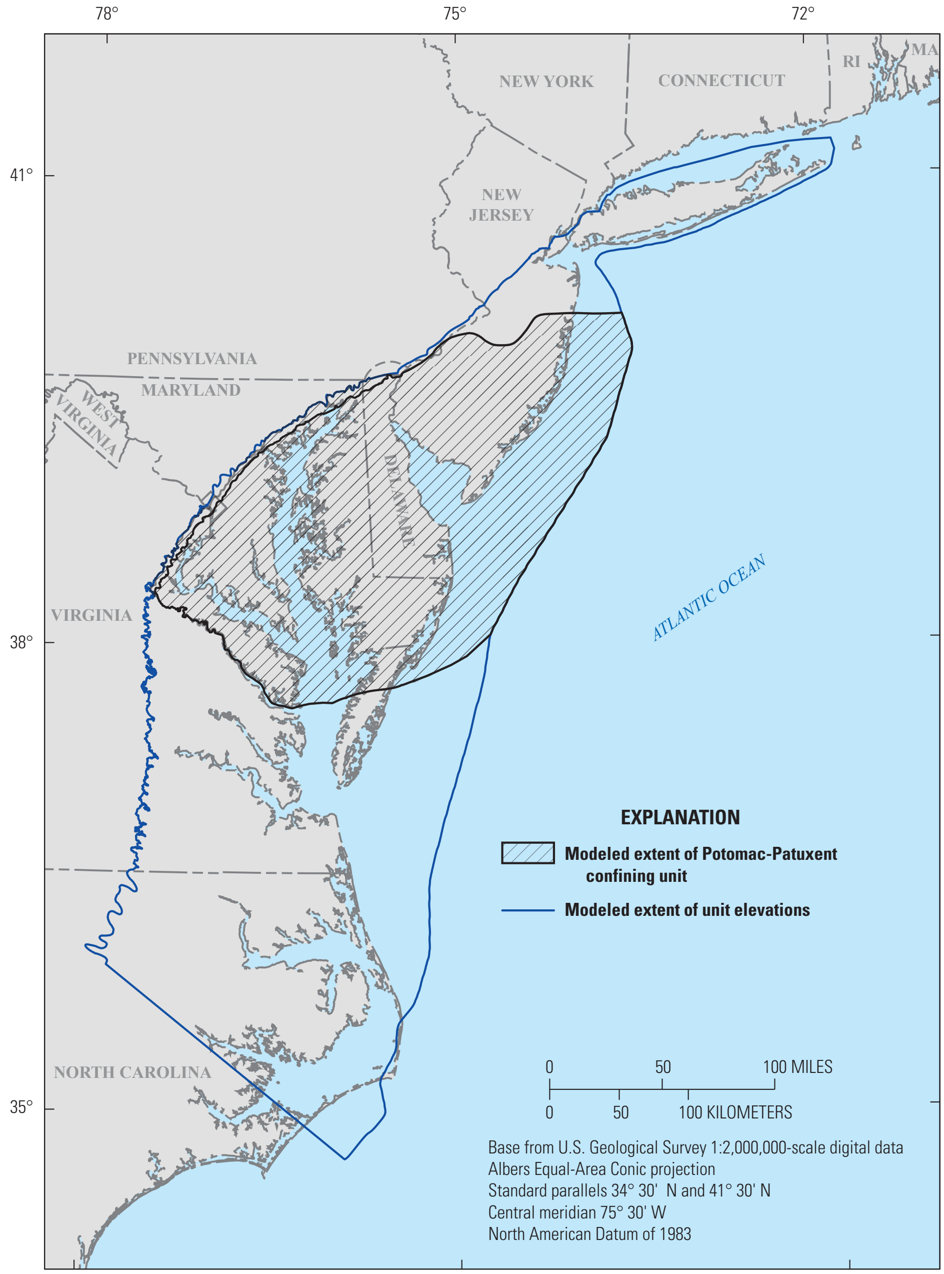


Figure 4. Location and extent of the Potomac-Patuxent regional confining unit.

Potomac-Patapsco Aquifer

The Potomac-Patapsco regional aquifer (fig. 5) includes the Lloyd aquifer in New York (Long Island), the Middle Potomac-Raritan-Magothy aquifer in New Jersey, the upper and lower Patapsco aquifers in Delaware and Maryland, the undifferentiated Potomac aquifer in Virginia, and the Lower Cretaceous aquifer in North Carolina (fig. 2). In Maryland and Delaware, the Potomac-Patapsco aquifer combines two local aquifers—the upper Patapsco and lower Patapsco—separated by an intervening confining unit (Andreasen and others, 2013).

In most of the Coastal Plain of Virginia (where the Potomac-Patuxent aquifer is absent) and North Carolina, the Potomac-Patapsco regional aquifer is composed of the single, heterogeneous Potomac aquifer (McFarland and Bruce, 2006; McFarland, 2013). In these locations, and in Long Island, N.Y., the Potomac-Patapsco aquifer is bounded below by the bedrock basement. The aquifer is bounded by an overlying confining unit over much of its extent, but the aquifer crops out or subcrops in the Fall Zone, where its top elevation approaches land surface and it may be hydrologically continuous with sediments of the unconfined surficial aquifer. Beneath the Eastern Shore of Virginia and the Chesapeake Bay, the Potomac-Patapsco aquifer is absent where it has been replaced by sediments of low permeability related to the Chesapeake Bay impact crater (fig. 5).

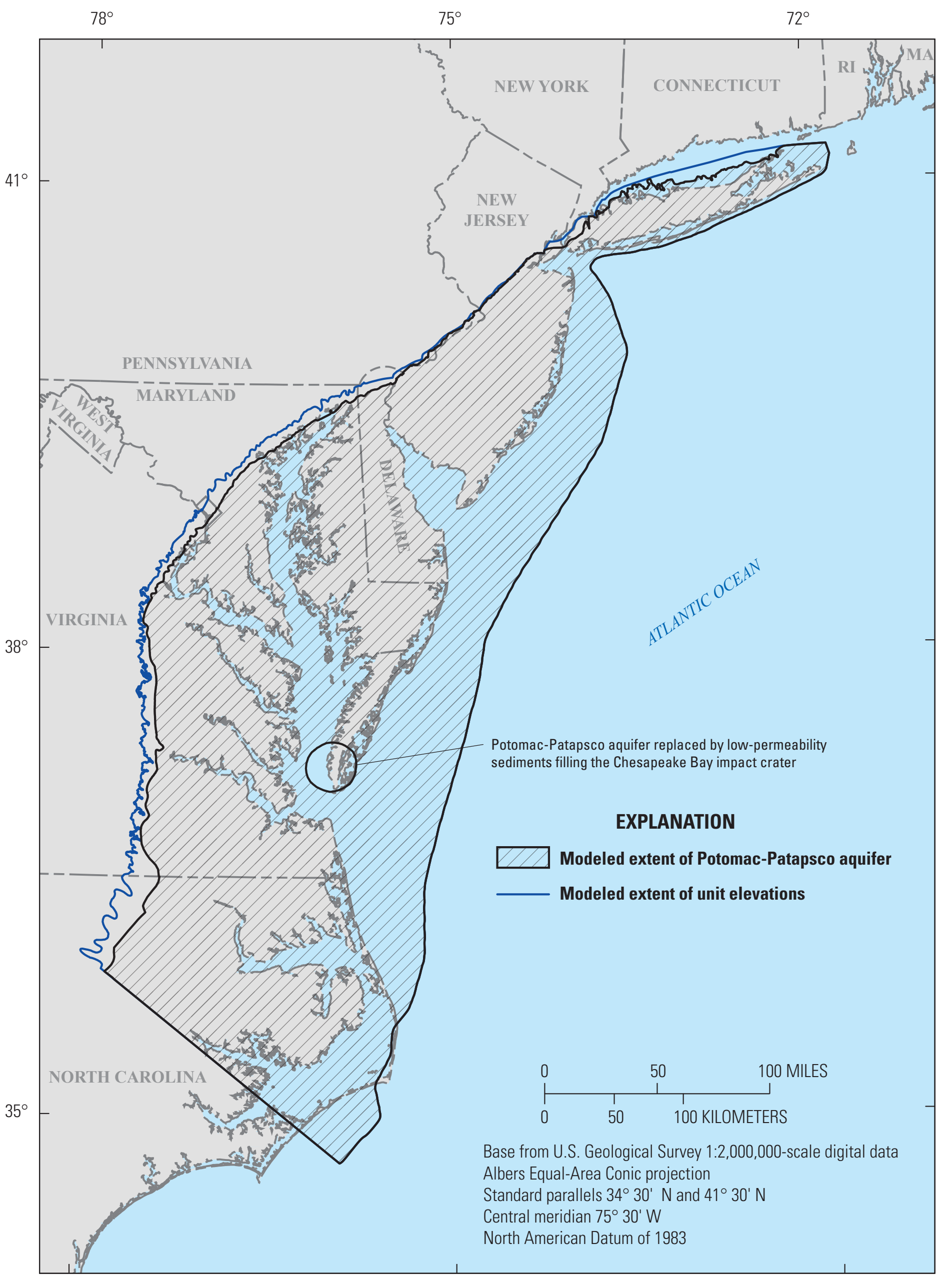


Figure 5. Location and extent of the Potomac-Patapsco regional aquifer.

Potomac Confining Unit

The Potomac-Patapsco aquifer is overlain over much of its extent by the regionally identified but locally highly variable Potomac regional confining unit (fig. 6). This unit is referred to as the Raritan confining unit in New York, the unnamed confining unit overlying the Middle Potomac-Raritan-Magothy aquifer in New Jersey, the Magothy-Patapsco confining unit in Delaware and Maryland, the Potomac confining zone in northern and central Virginia, and the upper Cenomanian confining unit in southeastern Virginia and northeastern North Carolina (fig. 2). Beneath the Eastern Shore of Virginia and the Chesapeake Bay, this unit is absent where it has been replaced by sediments of low permeability related to the Chesapeake Bay impact crater (fig. 6).

Magothy Aquifer

The Magothy regional aquifer is composed of two geographically separate northern and southern sections (fig. 7). The northern section is composed of the Magothy aquifer in New York, Delaware, and Maryland; and the upper Potomac-Raritan-Magothy aquifer in New Jersey (fig. 2). The Magothy aquifer is confined over much of its extent, but it crops out or subcrops in the Fall Zone where its top elevation approaches land surface and it may be hydrologically continuous with sediments of the unconfined surfical aquifer. On Long Island, sediments of the overlying Matawan and Monmouth Groups, as well as the local Jameco Gravel of Pleistocene age, are included in this regional aquifer (Smolensky and others, 1989).

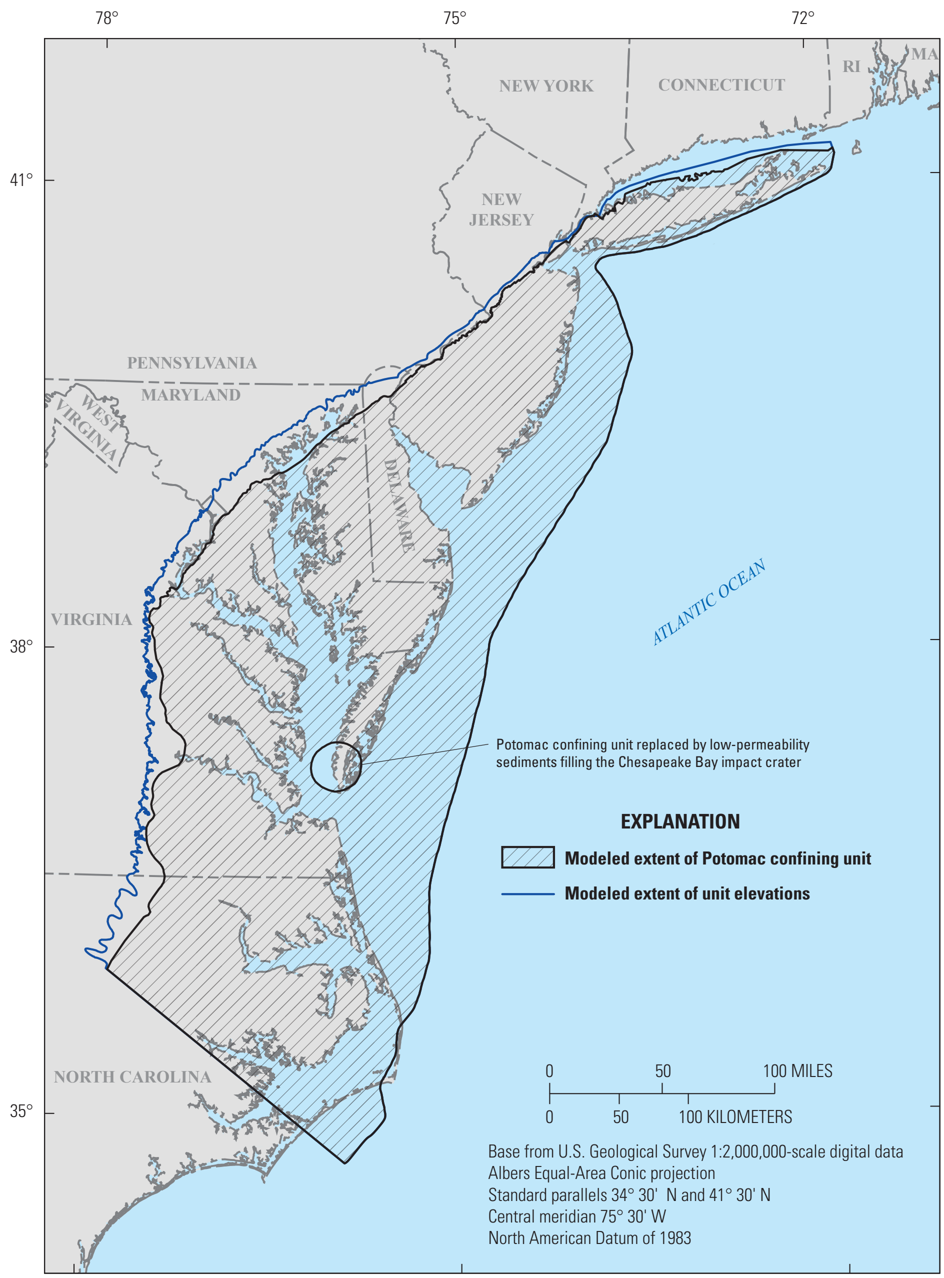


Figure 6. Location and extent of the Potomac regional confining unit.

The Magothy aquifer on Long Island is in direct connection with the overlying unconfined upper glacial aquifer (regionally, the surficial aquifer) over most of its extent, and the water table is known to be present in the Magothy aquifer in some locations (Smolensky and others, 1989). The boundary between the surficial upper glacial aquifer and the Magothy aquifer on Long Island only is an unconformity that reflects the modification of the top of the Magothy aquifer by glacial activity in this area (Smolensky and others, 1989). The southern boundary of this section of the regional Magothy aquifer is north of the Potomac River in Maryland.

The separate southern section of the Magothy aquifer is composed of the upper and lower Cape Fear aquifers in northeastern North Carolina. The sediments of these aquifers are of similar age and composition to the northern section of the Magothy aquifer, but these units are entirely separate. The Cape Fear aquifers are identified in North Carolina but not in Virginia, and their relation with the aquifers of southern Virginia is uncertain (McFarland and Bruce, 2006; McFarland, 2013). Consequently, the modeled extent of the southern section of the Magothy regional aquifer in this report is coincident with the border between Virginia and North Carolina. The known extent of this unit is not well constrained, and its correlation with other units is not well understood, but this unit may represent a subdivision of the Virginia Beach aquifer in Virginia.

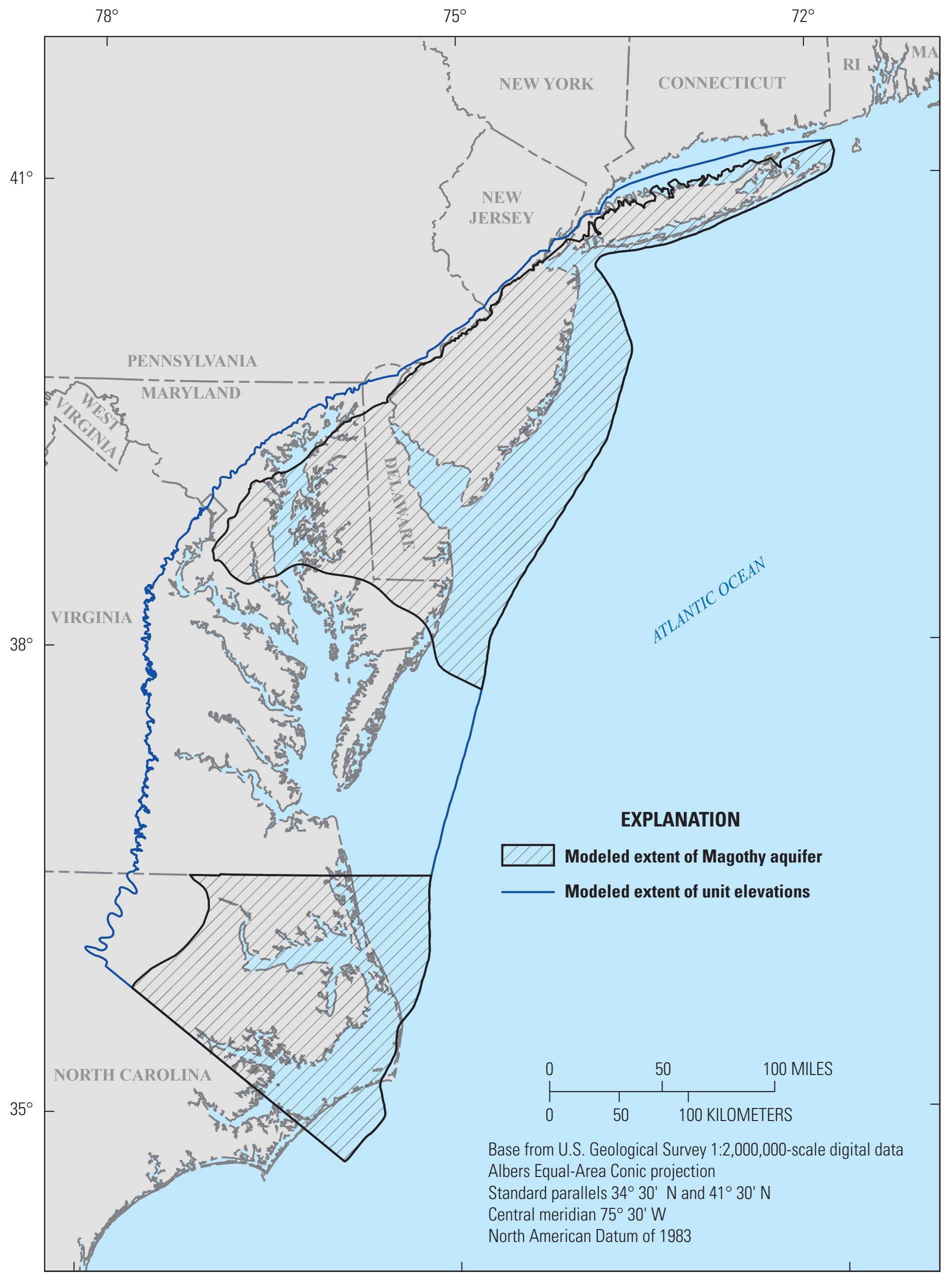


Figure 7. Location and extent of the Magothy regional aquifer.

Magothy Confining Unit

Like the Magothy aquifer, the Magothy regional confining unit is composed of two geographically separate northern and southern sections (fig. 8). In the northern section, the Magothy confining unit overlies the Magothy regional aquifer over most of its extent, except on Long Island where the surficial aquifer directly overlies the Magothy aquifer, and except where it outcrops or subcrops in the Fall Zone. The regional confining unit includes the Merchantville-Woodbury confining unit in New Jersey and the Matawan-Magothy confining unit in Delaware and Maryland (Andreasen and others, 2013). On Long Island, the Magothy aquifer is confined over a limited extent along the southern shore by the local Gardiners Clay (Smolensky and others, 1989), but the Gardiners Clay is not included in the regional confining unit because of uncertainty regarding continuity with the rest of the regional unit. The Gardiners Clay also has a much different composition than the regional confining unit and includes sediments of much different ages (Smolensky and others, 1989).

The southern section of the Magothy regional confining unit has an approximate and modeled extent coincident with the border between Virginia and North Carolina. This section is composed of the Cape Fear confining unit identified in North Carolina but not in Virginia. Regionally, this confining unit delineates a subdivision of the Virginia Beach aquifer in Virginia into the Black Creek and Cape Fear aquifers in northern North Carolina, reflecting different interpretations of the unit configuration in the two locations. However, the extent of this possible division is not well constrained, so it is represented here with an extent following the State-line boundary.

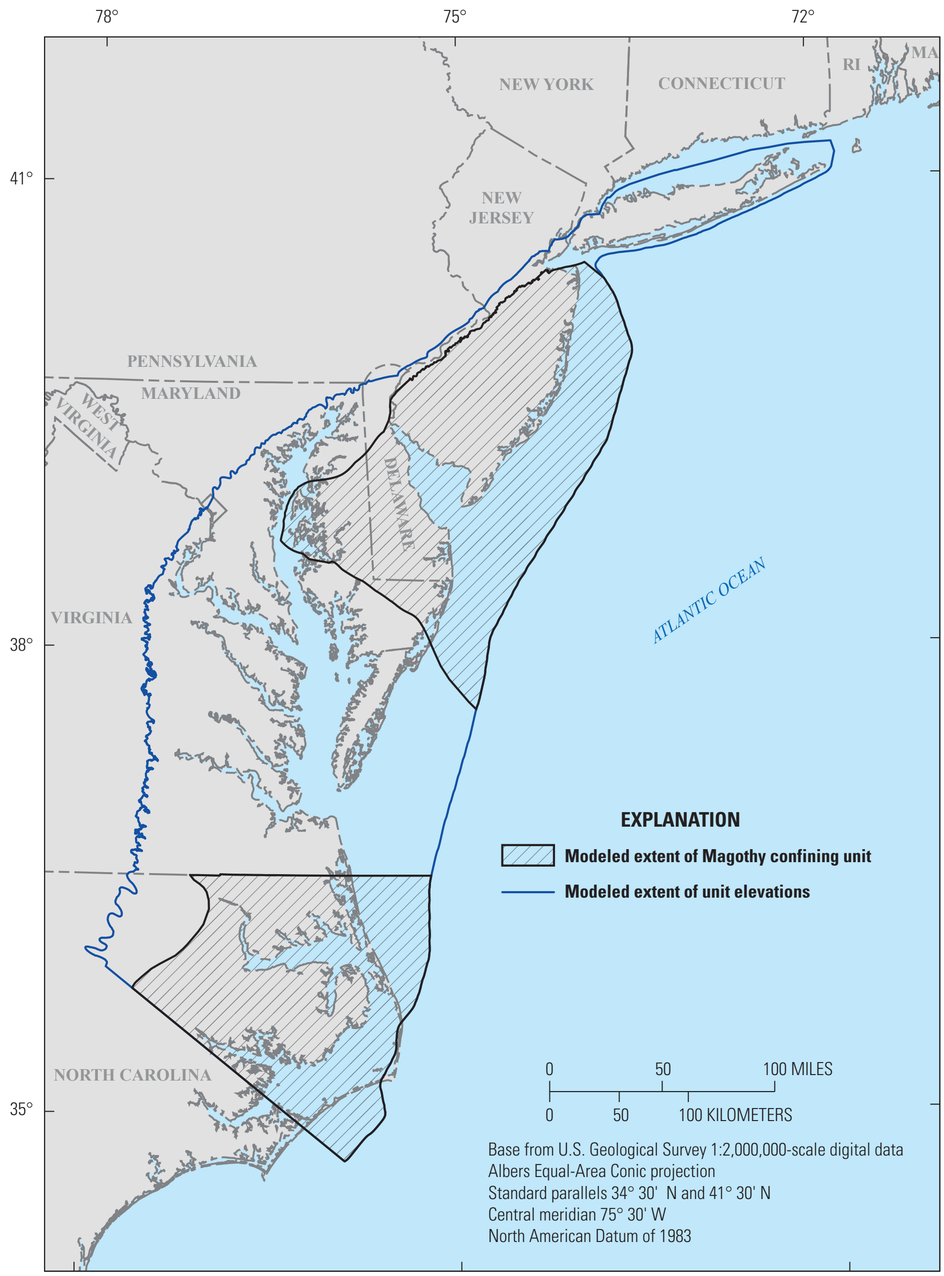


Figure 8. Location and extent of the Magothy regional confining unit.

Matawan Aquifer

The Matawan regional aquifer includes a northern section in New Jersey, Delaware, and Maryland and a laterally discontinuous southern section in southeastern Virginia and northeastern North Carolina (fig. 9). The northern section of the Matawan regional aquifer includes the Englishtown aquifer in New Jersey and Delaware and the Matawan aquifer in Maryland (fig. 2). On Long Island, the regional Matawan aquifer is absent, though equivalent sediments of the Matawan Group are included with the regional Magothy aquifer (Smolensky and others, 1989). The southern limit of this section of the Matawan aquifer is north of the Maryland-Virginia State line and east of the Chesapeake Bay.

In the southern part of the study area, sediments of similar age and composition to the northern section of the Matawan aquifer form a local unit known as the Virginia Beach aquifer in southeastern Virginia that may be the thin northern edge of the Black Creek aquifer of North Carolina (McFarland and Bruce, 2006). The Virginia Beach and Black Creek aquifers are entirely separate from the units making up the Matawan aquifer of Maryland, Delaware, and New Jersey, but approximately equivalent in stratigraphic position.

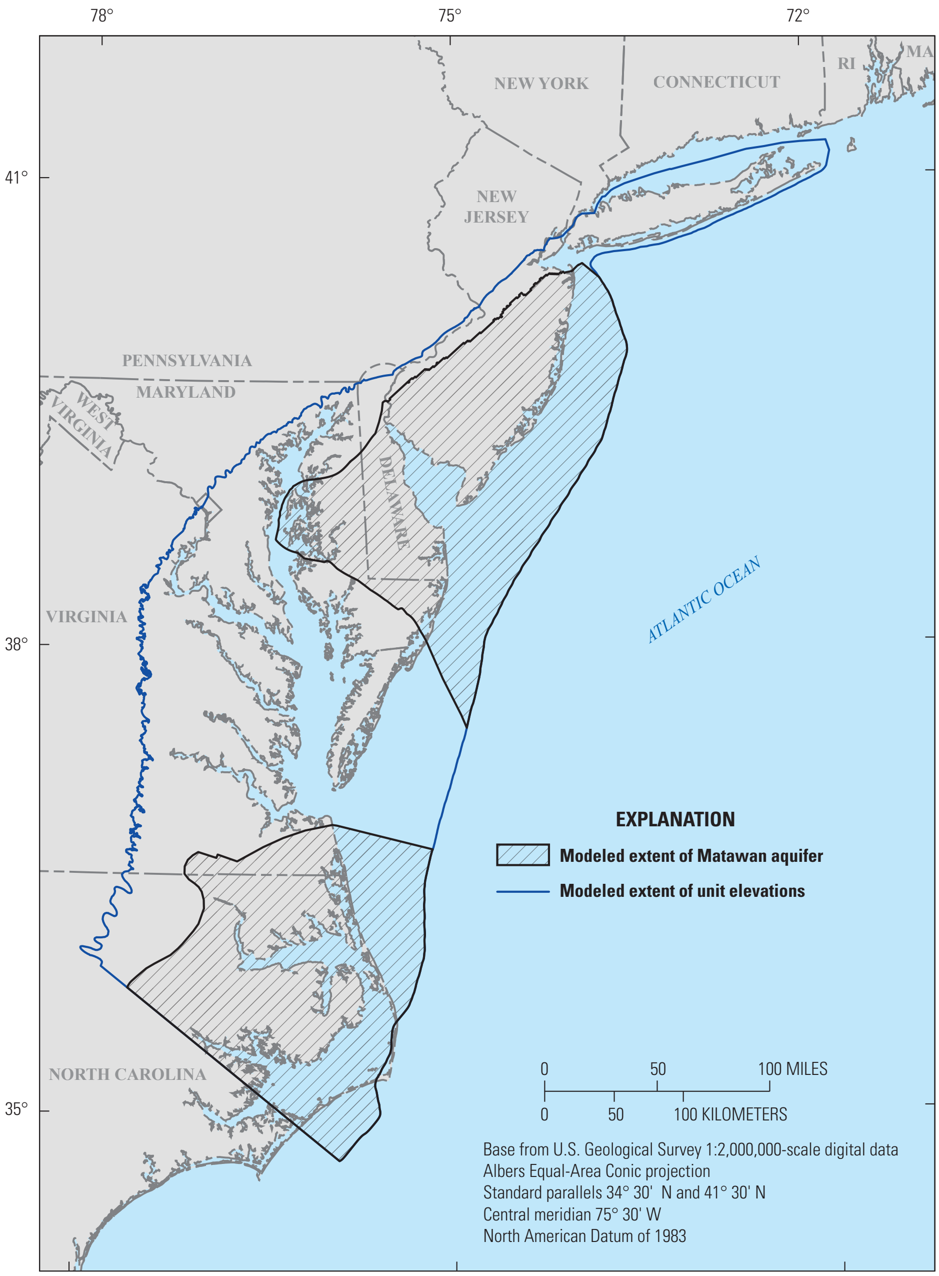


Figure 9. Location and extent of the Matawan regional aquifer.

Matawan Confining Unit

The Matawan regional confining unit, like the Matawan aquifer it overlies, consists of two discontinuous sections in the northern and southern parts of the study area (fig. 10). In the northern section, the Monmouth-Mount Laurel aquifer is separated from the Matawan aquifer below by a regional confining unit that includes the Marshalltown-Wenonah confining unit in New Jersey and the Matawan confining unit in Delaware and Maryland (fig. 2).

In the southern section in Virginia and Maryland, the regional confining unit separates the overlying Peedee aquifer from underlying units. This part of the Matawan confining unit includes the Virginia Beach confining zone in Virginia and the Black Creek confining unit in North Carolina.

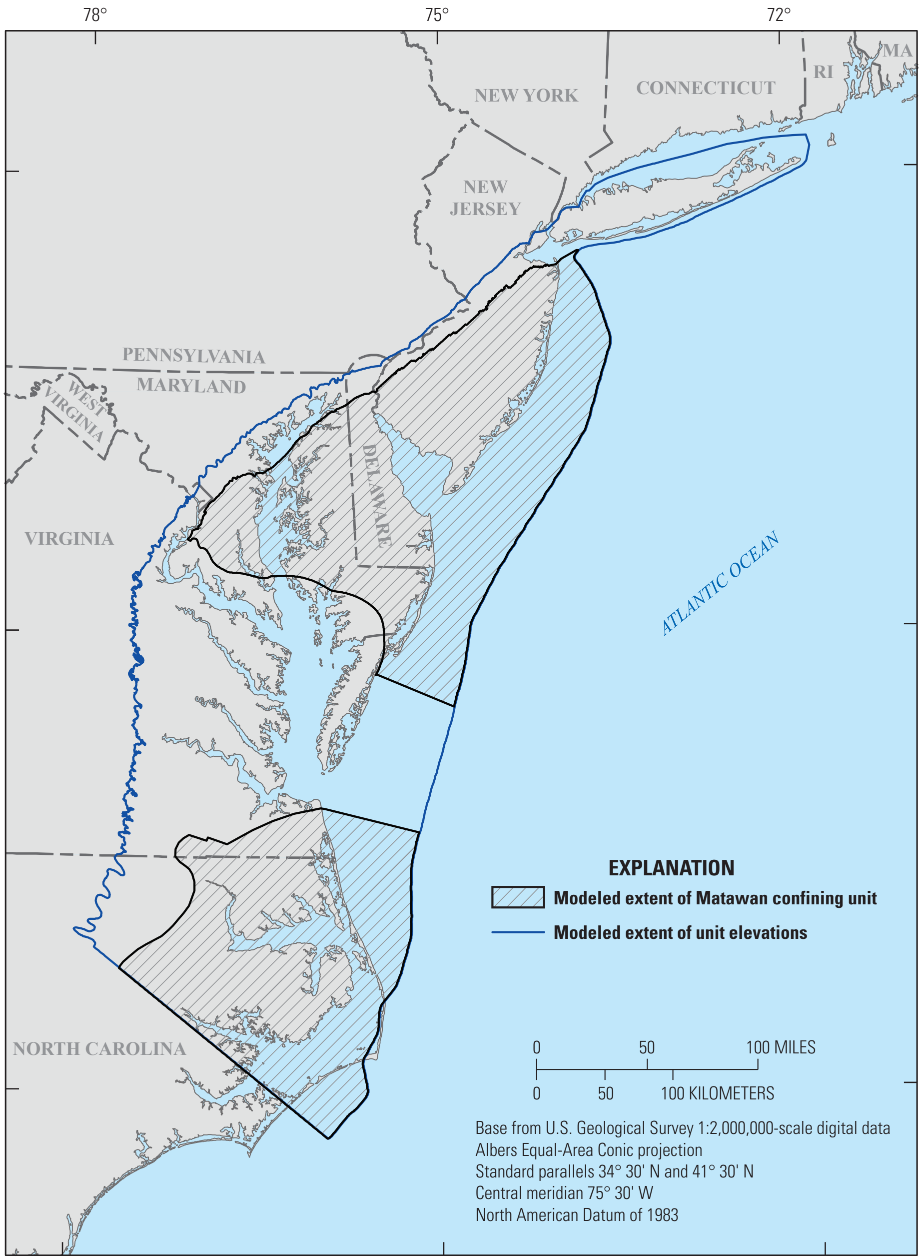


Figure 10. Location and extent of the Matawan regional confining unit.

Monmouth-Mount Laurel Aquifer

The Monmouth-Mount Laurel regional aquifer includes a northern section in New Jersey, Delaware, and Maryland and a laterally discontinuous southern section in southeastern Virginia and northeastern North Carolina (fig. 11). The northern section of the Monmouth-Mount Laurel regional aquifer includes the Wenonah-Mount Laurel aquifer in New Jersey, the Mount Laurel aquifer in Delaware, and the Monmouth aquifer in Maryland (fig. 2). On Long Island, laterally equivalent sediments are included and grouped with the regional Magothy aquifer.

In the southern part of the study area, sediments of similar age form a unit known locally as the Peedee aquifer, which is not continuous with the northern section of the Monmouth-Mount Laurel aquifer but is considered part of the same regional aquifer. The extent of the Peedee aquifer is poorly constrained in southern Virginia because of sparse data (McFarland and Bruce, 2006).

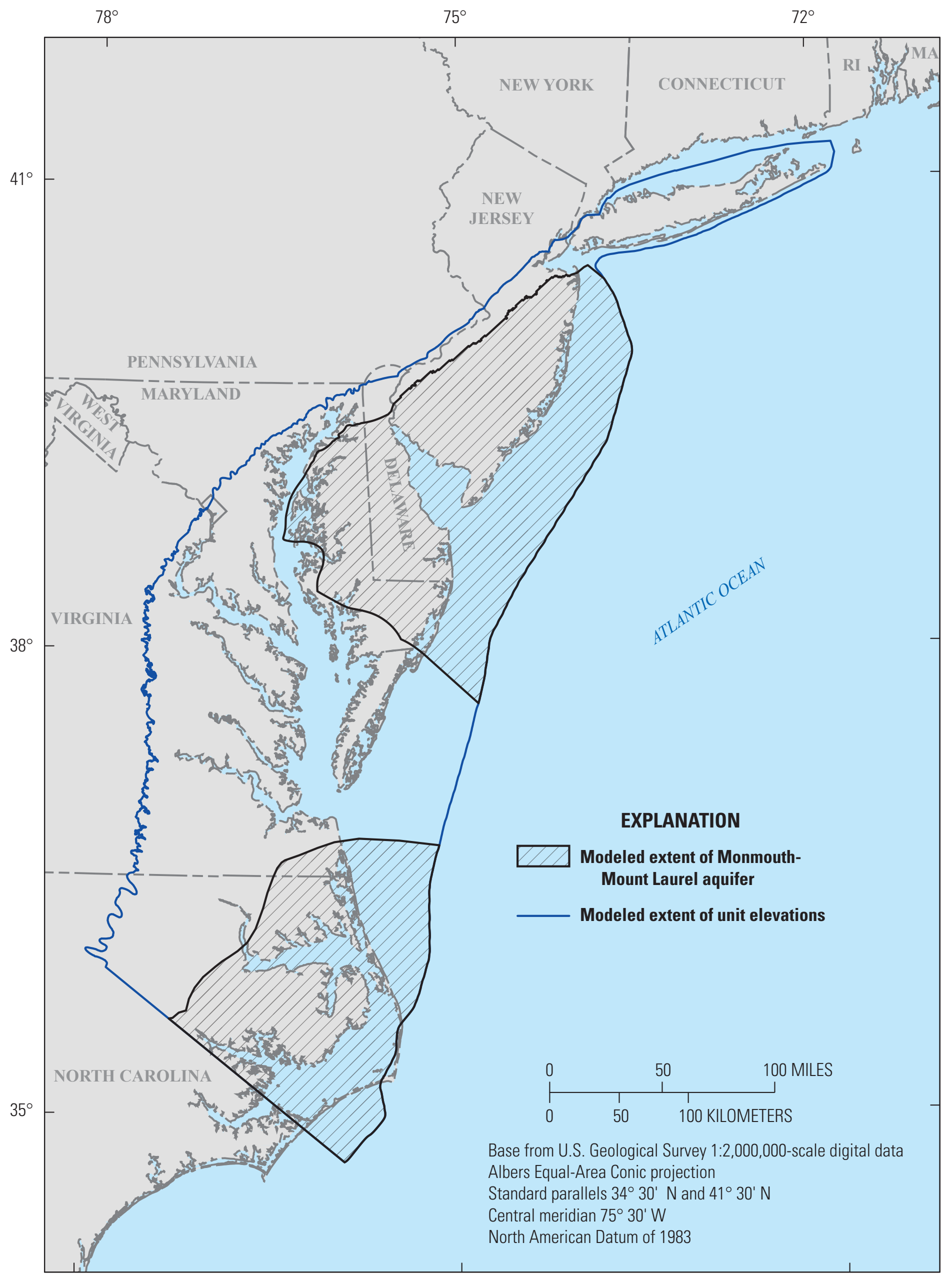


Figure 11. Location and extent of the Monmouth-Mount Laurel regional aquifer.

Monmouth-Mount Laurel Confining Unit

The Monmouth-Mount Laurel regional confining unit, like the Monmouth-Mount Laurel aquifer, consists of two discontinuous sections in the northern and southern parts of the study area (fig. 12). The northern section of the Monmouth-Mount Laurel regional aquifer is separated from the Aquia aquifer above by the regional confining unit that includes the Navesink-Hornerstown confining unit in New Jersey and the Severn confining unit in Delaware and Maryland (fig. 2). The thickness of the Monmouth-Mount Laurel confining unit is generally less than 100 ft.

The southern section of the regional confining unit includes the Peedee confining zone in Virginia and the Peedee confining unit in North Carolina. The designation of the unit as a confining zone in Virginia reflects the variable configuration and composition of the sediments above the Peedee aquifer and the transition to the overlying Aquia aquifer (McFarland and Bruce, 2006). The thickness of this section may be as great as several tens of feet in Virginia and up to 50 ft in North Carolina (McFarland and Bruce, 2006; Gellici and Lautier, 2010).

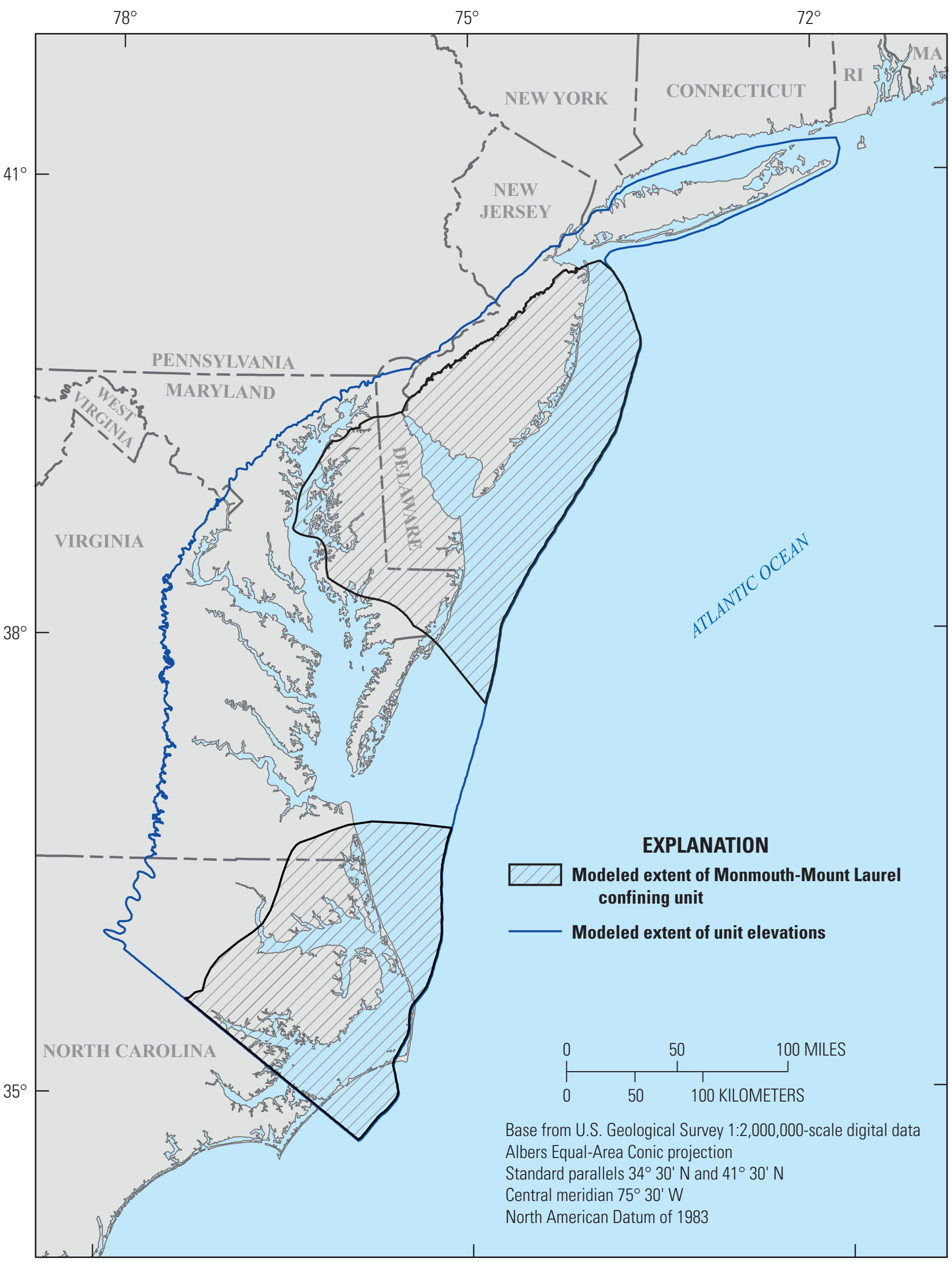


Figure 12. Location and extent of the Monmouth-Mount Laurel regional confining unit.

Aquia Aquifer

The Aquia regional aquifer (fig. 13) includes the Vincentown aquifer in New Jersey, the Rancocas aquifer in Delaware, the Aquia aquifer in Maryland and Virginia, and the Beaufort aquifer in North Carolina (fig. 2). The Aquia aquifer is not present on Long Island, but it may exist offshore south and east of Long Island. In the vicinity of the Chesapeake Bay impact crater in Virginia, the Aquia aquifer has been replaced by units related to the impact crater (McFarland and Bruce, 2006). Otherwise, the aquifer pinches out along its eastern boundary and has a very narrow extent in New Jersey. It is confined over most of its extent, but it crops out or subcrops in a narrow band in the Fall Zone where its top elevation approaches land surface.

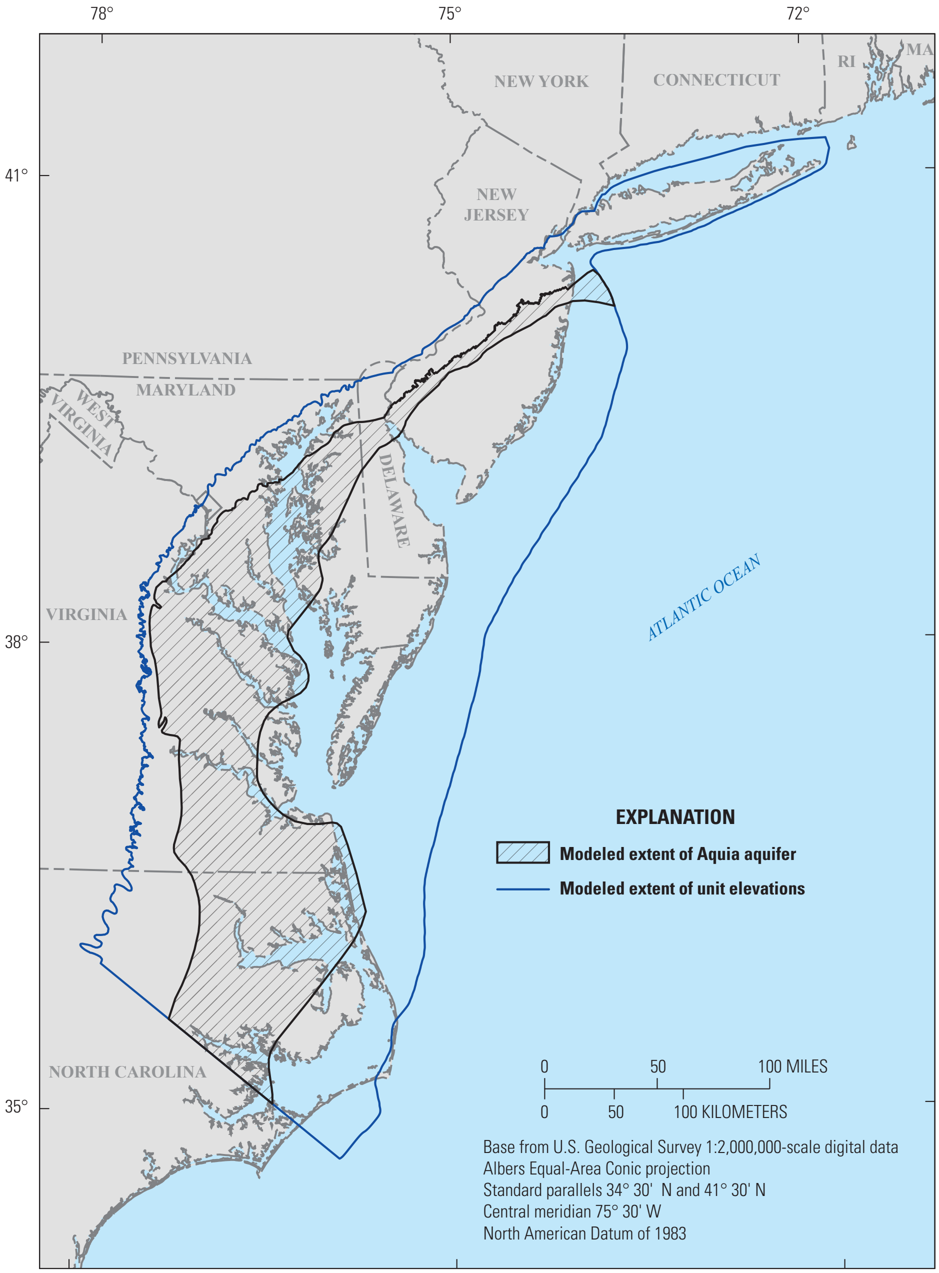


Figure 13. Location and extent of the Aquia regional aquifer.

Nanjemoy-Marlboro Confining Unit

Over most of its extent, the Aquia aquifer is overlain by the Nanjemoy-Marlboro regional confining unit, which separates the aquifer from the Piney Point regional aquifer above (fig. 14). This regional confining unit includes the Vincentown-Manasquan confining unit in New Jersey; the Nanjemoy-Marlboro Clay confining unit in Delaware, Maryland, and Virginia; and the Beaufort confining unit in North Carolina (fig. 2).

In the vicinity of the Chesapeake Bay impact crater, the Nanjemoy-Marlboro regional confining unit includes sediments related to the impact crater. The impact disrupted or removed older and deeper sedimentary units that were present at the time of the impact, and the resulting crater was filled by impact-related sediments. The hydrogeologic units related to the impact crater and described in detail by McFarland and Bruce (2006) include the Exmore matrix and Exmore clast confining units, composed of crater-fill material deposited during and immediately after the impact, and the Chickahominy confining unit, composed of sediments which were later deposited in a depression above the impact-related sediments and extend well beyond the immediate area of the impact. Together, the Exmore confining units reach a maximum thickness of more than 4,500 ft. The confining units fill the area within the impact crater, either directly overlying the basement in the crater center or overlying the Potomac-Patapsco confining unit and aquifer around the crater margin where those units were not removed by the impact. For the purposes of regional hydrogeology, these units are all quite impermeable and have been grouped together in the same confining unit.

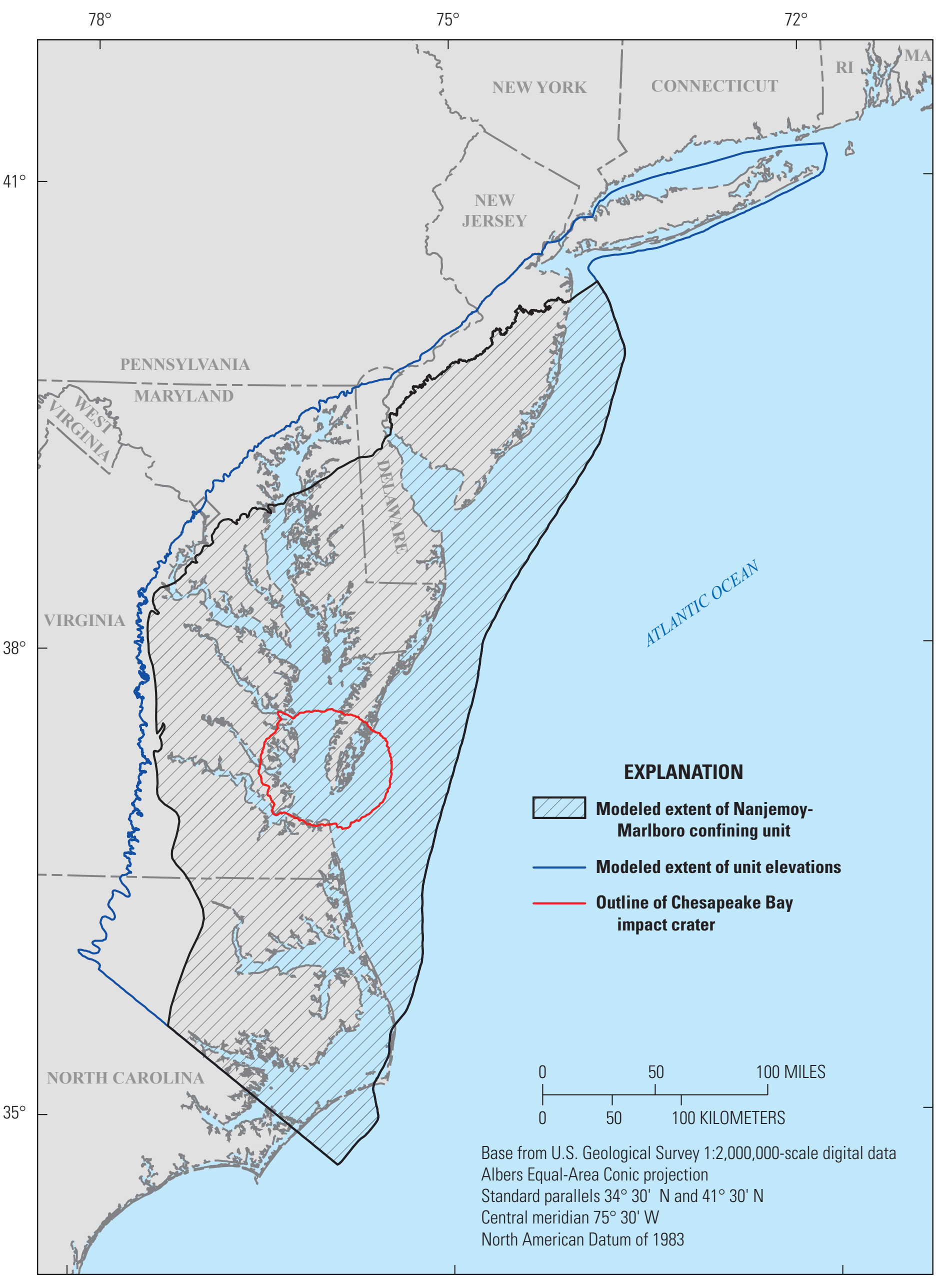


Figure 14. Location and extent of the Nanjemoy-Marlboro regional confining unit.

Piney Point Aquifer

The Piney Point regional aquifer (fig. 15) includes the Piney Point aquifer in New Jersey, Delaware, Maryland, and Virginia, as well as the Castle Hayne aquifer in North Carolina (fig. 2). The Piney Point aquifer has not been identified onshore north of New Jersey (Smolensky and others, 1989). The aquifer is confined over its extent. It is thickest in the west and thinnest in the east, where it pinches out just offshore of the Atlantic Coast.

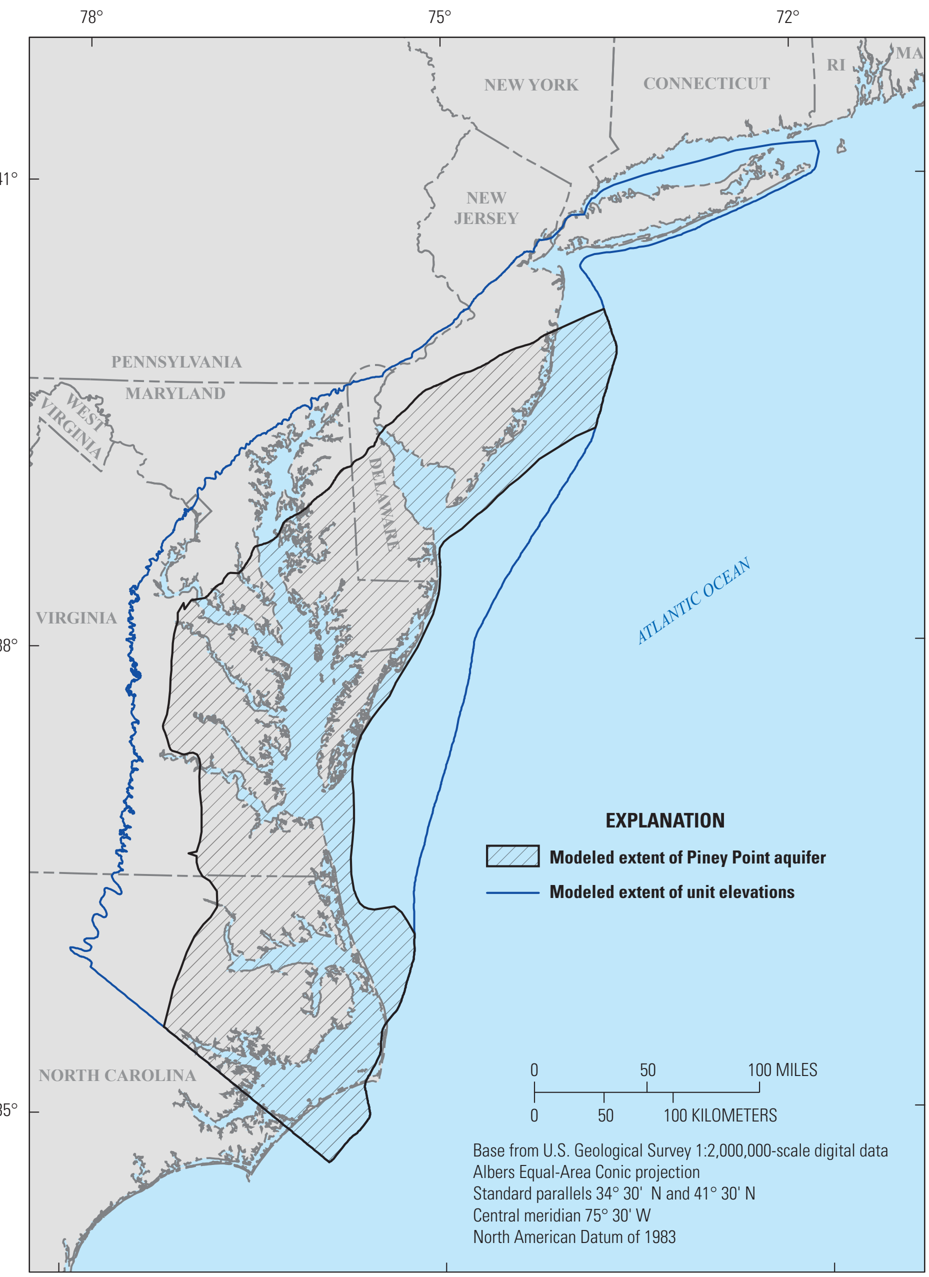


Figure 15. Location and extent of the Piney Point regional aquifer.

Calvert Confining Unit

The Calvert regional confining unit (fig. 16) separates the Piney Point regional aquifer from the lower Chesapeake regional aquifer above and includes the basal Kirkwood confining unit in New Jersey, the Calvert confining unit in Delaware, Maryland, and Virginia, and the Castle Hayne confining unit in North Carolina (fig. 2). As with the aquifers it separates, this confining unit is absent in Long Island (fig. 16).

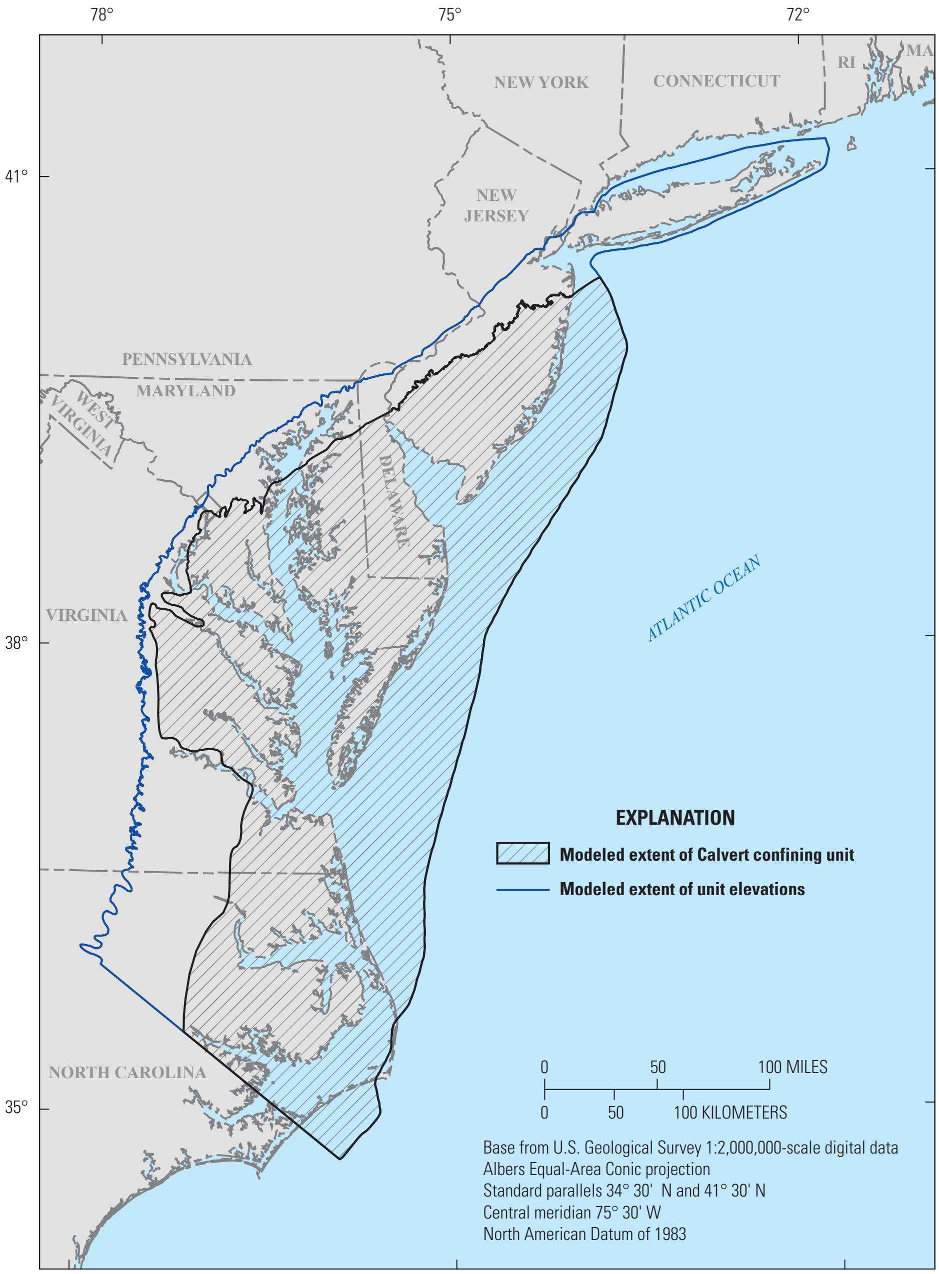


Figure 16. Location and extent of the Calvert regional confining unit.

Lower Chesapeake Aquifer

The lower Chesapeake regional aquifer is composed of two discontinuous northern and southern sections (fig. 17). It includes the lower Kirkwood-Cohansey and confined Kirkwood aquifer system in New Jersey, the Milford, Frederica, Federalsburg, and Cheswold local aquifers in Delaware, the Choptank and Calvert local aquifers in Maryland, the Saint Marys aquifer in Virginia, and the Pungo River aquifer in North Carolina (fig. 2). The lower Chesapeake aquifer is absent on Long Island (Smolensky and others, 1989). In Maryland, this aquifer is limited to the Delmarva Peninsula and a small section west of the Chesapeake Bay (Andreasen and others, 2013). In Virginia, it is mostly absent west of the Chesapeake Bay except for a small portion south of the James River (McFarland and Bruce, 2006).

The lower Chesapeake aquifer is confined over most of its extent, but it includes updip, unconfined sections in New Jersey, Delaware, and Maryland where overlying confining units are absent and the aquifer likely is in direct hydraulic connection with the unconfined surficial aquifer (Andreasen and others, 2013).

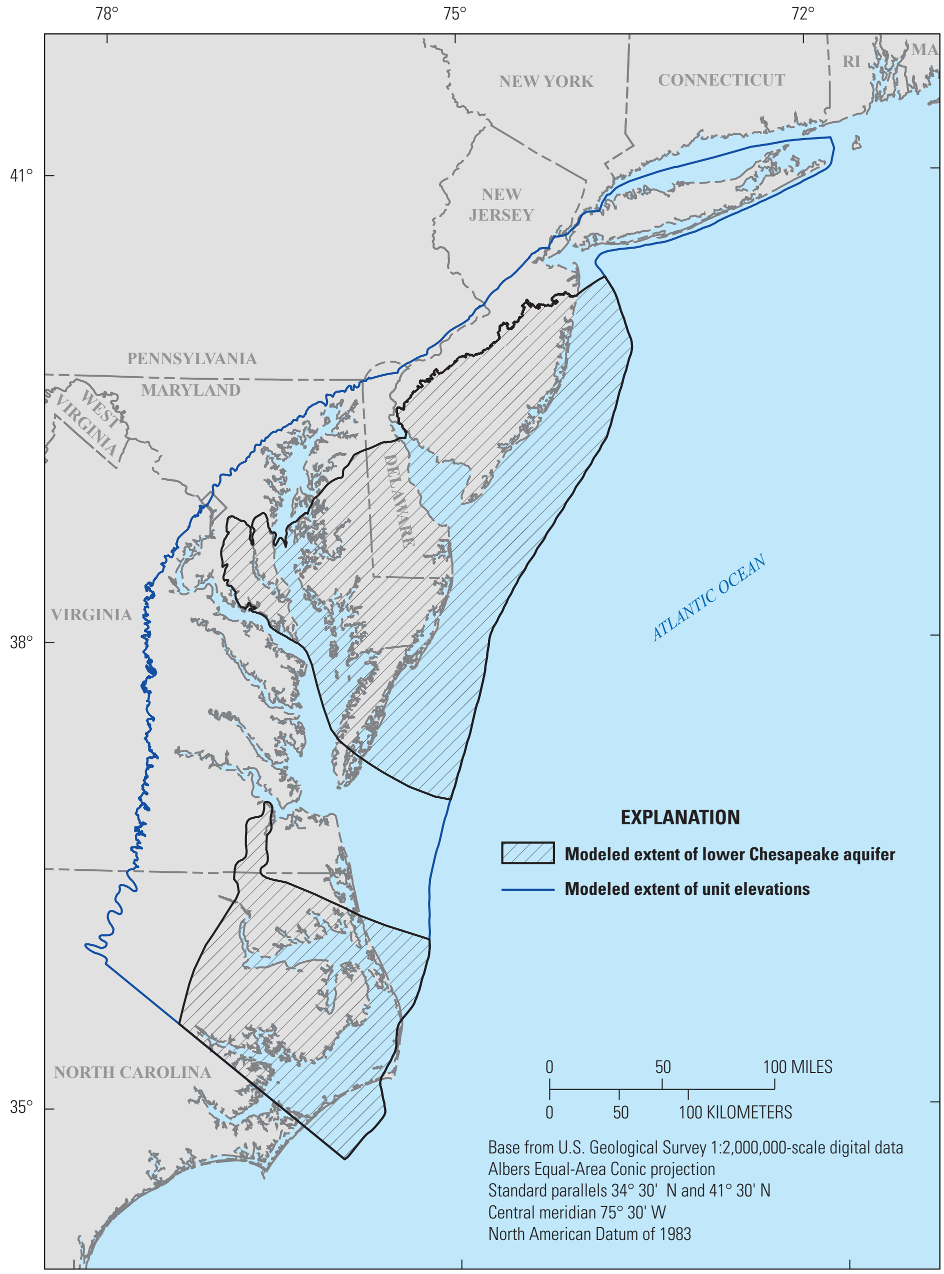


Figure 17. Location and extent of the lower Chesapeake regional aquifer.

Lower Chesapeake Confining Unit

The lower Chesapeake regional confining unit (fig. 18), separating the lower Chesapeake aquifer below from the upper Chesapeake aquifer above, includes an unnamed confining unit in New Jersey, the Saint Marys confining unit in Delaware, Maryland, and Virginia, and the Pungo River confining unit in North Carolina (fig. 2). The extent of the lower Chesapeake confining unit is shown in figure 18.

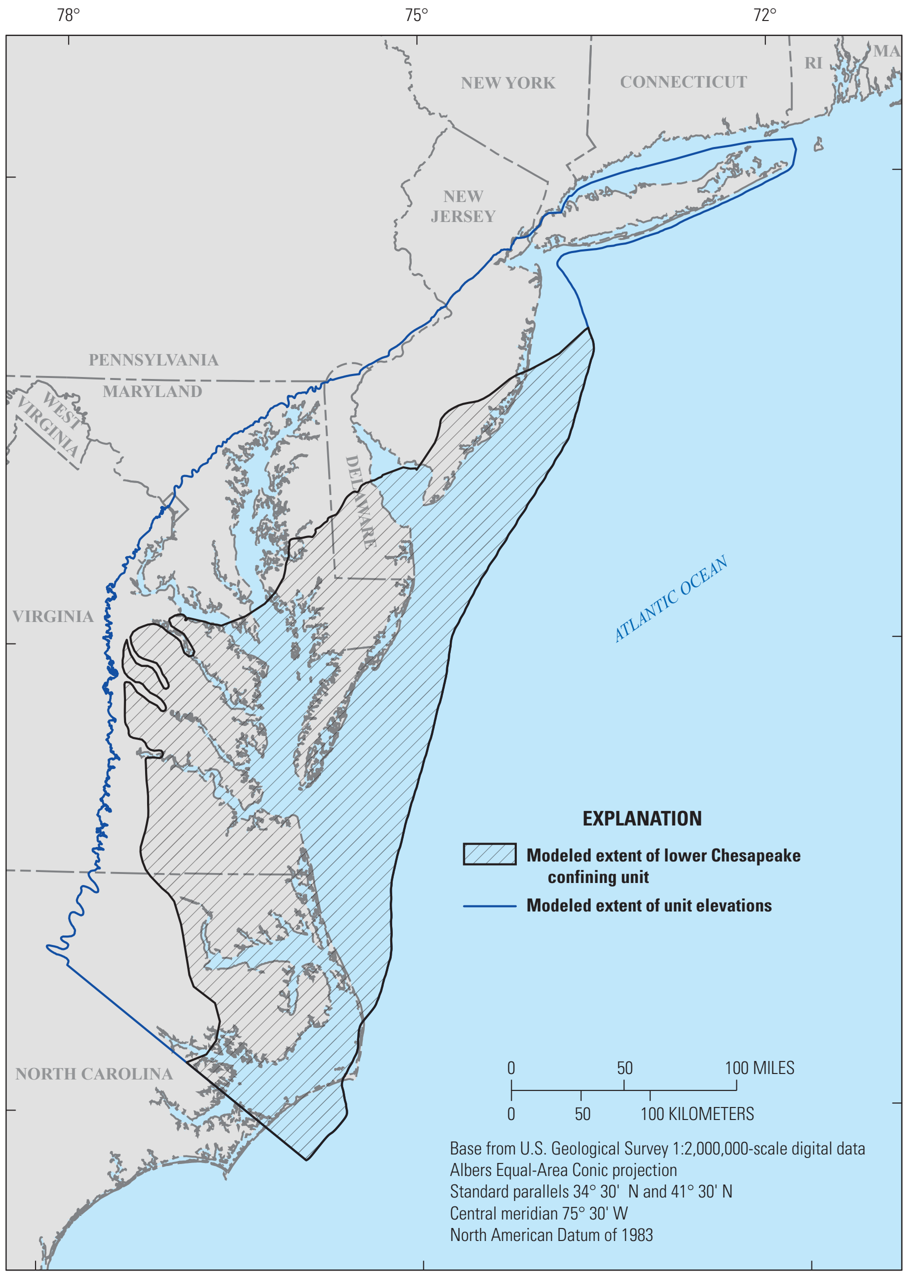


Figure 18. Location and extent of the lower Chesapeake regional confining unit.

Upper Chesapeake Aquifer

The upper Chesapeake regional aquifer (fig. 19) includes the confined part of the upper Kirkwood-Cohansey aquifer in New Jersey; the Pocomoke and Manokin aquifers in Delaware; the Pocomoke, Ocean City, and Manokin aquifers in Maryland; the Yorktown-Eastover aquifer in Virginia; and the Yorktown aquifer in North Carolina (fig. 2). The upper Chesapeake aquifer is absent on Long Island (Smolensky and others, 1989).

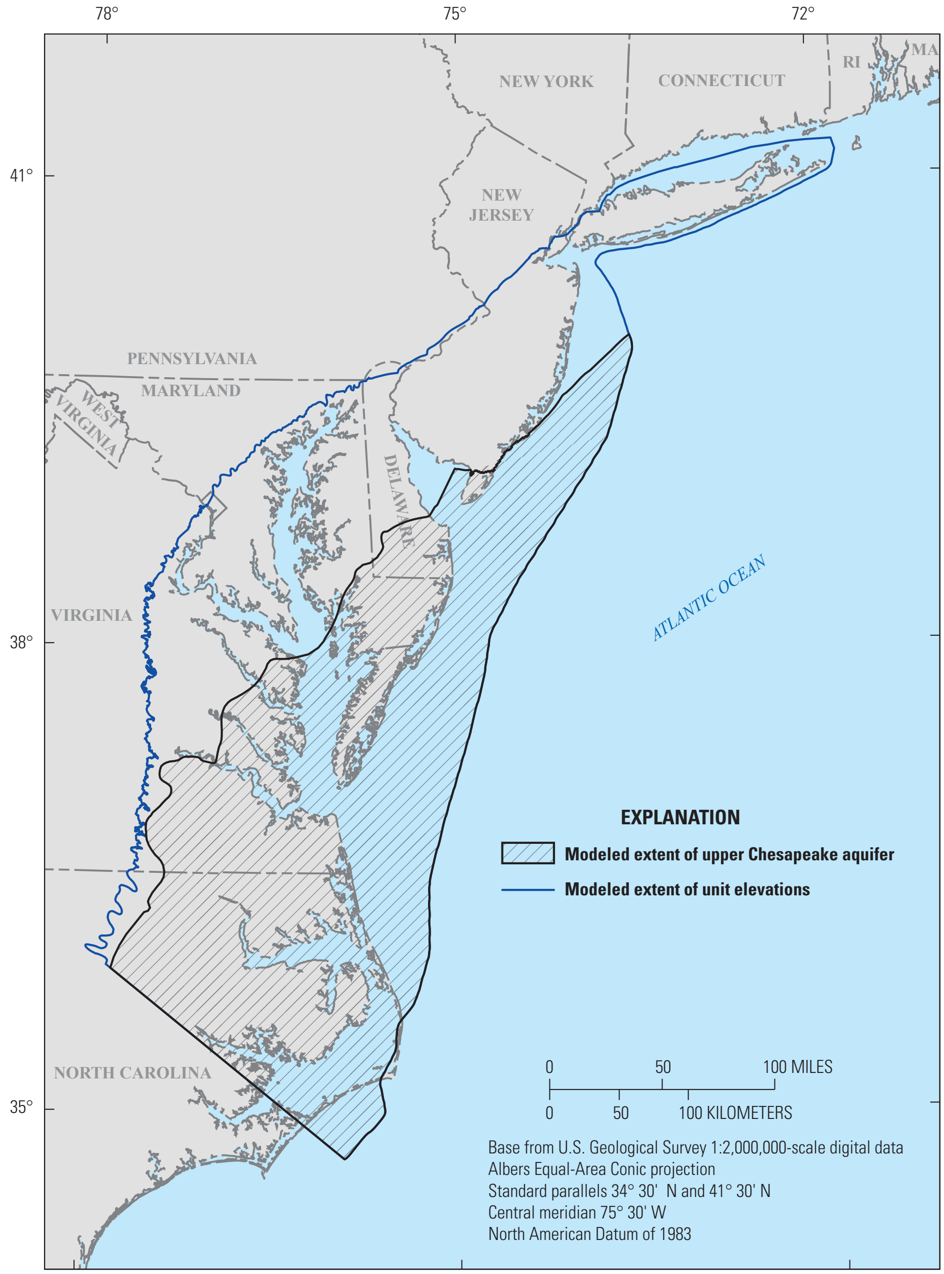


Figure 19. Location and extent of the upper Chesapeake regional aquifer.

Upper Chesapeake Confining Unit

The upper Chesapeake regional confining unit (fig. 20) overlies the upper Chesapeake aquifer over much of its extent and underlies the unconfined surficial aquifer. The regional confining unit includes the Holly Beach confining unit in New Jersey (only on the Cape May peninsula), the upper Chesapeake confining unit in Delaware and Maryland, the Yorktown confining zone in Virginia, and the Yorktown confining unit in North Carolina (fig. 2). The extent of the upper Chesapeake confining unit is shown in figure 20.

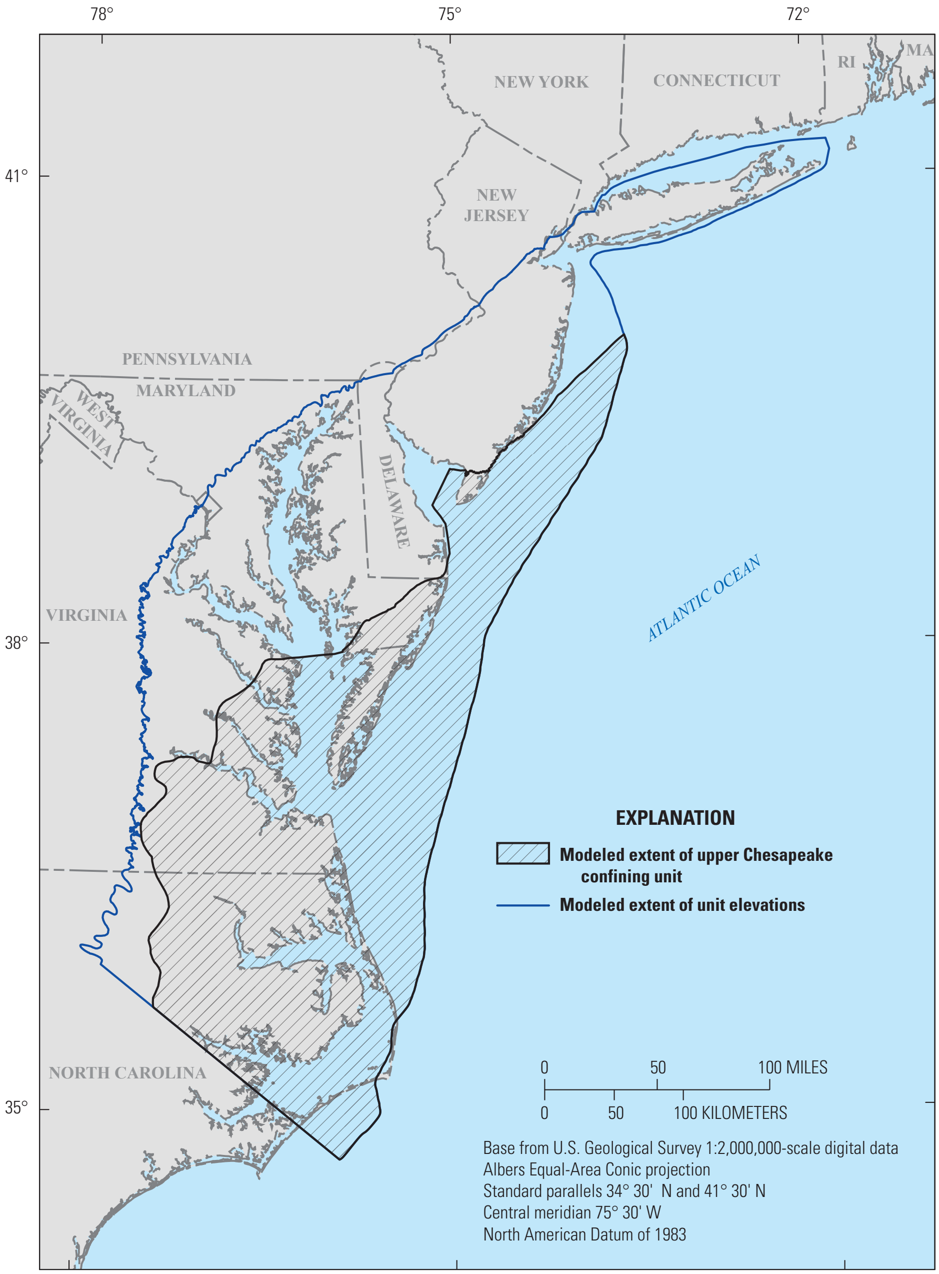


Figure 20. Location and extent of the upper Chesapeake regional confining unit.

Surficial Aquifer

The surficial aquifer is the uppermost aquifer in the NACP aquifer system, with its top defined as the land or bathymetric surface. The surficial aquifer is unconfined, mostly shallow, and exists throughout the NACP (fig. 1). Its thickness and characteristics are highly variable depending on local topography and depositional and erosional history. Across the NACP, the surficial aquifer is composed largely of permeable surficial sediments of Pleistocene to Holocene age, but may also include hydrologically continuous, permeable, older, underlying sediments where those sediments have not been differentiated from other units. In New Jersey, the regional surficial aquifer presented in this report includes the unconfined part of the undifferentiated upper Kirkwood-Cohansey aquifer and overlying local units that are hydraulically connected. The local, relatively shallow Holly Beach aquifer near Cape May, New Jersey, is also included in the regional surficial aquifer, where the underlying Kirkwood-Cohansey aquifer is confined. On Long Island, the surficial aquifer primarily is composed of thick glacial deposits and is referred to as the upper glacial aquifer. Across much of its extent on Long Island, the unconfined upper glacial aquifer is hydraulically continuous with the underlying Magothy aquifer (Smolensky and others, 1989). As a result, the bottom of the surficial upper glacial aquifer corresponds to the top of the Magothy aquifer on Long Island.

The western extent of the surficial aquifer (and of the NACP) is defined by the extent of continuous Coastal Plain sediments in the Fall Zone, derived from a variety of surficial geologic maps of the study area and delineated by the extent polygon for the surficial aquifer, which also encompasses the extents of all other hydrogeologic units described in this report (fig. 1; table 1).

Limitations and Recommended Use of Data

The focus of this hydrogeologic framework is regional, and the regional correlation of the various hydrogeologic units involved considerable interpolation and extrapolation of unit elevations in areas where data were limited or absent. Conflicts between unit elevations among overlapping state-level investigations were resolved by approximating unit elevations in the overlapping areas. In addition, the delineation of regional hydrogeologic units in some instances required aggregation of two or more local hydrogeologic units. Because of these necessary approximations, the most appropriate use of these data is for large-scale, regional-level analyses, as discussed in Masterson and others (2013) and Masterson and others (2016a). The use of state-level datasets that provided the fundamental data for this study (see Sources of Data) is suggested for more detailed work. These source publications also provide additional information on the spatial variability of data incorporated into the interpretations of hydrogeologic units described in this report.

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File Organization

File names provided in table 2 relate the documented digital geospatial files provided in the related data release (Pope and others, 2016) to the unit names given in this report.

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