HYDROGEOLOGIC FRAMEWORK OF THE NORTHERN ATLANTIC COASTAL PLAIN IN PARTS OF NORTH CAROLINA, VIRGINIA, MARYLAND, DELAWARE, NEW JERSEY, AND NEW YORK

REGIONAL AQUIFER-SYSTEM ANALYSIS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1404-G

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Hydrogeologic Framework of the Northern Atlantic Coastal Plain in Parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York

By HENRY TRAPP, JR.

REGIONAL AQUIFER-SYSTEM ANALYSIS—
NORTHERN ATLANTIC COASTAL PLAIN

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FOREWORD

THE REGIONAL AQUIFER-SYSTEM ANALYSIS PROGRAM

The Regional Aquifer-System Analysis (RASA) Program was started in 1978 following a congressional mandate to develop quantitative appraisals of the major ground-water systems of the United States. The RASA Program represents a systematic effort to study a number of the Nation's most important aquifer systems, which in aggregate underlie much of the country and which represent an important component of the Nation's total water supply. In general, the boundaries of these studies are identified by the hydrologic extent of each system and accordingly transcend the political subdivisions to which investigations have often arbitrarily been limited in the past. The broad objective for each study is to assemble geologic, hydrologic, and geochemical information, to analyze and develop an understanding of the system, and to develop predictive capabilities that will contribute to the effective management of the system. The use of computer simulation is an important element of the RASA studies, both to develop an understanding of the natural, undisturbed hydrologic system and the changes brought about in it by human activities, and to provide a means of predicting the regional effects of future pumping or other stresses.

The final interpretive results of the RASA Program are presented in a series of U.S. Geological Survey Professional Papers that describe the geology, hydrology, and geochemistry of each regional aquifer system. Each study within the RASA Program is assigned a single Professional Paper number, and where the volume of interpretive material warrants, separate topical chapters that consider the principal elements of the investigation may be published. The series of RASA interpretive reports begins with Professional Paper 1400 and thereafter will continue in numerical sequence as the interpretive products of subsequent studies become available.

Dallas L. Peck
Director

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ILLUSTRATIONS

(Plates are in separate volume)

CONVERSION FACTORS AND ABBREVIATIONS

For those readers who prefer to use metric (International System) units, the conversion factors for the inch-pound units are listed below:

Multiply inch-pound unit	*By*	*To obtain metric unit*
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	259.0	hectare (ha)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square foot per day (ft^2/day)	0.09290	square meter per day (m^2/day)
foot per day per foot (ft/day)/ft	1	meter per day per meter (m/d)/m

In this report, sea level refers to the National Geodetic Vertical Datum (NGVD) of 1929, a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929." Altitude is defined as distance above or below the NGVD of 1929.

HYDROGEOLOGIC FRAMEWORK OF THE NORTHERN ATLANTIC COASTAL PLAIN IN PARTS OF NORTH CAROLINA, VIRGINIA, MARYLAND, DELAWARE, NEW JERSEY, AND NEW YORK

By HENRY TRAPP, JR.

ABSTRACT

The area of the Regional Aquifer-System Analysis (RASA) of the northern Atlantic Coastal Plain extends along the Atlantic Coastal province from Long Island, N.Y., through North Carolina. Its western limit is the landward edge of water-bearing strata of Cretaceous through Pleistocene age, which approximates the Fall Line. Its extreme eastern limit is the Continental Slope, but the primary focus is the emergent Coastal Plain and its adjoining bays, lagoons, sounds, and estuaries. Thus limited, the area of study covers about 50,000 square miles.

The northern Atlantic Coastal Plain contains a multilayered aquifer system, capable of large yields and composed of sedimentary deposits. The Coastal Plain sediments were deposited on a basement surface that slopes gently toward the Atlantic Ocean. The basement rock is similar to the exposed rock of the Piedmont Plateau province, of which it is continuous. Igneous and metamorphic Precambrian and Paleozoic rocks, and rift-basin Triassic and Jurassic sedimentary and volcanic rocks have been mapped below the Coastal Plain sediments.

The thickness of the sediments on the emergent Coastal Plain ranges from 0 feet near the Fall Line to about 10,000 feet at Cape Hatteras, N.C., and 8,000 feet along the Atlantic coast of Maryland. Offshore from New Jersey and the Delmarva Peninsula, the thickness of sediments in the Baltimore Canyon Trough, estimated from magnetic and seismic surveys, exceeds 7.5 miles.

The Coastal Plain sediments range in age from Jurassic to Holocene. Upper Jurassic sediments have been identified in a few wells near the coast, but mostly, the Jurassic sediments are offshore and not fresh-water aquifers. In general, the lowermost Cretaceous Coastal Plain deposits are fluvial or fluviodeltaic in origin and contain discontinuous lenses of sand, silt, clay, and gravel, with minor amounts of lignite. Most younger deposits progressively overlap older ones in a landward direction. In the Cretaceous section, there is a general upward transition from fluvial and fluviodeltaic to marginal-marine to marine deposits. The marine parts of the section consist primarily of glauconitic sand, silt, clay, and limestone beds, which are traceable over longer distances than the more lenticular nonmarine beds. The Tertiary sediments are predominantly marine except for the upper Miocene and Pliocene beds, which are in part nonmarine. The Pleistocene section includes glacial drift on Long Island and marine, dune, and terrace deposits elsewhere. The Holocene section includes alluvial, marine, estuarine, beach, and dune deposits.

For this study, the Coastal Plain sediments have been subdivided into 11 regional aquifers separated by 9 confining units. The basis for definition of the aquifers is continuity of permeability. In sedimentary rocks, the principal direction of permeability tends to follow beds of sand, gravel, or limestone, which in turn run approximately parallel to the upper and lower boundaries of formations. Adjacent permeable beds, or those separated by only thin beds of low permeability such as clay or silt, may be considered parts of the same aquifer. A regional aquifer may coincide with a recognized local or subregional aquifer in one area and comprise several such aquifers in another, or it may constitute only part of a local aquifer.

Manuscript approved for publication December 10, 1987.

INTRODUCTION

The northern Atlantic Coastal Plain contains a multilayered aquifer system composed of sedimentary deposits. Although the system is capable of providing large ground-water supplies, the increasing demand for water has led to declining ground-water levels over large areas. Declining water levels may be inducing saltwater intrusion from the ocean, bays, and estuaries and from saline ground water in the deeper parts of the aquifers. A quantitative evaluation of this complex aquifer system is needed to develop and manage the ground-water resource safely and effectively.

The U.S. Geological Survey conducted the Regional Aquifer System Analysis (RASA) study of the northern Atlantic Coastal Plain to acquire a comprehensive understanding of the aquifer system and its response to pumping stress (Meisler, 1980, p. 9–10).

PURPOSE AND SCOPE

The purpose of this report is to define the aquifer system of the northern Atlantic Coastal Plain as it is related to areal geology. The resulting hydrogeologic framework serves as a basis for the geochemical study and digital simulation of the aquifer system.

The hydrogeologic framework is defined in terms of 11 regional aquifers separated by 9 confining units on the basis of continuity of permeability. The distribution of permeability was determined by the geologic history of the Coastal Plain, which is reviewed in this report.

Companion chapters of Professional Paper 1404, with their letter designations, describe (1) the hydrogeologic framework of the Coastal Plain in more detail for North Carolina (I), Virginia (C), Maryland and Delaware (E), and New Jersey (B); (2) the distribution of saltwater in the Coastal Plain sediments (D); (3) the geochemistry of the Coastal Plain aquifer system (L); (4) the regional ground-water flow and hydraulic properties of aquifers and confining units, as studied through digital simulation (K); and (5) the results of more detailed simulations in North Carolina (M), Virginia (F), Maryland-Delaware (J), and New Jersey (H). Professional Paper 1404 also contains a summary chapter (A).

GEOGRAPHIC SETTING

The area of the study extends along the Atlantic Coastal province (Murray, 1961, p. 1–5) from Long Island, N.Y., through North Carolina (fig. 1). Its western limit is the landward edge of water-bearing strata of Cretaceous through Pleistocene age, which approximates the Fall Line. Its extreme eastern limit is the Continental Slope, but the primary focus is the emergent Coastal Plain plus the adjoining bays, lagoons, sounds, and estuaries. Thus limited, the area of study covers about 50,000 mi^2.

ORGANIZATION AND APPROACH

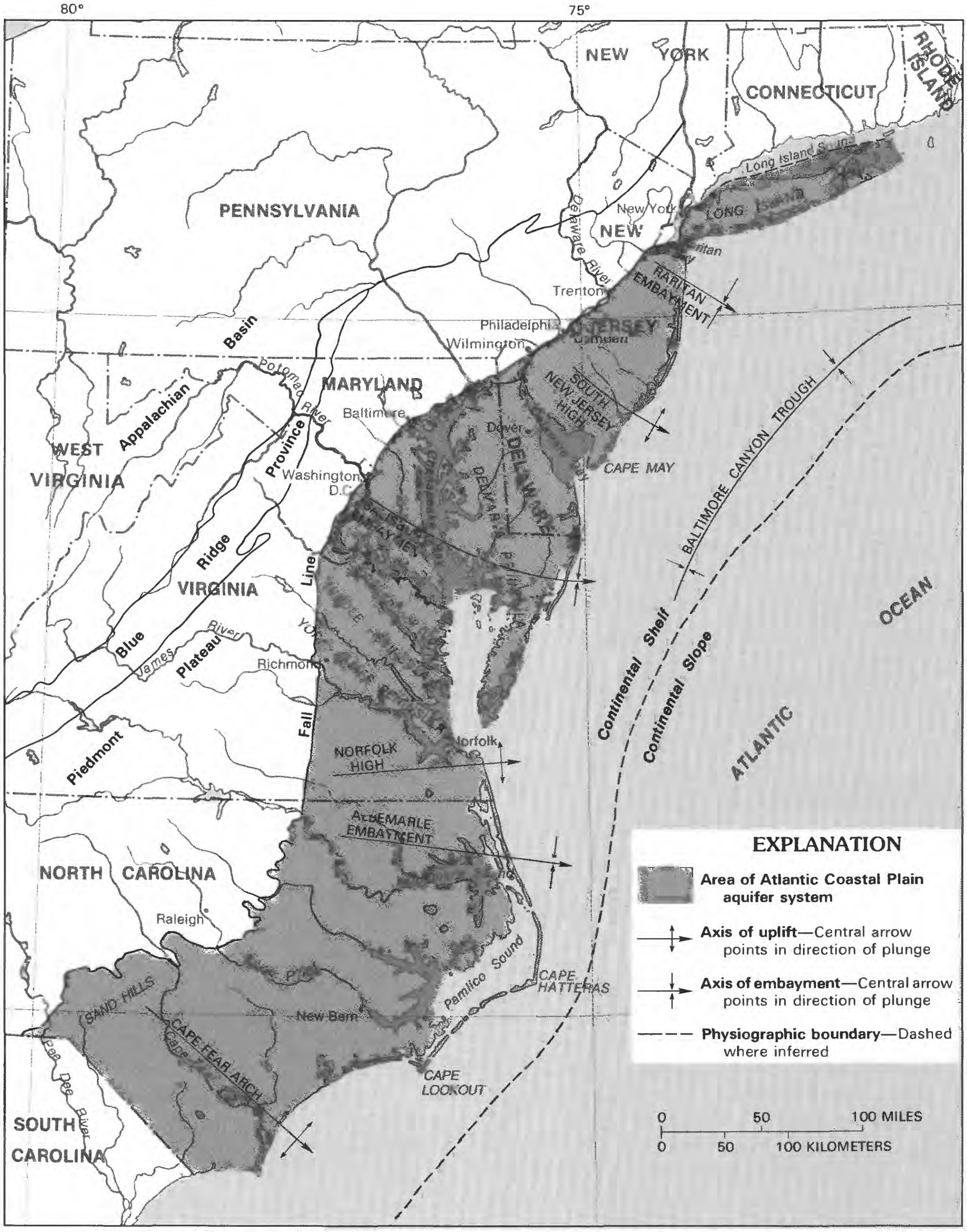
The Northern Atlantic Coastal Plain RASA was conducted by the regional project staff in coordination with five subregional project staffs, which studied the Coastal Plain aquifer systems in Long Island, New Jersey, Delaware and Maryland, Virginia, and North Carolina. The regional project staff, located in Trenton, N.J., designed the overall study and coordinated the regional and subregional projects. With respect to development of the hydrogeologic framework, subregional staffs collected and interpreted geologic and hydrologic data, prepared maps and sections delineating 11 regional aquifers and 9 intervening confining units, and wrote reports describing the hydrogeologic framework for each of the subregions. Their data and interpretations form the basis for the hydrogeologic framework described in this report. The principal investigators responsible for the subregional frameworks, with references to their publications, are

M.S. Garber (1987)—New York (Long Island)
O.S. Zapecza (1989)—New Jersey
D.A. Vroblesky and W.B. Fleck (in press)—Maryland-Delaware
A.A. Meng, III, and J.F. Harsh (1988)—Virginia
M.D. Winner, Jr., and R.W. Coble (in press)—North Carolina

Additional control for delineation of aquifers on Long Island, other than the Lloyd, was derived from publications that included those of Suter and others (1949), McClymonds and Franke (1972), and Getzen (1977) and others covering local areas (Bachman and Pitt, 1984). Additional control for the regional configuration of the basement surface came from Brown and others (1972) and their supplementary computerized well data, Gleason (1979a, b, 1980, 1982a, b), Svetlichny and Lambiase (1979), Svetlichny (1980), Trapp and others (1984), and interpretations from seismic mapping in the New Jersey Coastal Plain (Gill and Farlekas, 1976, sheet 1) and the adjoining part of Delaware (Cushing and others, 1973, fig. 2).

WELL-NUMBERING SYSTEM

Most of the wells used as data control points for this report were selected from those used as controls for the subregional studies. They are numbered sequentially from north to south within each State and, where two or more are at the same latitude (to the nearest second), from east to west (pl. 1*A*). The numbering sequence extends from State to State in a southerly direction, beginning with New York (Long Island). Locations, descriptions, and hydrogeologic data for the wells are listed in the appendix. The table, which makes up the appendix, includes the U.S. Geological Survey's Ground-Water Site Inventory (GWSI) numbers for those wells that were assigned them during tabulation. The GWSI is a computerized data base; its numbers are used to compile and access data relating to wells and are based on the locations of the wells as they were known during compilation. The first six digits (for example, 410745 for well 1 in the appendix) represent the latitude, and the next seven digits the longitude (for example, 0721600 for well 1). Each is given in degrees, minutes, and seconds in the fourth column. The two digits after the decimal point represent a sequence number for wells and other sites that share the same preceding 13 digits. Once site identification numbers are entered into the GWSI system, they are not changed even though the latitude or longitude values may be corrected.



Base enlarged from U.S. Geological Survey National Atlas, 1970, 1:7,500,000

Positions of structural features adapted from Uchupi (1968), Maher (1971), and Owens and Gohn (1985).

FIGURE 1.—Location of the northern Atlantic Coastal Plain and major structural features.

ACKNOWLEDGMENTS

The author acknowledges the cooperation of State agencies that provided data on wells and geology for the subregional studies and, ultimately, for this report. These agencies include the New Jersey Department of Environmental Protection, the Delaware Geological Survey, the Maryland Geological Survey, the Virginia Division of Mineral Resources, the Virginia Water Control Board, and the North Carolina Department of Natural Resources and Community Development (NRCD). P.M. Brown, chief of the Geologic Section of NRCD and formerly with the U.S. Geological Survey, provided copies of many logs of North Carolina and Virginia wells. Drilling contractors, consultants, local water-supply agencies, and industries also contributed data used in developing the hydrogeologic framework. J.K. Costain, from the Virginia Polytechnic Institute and State University, provided copies of reports, prepared for the U.S. Department of Energy, on geothermal resources in the area of this study. Trapp and others (1984, p. 1–2) acknowledged the individuals and agencies that assisted in drilling the test well at Cambridge, Md., for this project and in acquiring and interpreting data from it.

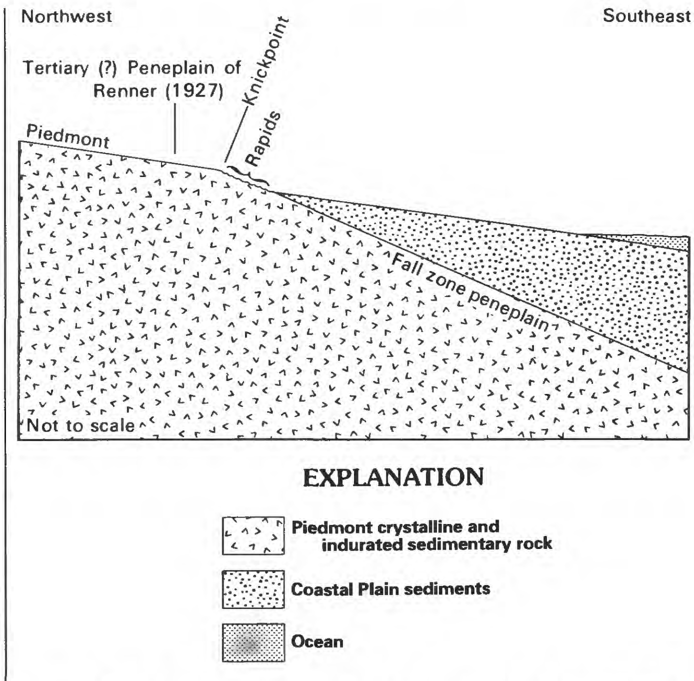


FIGURE 2.—Diagrammatic stream profile and geologic section, with knickpoint at contact between Piedmont surface and eroding edge of buried "Fall Zone Peneplain."

HYDROGEOLOGY

PHYSIOGRAPHY

The Atlantic and Gulf Coastal province is continuous from north of Newfoundland to Honduras and extends from the landward edge of strata of Cretaceous through Pleistocene age eastward to the Continental Slope and Rise. The submerged coastal province is the Continental Shelf; north of Cape Cod, it is entirely submerged (Fenneman, 1938, p. 1–3; Murray, 1961, p. 1–2). The emergent coastal province constitutes the Coastal Plain in the area of this study. Southward, the Coastal Plain broadens to be as wide as 140 mi in North Carolina, and the Continental Shelf correspondingly narrows.

The Fall Line, which marks the boundary between the Coastal Plain and the Piedmont Plateau province (fig. 1), is so named because of the prevalence of falls and rapids at the points where streams cross the contact between the indurated rocks of the Piedmont and the unconsolidated and partly consolidated sediments of the Coastal Plain. The increase in stream gradient at the contact provided favorable locations for water power, and on most major rivers, it coincided with the head of ocean navigation. Thus, major cities grew along it, including Trenton, N.J.; Philadelphia, Pa.; Wilmington, Del.; Baltimore, Md.; Washington, D.C.; and Richmond, Va.

The cause of the rapids at the Fall Line is not only the change from hard to soft rock, but also the eroding contact of the present Piedmont surface (whose gradient is approximately adjusted to present sea level (fig. 2)) and the more steeply sloping buried erosion surface that underlies the Coastal Plain strata (Renner, 1927, p. 284–285, fig. 12–13). That erosion surface is the "Fall Zone Peneplain" (Sharp, 1929; Johnson, 1931, p. 15–22). The knickpoints and resulting rapids (fig. 2) in the stream profiles do not coincide exactly with the eroded edges of the Coastal Plain sediments. Flint (1963) identified the Fall Zone with a facetlike surface in a band 10 to 15 mi wide in coastal Connecticut, which he concluded was originally covered with Cretaceous sediments. When projected southward, the altitude of the surface appeared to match that of the bedrock surface underlying Long Island Sound and Long Island.

The Fall Line is sharply defined near Washington, D.C., where the buried basement surface has a slope of 100 ft/mi, but becomes less distinct southward, especially in North Carolina. There the basement surface slopes more gently, and in places, the easternmost rocks of the Piedmont Plateau are Triassic strata that are only a little more resistant to erosion than are the adjacent and overlying Coastal Plain Cretaceous strata. Under these conditions, zones of rapids are not necessarily related to the landward limit of Coastal Plain sediments. In North Carolina, the Piedmont-Coastal Plain contact in the beds of some of the major rivers is offset 20 mi or more downstream from the contact in the divide areas. These rivers, although walled by banks of Cretaceous strata, are incised into crystalline rocks (Fenneman, 1938, p. 126–129).

Most of the area of this study, from Cape Lookout, N.C., northward, is in the embayed section of the Coastal Plain, "so indented by branching bays or estuaries that it is little more than a fringe of peninsulas, narrowing to zero at New York and represented beyond that by islands *** the edge of the continent has here been depressed *** the amount of depression increases toward the north. The rivers of this section as far south as the James and Appomattox are drowned to the Fall Line" (Fenneman, 1938, p. 13). Barrier islands fringe the coast. From New Jersey to the Rappahannock River, a feature of the embayed section is a band of highly dissected Cretaceous outcrop along the Fall Line. On Long Island, the Cretaceous is mantled by glacial deposits, including two terminal moraines (Veatch and others, 1906; Fuller, 1914; Fleming, 1935). It is mostly buried by Tertiary sediments south of the Rappahannock.

The area of investigation south of Cape Lookout is part of the Sea Island section of the Coastal Plain discussed by Fenneman (1938, p. 38–40, 45–46). According to Fenneman's interpretation, the offshore islands in this section are remnants of the mainland, cut off by enlarged tidal channels. More recent studies have attributed the origin of barrier islands along the coast from New England to Texas to the reworking of deltaic and beach sands by the rising ocean after the Pleistocene Epoch (Dolan and Lins, 1986, p. 11–14). Nevertheless, Fenneman noticed that drowning of the rivers is less pronounced in the Sea Island section than in the embayed section, and as was previously stated, the Fall Line is less distinct.

In both the embayed and Sea Island sections of the Coastal Plain, as many as eight terrace levels have been identified (Fenneman, 1938, fig. 10). The scarps of the terraces are roughly parallel to the present shoreline and major embayments and rivers. Their typical altitudes range from 12 to 270 ft above sea level, but surfaces as high as 500 ft have been correlated with the uppermost (Brandywine) terrace. Their number, correlation, and origin are controversial and will be discussed in the next section, Previous Work.

Land-surface altitudes in the area of study range from 0 ft to as much as 715 ft in the Sand Hills of the southwestern North Carolina Coastal Plain. The Sand Hills also have the greatest local relief, as much as 350 ft (Fenneman, 1938, p. 39), within the area of this study.

PREVIOUS WORK

EARLY GEOLOGICAL OBSERVATIONS

J.D. Schöpf (1787), a German physician who accompanied Hessian troops during the Revolutionary War, was one of the first scientists to publish geologic observations of the Atlantic Coastal Plain. He noted the rough parallelism of the Appalachian ranges with the coastline, described the Fall Line, and recognized the Coastal Plain basement as an extension of the harder rocks inland. He inferred that the Coastal Plain sediments, because of their unconsolidated nature, were the youngest formations in the area, and that they were formed in the same way as the offshore banks of New England. The Gulf Stream helped shape the Coastal Plain and probably impinged on it in the past. He believed that all the rocks, including those at the tops of the mountains, had been covered by the ocean, but a problem remained: where did the water go? He concluded that the water drained from the continent because of deepening of the ocean basin, accompanied by subsidence of the coastal and Piedmont areas. Schöpf also studied fossiliferous strata (especially around Yorktown, Va.), which had been described previously by Lincoln (1783).

Maclure (1809, 1817) prepared the first geologic maps of the United States up to the frontier of that period that were based on first-hand observation. He followed the Wernerian classification of rocks and mapped the Coastal Plain formations as "The Alluvial."

John Finch, of the University of Birmingham (England), disagreed with the interpretation of the Coastal Plain as a single alluvial formation. He wrote: "in America, an immense tract of country, extending from Long Island to the sea of Mexico, and from thirty to two hundred miles in width, is called an alluvial formation, by most of the geologists who have written upon the subject, and by some it appears to be considered as an exception to the general arrangement and position of strata, which are found to occur in other countries.***I wish to suggest that what is termed the alluvial formation in the geologic maps of Messrs. Maclure and Cleaveland is identical and contemporaneous with the newer secondary and tertiary formations of France, England, Spain, Germany, Italy, Hungary, Poland, Iceland, Egypt, and Hindoostan.***There are no rivers on the coast which could have deposited such an accumulation of sand and marle, and the hills of limestone" (Finch, 1824, p. 32–33).

The earliest State geologic surveys of the Coastal Plain, including those of New Jersey (Rogers, 1836, 1840), Delaware (Booth, 1841), Maryland (Ducatel, 1835, 1836, 1837a, 1838b), Virginia (Rogers, 1841, 1884), and North Carolina (Olmsted, 1824, 1827; Mitchell, 1827, 1828), were reconnaissance in nature, with an emphasis on locating natural resources such as clay and lime and on relating geology to soil fertility. As an example, Booth was retained for a geological survey of Delaware to be conducted in 1837 and 1838, with the proviso that "an equal portion of the appropriation be expended in each county," which he interpreted to mean spending equal time working in each of Delaware's three counties (Booth, 1841, p. iii, preface). However, he became "convinced that few important geological inquiries would demand my attention in the lower counties, particularly in Sussex," because of a lack of exposures, and therefore he "determined on traversing different parts of those counties, with the view of imparting such knowledge relative to their agriculture as lay within the sphere of my information," and "for the same reason also, many sections of this memoir are devoted exclusively to agricultural essays" (Booth, 1841, p. iii, preface).

Lyell (1845a, b) visited fossil-collection localities on the Coastal Plain from Maryland to Georgia and related the Tertiary strata to the Tertiary section of Europe. He concluded that this area of the North American Coastal Plain, although at a lower latitude than that of Europe, had a similar climate during the Miocene Epoch, on the evidence of fossil mollusks. He also noted that the European mollusk species that survived from the Miocene Epoch are not living along the American coast and vice versa.

Early State geologic maps covering parts of the Coastal Plain include those of New Jersey for 1868 (Cook, 1868); North Carolina for 1875 (Kerr, 1875); Delaware for 1884 (Chester, 1884); Virginia for 1876 (as reported by Rogers (1884, p. iv, plate)); and Maryland for 1897 (Clark, 1897).

Early drilling of artesian wells in the Middle Atlantic States, partly in the Coastal Plain, was reported by Silliman (1827).

DEVELOPMENT OF STRATIGRAPHIC NOMENCLATURE

In the northern Atlantic Coastal Plain, the application of stratigraphic names based on type localities began with Conrad (1865, p. 73) with the naming and description of the Shark River Marl (Eocene) in New Jersey. Outside the area of study, Ruffin (1843, p. 24–27) earlier had named the Upper Cretaceous Peedee Formation (which he called the "Peedee bed") for its exposures along the Pee Dee River (in South Carolina); it was later traced into North Carolina (Stephenson, 1912a, p. 145–170).

Summaries of the stratigraphy of the Coastal Plain by State, with formation and age designations approaching present usage, were published as early as 1906 for Long Island, N.Y. (Veatch and others, 1906); 1905 and 1907 for New Jersey (Weller, 1905, 1907); 1884 for Delaware (Chester, 1884); 1901–1916 for Maryland (Clark and others, 1901, 1904, 1911, 1916; Shattuck and others, 1906); and 1912 for Virginia (Clark and Miller, 1912) and for North Carolina (Clark and others, 1912).

Some of the surficial sediments of the Coastal Plain were named as formations in conjunction with terraces found at similar altitudes, although the sediments generally were not distinguished from each other on the basis of fossils or lithology. Darton (1891) mapped terrace gravels in eastern Virginia and Maryland, which he referred to the Columbia and Appomattox Formations of McGee (1888, art. 31, p. 367–388; art. 27, p. 328–330, respectively). Shattuck (1901) recognized four terraces in the Maryland Coastal Plain and interpreted them to be marine, with each underlain by associated deposits of Pleistocene or late Tertiary age and with the older terrace formations at successively higher altitudes. According to his interpretation, the terraces represented stands of the sea that stood higher in relation to the land during Tertiary time than they did during later geologic time. Others, notably Cooke (1925, 1930, 1931, 1932, 1935, 1936, 1958), accepted and expanded on the "terrace-formation" concept and traced as many as eight terraces around the Coastal Plain as far as northwestern Florida. Antevs (1929) attempted to correlate these terraces with those around the Mediterranean.

The principal terrace formations from the highest altitude (presumed oldest) downward are Brandywine (Clark, 1915), Coharie (Stephenson, 1912b), Sunderland and Wicomico (Shattuck, 1901), Penholoway (Cooke, 1925), Talbot (Shattuck, 1901), Pamlico (Stephenson, as reported by Clark (1910)), and Princess Anne (Wentworth, 1930). Cederstrom (1957) placed these formations in the Columbia Group (Pleistocene), the name being derived from the Columbia Formation of McGee (1886), which was originally applied to surficial sand and gravel around the District of Columbia.

Although the terrace-formation concept of Shattuck (1901) and Cooke (1925, 1930, 1931, 1932, 1935, 1936, 1958) was widely accepted, Wentworth (1930) and Flint (1940) interpreted the higher terraces to be of fluvial rather than marine origin. Campbell (1931), Hack (1955), and Schlee (1957) showed that the Brandywine and Sunderland Formations were not marine. Oaks and Coch (1963, 1973), Oaks (1964), Coch (1965), Oaks and others (1974), and Oaks and DuBar (1974) demonstrated the complexity of coastal physiographic features in southeastern Virginia and of the associated post-Miocene depositional patterns. Oaks and others (1974, p. 86) recommended abandonment of terrace-formation names, at least outside the areas where they were first applied. As of 1987, however, the names Columbia Group and Brandywine, Coharie, Sunderland, Wicomico, Penholoway, Talbot, Pamlico, and Princess Anne Formations were still accepted for use by the U.S. Geological Survey.

DEVELOPMENT OF CONCEPTS OF REGIONAL STRUCTURE AND GEOLOGIC HISTORY

Geophysical investigations, beginning in the late 1930's, provided an increasing volume of data on the layering and nature of the sediments of the Coastal Plain-Continental Shelf wedge, the regional structure, and the depth and inferred lithology of bedrock (Ewing and others, 1937, 1939, 1940, 1950; Miller, 1937; Ewing, 1940). The early geophysical work, largely refraction-seismic and gravity surveys, indicated that the sedimentary layers of the emergent Coastal Plain were a continuation of similar layers underlying the Continental Shelf. Major offshore trends of geophysical anomalies, interpreted as belts of rock of contrasting densities and seismic velocities, were shown to run roughly parallel to Appalachian structural trends (Murray, 1961, p. 21–29).

Brown and others (1972) divided the northern Atlantic Coastal Plain sedimentary section into 17 chronostratigraphic units and mapped thicknesses, lithofacies, and relative intrinsic permeabilities. They also proposed recurrently reversing vertical movement along wrench faults during deposition as a hypothesis to account for variations in thickness and facies of the chronostratigraphic units. Movement along the wrench faults was interpreted as the near-surface expression of the displacement of basement blocks.

Drake and others (1959) interpreted refraction-seismic, magnetic, and gravity surveys on the Continental Shelf and Slope in terms of Kay's (1951) concepts of sedimentary-basin development. The general trend of seaward thickening was interrupted by a buried basement ridge near the Continental Slope. An inner trough underlying the shelf was interpreted as a miogeosyncline (geosyncline located near the craton) separated by the buried volcanic(?) ridge from an outer, deeper trough, a eugeosyncline (geosyncline located away from the craton and in which volcanism is associated with sedimentation) underlying the slope and rise.

Murray (1961, p. 79–166) described the Atlantic and Gulf Coastal province as a geosyncline, separated into two segments by the Ocala arch of Florida and central Georgia. He summarized the results of geophysical exploration up through 1960 on the Coastal Plain and in the western Atlantic Ocean (Murray, p. 21–47).

The development of plate-tectonic theory (Wilson, 1968) provided new insights into the deposition of sediments along continental margins, which were applicable to the Atlantic and Gulf coastal province. Rifting, the first stage of continental breakup, began between North America, Eurasia, and Africa in the Triassic, with wrench and transform faults associated with a thinned continental crust. In North America, the major faults generally ran parallel to old Appalachian lineaments. Sediments accumulated in the rift basins along the faults during Triassic and Early Jurassic time under conditions of great crustal instability, with tilting, folding, igneous intrusion, and widespread volcanism, in addition to faulting. After the opening of the early Atlantic Ocean and the beginning of sea-floor spreading, the environment of deposition was characterized by gentle subsidence of the continental margin and marine incursions (Manspeizer and others, 1978; Manspeizer, 1981). The post-rifting Coastal Plain and Continental Shelf sediments were deposited during this second phase, which persists to the present.

PREVIOUS GEOLOGIC AND GROUND-WATER STUDIES

Largely from the impetus to search for oil, offshore drilling and improved geophysical exploration methods added greatly to the knowledge of the geometry and lithology of the sediments underlying the Continental Shelf and therefore the history of their extensions to the emergent Coastal Plain. Only a few examples from the extensive literature will be mentioned here. Perry and others (1975) correlated the geologic section along the coast from Cape Hatteras, N.C., to Long Island, N.Y., as key to interpreting the Continental Shelf, for which they had new data from bottom samples. Schlee and others (1976) refined the interpretation of the structural-stratigraphic framework of the shelf from Cape Hatteras to New England on the basis of multichannel reflection-seismic data. Scholle (1977, 1980) discussed the Continental Offshore Stratigraphic Test (COST) wells B-1 and B-2, the first two deep test wells drilled offshore from the area of this study, and the information gained from them on the geologic history, stratigraphy, and structure of the Coastal Plain province and continental margin, with emphasis on the Baltimore Canyon Trough. Libby-French (1981, 1984) interpreted Jurassic and Cretaceous environments of deposition from the New Jersey coast offshore on the basis of the COST wells and commercial oil tests in the Baltimore Canyon Trough and correlated the section with that of the Scotian Shelf farther north.

Darton (1896) and Fuller (1905a) published the first comprehensive reports on the ground-water resources of the area of this study. Sanford (1911) presented information on saline waters. LeGrand (1964) described the hydrogeologic framework of the Atlantic Coastal Plain, including the Gulf Plain. He noted that the interlayering of relatively permeable material with less permeable material has characteristically resulted in several distinct aquifers in most of the Coastal Plain and that most ground-water recharge is short-circuited to effluent stream valleys through near-surface aquifers, except in the semiarid part of Texas. Back (1966) related hydrochemical facies to ground-water flow patterns in the area of this study. Cederstrom and others (1971, 1979) and

Sinnott and Cushing (1978) summarized information on the ground-water resources of the Coastal Plain and adjacent areas. Brown and Reid (1976) and Lloyd and others (1985) studied the saltwater-saturated part of the Coastal Plain aquifer system with respect to its potential for storage of wastes.

With respect to general geologic and stratigraphic studies that cover areas of the Coastal Plain that extend beyond one State, Darton (1891) described the Coastal Plain formations of Maryland, Delaware, and Virginia. Clark (1910) correlated formations between Long Island and North Carolina. Carter (1937) described fresh continuous exposures of Upper Cretaceous sediments as they were exposed along the newly dredged Chesapeake and Delaware Canal in Maryland and Delaware. Owens and others (1970) correlated outcropping Upper Cretaceous formations between New Jersey and the northern Delmarva Peninsula. Sohl (1977) described the Upper Cretaceous marine mollusks of New Jersey and Delaware and related them to transgressive and regressive facies. Wolfe and Pakiser (1971) correlated the Magothy Formation in New Jersey with Upper Cretaceous outcrops in Maryland on the basis of palynology and redefined the base of the Magothy in New Jersey.

Hydrogeologic and ground-water resource studies covering more than one State in the Coastal Plain include those by Clark and others (1918) for Maryland, Delaware, and the District of Columbia; Barksdale and others (1958), Hely and others (1961), and Parker and others (1964) for the Delaware River basin; Johnston (1964) and Papadopulos and others (1974) for the area around the District of Columbia; Slaughter (1962) for Maryland and Delaware beach areas; and Cushing and others (1973) for the Delmarva Peninsula.

Selected geologic and hydrogeologic studies that covered parts of the northern Atlantic Coastal Plain are summarized here by State.

New York (Long Island).—Mather (1843) was the first to examine the geology of Long Island in detail in the field; he prepared a geologic map. Upham (1879) mapped the glacial moraines. Dana (1890) presented his interpretation of the origin of Long Island Sound as a river and its relation to Pleistocene glaciation. Hollick (1893, 1894) studied the Cretaceous deposits of Long Island, and Woodworth (1901) studied the glacial deposits of the western part of the island.

De Varona (1896), Crosby (1900), and Freeman (1900) studied the water resources of the western part of Long Island. Veatch (1903) described the glacial geology and named the Pleistocene Jameco Gravel. Fuller (1905c) described the geology of Fisher's Island and named the Pliocene (?) Mannetto Gravel (which he considered Pleistocene) and the Pleistocene Gardiners Clay. Later, he wrote a comprehensive report on the geology of Long Island (Fuller, 1914). In a report that included a geologic map of the State by F.J.H. Merrill that showed Cretaceous outcrops on the northwestern shore of the island, Rafter (1905) recommended that the sand deposits of Long Island be considered great natural underground reservoirs.

Veatch and others (1906, p. 18–19) named the Lloyd Sand and correlated it with the Raritan Formation of New Jersey, and de Laguna (1948) assigned the Lloyd Sand as the lower member of the Raritan. Thompson and others (1937) contributed to a better understanding of the process by which the confined aquifers were recharged and recommended that withdrawals from them be restricted to situations where the unconfined aquifers are inadequate or contaminated. Suter and others (1949) prepared structure-contour maps and geologic sections based largely on correlations of wells and data from previous reports (Veatch and others, 1906; Fuller, 1914). Perlmutter and Crandell (1959) summarized information on the geology and ground water along the south shore of the island and briefly discussed the occurrence of glauconite and Foraminifera in beds of Late Cretaceous age. Perlmutter and Todd (1965) revised the Magothy(?) Formation, using foraminiferal evidence to show that a marine greensand unit locally at the top correlated with the Monmouth Group of New Jersey, underlain by the Matawan Group and Magothy Formation, undifferentiated. Cohen and others (1968) prepared an atlas of Long Island's water resources. McClymonds and Franke (1972) described the hydrogeologic framework of the island in terms of four principal aquifers (the upper glacial, Jameco, Magothy, and Lloyd) and prepared maps, graphs, and tables showing their hydraulic properties.

Sirkin (1974) presented palynologic evidence to show that the upper part of what had been correlated on lithologic grounds as the Raritan Formation should be included in the Magothy Formation instead and (Sirkin, 1986) continued with the correlation of the Long Island and New Jersey sections on the basis of palynology.

Williams (1976) described the results of shallow-penetration seismic exploration and coring on the inner Continental Shelf within about 20 mi of the south shore of Long Island and around its eastern end. The report shows numerous buried channels filled with Pleistocene sediment. Hutchinson and Grow (1982) described the configuration of the sedimentary bedding and of a fault in the New York Bight, as disclosed by seismic exploration.

Getzen (1977) designed a five-level electric analog flow model of the aquifer system of Long Island. The lowermost aquifer (Lloyd) was excluded from the simulation because of its assumed hydraulic isolation and the lack of knowledge of its hydraulic properties. Reilly and

Harbaugh (1980) constructed a digital model simulating the same hydraulic data as the analog model.

Reports resulting from water-resources studies on Long Island by the U.S. Geological Survey, mostly in cooperation with State and local agencies, were listed by Bachmann and Pitt (1984).

New Jersey.—The present geologic map of New Jersey was prepared in its original form by Lewis and Kümmel in 1912 and revised by Kümmel in 1931 and by Johnson (1950) in 1950.

Johnson and Richards (1952) described the stratigraphy of the New Jersey Coastal Plain. Richards and others (1962) prepared generalized structural contour maps. Stratigraphic studies of the sedimentary section up through the Magothy Formation include those of Berry (1906, 1910, 1911), Weller (1907), Owens and Sohl (1969), and Christopher (1977, 1979). Petters (1976) studied the Upper Cretaceous subsurface stratigraphy of the New Jersey Coastal Plain.

Cooke and Stephenson (1928) and Minard and others (1969) placed the Cretaceous-Tertiary boundary at an unconformity at the base of the Hornerstown Formation in New Jersey. Enright (1969) described the stratigraphy of the Eocene formations. Adams (1963) studied the petrology of the lower Tertiary formations.

Olsson (1980, p. 125) and in the American Association of Petroleum Geologists, Coastal Plain Province Committee (1983), proposed a late Oligocene age, based on Foraminifera, for the Piney Point Formation, which was regarded by others as Eocene.

For the upper Tertiary section, Isphording (1970) redefined the Kirkwood Formation and Carter (1978) studied the environment of deposition of the Cohansey Sand.

Knapp (1905) summarized information on the ground-water resources of New Jersey. Thompson (1928, 1930, 1932) named and traced some of the Coastal Plain aquifers. Barksdale and others (1943), Farlekas (1979), and Luzier (1980) conducted hydrogeologic studies of New Jersey Coastal Plain aquifers that contain sediments of the Potomac Group and the Raritan and Magothy Formations. Nemickas (1976) and Nichols (1977a, b) described the hydrogeology of the Wenonah-Mount Laurel and Englishtown aquifers, respectively, in connection with digital-flow models. Nemickas and Carswell (1976) extended correlation of the Piney Point aquifer from the Delmarva Peninsula to New Jersey. Rhodehamel (1970, 1973) emphasized the Kirkwood Formation and Cohansey Sand in a study of the geology and ground-water resources of an area in the southern part of the New Jersey Coastal Plain. Gill and Farlekas (1976) prepared structure-contour maps of the Potomac-Raritan-Magothy aquifer system.

Delaware.—Matson (1913) described the clays of Delaware. Groot (1955) described the petrology of the Upper Cretaceous section of northern Delaware. Jordan (1962, 1964, 1968, 1974) and Jordan and Talley (1976) described the stratigraphy and lithology of the Delaware Coastal Plain formations. Jordan and Adams (1962) identified a bentonite marker bed near the Tertiary-Cretaceous boundary. Spoljaric (1967a, b, 1972a, b, 1973) analyzed lithofacies of the Potomac Formation and described Pleistocene channels, the Fall Zone, Late Cretaceous marine transgression, and basement faults, respectively. Spoljaric and Jordan published the State geologic map in 1966, which was revised by Pickett (1976). Spoljaric and others (1976) interpreted the tectonic evolution of Delaware from LANDSAT–1 imagery. Woodruff (1976) discussed geophysical borehole logging in Delaware.

Kraft and Maisano (1968) published a geologic cross section of Delaware. Pickett (1969) discussed the geology of part of the coastal area. Weil (1971) studied the sediments, structure, and evolution of Delaware Bay. Sheridan and others (1974) inferred a rate of coastline retreat of 0.6 ft/yr from about 7,500 yr ago to present from evidence on the position of the barrier complex in the early Holocene Epoch on the Atlantic inner shelf off Delaware.

Darton (1895) discussed the prospects for artesian wells and (Darton, 1905) presented data on the deep wells in Delaware. Clark and others (1918) included Delaware in a report on water resources centered in Maryland. Marine and Rasmussen (1955) published a comprehensive report on the geology and ground-water resources of the State, including a geologic map, structure maps, and maps of aquifers. Rasmussen and others (1957) discussed the water resources of northern Delaware. Woodruff (1969, 1970) described saline ground water and ground-water quality. Johnston (1973) described the hydrology of the surficial aquifer (Columbia of local use) and (Johnston, 1977) the simulation of flow in the aquifer. Johnston and Leahy (1977) combined model results and base-flow data to study recharge and leakage areas of artesian aquifers. Other model-based studies of aquifers include those by Leahy (1976, 1979, 1982), Hodges (1984), and Martin (1984).

Maryland.—Publications on the general geology and stratigraphy of Maryland include the State geologic map by Cleaves and others (1968) and the description of the geology of the State by Overbeck (1950) and Edwards (1974) and of southern Maryland by Glaser (1968).

Many authors contributed to knowledge of the Maryland stratigraphic section. Clark and Bibbins (1897), Brenner (1963), and Hansen (1969a, b) discussed the Potomac Group and its correlation. Clark and others (1911, 1916) wrote treatises on the Lower and Upper Cretaceous sediments, respectively. Hansen (1968) demonstrated geophysical-log correlation of the Cretaceous and described (Hansen, 1978) the pinchout of the Upper Cretaceous and Paleocene sediments in southern Maryland. Minard and others (1977) reintroduced the Severn Formation in Maryland to replace the Monmouth Formation. Clark and others (1901) and Shifflett (1948) described the Eocene section. Harris (1893), Clark and others (1904), Dryden (1936), Gernant (1970), Stefansson and Owens (1970), and Gernant and others (1971) discussed the Miocene sediments, and Shattuck and others (1906), Hansen (1966, 1981), and Weigle (1972) discussed the Pliocene and Pleistocene sections.

Petrologic studies included those of Glaser (1969) on the Potomac Group and Magothy Formation and Schluger and Roberson (1975) on the Patapsco Formation. Knechtel and others (1961) studied the physical properties of nonmarine Cretaceous clays. Chapelle and Knobel (1983) studied glauconite in relation to aqueous geochemistry in the Paleocene Aquia Formation.

Miscellaneous geologic studies of the Maryland Coastal Plain include those by Darton (1939) on sand-and-gravel deposits, Jacobeen (1972) on geophysical evidence for high-angle reverse faulting, and Edwards and Hansen (1979) on the structural significance of the upper Chesapeake Bay magnetic anomaly.

Darton and Fuller (1905a, b) presented data on artesian wells in the District of Columbia and Maryland, respectively. Miller and others (1982) summarized information on Maryland's ground water. The Maryland State Planning Department and Maryland Geological Survey (1969) and Hansen (1971a, b, 1972a, b) described the Maryland Coastal Plain aquifers. Otton (1955), Barnes and Back (1964), Weigle and others (1970), Mack and Mandle (1977), and Chapelle and Drummond (1983) described aspects of the water resources of southern Maryland. Bachman (1984) studied the surficial aquifer (Columbia of local use) on the Delmarva Peninsula.

Virginia.—The current State geologic map was prepared by Calver and others (1963). Teifke (1973) summarized knowledge of the general geology of the Coastal Plain in Virginia, particularly in stratigraphy, prior to more intensive work in paleontology. Other publications on the geology of the Coastal Plain of Virginia that have not been cited previously include Cederstrom's (1945b) work on the structural geology of southeastern Virginia and Sabet's (1973) geophysical exploration of the southern Delmarva Peninsula. McConnell (1980) reviewed the stratigraphic and structural framework of the Virginia Coastal Plain.

Darton and Fuller (1905c) presented data on deep wells in Virginia. Sanford (1913), and, more recently, Larson (1981) described the occurrence of saline water. Hydrogeologic and ground-water resource studies covering substantial parts of the Virginia Coastal Plain include those of Cederstrom (1941, 1943a, b, 1945a, 1946a, b), Sinnott and Tibbitts (1954, 1957), DeBuchananne (1968), Sinnott (1969), and Rogers and Spencer (1971). Cosner (1975) studied ground-water flow in the Lower Cretaceous section in an area of major withdrawals in southern Virginia by means of digital simulation.

The Virginia State Water Control Board published reports (1970, 1973, 1974, 1975, 1977) on areas of the Coastal Plain; other reports were published under the names of its staff (Siudyla and others, 1977; Newton and Siudyla, 1979; Fennema and Newton, 1982). Bal (1977, 1978) simulated ground-water flow on the Virginia Delmarva and York-James-Middle Peninsulas. Geraghty and Miller, Inc., (1979) prepared a report for the board on the availability of ground water in southeastern Virginia.

North Carolina.—In addition to references previously cited, early stratigraphic and geologic studies of the North Carolina Coastal Plain include the State Geological Survey reports of Emmons (1852) and Kerr (1875) and a report on the Tertiary section by Dall (1892).

Clark and others (1912) published the first comprehensive study of the general geology of the Coastal Plain and included a geologic map. Prouty (1936) summarized the geology and stated that magnetometer surveys substantiated interpretations of basement warping and increased gradient toward the coast. Richards (1950) described the geology, geologic history, and mineral resources of the North Carolina Coastal Plain and tabulated fossils and control points for basement elevations. Bonini and Woollard (1960) mapped basement structure and lithology from refraction-seismic data. Mixon and Pilkey (1976) studied the geology of the submerged and emerged Cape Lookout area.

Among the reports dealing with the stratigraphy of the North Carolina Coastal Plain, Stephenson and Rathbun (1923) described the Cretaceous section, with emphasis on the invertebrate fauna. Heron and Wheeler (1964) and Swift and Heron (1967, 1969) concentrated on environments of deposition of the Cretaceous Cape Fear, Middendorf, and Peedee Formations. Christopher and others (1979) identified Late Cretaceous palynomorphs, with affinity to the Magothy fauna, from the Cape Fear Formation. Sohl and Christopher (1983) presented evidence for a disconformity between the Black Creek and Peedee Formations. They correlated the Black Creek with the Wenonah and Marshalltown Formations and the Peedee with the Mount Laurel Sand of New Jersey (Sohl and Christopher, 1983, fig. 12). Fallaw and Wheeler (1963) and Wheeler and Curran (1974) described examples of the Cretaceous-Tertiary boundary in outcrops.

Miller (1910) described erosion intervals in the Tertiary section of North Carolina and Virginia and asserted that each Tertiary formation in North Carolina was bounded by unconformities. He found that denudation seemed to have occurred south of a "Hatteras axis" (approximately along the Neuse River) at the same time that deposition was taking place north of the axis and vice versa. Ward (1980) discussed the stratigraphy of the Eocene, Oligocene, and lower Miocene formations of the Carolinas.

Cheetham (1961) and Baum and others (1979) discussed the Eocene section, namely, the Castle Hayne Limestone. Kimrey (1964, 1965) described and named the Miocene Pungo River Formation; Gibson (1967), Miller (1982), and Scarborough and others (1982) further described its stratigraphy and petrology. Snyder and others (1982) studied Miocene seismic stratigraphy and sea-level cyclicity.

Blackwelder and Ward (1979) revised the correlation and nomenclature of the Pliocene formations, and Fallaw and Wheeler (1969) redefined the marine Pleistocene section.

Structural geology in the North Carolina Coastal Plain was studied by MacCarthy (1936), Ferenczi (1959), and Brown and others (1977). Thayer and Textoris (1972) discussed the petrology of the carbonate aquifers.

The State geologic map by Brown and Parker (1985) supersedes the one by Stuckey (1958).

Fuller (1905b) and MacCarthy (1907) presented data on deep wells in North Carolina. Stephenson and others (1912) discussed the water resources of the Coastal Plain. Heath and others (1975) described the water resources of the State and showed the freshwater-saturated thickness of the Coastal Plain sediments, water levels, and dissolved-solids concentration maps. Billingsley and others (1957), Fish and others (1957), and Floyd and Peace (1974) reported on the water resources of the Neuse, Yadkin-Pee Dee, and upper Cape Fear River basins, respectively. Heath (1975) described the hydrology of the area around Albemarle and Pamlico Sounds. Wilder and others (1978) described the water resources of northeastern North Carolina. DeWiest and others (1967) studied the effects of phosphate mining on the water resources of the Coastal Plain. Peek and Nelson (1967) described the impact of heavy withdrawals on water levels and possible saltwater intrusion, and Peek and Register (1975) reported high artesian heads in southeastern North Carolina and presented a hypothesis to explain them.

GEOLOGY

STRUCTURAL SETTING

The northern Atlantic Coastal Plain consists of a seaward-thickening wedge of Mesozoic and Cenozoic sediments overlying the basement (pl. 2*A*,*B*) composed of igneous and metamorphic Precambrian and Paleozoic and rift-basin Triassic and Jurassic rocks (Gleason, 1982a, fig. 1; Hansen and Edwards, 1986). Two regional southeast-trending structural features are apparent on plate 2*A* and *B*: (1) a thickening, or basement depression, in the center of the area (Salisbury Embayment) and (2) a thinning, or basement arch, in the southern part (Cape Fear arch). The thickness of more than 10,000 ft at Cape Hatteras, N.C., the maximum shown on plate 2*A*, is the result of the Cape projecting farther into the Continental Shelf environment (closest to the Continental Slope) than any point on the emergent Coastal Plain within the study. The section penetrated by well 381 on the Cape (pl. 1*A*; appendix) is equivalent to offshore sections elsewhere (Sheridan, 1974, p. 398).

The basement surface dips seaward, with the dip increasing in a seaward direction. The increase is abrupt in places, such as in North Carolina. Prouty (1946) ran a magnetometer traverse from the Piedmont to Cape Lookout and attributed the indicated change in basement dip to the intersection of buried peneplains (the gently sloping Schooley Peneplain to the northwest, and the steeply sloping Fall Zone Peneplain to the southeast). G.W. Berry (1948) noted a change in basement slope from 14 to 122 ft/mi in the same area and explained the change as the intersection of peneplains. E. Willard Berry (1951) offered three possible explanations: (1) monoclinal folding, (2) faulting, or (3) intersection of peneplains.

The seaward dip of the basement surface is primarily the result of subsidence. In the Baltimore Canyon Trough (fig. 1), which lies off the Atlantic Coast between New Jersey and Virginia, depths to basement (estimated from magnetic and seismic surveys) exceed 7.5 mi (Klitgord and Behrendt, 1979, figs. 1, 12*C*). Exploratory wells, such as the COST B-2 (well 121, in the appendix and on pls. 1*A*, 4*B*), penetrated a Quaternary to Jurassic sedimentary section more than 16,000 ft thick (Adinolfi and Jacobson, 1979, p. 34, pl. 2).

The sedimentary section of the Baltimore Canyon Trough consists largely of unconsolidated sand and clay down through the Miocene sediments, underlain by sandstone and shale with subordinate amounts of carbonate, evaporite, coal, and lignite (Bayer and Mattick, 1980, fig. 3), deposited in subaerial to shallow marine (outer shelf) environments. The shallow (as compared to present depth to basement) water depths of up to about 1,600 ft during deposition (according to Watts, 1981, p. 2–2, 2–4) "suggest that sedimentary loading is not the only cause of subsidence of the U.S. margin *** and that other factors must be involved," such as stretching and thinning of the underlying crust associated with heating and continental rifting. The progressive onlap of sediments may be explained by inland migration of a thermal bulge and flexural depression and by increasing flexural rigidity of the basement (Watts, 1981, 2–47 to 2–56).

A series of arches and embayments extends along the northern Atlantic Coastal Plain, with axes approximately perpendicular to the coast. From north to south, the principal features are the Raritan Embayment, South New Jersey High, Salisbury Embayment, Norfolk High, Albemarle Embayment, and Cape Fear arch (fig. 1). The arches and embayments reflect warping of the basement (Perry and others, 1975, p. 1533–1534, fig. 5). The embayments can be considered salients of the Baltimore Canyon Trough. Although the axes of the embayments coincide with the greatest present thickness of sediments, basin centers of deposition have shifted over time, as was recognized by Brown and others (1972, p. 7–10) and Owens (1983, p. 35–36).

The basement surface is not smooth, and its strike and dip are not regular. The apparent smoothness of the surface as contoured in plate *2B* is the result of sparse control. The irregularities of the contours in part of New Jersey, Delaware, and Maryland are based on unpublished seismic mapping as adapted by Gill and Farlekas (1976, sheet 1) and Cushing and others (1973, fig. 2). Faults have been mapped on the surface of the emergent Coastal Plain (Jacobeen, 1972; Spoljaric, 1973; York and Oliver, 1976; Mixon and Newell, 1977, 1978), but their displacement of the basement generally is not known. Brown and others (1977) presented evidence for a northeast-trending wrench-fault zone in the North Carolina Coastal Plain. Harris and others (1979) portrayed this zone as extending across the northern half of the North Carolina Coastal Plain, and also showed a parallel fault and two southeast-trending faults in the southern half of the North Carolina Coastal Plain. Hansen (1978, figs. 5, 7, 15–16, 19–20) mapped basement faults intersected by seismic lines in the area of the Salisbury Embayment. He hypothesized that the faults originated in a Triassic rift system and that sporadic movement along the faults influenced deposition and erosion of Coastal Plain sediments throughout Cretaceous and early Tertiary time.

DEPOSITIONAL HISTORY

Deposition of the Coastal Plain section began with the opening of the Atlantic Ocean in Jurassic time. Although the processes of both onlap and offlap contributed to the building of the Coastal Plain sedimentary wedge, its early history was dominated by onlap, interpreted as the result of subsidence relative to sea level.

Figure 3 shows the names and generalized stratigraphic positions of the Coastal Plain formations referred to in this report.

Jurassic.—A thick section of predominantly marine Jurassic sediments has been mapped offshore in connection with exploration for oil. The COST B-2 well (well 121, in the appendix and on plate 1*A*) bottomed in the Jurassic (Poag, 1980, p. 35, figs. 28, 29). Over most of the emergent Coastal Plain, rocks positively identified as Jurassic are absent.

Brown and others (1972, p. 37–39, pls. 6–7, 40) assigned the lowermost sedimentary section in part of the emergent Coastal Plain to "rocks of Jurassic(?) age, rocks of Unit I" and "rocks of Cretaceous and Late Jurassic(?) age, rocks of Unit H." They (Brown and others, 1972, pl. 6) showed the rocks of Unit I to be confined onshore to two coastal areas: one around Cape Hatteras, N.C., and the other from Maryland to the southern tip of New Jersey. Unit I includes unfossiliferous feldspathic sand and red, green, and brown shale and is continental in origin. The rocks of Unit H were depicted as more extensive than the rocks of Unit I (Brown and others, 1972, pl. 7), and include predominantly marine dolomite, limestone, sand, shale, and anhydrite in North Carolina and nonmarine clastics in Virginia and northward. However, palynologic studies by Doyle and Robbins (1977) and Doyle (1982) indicated an Early Cretaceous age for the Unit H section in wells on the Delmarva Peninsula, which suggests that the nonmarine clastic rocks mapped as Unit H elsewhere in the Coastal Plain may also be Cretaceous rather than Jurassic. Owens (1983, fig. 7) showed no upper Lower Jurassic (post-rifting) to Upper Jurassic rocks extending onshore north of Florida.

The small extent or absence of post-rifting Jurassic rocks in the emergent Coastal Plain sedimentary wedge indicates that either the Jurassic shoreline was mostly on the present Continental Shelf, while most of the area of the present emergent Coastal Plain was undergoing erosion, or that Jurassic sediments on the Coastal Plain have largely been removed by erosion.

Cretaceous.—In addition to "rocks of Unit H" in North Carolina, described by Brown and others (1972), the oldest Cretaceous rocks on the emergent Coastal Plain are predominantly sand, gravel, and clay or their lithified equivalents (the Potomac Group in Maryland, the District of Columbia, and New Jersey and the Potomac Formation in Virginia and Delaware). The lowermost part of the Cretaceous section in southeastern Maryland and adjoining Virginia, named the Waste Gate Formation of the Potomac Group by Hansen (1982), has been dated as old as mid-Berriasian and hence is much older than the Potomac Group updip at its Baremian-Aptian outcrop (Doyle, 1982, p. 51; see American Association of Petroleum Geologists, Atlantic Coastal Plain Province Committee (1983) for column showing European stage names). The Waste Gate Formation includes the oldest-known sediments of the emergent Coastal Plain except possibly for Jurassic rocks and also some of the Lower Cretaceous section of the Cape Hatteras region of North Carolina. Younger sediments of the Potomac Group successively overlap the Waste Gate and extend farther to the west, which indicates subsidence of the Coastal Plain relative to sea level during deposition.

Lower Cretaceous sediments do not crop out in North Carolina, but unnamed subsurface sediments similar in lithology to the Potomac Formation (or Group where differentiated) appear to be continuous with the Potomac of Virginia. They do not extend as far south as the South Carolina line, however. The Potomac is absent in the northwestern part of the New Jersey Coastal Plain and on Long Island.

The environment of deposition of the Coastal Plain sediments during Early Cretaceous time was characterized by a subsiding surface on which rivers deposited clastic material derived from the erosion of an adjoining upland. The coastline was well out on the present Continental Shelf off New Jersey but was west of the present Cape Hatteras. The southern part of the North Carolina Coastal Plain was either too high to be covered by fluviodeltaic sediments or uplifted and the sediments removed before the plain was buried by Upper Cretaceous sediments. The same applies to Long Island and the northwestern part of the New Jersey Coastal Plain. The greatest thickness of Lower Cretaceous sediments is in the Salisbury Embayment (fig. 1), the axis of which passes through the Delmarva Peninsula. Deposition was predominantly fluviodeltaic in the embayment. However, evidence for minor marine incursions includes the presence of glauconite (Anderson, 1948, p. 14–15, 400, 406, 415, 422, 424–425, 435) and brackish-to-marine dinoflagellates (Doyle and Robbins, 1977, p. 71–73) in Lower Cretaceous sections penetrated by wells on the Delmarva Peninsula, and glauconite in the Potomac Formation penetrated by a test well (well 237, in the appendix and on pl. 1*A*) in the northwestern Virginia Coastal Plain (Reinhardt and others, 1980, p. 44, 46).

Fluviodeltaic deposition continued into early Late Cretaceous time with the upper part of the Potomac Group in Maryland and the Potomac Formation of Delaware and Virginia. Most recent interpretations show the Upper Cretaceous to be missing in Virginia west of Chesapeake Bay (Owens and others, 1977, fig. 8); however, Sirkin identified Upper Cretaceous pollen (zones III and IV) in core samples (one of marine sand) from three wells in southern Virginia west of the bay: well 271 (in appendix and on plate 1) and two wells southwest of Norfolk (L.A. Sirkin, Adelphi University, written commun., 1982; A.A. Meng, U.S. Geological Survey, written commun., 1985).

Deposition under fluviodeltaic conditions continued in early Late Cretaceous time in New Jersey, Maryland, and Long Island with the Raritan Formation (Suter and others, 1949, p. 33–36; American Association of Petroleum Geologists, Atlantic Coastal Plain Province Committee, 1983). In the northeastern part of the New Jersey Coastal Plain, the Raritan Formation includes beds of marine origin (Sohl, 1977, p. 76–78) as do parts of the Potomac section on the Delmarva Peninsula, which suggests deposition in marginal deltaic and estuarine environments (Jordan, 1983, p. 29).

The ocean encroached over much of the North Carolina Coastal Plain in the early part of Late Cretaceous time, with deposition of the lagoonal, estuarine, and nearshore marine Cape Fear Formation. It is characterized by continuous, uniform beds of sand and sandy mud. Fossils are scarce (Swift and Heron, 1969, p. 208, 210–213). The Cape Fear Formation has been ascribed to both Lower Cretaceous (Stephenson, 1907) and Upper Cretaceous (Cooke, 1926), partly on the basis of stratigraphic position and similarity to formations in adjoining areas. Biostratigraphic work by Christopher and others (1979, p. 145) indicates a Late Cretaceous age (middle Turonian to late Santonian) for the Cape Fear, at least in its outcrop. Hazel and others (1977, p. 71, 73, fig. 3) dated the subsurface Cape Fear downdip in South Carolina as Cenomanian, older than Turonian but still Late Cretaceous.

A shift in environment from predominantly continental to marine began from Long Island to southern Maryland with deposition of the Magothy Formation (Perlmutter and Todd, 1965, p. I2-I3, table 2; Owens and Sohl, 1969, p. 239–258, fig. 16; Glaser, 1969, p. 73; Doyle and Robbins, 1977, p. 45). Christopher (1977, p. 65, fig. 70) assigned a middle Turonian to late Santonian age to the Magothy in New Jersey; other assignments of its age extend from Turonian-Coniacian (Groot and others, 1961) to Santonian-early Campanian (Doyle, 1969). The Magothy includes sand, gravel, silt, clay, plant remains, and lignite fragments. In Maryland, the Magothy changes facies from coarse clastics along its southwestern outcrop to interbedded lignitic silt and clay and moderately sorted sand in the east and northeast. Glaser (1969, p. 73, 76–77) interpreted its facies distribution to represent fluvial deposition to the southwest and estuarine deposition to the north and northeast. Perlmutter and Todd (1965, p. I3) suggested deltaic and lagoonal-estuarine environments for the Magothy Formation and Matawan Group, undifferentiated, on Long Island.

The Magothy is overlain by predominantly marine sediments of the Matawan and Monmouth Groups and their equivalents from Maryland to Long Island. According to Owens and others (1977, p. 27), this part of the section is strongly cyclical, characterized by repetition of

ERATHEM	SYSTEM	SERIES	NORTH CAROLINA	VIRGINIA	MARYLAND
Cenozoic	Quaternary	Holocene	Alluvial, Marine, Estuarine, Lagoonal, Marsh, Dune, and Offshore-bar Deposits		
		Pleistocene	Undifferentiated deposits	Undifferentiated deposits	Undifferentiated deposits; Sinepuxent Formation; Ironshire Formation; Parsonsburg Sand; Kent Island Formation; Omar Formation
	Tertiary	Pliocene	Upper Pliocene, undifferentiated, Yorktown Formation	Chesapeake Group: Upper Pliocene, undifferentiated, Yorktown Formation	Walston Silt; Beaverdam Sand
		Miocene	Eastover Formation; Pungo River Formation; Belgrade Formation	Chesapeake Group: Eastover Formation; St. Marys Formation; Choptank Formation; Calvert Formation	Chesapeake Group: Eastover Formation; Pensauken Formation; Brandywine Formation; St. Marys Formation; Choptank Formation; Calvert Formation
		Oligocene	River Bend Formation	Chesapeake Group: Old Church Formation	Chesapeake Group: Old Church Formation
		Eocene	Castle Hayne Limestone	Chickahominy Formation; Piney Point Formation; Nanjemoy Formation	Piney Point Formation; Nanjemoy Formation
		Paleocene	Beaufort Formation	Marlboro Clay; Aquia Formation; Brightseat Formation	Marlboro Clay; Aquia Formation; Brightseat Formation
Mesozoic	Cretaceous	Upper Cretaceous	Peedee Formation; Black Creek Formation; Middendorf Formation; Cape Fear Formation		Severn Formation; Matawan Formation; Magothy Formation
		Lower Cretaceous	Unnamed	Potomac Formation; Waste Gate Formation of Hansen (1982)	Potomac Group: Patapsco Formation; Arundel Formation; Patuxent Formation; Waste Gate Formation of Hansen (1982)
	Jurassic	Upper Jurassic	Unnamed		

FIGURE 3.—Generalized stratigraphic correlations of the northern Atlantic Coastal Plain.

sequences of (1) a glauconitic unit overlain by (2) silt and capped by (3) sand, which resulted from deposition during alternating transgressions and regressions of the sea. The sands that compose aquifers were deposited mostly during the regressions.

Deposits equivalent to the Magothy, Matawan, and Monmouth are absent over most of the Virginia Coastal Plain. In North Carolina, approximate time equivalents of the Matawan and Monmouth Groups include, in ascending order, the fluvial Middendorf Formation in the southwestern part of the Coastal Plain, the estuarine Black Creek Formation, and the marine Peedee Formation. Swift and Heron (1969) considered the Black Creek-Peedee contact to be a "ravinement" (a minor discon-

ERATHEM	SYSTEM	SERIES	DELAWARE	NEW JERSEY	NEW YORK
Cenozoic	Quaternary	**Holocene**	Alluvial, Marine, Estuarine, Lagoonal, Marsh, Dune, and Offshore-bar Deposits		
		Pleistocene	Sinepuxent Formation Ironshire Formation Omar Formation Parsons-burg Sand Kent Island Formation	Cape May Formation, undifferentiated deposits	Upper Pleistocene deposits Gardiners Clay Jameco Gravel
	Tertiary	**Pliocene**	Walston Silt Beaverdam Sand		Mannetto Gravel (Pliocene ?)
		Miocene	Chesapeake Group: Pensauken Formation Chesapeake Group, undivided	Pensauken Formation Bridgeton Formation Beacon Hill Gravel Cohansey Sand Kirkwood Formation	Coastal Plain deposits missing
		Oligocene	Chesapeake Group: Old Church (?) Formation	Old Church (?) Formation	
		Eocene	Piney Point Formation Nanjemoy Formation	Piney Point Formation Shark River Formation Rancocas Group: Manasquan Formation	
		Paleocene	Rancocas Group: Vincentown Formation Hornerstown Sand	Rancocas Group: Vincentown Formation Hornerstown Sand	
Mesozoic	**Cretaceous**	**Upper Cretaceous**	Severn Formation Mount Laurel Sand	Monmouth Group: Tinton Sand Red Bank Sand Navesink Formation Mount Laurel Sand	Monmouth Group
			Marshalltown Formation Englishtown Formation Woodbury Clay Merchantville Formation	Matawan Group: Wenonah Formation Marshalltown Formation Englishtown Formation Woodbury Clay Merchantville Formation	Matawan Group
			Magothy Formation	Magothy Formation	Magothy Formation
				Raritan Formation	Raritan Formation: Clay Member Lloyd Sand Member
		Lower Cretaceous	Potomac Formation	Potomac Group	Basement
	Jurassic	**Upper Jurassic**	Basement	Basement	Basement

FIGURE 3.—Continued.

formity caused by a sea advancing over shore and lagoonal deposits), but Sohl and Christopher (1983) presented field and paleontological evidence for a more substantial break at the contact.

Tertiary.—Cyclical deposition continued through most of the Tertiary as it did in Late Cretaceous time in New Jersey, Maryland, and Delaware (Owens and Sohl, 1969, p. 257–259). Glauconite is distributed throughout the section but is associated especially with marine transgressive deposits. The oldest Tertiary deposits on the middle Atlantic Coast include the Hornerstown Sand in New Jersey, Delaware, and northeastern Maryland and the Brightseat Formation of southern Maryland and northeastern Virginia, which unconformably overlies Cretaceous formations (Ward, 1985, p. 6).

Whether the contact between the Cretaceous and Tertiary is conformable in New Jersey, Delaware, and northeastern Maryland has been a matter of controversy. Loeblich and Tappan (1957) reviewed the literature and stated that planktonic Foraminifera show a sharp break at the boundary, exemplified by the fauna of the Paleocene Hornerstown in New Jersey and of the Brightseat of Maryland. Olsson (1963, 1975) proposed a single cycle of deposition of glauconitic sediments through latest Cretaceous and earliest Tertiary time, interrupted locally by influxes of sand, but with no major unconformity in the New Jersey Coastal Plain. Minard and others (1969) interpreted an unconformity at the base of the Hornerstown, on the basis of successive overlap of older formations. Richards and Gallagher (1974) found Cretaceous vertebrate fossils in what they identified as the lower part of the Hornerstown. If their interpretation is correct and the fossils were not reworked, the Hornerstown would cross the system boundary, with no major break. J.P. Owens and N.F. Sohl (U.S. Geological Survey, oral commun., Oct. 10, 1985) regarded the fossils as reworked. This report assumes a Cretaceous-Tertiary unconformity (pl. 3). However, the correlation chart of the American Association of Petroleum Geologists, Atlantic Coastal Plain Province Committee (1983), shows the Cretaceous-Paleocene boundary passing through the Hornerstown with no unconformity in New Jersey and northern Delaware.

In North Carolina, the Paleocene Beaufort Formation is the lowermost representative of the Tertiary section, unconformably overlying the Upper Cretaceous Peedee Formation. It consists of glauconitic and argillaceous sands, shells, and impure limestone and has been dated as early Paleocene (Midway) (Brown, 1959, p. 25, table 1). Harris and Baum (1977) interpreted the upper part of the Beaufort to be of late Paleocene age.

From New Jersey to Virginia, Eocene through Miocene time was characterized by the continued cyclic deposition of clastic deposits, with glauconite particularly abundant in the Eocene. In North Carolina, the Eocene Castle Hayne Limestone and Oligocene River Bend Formation are predominantly limestone. Until recent years, the Oligocene had not been recognized in the emergent Coastal Plain north of North Carolina. However, Olsson and Miller (1979) identified Oligocene Foraminifera in core samples from wells in the New Jersey Coastal Plain. Olsson (1980, p. 125) referred the sediments containing the Foraminifera to the Piney Point Formation, which generally has been regarded as Eocene, and stated that it was deposited in a late Oligocene transgressive sea upon an eroded and beveled Eocene surface. J.P. Owens (U.S. Geological Survey, oral commun., Feb. 19, 1985) reported that cores from a test well in southeastern New Jersey included rocks of both early and late Oligocene ages. Ward and others (1978, p. F13) noted "unnamed Chickasawayan [Oligocene] sediments along the Pamunkey and Chickahominy Rivers in Virginia," and Ward (1984, p. 52–53; 1985) named and described the upper Oligocene and lower Miocene Old Church Formation in the same area. The extent and correlation of Oligocene deposits are not yet well known north of Virginia.

Early and middle Miocene marine deposition was widespread in both the Salisbury and Albemarle Embayments; the Salisbury Embayment section is characterized by clastic deposits and diatomaceous clay, whereas the Albemarle Embayment section includes phosphatic and carbonate rocks as well as diatomaceous clay. The upper Miocene consists of clastic deposits in both basins. Miocene deposition was episodic, particularly in the Albemarle Embayment. Deposition began under open-marine conditions in the Salisbury Embayment, but delta building associated with uplift to the northwest restricted oceanic circulation later in the epoch. In the Albemarle Embayment under deeper marine (to mid-shelf) conditions, sedimentation proceeded at a slower rate (Gibson, 1982).

According to Owens and Denny (1979) and Owens and Minard (1979), high-level gravels of the Bridgeton Formation and Beacon Hill Gravel of New Jersey, the Pensauken Formation of New Jersey and the Delmarva Peninsula, and the Brandywine Formation of Maryland are Miocene rather than Pleistocene, as they are regarded by many authors (Shattuck, 1901; Bascom and Miller, 1920; Jordan, 1964; Spoljaric, 1967b; Hansen, 1981). Owens and Denny (1979, p. A12, A26–A27) reported that the Pensauken interfingers with the "Yorktown and Cohansey(?)" of Rasmussen and Slaughter (1955). The "Yorktown and Cohansey (?)" was later included in the Eastover Formation of Ward and Blackwelder (1980) by Gibson (1982, p. 18, fig. 14).

A transgressive, marginal- to open-marine environment prevailed throughout most of early Pliocene time, with deposition of the Yorktown Formation (Ward and Blackwelder, 1980, p. D32), in the upper part of the predominantly Miocene Chesapeake Group. Around its type locality, the Yorktown consists of a "basal, pebbly coarse-grained sand unit, a very fine-grained sandy clay unit, and an upper sandy shell hash" (Ward and Blackwelder, 1980, p. D29). The center of deposition in the Salisbury Embayment shifted southward into Virginia in the late Miocene and remained there during much of the Pliocene. A late Pliocene marine transgression covered the southeasternmost part of the Salisbury Embayment, the eastern part of the Albemarle Embayment, and the

Cape Fear arch, with deposition continuing into early Pleistocene (Gibson, 1983). Blackwelder (1981, p. B12–B13) ascribed the unconformity within the Pliocene between the Yorktown and the overlying upper Pliocene formations in this area to a time of global cooling and ice formation that resulted in a lowering of sea level, followed by melting and marine transgression. The unconformity at the Pliocene-Pleistocene boundary was attributed to the regression of the sea associated with a cooling trend at the beginning of the Pleistocene.

Marine deposits on the central Delmarva Peninsula, including sand with gravelly beds (Beaverdam Sand) and overlying silt, clay, and sand (Walston Silt), were tentatively dated as Pliocene and interpreted to have been deposited either in a post-Yorktown marine advance and regression or as facies of the Yorktown by Owens and Denny (1979, p. A12–A16, figs. 5, 6). The change in age designation from its original Pleistocene (Rasmussen and Slaughter, 1955, p. 113, 115 (table 17), 116–117) was based on the presence of "exotic" plant fossils (fossils of species that survived the Pleistocene only outside of North America) in a warm-climate, oak-hickory assemblage and also on the deep weathering of the Walston Silt.

The Mannetto Gravel, found on hills on Long Island, is the northernmost onshore remnant of possible Pliocene age in the area of this study if its age designation by Cooke and others (1943, chart 12) is correct. Fuller (1905c, p. 367–390; 1914, p. 80–85) named it and considered it to be Pleistocene. Its depositional history is obscure.

Pleistocene.—Pleistocene ice sheets advanced as far south as Long Island on the Coastal Plain, leaving the island largely covered by terminal and ground moraines and outwash deposits. The advancing ice planed and deformed the Cretaceous sediments that form the backbone of the island (Woodworth, 1901, p. 622; Mills and Wells, 1974) and, in places, scored the bedrock surface. Material scraped from the older rocks was reworked, mixed with rock debris transported by the ice, and deposited as glacial drift. Meltwater streams eroded deep valleys that were subsequently filled with glacial deposits. Outwash sand and gravel was deposited by meltwater in sheets as well as in channels, and some of it was carried far beyond the limits of glaciation. Fleming (1935) found evidence for three glacial advances on Long Island, all of Wisconsin age. Parts of the island were submerged by one or more rises in sea level during interglacial warm episodes; the most extensive record is preserved by the Gardiners Clay.

Pleistocene sea-level variations affected the Coastal Plain south of the limit of glaciation by alternately submerging and exposing parts of the coast and by altering rates of stream erosion and deposition. Examples of Pleistocene marine deposits include sediments on the Cape May Peninsula at the southern tip of New Jersey (Salisbury, 1898, p. 18–20; MacClintock and Richards, 1936, p. 305–317; Gill, 1959, 1962a, b) and the Omar, Ironshire, and Sinepuxent Formations of the Delmarva Peninsula (Owens and Denny, 1979, p. A16–A24). Beach, lagoonal, and estuarine deposits are found along the Chesapeake Bay coast of the Delmarva Peninsula (Kent Island Formation) (Owens and Denny, 1979, p. A24–A26), in southeastern Virginia (Oaks and others, 1974), and in southeastern North Carolina (DuBar, Johnson, and others, 1974; DuBar, Solliday, and Howard, 1974). Examples of Pleistocene gravels deposited largely under fluvial conditions include the Spring Lake and Van Sciver Lake beds along the lower Delaware Valley. Owens and Minard (1979, p. D29–D47) interpreted their depositional histories in the following sequence: (1) drop in sea level, (2) rapid down-cutting of the river valley, and (3) rise in sea level, inducing refilling of the valley and upstream migration of the estuarine environment.

The Pleistocene Parsonsburg Sand of the central Delmarva Peninsula (Rasmussen and Slaughter, 1955) has been interpreted as partly eolian in origin, with dunes still recognizable (Jordan, 1964, 1974; Hansen, 1966, p. 22; Denny and others, 1979). Pleistocene climatic factors, namely, temperature, precipitation, and wind velocity, appear to have controlled its deposition.

Post-Pleistocene sediments in the Coastal Plain include beach, offshore bar, valley fill, bay, lagoonal, and marsh deposits. Marine transgression has predominated in the Holocene, drowning the lower reaches of streams.

HYDROGEOLOGIC FRAMEWORK

BASIS FOR SUBDIVISION

For this study, the Coastal Plain sediments have been subdivided into 11 regional aquifers separated by 9 confining units. The basis for definition of the aquifers is continuity of permeability. In sedimentary rocks, the principal direction of permeability tends to follow beds of sand, gravel, or limestone, which in turn run approximately parallel to the upper and lower boundaries of formations. Adjacent permeable beds or those separated by only minor thicknesses of material of low permeability, such as clay or silt, may be considered to be parts of the same aquifer. A regional aquifer may coincide with a recognized local or subregional aquifer in one area and comprise several in another, or it may constitute only part of a local aquifer.

The framework of the flow system could have been represented by a larger or smaller number of aquifers than 11. Available subsurface data are insufficient to support further regional subdivision of the sedimentary section, although locally additional aquifers could be defined. In comparison, the aquifer system of the adjoining southeastern Coastal Plain was represented in a companion regional aquifer system analysis by four regional aquifers, excluding the surficial and Floridan aquifers (Renken, 1984, Wait and others, 1986).

The names assigned to the 11 regional aquifers are based on names used in the hydrogeologic frameworks of the North Carolina (Winner and Coble, in press), Virginia (Meng and Harsh, 1988), and Maryland-Delaware (Vroblesky and Fleck, in press) subregional RASA studies. At most, two subregional names form the name of each regional aquifer; where there are two names, they are hyphenated and the name of the more southerly aquifer appears first. A brief definition of each of the regional aquifers follows.

1. *Surficial aquifer.*—This term applies to surficial water-saturated sand and gravel of Miocene to Holocene age. The name was used for the uppermost aquifer in the subregional RASA reports for North Carolina (Winner and Coble, in press) and Maryland and Delaware (Vroblesky and Fleck, in press).
2. *Upper Chesapeake aquifer.*—This aquifer consists of permeable beds in the upper part of the Chesapeake Group of Miocene-Pliocene age and their approximate stratigraphic equivalents. The name was chosen because of its association with the Chesapeake Group; it has also been applied in the subregional RASA study covering Maryland and Delaware (Vroblesky and Fleck, in press). The Virginia and North Carolina subregional RASA studies use names for the corresponding aquifer based on names of formations in the upper part of the Chesapeake Group.
3. *Lower Chesapeake aquifer.*—The justification for the nomenclature is similar to that for the upper Chesapeake aquifer.
4. *Castle Hayne-Piney Point aquifer.*—This aquifer is a limestone and lime sand aquifer (Castle Hayne) in North Carolina and a sand aquifer in Virginia, Maryland, Delaware, and New Jersey, predominantly of Eocene age. The use of the name "Castle Hayne aquifer" is established in North Carolina and is used in the North Carolina subregional RASA study. Use of the name "Piney Point aquifer" is established in Virginia, Maryland, Delaware, and New Jersey. Both are based on formational names.
5. *Beaufort-Aquia aquifer.*—This aquifer includes the local Beaufort aquifer in North Carolina, the Aquia aquifer in Virginia and Maryland, the Rancocas aquifer in Delaware, and the Vincentown aquifer in New Jersey. All are composed of Paleocene sands. The aquifer names "Beaufort," "Aquia," and "Aquia-Rancocas" are used in the North Carolina, the Virginia, and the Maryland-Delaware subregional RASA studies, respectively, and are based on formational names.
6. *Peedee-Severn aquifer.*—This aquifer includes the local Peedee aquifer in North Carolina, the Severn aquifer in Maryland and Delaware, and the Wenonah-Mount Laurel aquifer in New Jersey, all consisting of Upper Cretaceous sands. The name "Peedee" is used in the North Carolina subregional RASA study and "Severn" in the Maryland-Delaware subregional RASA study; both are based on formational names.
7. *Black Creek-Matawan aquifer.*—This aquifer includes the local Black Creek aquifer of North Carolina, the Matawan aquifer of Maryland and Delaware, and the Englishtown aquifer of New Jersey, all consisting of Upper Cretaceous sands. The names "Black Creek" and "Matawan" are used in the North Carolina and the Maryland-Delaware subregional RASA studies; both are based on formational and group names.
8. *Magothy aquifer.*—This aquifer includes the Magothy aquifer of Maryland, Delaware, New York, and New Jersey and the upper aquifer of the Potomac-Raritan-Magothy aquifer system in New Jersey. It is essentially identical to the Magothy Formation of Late Cretaceous age, except that on Long Island, N.Y., the aquifer includes beds equivalent to the Matawan and Monmouth Groups and hydraulically connected Pleistocene sand and gravel.
9. *Upper Potomac aquifer.*—This aquifer is named in the subregional Virginia RASA study (Meng and Harsh, 1988, p. C38–C39) for the upper part of the Potomac Formation of Cretaceous age. The regional aquifer also includes the local Brightseat aquifer (Meng and Harsh, 1988, p. C41–C42) in northern Virginia and southern Maryland. In Virginia, this overlies the main body of the aquifer, but it is the sole representative of the aquifer in Maryland.

   The regional aquifer also includes the upper Cape Fear aquifer of the North Carolina subregional RASA study (Winner and Coble, in press).
10. *Middle Potomac aquifer.*—This aquifer consists predominantly of nonmarine sands and gravels of Early Cretaceous age in Virginia, Maryland, and Delaware and those of Late Cretaceous age in North Carolina, New Jersey, and Long Island. The name was used in the subregional RASA study of Virginia and includes the lower Cape Fear aquifer of the North Carolina subregional study, the Patapsco aquifer of Maryland and Delaware, the middle aquifer of the Potomac-

Raritan-Magothy aquifer system of New Jersey, and the Lloyd aquifer of New York (Long Island).

11. *Lower Potomac aquifer.*—This aquifer consists predominantly of nonmarine sands of Early Cretaceous age. The name was used in the subregional RASA study of Virginia and includes the Lower Cretaceous aquifer of the North Carolina subregional study, the Patuxent aquifer of Maryland and Delaware, and the lower aquifer of the Potomac-Raritan-Magothy aquifer system of New Jersey.

Wherever practicable, the mapping of the aquifers and intervening confining units was based on the distribution of permeable zones as indicated by well logs, hydraulic data, and water chemistry. Personnel in field offices traced and mapped the hydrologic units on a local scale and then compiled them into regional maps. Because of changes in the distribution of permeable zones in Coastal Plain sediments from place to place, some of the aquifers consist of sediments of different ages in different areas, as is the case in the middle Potomac aquifer, which contains both Lower and Upper Cretaceous sediments. The aquifers are extended by projection into areas where data are lacking.

Plate 3 shows the relationship between the regional aquifers and confining units, local aquifers, and geologic formations by means of composite sections for each of the States included in this study.

Although each confining unit has been defined in terms of the aquifer that it overlies, some have been traced beyond the limits of their underlying aquifers, either through identity with stratigraphic units that can be mapped or through arbitrary subdivision of confining material.

Figures 4–8 show logs of representative wells from North Carolina, Virginia, Maryland-Delaware, New Jersey, and New York (Long Island), respectively, with boundaries of the regional aquifers indicated. The configuration of the aquifers along a section roughly parallel to the coast from North Carolina to Long Island is shown on plate 4*A*. The configuration of the aquifers along sections roughly perpendicular to the coast is shown on plates 4*B–E*, in which the seaward thickening of the sedimentary section of the Coastal Plain is evident. The locations of the sections are shown on plate 1*A*.

In part of the section along the South Carolina State line, the Black Creek-Matawan, upper Potomac, and middle Potomac aquifers and associated confining units are not differentiated (pl. 4*E*). Hydraulic data suggest that the undifferentiated sediment acts as a single

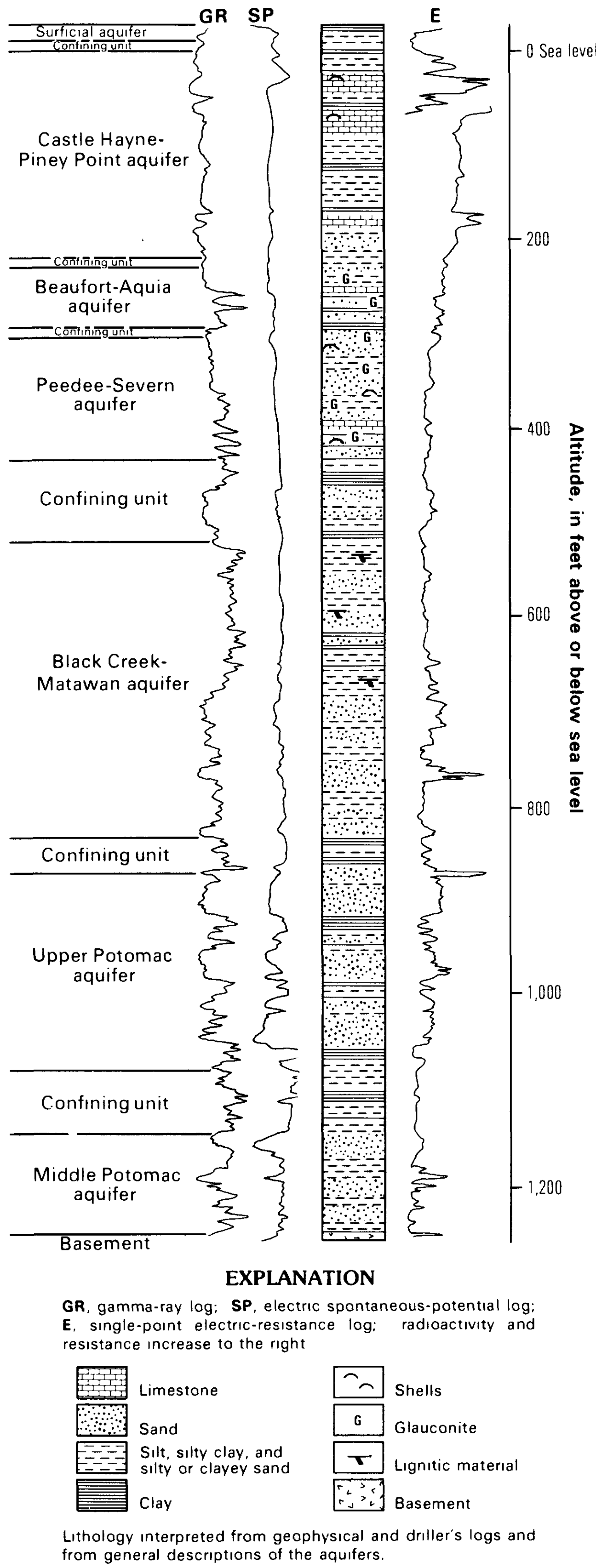


FIGURE 4.—Log of representative well in the North Carolina Coastal Plain, with boundaries of regional aquifers: well 390, NRCD Clarks Research Station. (Location shown on plate 1*A*; well number and owner taken from appendix.) ▶

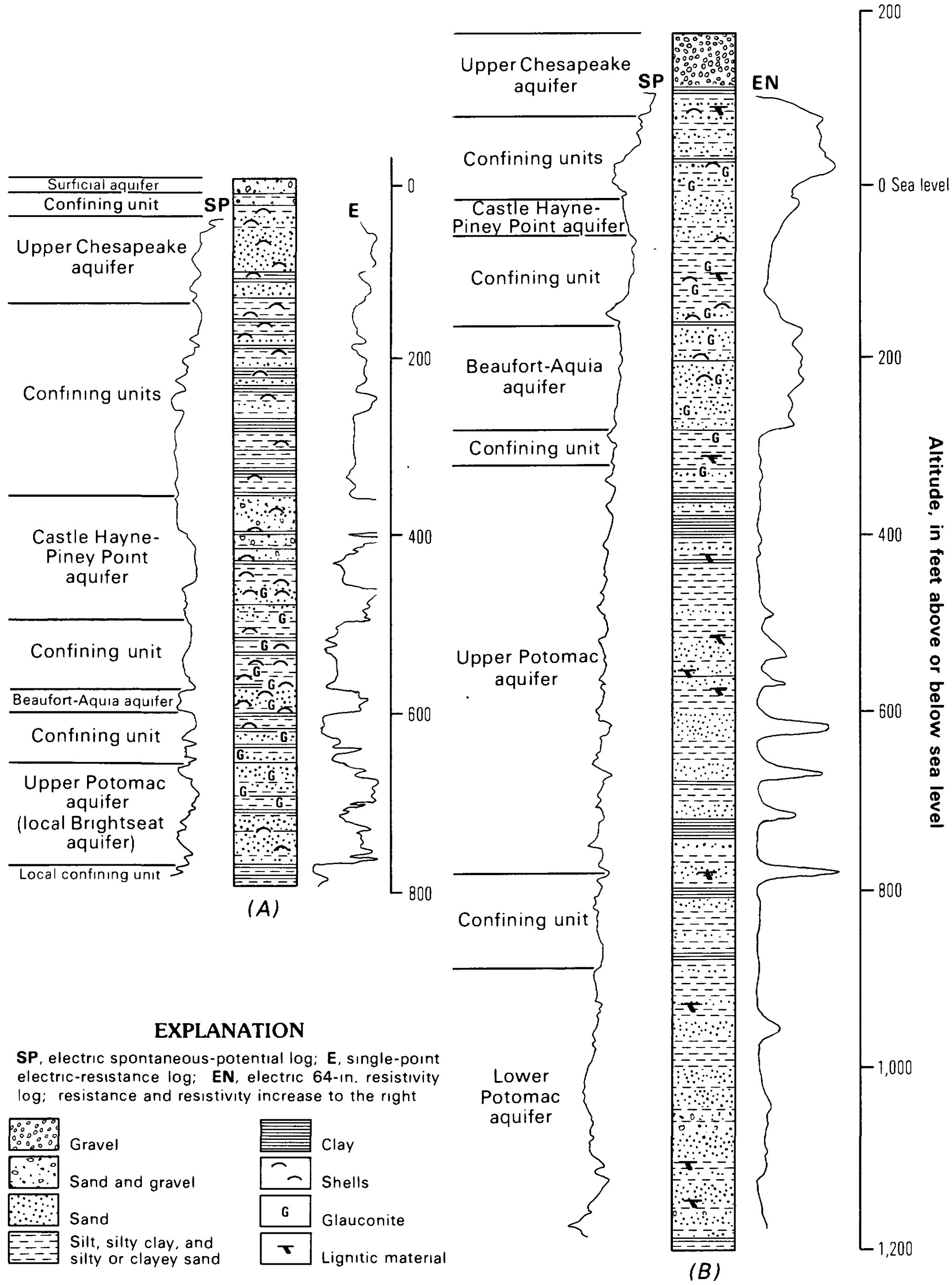


FIGURE 5.—Logs of representative wells in the Virginia Coastal Plain, with boundaries of regional aquifers: (*A*) well 250, Haynie Products, Inc., and (*B*) well 237, USGS Oak Grove Core. (Locations shown on plate 1*A*; well number and owners taken from appendix.)

aquifer within this area, but it is equivalent to material that is delineated into separate aquifers outside the area in North Carolina and South Carolina. The stratigraphic correlation of beds on opposite sides of the section (pl. 4*E*) is open to question, but the distribution of permeability is interpreted for this study as it is shown on plate 4*E*. The area corresponding to the undifferentiated section is labeled "correlation uncertain" on maps of the aquifers (pls. 11*A*,*B*; 12*A*,*B*).

The description of the regional aquifers and their overlying confining units follows, in descending order. Unless otherwise noted, ranges of values of transmissiv-

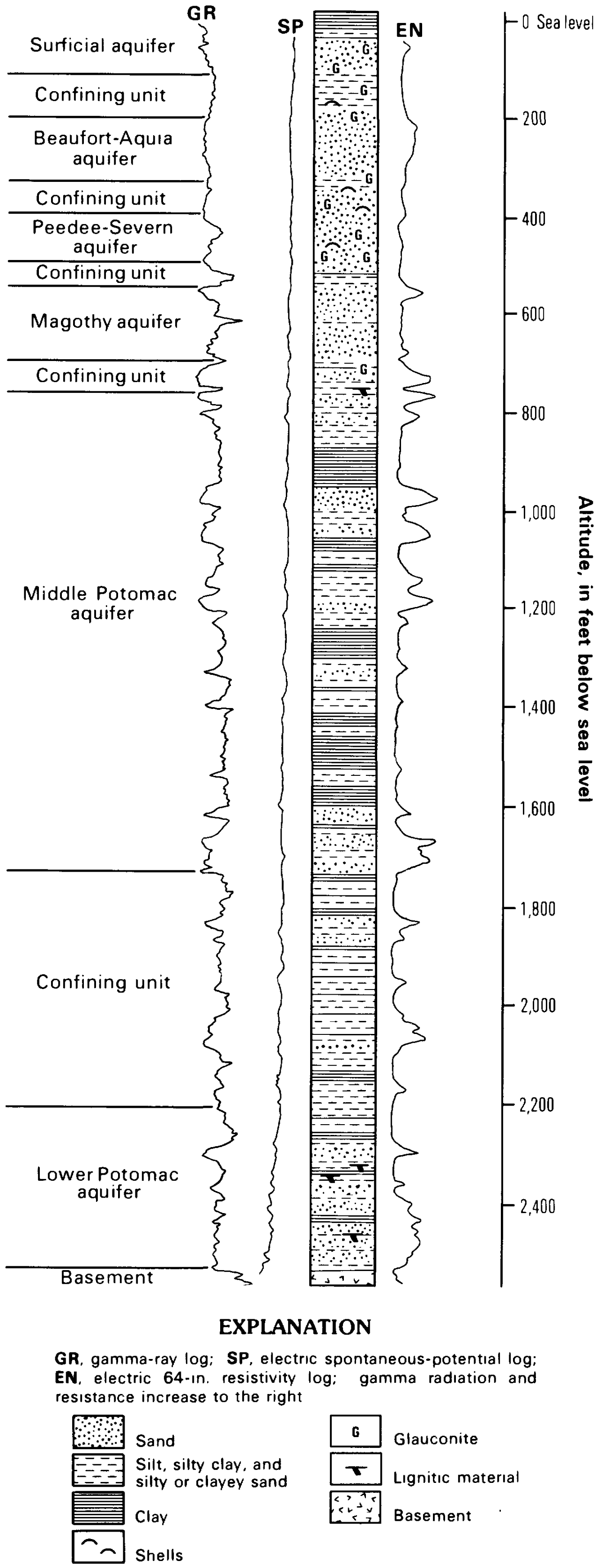


FIGURE 6.—Log of representative well in the Maryland-Delaware Coastal Plain, with boundaries of regional aquifers: well 171, USGS QA-EB 110, Kent Island. (Location shown on plate 1A; well and local numbers taken from appendix.)

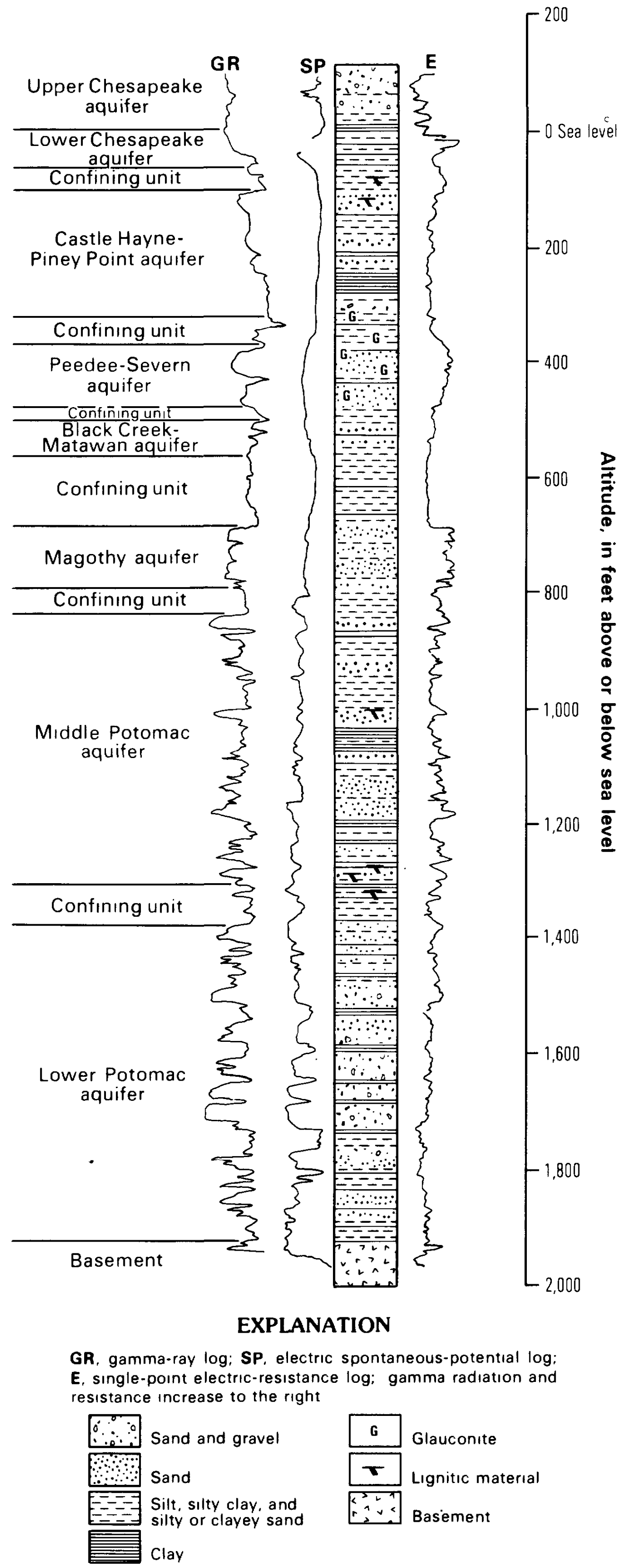
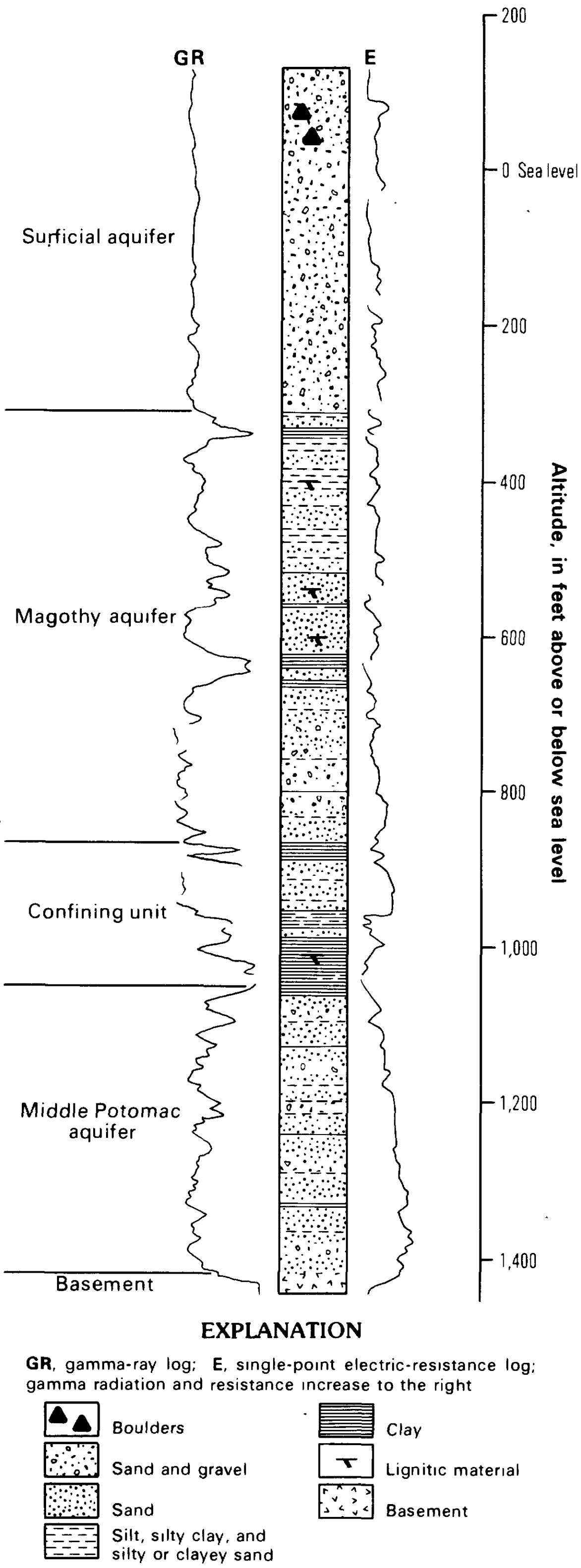


FIGURE 7.—Log of representative well in the New Jersey Coastal Plain, with boundaries of regional aquifers: well 97, USGS New Brooklyn Park 1. (Location shown on plate 1A; well number and name taken from appendix.)



◄ FIGURE 8.—Log of representative well in the New York (Long Island) Coastal Plain, with boundaries of regional aquifers: well 13, USGS Test Well S33379T. (Location shown on plate 1A; well and local numbers taken from appendix.)

ity and leakance have been taken from the calibrated regional digital-flow model (Leahy and Martin, in press). In the model, leakance values were assigned to sand-on-sand contacts beyond the limits of the confining units; these are excluded from this report, as are values for offshore areas.

SURFICIAL AQUIFER

The surficial aquifer consists of unconsolidated sand and gravel. It covers most of the North Carolina Coastal Plain, where it is composed of post-Yorktown deposits. In Virginia, it is called the Columbia aquifer and is composed of valley and terrace deposits and of marine sediments covering lowlands in the southeastern part of the State and on the Delmarva Peninsula. In New York (Long Island), it includes the upper glacial aquifer. The aquifer is unconfined, although it includes local confined zones.

The surficial aquifer in Maryland and Delaware includes Holocene to Pleistocene sands and also gravels in the Pensauken Formation and the Brandywine Gravel that have been regarded as Pleistocene by many investigators, including Jordan (1964), Cushing and others (1973), and Hansen (1981), or Pliocene(?) (Rasmussen and Slaughter, 1955). In this report, the Pensauken and Brandywine Formations are included in the Miocene (pl. 3), in accordance with the interpretation of Owens and Denny (1979).

The regional surficial aquifer of this study in New Jersey is restricted to Pleistocene sand and Holocene beach and dune deposits on the Cape May Peninsula at the southern tip of the State. There it comprises the local Holly Beach aquifer (Gill, 1962a), but beach deposits north of the peninsula are included in aquifers consisting mostly of older deposits: the upper Chesapeake aquifer in particular (Mary Martin, U.S. Geological Survey, oral commun., July 18, 1986).

On Long Island, the surficial aquifer is composed of glacial sediments (the upper glacial aquifer of local use), consisting of moraines, outwash, and glaciolacustrine deposits that cover almost all of the surface (McClymonds and Franke, 1972, p. E13–E15, pl. 1, table 1). The aquifer extends over the entire island except for a few places in the western part where bedrock is exposed, bluffs along the north shore where Cretaceous sediments outcrop, and irregular patches where the upper Pleistocene deposits are completely above the water table. It is unconfined, and the more permeable parts consist of outwash sand and gravel and the rest of till. It has no lateral connection with the Coastal Plain aquifers of New Jersey (pl. 4*A*).

In this report, the top of the surficial aquifer is represented by the approximate average water table over its extent, as determined for the period 1980–84 (pl. 1*B*). The control for the contouring consisted mostly of altitudes of land and water surfaces rather than of well data.

The thickness of the surficial aquifer is highly variable. The average saturated thickness of the aquifer on Long Island is about 250 ft (McClymonds and Franke, 1972, pl. 1). For the area south of Long Island, the average is probably about 50 ft, with the greatest thicknesses, as much as 180 ft in Delaware and 220 ft in Maryland, in buried channels on the Delmarva Peninsula (Mack and Thomas, 1972; Johnston, 1973; Bachman, 1984, pl. 5). The saturated section tends to be thin in the higher level terrace deposits, particularly in the western part of the Coastal Plain.

On Long Island, the average transmissivity of the surficial aquifer is about 27,000 ft^2/day (McClymonds and Franke, 1972, table 6). Outside of Long Island, its transmissivity is generally less than 1,000 ft^2/day except on the Delmarva Peninsula. There it is commonly on the order of 8,000 ft^2/day and ranges up to 20,000 ft^2/day in buried channels in Delaware (Johnston, 1977, p. 5, figs. 2, 12) and 53,000 ft^2/day in the Salisbury paleochannel in Maryland (Weigle, 1972, p. 86).

UPPER CHESAPEAKE AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—Over most of its area, the upper Chesapeake aquifer is separated from the overlying surficial aquifer by a confining unit. In North Carolina and Virginia, the confining unit consists of clay, silty and sandy clay, and shells of late Pliocene age. In Maryland and Delaware, it consists of sediments of similar lithology but of late Miocene age. In New Jersey, the confining unit is limited to the Cape May Peninsula and consists of Pleistocene estuarine clays (Gill, 1962a; Mary Martin, U.S. Geological Survey, oral commun., May 7, 1985). Its extent and thickness are shown on plate 5*A*. Over nearly half of its area, it is less than 20 ft thick. The leakance of the confining unit ranges from about 1×10^{-6} to 0.1 (ft/day)/ft.

Aquifer.—In North Carolina and Virginia, the upper Chesapeake aquifer (pl. 3) consists of most of the Pliocene Yorktown Formation and upper Miocene Eastover Formation. In Maryland and Delaware, it consists of sand zones in the upper Miocene Eastover and St. Marys Formations: the local Manokin and Pocomoke aquifers, which extend into Virginia on the Delmarva Peninsula (Cushing and others, 1973, p. 45–46, pls. 9, 10), and the Ocean City aquifer (Weigle, 1974, p. 16).

The upper Chesapeake is discontinuous in the southern half of the North Carolina Coastal Plain, and only one outlier, along the South Carolina line, was mappable on a regional scale (pl. 5*B*). In the northern part of the North Carolina Coastal Plain, it is exposed in only a few places, mostly along valleys, where streams have cut through the sediments of the surficial aquifer. It consists primarily of fine sand of marine origin, with beds of shells and clayey and silty material.

In the inner Coastal Plain of Virginia, post-Yorktown sediments are thin or missing from the interfluves, where the upper Chesapeake aquifer is exposed. The lithology of the upper Chesapeake is similar in Virginia and North Carolina, except that in Virginia it includes more coarse sand.

In Maryland and Delaware, the upper Chesapeake aquifer is restricted to the Delmarva Peninsula. Toward its northwestern limit, it directly underlies the surficial aquifer in an area shown as "subcrop of upper Chesapeake aquifer under surficial aquifer" on plate 5*B*. The three local aquifers making up the upper Chesapeake (Pocomoke, Ocean City, and Manokin) are composed of fine to coarse sand with some gravel and lignite fragments.

In the downdip part of the New Jersey Coastal Plain, the regional upper Chesapeake aquifer is equivalent to the local Kirkwood-Cohansey aquifer system (pl. 3), which consists primarily of the Cohansey Sand. It is separated from the local Rio Grande water-bearing zone and Atlantic City 800-foot sand (which form part of the lower Chesapeake aquifer) by confining beds (Zapecza, 1989, fig. 5). The confining beds pinch out updip, but their projected position subdivides the Kirkwood-Cohansey aquifer system into the upper and lower Chesapeake aquifers. In the updip area of the New Jersey Coastal Plain, the upper Chesapeake aquifer includes the Cohansey Sand and the upper part of the Kirkwood Formation. Both are of Miocene age. The upper Chesapeake aquifer also includes the high-level gravels of the Bridgeton Formation and Beacon Hill Gravel. The Bridgeton had been mapped as Tertiary and the Beacon Hill as Pleistocene (Johnson, 1950), but Owens and Minard (1979) interpreted the age of both as late Miocene. The upper Chesapeake aquifer crops out over most of the New Jersey Coastal Plain (pl. 5*B*). The Cohansey Sand is gravelly. The sand of the Kirkwood Formation is similar to that of the Cohansey, except that it tends to be finer grained. Minor components of the aquifer include Holocene beach-sand deposits and dunes along the Atlantic coast, overlying the Cohansey Sand.

The extent of the upper Chesapeake aquifer and altitude of its upper surface are shown on plate 5*B*. In the areas of outcrop, its altitude is approximated by the water table (pl. 1*B*). The average thickness of the aquifer penetrated by wells, based on data from the appendix, is about 75 ft in North Carolina, 140 ft in Virginia, 400 ft in Maryland and Delaware, and 190 ft in New Jersey. The average thickness for Maryland, Delaware, and, to a lesser extent, Virginia includes a substantial amount of material of low permeability between the local Pocomoke, Ocean City, and Manokin aquifers.

The transmissivity of the upper Chesapeake aquifer ranges up to about 6,000 ft^2/day in North Carolina, 3,000 ft^2/day in Virginia, 24,000 ft^2/day in Maryland just south of Delaware, and 10,000 ft^2/day in New Jersey.

LOWER CHESAPEAKE AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—Over most of its extent, the lower Chesapeake aquifer is overlain by a confining unit consisting primarily of silt and clay of Miocene age. The confining unit is silty and shelly in Virginia, Maryland, and Delaware and diatomaceous in New Jersey. It is traced west of Chesapeake Bay in Virginia, beyond the limits of the lower Chesapeake aquifer. Its extent and thickness are shown on plate 6*A*. Its thickness is greater than 100 ft over more than half its area. The leakance ranges from about 1×10^{-6} to 1×10^{-3} (ft/day)/ft.

Aquifer.—From North Carolina through New Jersey, the lower Chesapeake aquifer (pl. 3) is composed of middle to lower Miocene sand beds of marine origin. These beds constitute the Pungo River aquifer of North Carolina and the St. Marys-Choptank aquifer of Virginia. In Maryland and Delaware, the lower Chesapeake aquifer comprises the local Frederica, Federalsburg, and Cheswold aquifers, which are sand layers separated by silt and clay (Cushing and others, 1973, p. 43–45). In New Jersey, the lower Chesapeake aquifer includes the lower part of the Kirkwood-Cohansey aquifer system (Zapecza, 1989, p. B17–B19) in the updip part of the Coastal Plain and the local Rio Grande permeable zone and Atlantic City 800-foot sand of the Kirkwood Formation downdip. As part of the Kirkwood-Cohansey aquifer system, the aquifer extends as much as 35 mi beyond the updip limit of the overlying confining unit, and directly underlies the upper Chesapeake aquifer (Zapecza, 1989, pl. 5, *L–L′*, *L′–A′*; pl. 23). Where the confining unit is absent (pl. 4*B*), the top of the lower Chesapeake aquifer is determined by the updip projection of the approximate horizon of the overlying confining unit.

The lower Chesapeake aquifer underlies most of the New Jersey Coastal Plain and the Delmarva Peninsula. In North Carolina, the aquifer is limited to an area around the Albemarle and Pamlico Sounds. It is absent in Virginia and Maryland west of the Chesapeake Bay. Its extent and altitude are shown on plate 6*B*. Near its northwestern limit in Maryland and Delaware, the permeable zones of the aquifer are truncated and directly overlain, together with the upper Chesapeake aquifer, by the surficial aquifer in an area shown on plate 6*B* as "subcrop of lower Chesapeake aquifer under surficial aquifer." Stratigraphic equivalents of the sediments making up the aquifer extend into southern Maryland but are too fine grained and low in permeability to be considered part of the regional aquifer.

The lower Chesapeake aquifer in North Carolina consists primarily of fine to medium phosphatic marine sands with shells and occasional beds of limestone and of very fine to fine sand in Virginia. In Maryland and Delaware, the permeable zones consist of medium to coarse sand with shells and traces of gravel, and in New Jersey, the aquifer is composed of fine to medium sand interbedded with coarse sand and gravel.

The average thickness of the lower Chesapeake aquifer penetrated by wells is about 50 ft in North Carolina, 275 ft on the Delmarva Peninsula, and 200 ft in New Jersey. (The average thickness for the Delmarva Peninsula includes a substantial amount of material of low permeability between the local Frederica, Federalsburg, and Cheswold aquifers, and the New Jersey thickness includes confining material in the downdip area of the Kirkwood Formation.)

The transmissivity of the lower Chesapeake aquifer generally ranges up to about 8,000 ft^2/day in North Carolina, 4,000 ft^2/day on the Delmarva Peninsula, and 10,000 ft^2/day in New Jersey.

CASTLE HAYNE-PINEY POINT AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The Castle Hayne-Piney Point aquifer is overlain by a confining unit consisting of clay and sandy clay, generally of Miocene age. The confining unit is thin in North Carolina, where it consists mostly of the lower part of the Pungo River Formation. In Virginia, Maryland, and Delaware, it consists of silty, diatomaceous clay of the Calvert Formation and also of Oligocene silt (Benson and others, 1985, pl. 3). In Maryland, west of Chesapeake Bay, it includes sediments of the lower part of the Chesapeake Group that are, in part, the stratigraphic equivalents of permeable zones in the lower Chesapeake aquifer on the Delmarva Peninsula. In New Jersey, the confining unit consists primarily of the silty basal clay of the Kirkwood Formation, but it may also include unnamed Oligocene and lower Miocene beds that may be equivalent to the Old Church Formation in Virginia.

The extent and thickness of the confining unit overlying the Castle Hayne-Piney Point aquifer are shown in plate 7*A*. In North Carolina, it is generally less than 50 ft thick; from Virginia northward, it is 100 to 250 ft thick over more than half its area. The leakance ranges from about 1×10^{-6} to 1×10^{-4} (ft/day)/ft.

Aquifer.—The Castle Hayne-Piney Point aquifer (pl. 3) comprises permeable zones of the Eocene Castle Hayne Limestone and the lithologically similar Oligocene River Bend Formation in North Carolina, the upper Oligocene-lower Miocene Old Church Formation and Eocene Chickahominy and Piney Point Formations in Virginia, and the Piney Point and Oligocene and lower Miocene sediments (Old Church Formation(?)) in Maryland, Delaware, and New Jersey. The extent and correlation of the Old Church Formation (Ward, 1984, 1985) have not been studied sufficiently to determine how much of the Castle Hayne-Piney Point aquifer is Oligocene from Virginia northward. Examples of the subsurface occurrence of possible Old Church Formation north of Virginia include Oligocene beds in New Jersey (J.P. Owens, U.S. Geological Survey, oral commun., Feb. 19, 1985) and a zone at the top of the Piney Point Formation in Delaware that Benson and others (1985, p. 45–46, pl. 3) interpreted as having been reworked during an Oligocene-Miocene transgression.

The aquifer extends about two-thirds of the distance from the coast to the limit of the Coastal Plain aquifer system from Virginia through New Jersey (pl. 4*B*,*C*), but only about half the distance or less in North Carolina (pls. 4*D* and 7*B*). Outlying erosional remnants of Castle Hayne Limestone were not included in the regional aquifer. A downdip change to a clay facies marks its eastern limit (pl. 7*B*) on the Delmarva Peninsula (Cushing and others, 1973, pl. 5; Williams, 1979, p. 9).

The aquifer consists of limestone, including calcirudite and calcarenite, sandy marl, and fine to coarse calcareous sand in North Carolina, and fine to coarse glauconitic sand with disseminated shells and indurated shell beds from Virginia through New Jersey. The average thickness of the Castle Hayne-Piney Point aquifer penetrated by wells is about 185 ft in North Carolina, 60 ft in Virginia, 150 ft in Maryland and Delaware, and 125 ft in New Jersey.

Transmissivity of the Castle Hayne-Piney Point aquifer ranges up to about 70,000 ft^2/day in North Carolina and generally to 5,000 ft^2/day from Virginia to New Jersey (in central Delaware, to 7,350 ft^2/day, according to Leahy (1979, p. 14, table 3)).

BEAUFORT-AQUIA AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The confining unit overlying the Beaufort-Aquia aquifer consists primarily of Paleocene and Eocene sediments of low permeability. It is made up of silt, clay, and sandy clay of the upper part of the Beaufort Formation and possibly some younger beds in North Carolina and the Marlboro Clay and the lower part of the Nanjemoy Formation in Virginia, Maryland, and Delaware. In New Jersey, it consists of the Manasquan and Shark River Formations and the upper part of the Vincentown Formation, as well as the entire thickness of the Vincentown downdip.

The extent and thickness of the confining unit are shown on plate 8*A*. Its thickness is less than 50 ft over most of the Coastal Plain of North Carolina but increases irregularly northward to more than 900 ft at the southern tip (Cape May) of New Jersey. The leakance ranges from about 1×10^{-8} to 1×10^{-5} (ft/day)/ft.

Aquifer.—The Beaufort-Aquia aquifer (pl. 3) is made up of permeable beds of Paleocene age. It includes the greater part of the Beaufort Formation in North Carolina and sands in the Aquia Formation in Virginia and Maryland, in the Rancocas Group in Delaware, and in the Vincentown Formation in New Jersey. In North Carolina and Virginia, it consists of fine to medium glauconitic marine sand with thin shell and limestone beds. In Maryland and Delaware, it is predominantly medium to coarse glauconitic sand with disseminated lignite fragments and shell beds. Thin shell and sandstone beds locally are cemented by calcite. In New Jersey, the aquifer consists of sparsely glauconitic quartz sand and fossiliferous, calcareous quartz sand. Its southeastern boundary from southeastern Virginia and across the Delmarva Peninsula is a clay facies of the Aquia Formation (Hansen, 1974, p. 32–37, figs. 9, 26–27; Chapelle and Drummond, 1983, p. 12, figs. 3–4). In New Jersey, the aquifer consists of a narrow band of sand bounded on the northwest by its outcrop and on the southeast by a clay facies (Zapecza, 1989, p. B15–B16, pl. 19).

The extent and altitude of the aquifer are shown on plate 8*B*. The average thickness of the Beaufort-Aquia aquifer penetrated by wells is about 90 ft in North Carolina, 45 ft in Virginia, 120 ft in Maryland and Delaware, and 70 ft in New Jersey. Transmissivity is generally less than 2,000 ft^2/day but ranges up to about 5,000 ft^2/day on the Delmarva Peninsula (Maryland).

PEEDEE-SEVERN AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The Peedee-Severn aquifer is overlain by a confining unit of marine silt, clay, and glauconitic sand of low permeability. In North Carolina, the confining unit consists of clay, in part silty and sandy, that may be either of Late Cretaceous or Tertiary age. In Maryland and Delaware, it consists of silt and clay of the Cretaceous Severn Formation and the Paleocene Brightseat Formation and is traced beyond the limits of the Peedee-Severn aquifer. In New Jersey, it consists primarily of silty and clayey glauconitic quartz sand of the Monmouth Group.

The confining unit overlying the Peedee-Severn aquifer is extended to include the confining material overlying the Magothy aquifer of Long Island because the aquifer there includes stratigraphic equivalents of the Peedee-Severn and Black Creek-Matawan, with no extensive intervening confining beds. On Long Island, the confining unit consists primarily of the Gardiners Clay and other Pleistocene glacial deposits of low permeability, but possibly includes Cretaceous clay.

The thickness and extent of the confining unit overlying the Peedee-Severn aquifer and, on Long Island, the Magothy aquifer are shown on plate 9*A*. It is generally less than 100 ft thick but is as much as 220 ft thick in central Delaware and 486 ft in a channel on western Long Island. The leakance generally ranges from 1×10^{-6} to 1×10^{-5} (ft/day)/ft, except on Long Island, where it ranges from 1×10^{-5} to 1×10^{-2} (ft/day)/ft.

Aquifer.—The Peedee-Severn aquifer is the uppermost regional aquifer in the Coastal Plain composed of Cretaceous sediments. It consists largely of permeable sand in the marine Peedee Formation in North Carolina, the Severn Formation in northern Maryland, the Mount Laurel Sand in Delaware, and the Wenonah Formation and Mount Laurel Sand in New Jersey. It is absent in Virginia, southern Maryland, and Long Island (pl. 9*B*).

The Peedee-Severn aquifer in North Carolina consists of gray, fine to medium sand interbedded with gray to black marine clay and silt and in places with impure limestone. Shells are common, and the sand contains varying percentages of glauconite. In Maryland and Delaware, it consists generally of reddish-brown, fine-grained, silty, glauconitic sand but is locally poorly sorted. In New Jersey, the Peedee-Severn aquifer is equivalent to the local Wenonah-Mount Laurel aquifer, and it is also glauconitic but generally coarser there than in Delaware.

The average thickness of the Peedee-Severn aquifer penetrated by wells is about 95 ft in North Carolina, 80 ft in Maryland, 100 ft in Delaware, and 80 ft in New Jersey. Transmissivity of the freshwater part of the aquifer ranges up to about 10,000 ft^2/day in North Carolina but is generally less than 2,000 ft^2/day from Maryland to New Jersey.

BLACK CREEK-MATAWAN AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The Black Creek-Matawan aquifer is overlain by a confining unit consisting primarily of Upper Cretaceous marine clay and silt. In North Carolina, the upper part of the Black Creek Formation constitutes most of the confining unit, but Tertiary sediments, such as parts of the Beaufort and Yorktown Formations, also make up part of it where intervening aquifers are absent. In Maryland and Delaware, the confining unit is composed of clay and silt of the Matawan and Severn Formations. In New Jersey, it consists of the glauconitic silt and sand of the Marshalltown Formation and micaceous, silty, glauconitic, fine sand of the Wenonah Formation. The confining unit has been traced beyond the limits of the Black Creek-Matawan aquifer from New Jersey through Maryland. Its extent and thickness are shown on plate 10*A*. The leakance generally ranges from 1×10^{-7} to 1×10^{-4} (ft/day)/ft and is typically 1×10^{-6} to 1×10^{-5} (ft/day)/ft.

Aquifer.—The Black Creek-Matawan aquifer includes permeable sand zones of Late Cretaceous age in the lagoonal to marine Black Creek and fluvial Middendorf Formations in North Carolina, the marine Matawan Formation in Maryland and Matawan Group in Delaware, and the marine and deltaic Englishtown Formation of the Matawan Group in New Jersey (pl. 3). In Maryland and Delaware, the Black Creek-Matawan aquifer is recognized only in part of the northern Delmarva Peninsula (pl. 10*B*) and it is not recognized in Virginia. In the northeastern New Jersey Coastal Plain, two sand bodies of the Englishtown Formation are separated by clayey silt, but the layers thin and are replaced by clay to the south and southeast.

The sands that make up the Black Creek-Matawan aquifer differ substantially in lithology. The sand in the Black Creek Formation is characterized by its high lignite content and is glauconitic, fossiliferous, and interlayered with gray clay. The Middendorf consists of predominantly fine to medium sand containing clay fragments, interbedded with light-colored and varicolored clay. It is crossbedded and lenticular. Sand in the Matawan Formation in Maryland and Delaware is dark gray, fine, silty to clayey, and glauconitic; sand in the Englishtown, however, is fine to medium and quartzose.

The average thickness of the Black Creek-Matawan aquifer penetrated by wells is about 180 ft in North Carolina and 55 ft in New Jersey. The aquifer is thin-to-missing in Maryland and Delaware. Transmissivity of the freshwater part of the aquifer ranges up to about 10,000 ft^2/day in North Carolina but is generally less than 2,000 ft^2/day in other parts of the study area.

MAGOTHY AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The thickness and extent of the confining unit overlying the Magothy and the upper Potomac aquifers are shown on plate 11*A*. The confining unit is bounded on the southwest by a line representing the approximate southwestern limit of the Magothy aquifer; southwest of the line, the lines of equal thickness show the thickness of the confining unit overlying the upper Potomac aquifer. The southwestern limit of the Magothy aquifer is also shown on plate 4*A*.

In Maryland and Delaware, the confining unit comprises silt and clay of the upper part of the Magothy Formation and the lower part of the overlying Matawan Formation (Group). In New Jersey, it consists of glauconitic and micaceous clay and silt of the Merchantville Formation and clayey silt of the Woodbury Clay of the Matawan Group (pl. 3).

South of Long Island, N.Y., the leakance of the confining unit generally ranges from 1×10^{-7} to 1×10^{-4} (ft/day)/ft and is typically 1×10^{-6} (ft/day)/ft. The confining unit overlying the Magothy aquifer on Long Island is depicted on plate 9*A* as an extension of the confining unit overlying the Peedee-Severn aquifer.

Aquifer.—The Magothy aquifer extends northward from Maryland to Long Island. It includes the principal permeable zones in (1) the Upper Cretaceous, fluvial to marginal-marine Magothy Formation in Maryland and Delaware, (2) the Magothy Formation (where it is recognized) or the upper part of the Magothy and Raritan Formations and Potomac Group, undifferentiated, in New Jersey, and (3) the Monmouth Group, undifferentiated, and Magothy Formation and Matawan Group, undifferentiated, on Long Island (pl. 3). The extent of the Magothy aquifer and altitude of its upper surface, as well as the extent and altitude of the upper Potomac aquifer, are shown on plate 11*B*. The northeast boundary of the upper Potomac aquifer is close to the southwest boundary of the Magothy aquifer; present data show no area of overlap.

On Long Island, Monmouth and Matawan sediments included in the Magothy aquifer (Perlmutter and Todd, 1965) are in part stratigraphically equivalent to the Peedee-Severn aquifer and underlying Black Creek-Matawan aquifer, but they do not constitute separate hydrogeologic units. Getzen (1977, p. 19) used three electric analog-model layers to represent the Magothy aquifer on Long Island, but these do not correspond to stratigraphic subdivisions. The regional flow model for this study (Leahy and Martin, in press) follows Getzen's subdivisions of the Magothy aquifer. However, in this report, the Magothy aquifer of Long Island is treated as part of the regional Magothy aquifer and is not differentiated into three layers (pl. 3).

The regional Magothy aquifer includes glacial sand and gravel on Long Island (for example, the local Jameco aquifer) and other overlying permeable sediments where there is no effective intervening confining bed. It also includes permeable material underlying the Magothy Formation, such as the local Sayreville Sand Member of the Raritan Formation in New Jersey. The aquifer is truncated in southern Maryland (Hansen, 1978), and its southwestern limit approximately coincides with the northeastern limit of the upper Potomac aquifer. Plates 4*A* and 11*B* show the Magothy aquifer separated laterally from the upper Potomac, an interpretation that does not violate available data.

The Magothy aquifer typically consists of well-stratified to crossbedded, very fine to medium quartz sand, with abundant discontinuous layers of carbonaceous, clayey silt. Coarse to very coarse sand and gravel are found in the thicker parts of the Magothy Formation and are associated with fluvial deposition (Hansen, 1972b, p. 51). Along its outcrop, the thickness of the formation ranges from about 20 ft in Maryland to 330 ft in New Jersey (Owens and others, 1977, p. 16–17), and the Magothy Formation and Matawan Group, undifferentiated, is as much as 1,100 ft thick on Long Island (Perlmutter and Todd, 1965, p. 3). The average thickness of the Magothy aquifer penetrated by wells is about 75 ft in Maryland and Delaware, 100 ft in New Jersey, and 460 ft on Long Island.

Transmissivity of the freshwater section ranges up to about 6,000 ft^2/day in Maryland, 3,000 ft^2/day in Delaware, 10,000 ft^2/day in New Jersey, and 56,000 ft^2/day on Long Island.

UPPER POTOMAC AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The confining unit overlying the upper Potomac aquifer consists of clay beds of Late Cretaceous age in North Carolina and in Virginia south of the limit of the local Brightseat aquifer (pl. 3). In North Carolina, the confining unit includes silty and sandy clay beds of the lower parts of the Middendorf and Black Creek Formations, together with clay beds in the uppermost Cape Fear Formation, especially downdip, where the Cape Fear thickens. South of the limit of the Brightseat aquifer in Virginia, the confining unit consists of micaceous, calcareous, slightly glauconitic, silty, and sandy clay, which is highly expandable (Brown and Silvey, 1977, p. 7). Where the local Brightseat aquifer forms the upper part of the regional aquifer in the northern Virginia Coastal Plain (Meng and Harsh, 1988, figs. 15, 16) and in southern Maryland, the confining unit is of Paleocene age and possibly Cretaceous age and consists of micaceous silty clay and clayey silt thinly interbedded with very fine sand (parts of the Aquia and possibly the Potomac Formations in Virginia and Aquia, Brightseat, and possibly Patapsco Formations in Maryland).

The thickness and extent of the confining unit are shown on plate 11*A*. Between the lines representing the approximate limits of the underlying local Brightseat aquifer in Virginia and Maryland, lines of equal thickness show the thickness of the confining unit overlying this zone of the regional aquifer. South of this area, lines of equal thickness apply to the confining material above the main body of the aquifer. To the northeast, they refer to the confining unit overlying the Magothy aquifer. The thickness of the confining unit is generally less than 50 ft except near the South Carolina State line, where it locally exceeds 150 ft, and along the North Carolina coast, where it is as much as 290 ft. The leakance generally ranges from 1×10^{-7} to 1×10^{-3} (ft/day)/ft and is typically 1×10^{-6} to 1×10^{-5} (ft/day)/ft.

Aquifer.—The upper Potomac aquifer consists of Upper Cretaceous marine and marginal-marine sands from North Carolina to the central Virginia Coastal Plain, but in northern Virginia it consists of two sand bodies separated by a confining unit. Meng and Harsh (1988, p. C41–C42) named the upper body the Brightseat aquifer and referred to the lower body as the upper Potomac aquifer. Their correlation of the upper body with the Brightseat Formation of Paleocene age was based on Hansen and Wilson's (1984, p. 13–15, fig. 5) assignment, on sparse palynologic evidence, of an early(?) Paleocene age to the section containing the aquifer in a well in southern Maryland. (Recent work on cores from two test holes, one in northern Virginia and the other in southern Maryland, has identified fossil pollen and spores of late Early Cretaceous (Albian) age (D.J. Nichols, U.S. Geological Survey, written commun., 1985; Ronald Litwin, U.S. Geological Survey, written commun., 1987) in deposits that are designated the Brightseat aquifer in this report. This indicates that the Brightseat aquifer does not correlate with the Brightseat Formation.) In Maryland, only the upper member (local Brightseat aquifer) of the regional upper Potomac aquifer is recognized.

The extent of the aquifer and altitude of its upper surface, together with the boundaries of the Magothy aquifer and the local Brightseat aquifer, are shown in plate 11*B*.

In North Carolina, the upper Potomac aquifer comprises the upper part of the Upper Cretaceous Cape Fear Formation, which consists mostly of alternating beds of nonfossiliferous fine to medium sand and clay. In the Virginia Coastal Plain, the main body of the aquifer includes sand interbedded with clay in the upper part of the Potomac Formation, the age of which has been determined by pollen analysis to be early Late Cretaceous (Cenomanian, palynostratigraphic zones III and IV) in several wells (Meng and Harsh, 1988, p. C38, fig. 13). (However, in the area where it underlies the Brightseat aquifer, it must be no younger than late Early Cretaceous if the Brightseat aquifer is Albian in age, as discussed earlier.) The sand consists of very fine to medium quartz grains, with micaceous and carbonaceous material; the clay is silty, micaceous, and carbonaceous. In northern Virginia and southern Maryland, the local Brightseat aquifer consists of interbedded fine, well-sorted sand and dark, micaceous, silty clay. The sand is glauconitic in part, and both the sand and the clay contain lignite fragments and sparse shells. The lithology of the part of the regional aquifer underlying the Brightseat aquifer in Virginia is similar to that of the undivided aquifer farther south.

In Maryland west of Chesapeake Bay, well 218 penetrated 245 ft of the aquifer, and well 226 on the Delmarva Peninsula penetrated 75 ft (appendix). The average thickness penetrated by wells is about 95 ft in Virginia and 160 ft in North Carolina.

Transmissivity of the freshwater section ranges up to about 6,000 ft^2/day in North Carolina, 3,000 ft^2/day in Virginia, and 1,000 ft^2/day in adjoining Maryland.

MIDDLE POTOMAC AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The confining unit overlying the middle Potomac aquifer in North Carolina is composed of clay and sandy clay beds of the Cape Fear Formation, except where the upper Potomac aquifer is missing, chiefly in the northwestern North Carolina Coastal Plain. There the confining unit may consist, in part, of Tertiary clayey sediments. In most of Virginia, the confining unit consists of Lower Cretaceous clayey beds, predominantly of palynostratigraphic zone II, with zone III (lower Upper Cretaceous) on the Delmarva Peninsula. The clay beds are typically varicolored and contain expandable illite-smectite clay minerals.

Plate 12*A* shows the extent and thickness of the confining unit. Over most of the North Carolina and Virginia Coastal Plain, its thickness is less than 100 ft, but it increases to more than 700 ft at the southern tip of New Jersey (Cape May) and is more than 150 ft over most of the Coastal Plain of Delaware, New Jersey, and New York (Long Island).

On plate 12*A*, dashed lines of equal thickness on the lower Delmarva Peninsula indicate an area of change in the stratigraphic position of the underlying aquifer. South of the area of dashed lines, the confining unit consists of low-permeability beds that underlie lower Upper Cretaceous (Cenomanian) permeable sands and overlie Lower Cretaceous sands; to the north, in the Eastern Shore of Maryland and Delaware, the confining unit overlies Cenomanian sands. This is shown diagrammatically in plate 4*A* by a shift in the stratigraphic position of the confining unit where the section underlies Chesapeake Bay.

Throughout most of the western shore of Maryland, the Cenomanian is missing, and the confining unit comprises clayey beds between the Lower Cretaceous middle Potomac aquifer and the next overlying aquifer: the upper Potomac, the Magothy, or the Beaufort-Aquia aquifer. The age of the sediments constituting the confining unit in this area may range from Early Cretaceous to Paleocene (pl. 3).

In New Jersey, the confining unit overlying the middle Potomac aquifer consists of the upper part of the Raritan Formation (the Woodbridge Clay Member where recognized) or approximate stratigraphic equivalents in the Magothy and Raritan Formations and Potomac Group, undifferentiated. Throughout much of New Jersey, especially more than about 12 mi downdip from the outcrop of the Potomac Group, the boundaries of the confining unit are indistinct. Its top and bottom have been selected to include less permeable sand per unit thickness than the aquifers above and below.

On Long Island, N.Y., the confining unit consists primarily of the upper clay member of the Raritan Formation, which is composed of laminated, silty clay with intercalated sand lenses and lignite seams (Suter and others, 1949, p. 17). In places along its northern limit, the middle Potomac (local Lloyd) aquifer extends beyond the limit of the overlying Magothy aquifer and is incised by channels (McClymonds and Franke, 1972, pls. 2*A*, 3*A*). The channels are filled with the surficial aquifer, which varies in lithology and permeability (Soren, 1978, p. 10–11, pl. 1, *C–C′*; Getzen, 1977, fig. 4, *A–A′*, *B–B′*, *E–E′*), and may locally confine the aquifer, depending on the contrast in permeability. The leakance generally ranges from 1×10^{-7} to 1×10^{-4} (ft/day)/ft. The higher values are found in the updip areas, where the confining unit is thinner.

Aquifer.—The middle Potomac aquifer (pl. 3) consists principally of the lower part of the Upper Cretaceous Cape Fear Formation in North Carolina; the middle part (Lower Cretaceous) of the Potomac Formation in Virginia; most of the Upper and Lower Cretaceous Patapsco Formation and its approximate equivalents in the undifferentiated Potomac Group in Maryland; and the upper part of the Potomac Formation in Delaware. It also consists of the permeable section in the Upper Cretaceous Raritan Formation and the middle part of the Potomac Group and Raritan and Magothy Formations, undifferentiated, in New Jersey; and the Lloyd Sand Member of the Raritan Formation on Long Island.

The extent of the middle Potomac aquifer and altitude of its upper surface are shown on plate 12*B*. In North Carolina, the aquifer is made up of fine to medium sand of nearshore marine origin, with some coarse sand and gravel, and feldspathic sand and silty clay of continental origin. In Virginia, Maryland, and Delaware, the aquifer consists of fluvial fine to coarse sand, predominantly medium, interlensing with silt and clay. Sundstrom and others (1967, p. 18) characterized the Potomac Formation in Delaware (and consequently both the middle and lower Potomac aquifers of this study) "as a clay-silt matrix with many relatively small sand bodies interspersed."

In Virginia, Meng and Harsh (1988, p. C36) defined the middle Potomac aquifer as upper Lower Cretaceous (palynostratigraphic zone II) sand beds. On the Delmarva Peninsula in Maryland and around the north end of Chesapeake Bay, lower Upper Cretaceous (Cenomanian) sand bodies appear to be hydraulically connected more closely to underlying Lower Cretaceous Patapsco sands than to the overlying Magothy aquifer and therefore are included in the middle Potomac aquifer. Clayey sediments separating Cenomanian sands from Lower Cretaceous sands are more prominent farther south in Virginia, and consequently there the Cenomanian sand is included in the upper Potomac aquifer rather than in the middle Potomac aquifer. The area over which the change occurs is indicated by dashed contours on plate 12*B* (see also plate 4*A*), which extend a short distance into Virginia to include the J & J Enterprises, Emmitt G. Taylor no. 1 well (well 249, in the appendix and on plate 1*A*). The well is near the southern limit of the area in which the sand bodies being discussed are assigned to the middle Potomac aquifer.

In New Jersey, the middle Potomac aquifer consists of lenticular sand bodies interbedded with clay and silt. It is predominantly fluvial in origin, except for marine beds along the coast. It includes the Farrington aquifer (composed principally of the Farrington Sand Member of the Raritan Formation in the Raritan Bay area), which was described by Farlekas (1979, p. 8–9) as predominantly fine to coarse sand with lignite and pyrite. It also includes glacial outwash gravel and other overlying materials in direct hydraulic contact. Outside of the Raritan Bay area, the Raritan Formation cannot be distinguished from the Potomac Group on the basis of lithology, but Farlekas and others (1976, p. 22) divided the Potomac-Raritan-Magothy section into lower, middle, and upper aquifers around Camden, N.J. This subdivision was extended by Zapecza (1989) and, for modeling purposes, further extended by Martin (1987) to the rest of the New Jersey Coastal Plain.

On Long Island, the middle Potomac aquifer consists primarily of the Lloyd Sand Member of the Raritan Formation. It is composed of discontinuous beds of fine to coarse sand and gravel with interbedded clay and silt. The sediments are of fluvial and deltaic origin. The aquifer also includes sand and gravel of glacial origin overlying it where there is no intervening effective confining bed.

The average thickness of the middle Potomac aquifer, as penetrated by wells, is about 285 ft in North Carolina, 350 ft in Virginia, 770 ft in Maryland and Delaware, 245 ft in New Jersey, and 225 ft on Long Island.

Transmissivity of the freshwater section ranges up to about 8,000 ft^2/day in North Carolina; 16,000 ft^2/day in Virginia, Maryland, Delaware, and New York; and 21,000 ft^2/day in New Jersey.

LOWER POTOMAC AQUIFER AND ITS OVERLYING CONFINING UNIT

Confining Unit.—The confining unit overlying the lower Potomac aquifer is composed generally of clay and sandy clay beds in the upper part of the Lower Cretaceous section or basal part of the Upper Cretaceous section. In Virginia and Maryland, the confining unit corresponds to the Arundel Formation and its approximate stratigraphic equivalents, and its clay is described as typically "tough" or hard (Meng and Harsh, 1988, p. C36; Vroblesky and Fleck, in press). In New Jersey, the confining unit consists predominantly of silt and clay of the Potomac Group and Raritan Formation and generally thickens eastward (pl. 13*A*). It was correlated with a relatively high degree of confidence for a distance of about 12 mi from its updip limit by Zapecza (1989) and was extended beyond this limit for simulation purposes by Martin (1987). The thickness of the confining unit is generally less than 100 ft in North Carolina and Virginia and is less than 50 ft in about half of its extent in these States. It increases from all landward directions toward the mouth of Delaware Bay, where it exceeds 1,000 ft. The leakance generally ranges from 1×10^{-8} to 1×10^{-4} (ft/day)/ft.

Aquifer.—The lower Potomac aquifer (pl. 3) is the lowermost aquifer that contains freshwater in the Coastal Plain aquifer system. It consists predominantly of Lower Cretaceous sediments, which are typically of fluvial and deltaic origin. It may also include sediments of Jurassic age, particularly along the coast. In North Carolina, the aquifer includes both marine and nonmarine sediments, with the proportion of marine beds in the section, including limestones, increasing seaward. The freshwater section of the aquifer in North Carolina is restricted to a small area south of the Virginia border, where lenses of mostly fine to medium sand are interbedded with clayey and silty material. Along the coast, where the aquifer contains saltwater, it has not been mapped in detail. The extent of the aquifer and altitude of its top are shown in plate 13*B*.

The lower Potomac aquifer was defined in Virginia by Meng and Harsh (1988, p. C34) to include sandy sediments of palynostratigraphic zone I and prezone I (early to middle Early Cretaceous age) in the Potomac Formation. It consists of massive lenses of predominantly medium to very coarse quartz sand with a substantial percentage of interstitial clay interbedded with clay and gravel. The sediments are typically arkosic and locally are lignitic, micaceous, and rarely glauconitic. Glauconite, indicative of marine origin, .was identified in a core from the lower part of the Potomac section in a well as far inland as 87 mi in northern Virginia (well 237, in the appendix and on plate 1) (Reinhardt and others, 1980, p. 38, 44, 46, fig. 2).

In Maryland, in and adjoining the outcrop area of the Potomac Group, the aquifer is essentially equivalent to the Patuxent Formation of the Potomac Group (Hansen, 1968, p. 19–20). Downdip from the area in which the Patuxent Formation is traceable, the aquifer comprises the lower dominantly sandy zone of the Potomac Group, undifferentiated.

In Delaware, the aquifer corresponds generally to the lower hydrologic zone of the Potomac Formation (Sundstrom and others, 1967, p. 21). In Maryland and Delaware, it is almost entirely of fluvial and deltaic origin, although Groot (1955, p. 103) interpreted some of the deposits to be of estuarine and lagoonal origin and Doyle and Robbins (1977, p. 71–72) reported marine dinoflagellates in sediments constituting part of the lower Potomac aquifer in the Socony Oil, Bethards 1, well on the Delmarva Peninsula (well 215, in the appendix and on plate 1*A*).

In Maryland and Delaware, the aquifer consists of lenses of sand and gravel with intervening layers of clayey and silty material. Around Baltimore, permeable sand zones constitute more than 60 percent of its thickness and gravel beds are common; however, sand beds constitute only about 20 percent of the aquifer in the southwestern part of the Maryland Coastal Plain (Vroblesky and Fleck, in press). As with the middle Potomac aquifer, the lower Potomac aquifer comprises greater thicknesses of clay-silt matrix than of permeable sand in most of the Delaware Coastal Plain. The sand is typically medium to coarse and often pebbly, with interstitial clay.

In New Jersey, the lower Potomac aquifer comprises sediments in the lower part of the Potomac Group and Raritan and Magothy Formations, undifferentiated. It corresponds to the lower aquifer of the Potomac-Raritan-Magothy aquifer system, as discussed in the section on the middle Potomac aquifer. In wide areas of the New Jersey Coastal Plain, it is lithologically indistinguishable from the middle aquifer of the Potomac-Raritan-Magothy aquifer system, and it is similar to the lower Potomac aquifer in Maryland and Delaware. In the area within 8 to 12 mi from its updip limit, permeable sand bodies constitute more than 70 percent of the aquifer thickness. The total thickness increases downdip (Zapecza, 1989). Although the lower Potomac aquifer has not been studied in detail eastward from this updip band, Martin (1987) extended the subdivision of the Potomac-Raritan-Magothy aquifer system to the coast (pl. 4*B*). The aquifer is absent in the northern third of the New Jersey Coastal Plain and from Long Island (pl. 13*B*).

The average thickness of the interval between the top of the lower Potomac aquifer and the basement penetrated by wells is about 285 ft in North Carolina, 525 ft in Virginia, 935 ft in Maryland and Delaware, and 345 ft in New Jersey. The wells used to derive the averages generally are concentrated in the updip area, where the aquifer is thinnest. Especially in the downdip area, the thicknesses making up these averages may include material that effectively is not part of the lower Potomac aquifer: clay between the deepest permeable sand and basement and also saltwater aquifers such as the Waste Gate aquifer.

Transmissivity of the freshwater section generally ranges up to about 8,000 ft^2/day in Virginia, 6,000 ft^2/day in Maryland, 4,000 ft^2/day in Delaware, and 10,000 ft^2/day in New Jersey.

SEDIMENTS UNDERLYING THE LOWER POTOMAC AQUIFER

Sediments underlying the lower Potomac aquifer include clay and silt, which are not aquifer material, and at least one brine aquifer: the Waste Gate aquifer on the Delmarva Peninsula (pls. 3 and 4*C*). Hansen (1982, 1984) assigned his Waste Gate Formation to the lowermost Potomac Group and regarded it (Hansen, 1982, p. 32, 40, 45) as isolated from the freshwater-flow system. No further effort has been made in this study to differentiate the Waste Gate aquifer or other brine aquifers from the lower part of the lower Potomac aquifer.

Basal sedimentary clay and silt may not be readily distinguishable from weathered bedrock, particularly when only drill cuttings and geophysical logs are available as evidence. Basal sedimentary clay and basement, weathered or unweathered, may function as parts of the confining unit underlying the Coastal Plain aquifer system.

SUMMARY

The sediments of the northern Atlantic Coastal Plain were deposited on a basement surface that slopes gently toward the ocean. Present knowledge suggests that the basement rock is similar to the exposed rock of the Piedmont Plateau, of which it is a continuation. Igneous and metamorphic Precambrian and Paleozoic and rift-basin Triassic and Jurassic sedimentary and volcanic rocks have been mapped below the Coastal Plain sediments. These rocks are not included in this report.

The Continental Shelf is the submerged part of the Coastal Plain. Although this report focuses on the emergent area, the inner Continental Shelf and the bays and estuaries are of interest with respect to freshwater-saltwater boundaries. The thickness of the sediments on the emergent north Atlantic Coastal Plain ranges from 0 ft near the Fall Line to 10,000 ft at Cape Hatteras, N.C., and to 8,000 ft along the coast of Maryland. Offshore from New Jersey and the Delmarva Peninsula, in the Baltimore Canyon Trough, the thickness of the sediments exceeds 7.5 mi.

The sediments range in age from Jurassic to Holocene. Upper Jurassic sediments have been identified in a few wells near the coast, but mostly, the Jurassic sediments are offshore and are not freshwater aquifers. In general, the lowermost Coastal Plain deposits are fluvial or fluviodeltaic in origin and contain discontinuous lenses of sand, silt, clay, gravel, and minor amounts of lignite. Younger deposits tend to overlap older ones. In the Cretaceous section, there is a general upward and eastward transition from fluvial and fluviodeltaic to marginal-marine to marine deposits. The marine parts of the Cretaceous and lower Tertiary section consist primarily of glauconitic sand, silt, clay, and limestone beds, which are traceable over longer distances than are the more lenticular nonmarine beds. The Tertiary sediments are predominantly marine, except in parts of the upper Miocene and Pliocene sections. The Pleistocene section includes glacial drift on Long Island and marine, estuarine, dune, and terrace deposits elsewhere. The Holocene section includes alluvial, marine, beach, and dune deposits.

For this study, the Coastal Plain sediments have been subdivided into 11 regional aquifers separated by 9 confining units. The basis for definition of the aquifers is continuity of permeability. In sedimentary rocks, the direction of maximum permeability tends to follow beds of sand, gravel, or limestone, which are approximately parallel to the upper and lower boundaries of formations. Adjacent permeable beds or those separated by only minor thicknesses of material of low permeability, such as clay or silt, may be considered parts of the same aquifer. A regional aquifer may coincide with a recognized local or subregional aquifer in one area and comprise several in another, or it may constitute only part of a local aquifer.

Although the Coastal Plain aquifers encompass materials of relatively low permeability such as silt and clayey sand, they are characterized primarily by permeable sand, except for the Castle Hayne-Piney Point aquifer in North Carolina, which consists of limestone and lime sand.

The aquifers defined in this report are, from the uppermost downward:

- *Surficial*—Quaternary and upper Tertiary marine and nonmarine deposits, unconfined. It includes the upper glacial aquifer of Long Island, which is composed of Pleistocene glacial drift.

- *Upper Chesapeake*—Pliocene and upper Miocene mostly marine deposits.
- *Lower Chesapeake*—Middle and lower Miocene marine deposits.
- *Castle Hayne-Piney Point*—Predominantly Eocene with some Oligocene and lower Miocene marine deposits.
- *Beaufort-Aquia*—Paleocene marine deposits.
- *Peedee-Severn*—Upper Cretaceous marine deposits in North Carolina; absent in Virginia; marine deposits from Maryland through New Jersey.
- *Black Creek-Matawan*—Upper Cretaceous. Fluvial to marine deposits in North Carolina; not recognized in Virginia; predominantly marine deposits from Maryland through New Jersey.
- *Magothy*—Predominantly Upper Cretaceous and marginal-marine to fluviodeltaic deposits. It extends from southern Maryland through Long Island. The Magothy aquifer on Long Island includes stratigraphic equivalents of the Peedee-Severn and Black Creek-Matawan aquifers and also hydraulically connected Pleistocene sand and gravel.
- *Upper Potomac*—Upper Cretaceous from North Carolina through central Virginia; may include Paleocene (?) and Lower Cretaceous beds in northern Virginia and southern Maryland. Marine to marginal-marine deposits.
- *Middle Potomac*—Straddles the Upper Cretaceous-Lower Cretaceous boundary. Predominantly fluvial and deltaic deposits except in North Carolina, where it is in predominantly nearshore marine deposits. Includes Pleistocene sand and gravel in hydraulic contact with underlying Cretaceous sand in New Jersey and Long Island.
- *Lower Potomac*—Lower Cretaceous, except for some possible Jurassic beds along the coast; predominantly fluvial and deltaic deposits, with some marine beds, particularly along the coast.

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APPENDIX

[Data from wells used to define the hydrogeologic framework of the northern Atlantic Coastal Plain]

LONG ISLAND

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...)[1] AND THICKNESSES OF CONFINING UNITS (C1, C2,...)[2] IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
1	L.I. STATE PARK COMMISSION	410745/721600	4107450721600.01	668	5	-612			-487	100	-208					0								
2	LONG ISLAND LIGHTING	405701/730448	4057010730443.01	891	15	-813			-595	98	-25					0								
3	PETER SALM	405628/722637	4056280722637.01	620	20						-135					61								
4	SANFORD & SONS	405604/721820	4056040721820.01	300	30						-125					15								
5	L.A. BEVIN	405602/732243	4056020732243.01	350	5				-325	80														
6	SUFFOLK COUNTY DEPT. OF HEALTH	405455/730258	4054550730258.02	1121	163	-938			-716	184	-49					0								
7	SUFFOLK COUNTY DEPT. OF HEALTH	405411/722330	4054110722330.01	1215	36				-1138	216	-154					0								
8	NORTHPORT VETERANS HOSPITAL	405329/731853	4053290731843.01	740	123				-572	172														
9	SUFFOLK COUNTY WATER AUTHORITY	405253/732635	4052530732635.01	790	82	-688			-443	125														
10	E. ROOSEVELT	405247/733020	4052470733020.01	465	5	-450					-95					0								
11	BROOKHAVEN NATIONAL LABORATORY	405223/725234	4052230725234.01	1600	85	-1404			-1101	49	-157					52								
12	SUFFOLK COUNTY WATER AUTHORITY	405124/723537	4051240723537.01	1629	45	-1501			-1125	210	-135					0								
13	USGS TEST WELL S33379T	404932/730559	4049320730559.01	1580	134	-1424			-1058	190	-310					0								
14	U.S. COAST GUARD	404931/723202	4049310723202.01	360	6						-219					108								
15	MERCHANT MARINE ACADEMY TEST	404841/734533	4048410734533.01	300	51	-235			-160	121														
16	HALLOCK-SMALL	404813/723648	4048130723648.01	225	5						-175					45								
17	ROSLYN PLAZA TEST WELL	404752/733953	4047520733953.01	753	188	-550			-398	146	112					0								
18	PILGRIM STATE HOSPITAL	404731/731647	4047310731647.01	1008	120				-858	152	-65					0								
19	COLLEGE THEATRE	404656/735039	4046560735039.01	220	37	-179			-126	60						0								
20	SOUTHBAY CONSOLIDATED WATER CO.	404552/730120	4045520730120.01	180	15						-137					65								
21	WESTBURY WATER DISTRICT TEST	404516/733434	4045160733434.01	858	114				-623	181	88					0								
22	GRUMMAN CORP.	404516/732442	4045160732442.01	207	122						89					0								
23	U.S. COAST GUARD	404457/724836	4044570724836.01	301	5						-270					173								
24	VILLAGE OF HEMPSTEAD	404306/733713	4043060733713.01	1003	65	-938			-698	179	-10					0								
25	______________	404245/725546	4042450725546.01	1942	5	-1906			-1505	226	-235					124								
26	NEW YORK DEPT. OF WATER SUPPLY	404230/733134	4042300733134.01	156	62						7					0								
27	JAMAICA WATER CO.	404200/734403	4042000734403.01	869	50	-811			-554	200	-55					0								
28	JAMAICA WATER CO.	404140/734716	4041400734716.01	681	23	-628			-458	220	-120					53								
29	DAVID E. KENNEDY CO.	404012/735935	4040120735935.01	175	9	-166					-136					1								
30	CITY OF NEW YORK	403953/734316	4039530734316.01	338	10						-57					1								
31	VILLAGE OF FREEPORT	403951/733418	4039510733418.01	658	20						-64					0								
32	KINGS COUNTY ICE AND FUEL	403929/735357	4039290735357.01	451	25	-426			-403	197	-120					19								
33	______________	403756/731313	4037560731313.01	375	10						-203					109								
34	WEST GILGO BEACH ASSOCIATION	403650/732455	4036500732455.01	300	10						-92					22								
35	QUEENSBORO GAS & ELECTRIC	403622/734529	4036220734529.01	1016	9				-853	256						486								
36	LIDO-POINT LOOKOUT WATER DIST.	403534/733527	4035340733527.01	1291	6				-1191	276	-115					21								
37	T.F. WHITE CO.	403445/735258	4034450735258.01	740	7				-683	190	-123													
38	NEW YORK DEPT. OF WATER SUPPLY	403441/735002	4034410735002.01	1049	6				-715	260	-240					48								
39	RUBEL ICE CO.	403440/735925	4034400735925.01	150	5	-625			-471	78	-163					13								

[1] A1--Lower Potomac aquifer; A2--Middle Potomac aquifer; A3--Magothy aquifer in Long Island, New Jersey, Delaware, and Maryland (except where indicated by asterisk (*)); Upper Potomac aquifer in Virginia, North Carolina, and Maryland with asterisk (*); A4--Black Creek-Matawan aquifer; A5--Peedee-Severn aquifer; A6--Beaufort-Aquia aquifer; A7--Castle Hayne-Piney Point aquifer; A8--Lower Chesapeake aquifer; A9--Upper Chesapeake aquifer; A10--Surficial aquifer.

[2] C1, C2, ...--The confining units overlying the aquifers with the corresponding numerical codes.

NEW JERSEY

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
40	JERSEY CENTRAL POWER & LIGHT 7-1972	402923/741651	4029230741651.01	165	12				-116															
41	NATIONAL PARK SERVICE, FORT HANCOCK 5A	402705/735959	4027050735959.01	878	14				-715	180	-394	292												
42	UNION BEACH WATER DEPARTMENT, UBWD 3 1977	402632/741051	4026320741051.02	609	10	-599			-452	158	-218													
43	MONROE TOWNSHIP MUNICIPAL UTILITIES AUTHORITY, OBS. 1-1961	402109/743013	4021090743013.01	203	107				-32															
44	MARLBORO STATE HOSPITAL 15	402102/741353	4021020741353.01	810	140				-575	156	-289	236	17	12	66	69								
45	RED BANK WATER DISTRICT 4-75	402054/740320	4020540740320.01	769	146						-458	200	-110	16	-34	180								
46	NEW JERSEY HOME FOR BOYS 4	402038/742345	4020380742345.01	432	95				-280	122	-80													
47	MONMOUTH BEACH 1971 DEEP	401930/735841	4019300735841.02	845	10						-720	306	-286	50	-182									
48	HIGHTSTOWN WATER DEPARTMENT, TEST 3	401625/743131	4016250743131.01	398	95	-296			-170	74	2													
49	NAVAL AIR DEFENSE EARLE 2(B)	401558/740908	4015580740908.01	836	135						-505	210	-205	31	-101	130	67	34						
50	BOY SCOUTS OF AMERICA, QUAIL HILL 2	401557/742318	4015570742318.01	527	250						-186	176	55	51	184									
51	WEST WINDSOR TOWNSHIP, TEST C	401535/743703	4015350743703.04	183	65	-105			-61															
52	GARDEN STATE WATER CO., PAXSON AVENUE 12	401420/744002	4014200744002.01	142	76				-38															
53	MONMOUTH CONSOLIDATED WATER CO., WHITESVLLE	401323/740156	4013230740156.01	777	18								-442	52	-318	112	-112	65		65				
54	AVON WATER DEPT., AWD 4	401137/740121	4011370740121.02	1298	29						-956	329	-510	67	-395	90		223		111				
55	PUNK BROS. DEEP WELL	401005/742939	4010050742939.01	952	129	-659			-457	82	-281	182	-17	85	88	41								
56	BRISBANE CHILD TREATMENT CENTER 1 (OLD 3-1971)	400952/740725	4009470740708.01	1040	60						-824	286	-446	48	-328	80		183		91				
57	GARDEN STATE WATER CO., CROSSWICKS 1	400954/743853	4009540743853.01	292	23				-215	94	-65													
58	FRANCIS GRAY	400749/743630	4007490743630.01	314	92						-171	168	41											
59	JACKSON TOWNSHIP MUNICIPAL UTILITIES AUTHORITY, JACKSON 9	400659/741707	4006520741717.02	1655	134	-1515	-1381	48	-945	133	-695	266	-357	80	-233	92	-99	77		77				
60	BRICK TOWNSHIP MUNICIPAL UTILITIES AUTHORITY FROG POND 9-73	400431/740832	4004310740832.01	1817	8	-1764	-1598	86	-1322	134	-1004		-614		-496	84		184		92				
61	TENNECO CHEMICAL, TEST WELL 4	400420/745245	4004200745245.01	194	10				-13															
62	USGS, COLLIERS MILLS TW 1	400414/742702	4004160742701.01	403	137								-249	40	-119	76	7	36			137			
63	JACKSON TOWNSHIP MUNICIPAL UTILITIES AUTHORITY SCM 2	400329/741945	4003200741952.01	1782	95	-1684	-1430	69	-990	119	-743	264	-417	56	-275					112	60			
64	U.S. AIR FORCE, MCGUIRE B	400300/743514	4003000743517.01	1008	130	-882			-654	147	-354	180	-124	56	6									
65	RHODIA CORP. 1	400242/744223	4002420744223.01	641	72	-566			-434	109	-206	170	8	25										
66	NEW JERSEY WATER CO., MANTOLOKING 7	400210/740310	4002100740310.02	1369	5						-1278	401	-841	76	-695						0			
67	MAR VAC BUILDING CO., HOUSE 1-74	400206/741253	4002060741253.01	231	100													178			10			
68	BURLINGTON COUNTY COUNTRY CLUB 2-1966	400150/744820	4001500744820.01	314	80						-146	136	50											

NEW JERSEY (CONT'D)

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
	NEW JERSEY																							
69	U.S. ARMY, FORT DIX 3	400138/743753	400138074375З.01	869	165				-670		-363	172	-137	39	-29	79	135	15		15				
70	WILLINGBORO MUNICIPAL UTILITIES AUTHORITY, DCB 12	400005/745237	4000050745237.01	524	18	-498	-401	31	-222	47	-132	130												
71	U.S. ARMY, FORT DIX 6	395939/743742	3959380743742.01	1140	160				-740	148	-476	217	-233	53	-98	70	1	22						
72	TOMS RIVER CHEMICAL, TEST 84	395929/741420	3959300741421.01	2254	67		-1868	228	-1357	122	-1052	309	-717	82	-589	84		243		122				
73	CAMPBELL SOUP 1	395841/745905	3958380745905.01	249	40						-10													
74	LAVALLETTE WATER DEPT., LWD 4	395808/740416	3958080740416.01	1515	10						-1334				-810						-40			
75	JENKINS & SONS 1961 WELL	395749/743448	3957490743448.01	284	70										-195			20		20				
76	CAMDEN CITY 5N	395616/750632	3956150750633.01	183	22		-80	23	-19	18														
77	MOUNT LAUREL MUNICIPAL UTILITIES AUTHORITY, MLWC 1	395607/745648	3956070745643.01	595	20	-574	-460	84	-250	43	-142	112												
78	USGS, MEDFORD OBSERVATION 4	395524/745025	3955250745026.01	1132	72		-764	61	-544	130	-322	130	-108	29	6	68								
79	SUNNY PINES CONSTRUCTION, TH 1-74	395328/743720	3953270743734.01	586	111										-297	56		129		65	70			
80	NEW JERSEY WATER CO., HADDON 15	395238/750316	3952380750316.01	594	65	-535	-388	87	-231	16	-127	104	8	26										
81	NEW JERSEY WATER CO., HUTTON HILL 1	395229/745712	3952290745712.01	562	158						-271	177	-80	72	24	54	112							
82	USGS, BUTLER PLACE 1	395122/743017	3951220743017.01	2265	140	-2098	-1816	157	-1334	260	-948	198	-681	19	-558	68		250	-175	85	-50			
83	STATE OF NEW JERSEY DOE C-39	395028/741044	3950280741044.01	967	15														-361	94	-160			
84	SHELL CHEMICAL CO., T.H. 1	394920/751226	3949420751226.01	442	30	-360	-276	34	-179	76	-35													
85	NEW JERSEY WATER CO., ELM TREE 2	394922/745630	3949220745633.01	1356	149	-1076	-802	142	-532	28	-398	152	-184	59	-71	47	20	20		20				
86	USGS, ISLAND BEACH 3	394829/740535	3948290740535.03	3881	9	-3844	-3329	363	-2362	452	-1742	432		62	-1190	66		559	-518	124	-220			
87	GARDEN STATE WATER CO., TEST 1	394759/750158	3947590750158.01	518	75						-316	161	-131	34	-17	46	45	15		15				
88	LANDTECT CORP., TEST WELL 7	394728/752219	3947280752219.01	202	5	-202	-145	40																
89	TRANSCONTINENTAL GAS, T.H. 18	394617/741933	3946170741933.01	1737	148						-1468	346	-1092	50	-978					141				
90	PURELAND WATER CO., T.H. 3	394608/752135	3946060752133.01	354	8	-340	-262	74	-133	23														
91	TRANSCONTINENTAL GAS, T.H. 13	394558/742950	3945580742950.01	1519	90						-1182	296	-860	20	-750				-266	131	-100			
92	CLEARVIEW HIGH SCHOOL 1	394501/751229	3945010751229.01	445	130						-230		-108	48	20	60								
93	BARNEGAT LIGHT WATER DEPARMENT, TEST 78	394454/740655	3944540740655.01	639	5														-590	171				
94	GINO'S RESTAURANT 1	394452/750243	3944520750243.01	310	150																75			
95	USGS, AMCOR 6011	394330/735836	3943300735836.01	956	0														-706	107	-305	47		
96	ZEE ORCHARDS 1-1980	394259/750853	3942590750853.01	607	140						-338		-175	21	-53	50	19							
97	USGS, NEW BROOKLYN PARK 1	394215/745617	3942150745617.01	2090	111	-1919	-1379	68	-841	52	-687	126	-502	25	-378	59			-100	62	-5			
98	E.I. DUPONT, CHAMBERS OBS-1	394131/753009	3941310753009.01	488	5	-480	-255	70	-35															
99	DUBOIS BROTHERS, IRRIGATION 74	394117/752207	3941170752207.01	417	51				-272	87	-159	89	-39	40										
100	ANCORA STATE HOSPITAL 3	394104/745134	3941040745134.01	356	109														-167	66	-50			
101	E.I. DUPONT, COURSES LAND 3	393912/752436	3939120752436.01	830	30		-640	77			-154													
102	CLAYTON WATER DEPARTMENT CWD 3	393913/750517	3939120750522.01	1000	133						-609	144	-445	30	-287				-68	96				

NEW JERSEY (CONT'D)

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
103	TRANSCONTINENTAL GAS T.H. 16	393847/743036	393847074303б.01	1658	18						-1401			22	-980									
104	SHIP BOTTOM WATER DEPARTMENT, TEST 1973	393845/741053	393845074105З.01	993	7														-675		-331	110		
105	STATE OF NEW JERSEY, BATSTO 2	393838/743855	3938440743855.01	546	35														-340	71	-140			
106	PENNSVILLE TOWNSHIP WATER DEPARTMENT TH 1-64	393750/753149	3937500753149.01	809	10		-475	110	-186	41	-103													
107	USGS, SALEM 1	393348/752755	3933480752757.01	800	6				-534	180	-309	115	-174	32	-54									
108	BEACH HAVEN WATER DEPARTMENT 8	393346/741430	3933460741430.01	656	5																-405	137		
109	PAUL ALGER 1	393330/751826	3933300751826.01	380	70										-246	40	-167	119		118				
110	E.I. DUPONT, TEST 2-66	393223/750442	3932230750442.01	1048	80						-860	190	-630	70	-450				-193	121	-50			
111	EGG HARBOR WATER WORKS OW41- 5	393206/743836	3932120743836.01	457	40																-225	68		
112	CUMBERLAND COUNTY, BOSTWICK 3	393202/751630	3932020751630.01	562	85										-307	34			-85	110	65			
113	PUBLIC SERVICE ELECTRIC & GAS CO., TH 1-80	392751/753207	3927510753207.01	1800	20		-1331	471	-740	270	-410	158			-146	28	-48							
114	LOWER ALLOWAY CREEK SCHOOL, LACTES 1	392751/752441	3927510752441.01	378	14										-302	62	-208	110	-79	110				
115	CUMBERLAND COUNTY VOCATIONAL SCHOOL 3	392732/750929	3927330750924.01	625	82														-196	108	-50			
116	HAMILTON TOWNSHIP MUNICIPAL UTILITIES AUTHORITY 5	392710/744440	3927090744439.01	367	20																-300	100		
117	SAM DEROSA, RAGOVIN 3600	392512/745212	3925120745212.01	3738	85	-3616	-2755	748	-1681	204	-1385	84		30	-1205	74		638	-479	79	-220			
118	CUMBERLAND COUNTY, SHEPPARDS 1	392442/751918	3924420751916.01	638	32														-146	108				
119	BRIGANTINE WATER DEPARTMENT BWD 4-66	392336/742330	3923240742314.01	840	10																-501	175		
120	DEPARTMENT OF ENERGY, DGE TW4-78	392246/742714	3922460742714.01	1050	5														-902	112	-472	160		
121	COST B-2	392232/724404		16043	90																			
122	CUMBERLAND COUNTY, JONES ISLAND 2	391829/751208	3918280751209.02	570	10														-343	79	-75			
123	USGS, JOBS POINT 1	391826/743709	3918270743710.01	1001	17														-808	128	-403	123		
124	NEW JERSEY WATER CO., SHORE DIVISION 12-1965	391604/743539	3916040743539.01	878	7																-471	191		
125	WONDER ICE CO.	390642/744248	3906420744248.01	896	5																-494	148		
126	NEW JERSEY WATER CO., NEPTUNUS TW1-1966	390525/744851	3905250744851.02	807	17																-398	134	-61	12
127	WILDWOOD WATER DEPARTMENT, RIO GRANDE 22	390135/745349	3901350745349.01	512	8																-478	231	-80	40
128	WILDWOOD WATER DEPARTMENT, 35-1987	385830/745021	3858300745021.01	979	8																-559	222	-101	46
129	ANCHOR GAS CO., DICKINSON 1	385718/745700	3957180745700.01	6407	22	-6357	-4758	1075	-2973	743	-2179	160		50	-1964	41		910	-923	155				
130	CAPE MAY CITY WATER DEPARTMENT, BROADWAY 2	385650/745535	3856500745535.03	600	12																		-61	19

DELAWARE

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
131	CD-43-15	394130/753258		---	---	-370																		
132	DB-12-1	393955/754303		---	---	-204																		
133	DC-15-6	393406/753554		---	---	-580																		
134	CANAL REALTY, EB-34-3	393204/754157		845	38	-722	-480	60	-210	100	-95	60		50										
135	PORT PENN FISHER, ED-51-3	393048/753439		943	26		-860	160	-395	90	-270	75		50	-65	40								
136	FB-33-6	392713/754307		850	---	-1406																		
137	MIDDLETOWN	392708/754259		590	65				-395	100	-265	80		55	-75	40								
138	SHELL OIL CO.	392212/753241		2310	21	-2269	-1715	345	-900	265	-595	105		80	-320	60	-140	110		75				
139	HC-24-4	391851/753618		584	35										-360	40	-165	185						
140	INTERNATIONAL LATEX	391215/753409		1200	---						-960	75	-865	70	-640	170	-470	190		115				
141	U.S. AIR FORCE, DOVER	390740/752859		1422	---						-1230	50			-1020	220		210	-320	95	-30	35		
142	USGS KB-32-1	390221/754354		867	55									90	-525	90		100	-265	70				
143	FELTON-SWIFT & CO.	390015/753443		583	---														-390	100	-80	75		
144	MILFORD	385459/752518		958	---															105	-175	90		
145	USGS, NC-13-3	384935/753659		1510	60										-1180	180		210	-520		-165	35		
146	BREADKILL BEACH, NH-24-1	384845/751141		732	---																-330			
147	REHOBOTH, OI-24-6	384258/750632		390	25																		-90	15
148	UNIVERSITY OF DELAWARE, OG-31-1	384243/751912		700	40																-315			
149	CHARLES JOHNSON	384001/754229		440	40																-140	70		
150	DELAWARE PARKS, PJ-12-1	363908/750400		369	7																		-125	65
151	USBS, PF-24-3	383730/752135		320	50																		-60	25
152	MILLSBORO, PG-53-13	383525/751741		---	22																		-75	5
153	STATE HIGHWAY DEPT., QH-44-1	363154/751130		204	22																		-105	5
154	USGS, RJ-22-05	382808/750305		493	5																		-120	25

MARYLAND

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
155	T. FOARD	393218/754753		695	65	-588	-385	20																
156	MGS HA-DB 3	392643/760415		777	12	-700	-420	30																
157	USGS CE-EE 29	392403/755218		1458	75	-1358	-1029	160	-315	140	-160				-10									
158	GALENA	392027/755243		476	70						-270													
159	USGS KE-AC 20	392007/760755		1151	7	-1121			-90															
160	USGS KE-BE 43	391823/755947		1672	70	-1534		180	-365	125	-200	50		50	-50	40	45							
161	BA-FG 66	391524/762456		791	20		-590	130																
162	KE-CB 36	391406/761014		1540	40	-1474	-1365	340	-275	70	-195			10	-40									
163	USGS QA-BE 15	391203/760243		2009	25	-1928	-1630	245	-435	60	-350	95			-200	20	-25							
164	ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	391036/764343	3910360764341.01	184	165		50																	
165	USGS KE-DB 40	390837/761404		1822	15	-1740	-1570	390	-445	80	-280	100		40	-50	40								
166	ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	390303/763443	3903030763443.01	1340	170	-1170	-880	320	-30															
167	STATE HIGHWAY ADMINISTRATION	390223/760418		375	60												-180							
168	ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	390207/762928	3902070762928.01	598	130				-370	45	-75	25			30									
169	HLH PRODUCTS, QA-EF 25	385859/755744		518	60												-380	185	-140	55				
170	LEVITT & SONS	385816/764345		1172	114	-1047	-840	260	-175	70	40													
171	USGS QA-EB 110, KENT ISLAND	385751/761716		2544	___	-2504	-2175		-730		-516	30		15	-370	50	-180	95						
172	O.N. HARRISON	385711/754859		303	20														-250	75				
173	ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	385528/763346	3855280763346.01	1105	35				-390	35	-216	15		10		10								
174	CAROLINE POULTRY FARMS, INC.	385306/755031	3853060755031.01	980	18								-925	50	-870	190		210	-315	30				
175	COLE ASSOCIATES	385304/763017	3853040763017.01	572	21						-330			25		30	-60	20						
176	T.H. CLOPPER	385244/755518		106	50																-15	35		
177	PAN AMERICAN REFINING CORP.	384914/761732	3849140761732.01	5254	13				-1025	60	-723	110				50	-290	145	-100	95				
178	USGS AA-FE 47	384843/763126	3848430763126.01	674	6				-625		-360	40		25		35	-110	65						
179	PG-EC 41	384744/765952		870	___		-440	160	40	25		25		25		25								
180	NEW GERMAN ORPHANAGE	384744/764834		924	215				-180	20	-120	10		10			20	110						
181	EASTON UTILITY	384740/760400	3847400760400.01	1200	40									50	-785	60	-565							
182	SCHLUDERBERG-KURDLE CO.	384656/755229		230	32																-70	62		
183	KAINE-SHORES	384458/763800	3844580763755.01	562	148						-350	30		33		50	-105		35					
184	WASHINGTON GAS LIGHT, MUDD 1	384400/765212		1727	124	-1366																		
185	HOF ELEMENTARY SCHOOL	384107/765842		710	104				-125	60		15		15		50								
186	WASHINGTON GAS LIGHT, WEDDING 1	383945/765520		1750	202	-1430																		
187	U.S. NAVAL RESERVE	383934/763202	3839340763202.01	1018	97				-690	60	-580	30		30		45		200	-70					
188	CHARLES COUNTY	383913/765102		1976	210	-1766	-1600	310	-400	10	-260					35	-93	85		85				
189	R. CARPENTER	383724/761642	3837240761642.01	1025	5						-780	65		35		45	-445	145	-210	55				
190	RIVERSIDE APARTMENTS	383458/760638	3834580760636.01	400	5														-320	90	-40	25		
191	U.S. NAVY	383436/771205		242	38		-390	70																
192	CARMEL WATER CO.	383403/765949		595	___				-310	90								120						
193	USGS DO-CE 88	383401/760320		3337	9.42	-3295	-2700	645	-1025	50	-861	20		25	-771	60		125	-341	45	-70	60		

MARYLAND (CONTD)

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							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
194	U.S. ARMY RADIO SCHOOL	383236/785639		2014	185	-1730	-1365	190	-325		-235						-110	100						
195	POTOMAC ELECTRIC POWER CO.	383228/764057	3832300764107.01	645	6						-550	30				80	-290	130		150				
196	T. C. MARTIN SCHOOL	383219/765035		661	—						-380	30		30		30	-185	70		240				
197	USGS, CH-C8 18	383120/764514		1030	165				-575	20	-500	20		30		45	-270	100		230				
198	USGS SCIENTIST CLIFF, CA-DC 35	383050/763055	3830500763055.01	1000	85				-760	40	-650						-375	150						
199	DELMARVA PALCO	382916/754917		588	10														-545	80	-170	90		
200	TAYLOR ISLAND SCHOOL	382806/761807		320	5														-235	70				
201	MARDELA SPRINGS	382748/754525		491	25																-220	100		
202	CH-DA 18	382654/771525		772	—		-450	85																
203	USGS, DO-DD 7	382649/760548	3826450760549.01	800	3						-780	10		10			-690	155		50				
204	BALTIMORE GAS & ELECTRIC CO.	382603/762643	3826030762643.01	789	117												-435	200	-135					
205	D. DONAHUE	382552/761746	3825520761746.01	505	7												-475	160	-275					
206	ESSO, MARYLAND 1	382419/750341		7710	22		-4193	265	-2785	275	-2350	95		45	-2125	135		370		110				55
207	SACRE LUMBER	382331/750621		1706	4																-690	170		45
208	GRUY FEDERAL, INC.	382326/754119		950	40														-700	80	-290	110		
209	COLUMBIA CORP.	382316/762436	3823160762432.01	824	120												-480	220	-235					
210	WI-CH 36	382254/752213		617	—																	135		
211	POTOMAC ELECTRIC CO.	382152/765823		1152	20				-345								-120	75						
212	OHIO OIL CO., HAMMOND 1	382048/752913		5568	70	-5428	-3707	200	-1680	155	-1460	40		25	-1360	100		210		235				
213	MARSHALL BORNT	382034/753304		1003	—																-350	145		
214	WI-D8 56	381844/755328		1220	—						-990	25		25		20		160	-600	70				
215	SOCONY OIL, BETHARDS 1	381755/751727		7178	43	-7097	-3864	404	-2130	180	-1880	70		30		155		260						
216	WI-DD 23	381757/754013		525	—																-380	140		
217	USGS SM-DD 49	381616/763647	3816160763647.02	619	115												-360	120	-135					
218	MGS LEXINGTON PARK SM-DF-84	381548/762721	3815480762721.01	2678	108	-2515	-2015	325	-860	45	-570	20					-440	136	-185	210				
219	MARYLAND DEPARTMENT OF PARKS	381327/752751		303	30																		-100	5
220	KITTS POINT UTILITY	380719/762518	3807230762520.01	940	7												-520		-270	250				
221	E. STEVENS	380457/755145		1170	—							15						170	-720		-285	170		
222	MARYLAND DEPARTMENT OF PARKS	380359/752515		113	7																		-80	5
223	MARYLAND OFFICE OF PUBLIC IMPROVEMENTS	380342/762005	3803420762005.01	733	3													120	-315					
224	POINT LOOKOUT STATE PARK	380312/761927	3803130761929.02	720	5															274				
225	U.S. DEPARTMENT OF ENERGY, CRISFIELD 1	380057/754932		5562	11.5	-4457	-2710	216																
226	J. BROWN	380034/755038		1514	21				-1095	80	-940	15						130	-720	110	-295	155		
227	SO-EA 11	375822/760003		990	—						-940	60						135	-620		-250	165		

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							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
228	FEATHERSTONE SITE	383630/771501	383630771501.01	240	10	-188																		
229	STAFFORD COUNTY SCHOOL BOARD	382526/772421	3825260772421.01	295	210	-85			98	32							160	5						
230	J.B. CRALLE CO.	382242/770347	3822430770346.01	677	110				-272	42							-83	83		35		37	110	
231	STAFFORD SCHOOL BOARD	381949/772508	3819490772508.01	240	200				58	42							113	42						
232	USGS, PRESIDENTA LAKE DEVELOPMENT	381733/771443	3817330771443.01	235	155												15	65	94	20		16		
233	SYDNOR HYDRODYNAMICS, ARGYLE HEIGHTS	381713/772559	3817130772559.01	427	150	-277	-226	40	20	42							86	24						
234	SYDNOR HYDRODYNAMICS, INC.	381454/772516	3814540772516.01	273	75	-198			-35	44							12	12						
235	MT. ROSE CANNING CO.	381418/770916	3814290770935.01	900	180		-662	86	-230	68							-58	94	64	38		25	180	
236	NATIONAL PARK SERVICE	381122/765531	3811220765531.01	810	20				-361	30		10					-199	110	-39	40				
237	USGS, OAK GROVE CORE	381010/770219	3810100770219.01	1360	180		-890	100	-324	30		14					-160	116	-14	68		52	180	
238	U.S. ARMY, A.P. HILL	380856/771945	3808560771945.01	500	160				-140	60							10	78	108	30			160	
239	H.T.E. CORP.	380855/764022	3808550764022.01	775	10						-494	32					-328	131	-136	86		50		
240	ARROWHEAD ASSOCIATION	380516/764730	3705160764730.01	817	145				-643	80	-383	11					-283	132	-102	73		88	145	
241	WESTMORELAND COUNTY	380428/764025	3804280764025.01	493	120												-332	114	-154	94		100	90	10
242	BOWLING GREEN	380323/772047	3803230772047.01	519	205		-266	57	-43	54							78	21	111	34			205	
243	BELRUH OYSTER CO.	380143/763400	3801430763400.01	320	20														-171	98		88		
244	WARSAW	375733/764518	3757330764518.01	700	130						-416	10					-297	97	-124	96		88	120	10
245	TAPPAHANNOCK	375541/765143	3755410765143.01	553	20				-466	42	-340	12					-242	99	-84	96		52		
246	DAVID C. BURRUSS	375402/771905	3754020771905.01	262	105				-103	74							-1	60	76	17				
247	NATIONAL PARK SERVICE	375324/752025	3753240752025.01	800	10																-748	318	-144	109
248	HOLLY FARMS, INC.	375321/753344	3753040753330.01	330	40																		-91	60
249	J. & J. ENTERPRISES, EMMITT G. TAYLOR 1	375303/753101	3753030753101.01	6272	53	-6133	-3210	173	-1560	70	-1286	60						172		324	-588	250	-106	70
250	HAYNIE PRODUCTS, INC.	374947/761634	3749470761634.01	809	10						-658	58					-574	78	-356	100		123	-35	20
251	SYDNOR HYDRODYNAMICS, INC.	374932/765642	3749320765642.01	300	170														-59	85		65	155	15
252	RICHMOND KIWANIS CLUB	374751/771955	3738150770005.01	320	190				-62	26							-2	60	72	44			190	
253	SYDNOR HYDRODYNAMICS, INC.	374621/763050	3746210763050.01	690	90						-510	16					-466	136	-230	80		101	10	14
254	LARRY A. LIPSCOMB	374540/770921	3745400770921.01	430	140				-244	44		12					-108	64	4	60		30	140	
255	PERDUE FOODS, INC.	374403/753937	3737400754000.01	340	50																		-74	60
256	ONANCOCK	374233/754429	3737350754000.01	280	15																		-85	72
257	KILMARNOCK	374212/762309	3742120762309.01	782	75						-588	16					-539	99	-313	128		114	-16	36
258	COLONIAL FOREST SUBDIVISION	374110/772115	3741100772115.01	320	185				-70	35							-1	54	71	38				
259	SYDNOR HYDRODYNAMICS, INC.	373915/772146	3739150772146.01	370	180				-6	20							29	31	70	40			180	
260	D. FLEET	373815/770750	3737350770005.01	368	30				-240	44		34					-92	58	-6	20				
261	SYDNOR HYDRODYNAMICS, INC.	373711/771930	3745350773005.01	410	170	-240			-77	30							-23	73	70	50				
262	ACCOMACK SCHOOL BOARD	373600/754638	3736000754638.01	450	45																		-89	48
263	RAPPAHANNOCK COMMUNITY COLLEGE	373352/763728	3733520763728.01	700	110					54	-384	10					-350	97	-174	55		78	28	22
264	BAPTIST GENERAL ASSOC. OF VA.	373201/762612	3732010762612.01	850	55						-579	41					-523	115	-384	126		114	-40	28
265	SYDNOR HYDRODYNAMICS, STOVE POINT	373158/781950	3731580761950.01	792	10						-610	25					-580	136	-422	170		118	-60	38
266	CHESAPEAKE CORP., AIRPORT WELL	373126/764541	3731260764541.01	1278	15	-1255	-931	32	-557	50	-330	21					-279	86	-119	50		20		
267	WOODHAVEN SHORES, INC.	372951/770719	3729510770719.01	500	110				-204	14	-146	15					-100	44	22	53			110	
268	HENRICO COUNTY SCHOOL BOARD	372859/772203	3728590772203.01	285	150			18	34	8							65	35		19			150	
269	NORTHAMPTON HOSPITAL	372830/755155	3728300755155.01	350	35																		-91	76
270	NEWPORT NEWS	372428/765615	3724280765615.01	778	10		-650	22	-304	20	-242	12					-168	44	-60	42				

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							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
271	VA. STATE WATER CONTROL BOARD GLOUCESTER TEST WELL	372331/763126	3723310763126.01	1868	75	-1772	-1179	18	-756	52	-600	21					-539	92	-323	78		87	-44	35
272	TIDEWATER WATER CO.	372310/764114	3723100764113.01	553	50				-436	30	-362	22					-296	74	-168	68		30	6	24
273	SAFEWAY STORES	372044/772240	3720440772240.01	233	180			16	58	31								18		19			180	
274	VA. STATE WATER CONTROL BOARD S.O.W. 66A	371956/770552	3719560770552.01	600	35	-545	-455	12	-206	26	-151	9					-74	18		10				
275	JAMES CITY SERVICE AUTHORITY	371905/764712	3719050764712.01	426	120				-279	19							-232	62	-104	60			56	23
276	CHARLES CITY COUNTY	371845/765613	3718450765613.01	338	35				-269	30	-209	22					-153	44	-58	44			20	
277	COLONIAL WILLIAMSBURG	371605/764203	3716050764203.01	498	70						-334	18					-288	66	-176	60		36	24	22
278	BAYSHORE CONCRETE	371539/760114	3715390760114.01	223	10																		-84	51
279	SYDNOR HYDRODYNAMICS, INC.	371434/764815	3714340764815.01	495	30				-368		-254	16					-211	53	-94	50		8	0	10
280	NORTHAMPTON SCHOOL BOARD	371159/755732	3711590755732.01	491	30																		-110	30
281	DOW BADISCHE	371120/763654	3711200763654.01	1560	20		-1124	46	-498	10	-398	30					-348	56	-234	77		49	-42	30
282	VEPCO	370951/764157	3709510764157.01	420	35						-357	24					-285	62	-167	60		47	-19	12
283	PRINCE GEORGE COUNTY	370933/771704	3709330771704.01	325	140				-14	14							27	33	68	14			140	
284	NASA RESEARCH CENTER	370538/762243	3705380762243.01	2063	10	-2053	-1364		-858	34	-696	26						84	-440	130		80	-80	30
285	DENDRON	370245/765606	3702450765606.01	510	110				-323	55	-192	32					-96	21	-66	40		20	45	27
286	DIXIE HOSPITAL	370043/762203	3700360762203.01	398	15																		-65	25
287	RESCUE WATER CO.	365939/763330	3659390763330.01	548	22				-510	14							-322	54	-191	46		25	-46	42
288	SMITHFIELD PACKING CO.	365927/763758	3659270763758.01	600	30				-502	31	-310	22					-279	47	-200	50		26	-28	18
289	J.ROSZEL, T.W. SPAIN	365845/770021	3658450770021.01	840	110	-678	-486	17	-262	44	-123	26					-60	24		28			54	20
290	VA. STATE WATER CONTROL BOARD S.O.W. 48	365843/770902	3658430770902.01	554	95	-448	-321	12	-101	28	-24	11					-3	16		10			60	28
291	STONEY CREEK	365636/772357	3656360772357.01	111	75	-35			25	20														
292	SUSSEX COUNTY SCHOOL BOARD	365509/771529	3655090771529.01	180	85				-53	33		12					15	18					85	
293	U.S. DEPT. OF ENERGY DH26, ISLE OF WIGHT	365430/764212		1680	80	-1308																		
294	IVOR	365415/765320	3654150765352.01	510	90				-271	26	-160	14					-112	28	-69	33			32	34
295	R.H. WHITE	365331/770208	3653310770208.01	370	115				-184	51	-95	31					-44	18	-19	20			43	20
296	VIRGINIA BEACH	365232/764056	3652320764056.01	960	50				-412	30	-290	30					-238	45	-140	38			-25	43
297	USGS, MORRIS BRIDGE	365221/761215	3652230761221.01	2572	15		-1580	60	-1015	35	-741	25						74	-570	122		110	-75	40
298	TIDEWATER WATER CO.	365218/762747	3639300763800.01	655	15						-493	30					-424	42	-314	62		42	-42	36
299	BUSH DEVELOPMENT CORP.	365200/755851	3652000755851.01	1587	20				-1404	82	-1105							68	-790	215		155	-142	42
300	PORTSMOUTH	365115/761917	3651150761917.01	1454	10		-1306	36	-875	20	-646	46					-582	95	-422	118		48	-61	27
301	U.S. DEPT. OF ENERGY DH25A, PORTSMOUTH	365101/762950		2005	23	-1772																		
302	AL WILLIAMS	365009/770354	3650090770354.01	355	115				-142	18	-62	17					-39	10	-22	19			37	44
303	LONE STAR CEMENT	364853/761709	3648530761709.01	800	10						-700	14					-670	86	-482	146		72	-53	38
304	M.H. ROBINSON	364847/764438	3648470764438.01	460	85						-267	40					-194	39	-137	36			-17	62
305	NORFOLK	364838/763709	3648380763709.01	939	40				-493	12	-357	41					-291	53	-182	36			-46	64
306	VIRGINIA DIVISION OF FORESTRY	364808/762315	3648080762315.01	653	20						-582	30					-532	86	-366	86		53	-30	32
307	VA. STATE WATER CONTROL BOARD	364711/760600	3647110760600.01	400	20																		-95	54
308	MERLE HOLT	364630/765917	3646300765917.01	330	90				-187	17	-124	12					-94	24	-38	31			17	47
309	UNION CAMP EXPERIMENTAL FARM	364622/771028	3646220771028.01	378	105		-201	40	-55	22	-19	15						17					45	35
310	VIRGINIA BEACH	364605/765318	3646050765318.01	914	15		-653	24	-313	34	-185	22					-141	20	-71	20			-20	
311	SUFFOLK	364605/763224	3646070763218.01	624	25				-551	18	-429	47					-325	26	-249	50		12	-35	30
312	SUFFOLK	364452/763514	3644520763514.01	1010	30				-538	31	-464						-306	48	-220	40			-55	45
313	SUFFOLK	364248/763913	3642480763913.01	716	55				-503	22	-298	42					-245	35	-158	47			3	22

VIRGINIA (CONT'D)

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...) AND THICKNESSES OF CONFINING UNITS (C1, C2,...) IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
314	DREWRYVILLE	364245/771820	3642450771820.01	300	110		-163	34	21	26		5											110	
315	VA. STATE WATER CONTROL BOARD	364227/760747	3642270760747.01	1200	20						-895	65					-774	59	-603	138		127	-75	25
316	F.E. NOTTINGHAM	364211/770543	3642110770543.01	263	50				-115	22	-58	29					-18	8					30	13
317	ANDREW SIPINZSKY	364204/770049	3642040770049.01	349	40				-179	28	-102	35					-46	13		17			17	23
318	JOHN LENSEY	364149/762019	3641490762019.01	822	15						-692						-569	5	-464	87		47	-87	44
319	UNION CAMP	364121/765451	3641210765451.02	714	30	-828	-677	47	-314	28	-188	22					-136	12	-63	11			5	13
320	PEARCE	364113/764547	3641130764547.01	500	80				-400	67	-250	20					-204	25	-119	28			-12	37
321	VA. STATE WATER CONTROL BOARD	363836/762017	3638360762017.01	980	15				-951	56	-752						-601	26	-471	126		54		
322	VA. STATE WATER CONTROL BOARD	363653/764554	3636530764554.01	1178	80		-834	50	-394	71	-265	28					-204	18	-120	26			9	21
323	VIRGINIA DEPARTMENT OF HIGHWAYS	363608/764007	3636080764554.01	620	70				-494	45	-369	44					-272	22	-158	47			3	22
324	HUNTER DARDEN	363607/765600	3636070765600.01	362	20				-254	56	-128	4					-110	18		8			10	
325	J.T. PARKER	363521/770636	3635210770636.01	348	100				-116	38	-48	16											26	26
326	BOYKINS	363504/771153	3635040771153.01	485	40	-445	-352	16	-77	24		21											16	11
327	CHESAPEAKE CORP.	363448/761212	3634480761212.01	700	10												-678	36	-536	70		113	-100	25
328	VA. STATE WATER CONTROL BOARD, ADAMS SWAMP	363409/763500	3634080763500.01	2017	60	-1822	-1154	67	-596	44	-416	54					-321	15	-222	34			-26	28

NORTH CAROLINA

MAP NO.	NAME, LOCAL NUMBER, OR OWNER	LATITUDE/ LONGITUDE (DEGREES, MINUTES, SECONDS)	GROUND-WATER SITE INVENTORY NUMBER	LOGGED DEPTH (FEET)	SURFACE ALTITUDE (FEET)	BASEMENT ALTITUDE (FEET)	ALTITUDES OF AQUIFERS (A1, A2,...), AND THICKNESSES OF CONFINING UNITS (C1, C2,...), IN FEET																	
							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
329	G.B. BARNES	363100/771426		310	120				-64	21	-16	23		0		0		0		0		0	33	26
330	KITTRELL FARM	363057/763546		416	42												-260	27	-219	43		0	-86	48
331	NRCD COMO RESEARCH STATION	363026/770019		818	62	-752	-625	19	-178	15	-90	32		0		0	-15	29		0		0	32	6
332	BUCKLAND SCHOOL	362830/764550		394	25						-280	22	-229	44		0	-156	20		0		0	-83	68
333	NRCD SUNBURY RESEARCH STATION	362646/763614		942	40				-560	12	-441	29	-352	16		0	-249	23	-214	4	-159	14	-82	30
334	CULLINAN, WEYERHAEUSER 1	362610/763005		2138	15	-2088	-1276	55	-746	35	-621	67	-455	29		0	-364	47	-303	23	-240	29	-87	32
335	CONWAY	362603/771339		520	105	-415			-82	55	-15	14		0		0		0		0		0	50	16
336	NRCD MORGANS CORNER RESEARCH STATION	362601/762307		1529	10		-1351	51	-938	50	-758	44	-598	26		0	-446	36	-372	4	-363	77	-115	73
337	EDWIN BLAIR, WEYERHAEUSER 1	362440/761030		3742	8	-2814	-1670	58	-1332	120	-1045	50	-862	44		0	-647	23	-541	7	-510			
338	NRCD ELIZABETH CITY RESEARCH STATION	362050/761637		500	7														-447	6	-437	58	-111	26
339	USGS, GLIDDEN TEST HOLE	361902/763634		940	36				-697	31	-518	28	-343	22		0	-258	27	-213	7	-194	33	-81	53
340	E.F. BLAIR & ASSOCIATES, TWIFORD 1	361810/755530		4553	5	-4516	-2267	64	-1910	147	-1469	46	-1220	160		0	-1000	52	-784	14	-759	144		
341	NRCD CALEDONIA RESEARCH STATION	361804/772612		220	37	-182			-67	18	-3	23		0		0		0		0		0		0
342	NRCD PARKVILLE RESEARCH STATION	361744/762744		1210	16				-989	67	-674	34	-558	48			-382	30	-319	0	-302	54	-88	17
343	RICH SQUARE	361635/771700		335	75				-120	21	-15	12		0		0		0		0		0	55	10
344	NRCD CREMO RESEARCH STATION	361002/765621		1192	67	-1033			-451	88	-145	31	-72	18		0	-50	5		0	-39	4	2	43
345	SCOTLAND NECK TEST WELL 1	360736/772442		338	93	-245			-150	61	11	10		0		0		0		0		0	53	12
346	USGS EDENTON AIRPORT TEST HOLE	360100/763438		847	8						-654	59	-543	55	-427	29	-289	26	-220	0	-182	34	-48	21
347	R.J. REYNOLDS CO.	355820/764310		452	25								-368	23	-323	34	-235	36	-149	0	-131	50	-25	13
348	SPEED	355817/772648		300	52						-26	20		0		0		0		0		0	25	19
349	NRCD SCUPPERNONG RESEARCH STATION	355459/762814		1312	8						-910	22	-714	69	-582	16	-498	50	-326	11	-200	60	-75	47
350	TARBORO 1899 WELL	355334/773218		349	50	-299					10	15												
351	EXCHANGE O&G CO., WESTVACO 2	355333/760935		4198	12	-3882					-1326	40	-1110	26	-928	16	-785	24						
352	E.F. BLAIR, WEST VIRGINIA PULP & PAPER 1	355150/755530		5147	3	-5119					-1852	143	-1612	101	-1355	31	-1207	80	-813	16	-617	85	-189	46
353	WILLIAMSTON	355111/770338		665	60						-435	32	-205	34	-165	8	-103	15	-74	7	-55	50	19	21
354	NRCD NEWLANDS RESEARCH STATION	355050/761607		1449	8						-1214	40	-1000	64	-844	20	-677	25	-477	5	-354	136	-94	28
355	ROBERSONVILLE	354932/771559		420	65						-307	34	-77	92		0		0		0		0	26	20
356	NRCD PLYMOUTH RESEARCH STATION	354925/764530		1494	33				-1148	64	-632	33	-395	54	-335	13	-238	22	-131	6	-105	37	-7	22
357	PINETOPS	354724/773822		317	108	-196					6	35				0		0		0		0	68	7
358	ALBERT GENTLES CO., WESTVACO 2	354515/754624		6079	12	-6057	-4080	66	-3290	330	-2705	98	-2248	292	-1787	25	-1690	140	-955	170	-720	55		
359	FRANK EASON	354504/774018		122	95						32	34		0		0		0		0		0	87	5
360	NRCD BETHEL RESEARCH STATION	354457/772155		690	65	-625			-561	30	-290	24	-16	21		0		0		0		0	27	12
361	USGS JAMESVILLE TEST HOLE	354232/765307		970	35						-615	33	-391	45	-318	29	-194	16	-67	15	-42	17	-3	17
362	COASTAL PLAINS, H.M. JACKSON 1	353815/765115		1526	40				-1243	70	-692	45	-570	117	-367	19	-245	23	-90	17	-63			
363	NRCD NEW LAKE RESEARCH STATION	353720/762118		1011	11										-927	30	-771	36	-437	8	-365	41	-68	10

NORTH CAROLINA (CONT'D)

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							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
364	COASTAL STATES OIL, THOMPSON 1	353611/774921		218	80	-122					-7	61		0		0		0		0		0	72	8
365	WASHINGTON	353320/770125		770	25						-658	61	-510	127	-302	36	-211	32	-45	18		0	-14	5
366	EUREKA	353222/775221		215	130	-85					10	15	65	20		0		0		0		0	96	11
367	NRCD MAURY RESEARCH STATION	352840/773555		568	78	-490					-202	42	-14	24	34	29		0		0		0		0
368	NRCD SAULSTON RESEARCH STATION	352812/775103		216	97	-119					-26	27	66	19		0		0		0		0		0
369	HARNETT COUNTY BOARD OF EDUCATION	352752/784643		457	290	209							264	14		0		0		0		0		0
370	MOBIL OIL CORP., STATE 2	352620/753435		8386	24	-8336	-5215	240	-4390	100	-3892	74	-3185	233	-2575	135	-2102	47	-1230	35	-970	180	-206	30
371	NRCD HYDELAND RESEARCH STATION	352527/761231		1505	3										-1230	12	-1095	34	-629	10	-501	136	-104	12
372	P.T. PERKINS	352256/784942		125	239	183							220	9		0		0		0		0		0
373	NRCD WILMAR RESEARCH STATION	352252/770507		918	40						-684	34	-390	52	-243	22	-197	10	-16	31		0		0
374	TUSCARORA SCOUT COUNCIL	352035/781525		139	125	14					70	16	108	9		0		0		0		0		0
375	WELLS REALTY CO.	351843/780157		214	135	-66					12	25	92	8		0		0		0		0		0
376	LA GRANGE	351836/774643		410	102	-304					-220	29	-2	32	58	18		0		0		0		0
377	NRCD KINSTON SUPPLY RESEARCH STATION	351609/773706		673	45	-587					-363	18	-138	81	23	14		0		0		0		0
378	LONGLEAF, INC.	351557/793523		191	605	414							593	4		0		0		0		0		0
379	NRCD HOBUCKEN RESEARCH STATION	351517/763547		1003	6										-851	27	-764	14	-326	24	-140	14	-46	22
380	NEWTON GROVE	351503/782053		325	180	-119					-1	15	108	22										
381	ESSO, HATTERAS LIGHT 1	351500/753145		10044	25	-9853	-6466	99	-4970	87	-4531	290	-3630	245	-3015	225	-2540	180	-1245	25	-729	215	-260	30
382	CLIFFS OF NEUSE STATE PARK	351430/775315		376	105	-257					-145	32	18	26	67	10		0		0		0		0
383	NEW BERN, DOVER TEST WELL	351300/772625		400	55								-289	98	-131	60	-27	18	21	18		0		0
384	HUGH W. DEAN	351257/790846		316	325	143					226	25	285	17		0		0		0		0		0
385	MT. OLIVE PICKLE CO.	351220/780430		354	180	-157					-44	12	123	17		0		0		0		0		0
386	PINEHURST, INC., TH 7	351219/792751		224	505	281					295	54	488	6		0		0		0		0		0
387	FALCON	351130/783915		230	143	-60					9	20	86	9										
388	NEW BERN COVE CITY TEST	351038/771752		894	34						-732	18	-363	63	-236	42	-116	8	24	0		0		0
389	SPRING LAKE WELL 11A	350957/785813		152	300								249	17		0		0		0		0		0
390	NRCD CLARKS RESEARCH STATION	350816/771018		1286	28	-1254			-1144	65	-860	30	-520	88	-300	8	-228	7	2	8		0		0
391	USGS NEW BERN PROPERTIES TH	350815/770620		956	27						-911	18	-553	52	-347	14	-289	23	1	16		0		0
392	WALTER MOORMAN	350709/785442		268	240	-28					74	39	224	10		0		0		0		0		0
393	USGS, OCRACOKE TEST	350647/755839		895	3														-820	10	-585	119	-132	37
394	CLEMENT SCHOOL	350616/783523		350	170	-180			-145	35	-5	46	74	29		0		0		0		0		0
395	NRCD ARAPAHOE RESEARCH STATION	350508/765008		1050	38								-991	144	-671	10	-609	26	-100	8	-60	15	0	8
396	CAROLINA PETROLEUM, NORTH CAROLINA PULPWOOD 1	350435/763900		3666	4	-3654							-1308	167	-952	31	-846	23	-260					
397	NRCD PINK HILL RESEARCH STATION	350323/774826		689	127	-553					-325	33	-115	72	35	32		0	74	11		0		0
398	W.W. CAMARAN, JR.	350200/792056		248	350	102					144	54	337	4		0		0		0		0		0
399	SALEMBURG	350122/783013		320	165				-133	20	-44	44	81	20		0		0		0		0		0
400	NRCD TURKEY RESEARCH STATION	345921/781123		455	145	-310			-208	18	-93	35	71	28		0		0		0		0		0

NORTH CAROLINA (CONT'D)

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							A1	C1	A2	C2	A3	C3	A4	C4	A5	C5	A6	C6	A7	C7	A8	C8	A9	C9
401	NRCD SEABROOK RESEARCH STATION	345915/784518		280	130	-103					-20	35	70	18		0		0		0		0		0
402	RAEFORD	345831/791412		308	253	-4					51	75	218	13		0		0		0		0		0
403	CLINTON	345831/781822		455	155	-297			-204	13	-112	45	81	23		0		0		0		0		0
404	NRCD COMFORT RESEARCH STATION	345809/773014		877	70						-702	39	-392	143	-156	36	-92	14	46	14		0		0
405	N.C. DEPT. OF TRANSPORTATION	345738/794728		304	340	225							317	15		0		0		0		0		0
406	BRYANT P. SEAY, HOFFMAN FOREST 1	345400/772345		1433	50	-1368			-1073	55	-954	66	-586	135	-330	37	-224	13						
407	HAMLET	345330/794110		287	325	117							283	20		0		0		0		0		0
408	DUPONT CORP. WELL P-4	345037/785018		384	147.4	-237					-119	33	113	12		0		0		0		0		0
409	NRCD REX RENNERT RESEARCH STATION	345035/790518		353	185	-167					-103	158	160	13		0		0		0		0		0
410	E.T. BURTON, HOFFMAN FOREST 1	345000/771640		1570	40	-1520			-1283	60	-1108	38	-745	76	-524	59	-322	17						
411	NRCD CHINQUAPIN RESEARCH STATION	344922/774847		822	45	-743			-700	30	-582	42	-247	54	33	4		0		0		0		0
412	GARLAND	344710/782349		404	125	-279			-259	28	-150	31	17	14	56	16		0		0		0		0
413	LAURENBURG-MAXTON AIRPORT	344559/792159		364	208	-156					-101	72	124	28		0		0		0		0		0
414	BIBSON	344535/793638		291	250	5					20	48	177	9		0		0		0		0		0
415	COASTAL PLAINS, HUNTLEY-DAVIS 1	344350/763430		4965	20	-4938	-3854	84	-3097	145	-2422	102	-2246	196	-1720	76	-1415	33	-245	60	-130	6	-68	16
416	NRCD PREVETTE RESEARCH STATION	344337/790534		469	166	-296					-184	152	132	22										
417	NRCD CAMP GLENN RESEARCH STATION	344323/764513		1120	8												-1096	14	-130	28	-58	10	-36	18
418	NORTH CAROLINA O&G CO., COWAN 1	344030/774230		1000	33	-956			-892	20	-791	112	-405	50	-47	20		0	18	6		0		0
419	U.S. MARINE CORPS TEST WELL T8	343920/771950		500	20										-454	42	-332	20	0	10		0		0
420	WEST POINT-PEPPERELL	343757/783715		518	130	-384			-330	19	-177	42	1	13	86	14		0		0		0		0
421	NRCD FOLKSTONE RESEARCH STATION	343642/772901		1220	67								-706	64	-291	12	-260	15	11	32		0		0
422	NRCD IVANHOE RESEARCH STATION	343625/781432		583	34	-544			-474	20	-294	39	-123	16	-30	31		0		0		0		0
423	NRCD BURGAW RESEARCH STATION	343616/775120		931	19	-912			-803	42	-726	91	-345	48	-47	24		0	2	6		0		0
424	NORTH CAROLINA O&G, JUSTICE 1	343300/772230		1681	8	-1660			-1417	70	-1229	67	-780	88	-435	43	-349	43						
425	NRCD ROWLAND RESEARCH STATION	343156/791747		548	145	-357					-288	118	33	28		0		0		0		0	100	5
426	NRCD BLADENBORO RESEARCH STATION	343027/784519		575	116	-459			-408	41	-196	45	-33	19	50	18		0		0		0		0
427	FAIRMONT	343004/790634		612	108	-504					-438	180	-10	50		0		0		0		0	64	24
428	USGS, NATIONAL PARK SERVICE MOORES CREEK	342731/780630		650	30						-486	69	-288	73	-5	17		0		0		0		0
429	NRCD KELLEY RESEARCH STATION	342718/781831		670	28	-642			-577	60	-407	41	-233	83	-14	8		0		0		0		0
430	NORTH CAROLINA O&G CO., BATTS 2	342600/773350		1462	10	-1445			-1267	65	-1092	86	-607	74	-246	25								
431	NORTH CAROLINA O&G CO., LEA 1	342235/774400		1253	34	-1213			-1137	61	-869	55	-480	41	-142	28								
432	NRCD MARIETTA RESEARCH STATION	342224/790738		549	94	-455					-368	102	-11	45		0		0		0		0	74	2
433	FAIRBLUFF	341846/790207		314	65								-66	49	12	25		0		0		0		0
434	USGS WILMINGTON TEST HOLE	341800/775140		684	25								-458	43										
435	NRCD CLARENDON RESEARCH STATION	341237/785342		879	108	-771			-586	44	-432	99	-204	17	6	25		0		0		0		0
436	NRCD GREEN SWAMP RESEARCH STATION	341230/782630		932	48	-884			-714	117	-476	28	-266	44	-30	22		0		0		0		0
437	COLONIAL O&G CO., TRASK 1	340820/775745		1235	15	-1220			-1041	66	-820	55	-507	72	-190	50		0	-35	10		0		0
438	NRCD BEAR PEN RESEARCH STATION	340743/782017		1118	64	-1054			-834	80	-618	26	-373	73										
439	NRCD NAKINA RESEARCH STATION	340733/783952		1028	60	-901			-742	95	-506	73	-290	18	-20	15		0		0		0		0
440	NORTH CAROLINA O&G, FT. FISHER 1	335825/775510		1558	9	-1536			-1247	200	-905	85	-648	93	-337	100		0	-55					
441	NRCD CALABASH RESEARCH STATION	335336/783522		1335	50	-1282			-868	66	-694	56	-416	67	-50	38		0		0		0		0

* U. S. GOVERNMENT PRINTING OFFICE : 1992 - 323-945 : QL 3

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